



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF WELLAND RIVER TWIN BRIDGE STRUCTURES
QUEEN ELIZABETH WAY (QEW)
CITY OF NIAGARA FALLS, ONTARIO
LAT. 43.046111°, LONG. -79.121667°
G.W.P. 2430-15-00**

GEOCRES No. 30M03-307

Report

to

WSP

Date: October 2, 2018

File: 18426



TABLE OF CONTENTS

PART 1 FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION	1
3	INVESTIGATION PROCEDURES	2
4	LABORATORY TESTING	4
5	DESCRIPTION OF SUBSURFACE CONDITIONS	4
5.1	Asphalt	5
5.2	Concrete	5
5.3	Sand and Gravel (Pavement Granulars)	5
5.4	Cohesionless Fill	5
5.5	Cohesive Fill	6
5.6	Topsoil	7
5.7	Peat	7
5.8	Organic Silt	7
5.9	Silty Clay	8
5.10	Silty Clay Till	10
5.11	Silt and Sand Till	11
5.12	Silt to Silty Sand	12
5.13	Dolostone Bedrock	13
5.14	Groundwater Conditions	14
6	MISCELLANEOUS	16

PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	GENERAL	18
8	Structure classification	19
9	FOUNDATION DESIGN	19
9.1	Driven Steel H-Piles	21
9.1.1	Axial Resistance	21
9.1.2	Pile Tips	23
9.1.3	Pile Installation	23
9.1.4	Downdrag	24
9.2	Driven Steel Pipe Piles	24
9.2.1	Axial Resistance	25



9.2.2	Pile Tips	26
9.2.3	Pile Installation	26
9.2.4	Downdrag.....	26
9.3	Lateral Resistance.....	27
9.3.1	Lateral Resistance in Soil	27
9.4	Frost Depth.....	30
10	ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES.....	30
11	APPROACH EMBANKMENTS	31
11.1	Global Embankment Stability.....	32
11.2	Settlement	34
11.3	EPS Embankment Design	36
12	EXCAVATION AND GROUNDWATER CONTROL.....	39
13	TEMPORARY PROTECTION SYSTEMS AND COFFERDAMS	40
14	EROSION AND SCOUR PROTECTION	40
15	SEISMIC CONSIDERATIONS	41
16	ADJACENT STRUCTURES AND BURIED UTILITIES	41
17	SOIL CORROSION POTENTIAL	42
18	CONSTRUCTION CONCERNS.....	43
19	CLOSURE	44

APPENDICES

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Borehole Locations and Soil Strata Drawings
Appendix D	Summary of Subsurface Conditions (Silty Clay)
Appendix E	Chemical Analysis Results
Appendix F	ConeTec Report
Appendix G	Site Photographs
Appendix H	Foundation Comparison
Appendix I	Global Stability Analysis Results
Appendix J	Alternate EPS Configurations
Appendix K	List of SPs and OPSS, and Suggested Text for Selected NSSPs



**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF WELLAND RIVER TWIN BRIDGE STRUCTURES
QUEEN ELIZABETH WAY (QEW)
CITY OF NIAGARA FALLS, ONTARIO
LAT. 43.046111°, LONG. -79.121667°
G.W.P. 2430-15-00**

GEOCRES No. 30M03-307

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the QEW twin bridge structures over Welland River in the City of Niagara Falls, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location plan and soil strata drawings, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to WSP, under the Ministry of Transportation of Ontario (MTO) Agreement Number 2016-E-0085.

2 SITE DESCRIPTION

Each of the two existing QEW twin bridges is a 290.8 m long, 18-span, steel-girder composite bridge comprised of a reinforced concrete deck and steel I-girders supported on reinforced concrete piers and abutments on timber piles. The bridges carry the northbound lanes (NBL) and southbound lanes (SBL) of the QEW in a north-south orientation over the Baden-Powell Park trail, a Canadian Pacific Railway (CPR) corridor, the Welland River, and Oakwood Drive.

Welland River is a major river which flows from west to east through the Niagara Region and empties into the Niagara River. At the structure site, the normal water level of the river is approximately 70 m wide and its base is located at approximately Elev. 165.5 m. It is located within a broad and relatively flat floodplain which ranges from about Elev. 172 m immediately north of the river up to as high as Elev. 177 m south of the river. The total width of the floodplain



is about 250 m and the floodplain is well vegetated with many bushes and shrubs and deciduous trees which rise several metres above the existing bridge deck. Based on preliminary General Arrangement (GA) drawings, the water level in the Welland River was at Elev. 170.87 m on January 27, 2018, which corresponds to a water depth of about 5 m. Selected photographs of the bridges and their immediate surroundings are presented in Appendix G.

The QEW SBL south approach embankment has a history of settlement and lateral movement (GEOCREs No. 30M3-212). This area was previously remediated with a stabilizing berm to arrest further distress and movement.

There is a 6.1 m wide concrete box culvert (Grassy Brook culvert) located approximately 140 m south of the south abutment which carries the Grassy Brook stream across the embankments.

Based on published physiographic mapping, the site is situated within the physiographic region known as the Haldimand Clay Plain. This region is characterized by a broad undulating plain which occupies nearly all of the Niagara peninsula and covers an area of about 1,350 square kilometers. The regional stratigraphy is mostly comprised of glaciolacustrine clay deposits overlying clay till underlain by shale and dolostone bedrock of the Salina formation.

The main surface drainage feature is the Welland River which is incised into the clay overburden. However, uneven ground surface within the region generally results in poor drainage and wet, swampy depressions.

The existing bridge piers and abutments are supported on a combination of spread footings and timber piles. Based on available Geocres data, the QEW SBL south approach embankment has a history of instability and a stabilizing berm was constructed along the south face of the south approach embankment sometime around 1994 in an attempt to arrest further movement.

3 INVESTIGATION PROCEDURES

The initial site investigation was carried out between March 14, 2018 and April 21, 2018 during which time twenty-four (24) boreholes (identified as 18-01 to 18-24) were advanced to depths ranging from 19.9 m to 39.8 m. Following the initial investigation, MTO approved the completion of an additional three (3) boreholes and two (2) piezocone tests (CPTu) to cover the additional length of the proposed grade raise to the structure. The additional boreholes were advanced to depths ranging from 24.4 m to 26.5 m and the piezocones were advanced to depths of 23.7 m and 37.1 m. The additional boreholes (identified as 18-25 to 18-27) and piezocones (CPT18-01 and CPT18-02) were completed between July 10 and 13, 2018.



Twelve (12) boreholes (18-06 to 18-17) were drilled near the proposed pier locations while six (6) boreholes (18-03 to 18-05 and 18-18 to 18-20) were drilled near the proposed bridge abutments. Nine (9) boreholes (18-01, 18-02, 18-21 to 18-27) were drilled along the approach embankments. The piezocones were advanced within 10 m behind the existing abutments. The approximate locations of the boreholes and piezocone tests are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix C. A summary of the piezocone sounding results, inferred stratigraphy, and results of the pore pressure dissipation tests and shear wave velocity tests are provided in Appendix F.

The boreholes within the river floodplain were advanced using a CME-55LC track-mounted drill rig. The boreholes from highway grade through the embankments were drilled using a CME 75 truck-mounted drill rig. All boreholes were drilled through the overburden using hollow stem augers and NW casing. Soil samples were obtained using a 50 mm outside diameter split-spoon sampler driven in conjunction with the Standard Penetration Test (SPT). In the cohesive soils, Field Vane Tests (FVTs) were performed using an MTO 'N' sized vane. Shelby tube samples of the cohesive soils were also recovered at selected locations. Where bedrock was encountered, NQ coring equipment was used to recover rock core samples.

ConeTec Investigations Ltd. of Richmond Hill, Ontario, supplied and operated the piezocone equipment. The piezocone was advanced using a truck-mounted rig supplied and operated by ConeTec.

Groundwater conditions were observed in the open boreholes throughout the drilling operations. 75 mm diameter standpipe piezometers were installed and enclosed in filter sand in selected boreholes to permit longer term monitoring of the groundwater levels at the site. The boreholes in which no monitoring wells were installed were backfilled in general accordance with Ontario Regulation 903 as amended (O.Reg. 903). Once the investigation is completed, the well installations will be decommissioned in general accordance with O.Reg. 903.

The field investigation was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of subsurface utilities, directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.



4 LABORATORY TESTING

Routine laboratory testing was carried out at Thurber's laboratory. The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. Point Load Testing was carried out on selected rock cores for estimating the unconfined compressive strength of intact rock.

More advanced testing was also carried out on recovered Shelby tube samples of the silty clay: Oedometer testing (one-dimensional incremental loading) was completed to determine the compressibility of the clay, and triaxial testing (Consolidated Isotropically Undrained – CIU) was carried out to determine the shear strength and deformability of the clay.

Results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the Borehole Locations and Soil Strata Drawings in Appendix C. Reference is also given to Appendix D which presents the results of in-situ and laboratory tests performed on the cohesive silty clay deposit. A general 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. It must be recognized that soil conditions will vary between and beyond the borehole locations.

In general, the subsurface stratigraphy below the embankment fill consists of a relatively thick deposit of silty clay overlying a deposit of silt and sand till. In some boreholes, the silt and sand till was interlayered with silty clay till and silty sand to sandy silt. The overburden soils were underlain by dolostone bedrock. Cobbles and boulders were encountered or inferred in the till layers. The groundwater levels measured in piezometers installed through the approach embankments ranged from 5.1 m to 12.6 m below highway grade (Elev. 179.2 m to 170.5 m). The groundwater levels measured in piezometers installed within the floodplain ranged from 0.1 m to 4.6 m (Elev. 171.7 m to 170.2 m) below ground surface. More detailed descriptions of the individual stratum are presented below.



5.1 Asphalt

Asphalt was encountered in the boreholes advanced through the embankments (Boreholes 18-01 to 18-05 and 18-18 to 18-27). The thickness of the asphalt ranged from 100 mm to 300 mm.

5.2 Concrete

Concrete was encountered underlying the asphalt in Borehole 18-20. The thickness of the concrete was 300 mm. It is likely that this borehole is located on the existing approach slab.

5.3 Sand and Gravel (Pavement Granulars)

Pavement granulars consisting of sand and gravel was encountered underlying asphalt in the boreholes drilled through the south and north approaches (Boreholes 18-01 to 18-05 and 18-18 to 18-27). The thickness of the sand and gravel ranged from 0.6 m to 1.6 m. The base of this fill was encountered at depths ranging from 0.8 m to 1.8 m (Elev. 183.4 m to 175.5 m).

The SPT 'N' values recorded in the fill ranged from 12 to over 100 blows per 0.3 m of penetration indicating a compact to very dense condition. The natural moisture contents measured on samples of the fill ranged from 1 percent to 21 percent and were generally between 2 percent and 10 percent.

The results of a grain size analysis conducted on a sample of sand and gravel fill is provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	35
Sand	48
Silt + Clay	17

5.4 Cohesionless Fill

Cohesionless fill was encountered underlying the sand and gravel fill in Boreholes 18-04, 18-05, 18-19, 18-20 and 18-22, and underlying topsoil in Boreholes 18-06, 18-07 and 18-08.

The cohesionless fill was variable in composition and ranged from gravelly sand to sandy gravel, sand to silty sand to sandy silt. The thickness of this fill ranged from 0.2 m to 0.7 m. The base of the cohesionless fill was encountered at depths ranging between 0.6 m to 1.9 m (Elev. 182.7 m to 174.7 m).

The SPT 'N' values recorded in the cohesionless fill ranged from 8 to 43 blows per 0.3 m of penetration indicating a loose to dense, but typically compact condition. The natural moisture



contents measured on samples of the cohesionless fill ranged from 5 percent to 25 percent.

The results of a grain size analysis conducted on a sample of the cohesionless fill is provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	11 to 64
Sand	30 to 53
Silt + Clay	6 to 36

5.5 Cohesive Fill

Cohesive fill was encountered underlying the sand and gravel fill in Boreholes 18-01, 18-02, 18-03, 18-18, 18-21, 18-23 and 18-24, underlying other cohesionless fill in Boreholes 18-04, 18-05, 18-06, 18-07, 18-19, 18-20, 18-22, 18-25 and 18-26, and underlying topsoil in Boreholes 18-11, 18-12, 18-15, and 18-16.

The fill generally consists of silty clay containing trace to some sand and trace gravel. The thickness of the cohesive fill ranges from 0.7 m to 8.9 m. The base of the cohesive fill was encountered at depths ranging between 0.8 m and 10.2 m (Elev. 177.4 m and 169.9 m).

The SPT 'N' values recorded in the cohesive fill ranged from 3 to 29 blows per 0.3 m of penetration indicating soft to very stiff consistency. In general, the consistency of the cohesive fill was stiff to very stiff. The natural moisture contents measured on samples of the cohesive fill ranged from 17 percent to 49 percent with typical values between 20 percent and 30 percent.

Undrained shear strengths measured by field vane shear tests in the fill ranged from 60 kPa to 111 kPa indicating a stiff to very stiff consistency.

The results of grain size analyses conducted on selected samples of the cohesive fill are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figures B3 to B5 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 to 38
Silt	28 to 53
Clay	27 to 72

Atterberg limits testing was carried out on selected samples of the cohesive fill and measured plastic limits of 18% to 21%, liquid limits of 36% to 48%, and corresponding plasticity indices of



19% to 28%. These results, which are plotted on Figure B24 in Appendix B, indicate that the deposit consists of silty clay fill of intermediate plasticity (CI).

5.6 Topsoil

Topsoil was encountered in the boreholes advanced within the river floodplain (Boreholes 18-06 to 18-17). The topsoil thickness ranged from 50 mm to 175 mm. The topsoil thickness may vary in other areas of the site as this limited data is not sufficient to estimate topsoil quantity.

5.7 Peat

A layer of peat with roots and rootlets was encountered underlying the cohesive fill in Borehole 18-15. The thickness of this layer was approximately 0.7 m. The base of the peat was encountered at Elev. 169.2 m.

An SPT 'N' value of 2 blows per 0.3 m of penetration was measured within the organics indicating a soft to very soft consistency. The natural moisture content measured on a sample of peat was 256 percent.

5.8 Organic Silt

Organic silt was encountered underlying topsoil in Borehole 18-09 and underlying the cohesive fill in Boreholes 18-15, 18-16, and 18-17.

The organic silt was described as containing trace roots and rootlets and occasional wood fibres. Some sand and trace gravel was noted in one sample of the organic silt. The thickness of the organic silt ranged from 0.8 m and 3.2 m. The surface of the organic silt was encountered at depths ranging between 0.1 m and 2.2 m (Elev. 174.9 m and 169.2 m). The base of the organic silt was encountered at depths ranging between 0.9 m and 4.7 m (Elev. 174.2 m and 166.7 m).

The SPT 'N' values recorded in the organic silt deposit ranged from 0 to 6 blows per 0.3 m of penetration indicating a very soft to firm consistency. Field vane tests (FVTs) performed in the organic silt measured undrained shear strengths ranging from 9 to 45 kPa indicating a very soft to firm consistency. The natural moisture contents measured on samples of the organic silt ranged from 79 percent to 147 percent.

Atterberg limits testing was carried out on a sample of the organic silt and measured a plastic limit of 39 percent, a liquid limit of 76 percent, and corresponding plasticity index of 37 percent. The results, which are plotted on Figure B25 in Appendix B, indicate that the deposit consists of organic silt of high plasticity (OH).



5.9 Silty Clay

An extensive deposit of grey to reddish brown silty clay was encountered underlying fill in Boreholes 18-01 to 18-08, 18-11, 18-12, and 18-18 to 18-27, underlying topsoil in Boreholes 18-10, 18-13, 18-14, and 18-17, and underlying the organic silt in Boreholes 18-09, 18-15 and 18-16.

The silty clay deposit generally contains trace to some sand. The thickness of the deposit ranged from 8.3 m to 23.0 m. In general, the thickness of the deposit is greatest at the south approach and decreases northerly towards the north approach. The surface of the deposit was encountered at depths ranging between 0.1 m and 10.2 m. The base of the deposit was encountered at depths ranging from 12.4 m and 30.8 m (Elev. 166.3 m and 151.5 m).

The results of in-situ and laboratory tests performed on the cohesive silty clay deposit are summarized graphically in Appendix D and further discussed below.

The SPT 'N' values recorded in the silty clay deposit ranged from 0 blows per 0.3 m penetration to 100 blows for less than 0.3 m of penetration near the base of the deposit in one borehole. Typically, the 'N' values recorded in the deposit ranged from 5 to 20 blows above Elev. 170 m, from 0 to 5 between Elev. 170 m and 162.5 m, and then increased with depth below Elev. 162.5 m. The higher 'N' values recorded near the top of the deposit are indicative of a crust.

Undrained shear strengths measured by field vane shear tests in the clay ranged from 22 kPa to 115 kPa indicating a firm to very stiff consistency. Based on the shear strengths, the deposit was generally stiff to very stiff above Elev. 170 m within the crust, firm between Elev. 170 m and 162.5 m, and stiff to very stiff below Elev. 162.5 m. The natural moisture contents measured on samples of the clay ranged from 10 percent to 70 percent with typical values between 20 percent and 40 percent.

The results of grain size distribution analyses carried out on selected samples of the silty clay are presented on the Record of Borehole Sheets in Appendix A and on Figures B6 to B18 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 3
Sand	0 to 18
Silt	28 to 68
Clay	32 to 72



The results of Atterberg Limits tests carried out on selected silty clay samples are shown on Figures B26 to B34 in Appendix B and summarized below:

Soil Property	Percentage (%)
Liquid Limit	25 to 55
Plastic Limit	13 to 23
Plasticity Index	11 to 33

The results of the Atterberg Limit tests indicate that the plasticity of the silty clay ranges from low to high, typically low plasticity (CL) with zones of medium to high plasticity (CI to CH).

Eight (8) relatively undisturbed samples of the silty clay collected in Shelby tubes were selected for consolidation testing. The results of these tests are summarized in Table 5.1 below. The detailed test results are also presented in Appendix B.

Table 5.1: Oedometer Test Results

Borehole	18-01	18-04	18-11	18-14	18-19	18-21	18-24	18-25
Sample No.	TW1	TW2	TW1	TW1	TW1	TW2	TW1	TW1
Depth (m)	12.5	15.4	7.2	4.9	9.5	14.0	12.5	12.5
Elevation (m)	171.2	168.8	168.1	168.2	170.6	164.9	169.0	168.3
Soil Type	Silty Clay (CI)	Silty Clay (CL)	Silty Clay (CL)	Silty Clay (CL)	Silty Clay (CL)	Silty Clay (CL)	Silty Clay (CL)	Silty Clay (CL)
e_0 - Initial Void Ratio	0.822	0.895	0.806	0.969	0.732	0.661	0.783	0.794
P'_0 - In situ effective vertical stress (kPa)	245	237	104	70	175	216	166	213
P'_c - Preconsolidation Pressure (kPa)	1170	260	210	285	900	365	570	415
OCR - Overconsolidation Ratio	4.8	1.1	2.0	4.1	5.2	1.7	3.4	2.0
C_c - Compression Index	0.252	0.290	0.229	0.306	0.174	0.149	0.163	0.206
C_r - Recompression Index	0.019	0.020	0.017	0.043	0.007	0.003	0.023	0.007
C_v - Coefficient of Consolidation in NC range ($m^2/year$)	8.4 – 17.8	12.7 – 20.4	6.4 – 10.5	5.8 – 11.0	6.1 – 7.7	19.4 – 30.1	25.3 – 33.1	13.9 – 19.6
C_{vr} - Coefficient of Consolidation in OC range ($m^2/year$)	13.4 – 17.5	20.7	30.8	21.3 – 23.1	2.4 – 4.3	46.4	45.1 – 54.6	22.3

The ratio of preconsolidation pressures to vertical effective stress ($OCR = P'_c / P'_0$) derived from the Oedometer test results indicate that the silty clay is overconsolidated. The OCR ratio inferred



from CPTUs shows an heavily overconsolidated crust with OCR generally ranging from about 10 to 30. Beneath the crust, the silty clay is slightly overconsolidated with inferred OCR ranging between 1 and 2.

The vertical coefficient of consolidation, c_v , measured during the Oedometer test is approximately 5 to 33 m^2/yr in the normally consolidated range and approximately 21 to 55 m^2/yr for the overconsolidated range. The compressibility characteristics will vary with depth in accordance with the moisture content and shear strength profiles.

In addition to the vertical coefficients of consolidation (c_v) obtained from Oedometer tests, horizontal coefficients of consolidation (c_h) were measured at various depths using CPTUs. Table 5-2 summarizes the results of the pore water dissipation tests.

Table 5.2: Horizontal Coefficient of Consolidation (c_h) from CPTU Dissipation Test

CPTU ID	Depth (m)	Approx. Elevation (m)	c_h (m^2/yr)
SCPT18-01	12.8	171.0	16
	15.8	168.0	74
SCPT18-02	10.8	169.2	74
	13.8	166.2	26

The results of two Consolidated Isotropically Undrained (CIU) triaxial tests carried out on selected samples of the silty clay are presented in Appendix B. The test results indicate that silty clay has an effective cohesion of 5 kPa and a drained friction angle ranging from 23 degrees to 27 degrees.

5.10 Silty Clay Till

A deposit of reddish brown silty clay till was encountered underlying the silty clay in Boreholes 18-03 to 18-06. The presence of silty clay till was also inferred in Borehole 18-08 below the silty clay deposit although a sample of the till was not recovered to confirm the soil type. The till generally contains some sand to with sand, and trace gravel. Cobbles were also encountered in the till deposits. Glacial tills inherently contain cobbles and boulders.

The thickness of the till deposit ranged from 3.0 m to 6.4 m. The surface of the deposit was encountered at depths ranging between 21.6 m and 30.8 m. The base of the deposit was encountered at depths ranging from 25.2 m and 35.4 m (Elev. 150.7 m and 148.9 m).

The SPT 'N' values recorded in the till deposit ranged from 12 blows per 0.3 m penetration to 50 blows for less than 0.3 m of penetration, indicating stiff to hard consistency. However, the majority of 'N' values exceeded 30 blows indicating a hard consistency. The natural moisture contents measured on samples of the till ranged from 9 percent and 35 percent with typical values between



20 percent and 35 percent.

The results of grain size distribution analyses carried out on selected samples of the silty clay till are presented on the Record of Borehole Sheets in Appendix A and on Figure B19 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	2 to 10
Sand	13 to 35
Silt	31 to 52
Clay	24 to 43

The results of Atterberg Limits tests carried out on a sample of the silty clay till are shown on Figures B35 in Appendix B and summarized below:

Soil Property	Percentage (%)
Liquid Limit	28
Plastic Limit	13
Plasticity Index	15

The results of the Atterberg Limit tests indicate that the silty clay till has low plasticity (CL).

5.11 Silt and Sand Till

A deposit of grey to reddish brown silt and sand till was encountered underlying the silty clay in Boreholes 18-07, 18-09 to 18-17 and 18-19 to 18-27, underlying the sandy silt in Borehole 18-01, underlying the silty clay till in Boreholes 18-04 and 18-05, and underlying the silty clay in Borehole 18-18. The till generally contains trace to some clay and trace to some gravel. Cobbles were also encountered in the till deposits. Glacial tills inherently contain cobbles and boulders. Drill casing refusal was encountered in the lower part of this deposit in a number of the boreholes and coring was required to get through these obstructions. The lower part of the till may also contain slabs of bedrock.

Where fully penetrated, the till deposit ranged from 1.4 m to 8.2 m thick. A number of boreholes were terminated in this till. The surface of the deposit was encountered at depths ranging between 12.4 m and 33.8 m.

The SPT 'N' values recorded in the deposit ranged from 7 blows per 0.3 m penetration to 100 blows for less than 0.3 m of penetration indicating a loose to very dense conditions. However, the majority of the 'N' values exceeded 50 blows per 0.3 m of penetration suggesting typically very dense conditions. The natural moisture contents measured on samples of the till ranged from 7



percent and 27 percent with typical values less than 15 percent.

The results of grain size distribution analyses carried out on selected samples of the silt and sand till are presented on the Record of Borehole Sheets in Appendix A and on Figure B20 to B22 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	5 to 30
Sand	11 to 41
Silt	27 to 54
Clay	9 to 25

The results of Atterberg Limits tests carried out on selected samples of the fine-grained portion of the silt and sand till are shown on Figures B36 in Appendix B and summarized below:

Soil Property	Percentage (%)
Liquid Limit	17 to 20
Plastic Limit	10 to 11
Plasticity Index	7 to 9

The results of the Atterberg Limit tests indicate that the this till has slight to low plasticity (CL-ML to CL).

5.12 Silt to Silty Sand

A deposit of grey to reddish brown silt to silty sand was encountered underlying the silty clay in Borehole 18-01 and underlying the silt and sand till in Boreholes 18-10 and 18-15 to 18-19. The silt to silty sand was also encountered in Boreholes 18-18 and 18-24 to 18-26 interbedded within the silty clay deposit. The silt to silty sand generally contains trace clay and trace gravel. However, in some of the boreholes, greater amounts of clay and gravel and some cobbles were encountered within the deposit. Drill casing refusal was encountered in this deposit in some of the boreholes and coring was required to get through these obstructions. The lower part of this deposit may also contain slabs of bedrock.

The deposit ranged from 0.5 m to 5.9 m thick. The surface of the deposit was encountered at depths ranging between 11.7 m and 27.7 m (Elev. 167.0 m and 153.8 m).

The SPT 'N' values recorded in the deposit ranged from 18 blows per 0.3 m penetration to 100 blows per 0.025 m of penetration. The majority of the 'N' values exceeded 30 blows per 0.3 m of penetration indicating a dense to very dense condition. The natural moisture contents measured



on samples of the silt to silty sand ranged from 8 percent and 28 percent and were generally between 15 percent and 25 percent.

The results of grain size distribution analyses carried out on selected samples of the silt to silty sand are presented on the Record of Borehole Sheets in Appendix A and on Figure B23 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	0 to 73
Silt	22 to 91
Clay	4 to 26

5.13 Dolostone Bedrock

Dolostone bedrock was encountered underlying the overburden in all of the boreholes advanced at the proposed abutment and pier locations. The table below summarizes depths to bedrock and top of bedrock elevations encountered in the boreholes.

Table 5.1 - Top of Bedrock

Foundation Element	Borehole Number	Top of Bedrock	
		Depth below existing road grade / native ground surface (m)	Elevation (m)
South Abutment	18-03	35.4	148.9
	18-04	35.3	148.9
	18-05	35.2	149.1
Pier 4	18-06	25.2	150.4
	18-07	25.3	150.1
	18-08	24.8	151.1
Pier 3	18-09	26.4	148.6
	18-10	26.3	149.0
	18-11	26.3	149.0
Pier 2	18-12	21.5	150.7
	18-13	22.3	151.5
	18-14	22.3	150.8
Pier 1	18-15	20.4	151.0
	18-16	20.7	150.9
	18-17	20.0	151.3



Foundation Element	Borehole Number	Top of Bedrock	
		Depth below existing road grade / native ground surface (m)	Elevation (m)
North Abutment	18-18	29.1	151.0
	18-19	29.1	151.0
	18-20	29.2	150.9

In general, the bedrock is described as slightly weathered, grey dolostone with largely horizontal to sub-horizontal joints.

Total Core Recovery (TCR) in the core runs was generally 100%. Solid Core Recovery (SCR) in the runs ranged from 38 percent to 100 percent and Rock Quality Designation (RQD) values ranged from 0 percent to 100 percent. The RQD values in the first runs (upper portion of the rock) ranged from 0% to 98% and were typically between 70% and 90% indicating fair to good rock quality for the upper portion of the rock. The RQD values in the second and third runs (lower portion of the rock) typically ranged from 80 percent to 100 percent indicating good to excellent rock quality, except for occasional zones of 13 percent to 34 percent in Boreholes 18-04 and 18-05 indicating very poor to poor rock quality. The Fracture Index (FI) of the rock, expressed as number of fractures per 0.3 m of core, ranged from greater than 25 near the top of the rock to 0 below the upper portion of the rock but was generally between 0 and 3.

The unconfined compressive strength (UCS) of the rock, estimated from the results of point load tests ranged from about 71 to 244 MPa indicating strong to very strong intact rock cores. These estimated rock strength values are based on correlation with point load test results that were conducted on selected intact rock cores recovered from the boreholes. The point load test results are included on the borehole logs in Appendix A and presented in Appendix B.

5.14 Groundwater Conditions

Standpipe piezometers were installed in a number of boreholes to permit long term monitoring of the groundwater level. The details of the piezometer installations and groundwater levels measured in the piezometers are presented in Table 5.2.

Table 5.2 - Piezometer Details and Groundwater Levels

Borehole Number	Location	Date	Groundwater Level		Screen Location (m)		Native Material at Screen
			Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	
18-02	South Approach	July 12, 2018	12.6	170.5	21.3	161.8	Silty Clay
18-03	South Abutment	July 12, 2018	5.1	179.2	36.6	147.7	Silty Clay Till / Dolostone Bedrock
18-05		July 12, 2018	12.6	171.6	36.6	147.6	Silt and Sand Till / Dolostone Bedrock
18-06	Pier 4	May 24, 2018	3.9	171.7	25.9	149.7	Silty Clay Till / Dolostone Bedrock
18-08		May 24, 2018	4.6	171.4	21.3	154.7	Silty Clay
18-09	Pier 3	-	N/A*	-	27.4	147.6	Silt and Sand Till / Dolostone Bedrock
18-11		May 24, 2018	3.8	171.5	27.4	147.9	Silt and Sand Till / Dolostone Bedrock
18-12	Pier 2	May 24, 2018	0.8	171.4	21.3	150.9	Silt and Sand Till
18-14		May 24, 2018	2.9	170.2	18.3	154.8	Silty Clay / Silt and Sand Till
18-15	Pier 1	May 24, 2018	0.1	171.3	12.2	159.2	Silty Clay
18-17	Pier 1	May 24, 2018	0.2	171.1	18.0	153.3	Silt and Sand Till / Silty Sand
18-18	North Abutment	-	-	-	25.9	154.2	Silt and Sand Till / Silt and Sand
18-20		July 12, 2018	6.6	173.5	27.4	152.7	Silt and Sand Till



Borehole Number	Location	Date	Groundwater Level		Screen Location (m)		Native Material at Screen
			Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	
18-21	North Approach	July 12, 2018	7.0	171.9	22.6	156.3	Silt and Sand Till

* Piezometer could not be found during site visit for water level readings, and appears to have been removed

Preliminary GA drawings indicate the water level in the Welland River to be at Elevation 170.87m on January 27, 2018.

The above water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected. It is anticipated that the groundwater conditions in the bridge area are governed by the Welland River. In particular, the groundwater and river water levels may be at a higher elevation after periods of significant or prolonged precipitation, or after snowmelt.

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario, supplied and operated drill rigs for the drilling, sampling and in-situ testing operations for the field investigation. The boreholes within the river floodplain were drilled with a track-mounted drill rig while the boreholes through the embankments were drilled with a truck-mounted drill rig.

The borehole drilling was supervised on a full-time basis by Ms. Eckie Siu, who logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing. The cone penetration testing was supervised by Mr. Liam Steers. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET, of Thurber.

Routine soil classification testing and some oedometer testing was performed by Thurber. Other oedometer testing and triaxial testing was performed by Golder.



THURBER ENGINEERING LTD.



Geoff Lay, P.Eng.
Geotechnical Engineer



Sydney Pang, P.Eng.
Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF WELLAND RIVER TWIN BRIDGE STRUCTURES
QUEEN ELIZABETH WAY (QEW)
CITY OF NIAGARA FALLS, ONTARIO
LAT. 43.046111°, LONG. -79.121667°
G.W.P. 2430-15-00**

GEOCRES No. 30M03-307

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report presents interpretation of the geotechnical data in the factual portion of this report and provides foundation recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed Welland River twin bridge structures replacement, the grade raise at the approaches and associated QEW platform widening.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of WSP and MTO, and shall not be used or relied upon for any other purposes or by any other parties. Contractors including design-build contractors must make their own interpretation based on the factual data in the first part of this report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Each of the two existing QEW twin bridges is a 290.8 m long, 18-span, steel-girder composite bridge comprised of a reinforced concrete deck and steel I-girders supported on reinforced concrete piers and abutments on timber piles. The bridges carry the northbound lanes (NBL) and southbound lanes (SBL) of the QEW in a north-south orientation over the Baden-Powell Park trail, a Canadian Pacific Railway (CPR) corridor, the Welland River, and Oakwood Drive.

The preliminary General Arrangement (GA) drawing dated June 2018 shows the existing piers and abutments supported on a combination of spread footings and timber piles.



Based on the preliminary GA drawing, the existing bridges will be replaced with a 300 m long, 5-span welded steel plate girder and concrete deck bridge. No piers are proposed in the river however the piers will be in the floodplain and the abutments will be at the QEW grade. The spans range from 43 m to 80 m in length and the bridge will be 27.85 m wide.

The highway grade to the proposed structure will be raised up to 2.3 m at the south approach and up to 2.5 m at the north approach. The south approach grade raise will extend from the south abutment (Sta. 10+200) to approximately 410 m south of the south abutment (Sta. 10+610). The north approach grade raise will extend from the north abutment (Sta. 21+550) to approximately 290 m north of the south abutment (Sta. 21+260).

The preliminary GA drawing indicates the proposed use of deep foundations to support the new abutments and piers.

The discussion and recommendations presented in this report are based on the information provided by WSP and on the factual data obtained during the course of this investigation.

8 STRUCTURE CLASSIFICATION

In accordance with the currently applicable Canadian Highway Bridge Design Code (CHBDC) (2014) CSA S6-14, the analysis and design of structures are influenced by its importance category and consequence classification. Such designations are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation of Ontario (MTO).

For the purpose of reporting, this structure has been classified as a Major-Route Bridge with Typical Consequence based on CHBDC S6-14 Sections 4.4.2 and 6.5.2, respectively.

Based on the above classification and Table 6.1 in Section 6.5.2 in the CHBDC, a consequence factor, ψ , of 1.0 has been used for assessing factored Ultimate Limit States (ULS) and Serviceability Limit States (SLS) geotechnical resistances. Should the consequence classification changes, the geotechnical assessment and recommendations will need to be reviewed and revised as necessary.

9 FOUNDATION DESIGN

In general, the subsurface stratigraphy below the embankment fill consists of a relatively thick deposit of silty clay overlying a deposit of dense to very dense silt and sand till. In some boreholes, the silt and sand till was interlayered with silty clay till and silty sand to sandy silt. The overburden soils were underlain by dolostone bedrock. Cobbles and boulders were encountered or inferred



in the till layers. The till layers just above the bedrock may contain pieces or fragments of bedrock. The groundwater levels measured in piezometers ranged from 0.1 m to 12.6 m below ground surface (Elev. 179.2 m to 170.2 m).

Based on the subsurface conditions and project requirements at this site, initial consideration was given to supporting the structure using the following foundation types:

- Spread footings on native soils or engineered fill
- Augered caissons (drilled shafts) socketed into bedrock
- Steel H-piles driven into the very dense (100-blow) glacial till or to bedrock
- Steel pipe piles driven into the very dense (100-blow) glacial till or to bedrock

A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix H. A preferred foundation alternative from a geotechnical engineering and constructability perspective is recommended. Recommendations for feasible foundation alternatives are presented in the following sections.

Shallow spread footings on native soils or engineered fill are not considered appropriate to support the bridge abutments and piers in view of the relatively low bearing resistance available from the compressible clay and the risk of large footing settlement. Accordingly, this option has not been developed further.

Augered caissons (drilled shafts) are technically possible but carry a higher risk with respect to installation which would likely involve advancing the caisson hole using temporary liners and slurry for stabilizing the sidewall and the base. This risk is particularly high in the floodplain where the groundwater is practically at the ground surface. The cost effectiveness of this alternative is anticipated to be less than that of driven piles and this option is not recommended at this site.

Steel H-piles driven into bedrock or to refusal in the very dense glacial till are considered a feasible foundation alternative for the bridges. This foundation option would require use of pile caps which would require localized excavation and may require the use temporary protection systems and dewatering especially for those located within the floodplain. It is assumed that the new pile caps would be “perched” within the approach embankments at the abutment locations. This foundation option would permit integral abutment design should it be considered. The locations of the new piles should be selected so as not to interfere with the existing timber piles.



Vibration as a result of pile driving and seating within dolostone bedrock or very dense silt and sand till could have adverse effects on the adjacent existing foundations and structures. A vibration and settlement monitoring program should be implemented as discussed in Section 16 below.

Open ended steel pipe piles may also be considered as a foundation alternative. All pipe piles should be driven to practical refusal which is anticipated to be achieved on dolostone bedrock or within the very dense silt and sand till. After seating the pile, the interior of each pipe should be filled with structural grade concrete. It should be noted that pipe piles driven into very dense or hard soils are more prone to pile tip damage and may cause more vibration in comparison to driven H-piles.

Issues on new pile locations relative to the existing timber piles and shallow footings, vibration and settlement monitoring are similar to those outlined above for driven H-piles.

Recommended Foundations

From a foundation engineering perspective and based on the subsurface conditions, steel H-piles driven into bedrock or the very dense glacial till are recommended for this site.

9.1 Driven Steel H-Piles

The soil conditions at the site are considered suitable for the use of driven steel H-piles.

9.1.1 Axial Resistance

It is recommended that the H-piles be driven to the dolostone bedrock or the very dense silt and sand till. The surface of the silt and sand till deposit was encountered at depths ranging between 12.4 m and 33.8 m (Elev. 161.1 m and 150.4 m). The bedrock surface was encountered at depths ranging between 20.0 m and 35.4 m (Elev. 151.5 m and 148.6 m). The shallower depths are referenced with the floodplain and the deeper depths are referenced with the QEW grade.

The estimated pile tip elevations and recommended axial geotechnical resistances for steel HP 310 x 110 and HP 360 x 132 piles are provided in the table below.



Table 9.1 – Preliminary Design Geotechnical Resistances and Pile Tip Elevations

Location (Reference Boreholes)	Estimated Pile Tip Elevation (m)	Founding Stratum	Factored ULS (kN)	Factored SLS (kN)
NBL Structure				
South Abutment (18-03 & 18-04)	148.9	Dense Silt and Sand Till or Dolostone Bedrock	1,500 (HP 310 x 110) 1,800 (HP 360 x 132)	1,250 (HP 310 x 110) 1,550 (HP 360 x 132)
Pier 4 (18-06 & 18-07)	150.1	Dense Silt and Sand Till or Dolostone Bedrock	1,200 (HP 310 x 110) 1,500 (HP 360 x 132)	1,000 (HP 310 x 110) 1,300 (HP 360 x 132)
Pier 3 (18-09 & 18-10)	148.6	Very Dense Silt and Sand Till or Dolostone Bedrock	1,300 (HP 310 x 110) 1,600 (HP 360 x 132)	1,100 (HP 310 x 110) 1,400 (HP 360 x 132)
Pier 2 (18-12 & 18-13)	150.7	Very Dense Silt and Sand Till or Dolostone Bedrock	1,300 (HP 310 x 110) 1,600 (HP 360 x 132)	1,100 (HP 310 x 110) 1,400 (HP 360 x 132)
Pier 1 (18-15 & 18-16)	150.9	Very Dense Silt and Sand Till or Dolostone Bedrock	1,150 (HP 310x 110) 1,400 (HP 360 x 132)	950 (HP 310x 110) 1,200 (HP 360 x 132)
North Abutment (18-18 & 18-19)	151.0	Very Dense Silt and Sand or Dolostone Bedrock	1,400 (HP 310 x 110) 1,800 (HP 360 x 132)	1,200 (HP310x110) 1,500 (HP 360 x 132)
SBL Structure				
South Abutment (18-04 & 18-05)	148.9	Very Dense Silt and Sand Till or Dolostone Bedrock	1,500 (HP 310 x 110) 1,800 (HP 360 x 132)	1,250 (HP 310 x 110) 1,550 (HP 360 x 132)
Pier 4 (18-07 & 18-08)	150.1	Very Dense Silt and Sand Till or Dolostone Bedrock	1,200 (HP 310 x 110) 1,500 (HP 360 x 132)	1,000 (HP 310 x 110) 1,300 (HP 360 x 132)
Pier 3 (18-10 & 18-11)	149.0	Very Dense Silt and Sand Till or Dolostone Bedrock	1,300 (HP 310 x 110) 1,600 (HP 360 x 132)	1,100 (HP 310 x 110) 1,400 (HP 360 x 132)
Pier 2 (18-13 & 18-14)	150.8	Very Dense Silt and Sand Till or Dolostone Bedrock	1,300 (HP 310 x 110) 1,600 (HP 360 x 132)	1,100 (HP 310 x 110) 1,400 (HP 360 x 132)

Location (Reference Boreholes)	Estimated Pile Tip Elevation (m)	Founding Stratum	Factored ULS (kN)	Factored SLS (kN)
Pier 1 (18-16 & 18-17)	150.9	Very Dense Silt and Sand Till or Dolostone Bedrock	1,150 (HP 310 x 110) 1,400 (HP 360 x 132)	950 (HP 310 x 110) 1,200 (HP 360 x 132)
North Abutment (18-19 & 18-20)	150.9	Very Dense Silt and Sand to Silt and Sand Till or Dolostone Bedrock	1,400 (HP 310 x 110) 1,800 (HP 360 x 132)	1,200 (HP 310 x 110) 1,500 (HP 360 x 132)

The above resistances are based on the piles being driven to refusal in the very dense till deposit since most piles may not reach bedrock, but could meet refusal in the dense till several metres above the bedrock. The actual pile tip elevations will be controlled as described in Section 9.1.3 Pile Installation.

Should the piles fully penetrate the glacial till and be seated into bedrock, the design Factored Geotechnical Resistance at ULS should be 2,000 kN for HP 310 x 110 and 2,400 kN for HP 360 x 132. The SLS condition does not govern geotechnical design of piles founded on bedrock.

The values of the Factored Geotechnical Resistance at ULS were assessed based on static analysis assuming a Consequence Factor equal to 1 (Typical), and a geotechnical resistance factor equal to 0.4 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The SLS values correspond to a maximum pile settlement of 25 mm within glacial tills. The Geotechnical Resistance at SLS was assessed based on static analysis assuming a geotechnical resistance factor of 0.8 for typical degree of understanding of the subsurface conditions. SLS resistance does not govern for piles founded on bedrock.

The structural resistance of the pile must be checked by the structural designer.

9.1.2 Pile Tips

Pile tip protection is recommended for driven H-piles to prevent pile damage when setting the piles in or driving the piles through the very dense till. The tips of all driven H-piles must be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent.

9.1.3 Pile Installation

Pile installation should be in accordance with OPSS.PROV 903.



Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance should be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile". "R" must have a value of twice the design load at ULS calculated by the structural engineer.

To facilitate pile installation, embankment fill through which piles will be driven must not contain any material with particle sizes greater than 75 mm.

Glacially derived soils inherently contain cobbles and boulders. At this site, the piles will have to be driven through very dense/hard glacial tills and therefore difficult driving conditions should be expected. In order to protect the piles while being driven through boulders, cobbles and harder/denser zones to achieve the required tip elevations and soil resistance, as recommended above the pile tips be reinforced with Titus Steel Standard H-points or an approved equivalent. Should a pile achieve the design ultimate geotechnical resistance at an elevation higher than that indicated above, the Contract Administrator (CA) should be informed immediately and should consult with the design team for resolution. Over-driving must be avoided to minimize the risk of damaging the pile.

The Contractor must be alerted to the pile driving conditions, testing, pile protection, avoidance of over-driving etc. as outlined above. Suggested texts for an NSSP are included in Appendix J to this effect.

9.1.4 Downdrag

EPS is being considered as fill for the grade raise. While EPS should help mitigate ground settlements and assuming the zero loading option is not used, it is possible that downdrag forces could develop along the length of the abutment piles embedded within compressible clays due to some remaining ground settlements. For design purposes, an unfactored downdrag load of 400 kN per pile should be used to evaluate the impact of downdrag as per CHBDC Commentary Clause C6.11.4.10. The factored dead load and downdrag load at the neutral plane, without live loads, should not exceed the factored structural resistance of a pile. The downdrag load does not affect the geotechnical resistance of the pile at ULS.

9.2 Driven Steel Pipe Piles

Steel pipe piles, driven open ended to achieve practical refusal on dolostone bedrock or within the very dense sand and silt till ("100-blow till") may also be used to support the abutments or



piers. It should be noted that pipe piles driven into hard/very dense till deposits are more prone to pile tip damage in comparison to H-piles.

For planning and design purposes, the estimated elevations at which the piles are expected to develop the required resistance are given in Table 9.1 above.

After the pile is seated, the interior of the pile should be filled with 35 MPa concrete.

9.2.1 Axial Resistance

A 324 mm or a 406 mm diameter pipe pile section driven to practical refusal within the glacial till may be used. For axial resistance, the geotechnical resistances presented in Table 9.2 below may be used.

Table 9.2 – Design Axial Resistance for Pipe Piles

Foundation Element	Pipe Section 324 mm diameter 12.7 mm thick wall		Pipe Section 406 mm diameter 12.7 mm thick wall	
	Factored ULS (kN)	SLS (kN)	Factored ULS (kN)	SLS (kN)
NBL Structure				
South Abutment (18-03 & 18-04)	1,250	1,050	1,800	1,500
Pier 4 (18-06 & 18-07)	1,000	850	1,450	1,200
Pier 3 (18-09 & 18-10)	1,100	900	1,600	1,300
Pier 2 (18-12 & 18-13)				
Pier 1 (18-15 & 18-16)	1,000	800	1,400	1,150
North Abutment (18-18 & 18-19)	1,200	1,000	1,700	1,400
SBL Structure				
South Abutment (18-04 & 18-05)	1,250	1,050	1,800	1,500
Pier 4 (18-07 & 18-08)	1,000	850	1,450	1,200
Pier 3 (18-10 & 18-11)	1,100	900	1,600	1,300
Pier 2 (18-13 & 18-14)				

Pier 1 (18-16 & 18-17)	1,000	800	1,400	1,150
North Abutment (18-19 & 18-20)	1,200	1,000	1,700	1,400

The above resistances are based on the pipe piles being driven to refusal in the very dense till deposit since most piles may not reach bedrock, but could meet refusal in the dense till several metres above the bedrock. The reference pile tip elevations are the same as those provided in Table 9.1. The actual pile tip elevations will be controlled as described in Section 9.1.3 Pile Installation.

Should the piles fully penetrate the glacial till and be seated into bedrock, the design Factored Geotechnical Resistance at ULS should be 2,000 kN for the 324 mm diameter x 12.7 mm wall thickness pipe pile, and 2,800 kN for the 406 mm diameter x 12.7 mm wall thickness pipe pile. The SLS condition does not govern geotechnical design of piles founded on bedrock.

The values of the Factored Geotechnical Resistance at ULS were assessed based on static analysis assuming a Consequence Factor equal to 1 (Typical), and a geotechnical resistance factor equal to 0.4 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The SLS values correspond to a maximum pile settlement of 25 mm. The Geotechnical Resistance at SLS was assessed based on static analysis assuming a geotechnical resistance factor of 0.8 for typical degree of understanding of the subsurface conditions.

The structural resistance of the pile must be checked by the structural designer.

9.2.2 Pile Tips

Pile tip protection should be provided for open ended pipe piles. It is recommended that the pile tips be reinforced with Titus Steel Open Cutting Shoe or an approved equivalent.

9.2.3 Pile Installation

Pipe pile installation should be carried out as discussed in section 9.1.3 above.

9.2.4 Downdrag

Downdrag on pipe piles should be assessed as outlined in section 9.1.4 above using the outside surface area of the pipe that would be in contact with the compressible clays.



9.3 Lateral Resistance

The preliminary GA drawing indicates that the lateral loads will be handled by battered piles. In addition to battered piles, lateral bridge loadings can be geotechnically resisted by the driven piles through passive pressure developed along the embedded portion of the piles below the abutment stems.

9.3.1 Lateral Resistance in Soil

The geotechnical lateral resistance of a pile in cohesionless soil may be calculated using a coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

	k_s	=	$n_h z / D$	(kN/m ³)
	p_{ult}	=	$3 \gamma' z K_p$	(kPa)
Where	z	=	depth of embedment along pile (m)	
	D	=	pile width or diameter (m)	
	n_h	=	coefficient related to soil density (kN/m ³)	
	γ'	=	submerged unit weight (kN/m ³)	
	K_p	=	coefficient of passive lateral earth pressure	

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

	k_s	=	$67 S_u / D$	(kN/m ³)
	p_{ult}	=	$9 S_u$	(kPa)
Where	S_u	=	undrained shear strength (kPa)	
	D	=	pile width or diameter in metres	

The above equations and recommended parameters in Table 9.3 below may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.



Table 9.3 – Soil Parameters for Lateral Pile Resistance

Foundation Unit	Soil Type	Elevation (m)		γ' (kN/m ³)*	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
South Abutment	Silty Clay Fill	178	175.5	20	-	-	80
	Silty Clay - Hard	175.5	174	11	-	-	200
	Silty Clay - Stiff	174	172	9	-	-	60
	Silty Clay - Firm	172	165	8	-	-	40
	Silty Clay - Stiff	165	161	9	-	-	60
	Silty Clay - Very Stiff	161	154	10	-	-	75
	Silty Clay Till - Hard	154	151	11	-	-	200
	Silt and Sand Till - Very Dense	151	149	11	7,000	3.7	-
Pier 4	Silty Clay – Stiff to Very Stiff	174	171	20	-	-	90
	Silty Clay - Firm	171	164	8	-	-	40
	Silty Clay - Stiff	164	154	9	-	-	60
	Silty Clay Till - Stiff	154	150	10	-	-	75
Pier 3	Silty Clay - Very Stiff	174	171	20	-	-	90
	Silty Clay - Firm	171	161	8	-	-	30
	Silty Clay - Stiff	161	154	9	-	-	60
	Silt and Sand Till - Very Dense	154	149	11	7,000	3.7	-
Pier 2	Silty Clay - Soft to Firm	174	172	17	-	-	35
	Silty Clay - Stiff	172	170	9	-	-	60
	Silty Clay - Firm	170	164	8	-	-	40
	Silty Clay - Stiff	164	156	9	-	-	60
	Silt and Sand Till - Dense to Very Dense	156	152	11	7,000	3.7	-

Table 9.3 – Soil Parameters for Lateral Pile Resistance

Foundation Unit	Soil Type	Elevation (m)		γ' (kN/m ³)*	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
Pier 1	Silty Clay - Soft	167	165	7	-	-	20
	Silty Clay - Firm	165	161	8	-	-	40
	Silty Clay - Stiff	161	157	9	-	-	75
	Silt and Sand Till - Compact to Very Dense	157	155	11	6,000	3.5	-
	Silty Sand to Sandy Silt - Compact to Very Dense	155	151	11	6,000	3.5	-
North Abutment	Silty Clay Fill	178.5	171	19	-	-	75
	Silty Clay - Firm	171	168	8	-	-	40
	Silty Clay – Soft to Firm	168	163	7	-	-	25
	Silty Clay - Very Stiff	163	161	10	-	-	100
	Silt and Sand Till - Compact to Very Dense	161	156	11	6,000	3.5	-
	Silt and Sand - Very Dense	156	151	11	7,000	3.7	-

*Buoyant unit weight below the water table.

The spring constant, K_s , for analysis may be obtained by the expression, $K_s = k_s L D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width or diameter (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} L D$. This represents the ultimate load at which geotechnical failure of the pile occurs and will not support any additional load at greater displacement.



The group efficiency factors can be calculated based on side-by-side and line-by-line factors shown in Figures C6.11.3(r), C6.11.3(s), and C6.11.3(t) of the CHBDC 2014, S6.1-14 (Commentary).

9.4 Frost Depth

The design depth of frost penetration at this site is 1.2 m as per OPSD 3090.100. The base of pile caps must be provided with a minimum 1.2 m earth cover, or its thermal equivalent, as protection against frost action.

10 ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the abutments should consist of free-draining granular material conforming to Granular A or B Type II specifications (OPSS.PROV 1010). The granular material should be placed to the extents shown in OPSD 3101.150 where applicable.

Earth pressures acting on the structure may be assumed to be triangular and governed by the characteristics of the abutment backfill. For a fully-drained condition, the pressures should be computed in accordance with the CHBDC (2014) but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where: p_h = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Table 10.1)
 γ = unit weight of retained soil (see Table 10.1)
 h = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC (2014), a compaction surcharge should be added. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501. Heavy compaction equipment should not be used adjacent to the abutment walls.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

If the structure allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the structure does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC (2014).

It is recommended that perforated sub-drains and/or weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the abutment walls. Reference may be made to OPSD 3101.150 where appropriate.

11 APPROACH EMBANKMENTS

Based on our review of available GEOCREs information, the QEW SBL south approach embankment has a history of distress due to settlement and lateral movement (GEOCREs No. 30M3-212). Following construction of the SBL embankment in 1955, cracks developed in the pavement. The pavement was subsequently resurfaced in 1965/1966 and again in 1983, however the pavement continued to experience cracking. In 1994, a foundation investigation was



competed to investigate the cause of the pavement cracking. Based on the results of the investigation, the cracking and embankment movement was attributed to improper function of the subdrains and possible leakage from a manhole which resulted in a perched groundwater condition in the fill and settlement of the fill due to fines migration. A stabilizing berm was constructed along the south face of the QEW SBL south approach embankment in an attempt to arrest further movement.

The cross-section drawings provided by WSP indicate that the stabilizing berm was constructed between approximately Sta. 10+200 and 10+375. The drawings also indicate that the proposed grade raise at the approach embankments to the new structures will be in the order of 2.5 m at the north abutment and 2.1 m at the south abutment.

11.1 Global Embankment Stability

Stability analyses were carried out for the proposed grade raises at selected sections of the approach embankments to the proposed bridges. The stability analyses were carried out utilizing the commercially available slope stability analysis program Slope/W (Version 7) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses. Analyses were completed for both static and seismic loading conditions.

The results of the stability analyses are presented on Figures I1 to I33 in Appendix I. The results are also summarized in Table 11.1 below.



Table 11.1 – Summary of Computed Factors of Safety

Locations and Types of Analysis	Approximate Embankment Height Incl. Grade Raise (m)	Factor of Safety (FOS)			Figure Number(s)
		Short Term	Long Term	Seismic	
South Approach - South Abutment Area (Sta. 10+222)					
Existing Condition	10	-	1.6	-	I1
Granular Fill Grade Raise		1.4	1.4	-	I2, I3
Cellular Concrete Grade Raise		1.5	1.5	1.1	I4, I5, I6
EPS Fill Grade Raise		1.5	1.5	1.1	I7, I8, I9
North Approach - North Abutment Area (Sta. 21+544)					
Existing Condition	10	-	1.6	-	I10
Granular Fill Grade Raise		1.3	1.3	-	I11, I12
Cellular Concrete Grade Raise		1.5	1.5	1.1	I13, I14, I15
EPS Fill Grade Raise		1.6	1.6	1.2	I16, I17, I18
South Approach - Grassy Brook Culvert Area (Sta. 10+325)					
Existing Condition	10	-	1.7	-	I19
Granular Fill Grade Raise		1.3	1.4	-	I20, I21
Cellular Concrete Grade Raise		1.6	1.6	1.1	I22, I23, I24
EPS Fill Grade Raise		1.7	1.7	1.2	I25, I26, I27
South Approach – Forward Slopes					
Cellular Concrete Grade Raise	10	1.7	1.7	1.2	I28, I29, I30
EPS Fill Grade Raise		1.7	1.8	1.2	I31, I32, I33

Stability analyses were carried out to assess the stability of the existing embankments. The results are presented in Figures I1, I10, and I19. Figures I1 and I10 present the results for the existing south and north approach embankments, respectively. Figure I19 presents the result for the existing embankment at the Grassy Brook culvert location. The computed Factors of Safety (FOS) ranged from about 1.6 to 1.7 indicating that the existing embankments are currently stable with side slopes inclined at approximately 2H : 1V.

The results of stability analyses for an embankment grade raise using granular fill are presented in Figures I2, I3, I11, I12, I20 and I21. FOS ranging from about 1.3 to 1.4 were computed for the



short-term condition (Figures I2, I11, I20). These FOS exceed the minimum factors of safety of 1.3 typically adopted for the short-term condition. For the long-term condition, the computed FOS also ranged from about 1.3 and 1.4 (Figures I3, I12 and I21) and were less than the minimum FOS of 1.5 typically adopted for the long-term condition.

Figures I4, I5, I6, I13, I14, I15, I22, I23, I24, I28, I29, and I30 present the results of stability analyses for an embankment grade raise using 2.1 m to 2.5 m of cellular concrete overlain with an assumed 1 m thick pavement structure. FOS ranging from about 1.5 to 1.7 were computed for the short-term condition (Figures I4, I13, I22 and I28) and exceed the minimum FOS of 1.3. For the long-term condition, the computed FOS also ranged from 1.5 to 1.7 (Figures I5, I14, I23 and I29). The FOS for the seismic condition were in the order of 1.1 to 1.2 (Figures I6, I15, I24, I30).

Figures I7, I8, I9, I16, I17, I18, I25, I26, I27, I31, I32, and I33 present the results for a grade raise using 2.1 m to 2.5 m thickness of EPS blocks overlain with a 1 m thick pavement structure. All computed FOS ranged from 1.5 to 1.7 and therefore exceeded the minimum FOS required for the short-term and long-term conditions.

Based on the results of the stability analyses, global stability of the embankments is not expected to be an issue if the grade raise and platform widening are completed using EPS blocks or cellular concrete with side slopes not steeper than 2H:1V. For grade raise with granular fill, the long-term FOS were less than 1.5.

11.2 Settlement

Settlement analyses were carried out for the proposed grade raise along the approach embankments to assess the magnitudes and rates of foundation settlements during construction and post construction (long term) using the commercially available software Settle3D developed by Rocscience. The geotechnical parameters used in the settlement analyses were determined from the geotechnical laboratory testing (e.g. 1D incremental consolidation test), in-situ testing (e.g. Standard Penetration Test – SPT, Cone Penetration Test – CPT) and empirical soil index correlations.

The currently applicable MTO embankment settlement criteria for design (July 2010) stipulates that the acceptable post-construction settlement are: 25 mm for the first 20 m behind the new abutments, and 50 mm between 20 m and 50 m behind the new abutments, 75 mm between 50 m and 75 m behind the new abutments, and 100 mm greater than 75 m behind the abutments.



The results of the settlement analyses using granular fill for the grade raise are presented in Table 11.2 below. For the south approach embankment, it is estimated that a 2.1 m grade raise at abutment using granular fill will produce approximately 50 mm of post-construction settlement beneath the raised and widened embankment platform. For the north approach, it is estimated that a 2.5 m grade raise will produce approximately 35 mm of post-construction settlement. If EPS blocks are used and there is zero net loading on the foundation soils (i.e. the existing granular fill materials are sub-excavated and replaced with EPS), the total foundation settlements due to the grade raise should essentially be zero. At the Grassy Brook culvert, it is expected that a grade raise using granular fill could produce up to 50 mm of post-construction foundation settlement.

Based on the results of the settlement analyses, in order to satisfy the MTO settlement criteria, at the north approach, the EPS should extend a distance of approximately 35 m behind the abutments (i.e. from approximately Sta. 21+550 to 21+515) including a 5H:1V transition zone and beyond Sta. 21+515 granular fill could be used. At the south approach, the EPS should extend a distance of approximately 170 m behind the abutments (i.e. from approximately Sta. 10+200 to 10+370) to include the south approach embankment and the fill over Grassy Brook culvert and a 5H:1V transition zone.

Table 11.2 – Summary of Computed Settlements Due to Grade Raise Using Granular Fill

Location	Station	Maximum Grade Raise (m)	Settlement During Construction over 6 months (mm)	Post Construction Settlement over 20 years after Construction (mm)	Total Settlement (mm)
South Approach	10+200 (Abutment)	2.1	46	48	94
	10+210	2.1	46	48	94
	10+220	2.2	48	50	98
	10+230	2.2	48	50	98
	10+240	2.3	50	52	102
	10+250	2.3	50	52	102
	10+260	2.3	50	52	102
	10+270	2.3	50	52	102
	10+280	2.3	50	52	102
	10+290	2.2	48	50	98
	10+300	2.2	48	50	98
North Approach	21+550 (Abutment)	2.5	35	36	71

Location	Station	Maximum Grade Raise (m)	Settlement During Construction over 6 months (mm)	Post Construction Settlement over 20 years after Construction (mm)	Total Settlement (mm)
	21+540	2.5	35	36	71
	21+530	2.4	33	34	67
	21+520	2.3	32	33	65
	21+510	2.2	31	32	63
	21+500	2.2	31	32	63
	21+490	2.1	30	31	61
	21+480	2.0	29	30	59
	21+470	2.0	29	30	59
	21+460	1.8	27	28	55
	21+450	1.7	26	27	53

Mid-height berms comprising 2 m wide benches should be incorporated along the length of embankments with heights at or exceeding 8 m as per OPSD 202.010. Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H : 1V, the existing earth or fill slope must be benched in accordance with OPSD 208.010.

11.3 EPS Embankment Design

Lightweight EPS fill proposed at this site for the grade raise to mitigate settlements should be designed with a thickness adequate to compensate for the additional weight of the pavement structure. There are alternatives between a grade raise using EPS only with zero net loading on foundation soils, or using some combination of EPS and granular fill that would satisfy the MTO embankment post construction settlement criteria (2010) and structural requirements for the existing structures.

It is assumed that the EPS blocks have a bulk unit weight of 1 kN/m³. A minimum 1 m thick granular fill cover (including the pavement structure) should be provided over the EPS. The thickness of the granular fill over the EPS at the abutments must be sufficient so that the abutment wall can develop sufficient lateral resistance. A concrete slab should be provided between the pavement structure and the EPS blocks and a polyethylene sheet must be provided between the slab and the EPS blocks. The side slopes of the EPS fill must also be provided with at least 1 m of soil cover.



Selection of the grade of EPS must be appropriate for the pavement and traffic loading. Design of the EPS embankment should be carried out in accordance with Transportation Research Board NCHRP Report 529, "Guideline and Recommended Standard for Geofoam Applications in Highway Embankments".

To avoid crushing the EPS, heavy construction equipment (i.e. dressed lifting cranes) must not be permitted on the EPS embankment.

To mitigate differential settlements between the EPS grade raise transitioning into granular fill, the EPS should be gradually reduced in thickness at a taper of 5H : 1V where the EPS meets the granular fill.

Two options for mitigating settlements due to grade raise are as follows:

Option 1 - Zero Net Loading

This can be accomplished by sub-excavation of the existing approach embankment and replacing with EPS to create a zero net loading effect on the foundation soils. The required depth of sub-excavation will vary along the alignment. This option will result in minimal settlement along the alignment where there would be grade raise. Given the structural requirements at the Grassy Brook Culvert, it is recommended that an EPS configuration with zero net loading be used above the culvert, along with a 5H : 1V taper in both longitudinal directions along QEW.

Option 2 - Combination of EPS and Granular Fill

Behind the Welland River Bridge abutments, some combination of EPS and granular fill may be considered. Figures J1 and J2 in Appendix J illustrate reference embankment configurations for the south and north approaches, respectively. Table 11.3 below summarizes the estimated settlements and major design requirements for these two scenarios.

Table 11.3 – Estimated Settlements for Selected EPS Configurations

Location	Grade Raise	Sub-excavation	EPS Thickness	Settlement during Construction over 6 months	Post Construction Settlement over 20 years	Total Settlement
South Approach	2.2 m	Existing asphalt only	1.2 m*	19 mm	22 mm	41 mm
North Approach	2.5 m	Existing asphalt and 0.5 m of granular fill	2.0 m*	25 mm	6 mm	31 mm



* Overlain by 150 mm thick concrete slab

These reference designs may be applied for a distance of 20 m behind the approaches to be followed by a 5H : 1V taper within the transition zone. Both configurations will result in ground settlements less than 25 mm that would satisfy the MTO embankment post construction settlement criteria (2010) within 20 m behind the abutments. The estimated settlements during construction range between 19 and 25 mm.

It is important to note that the above reference EPS designs are for information only. The design-build contractor should evaluate and confirm the final design configurations based on relevant design issues including, but not limiting to, the following:

- Assess if the existing bridges are capable of sustaining up to 25 mm of settlement without affecting their structural integrity, taking into account that there may already be pre-existing settlements in the structure.
- Assess the impact of potential downdrag on the existing timber piles and settlement implications on the adjacent operating roadway behind the temporary protection systems.
- Carry out monitoring of potential movements of the existing bridge and adjacent infrastructures during construction.

Buoyancy of the EPS is not considered to be a concern at this site given the depth of the water level. Any perched water should be drained prior to placing EPS blocks which must be installed in the dry. Subdrains should be provided below the EPS blocks to keep the EPS dry.

In areas where EPS blocks are installed adjacent to or close to the roadway protection, the roadway protection must not be extracted after completing the work since this extraction process will disturb the EPS. Where the protection system is left in place, the top shall be removed to a depth as recommended by OPSS 539. An NSSP to this effect is attached in Appendix K.

Should EPS be selected as grade raise fill, a Special Provision addressing the supply and installation of the EPS should be included in the contract documents. A sample Special Provision is included in Appendix K.

Prior to placement of the EPS blocks, the embankment subgrade preparation and construction should be carried out in accordance with OPSS.PROV 206 and OPSS.PROV 501. Any conventional fill material that would be required should consist of OPSS.PROV 1010 Selected



Subgrade Material (SSM) or Granular A or B Type II materials. Benching of existing fill slopes should be carried out as per OPSD 208.010 prior to placing new fill.

Slope face treatment/surficial erosion protection for embankment slopes should be provided in general accordance with OPSS.PROV 804.

12 EXCAVATION AND GROUNDWATER CONTROL

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). At the abutments, the foundation excavations would extend through the existing embankment fill. At the piers, the excavations would extend through the firm to very stiff native silty clay. For the purposes of the OHSA, the embankment fill and the firm to very stiff native silty clay may be classified as Type 3 soil.

While excavations for the new abutment foundations are expected to be maintained above the groundwater level, the excavations at the piers will extend below the groundwater level. A groundwater cut-off system (cofferdam or similar measure) is recommended for the piers located within the floodplain to minimize dewatering requirements and potential environmental impacts. It is expected that the excavations for the piers which are not located near the river can be dewatered using sumps and pumps. All pile caps should be constructed in the dry.

The design of the dewatering system is the responsibility of the Contractor. The design the dewatering system must take into account the maximum river level that would likely be reached during construction. Filtered sumps must be properly designed to control loss of fines and ground loss. The dewatering system should be designed in accordance with SP FOUN0003 which amends OPSS 902.

The dewatering scheme must be effective to maintain the groundwater level at a depth of at least 0.5 m below the final subgrade level. Dewatering must remain operational and effective until the pier foundations are constructed and backfilled. Suggested wording for an NSSP in this regard is included in Appendix K.

It is understood that the requirements for a Ministry of Environment (MOE) Permit to Take Water (PTTW) or Environmental Activity and Sector Registry (EASR) will be assessed by WSP.

Water discharged from unwatering operations or displaced during concrete placement may not be suitable for direct discharge to the river. The contract documents must alert the contractor to this fact and include an item for treatment of the water to the satisfaction of MOE, Ministry of



Natural Resources (MNR), Department of Fisheries and Oceans (DFO) or other agencies having jurisdiction, prior to discharge to the river.

13 TEMPORARY PROTECTION SYSTEMS AND COFFERDAMS

Temporary protection (shoring) systems will be required at various locations along the QEW for maintaining live traffic at all times during abutment construction and approach reconstruction. Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring systems is a function of the construction sequence and relative flexibility of the wall and these factors must be considered when designing the shoring system.

The selection and design of the temporary protection systems is the responsibility of the contractor. The design of the such systems must incorporate traffic loading and surcharge loading due to the construction equipment and operations. For conceptual planning and costing purposes, interlocking sheetpiles installed to sufficient depth through the embankment fill and into the underlying silty clay deposit are considered suitable for the shoring.

Within the floodplain, groundwater cutoff may be provided in the form of interlocking sheet pile enclosures installed to sufficient depth into the silty clay deposit.

The following soil parameters may apply for design of the temporary protection systems and the cofferdam enclosures with horizontal backfill.

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
K_a	=	0.33 (approach fills)
	=	0.41 (native silty clay)
K_p	=	3.0 (approach fills)
	=	2.4 (native silty clay)

14 EROSION AND SCOUR PROTECTION

Erosion and scour protection must be provided around the pier foundations, along the river banks and over all surfaces that may be in contact with the river flow. Erosion and the depth of scour of the river must be determined by a river hydraulics specialist who should assess the erosion and

scour protection requirements. Reference should be made to OPSS 511 for selection of rock protection materials and construction.

Slope face treatment/surficial erosion protection should be provided for embankment slopes in general accordance with OPSS.PROV 804.

15 SEISMIC CONSIDERATIONS

According to Clause 4.4.4 of the CHBDC 2014, an earthquake with a 2475-year return period or 2% probability of exceedance in 50 years should be used for seismic design.

In accordance with the bridge code, the selection of the seismic site classification is based on the conditions encountered in the upper 30 m of the stratigraphy.

The seismic site classification for this site is based on the N_{60} criteria, which corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.205 g as per the National Building Code of Canada (NBCC). The above PGA value should be assigned a site coefficient of 1.10 based on Table 4.8 of the CHBDC.

In accordance with Clause 4.6.5 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in the table below may be used.

Table 15.1 – Lateral Earth Pressure Coefficients during Earthquake (K_E)

Loading Condition	OPSS Granular A or Granular B Type II $\phi' = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or III $\phi' = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33
At-rest (K_{OE})**	0.49	0.53
Passive (K_{PE})	3.6	3.2

* After Mononobe and Okabe

** After Woods

16 ADJACENT STRUCTURES AND BURIED UTILITIES

It is recommended that the exact locations and elevations of any utilities present in the vicinity of the site be established by the designer and compared with the extent of the potential work zones related to the proposed demolition and new construction works. These utilities must not be damaged during or following construction and, if necessary, should be relocated and/or otherwise

protected. The settlement and displacement/rotation tolerances of the utilities should also be established.

Pile driving will be required close to the adjacent existing bridges. Therefore, it is recommended that the following be carried out prior to commencement of foundation construction:

- Carry out pre-construction condition survey including documentation of any existing distress on the bridge foundations and super-structures.
- Implement a vibration and settlement monitoring program during and after construction of the new abutments to assess any potential adverse impact on the existing operating bridges.
- Inspection of the existing operating bridges during foundation construction to monitor if there is any movement or distress.
- The structural designers should assess the magnitude of vibration that would constitute a concern for the stability or serviceability of the existing operational structures prior to their demolition. These limits should be incorporated into the monitoring program as review and alert levels.

17 SOIL CORROSION POTENTIAL

Four samples of soil were submitted to AGAT Laboratories Inc. for analytical testing to evaluate the potential for soil corrosion on buried concrete and metal elements of the foundations. The results of the testing are provided in Appendix E and are summarized as follows:

Table 17.1 – Results of Corrosivity Testing

Borehole	Depth (m)	Soil Type	Resistivity (ohm-cm)	pH	Redox Potential (mV)	Chlorides (µg/g)	Sulphates (µg/g)
18-03	3.0 – 3.7	Silty Clay Fill	741	7.66	196	264	1190
18-10	9.1 – 9.8	Silty Clay	3020	7.86	185	39	197
18-16	15.2 – 15.8	Silt and Sand Till	2840	7.95	175	24	260
18-20	13.7 – 14.3	Silty Clay	2460	7.88	164	15	310



The results of the corrosivity and sulphate analytical tests conducted on the soil samples indicate the following conditions at the locations tested:

- The potential for sulphate attack on concrete foundations from the fill and native soils is considered to be moderate.
- The potential for soil corrosion on metal is considered to be moderate for the native soils and very severe for the fill based on the relatively low resistivity values. The corrosion potential for the fill is considered moderate.
- The effects of road de-icing salts should also be considered when selecting the class of concrete and corrosion mitigation measures.
- Appropriate protection measures are recommended for metal and concrete foundation elements.

18 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to, the following:

1. Obstructions

Till deposits inherently contain cobbles and boulders. These obstructions may affect installation of the driven piles. The Contractor shall be prepared to penetrate and/or drill through these obstructions and extend the foundation elements to the design founding stratum.

2. Pile Lengths

At this site, the piles may reach refusal on the very dense till present above the bedrock. Accordingly, the length of the pile may vary at each foundation element.

3. Foundation Construction Below the Groundwater Level

Excavation for the piers located within the floodplain will extend below the groundwater level. A groundwater cut-off system (cofferdam or similar measure) will need to be implemented to facilitate a reasonably dry condition for construction. The Contractor shall facilitate the equipment, design and operate such systems for the full duration of construction.



19 CLOSURE

Engineering analysis and preparation of the foundation design report was carried out by Mr. Geoff Lay, P.Eng and Dr. Sydney Pang, P.Eng. Dr. P. K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.

THURBER ENGINEERING LTD.



Geoff Lay, P.Eng.
Geotechnical Engineer



Sydney Pang, P.Eng.
Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


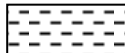



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No 18-01

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
183.7	GROUND SURFACE																		
0.0	ASPHALT																		
0.2	SAND and GRAVEL Dense to Compact Grey Moist (FILL)		1	SS	39		183												
182.4			2	SS	29														
1.3	Silty CLAY, some sand, trace gravel Very Stiff Reddish Brown Moist (FILL)		3	SS	18		182												
			4	SS	21		181												
			5	SS	20		180												
			6	SS	22		179										0	0	
			7	SS	27		178												
			8	SS	29		176												
176.5			9	SS	34		175												
7.2	Silty CLAY, trace to some sand Very Stiff to Hard Reddish Brown Moist						174										0	0	

Continued Next Page


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

RECORD OF BOREHOLE No 18-01

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES
DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL	
	Continued From Previous Page							20	40	60	80	100	20	40	60					
	Silty CLAY , trace to some sand Very Stiff Reddish Brown Moist Firm Wet					173														
			10	SS	15															
			1	TW	PH															
			11	SS	3															
			12	SS	2															

Continued Next Page

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

RECORD OF BOREHOLE No 18-01

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

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			SHEAR STRENGTH kPa																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
								20 40 60 80 100						PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
			14	SS	6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										</

Continued Next Page

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

RECORD OF BOREHOLE No 18-01

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
	Continued From Previous Page																
30.0	SILT and SAND , trace clay, trace gravel Very Dense Grey Moist (TILL)						153										
							152										
151.6			18	SS	100/												
32.1	END OF BOREHOLE AT 32.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.2m, SAND TO 0.3m, CEMENT TO 0.1m THEN ASPHALT TO SURFACE.				0.050												

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-02

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 191.5 E 335 631.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.08 - 2018.04.09 LATITUDE 43.043907 LONGITUDE -79.121663 CHECKED BY GRL

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _P W W _L WATER CONTENT (%)							
183.1	GROUND SURFACE																		
0.0	ASPHALT						183												
0.1	SAND and GRAVEL Dense Grey Moist (FILL)		1	SS	45		182												
181.6																			
1.5	Silty CLAY, some sand, trace gravel Very Stiff Brown Moist (FILL)		2	SS	25		181												
			3	SS	17		180												
			4	SS	15														
							179												
			5	SS	26		178												
177.4																			
5.6	Silty CLAY, trace sand Very Stiff to Hard Reddish Brown to Grey Moist		6	SS	18		177												
							176												
			7	SS	24		175												
			8	SS	54		174												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15 10 5 0
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-02

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 191.5 E 335 631.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.08 - 2018.04.09 LATITUDE 43.043907 LONGITUDE -79.121663 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
	Continued From Previous Page						20	40	60	80	100	20	40	60		GR	SA	SI	CL
	Silty CLAY , trace sand Hard Reddish Brown to Grey Moist		9	SS	47														
	Soft Wet		1	TW	PH														
			10	SS	2														
	Firm																		
			2	TW	PH														
			11	SS	3														
	cobbles at 17.7m																		
			12	SS	3														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-02

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 191.5 E 335 631.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.08 - 2018.04.09 LATITUDE 43.043907 LONGITUDE -79.121663 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
	Continued From Previous Page		13	SS	4		163												
							162												
161.1	Silty CLAY , trace sand Stiff to Very Stiff Reddish Brown to Grey Wet		14	SS	25														
21.9	END OF BOREHOLE AT 21.9m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.12 12.6 170.5																		

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-03

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 239.4 E 335 651.3 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.09 - 2018.04.10 LATITUDE 43.044355 LONGITUDE -79.121260 CHECKED BY GRL

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 (%) 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							
184.3	GROUND SURFACE																		
0.0	ASPHALT																		
0.2	SAND and GRAVEL Dense to Compact Grey Moist (FILL)		1	SS	34		184												
			2	SS	26														
182.7							183												
1.5	Silty CLAY , some sand, trace gravel Very Stiff to Stiff Reddish Brown Moist (FILL)		3	SS	21														
			4	SS	19														
			5	SS	15														
			6	SS	15														
			7	SS	14														
175.6	Silty CLAY , trace sand Hard Reddish Brown to Grey Moist																		
			8	SS	12														
8.7																			
	Silty CLAY , trace sand Hard Reddish Brown to Grey Moist		9	SS	47		175												

Continued Next Page

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

RECORD OF BOREHOLE No 18-03

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 239.4 E 335 651.3 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.09 - 2018.04.10 LATITUDE 43.044355 LONGITUDE -79.121260 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L				
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100		20 40 60			GR SA SI CL	
	Silty CLAY , trace sand Firm Reddish Brown Wet						174							
			1	TW	PH						○			
							173							
							172							
			10	SS	3						┌───○		0 4 42 54	
							171	7.0 ├─┘						
			11	SS	2						○			
							170							
							169	4.5 ├─┘						
			2	TW	PH						○			
	Stiff						168							
							167				┌───○		0 0 64 36	
							166	4.0 ├─┘						
			13	SS	9						○			
							165							
								5.1 ├─┘						

Continued Next Page

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

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	
			NUMBER		
Continued From Previous Page					
	<p>Silty CLAY, trace sand Stiff Reddish Brown Wet</p> <p>Very Stiff occasional sand seams</p>		14	SS	8
			15	SS	17
			16	SS	24
155.3 29.0	<p>Silty CLAY, with sand, trace gravel Hard Reddish Brown Wet (TILL)</p>		17	SS	86/ -0.200

+³, ×³: Numbers refer to Sensitivity

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

METRIC

[illegible]

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-04

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

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			SHEAR STRENGTH kPa					
184.2	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT							20 40 60 80 100					
0.2	SAND and GRAVEL Dense Grey Moist (FILL)		1	SS	42		184						
183.4													
0.8	Sandy GRAVEL , trace silt Dense Brown Wet (FILL)		2	SS	43		183						64 30 6 (SI+CL)
182.7													
1.5	Silty CLAY , some sand, trace gravel Very Stiff Brown Moist (FILL)		3	SS	18		182						
			4	SS	15								
			5	SS	20		181						
							180						
			6	SS	15								0 0 40 60
							179						
			7	SS	20		178						
							177						
			8	SS	25								
							176						
175.5													
8.7	Silty CLAY , trace sand Hard Reddish Brown Moist						175						
			9	SS	39								

Continued Next Page

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

RECORD OF BOREHOLE No 18-04

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL	
	Continued From Previous Page							20	40	60	80	100		20	40	60				
	Silty CLAY , trace sand Stiff Reddish Brown Wet 																			

Continued Next Page

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

METRIC

[illegible]

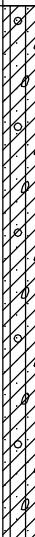
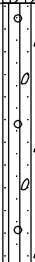

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-04

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)								
								SHEAR STRENGTH kPa										
							○ UNCONFINED + FIELD VANE											
							● QUICK TRIAXIAL × LAB VANE											
							20 40 60 80 100			20 40 60								
30.0	Continued From Previous Page		18	SS	31		154											
	Silty CLAY , some sand, trace gravel, containing cobbles Hard Reddish Brown Wet (TILL)						153											
	casing refusal, switch to coring gravel and cobbles (max. 150mm) from 32.6m to 35.1m						152											
							151											
150.7							150											
33.5	SILT and SAND , some clay, some gravel, containing cobbles Very Dense Reddish Brown Moist (TILL)						149											
148.9			19	SS	100/										11 33 37 19			
35.3	DOLOSTONE BEDROCK slightly weathered, very strong, grey horizontal fracture at 35.4m, 35.5m, 35.8m, 36.1m, 36.4m, 36.6m and 36.7m sub vertical fracture at 35.5m and 35.6m horizontal fracture at 36.9m, 37.0m, 37.1m and 37.2m sub vertical fracture at 37.1m, (50mm) at 37.2m, 37.4m, (100mm) at 37.4m and (75mm) at 37.7m		1	RUN	0.225		148								RUN #1 TCR=100% SCR=95% RQD=92% UCS=147.8MPa (average)			
			2	RUN				147								RUN #2 TCR=100% SCR=100% RQD=34% UCS=123.6MPa (average)		
			3	RUN				146								RUN #3 TCR=100% SCR=100% RQD=100% UCS=180MPa (average)		
145.7																		
38.5	END OF BOREHOLE AT 38.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.8m, SAND TO 0.2m, CEMENT TO 0.1m THEN ASPHALT TO SURAFCE.																	

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

RECORD OF BOREHOLE No 18-05

1 OF 5

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 237.6 E 335 627.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.07 - 2018.04.08 LATITUDE 43.044330 LONGITUDE -79.121719 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
184.2	GROUND SURFACE							20	40	60	80	100	W _P	W	W _L	kN/m ³	GR	SA	SI	CL
0.0 0.1	ASPHALT																			
183.4	SAND and GRAVEL Compact Grey Moist (FILL)		1	SS	27								○							
0.9																				
182.7	SAND, trace gravel, trace silt Compact Reddish Brown Moist (FILL)		2	SS	22								○							
1.5																				
	Silty CLAY, some sand, trace gravel Stiff to Very Stiff Reddish Brown Moist (FILL)		3	SS	11								○							
			4	SS	12								○							
			5	SS	10								○							
			6	SS	8								○							
			7	SS	14								○							
			8	SS	16								○							
175.5																				
8.7	Silty CLAY, trace sand Hard Reddish Brown Moist																			
			9	SS	50								○							

Continued Next Page

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

RECORD OF BOREHOLE No 18-05

2 OF 5

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 237.6 E 335 627.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.07 - 2018.04.08 LATITUDE 43.044330 LONGITUDE -79.121719 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	Continued From Previous Page						20 40 60 80 100	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _P W W _L WATER CONTENT (%)					
	Silty CLAY , trace sand Very Stiff to Stiff Reddish Brown Moist 												

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-05

3 OF 5

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 237.6 E 335 627.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.07 - 2018.04.08 LATITUDE 43.044330 LONGITUDE -79.121719 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	Silty CLAY , trace sand Firm Reddish Brown Wet		14	SS	1		164							
							163	4.0 +						
							162							
	Very Stiff		15	SS	15		161							0 9 41 50
							160							
							159							
			16	SS	13		158							
							157							
							156							
	Very Stiff		17	SS	16		155							

Continued Next Page

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

RECORD OF BOREHOLE No 18-05

4 OF 5

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 237.6 E 335 627.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.07 - 2018.04.08 LATITUDE 43.044330 LONGITUDE -79.121719 CHECKED BY GRL

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
	Continued From Previous Page							20	40	60	80	100				
								○ UNCONFINED	+	FIELD VANE						
								● QUICK TRIAXIAL	×	LAB VANE						
								20	40	60	80	100	20	40	60	
153.4	Silty CLAY , trace sand Very Stiff Reddish Brown Wet						154									
30.8	Silty CLAY , some sand, trace gravel, containing cobbles Hard Reddish Brown Wet (TILL)						153									
			18	SS	36		152									3 17 37 43
	casing refusal, switch to coring gravel and cobbles (max. 100mm) from 32.6m to 34.7m						151									
150.4							150									
33.8	SILT and SAND , some gravel to gravelly, some clay, containing cobbles Very Dense Grey Moist (TILL)						149									
149.1			19	SS	100/		149								FI	
35.2	DOLOSTONE BEDROCK slightly weathered, strong to very strong, grey				0.100		148								>25	RUN #1 TCR=100% SCR=50% RQD=0% UCS=71.2MPa (average)
	vertical fracture (25mm) at 35.7m and 35.9m sub vertical fracture (50mm) at 35.8m		1	RUN			147								>25	RUN #2 TCR=67% SCR=38% RQD=0% UCS=226.5MPa (average)
	sub vertical fracture (50mm) at 36.6m and (25mm) at 36.8m		2	RUN			146								5	
	vertical fracture (25mm) at 36.9m						145								>25	RUN #3 TCR=98% SCR=55% RQD=13% UCS=135.9MPa (average)
	vertical fracture (50mm) at 36.9m and (125mm) at 37.8m sub vertical fracture (50mm) at 37.3m, (25mm) at 38.0m and (50mm) at 38.1m		3	RUN											>25	RUN #4 TCR=100% SCR=100% RQD=100% UCS=167.8MPa (average)
	highly broken zone (50mm) at 37.3m, (75mm) at 37.6m and (50mm) at 37.8m		4	RUN											10	
															3	
															0	
															0	
144.4															1	
39.8	END OF BOREHOLE AT 39.8m.														0	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-05

5 OF 5

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 237.6 E 335 627.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.07 - 2018.04.08 LATITUDE 43.044330 LONGITUDE -79.121719 CHECKED BY GRL

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.12 12.6 171.6																

RECORD OF BOREHOLE No 18-06

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 304.6 E 335 650.6 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.26 - 2018.03.27 LATITUDE 43.044934 LONGITUDE -79.121341 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
175.6	GROUND SURFACE												
0.0 0.1	TOPSOIL: (75mm)												
174.9	Sandy SILT , some clay, trace gravel, trace rootlets		1	SS	11								
0.7	Compact Dark Brown Moist (FILL)		2	SS	13								0 0 39 61
	Silty CLAY , some sand, trace gravel Stiff Brown Moist (FILL)		3	SS	28								
173.3													
2.3	Silty CLAY , trace sand, trace gravel Very Stiff Reddish Brown Moist		4	SS	20								
			5	SS	16								
			6	SS	6								0 0 53 47
	Firm Grey Wet												
			1	TW	PH								
			7	SS	5								0 0 59 41
			8	SS	4								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-06

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 304.6 E 335 650.6 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.26 - 2018.03.27 LATITUDE 43.044934 LONGITUDE -79.121341 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL
	Continued From Previous Page							20	40	60	80	100							
	Silty CLAY , trace sand, trace gravel Firm to Stiff Reddish Brown Wet <																		

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-07

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 278.7 E 335 638.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.28 - 2018.03.28 LATITUDE 43.044702 LONGITUDE -79.121495 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)		
175.4	GROUND SURFACE							20	40	60	80	100	20	40	60				
0.0	TOPSOIL: (50mm)																		
174.7	Silty SAND , some clay, trace gravel, trace roots Compact Dark Brown Moist (FILL)		1	SS	10									○					
			2	SS	14									○					
			3	SS	14										○				
173.2	Clayey SILT , some sand, trace gravel, trace organics Stiff to Very Stiff Reddish Brown Moist (FILL)																		
			4	SS	16										○				
			5	SS	10											○			
2.2	Silty CLAY , trace sand Very Stiff to Stiff Reddish Brown Moist																		
			6	SS	5											○			
			7	SS	4											○			
			1	TW	PH												○		
	Wet																		
	Firm																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-08

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 276.5 E 335 616.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.27 - 2018.03.28 LATITUDE 43.044683 LONGITUDE -79.121766 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL		
176.0	GROUND SURFACE							20	40	60	80	100									
0.0	TOPSOIL: (75mm)																				
0.1	Silty SAND, some clay, some gravel, trace rootlets Loose		1	SS	8								○					11	53	22	14
175.2	Dark Brown Moist (FILL)		2	SS	14		175						○								
0.8	Silty CLAY, trace to some sand, trace gravel, trace organics Stiff to Very Stiff Reddish Brown Moist		3	SS	25		174						○								
			4	SS	20								○					0	0	52	48
			5	SS	15		173						○								
							172														
			6	SS	10		171						○								
							170			4.0	+										
	Firm Wet		1	TW	PH		169						○								
							168			3.2	+										
			7	SS	3		167						○					0	0	53	47
							166			3.5	+										
			8	SS	6								○								

Continued Next Page

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

RECORD OF BOREHOLE No 18-08

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 276.5 E 335 616.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.27 - 2018.03.28 LATITUDE 43.044683 LONGITUDE -79.121766 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				GR	SA	SI	CL
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L							
	Silty CLAY , some sand Firm Reddish Brown Wet 																

Continued Next Page

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

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE
<div>DYNAMIC CONE PENETRATION RESISTANCE PLOT</div> <div>SHEAR STRENGTH kPa</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>WATER CONTENT (%)</div> <div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div> <div>UNIT WEIGHT γ</div> <div>REMARKS & GRAIN SIZE DISTRIBUTION (%)</div>					
	Continued From Previous Page				
152.2	Silty CLAY , some sand Stiff Reddish Brown Wet		14 SS 10		
23.8					
151.1	probable silty clay till from 23.8m to 24.8m gravel and cobbles (max. 125mm) from 23.8m to 24.4m		15 SS 6		
24.8	DOLOSTONE BEDROCK slightly weathered, very strong, grey rubble zone from 25.0m to 25.2m horizontal fracture at 25.4m, 25.6m, 25.8m and 26.1m sub vertical fracture at 25.9m horizontal fracture at 26.5m, 26.7m, 26.7m, 27.0m and 27.3m sub vertical fracture at 27.5m and 27.7m		1 RUN 2 RUN 3 RUN		
147.6					
28.3	END OF BOREHOLE AT 28.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.05.24 4.6 171.4				

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-09

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 350.3 E 335 648.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.17 - 2018.03.18 LATITUDE 43.045346 LONGITUDE -79.121363 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIQUID LIMIT MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
175.0	GROUND SURFACE							20 40 60 80 100		20 40 60			
0.0	TOPSOIL: (125mm)							○ UNCONFINED + FIELD VANE					
0.1	Organic SILT, some sand, trace gravel, trace roots		1	SS	6			● QUICK TRIAXIAL × LAB VANE					
174.2	Firm												
0.9	Dark Brown												
	Moist												
	Silty CLAY, trace to some sand, trace gravel		2	SS	10		174						
	Stiff to Very Stiff												
	Reddish Brown		3	SS	20		173						
	Moist												
			4	SS	17		172						
			5	SS	10		171						
							170						
	Firm		6	SS	7								
							169						
			7	SS	3								
							168						
			1	TW	PH		167						
							166						
			8	SS	2								

Continued Next Page

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

RECORD OF BOREHOLE No 18-09

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 350.3 E 335 648.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.17 - 2018.03.18 LATITUDE 43.045346 LONGITUDE -79.121363 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W _P	W		W _L				
Continued From Previous Page							○ UNCONFINED + FIELD VANE													
							● QUICK TRIAXIAL × LAB VANE													
							20	40	60	80	100	20	40	60						
Silty CLAY , trace sand Firm Reddish Brown Moist 																				

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0 (%) STRAIN AT FAILURE

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE
<div>DYNAMIC CONE PENETRATION RESISTANCE PLOT</div> <div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div><div>20406080100</div></div> <div><div>PLASTIC LIMITNATURAL MOISTURE CONTENTLIQUID LIMIT</div><div>w_pww_L</div><div>WATER CONTENT (%)</div><div>204060</div></div>					
<div>UNIT WEIGHTγkN/m³</div> <div>GRSA SICL</div>					
Continued From Previous Page					
153.4	Silty CLAY, trace sand Stiff Reddish Brown Moist		15SS8		154
21.6	SILT and SAND, some clay, trace gravel, containing cobbles Loose to Very Dense Reddish Brown Wet (TILL)		16SS7		153
	casing refusal, switch to coring gravel and cobbles (max. 175mm) from 23.5m to 25.9m				152
					151
					150
					149
148.6			17SS100/ 0.200		148
26.4	DOLOSTONE BEDROCKslightly weathered, very strong, grey sub vertical fracture at 26.5m		1RUN		147
	horizontal fracture at 27.2m		2RUN		146
	sub vertical fracture (75mm) at 28.1m and (25mm) at 29.1m horizontal fracture at 28.3m, 28.6m and 28.8m		3RUN		
145.4	END OF BOREHOLE AT 29.6m. Piezometer installation consists of				
29.6					

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-09

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 350.3 E 335 648.7 ORIGINATED BY ES
DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.03.17 - 2018.03.18 LATITUDE 43.045346 LONGITUDE -79.121363 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.																

ONTMT452 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity


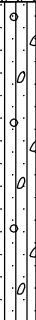
ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-10

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL			
	Continued From Previous Page							20	40	60	80	100										
157.5	Silty CLAY , trace sand Firm Reddish Brown Wet switch to casing cobble from 13.0m to 13.9m Stiff																					
			10	SS	3																	
			11	SS	5																	
			12	SS	9																	
			13	SS	9																	
			14	SS	11																	
17.8	SILT and SAND , gravelly, trace clay Compact Reddish Brown Wet (TILL)		15	SS	12																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-10

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

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			SHEAR STRENGTH kPa						
								20 40 60 80 100						
	Continued From Previous Page													
154.0	SILT and SAND , gravelly, trace clay Compact Reddish Brown Wet (TILL)		16	SS	13		155							30 34 27 9
21.3	SILT , clayey, trace sand, containing cobbles Very Dense Reddish Brown Moist						154							
							153							
	casing refusal, switch to coring gravel and cobbles (max. 75mm) from 23.1m to 25.9m		17	SS	100/ 0.250		152							0 5 69 26
							151							
							150							
149.0			18	SS	100/ 0.175		149							
26.3	DOLOSTONE BEDROCK slightly weathered, very strong, grey horizontal fracture at 26.5m, 26.6m, 26.8m, 26.9m, 27.0m and 27.4m		1	RUN			148							
	sub horizontal fracture (25mm) at 27.3m						147							
	horizontal fracture at 27.9m, 28.0m, 28.4m and 28.5m		2	RUN			146							
	sub vertical fracture (50mm) at 29.3m		3	RUN										
145.5														
29.8	END OF BOREHOLE AT 29.8m.													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

[illegible]

RECORD OF BOREHOLE No 18-11

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 337.2 E 335 614.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.14 - 2018.03.15 LATITUDE 43.045230 LONGITUDE -79.121789 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
175.3	GROUND SURFACE							20 40 60 80 100		W _P W W _L			
0.0 0.1	TOPSOIL: (75mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
174.4	Silty CLAY , some sand, trace rootlets Soft Brown Moist (FILL)		1	SS	3		175				○		
0.9	Silty CLAY , trace to some sand, trace gravel Firm to Stiff Reddish Brown Moist		2	SS	7		174				○		
			3	SS	14						○ —		0 0 52 48
	occasional sand pockets		4	SS	12		173				○		
			5	SS	5		172				○		
							171				○		
			6	SS	3		170				○		
	Wet												
			7	SS	3		169				— ○		0 0 49 51
			1	TW	PH		168					○	
							167					○	0 0 59 41
			8	SS	2								
			2	TW	PH		166				○		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-11

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 337.2 E 335 614.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.14 - 2018.03.15 LATITUDE 43.045230 LONGITUDE -79.121789 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL			
	Continued From Previous Page							20	40	60	80	100	W _P	W	W _L							
	Silty CLAY , trace to some sand Firm to Very Stiff Reddish Brown Wet																					
			9	SS	3													0	0	53	47	
				10	SS	3																
				11	SS	3																
				12	SS	7																
			13	SS	9														0	18	47	35
	casing refusal at 17.9m on boulder, switched to NQ Coring boulder (275mm) at 18.3m																					
			14	SS	18																	

Continued Next Page

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

RECORD OF BOREHOLE No 18-11

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 337.2 E 335 614.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.14 - 2018.03.15 LATITUDE 43.045230 LONGITUDE -79.121789 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								20 40 60 80 100										
Continued From Previous Page							○ 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				20 40 60							
154.3							155											
21.0	SILT and SAND , clayey, trace gravel, containing cobbles Very Dense Grey Moist (TILL)						154											
							153											
	gravel and cobbles (max. 125mm) from 23.1m to 25.9m		15	SS	50/ 0.125		152											
							151											
							150											
149.0	rubble zone from 26.1m to 27.3m		16	SS	100/ 0.175		149											
26.3	DOLOSTONE BEDROCK slightly weathered, very strong, grey		1	RUN			148											
	horizontal fracture at 26.4m and 27.0m						147											
	horizontal fracture at 27.3m, 27.4m, 28.0m and 28.1m sub horizontal fracture at 27.8m		2	RUN														
	horizontal fracture at 28.3m and 28.5m		3	RUN														
146.0	END OF BOREHOLE AT 29.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.																	
29.3																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity
20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-11

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 337.2 E 335 614.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.14 - 2018.03.15 LATITUDE 43.045230 LONGITUDE -79.121789 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page																
	WATER LEVEL READINGS																
	DATE DEPTH(m) ELEV.(m)																
	2018.05.24 3.8 171.5																

RECORD OF BOREHOLE No 18-12

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 397.7 E 335 643.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.19 - 2018.03.20 LATITUDE 43.045773 LONGITUDE -79.121420 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	20 40 60	GR	SA	SI		CL			
172.2	GROUND SURFACE																	
0.0	TOPSOIL: (75mm) Silty CLAY , trace sand, trace roots Firm Dark Brown Moist		1	SS	4		172											
0.1																		
171.5																		
0.8	Silty CLAY , trace sand, trace gravel, trace roots Firm to Stiff Reddish Brown to Grey Moist		2	SS	7		171											
	occasional wood fibre		3	SS	10		170								0 0 51 49			
	Wet		4	SS	5		169											
			5	SS	4		168	3.2										
			6	SS	3		167	3.0										
			7	SS	3		166											
							165	2.8										
			8	SS	4		164								0 0 68 32			
							163	3.6										
			9	SS	5													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-12

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 397.7 E 335 643.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.19 - 2018.03.20 LATITUDE 43.045773 LONGITUDE -79.121420 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _P	W	W _L			WATER CONTENT (%)	GR	SA	SI	CL	
	Continued From Previous Page							20	40	60	80	100										
	Silty CLAY , trace sand Stiff Grey Wet						162			3.0												
			10	SS	5																	
							161															
										3.4												
			1	TW	PH		160															
	switch to casing						159															
			11	SS	5		158											0	7	45	48	
	casing grinding at 14.5m						157															
			12	SS	13		156															
							155															
155.0			2	TW	PH		154															
17.2	SILT and SAND , some gravel, trace clay, containing cobbles Dense to Very Dense Reddish Brown Moist (TILL)						153															
			13	SS	38														19	41	31	9
			14	SS	100/																	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-12

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 397.7 E 335 643.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.19 - 2018.03.20 LATITUDE 43.045773 LONGITUDE -79.121420 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ 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 (%)						
	Continued From Previous Page				0.075									
150.7			15	SS	100/								FI	
21.5	DOLOSTONE BEDROCK slightly weathered, very strong, grey		1	RUN	0.100								>20	
	horizontal fracture at 21.7m, 21.8m, 22.4m and 22.5m												7	RUN #1
	sub horizontal fracture at 21.6m, 21.8m and 22.3m												0	TCR=100%
	horizontal fracture at 22.6m and 23.5m												3	SCR=95%
													3	RQD=95%
	sub horizontal fracture at 22.6m, 22.9m, 23.1m, 23.3m and 23.4m		2	RUN									2	UCS=121.9MPa (average)
													1	RUN #2
													1	TCR=100%
	sub horizontal fracture at 24.1m		3	RUN									0	SCR=95%
147.6													1	RQD=93%
24.7	END OF BOREHOLE AT 24.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.													UCS=233.9MPa (average)
														RUN #3
														TCR=100%
														SCR=100%
														RQD=100%
														UCS=157.1MPa (average)

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

RECORD OF BOREHOLE No 18-13

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

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			SHEAR STRENGTH kPa						
173.8	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL: (175mm)							20 40 60 80 100						
0.2	Silty CLAY , trace rootlets Soft to Firm Brown to Reddish Brown Wet		1	SS	2		173							
	occasional wood fibres		2	SS	6									0 0 32 68
172.3														
1.5	Silty CLAY , trace sand Stiff to Firm Reddish Brown Moist		3	SS	8		172							
			4	SS	12		171							
			5	SS	6		170							
			6	SS	4		169							0 0 28 72
							168							
			7	SS	3		167							
							166							
			8	SS	3		165							
							164							
			9	SS	3									0 4 53 43

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity


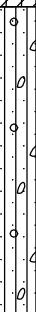
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-13

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	Continued From Previous Page							20 40 60 80 100		20 40 60			GR SA SI CL
156.0	Silty CLAY , trace sand Stiff Reddish Brown to Grey Wet						163	3.2					0 0 51 49
			10	SS	4		162	4.0					
							161						
			11	SS	4		160						
							159	3.3					
			12	SS	4		158						
							157	3.5					
			13	SS	5		156						
							155	4.0					
			14	SS	5		154						
17.8	SILT and SAND , gravelly, some clay, containing cobbles Dense to Very Dense Grey Wet (TILL)		15	SS	48		155					22 35 30 13	
			16	SS	100/		154						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-13

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

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 (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
	Continued From Previous Page				0.050			20	40	60	80	100					GR	SA	SI	CL
							153													
	casing refusal, switch to coring gravel and cobbles (max. 150mm) from 21.4m to 22.1m		17	SS	100/		152													
					0.075															
151.5	rubble zone from 22.1m to 22.3m																FI			
22.3	DOLOSTONE BEDROCK slightly weathered, very strong, grey horizontal fracture at 22.4m, 22.5m, 22.6m, 23.0m, 23.1m and 23.3m		1	RUN			151										4			
																	1			
																	4			
																	1			
	horizontal fracture (50mm) at 23.9m and 24.7m		2	RUN			150										2			
																	1			
																	0			
																	0			
148.5			3	RUN			149										1			
																	0			
25.3	END OF BOREHOLE AT 25.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																0			

ONTMT452 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-14

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 394.0 E 335 608.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.20 - 2018.03.21 LATITUDE 43.045741 LONGITUDE -79.121851 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
173.1	GROUND SURFACE							20 40 60 80 100		W _P W W _L			GR SA SI CL	
0.0	TOPSOIL: (125mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
0.1	Silty CLAY , some sand, trace rootlets Firm Dark Brown Moist		1	SS	5		173				○			
172.5														
0.6	Silty CLAY , trace sand, trace gravel Very Stiff to Stiff Reddish Brown Moist		2	SS	16		172				○			
			3	SS	17		171				○			
			4	SS	13		170				○			
			5	SS	10		169				○			

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-15

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 487.9 E 335 641.6 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.22 - 2018.03.23 LATITUDE 43.046585 LONGITUDE -79.121441 CHECKED BY GRL

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			SHEAR STRENGTH kPa										
171.4	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (50mm)							20	40	60	80	100						
	Silty CLAY , sandy to some sand, trace gravel, trace rootlets Firm Brown Wet (FILL)		1	SS	4		171											
			2	SS	4		170											
169.9																		
1.5	PEAT , roots and rootlets Soft to Very Soft Dark Brown Wet		3	SS	2		169										258	
169.2																	127	
2.2	Organic SILT Soft Dark Brown Wet		4	SS	1		168										147	
			5	SS	0		167											
166.7																		
4.7	Silty CLAY , trace sand Very Soft to Firm Grey Wet		6	SS	2		166											
			1	TW	PH		165											
			2	TW	PH		164											
							163											
			7	SS	5		162											

Continued Next Page

+³ ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	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
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	Silty CLAY , trace sand Stiff Grey Wet												
	cobble (100mm) at 11.0m		8	SS	50/ 0.025								
			9	SS	4								
157.4													
13.9	SILT and SAND , some clay, trace gravel Compact to Very Dense Reddish Brown Moist (TILL)		10	SS	13								
			11	SS	64								
154.6													
16.8	Silty SAND , with gravel, trace clay, containing cobbles Compact to Very Dense Grey Wet		12	SS	50/ 0.100								
	casing refusal, switch to coring cobble (75mm) at 17.7m												
			13	SS	29								
	gravel and cobbles (max. 150mm) from 19.8m to 20.3m		14	SS	100/ 0.075								


+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-15

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 487.9 E 335 641.6 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.22 - 2018.03.23 LATITUDE 43.046585 LONGITUDE -79.121441 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
	Continued From Previous Page				0.025		20	40	60	80	100		W _P	W	W _L		GR SA SI CL	
151.0	rubble zone from 20.3m to 20.4m																	
20.4	DOLOSTONE BEDROCK slightly weathered, strong to very strong, grey horizontal fracture at 20.4m, 20.6m, 20.8m, 21.1m and 21.2m horizontal fracture at 21.4m, 21.6m, 21.7m, 21.9m and 22.0m		1	RUN													FI	
																	>10	
																		2
																		3
			2	RUN													3	
																	>5	
																	3	
			3	RUN													0	
																		0
																		0
147.7	horizontal fracture at 23.5m																0	
23.7	END OF BOREHOLE AT 23.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.05.24 0.1 171.3																1	

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-16

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

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	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
171.5	GROUND SURFACE												
0.0 0.1	TOPSOIL: (75mm)												
	Silty CLAY , with sand, trace roots, occasional wood fibres Firm to Soft Brown Moist (FILL)		1	SS	5		171						
			2	SS	17								0 38 35 27
170.1							170						
1.4	Organic SILT , trace roots Very Soft Dark Brown Wet		3	SS	3								
			4	SS	2		169						
			5	SS	1		168						
166.9							167						
4.6	Silty CLAY , trace sand Firm Reddish Brown Wet		6	SS	3		166						
			7	SS	2		165						
			8	SS	4		164						0 6 48 46
							163						
			1	TW	PH		162						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-16

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE	W _P W W _L	20 40 60	GR SA SI CL						
	Continued From Previous Page																		
	Silty CLAY , trace sand Firm to Stiff Reddish Brown Wet		9	SS	7		161	3.0											
							160	3.5											
			10	SS	8		159												
158.2																			
13.3	SILT and SAND , clayey, trace gravel, containing cobbles Comapct to Very Dense Reddish Brown Moist (TILL)		11	SS	21		158												
							157												
			12	SS	34		156												
							155												
	gravelly zone with cobbles casing refusal, switch to coring		13	SS	50/ 0.125		154												
153.8																			
17.7	Sandy SILT , trace clay, trace gravel Very Dense Reddish Brown Wet		14	SS	68		153												
							152												
			15	SS	50/														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-16

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

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 (%) 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				
Continued From Previous Page																
150.9	DOLOSTONE BEDROCK slightly weathered, very strong, grey horizontal fracture at 21.0m sub vertical fracture (100mm) at 21.1m quartz interbed at 23.3m horizontal fracture at 23.4m				0 100		151								FI	RUN #1 TCR=100% SCR=88% RQD=70% UCS=149.2MPa (average)
20.7			1	RUN			150								>5 1 2	
			2	RUN			149								0 0 0	
			3	RUN			148								0 0 1 0	
147.5																
24.0	END OF BOREHOLE AT 24.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-17

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 483.5 E 335 603.1 ORIGINATED BY ES
DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.03.24 - 2018.03.25 LATITUDE 43.046547 LONGITUDE -79.121914 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
171.3	GROUND SURFACE							20 40 60 80 100		W _p W W _L				
0.0	TOPSOIL: (50mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
	Silty CLAY , sandy to some sand, trace gravel, trace roots Firm Dark Brown Wet		1	SS	6		171							
			2	SS	2		170							
169.9	Organic SILT , trace roots, occasional wood fibres Very Soft to Soft Dark Brown Moist to Wet		3	SS	3		169							
1.4			4	SS	1		168							
			5	SS	0		167							
167.2	Silty CLAY , trace sand Firm Reddish Brown to Grey Wet		6	SS	2		166							
4.1			7	SS	2		165							
			1	TW	PH		164							
			8	SS	3		163							
							162							

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
20
15
10
5
0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-17

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 483.5 E 335 603.1 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.03.24 - 2018.03.25 LATITUDE 43.046547 LONGITUDE -79.121914 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L				
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100		20 40 60			GR SA SI CL	
158.9	Silty CLAY , trace sand Firm Reddish Brown to Grey Wet		9	SS	6		161	3.1					0 0 58 42	
12.4	SILT , clayey, some sand, trace gravel to gravelly, containing cobbles Very Dense Reddish Brown Moist (TILL) casing grinding at 12.8m cobble (150mm) at 14.0m		10	SS	52		159							
			11	SS	50/ 0.125		158							
			12	SS	60		156						10 11 54 25	
154.5			13	SS	41		154							
16.8	Silty SAND , trace clay Dense to Very Dense Reddish Brown Wet		14	SS	83		153						0 73 22 5	
151.3			15	SS	100/		152							

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-18

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 538.9 E 335 628.4 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.12 - 2018.04.12 LATITUDE 43.047048 LONGITUDE -79.121526 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				GR	SA	SI	CL
180.1	GROUND SURFACE							20 40 60 80 100		w _P w w _L							
0.0	ASPHALT						180	○ UNCONFINED + FIELD VANE									
179.8								● QUICK TRIAXIAL × LAB VANE									
0.3	SAND and GRAVEL Compact to Dense Grey Moist (FILL)		1	SS	27					○							
			2	SS	35		179			○							
178.5																	
1.5	Silty CLAY, trace sand, trace gravel Very Stiff to Stiff Brown to Reddish Brown Moist (FILL)		3	SS	16		178			○							
			4	SS	19					○							
							177										
			5	SS	14					○							
							176										
			6	SS	11					○							
							175										
								3.4 +									
							174										
			7	SS	10					○							
							173			3.3 +							
			8	SS	10		172			○							
								3.2 +									
							171										
170.9																	
170.7	ORGANICS trace rootlets Dark Brown Moist		9	SS	10					○							
9.3	Silty CLAY, trace sand Firm to Soft																

0 0 43 57

Continued Next Page

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

RECORD OF BOREHOLE No 18-18

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 538.9 E 335 628.4 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.12 - 2018.04.12 LATITUDE 43.047048 LONGITUDE -79.121526 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				GR	SA	SI	CL
	Continued From Previous Page							20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100						
	Reddish Brown to Grey Wet						170											
			10	SS	6		169											
							168											
			1	TW	PH		167											
							166											
			11	SS	1		165											
							164											
			12	SS	0		163											
							162											
			2	TW	PH		161											
163.0							160											
17.0	SILT , trace sand Compact Reddish Brown Wet						159											
							158											
161.6							157											
18.5	Silty CLAY , trace sand Very Stiff Reddish Brown Moist		13	SS	18		156											
							155											
160.6							154											
19.4	SILT and SAND , some clay, some gravel, trace gravel Very Dense Reddish Brown						153											

Continued Next Page

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

RECORD OF BOREHOLE No 18-18

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 538.9 E 335 628.4 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.12 - 2018.04.12 LATITUDE 43.047048 LONGITUDE -79.121526 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				w _P w w _L				
Continued From Previous Page																
	Wet (TILL)		14	SS	50/ 0.100		160									
							159									
							158									
156.7			15	SS	106		157								9 31 39 21	
23.3	SILT and SAND , trace clay, containing cobbles Very Dense Reddish Brown Wet gravel and cobbles (max. 100mm) from 23.3m to 25.9m						156									
							155									
			16	SS	100/ 0.225		154								0 54 42 4	
							153									
							152									
151.0			17	SS	100/ 0.075		151									
29.1	DOLOSTONE BEDROCK slightly weathered, very strong, grey Clay seam (25mm) at 29.1m and 29.3m		1	RUN												

Continued Next Page




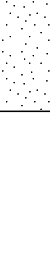

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-18

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 538.9 E 335 628.4 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.12 - 2018.04.12 LATITUDE 43.047048 LONGITUDE -79.121526 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)			
	Continued From Previous Page						20	40	60	80	100									
147.6	Horizontal fracture (25mm) at 29.2m, 29.3m, 29.4m, 29.7mm 29.9m and 30.0m		2	RUN			150									1	RUN #2 TCR=97% SCR=97% RQD=83% UCS=172.9MPa (average)			
																		1		
																			4	
																			2	
32.4	Horizontal fracture (25mm) at 30.7m, 30.9m, 31.1m and 31.3m		3	RUN			149									1	RUN #3 TCR=100% SCR=100% RQD=100% UCS=141.9MPa (average)			
																			3	
																				1
																				0
	Horizontal fracture (25mm) at 32.0m						148													
	END OF BOREHOLE AT 32.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																			

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-19

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES
DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

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 (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20 40 60 80 100									20 40 60			
	Continued From Previous Page																			
	(TILL) casing refusal, switch to coring boulder (350mm) at 19.6m						160													
							159													
			14	SS	33		158									11 36 34 19				
							157													
156.9							156													
23.2	Silty SAND , trace clay Very Dense Reddish Brown Wet		15	SS	100/ 0.275		155									0 70 25 5				
							154													
							153													
			16	SS	100/ 0.250		152													
	gravel and cobbles (max. 125mm) from 27.7m to 29.1m						151													
151.0																				
29.1	DOLOSTONE BEDROCK slightly weathered, very strong, grey																			
	horizontal fracture at 29.2m, 29.4m, 29.6m, 29.8m, 30.0m and 30.1m		1	RUN												RUN #1 TCR=100% SCR=100% RQD=83% UCS=153.1MPa (average)				

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-19

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
	Continued From Previous Page															
	horizontal fracture at 30.4m, 30.5m, 30.7m, 30.9m, 31.4m and 31.6m sub vertical fracture at 30.7m		2	RUN			150							1	RUN #2 TCR=100% SCR=100% RQD=88% UCS=211.5MPa (average)	
		horizontal fracture at 31.8m		3	RUN			149								6
147.5														0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=172.4MPa (average)	
32.6	END OF BOREHOLE AT 32.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CEMENT AND ASPHALT TO SURFACE.													1		
														0		

RECORD OF BOREHOLE No 18-20

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 536.9 E 335 603.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.05 - 2018.04.06 LATITUDE 43.047024 LONGITUDE -79.121986 CHECKED BY GRL

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			SHEAR STRENGTH kPa					
180.1	GROUND SURFACE							20 40 60 80 100					
0.0	ASPHALT							20 40 60 80 100					
0.1	CONCRETE							20 40 60 80 100					
179.7								20 40 60 80 100					
0.4	SAND and GRAVEL Dense Brown to Grey Moist (FILL)		1	GS				20 40 60 80 100					
178.8			1	SS	40			20 40 60 80 100					
1.2	Silty SAND, trace gravel Dense Reddish Brown Moist (FILL)		2	SS	6			20 40 60 80 100					
178.6								20 40 60 80 100					
1.4	Silty CLAY, trace sand, trace gravel Firm to Very Stiff Reddish Brown Moist (FILL)		3	SS	8			20 40 60 80 100					
			4	SS	12			20 40 60 80 100					
								20 40 60 80 100					
			5	SS	15			20 40 60 80 100					
								20 40 60 80 100					
			6	SS	11			20 40 60 80 100					
								20 40 60 80 100					
			7	SS	16			20 40 60 80 100					
								20 40 60 80 100					
			8	SS	21			20 40 60 80 100					
								20 40 60 80 100					
170.1	Wet roots and rootlets							20 40 60 80 100					

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-20

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 536.9 E 335 603.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.05 - 2018.04.06 LATITUDE 43.047024 LONGITUDE -79.121986 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				w _p w w _L								
Continued From Previous Page								20	40	60	80	100	20	40	60					
10.0	Silty CLAY , trace sand Very Stiff Reddish Brown to Grey Wet 																			

Continued Next Page

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

RECORD OF BOREHOLE No 18-20

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 536.9 E 335 603.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.05 - 2018.04.06 LATITUDE 43.047024 LONGITUDE -79.121986 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
159.1	Silty CLAY , trace sand Hard Reddish Brown Moist		14	SS	55/ 0.250		160							
21.0	SILT and SAND , some clay, trace gravel, occasional cobbles Very Dense Reddish Brown Wet (TILL)		15	SS	55		157							8 37 35 20
			16	SS	100/ 0.225		154							
150.9	spoon refusal, switch to coring gravel and cobbles from 29.0m to 29.2m		17	SS	100/ 0.025		151							
29.2	DOLOSTONE BEDROCK slightly weathered, strong to very strong, grey clay seam at 29.5m		1	RUN									FI >5	RUN #1 TCR=87% SCR=81% RQD=74% UCS=179.0MPa (average)

Continued Next Page

+³ ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-20

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 536.9 E 335 603.0 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.05 - 2018.04.06 LATITUDE 43.047024 LONGITUDE -79.121986 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)				
	Continued From Previous Page							20	40	60	80	100		20	40	60					
147.8	horizontal fracture at 29.5m, 29.6m, 29.8m, 30.0m, 30.3m, 30.4m and 30.6m						150														
	sub vertical fracture (25mm) at 30.5m																				
32.3	horizontal fracture at 30.9m, 31.2m, 31.5m and 31.9m		2	RUN			149														
	sub vertical fracture (25mm) at 30.9m and 31.0m																				
											</										

RECORD OF BOREHOLE No 18-21

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 592.1 E 335 623.9 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.17 - 2018.04.17 LATITUDE 43.047527 LONGITUDE -79.121586 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
178.9	GROUND SURFACE													
0.0	ASPHALT													
0.2	SAND and GRAVEL Dense Grey Moist (FILL)		1	SS	42									
177.7			2	SS	47									
1.2	Silty CLAY, trace sand, trace gravel Very Stiff Reddish Brown Moist (FILL)		3	SS	28									
			4	SS	29									0 0 44 56
			5	SS	7									
174.6														
4.3	Silty CLAY, trace sand Very Stiff Reddish Brown to Grey Moist		6	SS	21									0 0 42 58
			7	SS	20									
			8	SS	26									
			1	TW	PH									
	Wet													

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-21

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 592.1 E 335 623.9 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.17 - 2018.04.17 LATITUDE 43.047527 LONGITUDE -79.121586 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
					0.100												
			15	SS	100/ 0.275												
155.8			16	SS	100/												
23.1	END OF BOREHOLE AT 23.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.07.12 7.0 171.9				0.200												

RECORD OF BOREHOLE No 18-22

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

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			SHEAR STRENGTH kPa							
179.4	GROUND SURFACE							20	40	60	80	100			
0.0	ASPHALT							20	40	60	80	100			
0.2	SAND, trace gravel Brown Moist (FILL)			GS			179								
178.7															
0.7	SAND and GRAVEL Dense Brown Moist (FILL)		1	SS	43		178								
177.9															
1.5	SAND, trace gravel Compact Brown Moist (FILL)		2	SS	24		177								
177.5															
1.9	Silty CLAY, trace sand, trace gravel Very Stiff Grey Moist		3	SS	16		176								0 0 49 51
			4	SS	19		175								
	trace rootlets		5	SS	15		174								
	Wet occasional wood fibre		6	SS	16		173								
			7	SS	16		172								0 0 53 47
170.7							171								
8.7	Silty CLAY, trace sand Very Stiff Reddish Brown to Grey Wet		8	SS	21		170								

Continued Next Page

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

RECORD OF BOREHOLE No 18-22

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) W _P W W _L				GR	SA	SI	CL
	Continued From Previous Page							20	40	60	80	100							
	Silty CLAY , trace sand Very Stiff to Stiff Reddish Brown to Grey Wet <																		

Continued Next Page

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

RECORD OF BOREHOLE No 18-22

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
19.9	(TILL) Continued From Previous Page END OF BOREHOLE AT 19.9m. WATER LEVEL AT 5.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.3m, CEMENT TO 0.07m THEN ASPHALT TO SURFACE.				0.075												

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-23

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 641.2 E 335 603.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.19 - 2018.04.19 LATITUDE 43.047968 LONGITUDE -79.121829 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L						
	Silty CLAY , trace sand Firm Reddish Brown Wet							20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE							
			1	TW	PH		167	2.9 +					○			
			10	SS	4		166	2.8 +					○			
								3.0 +								
			11	SS	3		164						— — ○		0 0 62 38	
							163	2.7 +								
			2	TW	PH		162						○			
								2.9 +								
			12	SS	3		161						○			
159.8							160									
17.8	SILT and SAND , some clay, some gravel, occasional cobbles Very Dense Grey Wet (TILL)		13	SS	100/ 0.200		159						○			
							158									

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) 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 (%) GR SA SI CL								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE														
							20	40	60	80	100	20	40	60								
Continued From Previous Page																						
	Casing refusal, switch to coring gravel and cobbles (max. 100mm) from 20.4m to 22.9m		14	SS	60		157							○								
	gravel and cobbles from 24.5m to 25.9m		15	SS	100/ 0.275		156															
151.6 26.1	END OF BOREHOLE AT 26.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.8m, SAND TO 0.2m THEN CEMENT TO SURAFCE.		16	SS	100/ 0.125		155															
			17	SS	100/ 0.200		154															
							153															
							152															

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-24

1 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

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			SHEAR STRENGTH kPa																
181.5	GROUND SURFACE							20	40	60	80	100												
0.0	ASPHALT							20	40	60	80	100												
0.2	SAND and GRAVEL Very Dense to Compact Grey Moist (FILL)		1	SS	63		181																	
			2	SS	12																			
180.2	Silty CLAY , some sand, trace gravel Very Stiff Reddish Brown Moist (FILL)						180																	
1.3			3	SS	17																			
			4	SS	18																			
178.5	Stiff						179																	
3.0			5	SS	12																			
177.4							178																	
4.1																								
								177																
								176																
					7	SS	15		175															
			8	SS	20		174																	
							173																	
			9	SS	26		172																	

Continued Next Page

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

RECORD OF BOREHOLE No 18-24

2 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)							
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L							
								20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE								
171.3																	
10.2	Silty CLAY , trace sand Very Stiff to Stiff Reddish Brown Moist		10	SS	15		171										
							170										
			1	TW	PH		169										
							168	4.2									
	Wet		11	SS	12		167										
							166										
166.7							165										
14.8	Firm		12	SS	7		164										
							163										
			2	TW	PH		162										
			13	SS	4												

Continued Next Page

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

RECORD OF BOREHOLE No 18-24

3 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)			GR	SA	SI	CL	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100	W _P	W	W _L					
	Silty CLAY , trace sand, trace gravel Firm Reddish Brown Wet		14	SS	6		161							○						
158.6																				
22.9	SILT , trace clay Dense Reddish Brown Wet		15	SS	33		158							○				0	0	
158.1																				
23.4	Silty CLAY , trace sand, trace gravel Very Stiff Reddish Brown Wet						157													
						</														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-24

4 OF 4

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP
 DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					

RECORD OF BOREHOLE No 18-25

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
180.8	GROUND SURFACE					▽		<div><div></div><div></div><div></div><div></div><div></div></div>				<div><div></div><div></div><div></div></div>				GR SA SI CL		
0.0	ASPHALT (225mm)							<div><div></div><div></div><div></div><div></div><div></div></div>				<div><div></div><div></div><div></div></div>						
0.2	Gravelly SAND, trace silt Compact Brown Moist (FILL)		1	GS														
			1	SS	24													
179.5																		
1.3	Silty CLAY, trace sand, trace gravel Firm to Very Stiff Brown Moist (FILL)																	
			2	SS	8													
			3	SS	6													
			4	SS	7													
			5	SS	9													
175.2	Soft																	
5.6	occasional oxide staining																	
			6	SS	3													
												</						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-25

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP
DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL		
	Continued From Previous Page							20	40	60	80	100									
	Silty CLAY , trace sand Stiff to Firm Reddish Brown Wet																				
			9	SS	0		170														
							169	5.0													
			1	TW	PH																
							168	2.5													
			2	TW	PH																
166.3																					
14.5	SILT and SAND , trace clay Compact to Dense Reddish Brown Wet						166														
			10	SS	27		165														
			11	SS	32		164											0	40	56	4
			12	SS	46		163														
							162														
161.4																					
19.4	Silty CLAY , trace sand Stiff to Firm Reddish Brown to Brown Wet						161														

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-25

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP
DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20 40 60 80 100	W _P	W	W _L									
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Silty CLAY , trace sand Stiff to Firm Reddish Brown to Brown Wet		13	SS	15		160							○						
			14	SS	5		159							○						
							158													
			15	SS	6		157							○						
							156													
155.5			16	SS	8		155													
25.3	SILT and SAND , some clay, trace gravel Dense Brown Moist (TILL)																			
			17	SS	48									○						
154.3																				
26.5	END OF BOREHOLE AT 26.5m. WATER LEVEL AT 1.8m UPON COMPELTION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.																			

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

RECORD OF BOREHOLE No 18-26

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
178.7	GROUND SURFACE					▽	178	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>													
0.0	ASPHALT (200mm)							<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>													
0.2	Gravelly SAND , trace silt Very Dense Brown Moist (FILL)	<div></div>	1	GS				<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>													
			1	SS	50/ 0.125			<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>													
								<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>													
176.9								▽	177	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>											
1.8	Silty CLAY , trace sand, trace gravel Stiff to Very Stiff Brown to Dark Brown Moist (FILL)	<div></div>	2	SS	13					<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>											
			3	SS	15					<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>											
			4	SS	13					<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>											
174.6										▽	175					<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>					
4.1	Silty CLAY , trace sand, trace organics, trace rootlets Stiff to Very Stiff Dark Brown Moist	<div></div>	5	SS	17	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>															
			6	SS	13	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>															
			1	TW	PH	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>															
	Firm					▽	170					<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>									
2	TW	PH	<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																		
			<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																		
			<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																		
								▽	169			<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>									
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					
<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																					

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-26

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

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			SHEAR STRENGTH kPa							
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE							
								20 40 60 80 100							
								20 40 60							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-26

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES
DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ 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 (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
	Continued From Previous Page						20	40	60	80	100						
158.6			11	SS	18												
20.1	Silty CLAY , trace sand, trace gravel Firm to Stiff Reddish Brown Wet																
			12	SS	5												
			13	SS	5												
154.8																	
23.9	SILT and SAND , gravelly Dense to Very Dense Brown Moist (TILL)		14	SS	48												
	occasional cobble																
152.7			15	SS	100/												
26.0	END OF BOREHOLE AT 26.0m. WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.				0.100												

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-27

1 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)			GR SA SI CL			
176.9	GROUND SURFACE															
0.0	ASPHALT (200mm)															
0.2	Gravelly SAND, trace silt Dense Brown Moist (FILL)		1	GS			176									
			1	SS	32											
175.5																
1.4	Silty CLAY, trace sand, trace gravel, trace organics Stiff to Very Stiff Brown Moist		2	SS	10		175									
			3	SS	13		174									
			4	SS	18											
							173									
			5	SS	6		172									
							171									
			6	SS	9											
							170									
			7	SS	6		169									
							168									
			8	SS	30											
							167									

Continued Next Page

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

RECORD OF BOREHOLE No 18-27

2 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ 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 (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
	Continued From Previous Page							20 40 60 80 100				W _P W W _L						
158.8 <																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-27

3 OF 3

METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES
 DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP
 DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

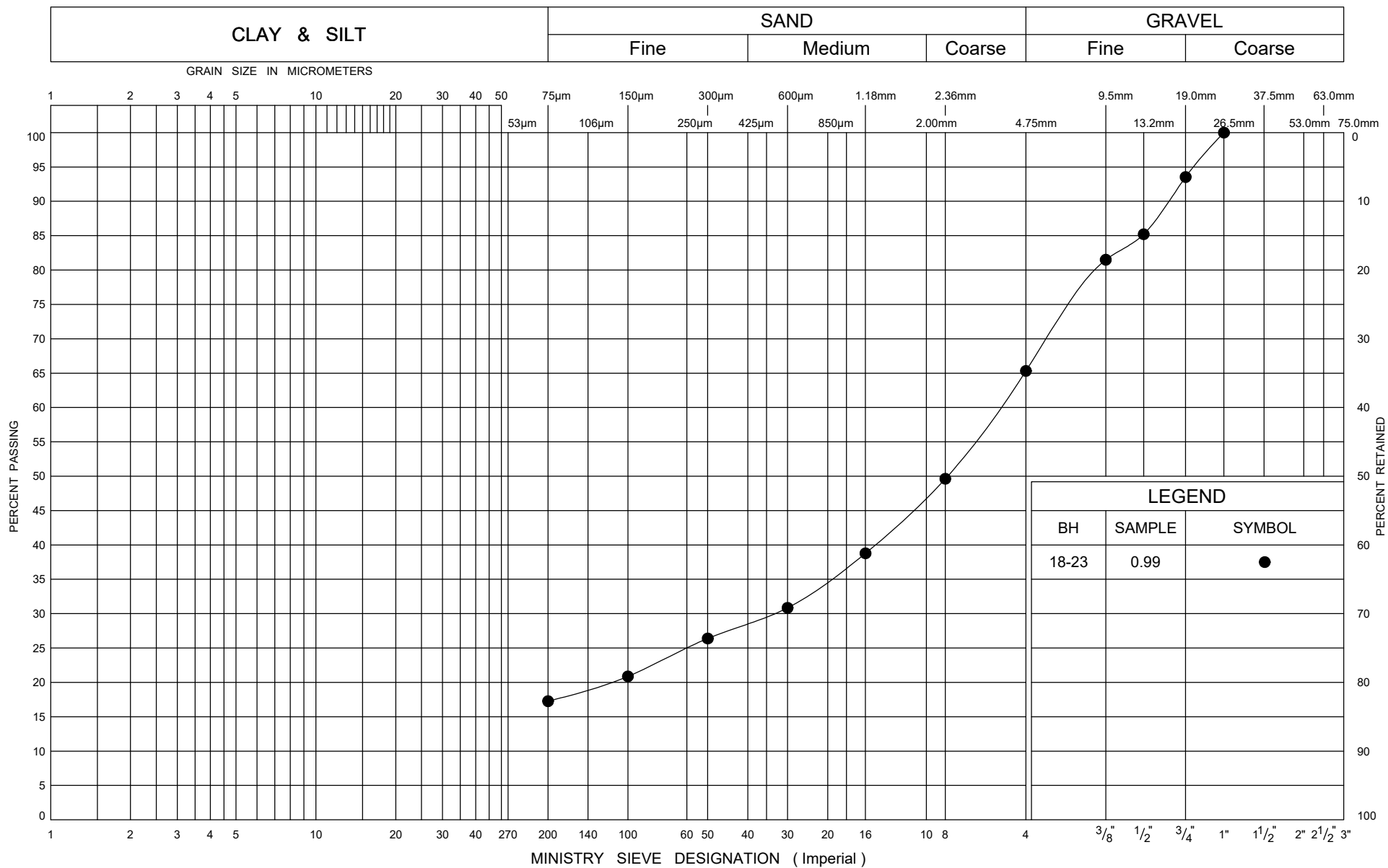
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								WATER CONTENT (%)						
	Continued From Previous Page						20 40 60 80 100							
			13	SS	78									
			14	SS	67									
	Dense		15	SS	47									
	possible cobbles and boulders													
152.5														
24.4	END OF BOREHOLE AT 24.4m. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.		16	SS	100/ 0.025									

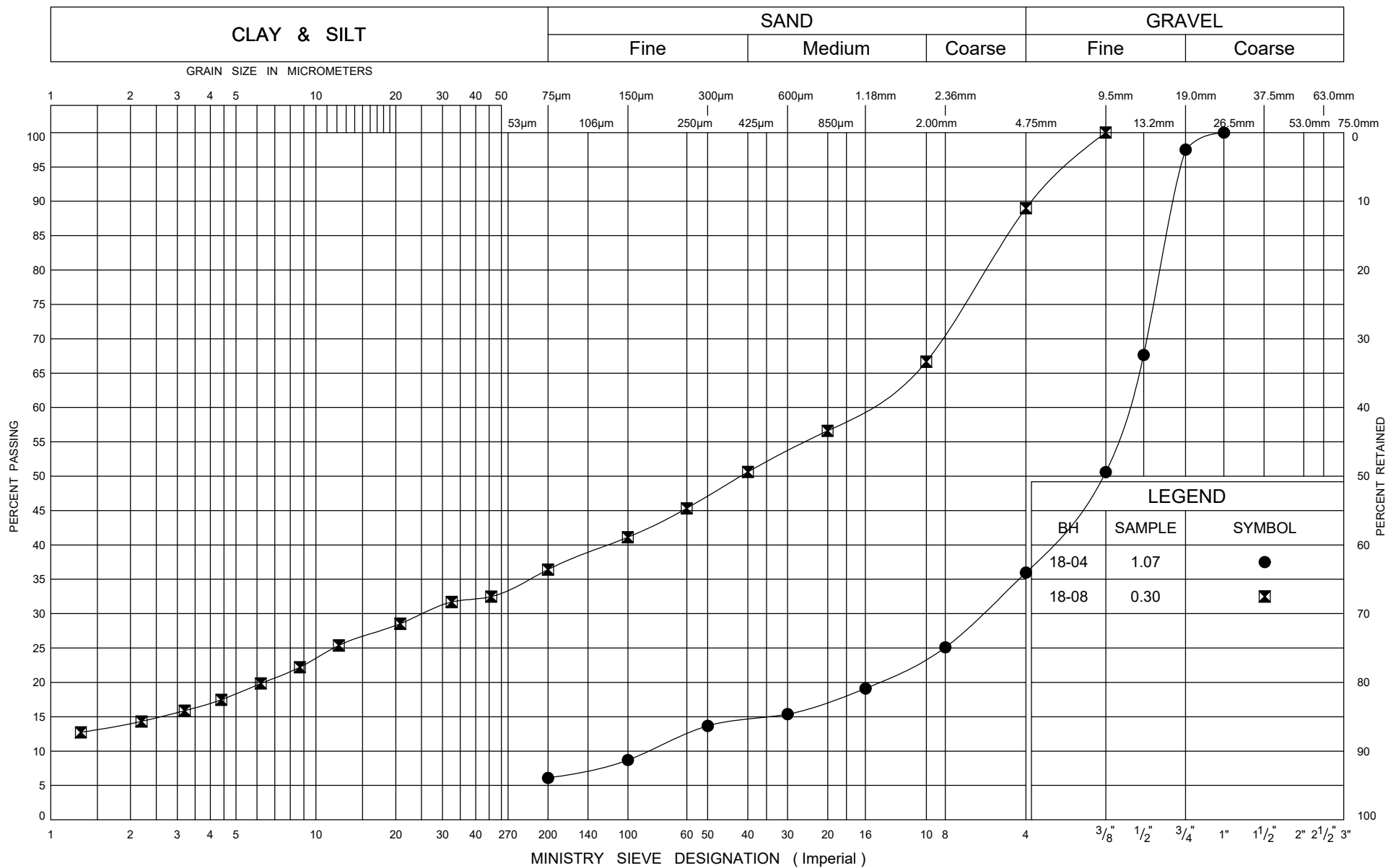
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 10 (%) STRAIN AT FAILURE

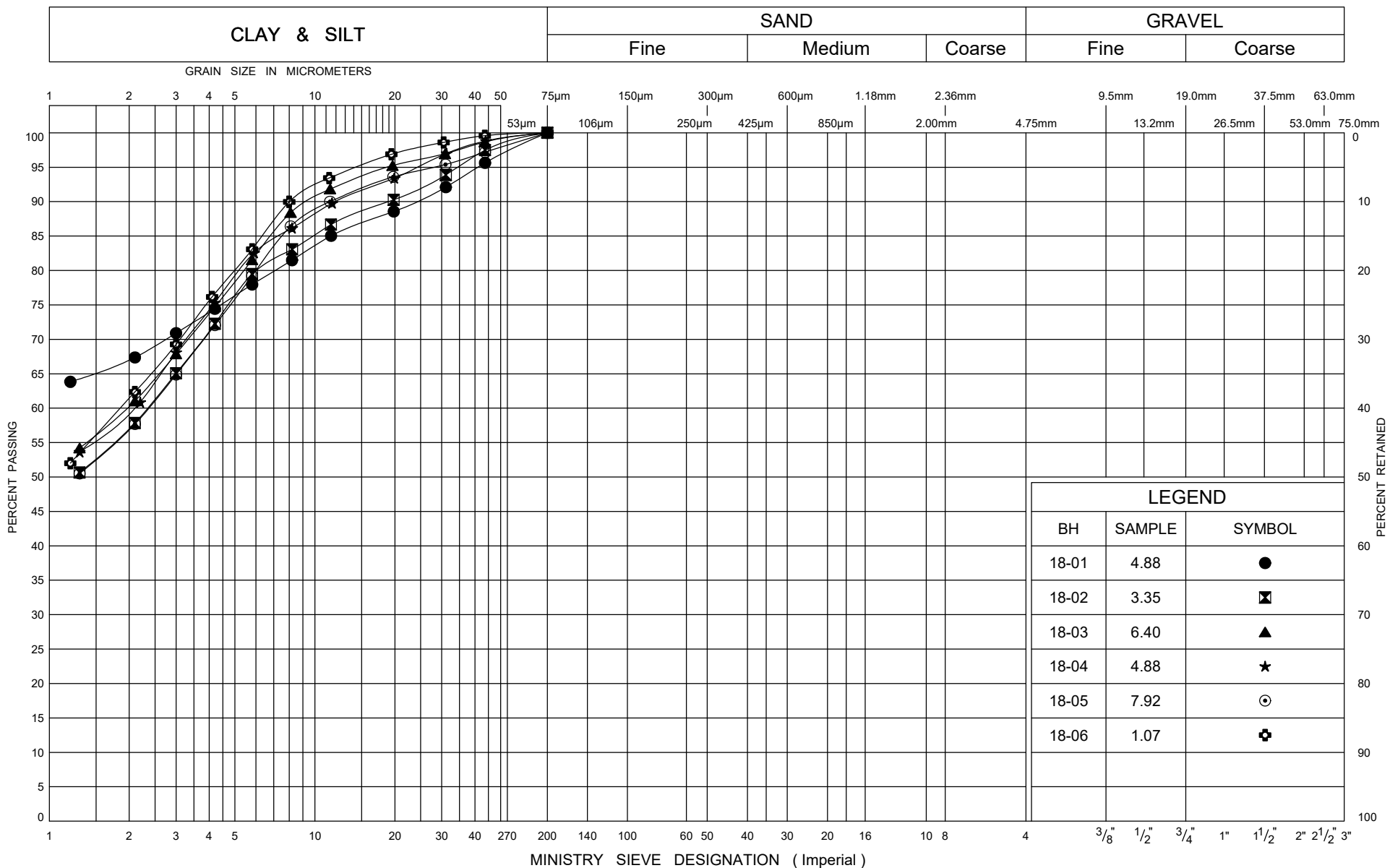


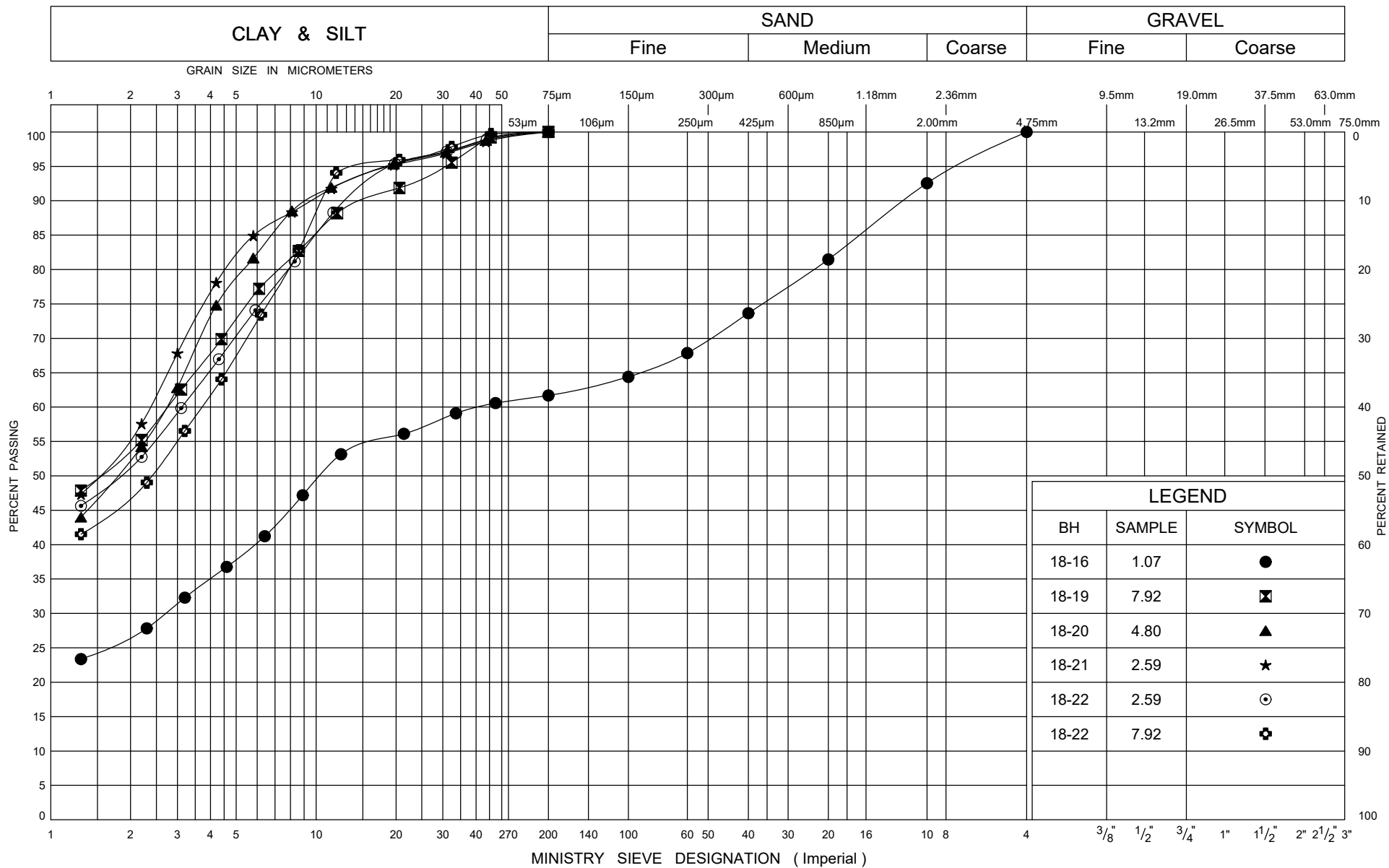
Appendix B

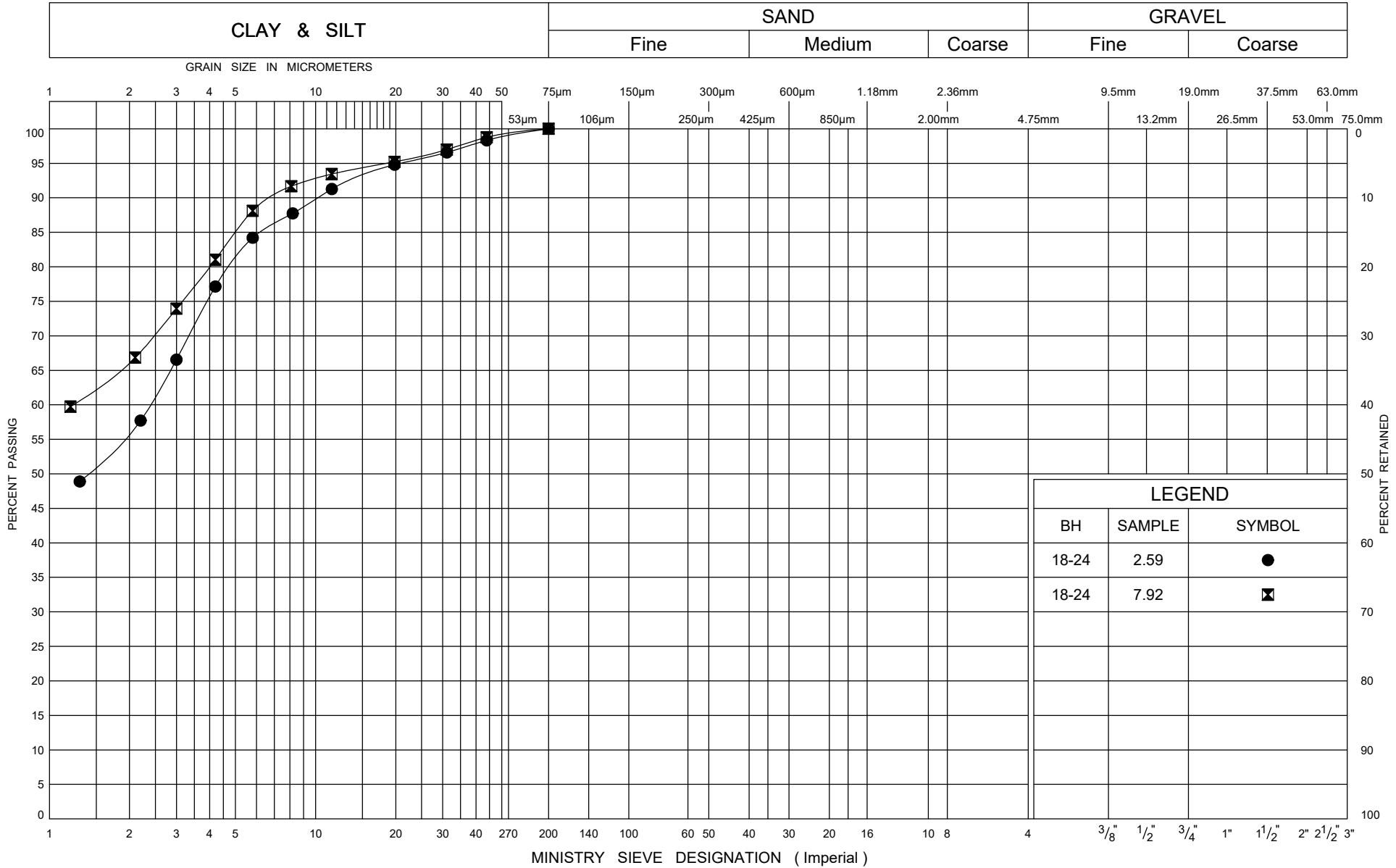
Laboratory Test Results

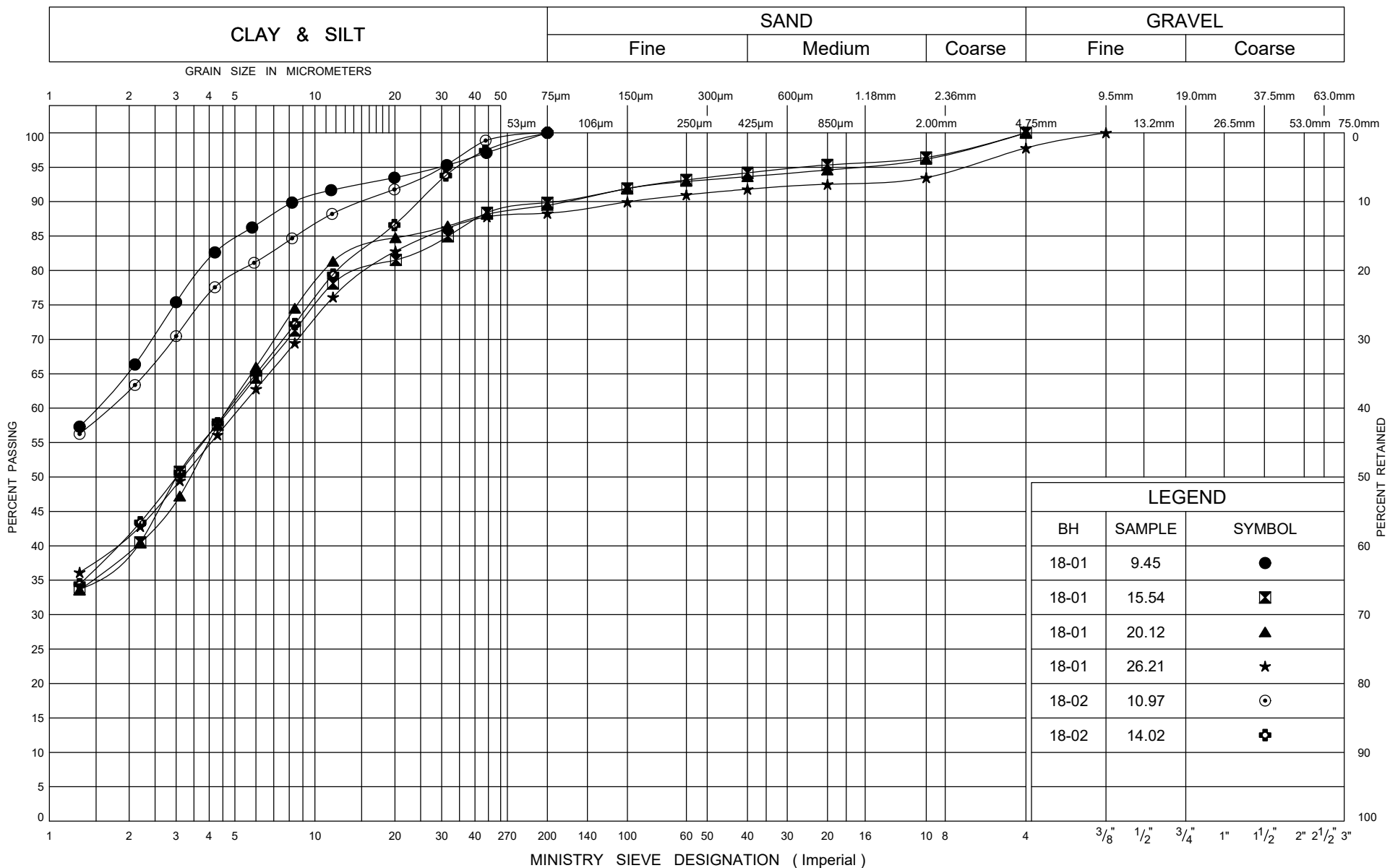


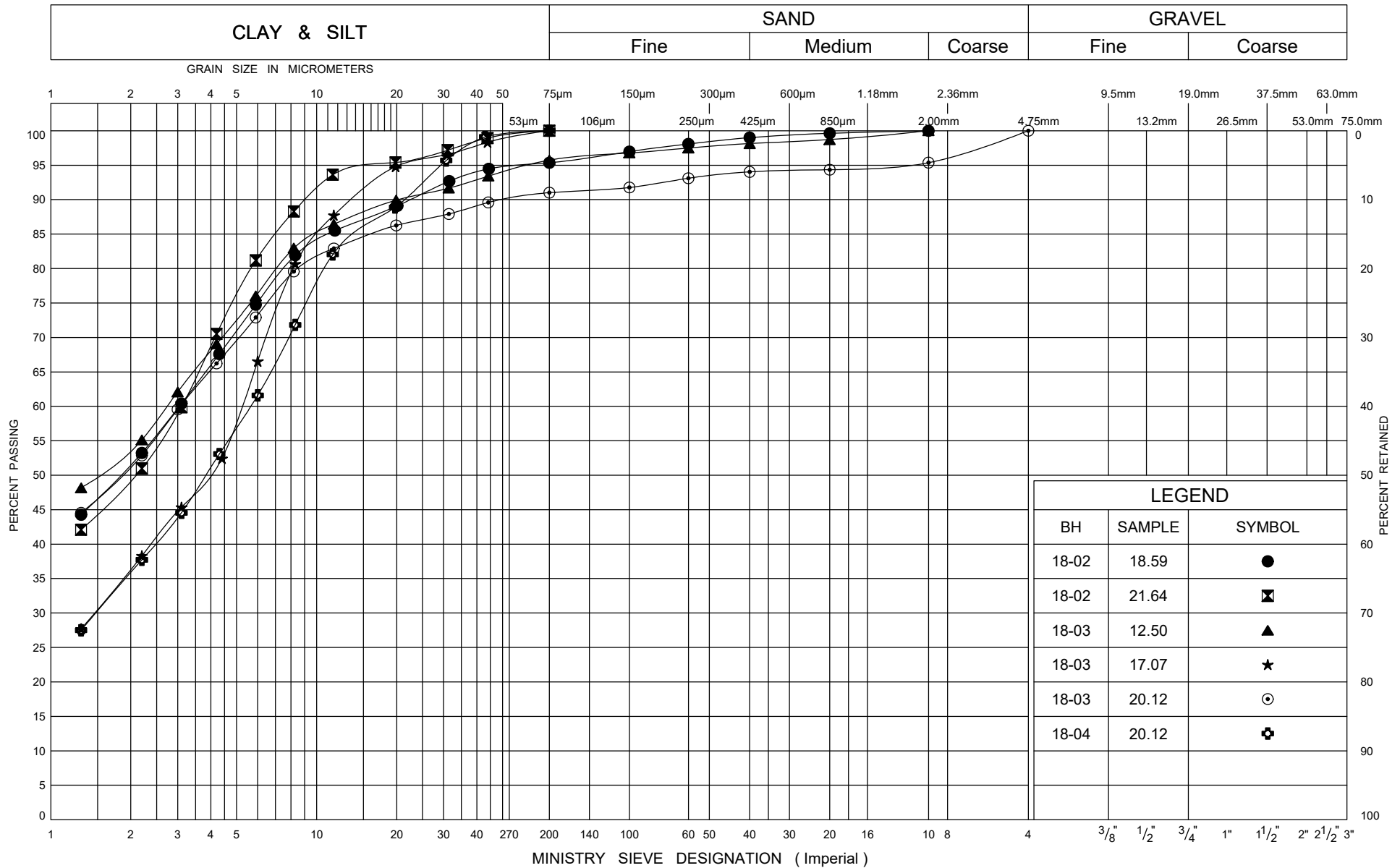












Ministry of
Transportation

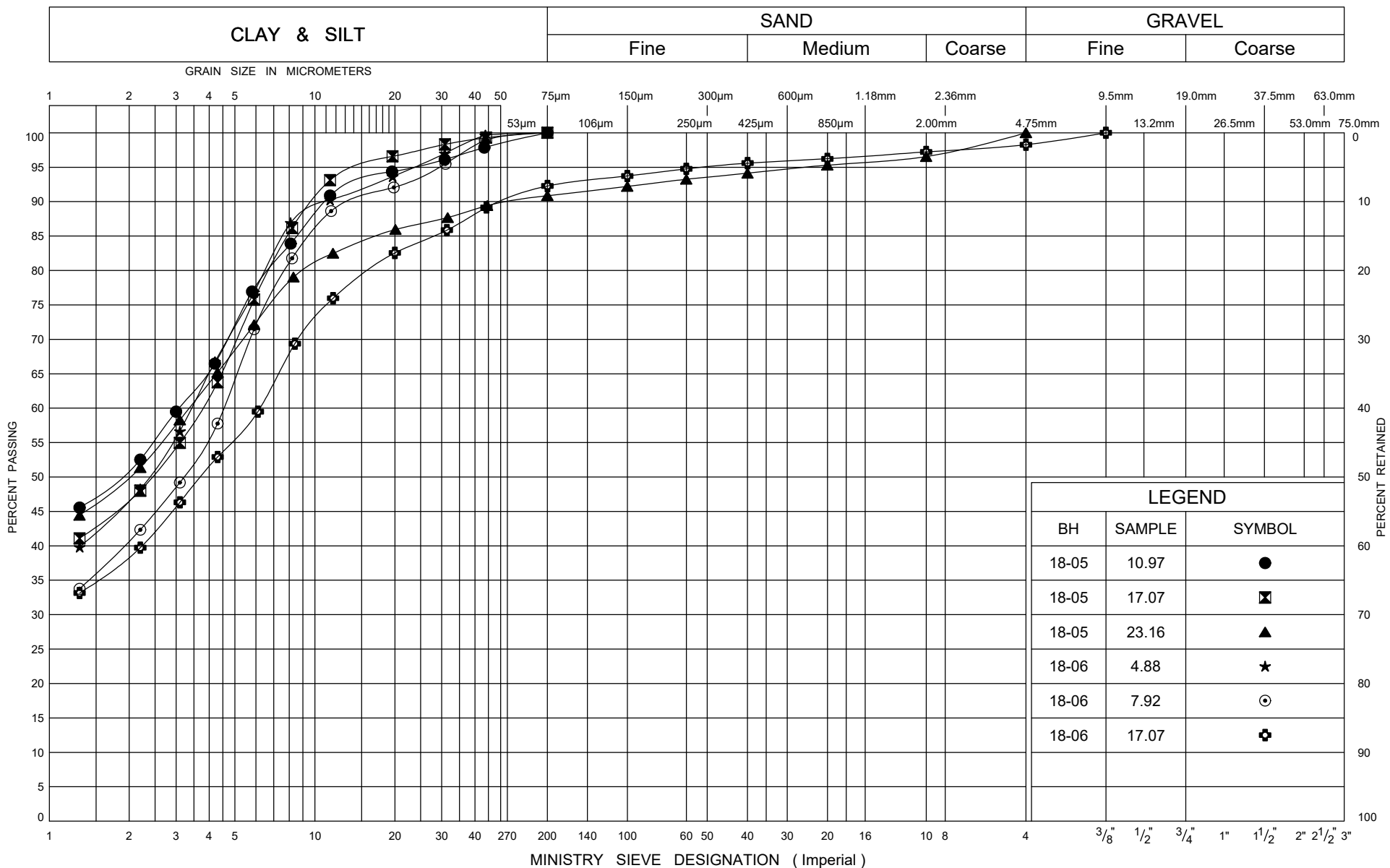
GRAIN SIZE DISTRIBUTION

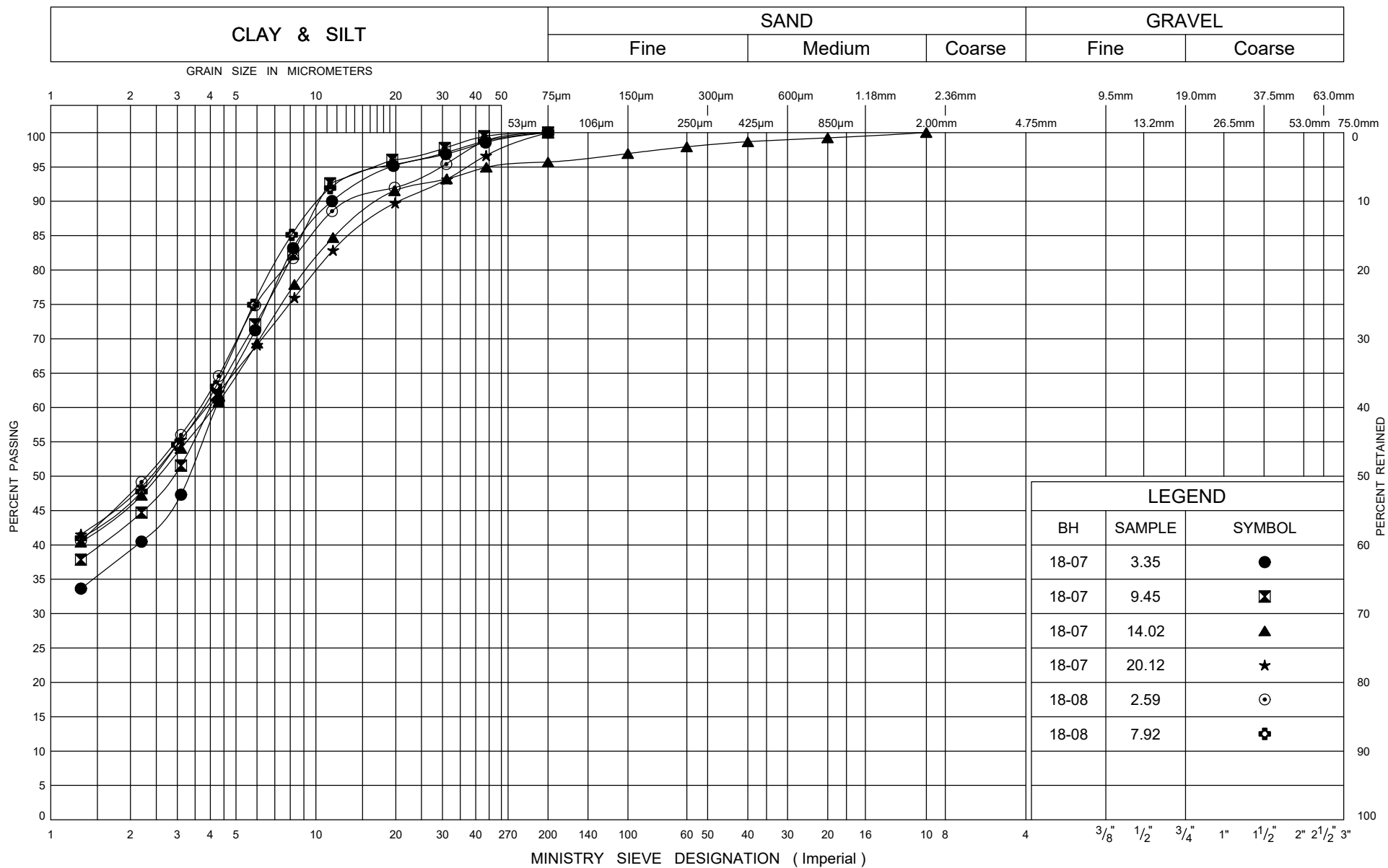
Silty CLAY

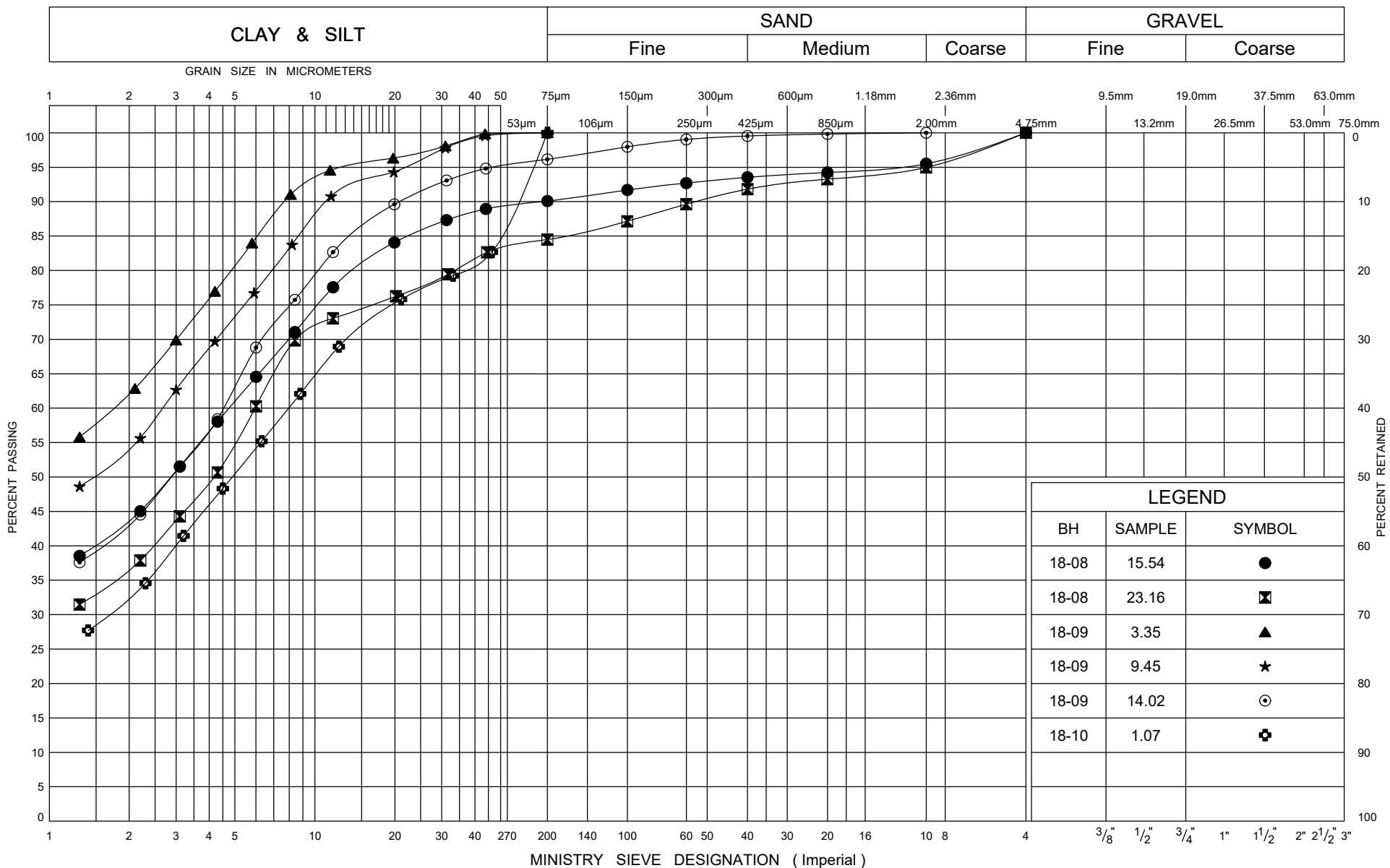
FIG No B7

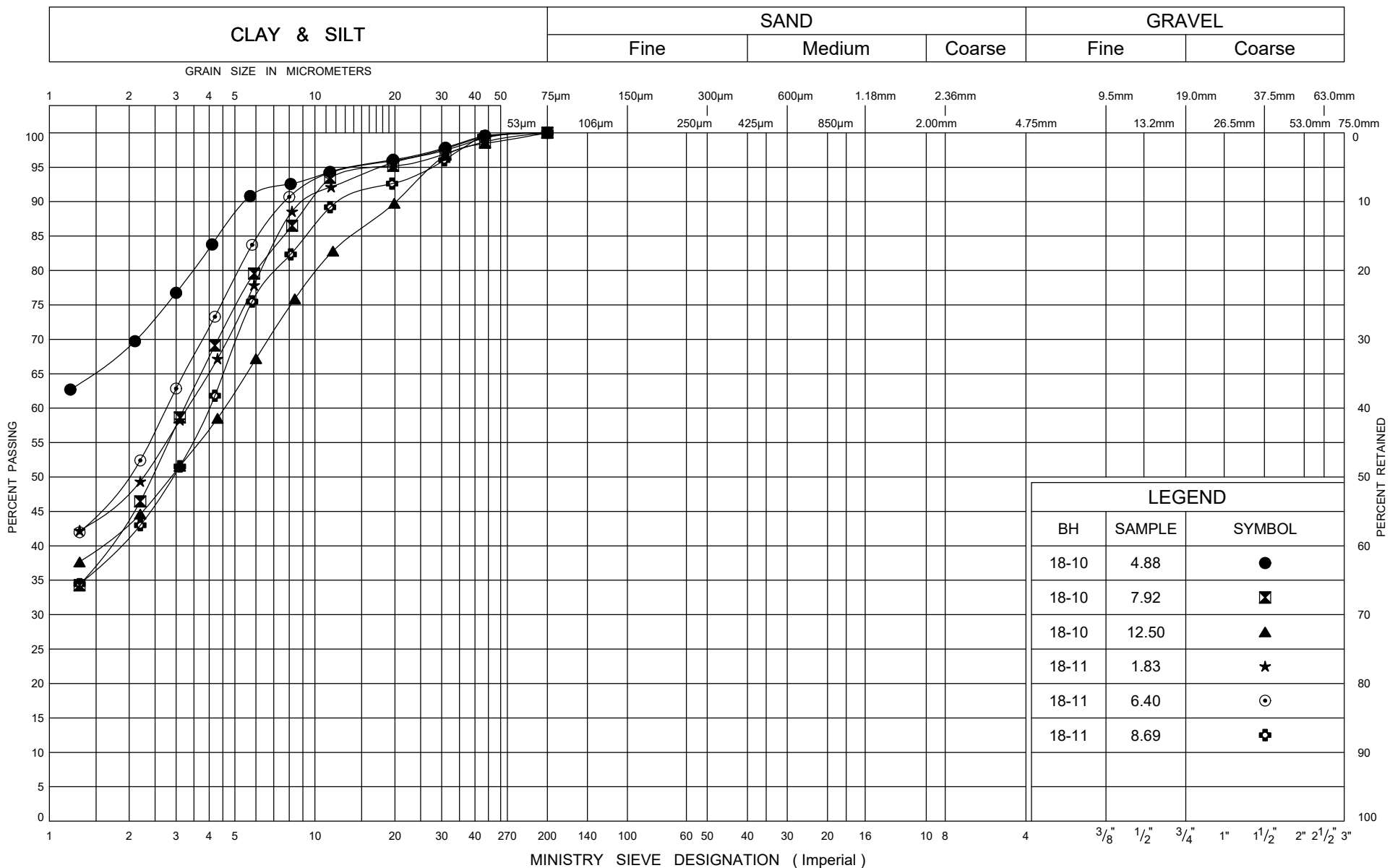
GWP 2430-15-00

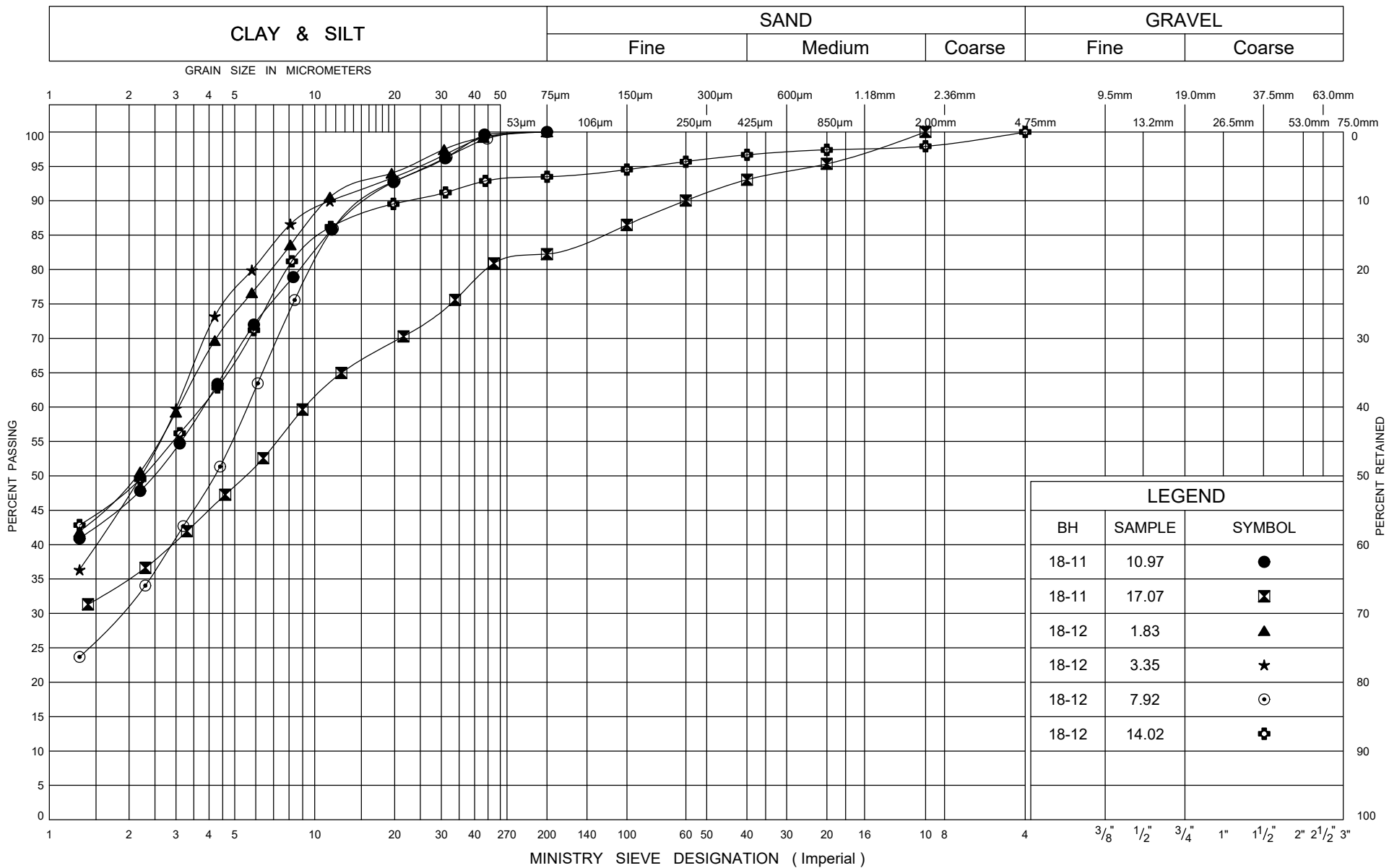
Welland River Bridge Replacement

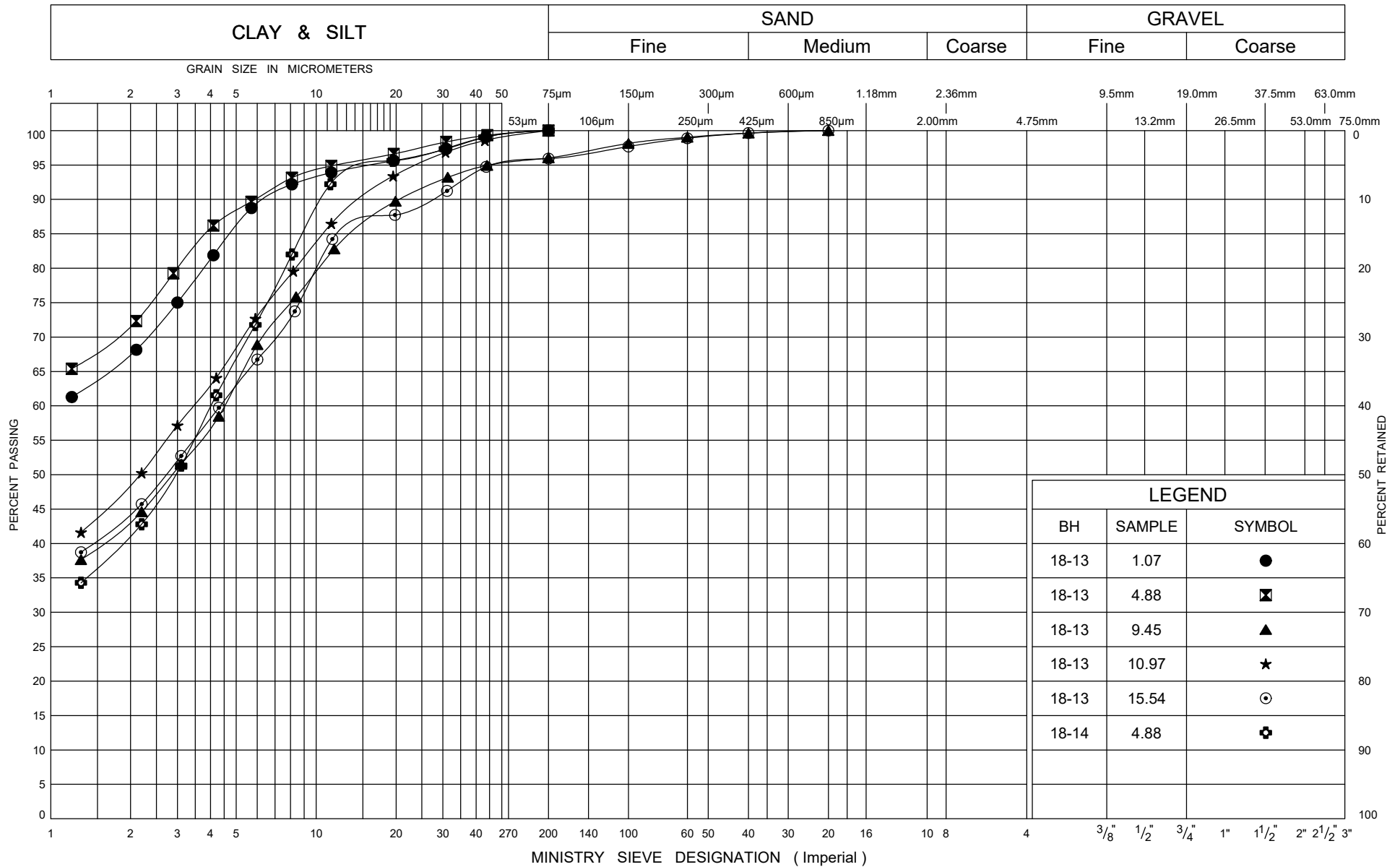












Ministry of
Transportation

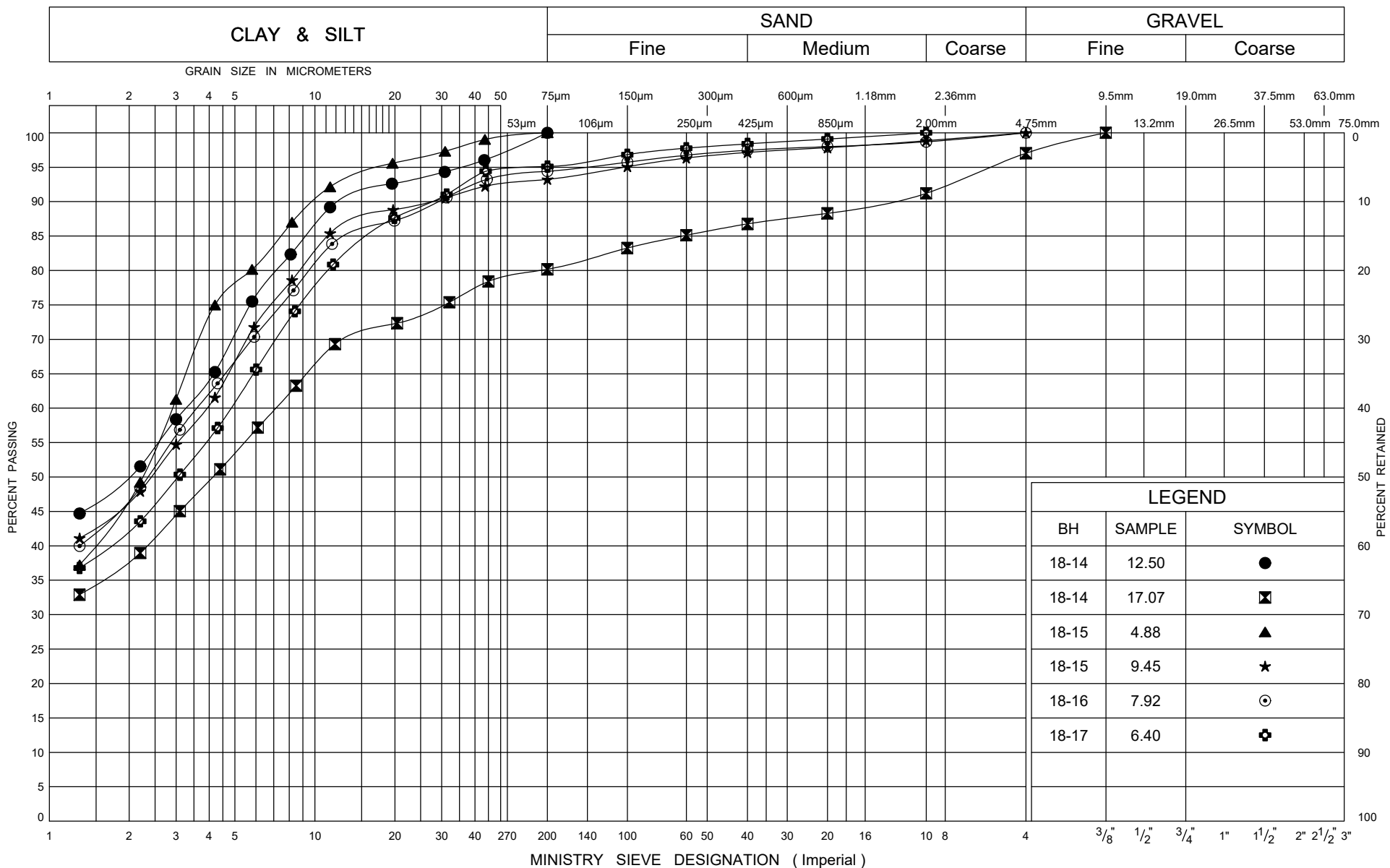
GRAIN SIZE DISTRIBUTION

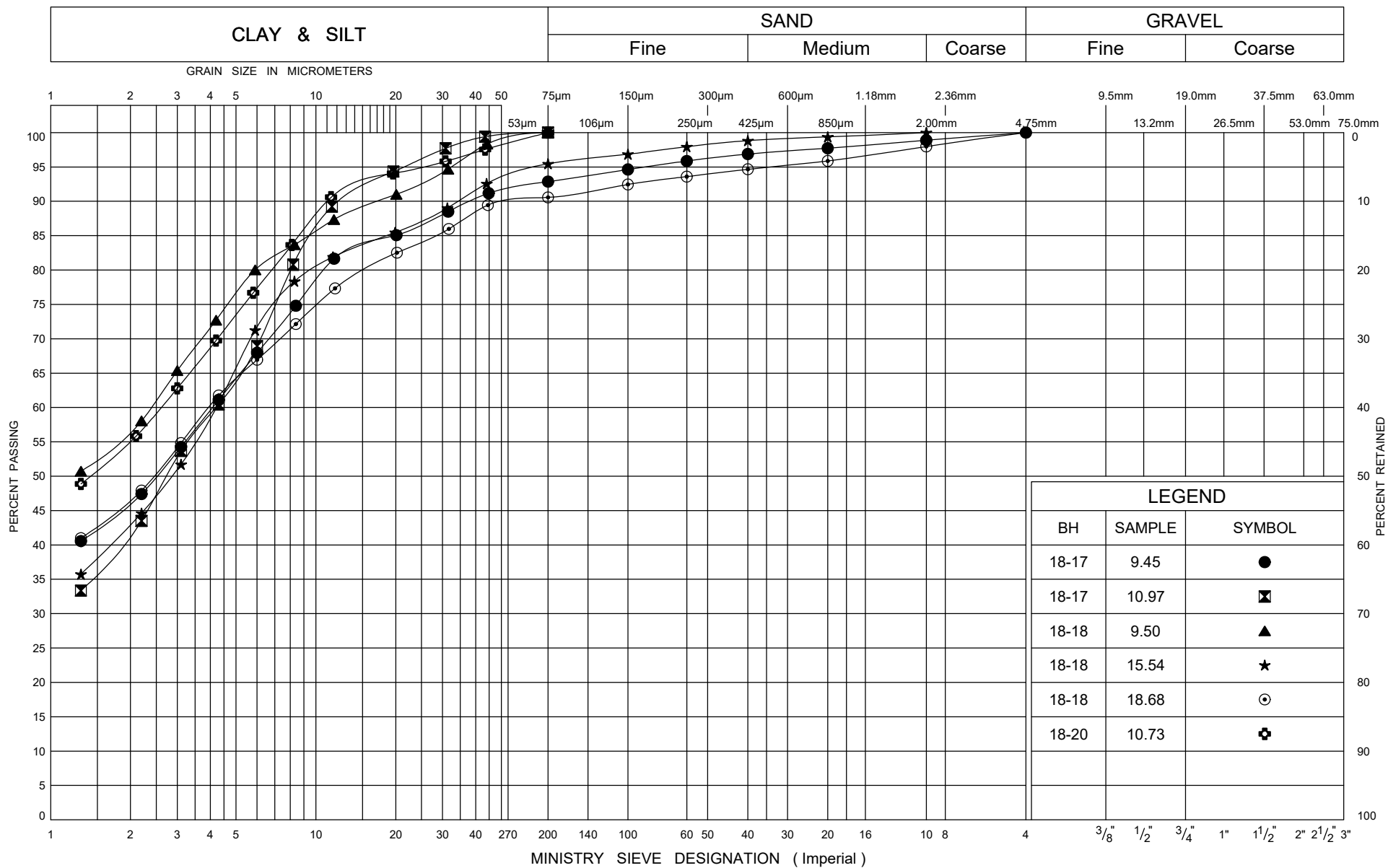
Silty CLAY

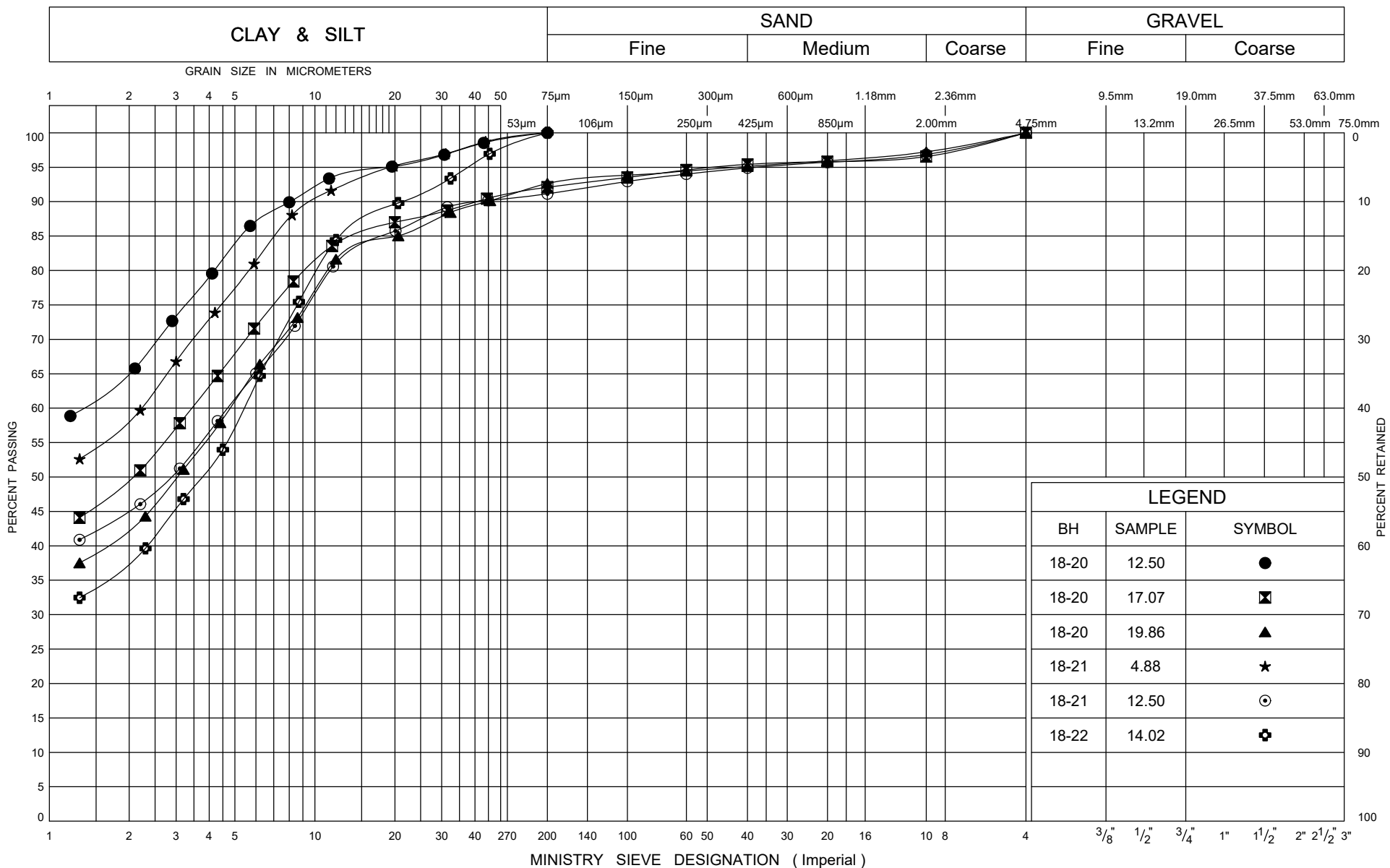
FIG No B13

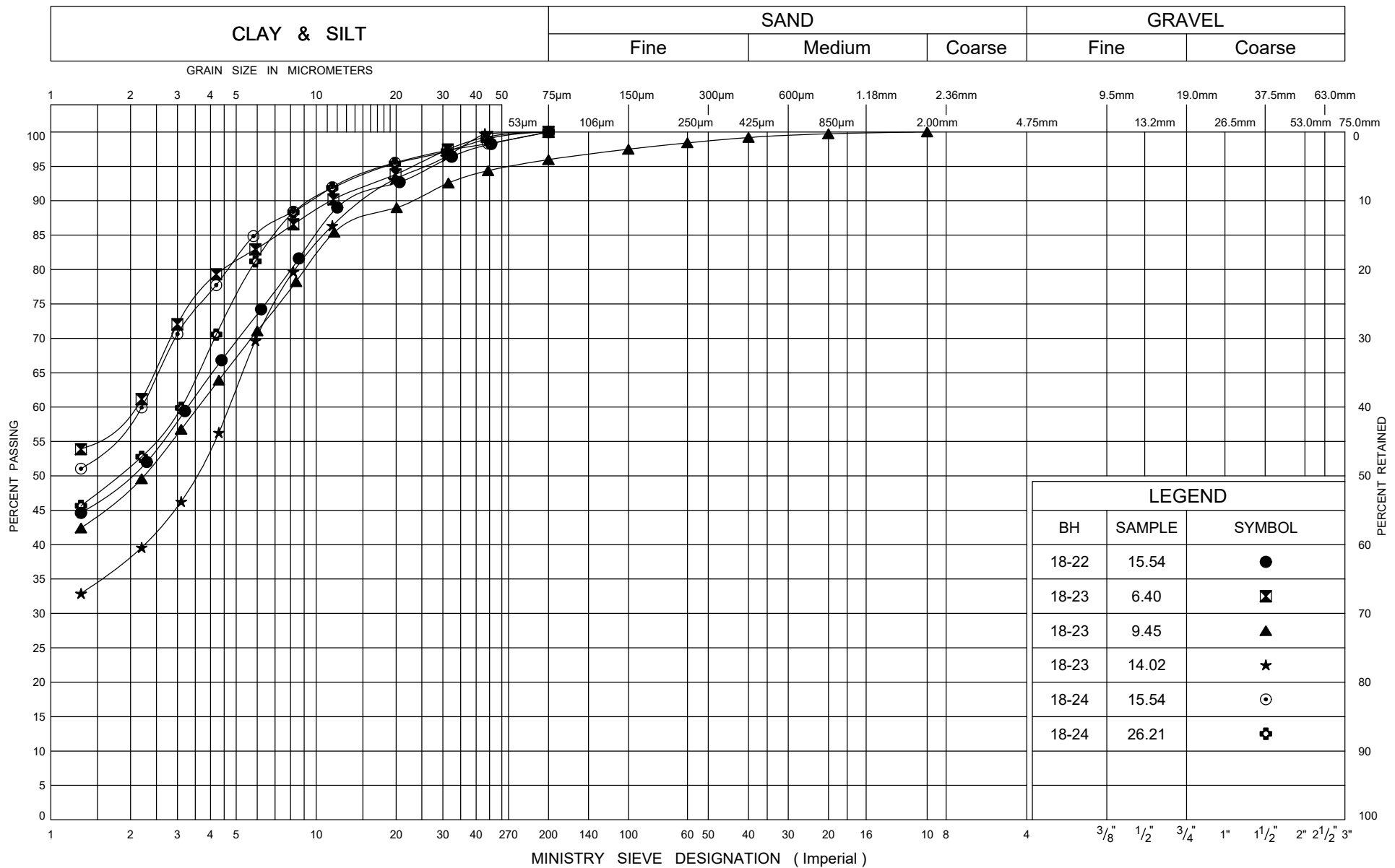
GWP 2430-15-00

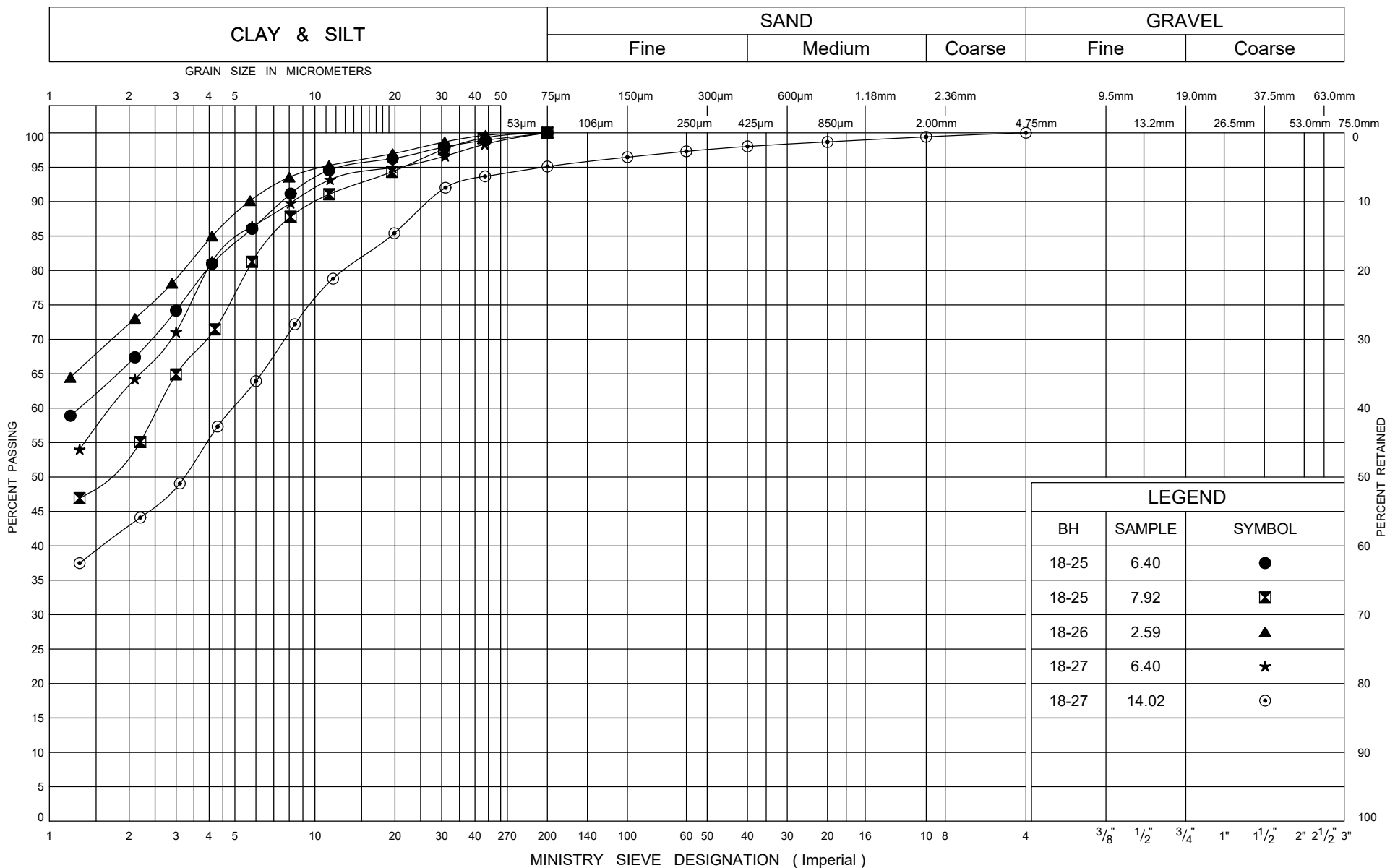
Welland River Bridge Replacement

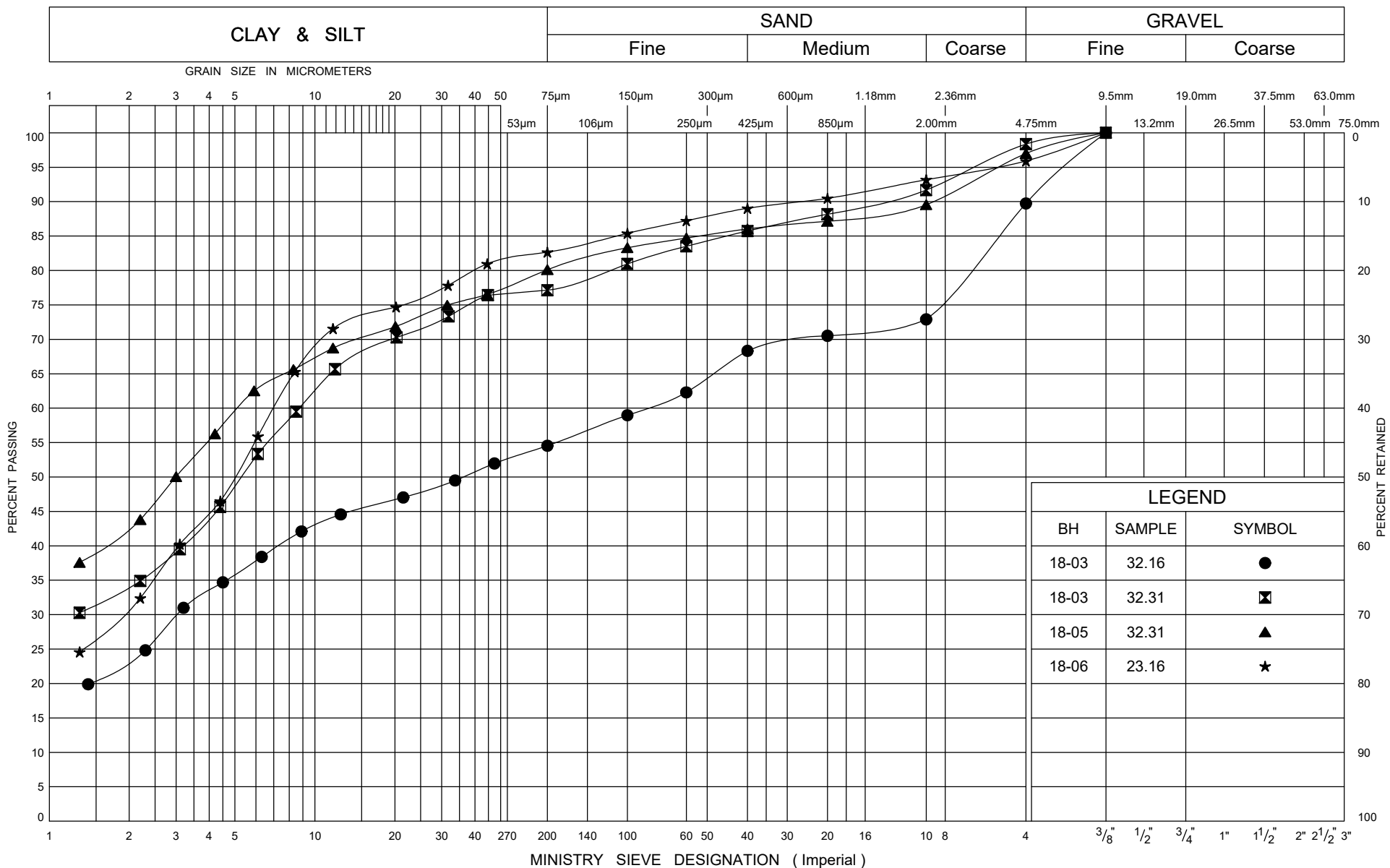


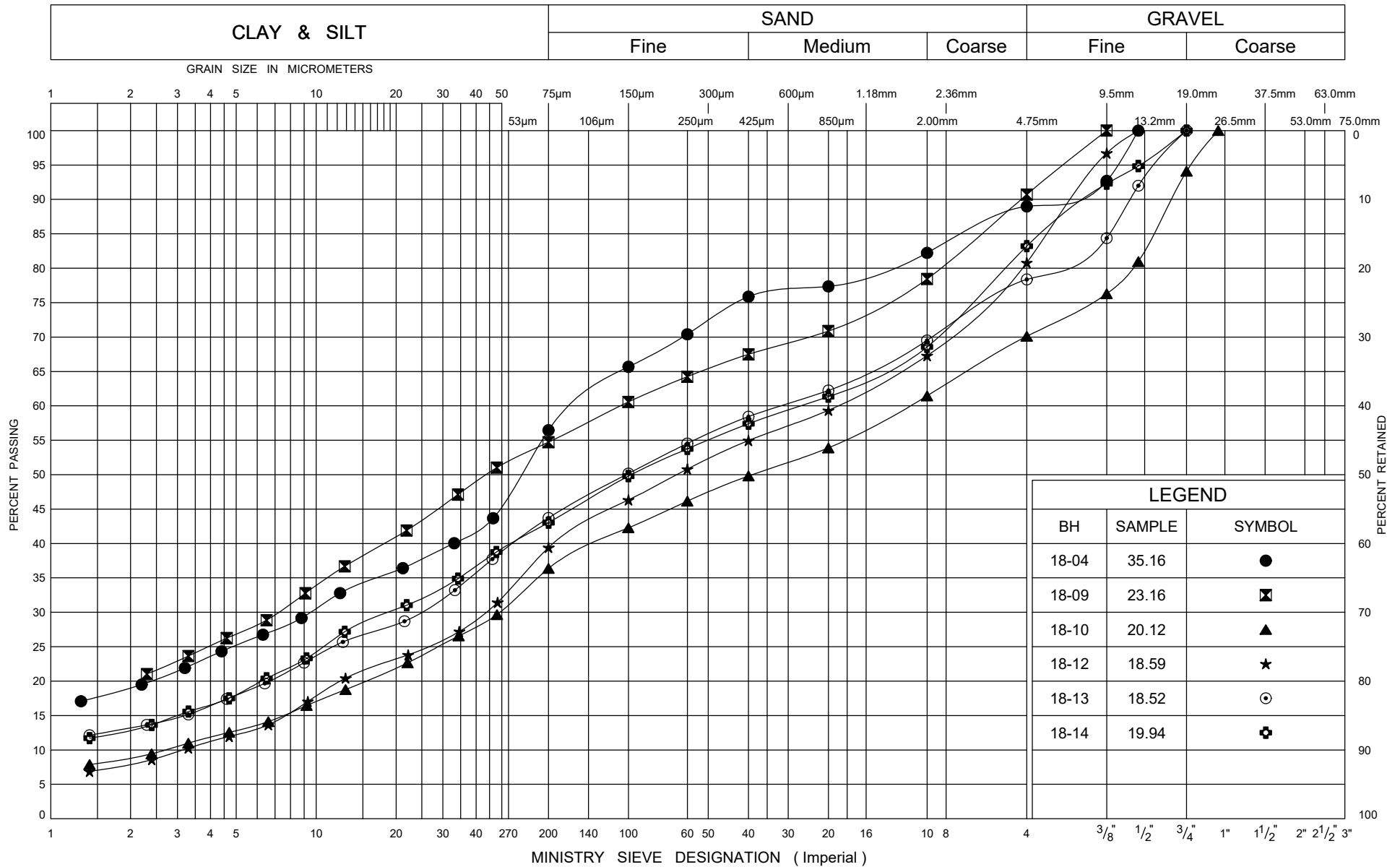












Ministry of
Transportation

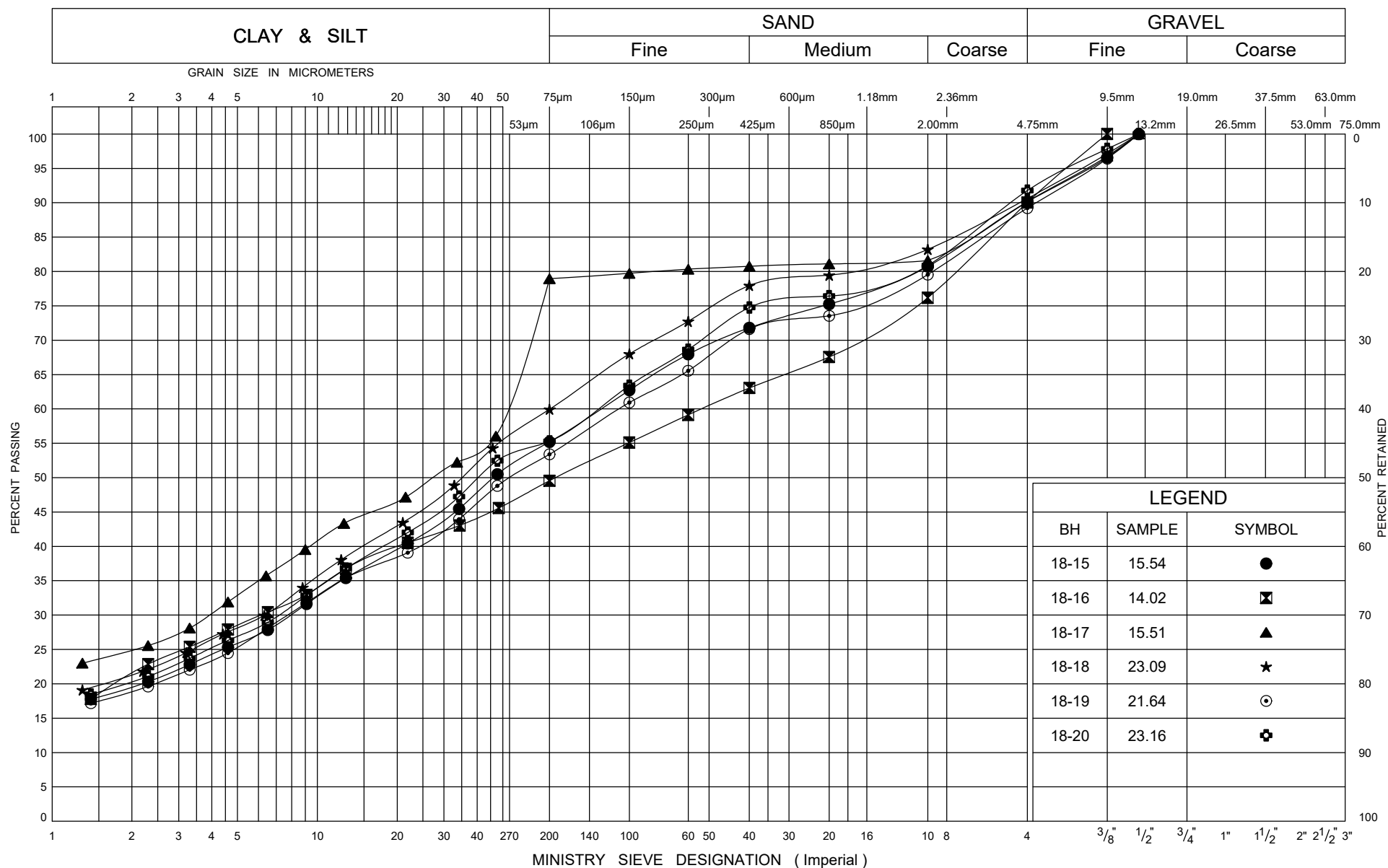
GRAIN SIZE DISTRIBUTION

SILT and SAND TILL

FIG No B20

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

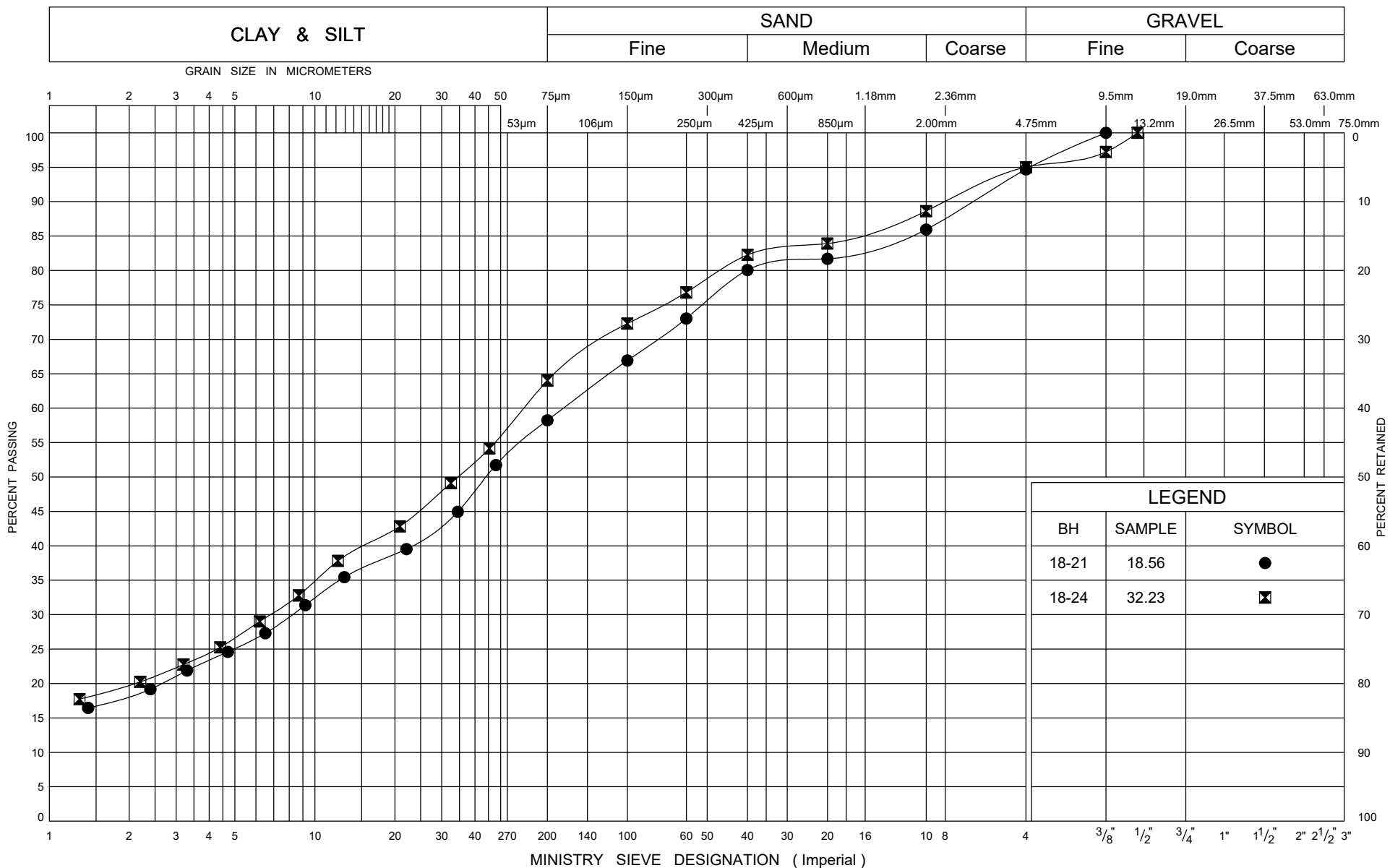
GRAIN SIZE DISTRIBUTION

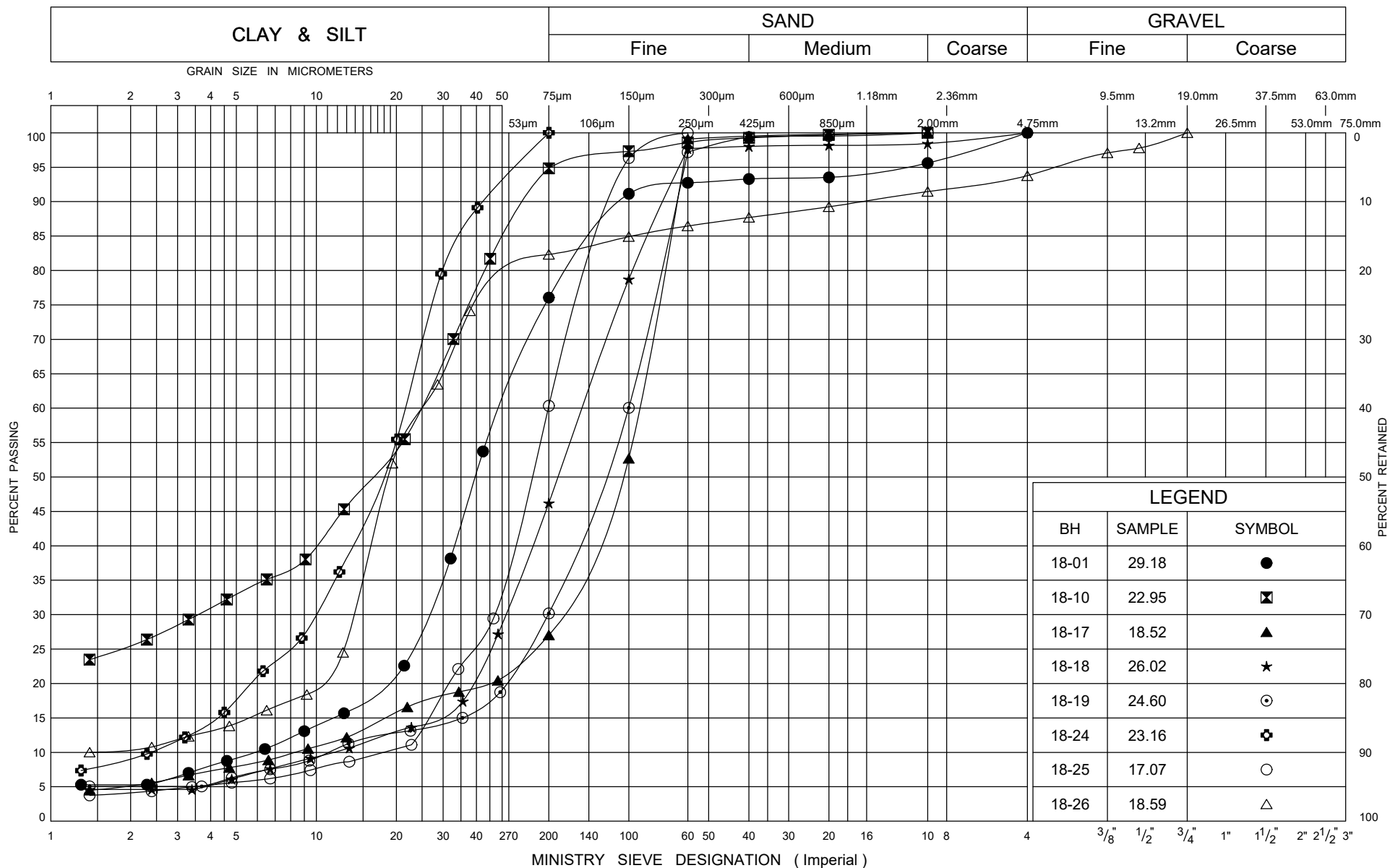
SILT and SAND TILL

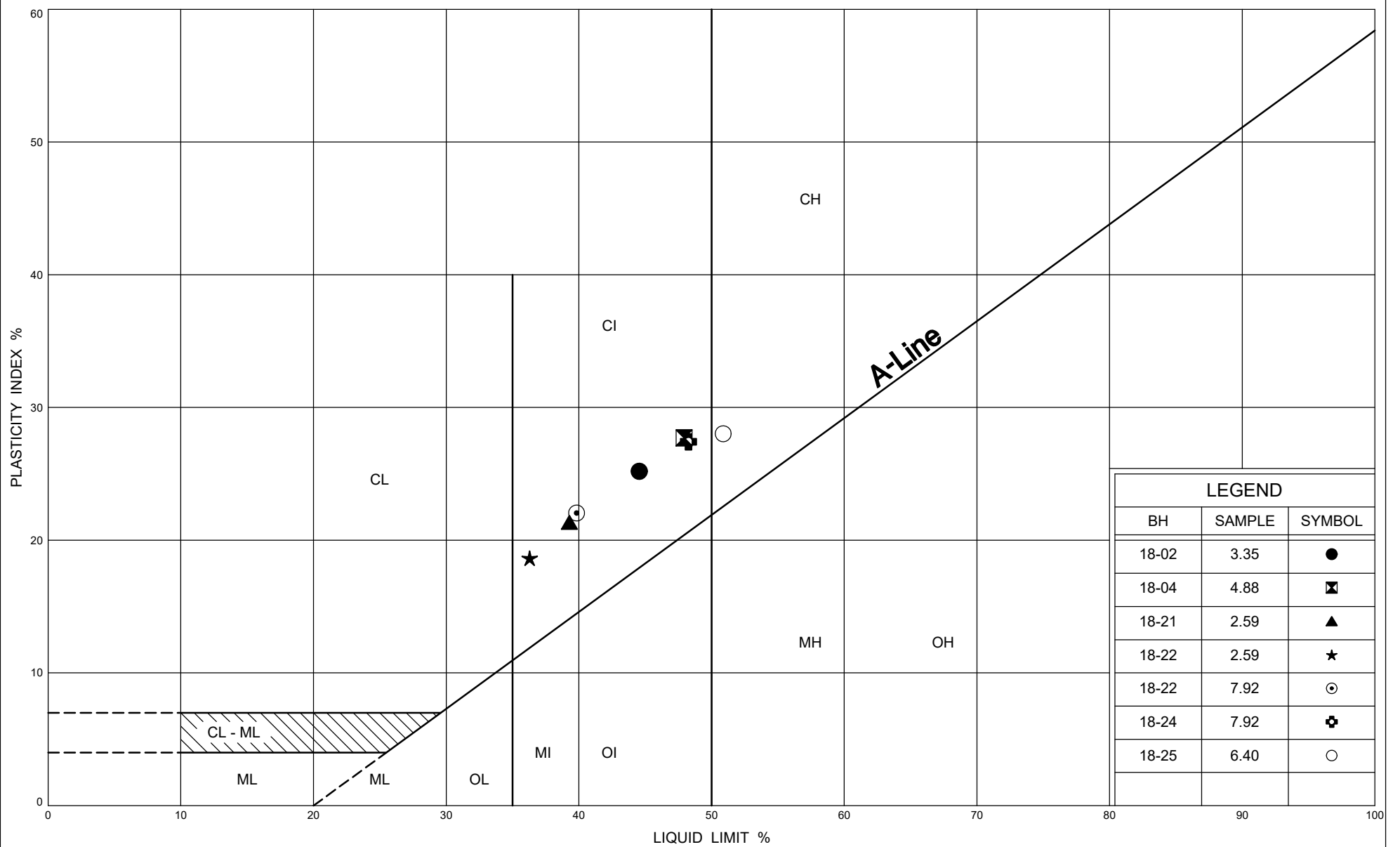
FIG No B21

GWP 2430-15-00

Welland River Bridge Replacement







Ministry of
Transportation

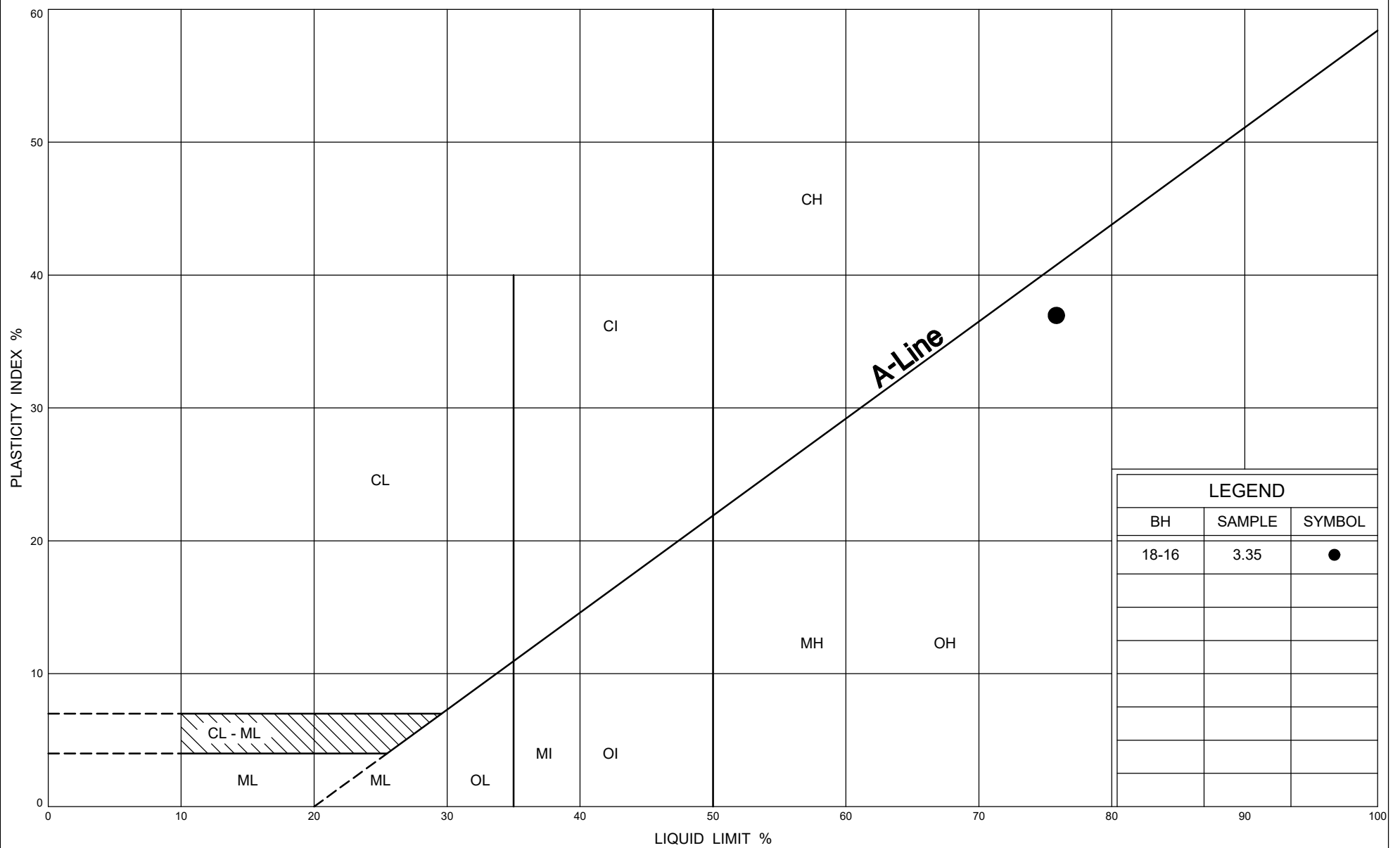
PLASTICITY CHART

Cohesive FILL

FIG No B24

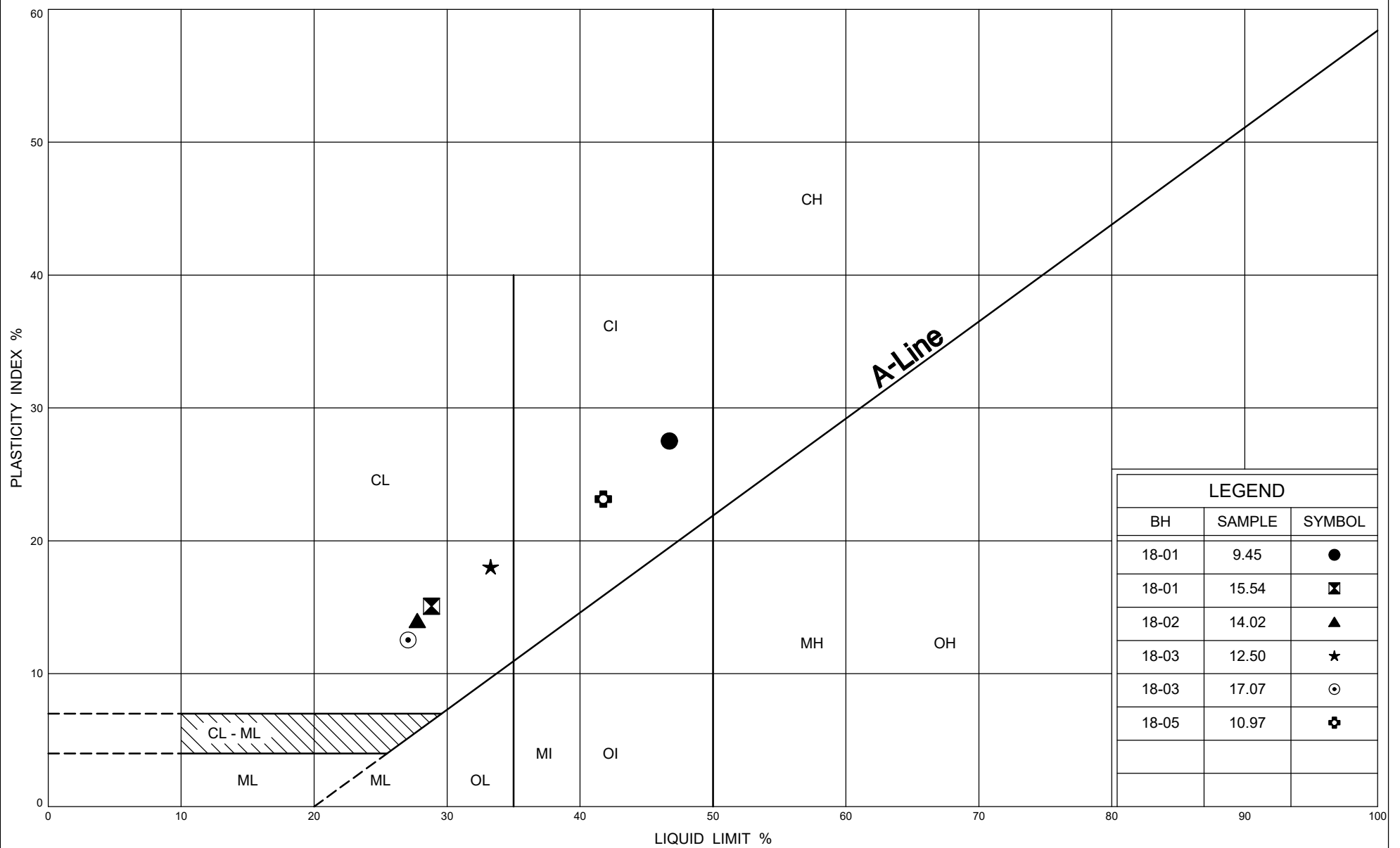
GWP 2430-15-00

Welland River Bridge Replacement



LEGEND		
BH	SAMPLE	SYMBOL
18-16	3.35	●

ONTARIO MOT PLASTICITY CHART MTO-18426.GPJ ONTARIO MOT.GDT 8/16/18



Ministry of
Transportation

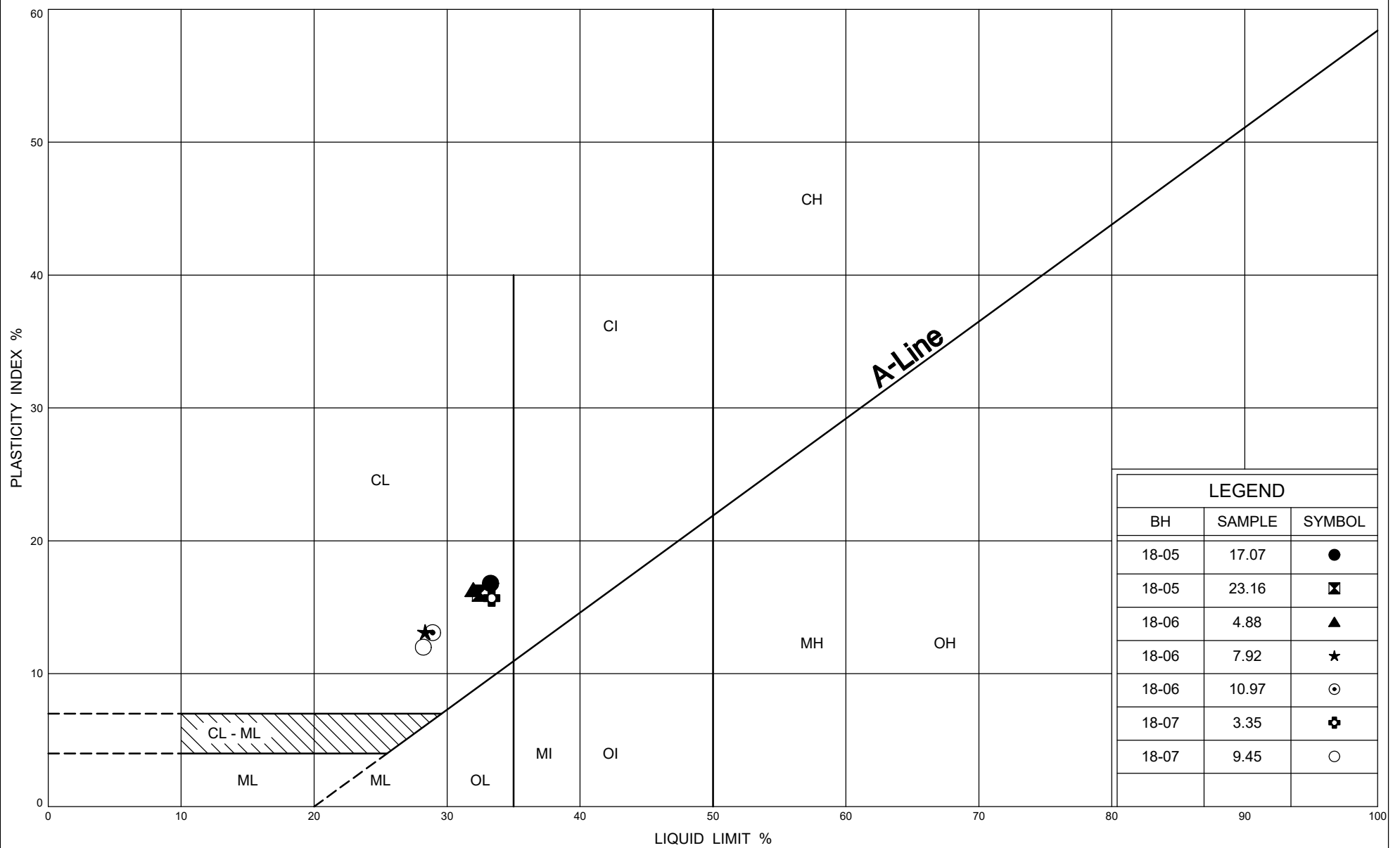
PLASTICITY CHART

Silty CLAY

FIG No B26

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

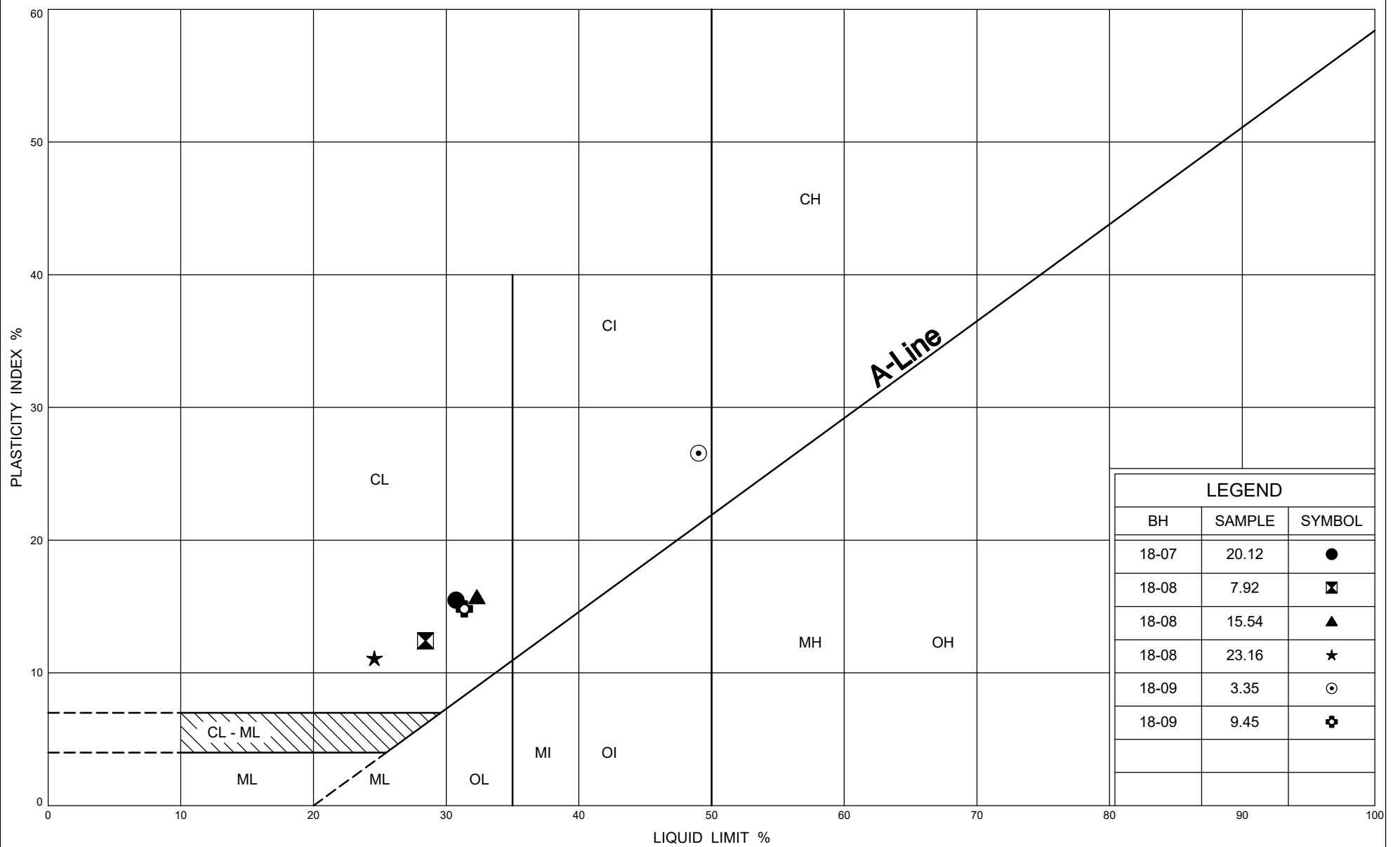
PLASTICITY CHART

Silty CLAY

FIG No B27

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

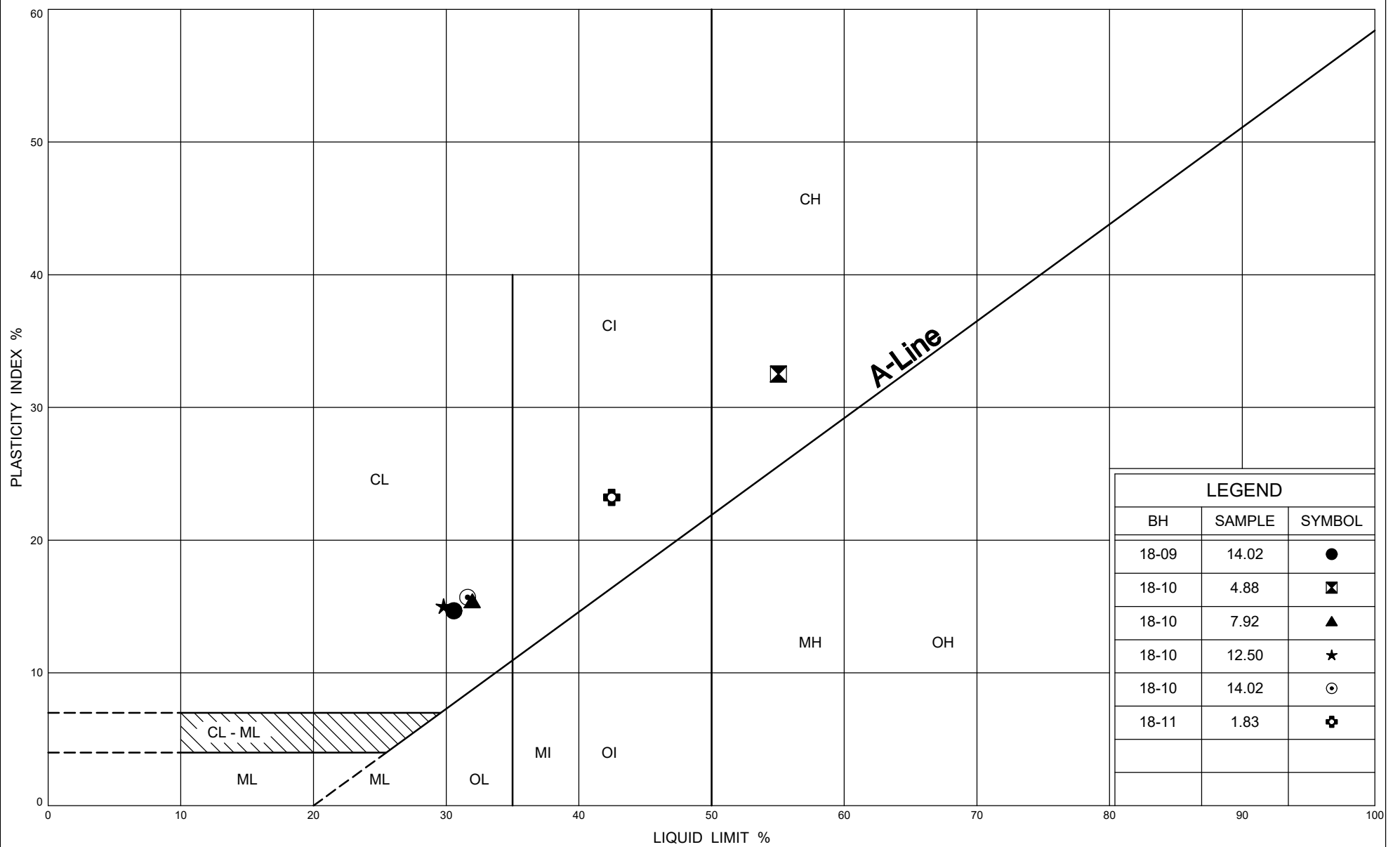
PLASTICITY CHART

Silty CLAY

FIG No B28

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

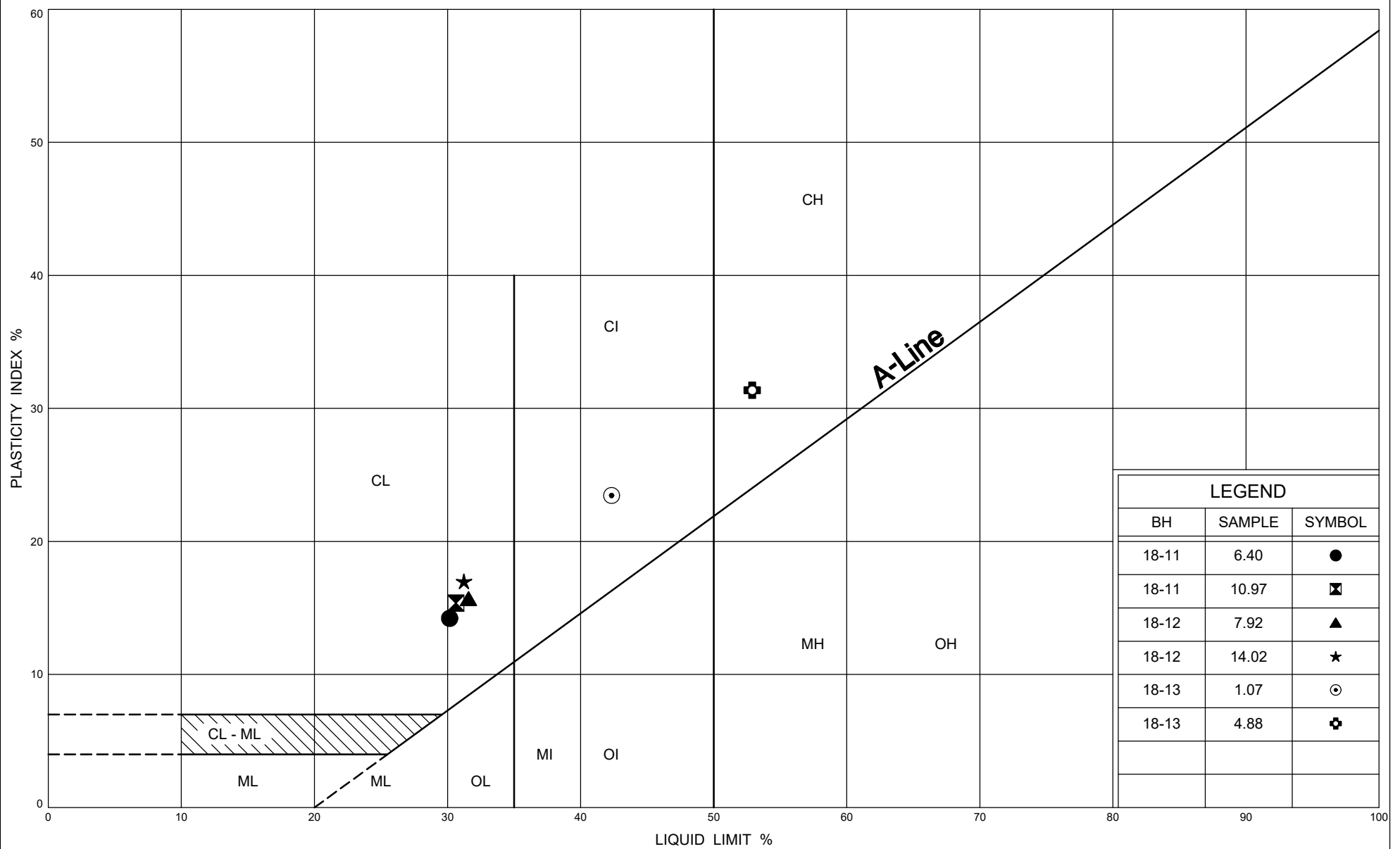
PLASTICITY CHART

Silty CLAY

FIG No B29

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

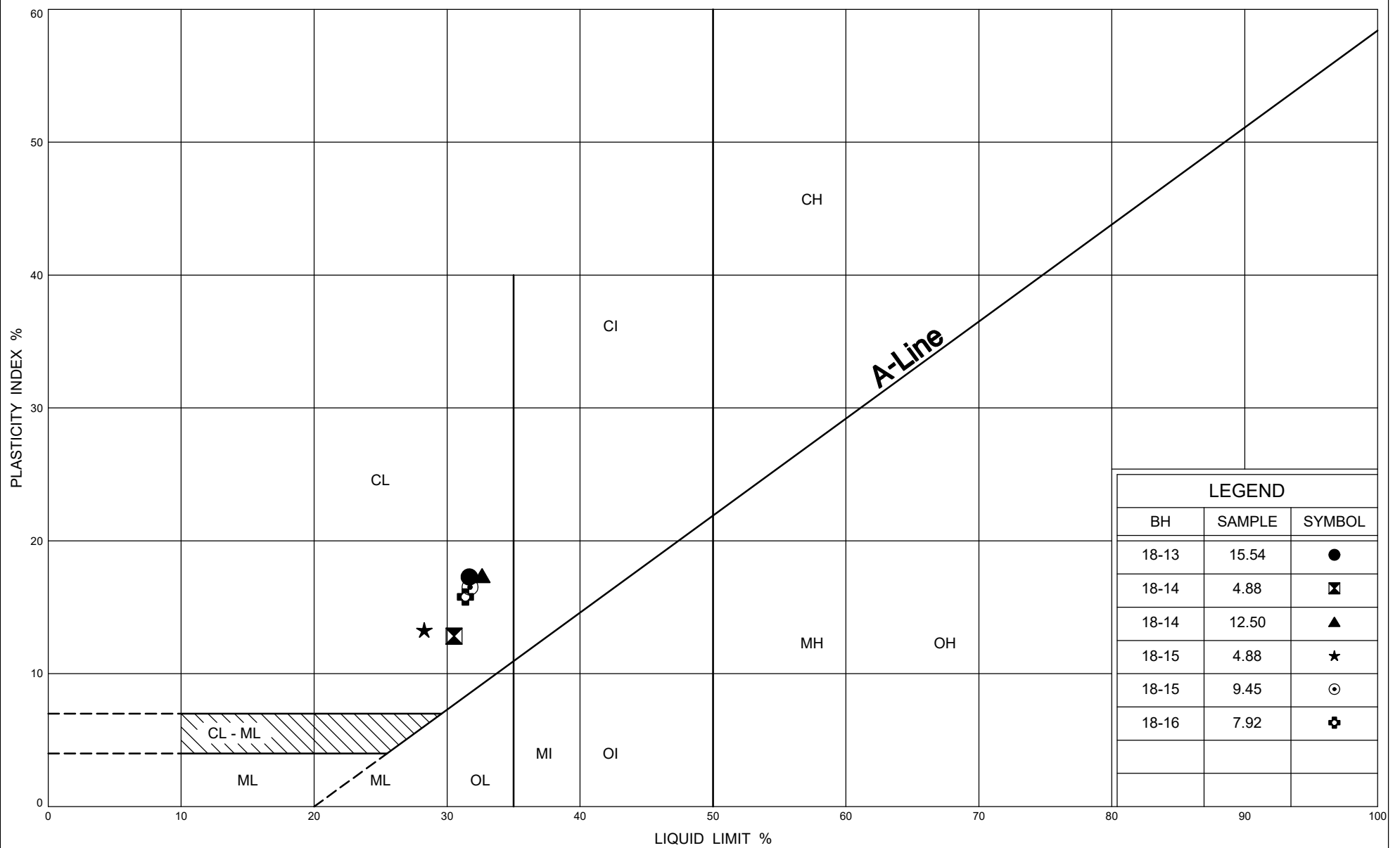
PLASTICITY CHART

Silty CLAY

FIG No B30

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

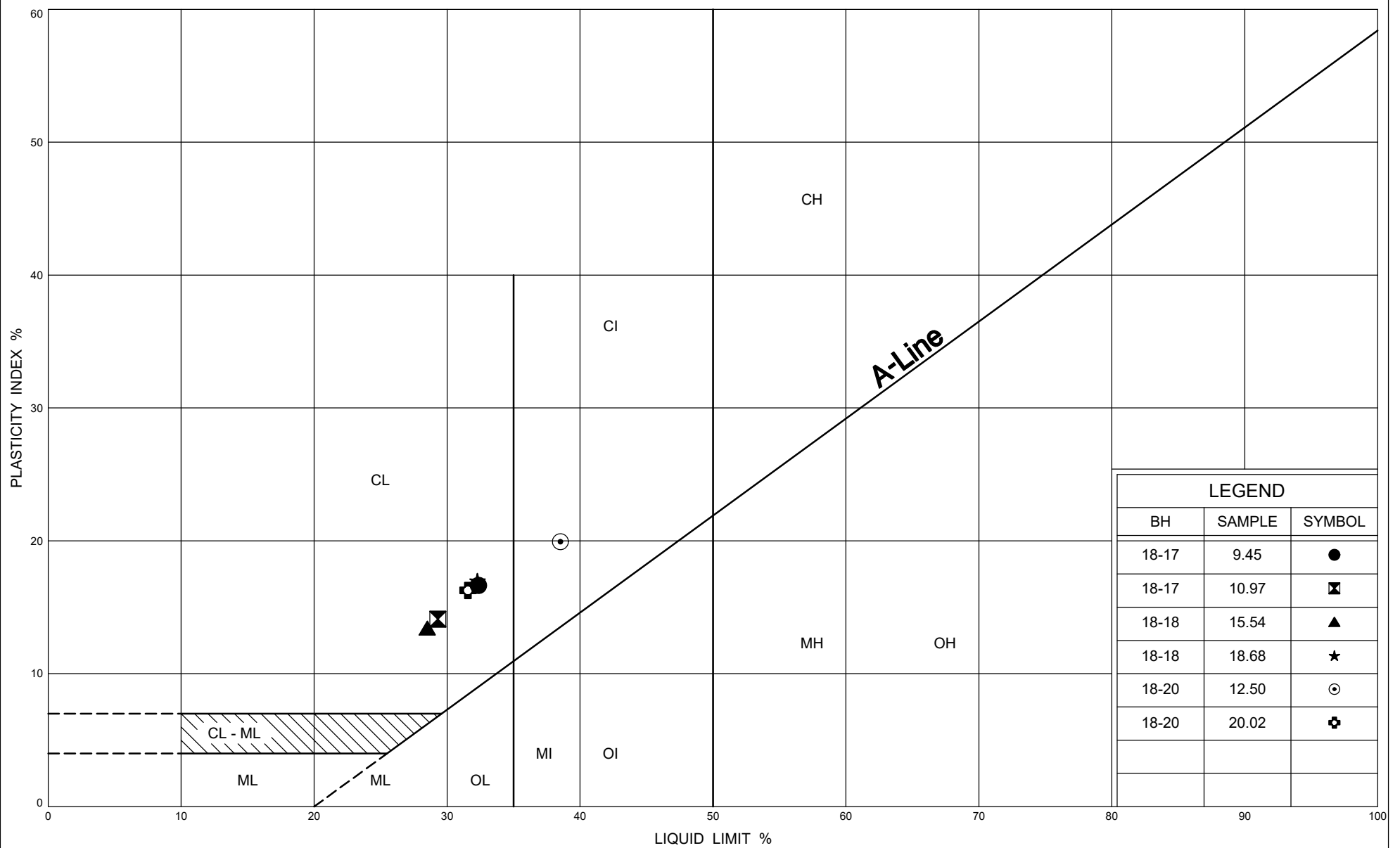
PLASTICITY CHART

Silty CLAY

FIG No B31

GWP 2430-15-00

Welland River Bridge Replacement



Ministry of
Transportation

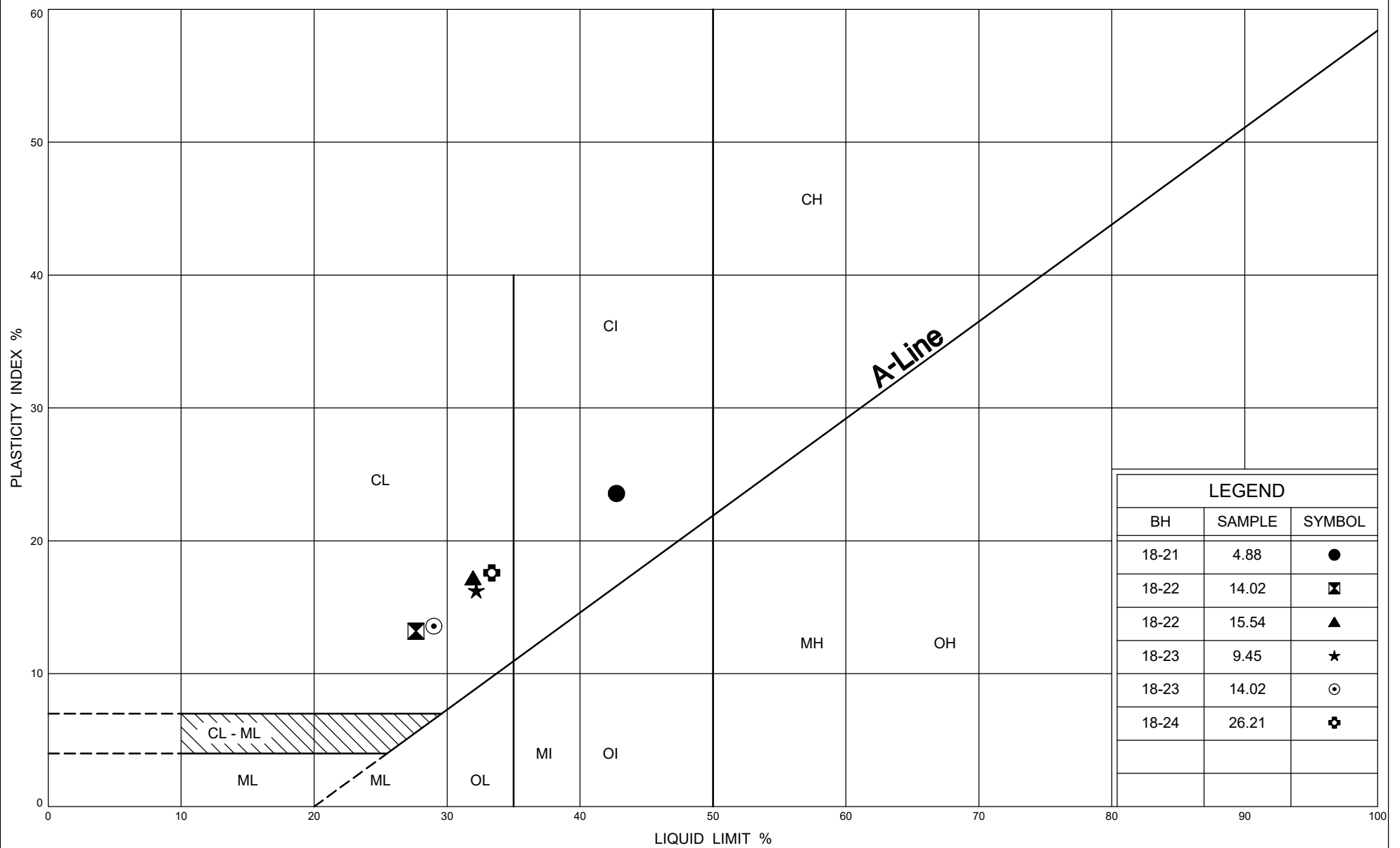
PLASTICITY CHART

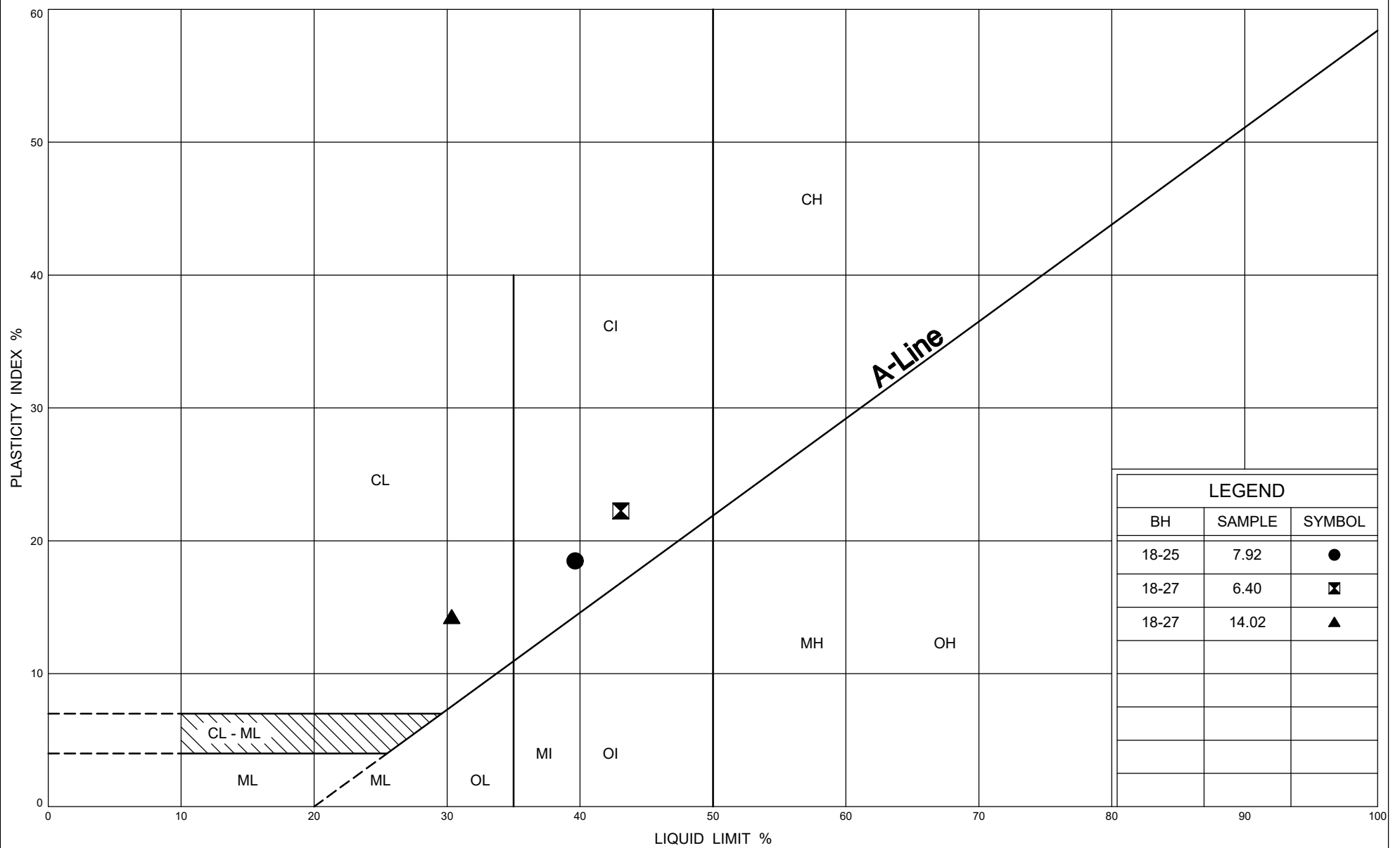
Silty CLAY

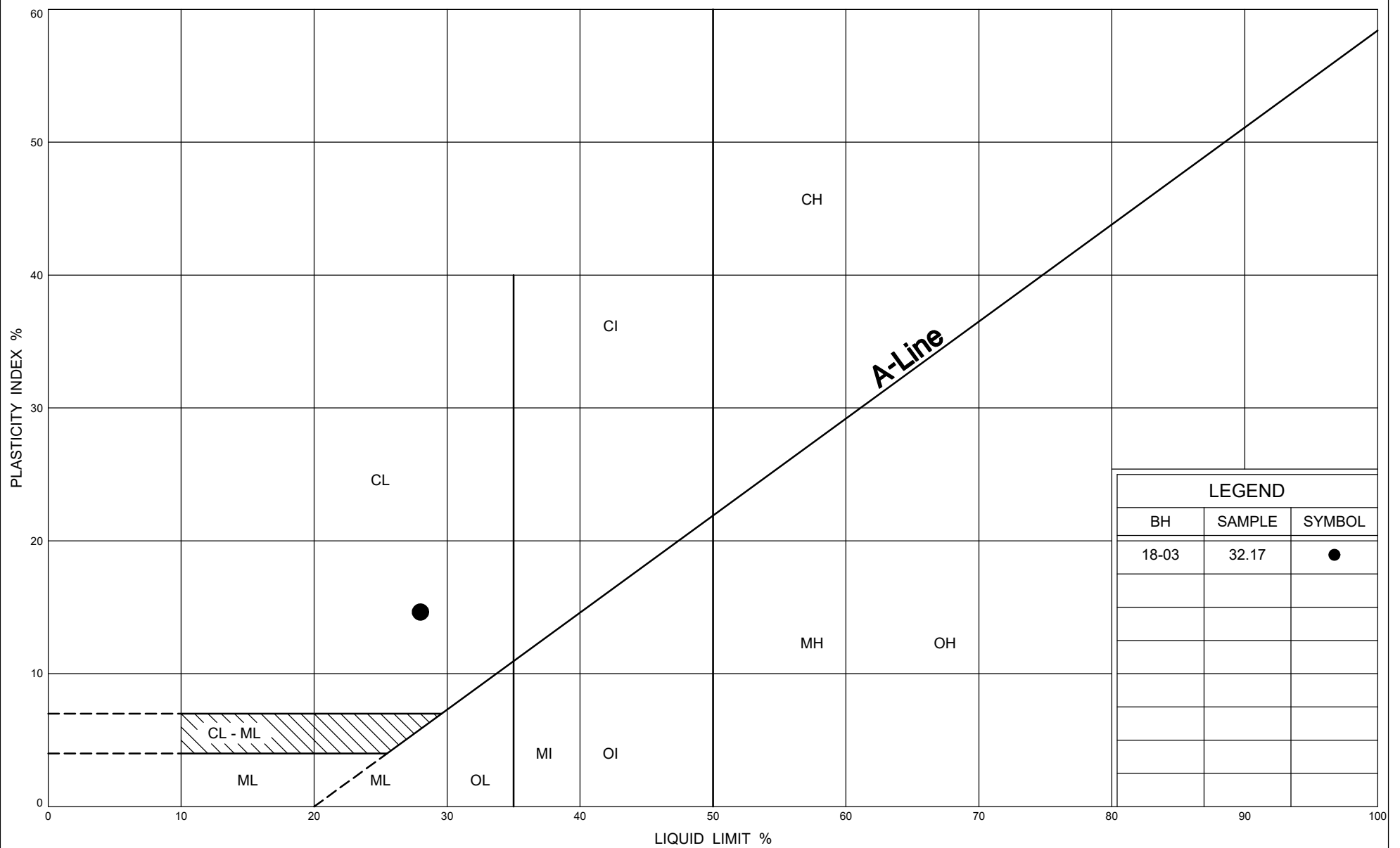
FIG No B32

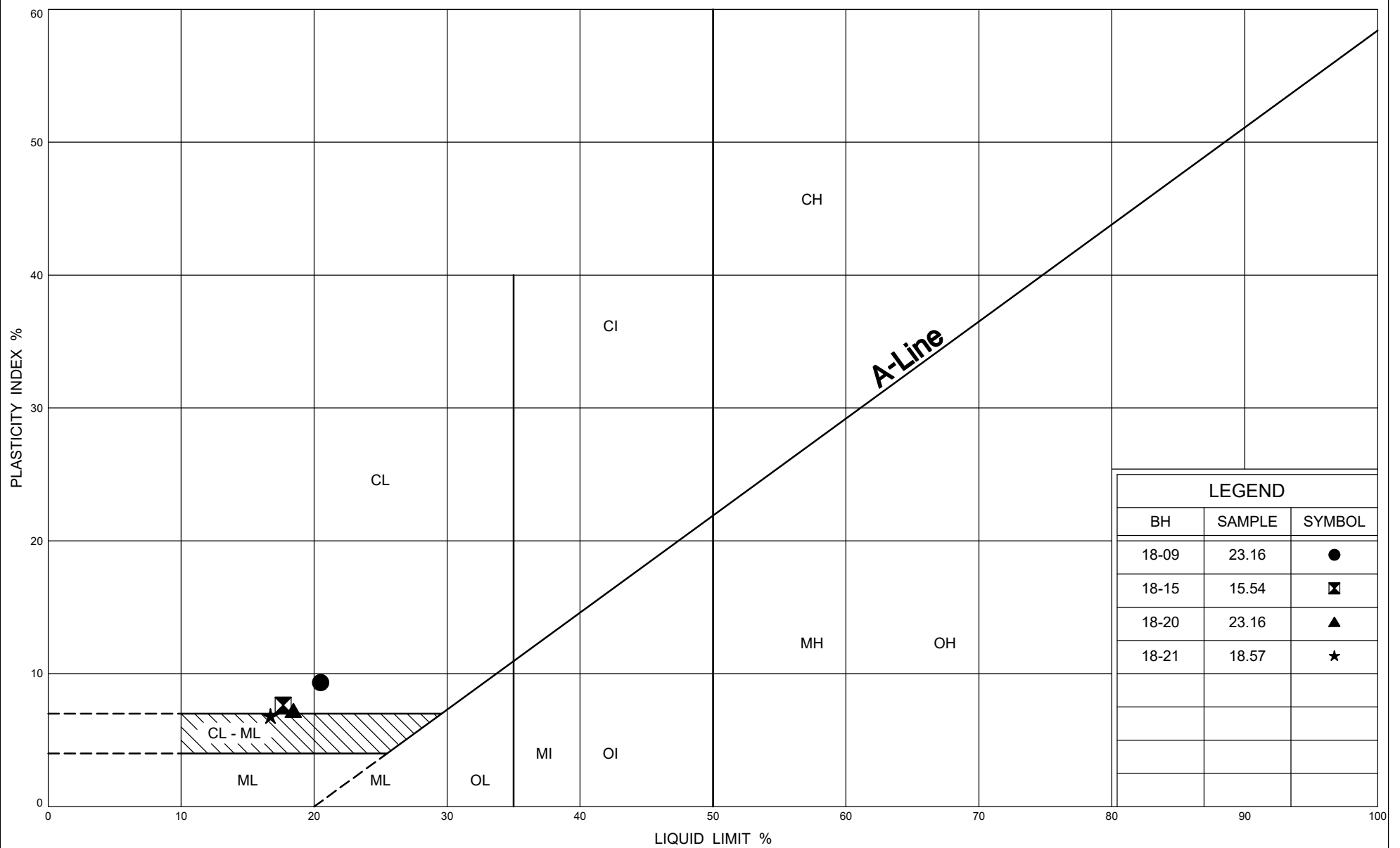
GWP 2430-15-00

Welland River Bridge Replacement









Consolidation Test Report

CLIENT: **WSP**

FILE NUMBER: **18426**

PROJECT: **Welland River Bridges**

REPORT DATE: **24-Apr-2018**

TEST DATES: **April 09, 2018 - April 22, 2018**

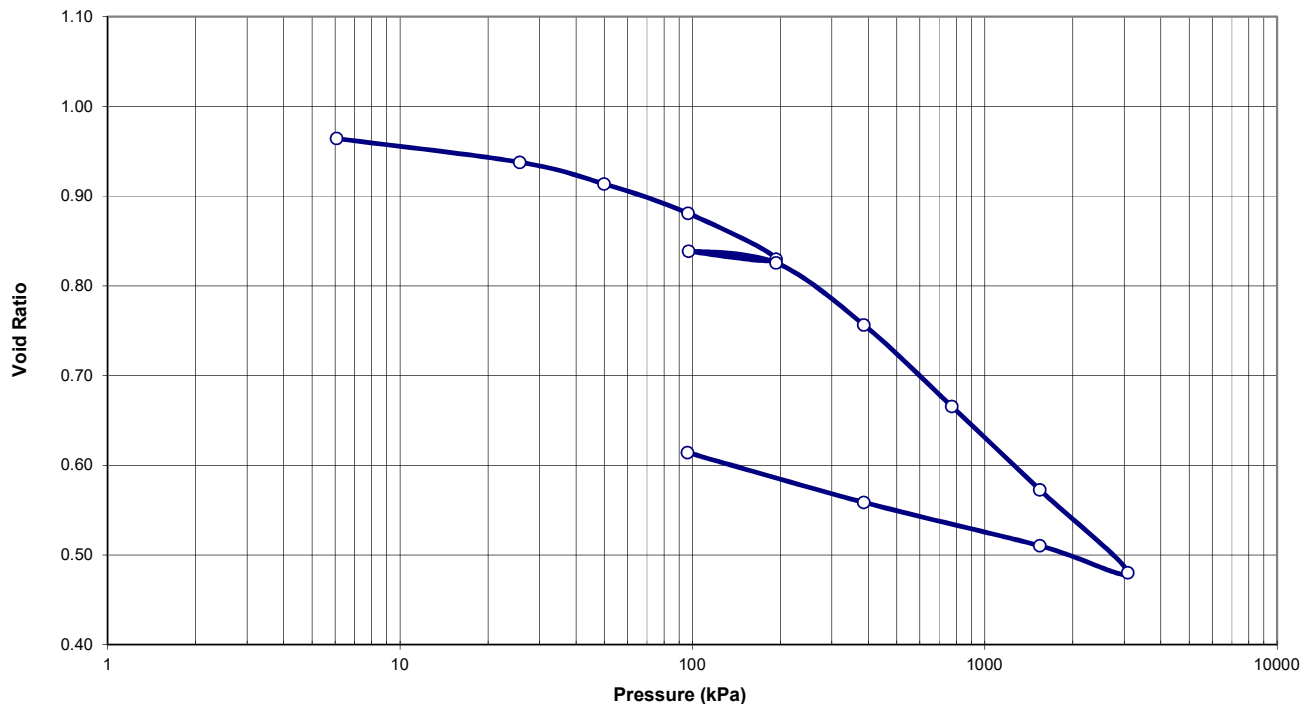
SAMPLE: **18-14 TW1 (15'-17')**
Silty Clay
Silt = 59%, Clay = 41%, LL=30.5%, PL=17.7%.

PROCEDURE: Test carried out in accordance with Standard Test Method for One-Dimensional Consolidation Properties of Soils, ASTM D 2435-04, method A

	<u>Start of Test</u>	<u>End of Test</u>
Wet Dens. (kg/m ³)	2000.8	2154.2
Dry Dens. (kg/m ³)	1411.0	1721.3
Moisture Cont. (%)	41.8	25.1
Void Ratio	0.969	0.614

Void Ratio vs. Pressure

Project #: 18426
 Client: WSP
 Project Name: Welland River Bridges
 Sample: 18-14 TW1 (15'-17')
 Oedometer Consolidation Test



Consolidation Test Report

Welland River Bridges

18426

18-14 TW1 (15'-17')

TRIMMING: The Specimen was manually trimmed to the size of consolidation ring, then mounted in a fixed ring consolidometer.

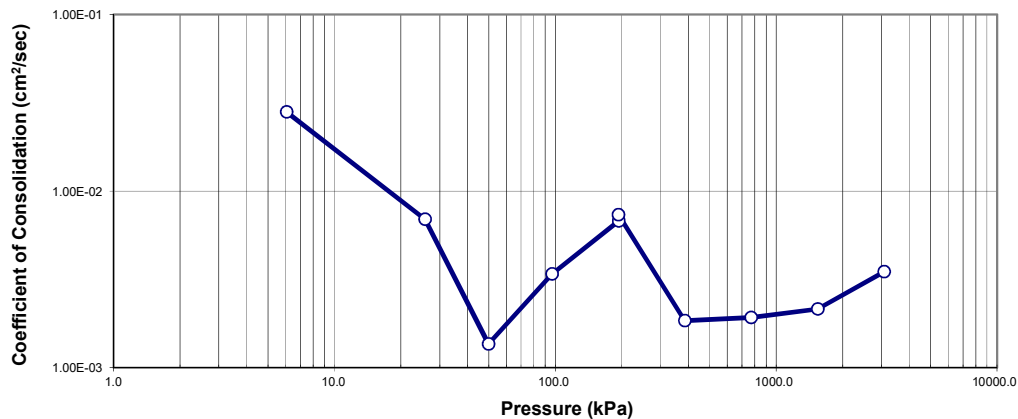
LOADING: A seating load of 6.1 kPa was applied and the consolidometer was flooded with distilled water. Sample was monitored to ensure no swelling effect occurred before the start of the test. Subsequent loads were applied after a constant load increment duration of 24 hours.

CALCULATIONS: Coefficients of Consolidation were calculated by the square root time method.

Pressure (kPa)	Corr. H. (mm)	Avg. H. (mm)	D ₉₀ (mm)	t ₉₀ (min)	c _v (cm ² /s)	Void Ratio	m _v (m ² /kN)	k (cm/s)
0.0	25.400					0.969		
6.1	25.338	25.369	-0.048	0.81	2.81E-02	0.964	4.02E-04	1.11E-06
25.7	24.996	25.167	-0.173	3.24	6.91E-03	0.938	6.89E-04	4.66E-07
49.9	24.685	24.840	-0.161	16.00	1.36E-03	0.914	5.15E-04	6.88E-08
96.6	24.263	24.474	-0.190	6.25	3.39E-03	0.881	3.65E-04	1.21E-07
193.2	23.601	23.932	-0.244	2.99	6.76E-03	0.830	2.82E-04	1.87E-07
97.0	23.717	23.659				0.839		
193.0	23.551	23.634	-0.089	2.690	0.007	0.826	7.27E-05	5.23E-08
385.7	22.658	23.104	-0.502	10.240	0.002	0.756	1.97E-04	3.56E-08
770.0	21.487	22.072	-0.659	8.94	1.93E-03	0.666	1.34E-04	2.54E-08
1540.0	20.288	20.887	-0.700	7.18	2.15E-03	0.573	7.25E-05	1.53E-08
3080.0	19.096	19.692	-0.646	3.92	3.49E-03	0.480	3.81E-05	1.31E-08
1540.0	19.482	19.289				0.510		
385.0	20.106	19.794				0.559		
96.3	20.821	20.463				0.614		

Coefficient of Consolidation vs. Pressure

Project #: 18426
Client: WSP
Project Name: Welland River Bridges
Sample: 18-14 TW1 (15'-17')
Oedometer Consolidation Test



Notes: C_v and k calculated using t₉₀ values

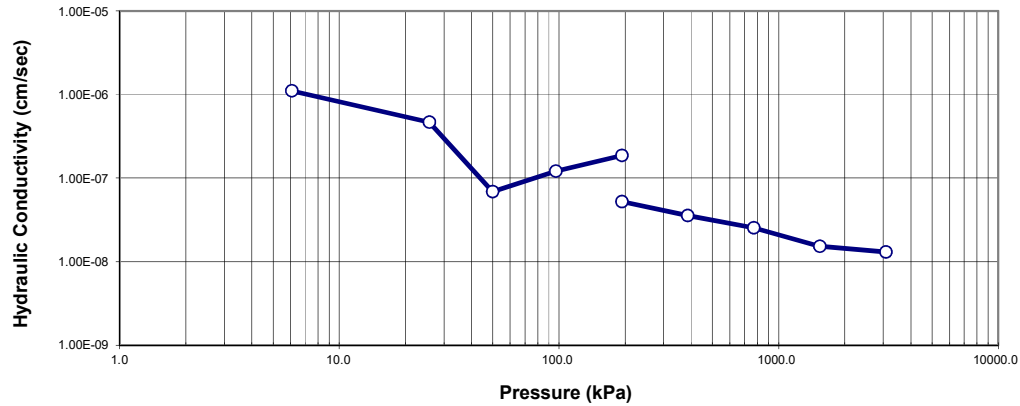
Consolidation Test Report

Welland River Bridges
18426

18-14 TW1 (15'-17')

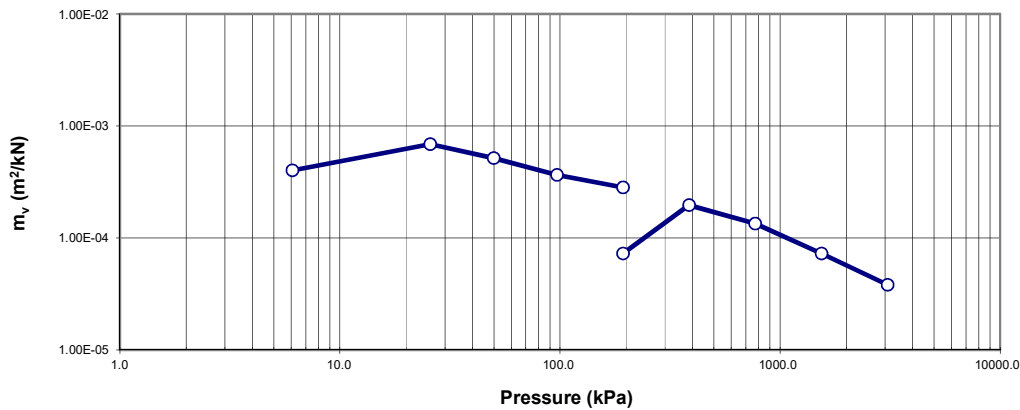
Hydraulic Conductivity vs. Pressure

Project #: 18426
Client: WSP
Project Name: Welland River Bridges
Sample: 18-14 TW1 (15'-17')
Oedometer Consolidation Test



m_v vs. Pressure

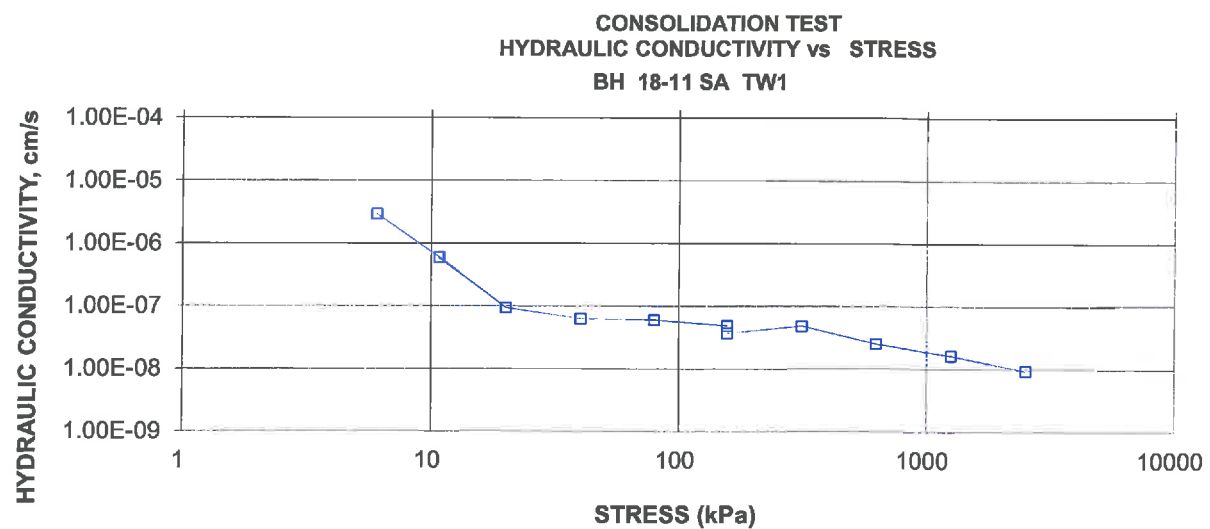
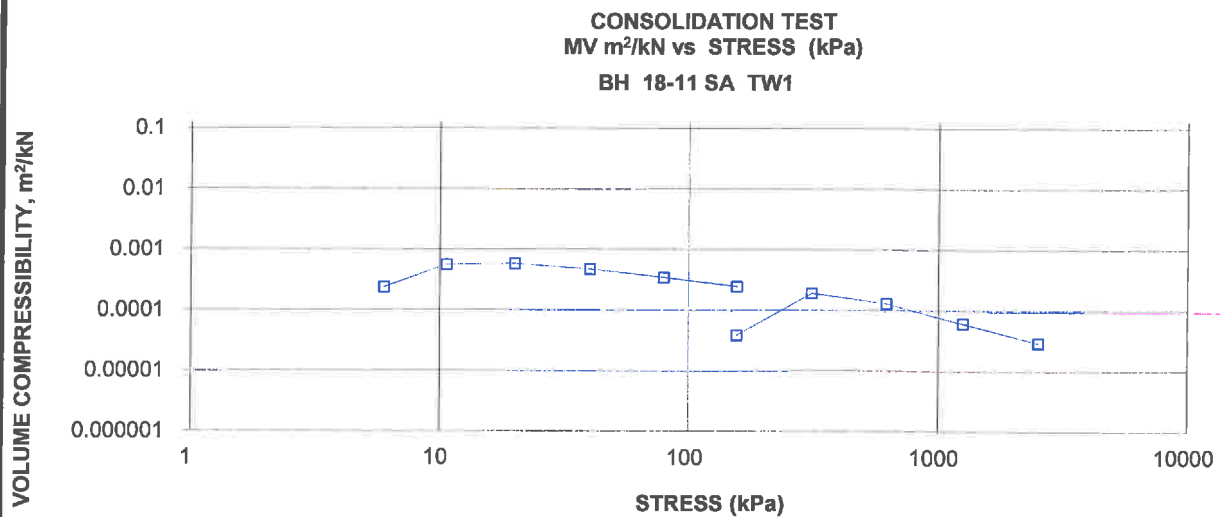
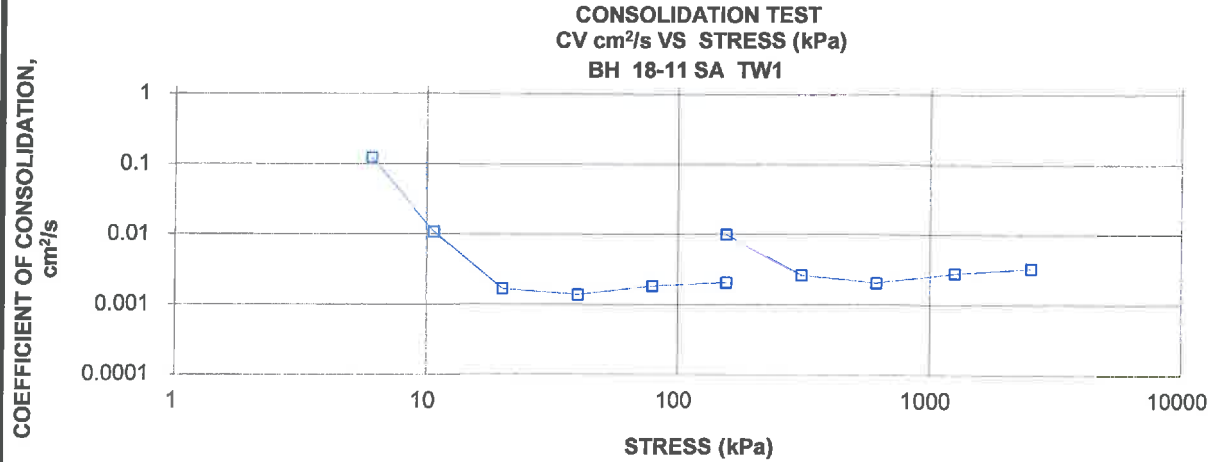
Project #: 18426
Client: WSP
Project Name: Welland River Bridges
Sample: 18-14 TW1 (15'-17')
Oedometer Consolidation Test



CONSOLIDATION TEST SUMMARY ASTM D2435/D2435M					FIGURE		
SAMPLE IDENTIFICATION							
Project Number	1897138(2000)			Sample Number	TW1		
Borehole Number	18-11			Sample Depth, m	6.86-7.47		
TEST CONDITIONS							
Test Type	Laboratory Standard			Load Duration, hr	24		
Oedometer Number	2						
Date Started	04/06/2018						
Date Completed	04/22/2018						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	2.54	Unit Weight, kN/m ³	19.26				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	14.93				
Area, cm ²	31.65	Specific Gravity, measured	2.75				
Volume, cm ³	80.29	Solids Height, cm	1.405				
Water Content, %	28.97	Volume of Solids, cm ³	44.46				
Wet Mass, g	157.69	Volume of Voids, cm ³	35.83				
Dry Mass, g	122.27	Degree of Saturation, %	98.8				
TEST COMPUTATIONS							
	Corr.		Average				
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.537	0.806	2.537				
6.01	2.533	0.803	2.535	11	1.24E-01	2.36E-04	2.87E-06
10.72	2.527	0.799	2.530	125	1.09E-02	5.52E-04	5.88E-07
20.17	2.513	0.789	2.520	799	1.68E-03	5.71E-04	9.44E-08
40.12	2.490	0.772	2.501	960	1.38E-03	4.64E-04	6.29E-08
79.27	2.456	0.748	2.473	714	1.82E-03	3.38E-04	6.02E-08
156.18	2.409	0.715	2.432	614	2.04E-03	2.42E-04	4.85E-08
79.27	2.412	0.717	2.411				
156.18	2.405	0.712	2.409	126	9.76E-03	3.84E-05	3.68E-08
310.96	2.331	0.659	2.368	454	2.62E-03	1.89E-04	4.85E-08
621.38	2.230	0.588	2.280	540	2.04E-03	1.27E-04	2.55E-08
1249.94	2.133	0.519	2.182	359	2.81E-03	6.08E-05	1.67E-08
2501.26	2.040	0.452	2.086	277	3.33E-03	2.95E-05	9.65E-09
1251.05	2.046	0.456	2.043				
314.18	2.074	0.476	2.060				
79.27	2.115	0.506	2.095				
20.68	2.163	0.540	2.139				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)</p> <p>Specimen taken 2-6 cm from top of the tube.</p>							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	2.16	Unit Weight, kN/m ³	21.12				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.52				
Area, cm ²	31.65	Specific Gravity, measured	2.75				
Volume, cm ³	68.45	Solids Height, cm	1.405				
Water Content, %	20.60	Volume of Solids, cm ³	44.46				
Wet Mass, g	147.46	Volume of Voids, cm ³	23.99				
Dry Mass, g	122.27						
<div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div>Prepared By: LH</div> <div style="text-align: center;">Golder Associates</div> <div>Checked By: </div> </div>							

CONSOLIDATION TEST SUMMARY

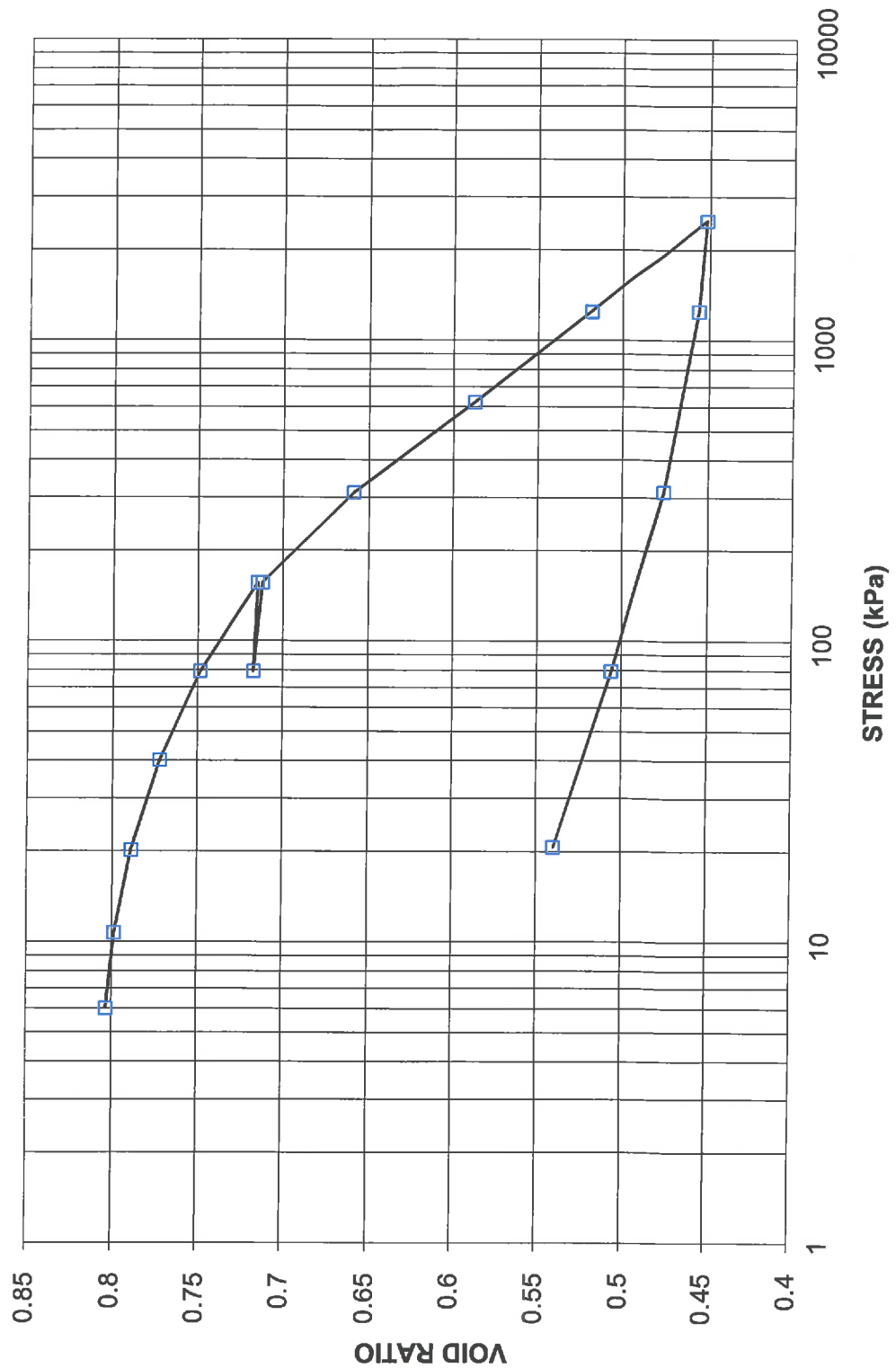
FIGURE



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-11 SA TW1**



Project No. 1897138(2000)

Prepared By: LH

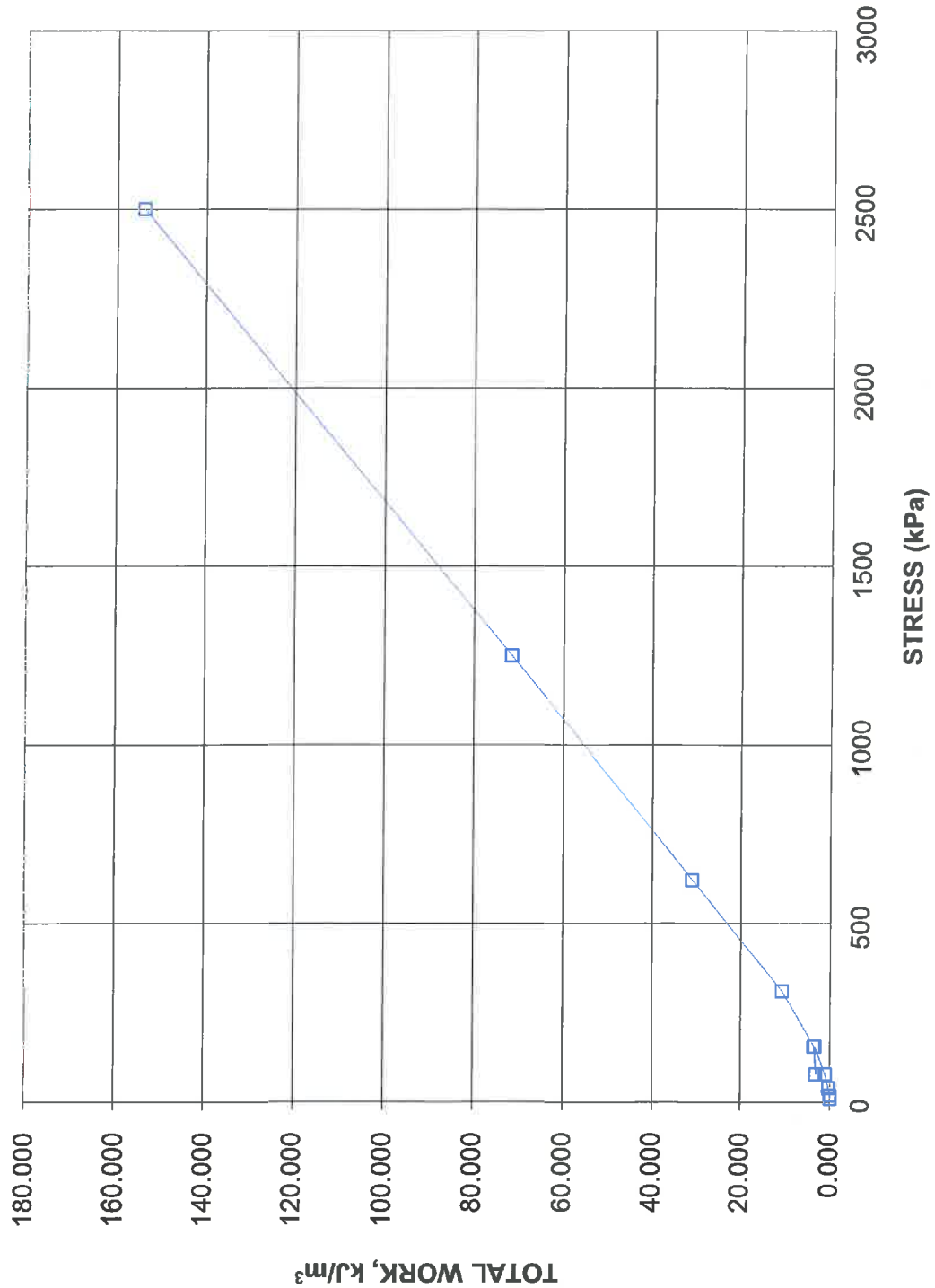
Golder Associates

Checked By: *[Signature]*

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH 18-11 SA TW1**



Project No. 1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *[Signature]*

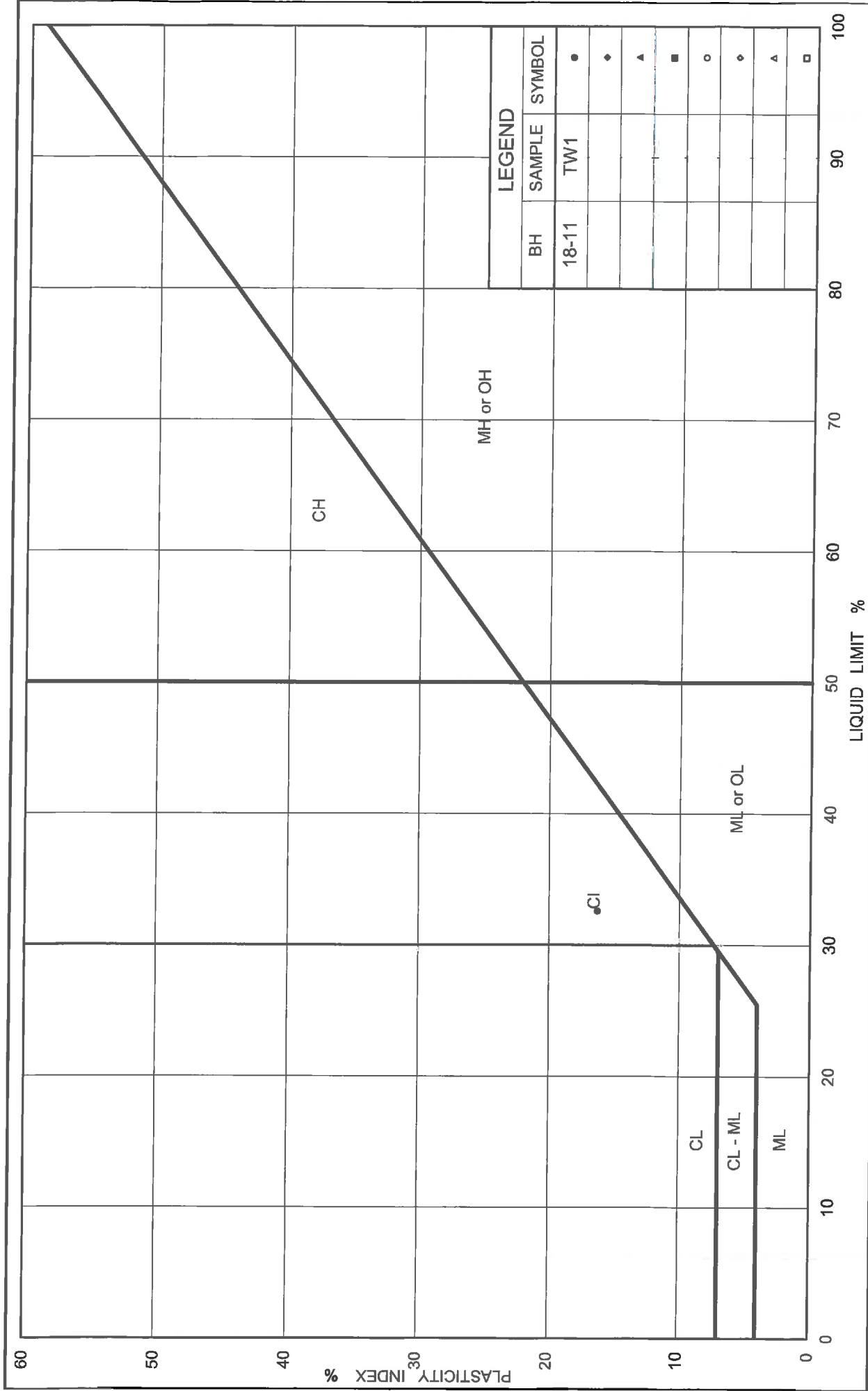
SUMMARY OF ATTERBERG LIMITS DETERMINATION

ASTM D 4318

PROJECT NUMBER	1897138 (2000)			
PROJECT NAME	ThurberEng/Lab Testing/Miss			
DATE TESTED	April 18, 2018			
Borehole No.	Sample No.	Depth (ft)	Depth (m)	Atterberg Limits LL=, PL=, PI=
18-11	TW1	22.5-24.5	6.86-7.47	LL=32.6, PL=16.3, PI=16.3

Checked By: 

Golder Associates



LEGEND		
BH	SAMPLE	SYMBOL
18-11	TW1	•
		◆
		▲
		■
		○
		◇
		△
		□



GOLDER

PLASTICITY CHART

Figure No.

Project No. 1897138 (2000)

Checked By: *11*

FIGURE



6.86 - 7.47

Date: 17-Apr-18



SPECIFIC GRAVITY TEST RESULTS

ASTM D 854 TEST METHOD B

PROJECT NUMBER	1897138 (2000)	
PROJECT NAME	ThurberEng/Lab Testing/Miss	
DATE TESTED	April 11, 2018	
Borehole	Sample	Specific
No.	No.	Gravity
18-11	TW1	2.75

Note: Test carried out on soil particles <4.75mm using distilled water.

Checked By: 

Golder Associates

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	1897138(2000)	Sample Number	TW2
Borehole Number	18-04	Sample Depth, ft	15.24-15.85

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	05/01/2018		
Date Completed	05/16/2018		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.56	Unit Weight, kN/m ³	18.72
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	14.12
Area, cm ²	31.67	Specific Gravity, measured	2.73
Volume, cm ³	80.91	Solids Height, cm	1.348
Water Content, %	32.57	Volume of Solids, cm ³	42.69
Wet Mass, g	154.50	Volume of Voids, cm ³	38.23
Dry Mass, g	116.54	Degree of Saturation, %	99.3

TEST COMPUTATIONS

Stress	Corr. Height	Void Ratio	Average Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.555	0.895	2.555				
5.87	2.559	0.898	2.557				
10.71	2.561	0.900	2.560				
20.45	2.557	0.897	2.559	228	6.09E-03	1.49E-04	8.87E-08
39.71	2.548	0.890	2.552	240	5.75E-03	1.97E-04	1.11E-07
78.56	2.531	0.878	2.539	192	7.12E-03	1.64E-04	1.15E-07
155.86	2.509	0.861	2.520	205	6.57E-03	1.13E-04	7.30E-08
78.56	2.514	0.865	2.511				
155.86	2.506	0.859	2.510	43	3.11E-02	3.90E-05	1.19E-07
310.90	2.467	0.830	2.487	154	8.51E-03	9.85E-05	8.21E-08
620.03	2.349	0.742	2.408	305	4.03E-03	1.50E-04	5.92E-08
1237.01	2.224	0.650	2.286	184	6.02E-03	7.89E-05	4.65E-08
2472.52	2.115	0.569	2.170	154	6.48E-03	3.45E-05	2.19E-08
309.29	2.161	0.603	2.138				
79.21	2.210	0.639	2.185				
20.45	2.264	0.679	2.237				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen swelled under 10.71kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.26	Unit Weight, kN/m ³	20.04
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	15.94
Area, cm ²	31.67	Specific Gravity, measured	2.73
Volume, cm ³	71.69	Solids Height, cm	1.348
Water Content, %	25.70	Volume of Solids, cm ³	42.69
Wet Mass, g	146.49	Volume of Voids, cm ³	29.00
Dry Mass, g	116.54		

Prepared By: LH

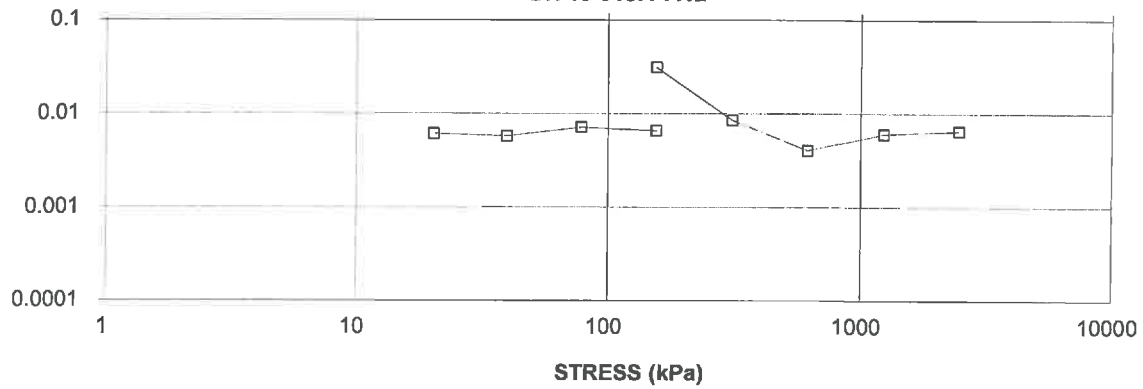
Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE

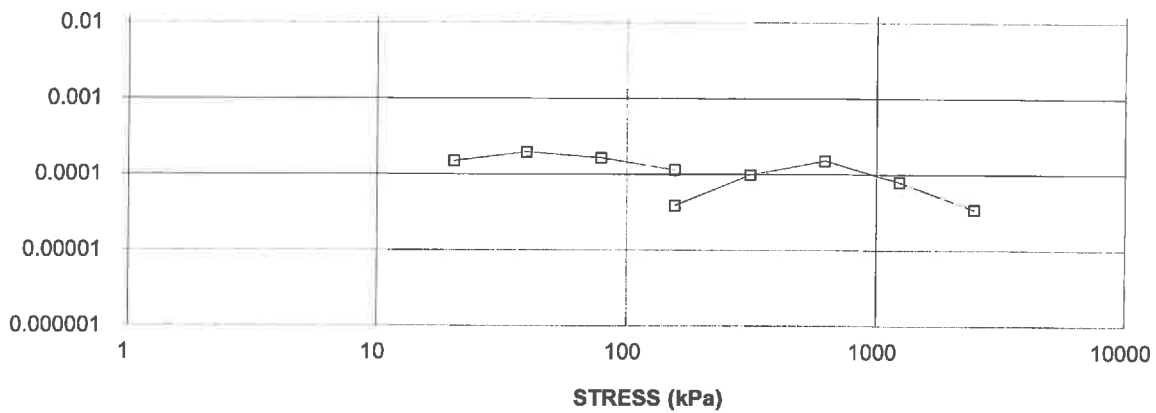
COEFFICIENT OF CONSOLIDATION, cm^2/s

CONSOLIDATION TEST
CV cm^2/s VS STRESS (kPa)
BH 18-04SA TW2



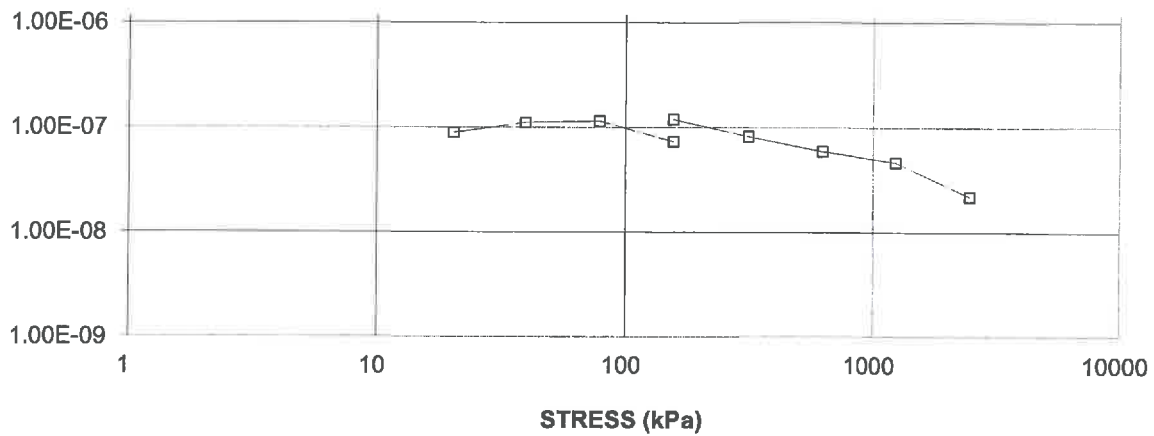
VOLUME COMPRESSIBILITY, m^2/kN

CONSOLIDATION TEST
MV m^2/kN vs STRESS (kPa)
BH 18-04SA TW2



HYDRAULIC CONDUCTIVITY, cm/s

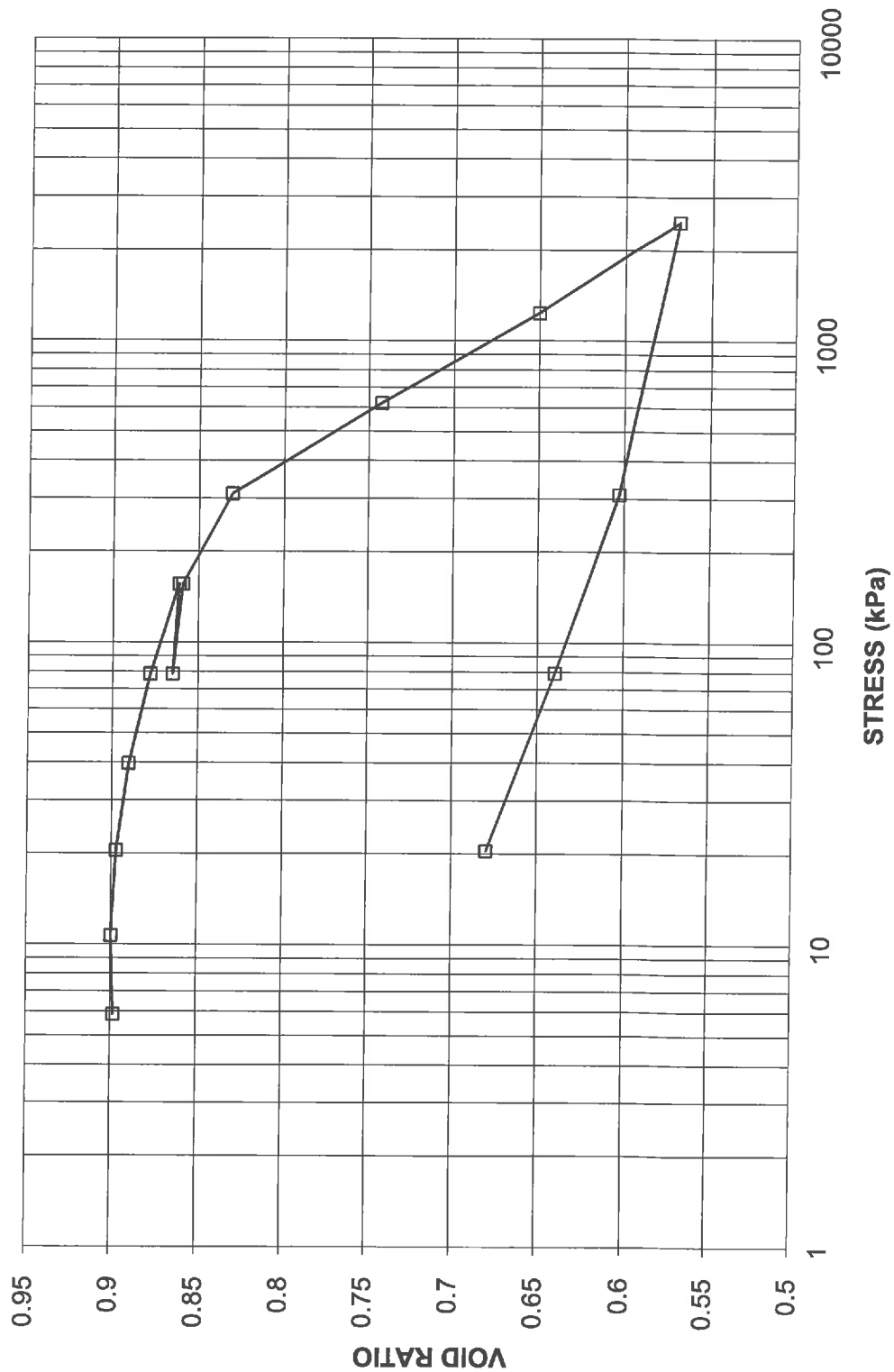
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 18-04SA TW2



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-04SA TW2**

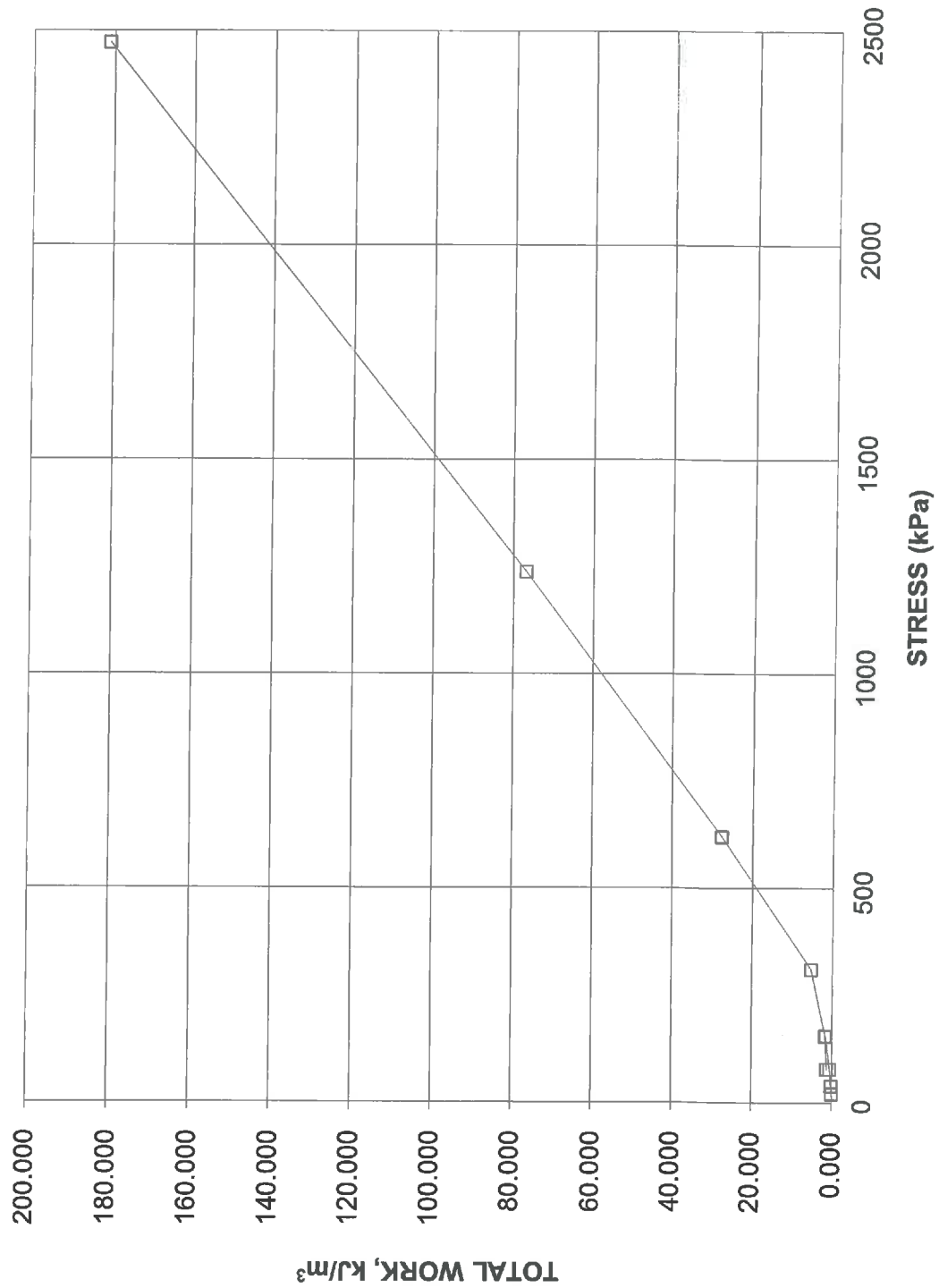


[Signature]

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH 18-04SA TW2**



Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *[Signature]*

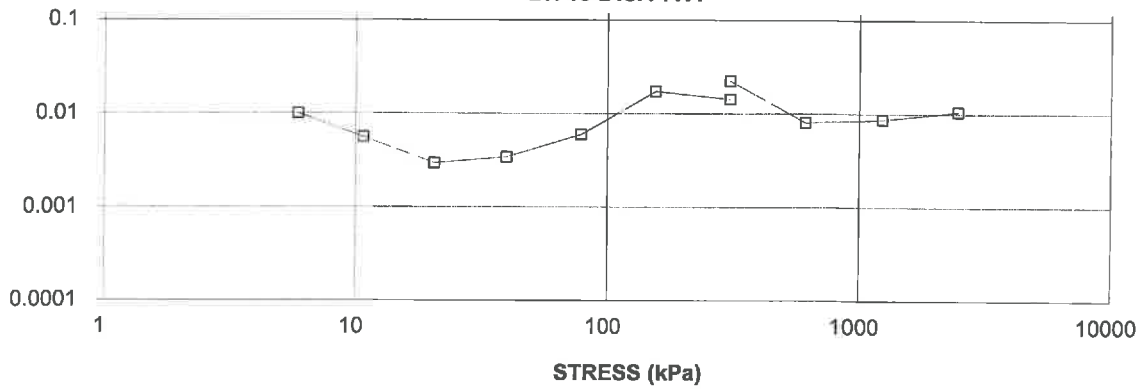
<div style="display: flex; justify-content: space-between;"> <div style="text-align: center;"> CONSOLIDATION TEST SUMMARY ASTM D2435/D2435M </div> <div style="text-align: center;"> FIGURE </div> </div>				
SAMPLE IDENTIFICATION				
Project Number	1897138(2000)	Sample Number	TW1	
Borehole Number	18-24	Sample Depth, ft	12.20-12.80	
TEST CONDITIONS				
Test Type	Laboratory Standard	Load Duration, hr	24	
Oedometer Number	2			
Date Started	05/01/2018			
Date Completed	05/17/2018			
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL				
Sample Height, cm	2.54	Unit Weight, kN/m ³	19.26	
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	14.96	
Area, cm ²	31.65	Specific Gravity, measured	2.72	
Volume, cm ³	80.29	Solids Height, cm	1.423	
Water Content, %	28.74	Volume of Solids, cm ³	45.04	
Wet Mass, g	157.71	Volume of Voids, cm ³	35.26	
Dry Mass, g	122.5	Degree of Saturation, %	99.9	
TEST COMPUTATIONS				
	Corr.	Average		
Stress	Height	Void	Height	t ₉₀
kPa	cm	Ratio	cm	sec
				cv.
				cm ² /s
				mv
				m ² /kN
				k
				cm/s
0.00	2.537	0.783	2.537	
5.88	2.527	0.776	2.532	135
10.72	2.519	0.770	2.523	240
20.68	2.504	0.760	2.511	454
40.08	2.484	0.745	2.494	386
78.73	2.458	0.728	2.471	217
156.03	2.428	0.706	2.443	73
310.63	2.387	0.677	2.407	86
156.03	2.390	0.680	2.389	
310.55	2.381	0.673	2.386	54
619.95	2.337	0.642	2.359	147
1238.70	2.275	0.598	2.306	130
2477.61	2.204	0.549	2.239	101
310.55	2.236	0.571	2.220	
78.62	2.267	0.593	2.252	
20.68	2.302	0.617	2.284	
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)</p>				
SAMPLE DIMENSIONS AND PROPERTIES - FINAL				
Sample Height, cm	2.30	Unit Weight, kN/m ³	20.39	
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	16.49	
Area, cm ²	31.65	Specific Gravity, measured	2.72	
Volume, cm ³	72.84	Solids Height, cm	1.423	
Water Content, %	23.63	Volume of Solids, cm ³	45.04	
Wet Mass, g	151.45	Volume of Voids, cm ³	27.80	
Dry Mass, g	122.5			
<div style="display: flex; justify-content: space-between;"> <div>Prepared By: LH</div> <div>Golder Associates</div> <div>Checked By: </div> </div>				

CONSOLIDATION TEST SUMMARY

FIGURE

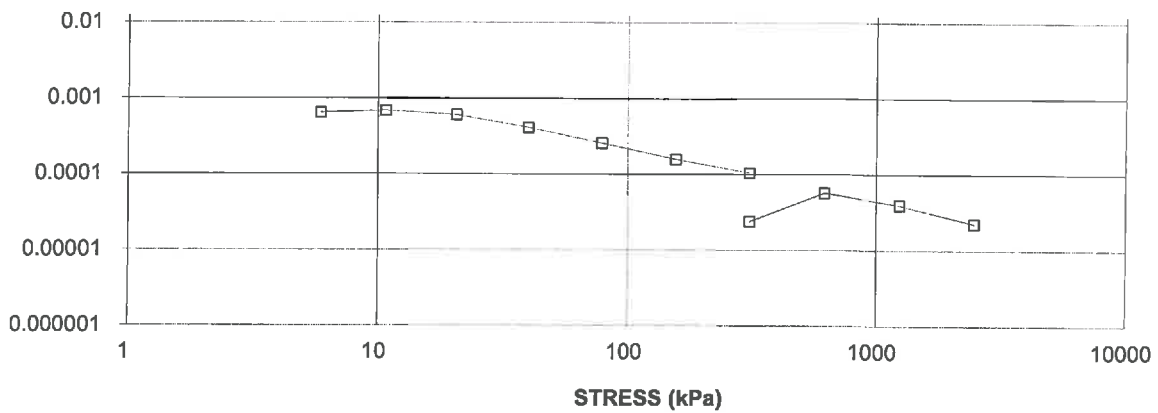
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 18-24SA TW1



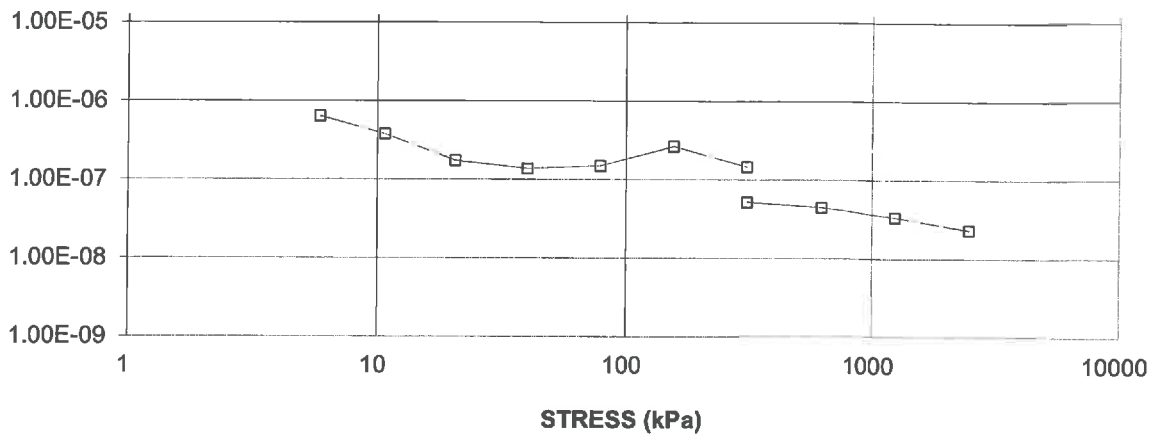
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 18-24SA TW1



HYDRAULIC CONDUCTIVITY, cm/s

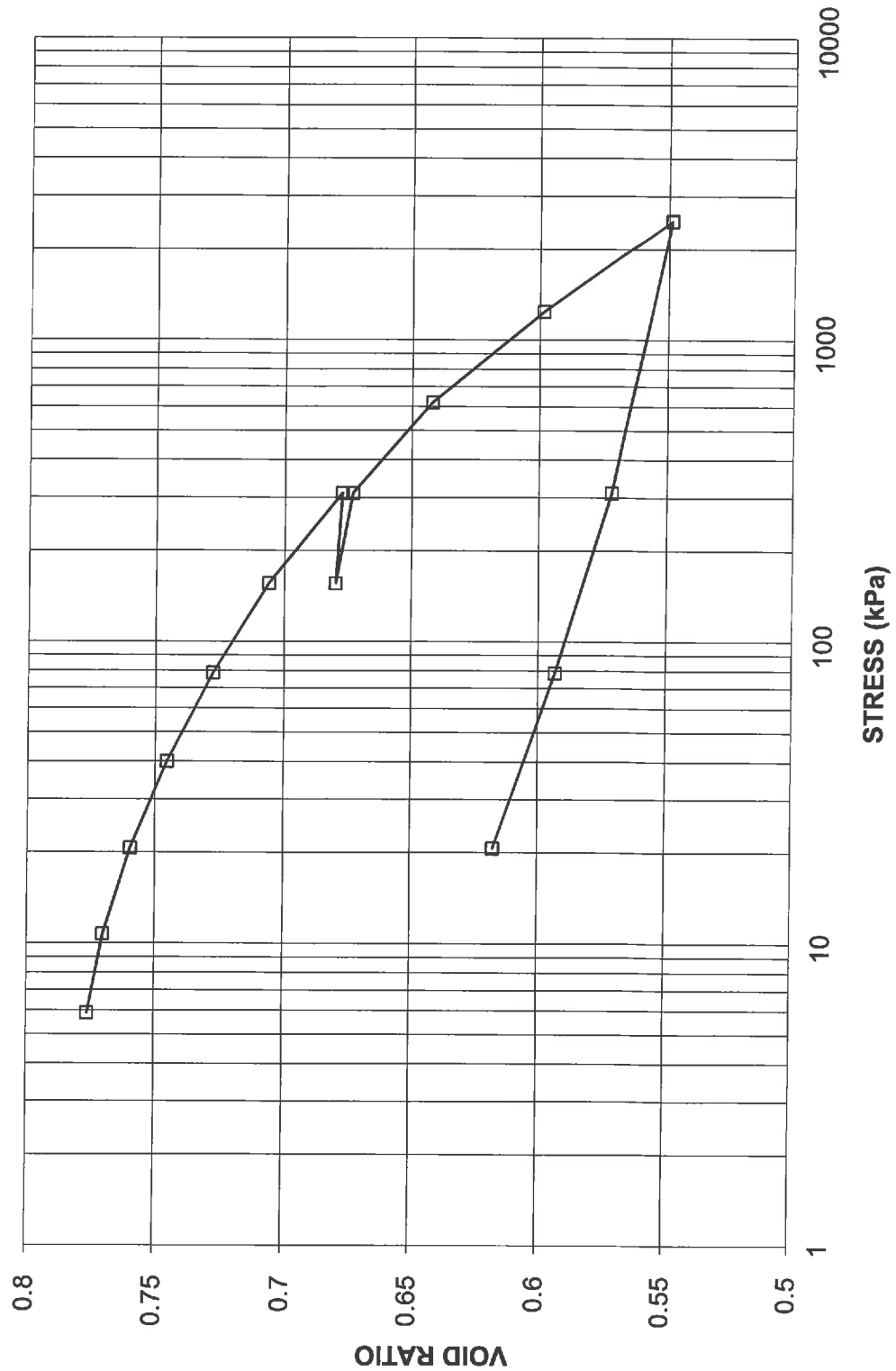
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 18-24SA TW1



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

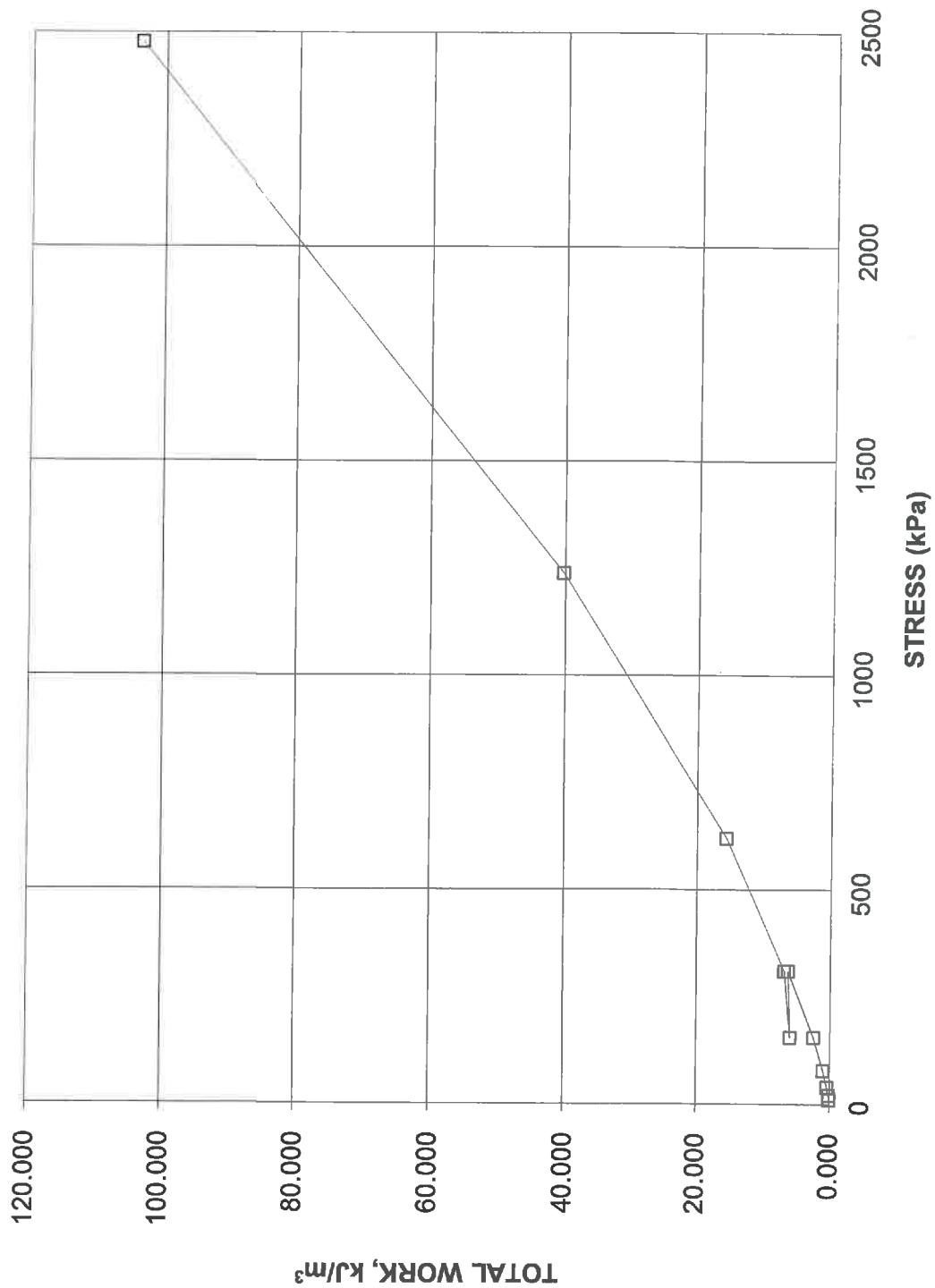
**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-24SA TW1**



**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 18-24SA TW1**



Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *[Signature]*



SPECIFIC GRAVITY TEST RESULTS

ASTM D 854 TEST METHOD B

PROJECT NUMBER	1897138 (2000)		
PROJECT NAME	ThurberEng/Lab Testing/Miss		
DATE TESTED	May 10, 2018		
Borehole No.	Sample No.	Specific Gravity	
18-04	TW2	2.73	
18-24	TW1	2.72	

Note: Test carried out on soil particles <4.75mm using distilled water.

Checked By: 

Golder Associates

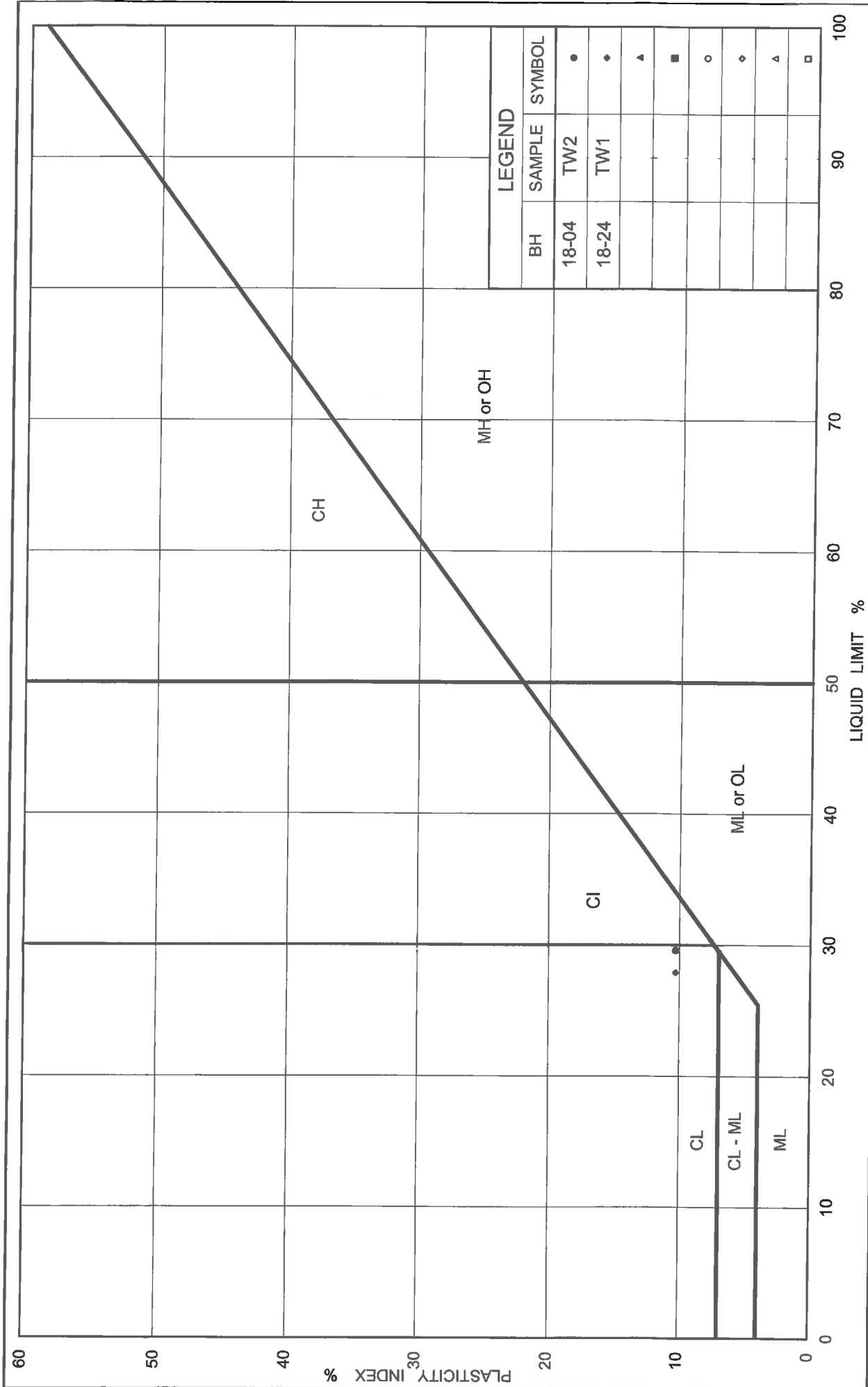


	Figure No.
	Project No. 1897138 (2000)
	Checked By: LM

SUMMARY OF ATTERBERG LIMITS DETERMINATION

ASTM D 4318

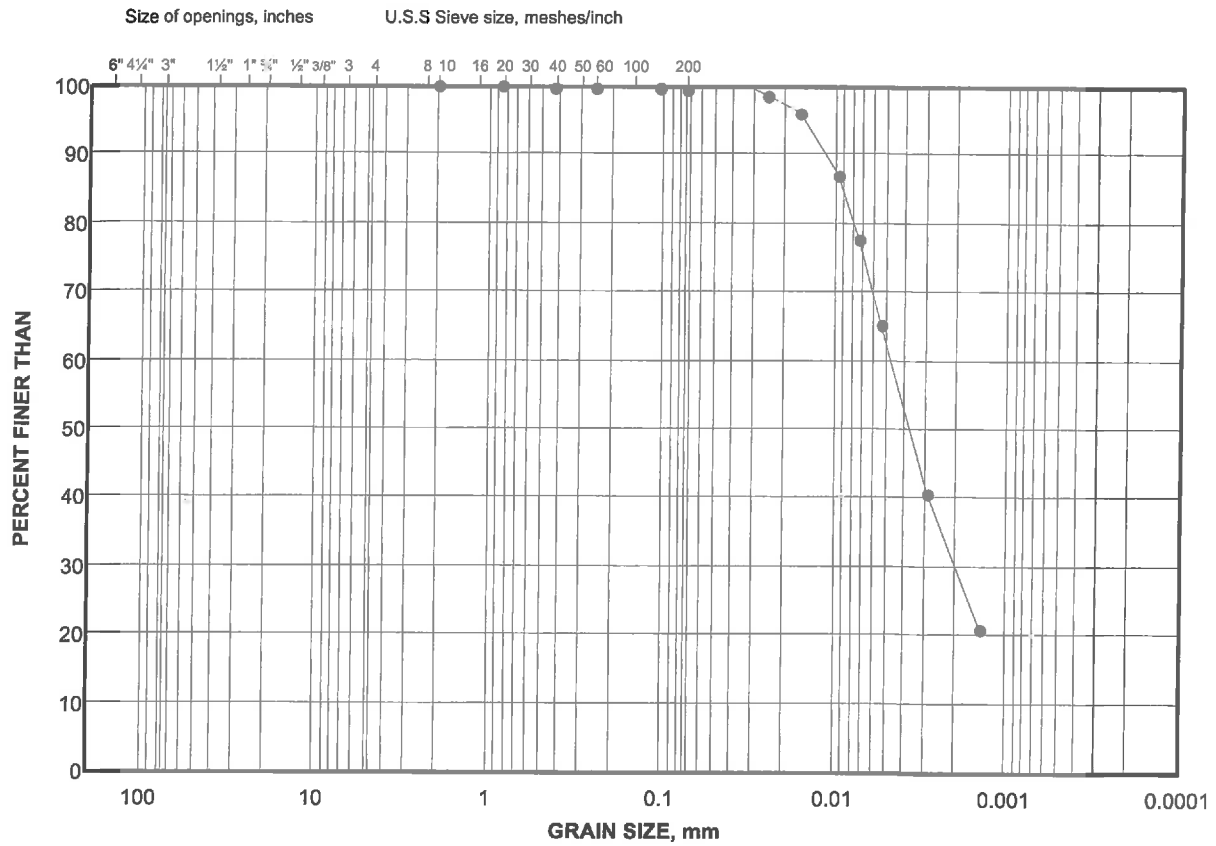
PROJECT NUMBER	1897138 (2000)			
PROJECT NAME	ThurberEng/Lab Testing/Miss			
DATE TESTED	May 29, 2018			
Borehole No.	Sample No.	Depth (ft)	Depth (m)	Atterberg Limits LL=, PL=, PI=
18-04	TW2	50-52	15.24-15.85	LL=29.6, PL=19.3, PI=10.3
18-24	TW1	40-42	12.19-12.80	LL=27.9, PL=17.6, PI=10.3

Checked By: 

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-04	TW2	15.24 - 15.85

Project Number: 1897138

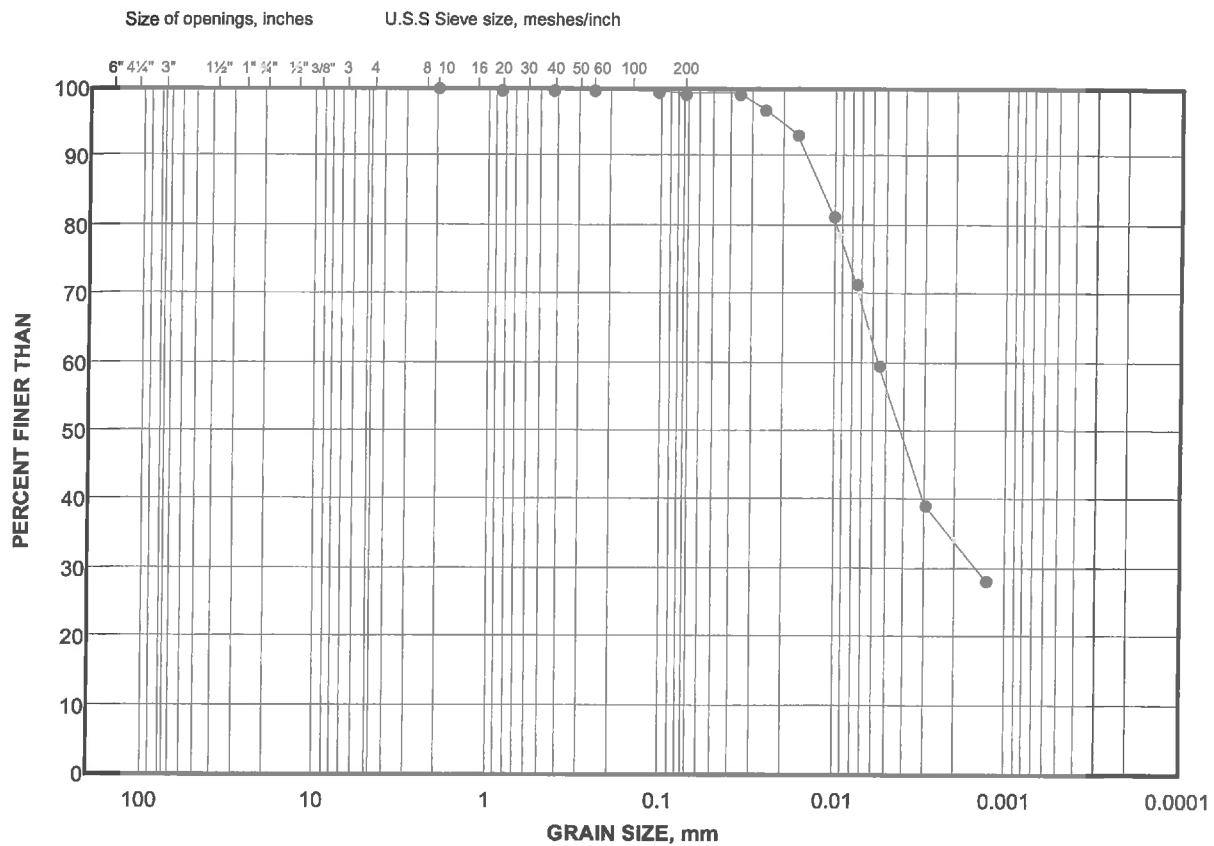
Checked By: LM

Golder Associates

Date: 29-May-18

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-24	TW1	12.20 - 12.80

Project Number: 1897138

Checked By: LM

Golder Associates

Date: 29-May-18



SPECIFIC GRAVITY TEST RESULTS

ASTM D 854 TEST METHOD B

PROJECT NUMBER	1897138 (2000)		
PROJECT NAME	ThurberEng/Lab Testing/Miss		
DATE TESTED	August 3, 2018		
Borehole No.	Sample No.	Specific Gravity	
18-01	TW1	2.79	
18-21	TW2	2.77	
18-25	TW1	2.76	
18-19	TW1	2.76	

Note: Test carried out on soil particles <4.75mm using distilled water.

Checked By: 

Golder Associates

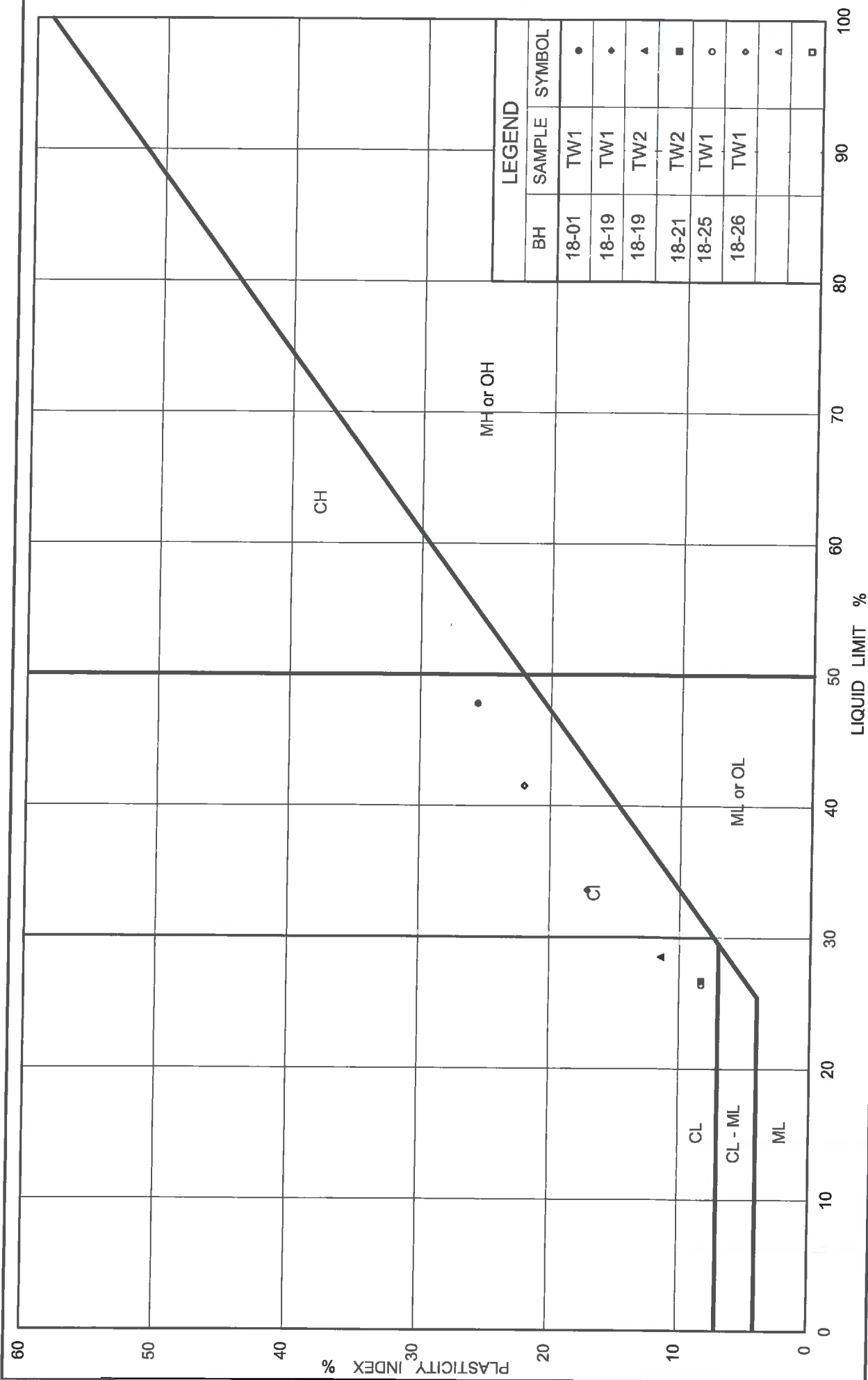
SUMMARY OF ATTERBERG LIMITS DETERMINATION

ASTM D 4318

PROJECT NUMBER	1897138 (2000)			
PROJECT NAME	ThurberEng/Lab Testing/Miss			
DATE TESTED	Aug 2, 2018			
Borehole No.	Sample No.	Depth (ft)	Depth (m)	Atterberg Limits LL=, PL=, PI=
18-01	TW1	40-42	12.19-12.80	LL=47.8, PL=22.2, PI=25.6
18-19	TW1	30-32	9.14-9.75	LL=33.6, PL=16.5, PI=17.1
18-19	TW2	45-47	13.72-14.33	LL=28.5, PL=17.1, PI=11.4
18-21	TW2	45-47	13.72-14.33	LL=26.7, PL=18.4, PI=8.3
18-25	TW1	40-42	12.19-12.80	LL=26.4, PL=18.1, PI=8.3
18-26	TW1	25-27	7.62-8.23	LL=41.5, PL=19.5, PI=22.0

Checked By: 

Golder Associates

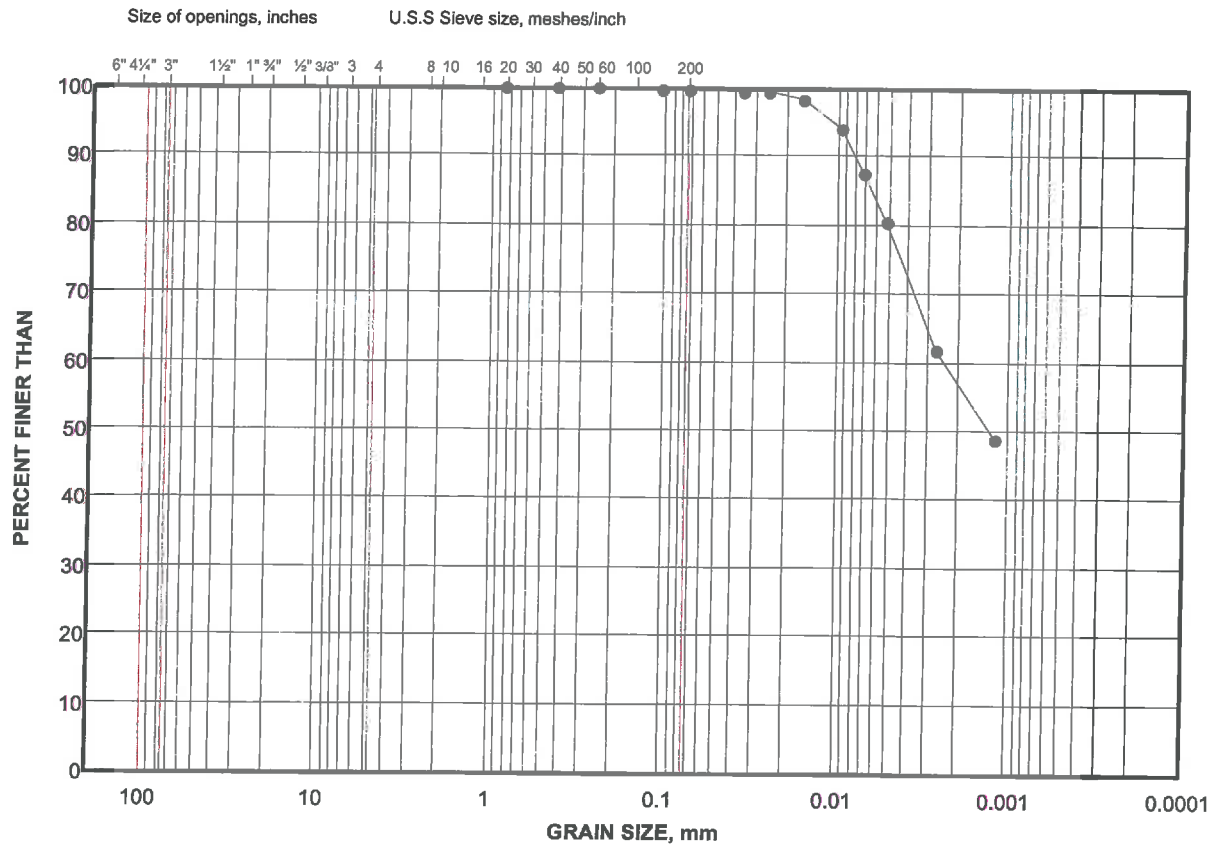


PLASTICITY CHART

Figure No.
Project No. 1897138 (2000)
Checked By: *Jul*

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-01	TW1	12.19 - 12.80

Project Number: 1897138

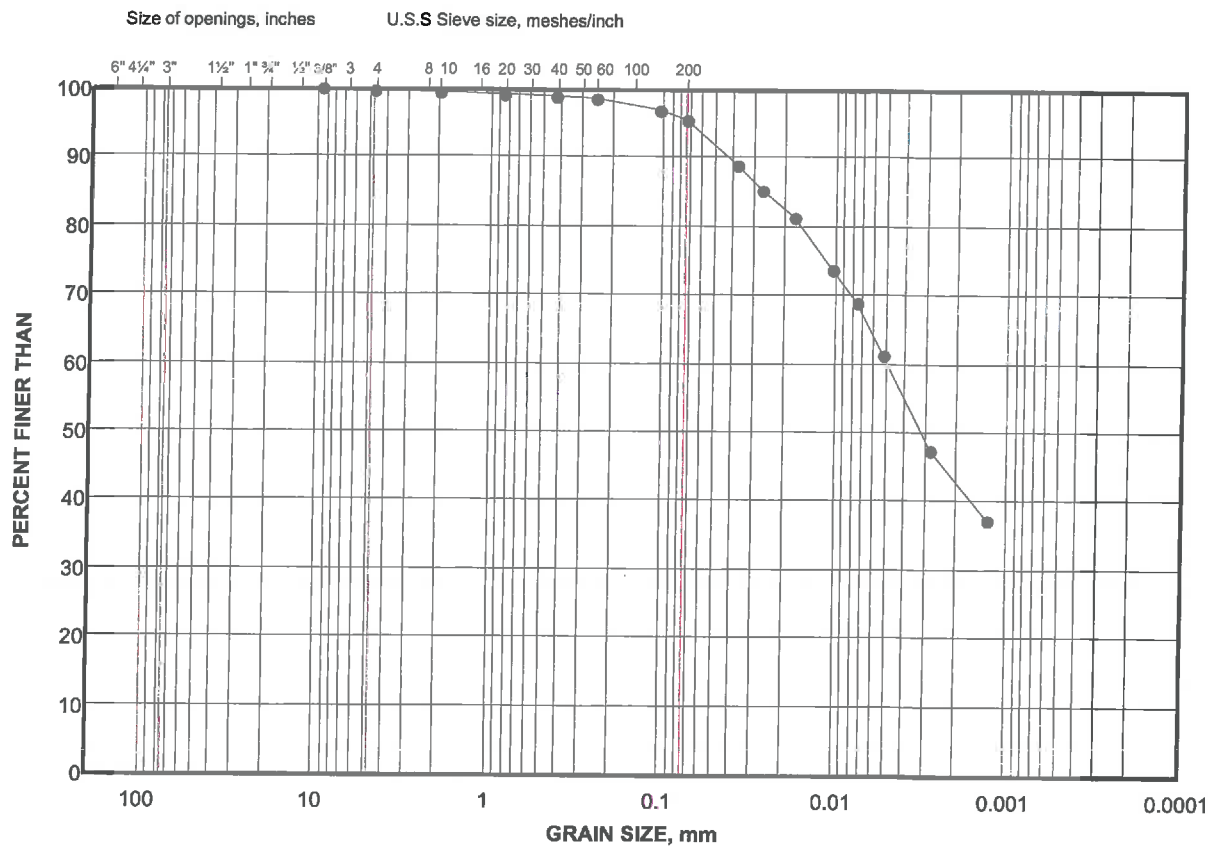
Checked By: *[Signature]*

Golder Associates

Date: 08-Aug-18

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-19	TW1	9.14 - 9.75

Project Number: 1897138

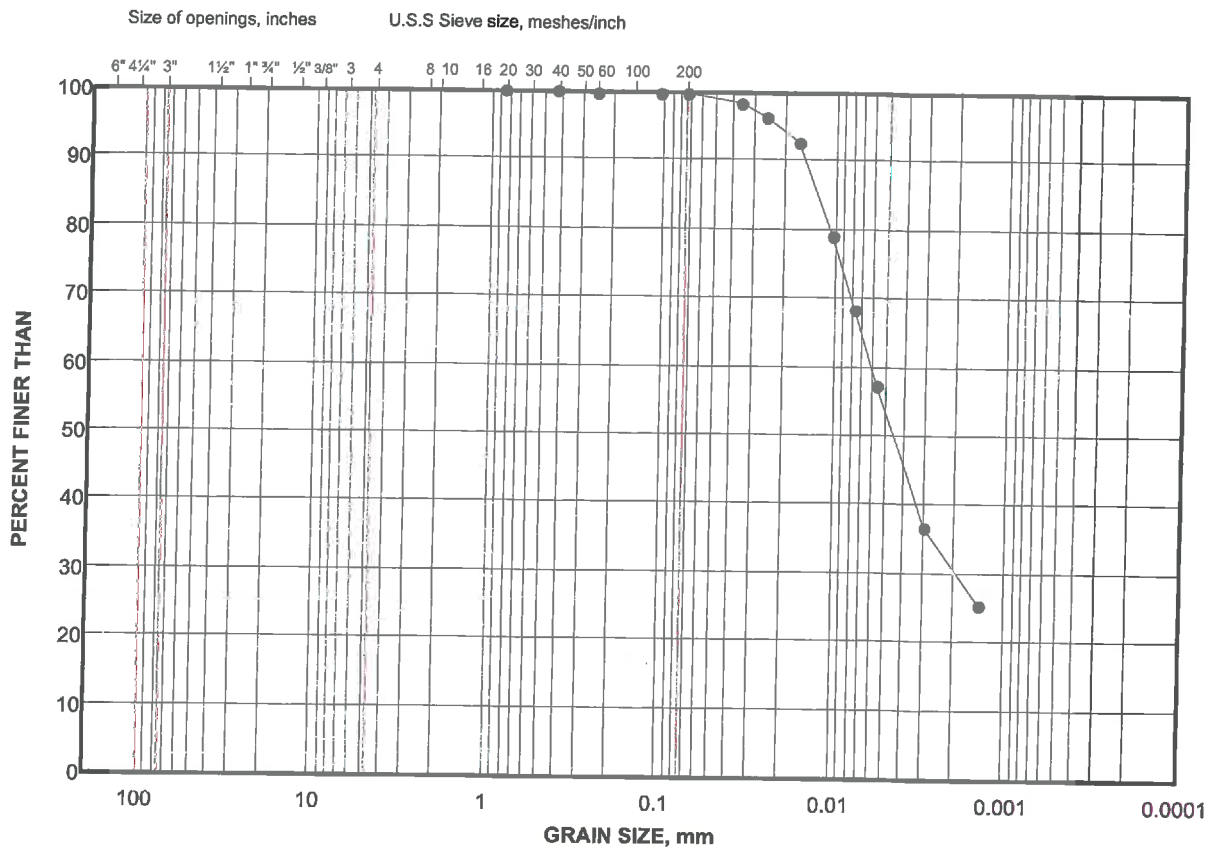
Checked By: 

Golder Associates

Date: 08-Aug-18

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-19	TW2	13.72 - 14.33

Project Number: 1897138

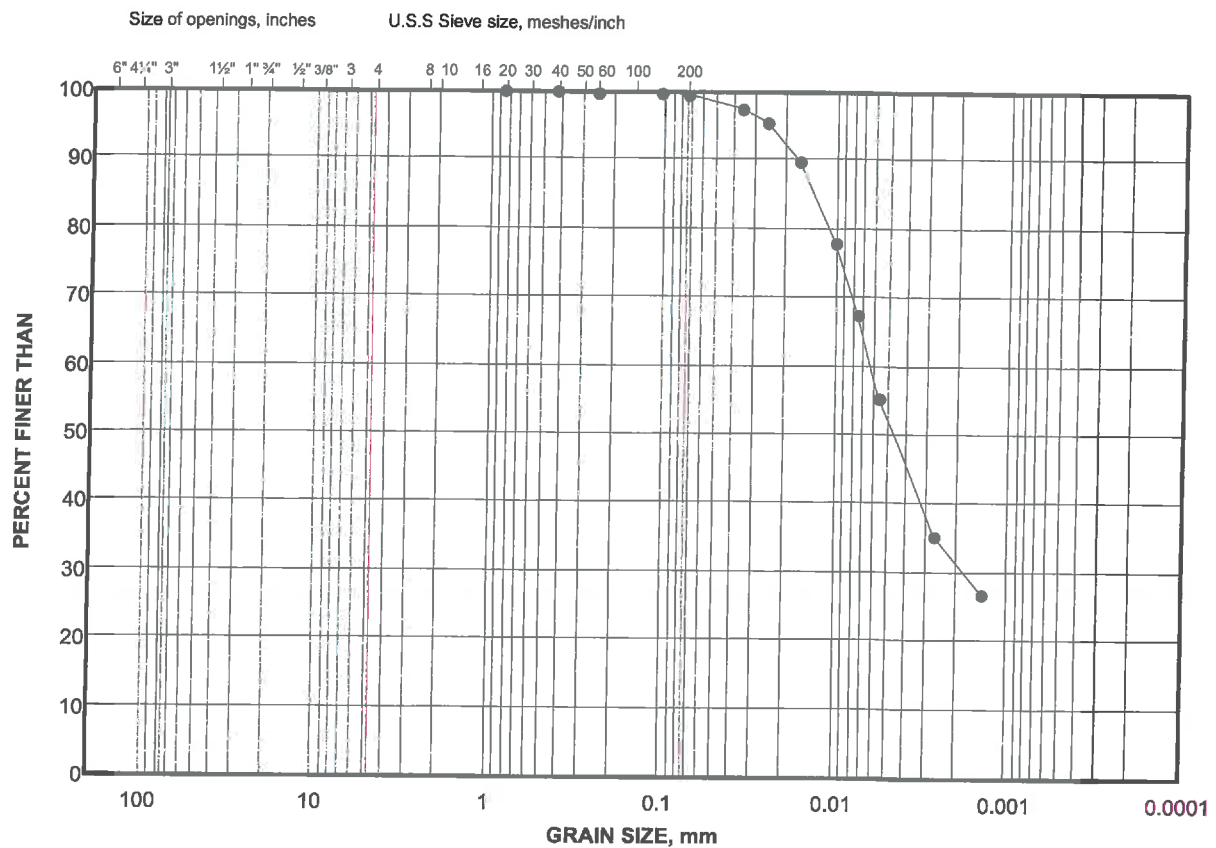
Checked By:

Golder Associates

Date: 08-Aug-18

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-21	TW2	13.72 - 14.33

Project Number: 1897138

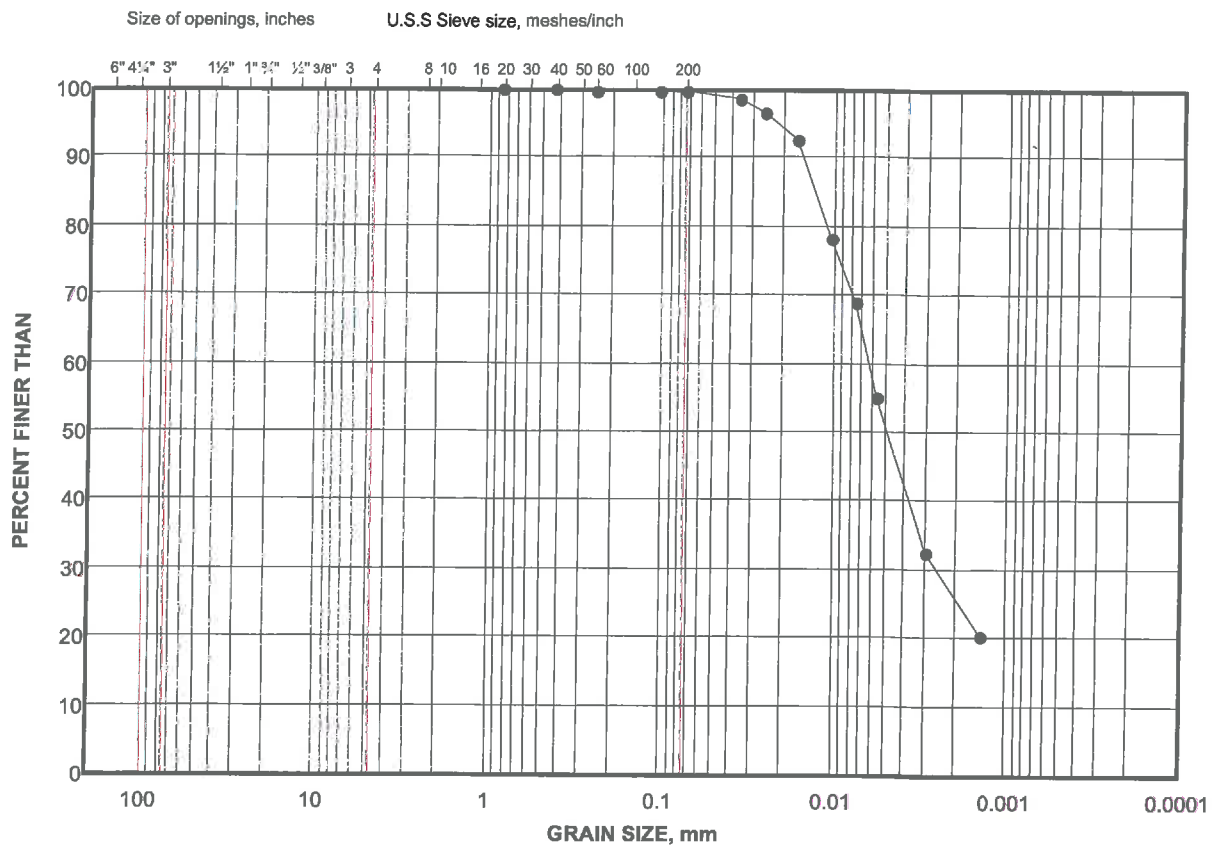
Checked By: *[Signature]*

Golder Associates

Date: 08-Aug-18

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-25	TW1	12.19 - 12.80

Project Number: 1897138

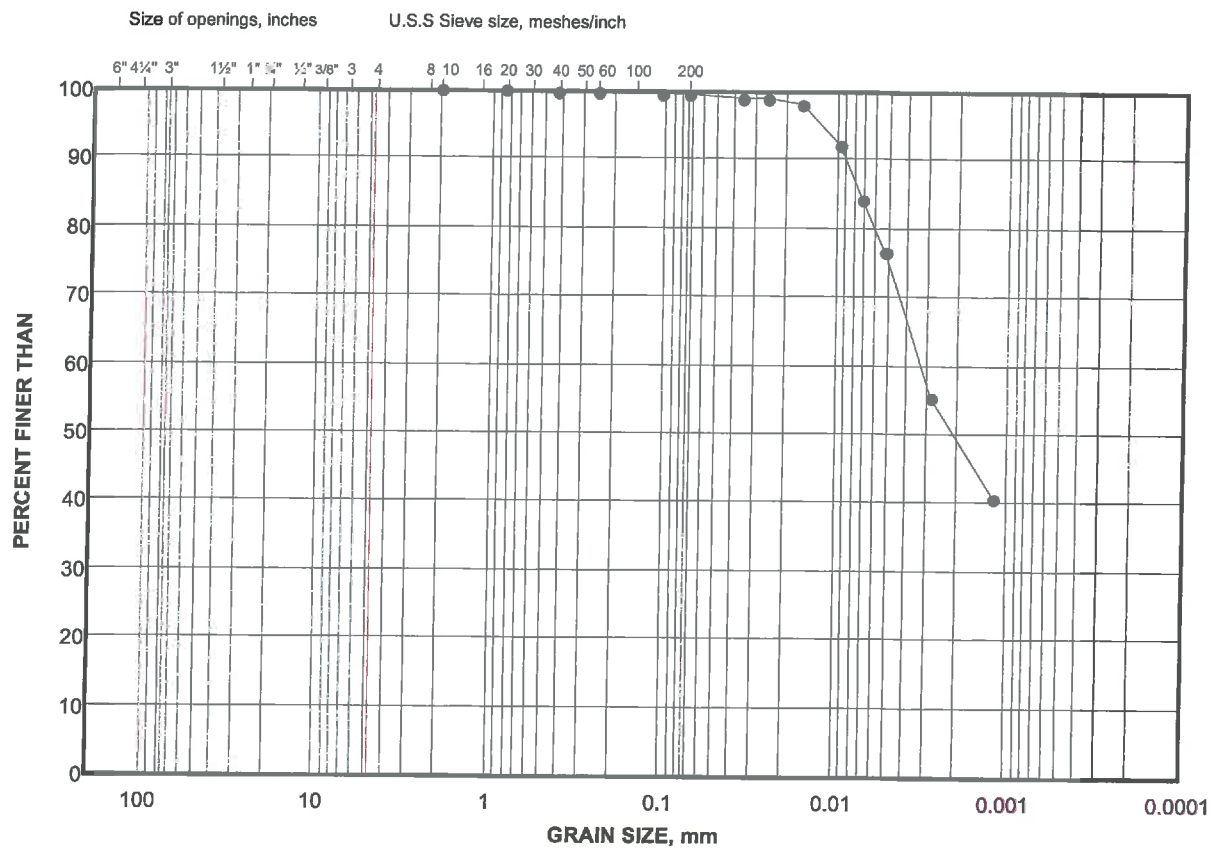
Checked By: *lbb*

Golder Associates

Date: 08-Aug-18

GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	Borehole	SAMPLE	DEPTH(m)
•	18-26	TW1	7.62 - 8.23

Project Number: 1897138

Checked By: *[Signature]*

Golder Associates

Date: 08-Aug-18

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	1897138(2000)	Sample Number	TW2
Borehole Number	18-21	Sample Depth, ft	13.72-14.33

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	07/26/2018		
Date Completed	08/10/2018		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m ³	20.25
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	16.36
Area, cm ²	31.50	Specific Gravity, measured	2.77
Volume, cm ³	59.94	Solids Height, cm	1.146
Water Content, %	23.81	Volume of Solids, cm ³	36.09
Wet Mass, g	123.79	Volume of Voids, cm ³	23.85
Dry Mass, g	99.98	Degree of Saturation, %	99.8

TEST COMPUTATIONS

Stress	Corr. Height	Void Ratio	Average Height	t ₉₀	cv.	mv	k
kPa	cm		cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.903	0.661	1.903				
6.49	1.903	0.661	1.903				
11.14	1.901	0.659	1.902	240	3.20E-03	2.03E-04	6.37E-08
21.23	1.895	0.654	1.898	154	4.96E-03	3.12E-04	1.52E-07
40.72	1.887	0.647	1.891	135	5.62E-03	2.26E-04	1.25E-07
79.55	1.874	0.635	1.880	60	1.25E-02	1.73E-04	2.12E-07
157.22	1.859	0.622	1.866	54	1.37E-02	1.03E-04	1.38E-07
79.55	1.859	0.622	1.859				
157.15	1.857	0.621	1.858	54	1.36E-02	1.35E-05	1.80E-08
311.77	1.833	0.600	1.845	49	1.47E-02	8.09E-05	1.17E-07
622.61	1.791	0.563	1.812	73	9.53E-03	7.22E-05	6.74E-08
1245.42	1.738	0.517	1.764	86	7.67E-03	4.40E-05	3.31E-08
2501.44	1.688	0.473	1.713	101	6.16E-03	2.13E-05	1.29E-08
1245.42	1.691	0.476	1.689				
314.13	1.701	0.484	1.696				
79.55	1.711	0.493	1.706				
21.00	1.725	0.506	1.718				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen swelled under 6.49kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

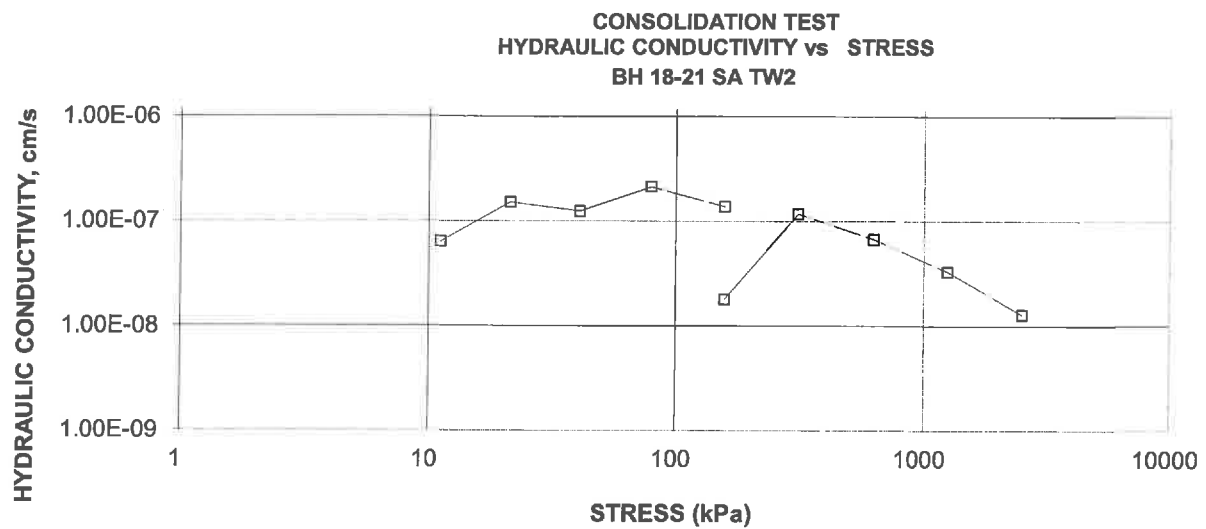
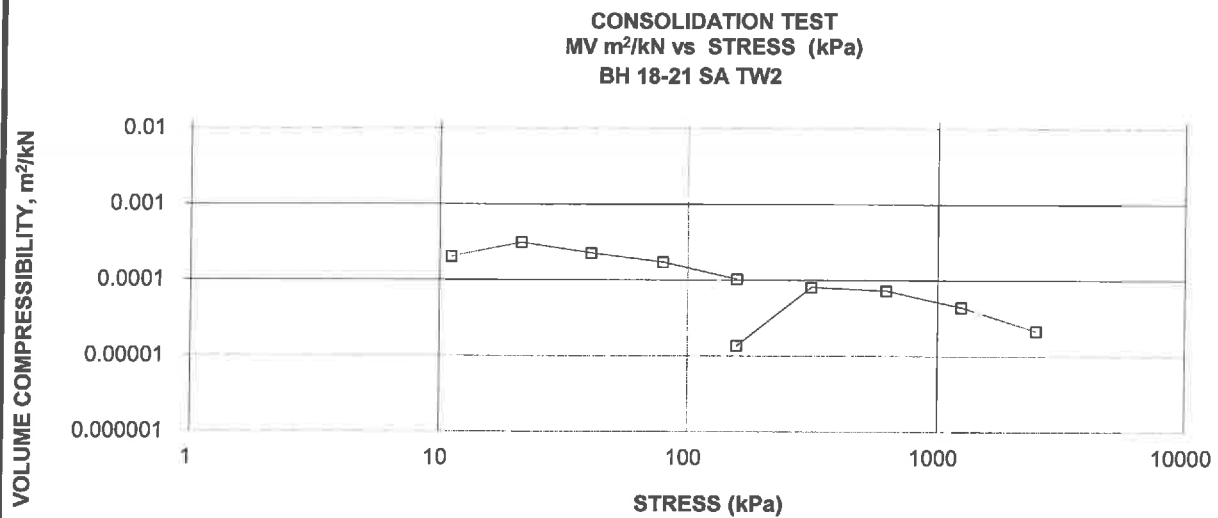
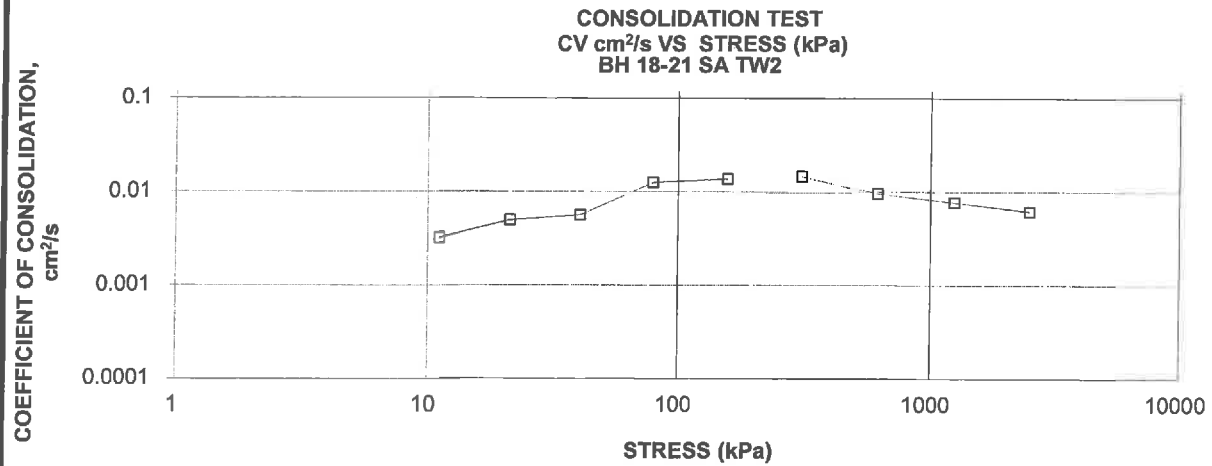
Sample Height, cm	1.73	Unit Weight, kN/m ³	21.55
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	18.04
Area, cm ²	31.50	Specific Gravity, measured	2.77
Volume, cm ³	54.34	Solids Height, cm	1.146
Water Content, %	19.42	Volume of Solids, cm ³	36.09
Wet Mass, g	119.40	Volume of Voids, cm ³	18.25
Dry Mass, g	99.98		

Prepared By: LH

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

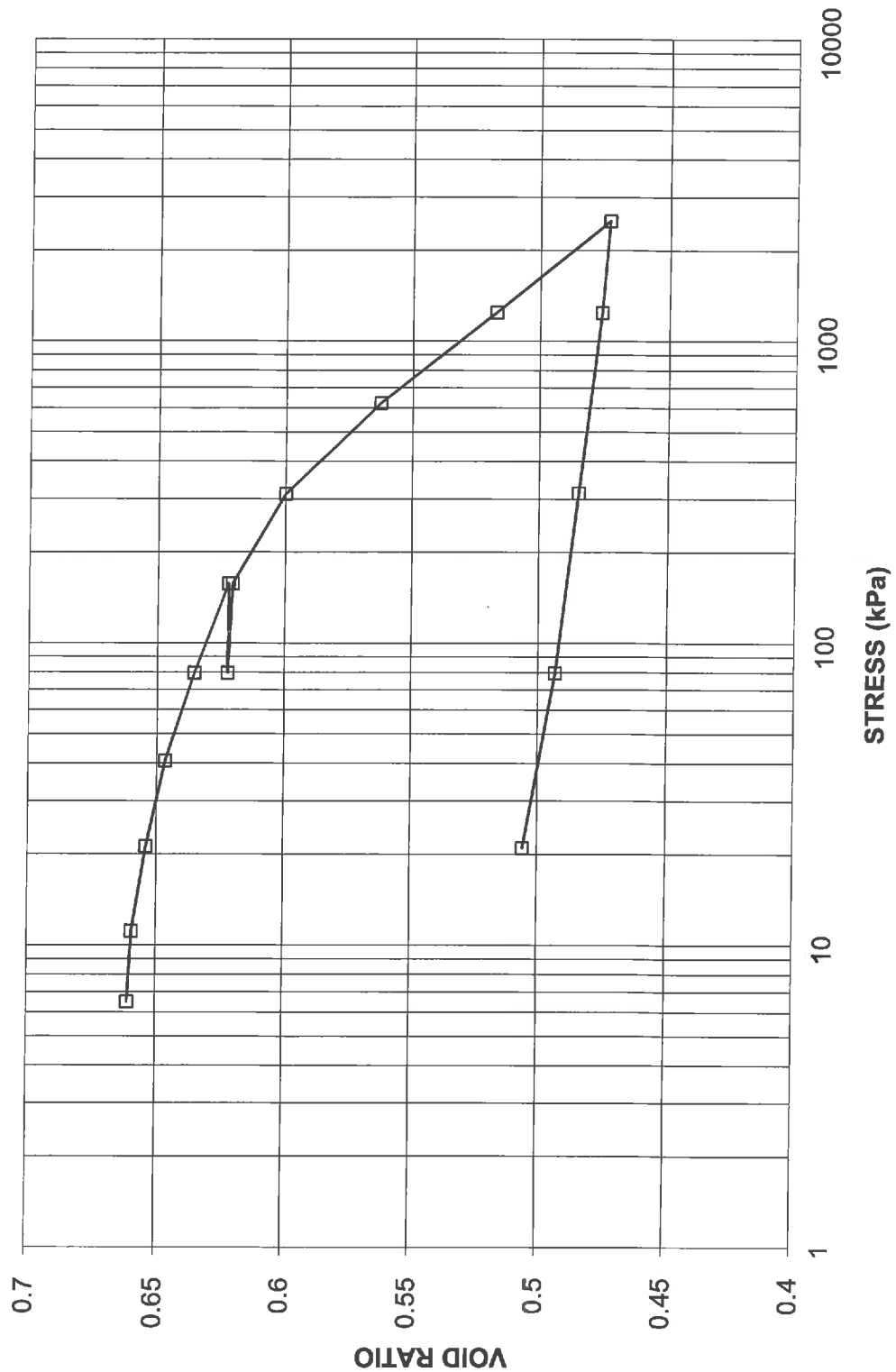
FIGURE



CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE

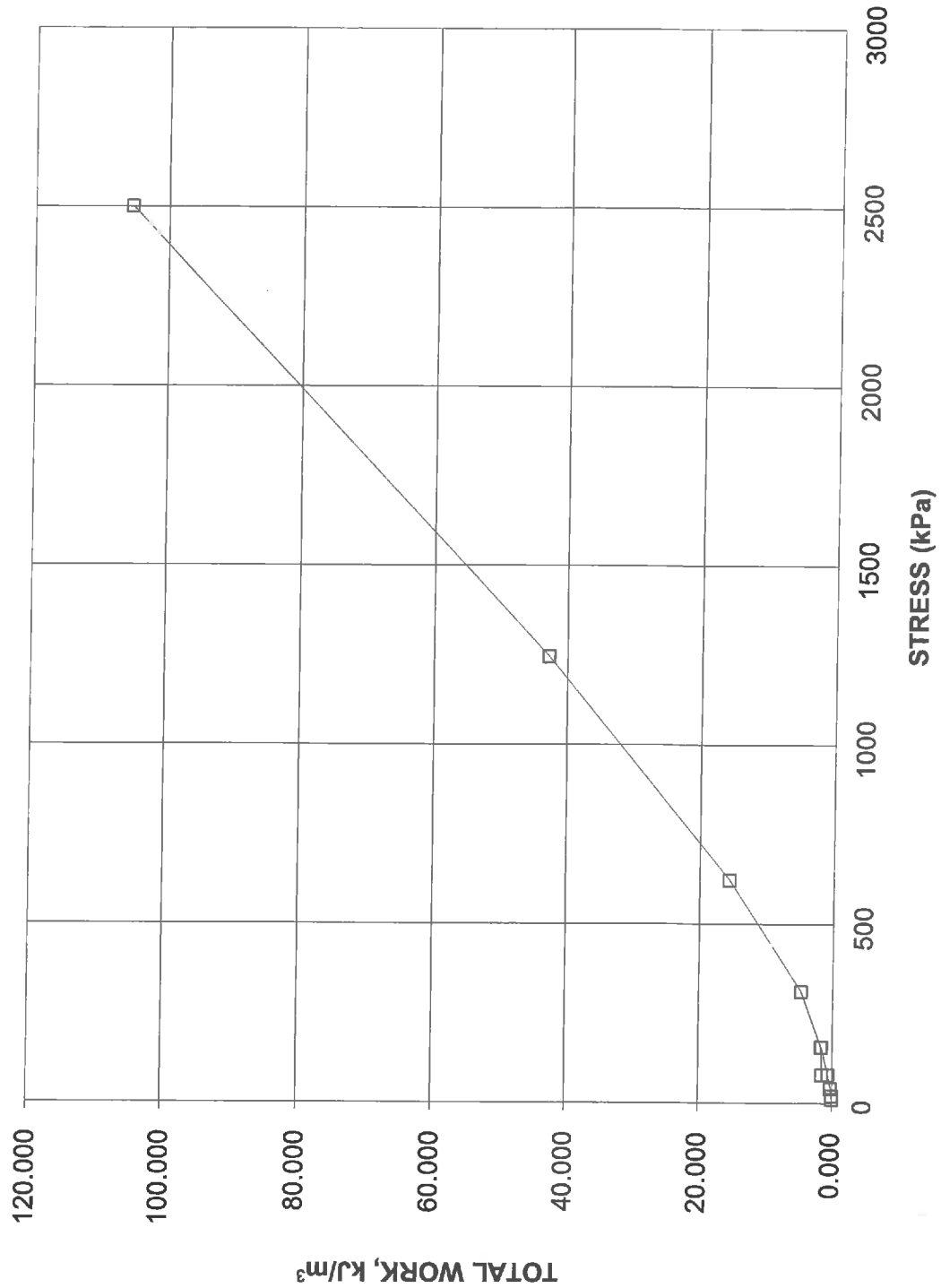
CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-21 SA TW2



**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 18-21 SA TW2**



Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *[Signature]*

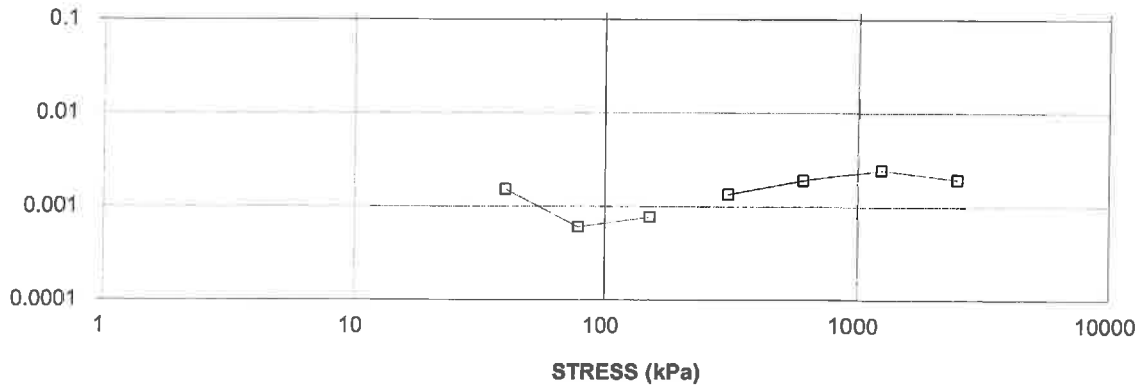
CONSOLIDATION TEST SUMMARY					FIGURE		
ASTM D2435/D2435M							
SAMPLE IDENTIFICATION							
Project Number	1897138(2000)			Sample Number	TW1		
Borehole Number	18-19			Sample Depth, ft	9.15-9.76		
TEST CONDITIONS							
Test Type	Laboratory Standard			Load Duration, hr	24		
Oedometer Number	6						
Date Started	07/26/2018						
Date Completed	08/09/2018						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.89			Unit Weight, kN/m ³	19.66		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m ³	15.63		
Area, cm ²	31.60			Specific Gravity, measured	2.76		
Volume, cm ³	59.72			Solids Height, cm	1.091		
Water Content, %	25.79			Volume of Solids, cm ³	34.49		
Wet Mass, g	119.74			Volume of Voids, cm ³	25.23		
Dry Mass, g	95.19			Degree of Saturation, %	97.3		
TEST COMPUTATIONS							
	Corr.		Average				
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.890	0.732	1.890				
5.88	1.899	0.740	1.895				
10.72	1.902	0.743	1.901				
20.45	1.903	0.744	1.903				
39.92	1.902	0.743	1.903	505	1.52E-03	2.16E-05	3.22E-09
78.10	1.897	0.738	1.900	1270	6.02E-04	6.94E-05	4.10E-09
151.26	1.885	0.727	1.891	987	7.68E-04	8.78E-05	6.61E-09
78.70	1.885	0.727	1.885				
152.21	1.883	0.725	1.884	154	4.89E-03	1.44E-05	6.89E-09
311.21	1.871	0.714	1.877	554	1.35E-03	3.94E-05	5.20E-09
621.14	1.845	0.690	1.858	390	1.88E-03	4.45E-05	8.19E-09
1240.72	1.807	0.656	1.826	290	2.44E-03	3.26E-05	7.78E-09
2501.07	1.749	0.603	1.778	346	1.94E-03	2.42E-05	4.59E-09
1250.96	1.751	0.604	1.750				
310.87	1.774	0.625	1.762				
78.70	1.806	0.655	1.790				
20.45	1.844	0.689	1.825				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)</p> <p>Specimen swelled under 20.45kPa.</p>							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.84			Unit Weight, kN/m ³	20.32		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m ³	16.02		
Area, cm ²	31.60			Specific Gravity, measured	2.76		
Volume, cm ³	58.27			Solids Height, cm	1.091		
Water Content, %	26.86			Volume of Solids, cm ³	34.49		
Wet Mass, g	120.76			Volume of Voids, cm ³	23.78		
Dry Mass, g	95.19						
Prepared By: LH				Golder Associates		Checked By:	

CONSOLIDATION TEST SUMMARY

FIGURE

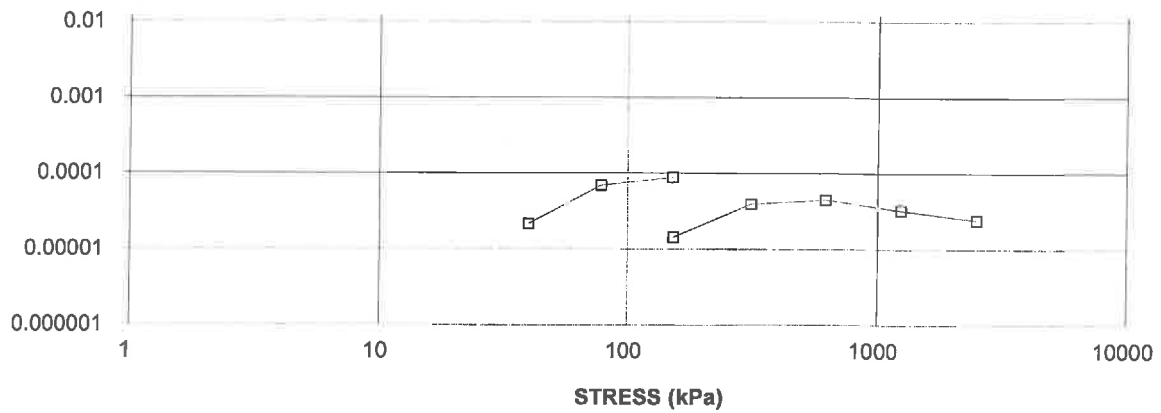
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s vs STRESS (kPa)
BH 18-19 SA TW1



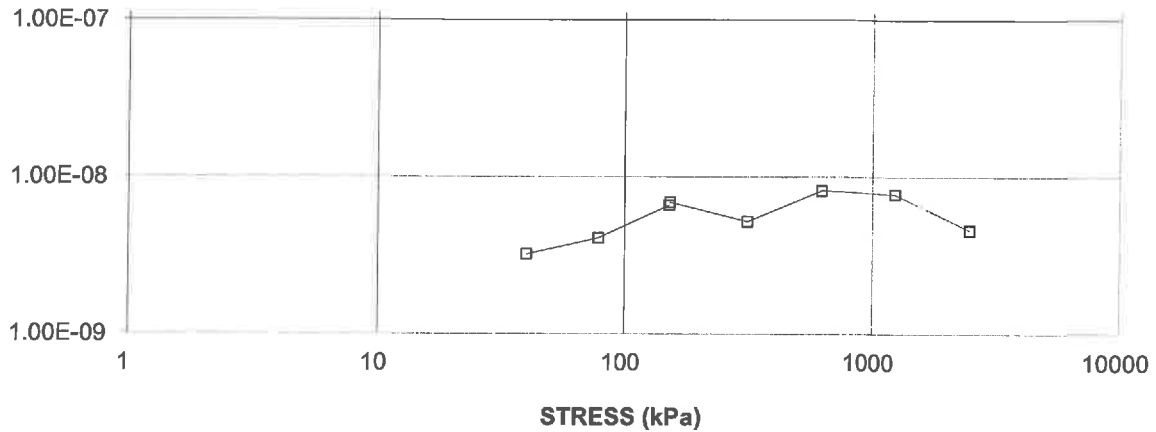
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 18-19 SA TW1



HYDRAULIC CONDUCTIVITY, cm/s

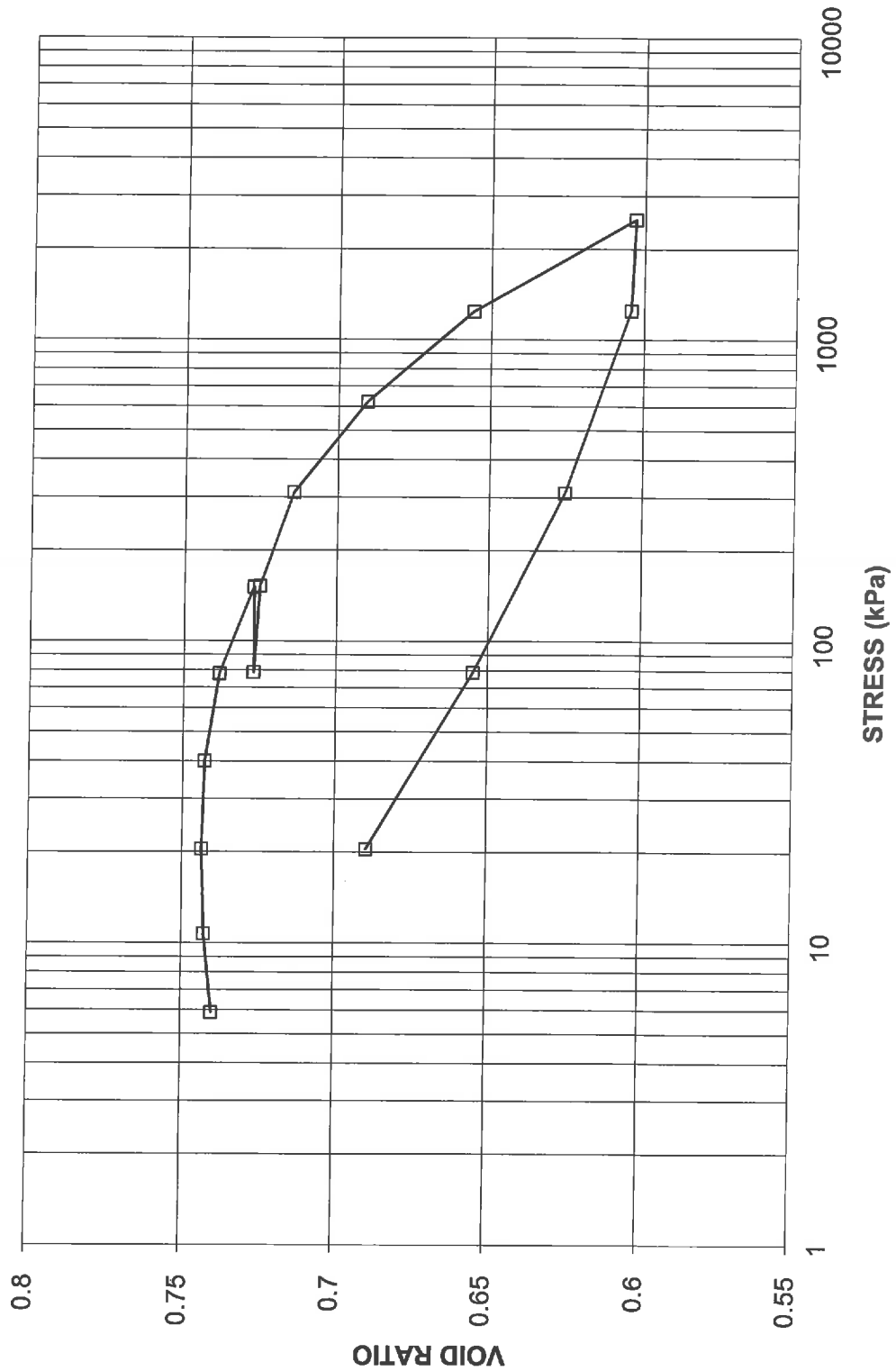
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 18-19 SA TW1



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-19 SA TW1**



Project No.1897138(2000)

Prepared By: LH

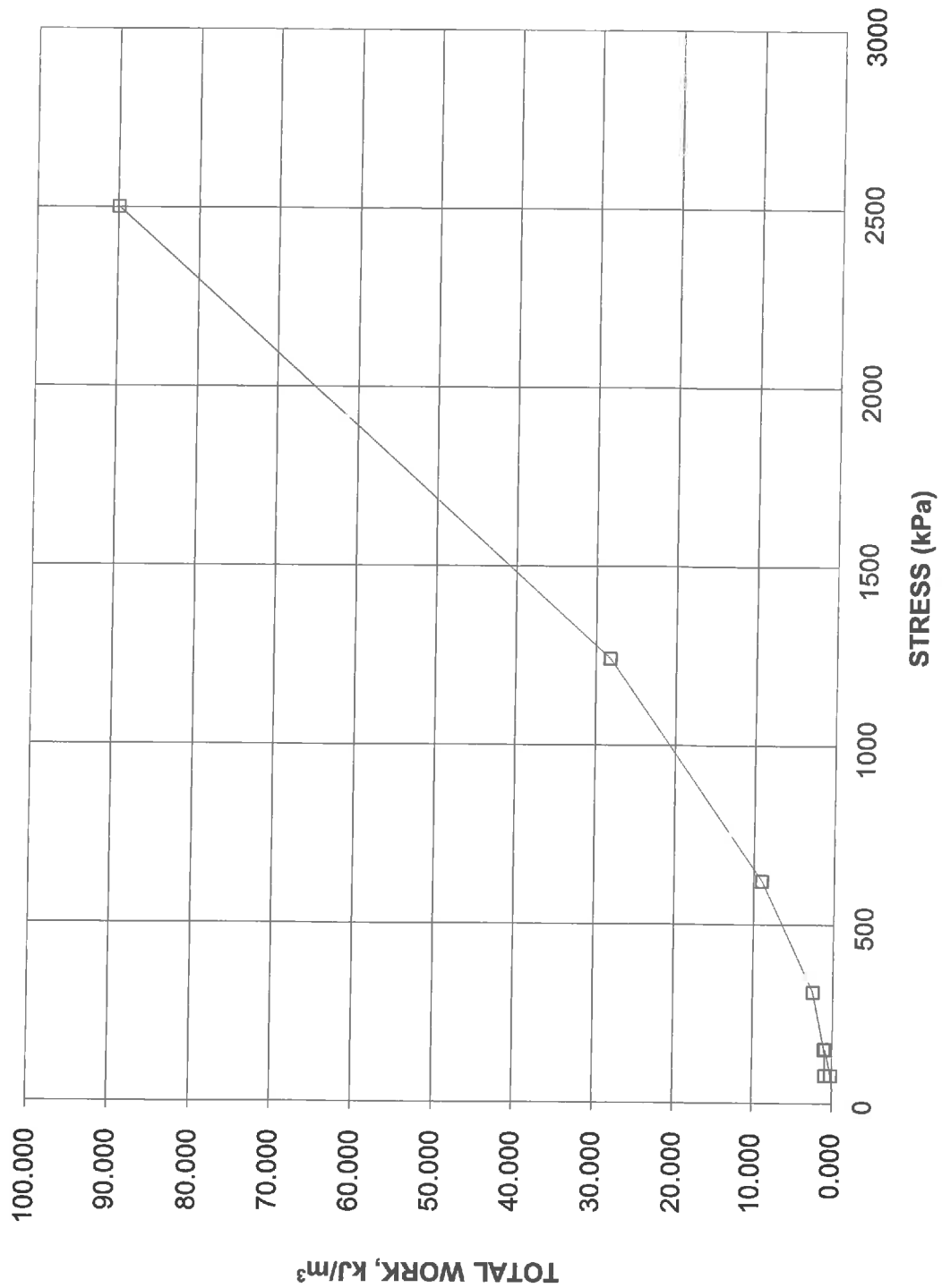
Golder Associates

Checked By: *ML*

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs. STRESS
BH 18-19 SA TW1**



Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *lll*

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	1897138(2000)	Sample Number	TW1
Borehole Number	18-25	Sample Depth, ft	12.20-12.80

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	07/26/2018		
Date Completed	08/10/2018		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.89	Unit Weight, kN/m ³	19.34
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	15.09
Area, cm ²	31.50	Specific Gravity, measured	2.76
Volume, cm ³	59.53	Solids Height, cm	1.053
Water Content, %	28.22	Volume of Solids, cm ³	33.18
Wet Mass, g	117.44	Volume of Voids, cm ³	26.35
Dry Mass, g	91.59	Degree of Saturation, %	98.1

TEST COMPUTATIONS

Stress	Corr.		Average				
kPa	Height	Void	Height	t ₉₀	cv.	mv	k
	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.890	0.794	1.890				
5.89	1.892	0.796	1.891				
10.76	1.891	0.795	1.892	46	1.65E-02	9.78E-05	1.58E-07
20.56	1.890	0.794	1.891	48	1.58E-02	6.03E-05	9.33E-08
40.07	1.887	0.791	1.888	37	2.04E-02	9.18E-05	1.84E-07
78.98	1.874	0.778	1.880	57	1.31E-02	1.78E-04	2.30E-07
156.63	1.854	0.760	1.864	54	1.36E-02	1.34E-04	1.79E-07
78.97	1.855	0.761	1.854				
156.63	1.853	0.759	1.854	73	9.98E-03	1.43E-05	1.40E-08
311.39	1.820	0.728	1.837	101	7.08E-03	1.11E-04	7.73E-08
622.23	1.757	0.668	1.789	154	4.40E-03	1.08E-04	4.65E-08
1246.55	1.689	0.603	1.723	101	6.23E-03	5.76E-05	3.52E-08
2501.13	1.625	0.542	1.657	94	6.19E-03	2.70E-05	1.64E-08
1246.55	1.632	0.550	1.629				
313.87	1.648	0.564	1.640				
78.98	1.667	0.582	1.658				
20.68	1.689	0.603	1.678				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen swelled under 5.89kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.69	Unit Weight, kN/m ³	20.61
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	16.89
Area, cm ²	31.50	Specific Gravity, measured	2.76
Volume, cm ³	53.19	Solids Height, cm	1.053
Water Content, %	22.04	Volume of Solids, cm ³	33.18
Wet Mass, g	111.78	Volume of Voids, cm ³	20.00
Dry Mass, g	91.59		

Prepared By: LH

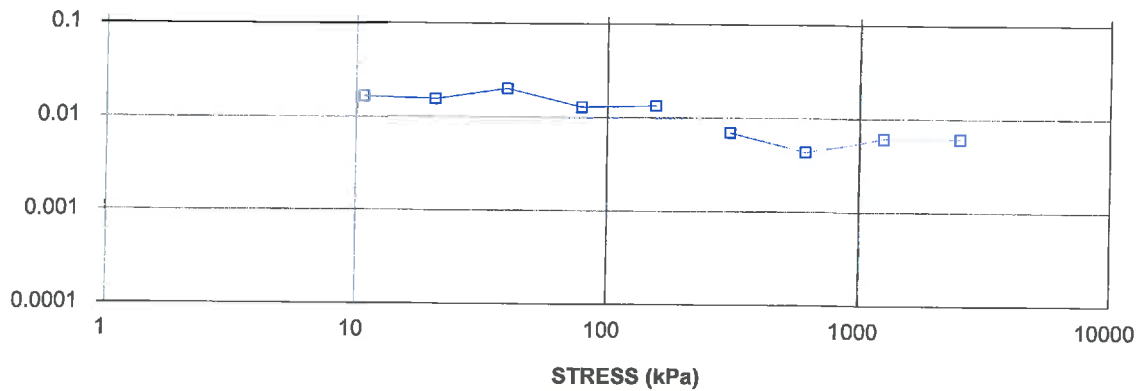
Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE

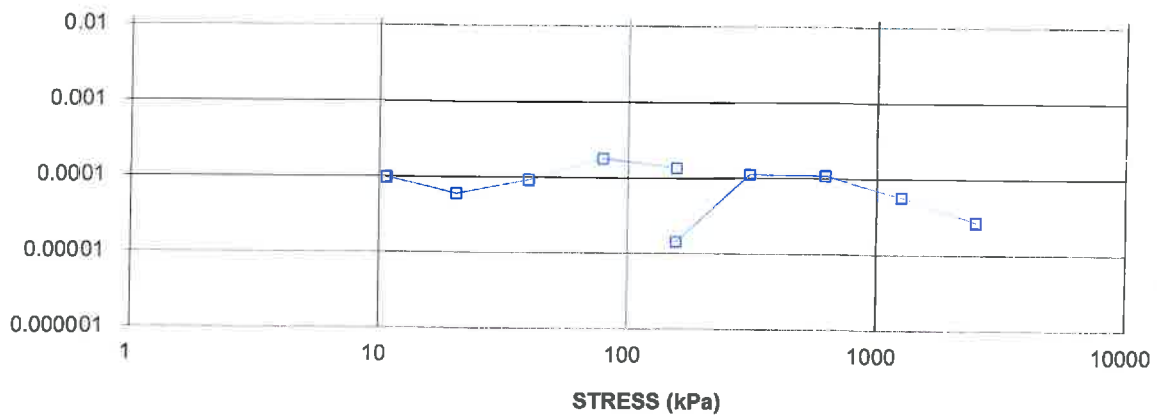
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 18-25 SA TW1



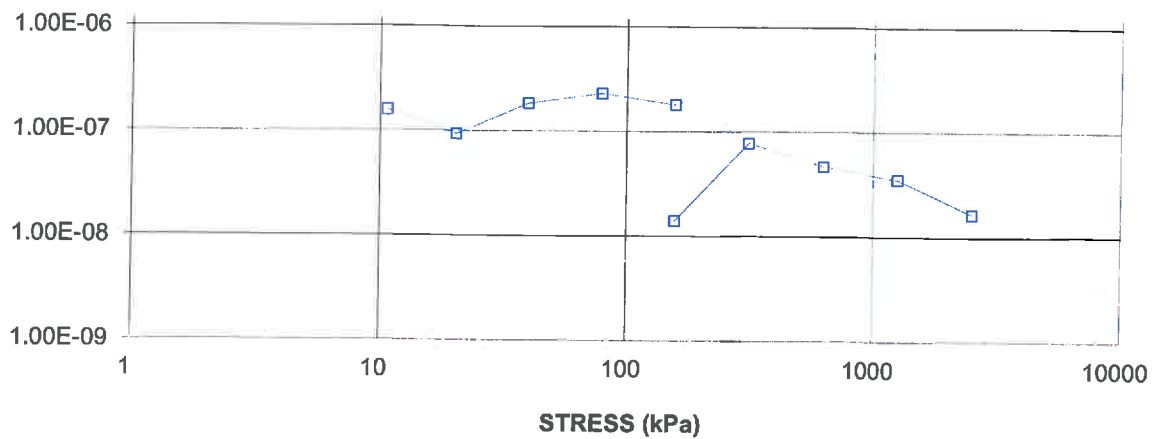
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 18-25 SA TW1



HYDRAULIC CONDUCTIVITY, cm/s

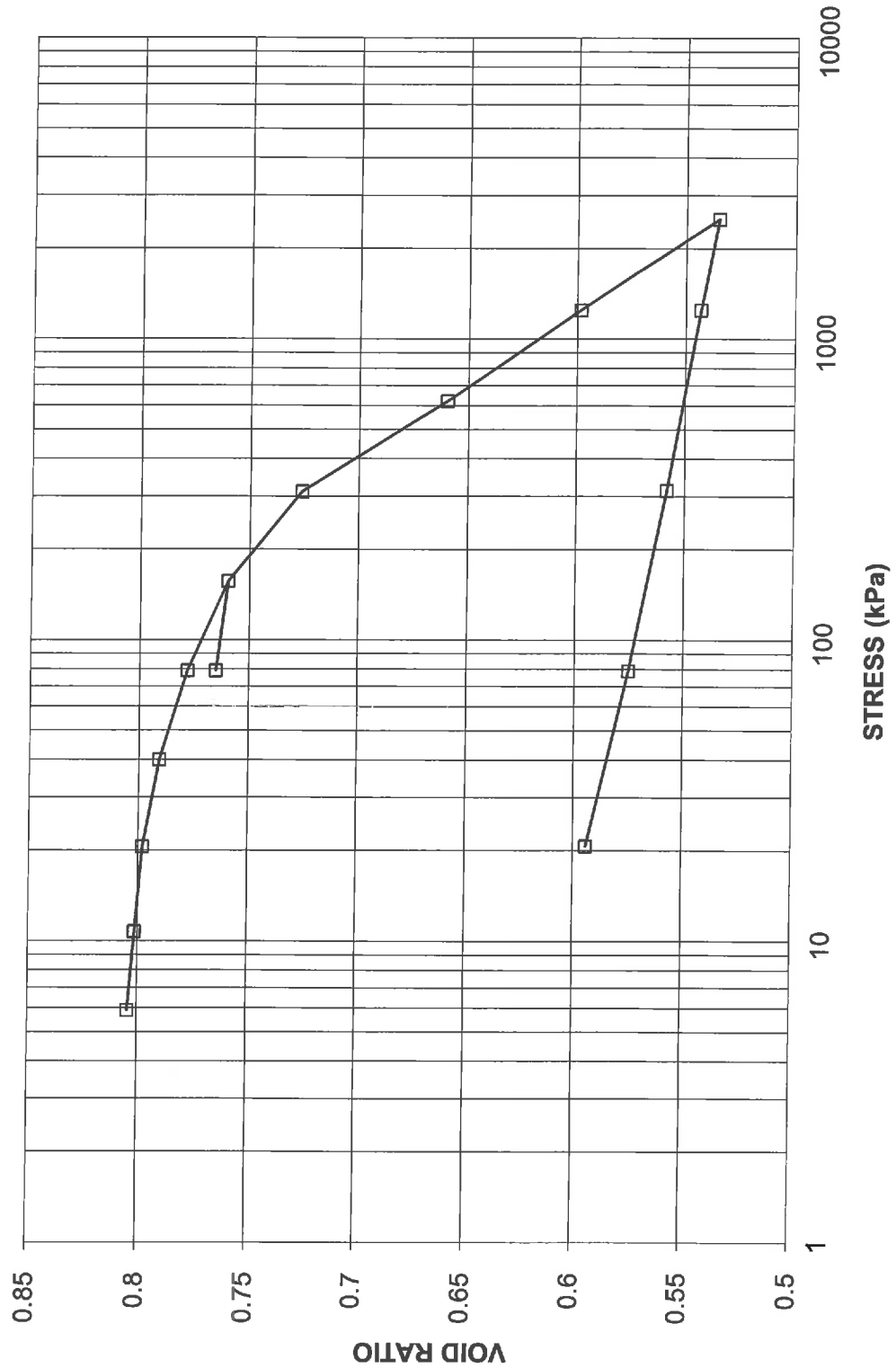
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 18-25 SA TW1



CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE

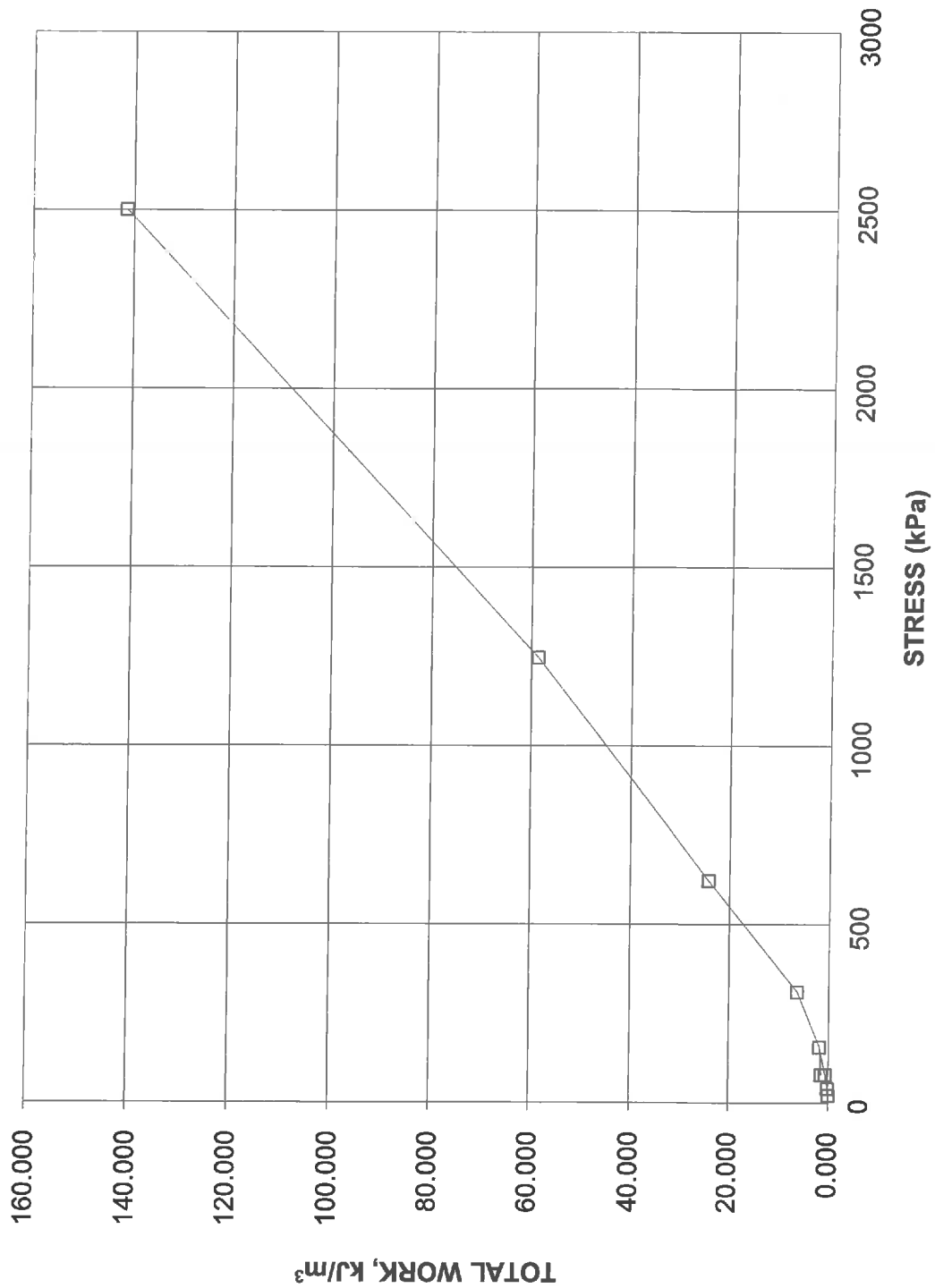
CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-25 SA TW1



**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 18-25 SA TW1**



Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *[Signature]*

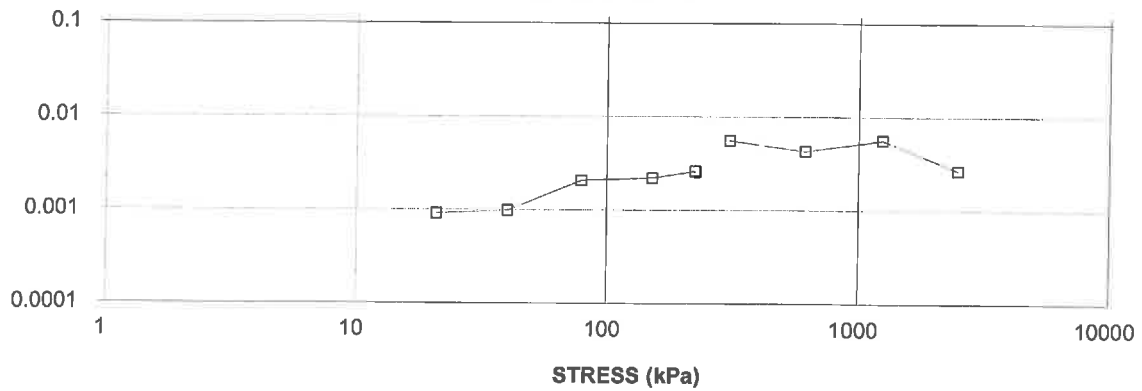
CONSOLIDATION TEST SUMMARY ASTM D2435/D2435M					FIGURE		
SAMPLE IDENTIFICATION							
Project Number	1897138(2000)	Sample Number	TW1				
Borehole Number	18-01	Sample Depth, ft	12.20-12.80				
TEST CONDITIONS							
Test Type	Laboratory Standard	Load Duration, hr	24				
Oedometer Number	5						
Date Started	07/26/2018						
Date Completed	08/09/2018						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.90	Unit Weight, kN/m ³	19.44				
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	15.02				
Area, cm ²	31.46	Specific Gravity, measured	2.79				
Volume, cm ³	59.84	Solids Height, cm	1.044				
Water Content, %	29.45	Volume of Solids, cm ³	32.84				
Wet Mass, g	118.60	Volume of Voids, cm ³	27.00				
Dry Mass, g	91.62	Degree of Saturation, %	99.9				
TEST COMPUTATIONS							
	Corr.		Average				
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.902	0.822	1.902				
6.26	1.938	0.856	1.920				
10.94	1.934	0.853	1.936				
20.91	1.929	0.848	1.932	866	9.14E-04	2.80E-04	2.51E-08
40.26	1.918	0.837	1.923	799	9.82E-04	3.10E-04	2.99E-08
79.31	1.904	0.824	1.911	375	2.06E-03	1.79E-04	3.62E-08
152.15	1.894	0.814	1.899	346	2.21E-03	7.70E-05	1.67E-08
226.51	1.881	0.802	1.888	290	2.60E-03	8.78E-05	2.24E-08
152.39	1.885	0.805	1.883				
311.54	1.874	0.796	1.879	135	5.55E-03	3.42E-05	1.86E-08
621.16	1.849	0.772	1.862	173	4.25E-03	4.23E-05	1.76E-08
1242.95	1.815	0.739	1.832	126	5.65E-03	2.92E-05	1.61E-08
2503.01	1.655	0.586	1.735	240	2.66E-03	6.66E-05	1.74E-08
1251.42	1.668	0.598	1.661				
312.43	1.707	0.636	1.688				
79.31	1.757	0.683	1.732				
20.91	1.806	0.730	1.782				
Note: Consolidation loading and unloading schedule assigned by the client. cv and k are approximate only based on t ₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M) Specimen swelled under 10.94kPa.							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.81	Unit Weight, kN/m ³	20.53				
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	15.81				
Area, cm ²	31.46	Specific Gravity, measured	2.79				
Volume, cm ³	56.83	Solids Height, cm	1.044				
Water Content, %	29.84	Volume of Solids, cm ³	32.84				
Wet Mass, g	118.96	Volume of Voids, cm ³	23.99				
Dry Mass, g	91.62						
Prepared By: LH				Golder Associates		Checked By:	

CONSOLIDATION TEST SUMMARY

FIGURE

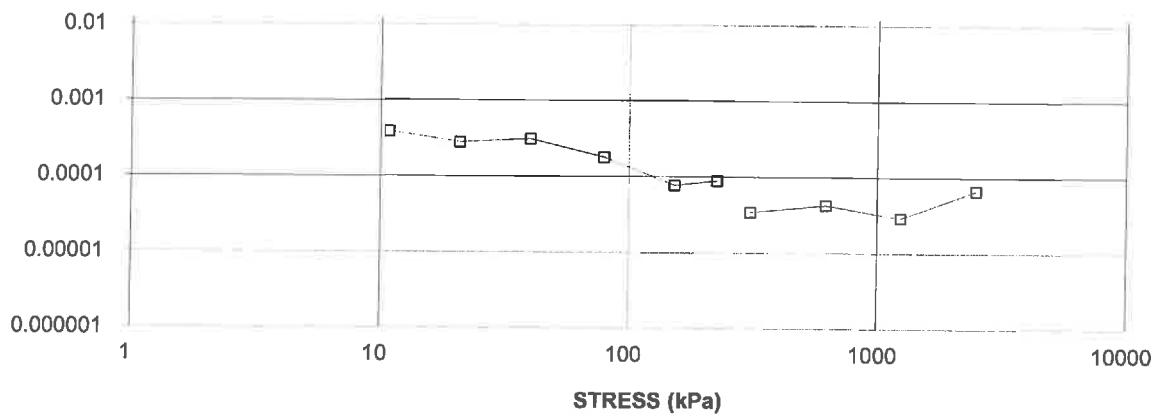
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 18-01 SA TW1



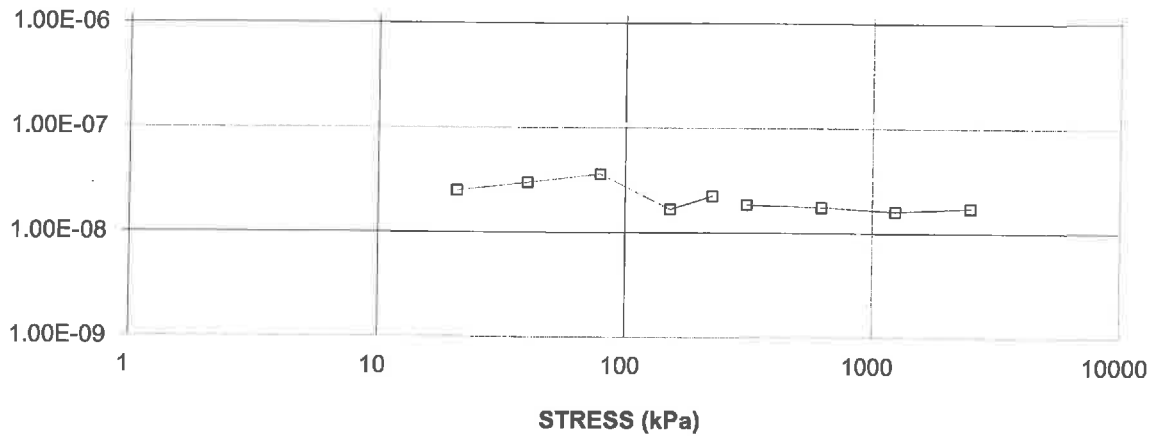
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 18-01 SA TW1



HYDRAULIC CONDUCTIVITY, cm/s

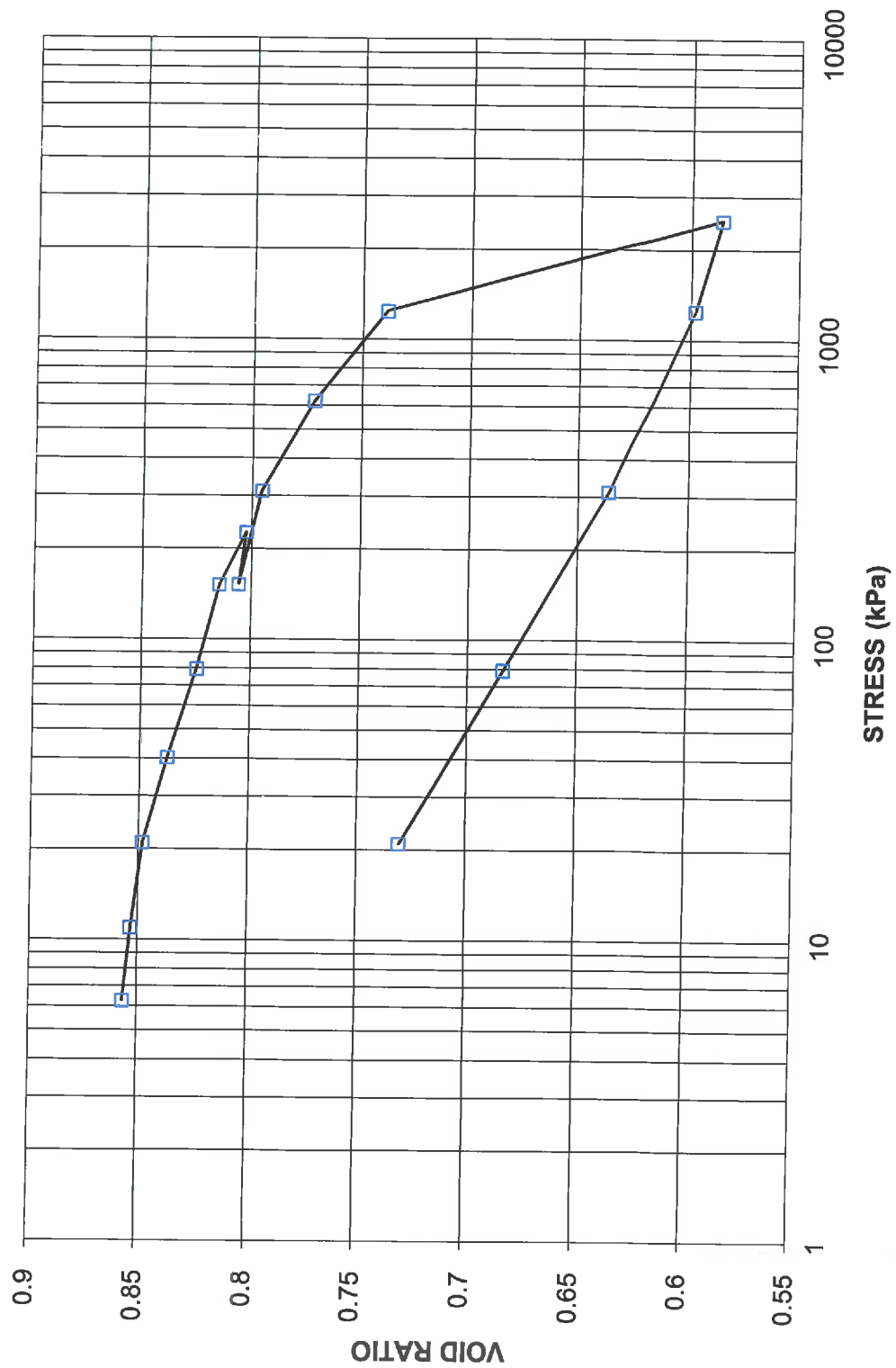
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 18-01 SA TW1



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 18-01 SA TW1**



Project No.1897138(2000)

Prepared By: LH

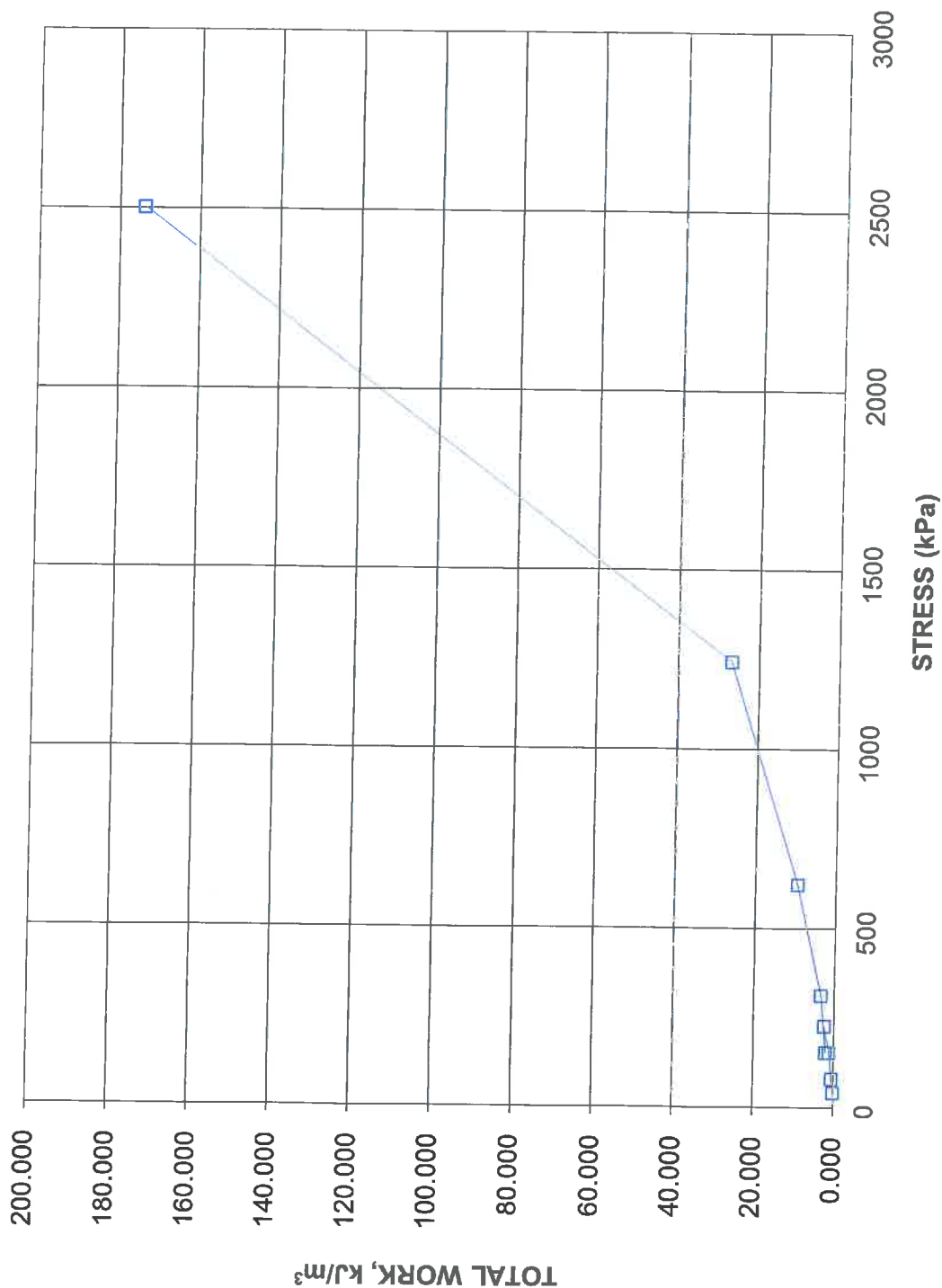
Golder Associates

Checked By: *bb*

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs. STRESS
BH 18-01 SA TW1**




Project No.1897138(2000)

Prepared By: LH

Golder Associates

Checked By: *hch*

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS ASTM D4767 SHEET 1 OF 4		FIGURE	
TEST STAGE	A	B	C
BOREHOLE NUMBER	18-19	18-21	
SAMPLE	T2	T2	
DEPTH, m	13.72-14.35	13.72-14.33	
SPECIMEN DIAMETER, cm	4.99	4.99	4.99
SPECIMEN HEIGHT, cm	10.17	10.10	10.11
NATURAL WATER CONTENT, %	31.5	29.4	28.0
DRY DENSITY, Mg/m ³	1.49	1.53	1.56
WATER CONTENT AFTER SATURATION, %	31.8	30.4	28.5
CELL PRESSURE, σ_3 , kPa	370.0	470.0	670.0
BACK PRESSURE, kPa	270.0	270.0	270.0
PORE PRESSURE PARAMETER "B"	0.95	0.95	0.95
EFFECTIVE CONSOLIDATION STRESS, σ_c , kPa	100.0	200.0	400.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	2.8	3.6	5.8
WATER CONTENT AFTER CONSOLIDATION, %	30.0	28.0	24.8
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, HOURS	9.6	5.1	4.7
WATER CONTENT AFTER TEST, %	29.7	27.1	24.1
MAX. DEVIATOR STRESS, $(\sigma_1 - \sigma_3)$, kPa	110.0	169.6	278.2
AXIAL STRAIN AT $(\sigma_1 - \sigma_3)$ maximum, %	4.8	2.5	2.3
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ'_1 / σ'_3) maximum	3.0	3.1	3.4
DEVIATOR STRESS AT (σ'_1 / σ'_3) maximum, kPa	106.8	135.5	267.7
AXIAL STRAIN AT (σ'_1 / σ'_3) maximum, %	7.9	13.7	11.5
PORE PRESSURE PARAMETER, Af, AT $(\sigma_1 - \sigma_3)$ maximum	0.39	0.57	0.84
PORE PRESSURE PARAMETER, Af, AT (σ'_1 / σ'_3) maximum	0.43	1.01	1.07
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES: <div style="text-align: center;">Effective consolidation stresses are assigned by the client.</div>			
FAILURE PLANE NUMBER	1.0	-	-
ANGLE OF FAILURE PLANE, DEGREES	60.0	Bulged	Bulged
Date: 8/20/18 Project No. 1897138(2000) <div style="text-align: right;"> Prepared By LH Checked By:  </div>			

Golder Associates

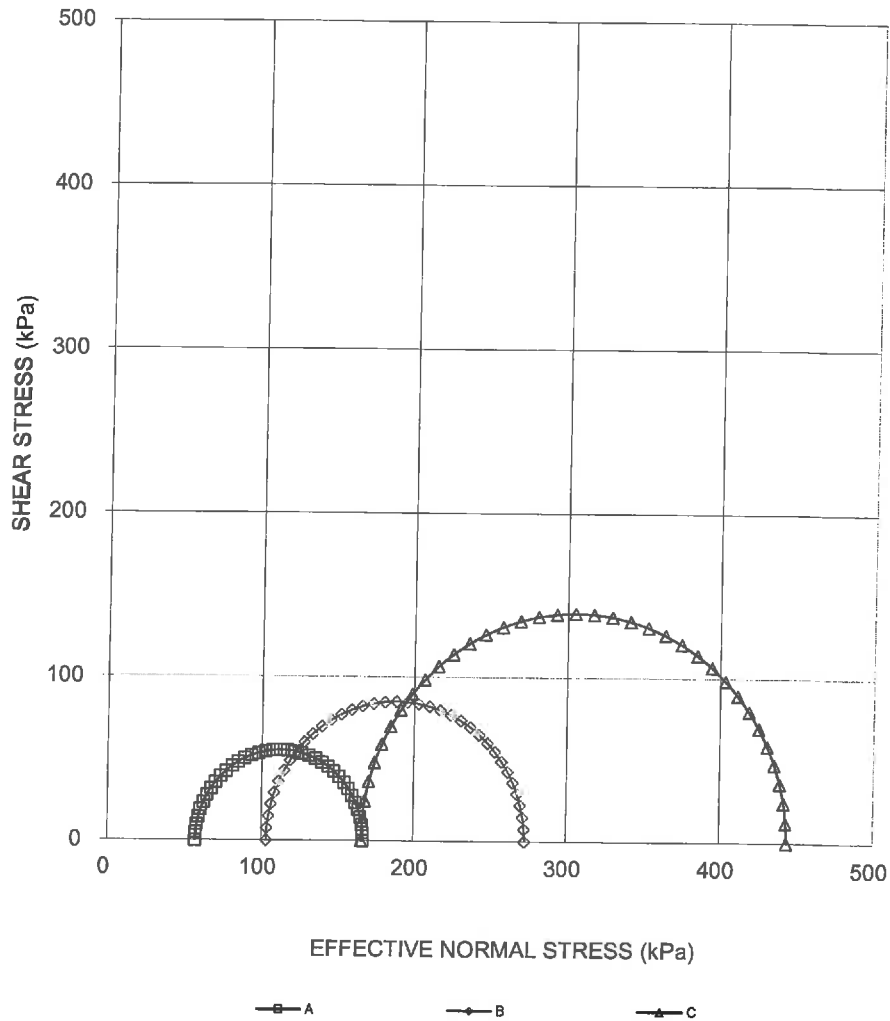
CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS

ASTM D4767

SHEET 2 OF 4

FIGURE

18-19 TW2 & 18-21 TW2



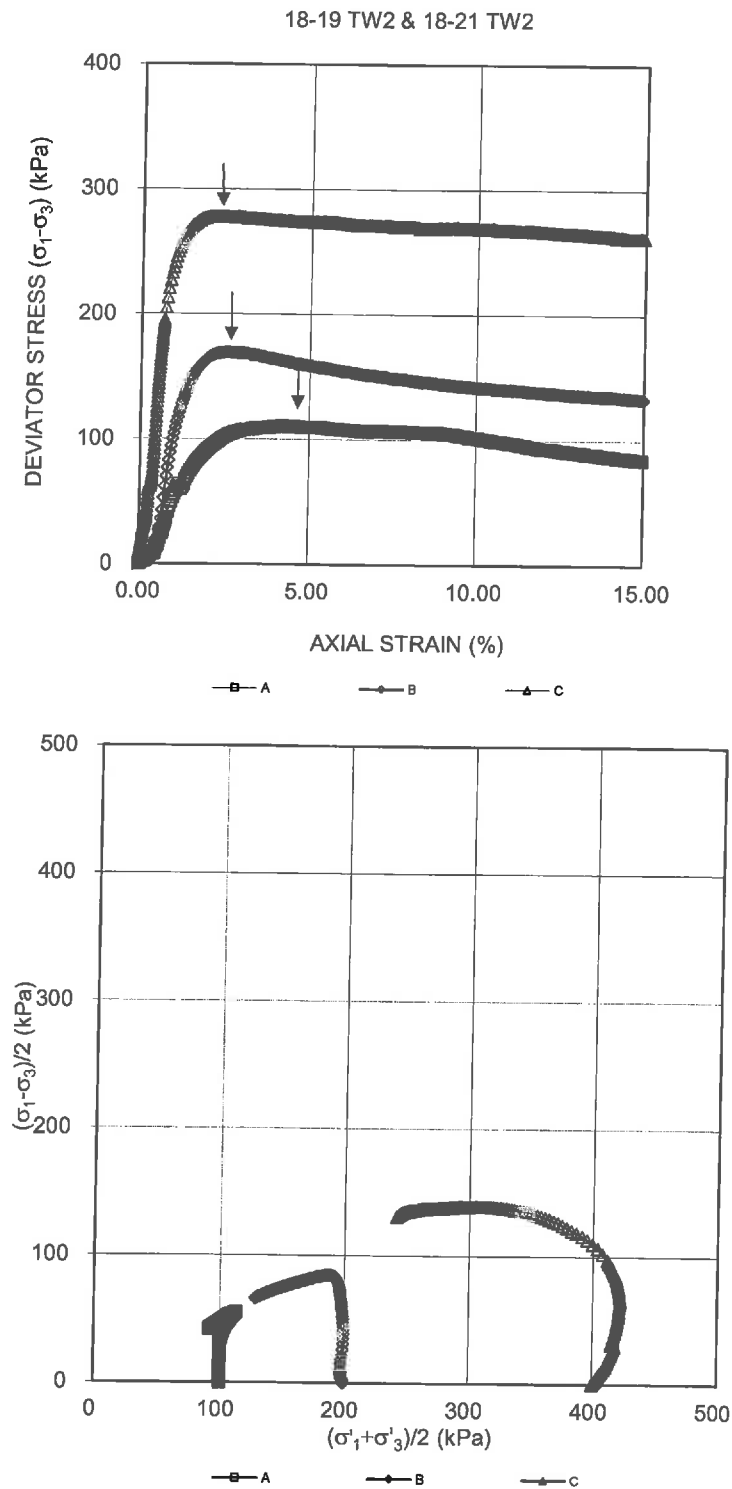
Date: 8/20/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: *[Signature]*

**CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 3 OF 4**

FIGURE



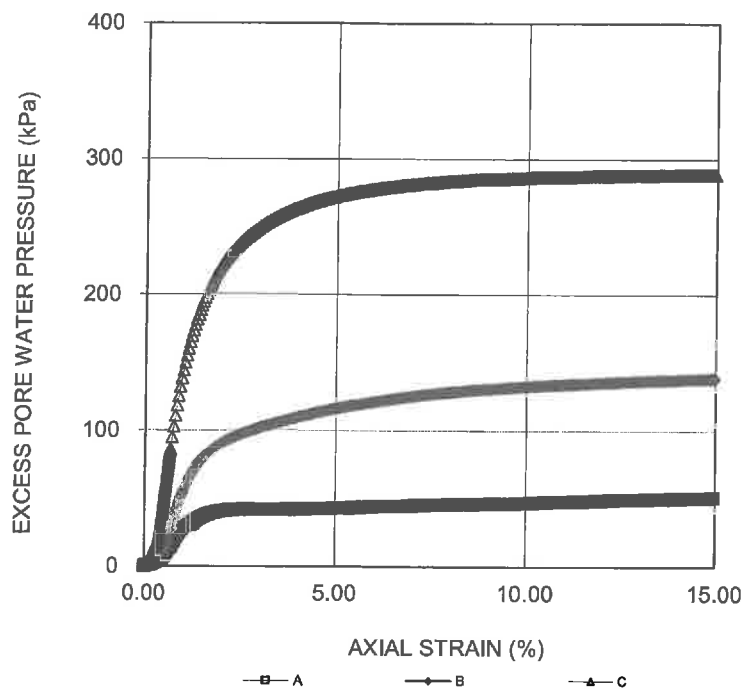
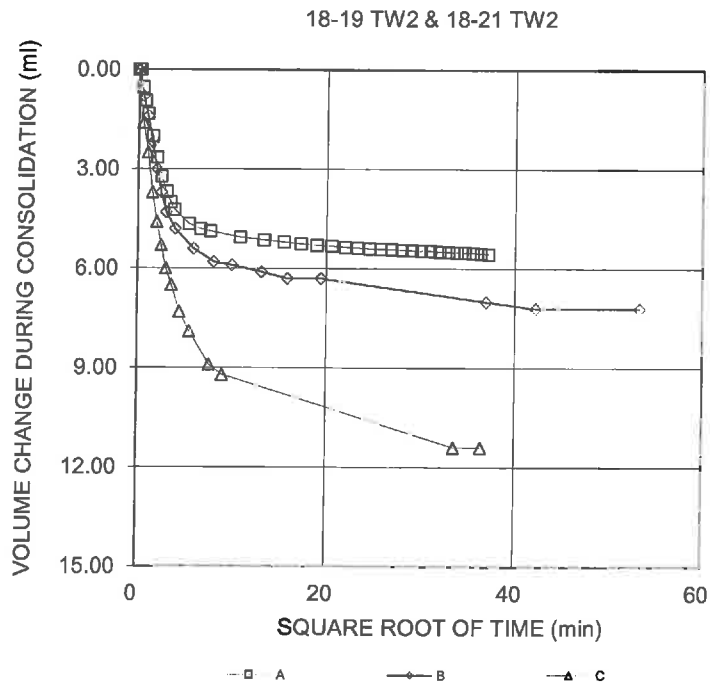
Date: 8/20/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: *[Signature]*

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 4 OF 4

FIGURE



Date: 8/20/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: *[Signature]*


**CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 1 OF 4**

FIGURE

TEST STAGE	A	B	C
BOREHOLE NUMBER	18-26		18-25
SAMPLE	T1		T1
DEPTH, m	7.62-8.23		12.20-12.80
SPECIMEN DIAMETER, cm	5.03	5.02	5.05
SPECIMEN HEIGHT, cm	10.12	10.13	10.14
NATURAL WATER CONTENT, %	26.9	31.0	29.1
DRY DENSITY, Mg/m ³	1.58	1.48	1.53
WATER CONTENT AFTER SATURATION, %	27.2	31.5	30.2
CELL PRESSURE, σ_3 , kPa	205.0	280.0	500.0
BACK PRESSURE, kPa	130.0	130.0	200.0
PORE PRESSURE PARAMETER "B"	0.96	0.96	0.96
EFFECTIVE CONSOLIDATION STRESS, σ_c , kPa	75.0	150.0	300.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	3.8	5.6	11.9
WATER CONTENT AFTER CONSOLIDATION, %	24.8	27.7	22.4
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, HOURS	7.5	13.1	3.5
WATER CONTENT AFTER TEST, %	27.1	28.6	24.5
MAX. DEVIATOR STRESS, $(\sigma_1 - \sigma_3)$, kPa	89.4	126.1	183.0
AXIAL STRAIN AT $(\sigma_1 - \sigma_3)$ maximum, %	3.8	6.5	1.7
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ'_1 / σ'_3) maximum	2.4	2.3	3.1
DEVIATOR STRESS AT (σ'_1 / σ'_3) maximum, kPa	86.9	123.7	156.5
AXIAL STRAIN AT (σ'_1 / σ'_3) maximum, %	3.1	3.4	14.8
PORE PRESSURE PARAMETER, Af, AT $(\sigma_1 - \sigma_3)$ maximum	0.12	0.41	0.85
PORE PRESSURE PARAMETER, Af, AT (σ'_1 / σ'_3) maximum	0.15	0.45	1.45
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES: <p style="text-align: center;">Effective consolidation stresses are assigned by the client.</p>			
FAILURE PLANE NUMBER	1.0	1.0	-
ANGLE OF FAILURE PLANE, DEGREES	35.0	60.0	Bulged

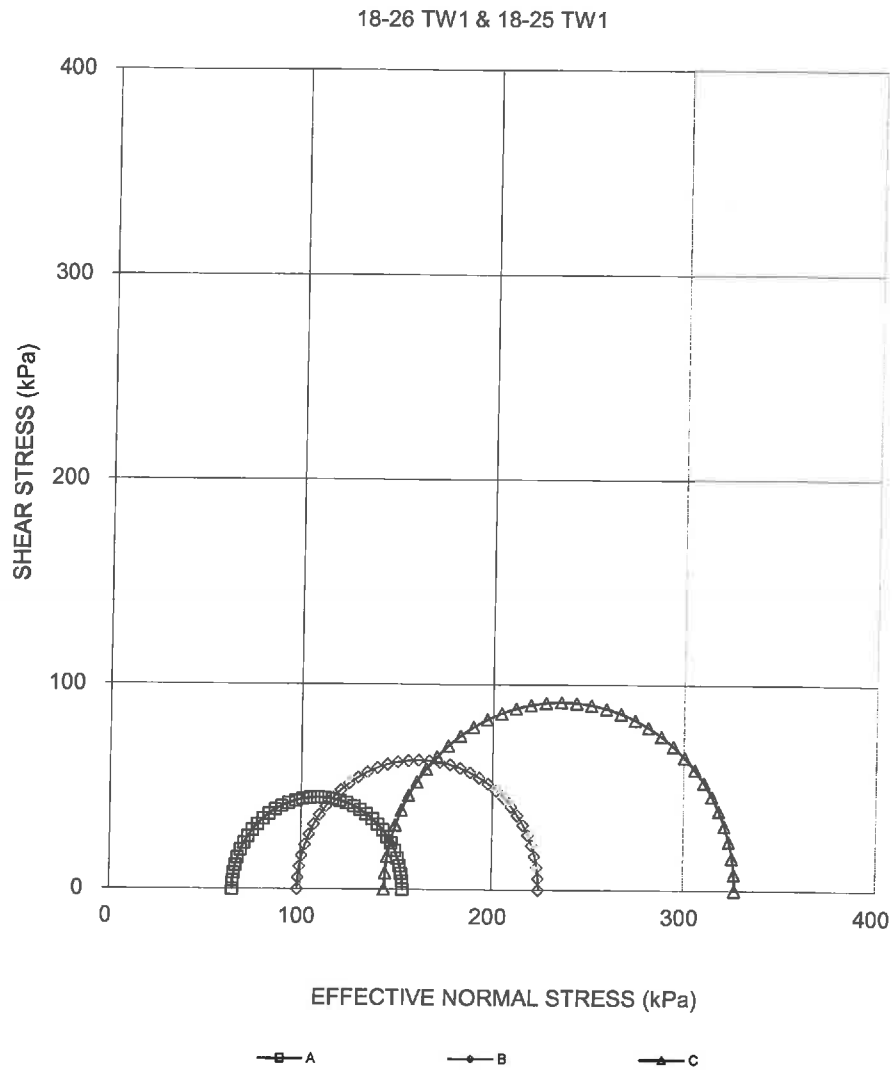
Date: 8/17/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: 

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 2 OF 4

FIGURE



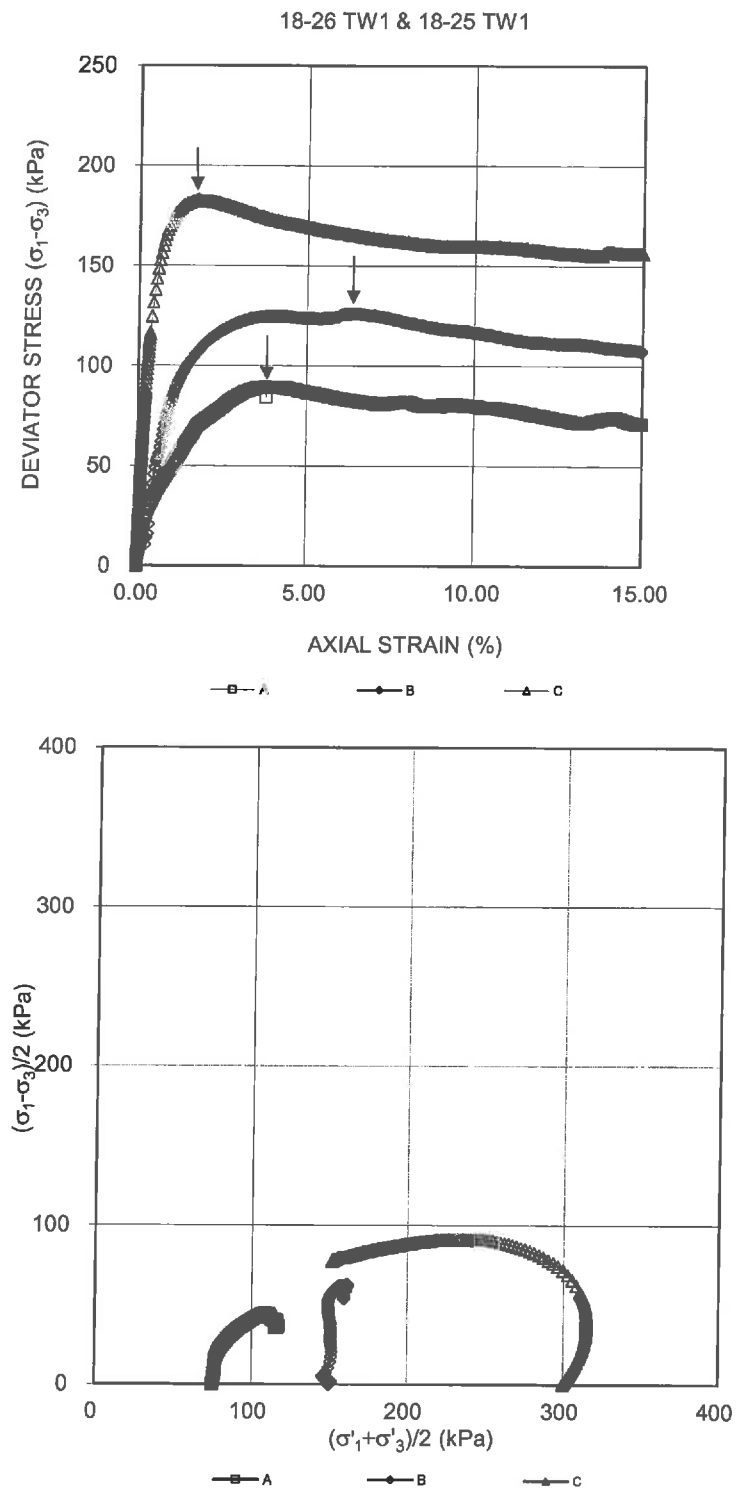
Date: 8/17/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: *hly*

**CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 3 OF 4**

FIGURE



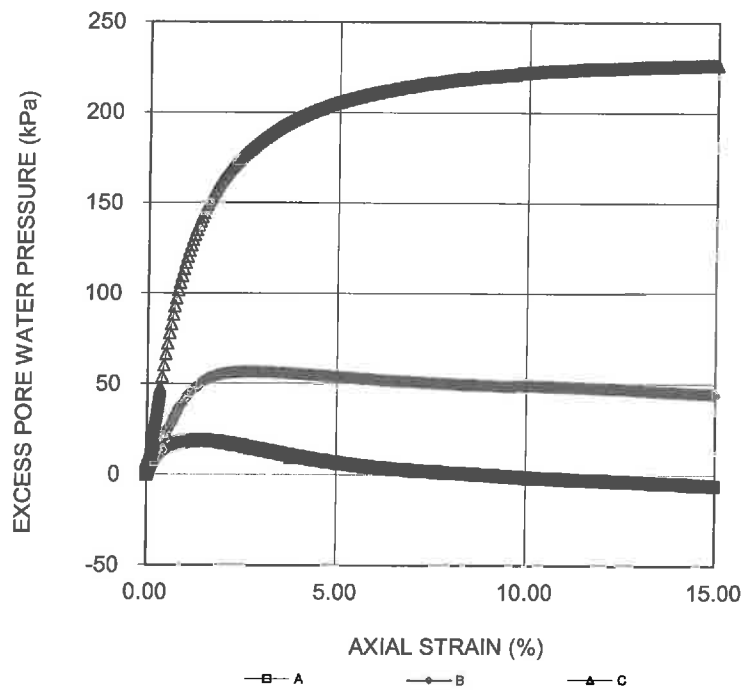
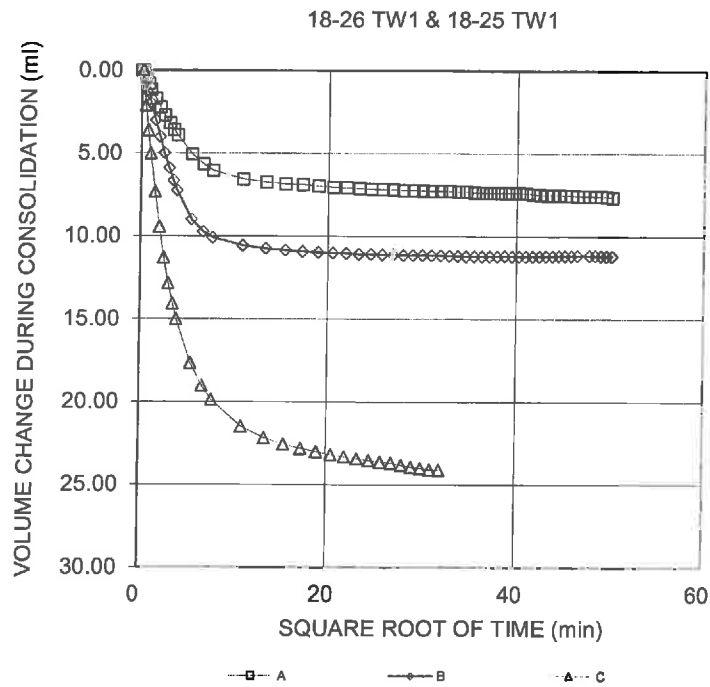
Date: 8/17/18
Project No. 1897138(2000)

Golder Associates

Prepared By LH
Checked By: *[Signature]*

**CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
ASTM D4767
SHEET 4 OF 4**

FIGURE



Date: 8/17/18
Project No. 1897138(2000)

Golder Associates

Prepared By: LH
Checked By: [Signature]

BOREHOLE: **18-03**
CORE RUN #1: 115' 3" – 118' 9"
CORE RUN #2: 118' 9" – 123' 9"
CORE RUN #3: 123' 9" – 127' 0"



BOREHOLE: **18-04**
CORE RUN #1: 115' 9" – 120' 9"
CORE RUN #2: 120' 9" – 123' 11"
CORE RUN #3: 123' 11" – 126' 2"



BOREHOLE: **18-05**
CORE RUN #1: 115' 4" – 118' 8"
CORE RUN #2: 118' 8" – 121' 1"
CORE RUN #3: 121' 1" – 126' 1"
CORE RUN #4: 126' 1" – 130' 6"



BOREHOLE: **18-06**
CORE RUN #1: 82' 6" – 83' 3"
CORE RUN #2: 83' 3" – 87' 11"
CORE RUN #3: 87' 11" – 92' 11"



BOREHOLE: **18-07**
CORE RUN #1: 82' 10" – 84' 5"
CORE RUN #2: 84' 5" – 89' 5"
CORE RUN #3: 89' 5" – 94' 0"



BOREHOLE: **18-08**
CORE RUN #1: 81' 6" – 86' 6"
CORE RUN #2: 86' 6" – 91' 6"
CORE RUN #3: 91' 6" – 93' 0"



BOREHOLE: **18-09**
CORE RUN #1: 86' 2" – 91' 2"
CORE RUN #2: 91' 2" – 96' 2"
CORE RUN #3: 96' 2" – 97' 2"



BOREHOLE: **18-10**
CORE RUN #1: 85' 7" – 90' 10"
CORE RUN #2: 90' 10" – 95' 3"
CORE RUN #3: 95' 3" – 97' 9"



BOREHOLE: **18-11**
CORE RUN #1: 85' 7" – 89' 4"
CORE RUN #2: 89' 4" – 92' 3"
CORE RUN #3: 92' 3" – 96' 0"



BOREHOLE: **18-12**
CORE RUN #1: 70' 2" – 73' 10"
CORE RUN #2: 73' 10" – 78' 10"
CORE RUN #3: 78' 10" – 80' 11"



BOREHOLE: **18-13**
CORE RUN #1: 72' 6" – 77' 7"
CORE RUN #2: 77' 7" – 81' 7"
CORE RUN #3: 81' 7" – 83' 2"



BOREHOLE: **18-14**
CORE RUN #1: 72' 8" – 74' 3"
CORE RUN #2: 74' 3" – 79' 3"
CORE RUN #3: 79' 3" – 83' 3"



BOREHOLE: **18-15**
CORE RUN #1: 66' 8" – 69' 10"
CORE RUN #2: 69' 10" – 73' 1"
CORE RUN #3: 73' 1" – 77' 10"



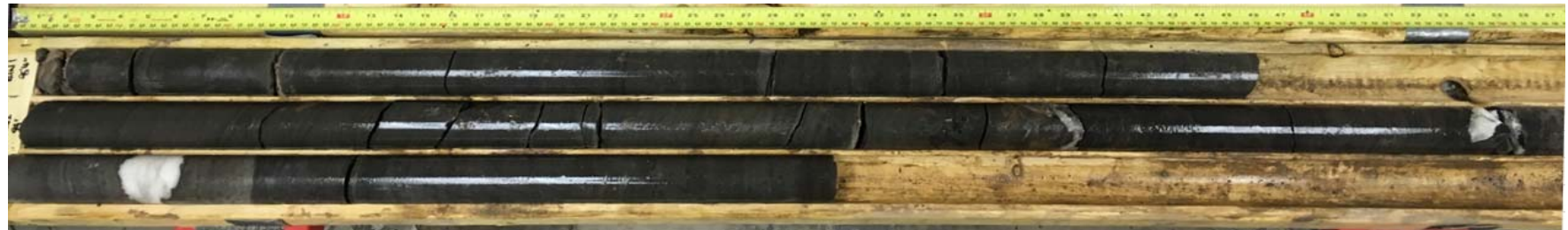
BOREHOLE: **18-16**
CORE RUN #1: 67' 9" – 69' 1"
CORE RUN #2: 69' 1" – 74' 1"
CORE RUN #3: 74' 1" – 78' 8"



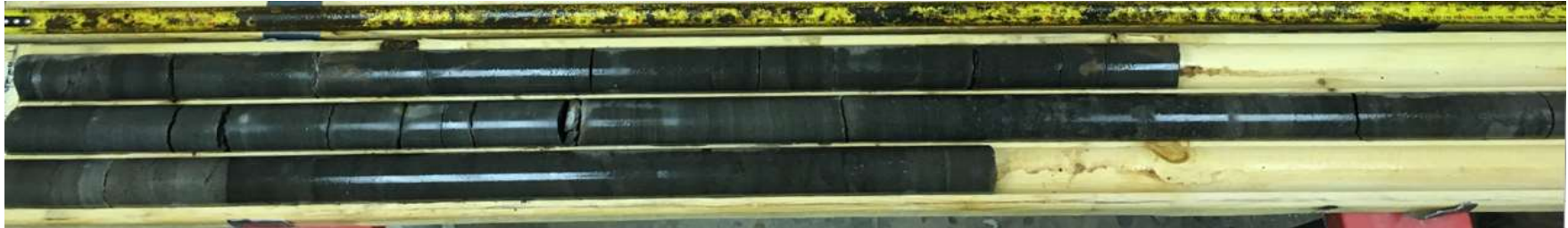
BOREHOLE: **18-17**
CORE RUN #1: 65' 3" – 69' 7"
CORE RUN #2: 69' 7" – 74' 7"
CORE RUN #3: 74' 7" – 76' 11"



BOREHOLE: **18-18**
CORE RUN #1: 95' 4" – 99' 0"
CORE RUN #2: 99' 0" – 104' 0"
CORE RUN #3: 104' 0" – 106' 5"



BOREHOLE: **18-19**
CORE RUN #1: 95' 5" – 98' 11"
CORE RUN #2: 98' 11" – 103' 11"
CORE RUN #3: 103' 11" – 106' 11"



BOREHOLE: **18-20**
CORE RUN #1: 95' 9" – 100' 11"
CORE RUN #2: 100' 11" – 105' 11"



**REPLACEMENT OF WELLAND RIVER TWIN BRIDGE STRUCTURES
REGIONAL MUNICIPALITY OF NIAGARA
CITY OF NIAGARA FALLS, ON**

Job No: 18426
Client: WSP

Date Drilled: 10-Apr-18
Date Tested: 18-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-03

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 20-Apr-18
Date Tested: 02-May-18

Project Name: Welland River Twin Bridge Structures
Core Size: NQ **BH No :** 18-04

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)



ASTM D5731-08

Date Drilled: 08-Apr-18
Date Tested: 18-Apr-18

Tester: GA
Reviewed by: GRL

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24. (Zhang, 2005)

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 18426
Client: WSP

Date Drilled: 27-Mar-18
Date Tested: 02-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-06

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)



ASTM D5731-08

Date Drilled: 28-Mar-18
Date Tested: 03-Apr-18

Tester: KF
Reviewed by: GRL

- * It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- * Diametral Test should have $0.7 \times D$ on either side of test point.
- * Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 27-Mar-18
Date Tested: 03-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-08

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 18-Mar-18
Date Tested: 21-Mar-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-09

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 12-Mar-18
Date Tested: 21-Mar-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-10

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 15-Mar-18
Date Tested: 16-Mar-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-11

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 20-Mar-18
Date Tested: 02-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-12

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 19-Mar-18
Date Tested: 21-Mar-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-13

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 21-Mar-18
Date Tested: 02-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-14

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 23-Mar-18
Date Tested: 03-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-15

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 24-Mar-18
Date Tested: 03-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-16

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 24-Mar-18
Date Tested: 02-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-17

Tester: KF
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 18-Mar-18
Date Tested: 21-Mar-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-18

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 18-Apr-18
Date Tested: 02-May-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-19

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)

Job No: 18426
Client: WSP

Date Drilled: 05-Apr-18
Date Tested: 18-Apr-18

Project Name:	Welland River Twin Bridge Structures		
Core Size:	NQ	BH No :	18-20

Tester: GA
Reviewed by: GRL

[illegible]

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24. (Zhang, 2005)



Appendix C

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2430-15-00



QEW
WELLAND RIVER BRIDGES
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

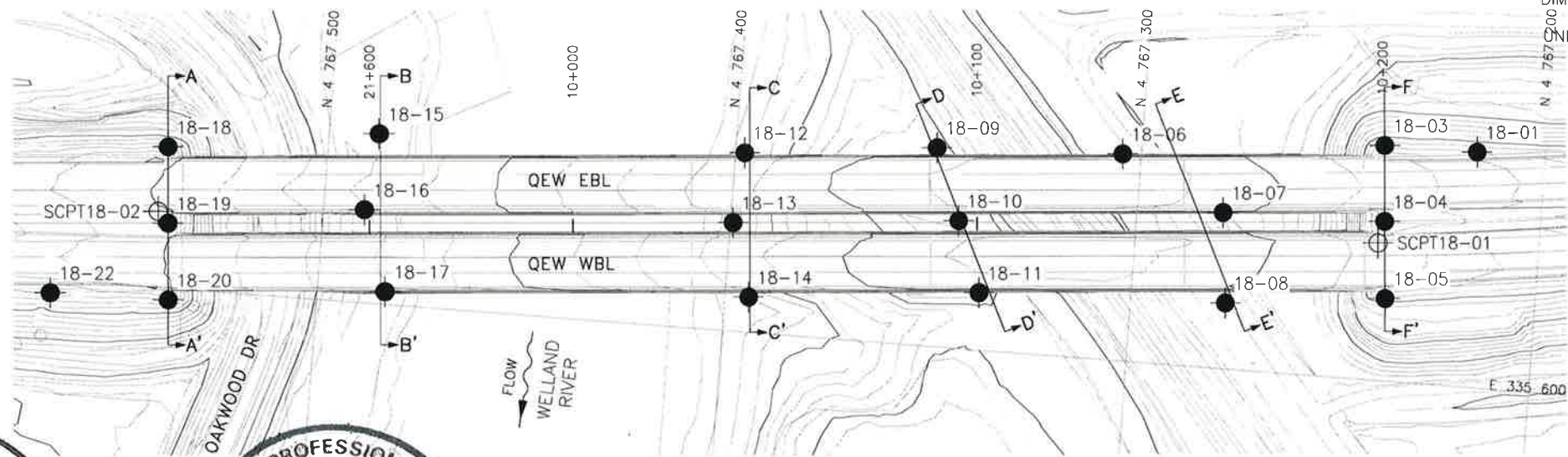
- Borehole
- SCPTU
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18-01	183.7	4 767 217.1	335 657.7
18-03	184.3	4 767 240.2	335 657.6
18-04	184.2	4 767 238.9	335 639.0
18-05	184.2	4 767 237.4	335 620.1
18-06	175.6	4 767 304.6	335 650.7
18-07	175.4	4 767 278.7	335 638.2
18-08	176.0	4 767 276.5	335 616.1
18-09	175.0	4 767 350.3	335 648.7
18-10	175.3	4 767 343.6	335 631.3
18-11	175.3	4 767 337.2	335 614.0
18-12	172.2	4 767 397.7	335 643.8
18-13	173.8	4 767 399.3	335 626.5

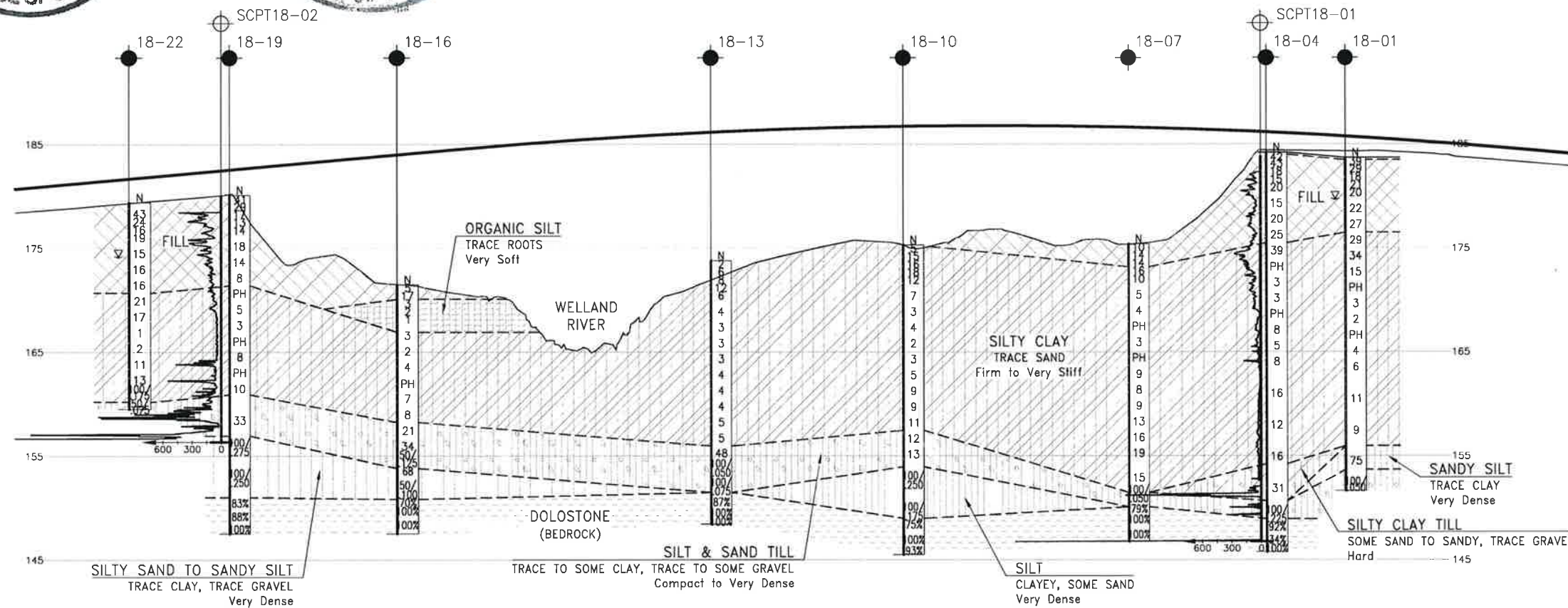
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M03-307






18-14	173.1	4 767 394.0	335 608.6
18-15	171.4	4 767 487.9	335 641.6
18-16	171.5	4 767 490.0	335 622.8
18-17	171.3	4 767 483.6	335 603.1
18-18	180.1	4 767 539.3	335 634.5
18-19	180.1	4 767 537.9	335 615.8
18-20	180.1	4 767 536.5	335 597.1
18-22	179.4	4 767 565.4	335 596.6
SCPT18-01	183.8	4 767 240.1	335 633.6
SCPT18-02	180.0	4 767 540.6	335 618.5

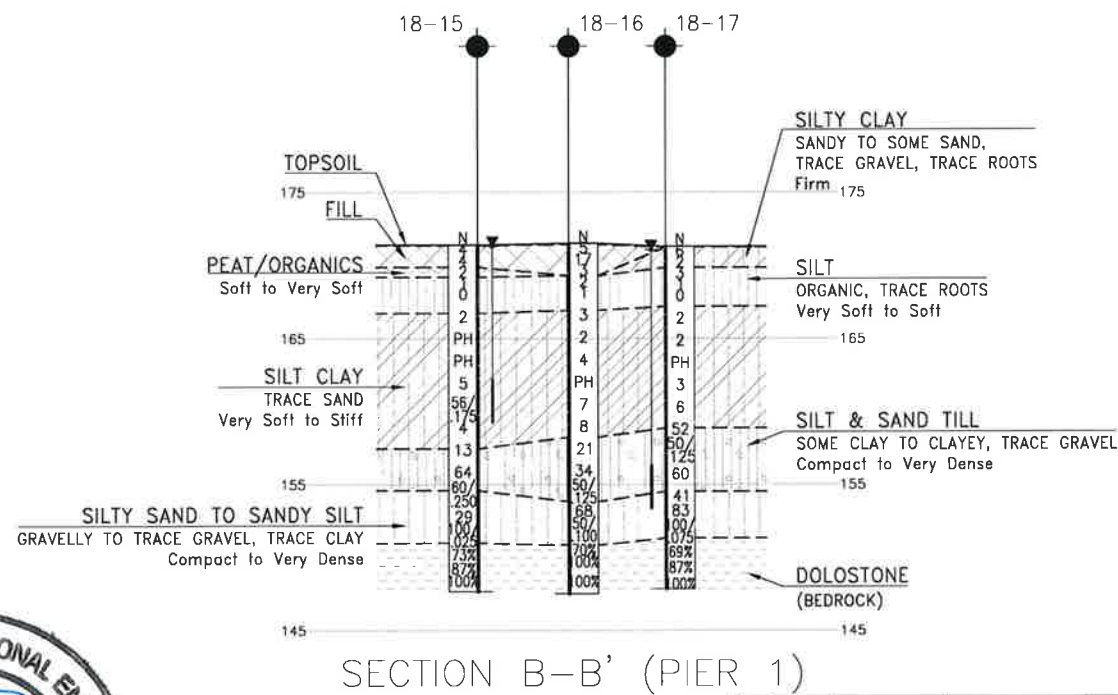


PROFILE ALONG EXIST. CL QEW

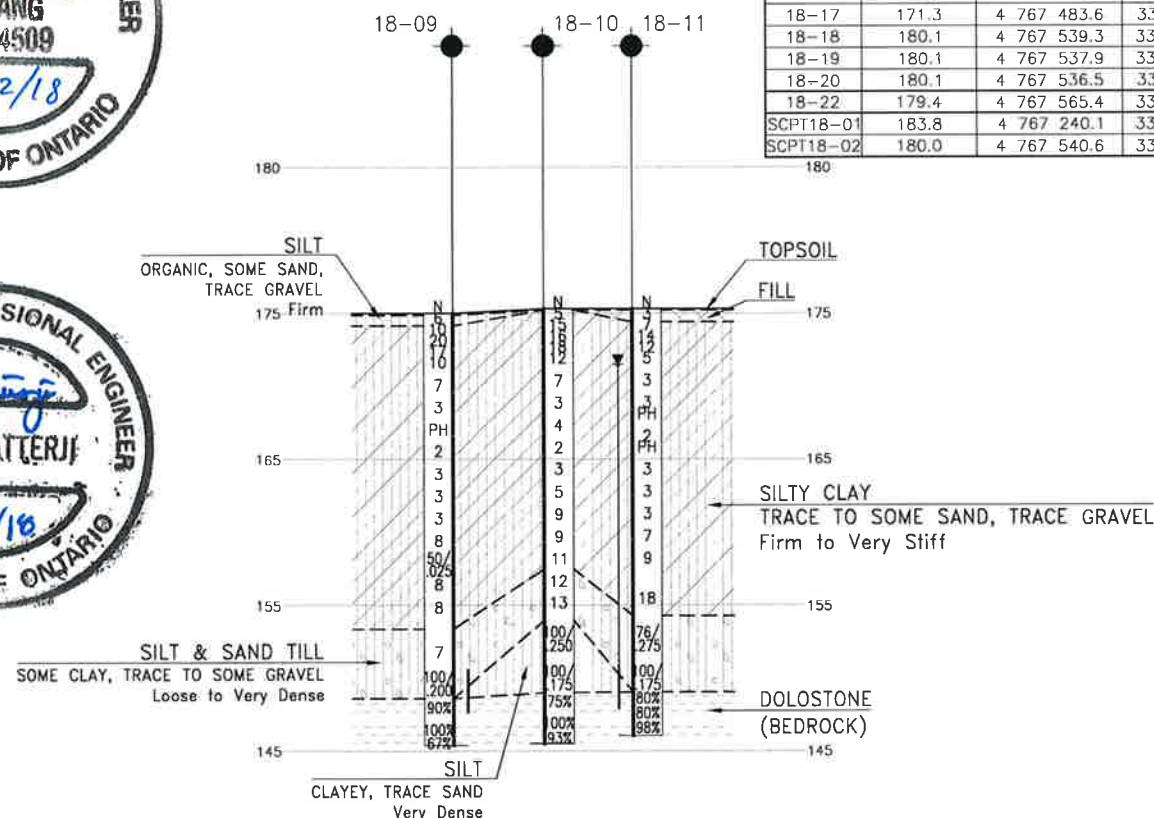


REVISIONS	DATE	BY	DESCRIPTION
DESIGN	GRL	CHK	SKP
LOAD	DATE	OCT 2018	
DRAWN	AN	CHK	GRL
SITE	STRUCT	DWG	1

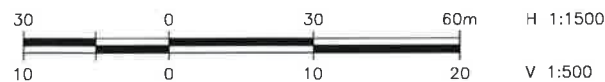
<p>ETRES RES HOWN</p>	<p>CONT No</p> <p>GWP No 2430-15-00</p>	<p>SHEET</p>
	<p>QEW WELLAND RIVER BRIDGES REPLACEMENT BOREHOLE LOCATIONS AND SOIL STRATA</p>	
		
 <p>THURBER ENGINEERING LTD.</p>		
		








SECTION B-B' (PIER 1)



Very Dense
SECTION D-D' (PIER 3)



KEYPLAN			
L E G E N D			
	Borehole		
	SCPTU		
N	Blows /0.3m (Std Pen Test, 475J/blow)		
CONE	Blows /0.3m (60° Cone, 475J/blow)		
PH	Pressure, Hydraulic		
	Water Level		
	Head Artesian Water		
	Piezometer		
90%	Rock Quality Designation (RQD)		
A/R	Auger Refusal		

NO	ELEVATION	NORTHING	EASTING
18-01	183.7	4 767 217.1	335 657.7
18-03	184.3	4 767 240.2	335 657.6
18-04	184.2	4 767 238.9	335 639.0
18-05	184.2	4 767 237.4	335 620.1
18-06	175.6	4 767 304.6	335 650.7
18-07	175.4	4 767 278.7	335 638.2
18-08	176.0	4 767 276.5	335 616.1
18-09	175.0	4 767 350.3	335 648.7
18-10	175.3	4 767 343.6	335 631.3
18-11	175.3	4 767 337.2	335 614.0
18-12	172.2	4 767 397.7	335 643.8
18-13	173.8	4 767 399.3	335 626.5

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 10.

GEOCREs No. 30M03-307

REVISIONS										
	DATE	BY	DESCRIPTION							DATE
	DESIGN	GRL	CHK	SKP	CODE	LOAD				OCT 2018
	DRAWN	AN	CHK	GRL	SITE	STRUCT				DWG 2

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

CONT No
GWP No 2430-15-00

QEW
WELLAND RIVER BRIDGES
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

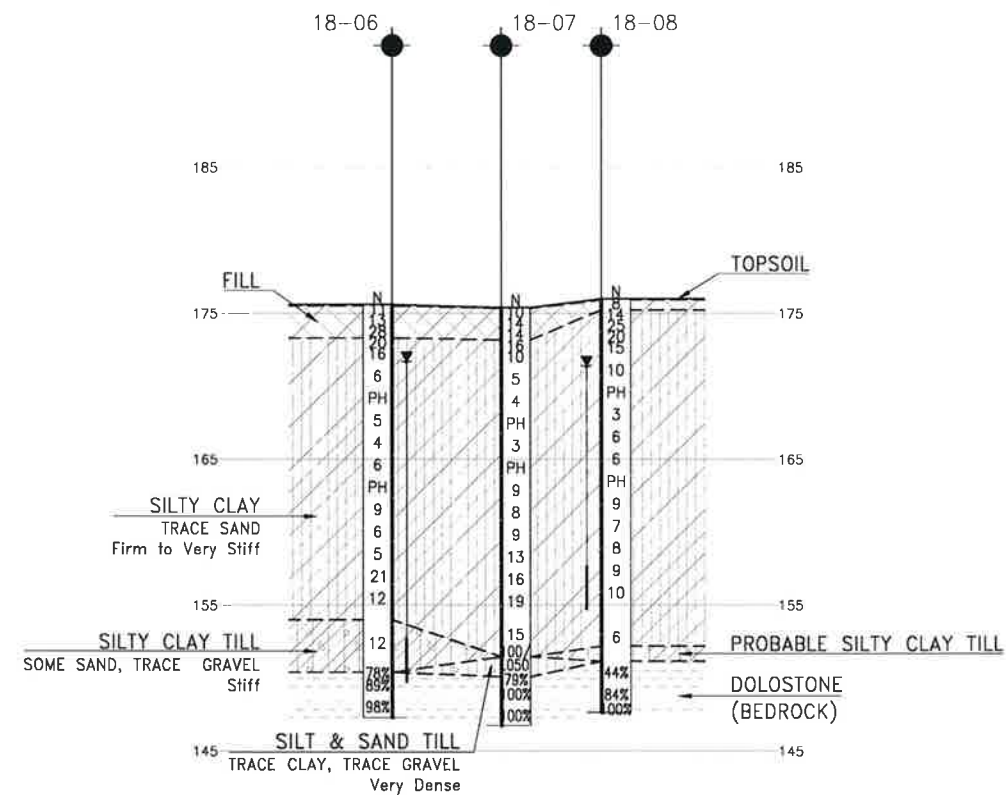
- Borehole
- SCPTU
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18-01	183.7	4 767 217.1	335 657.7
18-03	184.3	4 767 240.2	335 657.6
18-04	184.2	4 767 238.9	335 639.0
18-05	184.2	4 767 237.4	335 620.1
18-06	175.6	4 767 304.6	335 650.7
18-07	175.4	4 767 278.7	335 638.2
18-08	176.0	4 767 276.5	335 616.1
18-09	175.0	4 767 350.3	335 648.7
18-10	175.3	4 767 343.6	335 631.3
18-11	175.3	4 767 337.2	335 614.0
18-12	172.2	4 767 397.7	335 643.8
18-13	173.8	4 767 399.3	335 626.5

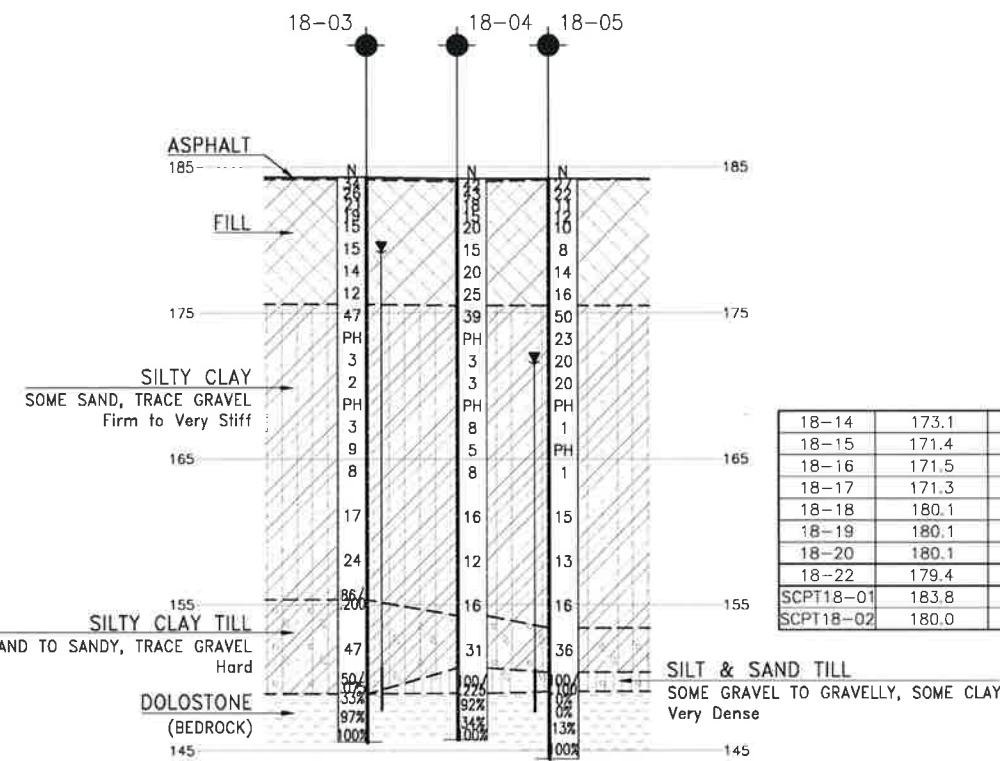
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M03-307



SECTION E-E' (PIER 4)



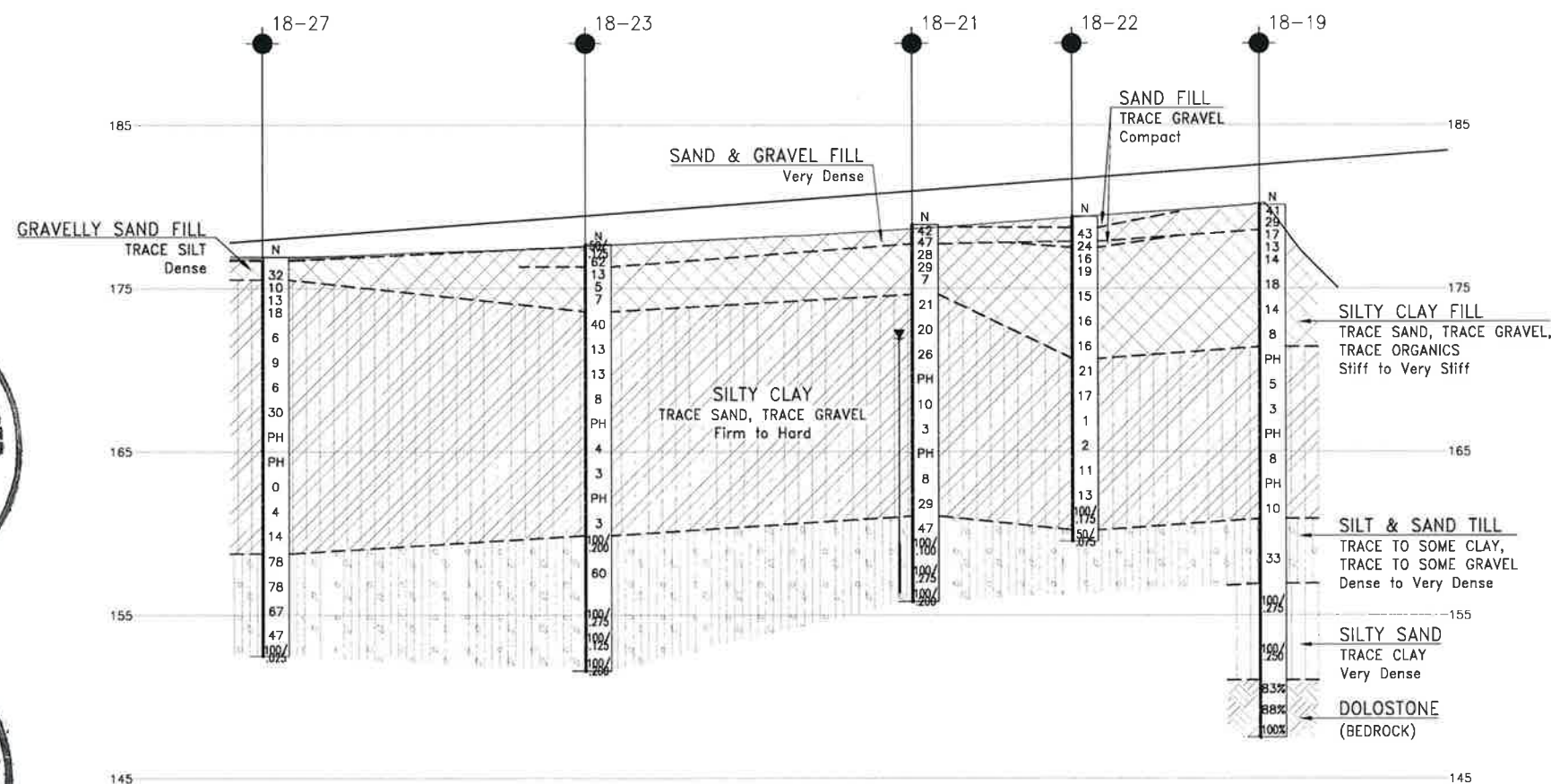
SECTION F-F' (SOUTH ABUTMENT)

18-14	173.1	4 767 394.0	335 608.6
18-15	171.4	4 767 487.9	335 641.6
18-16	171.5	4 767 490.0	335 622.8
18-17	171.3	4 767 483.6	335 603.1
18-18	180.1	4 767 539.3	335 634.5
18-19	180.1	4 767 537.9	335 615.8
18-20	180.1	4 767 536.5	335 597.1
18-22	179.4	4 767 565.4	335 596.6
SCPT18-01	183.8	4 767 240.1	335 633.6
SCPT18-02	180.0	4 767 540.6	335 618.5



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	GRL	CHK SKP	CODE
DRAWN	AN	CHK GRL	SITE
			STRUCT
			DWG 3
			DATE OCT 2018

PLAN



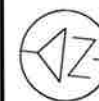
PROFILE ALONG EXIST. A-A'



Y 1:400

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

CONT No
GWP No 2430-15-00



SHEET

QEW
WELLAND RIVER BRIDGES
NORTH APPROACH
BOREHOLE LOCATIONS AND SOIL STRATA








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- | | |
|---|---------------------------------------|
|  | Borehole |
|  | SCPTU |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60° Cone, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level |
|  | Head Artesian Water |
|  | Piezometer |
| 90% | Rock Quality Designation (RQD) |
| A/R | Auger Refusal |

NO	ELEVATION	NORTHING	EASTING
18-18	180.1	4 767 539.3	335 634.5
18-19	180.1	4 767 537.9	335 615.8
18-20	180.1	4 767 536.5	335 597.1
18-21	178.9	4 767 592.5	335 629.4
18-22	179.4	4 767 565.4	335 596.6
18-23	177.7	4 767 641.4	335 609.4
18-27	176.9	4 767 690.4	335 601.8
SCPT18-02	180.0	4 767 540.6	335 618.5

-NOTES-

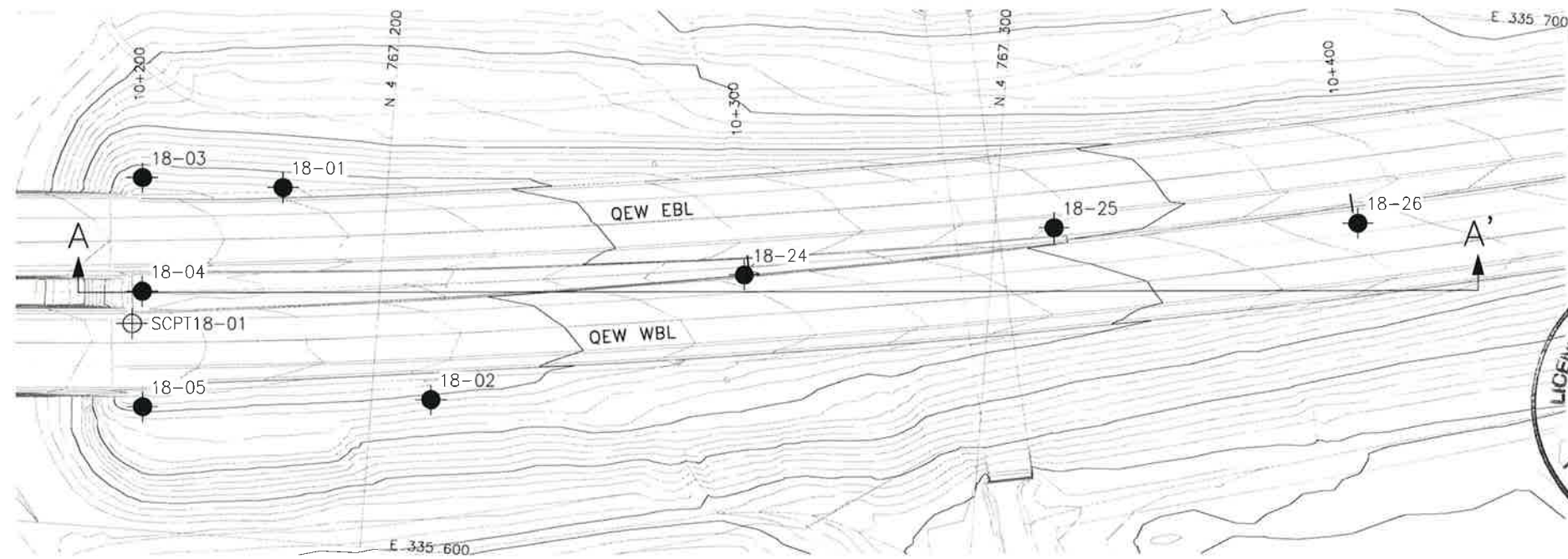
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M03-307



REVISIONS									
	DATE	BY				DESCRIPTION			
DESIGN	GRL	CHK SKP	CODE			LOAD		DATE	OCT 2018
DRAWN	AN	CHK GRI	SITE			STRUCT	INDWG		

NAME	DATE	TIME	LOCATION	REMARKS
...



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



CONT No
GWP No 2430-15-00

QEW
WELLAND RIVER BRIDGES
SOUTH APPROACH
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

●	Borehole
⊕	SCPTU
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
↑	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

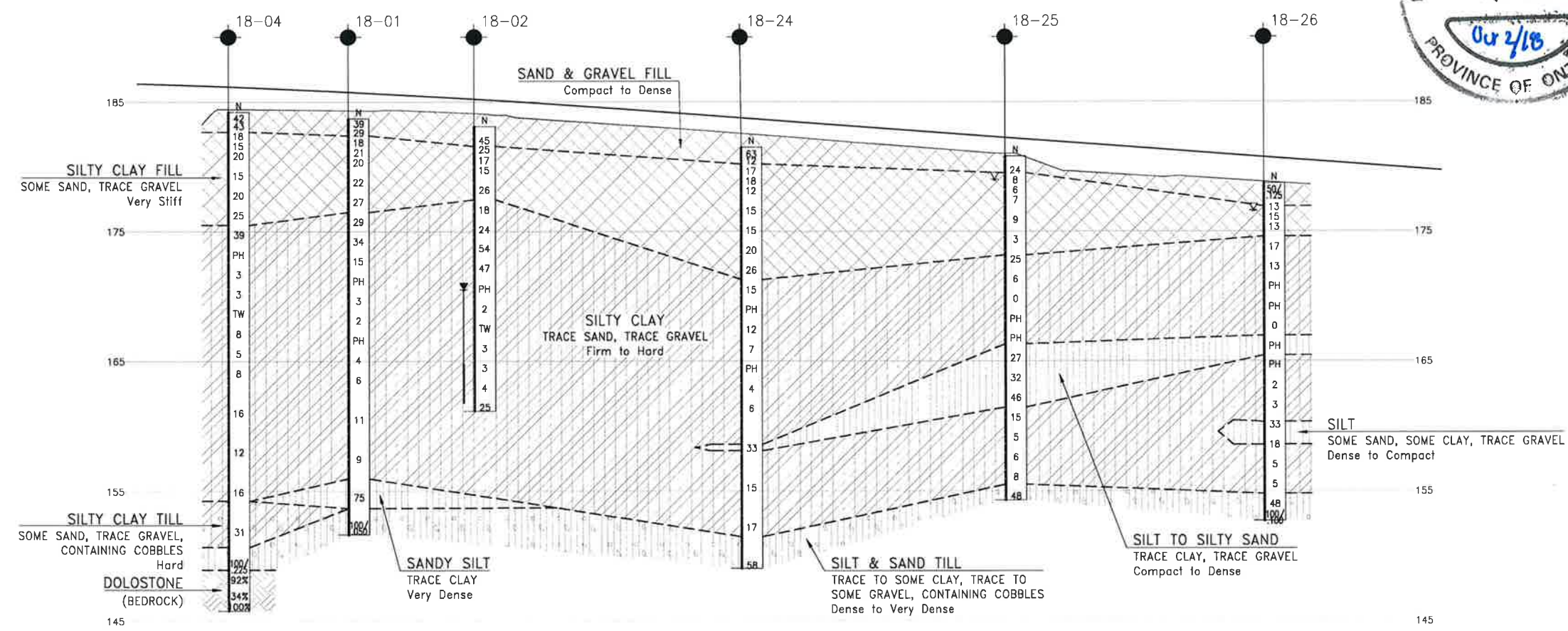
NO	ELEVATION	NORTHING	EASTING
18-01	183.7	4 767 217.1	335 657.7
18-02	183.1	4 767 190.4	335 624.9
18-03	184.3	4 767 240.2	335 657.6
18-04	184.2	4 767 238.9	335 639.0
18-05	184.2	4 767 237.4	335 620.1
18-24	181.5	4 767 140.6	335 649.1
18-25	180.8	4 767 090.2	335 660.7
18-26	178.7	4 767 040.3	335 665.2
SCPT18-01	183.8	4 767 240.1	335 633.6

-NOTES-

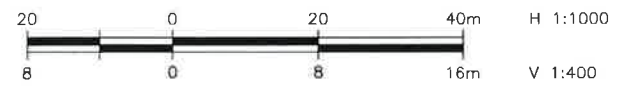
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M03-307

FILENAME: H:\Drawing\18000\18425\18425-PR-Approach.dwg
PLOT DATE: 10/2/2016 1:27 PM



PROFILE ALONG EXIST. A-A'



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	GRL	CHK	SKP
DRAWN	AN	CHK	GRL
		SITE	STRUCT
			DWG 2

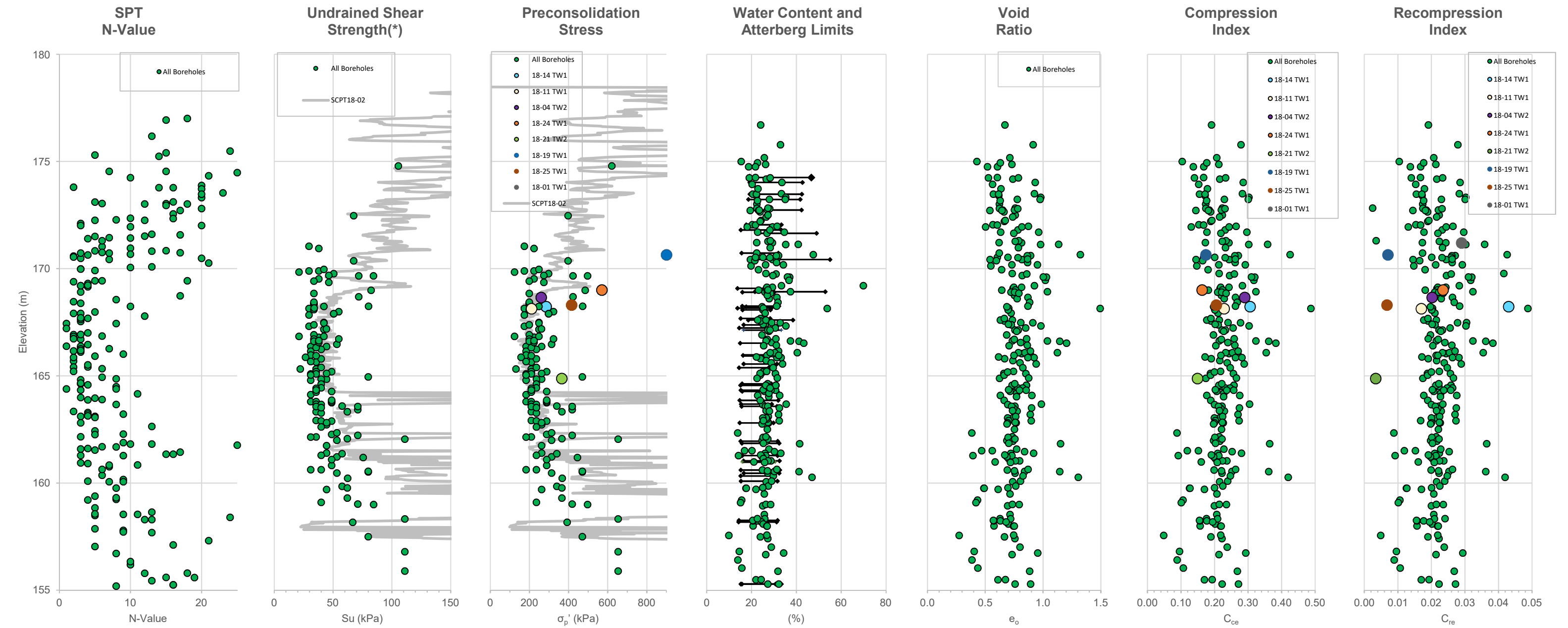


Appendix D

Summary of Subsurface Conditions (Silty Clay)

FIGURE D1

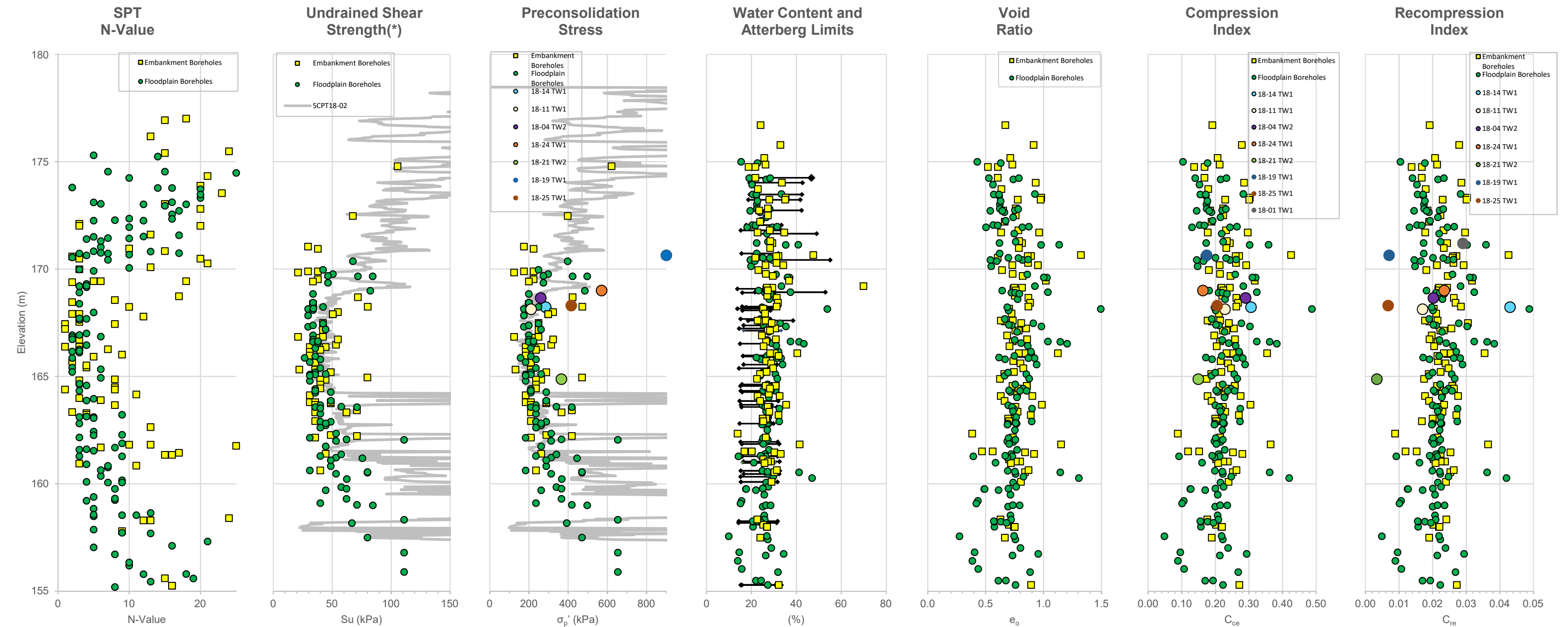
SUMMARY OF SUBSURFACE CONDITIONS (SILTY CLAY)
ALL BOREHOLES



(*)corrected for plasticity

FIGURE D2

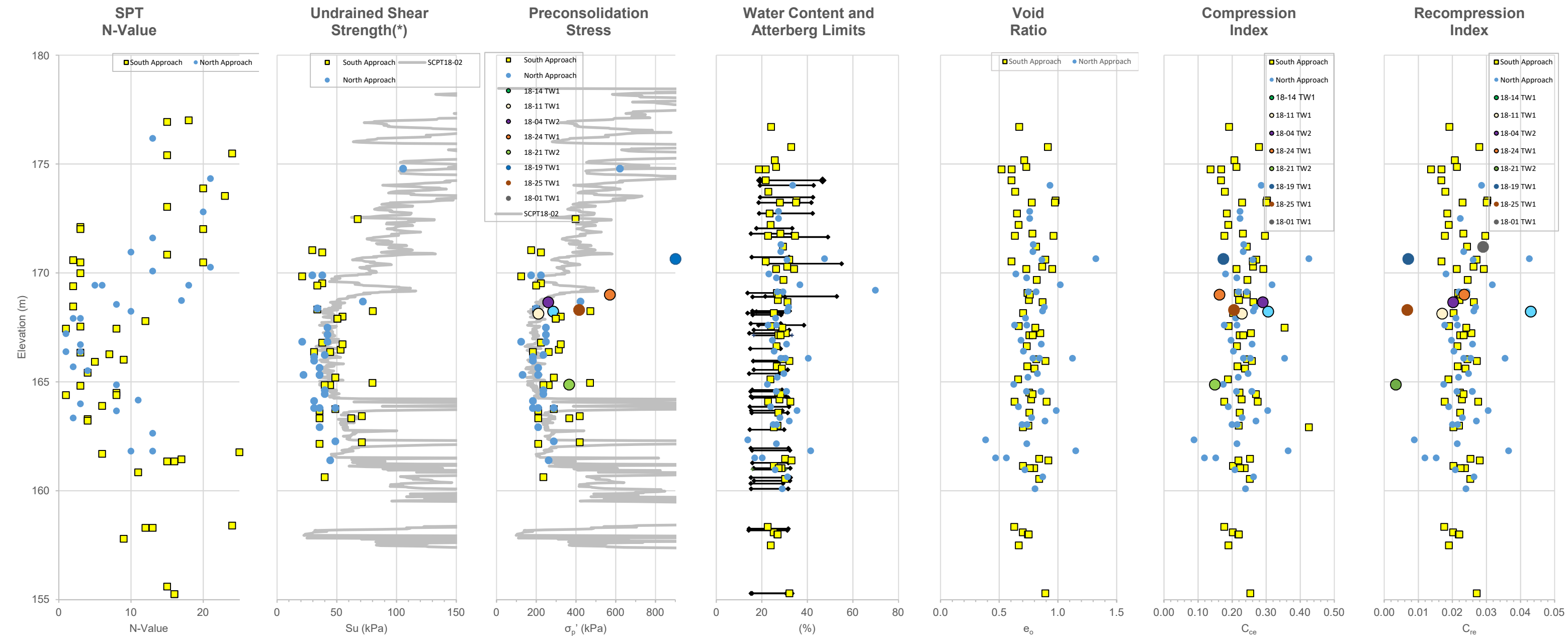
SUMMARY OF SUBSURFACE CONDITIONS (SILTY CLAY)
FLOODPLAIN VS. EMBANKMENT



(*)corrected for plasticity

FIGURE D3

SUMMARY OF SUBSURFACE CONDITIONS (SILTY CLAY)
SOUTH APPROACH VS. NORTH APPROACH



(*)corrected for plasticity



Appendix E

Chemical Analysis Results

**CLIENT NAME: THURBER ENGINEERING LTD
SUITE 103, 2010 WINSTON PARK DRIVE
OAKVILLE, ON L6H5R7
(905) 829-8666**

ATTENTION TO: Abdul Nasri

PROJECT: 18426 Welland River Bridge

AGAT WORK ORDER: 18T339355

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: May 22, 2018

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



Certificate of Analysis

AGAT WORK ORDER: 18T339355

PROJECT: 18426 Welland River Bridge

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Abdul Nasri

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2018-05-15

DATE REPORTED: 2018-05-22

		SAMPLE DESCRIPTION:		18-03 SS#5		18-10 SS#9	18-16 SS#12	18-20 SS#11
		SAMPLE TYPE:		Soil		Soil	Soil	Soil
		DATE SAMPLED:		2018-04-09		2018-03-16	2018-03-23	2018-04-05
Parameter	Unit	G / S	RDL	9246635	RDL	9246636	9246637	9246638
Sulfide (S2-)	%		0.05	<0.05	0.05	0.32	0.15	0.42
Chloride (2:1)	µg/g	NA	4	264	2	39	24	15
Sulphate (2:1)	µg/g		4	1190	2	197	260	310
pH (2:1)	pH Units		NA	7.66	NA	7.86	7.95	7.88
Electrical Conductivity (2:1)	mS/cm	1.4	0.005	1.35	0.005	0.331	0.352	0.407
Resistivity (2:1)	ohm.cm		1	741	1	3020	2840	2460
Redox Potential (2:1)	mV		5	196	5	185	175	164

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Table 3: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition - Soil - Industrial/Commercial/Community Property Use - Medium and Fine Textured Soils
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.

9246635 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
*Sulphide analyzed at AGAT 5623 McAdam

Samples were received and analyzed past hold time.

Elevated RDL indicates the degree of sample dilution prior to the analysis in order to keep analytes within the calibration range of the instrument and to reduce matrix interference.

9246636-9246638 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
*Sulphide analyzed at AGAT 5623 McAdam

Samples were received and analyzed past hold time.

Certified By:

Amanjot Bhela

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 18T339355

PROJECT: 18426 Welland River Bridge

ATTENTION TO: Abdul Nasri

SAMPLING SITE:

SAMPLED BY:

Soil Analysis

RPT Date: May 22, 2018

RPT Date: May 22, 2018			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Sulfide (S2-)	9246635	9246635	< 0.05	< 0.05	NA	< 0.05	95%	80%	120%						
Chloride (2:1)	9237761		1420	1450	2.1%	< 2	102%	80%	120%	104%	80%	120%	94%	70%	130%
Sulphate (2:1)	9237761		37	37	0.0%	< 2	97%	80%	120%	102%	80%	120%	106%	70%	130%
pH (2:1)	9252079		8.47	8.53	0.7%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	9245893		0.245	0.244	0.4%	< 0.005	95%	90%	110%	NA			NA		
Redox Potential (2:1)	9237761		184	181	1.6%	< 5	103%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:



Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 18T339355

PROJECT: 18426 Welland River Bridge

ATTENTION TO: Abdul Nasri

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulfide (S ²⁻)	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H ⁺ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE



Appendix F

ConeTec Report

PRESENTATION OF SITE INVESTIGATION RESULTS

QEW at Welland River Bridge

Prepared for:

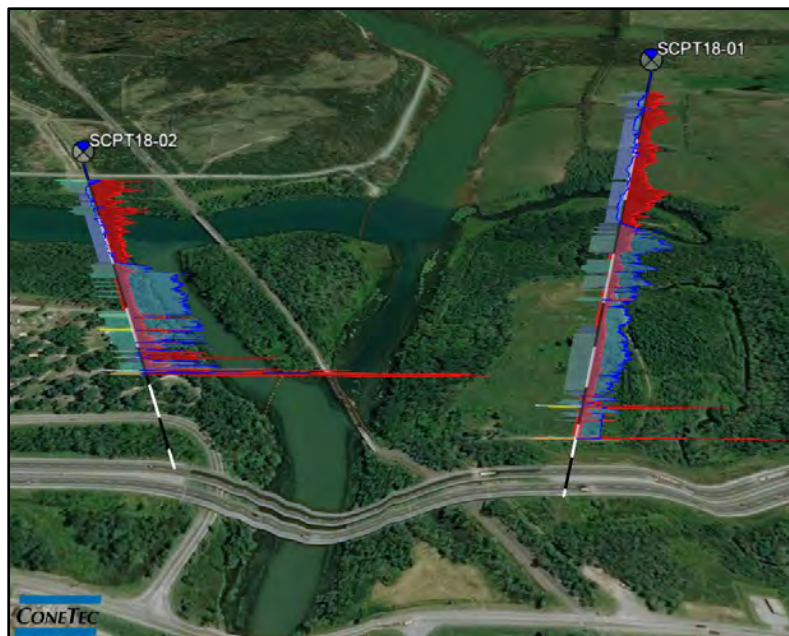
Thurber Engineering Ltd.

ConeTec Job No: 18-05043

Project Start Date: 13-Jul-2018

Project End Date: 13-Jul-2018

Report Date: 18-Jul-2018



Prepared by:

ConeTec Investigations Ltd.
9033 Leslie Street, Unit 15
Richmond Hill, ON L4B 4K3

Tel: (905) 886-2663

Fax: (905) 886-2664

Toll Free: (800) 504-1116

Email: conetecON@conetec.com

www.conetec.com

www.conetecdataservices.com



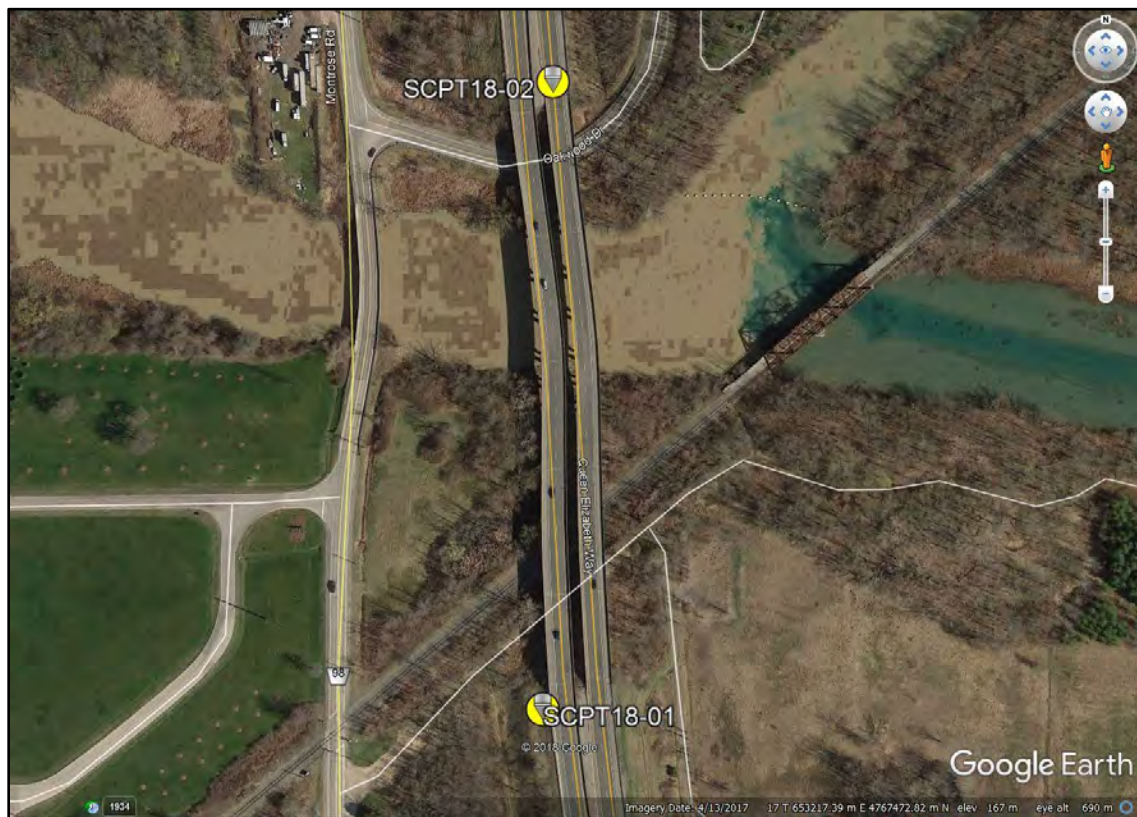
Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec Investigations Ltd. for Thurber Engineering Ltd. on Queen Elizabeth Way at the Welland River Bridge, Niagara Falls. The program consisted of two seismic cone penetration tests (SCPTs).

Project Information

Project	
Client	Thurber Engineering Ltd.
Project	QEW at Welland River Bridge
ConeTec project number	18-05043

A plan view from Google Earth including the CPT test locations is presented below.



Rig Description	Deployment System	Test Type
CPT truck rig (C3)	30 ton rig cylinder	SCPT

Coordinates		
Test Type	Collection Method	EPSG Number
SCPT	Consumer grade GPS	32617

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	Soil behaviour type (SBT) scatter plots, seismic plots and advanced plots are provided in the data release package.

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm ²)	Sleeve Area (cm ²)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
545:T1500F15U500	545	15	225	1500	15	500
Cone 545 was used for all CPT soundings.						

Calculated Geotechnical Parameter Tables	
Additional information	<p>The Normalized Soil Behaviour Type Chart based on Q_{tn} (SBT Q_{tn}) (Robertson, 2009) was used to classify the soil for this project. A detailed set of calculated CPT parameters have been generated and are provided in Excel format files in the release folder. The CPT parameter calculations are based on values of corrected tip resistance (q_t) sleeve friction (f_s) and pore pressure (u_2).</p> <p>Soils were classified as either drained or undrained based on the Normalized Soil Behaviour Type Chart (SBT Q_{tn}) (Robertson, 2009). Calculations for both drained and undrained parameters were included for materials that classified as silt mixtures – clayey silt to silty clay (zone 4).</p>

Limitations

This report has been prepared for the exclusive use of Thurber Engineering Ltd. (Client) for the project titled "QEW at Welland River Bridge". The report's contents may not be relied upon by any other party without the express written permission of ConeTec Investigations Ltd. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.



The cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd. of Richmond, British Columbia, Canada.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm² and 15 cm² tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first Appendix. The 15 cm² penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm² piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u₂" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meets or exceeds those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.



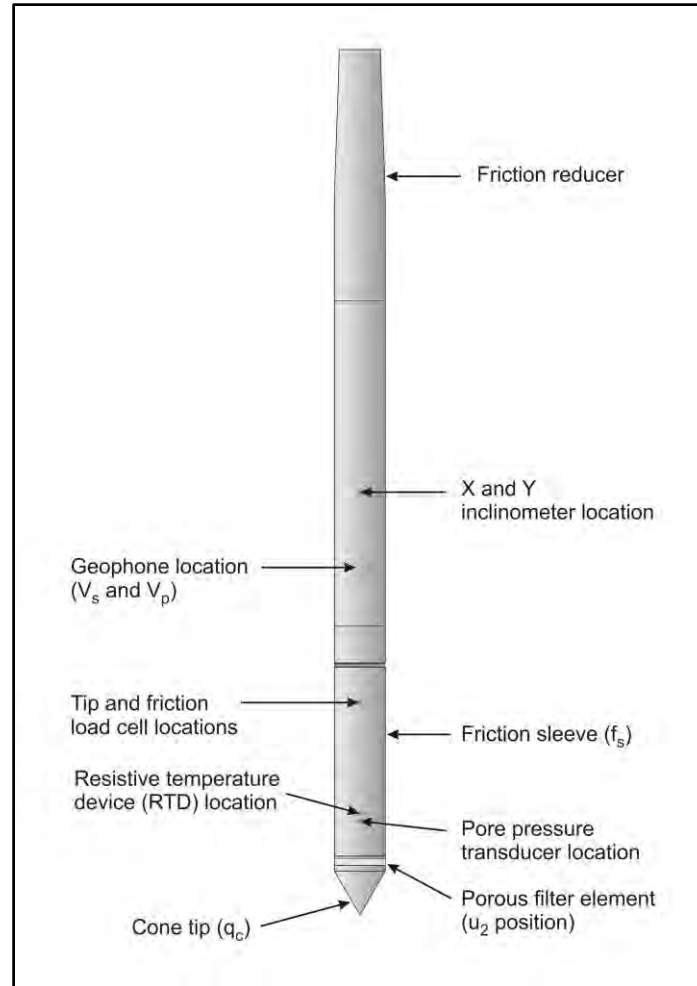


Figure CPTu. Piezocone Penetrometer (15 cm²)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording intervals are either 2.5 cm or 5.0 cm depending on project requirements; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerine or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerine under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behaviour type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

$$q_t = q_c + (1-a) \cdot u_2$$

where: q_t is the corrected tip resistance

q_c is the recorded tip resistance

u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)

a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (R_f) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high



friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of interpretation files were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the interpretation methods used is also included in the data release folder.

For additional information on CPTu interpretations, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

Shear wave velocity testing is performed in conjunction with the piezocone penetration test (SCPTu) in order to collect interval velocities. For some projects seismic compression wave (V_p) velocity is also determined.

ConeTec's piezocone penetrometers are manufactured with a horizontally active geophone (28 hertz) that is rigidly mounted in the body of the cone penetrometer, 0.2 meters behind the cone tip.

Shear waves are typically generated by using an impact hammer horizontally striking a beam that is held in place by a normal load. In some instances an auger source or an imbedded impulsive source maybe used for both shear waves and compression waves. The hammer and beam act as a contact trigger that triggers the recording of the seismic wave traces. For impulsive devices an accelerometer trigger may be used. The traces are recorded using an up-hole integrated digital oscilloscope which is part of the SCPTu data acquisition system. An illustration of the shear wave testing configuration is presented in Figure SCPTu-1.

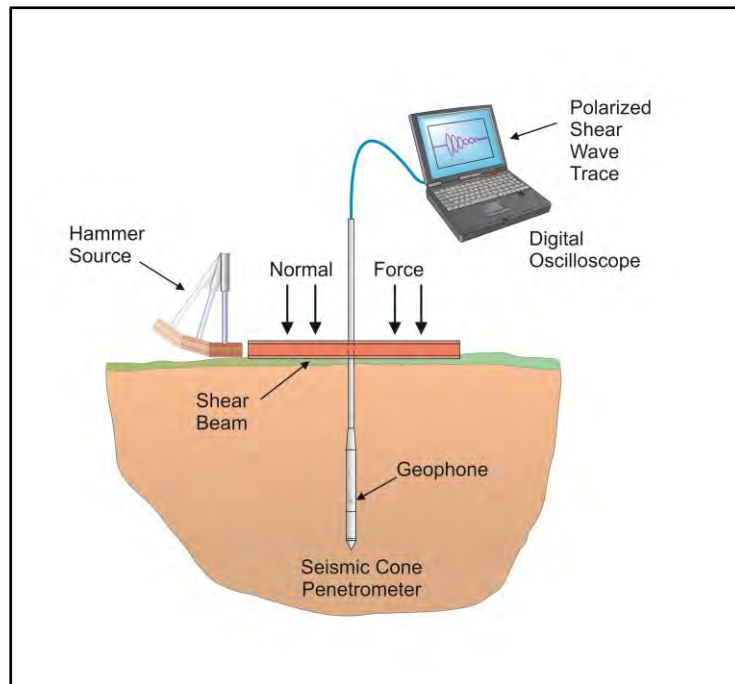


Figure SCPTu-1. Illustration of the SCPTu system

All testing is performed in accordance to ConeTec's SCPTu operating procedures.

Prior to the start of a SCPTu sounding, the procedures described in the Cone Penetration Test section are followed. In addition, the active axis of the geophone is aligned parallel to the beam (or source) and the horizontal offset between the cone and the source is measured and recorded.

Prior to recording seismic waves at each test depth, cone penetration is stopped and the rods are decoupled from the rig to avoid transmission of rig energy down the rods. Multiple wave traces are recorded for quality control purposes. After reviewing wave traces for consistency the cone is pushed to the next test depth (typically one meter intervals or as requested by the client). Figure SCPTu-2 presents an illustration of a SCPTu test.

For additional information on seismic cone penetration testing refer to Robertson et.al. (1986).

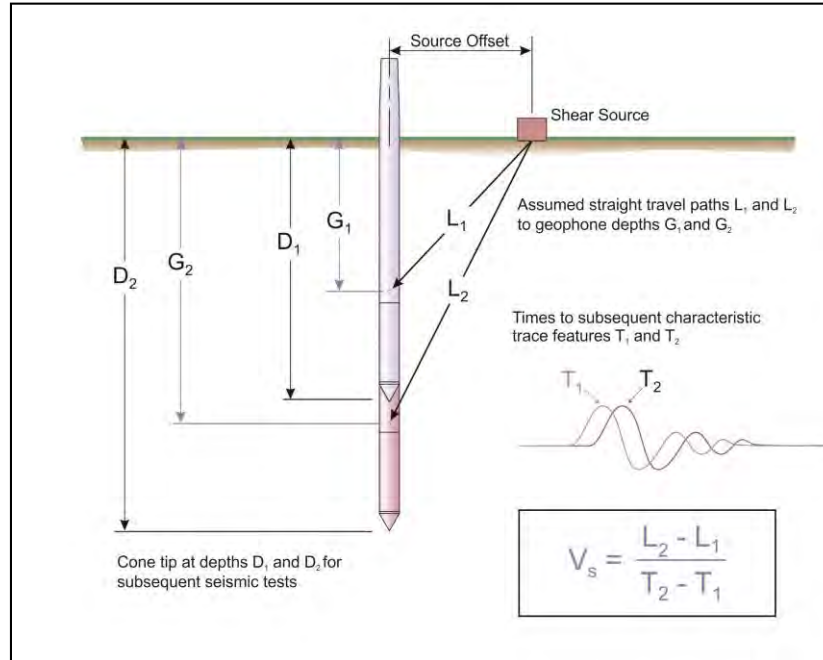


Figure SCPTu-2. Illustration of a seismic cone penetration test

Calculation of the interval velocities are performed by visually picking a common feature (e.g. the first characteristic peak, trough, or crossover) on all of the recorded wave sets and taking the difference in ray path divided by the time difference between subsequent features. Ray path is defined as the straight line distance from the seismic source to the geophone, accounting for beam offset, source depth and geophone offset from the cone tip.

The average shear wave velocity to a depth of 30 meters (V_{s30}) has been calculated and provided for all applicable soundings using an equation presented in Crow et al., 2012.

$$V_{s30} = \frac{\text{total thickness of all layers (30m)}}{\sum(\text{layer traveltimes})}$$

The layer travel times refers to the travel times propagating in the vertical direction, not the measured travel times from an offset source.

Tabular results and SCPTu plots are presented in the relevant appendix.

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

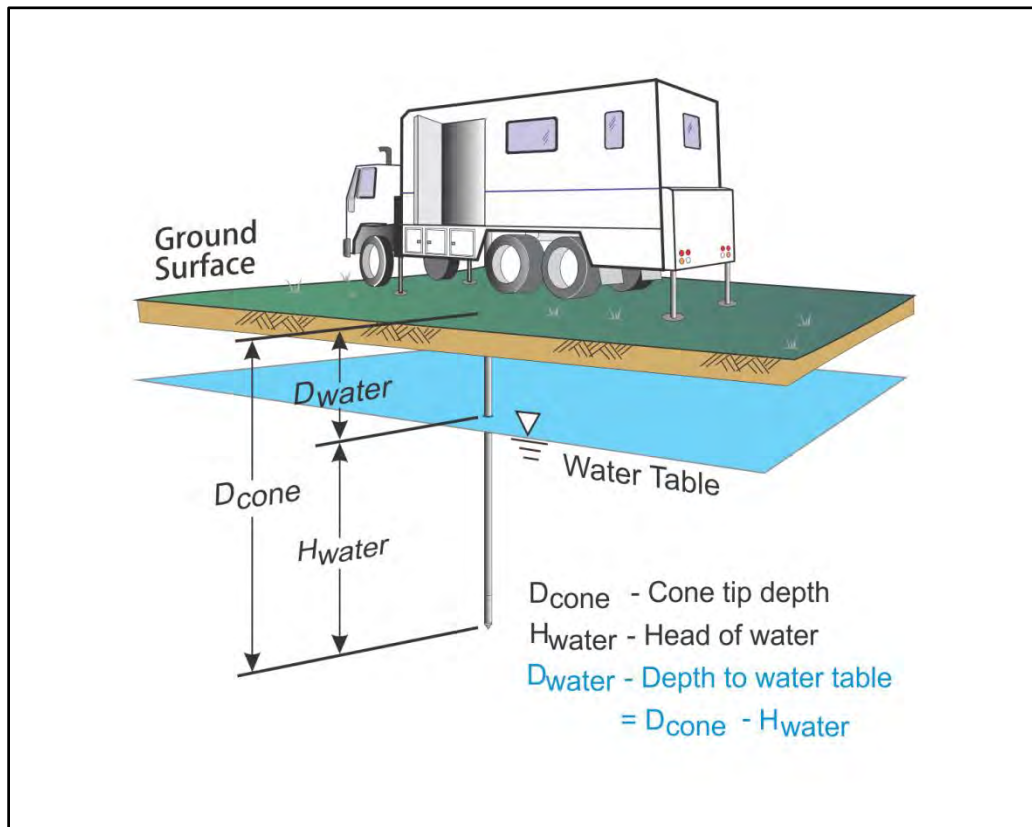


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behaviour.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

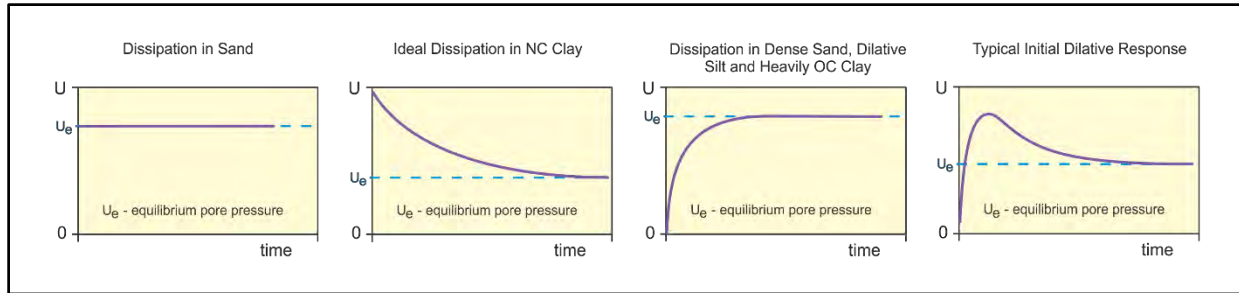


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve of Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100} . In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100} . A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T^*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

- T^* is the dimensionless time factor (Table Time Factor)
- a is the radius of the cone
- I_r is the rigidity index
- t is the time at the degree of consolidation

Table Time Factor. T^* versus degree of dissipation (Teh and Houlsby, 1991)

Degree of Dissipation (%)	20	30	40	50	60	70	80
$T^* (u_2)$	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50} , dissipation tests must be taken to a pressure less than u_{50} . The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100} . To estimate u_{50} , both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby, 1991), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50} . In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r , the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50} , other methods should be applied to confirm the results for c_h .

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

REFERENCES

- ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM, West Conshohocken, US.
- Burns, S.E. and Mayne, P.W., 1998, "Monotonic and dilatatory pore pressure decay during piezocone tests", *Canadian Geotechnical Journal* 26 (4): 1063-1073.
- Burns, S.E. and Mayne, P.W., 2002, "Analytical cavity expansion-critical state model cone dissipation in fine-grained soils", *Soils & Foundations*, Vol. 42(2): 131-137.
- Crow, H.L., Hunter, J.A., Bobrowsky, P.T., 2012, "National shear wave measurement guidelines for Canadian seismic site assessment", *GeoManitoba 2012*, Sept 30 to Oct 2, Winnipeg, Manitoba.
- Jones, G.A. and Van Zyl, D.J.A., 1981, "The piezometer probe: a useful investigation tool", *Proceedings, 10th International Conference on Soil Mechanics and Foundation Engineering*, Vol. 3, Stockholm: 489-495.
- Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, "Cone Penetration Testing in Geotechnical Practice", Blackie Academic and Professional.
- Mayne, P.W., 2013, "Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests", *Sound Geotechnical Research to Practice (Holtz Volume) GSP 230*, ASCE, Reston/VA: 406-420.
- Mayne, P.W., 2014, "Interpretation of geotechnical parameters from seismic piezocone tests", *CPT'14 Keynote Address*, Las Vegas, NV, May 2014.
- Mayne, P.W. and Peuchen, J., 2012, "Unit weight trends with cone resistance in soft to firm clays", *Geotechnical and Geophysical Site Characterization 4*, Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.
- Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", *Canadian Geotechnical Journal*, Volume 27: 151-158.
- Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", *Canadian Geotechnical Journal*, Volume 46: 1337-1355.
- Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", *Proceedings of InSitu 86*, ASCE Specialty Conference, Blacksburg, Virginia.
- Robertson, P.K., Campanella, R.G., Gillespie D and Rice, A., 1986, "Seismic CPT to Measure In-Situ Shear Wave Velocity", *Journal of Geotechnical Engineering ASCE*, Vol. 112, No. 8: 791-803.
- Robertson, P.K., Sully, J.P., Woeller, D.J., Lunne, T., Powell, J.J.M. and Gillespie, D.G., 1992, "Estimating coefficient of consolidation from piezocone tests", *Canadian Geotechnical Journal*, 29(4): 551-557.
- Sully, J.P., Robertson, P.K., Campanella, R.G. and Woeller, D.J., 1999, "An approach to evaluation of field CPTU dissipation data in overconsolidated fine-grained soils", *Canadian Geotechnical Journal*, 36(2): 369-381.

REFERENCES

Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", *Geotechnique*, 41(1): 17-34.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots with I_c , $S_u(N_{kt})$, OCR and $N1(60)I_c$
- Seismic Cone Penetration Test Tabular Results
- Seismic Cone Penetration Test Plots
- Seismic Cone Penetration Test Time Domain Traces
- Soil Behaviour Type (SBT) Scatter Plots
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

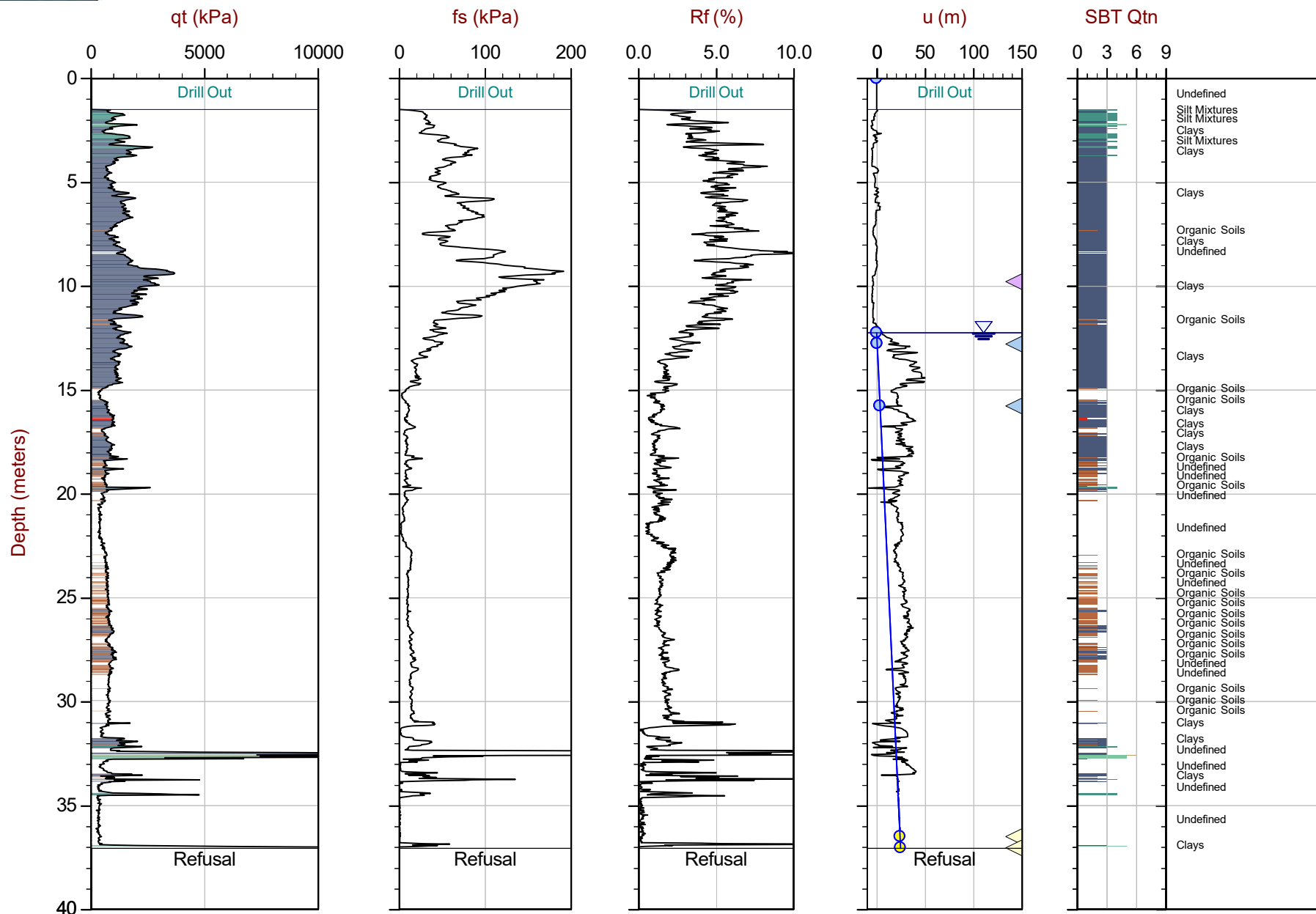


Job No: 18-05043
Client: Thurber Engineering Ltd.
Project: QEW at Welland River Bridge
Start Date: 13-Jul-2018
End Date: 13-Jul-2018

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface ¹ (m)	Final Depth (m)	Northing ² (m)	Easting (m)	Refer to Notation Number
SCPT18-01	18-05043_SP01	13-Jul-2018	545:T1500F15U500	12.2	37.075	4767443	652987	
SCPT18-02	18-05043_SP02	13-Jul-2018	545:T1500F15U500	6.9	23.675	4767761	652985	






1. The assumed phreatic surface was based on pore pressure dissipation tests. Hydrostatic conditions were assumed for the calculated parameters.
2. Coordinates were collected with a consumer grade GPS device in datum WGS84/UTM Zone 17 North.



Max Depth: 37.075 m / 121.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-05043_SP01.COR
UnitWt: SBTQtn (PKR2009)

SBT: [Robertson, 2009 and 2010](#)
 Coords: [UTM 17NN:4767443mE:652987m](#)
 SheetNo: 1 of 1

 Equilibrium Pore Pressure (Ueq)
  Assumed Ueq
  Dissipation, Ueq achieved
  Dissipation, Ueq assumed
  Hydrostatic Line

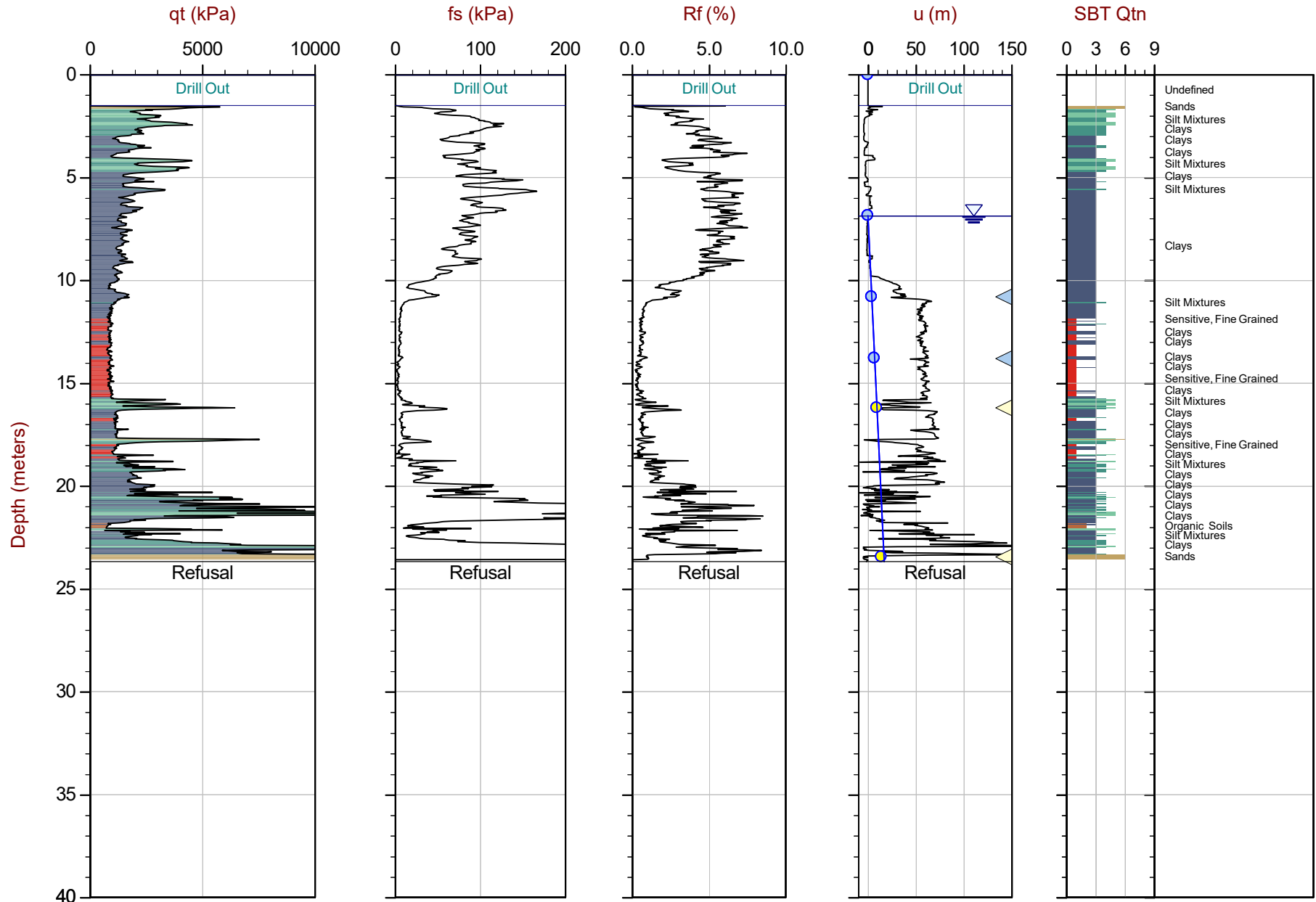
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

Job No: 18-05043
Date: 2018-07-13 23:52
Site: Niagara Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500



Max Depth: 23.675 m / 77.67 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-05043_SP02.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 17N: 4767761mE: 652985m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▲ Dissipation, Ueq assumed — Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Advanced Cone Penetration Test Plots with I_c , S_u (Nkt), OCR
and $N1(60)I_c$



Thurber Engineering

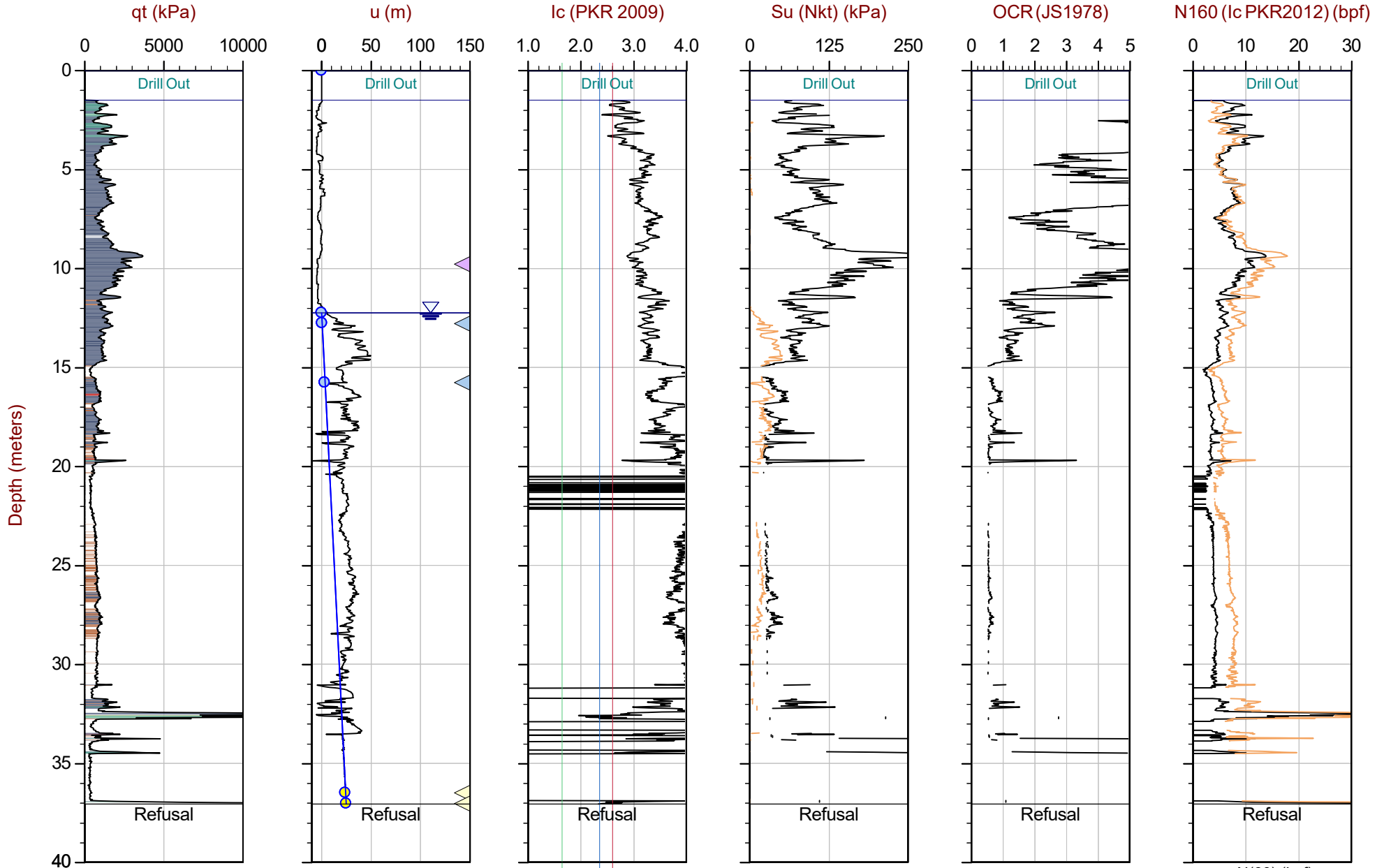
Job No: 18-05043

Date: 2018-07-13 20:02

Site: Niagara Falls, ON

Sounding: SCPT18-01

Cone: 545:T1500F15U500



Max Depth: 37.075 m / 121.64 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

File: 18-05043_SP01.COR

Unit Wt: SBTQtn (PKR2009)

Su Nkt/Ndu: 12.5 / 9.0

SBT: Robertson, 2009 and 2010

Coords: UTM 17N N: 4767443m E: 652987m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq)

● Assumed Ueq

◀ Dissipation, Ueq achieved

◀ Dissipation, Ueq assumed

— Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

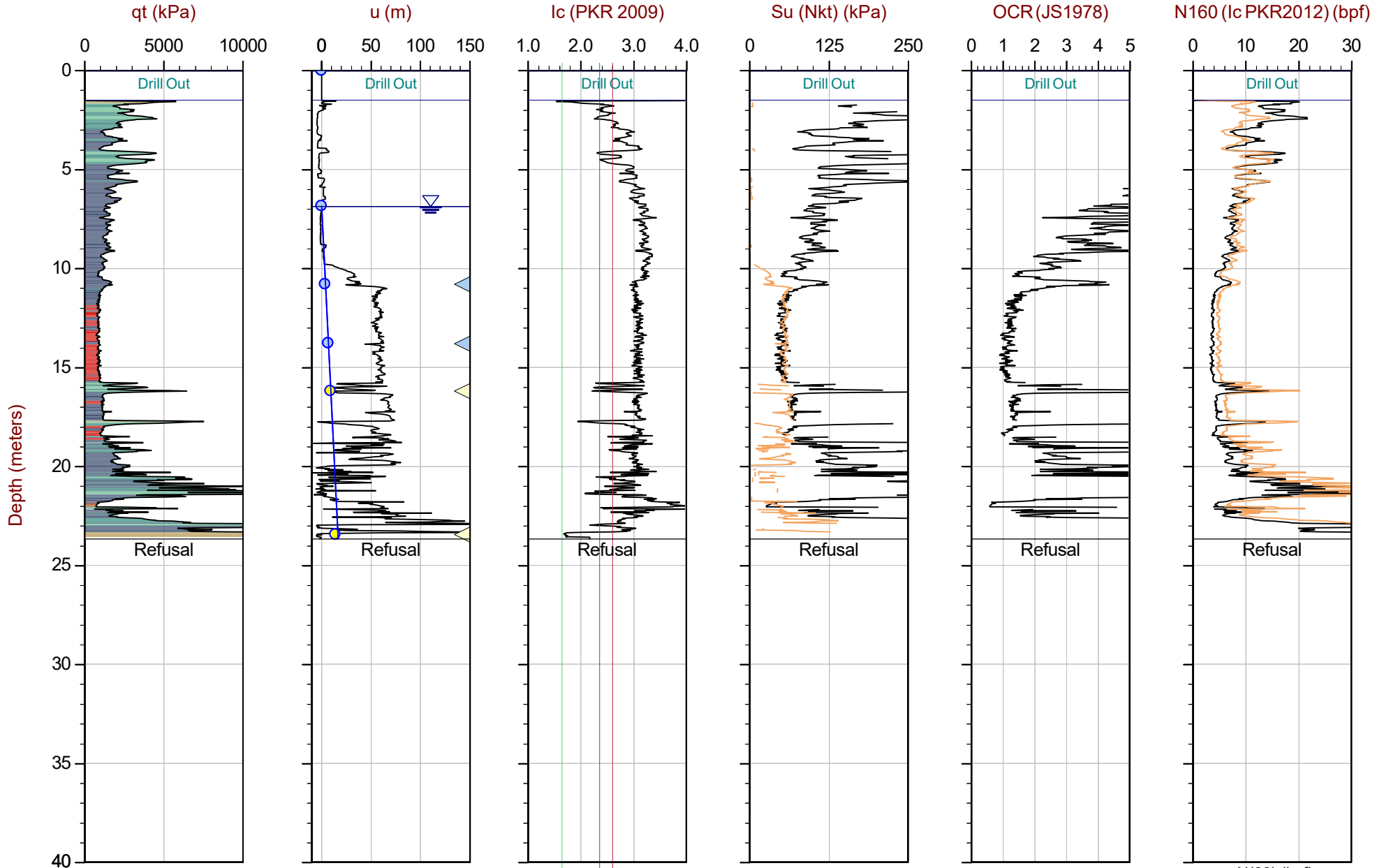
Job No: 18-05043

Date: 2018-07-13 23:52

Site: Niagra Falls, ON

Sounding: SCPT18-02

Cone: 545:T1500F15U500



Max Depth: 23.675 m / 77.67 ft

Depth Inc: 0.025 m / 0.082 ft

Avg Int: EveryPoint

File: 18-05043_SP02.COR

Unit Wt: SBTQtn (PKR2009)

Su Nkt/Ndu: 12.5 / 9.0

SBT: Robertson, 2009 and 2010

Coords: UTM 17N N: 4767761m E: 652985m

Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq)

● Assumed Ueq

◀ Dissipation, Ueq achieved

◀ Dissipation, Ueq assumed

— Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Tabular Results



Job No: 18-05043
Client: Thurber Engineering Ltd.
Project: QEW at Welland River Bridge
Sounding ID: SCPT18-01
Date: 13-Jul-2018

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.78	1.58	1.67			
2.77	2.57	2.63	0.96	6.72	142
3.77	3.57	3.61	0.98	7.16	137
4.78	4.58	4.61	1.00	6.22	161
5.78	5.58	5.61	0.99	5.96	167
6.78	6.58	6.60	1.00	6.12	163
7.78	7.58	7.60	1.00	6.42	155
8.78	8.58	8.60	1.00	5.73	174
9.78	9.58	9.60	1.00	3.51	285
10.78	10.58	10.59	1.00	4.40	227
11.78	11.58	11.59	1.00	3.62	276
12.78	12.58	12.59	1.00	3.96	252
13.78	13.58	13.59	1.00	4.71	212
14.78	14.58	14.59	1.00	5.33	187
15.78	15.58	15.59	1.00	5.71	175
16.77	16.57	16.58	0.99	5.80	171
17.77	17.57	17.58	1.00	4.99	200
18.77	18.57	18.58	1.00	3.71	269
19.77	19.57	19.58	1.00	3.77	265
20.77	20.57	20.58	1.00	5.52	181
21.77	21.57	21.58	1.00	4.64	216
22.77	22.57	22.58	1.00	4.04	247
23.77	23.57	23.58	1.00	4.74	211
24.77	24.57	24.58	1.00	4.94	202
25.77	25.57	25.58	1.00	4.29	233
26.77	26.57	26.58	1.00	4.04	248
27.77	27.57	27.58	1.00	4.70	213
28.77	28.57	28.58	1.00	3.85	260
29.77	29.57	29.58	1.00	4.93	203



Job No: 18-05043
Client: Thurber Engineering Ltd.
Project: QEW at Welland River Bridge
Sounding ID: SCPT18-01
Date: 13-Jul-2018

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
30.77	30.57	30.57	1.00	3.15	317
31.77	31.57	31.57	1.00	1.76	570



Job No: 18-05043
Client: Thurber Engineering Ltd.
Project: QEW at Welland River Bridge
Sounding ID: SCPT18-02
Date: 13-Jul-2018

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
1.80	1.60	1.69			
2.80	2.60	2.66	0.97	6.69	144
3.80	3.60	3.64	0.98	6.80	145
4.80	4.60	4.63	0.99	6.03	164
5.80	5.60	5.63	0.99	5.47	182
6.80	6.60	6.62	1.00	5.38	185
7.80	7.60	7.62	1.00	5.86	170
8.80	8.60	8.62	1.00	6.05	165
9.80	9.60	9.62	1.00	6.07	164
10.80	10.60	10.61	1.00	6.27	159
11.80	11.60	11.61	1.00	5.94	168
12.80	12.60	12.61	1.00	5.16	193
13.80	13.60	13.61	1.00	4.60	217
14.80	14.60	14.61	1.00	5.27	190
15.80	15.60	15.61	1.00	4.66	214
16.80	16.60	16.61	1.00	4.22	237
17.80	17.60	17.61	1.00	4.38	228
18.80	18.60	18.61	1.00	3.42	292
19.80	19.60	19.61	1.00	2.46	406
20.80	20.60	20.61	1.00	2.41	415
21.77	21.57	21.58	0.97	1.84	526
22.80	22.60	22.61	1.03	2.05	502
23.68	23.48	23.49	0.88	1.26	699

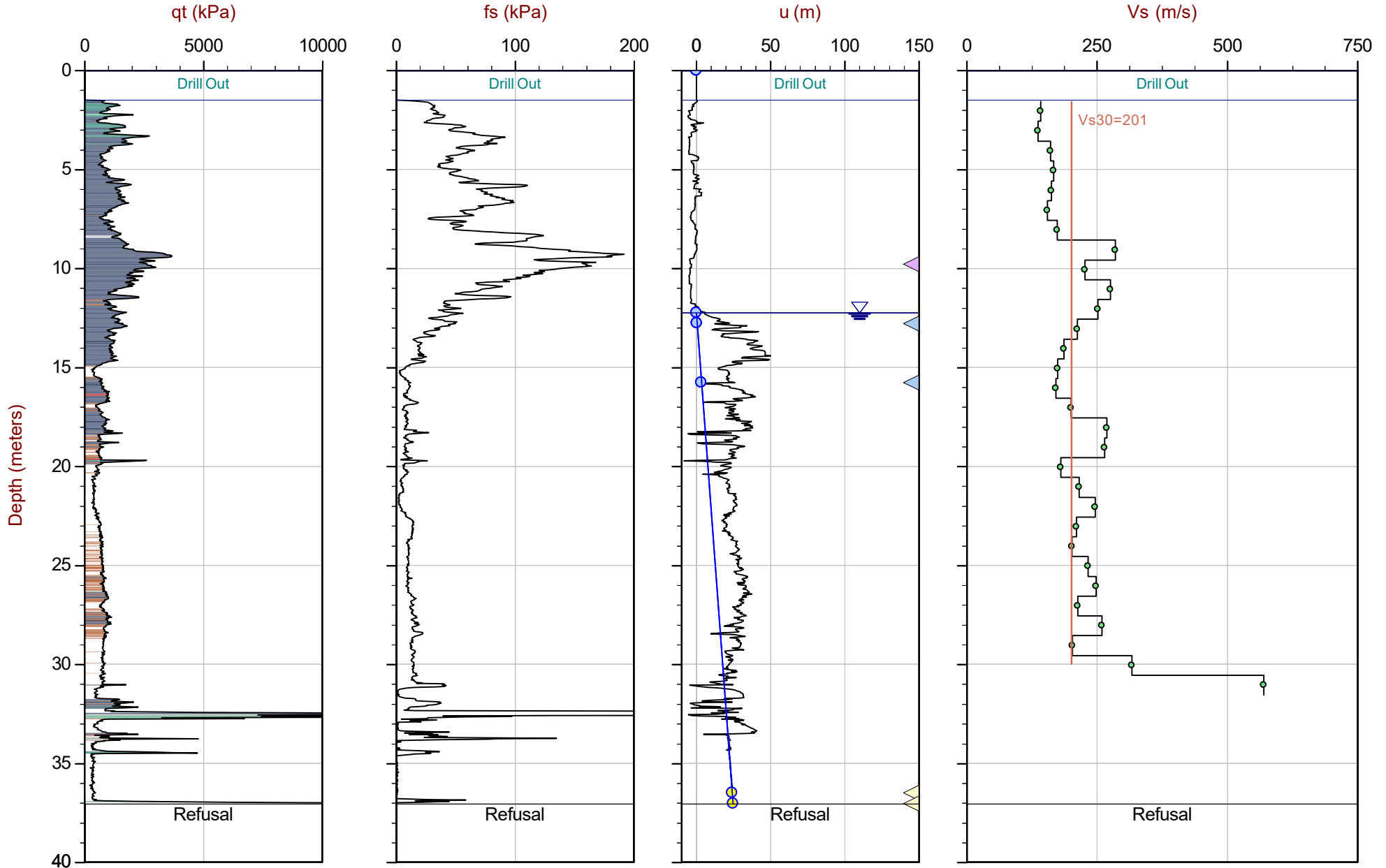
Seismic Cone Penetration Test Plots



Thurber Engineering

Job No: 18-05043
Date: 2018-07-13 20:02
Site: Niagara Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500



Max Depth: 37.075 m / 121.64 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 18-05043_SP01.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 17N N: 4767443m E: 652987m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▲ Dissipation, Ueq assumed — Hydrostatic Line

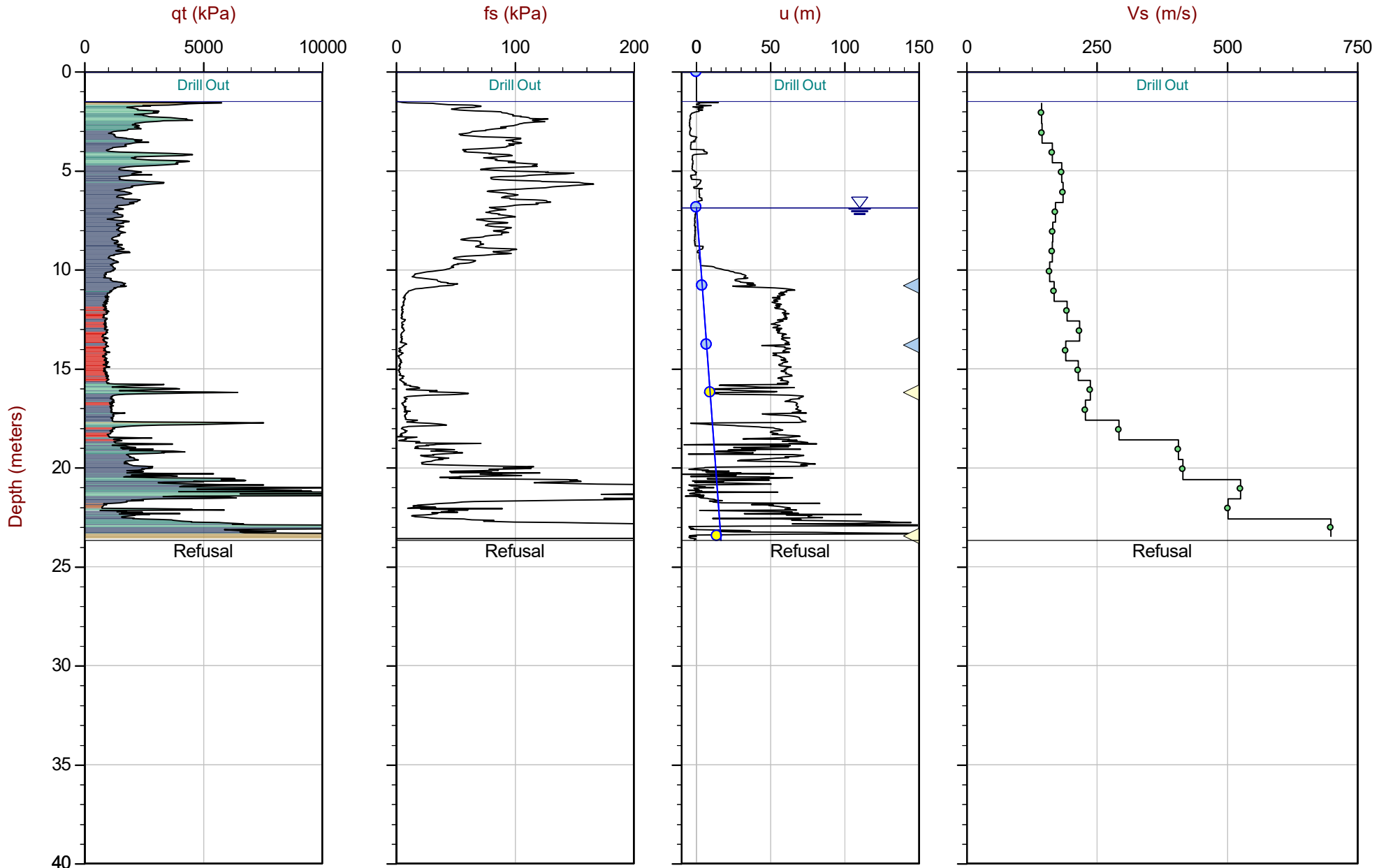
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.



Thurber Engineering

Job No: 18-05043
Date: 2018-07-13 23:52
Site: Niagara Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500



Max Depth: 23.675 m / 77.67 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: EveryPoint

File: 18-05043_SP02.COR
Unit Wt: SBTQtn(PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 17N N: 4767761m E: 652985m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ▲ Dissipation, Ueq achieved ▲ Dissipation, Ueq assumed — Hydrostatic Line
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Seismic Cone Penetration Test Time Domain Traces





Job No: 18-05043

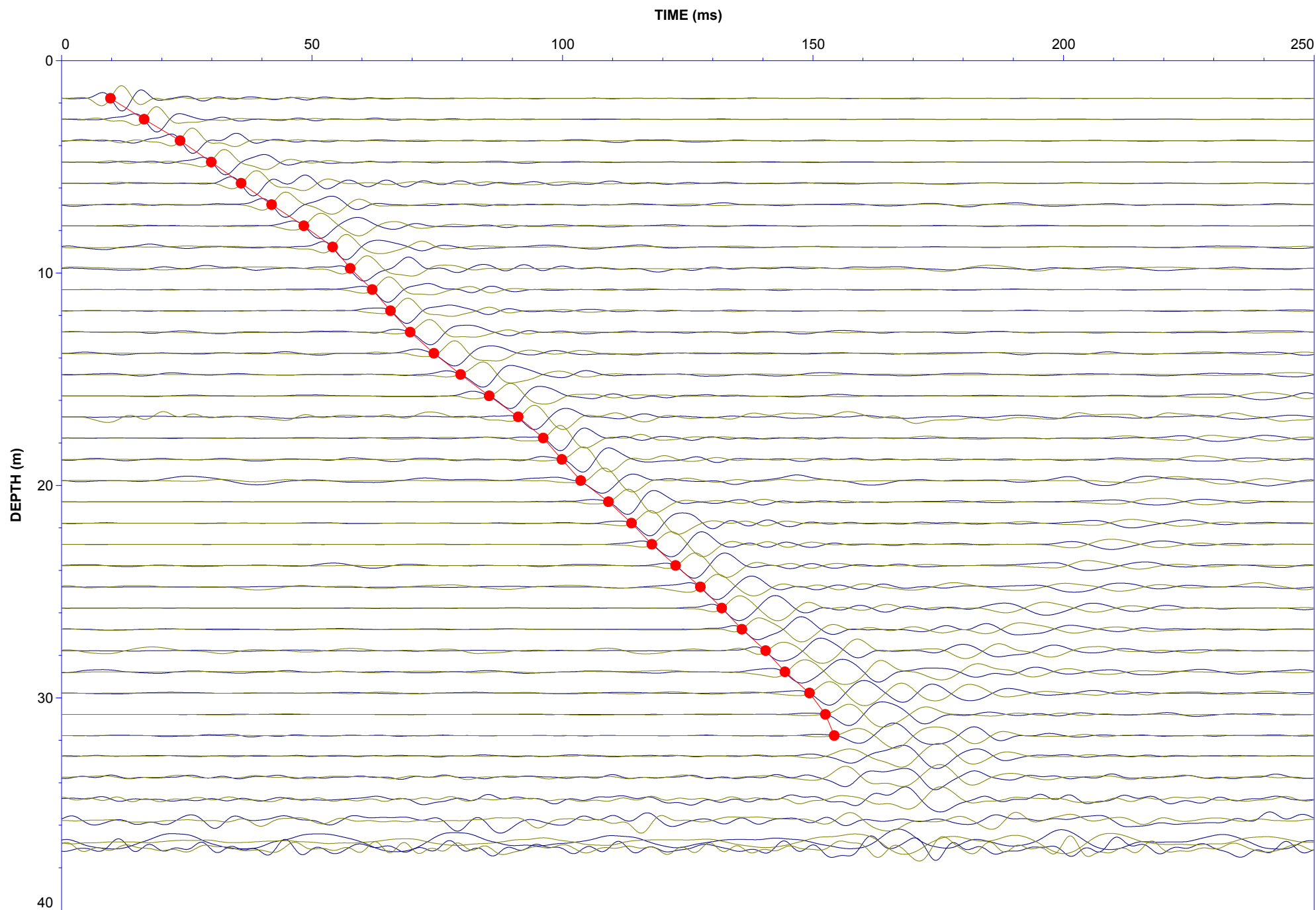
Client: Thurber Engineering Ltd.

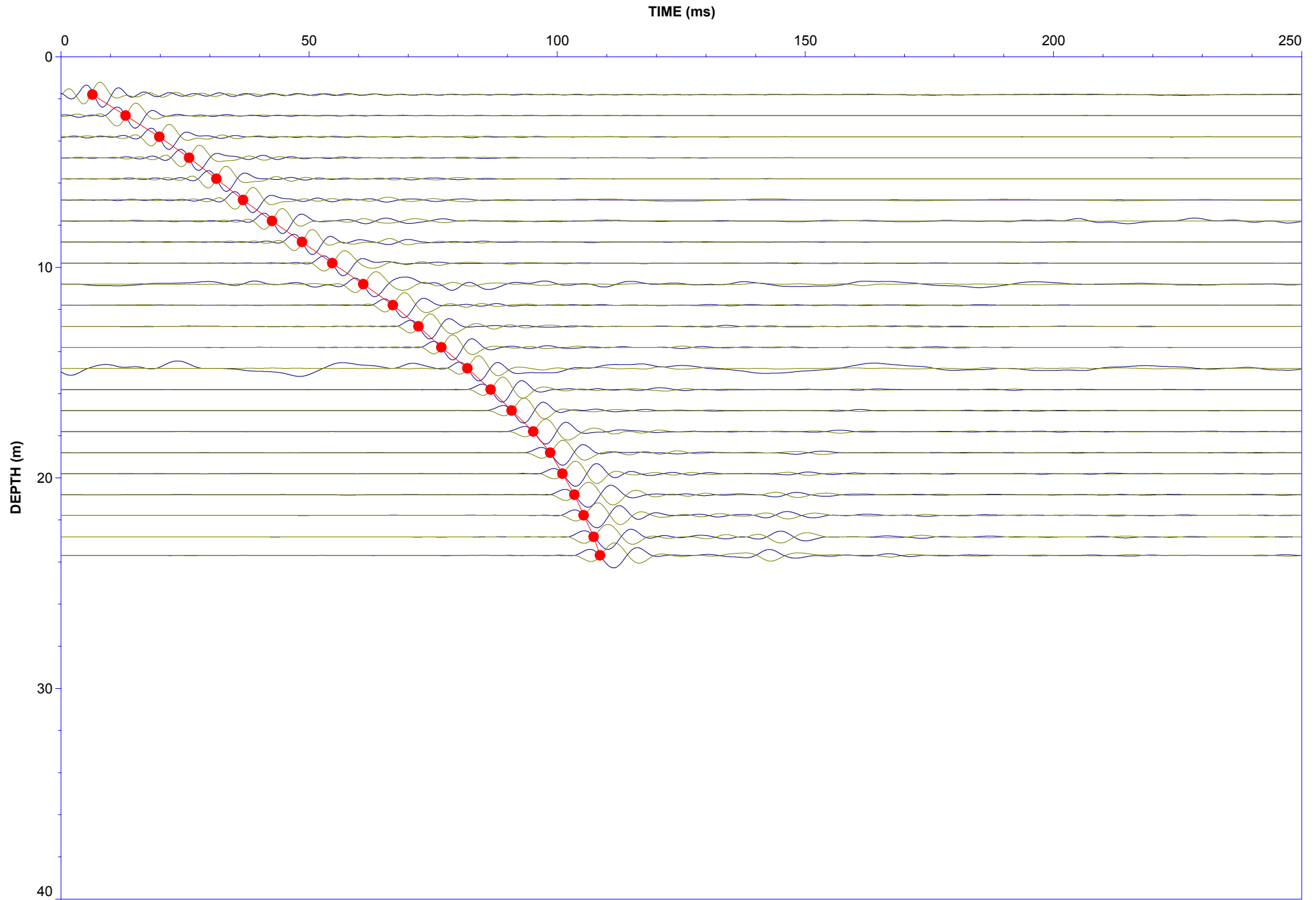
Project Title: QEW at Welland River Bridge

Filter: 0-200 Hz

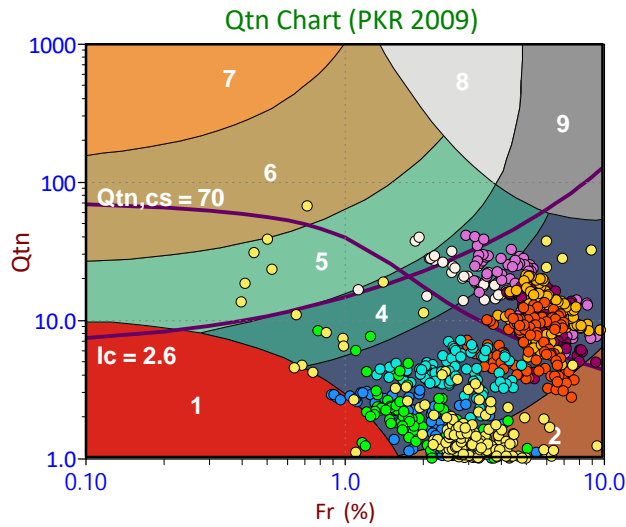
Souding: SCPT18-01

Date: 13-Jul-2018





Soil Behaviour Type (SBT) Scatter Plots

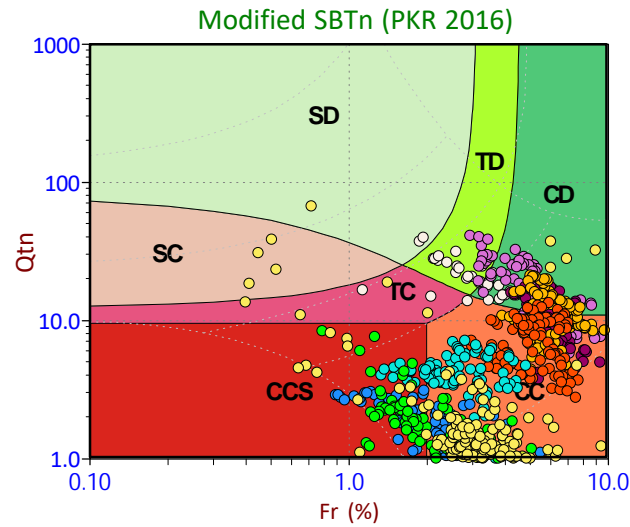


Depth Ranges

- >0.0 to 2.5 m
- >2.5 to 5.0 m
- >5.0 to 7.5 m
- >7.5 to 10.0 m
- >10.0 to 12.5 m
- >12.5 to 15.0 m
- >15.0 to 17.5 m
- >17.5 to 20.0 m
- >20.0 to 22.5 m
- >22.5 to 25.0 m
- >25.0 m

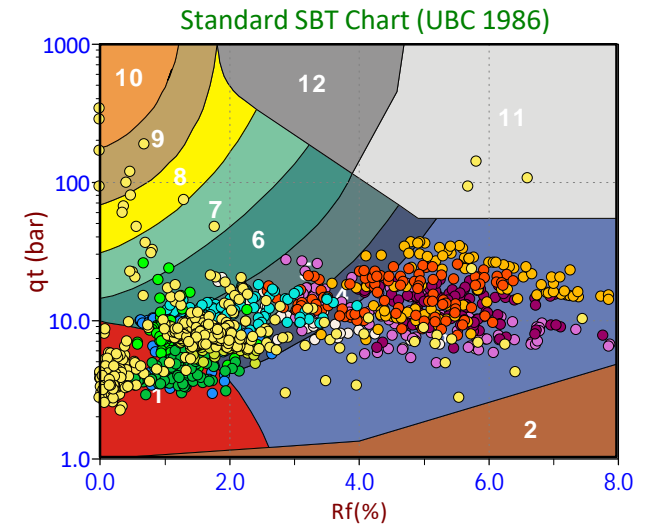
Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained



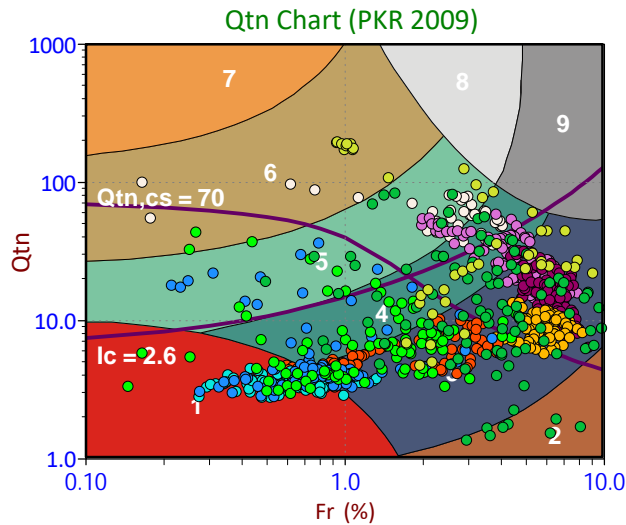
Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)



Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

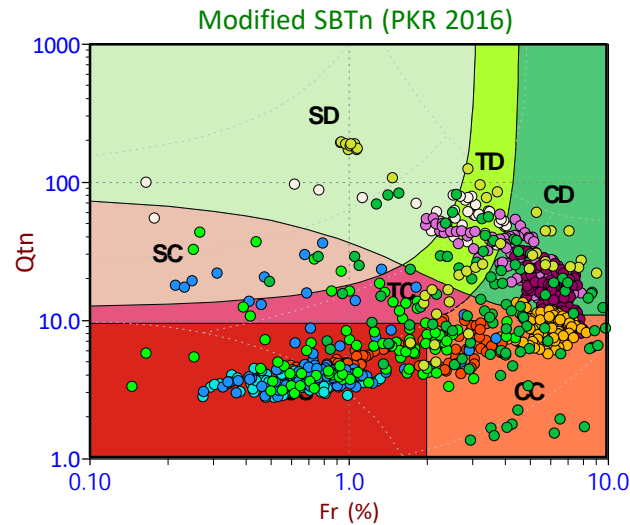


Depth Ranges

- >0.0 to 2.5 m
- >2.5 to 5.0 m
- >5.0 to 7.5 m
- >7.5 to 10.0 m
- >10.0 to 12.5 m
- >12.5 to 15.0 m
- >15.0 to 17.5 m
- >17.5 to 20.0 m
- >20.0 to 22.5 m
- >22.5 to 25.0 m
- >25.0 m

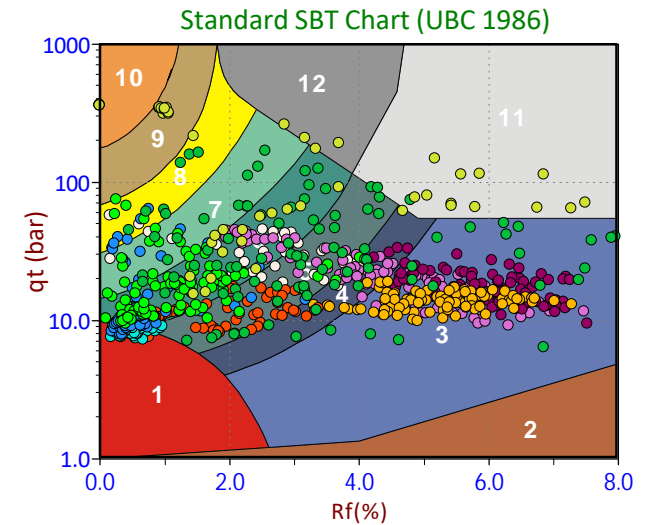
Legend

- Sensitive, Fine Grained
- Organic Soils
- Clays
- Silt Mixtures
- Sand Mixtures
- Sands
- Gravelly Sand to Sand
- Stiff Sand to Clayey Sand
- Very Stiff Fine Grained



Legend

- CCS (Cont. sensitive clay like)
- CC (Cont. clay like)
- TC (Cont. transitional)
- SC (Cont. sand like)
- CD (Dil. clay like)
- TD (Dil. transitional)
- SD (Dil. sand like)



Legend

- Sensitive Fines
- Organic Soil
- Clay
- Silty Clay
- Clayey Silt
- Silt
- Sandy Silt
- Silty Sand/Sand
- Sand
- Gravelly Sand
- Stiff Fine Grained
- Cemented Sand

Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots



Job No: 18-05043
 Client: Thurber Engineering Ltd.
 Project: QEW at Welland River Bridge
 Start Date: 13-Jul-2018
 End Date: 13-Jul-2018

CPT_u PORE PRESSURE DISSIPATION SUMMARY

Sounding ID	File Name	Cone Area (cm ²)	Duration (s)	Test Depth (m)	Estimated Equilibrium Pore Pressure U _{eq} (m)	Calculated Phreatic Surface (m)	Estimated Phreatic Surface (m)	t ₅₀ ^a (s)	Assumed Rigidity Index (I _r)	c _h ^b (cm ² /min)
SCPT18-01	18-05043_SP01	15	300	9.775	Not Achieved					
SCPT18-01	18-05043_SP01	15	2605	12.775	Not Achieved		12.2	2429	100	0.3
SCPT18-01	18-05043_SP01	15	750	15.775	Not Achieved		12.2	494	100	1.4
SCPT18-01	18-05043_SP01	15	300	36.500	24.3	12.2				
SCPT18-01	18-05043_SP01	15	305	37.050	24.8	12.2				
SCPT18-02	18-05043_SP02	15	800	10.800	Not Achieved		6.9	486	100	1.4
SCPT18-02	18-05043_SP02	15	2150	13.800	Not Achieved		6.9	1555	100	0.5
SCPT18-02	18-05043_SP02	15	300	16.200	9.3	6.9				
SCPT18-02	18-05043_SP02	15	300	23.450	14.1	9.4				

a. Time is relative to where u_{max} occurred

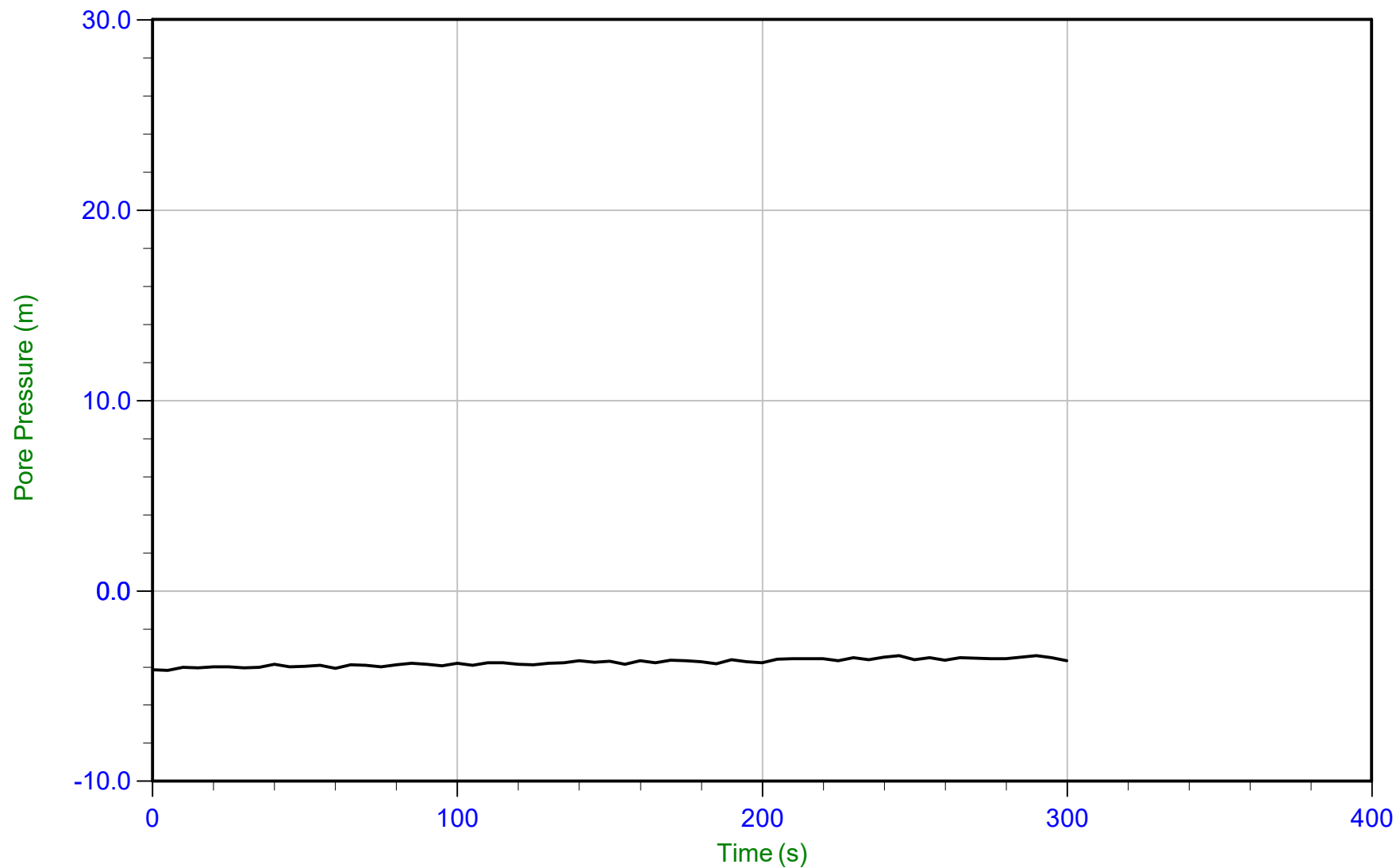
b. Houlsby and Teh, 1991



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 20:02
Site: Niagara Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500 Area=15 cm²



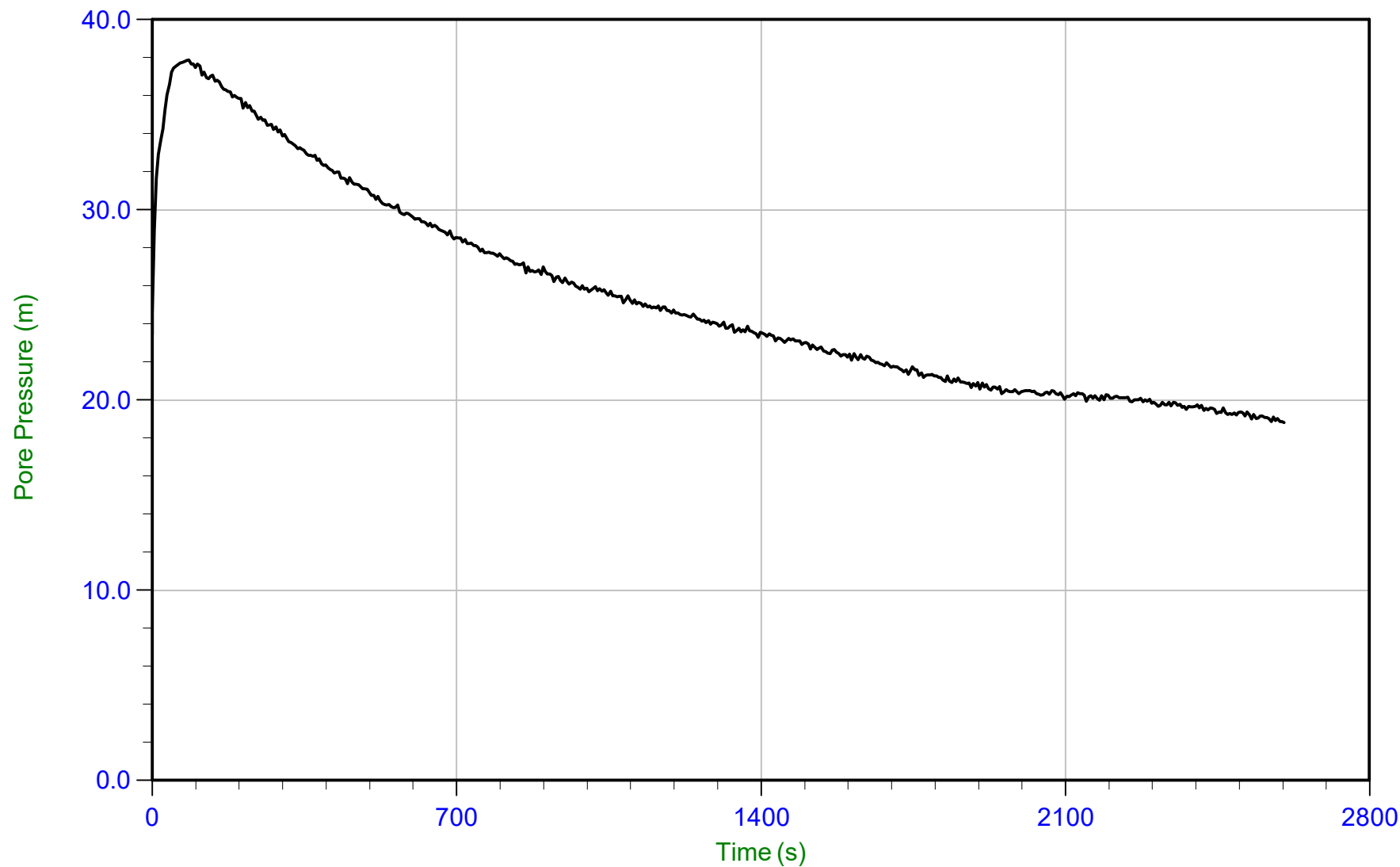
Trace Summary: Filename: 18-05043_SP01.PPF U Min: -4.2 m
 Depth: 9.775 m / 32.070 ft U Max: -3.4 m
 Duration: 300.0 s



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 20:02
Site: Niagra Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 18-05043_SP01.PPF
Depth: 12.775 m / 41.912 ft
Duration: 2605.0 s

U Min: 18.8 m
U Max: 37.9 m

WT: 12.244 m / 40.170 ft
Ueq: 0.5 m
U(50): 19.20 m

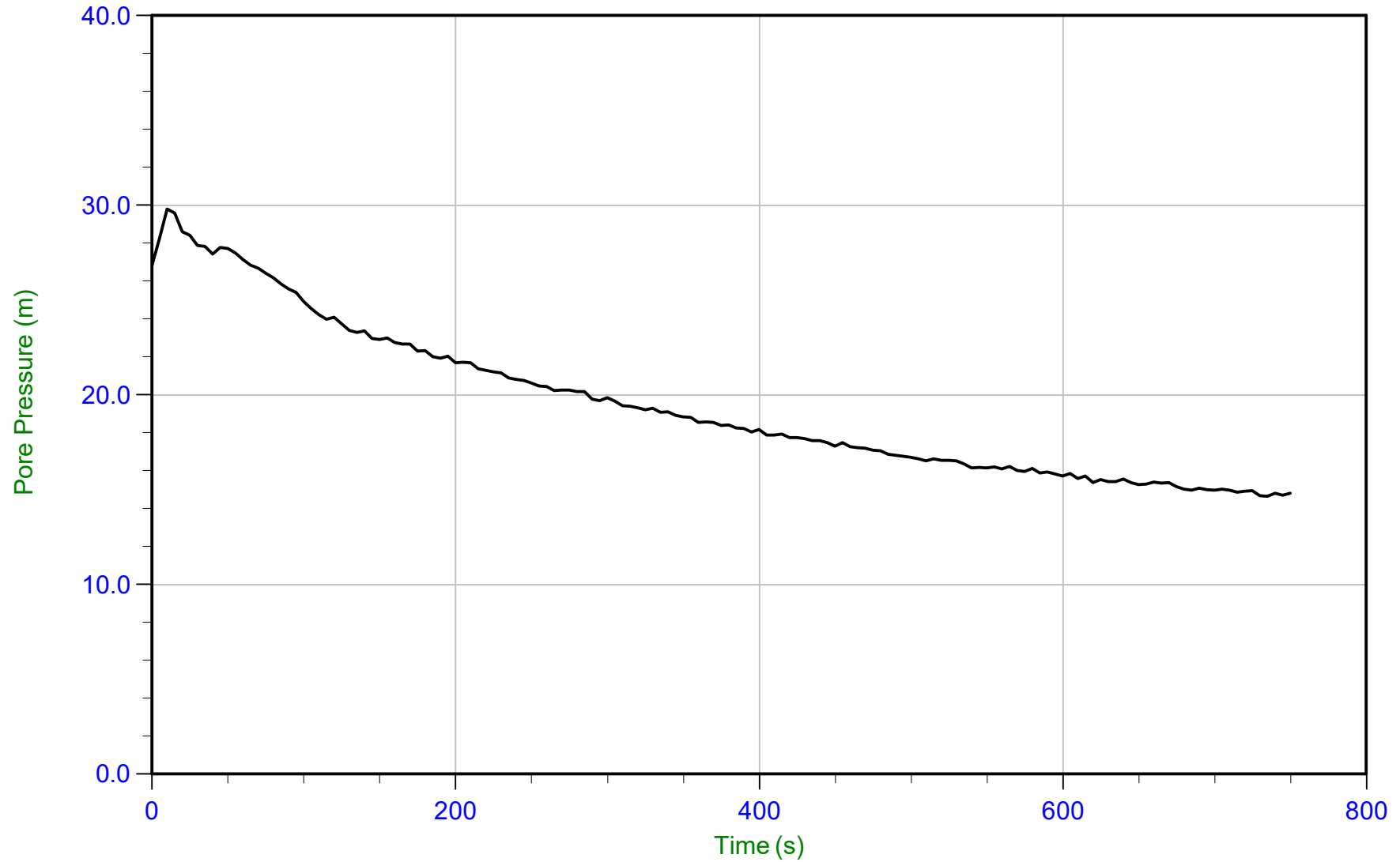
T(50): 2428.5 s
Ir: 100
Ch: 0.3 sq cm/min



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 20:02
Site: Niagra Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500 Area=15 cm²



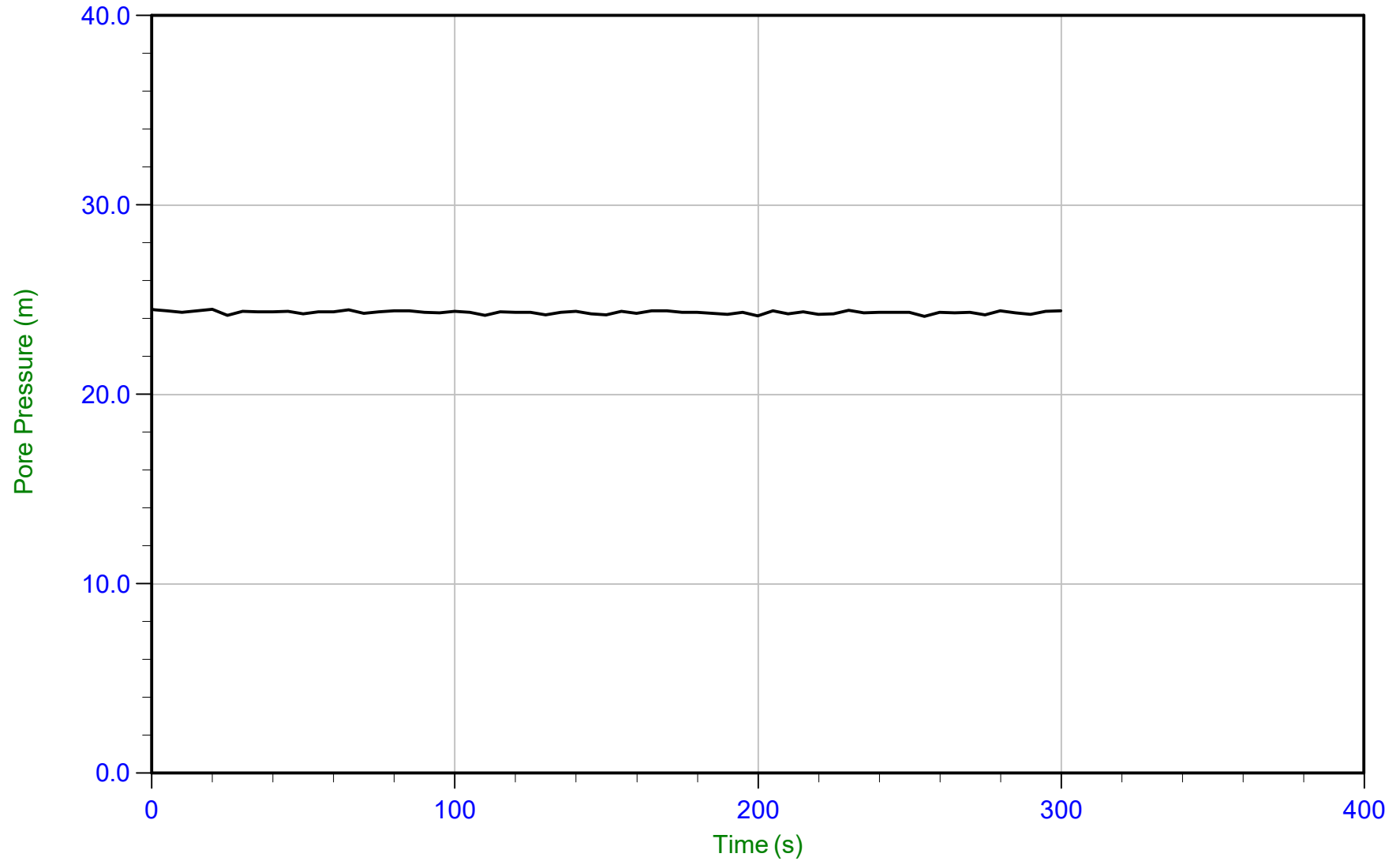
Trace Summary:	Filename: 18-05043_SP01.PPF	U Min: 14.6 m	WT: 12.244 m / 40.170 ft	T(50): 493.7 s
	Depth: 15.775 m / 51.755 ft	U Max: 29.8 m	Ueq: 3.5 m	Ir: 100
	Duration: 750.0 s		U(50): 16.66 m	Ch: 1.4 sq cm/min



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 20:02
Site: Niagra Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500 Area=15 cm²



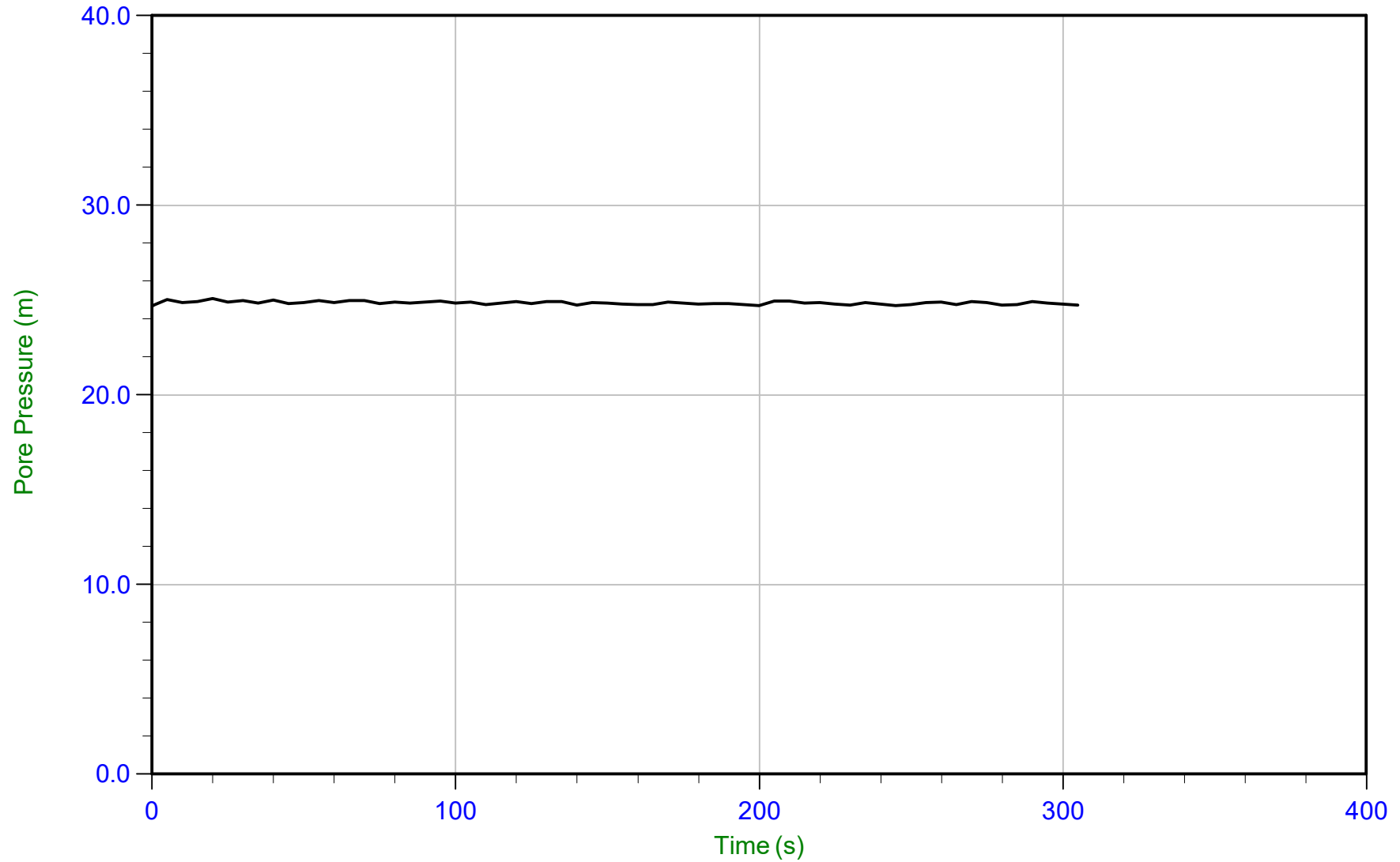
Trace Summary: Filename: 18-05043_SP01.PPF U Min: 24.1 m WT: 12.244 m / 40.170 ft
Depth: 36.500 m / 119.749 ft U Max: 24.5 m Ueq: 24.3 m
Duration: 300.0 s



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 20:02
Site: Niagra Falls, ON

Sounding: SCPT18-01
Cone: 545:T1500F15U500 Area=15 cm²



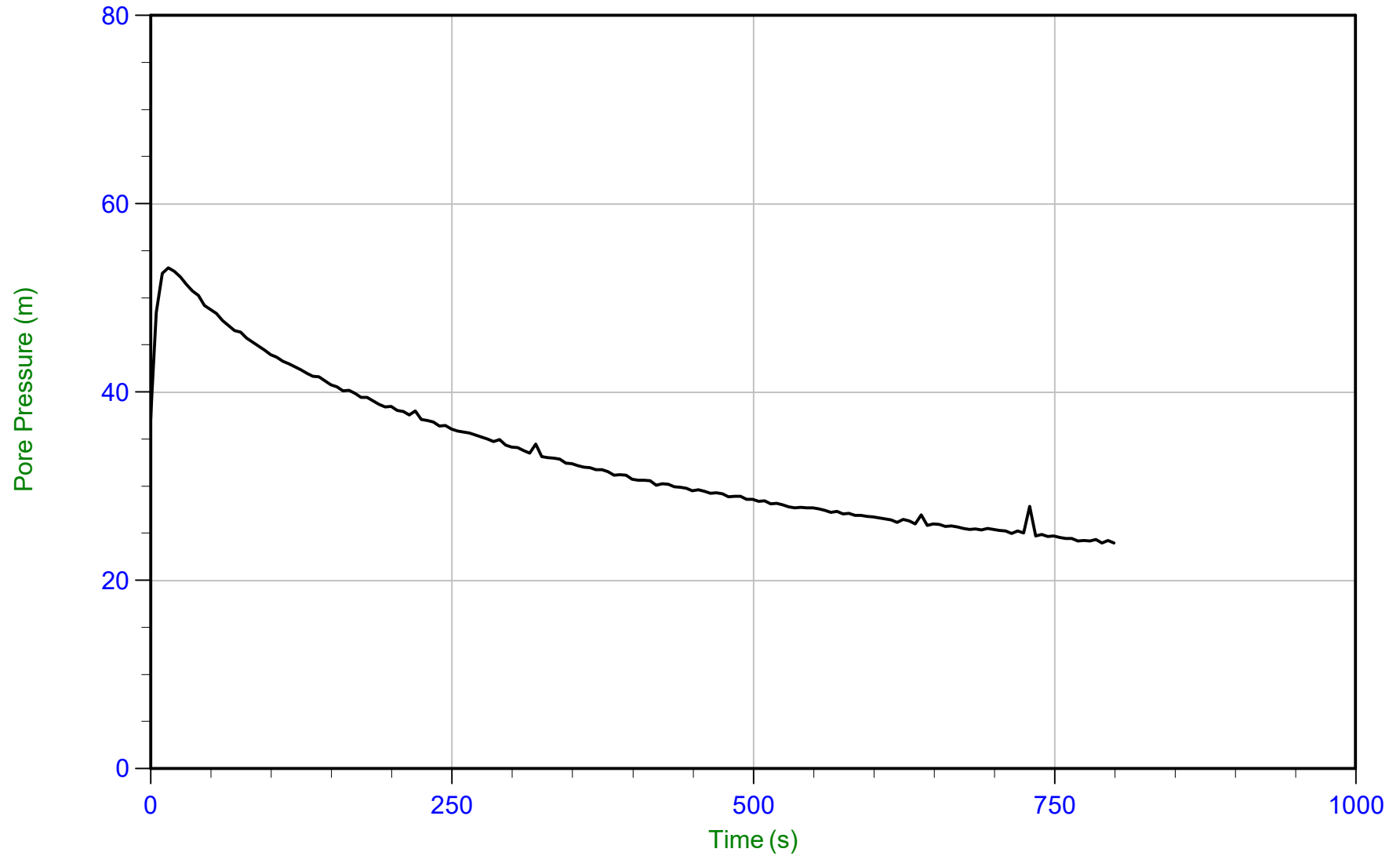
Trace Summary: Filename: 18-05043_SP01.PPF U Min: 24.7 m WT: 12.245 m / 40.173 ft
Depth: 37.050 m / 121.554 ft U Max: 25.1 m Ueq: 24.8 m
Duration: 305.0 s



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 23:52
Site: Niagra Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 18-05043_SP02.PPF
Depth: 10.800 m / 35.433 ft
Duration: 800.0 s

U Min: 24.0 m
U Max: 53.2 m

WT: 6.864 m / 22.519 ft
Ueq: 3.9 m
U(50): 28.57 m

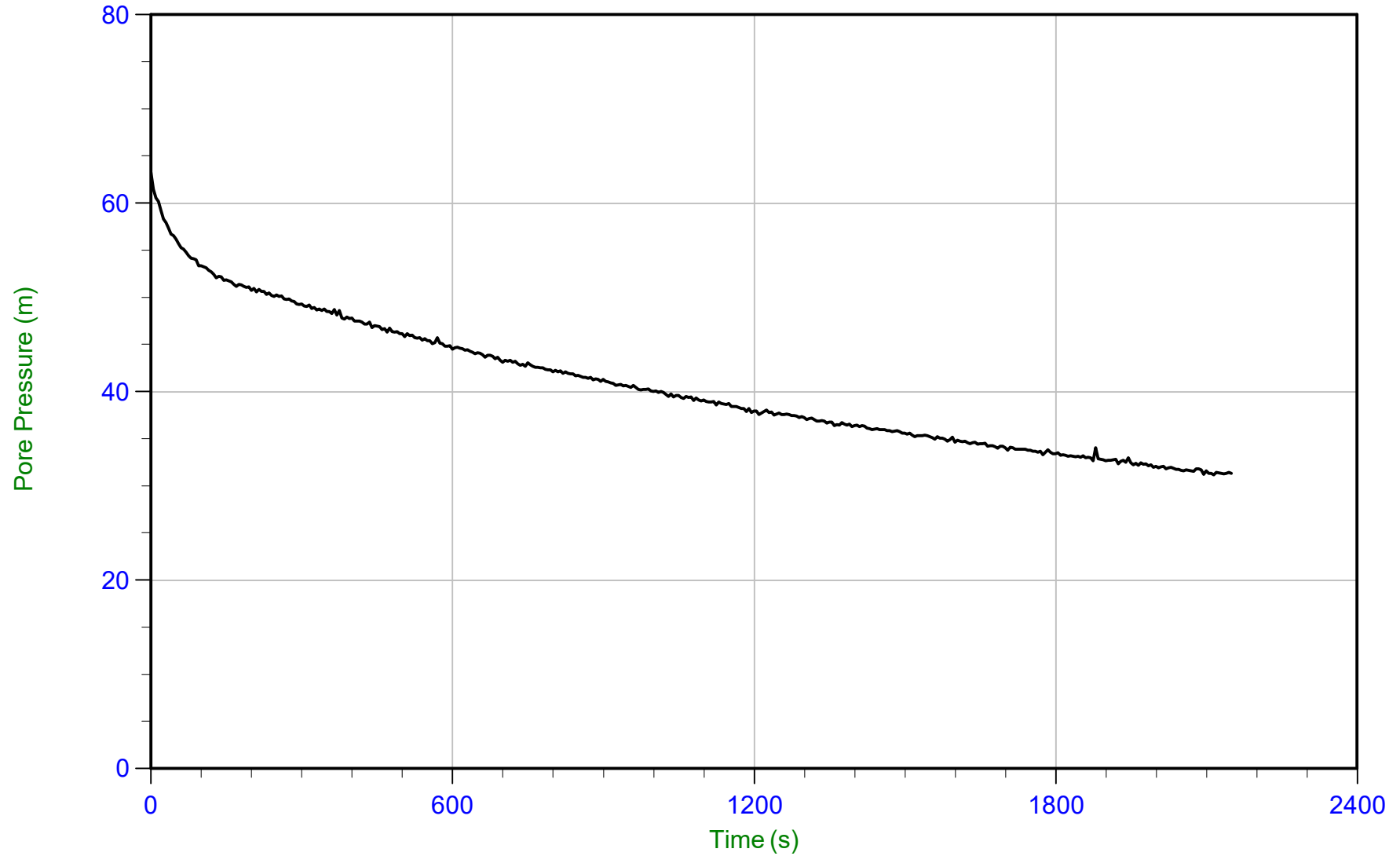
T(50): 485.9 s
Ir: 100
Ch: 1.4 sq cm/min



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 23:52
Site: Niagara Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 18-05043_SP02.PPF
Depth: 13.800 m / 45.275 ft
Duration: 2150.0 s

U Min: 31.2 m
U Max: 63.3 m

WT: 6.864 m / 22.519 ft
Ueq: 6.9 m
U(50): 35.11 m

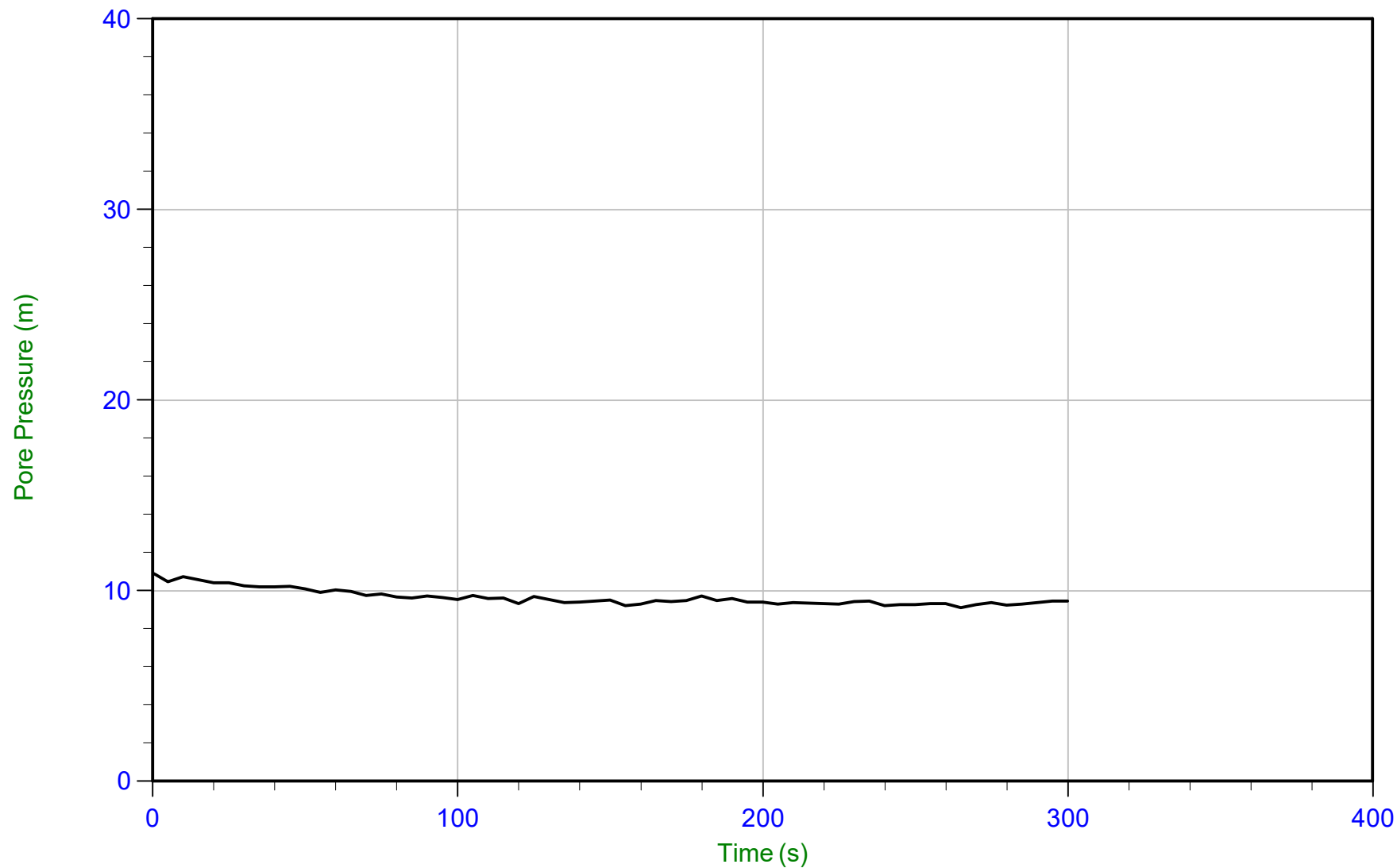
T(50): 1555.0 s
Ir: 100
Ch: 0.5 sq cm/min



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 23:52
Site: Niagara Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500 Area=15 cm²



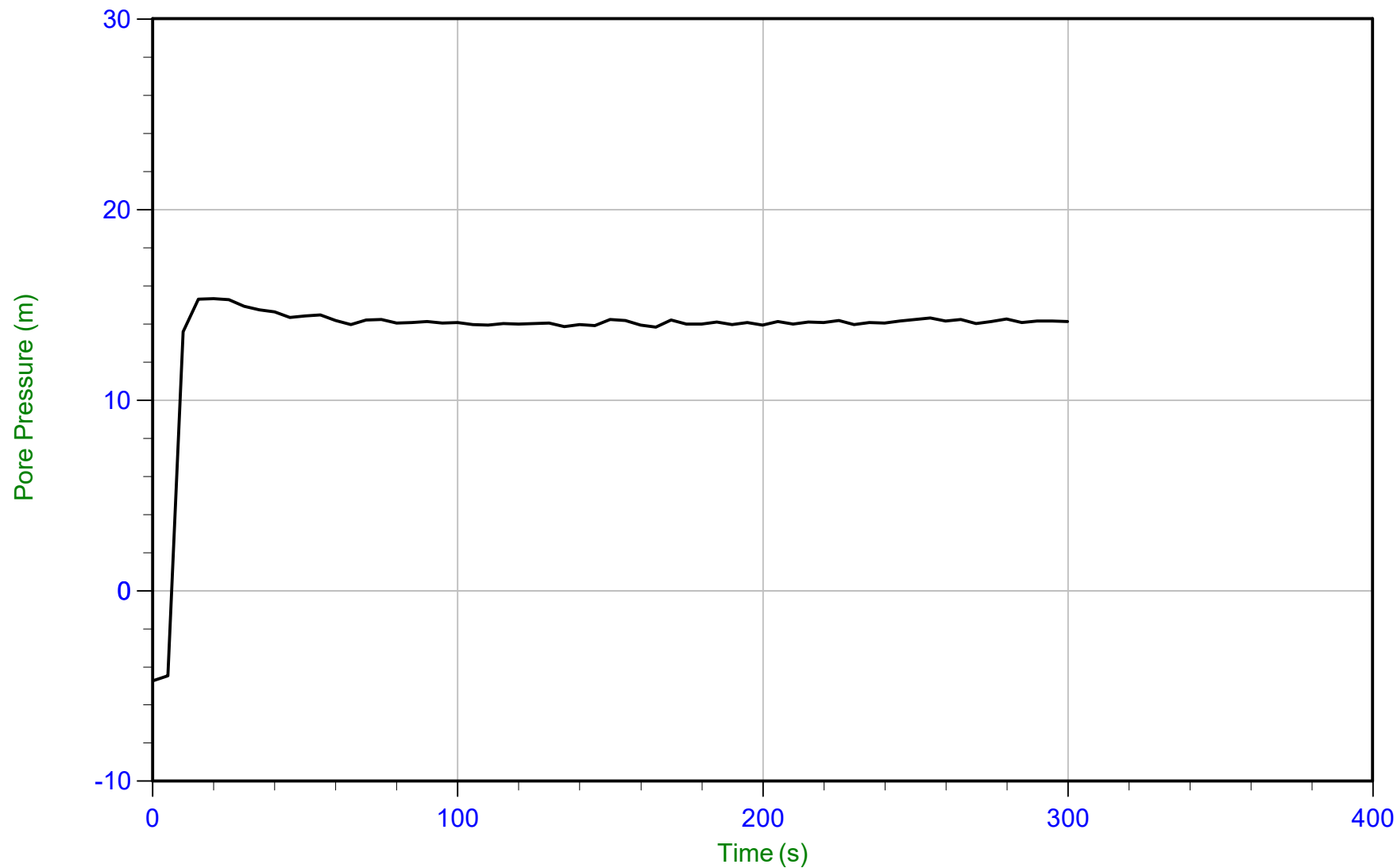
Trace Summary: Filename: 18-05043_SP02.PPF U Min: 9.1 m WT: 6.864 m / 22.519 ft
Depth: 16.200 m / 53.149 ft U Max: 10.9 m Ueq: 9.3 m
Duration: 300.0 s



Thurber Engineering

Job No: 18-05043
Date: 07/13/2018 23:52
Site: Niagra Falls, ON

Sounding: SCPT18-02
Cone: 545:T1500F15U500 Area=15 cm²



Trace Summary: Filename: 18-05043_SP02.PPF U Min: -4.7 m WT: 9.377 m / 30.764 ft
Depth: 23.450 m / 76.935 ft U Max: 15.3 m Ueq: 14.1 m
Duration: 300.0 s



Appendix G

Site Photographs



Photo 1 – Underside of QEW twin bridge structures, looking south



Photo 2 – QEW twin bridge structures over Oakwood Drive, looking west



Photo 3 – QEW twin bridge structures over CPR track, looking north



Appendix H

Foundation Comparison



COMPARISON OF FOUNDATION ALTERNATIVES

Spread Footings	Driven H-Piles	Driven Pipe Piles	Augured Caissons (Drilled Shafts)
<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly than deep foundation elements. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High bearing resistance available for H-piles driven into bedrock or to refusal in the very dense glacial till. ii. Minimal excavation and dewatering required. iii. Pile driving could continue in freezing weather. iv. Allows integral abutment design. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High bearing resistance available for pipe piles driven to bedrock or to refusal in the very dense glacial till. ii. Excavation and dewatering requirements are minimized. iii. Generally higher lateral resistance than driven H-piles. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance available for caissons socketed into bedrock ii. Construction of caissons could continue in freezing weather. iii. Excavation and dewatering requirements are minimized.
<p>Disadvantages:</p> <ul style="list-style-type: none"> ii. Relatively low bearing resistance available and risk of large footing settlement 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Potential for pile deflection or refusal on cobbles, boulders and rock fragments within glacial till. ii. Potential for varying pile lengths within a foundation unit. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Possibly higher unit cost compared to other foundation options such as footings. ii. Specialized installation. iii. Installation through cobbles and boulders will be difficult. iv. Pipe piles are more prone to pile tip damage in comparison to H-piles. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to other foundation options such as footings or driven piles. iv. Specialized installation measures such as temporary liners and slurry required to install caissons below the water table. ii. Potential difficulty in cleaning and inspecting base. iii. Installation through cobbles and boulders will be difficult.
NOT RECOMMENDED	RECOMMENDED	FEASIBLE	NOT RECOMMENDED



Appendix I

Global Stability Analysis Results



FIGURE I1

File Name: Hubber Abutment - Existing Condition LT.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

B-Bar: 0

Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

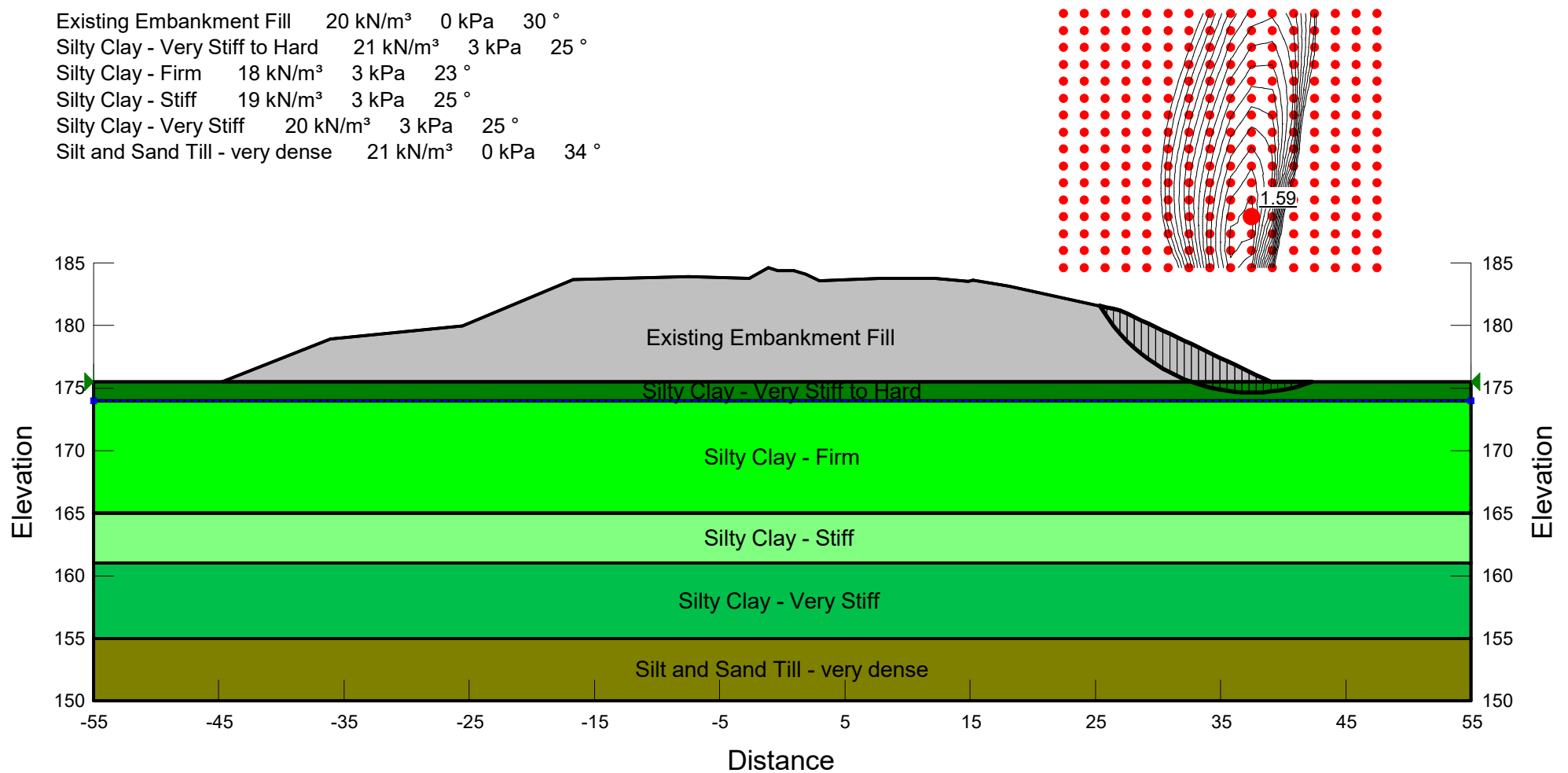




FIGURE I2

File Name: South Abutment - Granular fill ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

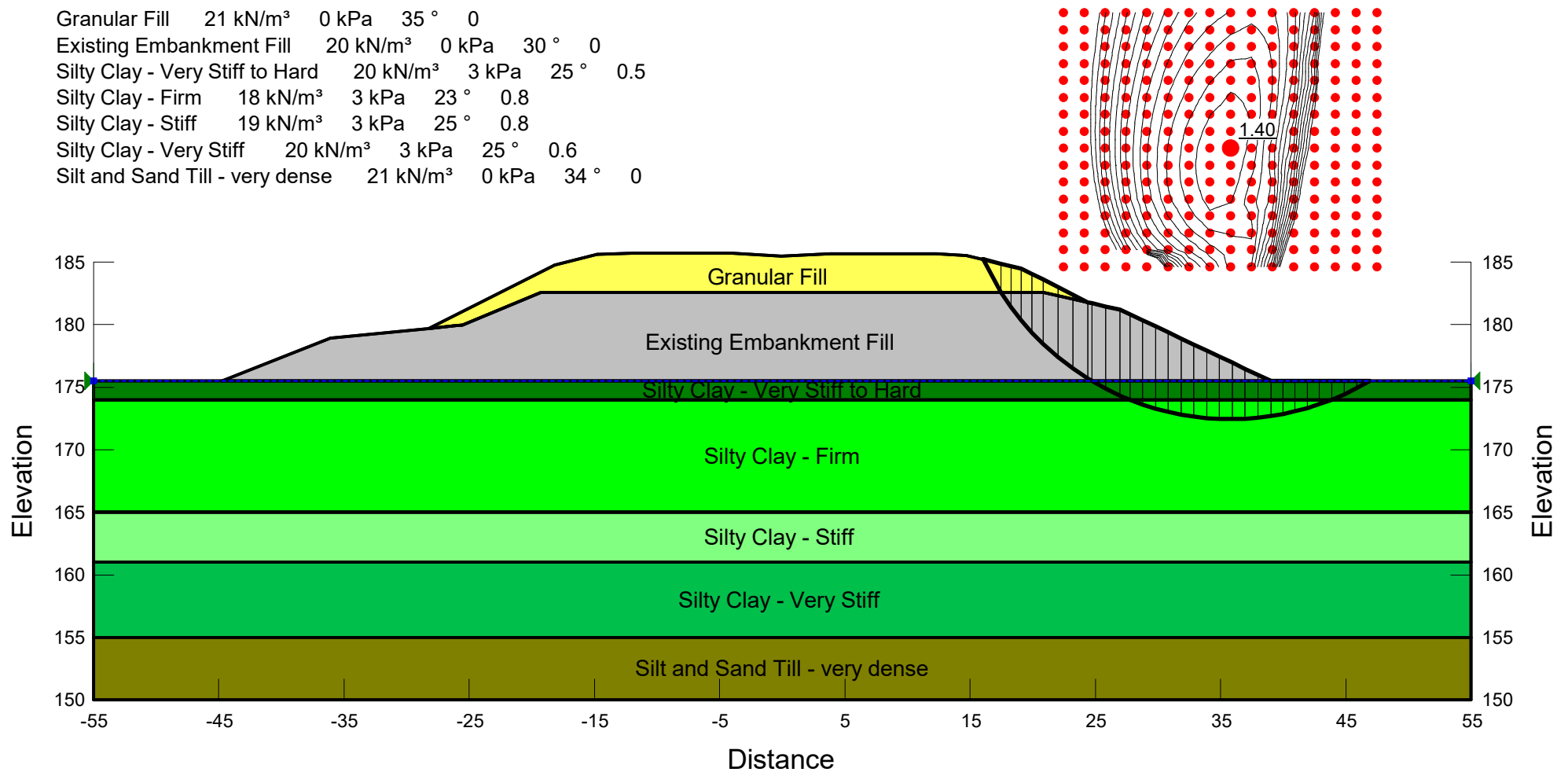




FIGURE I3

File Name: South Abutment - Granular fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

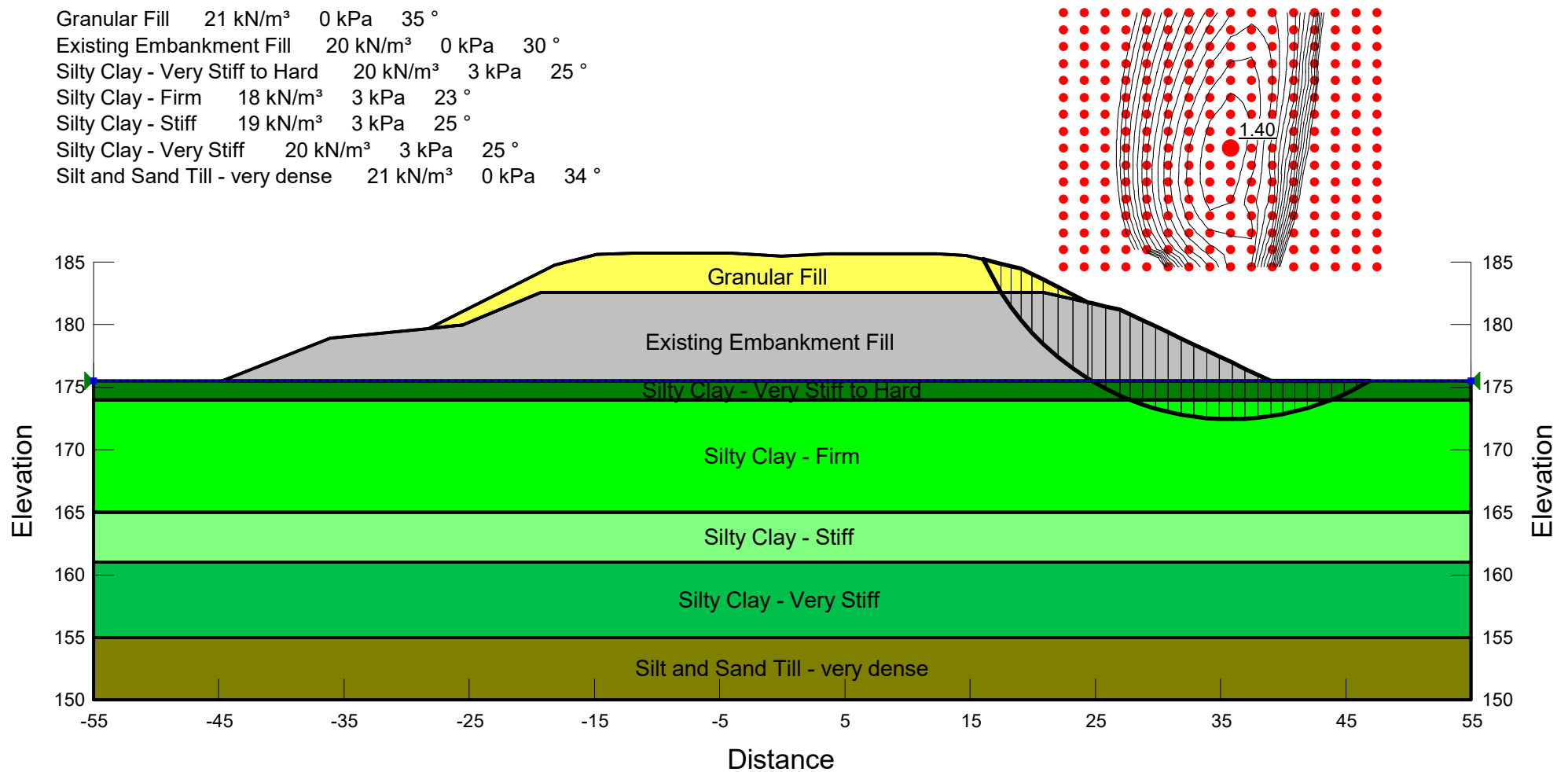




FIGURE I4

File Name: South Abutment - Cellular Concrete ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

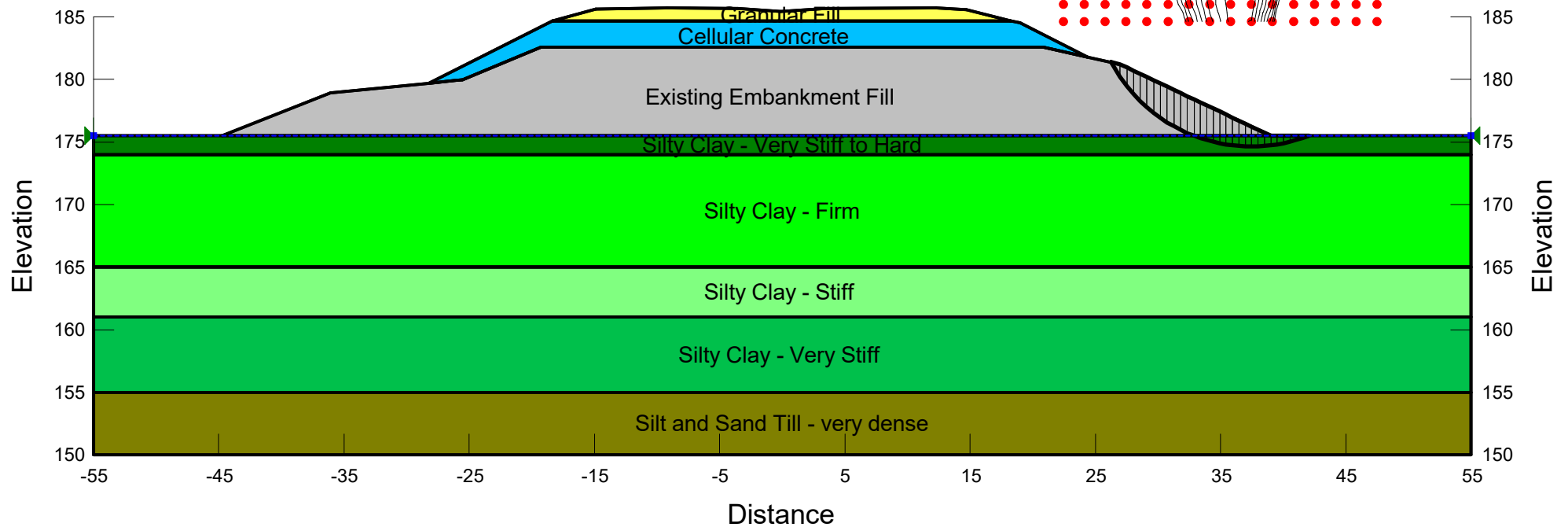


FIGURE I5



File Name: South Abutment - Cellular Concrete LT.gsz
 Created By: Geoff Lay
 Date: 8/29/2018

Method: Morgenstern-Price
 Minimum Slip Surface Depth: 1 m
 Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Cellular Concrete	5 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

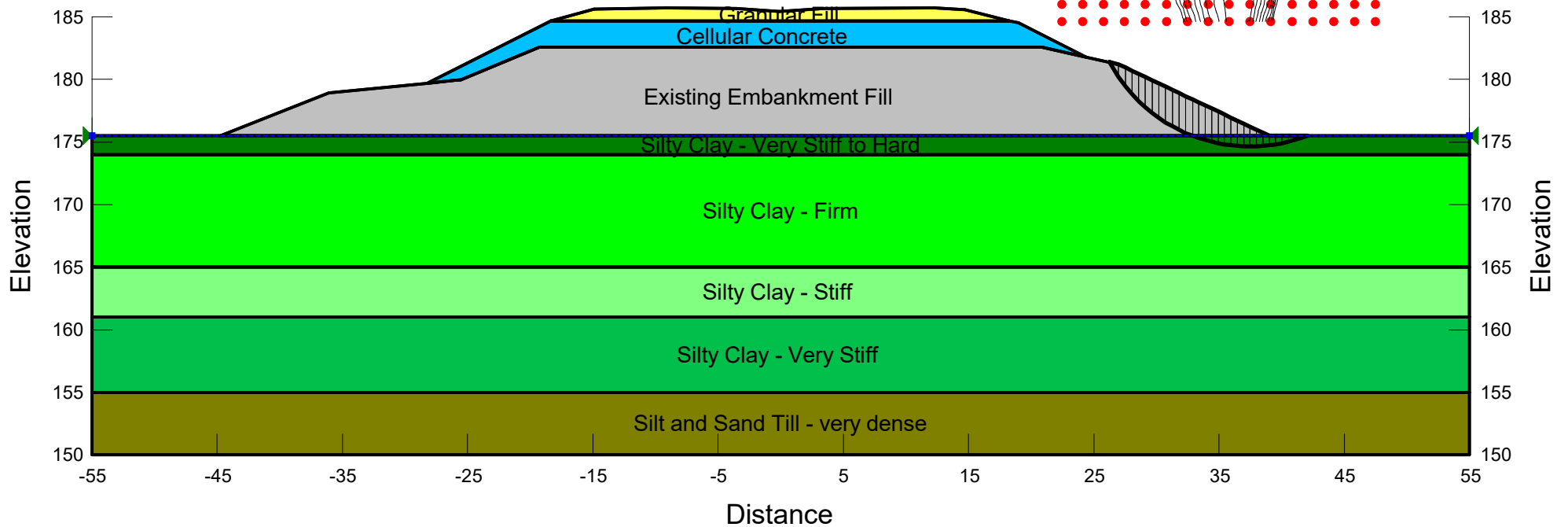


FIGURE I6



File Name: South Abutment - Cellular Concrete Seismic.gsz
 Created By: Geoff Lay
 Date: 8/29/2018

Method: Morgenstern-Price
 Minimum Slip Surface Depth: 1 m
 Seismic: 0.1g

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

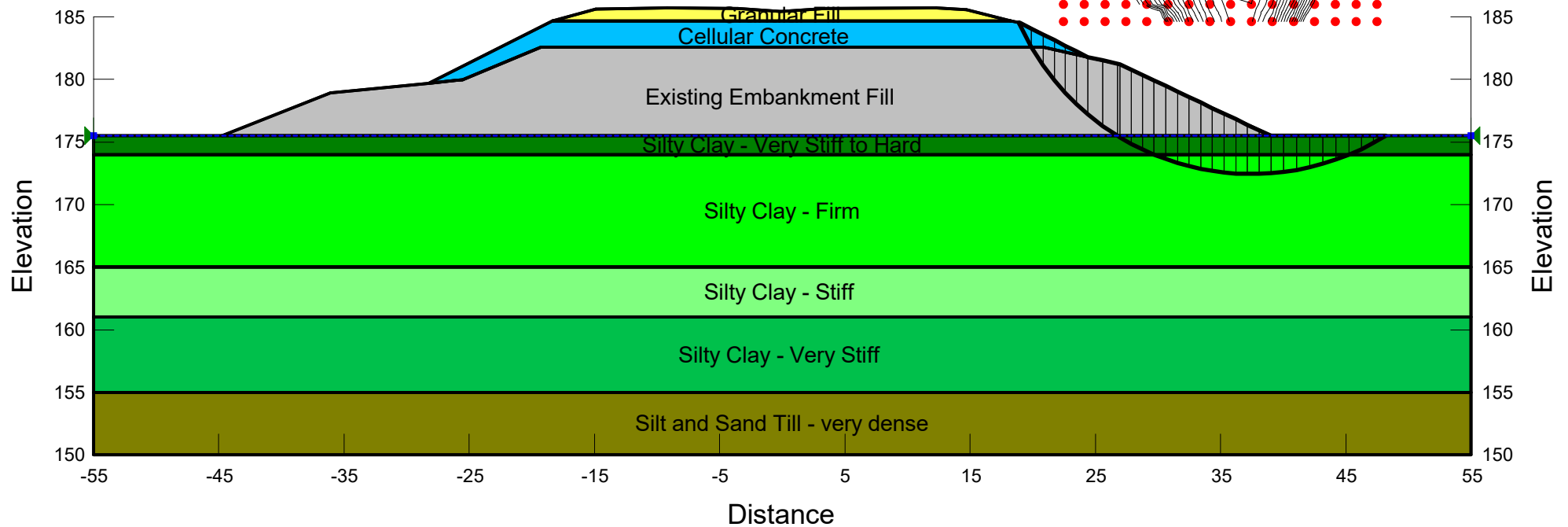




FIGURE I7

File Name: South Abutment - EPS fill ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
EPS	1 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

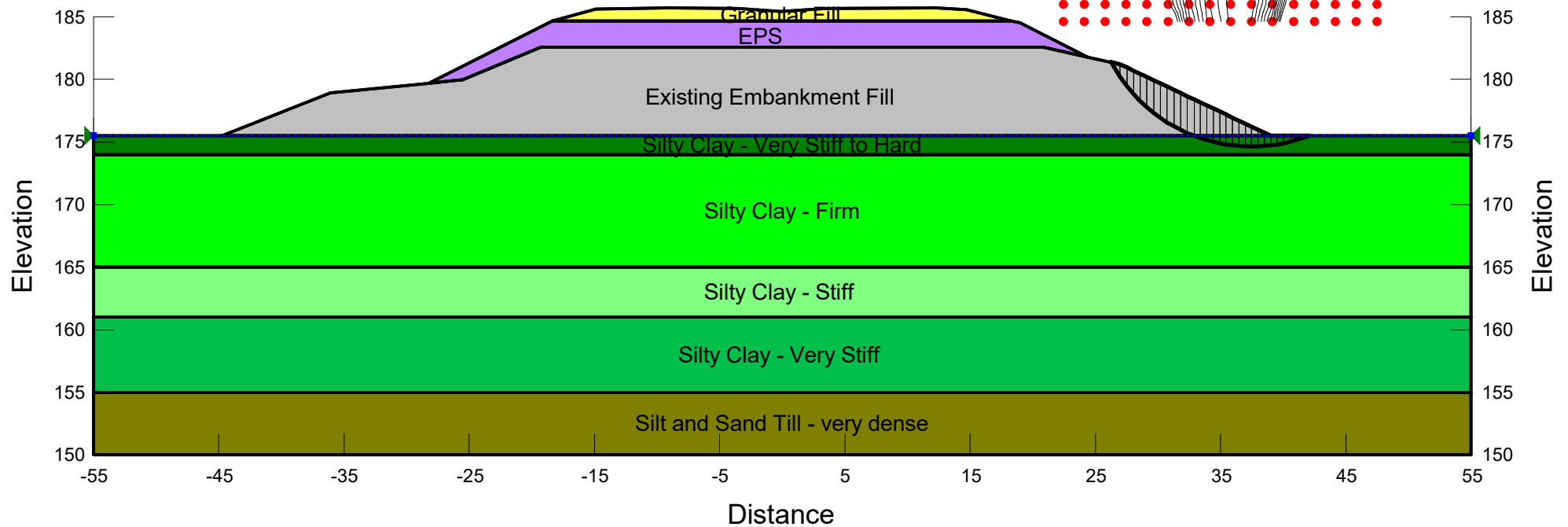




FIGURE I8

File Name: South Abutment - EPS fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
EPS	1 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

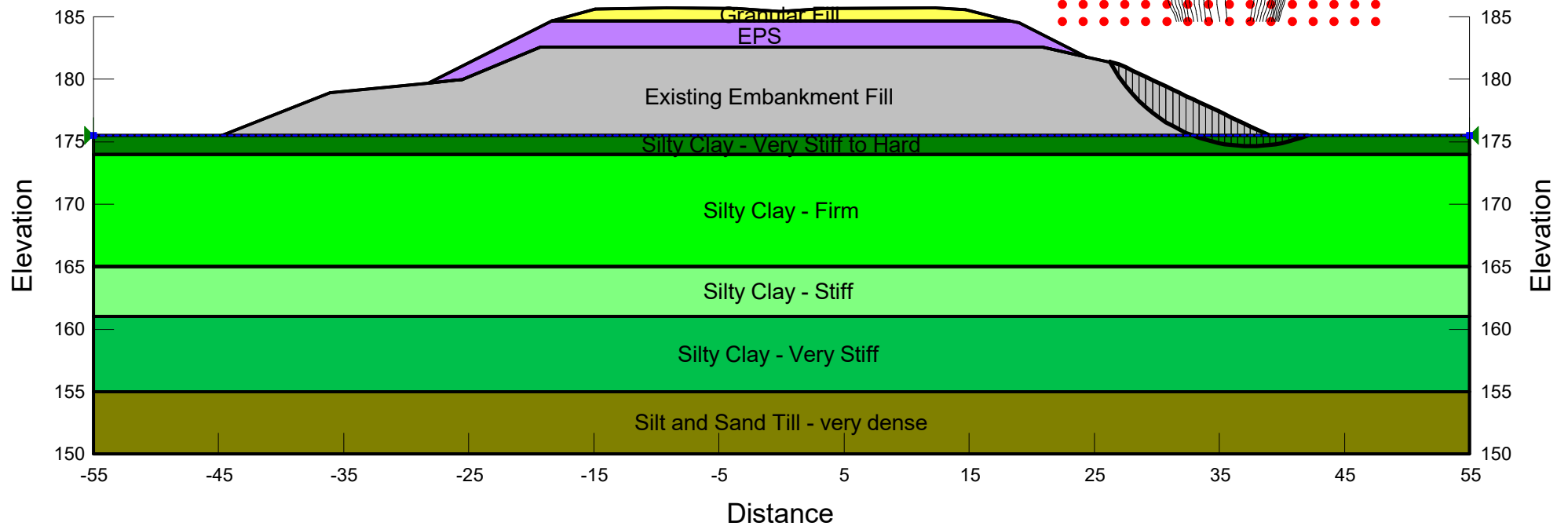


FIGURE I9



File Name: South Abutment - EPS fill Seismic.gsz
 Created By: Geoff Lay
 Date: 8/29/2018

Method: Morgenstern-Price
 Minimum Slip Surface Depth: 1 m
 Seismic: 0.1g

Granular Fill	21 kN/m ³	0 kPa	35 °
EPS	1 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Very Stiff to Hard	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

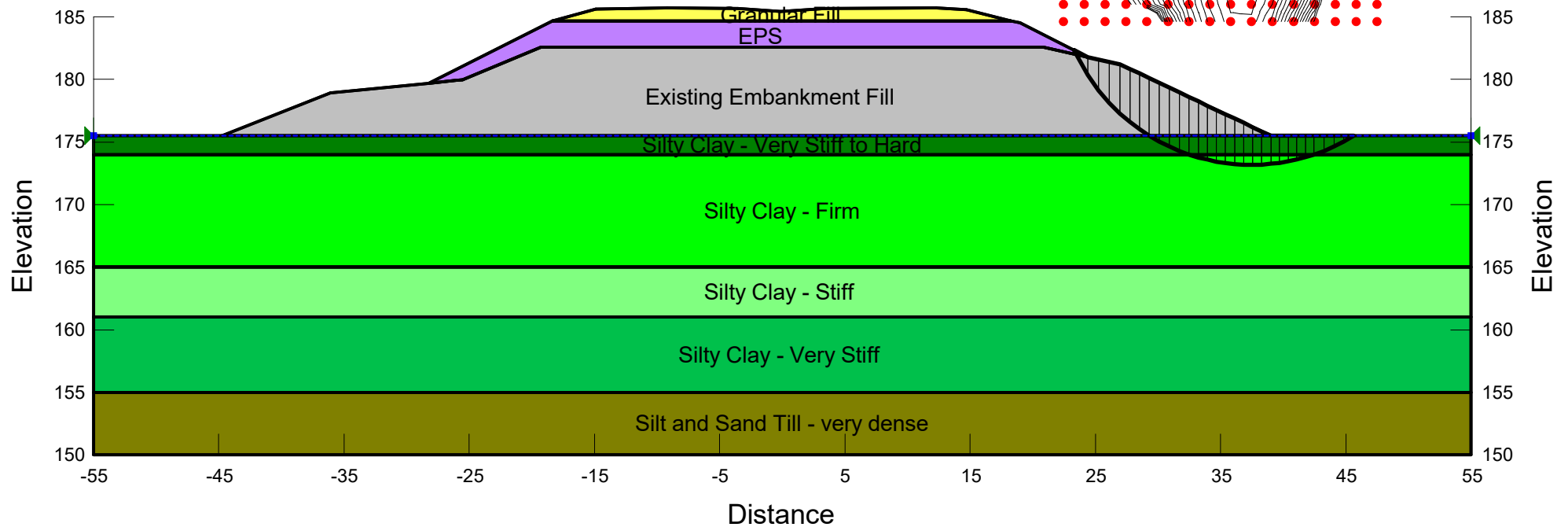




FIGURE I10

File Name: North Abutment - Existing Condition LT.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

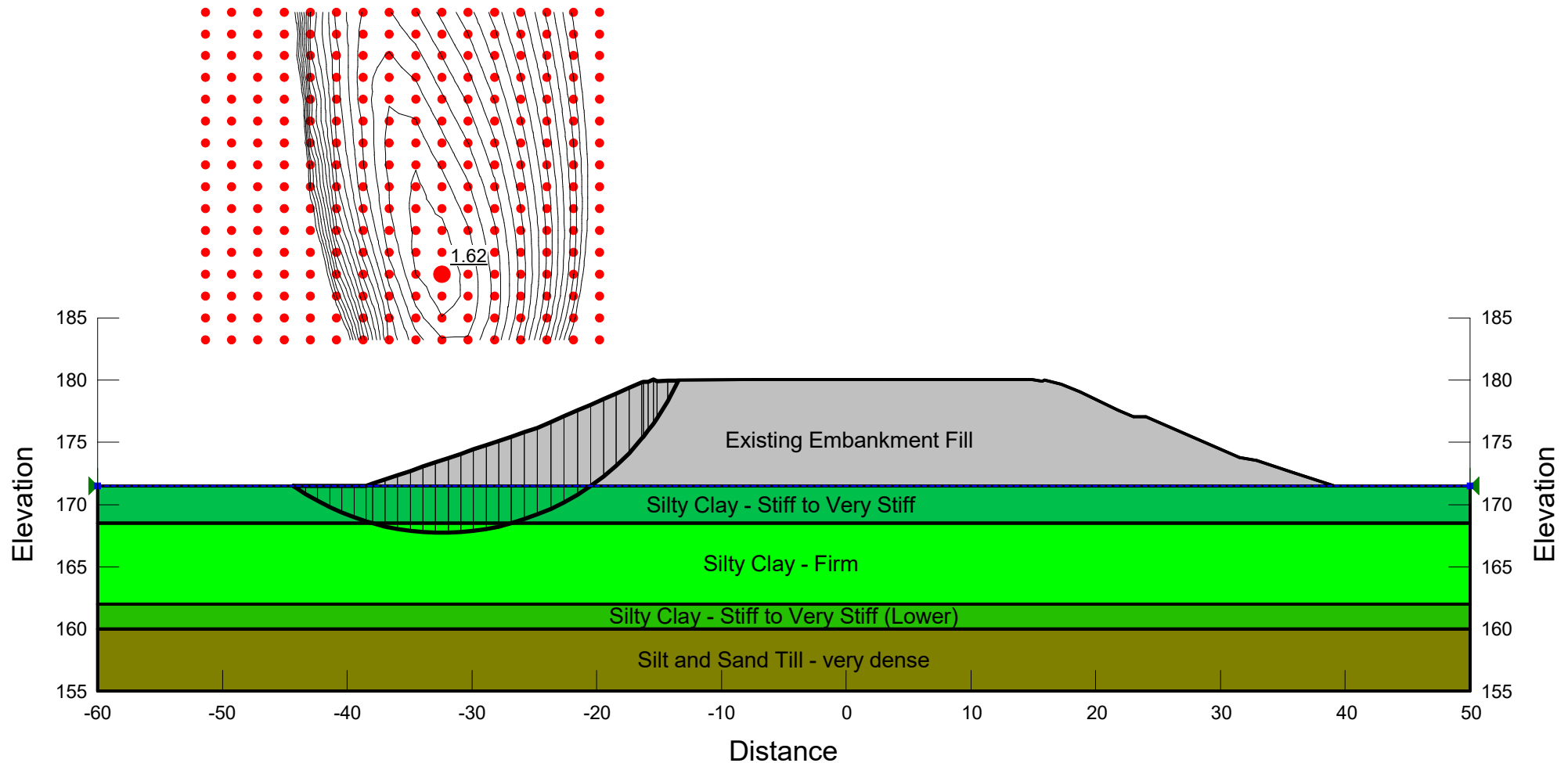




FIGURE I11

File Name: North Abutment - Granular Fill ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

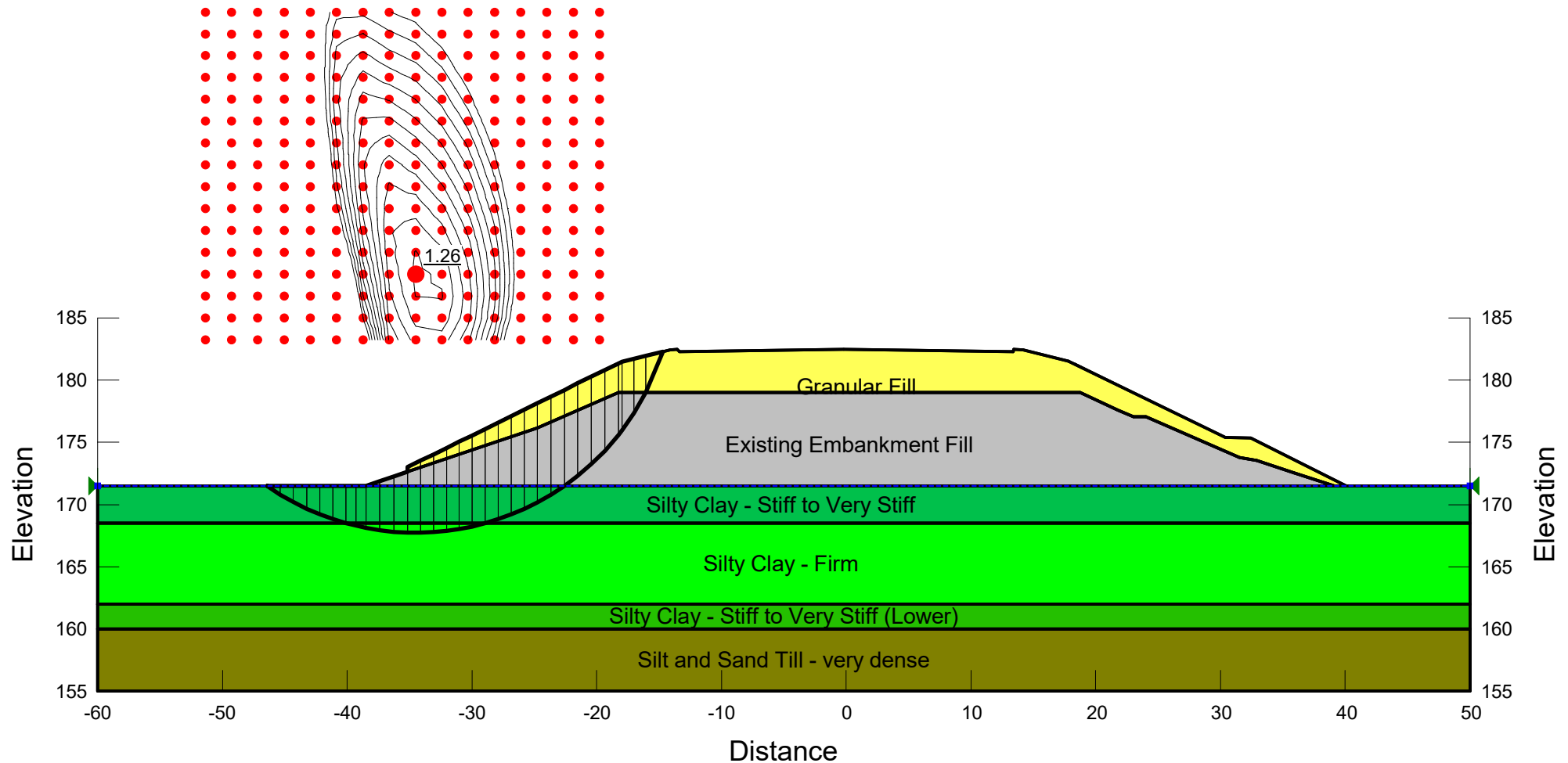




FIGURE I12

File Name: North Abutment - Granular Fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

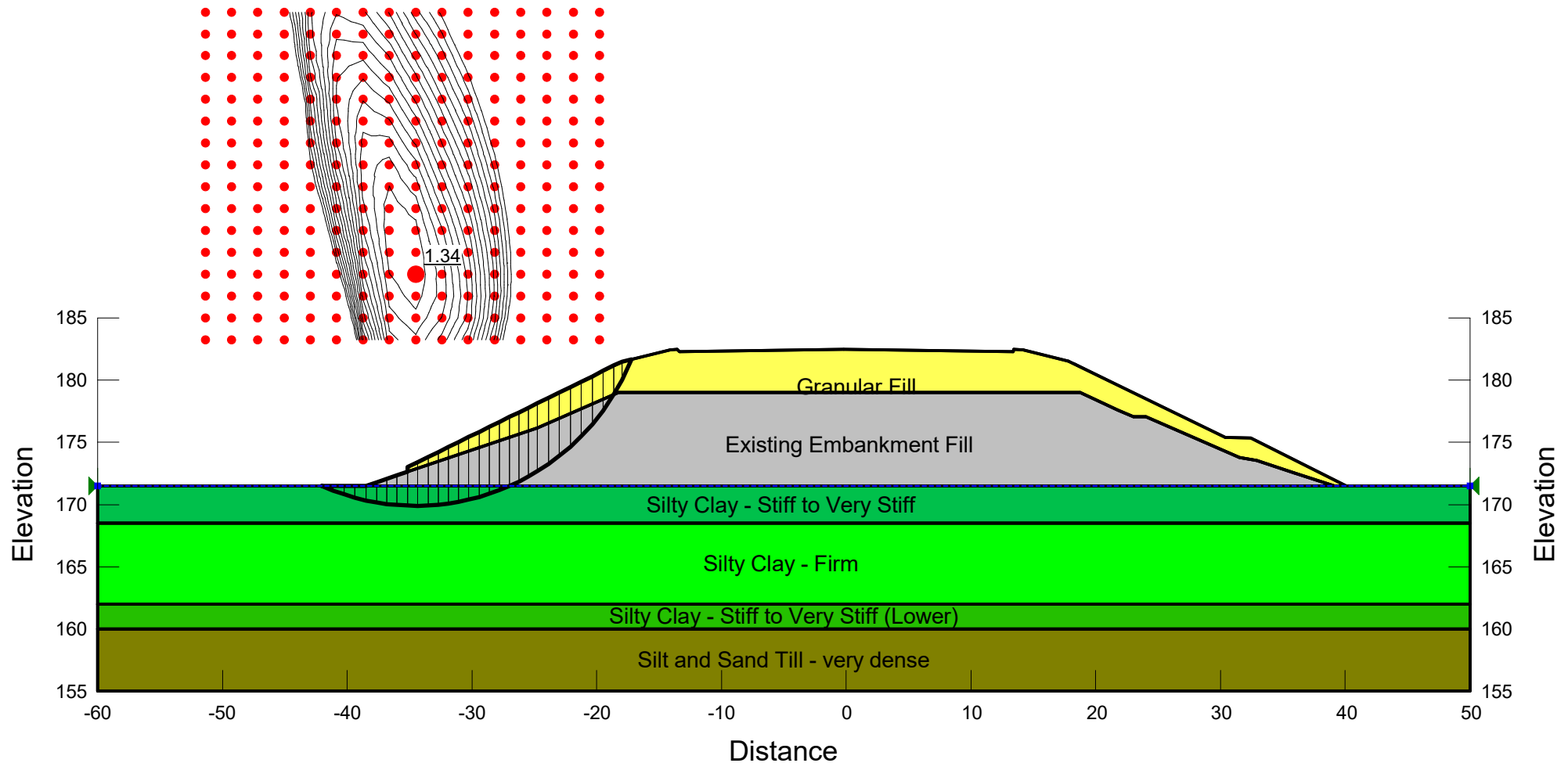




FIGURE I13

File Name: North Abutment - Cellular Concrete ST.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

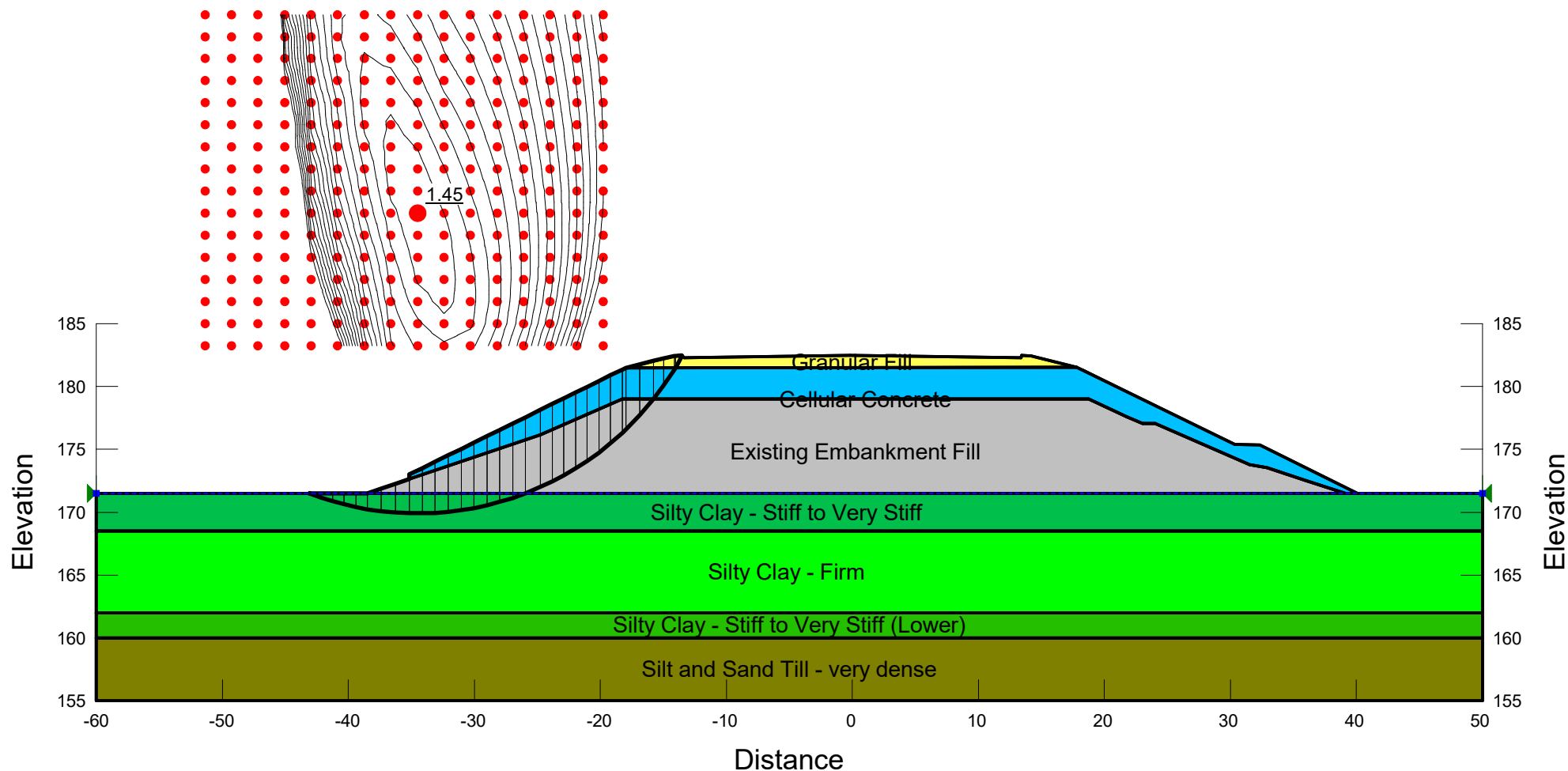




FIGURE I14

File Name: North Abutment - Cellular Concrete LT.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Cellular Concrete	5 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

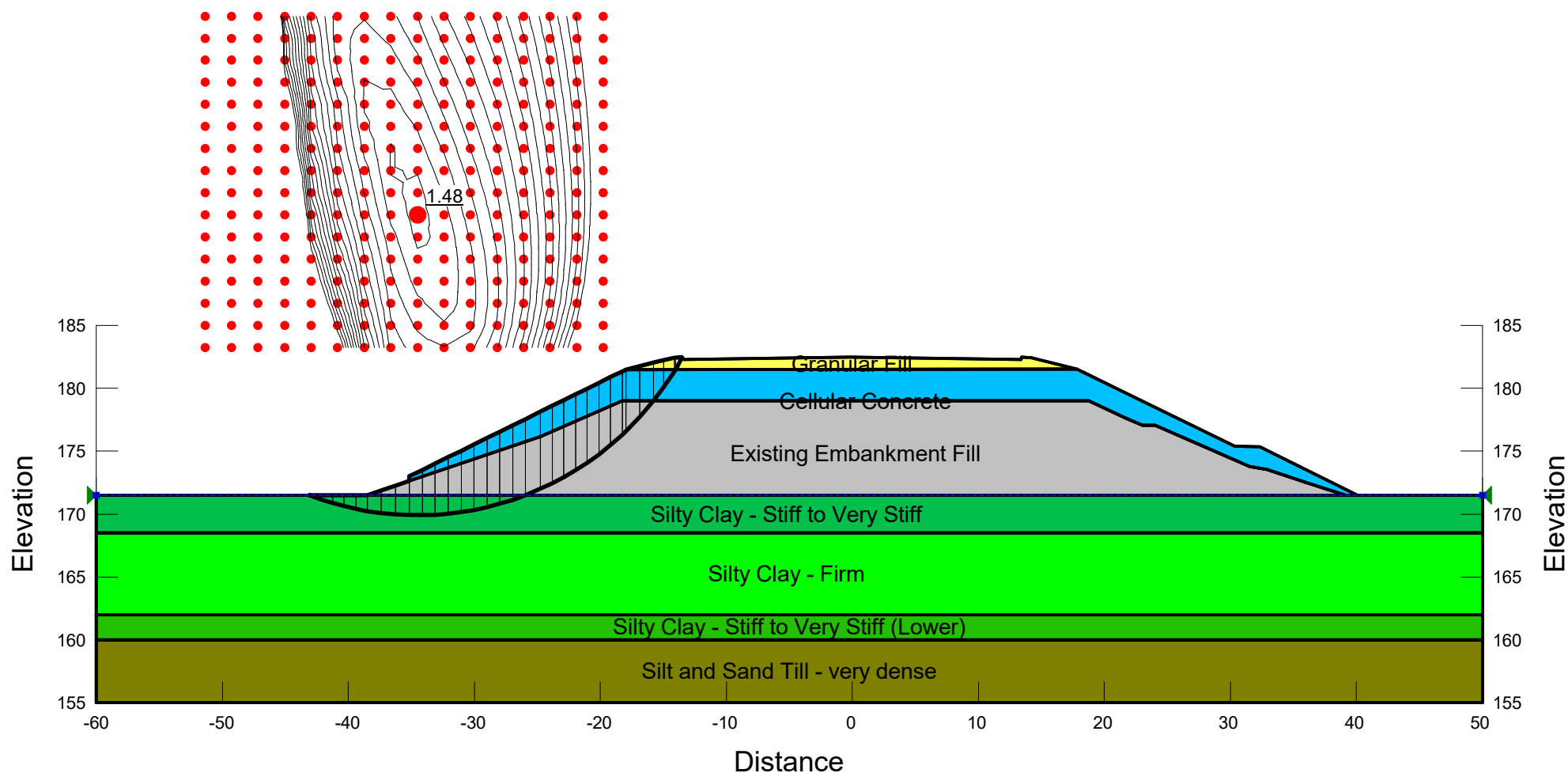




FIGURE I15

File Name: North Abutment - Cellular Concrete Seismic.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0.1g

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

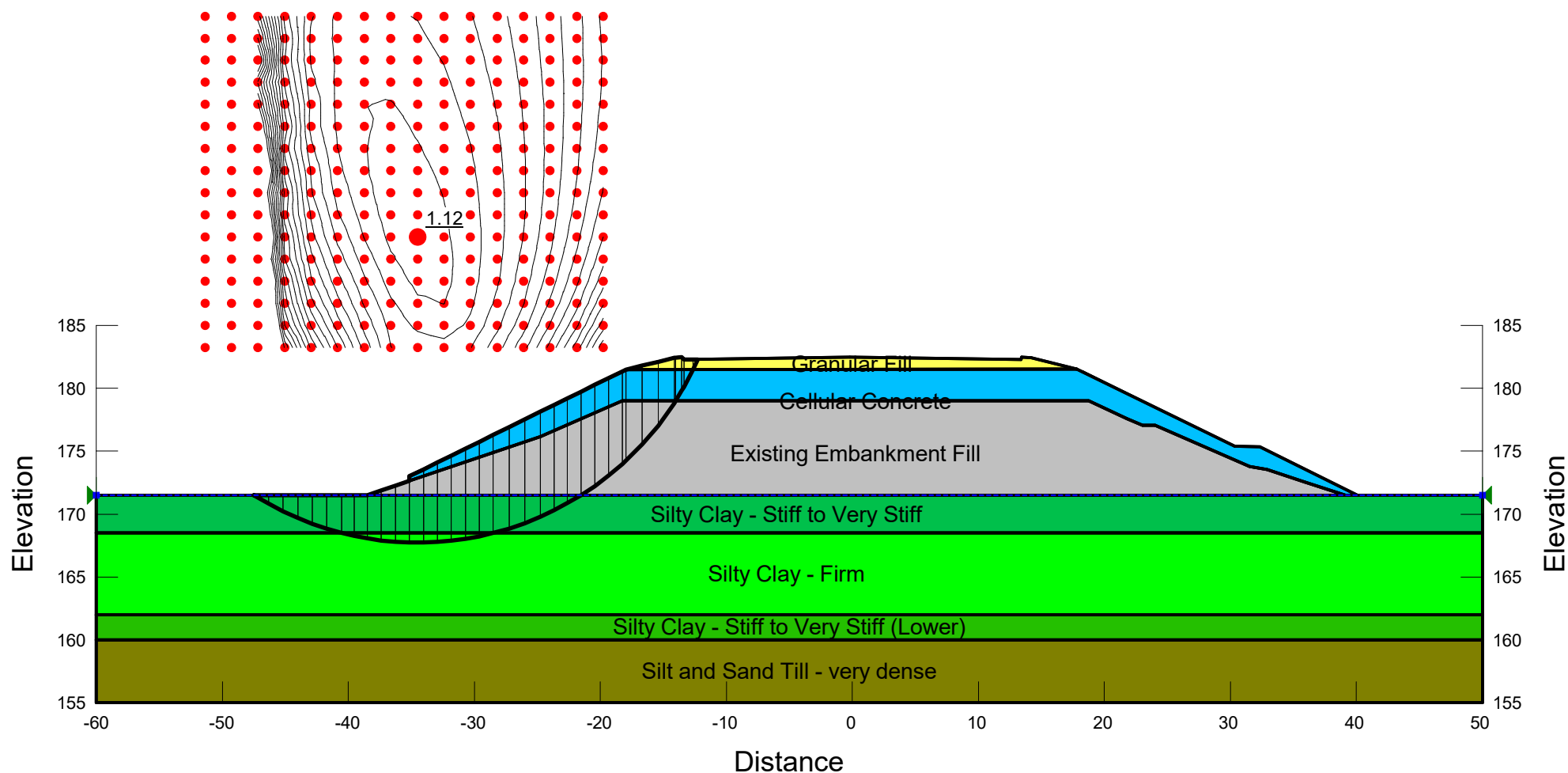




FIGURE I16

File Name: North Abutment - EPS Fill ST.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill 21 kN/m³ 0 kPa 35 ° 0

EPS 1 kN/m³ 0 kPa 0 ° 0

Existing Embankment Fill 20 kN/m³ 0 kPa 30 ° 0

Silty Clay - Stiff to Very Stiff 20 kN/m³ 3 kPa 25 ° 0.6

Silty Clay - Firm 18 kN/m³ 3 kPa 23 ° 0.8

Silty Clay - Stiff to Very Stiff (Lower) 20 kN/m³ 3 kPa 25 ° 0.6

Silt and Sand Till - very dense 21 kN/m³ 0 kPa 34 ° 0

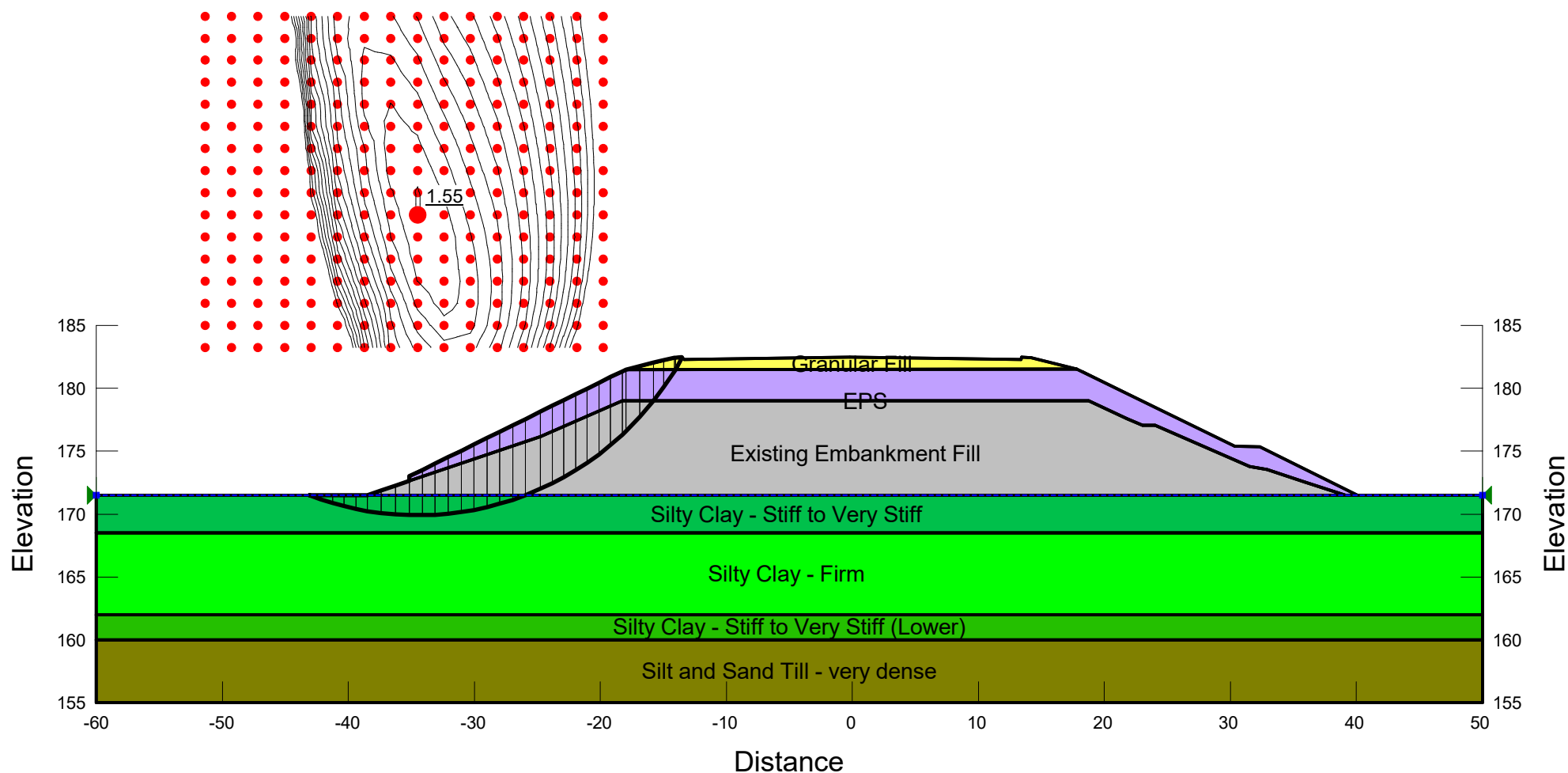




FIGURE I17

File Name: North Abutment - EPS Fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
EPS	1 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff to Very Stiff (Lower)	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

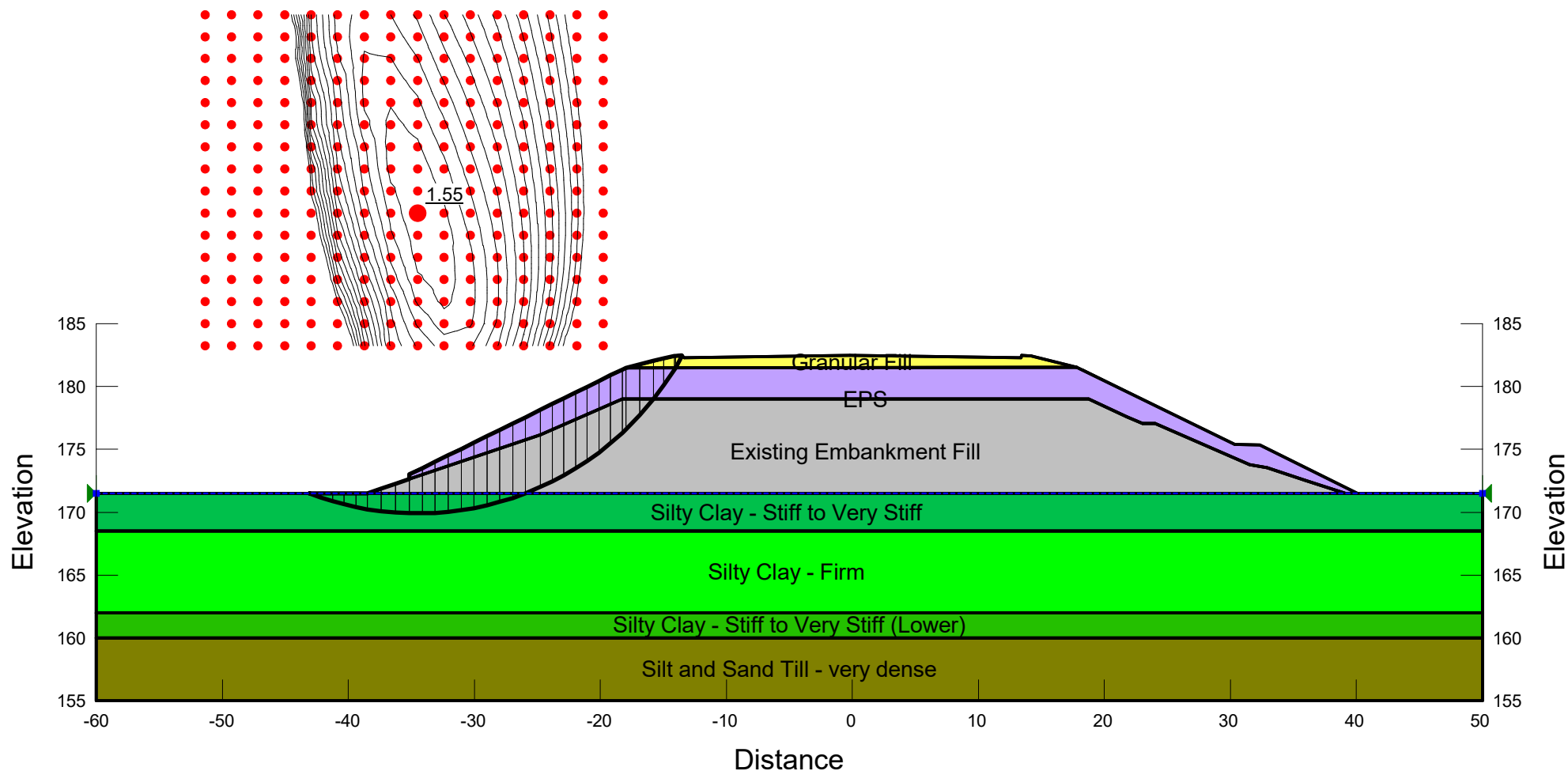




FIGURE I18

File Name: North Abutment - EPS Fill Seismic.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0.1g

Granular Fill 21 kN/m³ 0 kPa 35 ° 0

EPS 1 kN/m³ 0 kPa 0 ° 0

Existing Embankment Fill 20 kN/m³ 0 kPa 30 ° 0

Silty Clay - Stiff to Very Stiff 20 kN/m³ 3 kPa 25 ° 0.6

Silty Clay - Firm 18 kN/m³ 3 kPa 23 ° 0.8

Silty Clay - Stiff to Very Stiff (Lower) 20 kN/m³ 3 kPa 25 ° 0.6

Silt and Sand Till - very dense 21 kN/m³ 0 kPa 34 ° 0

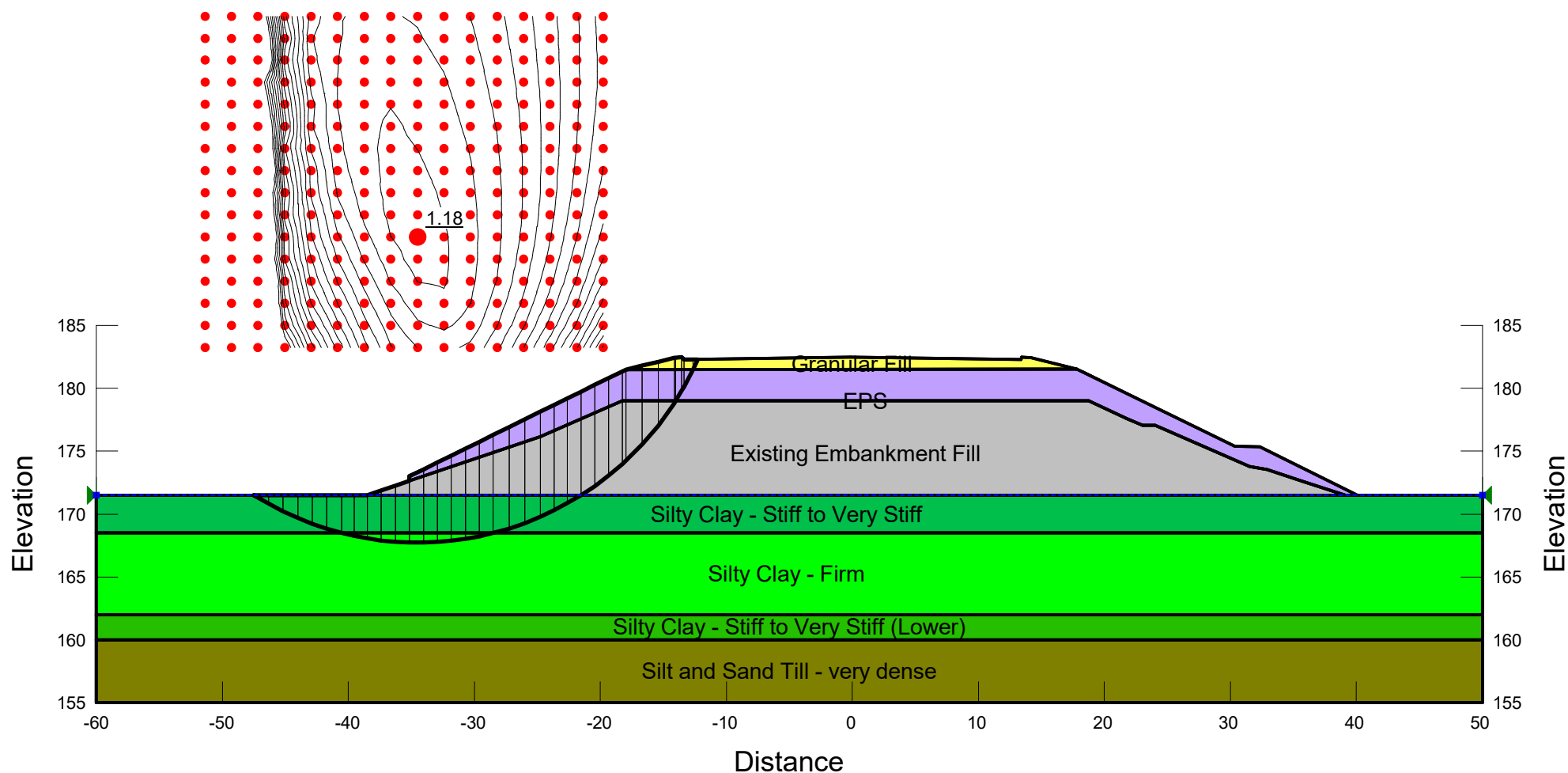




FIGURE I19

File Name: Grassy Brook Culvert - Existing Condition LT.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Existing Embankment Fill 20 kN/m³ 0 kPa 30 °

Silty Clay - Stiff to Very Stiff 20 kN/m³ 3 kPa 25 °

Silty Clay - Firm 18 kN/m³ 3 kPa 23 °

Silt and Sand - compact to dense 21 kN/m³ 0 kPa 31 °

Silty Clay - Stiff 19 kN/m³ 3 kPa 25 °

Silty Clay - Firm (Lower) 18 kN/m³ 3 kPa 23 °

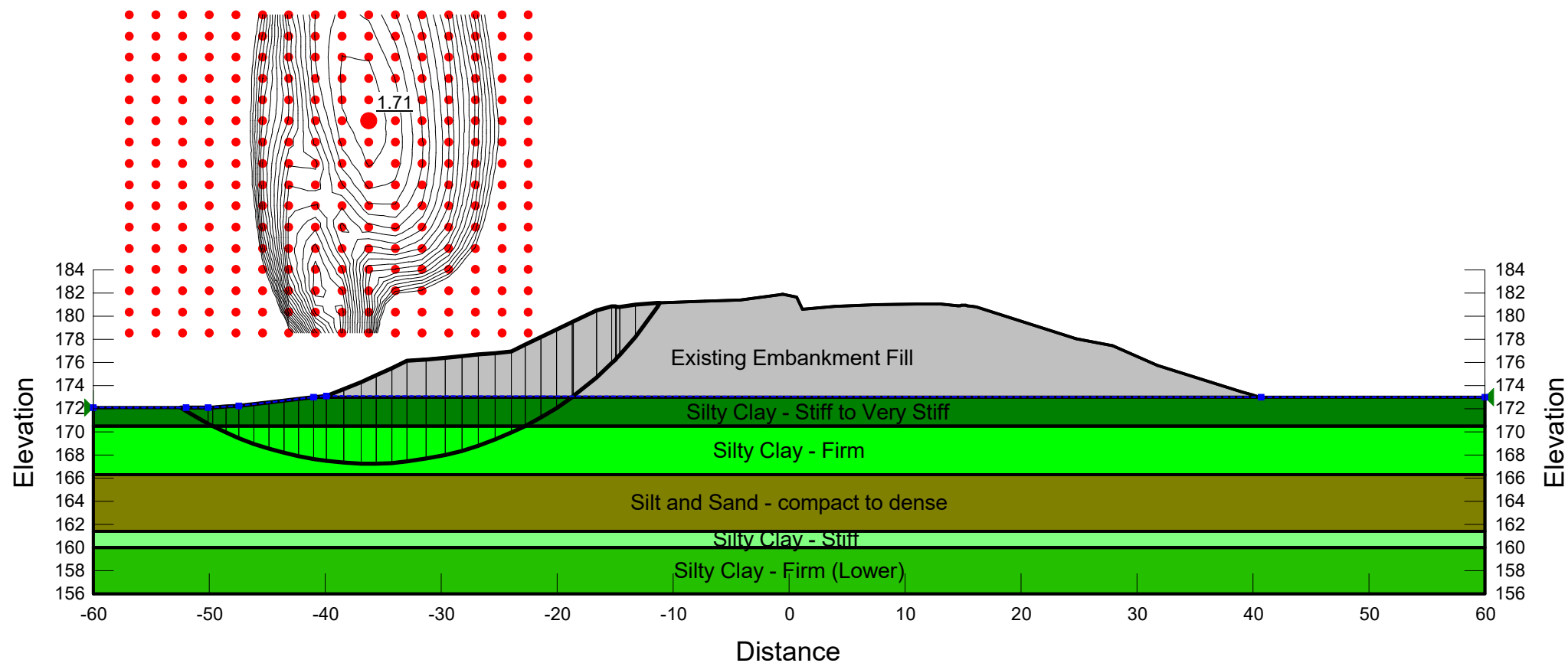




FIGURE I20

File Name: Grassy Brook Culvert - Granular Fill ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °	0
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °	0.8

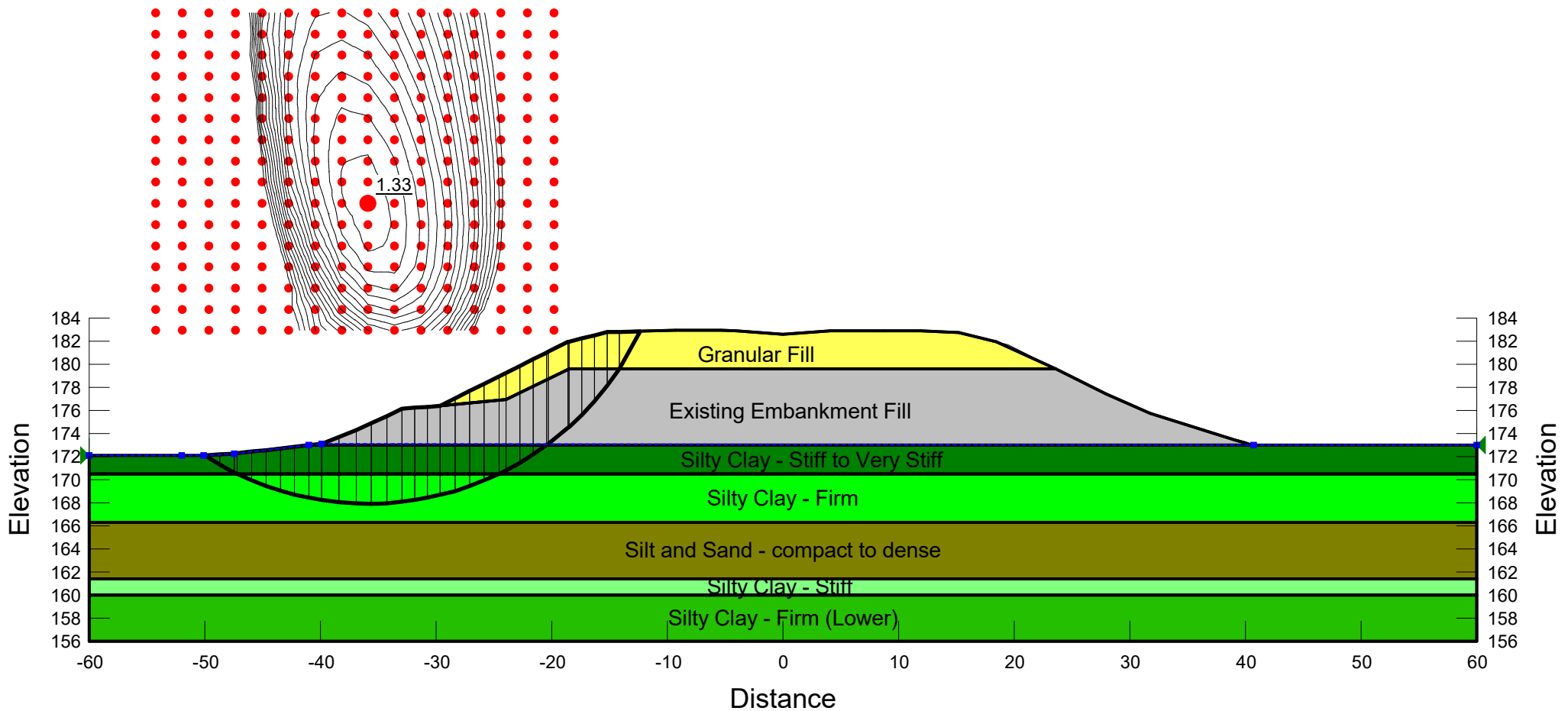




FIGURE I21

File Name: Grassy Brook Culvert - Granular Fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °

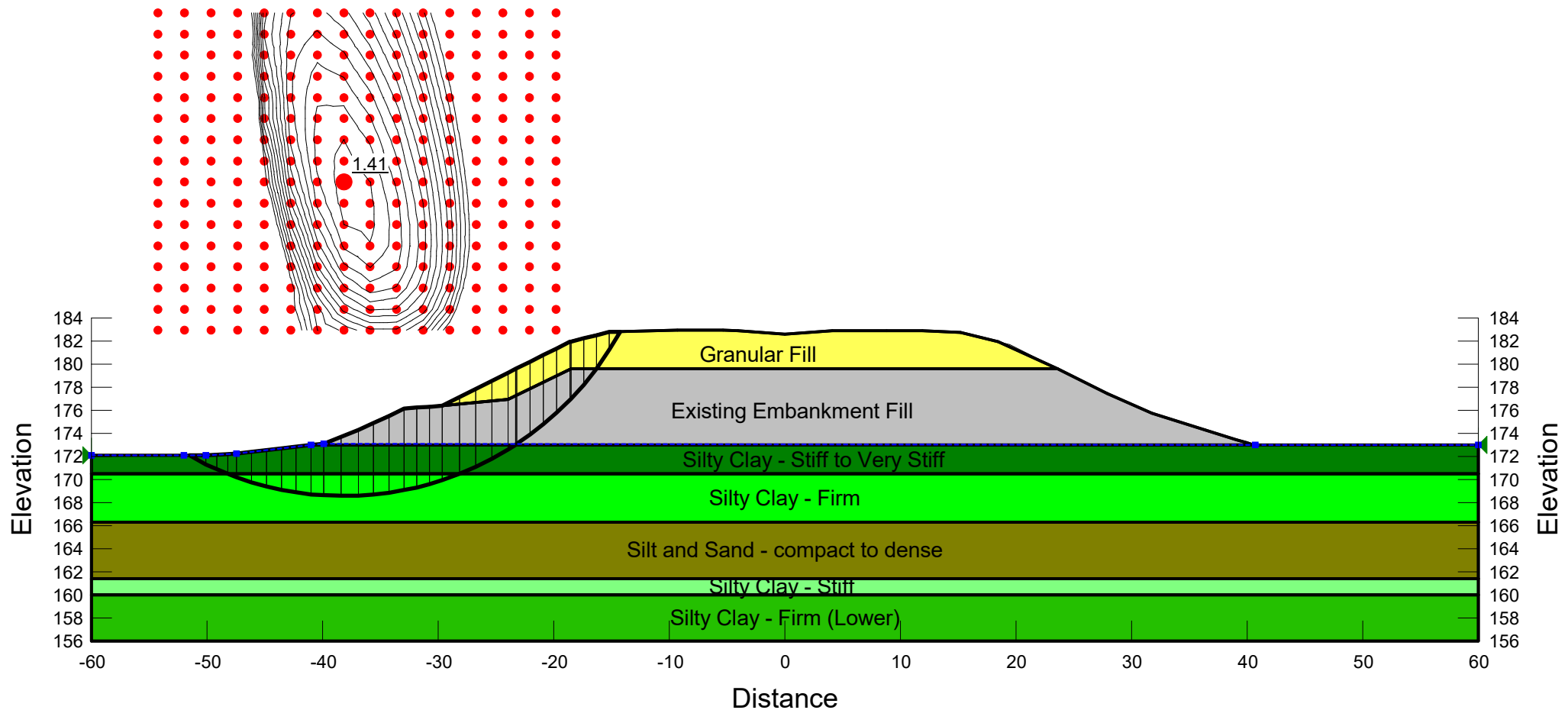




FIGURE I22

File Name: Grassy Brook Culvert - Cellular Concrete ST.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °	0
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °	0.8

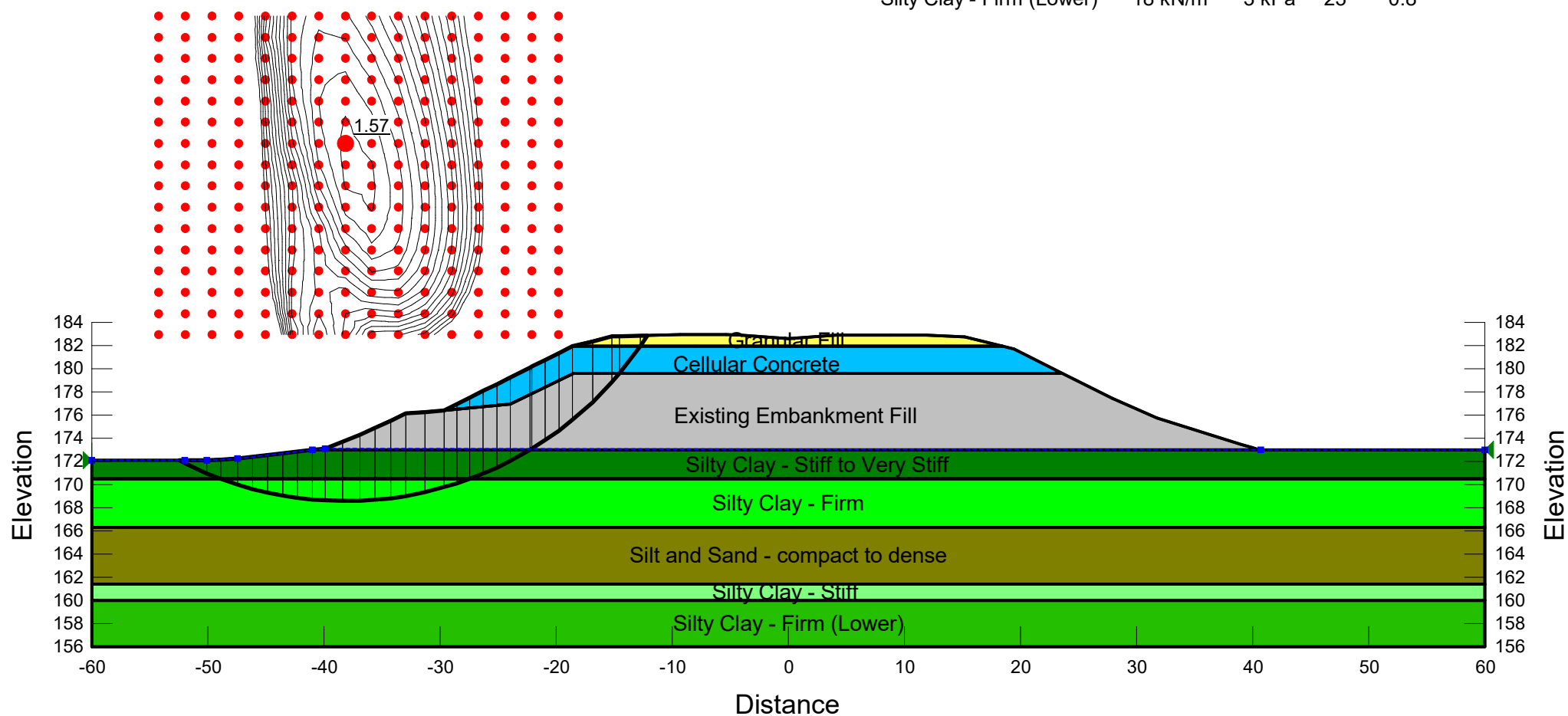




FIGURE I23

File Name: Grassy Brook Culvert - Cellular Concrete LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
Cellular Concrete	5 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °

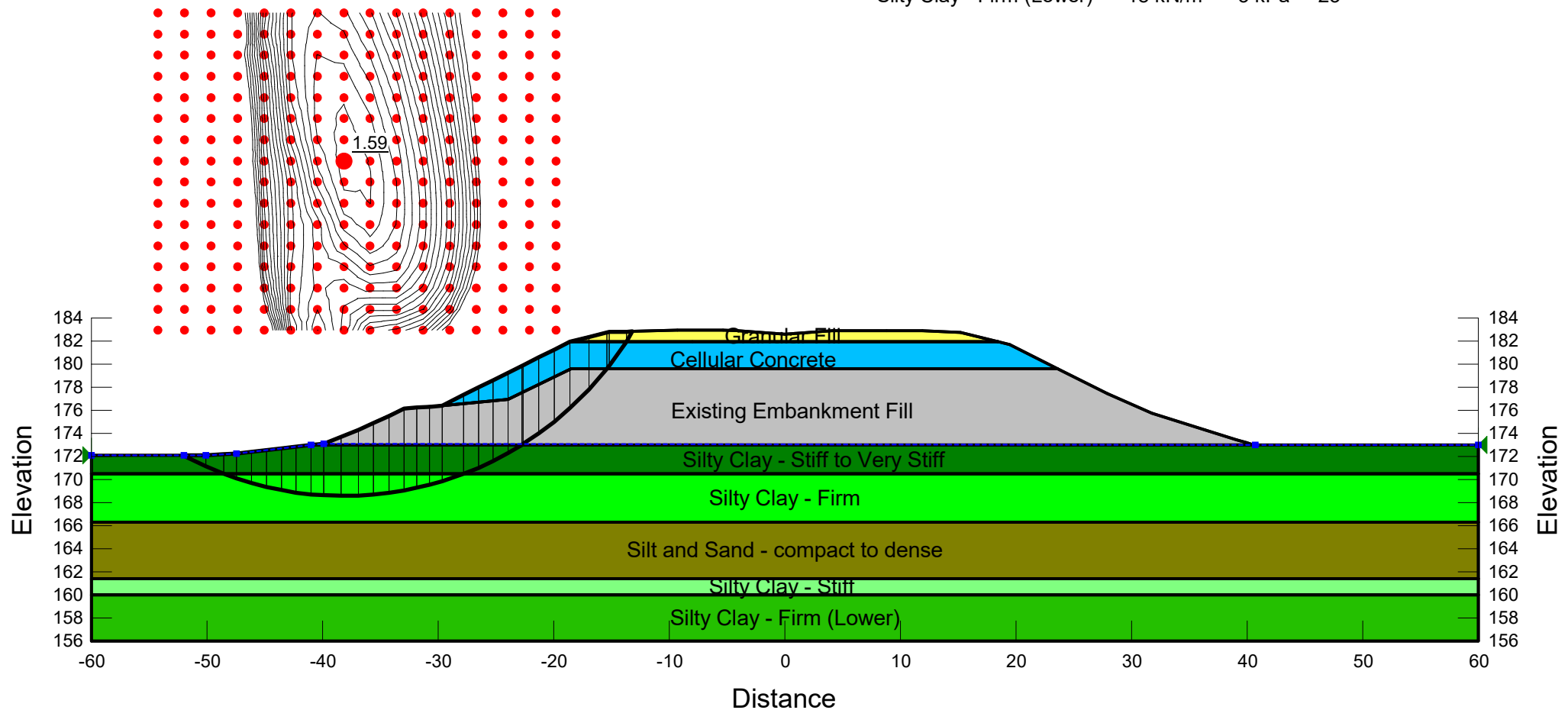




FIGURE I24

File Name: Grassy Brook Culvert - Cellular Concrete Seismic.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0.1g

Granular Fill	21 kN/m ³	0 kPa	35 °	0
Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °	0
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °	0.8

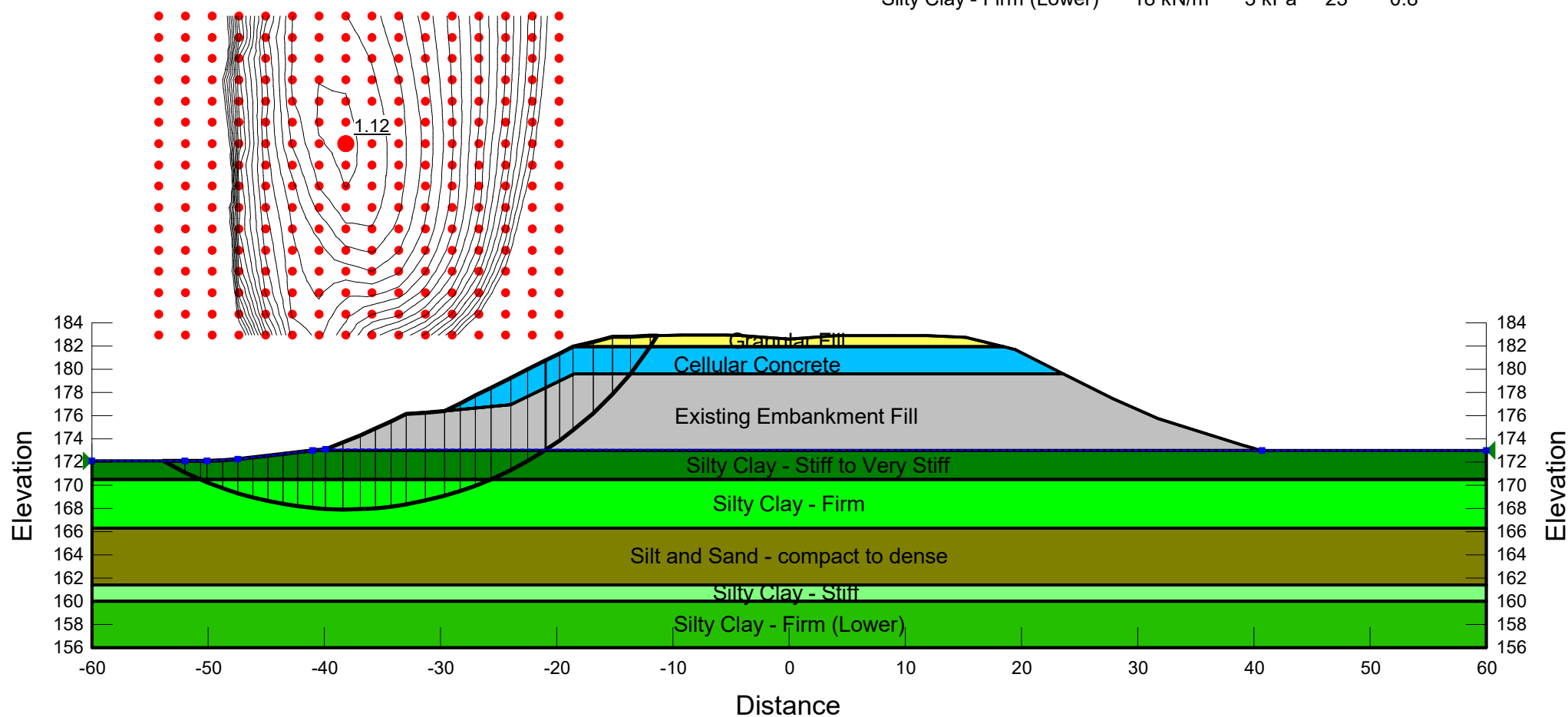




FIGURE I25

File Name: Grassy Brook Culvert - EPS fill ST.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill 21 kN/m³ 0 kPa 35 ° 0

EPS 1 kN/m³ 0 kPa 0 ° 0

Existing Embankment Fill 20 kN/m³ 0 kPa 30 ° 0

Silty Clay - Stiff to Very Stiff 20 kN/m³ 3 kPa 25 ° 0.6

Silty Clay - Firm 18 kN/m³ 3 kPa 23 ° 0.8

Silt and Sand - compact to dense 21 kN/m³ 0 kPa 31 ° 0

Silty Clay - Stiff 19 kN/m³ 3 kPa 25 ° 0.8

Silty Clay - Firm (Lower) 18 kN/m³ 3 kPa 23 ° 0.8

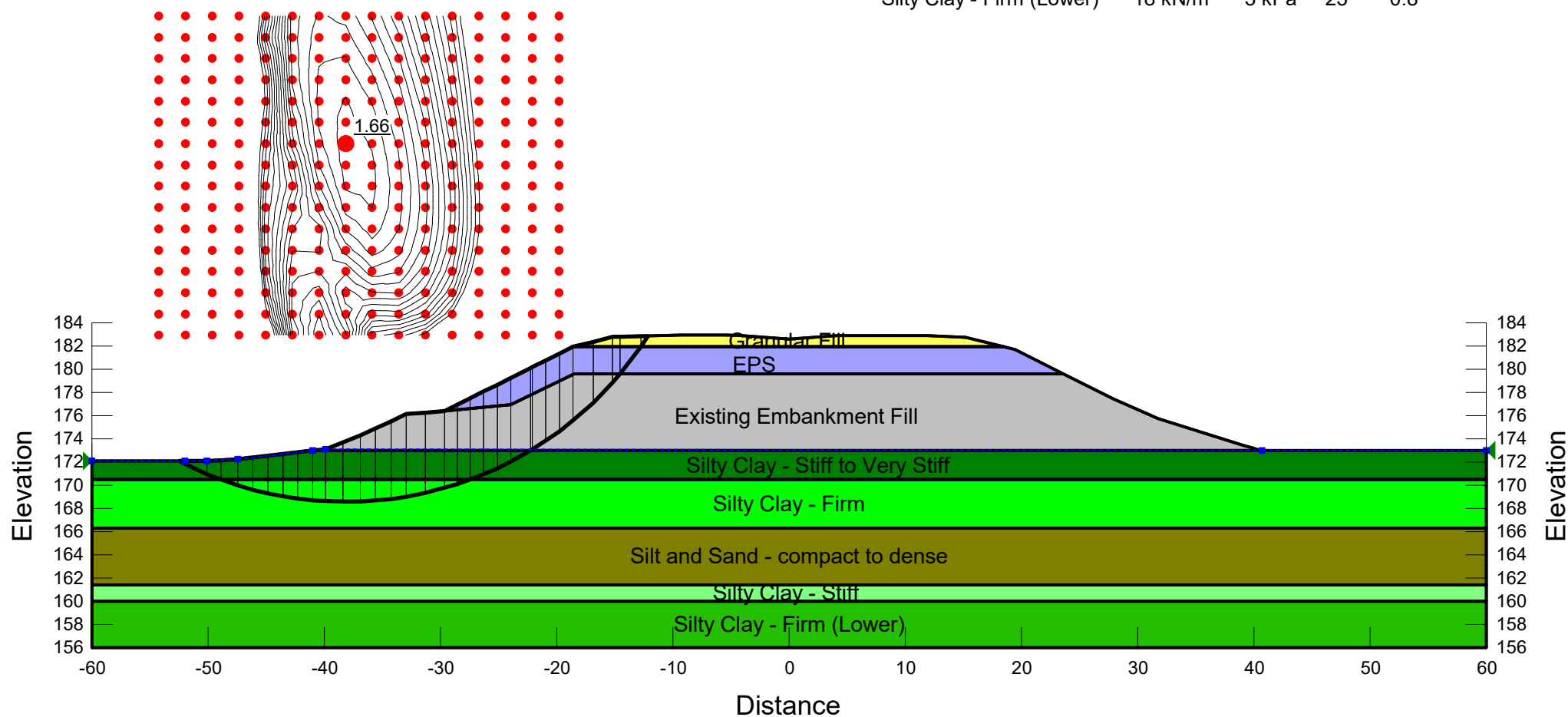




FIGURE I26

File Name: Grassy Brook Culvert - EPS fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Granular Fill	21 kN/m ³	0 kPa	35 °
EPS	1 kN/m ³	0 kPa	0 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °

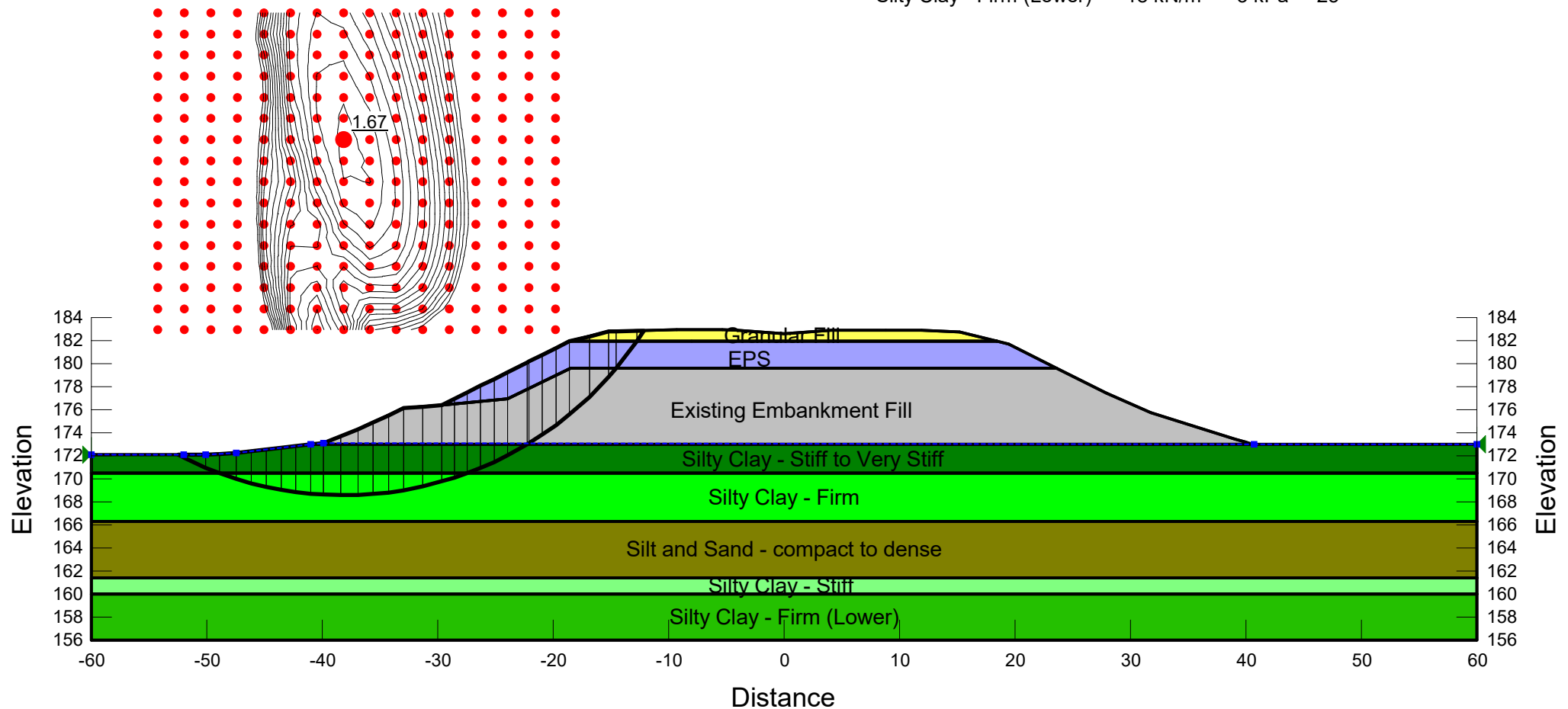




FIGURE I27

File Name: Grassy Brook Culvert - EPS fill Seismic.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0.1g

Granular Fill	21 kN/m ³	0 kPa	35 °	0
EPS	1 kN/m ³	0 kPa	0 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Silty Clay - Stiff to Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silt and Sand - compact to dense	21 kN/m ³	0 kPa	31 °	0
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Firm (Lower)	18 kN/m ³	3 kPa	23 °	0.8

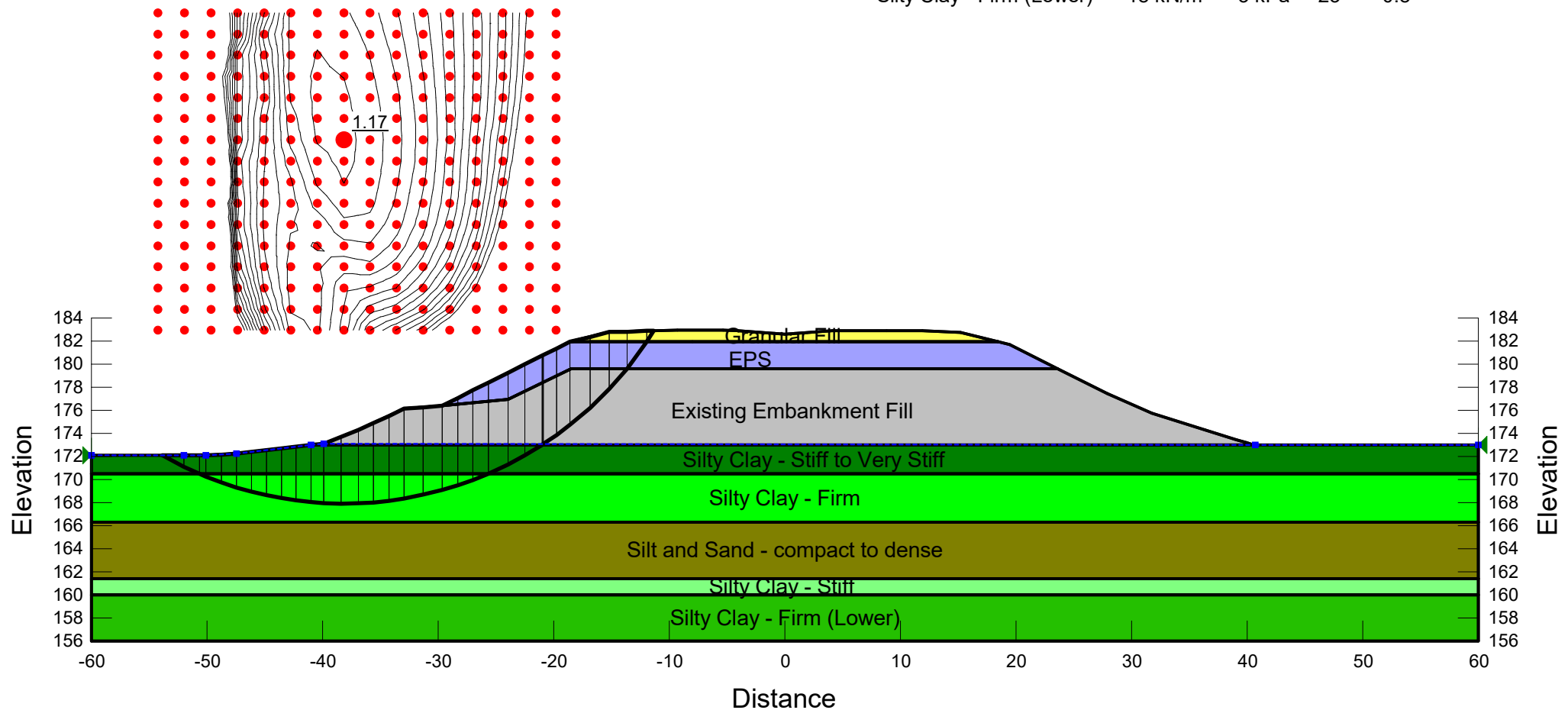




FIGURE I28

File Name: South Abutment Longitudinal - Cellular Concrete ST.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Concrete	1 kN/m ³	0 kPa	1,000 °	0
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

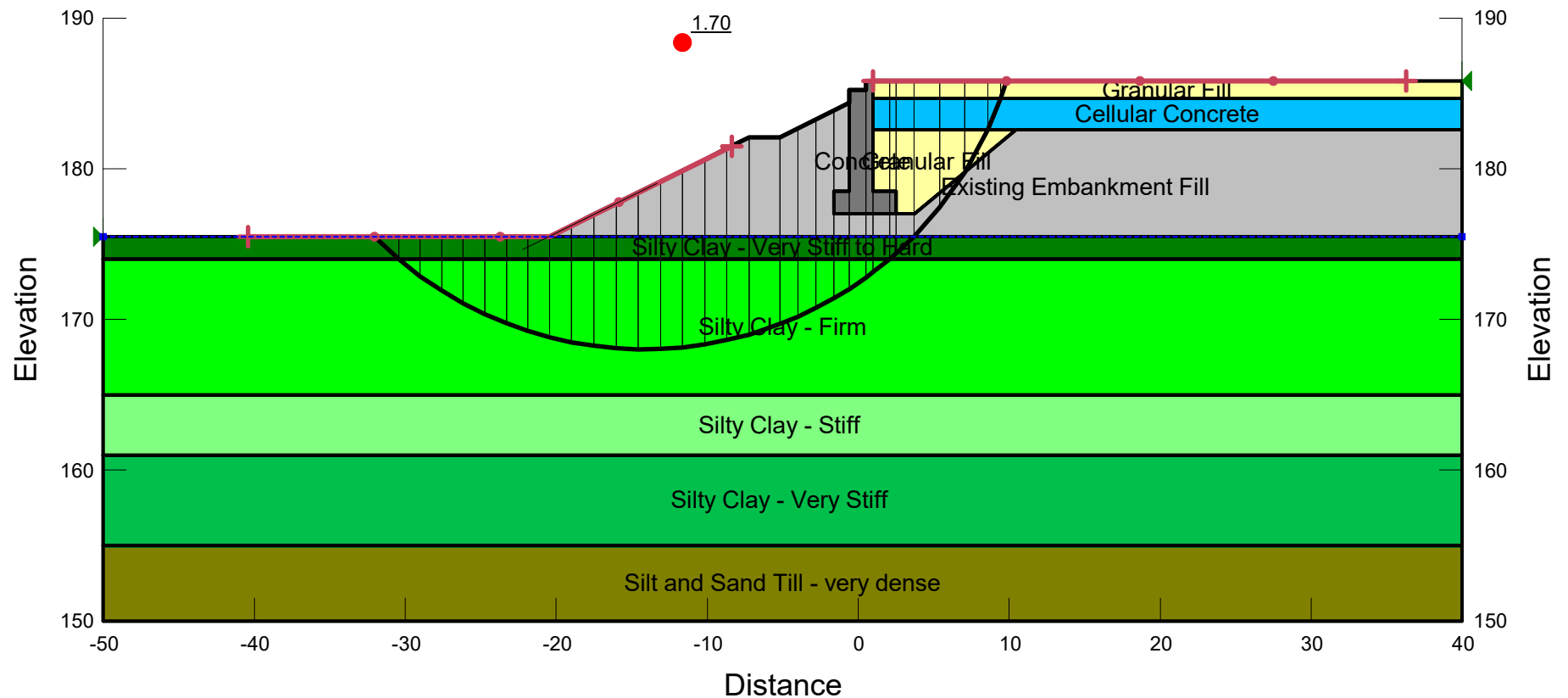




FIGURE I29

File Name: South Abutment Longitudinal - Cellular Concrete LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

Cellular Concrete	5 kN/m ³	0 kPa	0 °
Granular Fill	21 kN/m ³	0 kPa	35 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Concrete	1 kN/m ³	0 kPa	1,000 °
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

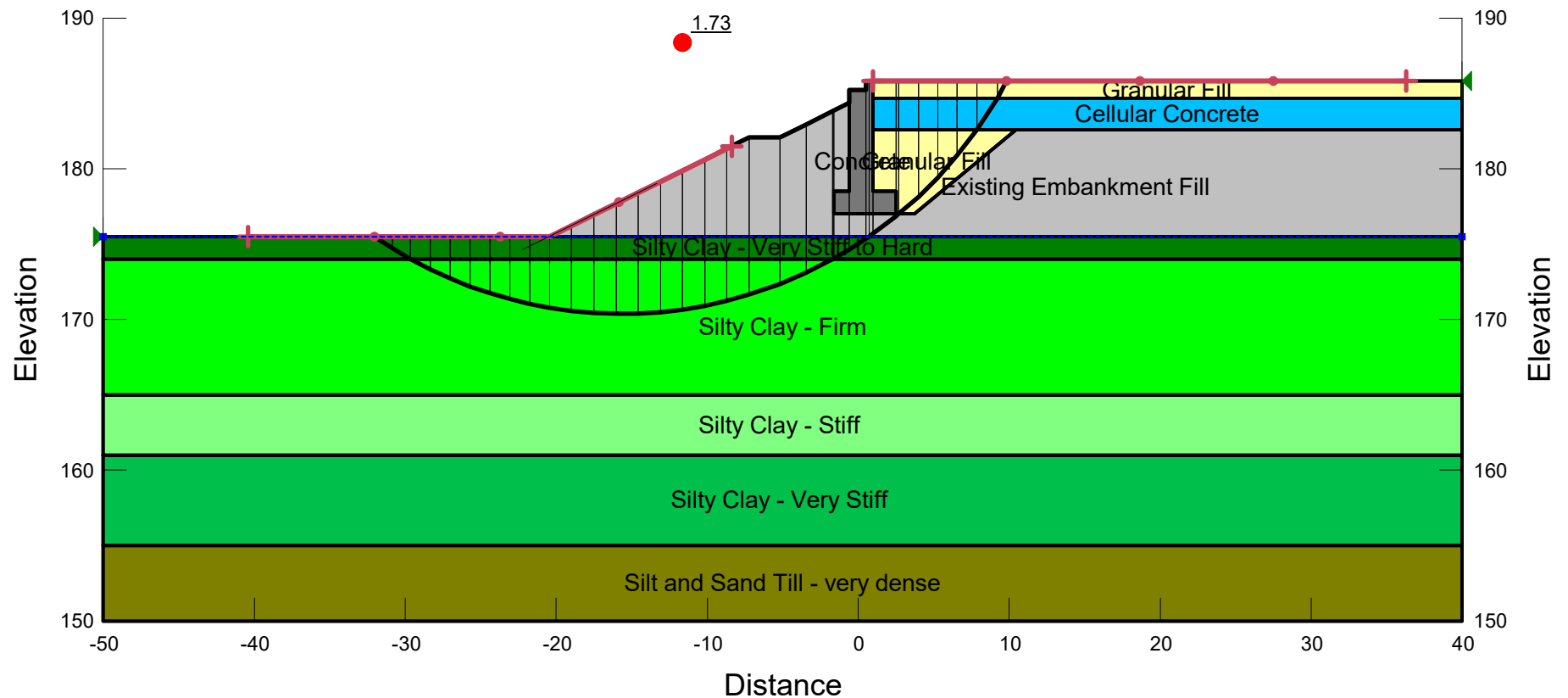


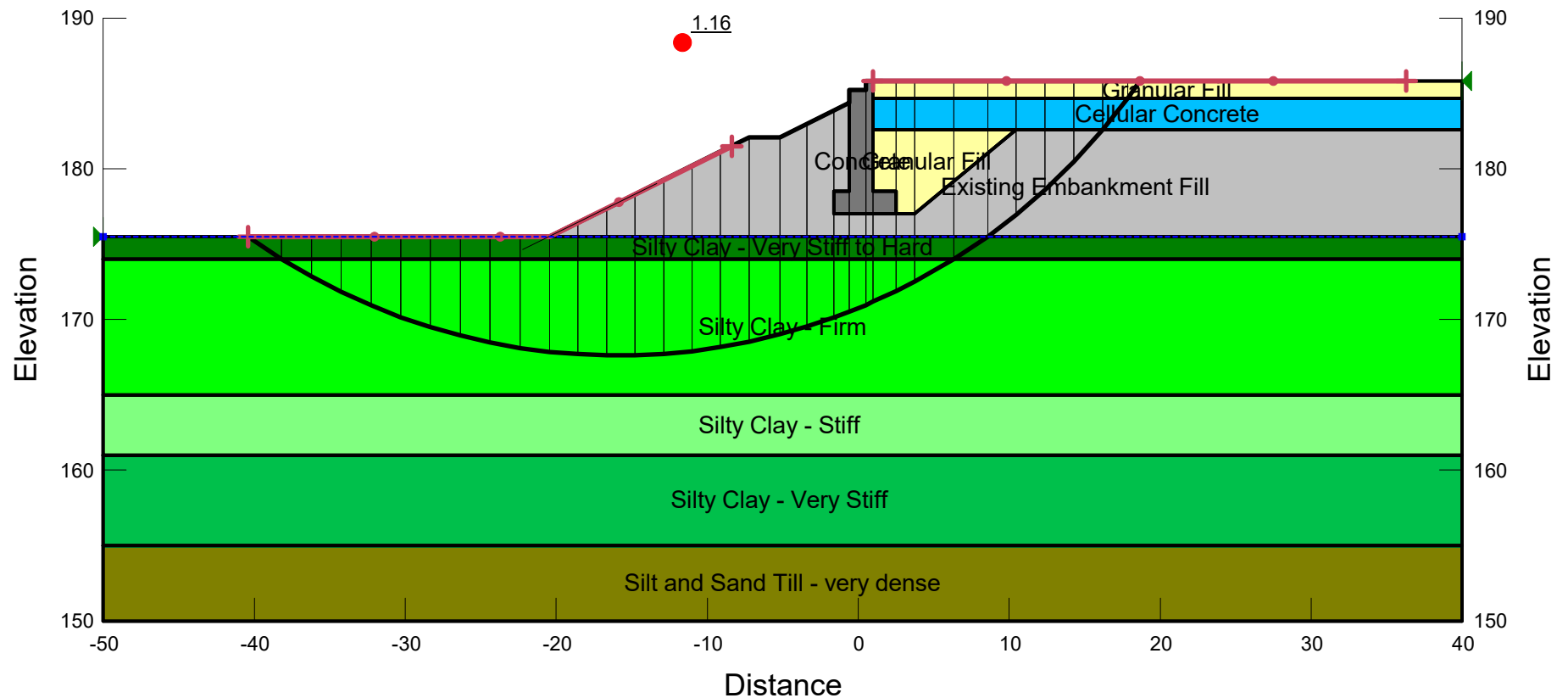


FIGURE I30

File Name: South Abutment Longitudinal - Cellular Concrete Seismic.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0.1g

Cellular Concrete	5 kN/m ³	0 kPa	0 °	0
Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Concrete	1 kN/m ³	0 kPa	1,000 °	0
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0





THURBER

File Name: South Abutment Longitudinal - EPS fill ST.gsz

Created By: Geoff Lay

Date: 8/29/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

FIGURE I31

EPS	1 kN/m ³	0 kPa	0 °	0
Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Concrete	1 kN/m ³	0 kPa	1,000 °	0
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0

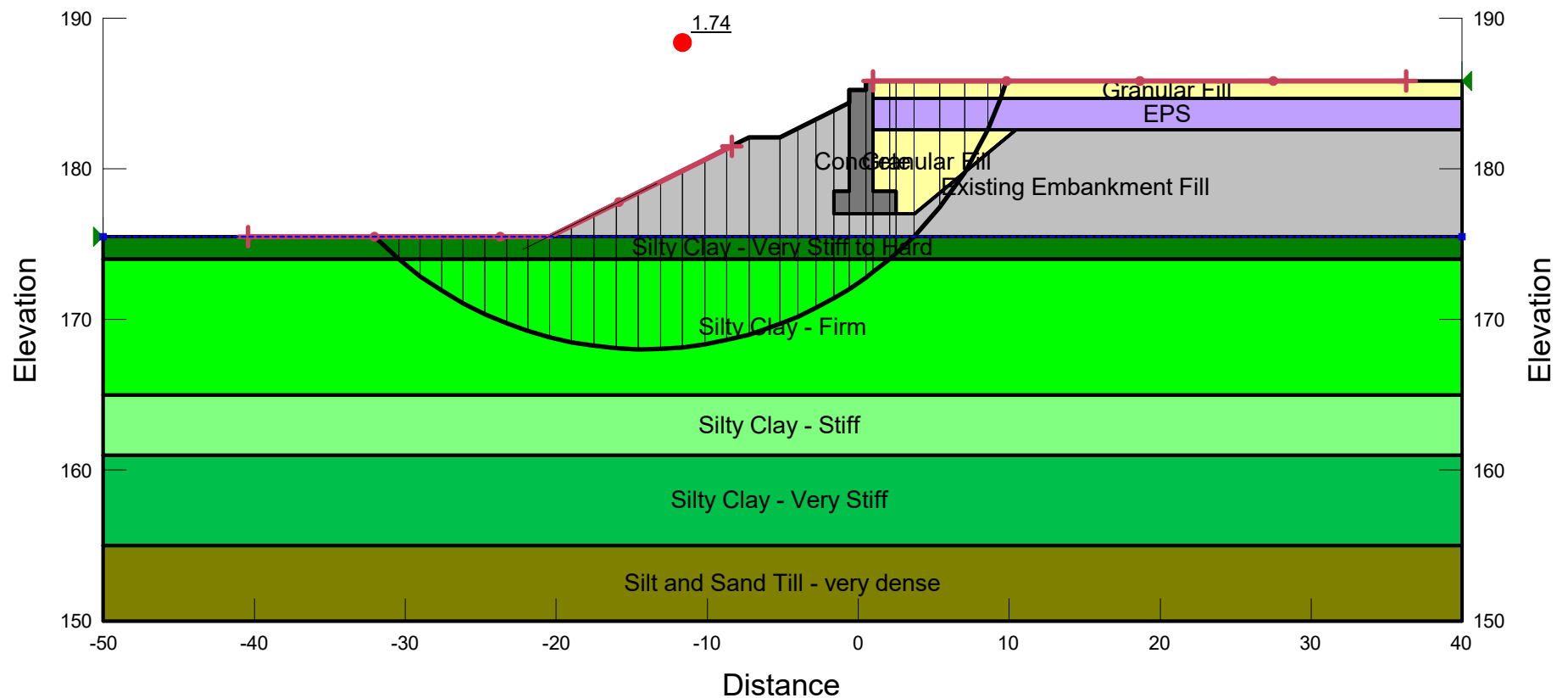




FIGURE I32

File Name: South Abutment Longitudinal - EPS fill LT.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

EPS	1 kN/m ³	0 kPa	0 °
Granular Fill	21 kN/m ³	0 kPa	35 °
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °
Concrete	1 kN/m ³	0 kPa	1,000 °
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °

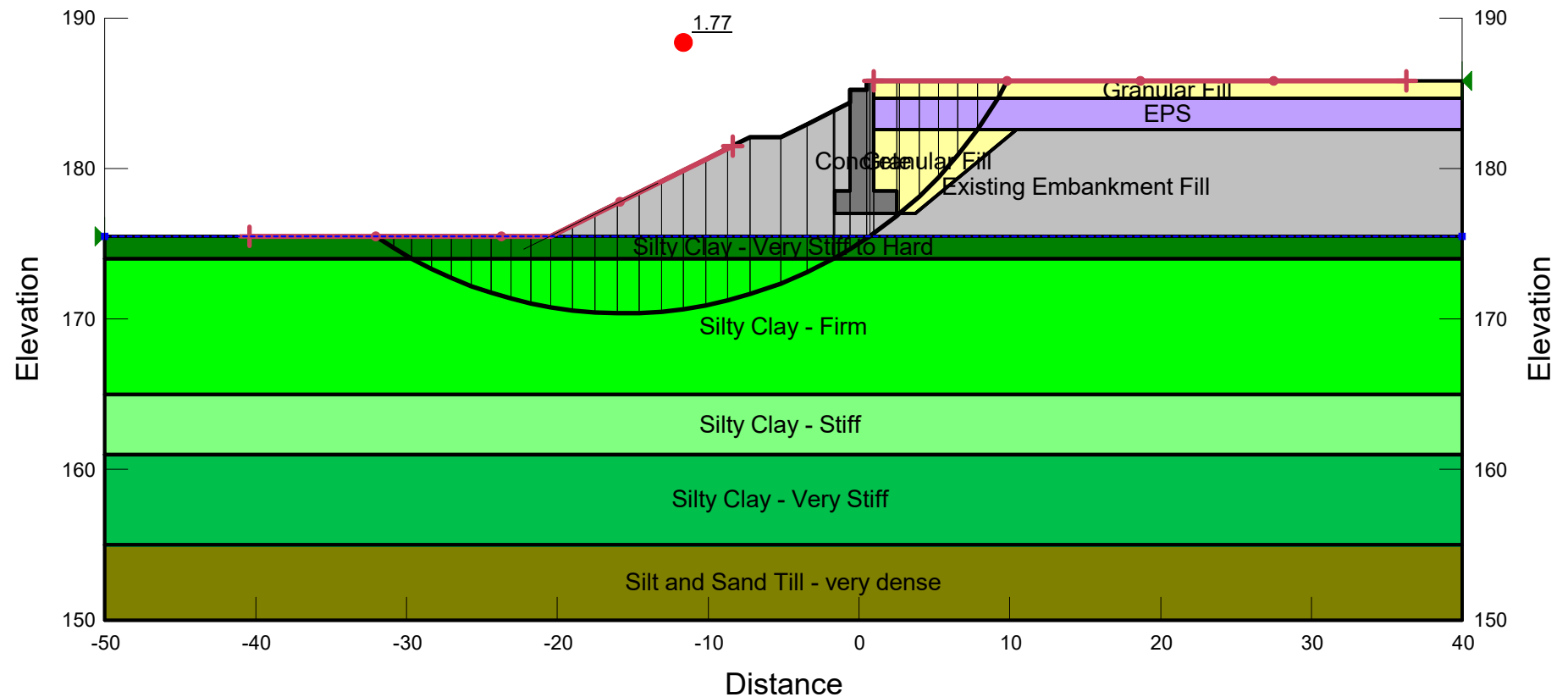


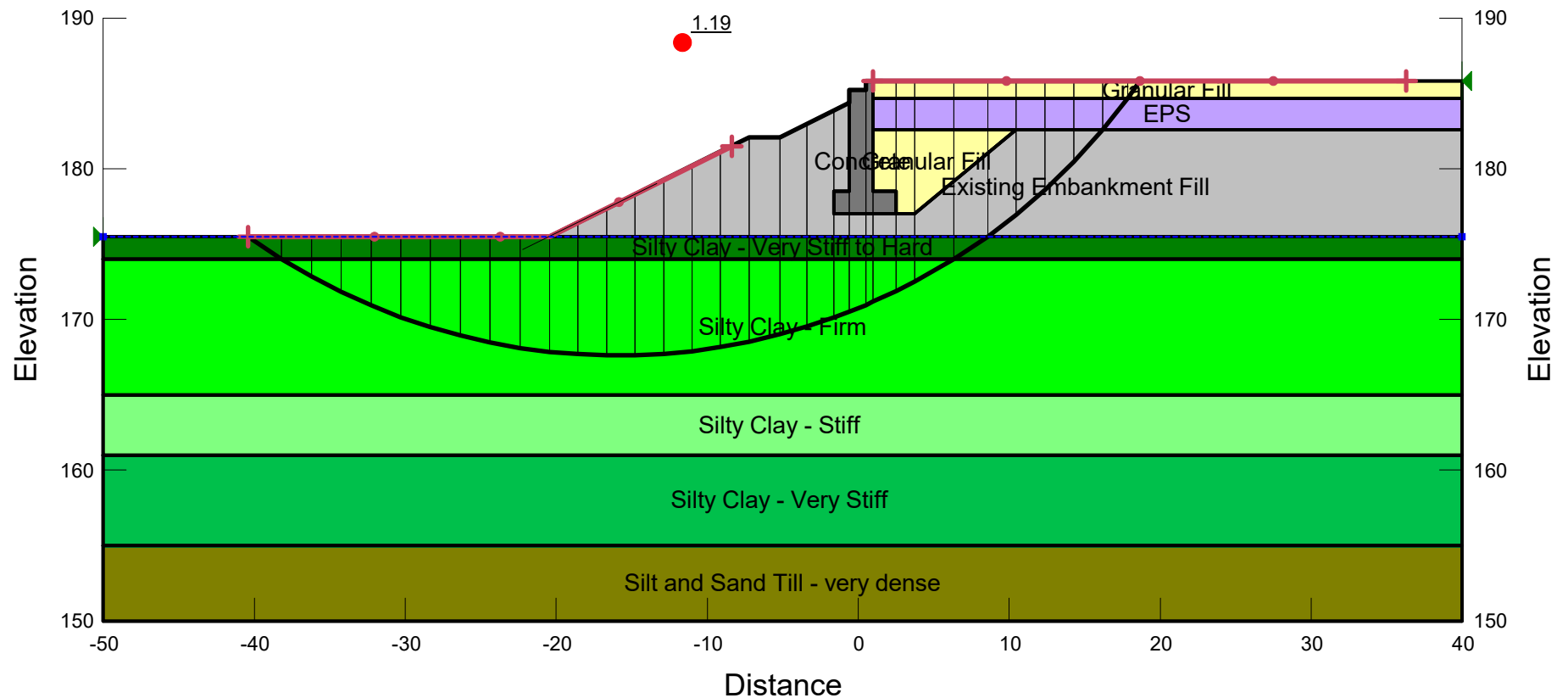


FIGURE I33

File Name: South Abutment Longitudinal - EPS fill Seismic.gsz
Created By: Geoff Lay
Date: 8/29/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0.1g

EPS	1 kN/m ³	0 kPa	0 °	0
Granular Fill	21 kN/m ³	0 kPa	35 °	0
Existing Embankment Fill	20 kN/m ³	0 kPa	30 °	0
Concrete	1 kN/m ³	0 kPa	1,000 °	0
Silty Clay - Very Stiff to Hard	21 kN/m ³	3 kPa	25 °	0.5
Silty Clay - Firm	18 kN/m ³	3 kPa	23 °	0.8
Silty Clay - Stiff	19 kN/m ³	3 kPa	25 °	0.8
Silty Clay - Very Stiff	20 kN/m ³	3 kPa	25 °	0.6
Silt and Sand Till - very dense	21 kN/m ³	0 kPa	34 °	0





Appendix J

Alternate EPS Configurations

FIGURE J1

South Approach (within 20 m of South Abutment)
2.2 m Grade Raise
- Remove existing asphalt (0.2 m thick)
- Place 1.2 m of EPS blocks
- Place 150 mm thick concrete slab above EPS blocks
- Construct pavement structure (~1050 mm)

Estimated Settlement:
- Settlement during construction
over 6 months = 19 mm
- Post-construction settlement
over 20 years = 22 mm

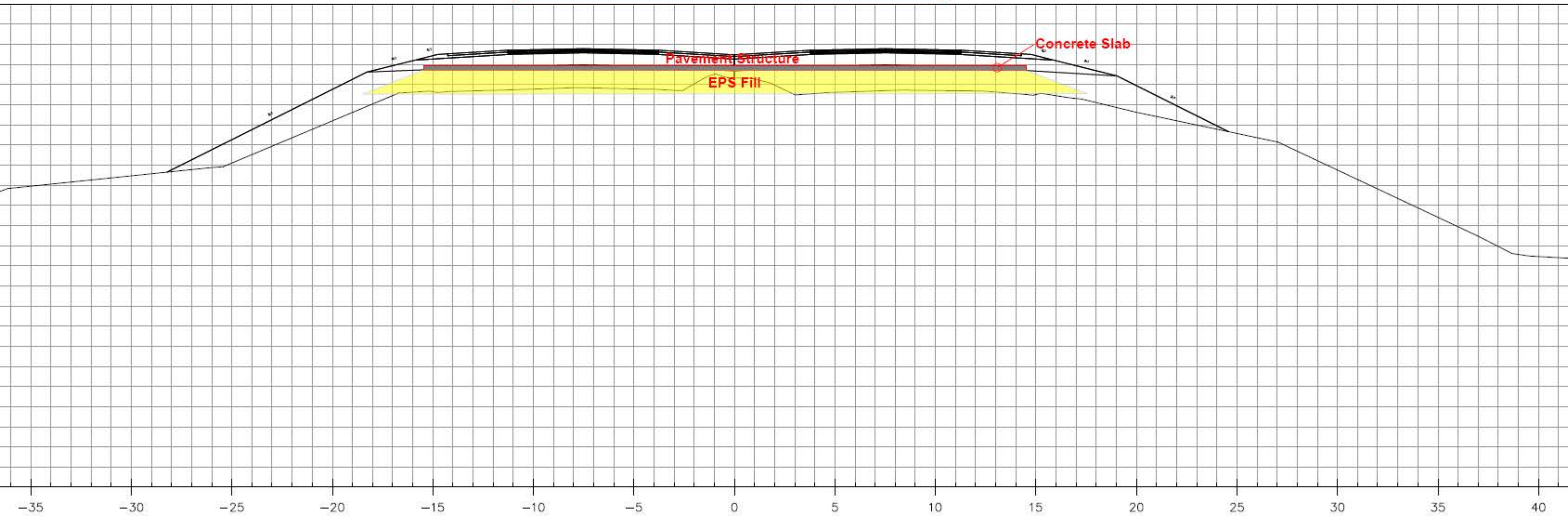
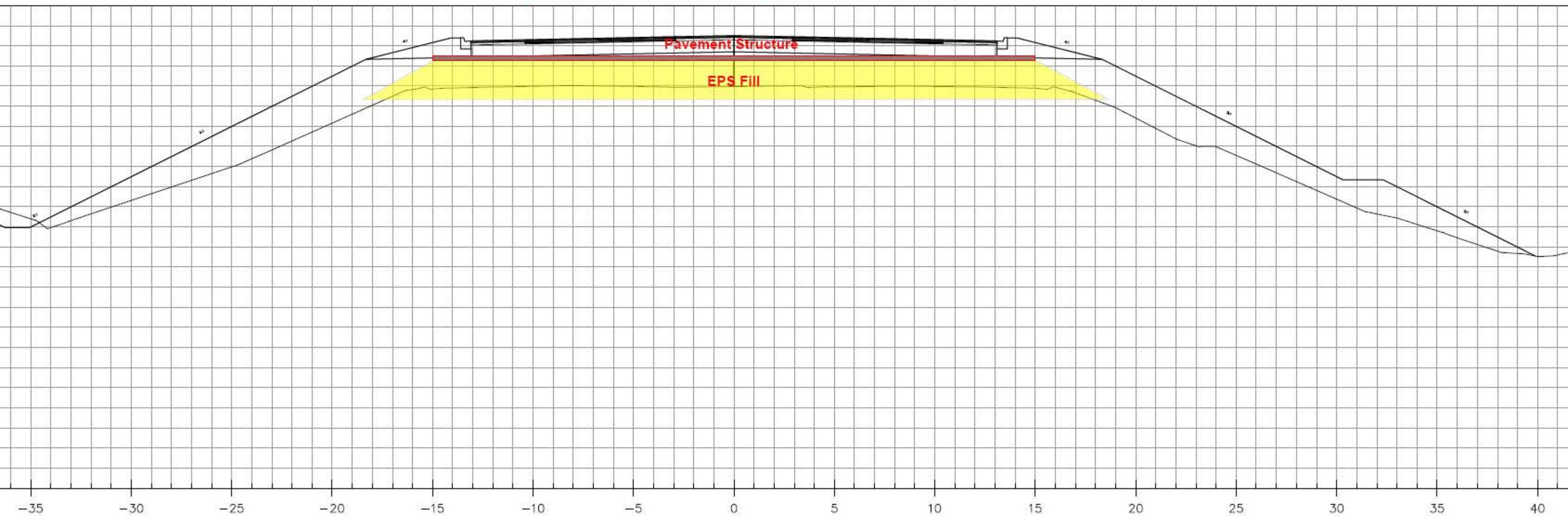


FIGURE J2

North Approach (within 20 m of North Abutment)
2.5 m Grade Raise
- Remove existing asphalt (0.2 m thick)
- Remove 0.5 m of existing sand and gravel fill
- Place 2.0 m of EPS blocks
- Place 150 mm thick concrete slab above EPS blocks
- Construct pavement structure (~1050 mm)

Estimated Settlement:
- Settlement during construction over 6 months = 25 mm
- Post-construction settlement over 20 years = 6 mm





Appendix K

List of SPs and OPSS, and Suggested Text for Selected NSSPs



1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS.PROV 206
- OPSS.PROV 501
- OPSS.PROV 517
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 903
- OPSS.PROV 1010
- OPSD 208.010
- OPSD 803.010
- OPSD 3090.100
- SP517F01
- SP FOUN0003

2. Suggested Text for NSSP on Pile Driving

The glacial till contains cobbles and boulders and slabs of bedrock. These cobbles and boulders and slabs may impede the driving of piles and at some locations the piles may not be able to penetrate the obstructions and reach the design depth of installation and refusal may be encountered at varying depths.

The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheet piles to the design depth.

The H-piles and pipe piles should be provided with pile tip protectors to minimize tip damage.

If the piles meet refusal at a depth less than the anticipated depth, the QVE must terminate driving before the pile is damaged due to over-driving. The QVE must immediately bring it to the attention of the CA. If the CA cannot resolve the issue, it must be referred to the design team for resolution.

3. Suggested Text for NSSP on Dewatering

Dewatering will be required to construct the pier foundations. The design of an effective dewatering system is the responsibility of the contractor. The dewatering system must be effective



to lower the groundwater table at a minimum of 0.5 m below the final subgrade level to avoid basal heave and base boiling. The dewatering system is to be designed in accordance with SP FOUN0003, OPSS.PROV.517 and SP517F01. A preconstruction survey is required. A dewatering engineer with a minimum of 5 years experience in designing dewatering systems shall be retained by the contractor for design of an effective dewatering system.

4. Suggested Text for NSSP on Temporary Protection Installation

The silty clay soils beneath the embankments are sensitive to vibrations. Roadway protection should not be installed using vibratory methods.

5. Suggested Text for NSSP on Removal of Temporary Protection

In areas where EPS blocks are installed adjacent to or close to the roadway protection, the roadway protection must not be extracted after completing the work since this extraction process will disturb the EPS. Where the protection system is left in place, the top shall be removed to a depth as recommended by OPSS 539.

6. Sample Special Provision for Rigid Expanded Polystyrene Embankment Fill

EXPANDED POLYSTYRENE FILL – Item No.

Special Provision

1.0 SCOPE

This special provision covers the requirements for the supply and construction of the rigid expanded polystyrene embankment fill and associated works as shown on the contract drawings.

2.0 REFERENCES

This special provision refers to the following standards, specifications or publications.

2.1 National Standards of Canada

CAN/CGSB - 51.20 M87

2.2 ASTM

ASTM D1621 Test Method for Compressive Properties of Rigid Cellular Plastics

ASTM C203 Test Method for Breaking Load and Flexural Properties of Block Type Thermal Insulation

ASTM C177 Test Method for Steady State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Apparatus

ASTM D2842 Test Method for Water Absorption by Rigid Cellular Plastics

ASTM D2863 Test Method for Measuring the Minimum Oxygen Content

ASTM D2126 Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging

2.3 OPSS - Ontario Provincial Standard Specification

OPSS 212 Borrow

OPSS 501 Compaction

OPSS 517 Dewatering

OPSS 1010 Aggregates – Granular A, B, M, and Selected Subgrade Material

OPSS 1605 Expanded Extruded Polystyrene Pavement Insulation

3.0 SUBSURFACE CONDITIONS

The subsurface conditions at the site are described in the Foundation Investigation Report for this Contract.

4.0 DEFINITIONS

For the purpose of this special provision, the following definitions apply:

Rigid Expanded Polystyrene: Moulded rigid blocks produced by a process of pre-expansion, aging and forming of petroleum based raw material.

Rigid Extruded Expanded Polystyrene: Rigid boards made by extrusion of expanded polystyrene beads.

Production Lot: The quantity of rigid polystyrene blocks produced in a continuous period of manufacturing the same grade and thickness of product within the same production day.

Quality Verification Engineer: Quality Verification Engineer means an Engineer with a minimum of five (5) years experience related to the design and/or construction of expanded polystyrene systems of similar scope to that in the Contract, or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to ensure conformance with the contract documents and issue of certificate(s) of conformance.

5.0 QUALIFICATION

The Contractor shall have on site at the commencement of the work, a representative of the supplier of the rigid expanded polystyrene to advise on recommended construction procedure.

The Contractor shall maintain liaison with the supplier throughout the construction of the embankment for advice and guidance as required. Periodic site visits by the supplier should be coordinated as required.

6.0 SUBMISSION AND DESIGN REQUIREMENTS

6.1 Submission of Shop Drawings

At least three weeks before the commencement of work, the Contractor shall submit to the Contract Administrator six copies of the shop drawings and method statement signed and sealed by the Quality Verification Engineer that provides full details of materials and construction procedure.

6.2 Delivery, Storage, Handling, and Protection

The Contractor shall submit the method of delivery, storage, handling and protection from damage by weather, traffic, construction staging and other causes as per the rigid expanded polystyrene manufacturers requirement.

6.3 Construction

The contractor shall submit full details of the following.

- a) The method of foundation excavation and preparation.
- b) Construction of levelling pad.
- c) The method of placement of expanded polystyrene blocks including temporary ballasting and protection of blocks during installation. The shop drawings shall indicate laying pattern and block dimensions on a layer-by-layer basis.
- d) The method and limits of placement of polyethylene sheeting.
- e) The method of placement of 125 mm reinforced concrete base pad (or equivalent).
- f) The method of placement of subbase material.
- g) The method of placement of side slope cover.

6.4 Quality Verification Engineer

- (1) The Contractor shall submit details of the sequence and method of installation to the Quality Verification Engineer for review. The submittals shall satisfy the specifications and at a minimum include a detailed description of proposed installation procedures. The details shall be submitted at least three weeks prior to the installation of the rigid expanded polystyrene embankments the Contractor shall also submit to the Contract Administrator, for information purposes, details of the sequence and method of installation. The submittals shall satisfy the specifications and at a minimum contain the above information as provided to the Contractor's Quality Verification Engineer.
- (2) The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the installation procedures are in conformance with the requirements and specifications of the contract documents. Quality test certificates for each production lot supplied, showing compliance with all requirements of this special provision shall be obtained by the Contractor and submitted to the Contract Administrator prior to installation. Upon completion of the Expanded Polystyrene Embankment the Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer stating that the Expanded Polystyrene Embankment has been constructed in conformance with the installation procedures and specifications of the contract documents.

7.0 MATERIALS

7.1 Granular Levelling Pad

The levelling pad shall consist of a Granular “A” material with gradation and physical requirements as specified in OPSS 1010.

7.2 Rigid Expanded Polystyrene

7.2.1 General

7.2.1.1 The Contractor shall submit:

1. A general statement as to the type, composition, and method of production of the material.
2. The manufacturer’s name, address, phone number, identification of a contact person and description of experience background in the manufacturing of the rigid expanded polystyrene.
3. Certification of compliance of physical and mechanical properties.
4. An identification of a laboratory accredited by the Standards Council of Canada to conduct the testing of the physical and mechanical properties of the rigid expanded polystyrene.
5. The physical and mechanical properties of the rigid expanded polystyrene including:
 1. Geometry
 2. Nominal Density
 3. Compressive Strength
 4. Flexural Strength
 5. Thermal Resistance
 6. Dimensional Stability
 7. Flammability
 8. Water Absorption
6. Aging and durability characteristics of the polystyrene including the chemical, biological and ultra-violet degradation resistance of the rigid polystyrene.
7. A sample of the expanded polystyrene material to the Quality Verification Engineer for review.
8. To the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the expanded polystyrene material is in conformance with the requirements and specifications of the contract documents.

7.2.1.2 Production Lots

Each block of the same production lot shall be stamped with the same production code showing plant identification, type and date of production. The polystyrene shall be free from defects affecting serviceability.

7.2.2 Detail Requirements

Requirements shall be as shown in Table 1 and as described below.

Table 1 – Material Properties

PROPERTY	UNIT	REQUIREMENTS	TEST PROCEDURE
Geometry - Linear - Flatness - Squareness - Thickness	mm	1200 x 600 x 300 with tolerances $\pm 1\%$ 10 mm in 3 m $\pm 0.5\%$ -3, +5	
Compressive Strength	kPa (min)	170	ASTM D1621 (Procedure A)
Flexural Strength	kPa (min)	345	ASTM C203
Dimensional Stability	% linear change (max)	1.5	ASTM D2126
Thermal Resistance	m ² .°C/W (min for 25 mm thickness)	0.7	ASTM C177 or C518
Flammability	Limiting Oxygen Index (min)	24	ASTM D2863
Water Absorption	% by Volume (max)	2	ASTM D2842

7.2.2.1 Geometry

The expanded polystyrene shall be supplied in the form of rectangular parallel blocks of minimum acceptable dimensions of 1200 mm x 600 mm x 300 mm.

The maximum deviation from the specified linear dimensions shall be $\pm 1\%$. The flatness of the block faces shall be within ± 10 mm of a line formed by a 3 m straight edge.

The maximum difference in corner-to-corner dimensions (squareness) shall be 0.5%. The thickness shall be within -3 to $+5$ mm.

7.2.2.2 Compressive Strength

The minimum compressive strength, measured in accordance with ASTM D1621, Procedure A, shall be 110 kPa at a strain of not more than 5%. The maximum permissible permanent stress level should not exceed 30% of the compressive strength of the material at 5% strain.

7.2.2.3 Flexural Strength

The minimum flexural strength of the polystyrene shall be 240 kPa. The flexural strength shall be determined in accordance to ASTM C203, method 1, Procedure B.2.7.4 Dimensional Stability.

7.2.2.4 Dimensional Stability

Dimensional Stability shall be determined in accordance with ASTM D2126, Procedure G. A tolerance of 1.5% shall be satisfied.

7.2.2.5 Thermal Resistance

The thermal resistance shall be $0.7 \text{ m}^2 \cdot ^\circ\text{C}/\text{W}$ for a 25 mm thickness using the following equation and using the average value from three specimens:

$$R_{25\text{mm}} = \frac{R_{\text{measured}}}{\text{thickness (mm)}} \times 25$$

The thermal resistance shall be measured in accordance with ASTM C177 or C518.

7.2.2.6 Flammability

The expanded polystyrene shall be classified as to surface burning characteristics in accordance with CAN/ULC - 51022 having a flame spread rating less than 500. The expanded polystyrene shall have a minimum limiting oxygen index measured in accordance with ASTM D2863

7.2.2.7 Water Absorption

The water absorption as measured by ASTM D2842 shall be limited to 4% by volume.

7.2.2.8 Chemical Resistance

The expanded polystyrene shall be resistant to common inorganic acids and alkalies. A table identifying the chemical resistance as either resistant limited or not resistant shall be submitted.

7.2.2.9 Biological Resistance

The expanded polystyrene shall be resistant to biological degradation caused by organisms or enzymes.

7.2.2.10 Environmental

The expanded polystyrene shall be inert, non-nutritive and highly stable and shall not produce undesirable gases or leachate.

8.0 DELIVERY, STORAGE AND HANDLING

The product shall be suitably marked to identify its type, number and the manufacturer's name or trademark.

The Contractor shall protect the expanded polystyrene from exposure to sunlight to avoid ultraviolet degradation as per manufacturer's recommendation.

Protection of materials and works from damage by weather, traffic, construction staging, fire or vandalism and other causes shall be the responsibility of the Contractor.

9.0 CONSTRUCTION

9.1 Foundation Excavation

Foundation excavation shall be carried out to the design elevations shown on the drawings. Any softened, loosened or deleterious materials at the foundation footing elevation shall be subexcavated and replaced with Granular 'A' or Granular 'B' material.

9.2 Leveling Pad

Place, level and compact a layer of Granular 'A' or Granular 'B' material in accordance with OPSS 501 to within ± 30 mm of the design elevation. The leveling pad shall not deviate by more than 10 mm at any place on a 3 m straight edge over the limits of the bottom course of blocks. The leveling pad shall not be placed on frozen ground.

9.3 Installation of Blocks

- (1) The individually marked blocks shall be placed on the prepared leveling pad. The top surface of the first layer of blocks is to be set plane and level. Local trimming of the blocks may be necessary.
- (2) Subsequent successive layers shall be oriented with the long axis of blocks positioned at 90° to the previous layer in order to avoid continuous joints. Block joints shall be offset and staggered between layers.
- (3) A continuous check shall be kept to ensure the evenness of the blocks is satisfactory in each layer. Blocks shall be laid with joints with maximum opening of 10 mm between blocks. Differences in heights between adjacent blocks in the same layer should not exceed 5 mm.
- (4) Sloping end adjustments at the abutments shall be accomplished by leveling terraces in the subsoil in accordance with the block thickness.
- (5) Temporary ballast shall be provided as necessary to prevent movement of expanded polystyrene both in storage and as placed due to windy conditions. Timber fasteners or equivalent shall be used as necessary.
- (6) The expanded polystyrene embankment shall be protected from accidental ignition due to welding, smoking, grinding or cutting tools, etc. The Contractor shall take all necessary precautions to prevent ignition of the expanded polystyrene.
- (7) The expanded polystyrene shall be protected from organic solvents and other aggressive, harmful chemicals during construction. The proposed method of protection during

construction shall be submitted to the Contractor's Quality Verification Engineer for review and to the Contract Administrator for information purposes.

- (8) Exposed blocks shall be covered immediately to avoid possible burrowing by animals.
- (9) Individually marked blocks shall be fabricated and placed to ensure the top surface matches the elevation and crossfall shown on the drawings.
- (10) The top surface and side surfaces of the expanded polystyrene shall be covered with 0.6 mil polyethylene sheeting extending onto adjacent work at the longitudinal ends of the embankment. All joints shall be lapped a minimum of 300 mm to provide a fully sealed enclosure.
- (11) The contractor shall install the concrete base pad as detailed elsewhere in the contract.
- (12) The side slope of the rigid expanded polystyrene embankment shall be covered with Lightweight fill and waste material as detailed elsewhere in this contract.

10.0 EQUIPMENT

All cutting of polystyrene materials shall be by electric equipment or by hand.

Heavy equipment shall be limited in weight and size and restricted in operation to avoid damaging the expanded polystyrene as per the manufacturer's requirement.

11.0 QUALITY ASSURANCE

General

The Contract Administrator may undertake an independent testing program of the expanded polystyrene. Sampling and testing will be carried out in conformance with the relevant test procedure. The physical and thermal property testing identified in Table 1 will be conducted. A recognized testing laboratory accredited by the Standards Council of Canada shall conduct the testing.

Sampling Frequency

Sufficient sample material shall be obtained from blocks randomly selected by the Contract Administrator from each production lot as soon as the material arrives on site. As a minimum, three blocks shall be tested.

Acceptance/Rejection

Failure of any one of the sample blocks to comply with any requirements of this special provision shall be cause for rejection of the production lot from which it was taken. Replacement of the blocks shall be at the Contractor's expense.

12.0 MEASUREMENT FOR PAYMENT

Actual Measurement

Measurement will be by volume in cubic metres measured in its original position and based on cross-sections.

13.0 PAYMENT

Basis of Payment

The Concrete Base pad and granular leveling pad shall be paid for with the appropriate tender items as detailed elsewhere in the contract.

Payment at the contract price for the above tender item shall be full compensation for all labour, materials and equipment to do the work as described above and no extra payments will be made.

WARRANT: Always with this tender item.