

**Foundation Investigation and  
Design Report – New Highway  
401 Interchange at  
Wonderland Road**

Highway 401, City of London

DB Contract 2012-3022  
G.W.P. 3031-11-00

Geocres No. 40I14-152



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# FOUNDATION INVESTIGATION AND DESIGN REPORT – NEW HIGHWAY 401 INTERCHANGE AT WONDERLAND ROAD

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## FOUNDATION INVESTIGATION REPORT

For

DB 2012-3022

G.W.P 3031-11-00

New Highway 401 at Wonderland Road Interchange  
City of London

## 1.0 Introduction

Aecon Construction and Materials Ltd. (Aecon) is constructing the interchange for the Ministry of Transportation of Ontario under a Design-Build agreement. Stantec Consulting Ltd. (Stantec) was retained by Aecon to undertake a detailed design for a new Highway 401 interchange at Wonderland Road South in the City of London, Ontario. The assignment includes a foundations assessment for new overpasses, retaining walls and interchange ramps. The project also includes the replacement of the Courtney Drain culvert beneath Highway 401, located approximately 700 m southwest of the proposed new interchange location.

This Foundation Investigation Report has been prepared specifically and solely for the proposed new interchange and culvert replacement.

Project Number: G.W.P.: 3031-11-00

Agreement Number: DB Contract 2012-3022

Project Location: Highway 401 at Wonderland Road South, London

## 2.0 Site Description and Geology

### Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A.

### General Site Description

At the project site, Highway 401 runs approximately in the southwest-northeast direction. Highway 401 is a four-lane (two lanes in each direction) divided freeway. The existing Wonderland Road South has a single lane in each direction and is oriented approximately north-south and terminates approximately 90 m north of Highway 401. It then continues approximately 240 m south of Highway 401 where it intersects with the existing Morrison Road and Manning Drive and runs in a slightly southeasterly direction. For the purpose of this project, Highway 401 is assumed to run in the east-west direction while Wonderland Road is assumed to run in the north-south direction.

Photographs 1 through 7 show the general site features.

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The existing drainage at this site consists of catch basins along the paved center median, leading to storm sewers, along with ditches and culverts along the outside lanes.

Chainage increases from west to east on Highway 401 and north to south on Wonderland Road.

## Physiographic Description

The site is located within a physiographic region known as the Mount Elgin Ridges (Chapman and Putnam, 1984). The ridges are generally moraines of pale brown calcareous clay or silty clay, whereas the vales generally consist of alluvium deposits of gravel, sand or silt. These regions were formed from clay till similar to that of Wyoming Moraine and the Stratford plain. The specific area of the project site is located within the western limits of the Westminster Moraine found within the Mount Elgin Ridge physiographic region. Existing geological information suggests that the subsurface soils within the general area of the project site consist predominantly of silty clays and clayey silt tills with localized lacustrine deposits.

In the vicinity of the project site the terrain is generally undulating with gentle slopes and, hence, features good natural drainage in some areas.

## **3.0 Investigation Procedures**

### **3.1 REVIEW OF EXISTING INVESTIGATION**

Geotechnical investigation results for two boreholes in the immediate vicinity of the proposed overpass were reviewed as part of the current report. The investigation results were made available to Stantec by MTO (Geocres Report No. 40I14-132). These boreholes were designated BH1 and BH2; their locations and the corresponding strata plots are shown on the Borehole Location Plan, Drawing No. 1A, 1B and 1C in Appendix A.

### **3.2 FIELD INVESTIGATION**

The geotechnical investigation for the Detail Design of the proposed new interchange and culvert replacement consisted of a total of 15 test holes. These included 10 drilled boreholes (BH13-1 through BH13-7, BH13-9, BH13-10 and BH13-12) and two piezocone soundings (CPTs) (CPT13-8 & 13-11) for the new interchange and three drilled boreholes for the culvert replacement (BH13-13 through BH13-15). In-situ undrained shear strength measurements were carried out at two locations in the immediate vicinity of the drilled boreholes (BH13-2 and BH13-5) using a digital vane (Nilcon® vane) to better characterize the site soil and establish a site-specific correlation.

The locations of the boreholes and CPT soundings are shown on the Borehole Location Plans, Drawing Nos. 1A, 1B and 1C in Appendix A.

Prior to carrying out the investigation, Stantec contacted the public utility authorities to clear the borehole locations of both private and public utilities.

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The field drilling program was carried out from October 21 through November 9, 2013. The boreholes were advanced using continuous flight hollow stem augers and tri-cone with solid stem augers. Drilling was carried out with a truck-mounted D-90 drill rig and a track-mounted CME 75 drill rig, both equipped for soil sampling.

The subsurface stratigraphy encountered in each borehole was recorded in the field by an experienced Stantec field technician. Standard Penetration Tests (SPT) were carried out in all drilled holes and split spoon samples were collected at regular intervals: every 760 mm for up to 10 m below existing ground surface, every 1.5 m from 10 to 20 m depth, and every 3.0 m for deeper strata. Twelve Shelby Tube samples were also retrieved. All SPT samples recovered were returned to our Ottawa laboratory for detailed classification and testing. The Shelby Tube samples were sent to the Golder Associates Mississauga laboratory for consolidation and unconfined strength testing.

Where a cohesive soil was encountered, the undrained shear strength of soils was determined with in-situ shear vane, pocket penetrometer tests, and laboratory unconfined compressive tests.

Vibrating wire piezometers were installed in four boreholes: BH13-1, BH13-3, BH13-4 and BH13-13. The piezometers were installed in these boreholes to depths of 9.1, 9.2, 9.1 and 6.1 m, respectively. Each vibrating wire piezometer consisted of sensor with a small diameter cylindrical housing containing a pressure transducer and a thermistor. An output cable is attached to this unit to transmit the readings to the ground surface. The installation of the vibrating wire piezometer was in accordance with the manufacturer's instructions. The collection zone consisted of a minimum 300 mm long region above and below the sensor tip and was backfilled with sand. The portion of the hole below the collection zone was backfilled with a bentonite seal. The portion of the hole above the collection zone was backfilled with a mix of bentonite and drill cuttings.

A groundwater monitoring well was installed in one borehole (BH13-5). The monitoring well consisted of a 50 mm diameter, 8.1 m long PVC pipe slotted over the lower 2 m. The annulus around the slotted pipe section was backfilled with sand. The hole below the sand and the annular section immediately above the slotted pipe section was backfilled with bentonite. The top 300 mm of the annulus was backfilled with sand to the ground surface.

Groundwater was also observed in open boreholes during drilling in all remaining boreholes.

Groundwater level measurements were carried out on November 10, 2013. Except for BH13-3, the groundwater level measurements were conducted at least one week after installation of vibrating wire piezometer or monitoring wells. The groundwater level in BH13-3 was measured two days after installation of vibrating wire piezometer.

The use of a seismic piezocone (cone penetration test) was proposed at five locations as part of this investigation to characterize the strength and settlement characteristics of the cohesive soils at the site. Due to the high stiffness of the cohesive soils, the drill rig lifted during pushing and three of the seismic piezocone could not be pushed. Three of the proposed seismic piezocone

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tests were replaced with conventional boreholes (BH13-9, BH13-10 and BH13-12) and a series of laboratory unconfined compressive tests.

After completion of drilling, boreholes were backfilled with a mix of bentonite and drill cuttings. Road holes were sealed with cold patch asphalt.

## 3.3 LOCATION AND ELEVATION SURVEY

The location and ground surface elevation at each borehole and CPT sounding location were surveyed by Stantec's Geomatics group in London, Ontario, after completion of drilling investigation. Summary information pertaining to the Stantec boreholes included in this report is given in Table 3.1.

**Table 3.1: Borehole Information Summary**

Test Hole	MTM Zone 11 Coordinates		Ground surface elevation (m)	Total depth drilled (m)	End of borehole elevation (m)	Depth augered (m)	Number of soil samples
	Northing	Easting					
BH13-1	4749172.4	406204.4	263.2	12.0	251.2	12.0	16
BH13-2	4749125.0	406237.7	264.6	12.0	252.6	12.0	16
BH13-3	4749089.8	406247.7	266.9	49.4	217.5	49.4	31
BH13-4	4749013.0	406243.7	267.6	29.9	237.7	29.9	27
BH13-5	4748980.7	406270.8	268.1	12.0	256.1	12.0	16
BH13-6	4748989.1	406294.0	267.8	12.0	255.8	12.0	16
BH13-7	4748877.6	406295.8	267.5	12.0	255.5	12.0	16
CPT13-8	4749119.7	406218.4	264.4	12.4 <sup>*)</sup>	252.0	NA	NA
BH13-9	4749030.2	406236.9	267.7	31.1	236.6	31.1	24
BH13-10	4749071.8	406253.8	267.3	31.1	236.2	31.1	25
CPT13-11	4749026.1	406262.3	266.8	10.3 <sup>*)</sup>	255.5	NA	NA
BH13-12	4748926.5	406282.8	268.0	12.0	256.0	12.0	16
BH13-13	4748459.5	405865.7	260.2	9.9	250.3	9.9	13
BH13-14	4748472.5	405909.9	263.7	12.0	251.7	12.0	16
BH13-15	4748475.8	405957.6	260.5	9.8	250.7	9.8	13

Note: No bedrock coring was carried out at this site.

## 3.4 LABORATORY TESTING

All samples were taken to Stantec's Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer.

The geotechnical laboratory testing program for the borehole samples is summarized in Table 3.2.

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**Table 3.2: Geotechnical Laboratory Testing Program**

Test Description	Number of Tests	Remarks
Moisture Content	258	by Stantec
Atterberg Limits	42	by Stantec
Grain Size Distribution (sieve & hydrometer)	46	by Stantec
Consolidation (oedometer)	4	by Golder
Unconfined Compression (soil)	12	by Golder
Specific Gravity	4	by Golder

Two soil samples were tested for pH, soluble sulphate content, chloride content, and resistivity. Organic content tests were performed on five samples.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by MTO.

## 4.0 Subsurface Conditions

### 4.1 OVERVIEW

The subsurface conditions will be presented separately for the new interchange site and the culvert replacement site.

It is noted that clay size particles include all particles smaller than 0.002 mm.

### 4.2 INTERCHANGE SITE

#### 4.2.1 General

The subsurface conditions observed in the 10 boreholes for the interchange site are presented in detail on the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix B.

#### Previous Investigation

The geotechnical investigation results for two boreholes from Geocres Report No. 40I14-132 are also included in Appendix B. Based on this report, the subsurface condition at the two boreholes generally consisted of variable thicknesses of topsoil underlain by 2.8 to 4.3 m of very stiff to hard clayey silt crust which was underlain by an extensive deposit of firm to hard clayey silt materials to the maximum investigation depth of 50.3 m (approximate elevation of 217.5 m). No bedrock was encountered within the depth of exploration. Both boreholes were noted to be dry (i.e., no standing groundwater) during drilling. However, groundwater level was inferred to be at approximate elevation 262 to 263 m.

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Based on the current investigation, the subsurface stratigraphy generally consisted of asphalt pavement over roadway fill material or topsoil over a silty clay/clayey silt crust layer over an extensive deposit of silty clay to clayey silt with occasional seams of silty fine sand and sandy silt.

It is noted that the subsurface profile encountered in the current boreholes is generally consistent with the two preliminary investigation boreholes summarized above (Geocres Report No. 40114-132).

Detailed descriptions of the subsurface conditions are given below. Borehole location plans and stratigraphic sections of the soils encountered within the boreholes are provided on Drawing Nos. 1a through 1c of Appendix A.

## 4.2.2 Overburden

### 4.2.2.1 Pavement

Asphalt pavement was encountered in two boreholes, BH13-9 and BH13-10. The observed asphalt thicknesses were approximately 100 and 150 mm.

### 4.2.2.2 Roadway Fill

Roadway fill material was encountered below topsoil or roadbase granulars in Boreholes BH13-1, BH13-3, BH13-4, BH13-5, BH13-7, and BH13-12 and immediately beneath asphalt in BH13-9 and BH13-10. The thickness of the fill material ranged approximately between 0.2 m (BH13-7) and 1.9 m (BH13-10), extending to base elevations 262.4 m (BH13-1) to 267.4 m (BH13-12).

The fill material was predominantly composed of sand and gravel with some clay and organics. The Standard Penetration Test (SPT) blow count (N-value) of the fill material ranged between 7 and 22 blows per 0.3 m.

Organic content tests performed on three samples of the fill material indicated organic content range of 3.2% to 5.5%.

Index tests carried out on representative samples of the fill material yielded the following results:

Gravel:	1 to 45%
Sand:	11 to 51%
Fines (silt & clay):	10 to 88%
Moisture Content:	5 to 28%

Representative grain size distribution plots for the fill material are given in Figure 1a and 1b of Appendix C. The Unified Soil Classification System (USCS) group symbol for the fill material is SM (silty sand with gravel) and CI (silty clay).

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## 4.2.2.3 Topsoil

Topsoil was encountered in BH13-2 and BH13-6. The observed thickness of topsoil was approximately 600 and 80 mm, respectively. The topsoil contained some organics. The topsoil had a moisture content of approximately 28%.

## 4.2.2.4 Silty Clay (Crust)

A silty clay layer was encountered in all boreholes immediately beneath the fill material or topsoil. The thickness of this layer varied from approximately 2.1 to 4.3 m and extended to base elevations 259.7 to 264.3 m.

This layer was composed of silty clay with some sand and trace amounts of gravel. The SPT N-value within this layer ranged from 8 to 44 blows per 0.3 m. Pocket penetrometer testing carried out on selected split-spoon samples indicated an undrained shear strength of 85 kPa to greater than 225 kPa. Undrained shear strength measurements were also made using a digital field vane and laboratory unconfined compression tests. The test results indicated an undrained shear strength of greater than 200 kPa suggesting a hard consistency.

Index tests carried out on representative samples from the silty clay crust layer yielded the following results:

Gravel:	0 to 7%
Sand:	8 to 15%
Silt:	45 to 52%
Clay:	35 to 47%
Moisture Content:	11 to 25%

Atterberg limits tests carried out on eight representative samples from this layer indicated a plasticity index range of 15 to 20. The USCS group symbol for this layer is CI (silty clay) (intermediate plasticity) to clayey silt (CL).

Representative grain size distribution plot and the corresponding plasticity charts for this layer are given in Figures 2a through 2e and 7a and 7b of Appendix C, respectively.

## 4.2.2.5 Silty Clay to Clayey Silt

A silty clay to clayey silt layer was encountered in all boreholes immediately beneath the silty clay crust layer. The layer was composed of silty clay to clayey silt materials with occasional seams of sand and sandy silt. In all boreholes, drilling was terminated within this layer upon reaching the planned termination depth of investigation. The drilled depths in these boreholes were 12 to 49.4 m from the existing ground surface with base elevations ranging from 256.1 to 217.5 m.

The SPT N-Value within this layer ranged from 7 to 36 blows per 0.3 m. Pocket penetrometer testing carried out on selected split-spoon samples indicated an undrained shear strength of 25 to 225 kPa. Undrained shear strength measurements were also made using a digital field vane

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and laboratory unconfined compression tests. The digital vane test results indicated an undrained shear strength of 66 to 202 kPa, suggesting a firm to hard consistency. The unconfined compression test results ranged from 44 kPa to 237 kPa. It is noted that one unconfined compression test carried out in BH13-4 at approximate elevation 247 m yielded an undrained shear strength of 13 kPa. The soil at this depth was found to be generally very silty, resulting in difficulty in sample preparation. In addition, the reported laboratory test result indicated that the length-to-diameter ratio of the tested sample did not meet the requirements of ASTM Standard (ASTM D 2166). Hence, this result is not considered to be representative of the soil layer under consideration. The unconfined compression test results are summarized in the following table.

**Table 4.1: Unconfined Compression Test Results (silty clay layer)**

Sample ID	Sample Elevation (m)	Moisture Content (%)	Unconfined Compressive Strength, UCS (kPa)	Estimated Undrained Shear Strength, $S_u$ ( $=1/2 \cdot UCS$ ) (kPa)	Strain at Failure (%)
BH13-3 ST-14	256.5	18.8	216	108	13.2
BH13-3 ST-26	232.9	13.4	456	228	12.2
BH13-3 ST-29	223.7	15.6	473	236	10.7
BH13-4 ST-17	255.0	21.7	133	66	5.8
BH13-4 ST-23	247.0	22.0	26	13	10.6
BH13-4 ST-27	237.8	18.2	87	43	10.8
BH13-7 ST-7	262.5	20.8	267	133	5.1
BH13-7 ST-11	259.4	19.4	346	173	8.2
BH13-9 ST-13	258.1	19.8	245	122	10.6
BH13-9 ST-22	241.5	17.7	350	175	12.2
BH13-10 ST-18	251.6	18.4	237	118	14.7
BH13-10 ST-23	240.9	17.1	244	122	14.1

Index tests carried out on representative samples from the silty clay to clayey silt layer yielded the following results:

Gravel: 0 to 26%  
 Sand: 1 to 14%  
 Silt: 38 to 67%  
 Clay: 23 to 48%  
 Moisture Content: 9 to 26%

Atterberg limits tests carried out on 25 representative samples from this layer indicated a plasticity index range of 12 to 20. The USCS group symbol for this layer is CI (silty clay) (intermediate plasticity) to clayey silt (low plasticity).

Representative grain size distribution plot and the corresponding plasticity charts for this layer are given in Figures 2a through 2e and 7a and 7b of Appendix C, respectively.



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The results of consolidation tests carried out on four clayey silt to silty clay samples from BH13-3, BH13-4, BH13-7 and BH13-9 are provided in Appendix C. The consolidation and index property test results for these samples are summarized in the following table.

**Table 4.2: Consolidation Test Results (silty clay layer)**

Sample ID	Sample Elevation	Moisture Content	Initial Void Ratio/Initial Unit Weight	Estimated Preconsolidation Stress, $P_c^1$	Recompression Index, $C_r$	Compression Index, $C_c$
BH13-3 ST-14	256.5 m	18%	0.5/21.4 kN/m <sup>3</sup>	271 kPa	0.013	0.14
BH13-4 ST-17	254.9 m	23%	0.6/20.4 kN/m <sup>3</sup>	384 kPa	0.023	0.20
BH13-7 ST-7	262.4 m	18%	0.5/21.3 kN/m <sup>3</sup>	442 kPa	0.017	0.18
BH13-9 ST-13	258.0 m	20%	0.5/20.9 kN/m <sup>3</sup>	391 kPa	0.013	0.19

Note 1: Based on the method of Boone (2010).

## 4.2.3 Bedrock

Borehole advancement was terminated above the bedrock level.

## 4.2.4 Groundwater

Vibrating wire piezometers were installed in Boreholes BH13-1, BH13-3 and BH13-4. A groundwater monitoring well was installed in BH13-5. The groundwater in the boreholes was measured on November 10, 2013, at least nine days after installation except in BH13-3 where it was measured two days after installation of the vibrating wire piezometer. The depth to groundwater was also estimated in all other boreholes at the time of drilling, between October 21, 2013, and November 9, 2013. These groundwater levels are not stabilized measurements, and hence will be referred to as “inferred”. The measured and inferred (i.e., at the time of drilling) groundwater levels are summarized in Table 4.2 below.

**Table 4.3: Measured and Inferred Groundwater Levels – Interchange Site**

Borehole No	Ground Surface Elevation (m)	Groundwater		Comments
		Depth (m)	Elevation (m)	
Measured				
BH13-1	263.2	5.5	257.7	VWP
BH13-3	266.9	4.8	262.1	VWP
BH13-4	267.6	1.7	265.9	VWP
BH13-5	268.1	7.1	261.0	MW
Inferred				
BH13-2	264.6	3.6	261.0	Standing groundwater was not established in the open boreholes; groundwater level was inferred from observed colour changes and measured water contents
BH13-6	267.8	3.7	264.1	
BH13-7	267.5	3.6	263.9	
BH13-9	267.7	6.1	261.6	
BH13-10	267.3	5.9	261.4	
BH13-12	268.0	4.9	263.1	

Note: VWP=Vibrating wire piezometer; MW=Monitoring well

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## 4.3 CULVERT SITE

### 4.3.1 General

The subsurface conditions observed in the three boreholes at the culvert site (BH13-13, BH13-14 and BH13-15) are presented in detail on the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix B.

In general, the subsurface conditions at the culvert location included asphalt pavement structure over embankment fill or topsoil overlying extensive deposit of silty clay to clayey silt deposit.

### 4.3.2 Overburden

#### 4.3.2.1 Pavement

Asphalt pavement was encountered in BH13-14. The observed asphalt thickness was approximately 150 mm.

#### 4.3.2.2 Roadway Fill

A roadway fill material was encountered immediately beneath asphalt in BH13-14. The thickness of the fill material was approximately 1.9 m, and extended to base elevation 261.7 m.

The fill material was composed predominantly of sand and gravel with some organics near the bottom of the fill layer. The SPT N-value of the fill material was 11 blows 0.3 m.

Index tests carried out on representative samples of the fill material yielded the following results:

Gravel:	38%
Sand:	51%
Fines (silt & clay):	11%
Moisture Content:	6 to 22%

Representative grain size distribution plot for the fill material at this site is given in Figure 1c of Appendix C. The Unified Soil Classification System (USCS) group symbol for the fill material is SM (silty sand with gravel).

#### 4.3.2.3 Topsoil

Topsoil was encountered in Boreholes BH13-13 and BH13-15. The observed thickness of topsoil in these boreholes was approximately 60 and 150 mm, respectively.

The topsoil had a moisture content of approximately 36%. Organic content test performed on one sample of the topsoil indicated organic content 7.5%.

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## 4.3.2.4 Silty Clay to Clayey Silt

This layer was encountered immediately beneath fill material in BH13-14 and the topsoil in BH13-13 and BH13-15. This layer was predominantly composed of silty clay and clayey silt with some organics and frequent sand seams (especially BH13-15). In all boreholes, drilling was terminated within this layer upon reaching the planned termination depth of investigation. The drilled depths in these boreholes were 9.8 to 12.0 m from the existing ground surface with base elevations ranging from 250.3 to 251.7 m.

The SPT N-value within this layer ranged from 2 to 29 blows per 0.3 m. Pocket penetrometer testing carried out on selected split-spoon samples indicated an undrained shear strength of 25 to greater than 225 kPa suggesting a firm to hard consistency.

Index tests carried out on representative samples from the silty clay to clayey silt layer yielded the following results:

Gravel:	0 to 11%
Sand:	5 to 20%
Silt:	38 to 61%
Clay:	13 to 53%
Moisture Content:	9 to 26%

Atterberg limits tests carried out on eight representative samples from this layer indicated a plasticity index range of 3 to 23. The USCS group symbol for this layer is CI (silty clay) (intermediate plasticity) to CL (clayey silt).

Representative grain size distribution plots for this layer are given in Figures 4 and 6 of Appendix C; the plasticity chart is given in Figure 7c.

## 4.3.2.5 Silty Sand to Silty Gravel

This layer was encountered in BH13-13 within the silty clay and clayey silt layer. The thickness of this layer was approximately 1.9 m and was encountered between elevation 254.3 and 252.4 m.

The SPT N-value within this layer was 5 and 16 suggesting a loose to compact state.

Index tests carried out on representative samples of this layer yielded the following results:

Gravel:	51%
Sand:	31%
Silt:	15%
Clay):	3%
Moisture Content:	6 and 8%

Atterberg limits test carried out on one representative sample of this layer indicated a plasticity index of 3. The USCS group symbol for this layer is GM (silty gravel with sand).

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### 4.3.3 Bedrock

Borehole advancement was terminated above the bedrock level.

### 4.3.4 Groundwater

Vibrating wire piezometer was installed in Borehole BH13-13. The groundwater in this borehole was measured on November 10, 2013, 11 days after vibrating wire piezometer installation. The depth to groundwater was not established in the remaining two boreholes but are inferred to be identical to that measured in BH13-13. The measured groundwater level is summarized in Table 4.3 below.

**Table 4.4: Measured and Inferred Groundwater Levels – Culvert Site**

Borehole No	Ground Surface Elevation (m)	Groundwater		Comments
		Depth (m)	Elevation (m)	
BH13-13	260.2	2.1	258.1	VWP

Note: VWP = Vibrating wire piezometer

Fluctuations in the groundwater level due to seasonal variations or in response to a particular precipitation event should be anticipated.

## 4.4 CHEMICAL TESTING

One representative sample each retrieved from the native soils at the new interchange and culvert replacement sites were tested for pH, water soluble sulphates and chloride concentrations, and resistivity. The analysis results are provided in Table 4.4.

**Table 4.5: Results of Chemical Analysis**

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
Interchange Site						
BH13-9	SS-4	2.3 to 2.9	7.7	361	41	15
Culvert Site						
BH13-15	SS-3a	1.5 to 2.1	7.7	16	27	43

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## 5.0 Miscellaneous

The field work was carried out under the supervision of Mr. Athir Nader, B.Eng., Geotechnical Engineering Intern, under the direction of Chris McGrath, P.Eng.

The private and public utility locates for the boreholes for the detailed design were carried out by Aecon Utility Engineering (AUE), an Aecon Group Inc (AGI) subsidiary, both of Toronto, Ontario.

The track-mounted CME 75 drilling equipment was supplied and operated by Pontil Drilling of Mount Albert, Ontario. The truck-mounted D-90 drilling equipment was supplied and operated by Walker Drilling of Utopia, Ontario.

Location and elevation survey of the Boreholes was carried out by Stantec's Geomatics Group in London, Ontario.

Traffic control service was provided by AGI, Toronto, Ontario.

Geotechnical laboratory testing was carried out at Stantec's Ottawa and Golder's Mississauga laboratories. Chemical testing for pH, soluble sulphate, and chloride content, and resistivity was carried out by Paracel Laboratories of Ottawa.

This report was prepared by Simon Gudina, P.Eng. and reviewed by Chris McGrath, P.Eng. and Raymond Haché, P.Eng, Designated Principal MTO Foundation Contact.

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## 6.0 Closure

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

Respectfully Submitted;

**STANTEC CONSULTING LTD.**



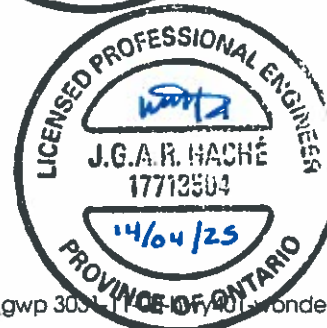
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## FOUNDATION DESIGN REPORT

For

DB 2012-3022

G.W.P 3031-11-00

New Highway 401 at Wonderland Road Interchange  
City of London

## 7.0 Discussions and Engineering Recommendations

### 7.1 PROJECT DESCRIPTION AND BACKGROUND

#### Project Purpose/Justification

This assignment involves the construction of a new interchange for Wonderland Road South at Highway 401. The current plan includes a new Parclo A-2 interchange for Wonderland Road at Highway 401 which accommodates the existing four lane condition of Highway 401.

Wonderland Road will be extended to cross under Highway 401 via new overpasses. It is understood that the cross-section of Wonderland Road will initially provide for two through lanes and will accommodate future upgrade to a Parclo A-4 interchange, widening of Highway 401 to eight lanes, and widening of Wonderland Road to four lanes. Manning Drive will be realigned south of its existing intersection at Wonderland Road and Morrison Road will be realigned to intersect Manning Drive to accommodate the interchange configuration.

This assignment also includes the replacement of the existing Courtney Drain culvert which is located approximately 700 m southwest of the proposed new interchange location.

#### Proposed Overpass Structure and Replacement Culvert

New Wonderland Road Overpasses are being proposed for the new interchange. The preliminary General Arrangement (GA) drawing indicates that the proposed overpasses include twin single-span, semi-integral abutment bridges with NU precast girders. Each bridge will have a span of 39 m and a skew of 35°. It is understood that high-performance, high-appearance RSS walls will be utilized as false abutments.

The proposed replacement culvert is understood to consist of a precast concrete rigid frame box culvert.

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Key approximate elevations associated with the proposed new overpasses and replacement culvert are as follows:

## Interchange Site

Proposed underside of pile cap elevation (west abutment, EBL):	264.2 m
Proposed underside of pile cap elevation (east abutment, EBL):	264.5 m
Proposed underside of pile cap elevation (west abutment, WBL):	264.3 m
Proposed underside of pile cap elevation (east abutment, WBL):	264.0 m
Proposed Hwy 401 final grade at west abutment, WBL:	267.7 m
Proposed Hwy 401 final grade at east abutment, WBL:	267.4 m
Proposed Hwy 401 final grade at west abutment, EBL:	267.8 m
Proposed Hwy 401 final grade at east abutment, EBL:	267.5 m
Proposed final grade of Wonderland Road:	260.8 m
Proposed final grade at the abutment:	260.5 m
Existing Grade on Highway 401	±267.5 m

## Culvert Site

Proposed invert of Courtney Drain culvert (box culvert) (inlet):	259.4 m
Proposed invert of Courtney Drain culvert (box culvert) (outlet):	259.1 m
Approximate streambed (inlet):	259.7 m
Approximate streambed (outlet):	259.4 m
Existing open footing foundation elevation:	258.0 m
Existing grade at Highway 401 centreline:	263.6 m
Proposed grade at Highway 401 centreline:	263.5 m

## 7.2 GEOTECHNICAL DESIGN PARAMETERS

### 7.2.1 Overpass Site

The soil conditions encountered at the overpass site generally consist of fill material over a clayey silt / silty clay crust layer over an extensive deposit of silty clay to clayey silt. The crust layer is generally very stiff to hard. The layer beneath the crust layer was generally firm to hard.

For design purposes, the soil profile indicated in Table 7.1 below can be used for the overpass site. The geotechnical soil profile was developed based on the synthesis of the measured in-situ shear strength, unconfined compression test, measured N-values and the laboratory index test results (including moisture contents) of soil samples retrieved from the site. The measured subsurface information from boreholes BH13-3, BH13-4, BH13-9, BH13-10 and boreholes BH 1 & BH 2 of Geocres Report No. 40I14-132 was used to develop the soil profile. The soil profile is indicated in Figure 8a & 8b of Appendix D.



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**Table 7.1: Representative Soil Profile at Proposed Wonderland Road Overpass Site**

Elevation (m)		Soil Type	Design Parameters			
From	To		$\gamma$ (kN/m <sup>3</sup> )	$\phi$ (°)	$S_u$ (kPa)	E (MPa)
Varies	265	Silty sand granular FILL	22.0	35	-	50
265.0	262.0	Silty clay / clayey silt crust (very stiff to hard)	Figure 8a & 8b			
< 262.0		Clayey silt /silty clay (firm to hard)				

Note: (1)  $\gamma$  = total unit weight,  $\phi$  = soil friction angle,  $S_u$  = undrained shear strength, and E = soil modulus.

(2) Groundwater will be assumed to be at approximate elevation of 262.0 m for design purposes. Submerged unit weight ( $\gamma'$ ) should be used below the groundwater level.

Cobbles and coarse gravel particles were present in the silty clay to clayey silt layer (elevation 239-240 m).

## 7.2.2 Culvert Site

For design purposes, the soil profile indicated in Table 7.2 below can be used for the culvert. The measured subsurface information from boreholes BH13-13, BH13-14 and BH13-15 was used to develop the soil profile.

**Table 7.2: Representative Soil Profile at Courtney Drain Culvert**

Elevation (m)		Soil Type	Design Parameters			
From	To		$\gamma$ (kN/m <sup>3</sup> )	$\phi$ (°)	$S_u$ (kPa)	E (MPa)
263.7	261.7	Silty sand granular FILL	22	35	-	50
< 261.7		Silty clay to clayey silt crust (firm to hard)	Figure 9a and 9b			

## 7.3 FROST PENETRATION

In accordance with OPSD 3090.101, the design frost penetration depth for foundations,  $f$ , at the site is 1.2 m. Therefore, footings and pile caps should be provided with a minimum of 1.2 m of soil cover or equivalent insulation for protection against frost heaving.

## 7.4 SEISMIC CONDITIONS

It is recommended that a Soil Profile II as defined in Canadian Highway Bridge Design Code (CHBDC, 2006) Section 4.4.6 be used in the seismic design of this site.

Table A3.1.1 of the CHBDC indicates that the Zonal Acceleration Ratio (ZAR) for London, Ontario, which is approximately 10 km north of the site, is 0.00. However, based on the 2010 National Building Code Seismic Hazard Calculation (NRCAN, 2013), the peak ground acceleration (PGA) value corresponding to a 10% probability of exceedance in years for this site is 0.023. This value is greater than the ZAR for London provided in Table A3.1.1 of the CHBDC. Hence, it is recommended that a ZAR of 0.023 should be used for this site.

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The potential liquefaction of the site soil under seismic loading conditions was assessed. The evaluation indicated that liquefaction of the foundation soils is not a concern for this site due to:

- (a) very low ZAR,
- (b) firm to hard nature of the site soil, and
- (c) relatively high fraction of fines content within the shallow soils.

Even though it is not likely very significant, seismically induced lateral earth pressures should be considered for this project with a Zonal Acceleration Ratio of 0.023.

## 7.5 FOUNDATION OPTIONS

For the proposed overpasses, both shallow and deep foundation options were evaluated. Shallow foundations would be placed within the hard silty clay/clayey silt crust layer and deep foundations would extend into the deeper very stiff to hard silty clay/clayey silt layer.

Table 7.3 compares the foundation options for the abutments of the proposed overpasses from a foundations design and constructability perspective:

**Table 7.3: Comparison of Foundation Options for Overpasses**

Option	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Shallow foundation within silty clay / clayey silt	<ul style="list-style-type: none"> <li>Excavation and drilling through difficult deposit not needed</li> <li>Generally suitable for semi-integral abutment bridges</li> </ul>	<ul style="list-style-type: none"> <li>May necessitate large footing area</li> <li>Larger excavation</li> </ul>	Low to medium	<ul style="list-style-type: none"> <li>Excessive settlement for large loads</li> <li>Differential settlement</li> </ul>
Piles End bearing on hard Till or hard rock	<ul style="list-style-type: none"> <li>High geotechnical resistances</li> <li>No or negligible settlement</li> </ul>	<ul style="list-style-type: none"> <li>Excessive pile length</li> </ul>	High	<ul style="list-style-type: none"> <li>Bedrock is &gt;42 m at this site</li> <li>Damage to pile during installation</li> </ul>
Frictional H-Piles	<ul style="list-style-type: none"> <li>Reduced pile length compared to piles to rock</li> <li>Reduced soil setup time compared to frictional pipe piles</li> </ul>	<ul style="list-style-type: none"> <li>Structural capacity may not be fully utilized</li> </ul>	Medium	<ul style="list-style-type: none"> <li>Long piles required for relatively small capacities</li> </ul>
Frictional Pipe Piles	<ul style="list-style-type: none"> <li>Reduced pile length compared to piles to rock</li> </ul>	<ul style="list-style-type: none"> <li>Structural capacity may not be fully utilized</li> <li>Longer soil setup time after pile driving when compared to frictional H-Piles</li> </ul>	Medium	<ul style="list-style-type: none"> <li>Long piles required for relatively small capacities</li> </ul>
Drilled Caissons	<ul style="list-style-type: none"> <li>Can transmit very large axial and lateral loads</li> </ul>	<ul style="list-style-type: none"> <li>Not suitable for installation through an RSS wall</li> </ul>	High	<ul style="list-style-type: none"> <li>Groundwater control</li> </ul>

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Based on the comparison presented above in Table 7.3 friction piles extending within the lower very stiff silty clay / clayey silt deposit will be recommended as the preferred option from the foundations perspective.

## 7.6 DEEP FOUNDATIONS

### 7.6.1 General

The design recommendations presented in the following sections have been developed in accordance with the requirements and methods described in the Canadian Highway Bridge Design Code (CHBDC, 2006).

### 7.6.2 Abutment Foundations

#### 7.6.2.1 Geotechnical Axial Resistance in Compression

It is anticipated that a pile foundation consisting of steel H-piles will be used to support the proposed overpass abutments. Based on the preliminary GA drawing, the underside of the pile caps (abutment wall) will be at approximate elevation of 264.2 m and 264.5 m, respectively, for the westbound and eastbound overpasses.

The axial resistance at Ultimate Limit State (ULS) for an HP310x110 pile was assessed using the American Petroleum Institute (API) design method using the program APILE developed by Ensoft (Ensoft, 2007) and the geotechnical model developed in Table 7.2. Given that friction piles are being proposed, the geotechnical resistances calculated for HP310x110 would also apply to pile sizes of HP310x94 and HP310x79. The selection of the pile size should be based on the structural capacity of the pile.

Figure 10 of Appendix D provides a profile of geotechnical axial resistance at ULS in compression for HP310x110 and includes a resistance factor of 0.4 applied to the calculated ultimate capacity.

The soil strengths measured on site were initially used to develop the geotechnical model to estimate the pile lengths. The results of full scale pile testing carried out by MTO in 1968 at a site located approximately 45 km southwest of the current project location (Test Site 25), where very similar soil conditions are present, was then used to further calibrate the model. The results of the test site values are also shown on Figure 10. The geotechnical conditions reported by MTO at Test Site 25 are included in Appendix B.

Based on the results presented in Figure 10, the factored geotechnical resistance at ultimate limit state ( $ULS_r$ ) of an HP 310x110 is 2000 kN for a pile length of 44 m. The geotechnical reaction at SLS of 1600 kN was estimated for this pile length. This SLS reaction was assumed to be 85 to 90% of the  $ULS_r$ ; the estimated geotechnical reaction at SLS for a 25 mm vertical settlement exceeds the geotechnical reaction at  $ULS_r$  given above.

The above values are based on piles being driven to the lower hard silty clay to clayey silt layer. A shorter pile can be selected if a smaller geotechnical capacity is required. For example, for a

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factored geotechnical resistance at  $ULS_f$  of 1,300 kN, the estimated pile length is 36 m (pile tip at elevation 229.0 m). The estimated pile tip settlement for a pile length of 36 m is in the order of 5 mm. A geotechnical reaction at SLS of 1100 kN would be appropriate for a 36 m long pile.

### PDA Testing and Pile Length Optimization

The geotechnical axial resistance of driven steel H-Piles within a stiff silty clay deposit can be quite variable depending on non-measurable site conditions. Therefore, Dynamic Pile Testing (PDA) must be carried out on the piles driven to support the bridge abutment. A pile-soil setup period of 2 weeks is recommended prior to carrying out PDA testing on the piles. Testing on at least four piles per bridge (two per abutment) should be carried out.

If contract scheduling permits, optimization of the pile lengths could be carried out on two piles driven to two different depths; the first to el. 233 m and the second to el. 229 m. PDA testing could then be carried out after a 2 week set-up period to determine if somewhat shorter piles could be used at this site.

### Downdrag

The proposed overpass structures will be constructed over a 7 m deep cut. No significant grade raise is anticipated at the overpass site. In addition, the site soil consists of very stiff to hard silty clay crust over a stiff to hard silty clay/clayey silt. Hence, negligible settlement is anticipated. Due to the proximity of the proposed Wonderland Road excavation cut, the calculated change in overburden soil effective stress along the pile lengths is calculated to be negative. Assuming an applied dead load of 750 kN per pile, negligible downdrag load is anticipated.

### Pile Group Settlement

The above SLS geotechnical resistance for an HP310x110 considered the settlement of a single pile. An assessment of the potential for pile group settlement was carried out by assuming an equivalent footing supporting the sum of the SLS loads at an elevation located 1/3 of the pile length up from the pile tip elevation. Pile center-to-center spacings of 2.4 m, SLS loads of 1000 kN, per pile and two rows of 13 piles were assumed in defining the equivalent footing size. Based on this calculation, the pile groups are anticipated to settle less than 15 mm with time.

### Relaxation of driven piles

For H-piles driven to hard silty clay / clayey silt, relaxation and reduction of pile capacity is not a concern.

### Soil Setup

Piles driven in saturated cohesive soils general gain capacity after driving has been completed and excess pore pressure has dissipated. This will take considerable amount of time. In the absence of site-specific pore pressure data from piezometers installed in conjunction with pile driving, the common practice is to delay static pile testing or restriking of piles in clayey soils for

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at least two weeks after driving or preferably for a longer period. It is recommended that the gain in pile capacity beyond two weeks be disregarded.

## Drivability

The site soil generally consists of very stiff to hard silty clay crust layer over a stiff to hard silty clay/clayey silt. As such, the site is not expected to pose unusual resistance to pile driving.

## Axial resistance in tension

For design against uplift, the tensile resistance provided in Table 7.4 is recommended. This value is based on a minimum pile length of 30 m (elevation of approximately 235 m or deeper).

**Table 7.4: Recommended Tensile Pile Resistance**

Pile Type	Minimum Pile Length(m)	Factored Geotechnical Resistance (Tension) at ULS <sub>r</sub> (kN)
HP310 x 110	30	720

A resistance factor,  $\phi$ , of 0.3 has been applied to calculate the ULS<sub>r</sub> resistance. The factored geotechnical resistance (tension) at ULS<sub>r</sub> provided above does not include the own weight of the pile. If shorter piles are found to be adequate, the axial capacity in tension will be correspondingly lower.

## **7.6.2.2 Geotechnical Lateral Resistance**

### ULS<sub>r</sub> and SLS Resistances

The geotechnical resistance of the pile against lateral loads is mobilized due to the passive resistance of the surrounding soil. Assessed values for horizontal passive resistance and geotechnical resistances at SLS for the proposed pile can be generated from information provided in Table C6.4 of the Commentaries to the Canadian Highway Bridge Design Code (CHBDC, 2006). A value at ULS<sub>r</sub> of 200 kN and a value at SLS of 110 kN may be used for an HP 310x110 pile in very stiff cohesive material. A horizontal displacement of 10 mm was assumed at ground surface for the SLS condition.

### SLS Resistance Modelling

The lateral capacity of piles was also evaluated using the program called LPile Plus v6.0 developed by Ensoft, Inc. (Ensoft, 2010). The resistance was calculated with the unfactored soil parameters presented in Table 7.5 below. A moment of inertia of  $237 \times 10^6 \text{ mm}^4$  was used for an HP310x110 pile section. A modulus of elasticity of 200 GPa was used for the pile material (steel). The pile was modelled with a total length of 42 m. The p-y modulus values in the following were based on values suggested by Ensoft, Inc. (Ensoft, 2010) for the identified subsurface condition.

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**Table 7.5: Recommended Parameters for Lateral Pile Capacity Evaluation**

Soil Layer	Depth Range (m)		Effective Unit weight, $\gamma$	Friction angle, $\phi$	Undrained shear strength, $S_u$	Deformation behavior	
	From	To				p-y Modulus, k	$\epsilon_{50}$
Silty clay (crust)	0	2.5	22	-	100	Not a required input for cohesive soils	0.005
Silty clay to clayey silt	2.5	3.0	12.2	-	100		
	3.0	21	11.2	-	55 to 110		
	21	32	11.7	-	110		
	32	44	11.7	-	180		

- Notes: (1) Groundwater level is assumed at 2.5 m from existing ground surface.  
 (2) Submerged unit weight should be used below groundwater level.  
 (3)  $\epsilon_{50}$  = the strain corresponding to one-half the principal stress difference.

Two plots from LPILE are presented in Figures 11 and 12 in Appendix D. Figure 11 shows the deformed shape of the pile for lateral (shear) force ranging between 90 and 140 kN. This plot indicates that the pile head undergoes negligible lateral deflection for depths below approximately 6 m below the bottom of pile cap (elevation 259 m). Based on this figure, a lateral load of 125 kN corresponds to a pile head (top) displacement of less than 10 mm. Therefore, the SLS geotechnical resistance of an HP 310x110 at this site is estimated as 125 kN.

Figure 12 presents the p-y plot that gives the non-linear response of the pile-soil interaction. It provides a series of curves obtained from program LPILE generated for selected depths below the pile head. These plots can be used in the structural evaluation of the proposed bridge founded on H-piles.

## Group Action

Group action of piles (pile interaction) for lateral loading should be considered if centerline spacing of piles is less than 8 pile diameters (or least lateral dimension of pile) parallel to the direction of lateral load or less than 4 pile diameters perpendicular to the load. The effect of interaction between piles can be considered by applying a reduction factor to the coefficient of lateral subgrade reaction (p-y modulus). The following reduction factors may be used to account for pile group action:

**Table 7.6: Recommended Reduction Factors for Pile Groups**

Pile spacing / pile diameter	Reduction Factor	Pile spacing / pile diameter	Reduction Factor
Load Parallel to Pile Spacing		Load Perpendicular to Pile Spacing	
7	1.0	4	1.0
4	0.8	3	0.9
3	0.7	2	0.75
2	0.6	-	-

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## 7.7 LATERAL EARTH PRESSURES

### 7.7.1 Backfill

It is recommended that the backfill within and behind structures for the proposed bridge consist of approved earth material placed and compacted using methods and equipment appropriate to the type of structure. For the purpose of this report, it is assumed that a backfill material meeting the requirements of OPSS Gran B Type I or Gran A and Gran B Type II material will be used. The surface of the backfill will be assumed to be horizontal.

### 7.7.2 Static Lateral Earth Pressures

Static lateral earth pressures will need to be considered in the design of abutments, retaining walls (wingwalls) and retained soil systems.

The bridge abutments should be backfilled with granular material in accordance with OPSSD3101.150.

Computation of earth pressures should be in accordance with Section 6.9 of the CHBDC. For retaining walls that are designed to allow rotation, active earth pressure may be used for design. For rigidly tied and unyielding structures, the at-rest earth pressure should be used for design. The unfactored soil parameters provided in Table 7.7 may be used for design of walls with a horizontal backfill. The effects of compaction should be accounted for by applying a compaction surcharge as shown in Figure 6.6 of the CHBDC.

The total active (PA) and passive (PP) thrusts can be calculated using the following equations:

$$P_A = \frac{1}{2} K_a \gamma H^2$$

$$P_O = \frac{1}{2} K_o \gamma H^2$$

$$P_P = \frac{1}{2} K_p \gamma H^2$$

where H is the height of the wall and  $\gamma$  is the unit weight of the backfill soil. Values for  $K_a$ ,  $K_p$ ,  $K_o$  and  $\gamma$  are provided in Table 7.7 for horizontal and sloping (2H:1V) backfill conditions, respectively. The thrust acts at a point one third up the height of the wall.

**Table 7.7: Recommended Non-Seismic Earth Pressure Parameters**

Parameter	OPSS Gran B Type I		OPSS Gran A and Gran B Type II	
	Horizontal	2H:1V	Horizontal	2H:1V
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	21.2		22.0	
Effective Friction Angle	32°		35°	
Coefficient of Earth Pressure at Rest ( $K_o$ )	0.47	0.47	0.43	0.43
Coefficient of Active Earth Pressure ( $K_a$ )	0.31	0.47	0.27	0.39
Coefficient of Passive Earth Pressure ( $K_p$ )	3.2	8.58	3.7	10.78

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## 7.7.3 Seismic Lateral Earth Pressures

The low zonal acceleration ratio for this site suggests that the lateral earth pressures on the bridge due to seismic loads will likely be negligible. The following design parameters are provided should the bridge abutment, wingwalls and retained soil systems also be designed to resist the earth pressures induced under seismic loading conditions. The seismic earth pressures may be calculated using the parameters detailed in Tables 7.8 and 7.9.

The total active and passive thrusts under seismic loading conditions can be calculated using the following equations:

- $P_{AE} = \frac{1}{2} K_{AE} \gamma H^2 (1 - k_v)$
- $P_{PE} = \frac{1}{2} K_{PE} \gamma H^2 (1 - k_v)$

where:

- $K_{AE}$  = active earth pressure coefficient (combined static and seismic)
- $K_{PE}$  = passive earth pressure coefficient (combined static and seismic)
- $H$  = height of wall
- $k_h$  = horizontal acceleration coefficient
- $k_v$  = vertical acceleration coefficient
- $\gamma$  = total unit weight

For this site, the following design parameters were used to develop the recommended  $K_{AE}$  and  $K_{PE}$  values. The site specific Zonal Acceleration Ratio or Peak Ground Acceleration was estimated as 0.023 based on Seismic Hazard Calculation Natural Resources Canada is. For transportation structures the PGA value corresponding to a 10% probability of exceedance in 50 years is typically selected.

- |  |                |                    |
|--|----------------|--------------------|
| • Zonal Acceleration Ratio, A or PGA         | 0.023          |                    |
| • Horizontal Acceleration Coefficient, $k_h$ | 0.012 yielding | 0.035 non-yielding |
| • Vertical Acceleration Coefficient, $k_v$   | 0.008 yielding | 0.023 non-yielding |
| • Horizontal Backslope to Wall               | 0°             |                    |
| • Vertical Back of Wall                      | 0°             |                    |

The above  $k_h$  value corresponds to ½ of the A value for yielding walls and 1.5 times for non-yielding walls. The  $k_v$  value corresponds to 0.67 of the  $k_h$  value. The angle of friction between the soil and the wall has been set at 0° to provide a conservative estimate.



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**Table 7.8: Recommended Seismic Earth Pressure Parameters (Horizontal Backfill)**

Parameter	OPSS Gran B Type I		OPSS Gran A and Gran B Type II		Silty Clay /Clayey Silt	
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	21.2		22.0		21.0	
Effective Friction Angle	32°		35°		29°	
Wall type: (a) yielding; (b) non-yielding	a	b	a	b	a	b
Active Earth Pressure ( $K_{AE}$ )	0.31	0.33	0.28	0.29	0.35	0.37
Height of Application of $P_{AE}$ from base as a ratio of wall height, (H)	0.337	0.344	0.337	0.345	0.337	0.343
Passive Earth Pressure, ( $K_{PE}$ )	3.23	-	3.67	-	2.86	-
Height of Application of $P_{PE}$ from base as a ratio of wall height, (H)	0.330	-	0.330	-	0.329	-

**Table 7.9: Recommended Seismic Earth Pressure Parameters (2H:1V Backfill)**

Parameter	OPSS Gran B Type I		OPSS Gran A and Gran B Type II		Silty Clay /Clayey Silt	
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	21.2		22.0		21.0	
Effective Friction Angle	32°		35°		29°	
Wall type: (a) yielding; (b) non-yielding	a	b	a	b	a	b
Active Earth Pressure ( $K_{AE}$ )	0.49	0.53	0.41	0.44	0.60	0.70
Height of Application of $P_{AE}$ from base as a ratio of wall height, (H)	0.341	0.356	0.340	0.355	0.345	0.375
Passive Earth Pressure, ( $K_{PE}$ )	8.58	-	10.75	-	6.92	-
Height of Application of $P_{PE}$ from base as a ratio of wall height, (H)	0.330	-	0.330	-	0.330	-

## 7.8 RETAINED SOIL SYSTEM (RSS) WALLS

### 7.8.1 General

A Retained Soil System (RSS) walls are being considered for the abutments (false abutment) to contain the soil behind the abutment. The RSS walls will extend immediately from the abutments back into the approach embankments effectively serving as wingwalls (for both west and east abutments of both overpasses).

For the design of RSS walls, the guidelines included in the following documents should be considered:

- RSS Design Guidelines (MTO, 2008);
- CHBDC Section 6.12 – MSE Structures (CHBDC, 2006); and
- CFEM Chapter 27 – Reinforced Soil Walls (CFEM, 2006)

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Retained soil systems are listed in the MTO Designated Sources of Materials (DSM) and under Special Provisions 599S22 and 599S23. The RSS should be tendered with the following attributes:

Application: False Abutment

Geometry: Vertical (GV)

Performance: High

Appearance: High

## 7.8.2 Site Specific Geotechnical Considerations

A 200 mm thick Granular A Leveling Pad should be constructed beneath the concrete elements of the RSS.

The overall external stability of RSS founded at an approximate elevation of 259.5 m (0.8 m below approximate proposed grade of Wonderland Road) was evaluated. The evaluation results are indicated in Figure 13 of Appendix D. The evaluation indicated that no sliding or general slope stability failure will be expected for the site soil condition. The evaluated factor of safety against general stability failure is in excess of the required factor of safety of 1.5 for long-term conditions and greater than 1.3 for short-term conditions.

The factored geotechnical resistance at ULS for the RSS built on the site soil is 350 kPa at the proposed foundation elevation of 259.5 m. This geotechnical resistance was evaluated based on assumed RSS dimensions, i.e., having a width of  $0.8H$  where  $H$  is the height of RSS wall (based on MTO's RSS Design Guidelines, MTO (2007)) and a length equal to the pile spacings along the abutment wall (assumed to be 2.86 m). A wall height of 6.7 m was assumed; hence, the width of the RSS wall will be approximately 5.4 m. The SLS resistance for 25 mm total settlement was estimated to be 225 kPa; this SLS value reflects that the RSS wall will be constructed entirely within an excavation and that additional soil stresses would be imposed only by groundwater lowering.

Unit weight and effective friction angles provided in Section 7.2 of this report may be used for design of the RSS wall.

## 7.9 CUT SLOPES

### 7.9.1 Construction of Cut Slopes

The proposed new interchange will require several cut slopes at the bridge structures and immediately north and south of Highway 401. Slope heights between 5 to 6 m are proposed. The cut slope is mainly in the very stiff to hard silty clay. Cut slopes in clays generally will lose shear strength with time. For this reason, cut slope should be designed by using effective strength parameters and effective stresses that will exist in the soil after the cut is made.

### 7.9.2 Stability of Cut Slopes

A slope stability evaluation was carried out using commercially available limit equilibrium based software called SLOPE/W (GEO-SLOPE, 2012). The analyses considered seismic loading using

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one-half of the ZAR. Long-term soil parameters,  $\phi' = 30^\circ$  and  $c' = 0$  kPa were considered appropriate for the silty clay to clayey silt material encountered at the site.

Slope stability analysis results are presented in Figure 14 of Appendix D. Based on this slope stability analysis, a 2.5H:1V slope is required for the long-term stability of the cut slope.

The results of the hydrogeological study suggest that soils have a low permeability, that long term groundwater lowering will extend only a limited distance, and that water will likely seep out of the face of the slope. Groundwater seepage from slope faces typically renders cut slopes prone to surficial slip failures; MTO has had issues with cut slope stability below the groundwater table within the clay and clay till soils within the Ontario Southwest Region. Although cut slopes at 2.5:1V will be stable against deeper rotational failures, drainage measures as discussed in Section 7.9.4 will be required to protect the slopes against surficial slip failures during wet seasons.

It is anticipated that permanent berms will be constructed using the material from cut. The height of the berm should be limited to 2 m and the berm side slopes should be no steeper than 3H:1V. The berm should not be placed within 10 m of any structures sensitive to movement or slope crests. Proposed berms exceeding these restrictions will need to be reviewed by a Geotechnical Engineer.

At the top of the cut slope a swale or interceptor ditch is being constructed to divert any drainage away from the slope face. A minimum setback of 1.0 m is required from the slope crest (top).

## 7.9.3 Settlement Associated with Groundwater Lowering

The long-term groundwater elevation at the cut is approximately 259.8 m (1.0 m below proposed Wonderland Road final grade). The design groundwater elevation is 262.0 m. This requires a groundwater lowering of approximately 2.2 m, corresponding to an increase in effective stress of approximately 22 kPa which will not result in settlement greater than 5 mm.

## 7.9.4 Long-term Groundwater Control/Slope Stabilization

In accordance with the hydrogeological report for this project, the long term groundwater inflow within the profile cut area could be in the range of 4700 litres per day to 298,000 litres per day.

The following approaches may be considered in order to control groundwater seepage to prevent long-term surficial slip failures.

### Drained Granular Buttress

This approach would include the following:

- Subdrain at toe of slope which could be the same as being used to drain the pavement structure.

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- 1.2 m thick granular buttress extending halfway up the slope. The 1.2 m thickness is to be measured perpendicular to the face of the slope.
- Class II non-woven geotextile to separate the clay soil subgrade from the granular buttress.
- The drained granular buttress material could consist of OPSS Granular B Type II material or other similar preapproved free draining material.

### Trench Drain

This approach will include the following:

- Installation of a trench drain at the top of the slope which would extend to within 1.5 m of the proposed adjacent bottom of slope.
- Installation of a toe drain which could also act as the pavement structure drain.
- The trench drain would typically be 1.0 m wide and would be backfilled with a class II non-woven geotextile and a free draining granular material such as the HL-8 coarse fraction gravel.
- The drain would consist of a 150 mm perforated pipe placed within the coarse free draining gravel.
- The perforated drain would need to discharge to the roadway drainage system (likely towards the lower ground at the east end of the cut).
- The trench drain would be constructed prior to cutting the slope.

The granular buttress approach would require that the top of slope be pushed back about 3 m to accommodate the thickness of the 1.2 m buttress.

Consideration was also given to the method of using shallower French drains installed in a chevron pattern on the face of the slope. This option was not carried forward due to the anticipated negative impact during frozen winter conditions.

Figures 15a and 15b in Appendix D show the result of stability analysis for the 1.2 m thick buttress and the trench drain approaches to confirm their suitability.

A design memo was issued on April 16, 2014, which discussed options based on these approaches, including a comparison table with ranking and drawings to demonstrate the design approaches. Appendix E includes a copy of the April 16, 2014, memo titled "New Wonderland Road Interchange at Highway 401, GWP 3031-11-00 Proposed Slope Stabilization (Addendum)". The four design options are summarized below:

- Option 1 - Do Nothing.
- Option 2 - Allow for an "if required" contingency plan where drainage buttresses would be placed in areas where long-term seepage from the slope face occurs.
- Option 2 - Construct a drainage trench at the top of the slope parallel to the slope crestline.
- Option 4 - Construct a drainage buttress along the full length of the cut.

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The design memo recommends Option 2 and provides two configurations which could be used in design; inserted drainage buttress and external drainage buttress.

## 7.10 COURTNEY DRAIN CULVERT REPLACEMENT

### 7.10.1 General

This section provides relevant foundation recommendations for the proposed replacement culvert. The proposed replacement culvert is understood to consist of a precast concrete rigid frame box culvert.

### 7.10.2 Geotechnical Vertical Resistance

The geotechnical resistances provided in Table 7.10 below may be used in the design provided the footings are placed on undisturbed native soil as described above.

**Table 7.10: Geotechnical Resistance for Courtney Drain Culvert**

Founding Element	Founding Elev. (m)	Footing Width(m)	Factored Geotechnical Resistance at ULS <sub>f</sub> (kPa)	Geotechnical Resistance at SLS (kPa)
Rigid frame box	259.0	2.5 to 4.0	470	225

In accordance with Section 6.6.2 of the CHBDC, a resistance factor of 0.5 has been applied in calculating the factored geotechnical resistance at Ultimate Limit State (ULS<sub>f</sub>).

It is noted that for the evaluation of the geotechnical resistance at ULS<sub>f</sub> given in Table 7.10, the representative soil properties provided in Table 7.2 were used for the analysis. The groundwater was conservatively assumed to be immediately beneath the proposed founding elevation.

The geotechnical resistance at Serviceability Limit State (SLS) corresponds to a maximum settlement of 25 mm.

We recommend including a 100 mm thick protective layer of lean concrete over the subgrade to protect the clay soil from disturbance.

### 7.10.3 Geotechnical Horizontal Resistance (Sliding)

The unfactored horizontal resistance of spread footings may be calculated using the following unfactored coefficients of friction:

- 0.45 between OPSS Granular A and precast concrete
- 0.25 between silty clay/clayey silt and precast concrete
- 0.30 between a precast concrete footings and a thin layer of uncompacted leveling sand

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In accordance with Table 6.1 of the CHBDC, a resistance factor against sliding of 0.8 should be applied to obtain the resistance at ULS<sub>r</sub>.

### **7.11 CEMENT TYPE AND CORROSION POTENTIAL**

One sample of the native soil from each of the overpass and culvert sites were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results together with the results for the sample from the bottom part of the fill are summarized in the Table 4.4.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The maximum soluble sulphate concentration for all the samples tested was 41 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH was 7.7 for both sites, which is within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided in Table 4.4 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

## **8.0 Construction Considerations**

### **8.1 CONSTRUCTION STAGING AND DETOUR**

The construction of the proposed overpasses is anticipated to involve staging. This will involve the closure of half of Highway 401 by using appropriate traffic control. The use of a temporary roadway protection system is anticipated to be required near the centerline of existing Highway 401.

Staged construction is also anticipated to be required during the proposed replacement of the Courtney Drain Culvert. This would also require the use of a roadway protection system and an appropriate traffic control.

No local detour is anticipated to be required during the construction of the underpasses and the culvert replacement. However, a local detour is anticipated to be required for the construction of the interchange ramps.

### **8.2 EXCAVATION AND BACKFILLING**

Excavation backfill for the new bridge structure should be carried out in accordance with OPSS 902 Construction Specification for Excavation and Backfilling – Structures.

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Native site soil encountered during geotechnical investigation predominantly included very stiff to hard silty clay deposit. The soils encountered at the site may be classified in accordance with the OHSA as follows:

Existing Roadway Fills	Type 3 Soil
Silty Clay and Silty/Clayey Silt Till	Type 2 Soil

Any vegetation, fill, organic soils and other deleterious materials must be removed from beneath proposed RSS wall footing, the pile cap and the culvert. Where deleterious materials are encountered, the materials should be excavated, removed and replaced. The lateral extent of such excavation should include all deleterious material within the influence zone of the above foundation elements.

Grading work should be carried out in accordance with OPSS 206 Construction Specification for Grading and SP 206S03.

Any side slopes for open cut excavations should conform to Occupational Health and Safety Act regulations for Construction Projects (OHSA).

### 8.3 TEMPORARY ROADWAY PROTECTION

A deep, near-vertical wall excavation will be required for the overpasses. This will necessitate temporary roadway protection during the staged excavation for the eastbound and westbound overpasses as well as the Courtney Drain Culvert replacement.

The roadway protection for both the overpass construction and culvert replacement will necessitate excavation below the groundwater levels. As such, unwatering of the excavation will be required for the construction of the overpass, and may also be required during installation of the roadway protection system.

The following table compares the available roadway protection options considered for the new overpasses and the culvert replacement:

**Table 8.1: Comparison of Roadway Protection Systems**

Option	Advantages	Disadvantages	Relative Cost	Risk & Consequences
H-Piles with timber lagging; struts/rakers	<ul style="list-style-type: none"><li>• simple installation</li></ul>	<ul style="list-style-type: none"><li>• not suitable beneath groundwater level</li></ul>	Low	<ul style="list-style-type: none"><li>• Groundwater seepage</li></ul>
Steel sheet pile (SSP)	<ul style="list-style-type: none"><li>• easier to install below waterline (no unwatering required during roadway protection installation)</li></ul>	<ul style="list-style-type: none"><li>• difficult to drive/install in hard silty clay</li></ul>	Medium	<ul style="list-style-type: none"><li>• Possible damage or loss of sheet pile walls during driving</li></ul>

Steel sheet pile presents itself as the most viable option for roadway protection at the site. This will be supported with struts or rakers from the construction side.

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A conceptual drawing showing the location of the roadway protection is provided on Drawing No. 3 in Appendix E.

The contractor will ultimately be responsible to develop and implement a roadway protection system meeting the requirements of OPSS 539, including establishing appropriate geotechnical design parameters.

Roadway protection design should meet the requirements of Performance Level 1b as per OPSS 539 and should consider traffic loading. Performance Level 1b specifies a Maximum Angular Distortion of 1:1000 and a Maximum Horizontal Displacement of 10 mm. Pile and raker spacing must be designed not to exceed these limits. Horizontal movement should be monitored throughout the culvert replacement process as described in OPSS 539. The monitoring requirements outlined in OPSS 539 are considered to be appropriate for this project.

### **8.4 REUSE OF EXCAVATED MATERIAL**

The material near the ground surface in the vicinity of the project site consists of silty clay to clayey silt material. This material will not be suitable as backfill within and behind the structures for the proposed overpasses.

### **8.5 PILE INSTALLATION**

It is essential that the compatibility of the pile driving equipment, the soil conditions, and the pile type being driven is properly accounted for in order to achieve the required pile penetration and a satisfactory pile foundation.

Piles shall have reinforced tips according to Ontario Provincial Standard Detail, OPSD 3000.100 Type I.

The pile driving equipment shall be appropriate to the driving conditions and capable of delivering a minimum specified energy of 50 kJ.

At least four production piles should be tested using a Pile Driving Analyser (PDA) to confirm that the ultimate pile capacities are greater than twice the design  $ULS_r$  values.

MTO's principal pile driving control tool is the Hiley Formula as defined on Structural Drawing SS103-11. As noted on the structural drawing this approach is applicable to non-cohesive soils and to soils that provide sufficient rebound for the Hiley Formula to be effective. The soils at this site are cohesive and therefore the Hiley Formula is not suitable to confirm the pile resistance. Nevertheless, Drawing SS103-11 shall be applied to each driven pile to provide a relative comparison between piles where PDA testing is carried out and the remaining piles. The "Hiley Formula Pile Resistance" for all piles shall be submitted to the geotechnical engineer for comparison with the PDA tested piles.



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## 8.6 UNWATERING (GROUNDWATER CONTROL)

At the overpass location, groundwater was measured at elevation of approximately 262 m, which is higher than the elevation of the anticipated bottom of excavation of approximately 259.5 m. The estimated hydraulic conductivity of the silty clay to clayey silt material is in the order of  $10^{-10}$  to  $10^{-9}$  m/s.

Based on the Hydrogeologic and Hydrologic Assessment report, the hydraulic conductivity was estimated (using the falling head test) to be approximately  $1.6 \times 10^{-10}$  m/s for the clayey silt with sand seam of BH13-5. This value is within the estimated range provided above and represents the average value. To account for the potential presence of sand seams, the hydraulic conductivity is considered to be three orders of magnitude higher (i.e., in the order of  $1.6 \times 10^{-7}$  m/s). Temporary unwatering of the excavation at the site using conventional sump and pump techniques is considered appropriate.

In accordance with the hydrogeological report for this project the long term groundwater inflow within the profile could be in the range of 4700 litres per day to 298,000 litres per day. Discussions relating to permit-to-take-water applications are presented in the hydrogeological report.

## 9.0 Specifications

The following specifications are referenced in this report:

Table 9.1: Specifications Referenced in Report

Document	Title
OPSD 3000.100	Foundation, Piles, Steel H-Pile Driving Shoe
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls – Abutment, Backfill – Minimum Granular Requirement
OPSS 206	Construction Specification for Grading
OPSS 902	Construction Specification for Excavation and Backfilling - Structures
OPSS 903	Construction Specification for Deep Foundations
SP 206S03	Earth Excavation, Grading
SP 599S22	Retained Soil System, False Abutment
SP 599S23	Retained Soil System, False Abutment

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## 10.0 Instrumentation and Monitoring

An Instrumentation and Monitoring Plan will be prepared three months prior to commencement of earthworks. The Plan will include:

- Pore water pressure measurement
- Ground movements and impact on Highway 401
- Potential impacts of proposed construction on surrounding facilities
- Check compliance with performance specifications
- Assess design assumptions and refine estimates of future performance
- Survey points on the abutments and approaches. Measurements of differential settlements between abutments and abutment approaches taken at months 3, 6, 12, 18 and 24.
- Survey points along the road surface. Immediately following paving, elevations at the centre line of each lane will be measured at all Bridge abutments and at distances of 20 m, 50 m, 75 m, and 100 m from abutments.

## 11.0 Miscellaneous

The field work under was carried out under the supervision of Mr. Athir Nader, B.Eng., Geotechnical Engineering Intern, under the direction of Chris McGrath, P.Eng.

The private and public utility locates for the boreholes for the detailed design were carried out by Aecon Utility Engineering (AUE), an Aecon Group Inc (AGI) subsidiary, both of Toronto, Ontario.

The track-mounted CME 75 drilling equipment was supplied and operated by Pontil Drilling of Mount Albert, Ontario. The truck-mounted D-90 drilling equipment was supplied and operated by Walker Drilling of Utopia, Ontario.

Location and elevation survey of the Boreholes was carried out by Stantec's Geomatics Group in London, Ontario.

Traffic control service was provided by AGI, Toronto, Ontario.

Geotechnical laboratory testing was carried out at Stantec's Ottawa and Golder's Mississauga laboratories. Chemical testing for pH, soluble sulphate, and chloride content, and resistivity was carried out by Paracel Laboratories of Ottawa.

This report was prepared by Simon Gudina, Ph.D., P.Eng. and reviewed by Chris McGrath, P.Eng. and Raymond Haché, M.Sc., P.Eng, Designated Principal MTO Foundation Contact.

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## 12.0 Closure

The recommendations made in this report are in accordance with our present understanding of the project. We request that we be permitted to review our recommendations when the drawings and specifications are complete.

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

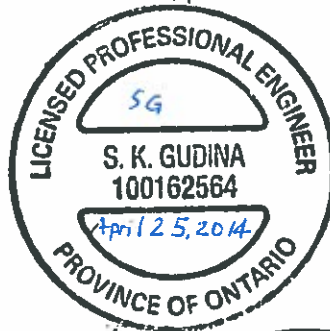
We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

Respectfully submitted,

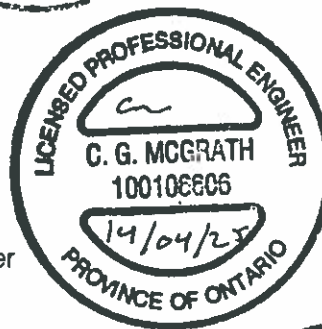
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## 13.0 References

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**FOUNDATION INVESTIGATION AND DESIGN REPORT – NEW HIGHWAY 401 INTERCHANGE  
AT WONDERLAND ROAD**

April 2014

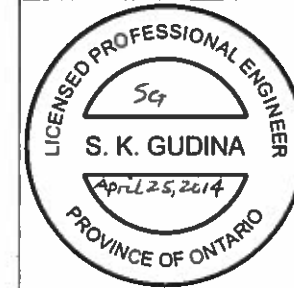
## **APPENDIX A**

Drawings No. 1 and 2 – Borehole Location Plan and Soil Strata Plots

Site Photographs



SHEET



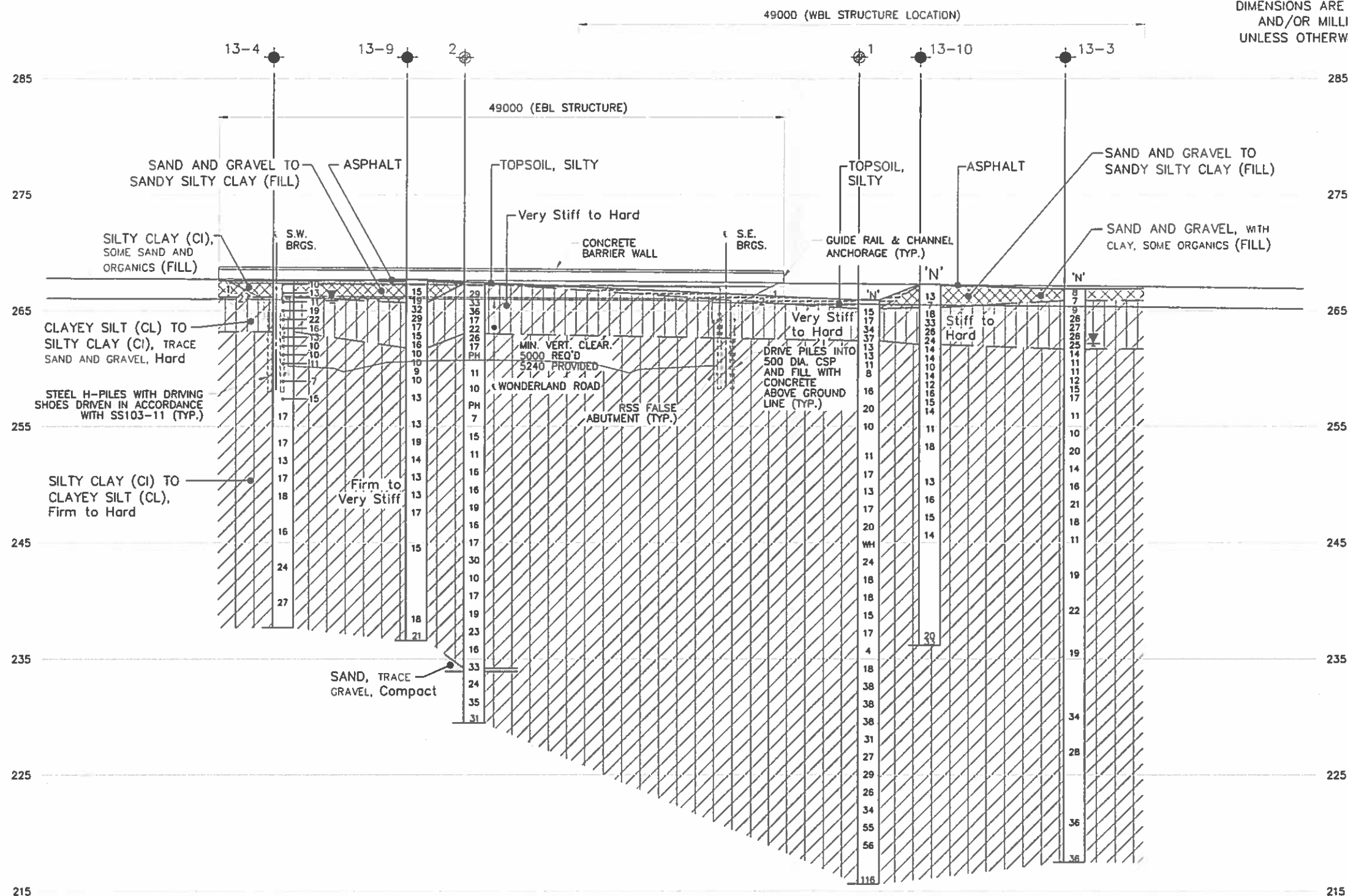
No	ELEVATION	MTM ZONE 11 NORTH	COORDINATES EAST
13-1	263.2	4 749 172.4	406 204.4
13-2	264.6	4 749 125.0	406 237.7
13-3	266.9	4 749 089.8	406 247.7
13-4	267.6	4 749 013.0	406 243.7
13-5	268.1	4 748 980.7	406 270.8
13-6	267.8	4 748 989.1	406 294.0
13-7	267.5	4 748 877.6	406 295.8
13-9	267.7	4 749 030.2	406 236.9
13-10	267.3	4 749 071.8	406 253.8
13-11	266.8	4 749 026.1	406 262.3
13-12	268.0	4 748 926.5	406 282.8
1	265.9	4 749 081.8	406 225.8
2	267.4	4 749 019.1	406 266.3

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

GEORES No 40114-152

HWY No 401			DIST
SUBM'D	CHECKED	DATE 2014-02-28	SITE 19-766
DRAWN GBB	CHECKED	APPROVED <i>SG</i>	DWG 1A

PROGRAM NAME: 165000876\_Plan & CS\_renderand\_id\_op-01.dwg  
CREATED BY: CBB MODIFIED: YY/MM/DD



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

PLATE No  
CONT 2012-3022  
WP 3031-11-00



HIGHWAY 401  
WONDERLAND ROAD OVERPASSES  
SOIL STRATA




SHEET



KEY PLAN

1 km 0 1 2 km

### LEGEND

-  Borehole By Stantec  
 Borehole By Others  
 (Geocres 40H4-132)  
 N Blows/0.3m (Std Pen Test,  
 475 J/blow)  
 Water Level at Time of  
 Investigation, Nov 2013

No	ELEVATION	MTM ZONE 11 COORDINATES	
		NORTH	EAST
13-3	266.9	4 749 089.8	406 247.7
13-4	267.6	4 749 013.0	406 243.7
13-9	267.7	4 749 030.2	406 236.9
13-10	267.3	4 749 071.8	406 253.8
1	265.9	4 749 081.8	406 225.8
2	267.4	4 749 019.1	406 266.3

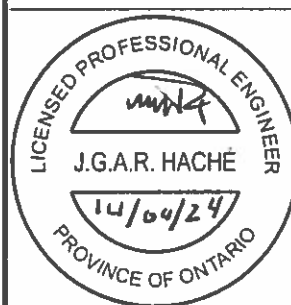
≡NOTES≡

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.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS			
DATE	BY	DESCRIPTION	
GEORES No 40114-152			
HWY No 401		DIST	
SUBMIT SKG	CHECKED	DATE 2013-12-20	SITE 19-766
DRAWN CBB	CHECKED	APPROVED SG	DWG 18

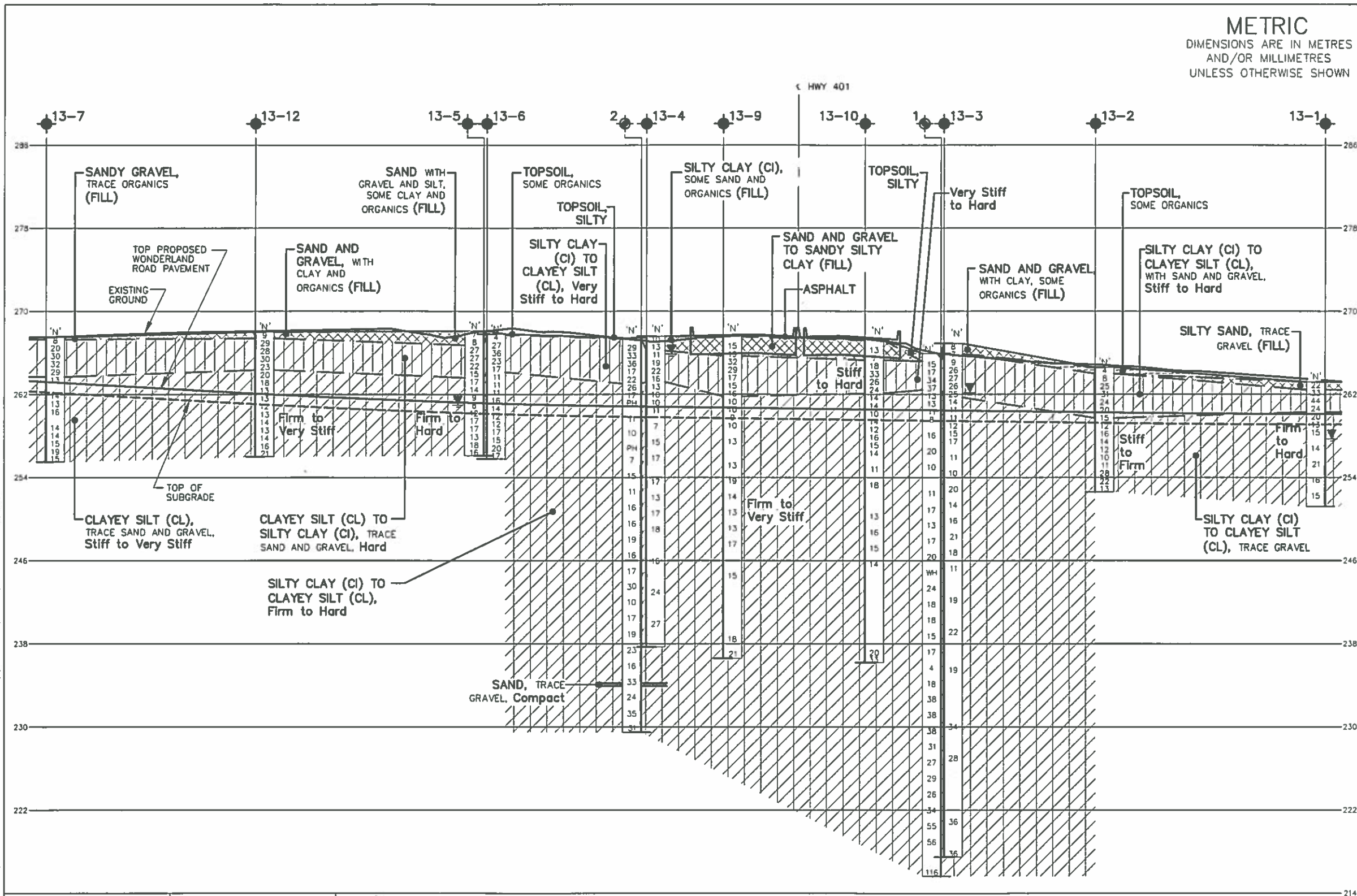


CROSS SECTION A-A'

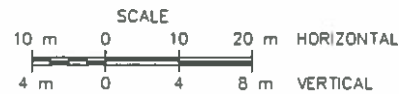
SCALE

4 m      0      4      8 m





CROSS SECTION B-B'



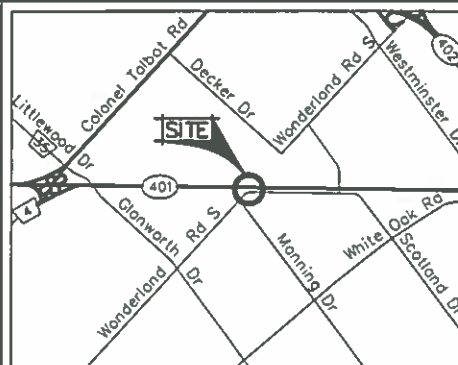
**METRIC**  
 DIMENSIONS ARE IN METRES  
 AND/OR MILLIMETRES  
 UNLESS OTHERWISE SHOWN

PLATE No  
**CONT 2012-3022**  
**WP 3031-11-00**



**HIGHWAY 401**  
**WONDERLAND ROAD OVERPASS**  
**SOIL STRATA**

**SHEET**



**LEGEND**

- Borehole By Stantec
- Borehole By Others (Geocres 40114-132)
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- Water Level at Time of Investigation, Nov 2013

No	ELEVATION	MTM ZONE 11 NORTH	COORDINATES EAST
13-1	263.2	4 749 172.4	406 204.4
13-2	264.6	4 749 125.0	406 237.7
13-3	266.9	4 749 089.8	406 247.7
13-4	267.6	4 749 013.0	406 243.7
13-5	268.1	4 748 980.7	406 270.8
13-6	267.8	4 748 989.1	406 294.0
13-7	267.5	4 748 877.6	406 295.8
13-9	267.7	4 749 030.2	406 236.9
13-10	267.3	4 749 071.8	406 253.8
13-12	268.0	4 748 926.5	406 282.8
1	265.9	4 749 081.8	406 225.8
2	267.4	4 749 019.1	406 266.3

**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.

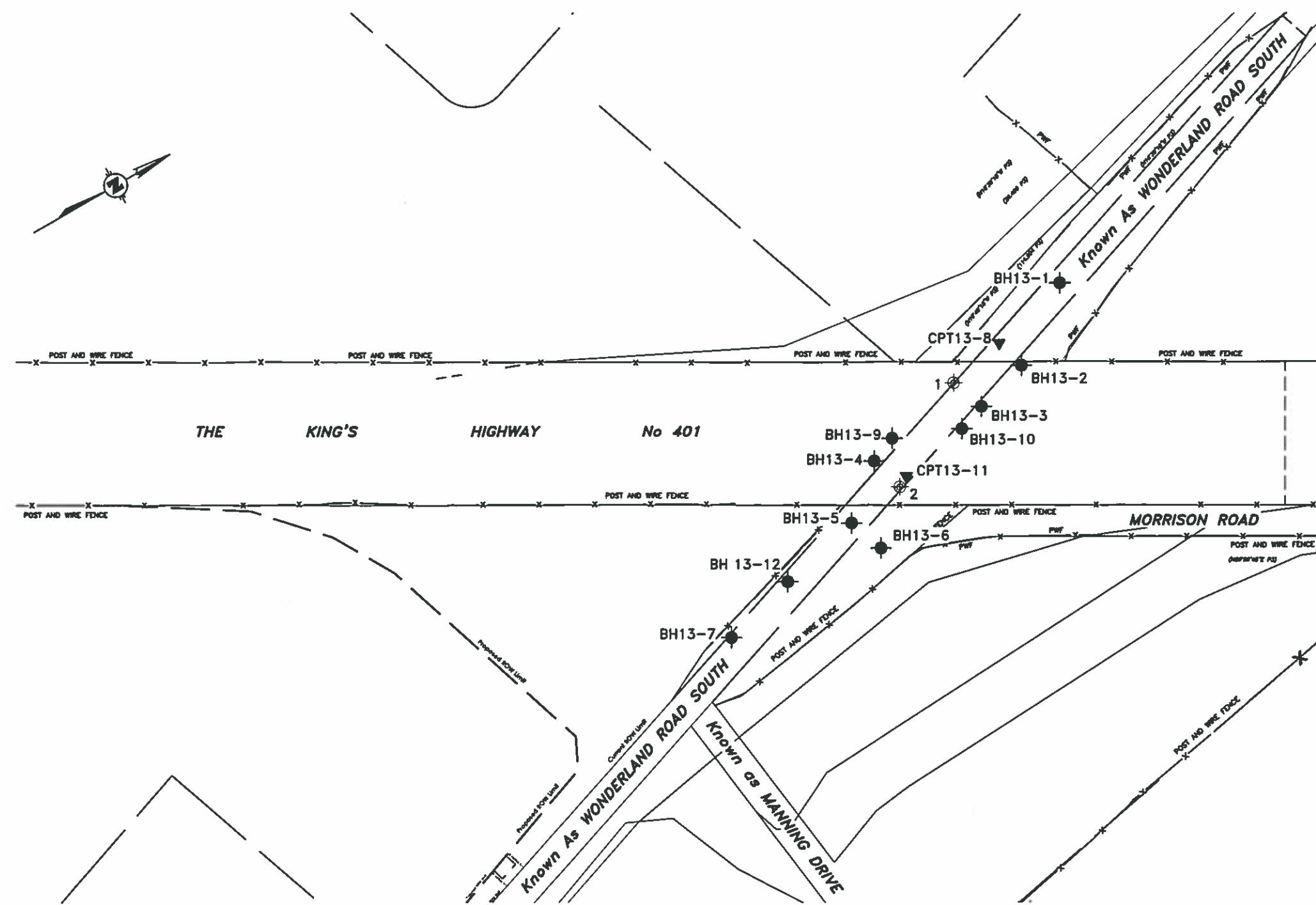
NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS	DATE	BY	DESCRIPTION

GEOCRES No 40114-152

HWY No 401	CHECKED	DATE 2014-02-27	DIST
SUBMIT SKG	CHECKED	SITE 19-766	
DRAWN GBB	CHECKED	APPROVED JG	DWG 1C





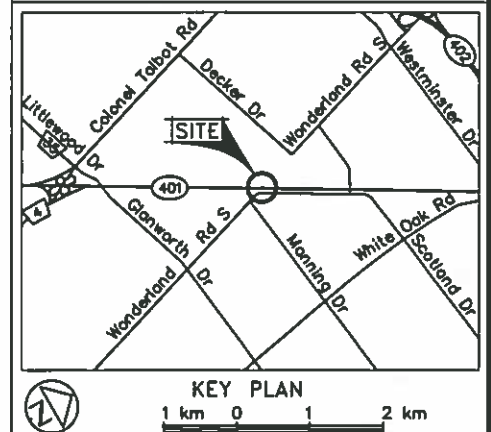
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

PLATE No  
CONT 2012-3022  
WP 3031-11-00




HIGHWAY 401  
WONDERLAND ROAD INTERCHANGE  
BOREHOLE LOCATIONS



SHEET



### LEGEND

-  Borehole By Stantec  
 Borehole By Others  
 (Geocres No. 4014-132)  
 Cone Penetration Test

No	ELEVATION	MTM_ZONE 11 NORTH	COORDINATES EAST
13-1	263.2	4 749 172.4	406 204.4
13-2	264.6	4 749 125.0	406 237.7
13-3	266.9	4 749 089.8	406 247.7
13-4	267.6	4 749 013.0	406 243.7
13-5	268.1	4 748 980.7	406 270.8
13-6	267.8	4 748 989.1	406 294.0
13-7	267.5	4 748 877.6	406 295.8
13-8	265.0	4 749 119.7	406 218.4
13-9	267.7	4 749 030.2	406 236.9
13-10	267.3	4 749 071.8	406 253.8
13-11	266.8	4 749 026.1	406 262.3
13-12	268.0	4 748 926.5	406 282.8
1	265.9	4 749 081.8	406 225.8
2	267.4	4 749 019.1	406 266.3

**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.




NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS					
DATE	BY			DESCRIPTION	
GEORES No 40114-152					
HWY No 401				DIST	
SUB/D	CHECKED	DATE	2014-02-06	SITE	19-766
DRAWN GBR	CHECKED	APPROVED	SG	DWG	1D



SCALE

4 m      0      4      8 m

	Project No.: 165000876	GWP: 3031-11-00	Site Photographs
	Project Name: New Highway 401 at Wonderland Road Interchange, City of London, ON DB Contract 2012-3022		Date: November 10, 2013
			
Site Photo No.: 1	Looking southeast at Highway 401 near BH13-9		
			
Site Photo No.: 2	Looking north at Highway 401 near BH13-10		





Project No.: 165000734

GWP: 3031-11-00

Site Photographs

Project Name: New Highway 401 at Wonderland  
Road Interchange, City of London, ON  
DB Contract 2012-3022

Date: November 10,  
2013



Site Photo No.: 3


Looking east along Highway 401 near BH13-4

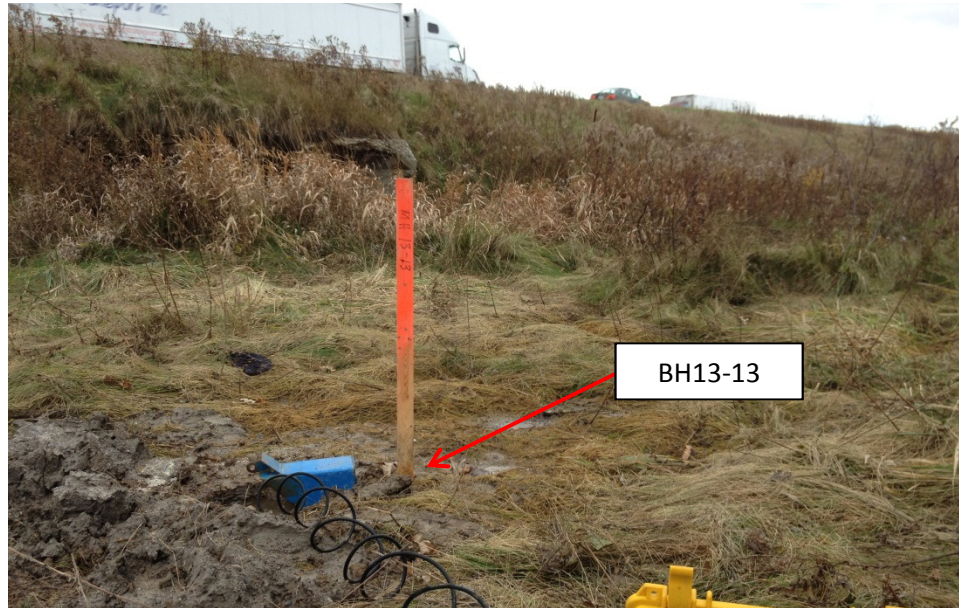


Site Photo No.: 4

Looking northwest near BH13-5





	Project No.: 165000734	GWP: 3031-11-00	Site Photographs
	Project Name: New Highway 401 at Wonderland Road Interchange, City of London, ON DB Contract 2012-3022		Date: November 10, 2013



Site Photo No.: 5      Looking south at Highway 401 near BH13-13 (outlet of Courtney Drain Culvert)



Site Photo No.: 6      Looking south along Highway 401 near BH13-15

	Project No.: 165000734	GWP: 3031-11-00	Site Photographs
	Project Name: New Highway 401 at Wonderland Road Interchange, City of London, ON DB Contract 2012-3022		Date: November 10, 2013
			
Site Photo No.: 7	Looking south near BH13-15 (inlet of Courtney Drain Culvert)		

**FOUNDATION INVESTIGATION AND DESIGN REPORT – NEW HIGHWAY 401 INTERCHANGE  
AT WONDERLAND ROAD**

April 2014

## **APPENDIX B**

Symbols and Terms Used on Borehole Records

Borehole Records

Terminology Used on SCPTu and CPTu Records

CPTu Results

Borehole Records from a Previous Investigation (Geocres Report No. 40I14-132)

Test Site 25 Pile Test Results



## SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

<i>Topsoil</i>	- mixture of soil and humus capable of supporting vegetative growth
<i>Peat</i>	- mixture of visible and invisible fragments of decayed organic matter
<i>Till</i>	- unstratified glacial deposit which may range from clay to boulders
<i>Fill</i>	- material below the surface identified as placed by humans (excluding buried services)

#### Terminology describing soil structure:

<i>Desiccated</i>	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
<i>Fissured</i>	- having cracks, and hence a blocky structure
<i>Varved</i>	- composed of regular alternating layers of silt and clay
<i>Stratified</i>	- composed of alternating successions of different soil types, e.g. silt and sand
<i>Layer</i>	- > 75 mm in thickness
<i>Seam</i>	- 2 mm to 75 mm in thickness
<i>Parting</i>	- < 2 mm in thickness

#### Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488). The classification excludes particles larger than 76 mm (3 inches). The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

#### Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present:

<i>Trace, or occasional</i>	Less than 10%
<i>Some</i>	10-20%
<i>Frequent</i>	> 20%

#### Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test N-Value (also known as N-Index). A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
<i>Very Loose</i>	<4
<i>Loose</i>	4-10
<i>Compact</i>	10-30
<i>Dense</i>	30-50
<i>Very Dense</i>	>50

#### Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests.

Consistency	Undrained Shear Strength	
	kips/sq.ft.	kPa
<i>Very Soft</i>	<0.25	<12.5
<i>Soft</i>	0.25 - 0.5	12.5 - 25
<i>Firm</i>	0.5 - 1.0	25 - 50
<i>Stiff</i>	1.0 - 2.0	50 - 100
<i>Very Stiff</i>	2.0 - 4.0	100 - 200
<i>Hard</i>	>4.0	>200



## ROCK DESCRIPTION

### Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	<i>Very Poor</i>
25-50	<i>Poor</i>
50-75	<i>Fair</i>
75-90	<i>Good</i>
90-100	<i>Excellent</i>

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

### Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 6000	<i>Extremely Wide</i>	-
2000-6000	<i>Very Wide</i>	<i>Very Thick</i>
600-2000	<i>Wide</i>	<i>Thick</i>
200-600	<i>Moderate</i>	<i>Medium</i>
60-200	<i>Close</i>	<i>Thin</i>
20-60	<i>Very Close</i>	<i>Very Thin</i>
<20	<i>Extremely Close</i>	<i>Laminated</i>
<6	-	<i>Thinly Laminated</i>

### Terminology describing rock strength:

Strength Classification	Unconfined Compressive Strength (MPa)
<i>Extremely Weak</i>	< 1
<i>Very Weak</i>	1 – 5
<i>Weak</i>	5 – 25
<i>Medium Strong</i>	25 – 50
<i>Strong</i>	50 – 100
<i>Very Strong</i>	100 – 250
<i>Extremely Strong</i>	> 250

### Terminology describing rock weathering:

Term	Description
<i>Fresh</i>	No visible signs of rock weathering. Slight discolouration along major discontinuities
<i>Slightly Weathered</i>	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
<i>Moderately Weathered</i>	Less than half the rock is decomposed and/or disintegrated into soil.
<i>Highly Weathered</i>	More than half the rock is decomposed and/or disintegrated into soil.
<i>Completely Weathered</i>	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.

## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders  
Cobbles  
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

## SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

## WATER LEVEL MEASUREMENT



measured in standpipe,  
piezometer, or well



inferred

## RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

## N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and N-values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N value corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

## DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to A size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil variability.

## OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
$\gamma$	Unit weight
$G_s$	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
$Q_u$	Unconfined compression
$I_p$	Point Load Index ( $I_p$ on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer



# RECORD OF BOREHOLE No BH13-1

1 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 172 E: 406 204 ORIGINATED BY AN  
 DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
 DATUM Geodetic DATE 2013 10 21 - 2013 10 21 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>P</sub> W      W <sub>L</sub> WATER CONTENT (%)			GR	SA	SI	CL				
								20   40   60   80   100															
								○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL      × LAB VANE															
263.2	Roadbase Granulars																						
0.0	FILL: silty sand, trace fine gravel		1	SS	22		263																
262.4																							
0.8	CLAYEY SILT (CL) to SILTY CLAY (CI), trace sand and gravel		2	SS	33		262									1	9	47	43				
	Hard																						
	Brown		3	SS	44		261																
			4	SS	24																		
260.3																			PP = 225 kPa				
2.9	SILTY CLAY (CI) to CLAYEY SILT (CL), trace gravel		5	SS	20		260												PP = 125 kPa				
	Firm to Hard																						
	Grey		6	SS	13		259									0	4	49	47				
	- trace sand and fine gravel at 4.1 m																		PP = 75 kPa				
			7	SS	15		258												PP = 75 kPa				
			8	SS	-		257												s <sub>v</sub> > 106 kPa @ 5.5 m				
			9	SS	14		256												PP = 75 kPa				
			10	SS	-		255									0	1	65	34				
			11	SS	21		254												s <sub>v</sub> > 106 kPa @ 7.2 m				
			12	SS	-														PP = 110 kPa				
			13	SS	16														s <sub>v</sub> > 106 kPa @ 8.7 m PP = 125 kPa				
	Tip of VWP at 9.1 m																		PP = 125 kPa				
253.2	PP = Pocket Penetrometer																		PP = 75 kPa				

Continued Next Page

×<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37



## RECORD OF BOREHOLE No BH13-1

2 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 172 E: 406 204 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
DATUM Geodetic DATE 2013 10 21 - 2013 10 21 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
							○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL    × LAB VANE													
10.0	(continued) SILTY CLAY, trace gravel  Hard to firm  Grey		14	SS	-		253											PP = 35 kPa 0 7 55 38 s <sub>u</sub> > 106 kPa @ 10.2 m		
			15	SS	15		252												PP = 50 kPa	
			16	SS	-														PP = 60 kPa s <sub>u</sub> > 106 kPa @ 11.7 m	
251.2	PP = Pocket Penetrometer																			
12.0	End of Borehole  Vibrating Wire Piezometer (VWP) Installed @ 9.1 m																			

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ^3$  STRAIN AT FAILURE



## RECORD OF BOREHOLE No BH13-2

1 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 125 E: 406 238 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
DATUM Geodetic DATE 2013 10 22 - 2013 10 22 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		
								○ UNCONFINED ● QUICK TRIAXIAL	✕ FIELD VANE ✕ LAB VANE	WATER CONTENT (%)				
264.6	Topsoil							20 40 60 80 100						
0.0	600 mm TOPSOIL - some organics		1	SS	4									
264.0	SILTY CLAY (CI) to CLAYEY SILT (CL) with sand and gravel						264							
0.6	Stiff to hard		2	SS	8									PP = 85 kPa
	Brown to greyish brown													
	- trace organics to 1.1 m depth						263							
			3	SS	25									PP >225 kPa
	- field vane >200 kPa		4	SS	31		262		>>✕		●	●		7 9 46 38 PP >225 kPa
	- field vane >200 kPa		5	SS	24		261		>>✕		○			PP = 225 kPa
	- field vane >200 kPa		6	SS	20		260		>>✕		○			PP = 175 kPa
259.7	SILTY CLAY (CI) to CLAYEY SILT (CL), trace gravel		7	SS	15		259			1.97	●	○	●	1 7 50 42 PP = 85 kPa
4.9	Stiff to firm													
	Grey		8	SS	12									
							258							PP = 85 kPa
			9	SS	16									
			10	SS	14		257		1.83	✕				PP = 85 kPa
			11	SS	12									PP = 60 kPa
	- moist from 8.4 m						256		✕		●	○	●	1 3 48 48 PP = 75 kPa
			13	SS	11		255							PP = 35 kPa
254.6	PP = Pocket Penetrometer													

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MTO.GDT 14/37



## RECORD OF BOREHOLE No BH13-2

2 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 125 E: 406 238 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
DATUM Geodetic DATE 2013 10 22 - 2013 10 22 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
10.0	(continued) SILTY CLAY, trace gravel  Grey  Stiff to firm - field vane 172 kPa		14	SS	28	254																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ^3$  STRAIN AT FAILURE

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 090 E: 406 248	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN/KKB
DATUM	Geodetic	DATE	2013 11 05 - 2013 11 08		CHECKED BY	SG

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$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

○ 3% STRAIN AT FAILURE



# RECORD OF BOREHOLE No BH13-3

2 OF 5

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 090 E: 406 248 ORIGINATED BY AN  
 DIST                      HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
 DATUM Geodetic DATE 2013 11 05 - 2013 11 08 CHECKED BY SG

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			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		
								○ UNCONFINED ● QUICK TRIAXIAL	× FIELD VANE × LAB VANE					
	SILTY CLAY (CI) to CLAYEY SILT (CL), some sand and gravel  Firm to hard  Brownish grey to grey <i>(continued)</i>		14	ST	-									
			15	SS	11		256							0 3 49 48 PP = 75 kPa
							255							
			16	SS	10		254							PP = 35 kPa
			17	SS	20		253							PP = 85 kPa
							252							
			18	SS	14		251							PP = 60 kPa
			19	SS	16		250							0 6 57 37 PP = 25 kPa
							249							
			20	SS	21		248							
							247							

Continued Next Page

×<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37



W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 090 E: 406 248	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN/KKB
DATUM	Geodetic	DATE	2013 11 05 - 2013 11 08		CHECKED BY	SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		WATER CONTENT (%)			
								○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
	SILTY CLAY (CI) to CLAYEY SILT (CL), some sand and gravel  Firm to hard  Brownish grey to grey <i>(continued)</i>		21	SS	18		246								PP = 35 kPa		
			22	SS	11		245								PP = 25 kPa		
			23	SS	19		242								2   5   58   35		
			24	SS	22		239								PP = 50 kPa		
							238										
							237										

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7



## RECORD OF BOREHOLE No BH13-3

4 OF 5

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 090 E: 406 248 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN/KKB  
DATUM Geodetic DATE 2013 11 05 - 2013 11 08 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						W <sub>P</sub> W                      W <sub>L</sub> WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED	× FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	20		40	60	80				
	SILTY CLAY (CI) to CLAYEY SILT (CL), some sand and gravel  Firm to hard  Brownish grey to grey <i>(continued)</i>						236													
			25	SS	19													PP = 50 kPa		
							235													
							234													
			26	ST	-		233													
							232													
							231													
			27	SS	34		230											PP = 75 kPa 2   9   53   36		
							229													
							228													
			28	SS	28		227													

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 090 E: 406 248	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN/KKB
DATUM	Geodetic	DATE	2013 11 05 - 2013 11 08		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE



# RECORD OF BOREHOLE No BH13-4

1 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 013 E: 406 244 ORIGINATED BY AN  
 DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
 DATUM Geodetic DATE 2013 10 31 - 2013 11 01 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
267.6 0.0	Topsoil		1	SS	10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

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×<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 013 E: 406 244	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Spitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 31 - 2013 11 01		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/77

Continued Next Page

**x<sup>3</sup>, x<sup>3</sup>:** Numbers refer to Sensitivity      **○<sup>3%</sup>** STRAIN AT FAILURE

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 013 E: 406 244	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Spitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 31 - 2013 11 01		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/77

Continued Next Page

**x<sup>3</sup>, x<sup>3</sup>:** Numbers refer to Sensitivity      **○<sup>3%</sup>** STRAIN AT FAILURE



## RECORD OF BOREHOLE No BH13-4

4 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 013 E: 406 244 ORIGINATED BY AN  
DIST                      HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 31 - 2013 11 01 CHECKED BY SG

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		
29.9	End of Borehole  Vibrating Wire Piezometer (VWP) Installed @ 9.1 m																

$\times^3, \times^3$ : Numbers refer to Sensitivity       $\circ$  3% STRAIN AT FAILURE



## RECORD OF BOREHOLE No BH13-5

1 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 748 981 E: 406 271 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 24 - 2013 10 25 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	✕ FIELD VANE ✕ LAB VANE							
268.1 0.0	Topsoil FILL: sand with gravel and silt, some clay and organics		1	SS	7		268							Org M=5.5% 20 49 (31)		
			2	SS	8		267									
266.7 1.4	CLAYEY SILT (CL) Hard Brownish grey to grey		3	SS	27		266							PP = 225 kPa		
			4	SS	27		265							PP = 225 kPa		
	- field vane 202 kPa		5	SS	22		264		>>✕					1 12 52 35 PP = 225 kPa		
	- moist from 3.8 m		6	SS	15		263							PP = 200 kPa		
263.6 4.5	CLAYEY SILT (CL) Firm to hard Grey		7	SS	17		262							PP = 125 kPa		
			8	SS	14		261							PP = 100 kPa		
	- sand seam at 6.6 m		9	SS	9		260		>>✕ 1.56					0 8 50 42 PP = 60 kPa		
	- field vane 132 kPa		10	SS	8		259							PP = 85 kPa		
			11	SS	12									PP = 35 kPa		
			12	SS	17									PP = 85 kPa		
			13	SS	17									PP = 85 kPa		

PP = Pocket penetrometer

Continued Next Page

 $\times^3, \times^3$ : Numbers refer to  
Sensitivity $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37






## RECORD OF BOREHOLE No BH13-5

2 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 748 981 E: 406 271 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 24 - 2013 10 25 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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												
	CLAYEY SILT (CL)		14	SS	13		258												PP = 85 kPa				
	Firm to hard																						
	Grey (continued) (continued) SILTY CLAY, trace gravel																						
	Stiff to very stiff		15	SS	18	257													PP = 100 kPa				
	Grey - silty sand seam at 10.4 m - sand seam at 11.3 m																		PP = 85 kPa				
256.1			16	SS	16																		
12.0	End of Borehole																						
	Monitoring Well Installed @ 12 m																						
					</																		



## RECORD OF BOREHOLE No BH13-6

1 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 748 989 E: 406 294 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 25 - 2013 10 25 CHECKED BY SG

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub> W                      W <sub>L</sub> WATER CONTENT (%)					
								○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							
267.8 267.0 266.9 0.1	Topsoil/soil 80 mm topsoil, some organics SILTY CLAY (Cl), trace organics  Hard  Brown to brownish grey		1	SS	4	267							Org M=4.1% PP = 135 kPa		
			2	SS	27										PP = 225 kPa
			3	SS	36		266								4   9   47   40
			4	SS	23										
	-moist from 3.18 m		5	SS	17	265								PP = 125 kPa PP = 175 kPa	
264.1 3.7	CLAYEY SILT (CL)  Stiff to very stiff  Grey, moist		6	SS	11		264								PP = 60 kPa
			7	SS	11	263									1   14   50   35 PP = 50 kPa PP = 60 kPa PP = 110 kPa
	- fine sandy silt seam at 5.6 m		8	SS	11		262								PP = 60 kPa PP = 150 kPa
			9	SS	16	261									PP = 60 kPa PP = 150 kPa
			10	SS	14		260								0   8   50   42 PP = 85 kPa
			11	SS	12	259									PP = 75 kPa
			12	SS	12		258								PP = 75 kPa
			13	SS	17										PP = 50 kPa PP = 75 kPa
	PP = Pocket penetrometer														

PP = Pocket penetrometer

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37



## RECORD OF BOREHOLE No BH13-6

2 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 748 989 E: 406 294 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 25 - 2013 10 25 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		
							○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL    × LAB VANE													
	CLAYEY SILT (CL)  Stiff to very stiff  Grey, moist (continued) (continued) SILTY CLAY, trace gravel  Stiff to very stiff  Grey, moist		14	SS	15		257										PP = 110 kPa			
			15	SS	20												0 7 49 44			
			16	SS	17		256										PP = 75 kPa			
255.8 12.0	End of Borehole																PP = 125 kPa PP = 75 kPa			

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 748 878 E: 406 296	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Spitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 24 - 2013 10 24		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/77

Continued Next Page

**✕<sup>3</sup>, ✕<sup>3</sup>:** Numbers refer to Sensitivity      **○<sup>3%</sup>** STRAIN AT FAILURE

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 748 878 E: 406 296	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 24 - 2013 10 24		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE





## RECORD OF BOREHOLE No BH13-9

2 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 030 E: 406 237 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 11 08 - 2013 11 09 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>P</sub>	W	W <sub>L</sub>		GR	SA	SI	CL	
	SILTY CLAY (CI) to CLAYEY SILT (CL)  Firm to very stiff  Grey (continued)		14	SS	13													PP = 85 kPa			
							257														
							256														
			15	SS	13		255											PP = 85 kPa			
							254														
	- fine sandy silt seam at 14.0 m		16	SS	19		253											PP = 75 kPa			
							252											PP = 60 kPa			
			17	SS	14		251														
			18	SS	13		250											PP = 85 kPa			
							249											PP = 85 kPa			
	- fine sandy silty clay seam at 19.3 m		19	SS	13		248														

Continued Next Page

×<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MTO.GDT 14/37

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 030 E: 406 237	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Spitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 11 08 - 2013 11 09		CHECKED BY	SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20   40   60   80   100	20   40   60   80   100	W <sub>P</sub> W   W <sub>L</sub>				
								SHEAR STRENGTH kPa		WATER CONTENT (%)				
	SILTY CLAY (CI) to CLAYEY SILT (CL)  Firm to very stiff  Grey ( <i>continued</i> )		20	SS	17									PP = 60 kPa
							247							
							246							
							245							
			21	SS	15									PP = 60 kPa
							244							
							243							
							242							
			22	ST	-									
							241							
							240							
							239							
	- trace fine sand observed from 29.0 m to 29.5 m		23	SS	18									PP = 35 kPa
							238							

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7





## RECORD OF BOREHOLE No BH13-9

4 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 030 E: 406 237 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 11 08 - 2013 11 09 CHECKED BY SG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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 <sub>p</sub> W W <sub>L</sub>					
						○ UNCONFINED × FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
						20 40 60 80 100					10 20 30					
236.6	SILTY CLAY (CI) to CLAYEY SILT (CL) Firm to very stiff Grey (continued)		24	SS	21	237										PP = 35 kPa
31.1	End of Borehole															



## RECORD OF BOREHOLE No BH13-10

1 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 072 E: 406 254 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 11 08 - 2013 11 09 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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						20	40	60
267.3	Roadbase																			
267.0	100 mm Asphalt																			
0.1	Fill: sand and gravel to sandy silty clay		1	BS	-		267													
			2	SS	13		266													
265.3			3	SS	7															
2.0	SILTY CLAY (CI), some sand and gravel						265										PP = 100 kPa			
	Stiff to hard		4	SS	18															
	Greyish brown		5	SS	33		264													
			6	SS	26		263													
			7	SS	24												PP = 135 kPa			
262.1							262										PP = 125 kPa			
5.2	CLAYEY SILT (CL) to SILTY CLAY (CI)		8	SS	14		261										PP = 85 kPa			
	Firm to hard		9	SS	14		260										PP = 60 kPa			
	Grey		10	SS	10		259										PP = 60 kPa			
			11	SS	14												PP = 75 kPa			
			12	SS	12		258										PP = 85 kPa			
			13	SS	16															

PP = Pocket penetrometer

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 072 E: 406 254	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 11 08 - 2013 11 09		CHECKED BY	SG

[illegible]

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 749 072 E: 406 254	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 11 08 - 2013 11 09		CHECKED BY	SG

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Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7



## RECORD OF BOREHOLE No BH13-10

4 OF 4

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Wonderland Road, London, ON N: 4 749 072 E: 406 254 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 11 08 - 2013 11 09 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	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										10 20 30				
	CLAYEY SILT (CL) to SILTY CLAY (CI)																					
	Firm to hard		24	SS	20																	
	Grey (continued)																					
			25	SS	33																	
236.2																						
31.1	End of Borehole															PP = 75 kPa						

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 748 927 E: 406 283	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 28 - 2013 10 28		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7



Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Wonderland Road, London, ON	N: 4 748 927 E: 406 283	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 10 28 - 2013 10 28		CHECKED BY	SG

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

 <sup>3</sup>,  $\times^3$ : Numbers refer to Sensitivity
  <sup>3%</sup> STRAIN AT FAILURE



## RECORD OF BOREHOLE No BH13-13

1 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Courtney Drain Culvert, London, ON N: 4 748 460 E: 405 866 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 29 - 2013 10 29 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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												
260.2	Topsoil							20	40	60	80	100								
260.1	60 mm topsoil																			
	SILTY CLAY (Cl), trace organics		1	SS	2		260										PP = 200 kPa			
	Hard																			
	Reddish brown to brown		2	SS	24		259										0 7 50 43			
258.3	CLAYEY SILT (CL)		3	SS	29		258													
1.9	Firm to very stiff																			
	Grey		4	SS	22															
	- moist from 1.9 m																			
			5	SS	19		257										PP = 200 kPa			
			6	SS	18		256										1 9 55 35			
																	PP = 225 kPa			
			7	SS	17		255										PP = 125 kPa			
			8	SS	13												PP = 35 kPa			
254.3	SILTY GRAVEL (GM) with sand						254													
5.9	Compact		9	SS	5															
	Grey																			
	Tip of VWP at 6.1 m		10	SS	16		253										51 31 15 3			
252.4	CLAYEY SILT (CL) , some sand and gravel		11	SS	13		252													
7.8	Very stiff																			
	Grey		12	SS	13												PP = 125 kPa			
							251													
			13	SS	18												11 14 47 28			
																	PP = 25 kPa			
250.3	PP = Pocket penetrometer																			

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MTO.GDT 14/3/7






## RECORD OF BOREHOLE No BH13-13

2 OF 2

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Courtney Drain Culvert, London, ON N: 4 748 460 E: 405 866 ORIGINATED BY AN  
DIST                      HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 29 - 2013 10 29 CHECKED BY SG

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
9.9	End of Borehole  Vibrating Wire Piezometer (VWP) Installed @ 6.1 m												

$\times^3, \times^3$ : Numbers refer to Sensitivity       $\circ$  3% STRAIN AT FAILURE

W.P.	GWP 3031-11-00	LOCATION	Highway 401 at Courtney Drain Culvert, London, ON	N: 4 748 473 E: 405 910	ORIGINATED BY	AN
DIST	HWY 401	BOREHOLE TYPE	8" Augers, Splitspoon Sampler		COMPILED BY	AN
DATUM	Geodetic	DATE	2013 11 09 - 2013 11 09		CHECKED BY	SG

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STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

Continued Next Page

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE

W.P. <u>GWP 3031-11-00</u>	LOCATION <u>Highway 401 at Courtney Drain Culvert, London, ON</u>	N: <u>4 748 473</u> E: <u>405 910</u>	ORIGINATED BY <u>AN</u>
DIST <u>          </u> HWY <u>401</u>	BOREHOLE TYPE <u>8" Augers, Splitspoon Sampler</u>	COMPILED BY <u>AN</u>	
DATUM <u>Geodetic</u>	DATE <u>2013 11 09 - 2013 11 09</u>	CHECKED BY <u>SG</u>	

[illegible]

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/3/7

$\times^3, \times^3$ : Numbers refer to Sensitivity
 
 $\bigcirc^{3\%}$  STRAIN AT FAILURE



## RECORD OF BOREHOLE No BH13-15

1 OF 1

METRIC

W.P. GWP 3031-11-00 LOCATION Highway 401 at Courtney Drain Culvert, London, ON N: 4 748 476 E: 405 958 ORIGINATED BY AN  
DIST HWY 401 BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY AN  
DATUM Geodetic DATE 2013 10 29 - 2013 10 29 CHECKED BY SG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
260.5	Topsoil							20	40	60	80	100								
260.4	150 mm topsoil with organics																			
0.2	SILTY CLAY (Cl), with organics, some sand, trace gravel		1	SS	4		260										Org M=7.5%			
	Firm																			
	Brownish grey		2	SS	7															
259.0							259													
1.5	SILTY CLAY (Cl)		3	SS	22												0 9 51 40			
	Very stiff to hard																			
	Brown to grey																			
	- frequent sand seams		4	SS	21		258													
	- trace organics at 3.0 m		5	SS	31		257													
			6	SS	18		256													
	- Clayey silt with sand at 4.8 m		7	SS	28												6 20 61 13			
255.3							255													
5.2	SILTY CLAY (Cl)		8	SS	13															
	Firm to hard																			
	Grey		9	SS	20		254													
			10	SS	14		253													
	- sandy silt seam at 7.5 m		11	SS	10		252										6 8 54 32			
			12	SS	15															
			13	SS	12		251													
250.7	PP = Pocket penetrometer																			
9.8	End of Borehole																			

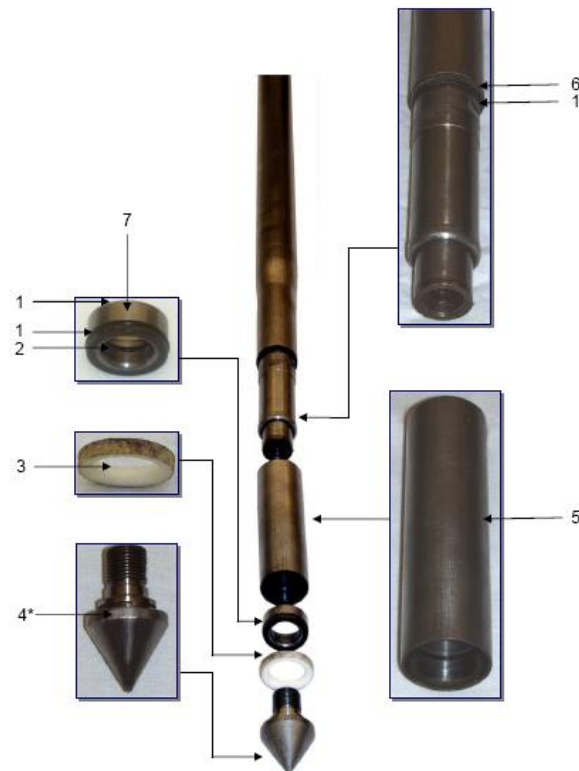
$\times^3, \times^3$ : Numbers refer to Sensitivity  $\circ$  3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000876 - WONDERLAND RD.GPJ ONTARIO MOT.GDT 14/37

## CPT Equipment and Details

Stantec Limited's standard method for cone penetration testing (CPT) uses a Vertek 4579 Digital Piezocone (serial number 2659.109) with a cone area of 10 cm<sup>2</sup> (1.5 in<sup>2</sup>) and a mass of 14500 kg (32,000 lb). It is capable of recording the following parameters:

- Tip Resistance,  $q_c$
- Sleeve Friction,  $f_s$  (Side Friction)
- Pore Water Pressure,  $u_2$
- Shear Wave Arrival Time
- Compression Wave Arrival Time
- Inclination
- Temperature



Item	Description
1	O-Ring
2	O-Ring
3	Piezo filter, saturated in de-aired silicone oil
4	Piezo tip
*	Standard tip (For use without piezo filter)
5	Friction Sleeve
6	X-Ring
7	Retainer Ring

The CPTu unit can be used to interpret subsurface stratigraphy. The piezocone is pushed at a rate of 2 cm/s, with a drill rig providing the thrust and reaction force. The piezocone measures force in two locations – at the tip of the penetrometer, as well as along the sleeve. The tip load cell, which measures tip resistance ( $q_c$ ) has a range of 100 kN (22,000 lb) and an accuracy of 0.2%. Other penetrometer specifications include:

- Cone Area: 10 cm<sup>2</sup>
- Net Area Ratio: 0.83
- Zero Drift: 0.006 %FS/degF
- Linearity: 0.10%FS (max)
- Overload Cap (%): 150

A load cell along the sleeve measures sleeve friction ( $f_s$ ) with a range of 20 kN (4,400 lb) and an accuracy of 0.2%. Further specifications include:

- Sleeve Area: 150 cm<sup>2</sup>
- Net Area Ratio: 1.00
- Zero Drift: 0.003 %FS/degF
- Linearity: 0.25 %FS (max)
- Overload Cap (%) 150

A piezofilter, saturated in de-aired silicone oil, acts as a pore pressure transducer. This instrument, which is situated behind the cone of the penetrometer (commonly referred to as position  $u_2$ ), has a standard range of 3.5 MPA (500 psi) and an accuracy of 0.5%. Further specifications are as follows:

- Burst Pressure: 150 %
- Rise Time (10-90%) <1 ms
- Zero Drift: 0.03 %FS/degF
- Static Error Band: 0.03 %FS (max)

The built-in inclinometer has a range of  $\pm 15^\circ$ , and an accuracy of  $1^\circ$ .

## Terminology Used on SCPTu and CPTu Records

### Key Terminology and Principles

#### **SCPTu:**

- Seismic Piezocone (SCPTu);
- A piezocone (CPTu) is an enhanced cone penetration test (CPT) probe that is able to measure porewater pressure ( $u$ );
- A seismic piezocone (SCPTu) is further enhanced to measure surface generated compression and shear waves at depth; used to define the shear wave velocity of soils.

#### **Equipment Type and Governing Standard:**

- 10 cm<sup>2</sup> seismic piezocone;
- 150 cm<sup>2</sup> friction sleeve;
- manufactured by Applied Research Associates, Inc.;
- ASTM Specification D3441.

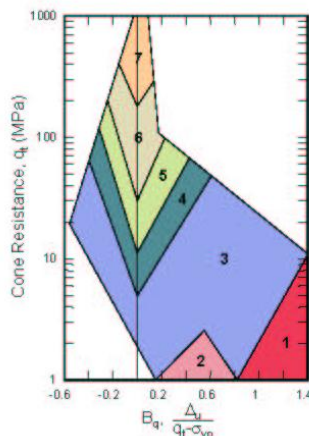
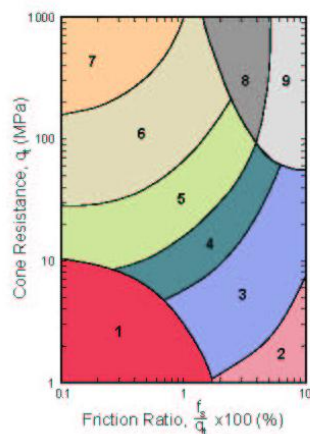
#### **SCPTu Investigation Objectives:**

- evaluate soil type and soil stratigraphy;
- estimate the relative density of granular soils and in situ undrained shear strength of cohesive soils.

#### **Soil Behavior Type (SBT):**

- The SBT is selected based on a soil's response to cone penetration, which is different from an explicit soil type defined by specified laboratory testing procedures, but is normally what the geotechnical engineer requires for design purposes.
- The SBT can be classified on the basis of the soil friction ratio,  $F_r$ ; ratio between the side shear on the friction sleeve and cone tip resistance.
- The SBT can also be classified on the basis of the normalized pore pressure,  $B_q$ ; a function of the pore water response to penetration and the cone tip resistance.
- The "CPTu Soil Behavior Type Legend" used for this project is presented below.

### CPTu Soil Behavior Type Legend (Robertson et al. 1990)



Zone	Soil Behavior Type
1	Sensitive, Fine Grained
2	Organic Soils-Peats
3	Clays; Clay to Silty Clay
4	Silt Mixtures; Clayey Silt to Silty Clay
5	Sand Mixtures; Silty Sand to Sandy Silt
6	Sands; Clean Sands to Silty Sands
7	Gravelly Sand to Sand
8	Very Stiff Sand to Clayey Sand*
9	Very Stiff Fine Grained*

\*Overconsolidated or Cemented



## Terminology and Key Engineering Relationships

Parameter	Description	Symbol/Equation
Depth/Elevation	Measured at the centroid of the sensor	
Sleeve Stress	Measured friction stress on the friction sleeve located above the cone tip	$f_s$
Tip Stress, Uncorrected	Measured compression stress on the cone tip surface	$q_c$
Corrected Tip Stress	Tip stress, corrected for probe geometry	$q_t = q_c + u_2 \cdot (1 - a)$ where $a$ is a geometry based ratio relating the diameters of the inner load cell and the cone
Ratio (%)	Friction ratio	$R_f = \frac{f_s}{q_t} \cdot 100 \%$
In situ Pore Pressure	In situ equilibrium or static value	$u_0$
Measured Pore Pressure	Penetration pore pressure value	$u_2$
Overburden Stress		$\sigma_{vo}$
Effective Overburden Stress		$\sigma'_{vo} = \sigma_{vo} - u_o$
Normalized Tip Stress		$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}}$
Normalized Friction Ratio		$F_r = \frac{f_s}{q_t - \sigma_{vo}}$
Normalized Pore Pressure		$B_q = \frac{\Delta u}{q_t - \sigma_{vo}}$ where $\Delta u = u_2 - u_0$

### Key References:

T. Lunne, P.K. Robertson, and J.J.M. Powell (1997). "Cone Penetration Testing in Geotechnical Practice"; Spon Press.

P.W. Mayne (1986). "CPT indexing of in situ OCR in Clays"; Proceedings of the ASCE Specialty Conference In Situ '86: Use of In Situ Tests in Geotechnical Engineering, Blacksburg, 780-93, ASCE.

P.K. Robertson and R.G. Campanella (1988). "Guidelines for geotechnical design using CPT and CPTU"; University of British Columbia, Vancouver, Department of Civil Engineering, Soil Mechanics Series 120.

P.K. Robertson (1990) "Soil classification using the cone penetration test", Canadian Geotechnical Journal, Vol. 27, No. 1, pp. 151-158.



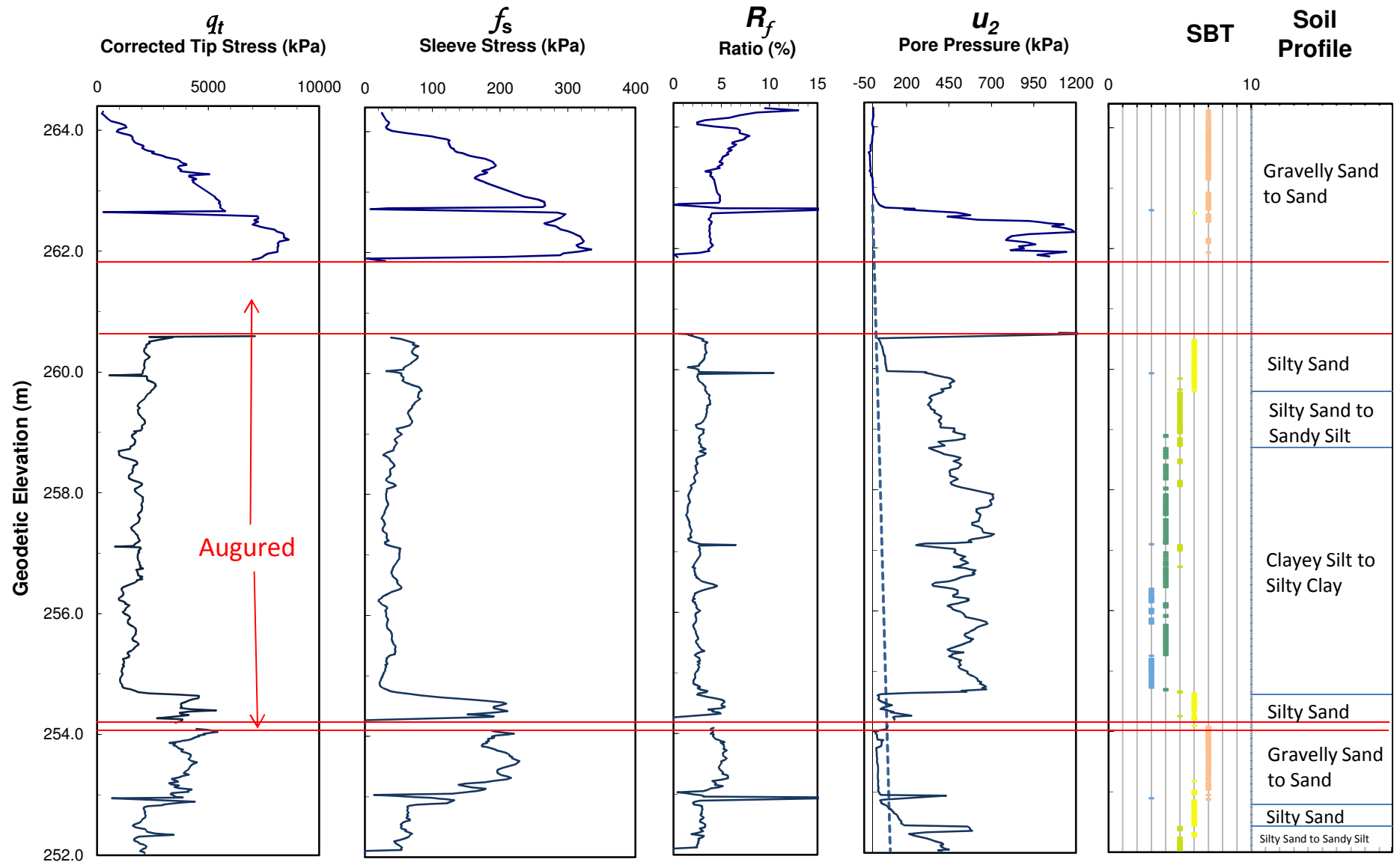


Elevation: 264.40 m  
SCPTu Start Elevation: 264.40 m  
Groundwater Elevation: 262.70 m

Test Date: 30-Oct-14  
Project No. 165000876

CPT 13-8

Client: Aecon Construction and Materials Limited  
Project: D-B Wonderland Rd/Hwy 401 IC



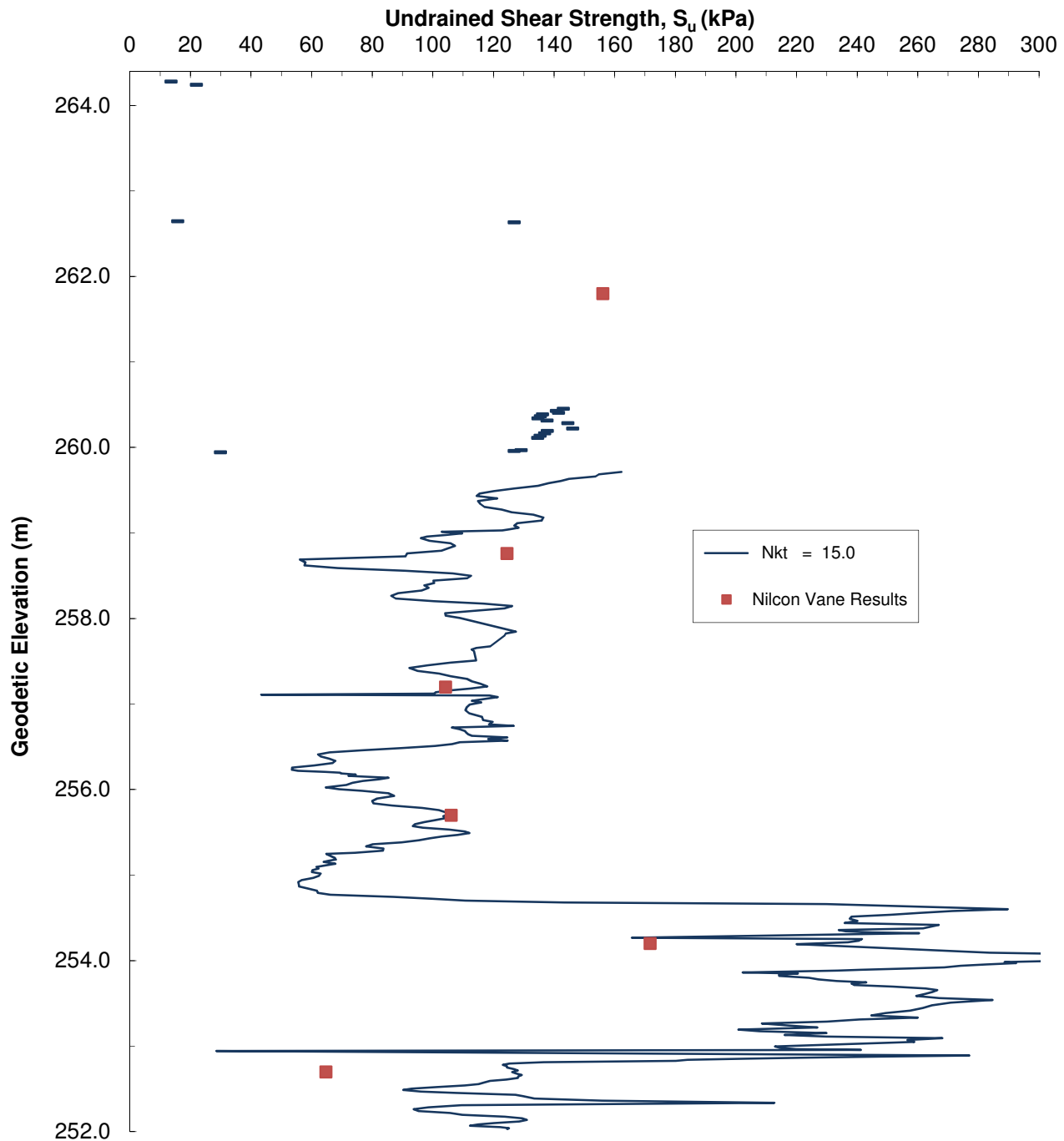
Class Fr: Friction Ratio Classification (Robertson 1990)



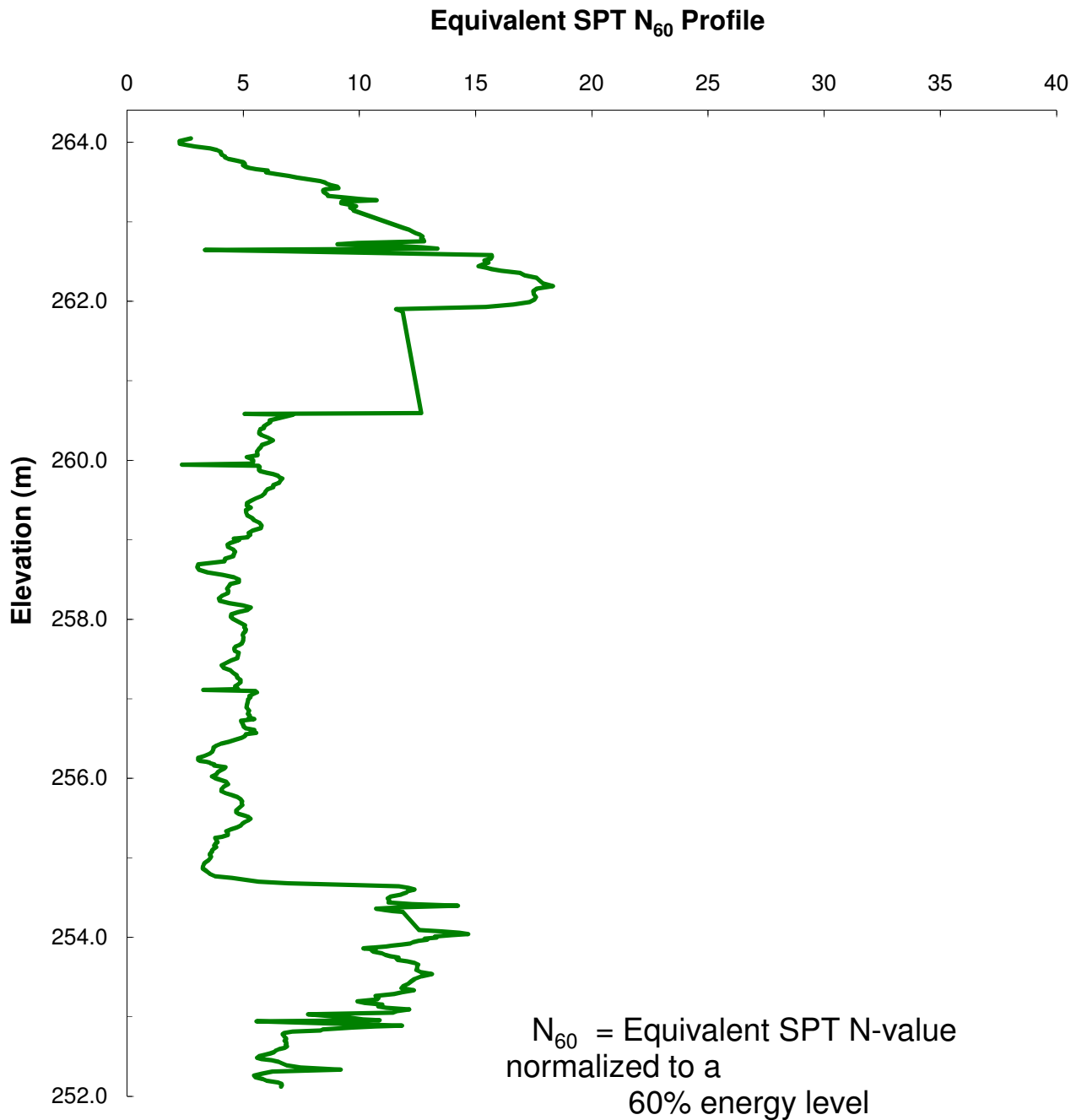
Stantec

# SCPTu RESULTS

Undrained Shear Strength,  $S_u$



CPT 13-8



The correlation from SCPTu data to equivalent SPT  $N_{60}$  values is based on the Jefferies and Davies

CPT 13-8

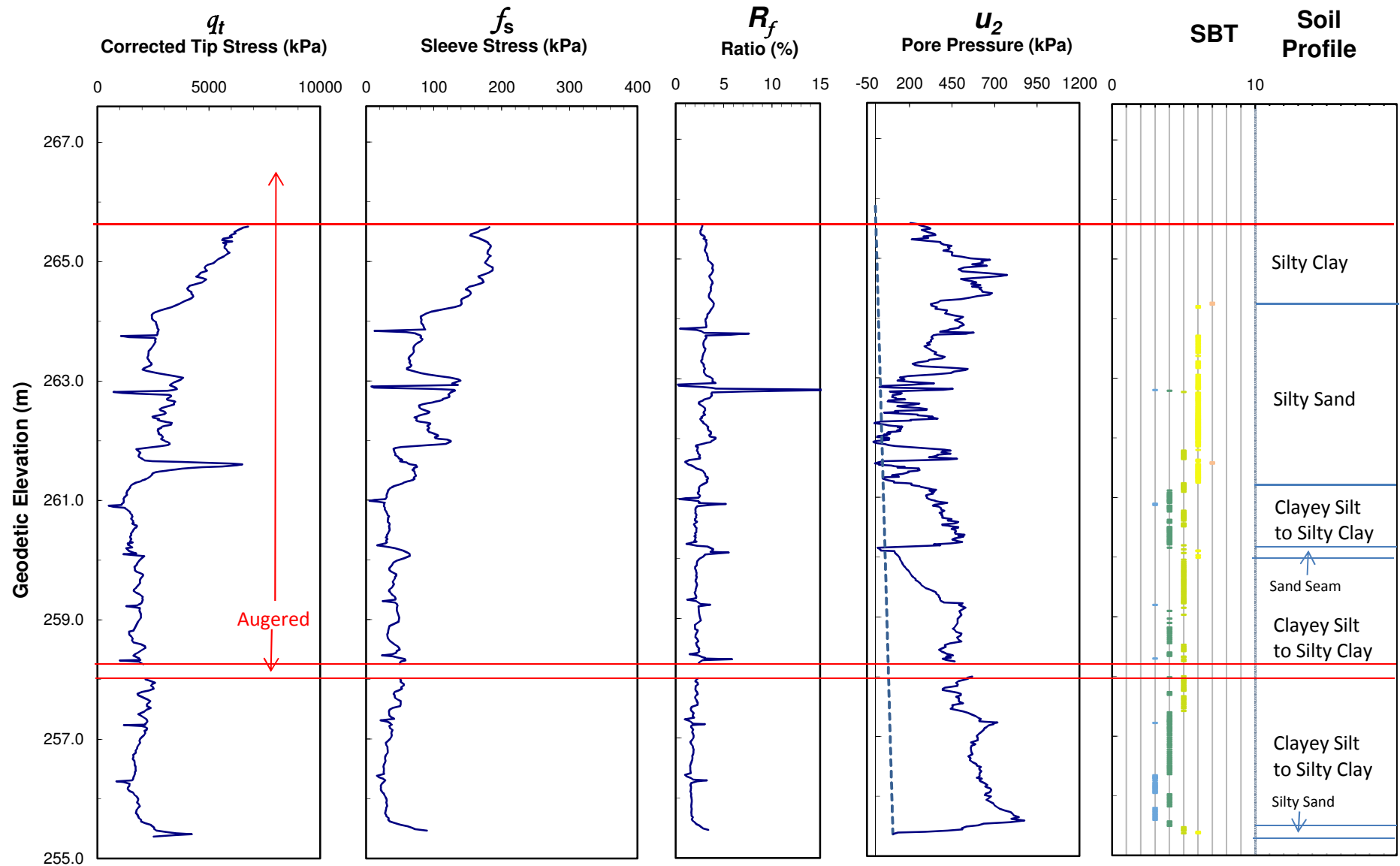


Elevation: 267.60 m  
 SCPTu Start Elevation: 265.64 m  
 Groundwater Elevation: 265.87 m

Test Date: 22-Oct-13  
 Project No. 165000876

CPT 13-11

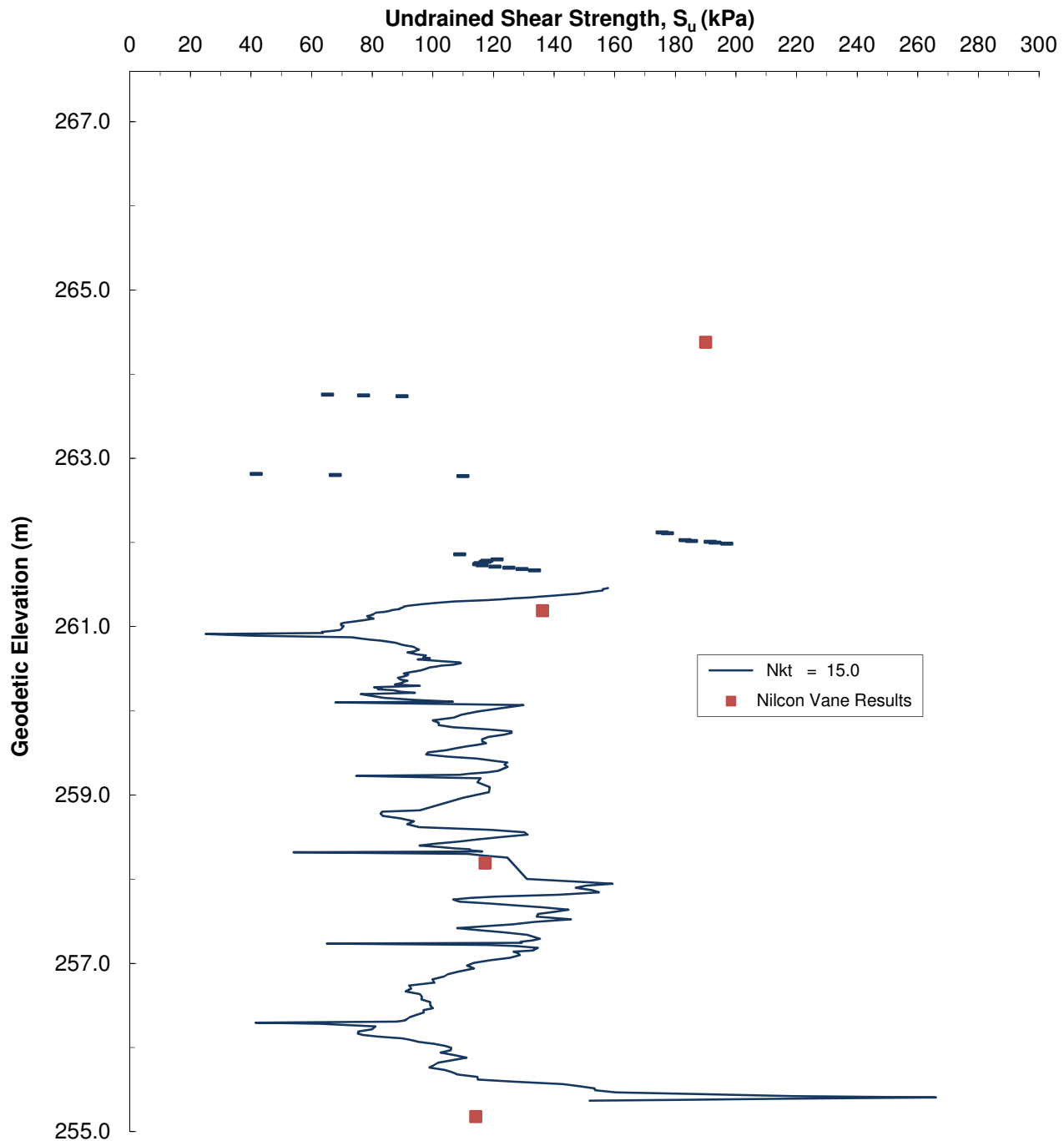
Client: Aecon Construction and Materials Limited  
 Project: D-B Wonderland Rd/Hwy 401 IC



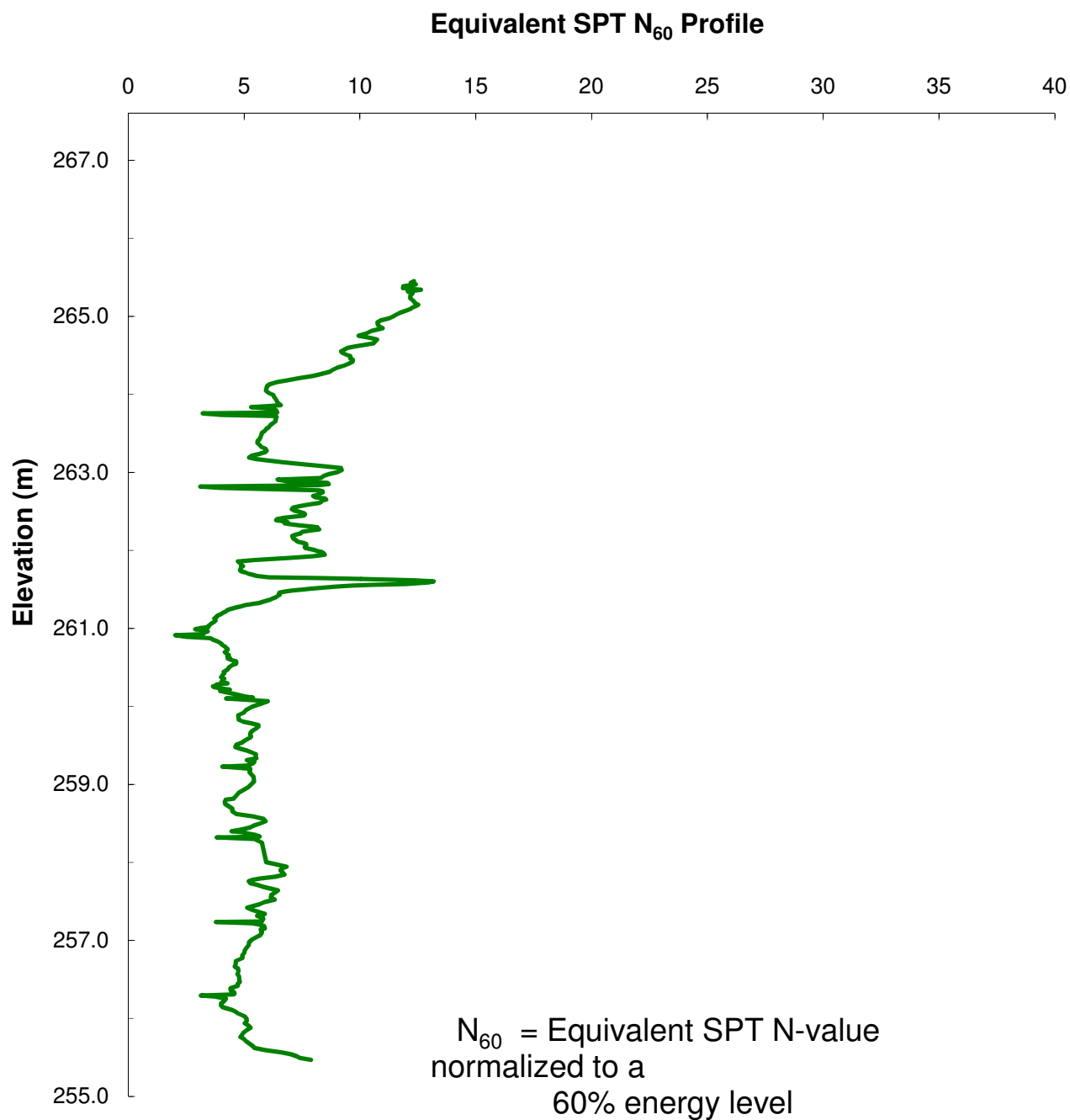
Class Fr: Friction Ratio Classification (Robertson 1990)



## SCPTu RESULTS Undrained Shear Strength, $S_u$



CPT 13-11



The correlation from SCPTu data to equivalent SPT  $N_{60}$   
values is based on the Jefferies and Davies (1993)

**CPT 13-11**

## **Geocres 40I14-132**

- Borehole Location and Soil Strata
- Borehole Records
- Laboratory Testing

**METRIC**  
MAKING STANDARDS SETTING  
EFFECTIVE NOW  
CALL IN 2005

DIST HWY. 401  
CONT. No.  
WP No. 476-89-00



WONDERLAND ROAD STRUCTURE

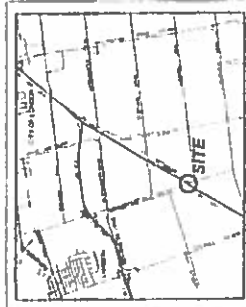
1991



**Golder  
Associates**

Holder Associates Ltd.  
1000A, 1000B, 1000C, 1000D

REFERENCE  
CLAIMING SUPPLIED BY MORRISON HERSFELD ENTITLED  
MAY 431 HENDERLAND ROAD UNDERPASS. GENERAL ARRANGEMENT  
DATED NOV 2001



## KEY PLAN

42

### LEGEND



	W	↓	↘	Dry
W	1000/0.3m	(Std. Per. Test. 475 l/min)		
↓	WL in piezometer			
↘	WL during drilling			
Dry	Barabeds during drilling			

No.	ELEVATION (metres)	CO-ORDINATES	
		NORTH	EAST
1	185.94	4 749 539.8	426 223.2
2	187.49	4 749 019.1	426 268.3

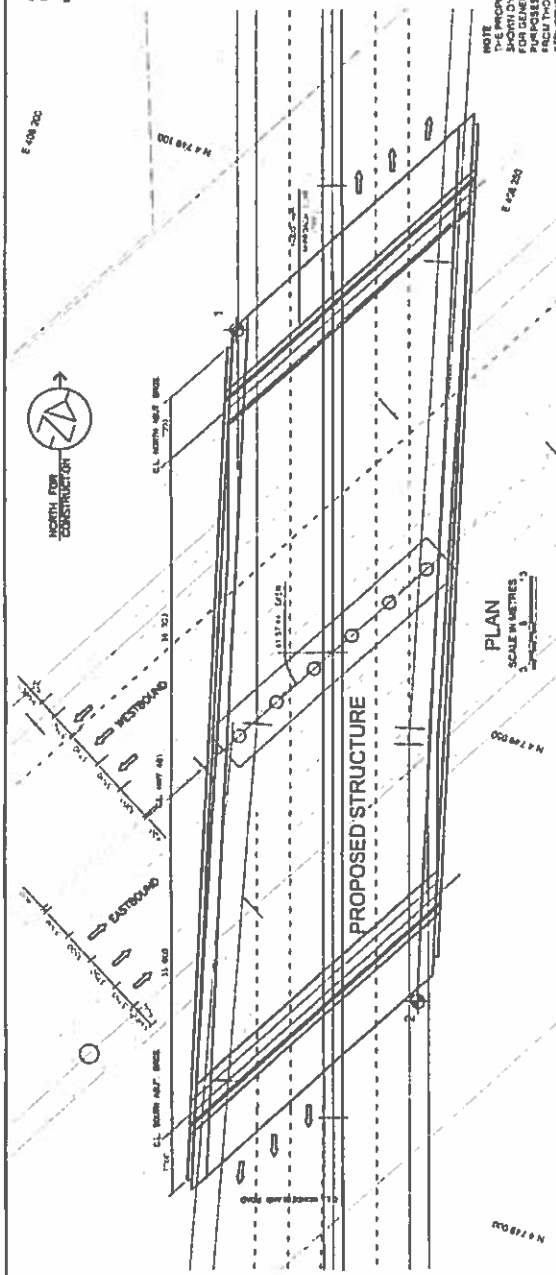
**NOTES**

The boundaries between and among them have been established primarily at Bureau meetings. Subject Statistics for companies are obtained from management systems.

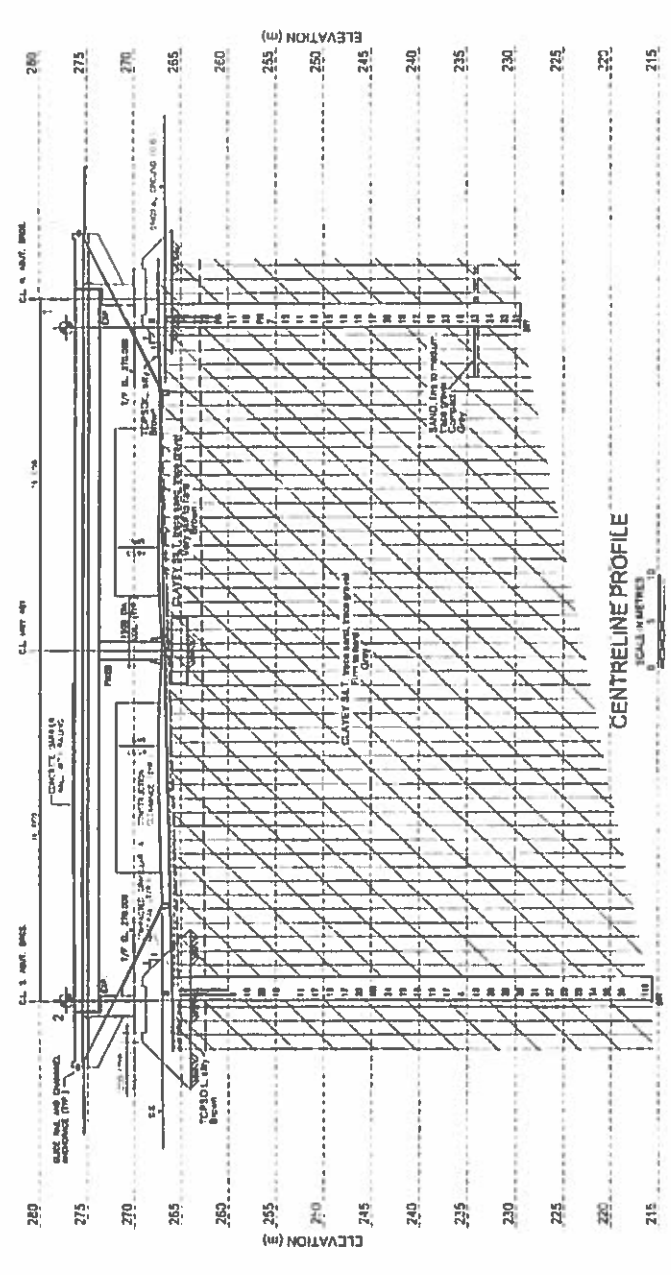
[illegible]

Concrete No. 4314-132

INT. NO. 431	PROJECT NO. C91-3225
SHEET 2	CHGB - DATE: NOV. 2001
DRAWN: WDF	CHGD: AMH
	APPR: 1
	DATE: 1



NOTE  
THE PROPOSED BRIDGE DETAILS  
SHOWN ON THIS DRAWING ARE  
ON GENERAL REFERENCE  
PURPOSES ONLY AND MAY DIFFER  
FROM THOSE SHOWN ON THE  
STRUCTURAL DRAWINGS



## CENTRELINE PROFILE

0 1 10



## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS Auger sample  
BS Block sample  
CS Chunk sample  
SS Split-spoon  
DS Denison type sample  
FS Foil sample  
RC Rock core  
SC Soil core  
ST Slotted tube  
TO Thin-walled, open  
TP Thin-walled, piston  
WS Wash sample

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Consistency

	$c_{u1} s_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

#### Dynamic Cone Penetration Resistance: $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.)

PH: Sampler advanced by hydraulic pressure  
PM: Sampler advanced by manual pressure  
WH: Sampler advanced by static weight of hammer  
WR: Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### IV. SOIL TESTS

w water content  
 $w_p$  plastic limit  
 $w_L$  liquid limit  
C consolidation (oedometer) test  
CHEM chemical analysis (refer to text)  
CID consolidated isotropically drained triaxial test<sup>1</sup>  
CIU consolidated isotropically undrained triaxial test with porewater pressure measurement<sup>1</sup>  
 $D_R$  relative density (specific gravity,  $G_s$ )  
DS direct shear test  
M sieve analysis for particle size  
MH combined sieve and hydrometer (H) analysis  
MPC Modified Proctor compaction test  
SPC Standard Proctor compaction test  
OC organic content test  
 $SO_4$  concentration of water-soluble sulphates  
UC unconfined compression test  
UU unconsolidated undrained triaxial test  
V field vane (LV-laboratory vane test)  
γ unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. General

$\pi$	3.1416
$\ln x$	natural logarithm of $x$
$\log_{10} x$	$x$ or $\log x$ , logarithm of $x$ to base 10
$g$	acceleration due to gravity
$t$	time
$F$	factor of safety
$V$	volume
$W$	weight

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{ve}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
$u$	porewater pressure
$E$	modulus of deformation
$G$	shear modulus of deformation
$K$	bulk modulus of compressibility

### III. SOIL PROPERTIES

#### (a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
$e$	void ratio
$n$	porosity
$S$	degree of saturation

#### (a) Index Properties (continued)

$w$	water content
$w_L$	liquid limit
$w_p$	plastic limit
$I_p$	plasticity index $= (w_L - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index $= (w - w_p)/I_p$
$I_C$	consistency index $= (w_L - w)/I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

$h$	hydraulic head or potential
$q$	rate of flow
$v$	velocity of flow
$i$	hydraulic gradient
$k$	hydraulic conductivity (coefficient of permeability)
$j$	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
$U$	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{ve}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction $= \tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
$p$	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
$q$	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 + \sigma_3)$
$S_i$	sensitivity

- Notes: 1  $\tau = c' + \sigma' \tan \phi'$   
 2 shear strength  $= (\text{compressive strength})/2$   
 \* density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  
 $\gamma = \rho g$  (i.e. mass density  $\times$  acceleration due to gravity)



**RECORD OF BOREHOLE No 1**

2 OF 4

**METRIC**

PROJECT 001-3225 LOCATION 4749081 8 N 408225 9 E (WONDERLAND ROAD SITE) ORIGINATED BY SM  
G.W.P. 476-89-00 DIST HWY 401 BOREHOLE TYPE POWER AUGER (HO-LOW STEM) & ROTARY DRILLING WITH MUD COMPILED BY DJM  
DATUM GEODETIC DATE 21.8.01 - 22.8.01 CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ KN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	γ <sub>f</sub> VALUES			20 40 60 80 100	100					
	CLAYEY SILT trace sand, trace gravel Firm to hard Gray		13	SS	17		250							
			14	SS	13		249							
			15	SS	17		248							
			16	SS	20		246							
			17	TW	W <sub>m</sub>		245							
			18	SS	24		243							
			19	SS	18		242							
			20	SS	18		240							
			21	SS	15		239							
			22	SS	17		237							

ON LOT 0013225A.GPJ ON LOT GDT 11/2002 DATA INPUT

Continued Next Page

+ 3 x 3 Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 001-3225 RECORD OF BOREHOLE No 1 3 OF 4 METRIC  
 G W P 476-89-00 LOCATION 4746391 8 N 406225 8 E / WONDERLAND ROAD SITE ORIGINATED BY SM  
 DIST            HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) & ROTARY DRILLING WITH MUD COMPILED BY DJM  
 DATUM GEODETTIC DATE 21.8.01 - 22.8.01 CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION: RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	TEST VALUES			20 40 60 80 100	20 40 60 80 100					
	CLAYEY SILT, trace sand trace gravel Fm to hard Gray		23	SS	4		235							
			24	SS	18		234							
			25	SS	38		233							
			26	SS	35		231							
			27	SS	38		230							
			28	SS	31		228							
			29	SS	27		226							
			30	SS	29		225							
			31	SS	28		223							
			32	SS	34		222							

2 11 49 38

OH, MOT 0013225A GPJ ON, MOT.GDT 11/2/02 DATA INPUT

Continued Next Page

+3 x 3 Numbers refer to Sensitivity 3% STRAIN AT FAILURE

PROJECT 001-3225 RECORD OF BOREHOLE No 1 4 OF 4 METRIC  
 GWP 476-89-00 LOCATION 4749081 S N 408225 S E (WONDERLAND ROAD SITE) ORIGINATED BY SM  
 DIST HWY 401 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) & ROTARY DRILLING WITH MUD COMPILED BY DJM  
 DATUM GEODETTIC DATE 21 8 01 - 22 8 01 CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	T <sub>N</sub> VALUES			20 40 60 80 100						
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
							WATER CONTENT (%) 20 40 60 80 100		10 20 30					
215.85	CLAYEY SILT, trace sand, trace gravel Firm to hard Grey		33	SS	55		220							2 17 48 33
								219						
								218						
								217						
								216						
50.29	End of Borehole Borehole remained dry during drilling Aug. 21 and 22, 2001		35	SS	115									

ON\_M01\_0013225A.GPJ CH M01 G01 11/2/02 DATA INPUT

PROJECT C01-3225

**RECORD OF BOREHOLE No 2**

1 OF 3

**METRIC**

G.W.P. 475-89-00

LOCATION 4749019.1 N, 405259.3 E (WONDERLAND ROAD SITE)

ORIGINATED BY SM

DIST HWY 401

BOREHOLE TYPE POWER AUGER (HOLLOW STEM) & ROTARY DRILLING WITH MUD

COMPILED BY DJM

DATUM GEODETIC

DATE 29 8 01

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	TV VALUES			20	40	60	80	100					
267.45	GROUND SURFACE																
0.89	TOPSOIL, silty Brown CLAYEY SILT, trace sand trace gravel Very stiff to hard Brown		1	SS	26		267							o			
			2	SS	33		266							c			
			3	SS	36		265							o			
			4	SS	17		264							o			
			5	SS	22		263							o			
263.03			6	SS	20		262							o			
4.42	CLAYEY SILT trace sand, trace gravel Firm to hard Grey		7	SS	17		261							o			
			8	TW	P=		260										
			9	SS	11		259										
			10	SS	10		258										
			11	TW	PH		257							o			
			12	SS	7		256										
			13	SS	15		255										
			14	SS	11		254							o			
							253							o			

ON MOT 0013225A.GPJ ON MOT GDT 11/2/02 DATA INPUT

Continued Next Page

+ 3 x 3 Numbers refer to Sensitivity O 3% STRAIN AT FAILURE





# RECORD OF BOREHOLE No 2

3 OF 3

METRIC

PROJECT 001-3225

G.W.P. 475-89-00

LOCATION 4749C19 1 N, 405266.3 E (WONDERLAND ROAD SITE)

ORIGINATED BY SM

DIST HWY 401

BOREHOLE TYPE POWER AUGER (HOLLOW STEM) & ROTARY DRILLING WITH MUD

COMPILED BY DJM

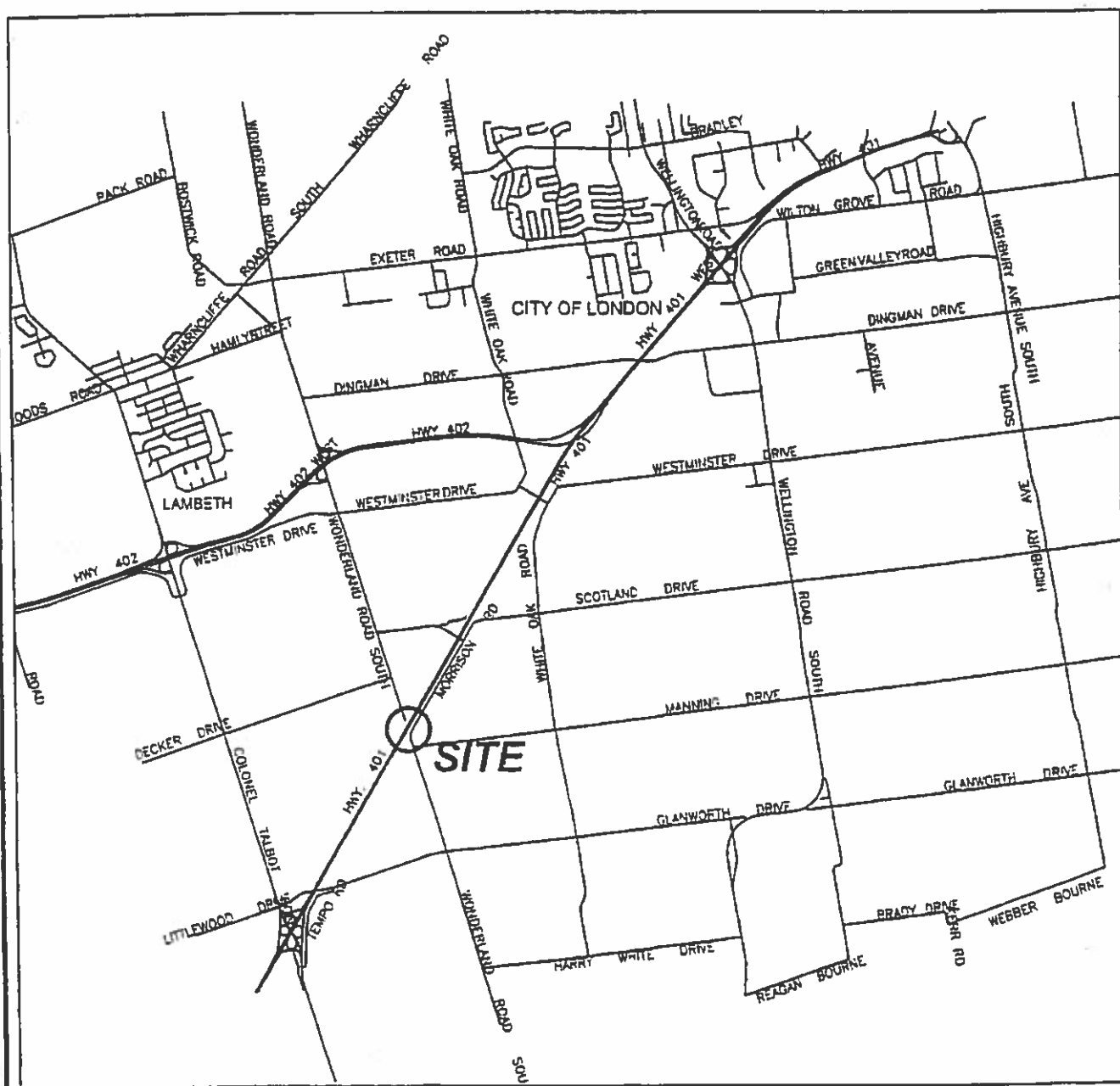
DATUM GEODETIC

DATE 29 8 01

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA S CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	7" VALUES			20 40 60 80 100	20 40 60 80 100					
	CLAYEY SILT, trace sand, trace gravel Firm to hard Grey		24	SS	23		237							
			25	SS	16		236							
							235							
234.23			26	SS	33		234							
33.22 233.62 33.53	SAND fine to medium, trace gravel; Compact Grey CLAYEY SILT, trace sand, trace gravel Very stiff to hard Grey						233							
			27	SS	24		232							
			28	SS	35		231							7 56 37
							230							
229.50 37.85	End of Borehole  Borehole remained dry during drilling Aug. 29, 2001													

001.M01 0013225A.GPJ DJM, M01.GDT 11/2/02 DATA INPUT



PROJECT	<b>WONDERLAND ROAD STRUCTURE</b> <b>WP. 476-89-00</b> <b>HWY. 401</b>
DATE	<h2 style="margin: 0;">SITE LOCATION MAP</h2>


 <b>Golder Associates</b> OGDON, ONTARIO	PROJECT No	001-3225	FILE No	00132250007
	DESIGN		SCALE	N.T.S. / RE 1
	CADD	WOF	11/18/01	
	CHECK	AMM	11/16/01	
	REVIEW			

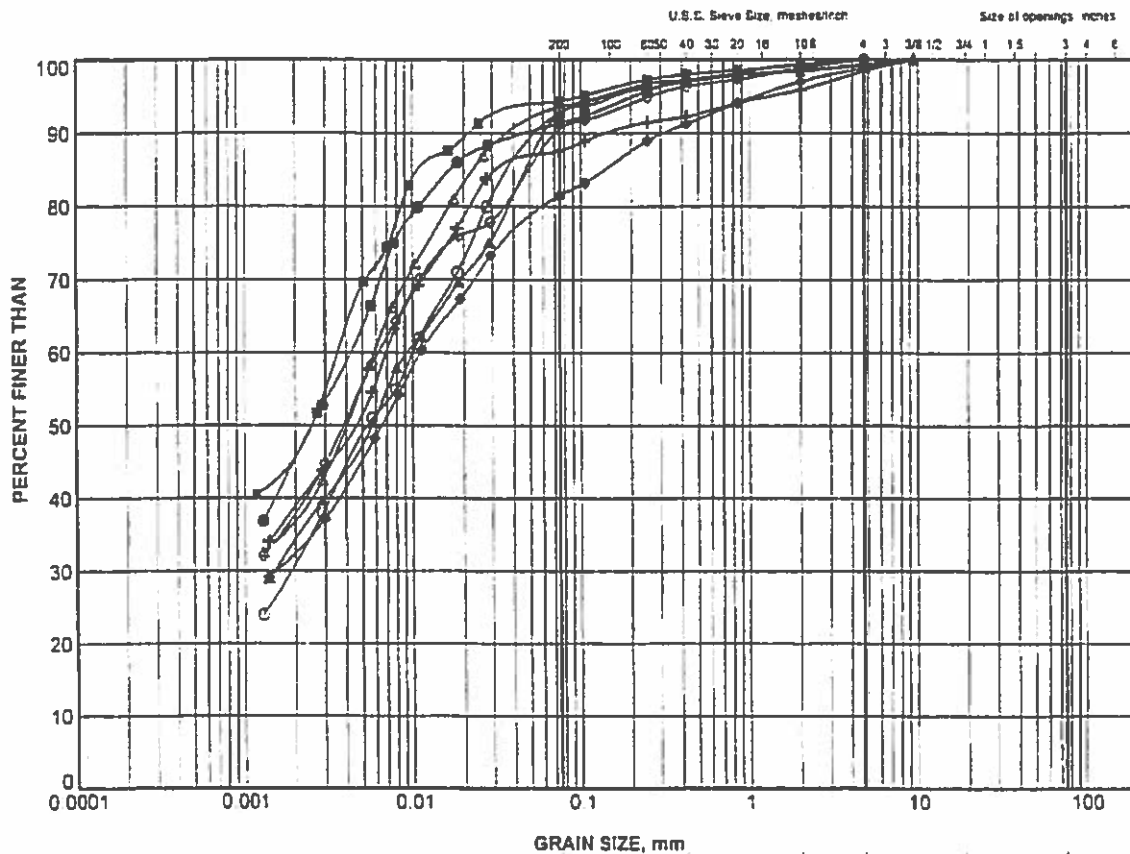
FIGURE 1

**APPENDIX A**  
**LABORATORY TEST DATA**

February 2002

001-3225

**Golder Associates**



CLAY AND SILT	fine	medium	coarse	fine	coarse	Coarse Sand
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	1	3	263.4
■	1	*1	255.0
▲	1	20	240.3
+	1	27	229.6
◆	1	34	218.6
○	2	8	261.1
○	2	16	246.5
△	2	28	231.3

PROJECT

PROPOSED WONDERLAND RD BRIDGE  
HIGHWAY 401, GWP 476-89-00

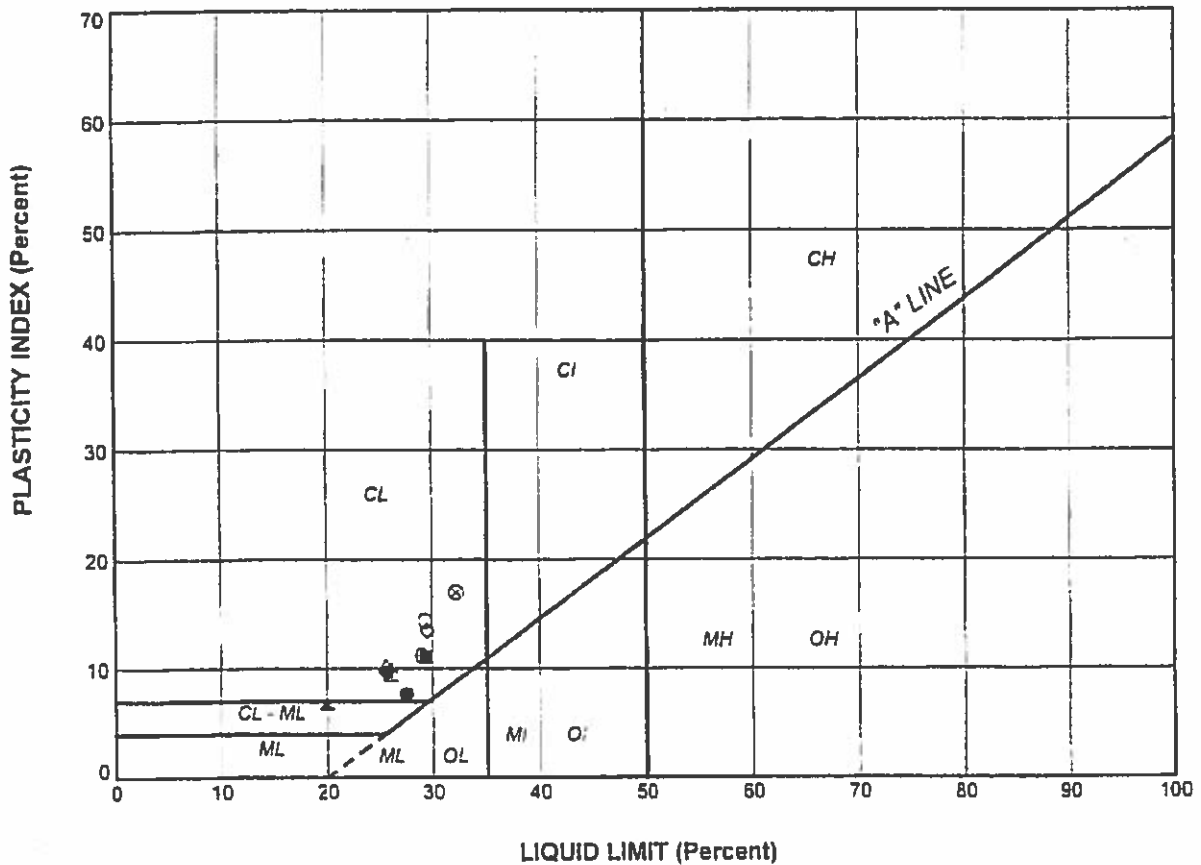
TITLE

GRAIN SIZE DISTRIBUTION CURVE  
CLAYEY SILT



Golder  
Associates  
LONDON, ONTARIO

PROJECT No		001-3225	FILE No		0013225A GP.
			SCALE	N/A	REV
DRAWN	WCF	12-11-01			
CHECK	mm	12-11-01	FIGURE A-1		



SOIL TYPE      PLASTICITY  
 C = Clay      L = Low  
 M = Silt      I = Intermediate  
 O = Organic    H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)	LL(%)	PL(%)	P <sub>i</sub>
●	1	3	263.7	27.5	19.9	7.6
■	1	7	260.5	29.4	18.3	11.1
▲	1	12	252.7	20.0	13.2	6.8
+	1	17	245.1	28.0	16.2	9.8
◆	1	20	240.5	25.6	16.0	9.6
○	1	23	235.9	29.5	16.0	13.5
○	1	27	229.8	29.3	14.9	14.4
△	1	34	219.2	25.5	15.2	10.3
⊗	2	8	261.4	32.2	15.2	17.0
⊗	2	10	258.5	28.0	17.8	11.2
□	2	28	231.5	26.0	16.5	9.5

PROPOSED WONDERLAND RD. BRIDGE  
 HIGHWAY 401, GWP 476-89-00

### PLASTICITY CHART



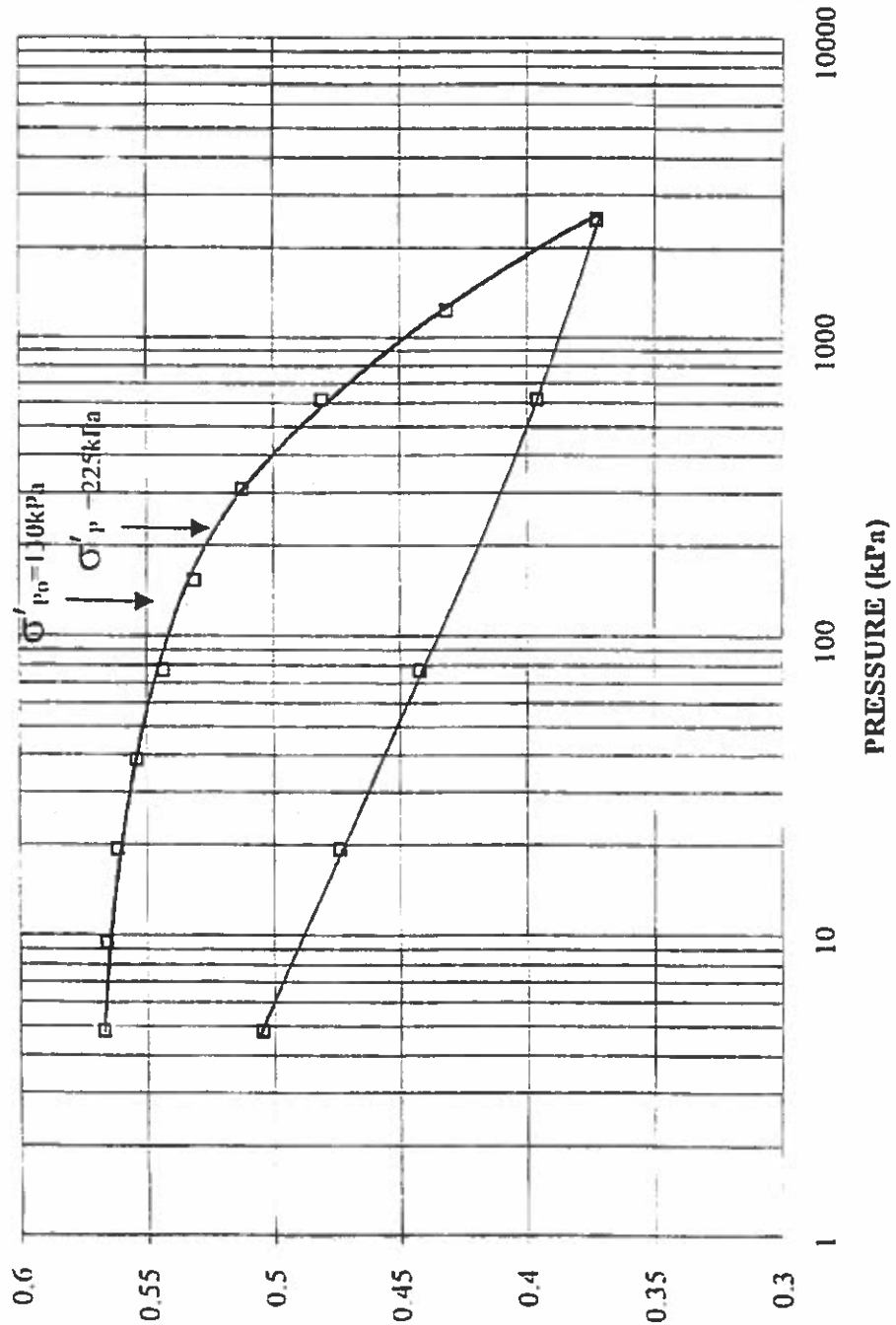
PROJECT No.		001-3225	FILE No.		0013225A.GPJ
DRAWN		WDF	12-11-01	SCALE	N/A
CHECK		AM	12-11-01	REV	

FIGURE A-2

CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE A-3

CONSOLIDATION TEST  
VOID RATIO vs. PRESSURE  
BH 2 SA 8  
Elev. 261



Project No. 001-3225

VOID RATIO

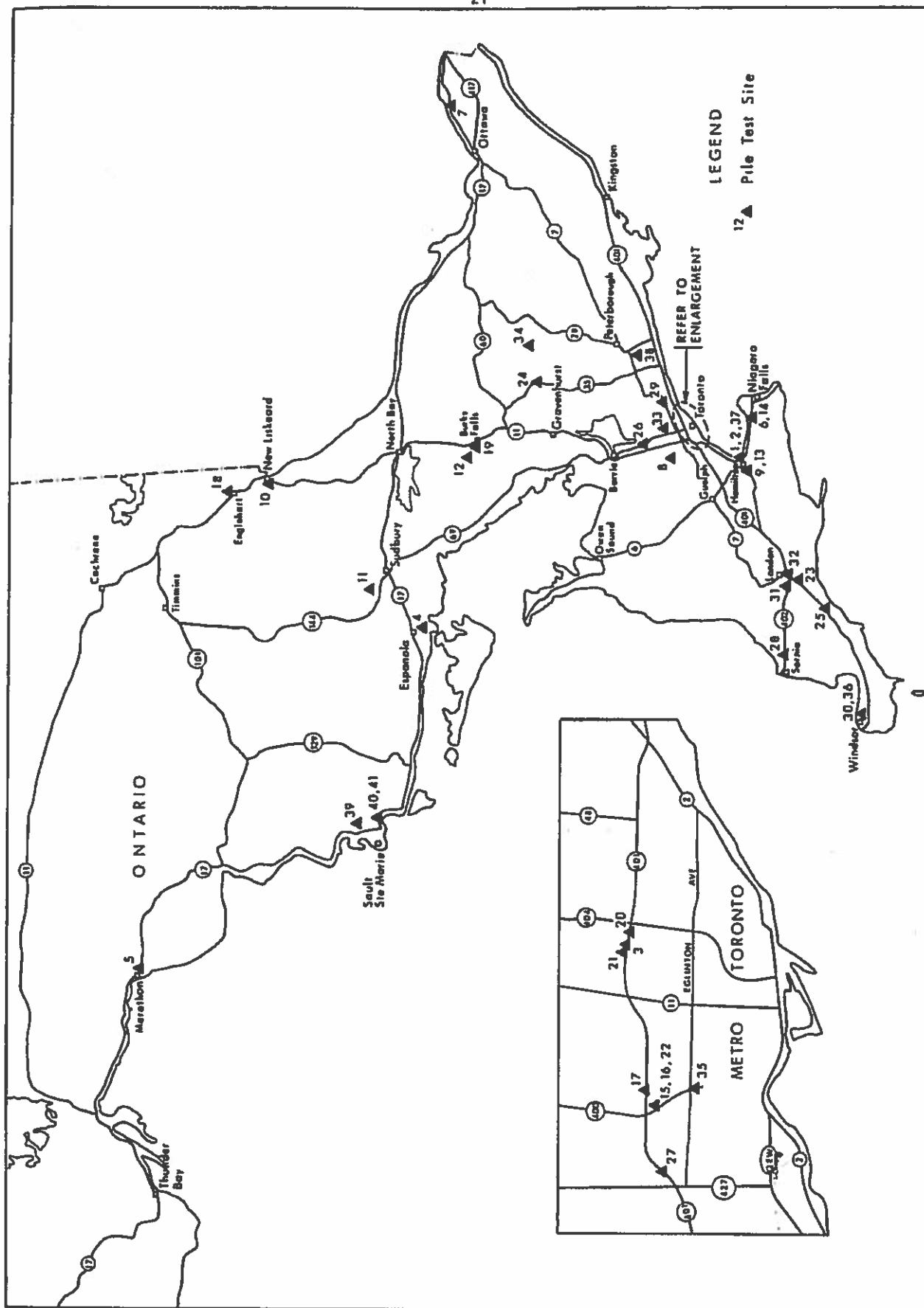
## **MTO Pile Test Data**

**Exert from MTO Report EM-48**

**Pile Load and Extraction Tests 1954 – 1992**

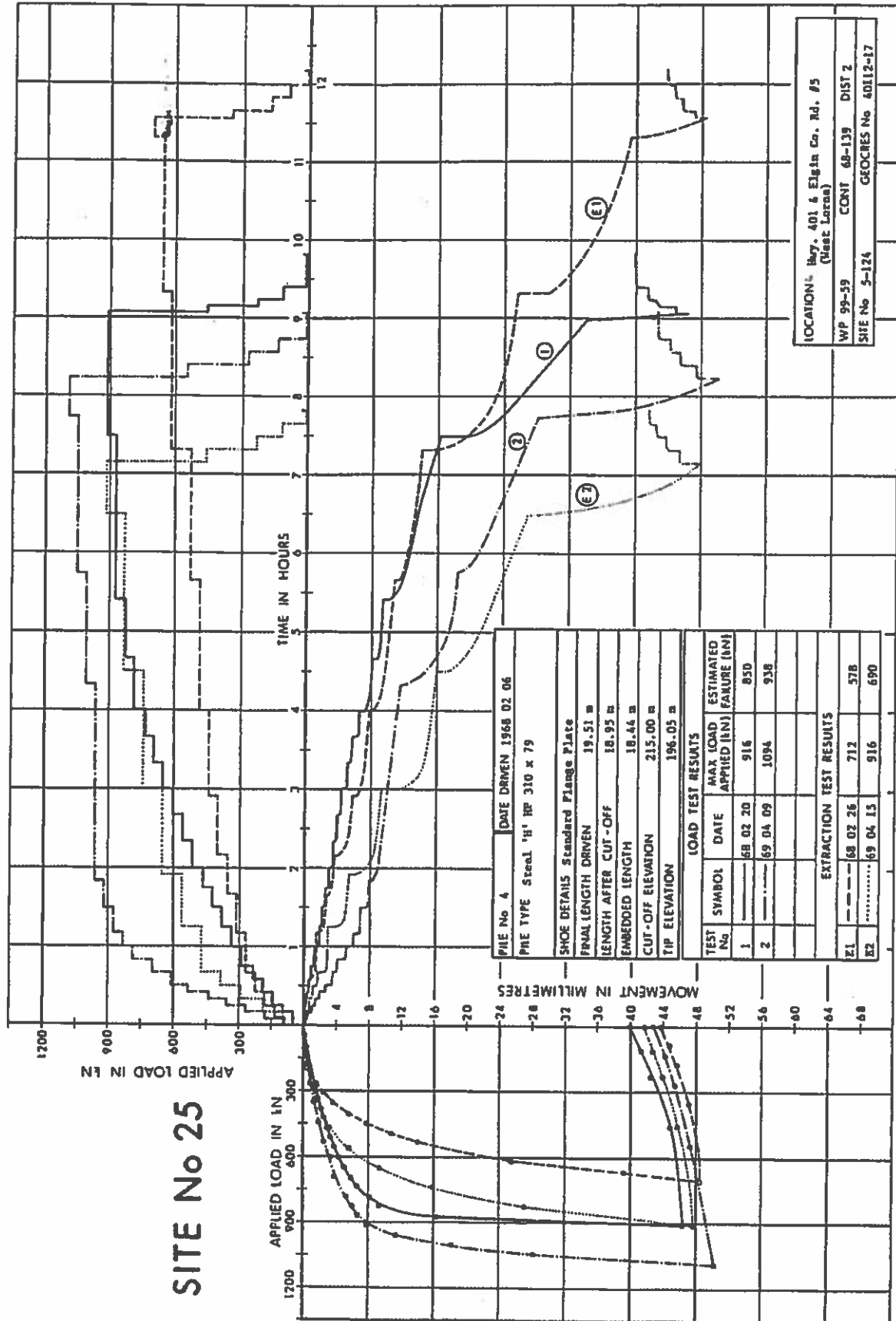
**Site 25 located 45 km SW of Hwy 401 /  
Wonderland Road Interchange Site**

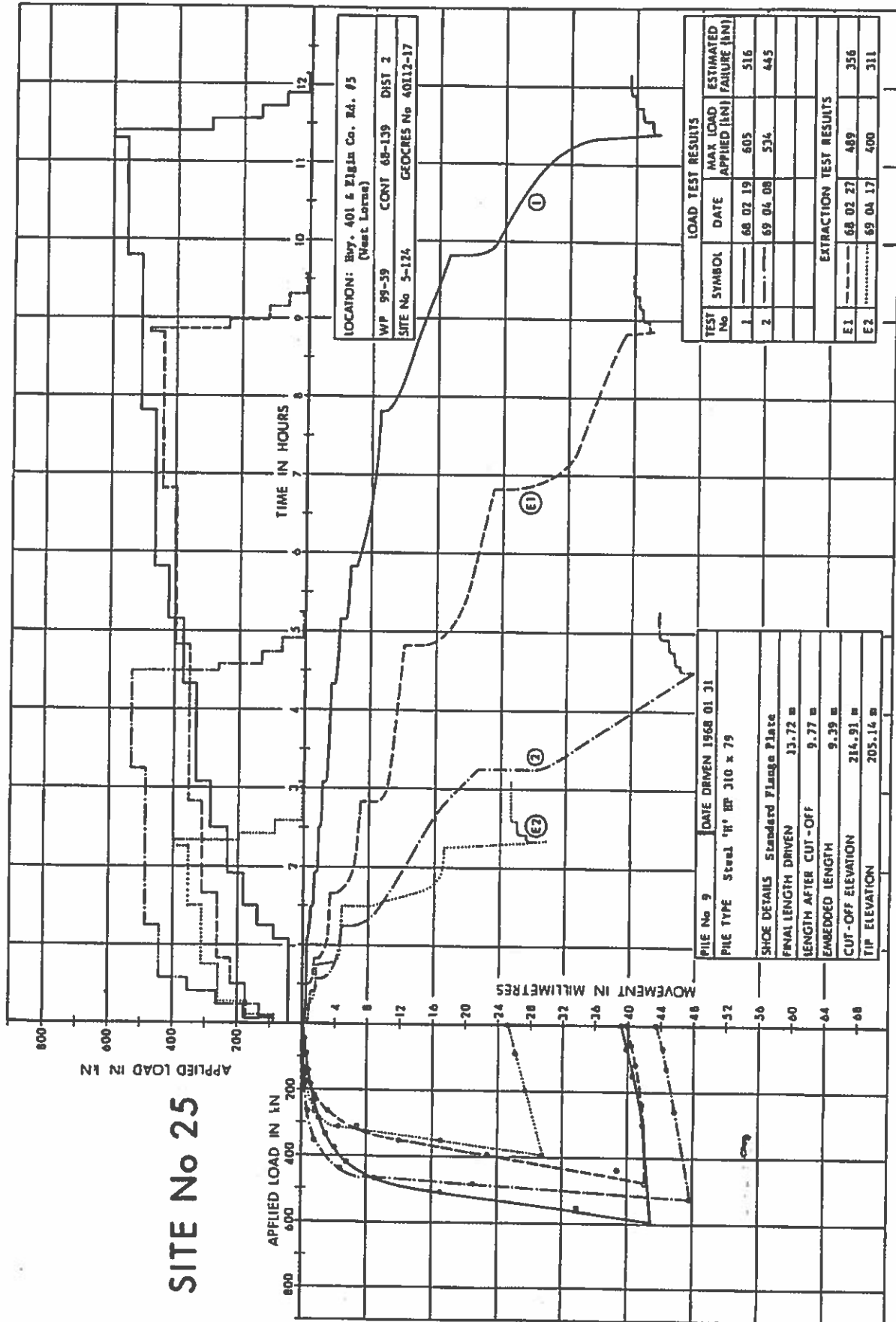
- Site Location map
- Borehole Record
- Pile Load Test Result





PILE TEST SITE # 25				RECORD OF BOREHOLE No P-1				METRIC					
W P 99-59		LOCATION Bvy. 401 & Elgin Co. Rd. #5 (West Lorne)		ORIGINATED BY P.P.									
DIST 2 HWY 401		BOREHOLE TYPE Solid Auger		COMPILED BY G.P.									
DATUM Geodetic		DATE 1968 02 03		CHECKED BY G.P.									
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMITS		NATURAL MOISTURE CONTENT		UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT	NUMBER			TYPE	'N' VALUES	20 40 60 80 100	W <sub>p</sub> W <sub>L</sub>	W <sub>p</sub> W <sub>L</sub>	W <sub>p</sub> W <sub>L</sub>		
214.5	Ground Level												
0.0													
	Silty Clay Trace of Sand and Gravel Stiff to Very Stiff		1	TW	PH							19.48	1 6 47 46
			2	TW	PH							20.11	1 9 54 36
			3	TW	PH							0 8 46 46	
			4	TW	PH							21.21	0 9 52 39
			5	TW	PH							0 7 39 54	
			6	TW	PH							20.42	0 7 43 50
			7	TW	PH							20.26	1 6 42 51
			8	TW	PH							20.26	1 6 46 47
			9	TW	PH							20.66	0 7 44 49
			10	TW	PH							20.11	0 6 43 51
			11	TW	PH								
			12	TW	PH							20.42	0 7 39 54
			13	TW	PH							20.19	1 6 43 50
			14	TW	PH							20.26	1 30 39 30
			15	TW	PH							20.03	0 6 44 50
			16	TW	PH							20.11	1 6 39 54
			17	TW	PH							20.26	1 6 38 55
			18	TW	PH							20.11	
			19	TW	PH							20.11	1 6 40 53
			20	TW	PH							20.26	8 6 38 48
			21	TW	PH							20.26	0 6 42 52
			22	TW	PH								
			23	TW	PH							19.01	
			24	TW	PH							20.81	2 6 40 52
			25	TW	PH							20.11	1 5 39 55
			26	TW	PH								
			27	TW	PH							20.11	0 6 39 55
			28	TW	PH								
			29	TW	PH								
			30	TW	PH								
192.7				31	TW	PH							20.19
21.8	End of Borehole												





## APPENDIX C

Laboratory Test Results

Figures 1 – 6: Grain Size Distribution Plots

Figure 7a – 7c: Plasticity Charts

Copy of Test Results from Golder (Preliminary)

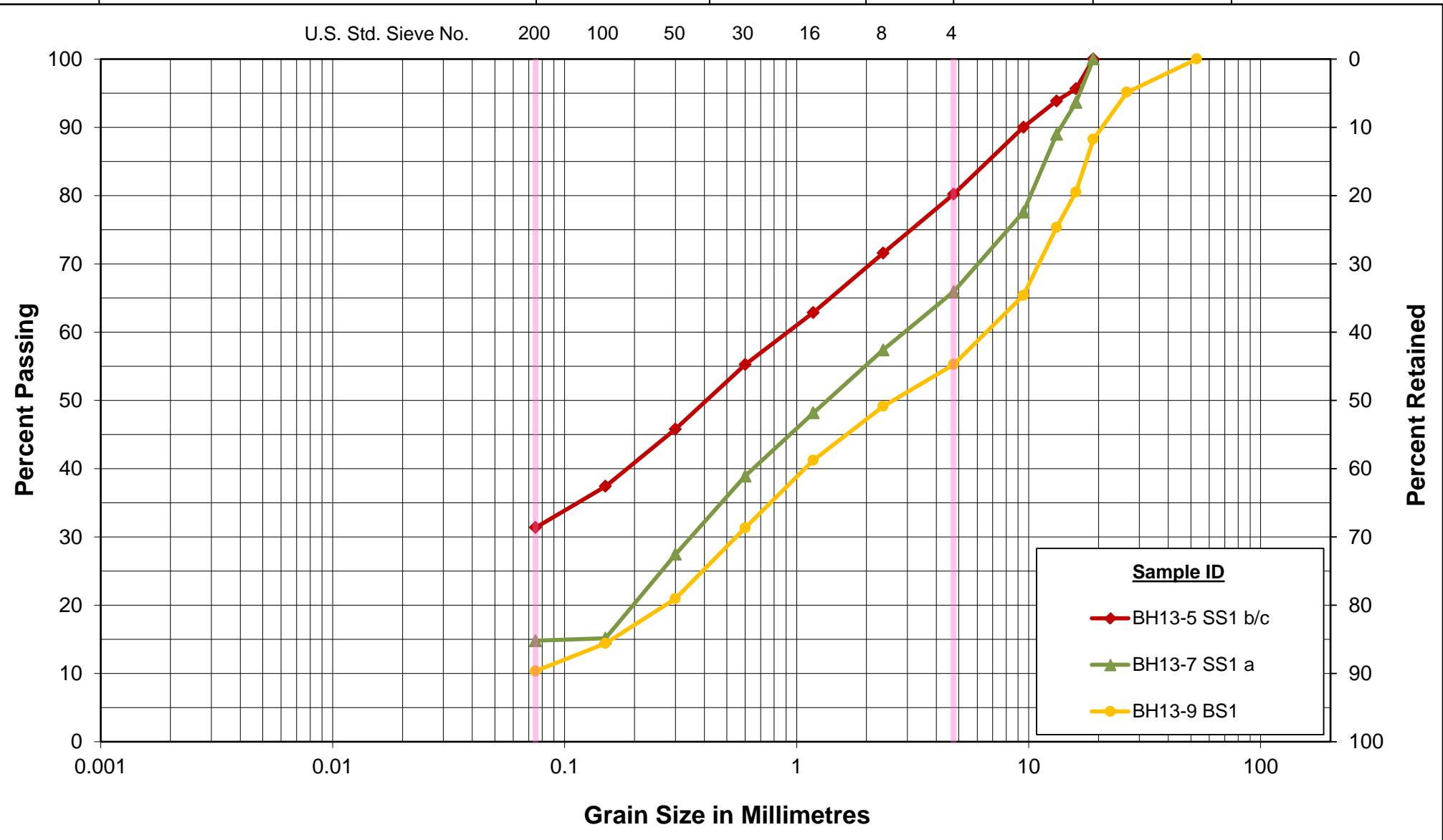
- Unconfined Compression Test

- Specific Gravity Test

- Consolidation Test

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

FILL: Silty sand with gravel (SM)  
(Interchange Site)

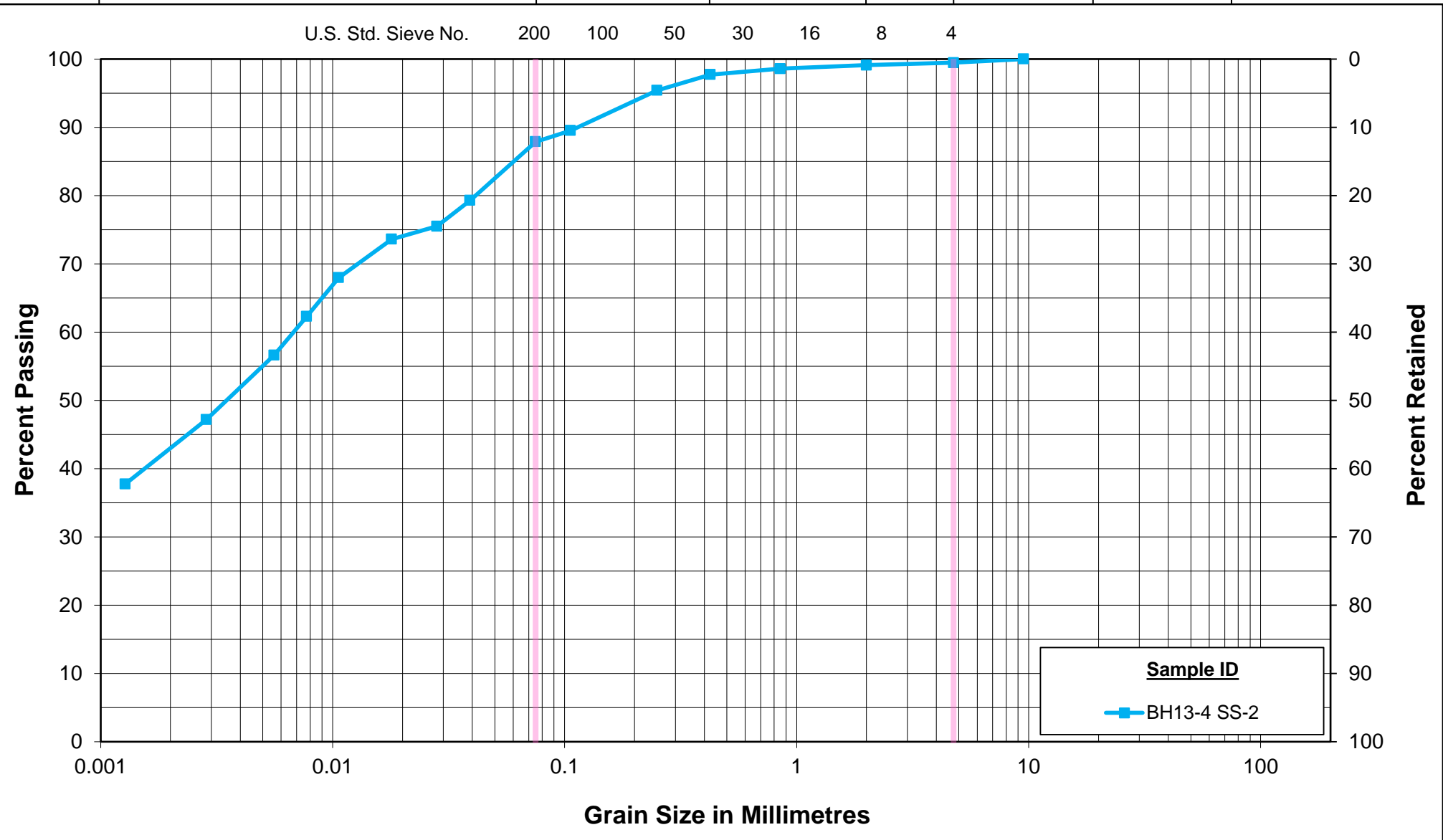
Figure No. 1a

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

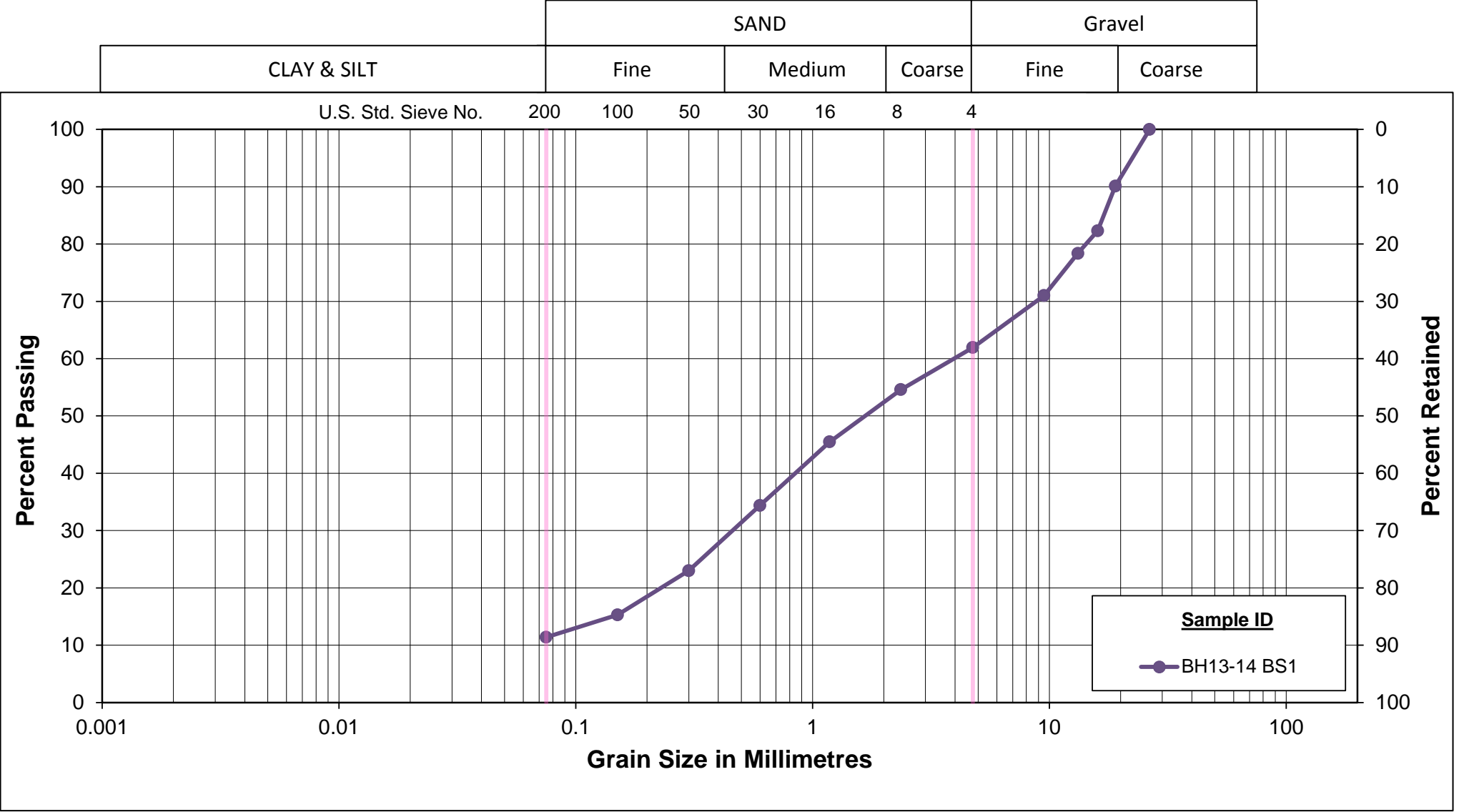
FILL: Silty clay (CI)  
(Interchange Site)

Figure No. 1b

Project No. 165000876

GWP 3031-11-00

Unified Soil Classification System



GRAIN SIZE DISTRIBUTION

FILL: Poorly graded sand with silt and gravel (SP-SM) (Culvert Site)

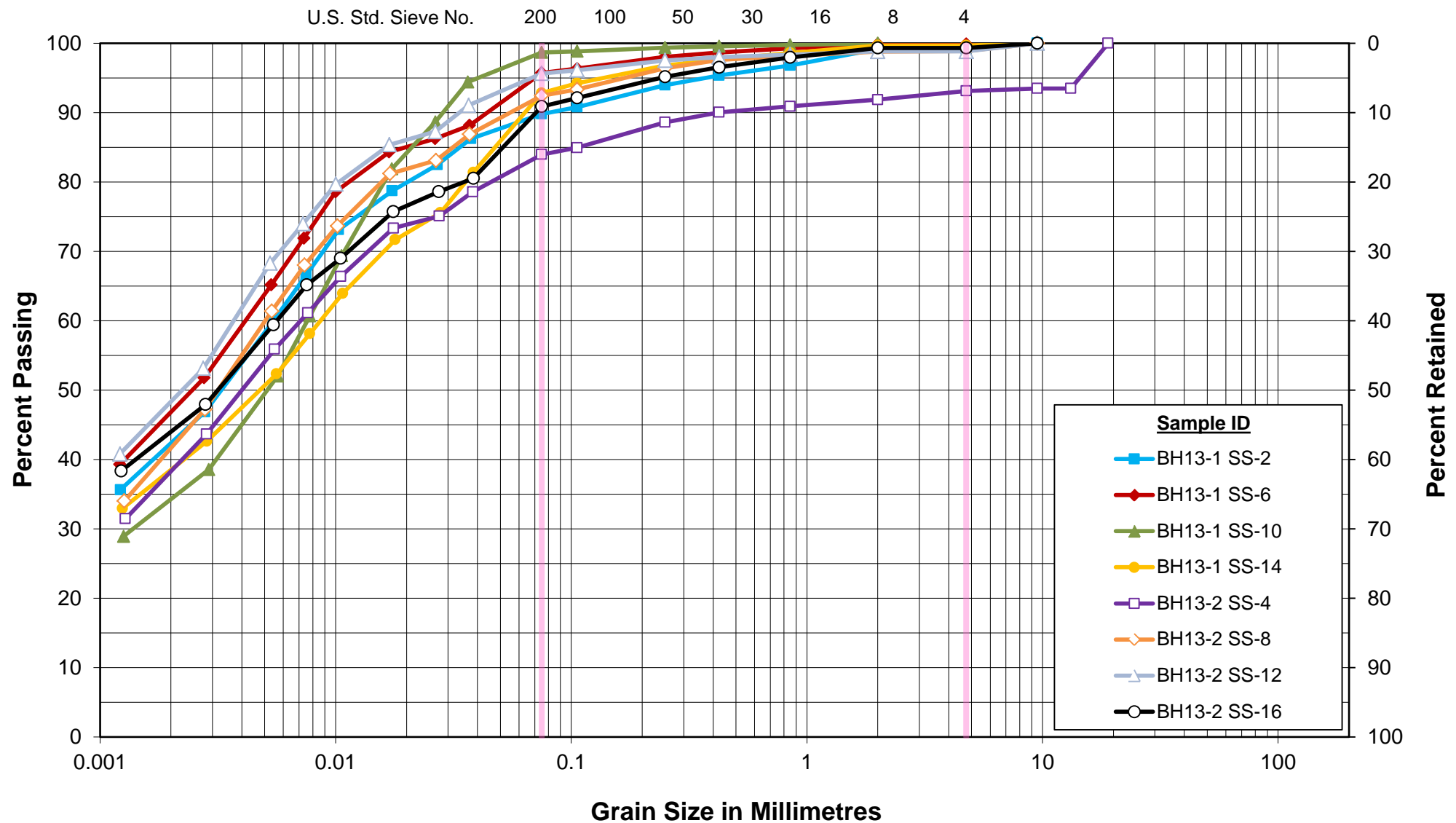
Figure No. 1c

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty clay (CI) to clayey silt (CL)  
(Interchange Site)

Figure No. 2a

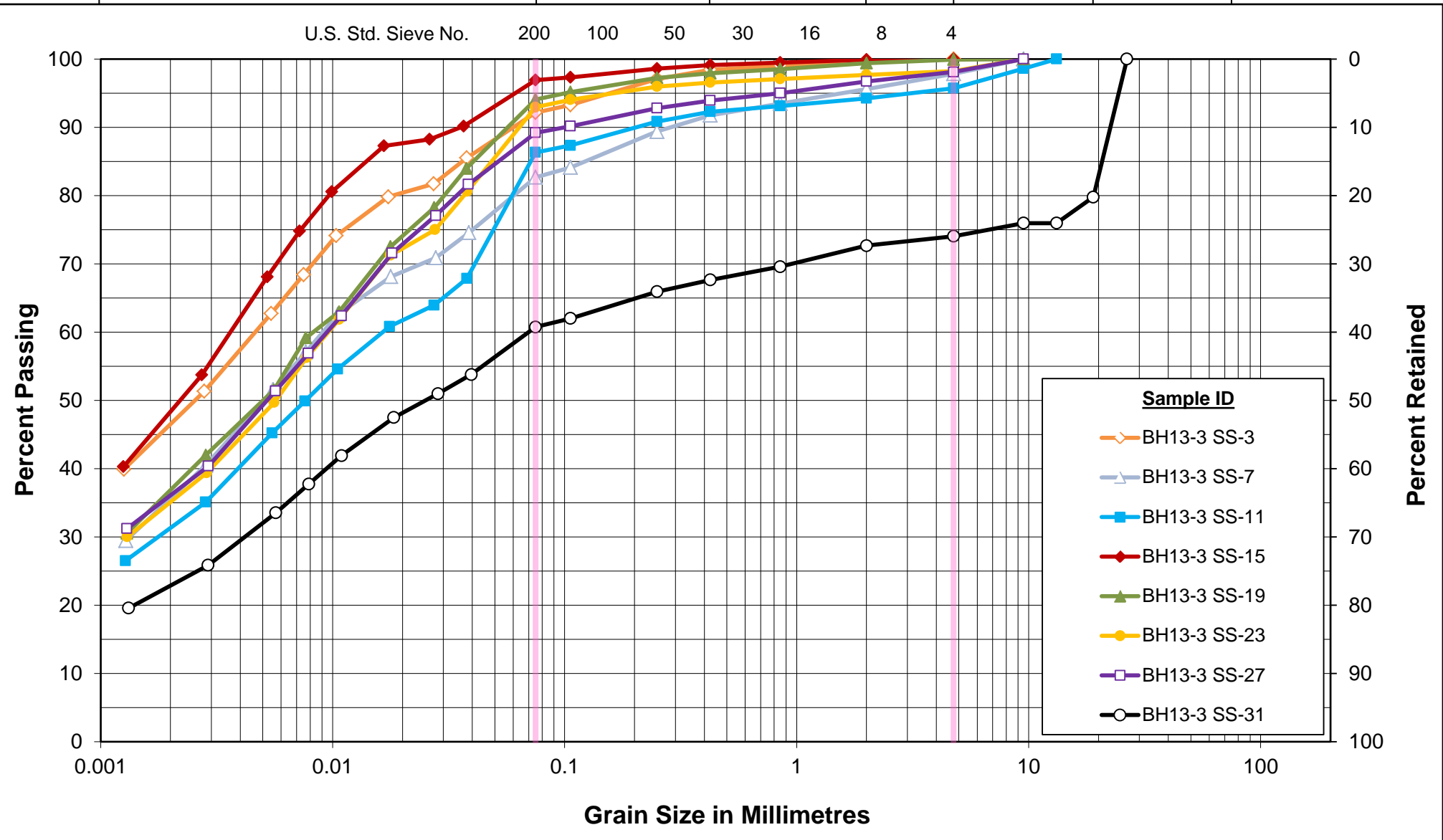
Project No. 165000876

GWP 3031-11-00



# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty clay (CI) /clayey silt(CL)  
(Interchange Site)

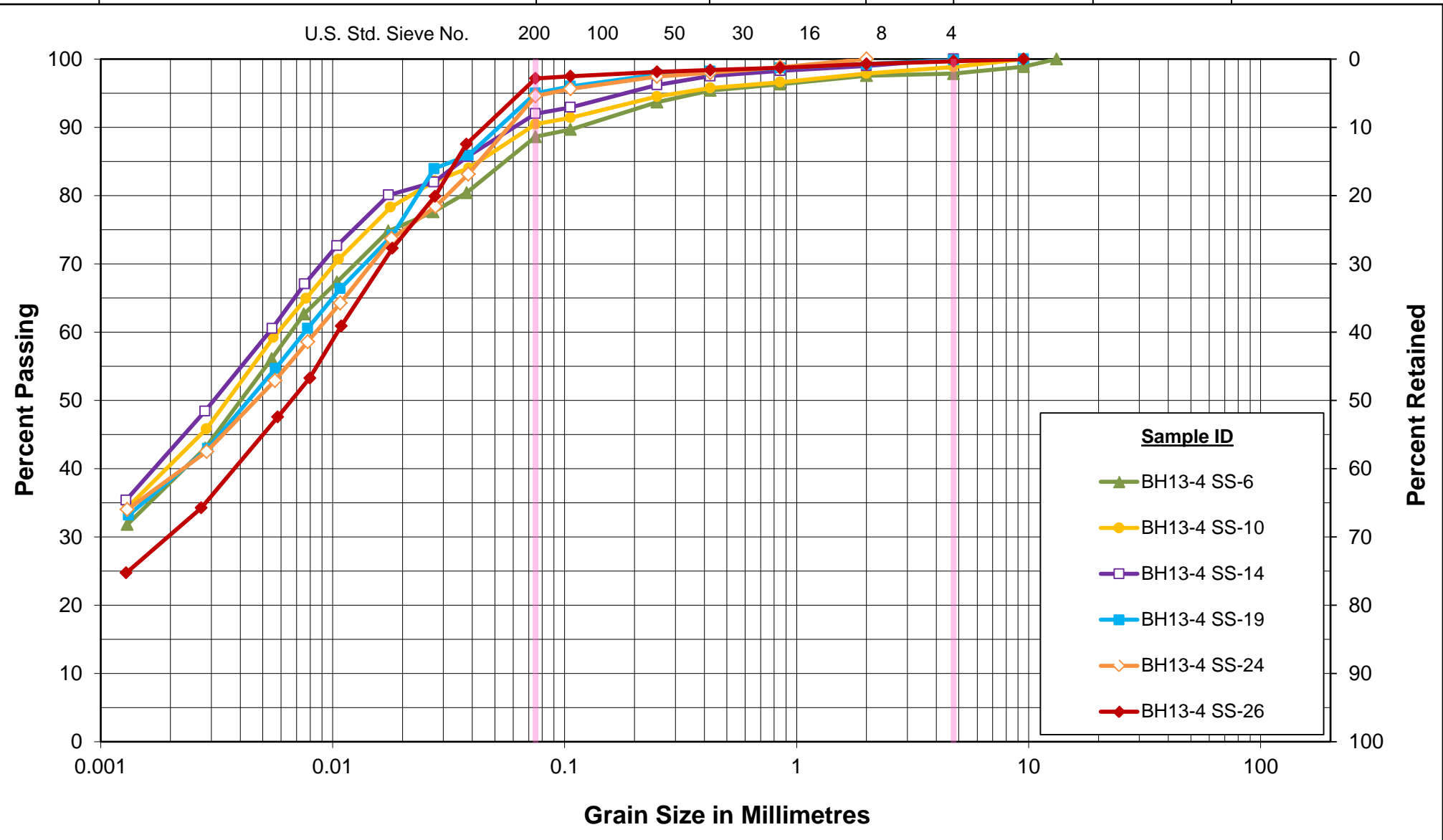
Figure No. 2b

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty clay (CI) to clayey silt (CL)  
(Interchange Site)

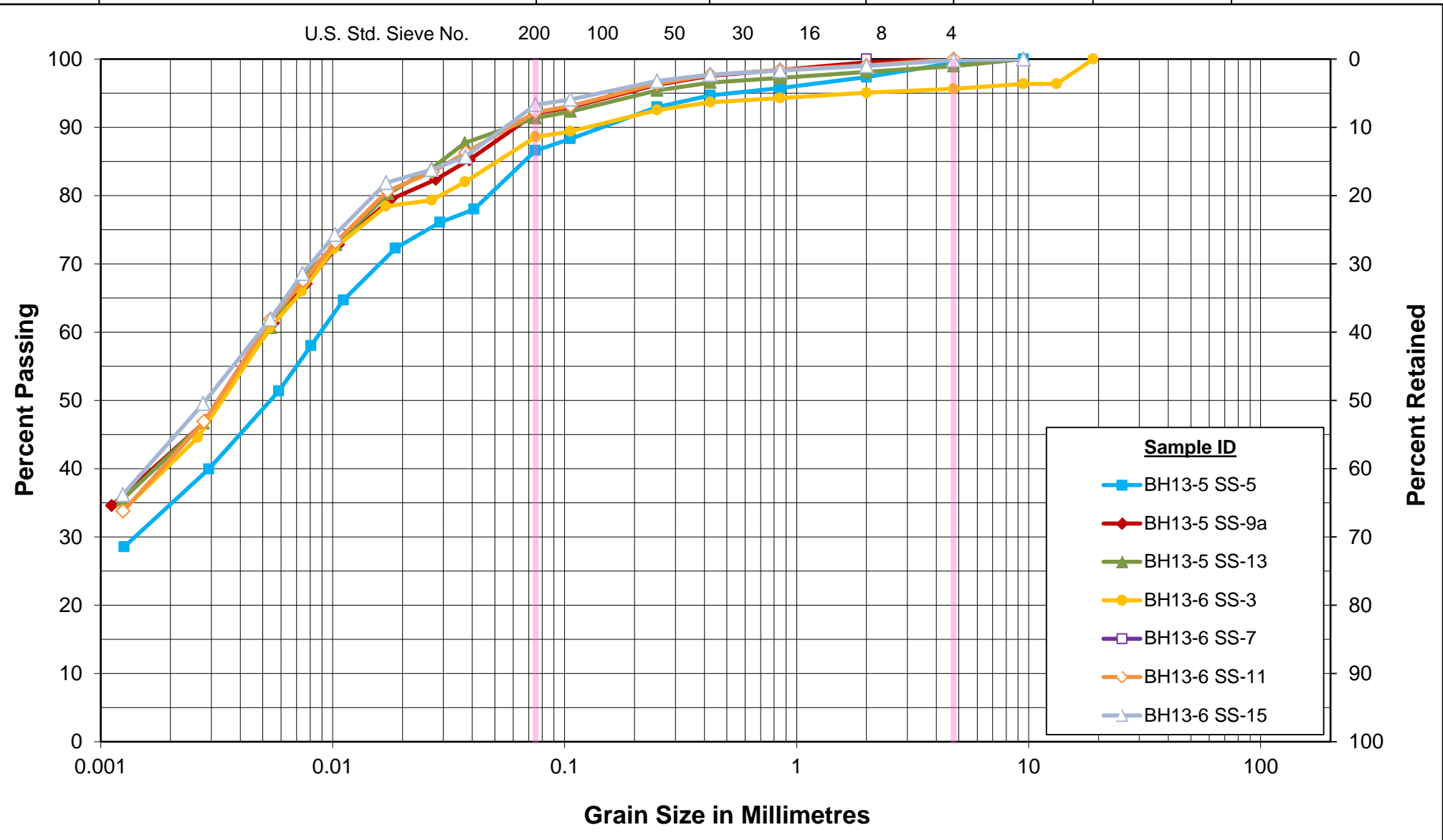
Figure No. 2c

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty clay (CI) to clayey silt (CL)  
(Interchange Site)

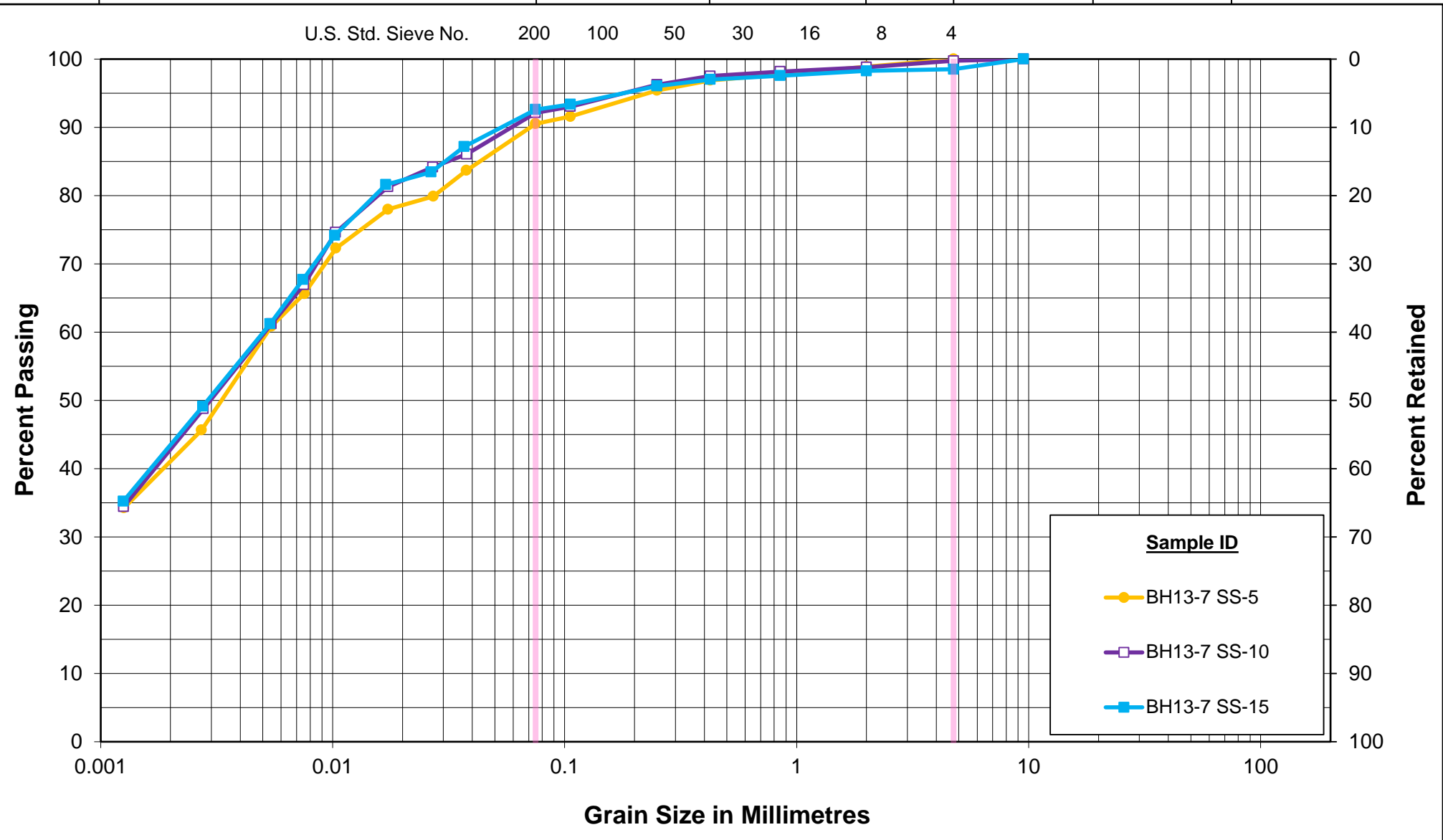
Figure No. 2d

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

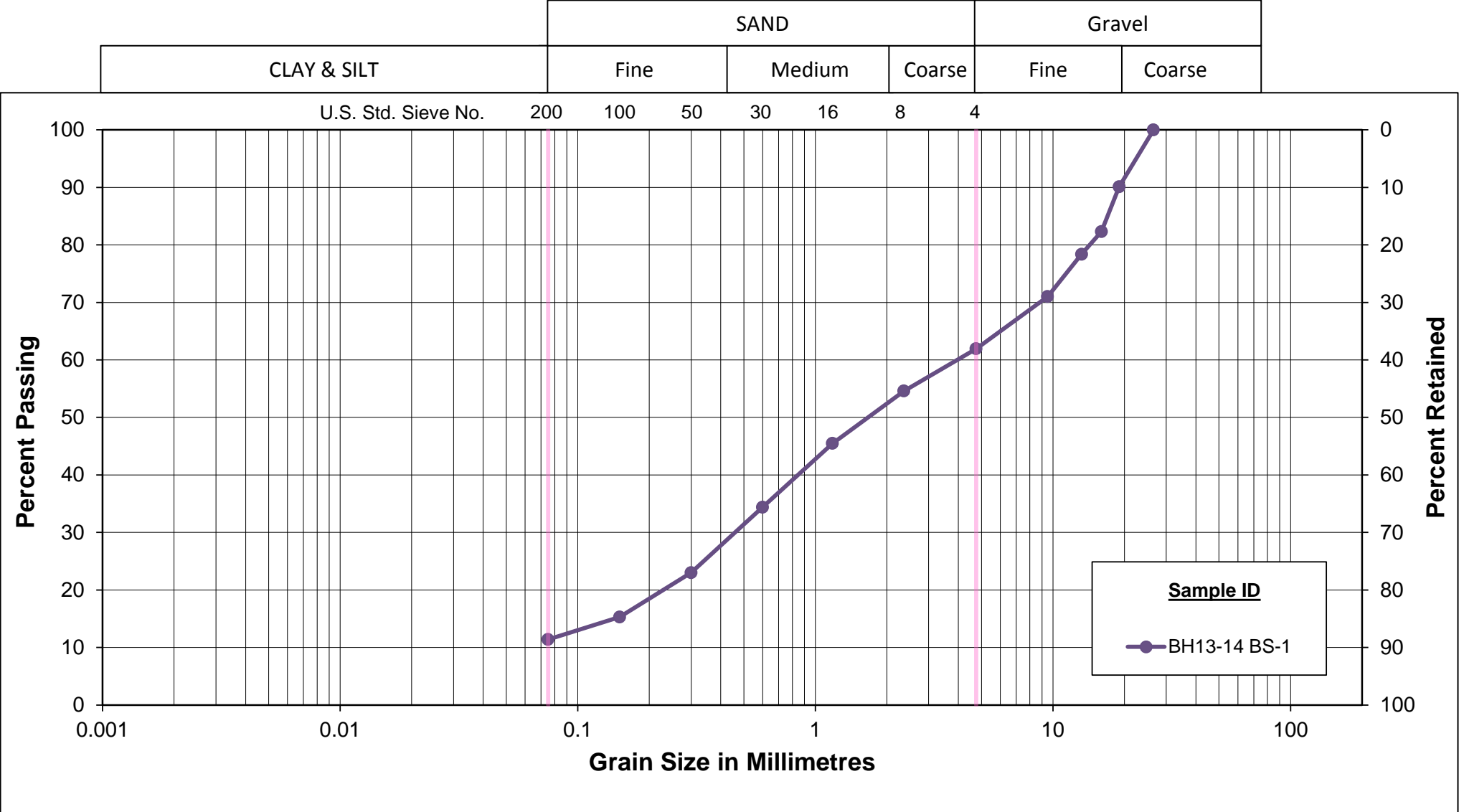
Silty clay (CI)  
(Interchange Site)

Figure No. 2e

Project No. 165000876

GWP 3031-11-00

Unified Soil Classification System



GRAIN SIZE DISTRIBUTION

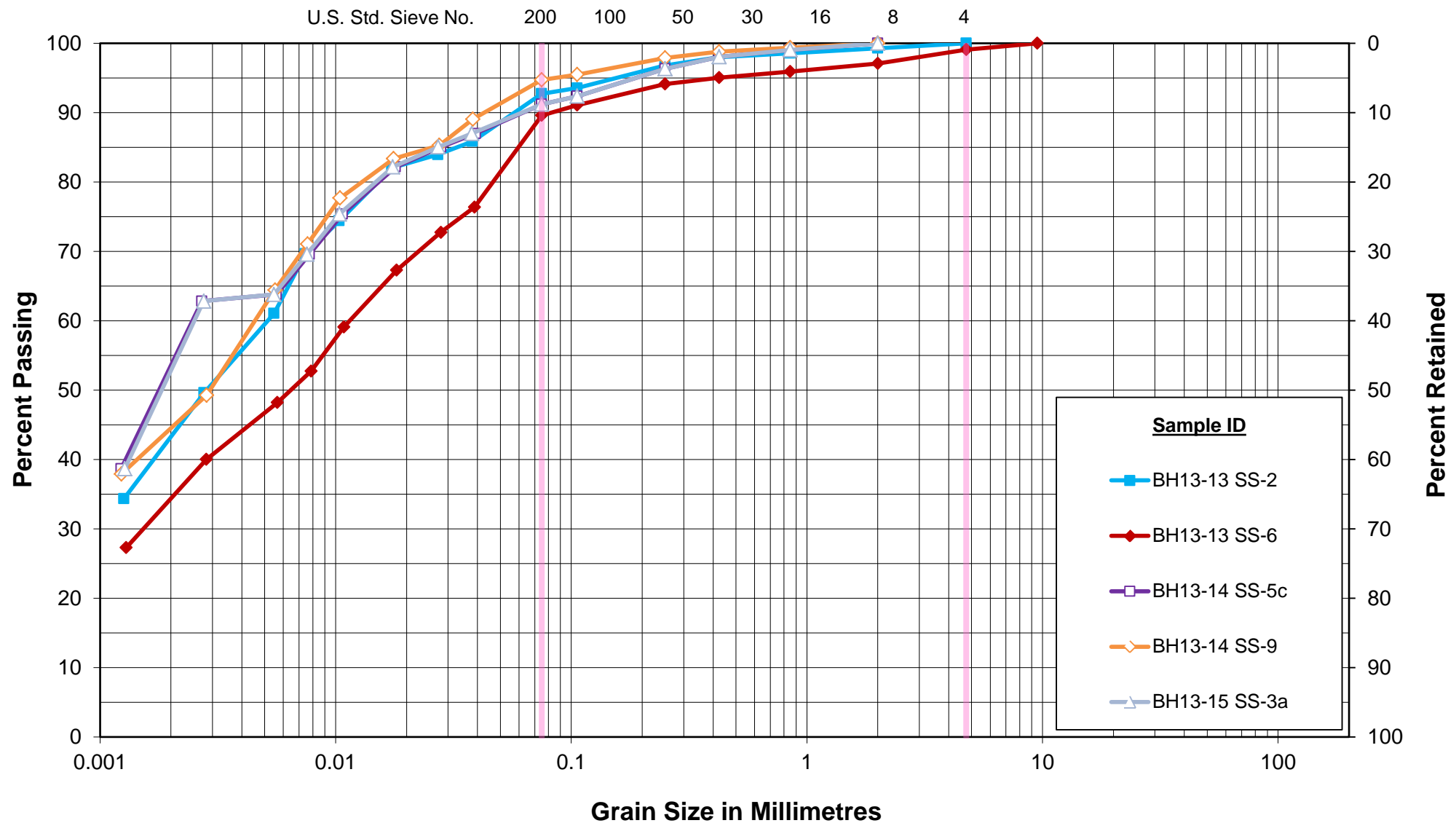
FILL: Poorly graded sand with silt and gravel (SP-SM) (Culvert Site)

Figure No. 3

Project No. 165000876  
GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty clay (CI)  
(Culvert Site)

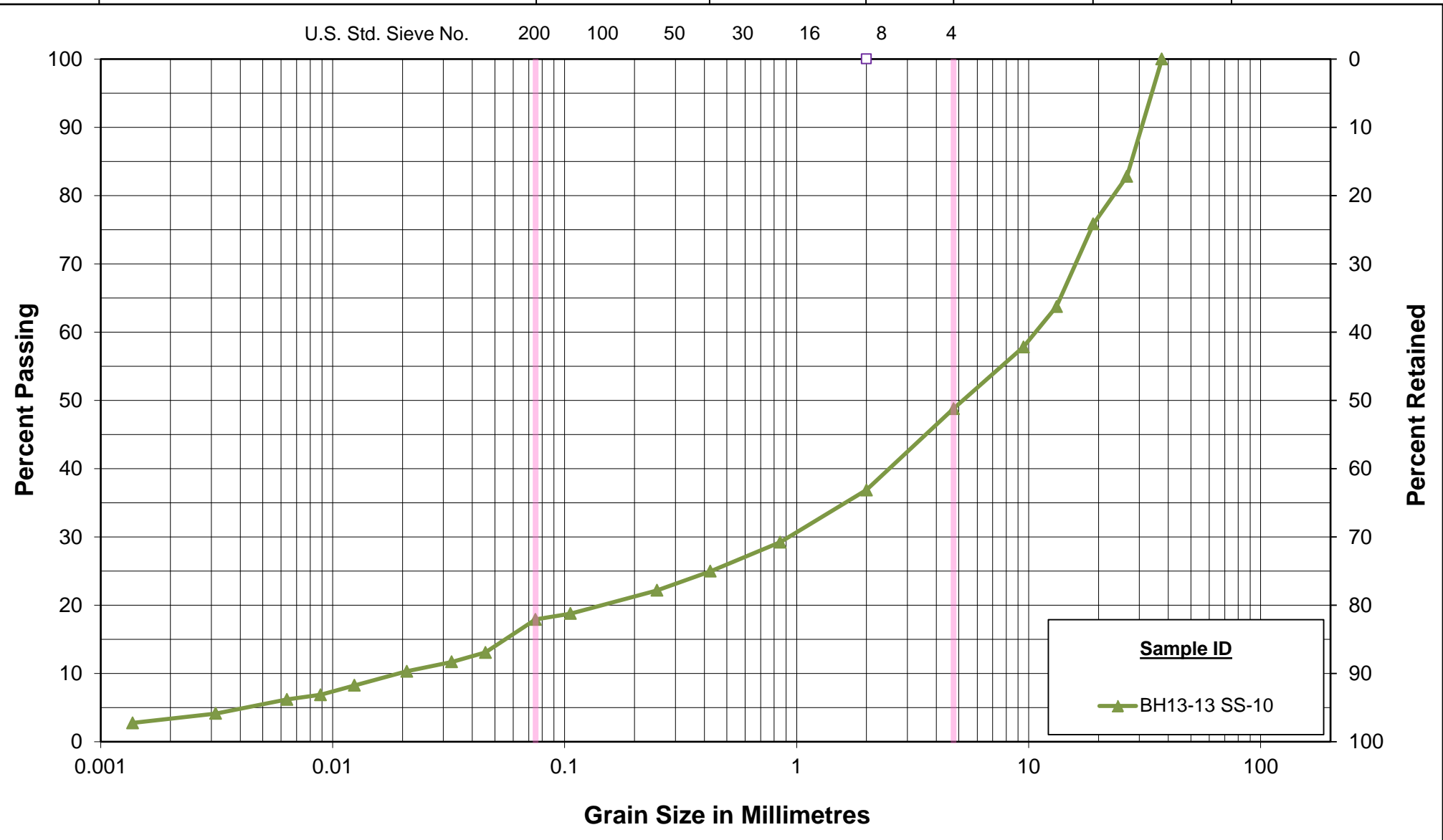
Figure No. 4

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

Silty gravel with sand (GM)  
(Culvert Site)

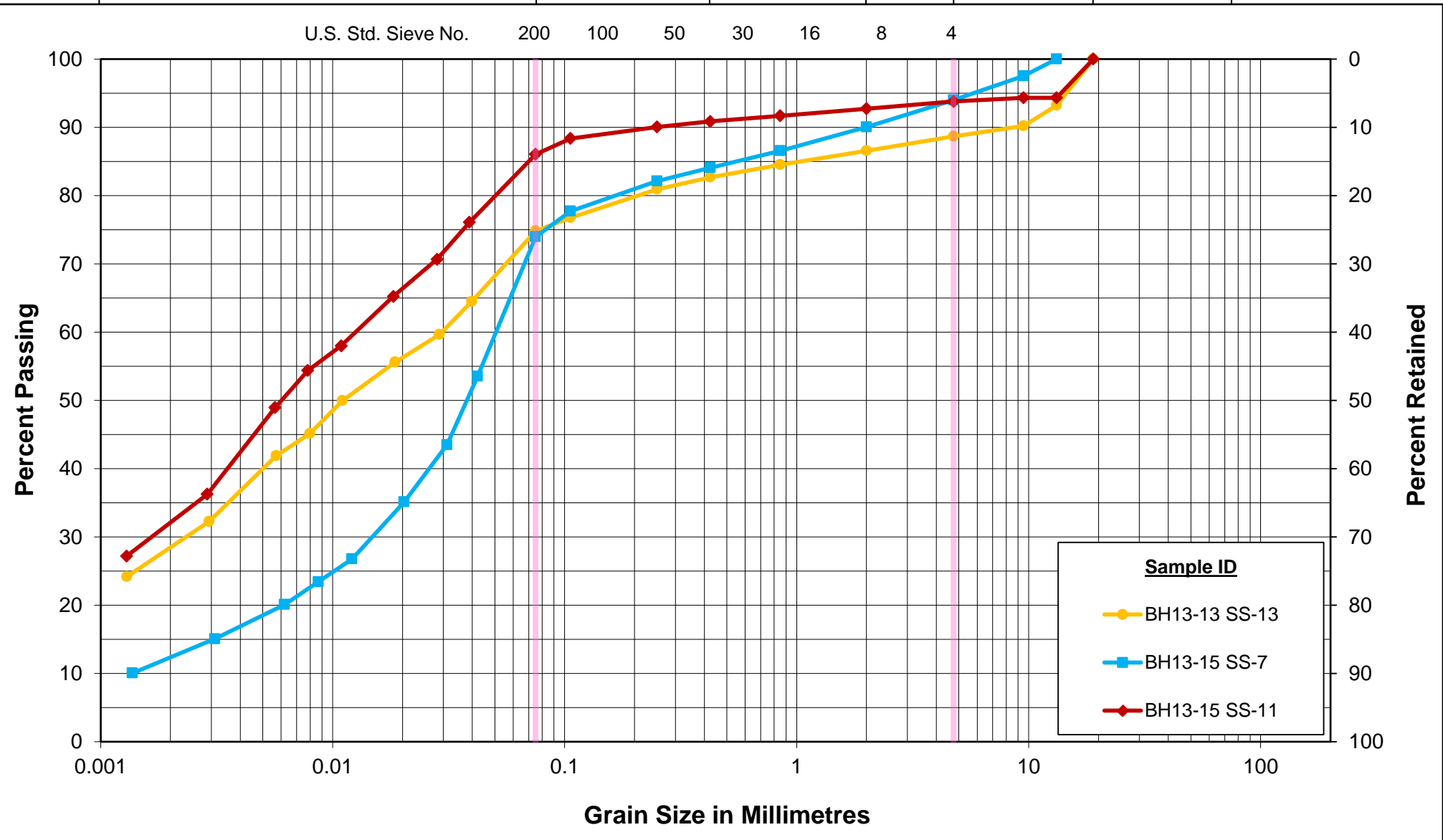
Figure No. 5

Project No. 165000876

GWP 3031-11-00

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

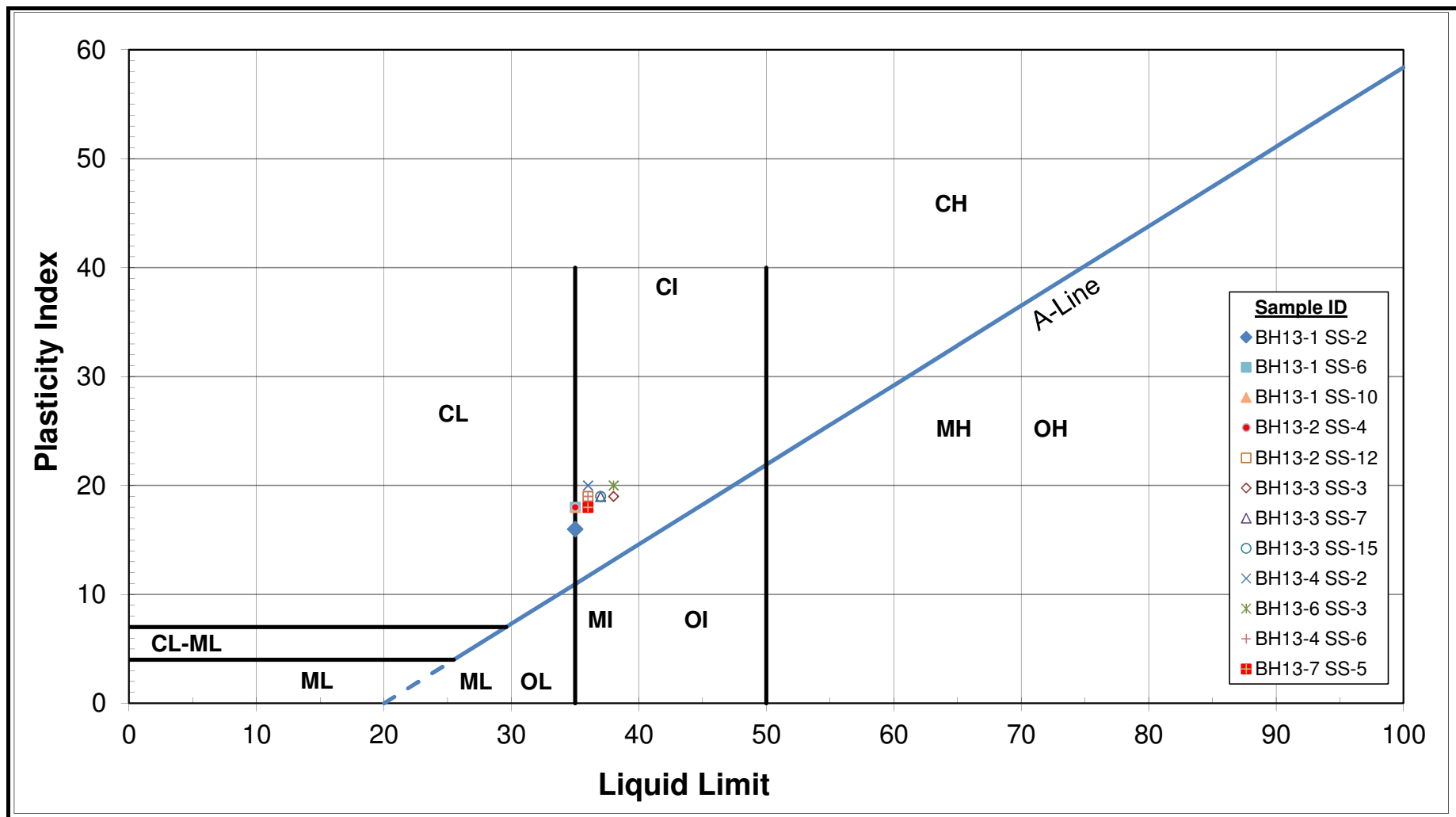
Clayey silt (CL)  
Curvert Site

Figure No. 6

Project No. 165000876

GWP 3031-11-00



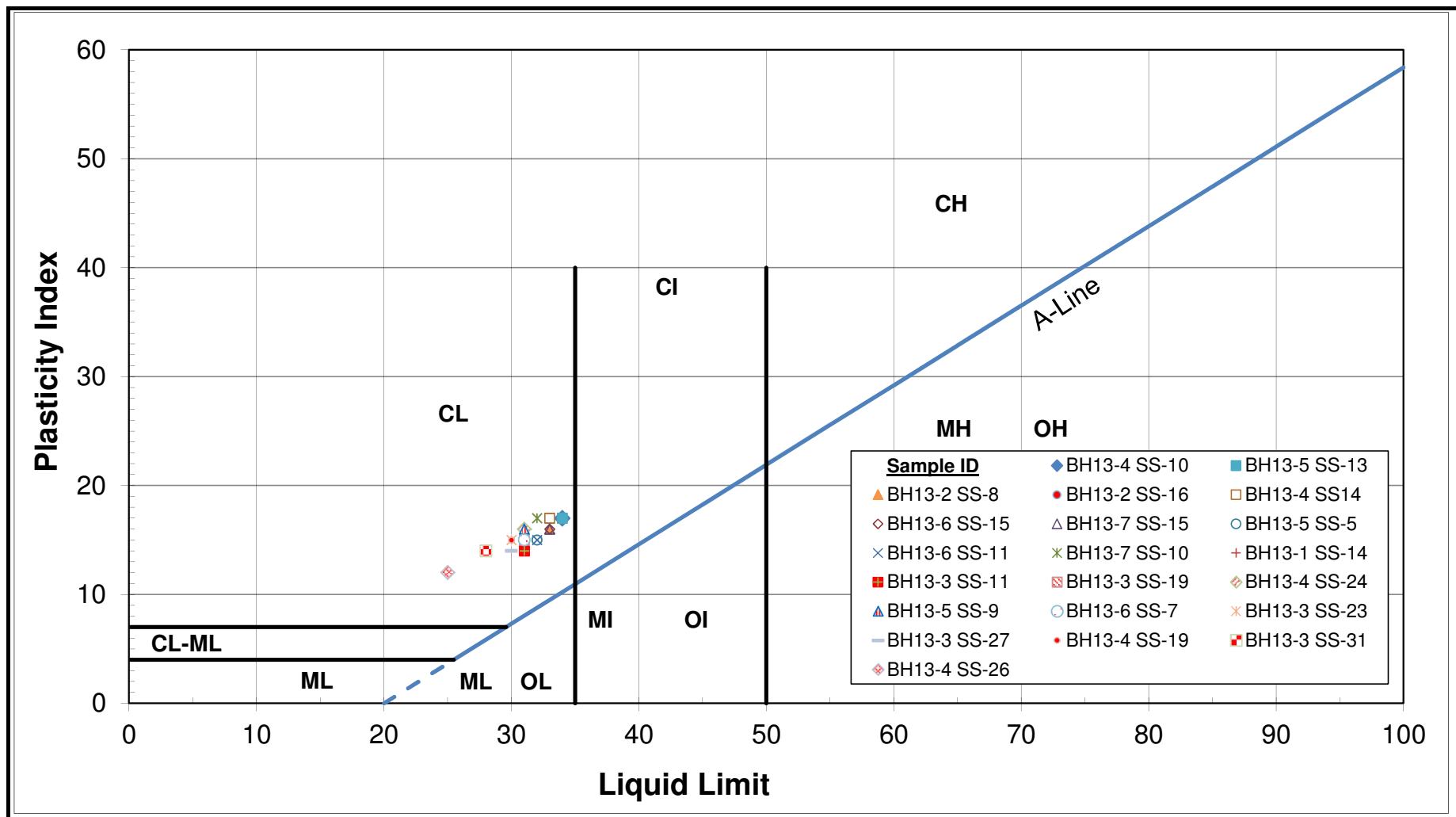


# PLASTICITY CHART

Silty clay (CI) (Interchange Site)

Figure No. 7a

Project No. 165000876  
GWP 3031-11-00



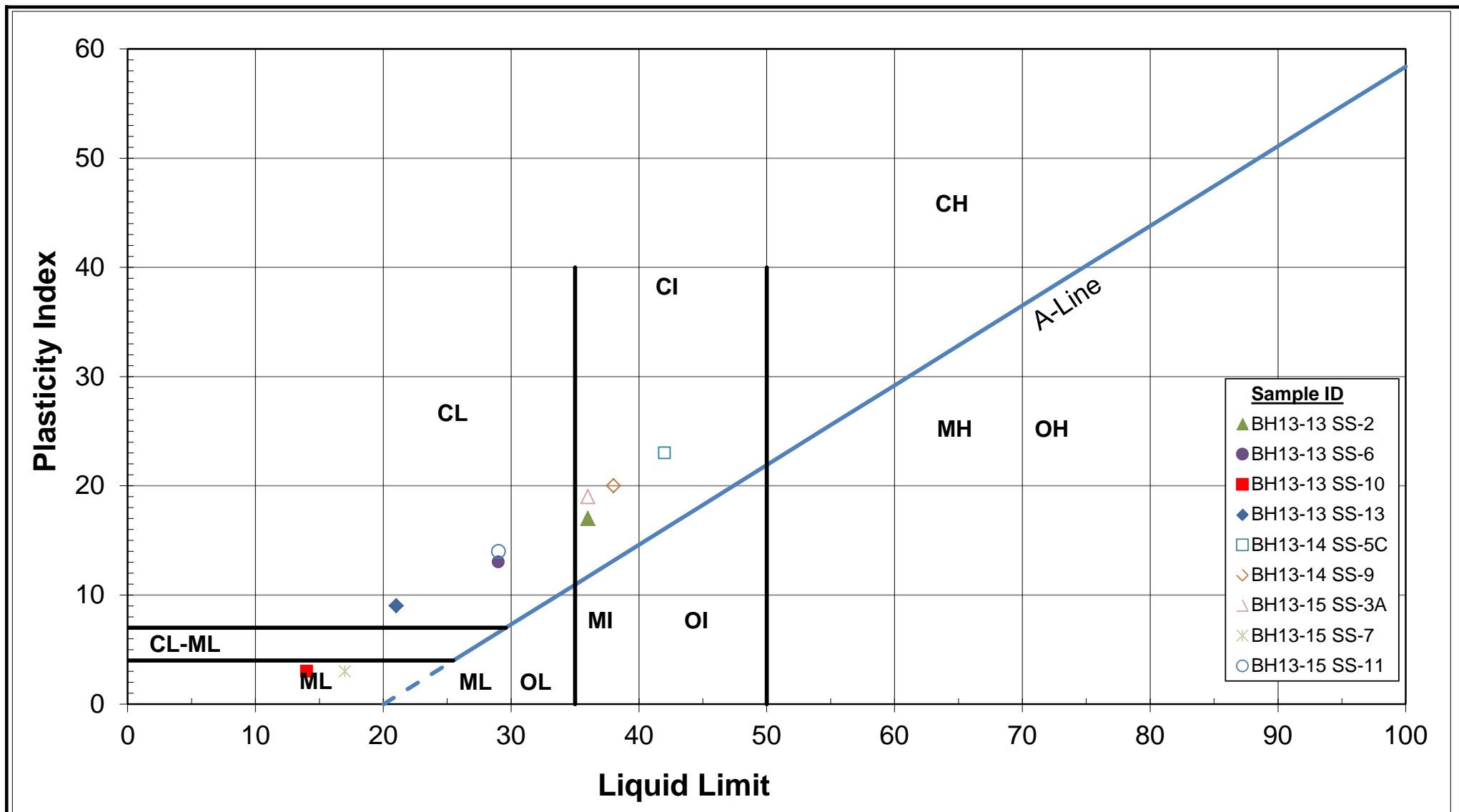
# PLASTICITY CHART

Clayey silt (CL) (Interchange Site)

Figure No. 7b

Project No. 165000876

GWP 3031-11-00



# PLASTICITY CHART

Silty clay (CI)/clayey silt (Culvert Site)

Figure No. 7c

Project No. 165000876

GWP 3031-11-00

December 24, 2013

Project No. 13-1183-0126

165000876

Mr. Simon Gudina  
Stantec Consulting Ltd.  
400-1331 Clyde Avenue  
Ottawa, Ontario  
K2C 3G4

## GEOTECHNICAL LABORATORY TESTING

Dear Sir,

This letter reports the results of laboratory testing carried out on the samples received at our office in Mississauga. The results of the tests are summarized in the attached tables and figures.

The testing services reported herein have been performed in accordance with the indicated recognized standard, unless noted otherwise. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability.

We trust that the results are sufficient for your current requirements. If you have any questions, please do not hesitate to call us.

**GOLDER ASSOCIATES LTD.**



Marijana Manojlovic  
Laboratory Manager

MM/lg



**Golder Associates Ltd.**

2900 Argentia Road, Unit 15, Mississauga, Ontario, Canada L5N 7X9  
Tel: +1 (905) 567 4444 Fax: +1 (905) 567 6561 [www.golder.com](http://www.golder.com)

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# UNCONFINED COMPRESSION TEST (UC)

## ASTM D 2166 - 06

### SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-14
BOREHOLE NUMBER	13-3	SAMPLE DEPTH, m	9.91-10.52

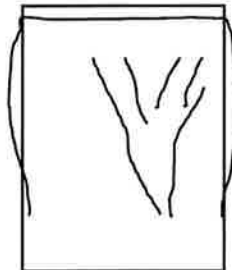
### TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.02

### SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	18.78
SAMPLE DIAMETER, cm	6.95	UNIT WEIGHT, kN/m <sup>3</sup>	21.07
SAMPLE AREA, cm <sup>2</sup>	37.90	DRY UNIT WT., kN/m <sup>3</sup>	17.74
SAMPLE VOLUME, cm <sup>3</sup>	531.41	SPECIFIC GRAVITY, measured	2.75
WET WEIGHT, g	1142.01	VOID RATIO	0.52
DRY WEIGHT, g	961.45		

### FAILURE SKETCH



### TEST RESULTS

STRAIN AT FAILURE, %	13.2	COMPRESSIVE STRESS, kPa	216
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REMARKS: Sample taken 11-27 cm from bottom of the tube

DATE:

11/16/2013

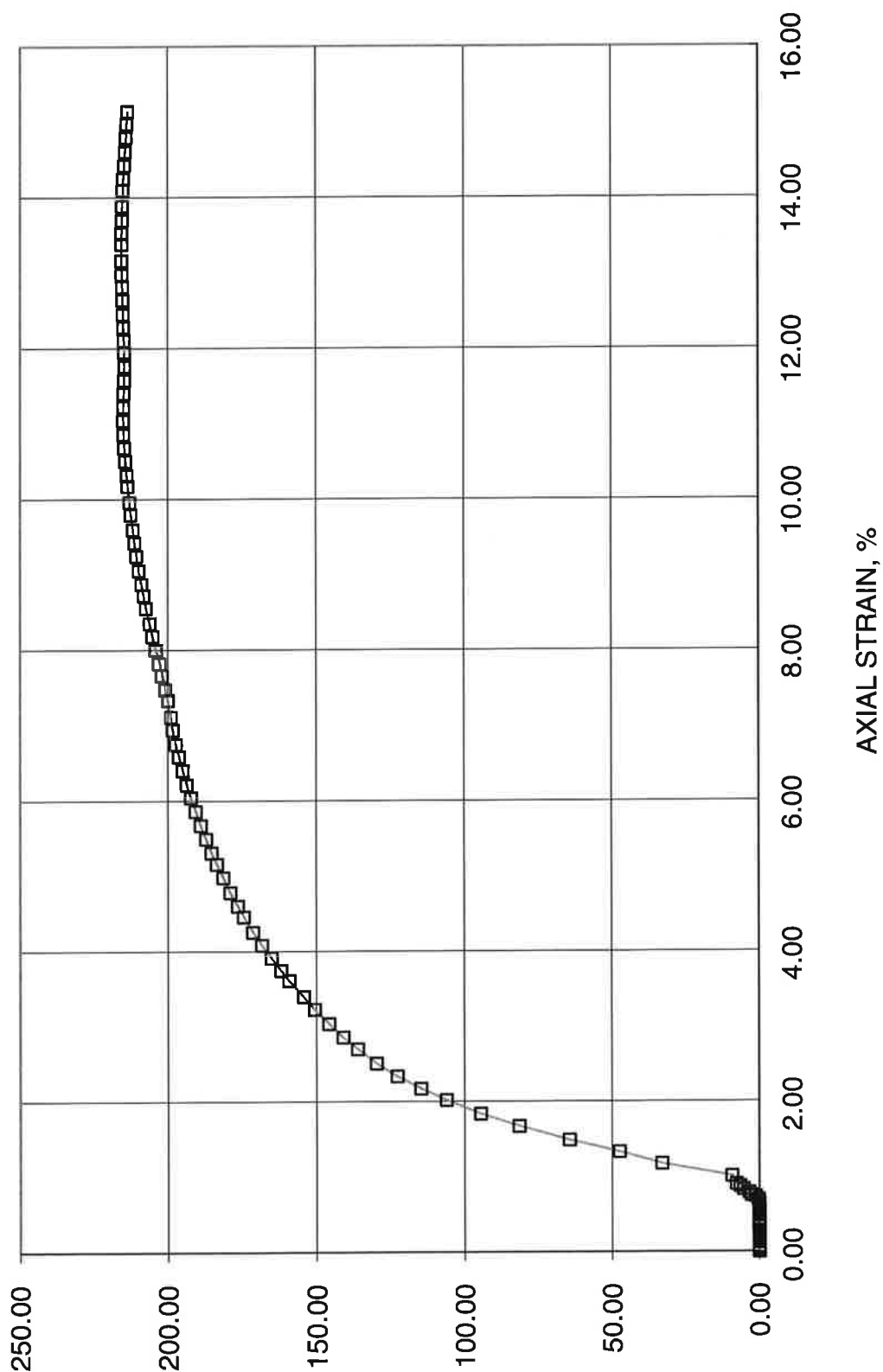
Checked By: *ML*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE

BOREHOLE NUMBER 13-3 SAMPLE NUMBER ST-14 SAMPLE DEPTH, m 9.91-10.52



Project No. 13-1183-0126

DEVIATOR STRESS, kPa

Checked By: *[Signature]*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-26
BOREHOLE NUMBER	13-3	SAMPLE DEPTH, m	33.50-34.10

## TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.02

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.01	WATER CONTENT, (specimen) %	13.35
SAMPLE DIAMETER, cm	6.94	UNIT WEIGHT, kN/m <sup>3</sup>	22.17
SAMPLE AREA, cm <sup>2</sup>	37.83	DRY UNIT WT., kN/m <sup>3</sup>	19.56
SAMPLE VOLUME, cm <sup>3</sup>	530.08	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1198.77	VOID RATIO	0.35
DRY WEIGHT, g	1057.59		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	12.2	COMPRESSIVE STRESS, kPa	456
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REMARKS: Sample taken 0-21 cm from bottom of the tube

DATE:

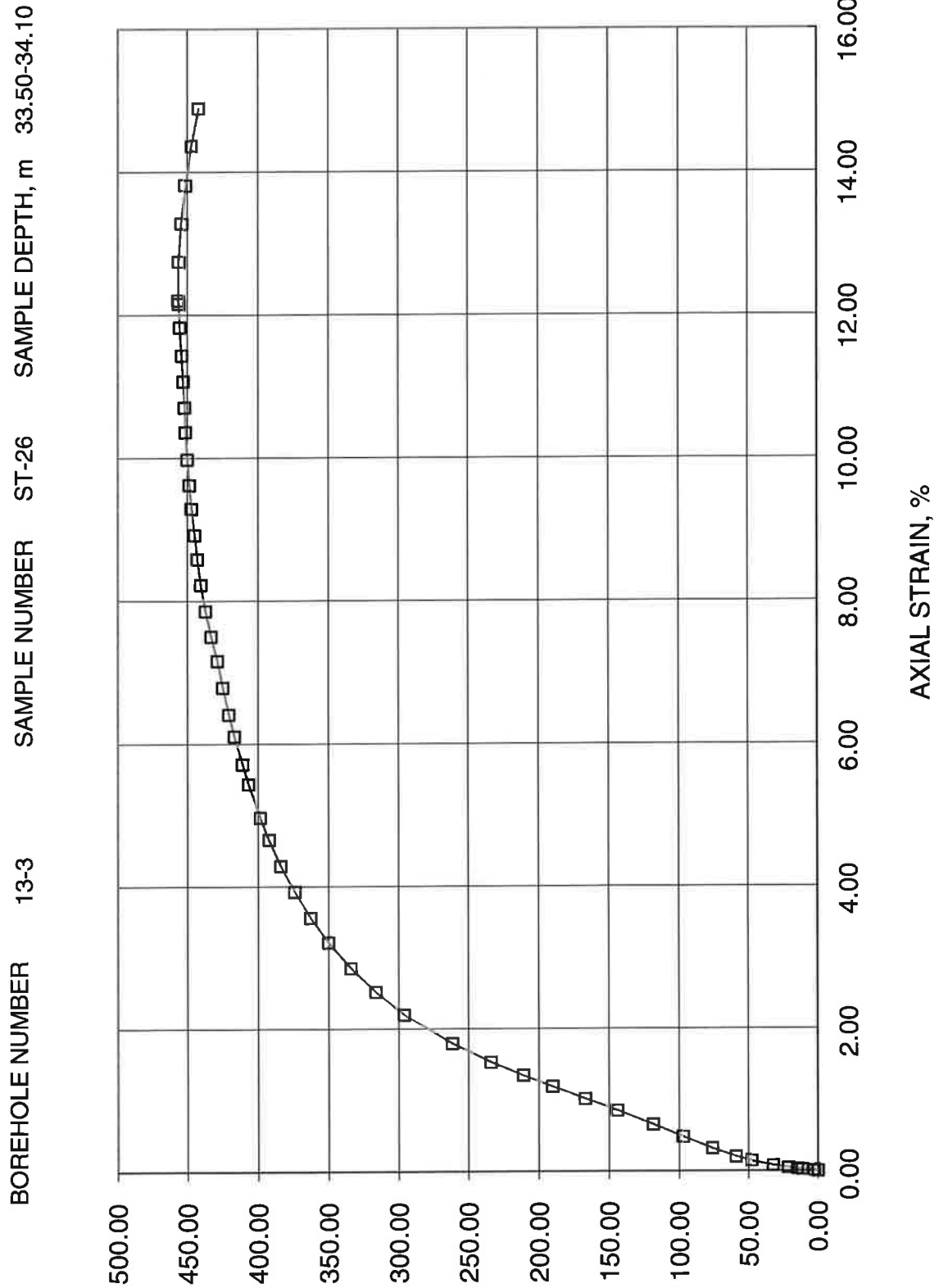
11/21/2013

Checked By: *llh*

Golder Associates

# UNCONFINED COMPRESSION TEST (UC)

FIGURE





# UNCONFINED COMPRESSION TEST (UC)

## ASTM D 2166 - 06

### SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-29
BOREHOLE NUMBER	13-3	SAMPLE DEPTH, m	42.7-43.3

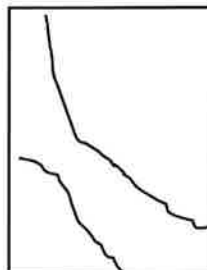
### TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.01

### SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	15.57
SAMPLE DIAMETER, cm	6.96	UNIT WEIGHT, kN/m <sup>3</sup>	21.61
SAMPLE AREA, cm <sup>2</sup>	38.09	DRY UNIT WT., kN/m <sup>3</sup>	18.70
SAMPLE VOLUME, cm <sup>3</sup>	533.83	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1176.63	VOID RATIO	0.42
DRY WEIGHT, g	1018.13		

### FAILURE SKETCH



### TEST RESULTS

STRAIN AT FAILURE, %	10.7	COMPRESSIVE STRESS, kPa	473
----------------------	------	-------------------------	-----

REMARKS: Sample taken 0-22 cm from bottom of the tube

DATE:

11/21/2013

Checked By: 

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

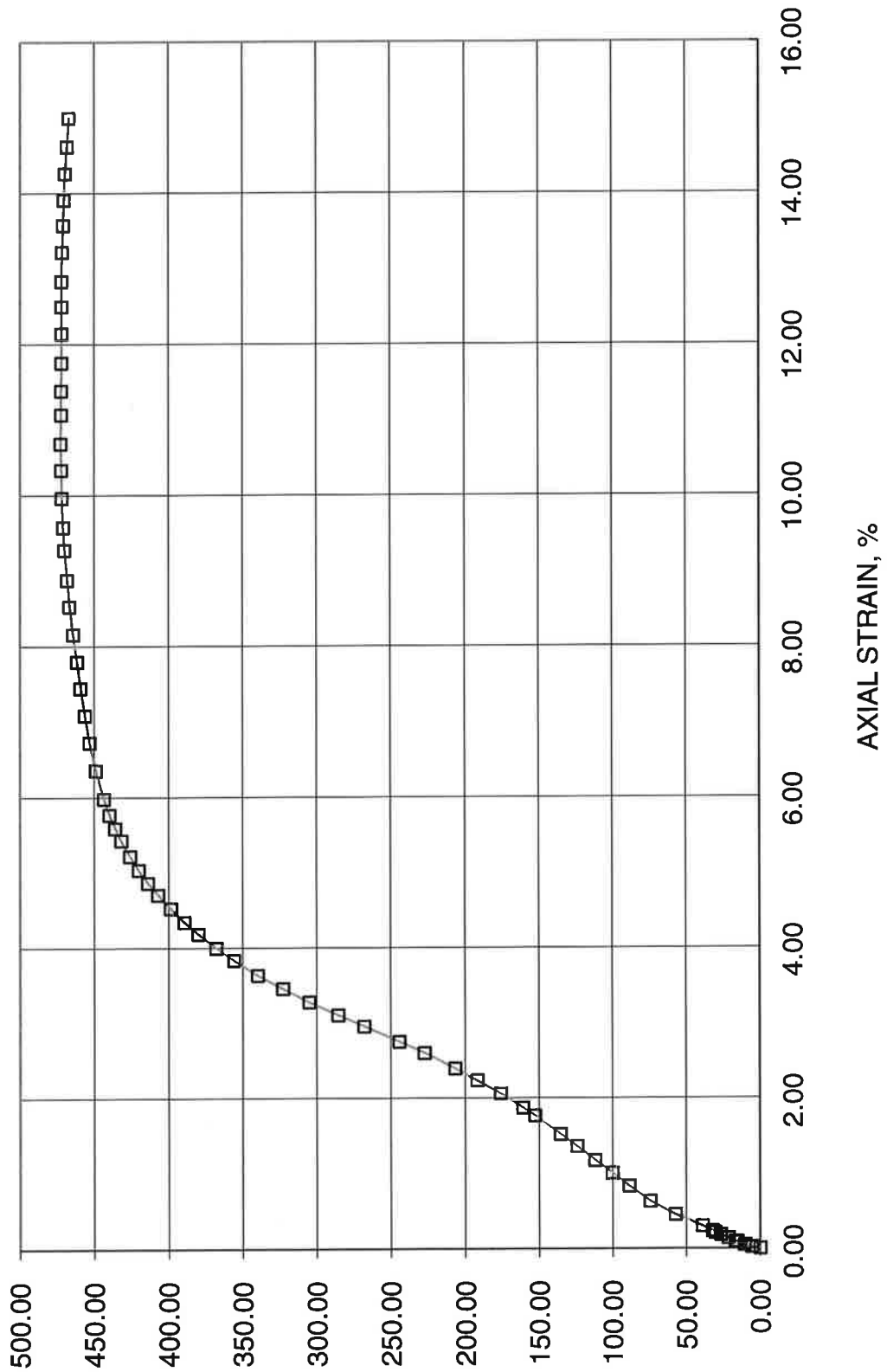
FIGURE

BOREHOLE NUMBER 13-3 SAMPLE DEPTH, m 42.7-43.3

SAMPLE NUMBER ST-29

SAMPLE NUMBER

13-3



*Handwritten signature*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-17
BOREHOLE NUMBER	13-4	SAMPLE DEPTH, m	12.20-12.80

## TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.02

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.03	WATER CONTENT, (specimen) %	21.71
SAMPLE DIAMETER, cm	6.95	UNIT WEIGHT, kN/m <sup>3</sup>	20.50
SAMPLE AREA, cm <sup>2</sup>	37.91	DRY UNIT WT., kN/m <sup>3</sup>	16.84
SAMPLE VOLUME, cm <sup>3</sup>	531.95	SPECIFIC GRAVITY, measured	2.74
WET WEIGHT, g	1112.46	VOID RATIO	0.59
DRY WEIGHT, g	914.03		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	5.8	COMPRESSIVE STRESS, kPa	133
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REMARKS: Sample taken 10-27 cm from bottom of the tube

DATE:

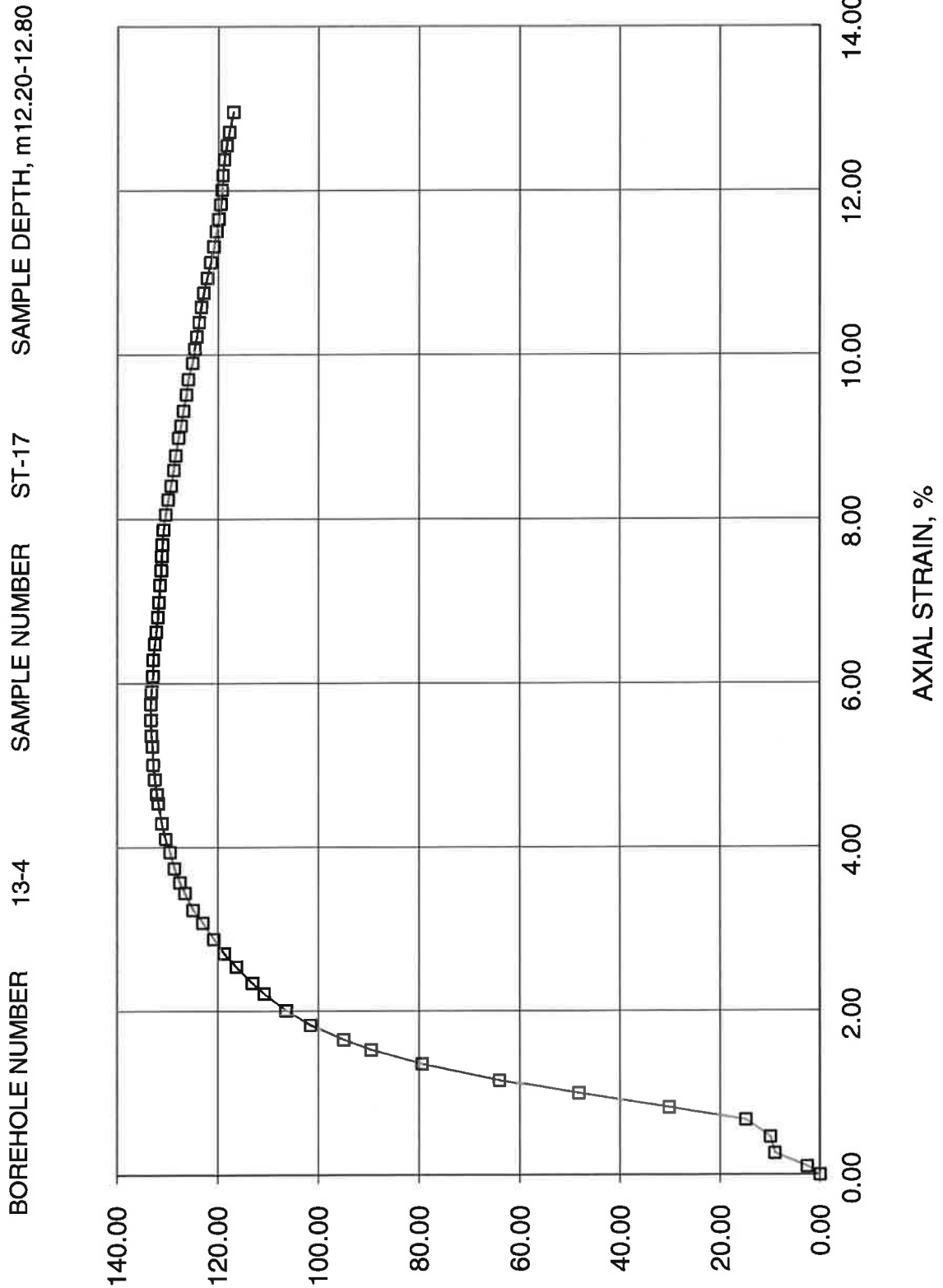
11/16/2013

Checked By: *hly*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



*hly*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-23
BOREHOLE NUMBER	13-4	SAMPLE DEPTH, m	20.10-20.70

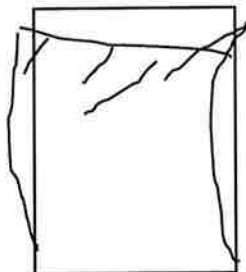
## TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.10	L/D	1.99

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.89	WATER CONTENT, (specimen) %	22.02
SAMPLE DIAMETER, cm	6.98	UNIT WEIGHT, kN/m <sup>3</sup>	20.58
SAMPLE AREA, cm <sup>2</sup>	38.21	DRY UNIT WT., kN/m <sup>3</sup>	16.87
SAMPLE VOLUME, cm <sup>3</sup>	530.66	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1113.97	VOID RATIO	0.57
DRY WEIGHT, g	912.96		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	10.6	COMPRESSIVE STRESS, kPa	26
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REMARKS: Sample taken 37-53 cm from bottom of the tube  
L/D Ratio not in accordance with ASTM Standard

DATE:

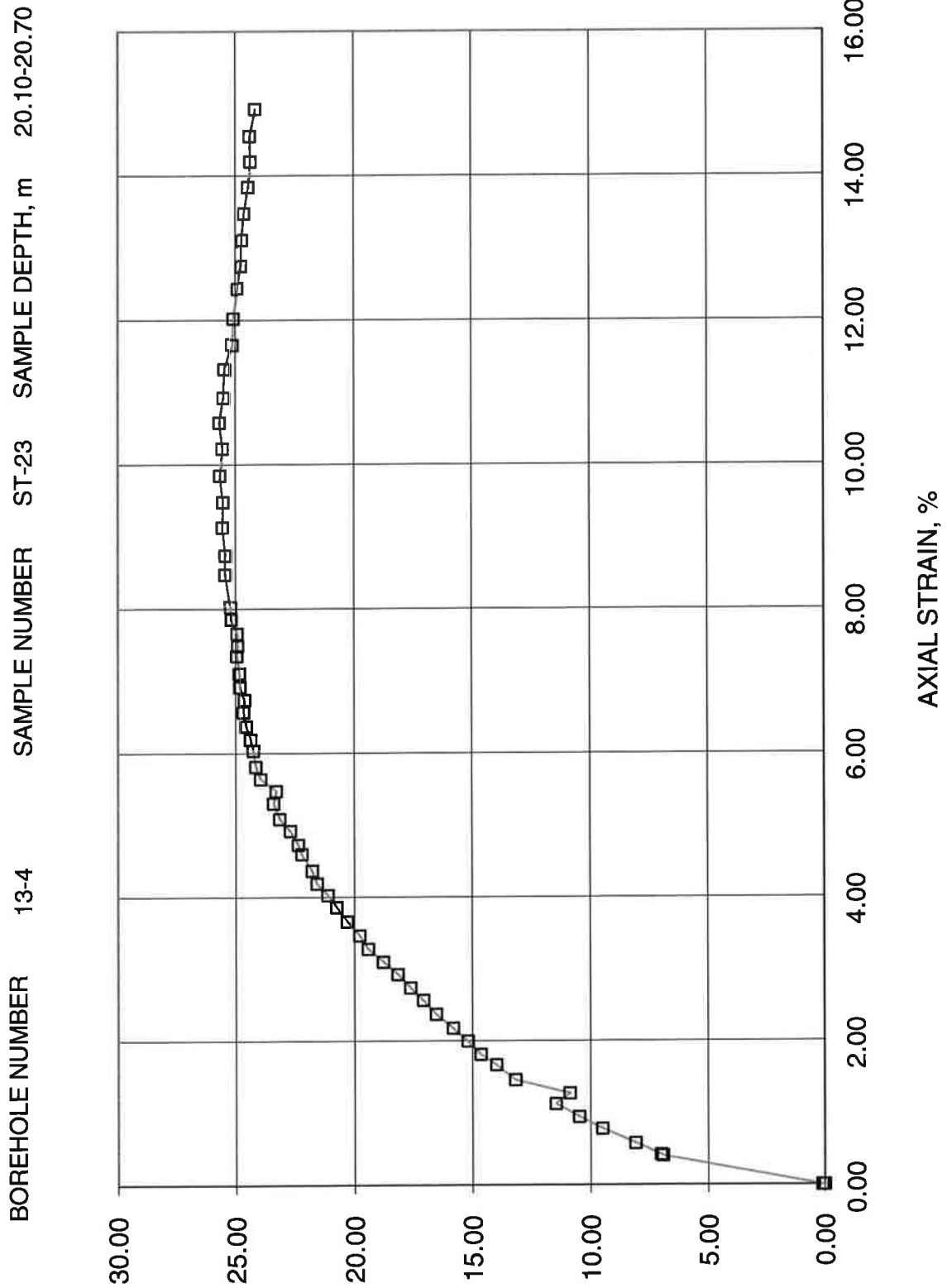
11/21/2013

Checked By: *My*

Golder Associates

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



*[Signature]*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-27
BOREHOLE NUMBER	13-4	SAMPLE DEPTH, m	29.57-29.88

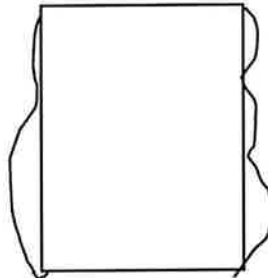
## TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.10	L/D	1.95

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.80	WATER CONTENT, (specimen) %	18.25
SAMPLE DIAMETER, cm	7.07	UNIT WEIGHT, kN/m <sup>3</sup>	20.83
SAMPLE AREA, cm <sup>2</sup>	39.21	DRY UNIT WT., kN/m <sup>3</sup>	17.62
SAMPLE VOLUME, cm <sup>3</sup>	540.95	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1149.70	VOID RATIO	0.50
DRY WEIGHT, g	972.27		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	10.8	COMPRESSIVE STRESS, kPa	87
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REMARKS: Sample taken 0-20 cm from bottom of the tube  
L/D Ratio not in accordance with ASTM Standard

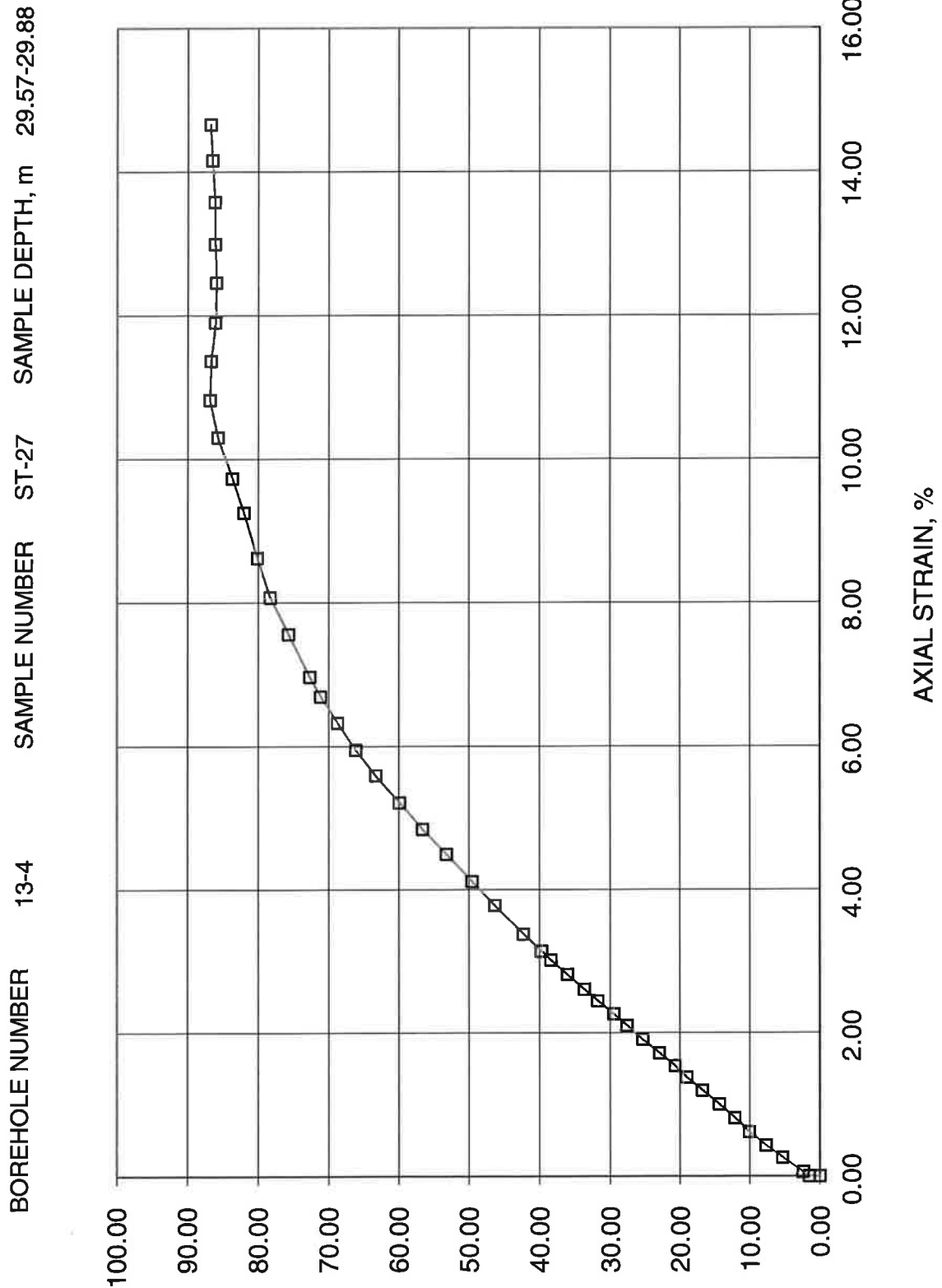
DATE: 11/21/2013

Checked By: *[Signature]*

Golder Associates

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



*bb*



# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-7
BOREHOLE NUMBER	13-7	SAMPLE DEPTH, m	4.57-5.17

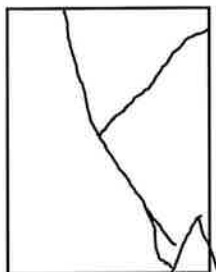
## TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.02

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	20.78
SAMPLE DIAMETER, cm	6.94	UNIT WEIGHT, kN/m <sup>3</sup>	20.65
SAMPLE AREA, cm <sup>2</sup>	37.86	DRY UNIT WT., kN/m <sup>3</sup>	17.10
SAMPLE VOLUME, cm <sup>3</sup>	530.80	SPECIFIC GRAVITY, measured	2.76
WET WEIGHT, g	1118.04	VOID RATIO	0.58
DRY WEIGHT, g	925.68		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	5.1	COMPRESSIVE STRESS, kPa	267
----------------------	-----	-------------------------	-----

REMARKS: Sample taken 13-28 cm from bottom of the tube

DATE:

11/16/2013

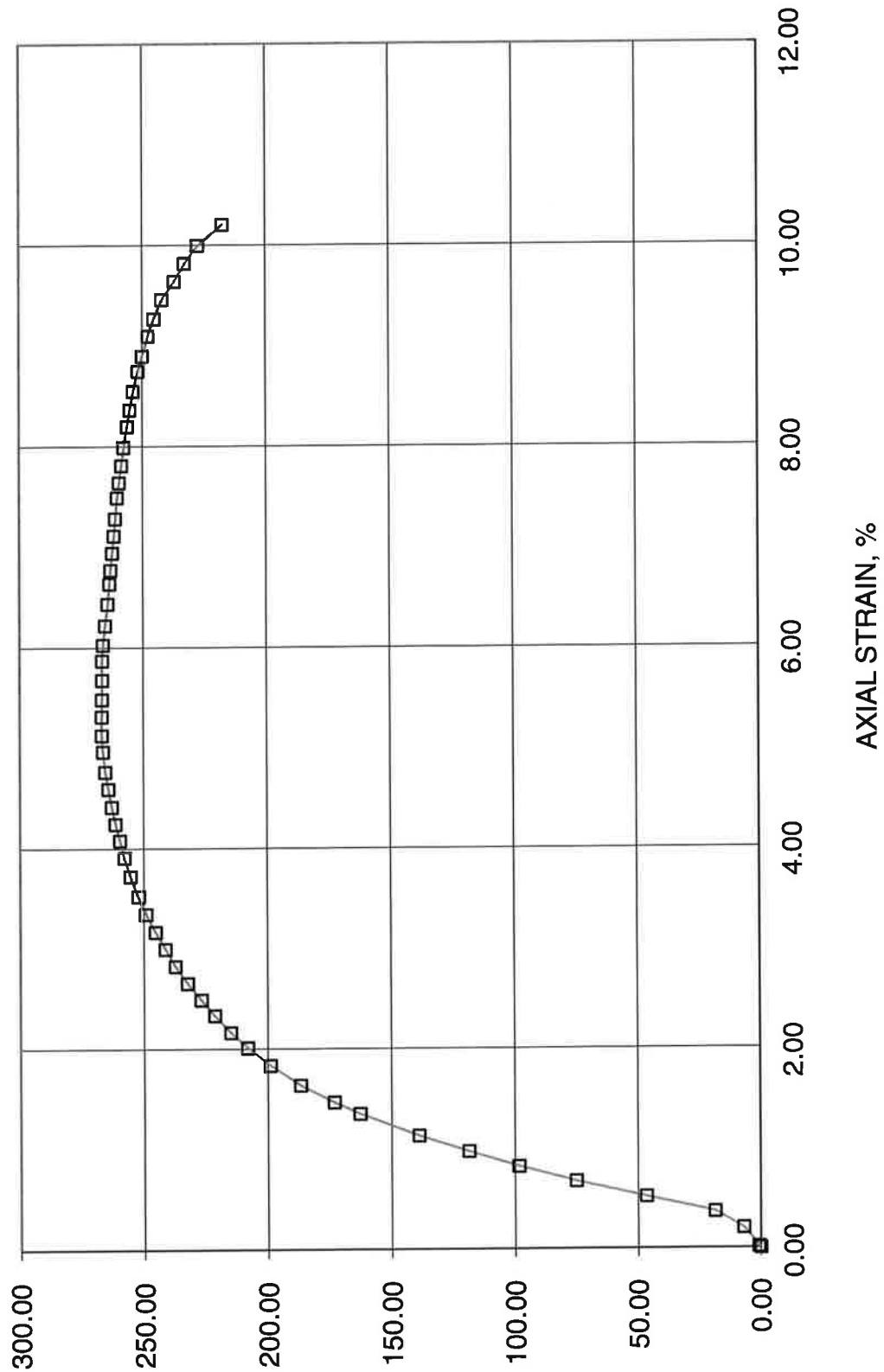
Checked By: *hly*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE

BOREHOLE NUMBER 13-7 SAMPLE NUMBER ST-7 SAMPLE DEPTH, m 4.57-5.17



*[Signature]*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-11
BOREHOLE NUMBER	13-7	SAMPLE DEPTH, m	7.60-8.20

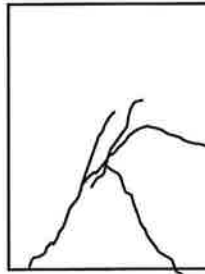
## TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.02

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	19.35
SAMPLE DIAMETER, cm	6.95	UNIT WEIGHT, kN/m <sup>3</sup>	20.99
SAMPLE AREA, cm <sup>2</sup>	37.90	DRY UNIT WT., kN/m <sup>3</sup>	17.59
SAMPLE VOLUME, cm <sup>3</sup>	531.26	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1137.73	VOID RATIO	0.50
DRY WEIGHT, g	953.25		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	8.2	COMPRESSIVE STRESS, kPa	346
----------------------	-----	-------------------------	-----

REMARKS: Sample taken 0-20 cm from bottom of the tube

DATE:

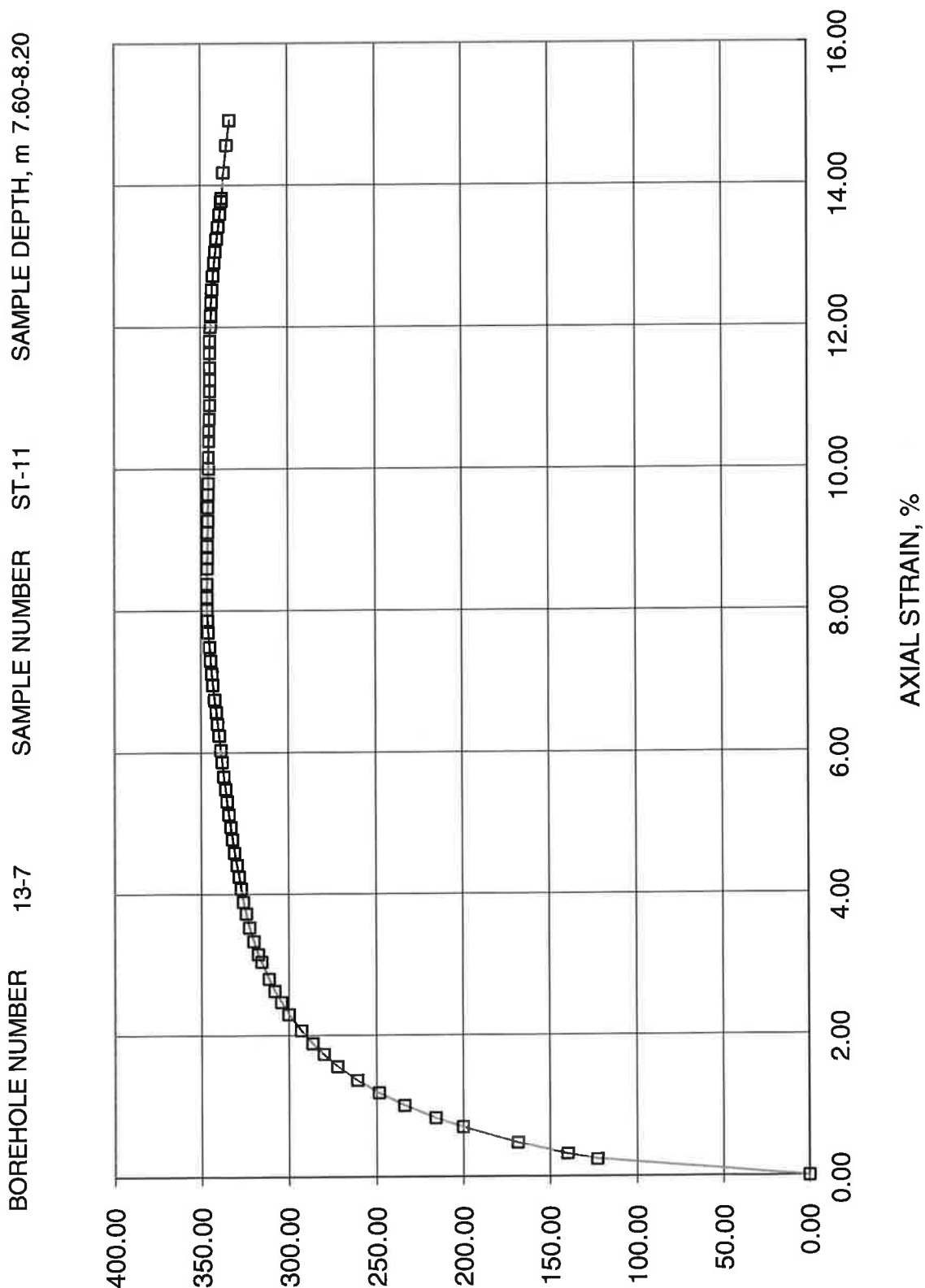
11/21/2013

Checked By: *[Signature]*

Golder Associates

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



*[Signature]*

# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-13
BOREHOLE NUMBER	13-9	SAMPLE DEPTH, m	9.15-9.75

## TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.03

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.04	WATER CONTENT, (specimen) %	19.83
SAMPLE DIAMETER, cm	6.92	UNIT WEIGHT, kN/m <sup>3</sup>	21.16
SAMPLE AREA, cm <sup>2</sup>	37.59	DRY UNIT WT., kN/m <sup>3</sup>	17.66
SAMPLE VOLUME, cm <sup>3</sup>	527.74	SPECIFIC GRAVITY, measured	2.75
WET WEIGHT, g	1139.34	VOID RATIO	0.53
DRY WEIGHT, g	950.80		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	10.6	COMPRESSIVE STRESS, kPa	245
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REMARKS: Sample taken 10-27 cm from bottom of the tube

DATE:

11/16/2013

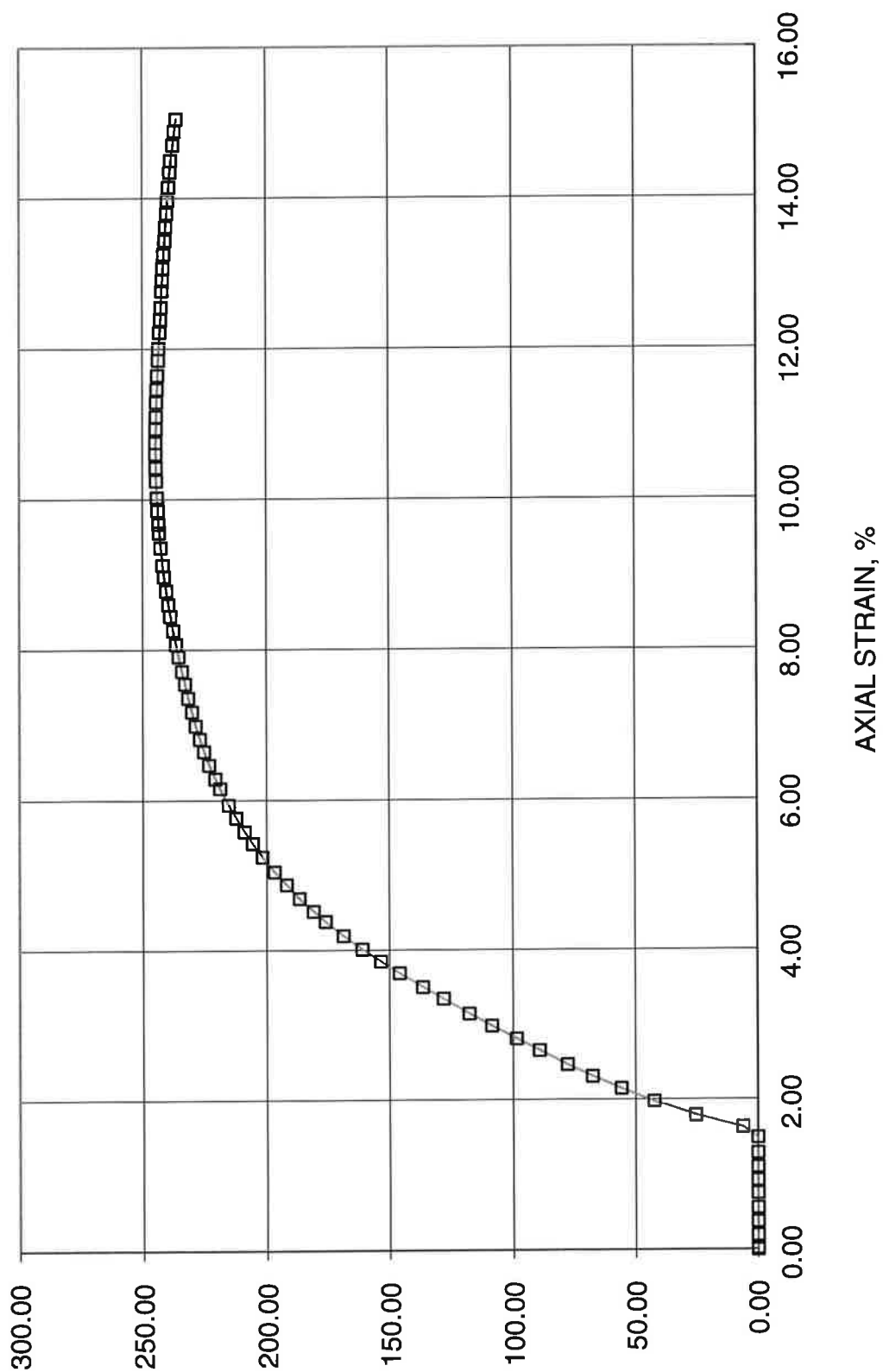
Checked By: *[Signature]*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE

BOREHOLE NUMBER 13-9 SAMPLE NUMBER ST-13 SAMPLE DEPTH, m 9.15-9.75



# UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

## SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-22
BOREHOLE NUMBER	13-9	SAMPLE DEPTH, m	25.90-26.50

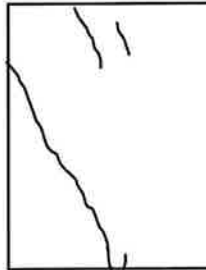
## TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.02

## SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	17.72
SAMPLE DIAMETER, cm	6.95	UNIT WEIGHT, kN/m <sup>3</sup>	21.21
SAMPLE AREA, cm <sup>2</sup>	37.95	DRY UNIT WT., kN/m <sup>3</sup>	18.02
SAMPLE VOLUME, cm <sup>3</sup>	531.91	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1150.84	VOID RATIO	0.47
DRY WEIGHT, g	977.60		

## FAILURE SKETCH



## TEST RESULTS

STRAIN AT FAILURE, %	12.2	COMPRESSIVE STRESS, kPa	350
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REMARKS: Sample taken 20-36 cm from bottom of the tube

DATE:

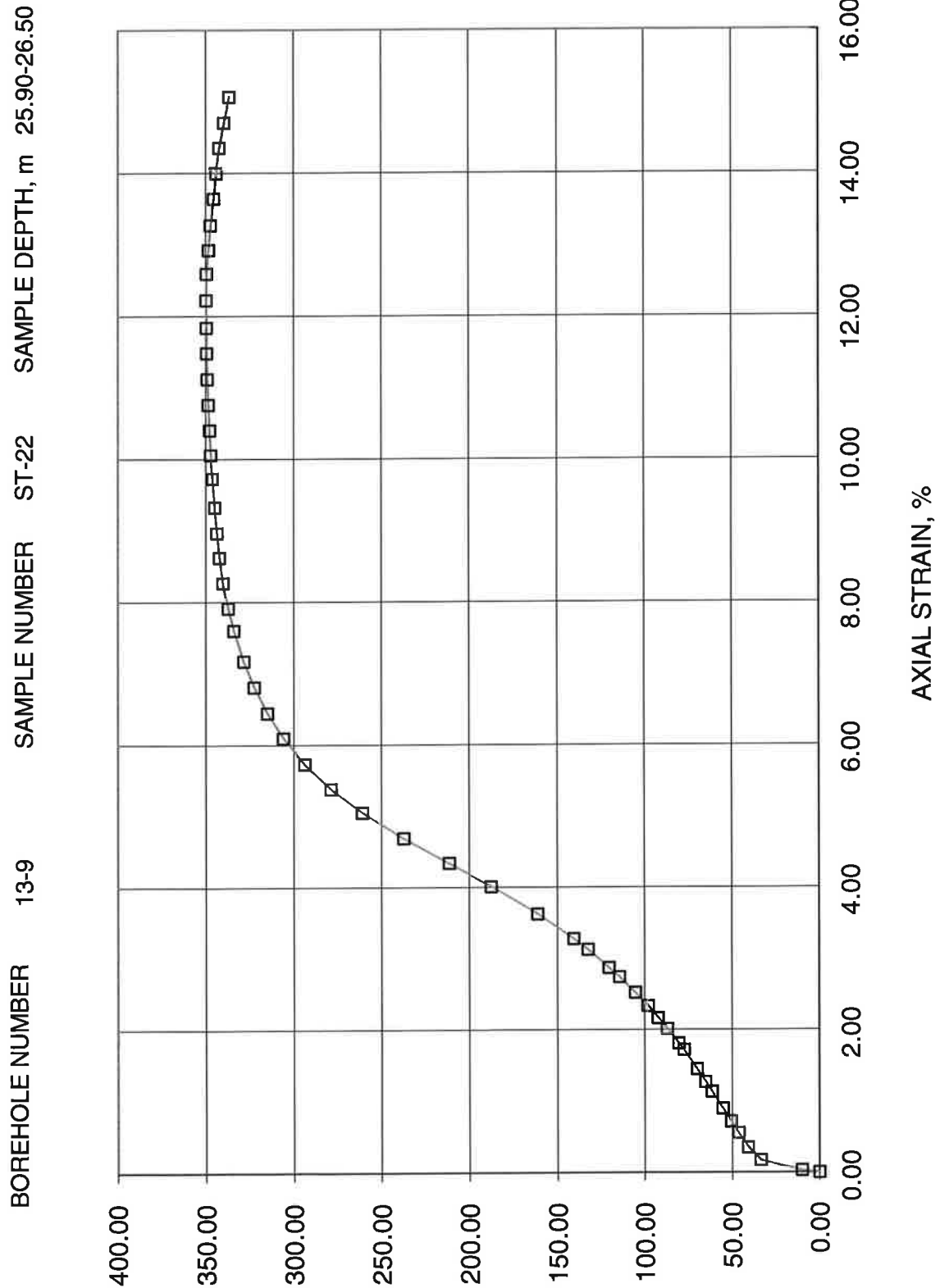
11/21/2013

Checked By: *[Signature]*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



*[Signature]*



# UNCONFINED COMPRESSION TEST (UC)

## ASTM D 2166 - 06

### SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-18
BOREHOLE NUMBER	13-10	SAMPLE DEPTH, m	15.20-15.80

### TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.01

### SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.01	WATER CONTENT, (specimen) %	18.37
SAMPLE DIAMETER, cm	6.98	UNIT WEIGHT, kN/m <sup>3</sup>	21.19
SAMPLE AREA, cm <sup>2</sup>	38.21	DRY UNIT WT., kN/m <sup>3</sup>	17.91
SAMPLE VOLUME, cm <sup>3</sup>	535.32	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1157.39	VOID RATIO	0.48
DRY WEIGHT, g	977.77		

### FAILURE SKETCH



### TEST RESULTS

STRAIN AT FAILURE, %	14.7	COMPRESSIVE STRESS, kPa	237
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REMARKS: Sample taken 0-21 cm from bottom of the tube

DATE:

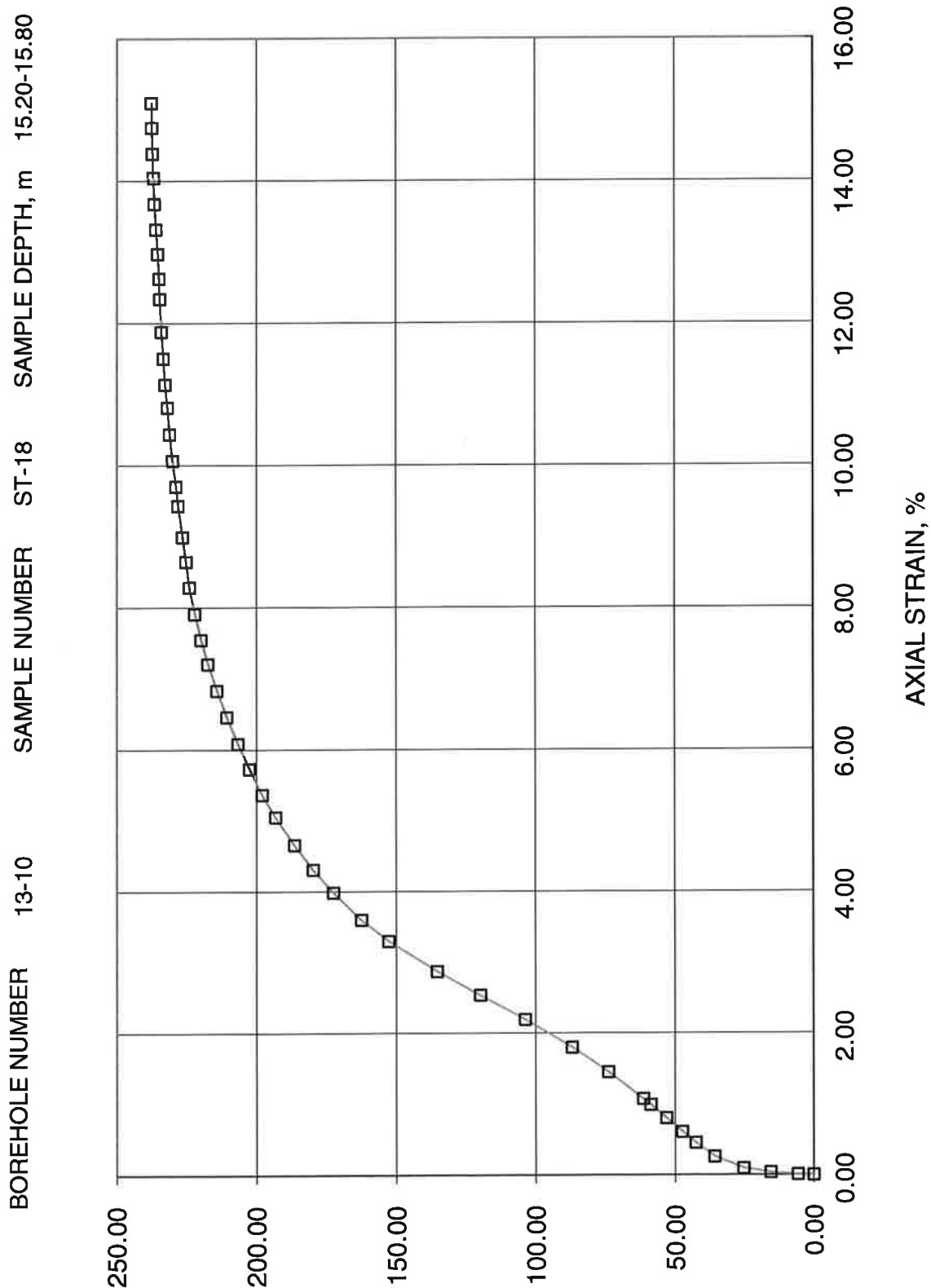
11/21/2013

Checked By: *hdy*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



# UNCONFINED COMPRESSION TEST (UC)

## ASTM D 2166 - 06

### SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0126	SAMPLE NUMBER	ST-23
BOREHOLE NUMBER	13-10	SAMPLE DEPTH, m	25.90-26.50

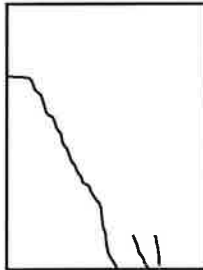
### TEST CONDITIONS

MACHINE SPEED, mm/min	1.52	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.09	L/D	2.03

### SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.02	WATER CONTENT, (specimen) %	17.08
SAMPLE DIAMETER, cm	6.91	UNIT WEIGHT, kN/m <sup>3</sup>	21.38
SAMPLE AREA, cm <sup>2</sup>	37.52	DRY UNIT WT., kN/m <sup>3</sup>	18.26
SAMPLE VOLUME, cm <sup>3</sup>	525.96	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	1147.06	VOID RATIO	0.45
DRY WEIGHT, g	979.74		

### FAILURE SKETCH



### TEST RESULTS

STRAIN AT FAILURE, %	14.1	COMPRESSIVE STRESS, kPa	244
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REMARKS: Sample taken 0-21 cm from bottom of the tube

DATE:

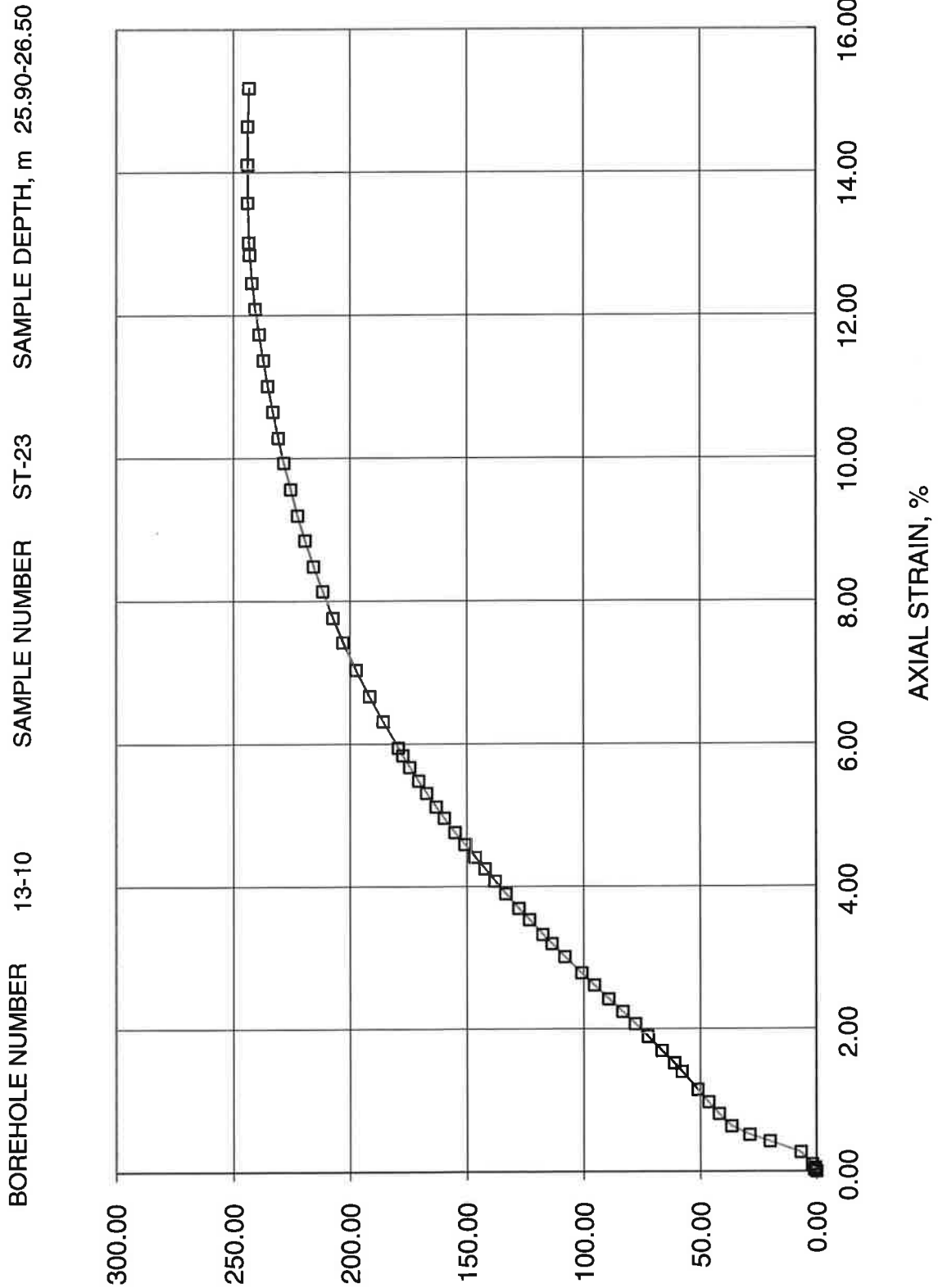
11/21/2013

Checked By: *gh*

**Golder Associates**

# UNCONFINED COMPRESSION TEST (UC)

FIGURE



## SPECIFIC GRAVITY TEST RESULTS

### ASTM D 854-06 TEST METHOD A

PROJECT NUMBER	13-1183-0126
PROJECT NAME	Stantec / Testing / 165000876
DATE TESTED	November, 2013

Borehole No.	Sample No.	Specific Gravity
13-3	ST-14	2.75
13-4	ST-17	2.74
13-7	ST-7	2.76
13-9	ST-13	2.75

Note: Test carried out on soil particles <2.00mm using distilled water.

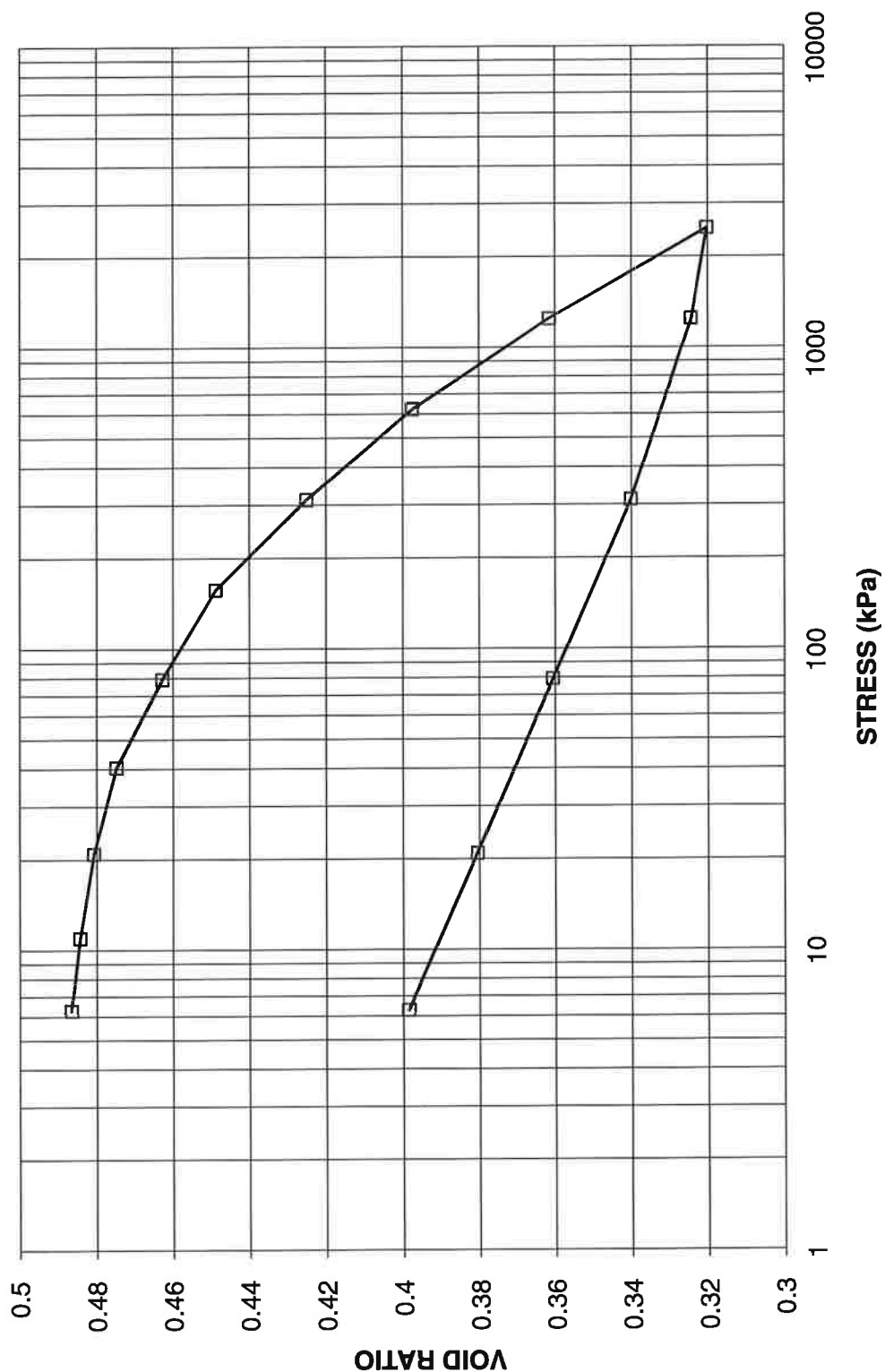
Checked By: 

**Golder Associates**

# CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST  
VOID RATIO vs STRESS  
BH 13-3 SA ST-14



Project No. 13-1183-0126

Prepared By: LG

Golder Associates

Checked By: *[Signature]*

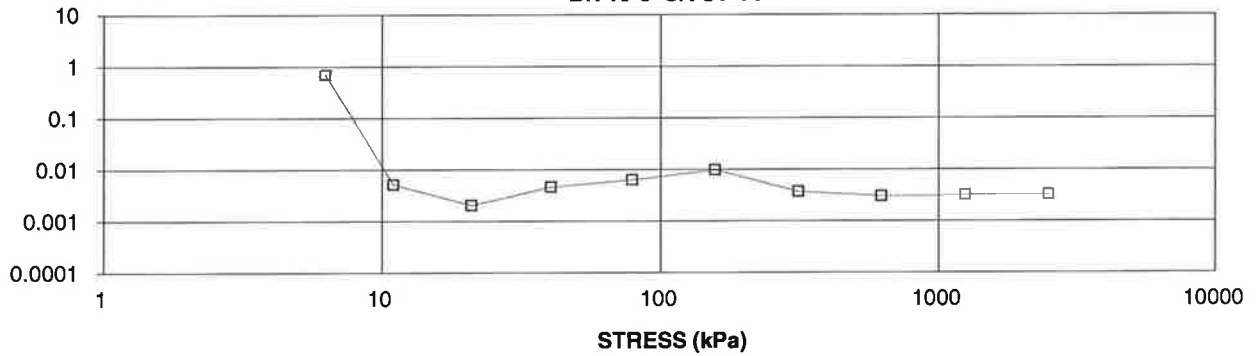
CONSOLIDATION TEST SUMMARY					FIGURE		
<b>SAMPLE IDENTIFICATION</b>							
Project Number	13-1183-0126			Sample Number	ST-14		
Borehole Number	13-3			Sample Depth, m	9.9-10.5		
<b>TEST CONDITIONS</b>							
Test Type	Standard			Load Duration, hr	24		
Oedometer Number	1						
Date Started	11/15/2013						
Date Completed	11/30/2013						
<b>SAMPLE DIMENSIONS AND PROPERTIES - INITIAL</b>							
Sample Height, cm	2.56			Unit Weight, kN/m <sup>3</sup>	21.37		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m <sup>3</sup>	18.14		
Area, cm <sup>2</sup>	31.54			Specific Gravity, measured	2.75		
Volume, cm <sup>3</sup>	80.58			Solids Height, cm	1.718		
Water Content, %	17.83			Volume of Solids, cm <sup>3</sup>	54.20		
Wet Mass, g	175.62			Volume of Voids, cm <sup>3</sup>	26.39		
Dry Mass, g	149.04			Degree of Saturation, %	100.7		
<b>TEST COMPUTATIONS</b>							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	2.555	0.487	2.555				
6.28	2.554	0.487	2.555	2	6.92E-01	3.74E-05	2.54E-06
10.96	2.551	0.484	2.553	266	5.19E-03	3.09E-04	1.57E-07
20.89	2.545	0.481	2.548	667	2.06E-03	2.44E-04	4.94E-08
40.45	2.534	0.475	2.539	296	4.62E-03	2.02E-04	9.15E-08
79.23	2.514	0.463	2.524	214	6.31E-03	2.09E-04	1.29E-07
156.80	2.490	0.449	2.502	135	9.83E-03	1.21E-04	1.17E-07
311.72	2.449	0.425	2.469	346	3.74E-03	1.03E-04	3.77E-08
622.18	2.402	0.398	2.425	409	3.05E-03	5.98E-05	1.79E-08
1243.10	2.340	0.362	2.371	386	3.09E-03	3.90E-05	1.18E-08
2485.34	2.269	0.320	2.304	359	3.14E-03	2.24E-05	6.88E-09
1243.10	2.276	0.324	2.272				
311.72	2.303	0.340	2.289				
79.23	2.338	0.361	2.320				
20.89	2.372	0.381	2.355				
6.28	2.404	0.399	2.388				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>Specimen taken 4-9cm from bottom of the tube</p> <p>k calculated using cv based on t<sub>90</sub> values.</p>							
<b>SAMPLE DIMENSIONS AND PROPERTIES - FINAL</b>							
Sample Height, cm	2.40			Unit Weight, kN/m <sup>3</sup>	22.52		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m <sup>3</sup>	19.28		
Area, cm <sup>2</sup>	31.54			Specific Gravity, measured	2.75		
Volume, cm <sup>3</sup>	75.81			Solids Height, cm	1.718		
Water Content, %	16.80			Volume of Solids, cm <sup>3</sup>	54.20		
Wet Mass, g	174.08			Volume of Voids, cm <sup>3</sup>	21.61		
Dry Mass, g	149.04						
<div style="display: flex; justify-content: space-between;"> <span>Prepared By: LG</span> <span><b>Golder Associates</b></span> <span>Checked By: </span> </div>							

# CONSOLIDATION TEST SUMMARY

FIGURE

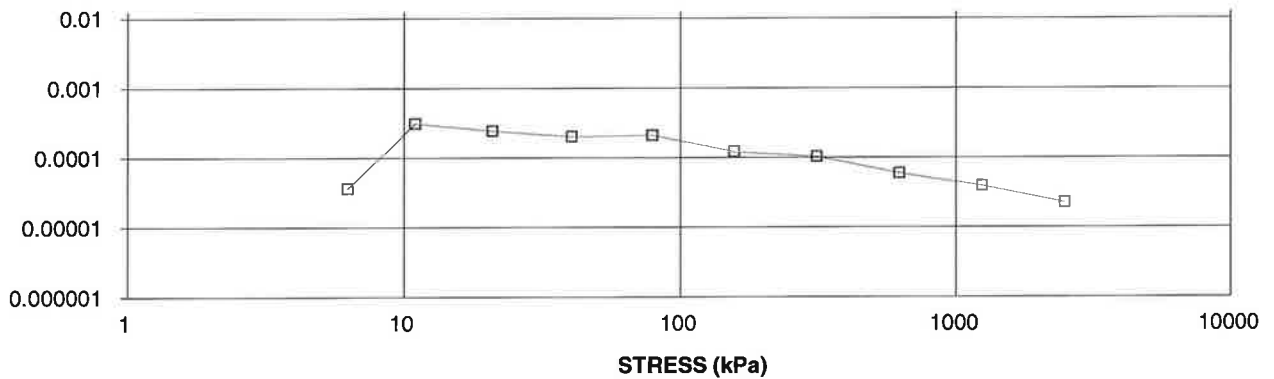
COEFFICIENT OF CONSOLIDATION,  
cm<sup>2</sup>/s

CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS STRESS (kPa)  
BH 13-3 SA ST-14



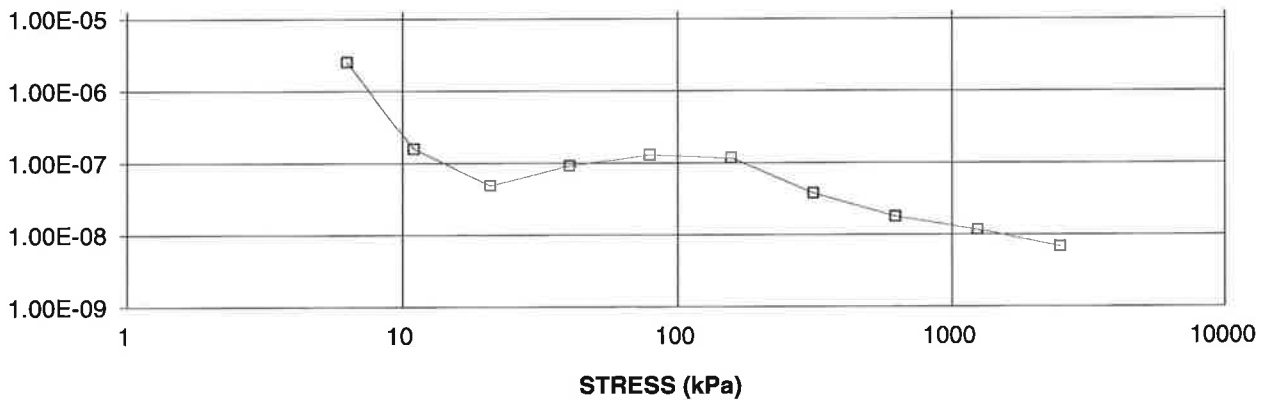
VOLUME COMPRESSIBILITY, m<sup>2</sup>/kN

CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs STRESS (kPa)  
BH 13-3 SA ST-14



HYDRAULIC CONDUCTIVITY,  
cm/s

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs STRESS  
BH 13-3 SA ST-14

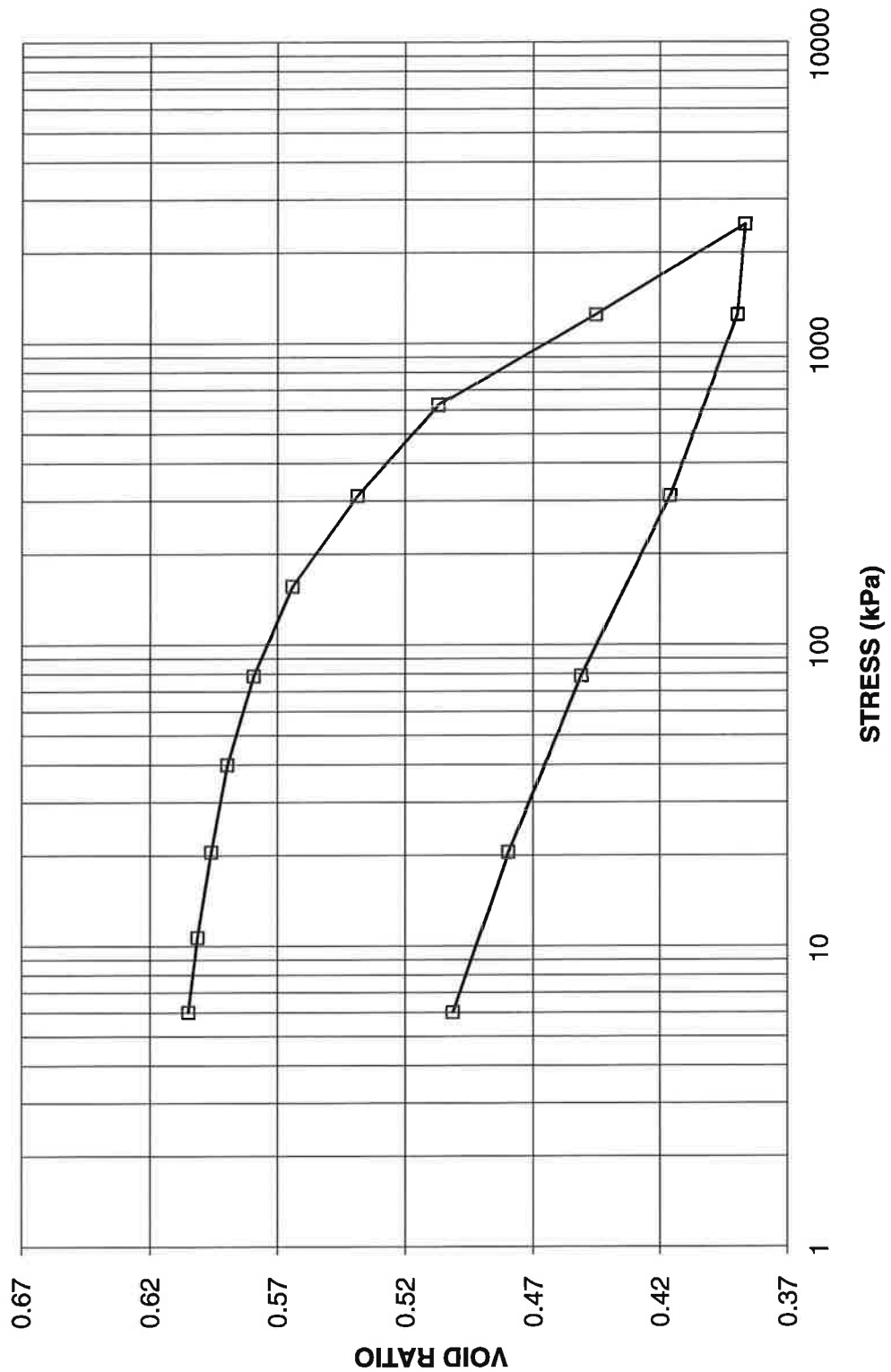




# CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST  
VOID RATIO vs STRESS  
BH 13-4 SA ST-17



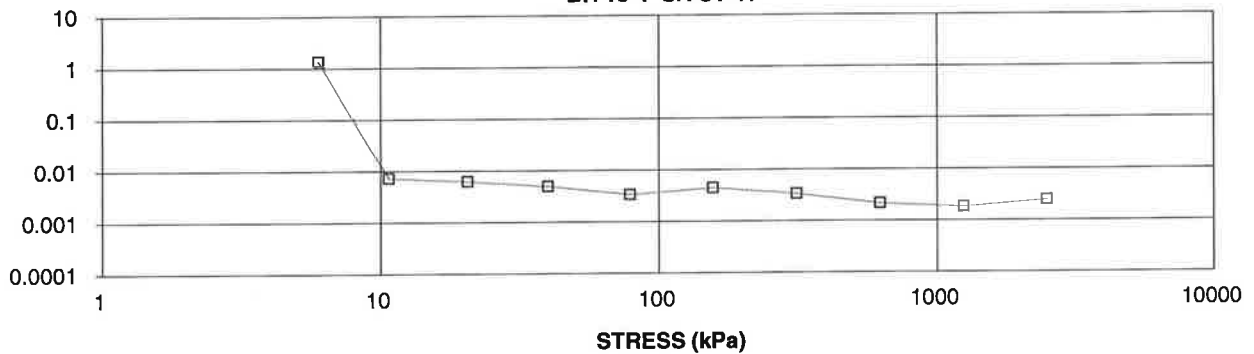
CONSOLIDATION TEST SUMMARY					FIGURE		
<b>SAMPLE IDENTIFICATION</b>							
Project Number	13-1183-0126			Sample Number	ST-17		
Borehole Number	13-4			Sample Depth, m	12.2-12.8		
<b>TEST CONDITIONS</b>							
Test Type	Standard			Load Duration, hr	24		
Oedometer Number	2						
Date Started	11/15/2013						
Date Completed	11/30/2013						
<b>SAMPLE DIMENSIONS AND PROPERTIES - INITIAL</b>							
Sample Height, cm	2.54			Unit Weight, kN/m <sup>3</sup>	20.43		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m <sup>3</sup>	16.67		
Area, cm <sup>2</sup>	31.60			Specific Gravity, measured	2.74		
Volume, cm <sup>3</sup>	80.17			Solids Height, cm	1.574		
Water Content, %	22.54			Volume of Solids, cm <sup>3</sup>	49.73		
Wet Mass, g	166.98			Volume of Voids, cm <sup>3</sup>	30.43		
Dry Mass, g	136.27			Degree of Saturation, %	100.9		
<b>TEST COMPUTATIONS</b>							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	2.537	0.612	2.537				
6.02	2.526	0.605	2.532	1	1.36E+00	7.14E-04	9.50E-05
10.67	2.520	0.601	2.523	185	7.30E-03	4.83E-04	3.45E-07
20.49	2.512	0.596	2.516	214	6.27E-03	3.37E-04	2.07E-07
39.96	2.502	0.590	2.507	267	4.99E-03	2.04E-04	1.00E-07
78.74	2.486	0.579	2.494	392	3.36E-03	1.66E-04	5.46E-08
156.11	2.462	0.564	2.474	290	4.47E-03	1.22E-04	5.34E-08
311.59	2.422	0.539	2.442	375	3.37E-03	1.01E-04	3.33E-08
622.75	2.372	0.507	2.397	560	2.18E-03	6.31E-05	1.34E-08
1243.00	2.275	0.445	2.323	628	1.82E-03	6.19E-05	1.11E-08
2481.31	2.183	0.387	2.229	427	2.47E-03	2.93E-05	7.08E-09
1243.00	2.187	0.390	2.185				
311.59	2.229	0.416	2.208				
78.74	2.284	0.451	2.256				
20.49	2.329	0.480	2.306				
6.02	2.363	0.502	2.346				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>Specimen taken 4 to 10cm from bottom of the tube</p> <p>k calculated using cv based on t<sub>90</sub> values.</p>							
<b>SAMPLE DIMENSIONS AND PROPERTIES - FINAL</b>							
Sample Height, cm	2.36			Unit Weight, kN/m <sup>3</sup>	21.85		
Sample Diameter, cm	6.34			Dry Unit Weight, kN/m <sup>3</sup>	17.90		
Area, cm <sup>2</sup>	31.60			Specific Gravity, measured	2.74		
Volume, cm <sup>3</sup>	74.68			Solids Height, cm	1.574		
Water Content, %	22.10			Volume of Solids, cm <sup>3</sup>	49.73		
Wet Mass, g	166.39			Volume of Voids, cm <sup>3</sup>	24.94		
Dry Mass, g	136.27						
<div style="display: flex; justify-content: space-between;"> <div>Prepared By: LG</div> <div style="text-align: center;"><b>Golder Associates</b></div> <div>Checked By: </div> </div>							

# CONSOLIDATION TEST SUMMARY

FIGURE

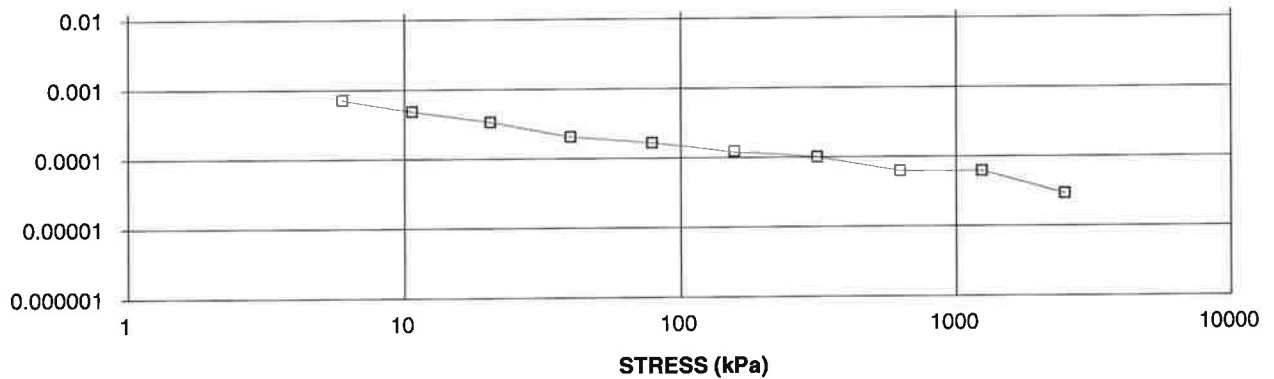
COEFFICIENT OF CONSOLIDATION,  
cm<sup>2</sup>/s

CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS STRESS (kPa)  
BH 13-4 SA ST-17



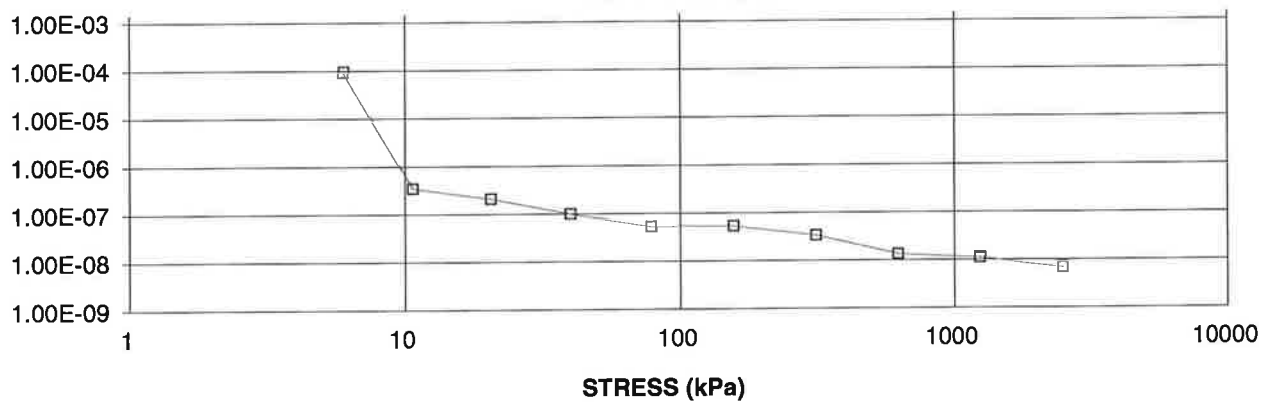
VOLUME COMPRESSIBILITY, m<sup>2</sup>/kN

CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs STRESS (kPa)  
BH 13-4 SA ST-17



HYDRAULIC CONDUCTIVITY,  
cm/s

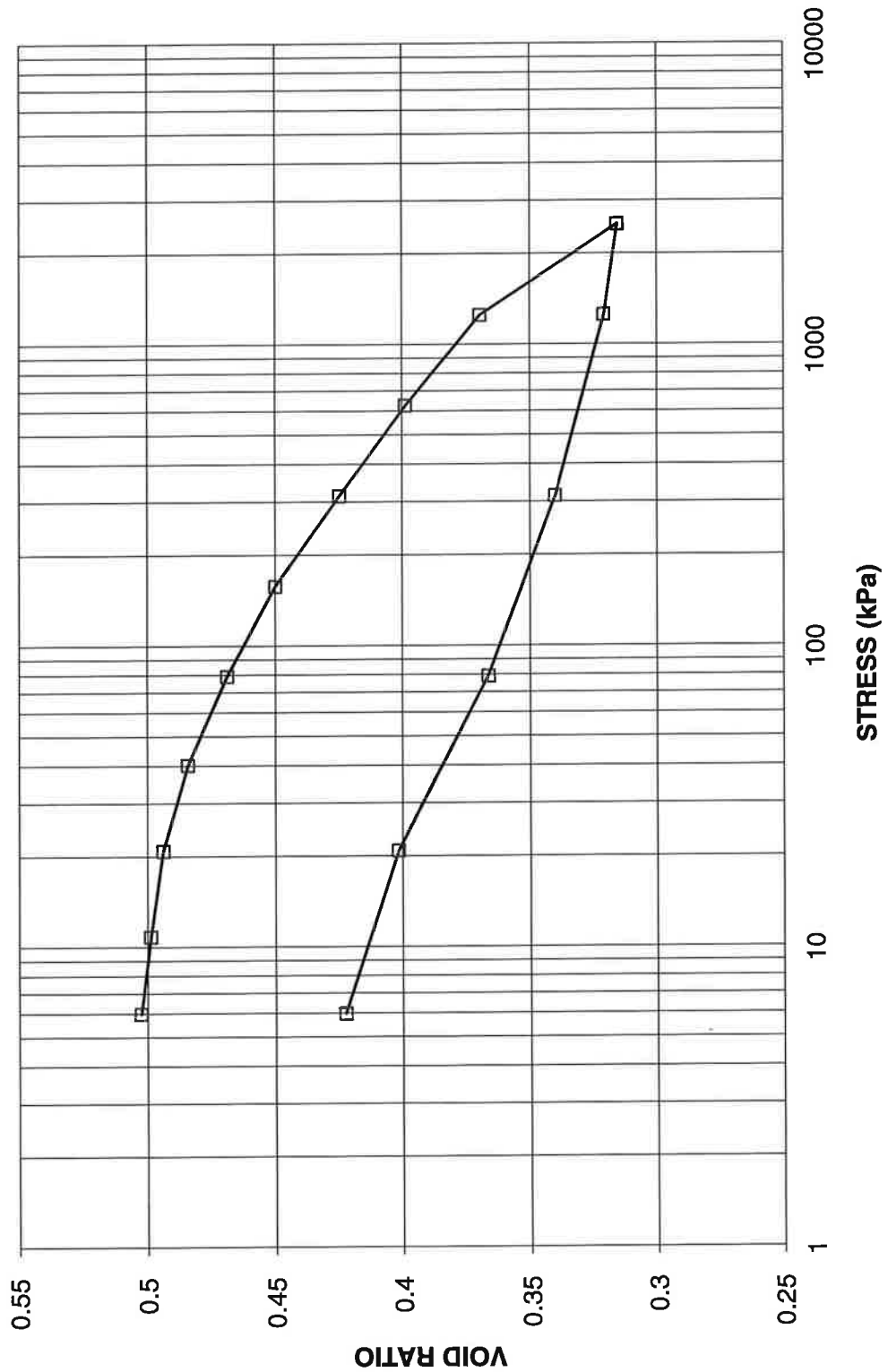
CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs STRESS  
BH 13-4 SA ST-17



**CONSOLIDATION TEST  
VOID RATIO VS LOG STRESS**

**FIGURE**

**CONSOLIDATION TEST  
VOID RATIO vs STRESS  
BH 13-7 SA ST-7**



Project No. 13-1183-0126

Prepared By: LG

**Golder Associates**

Checked By: *[Signature]*

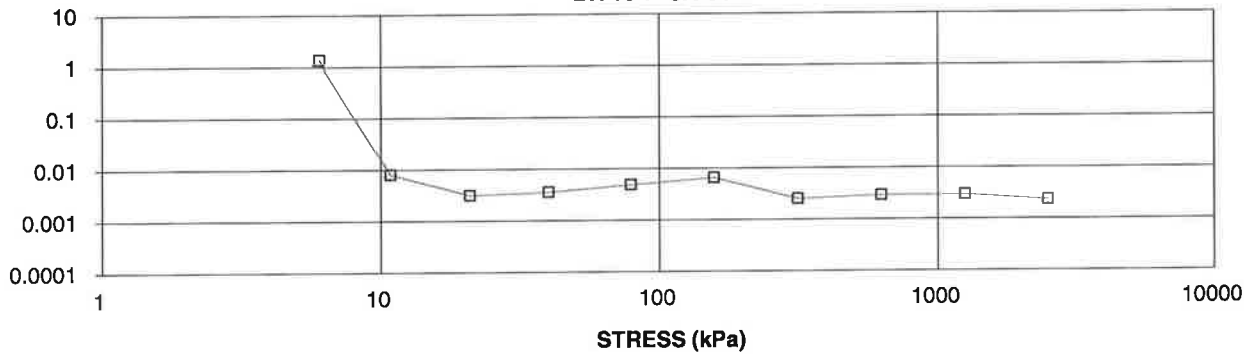
CONSOLIDATION TEST SUMMARY					FIGURE		
<b>SAMPLE IDENTIFICATION</b>							
Project Number	13-1183-0126			Sample Number	ST-7		
Borehole Number	13-7			Sample Depth, m	4.6-5.2		
<b>TEST CONDITIONS</b>							
Test Type	Standard			Load Duration, hr	24		
Oedometer Number	3						
Date Started	11/15/2013						
Date Completed	11/30/2013						
<b>SAMPLE DIMENSIONS AND PROPERTIES - INITIAL</b>							
Sample Height, cm	2.54			Unit Weight, kN/m <sup>3</sup>	21.29		
Sample Diameter, cm	6.33			Dry Unit Weight, kN/m <sup>3</sup>	17.99		
Area, cm <sup>2</sup>	31.43			Specific Gravity, measured	2.76		
Volume, cm <sup>3</sup>	79.77			Solids Height, cm	1.687		
Water Content, %	18.34			Volume of Solids, cm <sup>3</sup>	53.01		
Wet Mass, g	173.15			Volume of Voids, cm <sup>3</sup>	26.76		
Dry Mass, g	146.31			Degree of Saturation, %	100.3		
<b>TEST COMPUTATIONS</b>							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	2.538	0.505	2.538				
5.98	2.534	0.502	2.536	1	1.36E+00	2.57E-04	3.43E-05
10.81	2.528	0.499	2.531	167	8.13E-03	5.14E-04	4.10E-07
20.82	2.520	0.494	2.524	427	3.16E-03	3.19E-04	9.88E-08
40.16	2.503	0.484	2.512	375	3.57E-03	3.32E-04	1.16E-07
79.17	2.478	0.469	2.490	267	4.92E-03	2.62E-04	1.26E-07
157.05	2.446	0.450	2.462	194	6.62E-03	1.62E-04	1.05E-07
313.08	2.403	0.425	2.424	487	2.56E-03	1.08E-04	2.70E-08
625.29	2.359	0.399	2.381	409	2.94E-03	5.53E-05	1.59E-08
1247.09	2.310	0.370	2.335	386	2.99E-03	3.12E-05	9.15E-09
2493.87	2.219	0.316	2.264	463	2.35E-03	2.87E-05	6.61E-09
1247.09	2.228	0.321	2.223				
313.08	2.260	0.340	2.244				
79.17	2.305	0.366	2.283				
20.82	2.364	0.402	2.334				
5.98	2.399	0.423	2.382				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>Specimen taken 7 to 13cm from bottom of the tube</p> <p>k calculated using cv based on t<sub>90</sub> values.</p>							
<b>SAMPLE DIMENSIONS AND PROPERTIES - FINAL</b>							
Sample Height, cm	2.40			Unit Weight, kN/m <sup>3</sup>	23.02		
Sample Diameter, cm	6.33			Dry Unit Weight, kN/m <sup>3</sup>	19.03		
Area, cm <sup>2</sup>	31.43			Specific Gravity, measured	2.76		
Volume, cm <sup>3</sup>	75.41			Solids Height, cm	1.687		
Water Content, %	20.97			Volume of Solids, cm <sup>3</sup>	53.01		
Wet Mass, g	176.99			Volume of Voids, cm <sup>3</sup>	22.40		
Dry Mass, g	146.31						
<div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div>Prepared By: LG</div> <div style="text-align: center;"><b>Golder Associates</b></div> <div>Checked By: </div> </div>							

# CONSOLIDATION TEST SUMMARY

FIGURE

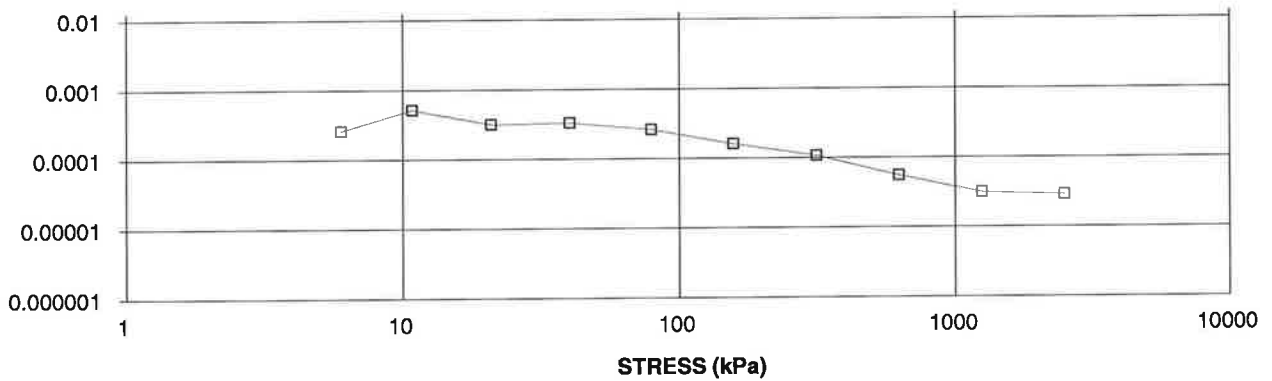
COEFFICIENT OF CONSOLIDATION,  
cm<sup>2</sup>/s

CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS STRESS (kPa)  
BH 13-7 SA ST-7



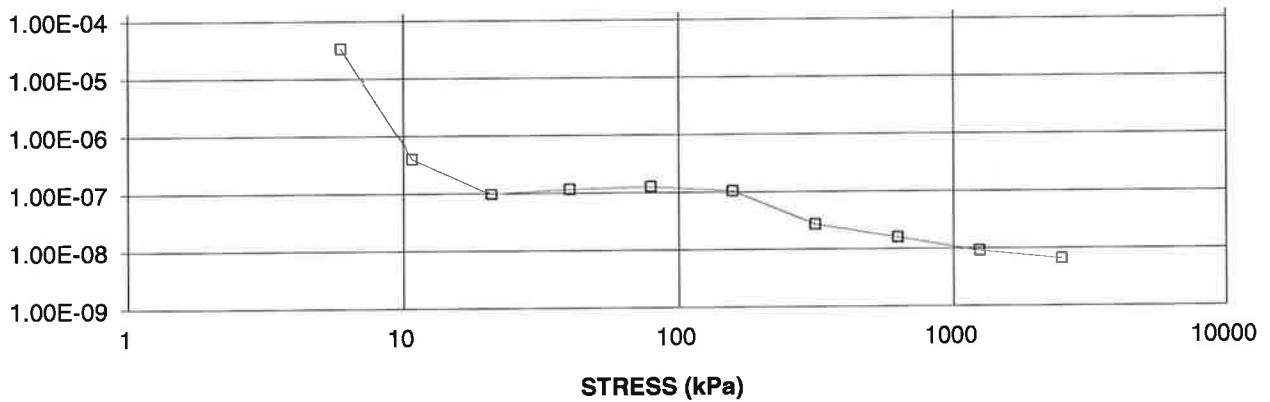
VOLUME COMPRESSIBILITY, m<sup>2</sup>/kN

CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs STRESS (kPa)  
BH 13-7 SA ST-7



HYDRAULIC CONDUCTIVITY,  
cm/s

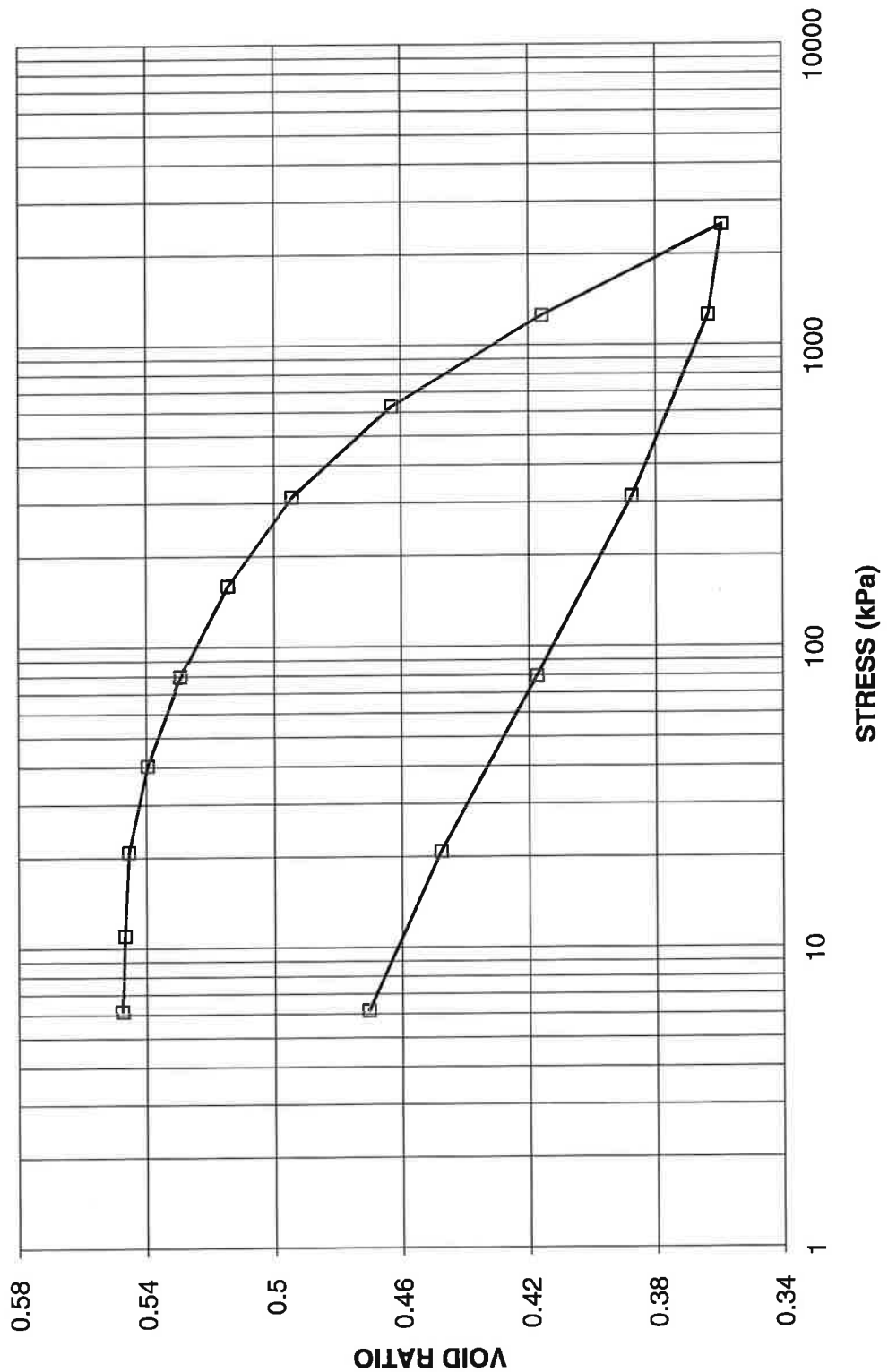
CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs STRESS  
BH 13-7 SA ST-7



**CONSOLIDATION TEST  
VOID RATIO VS LOG STRESS**

**FIGURE**

**CONSOLIDATION TEST  
VOID RATIO vs STRESS  
BH 13-9 SA ST-13**



Project No. 13-1183-0126

Prepared By: LG

**Golder Associates**

Checked By: *hhl*

CONSOLIDATION TEST SUMMARY					FIGURE		
<b>SAMPLE IDENTIFICATION</b>							
Project Number	13-1183-0126			Sample Number	ST-13		
Borehole Number	13-9			Sample Depth, m	9.1-9.8		
<b>TEST CONDITIONS</b>							
Test Type	Standard			Load Duration, hr	24		
Oedometer Number	4						
Date Started	11/15/2013						
Date Completed	11/28/2013						
<b>SAMPLE DIMENSIONS AND PROPERTIES - INITIAL</b>							
Sample Height, cm	2.54			Unit Weight, kN/m <sup>3</sup>	20.92		
Sample Diameter, cm	6.32			Dry Unit Weight, kN/m <sup>3</sup>	17.42		
Area, cm <sup>2</sup>	31.37			Specific Gravity, measured	2.75		
Volume, cm <sup>3</sup>	79.81			Solids Height, cm	1.643		
Water Content, %	20.11			Volume of Solids, cm <sup>3</sup>	51.55		
Wet Mass, g	170.28			Volume of Voids, cm <sup>3</sup>	28.25		
Dry Mass, g	141.77			Degree of Saturation, %	100.9		
<b>TEST COMPUTATIONS</b>							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	2.544	0.548	2.544				
6.16	2.543	0.547	2.544	1	1.37E+00	6.38E-05	8.58E-06
11.02	2.542	0.547	2.543	3	4.57E-01	8.09E-05	3.62E-06
20.89	2.540	0.546	2.541	150	9.12E-03	8.76E-05	7.83E-08
40.42	2.530	0.540	2.535	240	5.68E-03	1.97E-04	1.10E-07
79.58	2.513	0.529	2.522	581	2.32E-03	1.70E-04	3.86E-08
159.24	2.489	0.514	2.501	501	2.65E-03	1.20E-04	3.12E-08
313.66	2.456	0.494	2.472	437	2.96E-03	8.43E-05	2.45E-08
626.01	2.404	0.463	2.430	421	2.97E-03	6.49E-05	1.89E-08
1254.63	2.327	0.416	2.365	427	2.78E-03	4.85E-05	1.32E-08
2502.73	2.233	0.359	2.280	483	2.28E-03	2.93E-05	6.56E-09
1254.63	2.240	0.363	2.237				
313.66	2.280	0.388	2.260				
79.58	2.330	0.418	2.305				
20.89	2.379	0.448	2.354				
6.16	2.416	0.470	2.398				
<p>Note:</p> <p>Consolidation loading and unloading schedule assigned by the client.</p> <p>Specimen taken 5 to 10cm from bottom of the tube</p> <p>k calculated using cv based on t<sub>90</sub> values.</p>							
<b>SAMPLE DIMENSIONS AND PROPERTIES - FINAL</b>							
Sample Height, cm	2.42			Unit Weight, kN/m <sup>3</sup>	22.02		
Sample Diameter, cm	6.32			Dry Unit Weight, kN/m <sup>3</sup>	18.34		
Area, cm <sup>2</sup>	31.37			Specific Gravity, measured	2.75		
Volume, cm <sup>3</sup>	75.80			Solids Height, cm	1.643		
Water Content, %	20.07			Volume of Solids, cm <sup>3</sup>	51.55		
Wet Mass, g	170.22			Volume of Voids, cm <sup>3</sup>	24.25		
Dry Mass, g	141.77						
<div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div>Prepared By: LG</div> <div style="text-align: center;"><b>Golder Associates</b></div> <div>Checked By: </div> </div>							

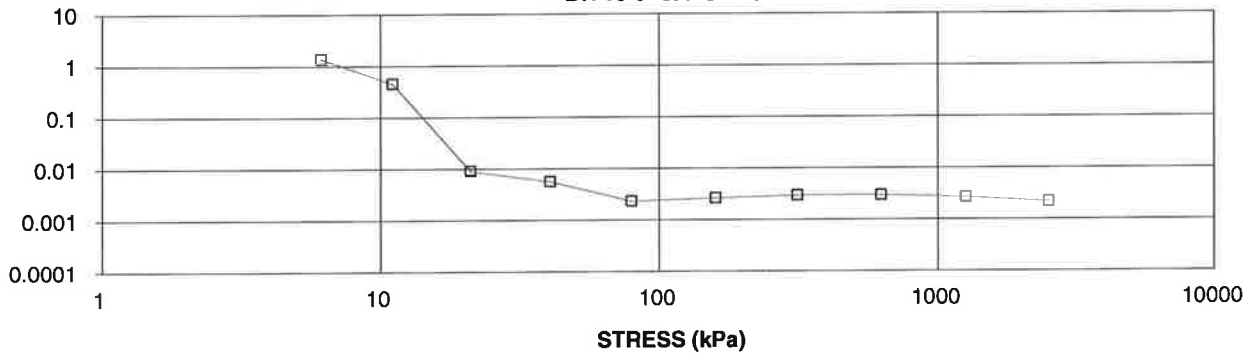


# CONSOLIDATION TEST SUMMARY

FIGURE

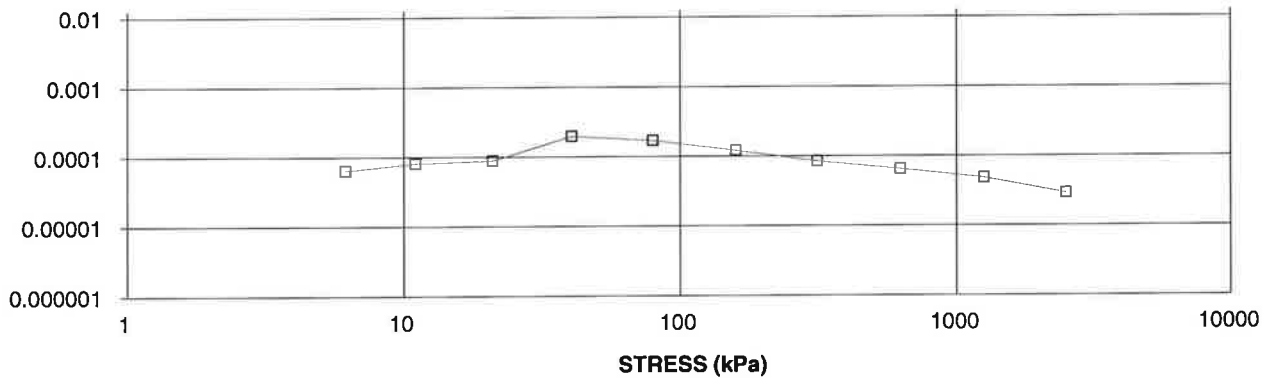
COEFFICIENT OF CONSOLIDATION,  
cm<sup>2</sup>/s

CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS STRESS (kPa)  
BH 13-9 SA ST-13



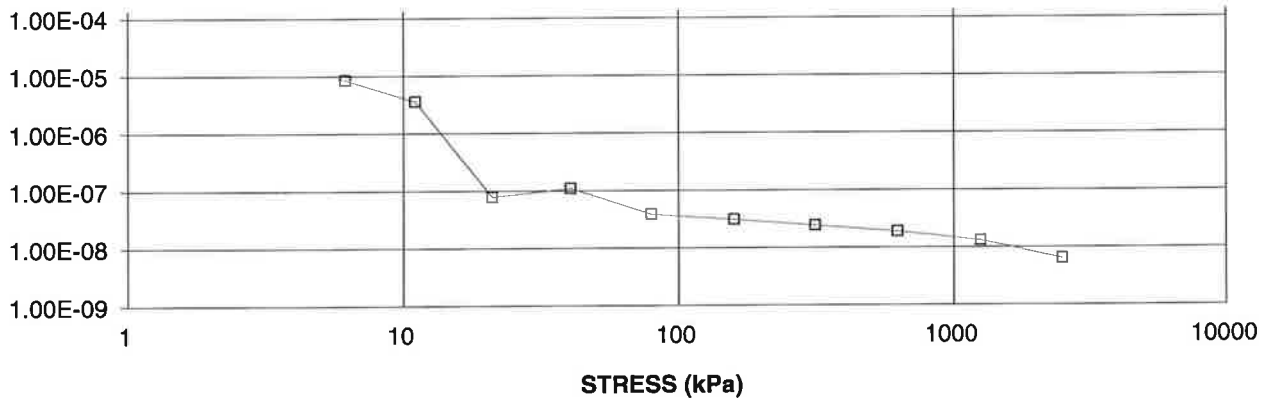
VOLUME COMPRESSIBILITY, m<sup>2</sup>/kN

CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs STRESS (kPa)  
BH 13-9 SA ST-13



HYDRAULIC CONDUCTIVITY,  
cm/s

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs STRESS  
BH 13-9 SA ST-13



Project No. 13-1183-0126

Prepared By: LG

**Golder Associates**

Checked By: *[Signature]*

## APPENDIX D

Figure 8 and 9: Design Parameters

Plots from LPILE Analysis Results:

Figure 8: Lateral Deflection for HP310x110

Figure 10: Factored Axial Capacity of HP310x110

Figure 11: Lateral Deflection of H-Pile 310x110

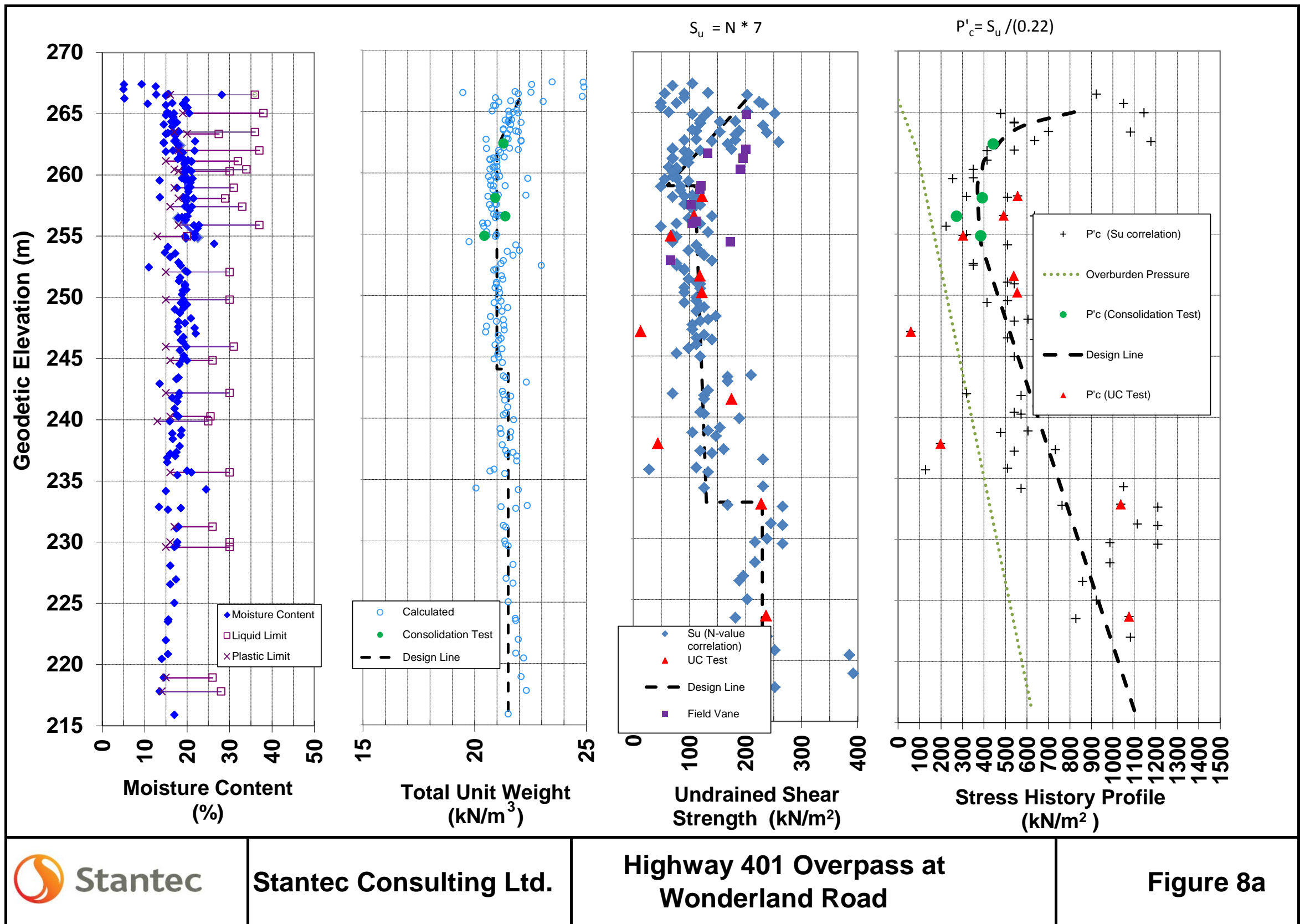
Figure 12: P-y Curves for Proposed HP310x110 Piles

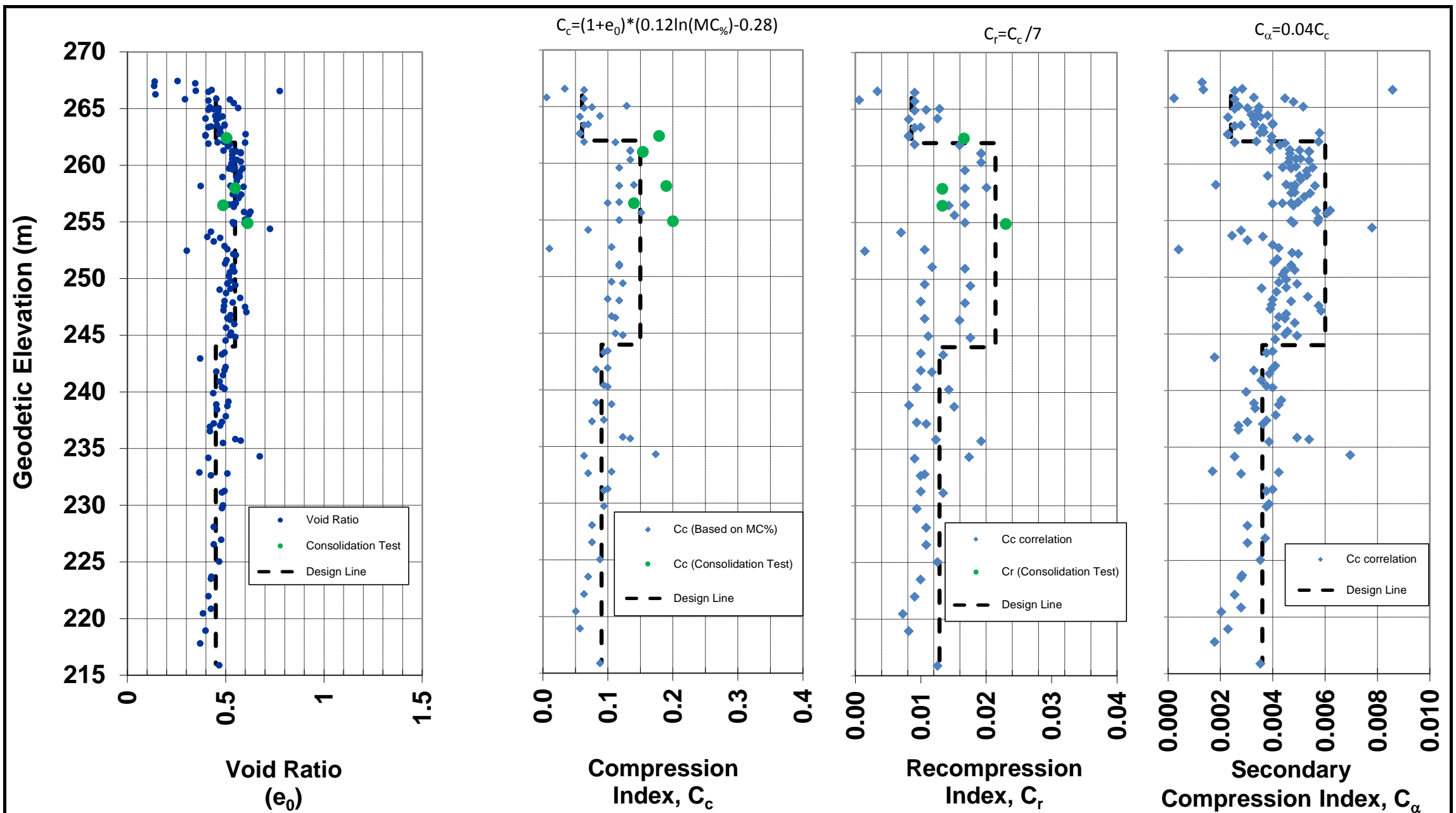
Slope Stability Evaluation:

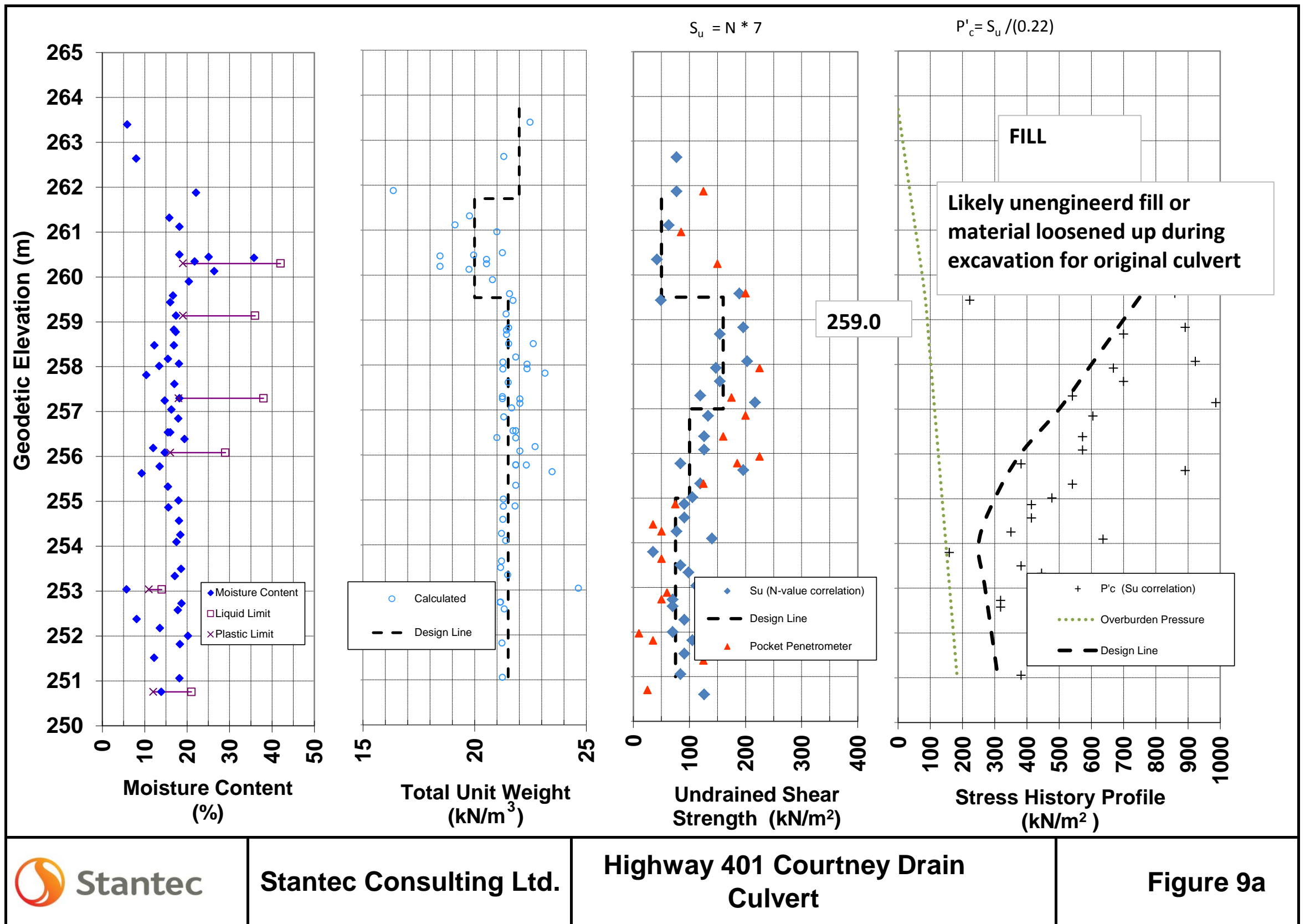
Figure 13a-c: RSS Wall

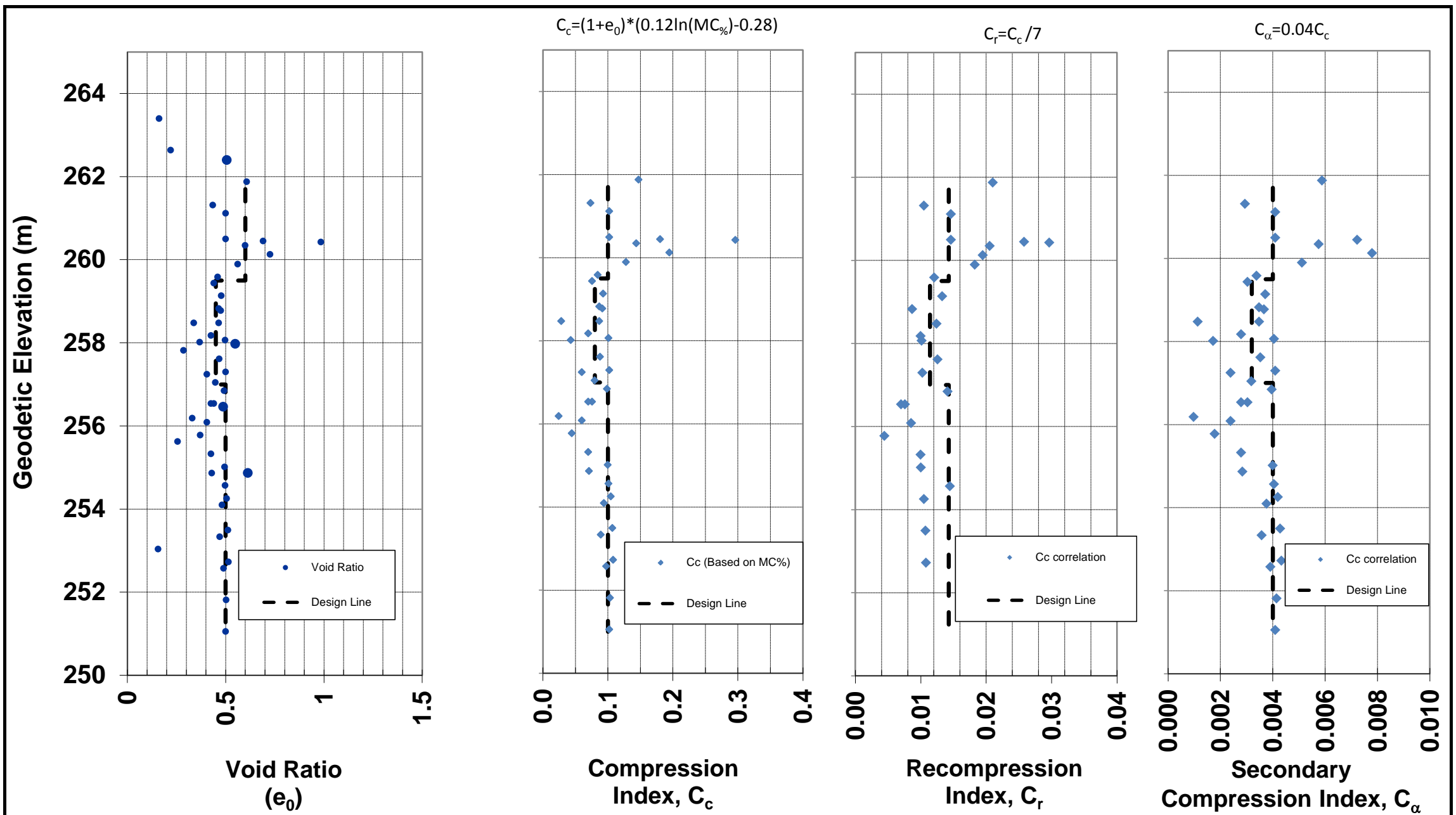
Figure 14a-c: Cut Slope

Figure 15a and 15b: Cut Slope Stabilization

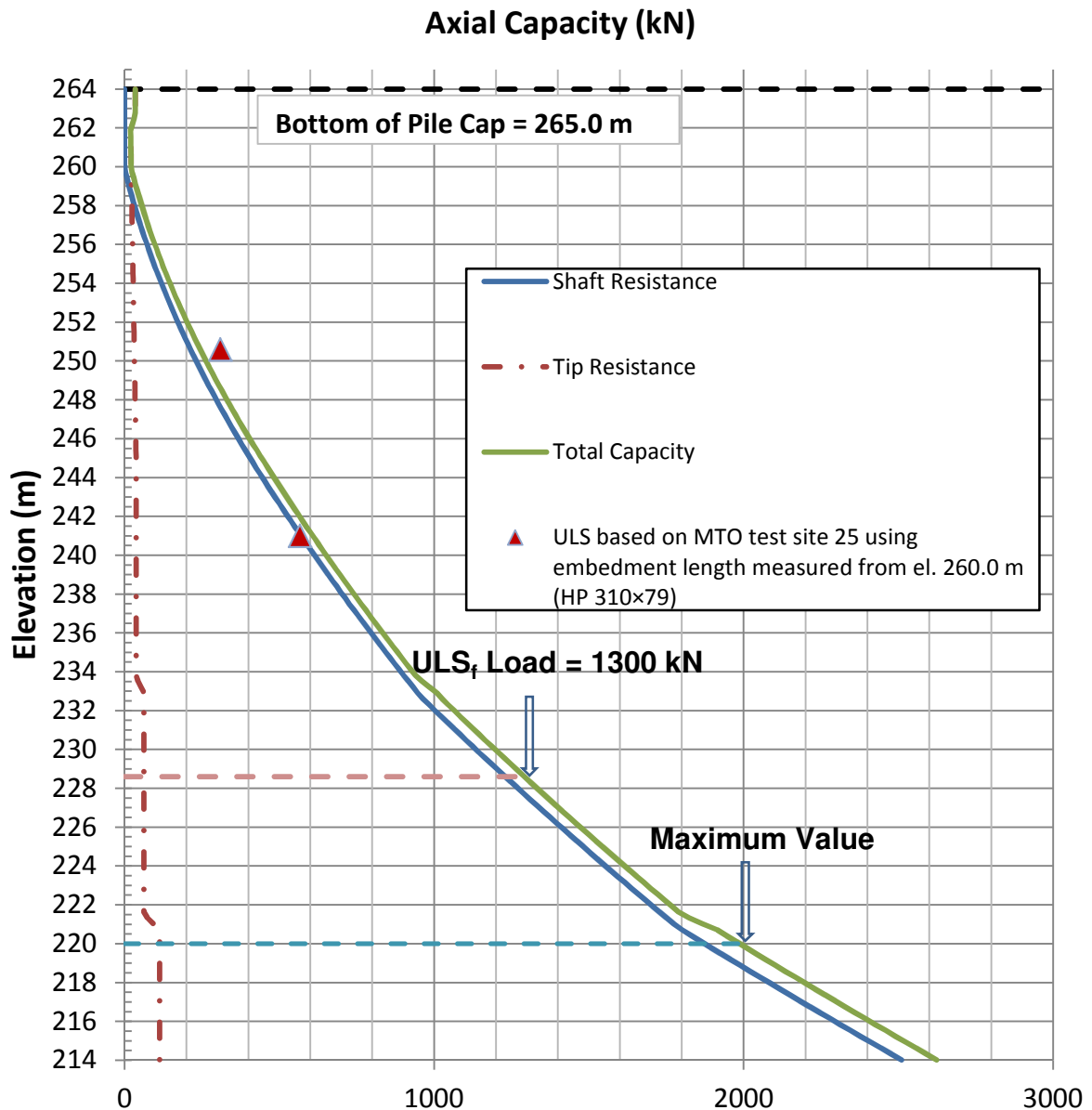






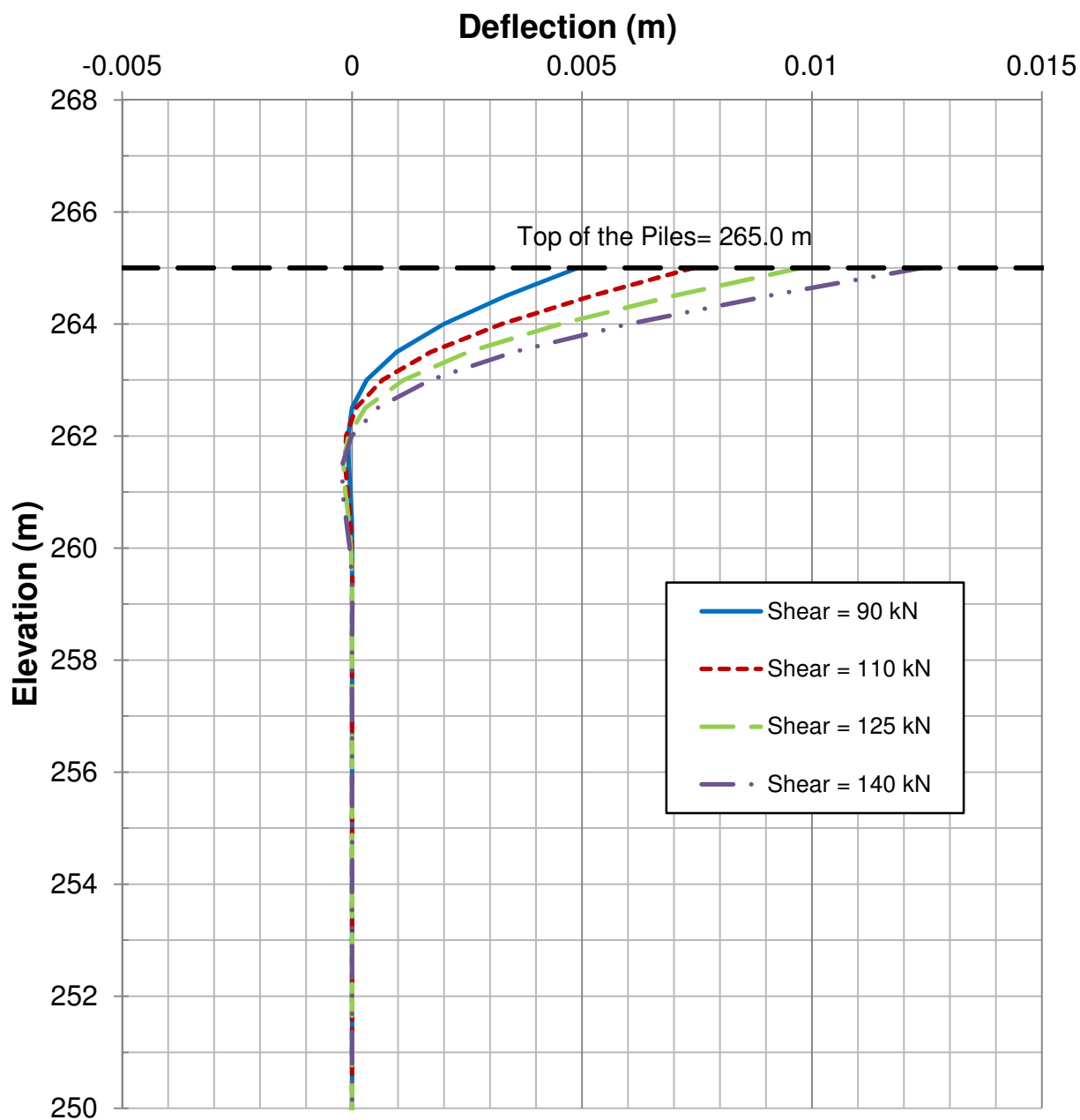


## Factored Axial Capacity of HP310x110 ( $\Phi = 0.4$ )



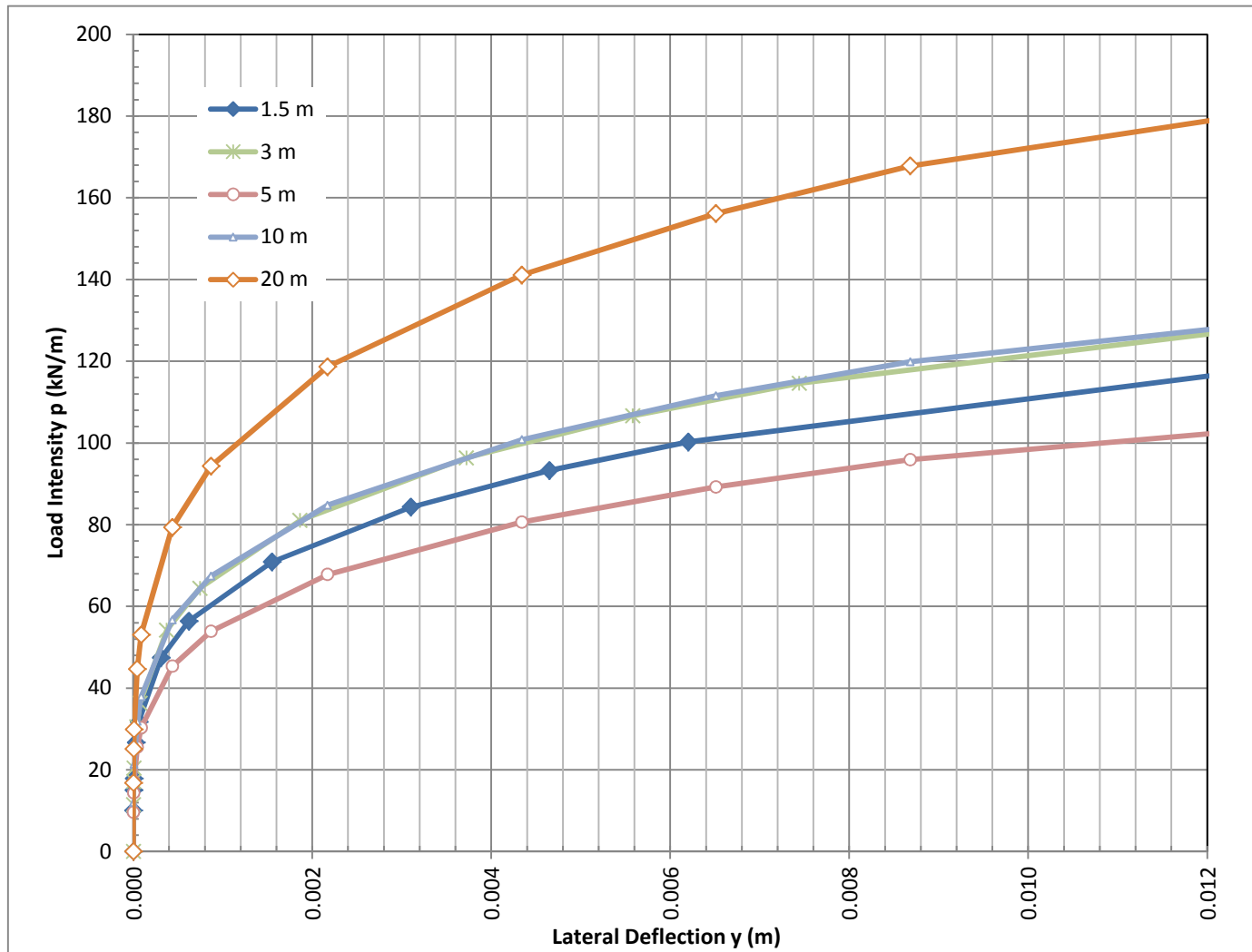
**Figure 10**  
 Factored Axial Capacity of HP310x110

## L-Pile Results - Lateral Deflection

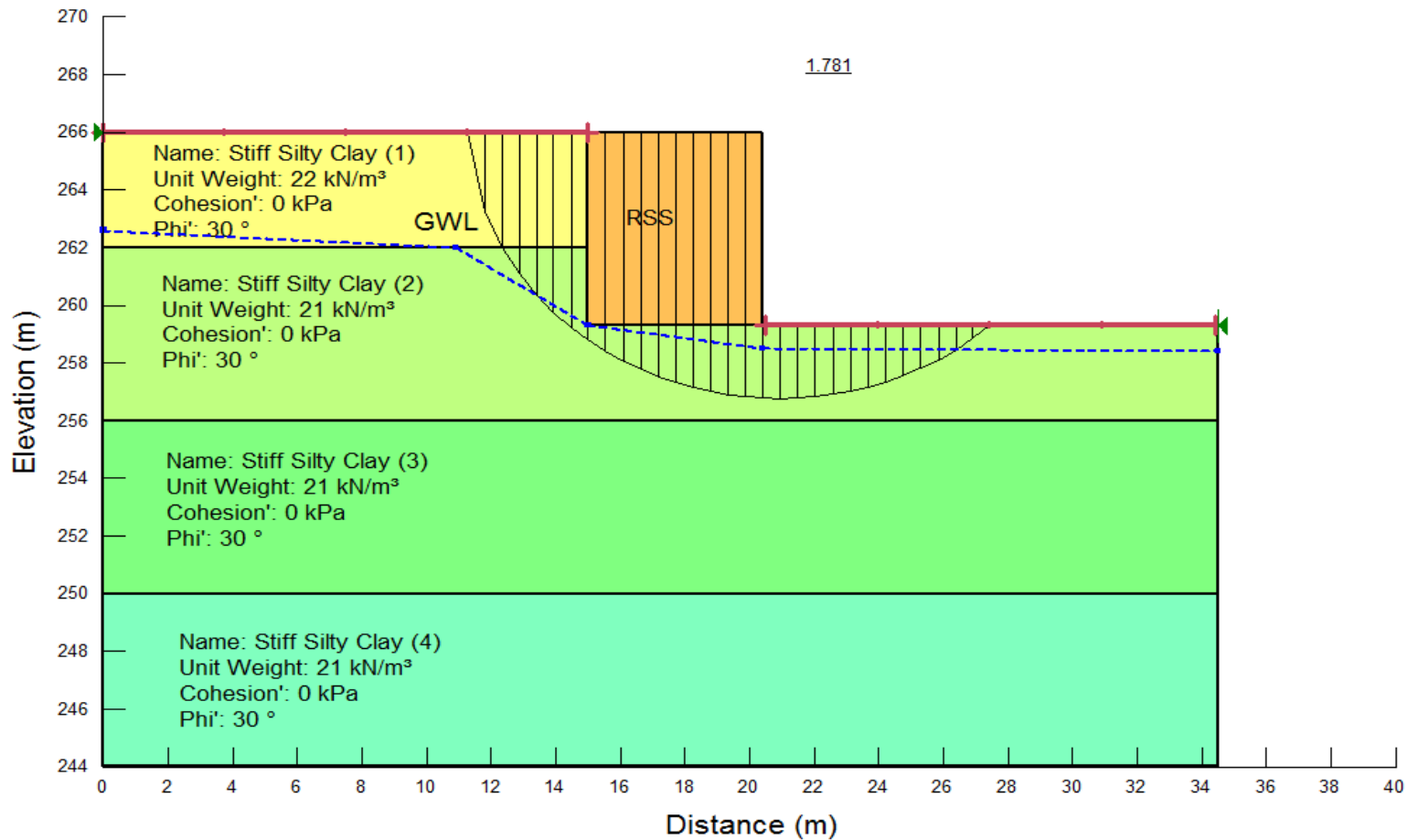


**Figure 11**  
**Lateral Deflection of H-Pile 310x110**





**Figure 12**  
**p-y Curves for Proposed HP 310x110 Piles**

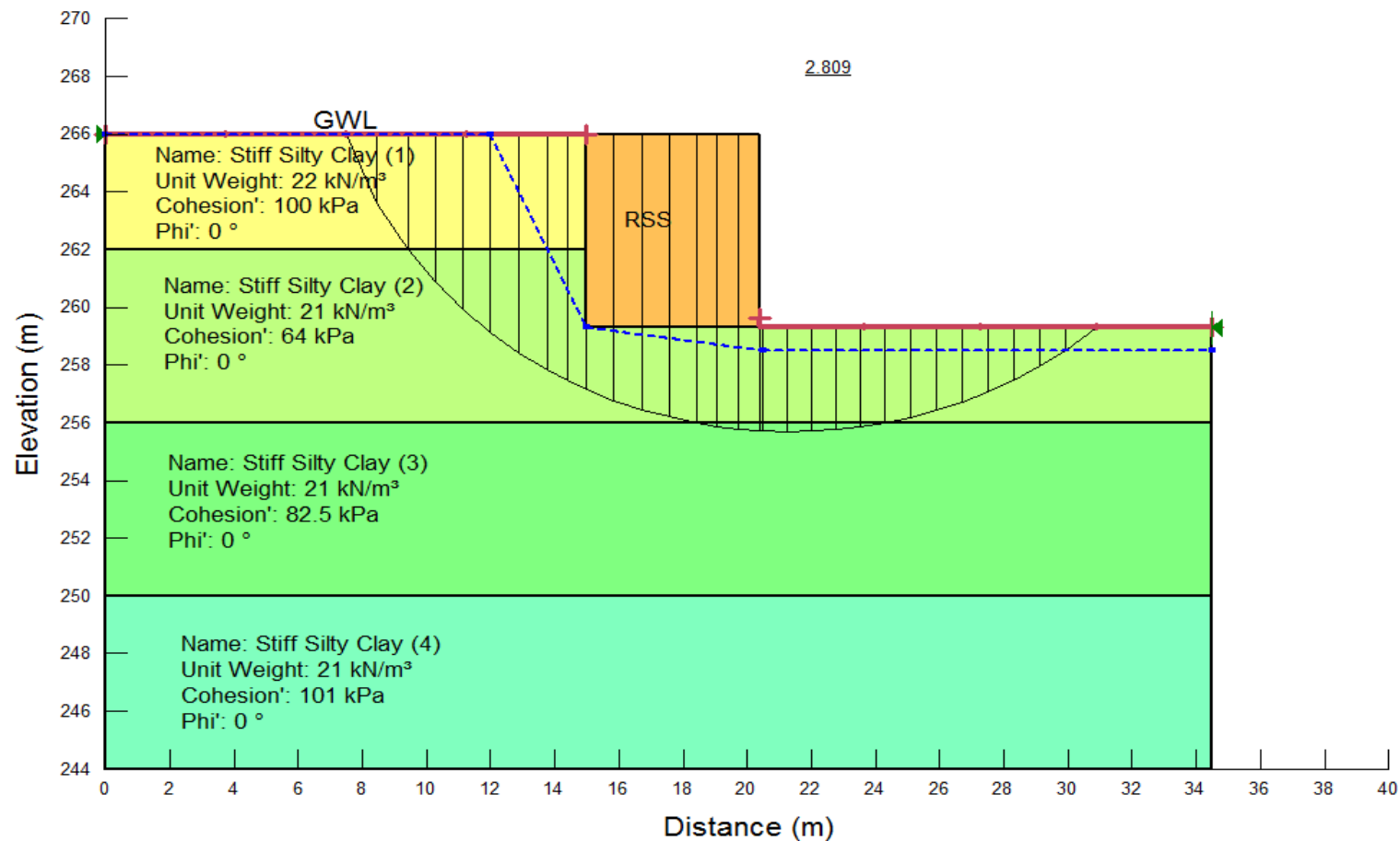


# Static Slope Stability Analysis (Drained) Highway 401 at Wonderland Road Interchange RSS Wall Global Stability

Figure 13a

Project No. 165000876

GWP 3031-11-00

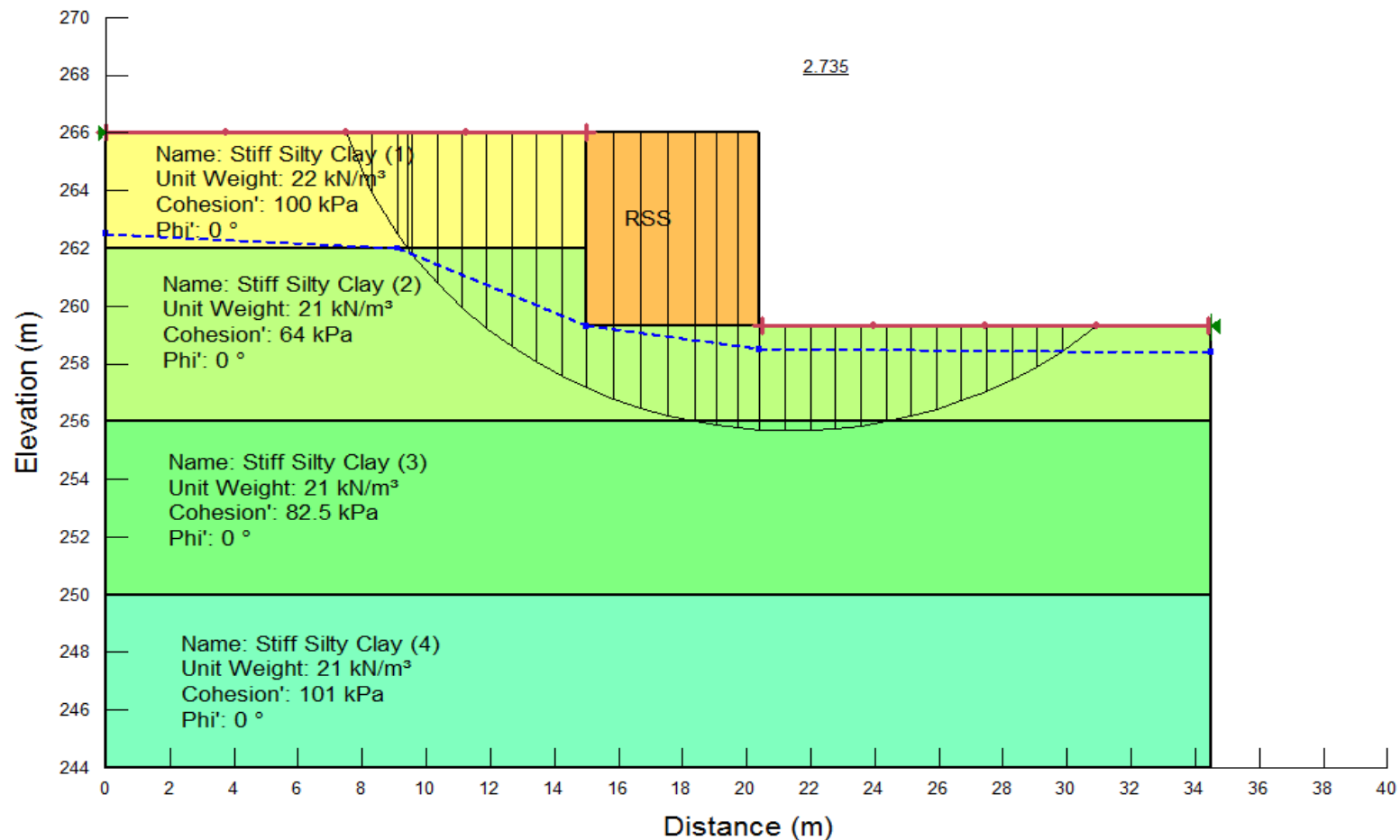


# Static Slope Stability Analysis (Undrained) Highway 401 at Wonderland Road Interchange RSS Wall Global Stability

Figure 13b

Project No. 165000876

GWP 3031-11-00



# Seismic Slope Stability Analysis

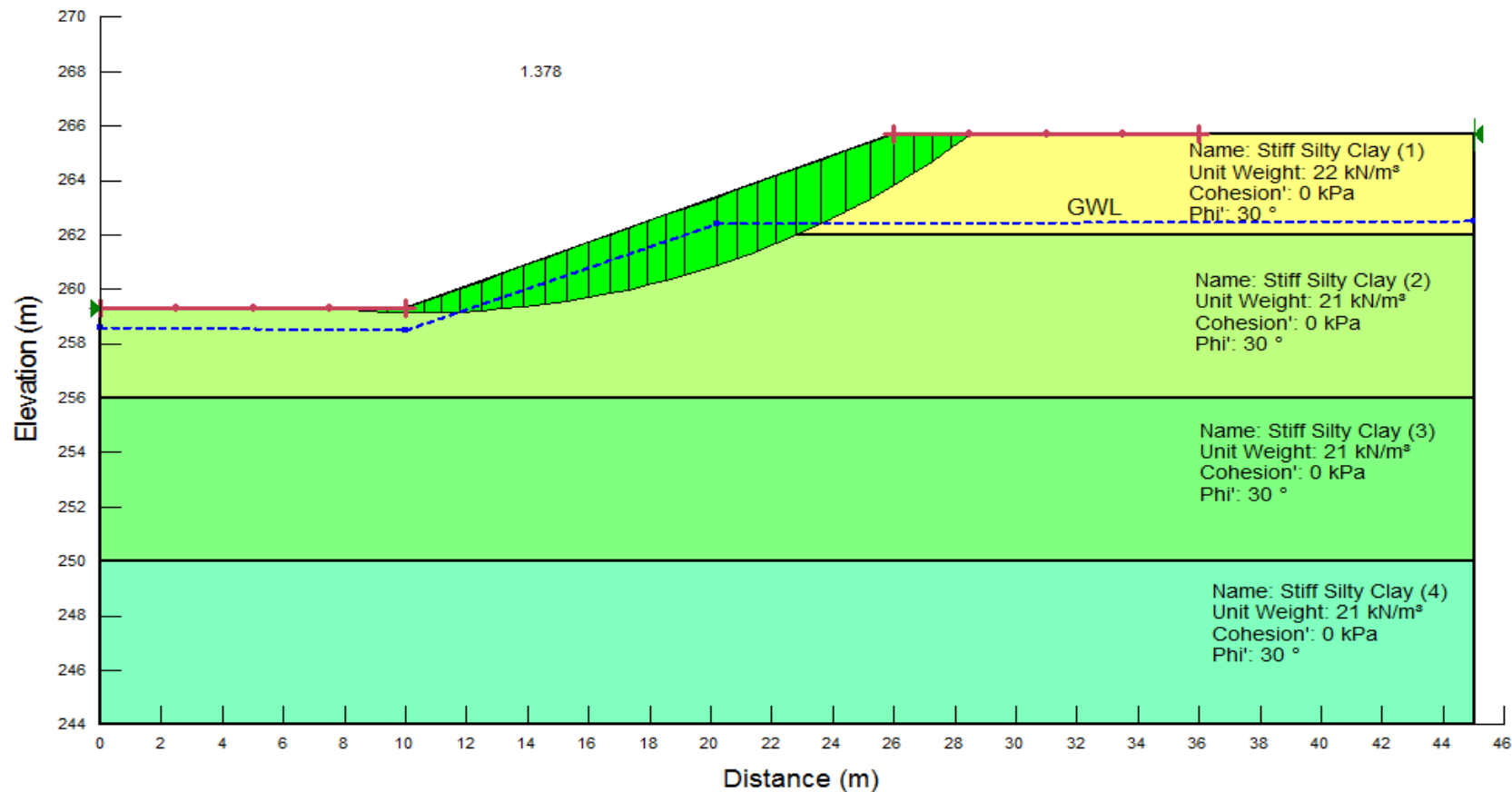
## Highway 401 at Wonderland Road Interchange

### RSS Wall Global Stability

Figure 13c

Project No. 16500876

GWP 3031-11-00

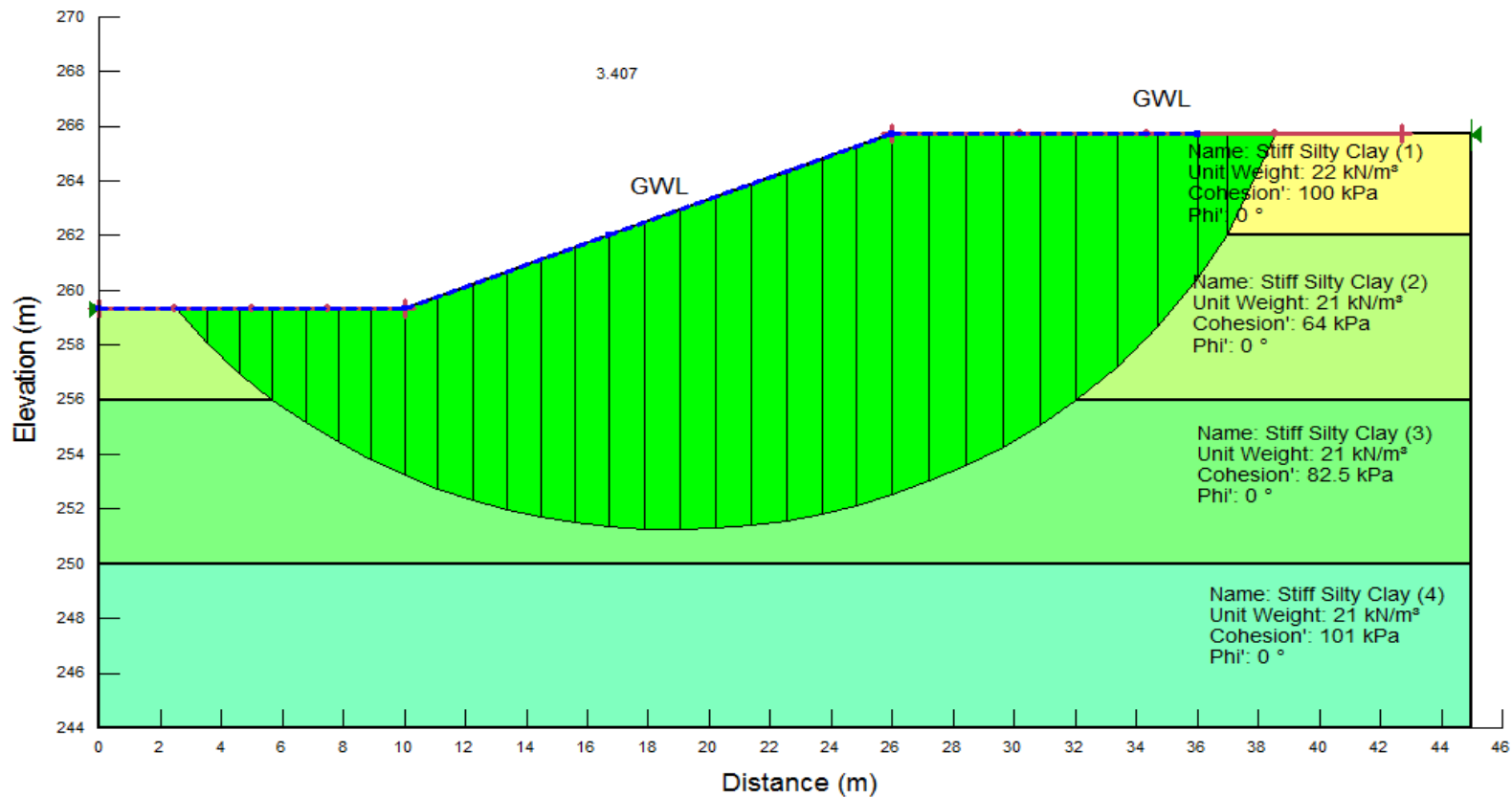


# Static Slope Stability Analysis (Drained) Highway 401 at Wonderland Road Interchange Wonderland Rd Cut Slope (2.5H:1V)

Figure 14a

Project No. 165000876

GWP 3031-11-00

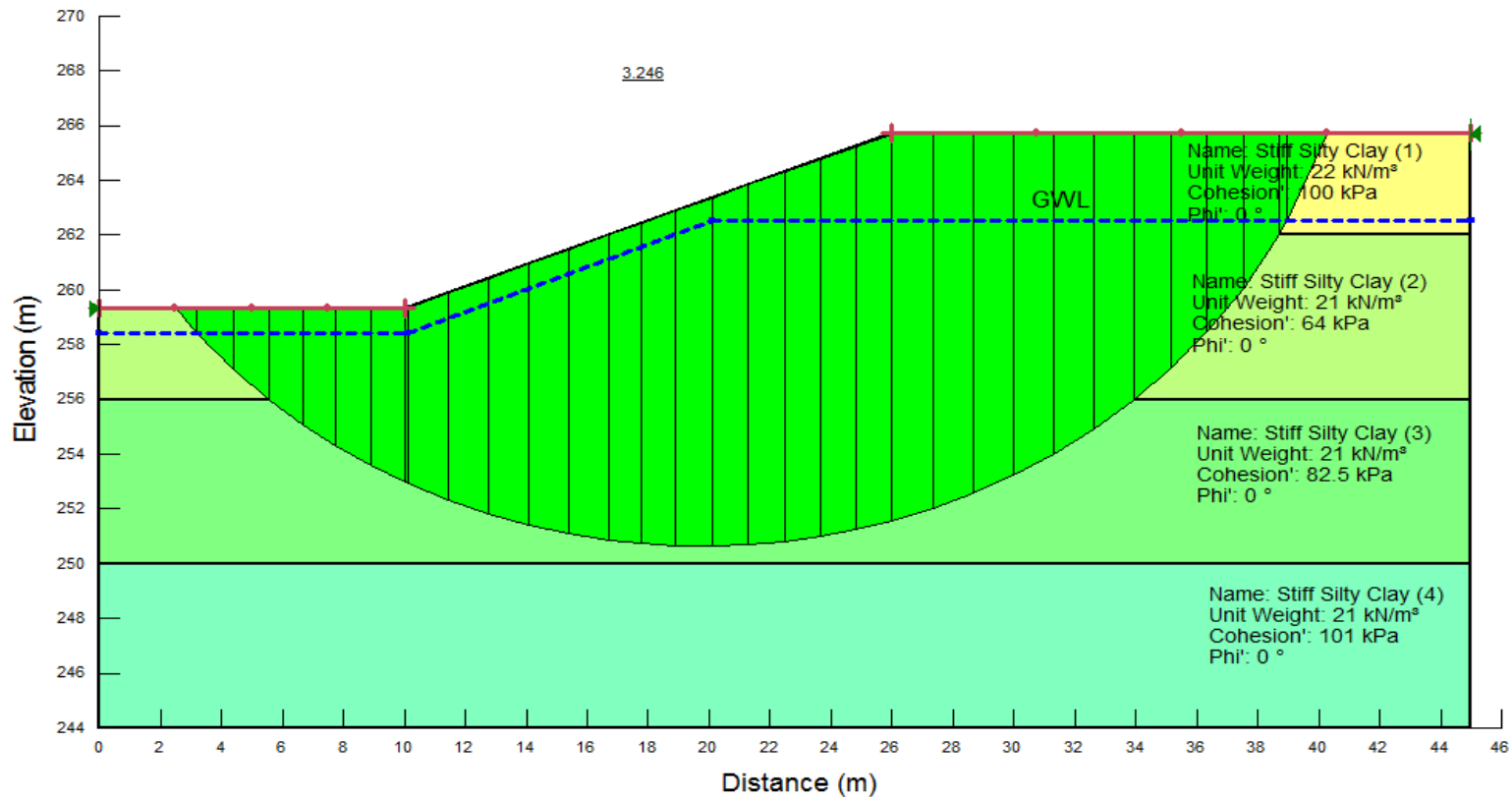


# Static Slope Stability Analysis (Undrained) Highway 401 at Wonderland Road Interchange Wonderland Rd Cut Slope (2.5H:1V)

Figure 14b

Project No. 165000734

GWP 3031-11-00



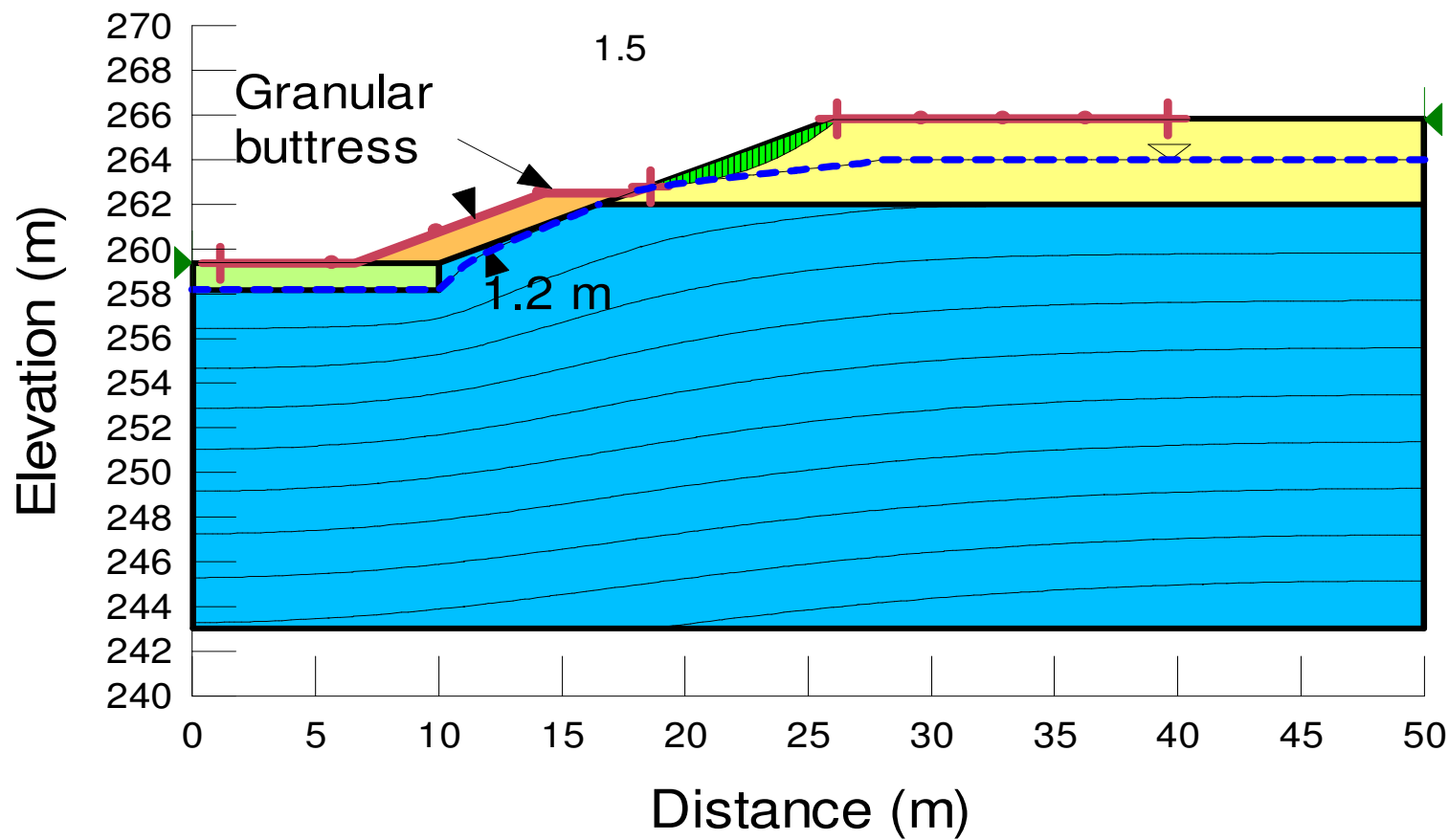
## Seismic Slope Stability Analysis

Highway 401 at Wonderland Road Interchange  
Wonderland Rd Cut Slope (2.5H:1V)

Figure 14c

Project No. 16500876

GWP 3031-11-00



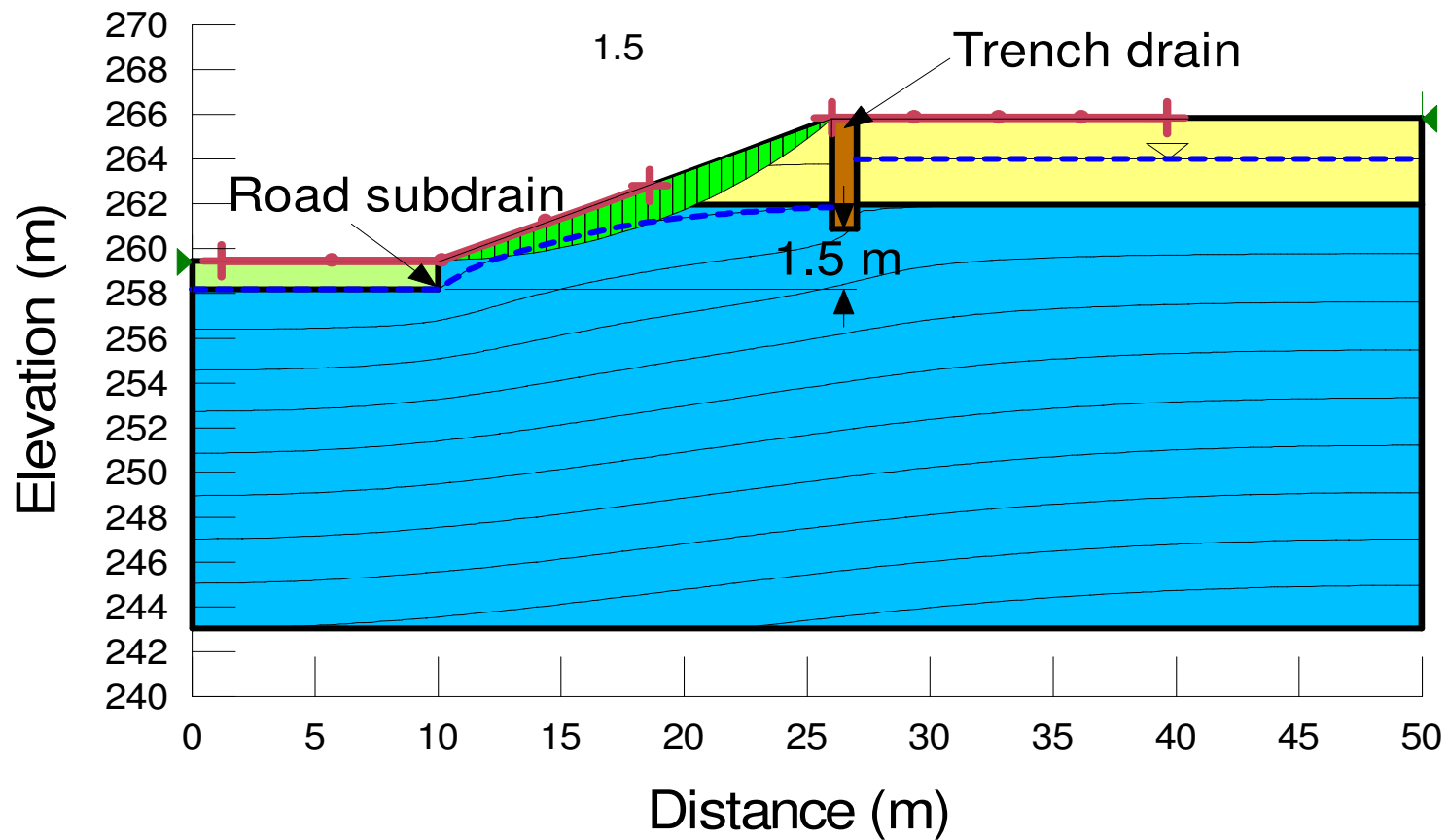
# **Slope Stability Analysis (Drained)** Highway 401 at Wonderland Road Interchange Cut Slope - With Buttress

Figure 15a

Project No. 165000876

GWP 3031-11-00





# **Slope Stability Analysis (Drained)** Highway 401 at Wonderland Road Interchange Cut Slope - with trench drain (1 m x 4.9 m)

Figure 15b

Project No. 16500876

GWP 3031-11-00

**FOUNDATION INVESTIGATION AND DESIGN REPORT – NEW HIGHWAY 401 INTERCHANGE  
AT WONDERLAND ROAD**


April 2014

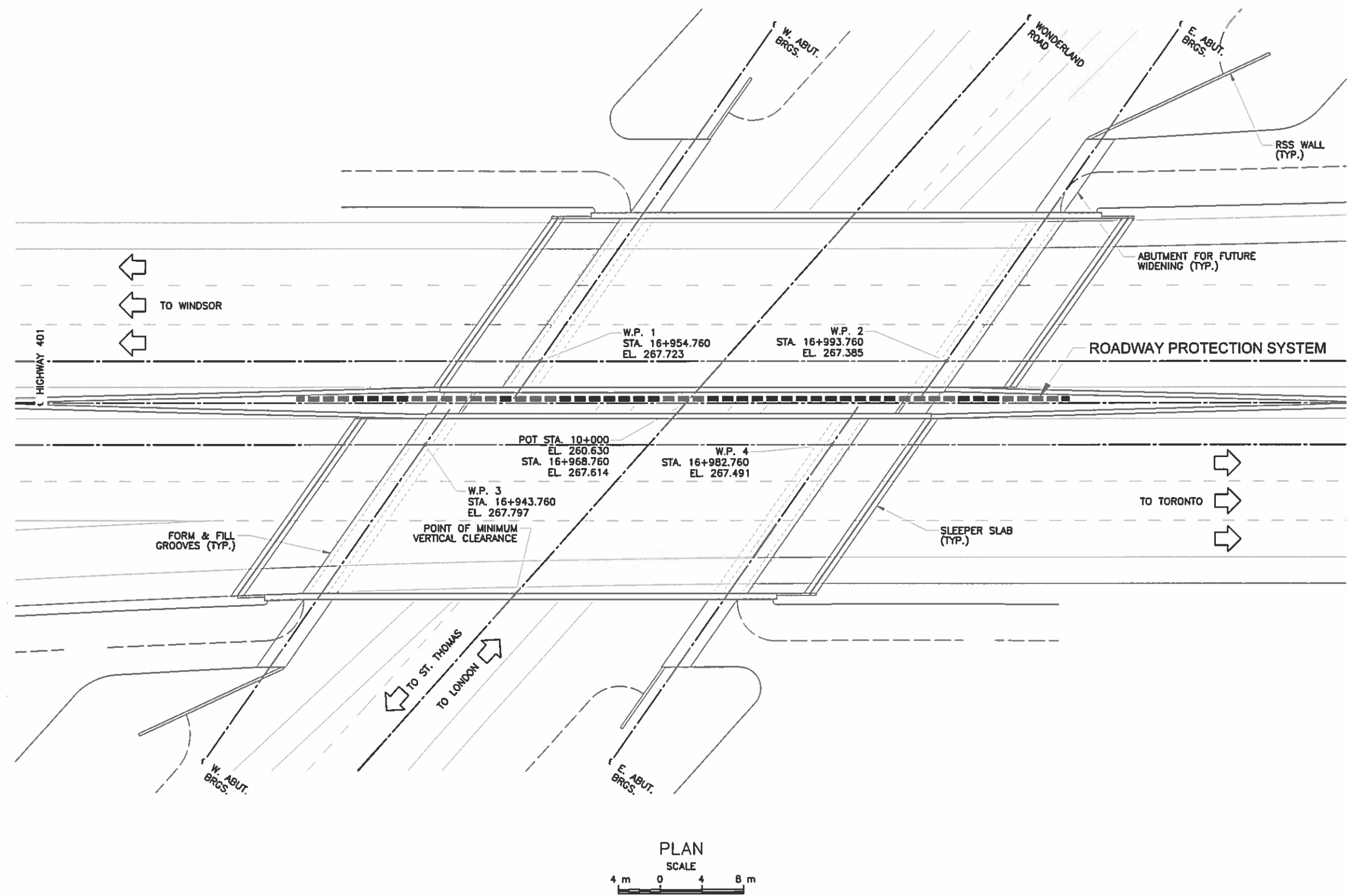
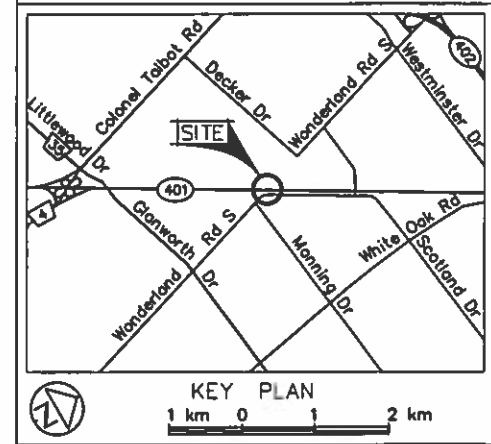
## **APPENDIX E**

Drawing No. 3 – Roadway Protection System Location

Proposed Slope Stabilization Memo April 16, 2014

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

PLATE No	CONT 2012-3022 WP 3031-11-00	
HIGHWAY 401 WONDERLAND ROAD OVERPASSES ROADWAY PROTECTION SYSTEM LOCATION	SHEET	



NOTES  
This drawing is for subsurface information only.  
Surface details and features are for conceptual  
illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REVISIONS				
DATE	BY		DESCRIPTION	
GEOREF No 40114-152				
HWY No 401				DIST
SUBMIT	CHECKED	DATE 2014-02-06	SITE	19-766
DRAWN C88	CHECKED	APPROVED	DWG	3

---

To:	Adam Barg	From:	Simon Gudina Raymond Haché
	Stoney Creek		Ottawa
File:	165000876	Date:	April 16, 2014

---

**Reference: New Wonderland Road Interchange at Highway 401, GWP 3031-11-00 Proposed Slope Stabilization (Addendum)**

## **INTRODUCTION**

This memo was prepared to discuss the available alternatives to provide long-term slope protection of the Wonderland Road cut slope and to provide recommendations for the preferred slope protection option. It supplements Section 7.9.4 of the Foundation Investigation and Design Report – New Highway 401 Interchange at Wonderland Road (Geocres No. 40114-152) prepared for this project. This section of the report discussed two possible options for the long-term groundwater control. This memorandum discusses additional options and provides recommendations for the preferred option.

This memorandum is based on the discussions made with the design and construction teams and the discussions with Mr. David Staseff of MTO Foundations Group.

It is noted that the recommendation provided is for a provisional slope protection method to be carried as part of the design and to be implemented only if long term seepage is observed within the slope face and only in those areas where this seepage occurs. This provisional slope protection recommendation is provided based on the results of the hydrogeological investigation carried out at the site.

## **LONG-TERM SLOPE PROTECTION OPTIONS**

The following alternatives are considered as possible options for the long-term slope protection of the Wonderland Road cut slope:

- Do nothing;
- Allow for a contingency plan. Place drainage buttress only in areas where groundwater seepage out of the slope face occurs;
- Construct a trench at the top of the slope (parallel to the slope crestline); and
- Construct a drainage buttress along the full length of the cut.

**Reference: New Wonderland Road Interchange at Highway 401, GWP 3031-11-00 Proposed Slope Stabilization (Addendum)**

These alternatives are briefly discussed in the following sections. A summary table containing the comparison of these alternatives with respect to advantages, disadvantages, risks and relative costs is provided in Table 1 following the text of this memo. Drawing Nos. 1 and 2 show the schematics of the options discussed herein.

**Do Nothing**

This option assumes that either no seepage will occur through the face of the Wonderland Road slope, or even if some seepage occurs, the proposed 2.5H:1V will continue to be stable. Given past experience in the area in which similar slopes in similar subsurface conditions were observed to fail in the long term, this option should not be carried forward. From the cost perspective, this alternative offers the least expensive option. However, it also involves the greatest risk to the future safety and performance of the Wonderland slope within the cut section.

**Put a Provisional Plan in Place and Provide a Drainage Buttress in Affected Areas Only**

This option calls for a provisional plan of action should seepage occur through the face of the cut slope in the long term. This option is based on the observation that similar slopes in the general area of the project have been found to be stable in the absence of groundwater seepage. This option is especially suitable for perched and localized seepage conditions. The main advantage of this option is that only affected slope area will be treated thus minimizing cost. The main drawback is the possible unsightliness of the slope face due to the non-uniform conditions of the slope face. The appearance of the slope face can be improved by utilizing an 'inserted' (as opposed to a protruding) version of the drainage buttress. The sketch showing the possible implementation of the 'inserted' contingency buttress is shown in the attached Drawing No. 1 (schematic on the left hand side). This alternative is considered the preferred option and should be carried forward.

**Construct a Trench at the Top of the Slope**

This option involves constructing a trench near and parallel to the slope crestline on both sides of Wonderland Road. The trench would extend from the top of the slope to within 1.5 m of the bottom of the slope to capture anticipated groundwater. The trench drain would be constructed prior to the slope being cut and would have a perforated drainage pipe that would discharge into the roadway drainage system likely near the northeast portion of the cut. The estimated length of the trench is 440 m on each side of the proposed Wonderland Road extension (a total of approximately 880 m). Typical depth of the trench is 5 m and is anticipated to be approximately 1 m wide. This rather deep and extensive trench, though feasible, is very expensive. In addition, it may lie outside the property line hence possibly requiring property acquisition. This option is not anticipated to be carried forward.

**Construct a Drainage Buttress along the Full Length of the Cut**

This option includes constructing approximately 1.2 m thick (perpendicular to the slope face). The drainage buttress would extend halfway up the slope on both sides of the proposed Wonderland Road. This option would require the slope crest to be offset (moved out) by approximately 3.2 m on each side of Wonderland Road in order to preserve the ditch cross section. This option is not anticipated to be carried forward due to the requirement of a wider cut. The schematic on the right hand side of the sketch in Drawing No. 2 shows the granular buttress on the lower half of the slope.

**Reference: New Wonderland Road Interchange at Highway 401, GWP 3031-11-00 Proposed Slope Stabilization (Addendum)**

## RECOMMENDATION

Based on the discussions presented above, the second alternative, i.e., the option of treating the affected parts of the slope as required in the long-term should be carried forward. Appearance (aesthetics) is the potential drawback of this option. However, if carefully planned, this option can overcome the aesthetic drawback. Further aesthetic enhancement could include replacing the outer 0.6 m of granular buttress with geotextile and topsoil which can be seeded and grassed so that the slope face will be visually uniform and aesthetically appealing. The lower 0.6 m of an enhanced approach would need to remain as rockfill to discharge the groundwater to the ditch.

## CLOSURE

We trust that this meets your current requirements. Please do not hesitate to contact us should you have any questions.

Yours truly,

**STANTEC CONSULTING LTD.**



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Fax: 613-722-2799  
[Simon.gudina@stantec.com](mailto:Simon.gudina@stantec.com)




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Geotechnical Engineering  
Phone: 613-738-6055  
Fax: 613-722-2799  
[Raymond.hache@stantec.com](mailto:Raymond.hache@stantec.com)

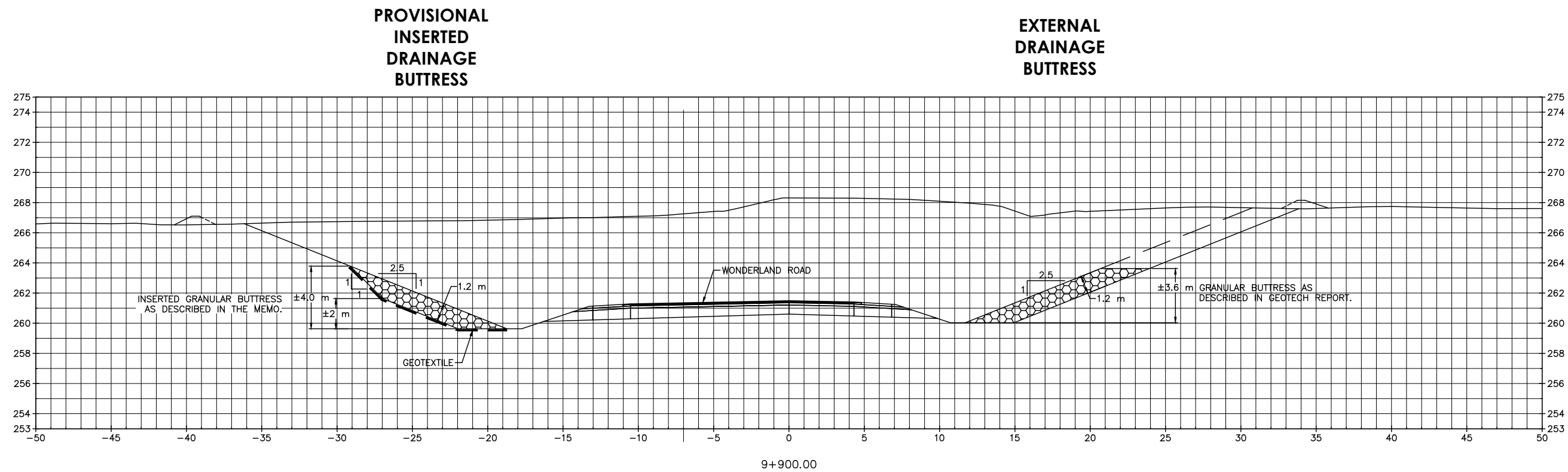
Enclosures: Table 1 - Comparison of Options for Wonderland Road Cut Slope Protection  
Drawings 1 and 2 - Schematics of the options considered

Table 1: Comparison of Alternatives for Long-Term Slope Protection of Wonderland Road Cut Slope

Slope Protection Option	Advantages	Disadvantages	Constructability	Relative Cost	Ranking
<b>Do nothing</b>	<ul style="list-style-type: none"> <li>No additional work required</li> </ul>	<ul style="list-style-type: none"> <li>Lack of slope protection measure</li> </ul>	N.A.	None	4
<b>Provisional drainage buttress treatment</b>	<ul style="list-style-type: none"> <li>Only affected areas are treated</li> <li>'Inserted' buttress option reduces visual impact</li> <li>Visual impacts can be further enhanced if required by use of topsoil surfacing over the drainage buttress</li> </ul>	<ul style="list-style-type: none"> <li>Non-consistent appearance of slope face</li> <li>Extent of treatment less certain</li> </ul>	<ul style="list-style-type: none"> <li>Treatment carried out from the Wonderland Road shoulder / ditch</li> </ul>	Low	1
<b>Place a trench drain at the top of the slope</b>	<ul style="list-style-type: none"> <li>No visible impact on the slope face</li> <li>Groundwater intercepted and discharged to the north away from the cut</li> </ul>	<ul style="list-style-type: none"> <li>Have to treat the entire cut section (see sketch in Drawing No. 2)</li> <li>Deep trench required</li> <li>Trench may lie outside property line</li> </ul>	<ul style="list-style-type: none"> <li>Trench placed at pre-determined alignment prior to Wonderland Road cut</li> </ul>	Medium	2
<b>Place a drainage buttress along the full length of the cut</b>	<ul style="list-style-type: none"> <li>Easy construction</li> </ul>	<ul style="list-style-type: none"> <li>Visual appearance</li> <li>Requires approximately 3.2 m offset of the slope crest to accommodate a 1.2 m thick drainage buttress; an 'inserted' buttress can avoid the need for an offset</li> </ul>	<ul style="list-style-type: none"> <li>Drainage buttress constructed after completion of the cut and in conjunction with construction of Wonderland Road</li> </ul>	High	3

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AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

PLATE No		
CONT	2012-3022	
WP	3031-11-00	
HIGHWAY 401 STA 9+900 CROSS SECTION		SHEET
		



**LONG-TERM SLOPE PROTECTION OPTIONS**

REVISIONS			
	DATE	BY	DESCRIPTION
GEOCRES No			
HWY No 401			DIST
SUBM'D SG	CHECKED	DATE 2014-04-16	SITE
DRAWN GBB	CHECKED	APPROVED	DWG 1



METRIC  
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AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

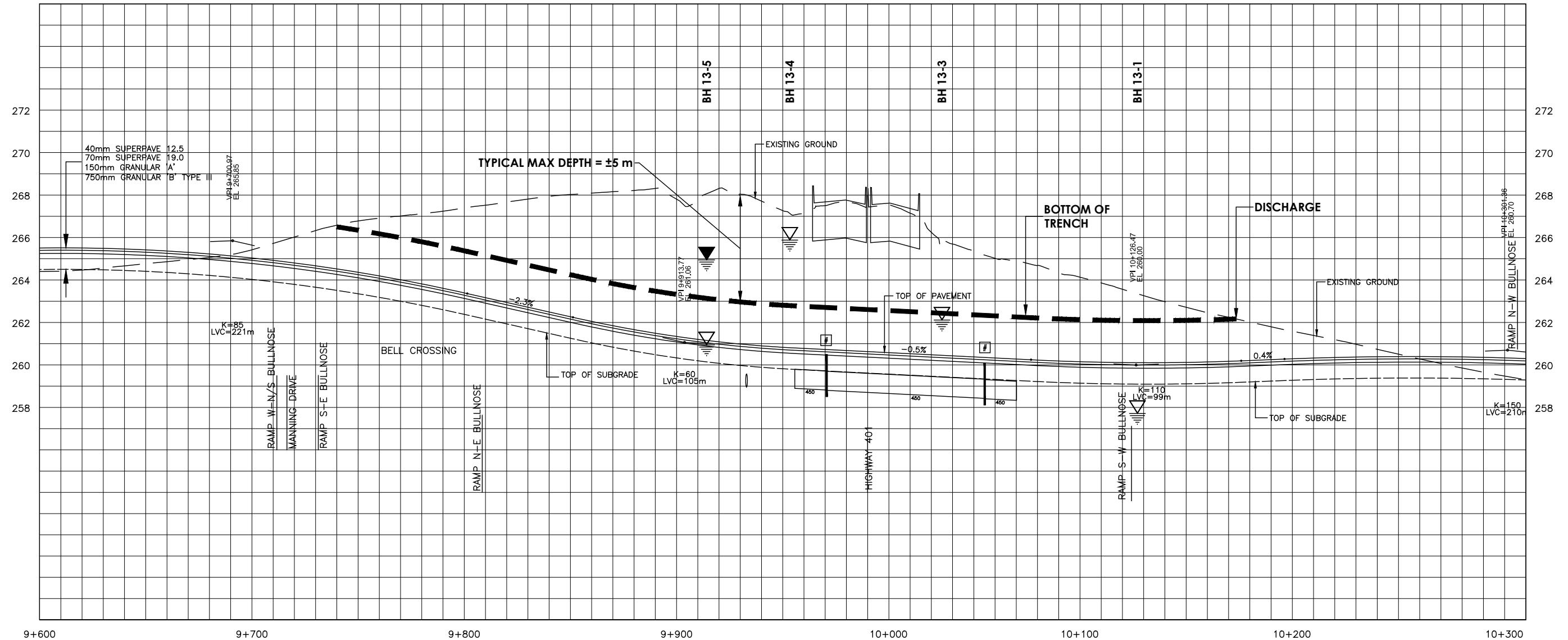
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WP	3031-11-00
HIGHWAY 401	
STA 9+750 TO STA 10+190	
PROFILE	

SHEET



LEGEND

- LEVELS ON NOV. 10, 2013
- LEVELS ON JAN. 10, 2014



LONG-TERM SLOPE PROTECTION OPTIONS  
TRENCH DRAIN

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CREATED BY: GBB  
T: \Autocad\Drawings\Project Drawings\2014\165000876\165000876\_Sta 9+900\_Profile.dwg (PROFILE) Printed: Apr 16, 2014

REVISIONS				
	DATE	BY	DESCRIPTION	
GEOCRE'S No				
HWY No 401			DIST	
SUBM'D SG	CHECKED	DATE 2014-04-16		SITE
DRAWN GBB	CHECKED	APPROVED		DWG 2