



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
NEW TREMAINE ROAD INTERCHANGE AT HIGHWAY 401
TREMAINE ROAD UNDERPASS STRUCTURE**

Geocres Number: 30M12-391

Report to

WSP

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

March 2, 2022
File: 19-5161-155

TABLE OF CONTENTS

PART 1 FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING	2
4	LABORATORY TESTING	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1	Pavement Structure	4
5.2	Fill.....	4
5.3	Topsoil	4
5.4	Upper Silty Clay Till	4
5.5	Upper Sand and Silt Strata.....	5
5.6	Middle Silty Clay to Clayey Silt Till	6
5.7	Lower Sand and Silt Strata	7
5.8	Sand and Silt Till	9
5.9	Lower Clayey Silt Till / Residual Shale	9
5.10	Shale Bedrock.....	10
5.11	Water Levels.....	11
6	MISCELLANEOUS.....	12

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	GENERAL	13
8	FOUNDATION DESIGN	13
8.1	Spread Footings on Native Soil	14
8.2	Spread Footings on Engineered Fill.....	15
8.3	Driven Steel H-Pile Foundations	16
8.4	Drilled Shafts (Caissons)	19
8.5	Recommended Foundation	22
9	FROST COVER	22
10	ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES	22
11	RETAINED SOIL SYSTEMS (RSS)	23
12	SEISMIC CONSIDERATIONS.....	25

13	APPROACH EMBANKMENTS	25
14	EXCAVATION AND GROUNDWATER CONTROL	26
15	CONSTRUCTION CONCERNS	27
16	CLOSURE.....	28

Appendices

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Site Photographs
Appendix D	Foundation Comparison
Appendix E	List of Standard Specifications and Special Provisions
Appendix F	Slope Stability Analyses
Appendix G	Borehole Locations and Soil Strata Drawings

**FOUNDATION INVESTIGATION AND DESIGN REPORT
NEW TREMAINE ROAD INTERCHANGE AT HIGHWAY 401
TREMAINE ROAD UNDERPASS STRUCTURE**

Geocres Number: 30M12-391

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed Tremaine Road Underpass structure planned in connection with the new Tremaine Road Interchange at Highway 401 in the Town of Milton, Ontario.

New Tremaine Road will be constructed on a new alignment approximately 600 m east of the existing Tremaine Road and cross Highway 401 as part of a new interchange. The interchange project will include construction of a new underpass structure carrying Tremaine Road over Highway 401, approach embankments to the structure, and access ramps connecting the new Tremaine Road and Highway 401.

The purpose of the investigation was to explore the subsurface conditions at the proposed Tremaine Road Underpass structure location and, based on the data obtained, to provide borehole logs, borehole location plans, stratigraphic profiles, and written descriptions of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to WSP (formerly MMM Group Limited) who are preparing the detailed interchange design for The Regional Municipality of Halton.

2 SITE DESCRIPTION

The proposed Tremaine Road interchange with Highway 401 will be located approximately 600 m east of the existing Tremaine Road underpass and about 2.0 km west of the Regional Road 25 interchange in the Town of Milton. The project limits along the new Tremaine Road alignment extend from 3rd Side Road south of Highway 401 northerly to approximately 100 m south of Campbellville Road. Highway 401 at the site is a six lane divided highway with a tall-wall median barrier.

The proposed interchange lands are generally agricultural with a faintly undulating topography. A small tributary of the Sixteen Mile Creek crosses from the northwest to the south end of the properties. Industrial buildings exist to the east, residential areas are located to the west and south,

and a heritage park and conservation/ski area are located to the southwest as well. Photographs of the site are provided in Appendix C.

The project site is located within the physiographic region known as the Peel Plain, characterized by a discontinuous veneer of glacio-lacustrine clay and silt underlain by glacial till consisting of clayey silt to silty clay (Halton Till). The underlying bedrock consists of the Queenston Formation, a reddish brown shale with siltstone and limestone interbeds. The site is located approximately 1.0 km northeast of the base of the Niagara Escarpment.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation at the proposed underpass location was generally carried out during the period from September 2 to October 30, 2014 with two boreholes (UP-03 and UP-04) drilled between April 28 and May 6, 2014. One borehole (UP-07) was subsequently drilled on April 14, 2016 due to property access restrictions. The borehole designation and depths are listed as follows:

Table 3.1 – Borehole Designations and Depths

Borehole Location	Borehole No.	Borehole Depth (m)
North Abutment	UP-01	19.7
	UP-02	25.2
Centre Pier	UP-03	26.8
	UP-04	23.2
South Abutment	UP-05	24.7
	UP-06	25.6
North Approach	UP-07	11.1
South Approach	UP-08	11.3
North Abutment Wingwalls	UP-09	11.3
	UP-10	9.8
South Abutment Wingwalls	UP-11	9.8
	UP-12	9.3

Boreholes UP-02 to UP-06 were advanced 3.0 to 7.0 m below the interpreted surface of the underlying shale bedrock by augering and rock coring methods. Borehole UP-01 was extended by rock coring methods to a depth of 3.2 m beyond auger refusal.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings attached in Appendix G.

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area.

Hollow stem augers and/or solid stem augers were used to advance the boreholes in the overburden. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the soil. NQ/HQ coring equipment was used to advance the boreholes into the bedrock and to recover rock core samples.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock core samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. 19 mm diameter standpipe piezometers were installed and enclosed in filter sand in selected boreholes to permit longer term groundwater level monitoring. The details of the piezometers are shown in Table 3.2.

The boreholes in which no piezometers were installed were backfilled with bentonite and cuttings to ground surface in general accordance with MOE Regulation 903.

Table 3.2 – Piezometer Details

Borehole	Piezometer Tip		Instrument Type	Slotted Screen Length (m)
	Depth (m)	Elevation (m)		
UP-01	19.7	199.7	19 mm Piezometer	1.5
UP-06	22.9	195.5	19 mm Piezometer	1.5

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were subjected to gradation analysis and Atterberg Limits testing. The results of this testing program are shown on the Record of Borehole sheets and on the laboratory test result figures attached in Appendix B.

Point load tests (PLT) were performed on selected intact rock core samples. Unconfined compressive strengths (UCS) of the rock cores correlated from the PLT results are shown on the Record of Borehole sheets in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general terms, the subsurface stratigraphy encountered in the boreholes consists of a pavement structure, fill or topsoil layer overlying a layer of silty clay till, underlain by a unit of cohesionless sands and silts, which is in turn underlain by a second layer of typically cohesive silty clay to clayey silt till, a second layer of cohesionless sands and silts, and then deposits of sand and silt to clayey silt till. The lower till deposits overlie shale bedrock.

More detailed descriptions of the individual strata are presented below.

5.1 Pavement Structure

Asphalt pavement was encountered in Boreholes UP-03 and UP-04 drilled in the paved median of Highway 401. The pavement structure consisted of 125 and 150 mm of asphalt overlying granular material (crushed limestone) extending to depths of 1.4 and 1.2 m (Elev. 218.6). Measured moisture contents in the granular material ranged from 2 to 3%.

5.2 Fill

Fill materials consisting of sand, some gravel, and silty clay, some sand, were encountered in borehole UP-07. SPT 'N' values of 11 and 12 blows per 0.3 m were obtained in the fill, indicating compact and stiff conditions. Moisture contents of 9 and 22% were measured in the sand and clay layers, respectively. The lower boundary of the fill was at 1.5 m depth (elevation 218.4).

5.3 Topsoil

Topsoil was encountered in all boreholes except boreholes UP-03, UP-04 and UP-07. The thickness of the topsoil ranged from 50 to 250 mm in the boreholes. The thickness may vary between and beyond the borehole locations.

5.4 Upper Silty Clay Till

A layer of brown silty clay till containing some sand (to sandy) was encountered below the fill, topsoil or pavement structure in all boreholes. The thickness of the layer ranged from 2.6 to 4.6 m, with the lower boundary at 2.8 to 5.6 m depth (elevation 216.4 to 213.5).

SPT 'N' values obtained in the clay till typically ranged from 14 to 59 blows per 0.3 m penetration, indicating a generally very stiff to hard consistency. 'N' values of 4 to 14 blows per 0.3 m were obtained in the upper 0.6 m below the ground surface, indicating a firm to stiff consistency. Measured moisture contents ranged from 9 to 23%.

The results of grain size distribution tests carried out on the cohesive samples are shown on Figures B1a and B1b included in Appendix B and also summarized below:

Gravel (%)	0 to 6
Sand (%)	18 to 29
Silt (%)	45 to 53
Clay (%)	23 to 35

The results of Atterberg Limits tests carried out on the till samples are shown on Figure B8 included in Appendix B and also summarized below:

Liquid Limit	27 to 31%
Plastic Limit	16 to 18%
Plasticity Index	11 to 14%

The results of the Atterberg Limit tests indicate that the silty clay till has low plasticity with a group symbol of CL.

Glacial till soils often contain cobbles and boulders, and these should be anticipated during construction.

5.5 Upper Sand and Silt Strata

A unit of generally cohesionless deposits varying in gradation from silt to sand and silt was encountered below the upper clay till stratum in all boreholes. The total thickness of this unit ranged from 3.0 to 5.5 m. Borehole UP-07 was terminated in the sand and silt. In several boreholes, a secondary layer of silt was encountered within the upper part of the underlying till deposit. Descriptions of the various substrata in this unit are presented below.

5.5.1 Silt

A relatively thin layer of grey silt was encountered below the cohesive till in Boreholes UP-07 and UP-09 to UP-12. The silt contained trace to some clay and sand. The silt layer ranged in thickness from 0.8 to 1.5 m, with a lower boundary at depths of 4.0 to 5.6 m (elevation 215.4 to 213.9).

SPT 'N' values of 16 to 39 blows per 0.3 m penetration were obtained in the silt, indicating a compact to dense relative density or very stiff consistency. Measured moisture contents ranged from 12 to 19%.

The results of grain size distribution tests carried out on the silt are shown on Figures B2a and B2c in Appendix B and summarized below:

Gravel (%)	0
Sand (%)	4 to 16
Silt (%)	77 to 80
Clay (%)	7 to 16

The results of Atterberg Limits tests carried out on a silt sample are shown on Figure B9 included in Appendix B and also summarized below:

Liquid Limit	22%
Plastic Limit	12%
Plasticity Index	10%

5.5.2 Sand and Silt

A layer of brown to grey sand and silt (locally grading to sandy silt) was encountered below the clay till or silt layer in all boreholes. The sand and silt contains trace to some

clay. The layer thickness ranged from 2.2 to 5.4 m, with the lower boundary at depths of 6.3 to 9.5 m (elevation 212.2 to 209.9). Borehole UP-07 was terminated in the sand and silt at 11.1 m depth (elevation 208.8).

SPT 'N' values recorded in the deposit generally ranged from 11 to 45 blows per 0.3 m penetration, indicating a compact to dense relative density. Isolated 'N' values of 3 and 7 blows per 0.3 m (very loose to loose) were obtained in Boreholes UP-05 and UP-09, possibly reflecting hydraulic disturbance. Measured moisture contents ranged from 11 to 27%.

The results of grain size distribution tests carried out on the cohesionless samples are shown on Figures B2b and B2c included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	27 to 49
Silt (%)	47 to 62
Clay (%)	4 to 11

5.5.3 Silt

A reddish brown silt layer with some clay and trace sand was encountered below the sand and silt locally in Borehole UP-08. In Boreholes UP-05, UP-06 and UP-11, a grey silt layer was encountered below the sand and silt, interbedded within the underlying till deposit. Where fully penetrated, the silt layer was 1.1 to 1.6 m thick with a lower boundary at depths of 7.9 to 10.2 m (elevation 210.6 to 208.3). Borehole UP-11 was terminated in the silt at 9.8 m depth (elevation 209.0).

SPT 'N' values of 12 to 37 blows per 0.3 m penetration were obtained in the silt, indicating a compact relative density or very stiff to hard consistency. Measured moisture contents ranged from 16 to 22%.

The results of grain size distribution tests carried out on the silt are shown on Figure B2a in Appendix B and summarized below:

Gravel (%)	0
Sand (%)	5 to 6
Silt (%)	80
Clay (%)	14 to 15

5.6 Middle Silty Clay to Clayey Silt Till

A layer of brown to grey silty clay to clayey silt till was encountered below the sand and silt in all boreholes. The till contains some sand (to sandy), trace gravel and occasional

cobbles and shale/limestone fragments. Locally in Borehole UP-08, this unit graded to sand and silt till with trace to some clay and some gravel.

Boreholes UP-08, UP-09, UP-10 and UP-12 were terminated within this layer at depths of 9.3 to 11.3 m (elevation 208.9 to 207.2). Borehole UP-11 was terminated at a depth of 9.8 m (elevation 209.0) within a silt layer interbedded in the clay till deposit. Where fully penetrated in Boreholes UP-01 to UP-06, the thickness of this till deposit ranged from 2.7 to 5.8 m, with the lower boundary at 12.2 to 13.7 m depth (elevation 207.2 to 205.6).

SPT 'N' values of 16 blows per 0.3 m penetration to 100 blows per 0.15 m penetration were obtained in the deposit, indicating a very stiff to hard consistency, locally very dense. Measured moisture contents ranged from 6 to 30%, typically about 10 to 23%.

The results of grain size distribution tests carried out on the till samples are shown on Figures B3a, B3b and B4 included in Appendix B and also summarized below:

Gravel (%)	0 to 13
Sand (%)	11 to 39
Silt (%)	35 to 70
Clay (%)	13 to 52

The results of Atterberg Limits tests carried out on the till samples are shown on Figure B10 included in Appendix B and also summarized below:

Liquid Limit	20 to 42%
Plastic Limit	13 to 19%
Plasticity Index	7 to 23%

The results of the Atterberg Limit tests indicate that the middle till varies from low to medium plasticity with a group symbol of CL to CI.

Glacial till soils often contain cobbles and boulders, and these should be anticipated during construction.

5.7 Lower Sand and Silt Strata

A second unit of generally cohesionless deposits varying in gradation from silt to sand and silt, locally sand and gravel, was encountered below the middle clay till stratum in Boreholes UP-01 to UP-06. The total thickness of this unit ranged from 1.4 to 5.2 m. Descriptions of the various substrata in this unit are presented below.

5.7.1 Silt

A brown to grey silt layer was encountered below the middle till deposit in Boreholes UP-01, UP-03 and UP-04. The silt contains trace to some clay and trace sand. The thickness of the silt layer penetrated in the boreholes ranged from 1.5 to 3.1 m with the lower boundary at 14.8 to 16.8 m depth (elevation 204.6 to 203.2).

SPT 'N' values recorded in the deposit ranged from 23 to 91 blows per 0.3 m penetration, indicating a compact to very dense relative density. Measured moisture contents ranged from 9 to 27%.

The results of grain size distribution tests carried out on the silt samples are shown on Figures B5 included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	5 to 6
Silt (%)	80 to 91
Clay (%)	4 to 14

5.7.2 Sand and Silt

A layer of brown sand and silt was encountered below the middle till in Boreholes UP-05 and UP-06. The sand and silt contains trace clay. The layer thickness was 1.4 and 5.2 m, with the lower boundary at depths of 13.9 and 17.8 m (elevation 204.6 and 200.6).

SPT 'N' values recorded in the deposit ranged from 34 to 120 blows per 0.3 m penetration, indicating a dense to very dense relative density. Measured moisture contents ranged from 11 to 19%.

The results of a grain size distribution test carried out on a cohesionless sample are shown on Figure B5 included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	35
Silt (%)	58
Clay (%)	7

5.7.3 Sand

A layer of brown sand was encountered below the till in Borehole UP-02 and below the silt in Boreholes UP-03 and UP-04. The layer thickness was 1.5 to 3.1 m, with the lower boundary at depths of 15.8 to 18.3 m (elevation 202.9 to 201.5).

SPT 'N' values recorded in the deposit ranged from 20 to 76 blows per 0.3 m penetration, indicating a compact to very dense relative density. Measured moisture contents ranged from 10 to 22%.

The results of a grain size distribution test carried out on a cohesionless sample are shown on Figure B6 included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	94
Silt & Clay (%)	6

5.7.4 Sand and Gravel

A layer of grey sand and gravel, trace silt, was encountered below the silt locally in Borehole UP-01. The thickness of the layer was 1.7 m with the lower boundary at 16.5 m depth (elevation 202.9).

An SPT 'N' value of 58 blows per 0.175 m penetration was recorded in the deposit, indicating a very dense relative density. A moisture content of 6% was measured.

The results of a grain size distribution test carried out on the sand and gravel is shown on Figure B6 included in Appendix B and also summarized below:

Gravel (%)	46
Sand (%)	52
Silt & Clay (%)	2

5.8 Sand and Silt Till

A discontinuous deposit of brown sand and silt till was encountered below the lower sand and silt strata in Boreholes UP-02, UP-05 and UP-06. The thickness of the sand and silt till ranged from 0.5 to 2.9 m, with the lower boundary at 16.8 to 18.3 m depth (elevation 201.7 to 200.1).

SPT 'N' values recorded in the cohesionless till ranged from 60 blows per 0.3 m penetration to 100 blows for 0.1 m penetration, indicating a very dense relative density. Measured moisture contents ranged from 10 to 13%.

The results of two grain size distribution tests carried out on the cohesionless till samples are shown on Figure B4 included in Appendix B and also summarized below:

Gravel (%)	10 to 16
Sand (%)	42 to 54
Silt (%)	30 to 35
Clay (%)	6 to 7

Glacial till soils often contain cobbles and boulders, and these should be anticipated during construction.

5.9 Lower Clayey Silt Till / Residual Shale

A layer of reddish brown to brown clayey silt till was encountered below the cohesionless strata and sand and silt till in all boreholes. The till contains some sand, trace gravel and occasional to numerous bedrock fragments, and may comprise weathered, residual or reworked bedrock. The thickness of the layer ranged from 1.5 to 4.9 m, with the lower boundary at 19.8 to 22.3 m depth (elevation 200.2 to 196.1). Rock coring equipment was

used to penetrate the till in Borehole UP-01, and the borehole was terminated in this material at 19.7 m depth (elevation 199.7).

SPT 'N' values of 112 blows per 0.3 m penetration to 100 blows for 0.1 m penetration were obtained in the deposit, indicating a hard consistency and/or possible cobbles and bedrock slabs. Measured moisture contents ranged from 4 to 18%.

The results of a grain size distribution test carried out on the cohesive till are shown on Figure B7 included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	15
Silt (%)	67
Clay (%)	18

5.10 Shale Bedrock

Shale bedrock of the Queenston Formation was encountered below the cohesive till in Boreholes UP-02 to UP-06. The table below summarizes the depth to bedrock and the bedrock surface elevations encountered in the boreholes.

Borehole	Depth to Bedrock (m)	Bedrock Elevation (m)
UP-02	19.9	198.8
UP-03	19.8	200.2
UP-04	20.1	199.7
UP-05	21.7	196.8
UP-06	22.3	196.1

The shale is generally described as reddish brown with grey limestone interbeds typically ranging from 25 to 50 mm in thickness. The transition from till to highly weathered bedrock with soil infilling is gradational, and demarcation of the bedrock surface is subject to interpretation.

Total Core Recovery (TCR) in the initial two runs of bedrock core in Boreholes UP-02 and UP-03 ranged from 0% (no recovery) to 40%. TCR in the remainder of the core runs ranged from 63 to 100%. The Rock Quality Designation (RQD) determined from the cores recovered below the upper highly weathered material ranged from 46 to 100%, indicating poor to excellent rock quality. The Fracture Index (FI) of the rock, expressed as number of fractures per 0.3 m of core, ranged from 0 to greater than 20.

The unconfined compressive strengths (UCS) of the rock, estimated from the results of point load tests, ranged between 7 and 45 MPa, indicating a weak to medium strong rock strength classification. The point load test results are included on the borehole logs in Appendix A.

5.11 Water Levels

The groundwater depths and elevations observed in the boreholes upon completion of drilling and measured in the monitoring wells after the drilling are summarized in the following table.

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
UP-01	Nov. 26, 2014	1.7	217.7	In piezometer
	Dec. 19, 2014	2.9	216.5	
UP-03	May 6, 2014	3.8	216.2	In open borehole
UP-04	Mar. 30, 2014	3.0	216.8	In open borehole
UP-06	Nov. 25, 2014	2.4	216.0	In piezometer
	Dec. 19, 2014	2.1	216.3	
UP-07	April 14, 2016	7.2	212.7	In open borehole
UP-08	Sep. 16, 2014	4.0	214.5	In open borehole
UP-09	Oct. 6, 2014	4.0	215.4	In open borehole
UP-11	Sep. 17, 2014	5.1	213.7	In open borehole
UP-12	Sep. 17, 2014	4.4	213.8	In open borehole

The above water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.

6 MISCELLANEOUS

WSP (formerly MMM Group Limited) staked out boreholes and determined the co-ordinates and ground elevations at borehole locations prior to the site investigation.

DBW Drilling of North York, Ontario, Walker Drilling of Utopia, Ontario, and Determination Drilling of Hamilton, Ontario, supplied and operated the drilling and sampling equipment for the field program.

Full time supervision of the field activities, including obtaining utility clearances, was carried out by various field technicians provided by Thurber Engineering. Overall supervision of the field program was performed by Mr. Matthew Whalen and Keli Shi, P.Eng. of Thurber.

Interpretation of the field data and preparation of the report was performed by Mr. Keli Shi, P.Eng. The report was reviewed by Mr. Murray Anderson, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Keli Shi, P.Eng.
Geotechnical Engineer



Murray R. Anderson, P.Eng.
Senior Geotechnical Engineer



Dr. P.K. Chatterji, P.Eng.
Review Principal

**FOUNDATION INVESTIGATION AND DESIGN REPORT
NEW TREMAINE ROAD INTERCHANGE AT HIGHWAY 401
TREMAINE ROAD UNDERPASS STRUCTURE**

Geocres Number: 30M12-391

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist selection and design of the foundation system for the new Tremaine Road underpass structure at Highway 401.

Tremaine Road will be realigned and cross Highway 401 at a location approximately 600 m east of the existing Tremaine Road underpass. Based on the preliminary General Arrangement drawing, the new underpass structure will be a two-span structure with a total span length of 88 m and a width of approximately 43.0 m. The structure will cross Highway 401 on an approximate 14° skew. Highway 401 is presently a six-lane divided highway at the site.

Proposed finished grades on the structure will range from approximate elevation 228.8 at the south abutment to elevation 230.2 at the north abutment. The structure approach embankments will have a height in the order of 10 to 11 m, and RSS wingwalls will be constructed on all four corners of the structure. Grades on Highway 401 are near elevation 219.0 to 220.5.

The discussion and recommendations presented in this report are based on the information provided by WSP (formerly MMM Group Limited) and on the factual data obtained during the investigation.

8 FOUNDATION DESIGN

In general terms, the subsurface stratigraphy encountered at the underpass location consists of a pavement structure or topsoil layer overlying a layer of very stiff to hard silty clay till, underlain by a unit of compact to dense, cohesionless sands and silts, which is in turn underlain by a second layer of very stiff to hard silty clay to clayey silt till, a second layer of compact to very dense cohesionless sands and silts, and then deposits of very dense sand and silt till to hard clayey silt till. The lower till deposits overly shale bedrock at depths of 19.8 to 22.3 m. Stabilized groundwater levels were measured in two piezometers in December 2014 at 2.1 and 2.9 m depth (Elev. 216.3 and 216.5).

Based on the subsurface conditions at the site, initial consideration was given to supporting the structures using the following foundation types:

- Spread footings on native soil or engineered fill
- Driven steel H-piles
- Drilled shafts (Caissons)

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

8.1 Spread Footings on Native Soil

Based on the subsurface conditions encountered at this site, consideration may be given to supporting the proposed structure on spread footings founded in the native very stiff to hard silty clay till.

The highest recommended founding levels at each foundation unit, based on the borehole data, are presented in Table 8.1. Footings should be founded at or below these elevations, subject to minimum requirements for frost protection.

Table 8.1 – Highest Recommended Founding Levels

Foundation Unit	Borehole	Highest Recommended Founding Level
North Abutment	UP-01	218.0
	UP-02	217.5
Pier	UP-03	218.0
	UP-04	218.0
South Abutment	UP-05	217.5
	UP-06	217.5

Spread footings founded on the native very stiff to hard silty clay till at or below the noted elevations should be designed using the following resistance values, assuming a minimum 2 m wide footing subjected to vertical concentric loading:

Factored Geotechnical Resistance at ULS = 375 kPa

Factored Geotechnical Resistance at SLS = 250 kPa

The geotechnical resistance at SLS is based on an estimated settlement not exceeding 25 mm. This settlement should be essentially complete by the end of construction.

The resistance values are for vertical, concentric loads. Where eccentric loads are applied, the foundation shall be considered to have an effective concentric loaded area as shown in Figure 6.2 of CHBDC (2019) Clause 6.10.2. For inclined loads, the factored geotechnical resistance must be reduced in accordance with the CHBDC (2019) Clause 6.10.2 by applying an inclination factor of i_c defined as follows:

$$i_c = (1 - \delta_f / 90^\circ)^2 \quad \text{where } \delta_f = \text{angle of inclination of load from vertical (degrees)}$$

The lateral resistance developed along the base of concrete footings founded on the silty clay till may be computed using an ultimate friction coefficient of 0.4.

All footings should be provided with a minimum of 1.2 m of earth cover over the footing base as protection against frost action.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed surface conforms to the design requirements, has been adequately prepared to receive concrete, and consists of undisturbed native silty clay till.

Founding surfaces should be protected from disturbance during construction. The exposed surface should be protected from deterioration by placing a minimum 75 mm thick working mat of concrete of the same class as the footing immediately following approval of the founding surface.

8.2 Spread Footings on Engineered Fill

Construction of spread footings on engineered fill placed over the very stiff to hard silty clay till may be considered for the abutments. Placement of engineered fill at the pier is unlikely to be cost-effective in view of the additional depth of excavation required for fill construction and the spatial constraints within the median of the existing highway.

The underside of the engineered fill pad should extend down to or below the elevations given in Table 8.1.

The engineered fill must consist of OPSS Granular “A” placed in 150 mm lifts and compacted to 100% of its SPMDD at $\pm 2\%$ of optimum moisture content and generally conforming to the geometry illustrated in Figure 1, Appendix E.

Provided a minimum footing width of 2 m is maintained, a footing bearing on the engineered fill may be designed for a concentric, vertical geotechnical resistances of 900 kPa at factored ULS and 350 kPa at factored SLS.

The resistance values are for vertical, concentric loads. Where eccentric loads are applied, the foundation shall be considered to have an effective concentric loaded area as shown in Figure 6.2 of CHBDC (2019) Clause 6.10.2. For inclined loads, the factored geotechnical resistance must be reduced in accordance with the CHBDC (2019) Clause 6.10.2 by applying an inclination factor of i_γ defined as follows:

$$i_{\gamma} = (1 - \delta_f / \phi')^2 \quad \text{where } \delta_f = \text{angle of inclination of load from vertical (degrees)} \\ \phi' = \text{effective friction angle of Granular "A"} = 35^{\circ}$$

For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is not expected to exceed 25 mm. Differential settlements are not expected to exceed 20 mm across the width of the structure.

The lateral resistance of the footings founded on engineered fill may be computed using an unfactored friction coefficient of 0.6.

8.3 Driven Steel H-Pile Foundations

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

8.3.1 Axial Resistance

It is recommended that H-piles be driven to refusal in the very dense/hard till deposits or shale bedrock encountered at depths of 13.9 to 18.3 m in the boreholes. The axial geotechnical resistances recommended for steel HP310x110 piles driven to refusal in the till/shale are as follows:

Factored Geotechnical Resistance at ULS = 1,600 kN

Factored Geotechnical Resistance at SLS = 1,400 kN

A pile tip level at elevation 199.5 is recommended for estimating purposes. The actual pile tip elevations will be controlled as described in Section 8.3.3 Pile Installation.

8.3.2 Pile Tips

Pile tip protection is recommended for driven H-piles to prevent pile damage when setting the piles in very dense/hard till and bedrock, or if cobbles or boulders are encountered in the till at various depths. The tips of all driven H-piles must be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent.

8.3.3 Pile Installation

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

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

The possibility exists that piles will achieve the specified resistance at different elevations, and that some piles may meet refusal on a large boulder in the till. Driving must be terminated before the pile is damaged by overdriving.

To facilitate pile installation, embankment fill through which piles may be driven must not contain oversize material, i.e. no particles exceeding 75 mm in size.

8.3.4 Downdrag

Downdrag on the piles is not an issue at this site.

8.3.5 Lateral Pile Resistance

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

$$k_s = n_h z / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 3 \gamma' z K_p \quad (\text{kPa})$$

Where z = depth of embedment along pile (m)

D = pile width or diameter (m)

n_h = coefficient related to soil density (kN/m^3)

γ' = effective unit weight (kN/m^3)

K_p = coefficient of passive lateral earth pressure

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

$$k_s = 67 S_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 S_u \quad (\text{kPa})$$

Where S_u = undrained shear strength (kPa)

D = pile width or diameter in metres

The above equations and recommended parameters in Table 8.2 below may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

Table 8.2 – Soil Parameters for Lateral Pile Design

Foundation Unit	Soil Type	Elevation (m)		γ' (kN/m ³)*	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
North Abutment	Silty Clay Till	218.5	216.5	20	-	3.2	130
	Silty Clay Till	216.5	215.0	10	-	3.2	130
	Sand & Silt	215.0	210.5	10	3,500	3.2	-
	Clay/Silt Till	210.5	207.0	11	-	3.2	150
	Silt	207.0	204.5	11	3,500	3.2	-
	Sand/Gravel	204.5	202.9	12	6,500	3.7	-
	Clayey Silt Till	202.9	198.8	12	-	3.5	250
Pier	Silty Clay Till	218.5	216.5	20	-	3.2	130
	Silty Clay Till	216.5	214.3	10	-	3.2	130
	Sand & Silt	214.3	210.8	10	3,500	3.2	-
	Clay/Silt Till	210.8	206.2	11	-	3.2	200
	Silt	206.2	204.0	12	3,500	3.2	-
	Sand	204.0	201.6	11	4,000	3.4	-
	Clayey Silt Till	201.6	200.0	12	-	3.7	250
South Abutment	Silty Clay Till	218.0	216.5	20	-	3.2	180
	Silty Clay Till	216.5	213.7	10	-	3.2	180
	Sand & Silt	213.7	208.5	10	3,500	3.2	-
	Clay/Silt Till	208.5	205.9	11	-	3.2	150
	Sand & Silt	205.9	201.0	11	4,500	3.4	-
	Clayey Silt Till	201.0	196.5	12	-	3.7	250

*Buoyant unit weight below the water table.

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

The ultimate lateral resistance may have to be reduced based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Figures C6.22 to C6.24 of the Commentary on the CHBDC (2019).

Consideration may be given to the use of battered piles if lateral pile capacities higher than the available geotechnical lateral resistances are required.

8.3.6 Integral Abutment Considerations

The ground conditions at this site are considered suitable for an integral abutment design. The use of H-piles at the abutments allows for the design of an integral abutment structure.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. The near surface native soils at this site are very stiff to hard and the lateral resistance of a pile in this soil may not provide sufficient flexibility. In addition, the upper 3 m of the pile may lie partially within the compacted fill of the approach embankment. Accordingly, to provide the required flexibility in the piles, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP as specified by the integral abutment design procedures.

After the pile is driven, the space between the pile and the CSP should be filled with sand. An NSSP should be included in the contract drawings specifying the gradation of the sand according to Table 8.4.

Table 8.4 – Integral Abutment Sand Backfill Grading

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80% - 100%
425 µm	#40	40% - 80%
250 µm	#60	5% - 25%
150 µm	#100	0% - 6%

8.4 Drilled Shafts (Caissons)

We understand that the use of caissons is preferred at the pier to minimize the size of the construction area in the median of Highway 401. Caisson installation would extend through successive layers of cohesionless soils below the groundwater table and require a steel liner to support the caisson sidewalls. Further, cobbles and boulders may be encountered in the till deposits, impeding caisson installation. Subject to these concerns, the use of caissons may be considered.

8.4.1 Axial Resistance

The native till and sand/silt deposits above the bedrock are not considered capable of providing resistance values suitable for efficient caisson design. To achieve an adequate geotechnical resistance for practical design, it is recommended that the caissons be socketed into the shale bedrock encountered near 20 m depth. The upper 3.0 m of the bedrock encountered in Borehole UP-03 is highly weathered and of very poor quality (Rock Quality Designation of 0%). In recognition of this weathering, the caisson bases should be placed no higher than Elev. 196.0.

The caissons will develop axial resistance through a combination of sidewall shear and end bearing in the rock socket. The axial geotechnical resistances at ULS recommended for design of caissons with diameters of 1.5 and 1.8 m are presented in the following table for several socket lengths. The geotechnical resistance at SLS will not govern design.

Table 8.5 – Axial Resistance of Caissons

Caisson Diameter (m)	Caisson Base Elevation	Factored Axial Geotechnical Resistance at ULS (kN)
1.5	196.0	7,400
	195.0	8,800
	194.0	10,200
1.8	196.0	9,700
	195.0	11,400
	194.0	13,100

The contribution of shaft resistance to the computed axial resistance was based on factored shaft resistances along the rock socket sidewalls of 175 kPa in the upper 3.0 m of highly weathered shale, and 300 kPa in the underlying sound shale. The contribution of end-bearing resistance was based on a factored base resistance of 2,000 kPa on sound shale. The resistance values assume that the socket sidewalls and base will not be softened, smeared, or fractured by drilling methods.

Uplift forces on the foundations will be resisted by shaft resistance developed along the sidewalls of the caisson socket in shale. For uplift resistance, factored shaft resistance values at ULS may be taken as 75% of the shaft resistance values indicate above for axial compressive loads. SLS conditions will not apply.

A minimum centre-to-centre spacing of two caisson diameters should be maintained between caissons.

8.4.2 Caisson Lateral Resistance

The recommendations and soil parameters presented for lateral pile design in Section 8.3.5 may be employed to evaluate the lateral resistance of caissons at the pier.

The lateral resistance that can be mobilized in front of a caisson socket in bedrock may be computed using the coefficient of horizontal subgrade reaction k_s and ultimate lateral resistance p_{ult} values provided below.

$$\begin{aligned}
 k_s &= 35,000 \text{ kN/m}^3 \text{ in the highly weathered bedrock; and} \\
 &= 75,000 \text{ kN/m}^3 \text{ in the less weathered bedrock.} \\
 p_{ult} &= 750 \text{ kPa in the highly weathered bedrock; and} \\
 &= 1,500 \text{ kPa in the less weathered bedrock.}
 \end{aligned}$$

8.4.3 Caisson Installation

Caisson installation must be in accordance with OPSS.PROV 903.

The caissons will be advanced through successive deposits of stiff to very stiff silty clay till, compact to dense sand and silt, very stiff to hard clayey silt to silty clay till, compact to

very dense silt and sand, and hard clayey silt till prior to contacting bedrock. The caisson drilling equipment supplied by the Contractor must be capable of advancing through these materials, penetrating very dense/hard material, and dislodging, removing or penetrating any obstructions such as cobbles, boulders, and rock fragments in the till deposits.

In general, caisson excavation will take place below the measured groundwater level on site. Synthetic drilling slurry and/or installation of a steel liner sealed into the shale bedrock will be required to support the caisson sidewalls in the cohesionless sand and silt layers. The use of synthetic slurry and/or maintaining an adequate head of water in the liner during drilling will be required to avoid hydraulic disturbance and heave at the caisson base. Caisson liners extended to the weathered bedrock may either be removed as the concrete is placed (temporary) or can be left in place (permanent), with no impact on the axial resistance which will be developed primarily in the rock socket.

The shale bedrock generally becomes harder/more sound with depth and contains hard siltstone or limestone interbeds. In addition, clay seams and highly fracture zones are present, particularly at the west end of the pier location. The presence of the hard layers, clay seams and fractured zones may impact auger production, and coring equipment may be required to penetrate hard layers during socketing of the caissons. The caisson drilling equipment selected by the contractor must be capable of advancing through shale of variable strength and quality.

Selection of the methods and equipment employed to install the caissons is the responsibility of the Contractor. However, the contract documents should contain a statement to alert bidders of the potential issues outlined above. Suggested wording for an NSSP to be included in the tender documents is provided in Appendix E.

Each caisson excavation must be cleaned and approved, and structural concrete must be placed expeditiously to prevent softening of the shale exposed on the base and sidewalls of the socket. Appropriate means such as a cleanout bucket, air lift, hydraulic pump, or other devices must be used to clean the bottom of the excavation; a clean-out bucket alone is not sufficient for final clean-out. The methods selected must enable direct contact between the concrete and undisturbed bedrock in the socket.

The bottom of the excavated shaft shall be inspected using a Shaft Inspection Device (SID), Shaft Quantitative Inspection Device (SQUID), down-hole camera, and/or an approved alternate to verify socket cleanliness and thickness of base sediment at the time of concreting. In this regard, suggested wording for an NSSP to replace Clause 903.07.03.03 “Inspection of the Excavation” of OPSS.PROV 903 is provided in Appendix E. Use of a downhole camera may not be suitable if slurry is used or the caisson excavation cannot be adequately flushed to remove suspended materials.

8.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven to refusal in the underlying very dense/hard till or shale bedrock are the preferred foundation option for this site. However, caissons may be preferred at the pier to minimize the impact on highway traffic staging.

9 FROST COVER

The depth of frost penetration at this site is 1.2 m. The base of footings or pile caps must be provided with a minimum of 1.2 m of earth cover as protection against frost action.

10 ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the abutments should consist of free-draining granular material conforming to OPS Granular A or B Type II specifications. The granular material should be placed to the extents shown in OPSD 3101.150.

Heavy compaction equipment should not be used adjacent to the abutment walls. Compaction should be carried out in accordance with OPSS.PROV 501.

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

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

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

The earth pressure coefficients are dependent on the material used as backfill. Recommended unfactored values are shown in Table 10.1. The at-rest coefficients should be employed for restrained walls. Active pressures should be used for any wingwalls or unrestrained walls.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.27 of the Commentary on the CHBDC (2019).

Table 10.1 – Lateral Earth Pressure Coefficients

Loading Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.39*	0.31	0.47*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wing walls.

In accordance with Clause 6.12.3 of the CHBDC (2019), a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I or 2.0 m for Granular A or Granular B Type II.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is generally preferred as it results in lower earth pressures acting on the wall. In the case of integral abutments, material with a lower passive pressure coefficient (e.g. Granular B, Type I) might be preferred as it results in lower forces acting on the ballast wall as the wall moves towards the soil mass.

The design of the abutment walls must incorporate measures such as weep holes to permit drainage of the backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

11 RETAINED SOIL SYSTEMS (RSS)

The preliminary general arrangement drawing indicates that retained soil system (RSS) walls will be employed for the abutment face and wingwalls. The ground surface behind and in front of the RSS walls will be sloped at an inclination of 2H:1V.

In general, RSS walls used in conjunction with the new abutments must be “High Performance” and “High Appearance”. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

To provide an acceptable foundation performance, the RSS mass must be founded on competent soils or engineered fill. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

The borehole information indicates that the soil conditions at the wall base levels will generally comprise very stiff to hard silty clay till. The highest recommended base levels, based on the borehole data, are presented in Table 11.1.

Where the design founding level is above that indicated in Table 11.1, engineered fill should be used to raise the grade. Engineered fill placed under the RSS mass to achieve the design founding

level should consist of OPSS Granular “A” compacted to 100% of its SPMD at a moisture content within 2% of optimum. The engineered fill pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

Table 11.1 – Highest Recommended Founding Levels

Structure Quadrant	Boreholes	Highest Recommended Base Level
Northwest	UP-01 UP-09	218.7
Northeast	UP-02 UP-10	218.0
Southwest	UP-05 UP-11	218.0
Southeast	UP-06 UP-12	217.6

Walls founded on engineered fill or very stiff to hard native silty clay till should be designed for Factored Geotechnical Resistances of 375 kPa at ULS and 250 kPa at SLS. The resistance values assume that the RSS wall reinforcement will extend a distance behind the wall face of approximately 70% of the wall height.

The geotechnical resistances provided above are for concentric, vertical loading. In accordance with Clause 6.19.9.4 of the CHBDC (2019), the effects of load inclination and eccentricity need to be evaluated by consideration of a uniform base pressure distribution over a reduced base width.

Any topsoil and soft/loose fill or native material should be stripped from the footprint of the RSS. All new embankment fill must be compacted in accordance with OPSS.PROV 501.

The RSS wall must also be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall on native silty clay till and engineered fill may be estimated using ultimate friction coefficients of 0.4 and 0.6, respectively. The internal stability of the RSS wall should be analysed by the supplier/designer of the proprietary product selected for this site.

In view of the soil conditions at this site, the estimated foundation settlement beneath RSS walls is expected to be in the order of 40 mm and will be essentially complete at the end of construction.

The global stability of the RSS wall is dependent on the characteristics of the foundation soils, the geometry of the embankment and location of the RSS within the embankment. Preliminary stability analyses were carried out for the south and north abutment wall geometries shown on the preliminary GA drawings. The stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 7) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses. A minimum reinforcing strip length of 0.7 times the wall height was

assumed for the RSS walls. The geotechnical model and the results of the analyses are presented in Appendix F.

The results indicate that a minimum factor of safety of 1.5 against slope instability is achieved for RSS walls founded on the native very stiff to hard silty clay till. Constructing the north abutment RSS on engineered fill above the level of the native clay till may be considered provided the base level is raised no higher than Elev. 221.5 (for the assumed slope geometry). Based on these analyses, global stability of the RSS walls should not be a concern. The stability analyses should be confirmed when further details of the wall design are established.

12 SEISMIC CONSIDERATIONS

In accordance with CHBDC (2109), the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the ground profile. The stratigraphy at this site generally consists of successive deposits of very stiff to hard cohesive till deposits and compact to very dense silts and sands, overlying shale bedrock at a depth of approximately 20 m. As per Table 4.1 and Clause 4.4.3.2 of the CHBDC (2019), the site may be classified as Seismic Site Class D (stiff soil).

Based on the National Building Code of Canada (NBCC 2015), the peak horizontal ground acceleration (PGA), corresponding to a design earthquake having a 2 percent probability of being exceeded in 50 years (i.e. 2,475 year return period) is 0.112 g at the site.

The coefficients of horizontal earth pressure for seismic loading on walls assuming a level backfill, a Site Class D, and a reference PGA of 0.112 g are presented in Table 12.1. The vertical acceleration coefficient k_v has been ignored ($k_v = 0$).

Table 12.1 – Earth Pressure Parameters for Seismic Loading

Loading Condition	Horizontal Acceleration Coefficient, k_h	Earth Pressure Coefficient (K_{AE})
		OPSS Granular A or Granular B Type II $\phi = 35^\circ$, $\gamma = 22.8 \text{ kN/m}^3$
Active (Unrestrained wall)	0.07	0.29
Active (Restrained wall)	0.14	0.33

The very stiff to hard till and compact to very dense silts and sands at this site are not considered susceptible to liquefaction under seismic loading.

13 APPROACH EMBANKMENTS

The foundation soils encountered below the proposed approach embankments generally consist of very stiff to hard silty clay till overlying compact to dense deposits of silt to sand and silt. The maximum proposed embankment height will be approximately 11.0 m.

Stability analyses were carried out for selected sections of the Tremaine Road high fill embankments at the approaches to the proposed underpass during concurrent preparation of the Foundation Investigation and Design Report for the High Fill Embankments. The stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 7) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses. Analyses were completed under both static and seismic loading conditions.

The minimum computed factors of safety against slope instability were approximately 1.6 for short-term (undrained) conditions and 1.7 for long-term (drained) conditions. Global stability of the embankments with standard side slope inclinations of 2H:1V is therefore not expected to be an issue.

The estimated foundation settlement beneath the new embankment fill is expected to be in the order of 70 to 80 mm under the highest fill and 40 mm at the abutment face. Settlement is expected to be essentially complete at the end of construction.

Embankment construction should be carried out in accordance with OPSS.PROV 206. Materials used to construct the embankments should comprise granular materials or Select Subgrade Material (SSM) in compliance with OPSS.PROV 1010, earth borrow as per OPSS.PROV 212, or on-site inorganic materials subject to geotechnical approval.

Mid-height berms comprising 2 m wide benches must be incorporated along the length of embankments with heights exceeding 8 m in earth fill. Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface, the existing earth or fill slope must be benched in accordance with OPSD 208.010.

Earth fill embankment slopes must be provided with erosion protection in accordance with OPSS.PROV 804. Design and implementation of the erosion protection works should include consideration of the surficial stability under heavy, prolonged rainfall and spring thaw conditions. Vegetation must be sufficiently established before the onset of winter. Use of granular sheeting may also be considered.

To minimize the erosion potential, surface water should be directed away from the embankment slopes and conveyed down the slope in appropriately designed drainage channels or storm sewers. Consideration should also be given to adopting flatter slope inclinations in sections of high uninterrupted slopes to increase infiltration and reduce flow velocities.

14 EXCAVATION AND GROUNDWATER CONTROL

All excavation must be carried out in accordance with OPSS.PROV 902 and the Occupational Health and Safety Act (OHSA). For the purposes of assessing excavation slope requirements in compliance with the OHSA, the upper silty clay till is classified as Type 2 soil. Excavation for foundation construction is not expected to extend in to the cohesionless soils below the water table.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. It is anticipated that a hydraulic excavator will be suitable. Provision must be made for the handling of pavement materials, potential obstructions in the fill, and possible cobbles, boulders and rock slabs in the till.

Roadway protection should be provided in accordance with OPSS.PROV 539 as amended by SP 105S09 and designed for Performance Level 2. Based on available subsurface information, a shoring system consisting of steel H-piles with timber lagging may be considered. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces.

Considering the consistency and low permeability of the clayey soils, groundwater control measures such as perimeter ditches and pumping from filtered sumps should be adequate to remove any accumulation of water from the footing/pile cap base prior to placing concrete. Additional pumps may be required if localized zones of perched water are encountered. All footings/pile caps must be constructed in the dry.

Selection of the equipment and methodology to excavate and prepare the subgrade is the responsibility of the Contractor. The design of the shoring and dewatering system that may be required is also the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.

15 CONSTRUCTION CONCERNS

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

- Driven steel H-piles may encounter cobbles or boulders in the till deposits above the design tip elevation. Cobbles and boulders may also be encountered during excavation for footing or pile cap construction.
- Driven steel H-piles may encounter refusal at varying depths on the hard/very dense till deposits overlying shale bedrock at this site. If the pile tip elevations vary by more than 3 m from the predicted values, the design team should be notified and permitted to review the possible implications.
- Caissons will be advanced through stiff to hard till deposits and compact to very dense sand and silt layers prior to contacting bedrock. The caisson drilling equipment must be capable of penetrating very dense/hard material, and dislodging or penetrating potential cobbles, boulders and rock fragments in the till deposits. Further, the caisson equipment must be capable of completing a socket within shale bedrock of variable strength and quality, containing hard limestone interbeds, clay seams, and highly fractured zones.
- Caisson excavation will advance through cohesionless sand and silt layers below the groundwater level on site. Caisson installation will require use of synthetic slurry and/or a steel liner sealed into the shale bedrock to support the caisson sidewalls.

The successful performance of the structure will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

16 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Murray R. Anderson, P.Eng.
Senior Geotechnical Engineer



Dr. P.K. Chatterji, P.Eng.
Review Principal



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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



Water Level

C_{pen}

Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS






ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
	(MPa)	(psi)	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

UNIFIED SOILS CLASSIFICATION

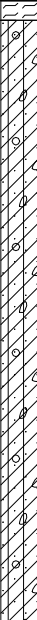
MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels,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

RECORD OF BOREHOLE No UP-01

1 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 628.1 E 586 538.3 ORIGINATED BY MKE
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
219.4	GROUND SURFACE							20	40	60	80	100	20	40	60				
0.0	TOPSOIL: (125mm)																		
0.1	Silty CLAY , some sand to sandy Firm to Hard Brown to Grey Moist (TILL)		1	SS	6														
			2	SS	18														
			3	SS	23														

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No UP-01

3 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 628.1 E 586 538.3 ORIGINATED BY MKE
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.10.30 - 2014.10.30 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	Continued From Previous Page Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov 26/ 14 1.7 217.7 Dec 19/ 14 2.9 216.5																

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No UP-02

2 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 636.2 E 586 580.8 ORIGINATED BY SLL
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.09.02 - 2014.09.05 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _P	W					
	Continued From Previous Page																		
			10	SS	100/ 0.150		208												
							207												
205.6			11	SS	21		206									0	11 37 52		
13.1	SAND , trace silt, trace to some gravel Very Dense Brown Wet		12	SS	67		205												
							204												
202.9			13	SS	76		203												
15.8	SAND and SILT , trace to some gravel, trace clay, occasional clayey silt seams Very Dense Brown Wet (TILL)		14	SS	60		202									10	54 30 6		
200.9							201												
17.8	Clayey SILT , some sand, trace gravel, with shale fragments Hard Brown Moist (TILL)		15	SS	100/ 0.200		200												
			16	SS	100/ 0.150		199												
198.8	Becoming residual shale		1	RUN													RUN #1 TCR=39% SCR=25% RQD=0%		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No UP-03

1 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 587.8 E 586 561.2 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.05.01 - 2014.05.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								WATER CONTENT (%) 20 40 60 80 100						
220.0	GROUND SURFACE													
0.0	ASPHALT:(125mm)													
0.1	SAND and GRAVEL Dense to Compact Brown Dry (FILL)		1	SS	33		219							
			2	SS	22									
218.6	Silty CLAY, some sand, trace gravel Very Stiff Brown Dry to Moist (TILL)		3	SS	18		218							
1.4			4	SS	21		217							0 18 47 35
			5	SS	20									
			6	SS	28		216							
							215							
214.4	SAND and SILT, trace clay Dense to Compact Brown Wet		7	SS	45		214							
5.6							213							
			8	SS	20		212							0 41 55 4
							211							
210.9	Clayey SILT, some sand, trace gravel, occasional shale fragments Very Stiff to Hard Brown to Reddish Brown Moist (TILL)		9	SS	41									
9.1														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-03

2 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 587.8 E 586 561.2 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.05.01 - 2014.05.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL		
								20 40 60 80 100					w _p w w _L									
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE														
			10	SS	28		209												0	15	70	15
							208															
			11	SS	37																	
							207															
206.3																						
13.7	SILT , trace to some clay, trace sand Very Dense to Compact Brown Wet		12	SS	28		206															
							205															
			13	SS	89														0	5	91	4
							204															
203.2																						
16.8	SAND , trace silt Compact Brown Wet		14	SS	20		203															
							202															
201.7																						
18.3	Clayey SILT , some sand, trace gravel		15	SS	100/ 0.150																	
	Hard Reddish Brown Moist to Wet (TILL)						201															
	Possible residual shale																					
200.2																						
19.8	SHALE highly weathered, reddish		16	SS	50/																	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10


(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-03

3 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 587.8 E 586 561.2 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.05.01 - 2014.05.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)					
								○ UNCONFINED		+ FIELD VANE							W P W W L					
	Continued From Previous Page				0.000			20	40	60	80	100					GR	SA	SI	CL		
	brown, frequent limestone fragments, with clayey silt infills		1	RUN				199									No recovery					
	2		RUN															RUN #2 TCR=40% SCR=5% RQD=0%				
	3		RUN																FI >10 2 >10 2 2	RUN #3 TCR=83% SCR=67% RQD=57% UCS=7.2MPa (Average)		
	4		RUN							196												RUN #4 TCR=100% SCR=100% RQD=93% UCS=32.8MPa (Average)
	5		RUN							195												RUN #5 TCR=100% SCR=100% RQD=93% UCS=24.9MPa (Average)
	193.2																					
26.8	END OF BOREHOLE AT 26.8m. BOREHOLE OPEN TO 26.8m AND WATER LEVEL AT 3.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.																					

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-04

1 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 600.2 E 586 598.9 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.04.28 - 2014.04.30 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL	
219.8	GROUND SURFACE															0 18 53 29				
0.0	ASPHALT:(150mm)																			
0.2	SAND and GRAVEL Dense to Compact Brown Dry (FILL)		1	SS	33															
218.6			2	SS	22															
1.2	Silty CLAY , some sand to sandy, trace gravel Very Stiff to Stiff Brown Dry to Moist (TILL)		3	SS	17															
			4	SS	23															
			5	SS	14															
			6	SS	29															
214.2																				
5.6	SAND and SILT , trace to some clay Dense to Compact Brown Wet		7	SS	31															
			8	SS	22															
210.7																				
9.1	Silty CLAY , some sand, trace gravel Hard Reddish Brown Moist (TILL)		9	SS	33															
	</																			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-04

2 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 600.2 E 586 598.9 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.04.28 - 2014.04.30 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100								
			10	SS	41		209						○				0 16 48 36			
							208													
			11	SS	32		207						○							
206.1																				
13.7	SILT , trace to some clay, trace sand Very Dense Brown Wet		12	SS	91		206						○							
							205													
204.6																				
15.2	SAND , trace silt Dense Brown Wet		13	SS	32		204						○				0 94 6 (SI+CL)			
							203						○							
			14	SS	38		202													
201.5																				
18.3	Clayey SILT , some sand, trace gravel		15	SS	112		201						○							
	Hard Reddish Brown Moist to Wet (TILL)																			
			16	SS	50/		200													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-04

3 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 600.2 E 586 598.9 ORIGINATED BY GA
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.04.28 - 2014.04.30 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			GR	SA	SI	CL
Continued From Previous Page								<div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div>																

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-05

1 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 551.6 E 586 582.2 ORIGINATED BY ADH
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.10.06 - 2014.10.08 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	W _P		W	W _L				
218.5	GROUND SURFACE						20	40	60	80	100										
0.0	TOPSOIL: (250mm)																				
218.2																					
0.3	Silty CLAY , sandy to some sand, trace gravel Stiff to Hard Light Brown to Brown Dry to Moist (TILL)		1	SS	8								○								
			2	SS	23								○ —					6	24	46	24
			3	SS	43								○								
			4	SS	30								○								
			5	SS	28								○								
213.9																					
4.6	SAND and SILT , trace clay Dense to Loose Brown to Grey Wet		6	SS	30								○								
			7	SS	7									○							
210.9																					
7.6	Clayey SILT , sandy to some sand Very Stiff Brown to Grey Moist (TILL)		8	SS	26								○								
209.8																					
8.7	SILT , some clay, trace sand Very Stiff Grey Moist to Wet		9	SS	28								○								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			w _P w w _L			
	Continued From Previous Page														
208.3 10.2	Clayey SILT , sandy to some sand Very Stiff to Hard Brown to Grey Moist (TILL)		10	SS	22		208								
								207							
								206							
206.0 12.5	SAND and SILT , trace clay Very Dense Brown Wet		11	SS	56		206								
							205								
							204								
204.6 13.9	SAND and SILT , some gravel, trace clay, occasional cobbles Very Dense Brown Wet (TILL)		12	SS	100/ 0.100		203								
							202								
							201								
			13	SS	60		200								
							199								
201.7 16.8	Clayey SILT , some sand, occasional limestone fragments Hard Reddish Brown to Brown Moist (TILL)		14	SS	100/ 0.125										
			15	SS	126										
			16	SS	100/ 0.100										



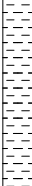

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No UP-05

3 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 551.6 E 586 582.2 ORIGINATED BY ADH
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.10.06 - 2014.10.08 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L						
	Continued From Previous Page				0.100			20	40	60	80	100		20	40	60		
196.8 21.7	Becoming residual shale		1	RUN			198										FI 7 4 1 3 1 2 2	RUN #1 TCR=31% SCR=3% RQD=0%
			2	RUN			197											RUN #2 TCR=100% SCR=88% RQD=67%
	SHALE fresh jointed to fresh, laminated, occasional grey limestone interbeds, reddish brown: (QUEENSTON FORMATION) Limestone interbeds (25mm to 50mm) at 21.9m and 22.2m		3	RUN			196											RUN #3 TCR=100% SCR=91% RQD=82% UCS=36.1MPa (Average)
	Limestone interbeds (25mm to 75mm) at 22.6m, 22.7m, 23.1m and 23.4m		4	RUN			195											RUN #4 TCR=100% SCR=100% RQD=81% UCS=45.1MPa (Average)
	limestone interbeds (25mm to 75mm) at 23.7m, 24.3m and 175mm at 23.5m		5	RUN			194											RUN #5 TCR=100% SCR=100% RQD=91%
193.8 24.7	END OF BOREHOLE AT 24.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																	

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-06

1 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 563.6 E 586 621.7 ORIGINATED BY ADH
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.09.12 - 2014.09.18 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
218.4	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL: (250mm)							20	40	60	80	100					
218.1																	
0.3	Silty CLAY , sandy, trace gravel Very Stiff to Hard Brown Moist (TILL)		1	SS	14		218										
			2	SS	41		217										
			3	SS	59		216										
			4	SS	36		215										
			5	SS	39		214										
							213										
213.5			6	SS	19		212										
4.9	SAND and SILT , trace clay Compact Grey Moist to Wet						211										
			7	SS	18		210										
							209										
210.5			8	SS	16		208										
7.9	Silty CLAY , sandy, trace gravel Very Stiff to Hard Reddish Brown Moist (TILL)						207										
209.7							206										
8.7	SILT , some clay, trace sand Hard Grey Wet						205										
			9	SS	37		204										
208.6							203										
9.8	Silty CLAY , sandy trace gravel						202										

Continued Next Page

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

RECORD OF BOREHOLE No UP-06

2 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 563.6 E 586 621.7 ORIGINATED BY ADH
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.09.12 - 2014.09.18 CHECKED BY KS

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

Continued Next Page

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

RECORD OF BOREHOLE No UP-06

3 OF 3

METRIC

W.P. _____ LOCATION Underpass N 4 819 563.6 E 586 621.7 ORIGINATED BY ADH
 HWY 401 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2014.09.12 - 2014.09.18 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20	40	60	80						100	20	40	60
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
Continued From Previous Page																				
								0.100												
Becoming residual shale																				
196.1																				
22.3	SHALE moderately weathered to fresh, laminated, reddish brown: (QUEENSTON FORMATION)								17 SS 80/ 0.025				○				FI 2			
																4				
Limestone interbed (50mm) at 22.3m								1				RUN				5				
Rubble zone from 24.3m to 24.4m																2				
Limestone interbeds (25mm to 75mm) at 22.8m, 23.1m, 23.3m and 24.1m								2				RUN				5				
Rubble zone from 24.7m to 25.0m																15				
Highly fractured zones from 25.0m to 24.5m and 25.9m to 26.0m																>20				
Limestone interbeds (38mm to 50mm) at 24.5m, 25.0m and 25.4m								3				RUN				14				
192.8																	3			
25.6	END OF BOREHOLE AT 25.6m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.																1			
WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m)																6				
Nov 25/ 14 2.4 216.0																				
Dec 19/ 14 2.1 216.3																				

RUN #1
TCR=100%
SCR=85%
RQD=65%
UCS=20MPa
(Average)

RUN #2
TCR=100%
SCR=79%
RQD=56%
UCS=21.4MPa
(Average)

RUN #3
TCR=100%
SCR=91%
RQD=46%
UCS=27.8MPa
(Average)

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-07

1 OF 2

METRIC

WP# 19-5161-155 LOCATION Underpass N 4 819 648.5 E 586 553.5 ORIGINATED BY ES
 HWY 401 BOREHOLE TYPE Solid Stem Augers/Geoprobe COMPILED BY AN
 DATUM Geodetic DATE 2016.04.14 - 2016.04.14 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100	W _P	W	W _L	kN/m ³				
219.9	GROUND SURFACE															
0.0	SAND , some gravel, trace silt Compact Brown Moist (FILL)		1	SS	11											
219.2																
0.7	Silty CLAY , some sand, trace gravel Stiff Brown Moist (FILL)		2	SS	12		219									
218.4																
1.5	Silty CLAY , some sand to sandy, trace gravel Very Stiff Reddish Brown Damp (TILL)		3	SS	20		218									
			4	SS	16											
							217									
			5	SS	25											
							216									
215.8																
4.1	SILT , some clay, trace sand Dense Grey Damp		6	SS	39		215									
214.3																
5.6	SAND and SILT , trace clay Compact Brown Wet		7	SS	22		214									
							213									
			8	SS	13		212									
							211									
			9	SS	11											
							210									

Continued Next Page

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

RECORD OF BOREHOLE No UP-07

2 OF 2

METRIC

WP# 19-5161-155 LOCATION Underpass N 4 819 648.5 E 586 553.5 ORIGINATED BY ES
 HWY 401 BOREHOLE TYPE Solid Stem Augers/Geoprobe COMPILED BY AN
 DATUM Geodetic DATE 2016.04.14 - 2016.04.14 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
208.8			10	SS	13		209										
11.1	END OF BOREHOLE AT 11.1m. BOREHOLE OPEN TO 8.8m AND WATER LEVEL AT 7.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 19-5161-155 (FOUNDATION) GPJ 2015TEMPLATE(MTO) GDT 12/6/16

RECORD OF BOREHOLE No UP-08

1 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 541.7 E 586 613.8 ORIGINATED BY DJP
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.16 - 2014.09.16 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W _P	W	W _L						
218.5	GROUND SURFACE																				
0.0	TOPSOIL: (100mm)																				
0.1	Clayey SILT , sandy to some sand, trace gravel Firm to Hard Reddish Brown to Brown Moist (TILL)		1	SS	7		218														
			2	SS	19		217														
			3	SS	33		216											2	21 48 29		
			4	SS	38		215														
			5	SS	45		214														
214.4																					
4.1	SAND and SILT , trace clay Dense to Compact Brown Wet		6	SS	38		213														
							212														
			7	SS	12		211											0	5 80 15		
212.2																					
6.3	SILT , some clay, trace sand Compact Reddish Brown Moist		8	SS	50/ 0.125		210														
210.6																					
7.9	SAND and SILT , trace to some clay, some gravel Very Dense Reddish Brown to Brown Moist to Wet (TILL)		9	SS	58		209											13	39 35 13		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-08

2 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 541.7 E 586 613.8 ORIGINATED BY DJP
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.16 - 2014.09.16 CHECKED BY KS

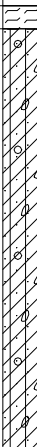
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
207.2			10	SS	51		208										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 9.8m AND WATER LEVEL AT 4.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

RECORD OF BOREHOLE No UP-09

1 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 622.1 E 586 519.0 ORIGINATED BY SLL
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.06 - 2014.10.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
								20 40 60 80 100									
219.4	GROUND SURFACE																
0.0	TOPSOIL: (150mm)																
0.2	Silty CLAY , sandy to some sand, trace gravel Firm to Hard Brown Moist (TILL)		1	SS	7												
			2	SS	18												
			3	SS	20											0 23 52 25	
			4	SS	32												
216.4																	
3.0	SILT , some clay, trace sand Compact Grey Moist		5	SS	16												
215.4																	
4.0	SAND and SILT , trace clay Loose to Compact Brown Wet		6	SS	3											0 49 47 4	
			7	SS	12												
			8	SS	18												
210.9																	
8.5	Silty CLAY , sandy, trace gravel, occasional shale fragments Very Stiff to Hard Brown (TILL)		9	SS	25											0 27 53 20	

Continued Next Page

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

RECORD OF BOREHOLE No UP-09

2 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 622.1 E 586 519.0 ORIGINATED BY SLL
 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.06 - 2014.10.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
							20	40	60	80	100						
	Continued From Previous Page																
208.1			10	SS	35												
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 4.7m AND WATER LEVEL AT 4.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.6m, THEN CUTTINGS TO SURFACE.																

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-10

1 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 643.0 E 586 597.9 ORIGINATED BY MKE
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					w _P w w _L							
218.5	GROUND SURFACE							20	40	60	80	100								
0.0	TOPSOIL: (175mm)							20	40	60	80	100								
0.2	Silty CLAY , sandy to some sand, trace to some gravel Firm to Hard Brown Moist (TILL)		1	SS	4		218								○					
															○					
			2	SS	21		217								○					
			3	SS	21		216								○					
			4	SS	62/ 0.250		215								○					
215.7																				
2.8	SILT , some clay, trace sand Very Stiff Grey Moist		5	SS	25		214								○					
214.4																				
4.1	SAND and SILT , trace clay Compact Brown to Grey Wet		6	SS	20		213								○					
			7	SS	21		212								○					
211.3																				
7.2	Clayey SILT , some sand to sandy, trace gravel Hard Brown/Grey Moist to Wet (TILL)		8	SS	41		211								○					
			9	SS	40		210								○					
208.7							209								○					
9.8	END OF BOREHOLE AT 9.8m.																			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-10

2 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 643.0 E 586 597.9 ORIGINATED BY MKE
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.10.29 - 2014.10.29 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	BOREHOLE OPEN TO 8.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

RECORD OF BOREHOLE No UP-11

1 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 541.0 E 586 565.3 ORIGINATED BY DJP
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.17 - 2014.09.17 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
218.8	GROUND SURFACE													
0.0	TOPSOIL: (100mm)													
0.1	Silty CLAY , sandy to some sand, trace gravel, occasional cobbles Stiff to Hard Brown Moist (TILL)		1	SS	9									
			2	SS	51									
			3	SS	28									
			4	SS	35									
			5	SS	29									
214.7														
4.1	SILT , some sand, trace clay Compact Grey Wet		6	SS	26									
213.9														
4.9	SAND and SILT , trace clay Compact Grey Wet		7	SS	18									0 16 77 7
211.6														
7.2	Silty CLAY , sandy, trace gravel Hard Reddish Brown/Grey Moist (TILL)		8	SS	43									7 25 43 25
210.1														
8.7	SILT , some clay, trace sand Very Stiff Grey Moist to Wet		9	SS	26									
209.0														
9.8	END OF BOREHOLE AT 9.8m.													

Continued Next Page

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

METRIC

[illegible]

RECORD OF BOREHOLE No UP-12

1 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 563.5 E 586 642.1 ORIGINATED BY DJP
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.17 - 2014.09.17 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								20 40 60 80 100				w _P w w _L							
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
218.2	GROUND SURFACE						218												
0.0	TOPSOIL: (100mm) Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Firm to Hard Dark Brown to Brown Dry to Moist (TILL)																		
0.1			1	SS	6														
			2	SS	43														
			3	SS	37														
		4	SS	39															
215.0								215											
3.2	SILT , trace clay and sand Dense Grey Damp		5	SS	36														
214.1								214											
4.1	SAND and SILT , trace clay Compact Brown to Grey Wet		6	SS	14														
							213												
							212												
211.0							211												
7.2	Clayey SILT , sandy, trace gravel, occasional cobbles Hard Brown to Grey Moist (TILL)		8	SS	73														
							210												
208.9			9	SS	95/		209												
9.3	END OF BOREHOLE AT 9.3m. BOREHOLE OPEN TO 4.6m AND WATER LEVEL AT 4.4m. BOREHOLE BACKFILLED WITH				0.175														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UP-12

2 OF 2

METRIC

W.P. _____ LOCATION Underpass N 4 819 563.5 E 586 642.1 ORIGINATED BY DJP
 HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2014.09.17 - 2014.09.17 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 19-5161-155 (FOUNDATION).GPJ 2015TEMPLATE(MTO).GDT 4/2/15

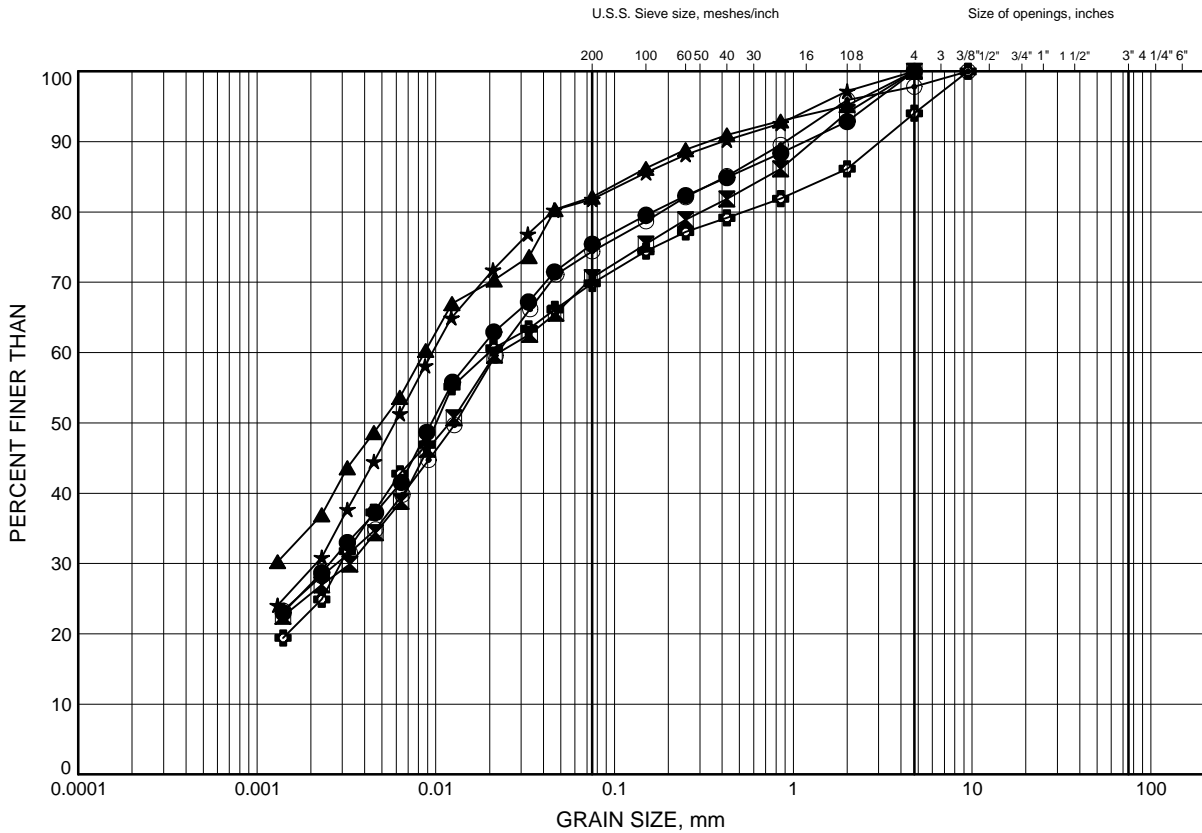
Appendix B

Laboratory Test Results

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B1a

Upper Silty CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-01	2.59	216.81
⊠	UP-02	2.51	216.19
▲	UP-03	2.59	217.41
★	UP-04	1.83	217.97
⊙	UP-04	4.88	214.92
⊕	UP-05	1.07	217.43

Date March 2015
 W.P. _____

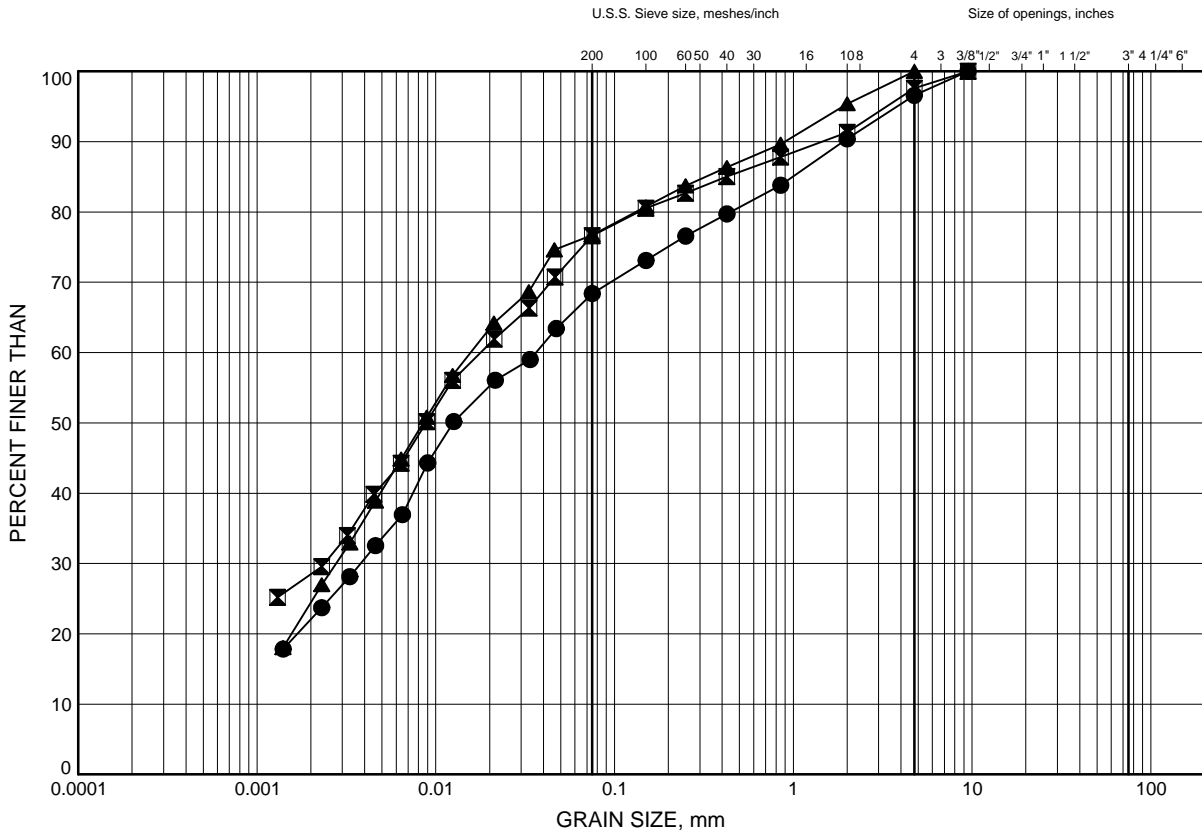


Prep'd AN
 Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B1b

Upper Silty CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-06	3.35	215.05
⊠	UP-08	1.83	216.67
▲	UP-09	1.83	217.57

Date March 2015
W.P. _____

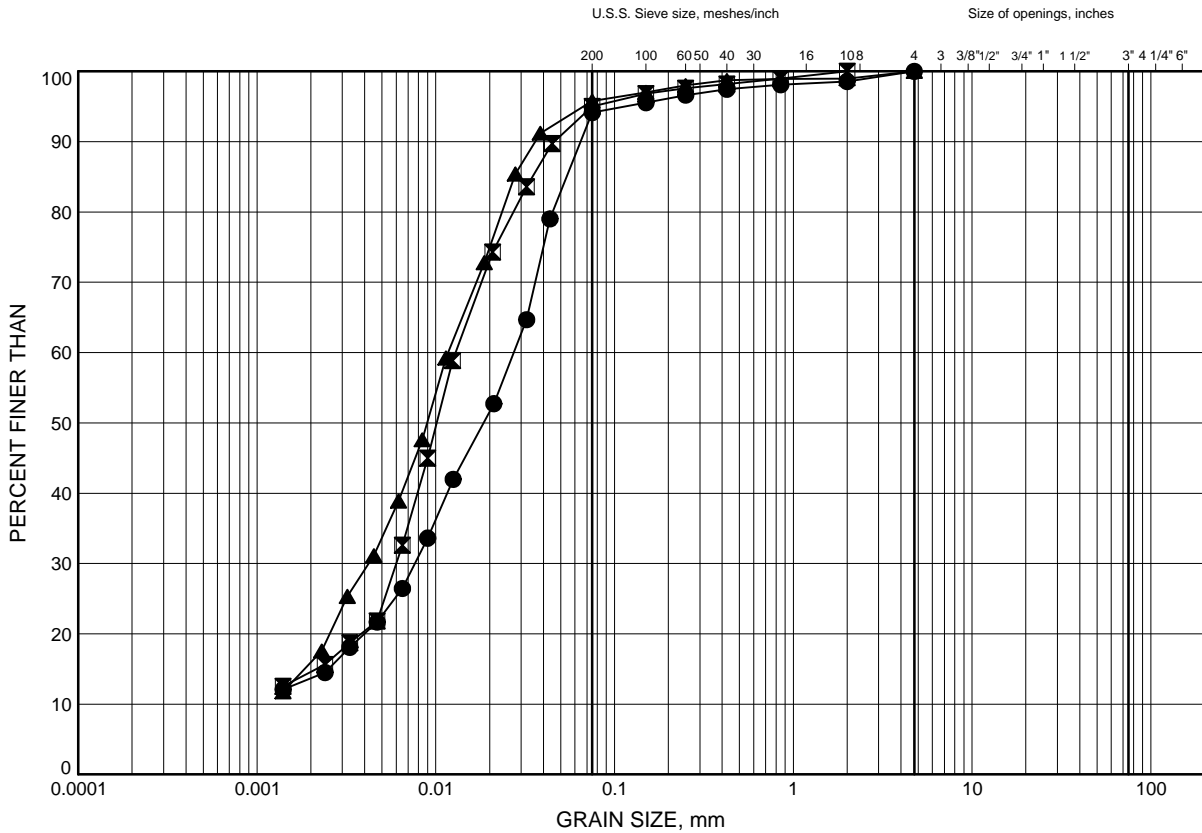


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B2a

Upper SILT, Some Clay



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-05	9.45	209.05
⊠	UP-08	6.53	211.97
▲	UP-10	3.35	215.15

Date March 2015
W.P. _____



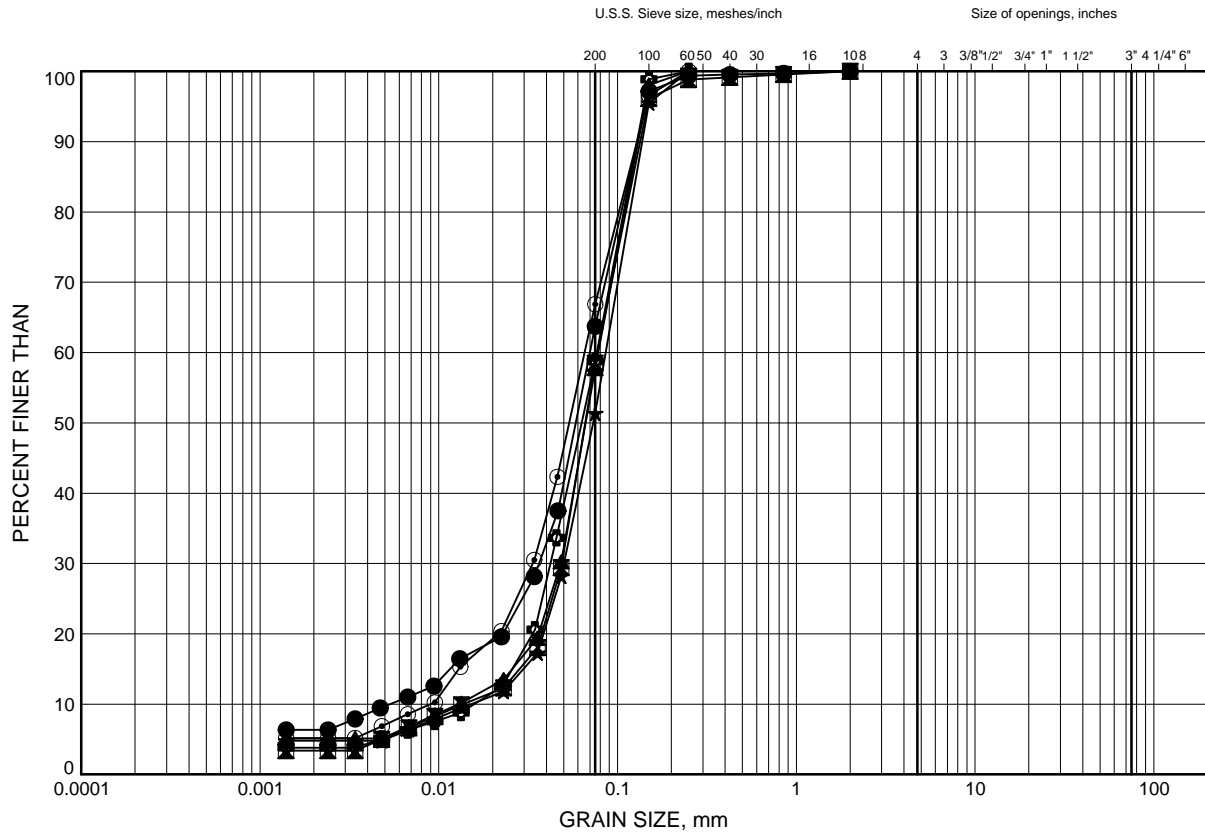
Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401

GRAIN SIZE DISTRIBUTION

FIGURE B2b

Upper SAND & SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-01	6.40	213.00
⊠	UP-03	7.92	212.08
▲	UP-06	6.40	212.00
★	UP-09	4.88	214.52
⊙	UP-10	6.40	212.10
⊕	UP-12	4.88	213.32

Date March 2015
W.P. _____

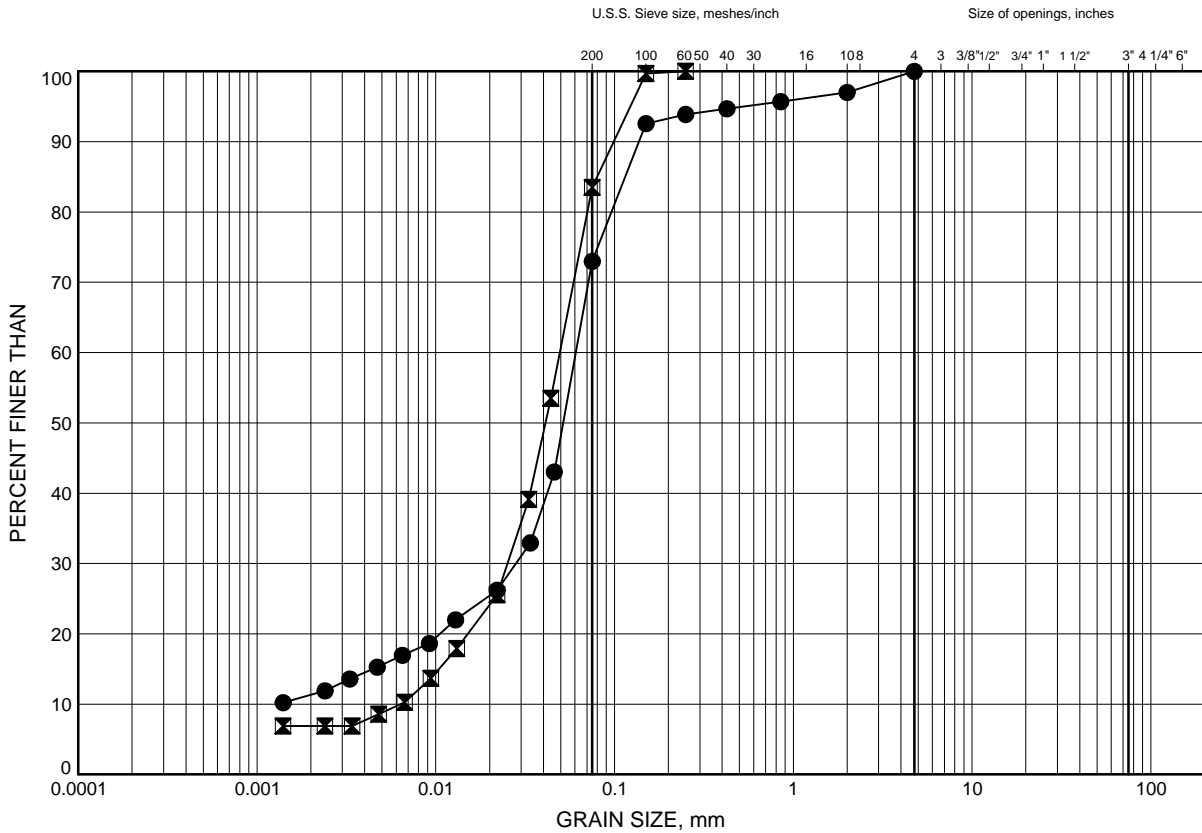


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B2c

Upper Sandy SILT to SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-04	6.40	213.40
⊠	UP-11	4.88	213.92

Date March 2015
W.P. _____

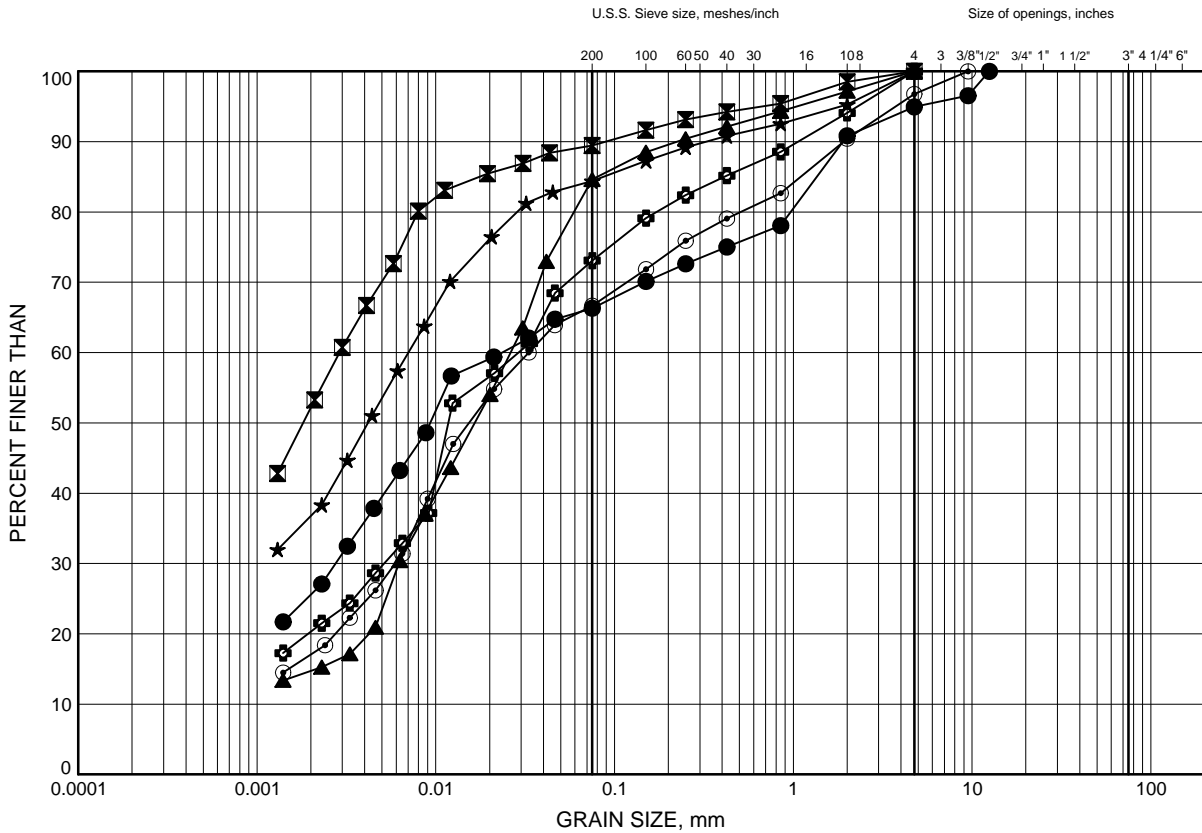


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B3a

Middle Silty CLAY to Clayey SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-02	9.45	209.25
⊠	UP-02	12.50	206.20
▲	UP-03	10.97	209.03
★	UP-04	10.97	208.83
⊙	UP-06	12.27	206.13
⊕	UP-09	9.45	209.95

Date March 2015
W.P. _____

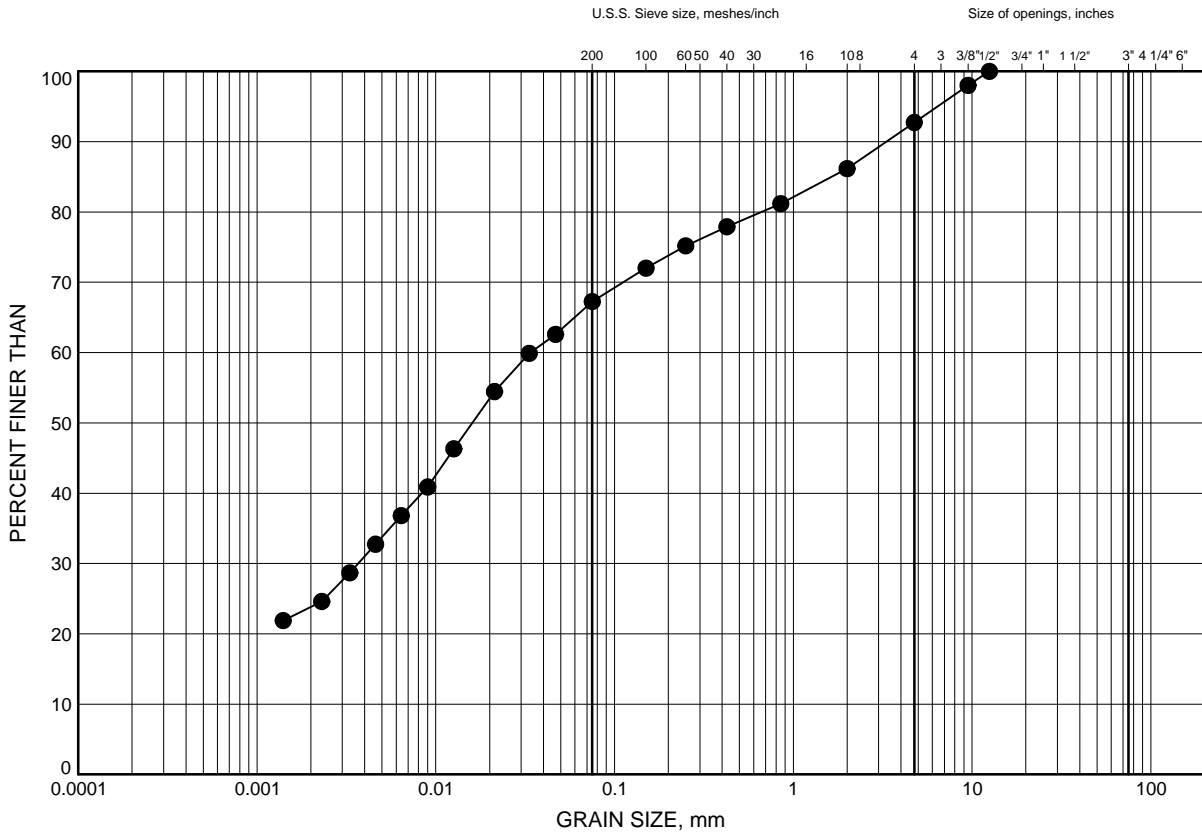


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B3b

Middle Silty CLAY to Clayey SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-11	7.92	210.88

Date March 2015
W.P. _____

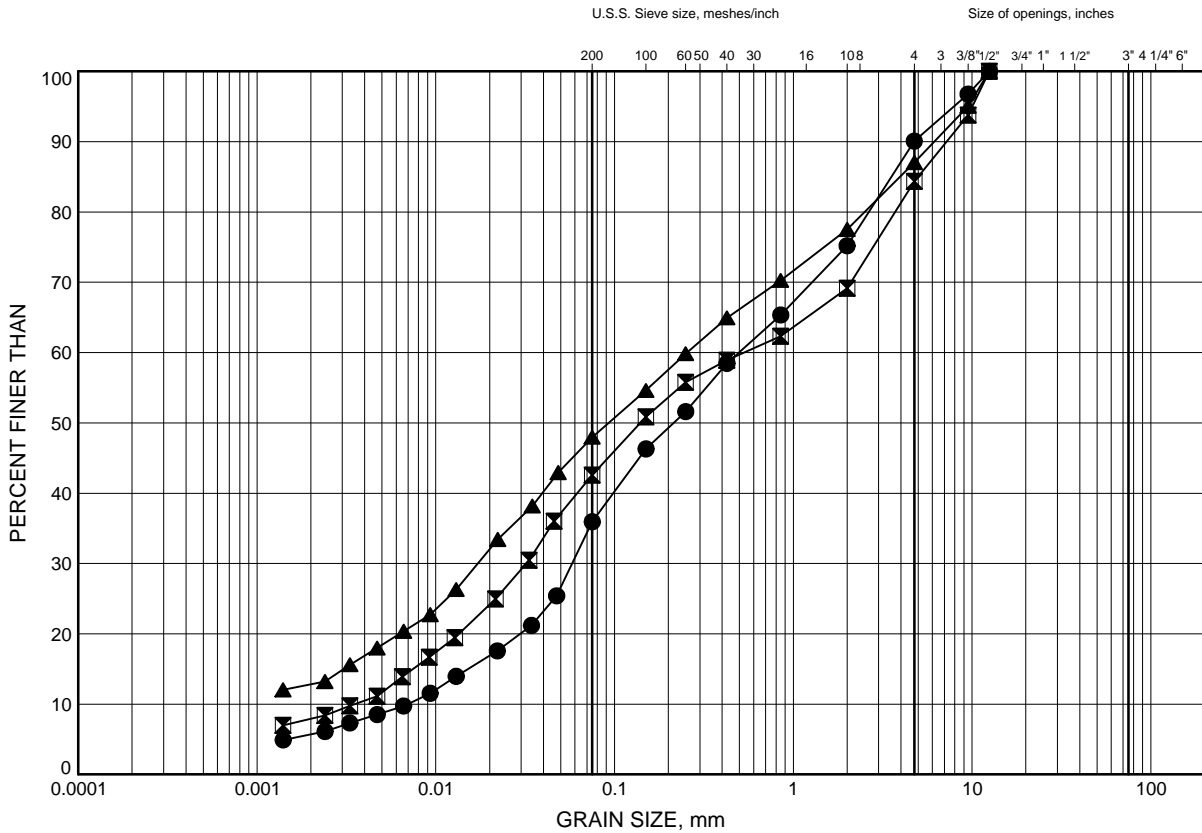


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND & SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-02	17.07	201.63
⊠	UP-05	15.54	202.96
▲	UP-08	9.45	209.05

Date March 2015
W.P. _____



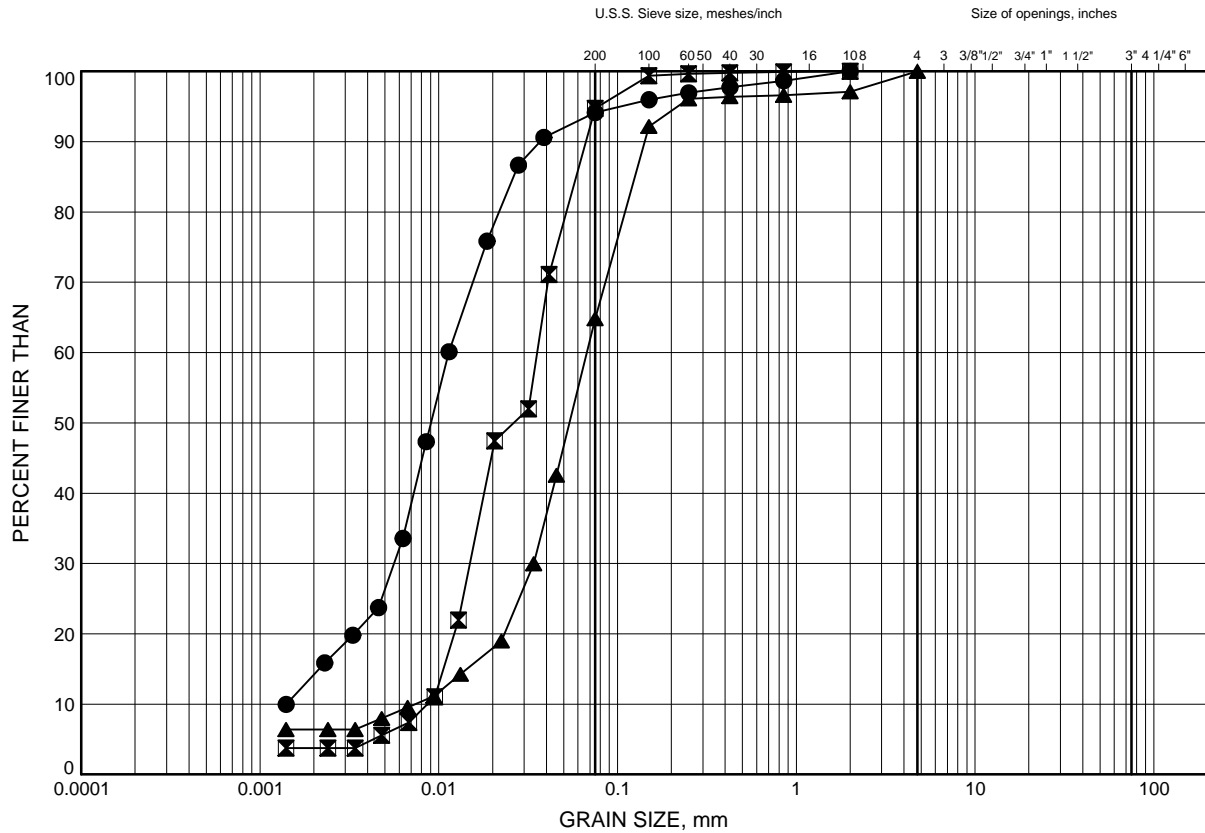
Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401

GRAIN SIZE DISTRIBUTION

FIGURE B5

Lower SILT to SAND & SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-01	12.50	206.90
⊠	UP-03	15.54	204.46
▲	UP-06	16.84	201.56

Date March 2015
W.P. _____

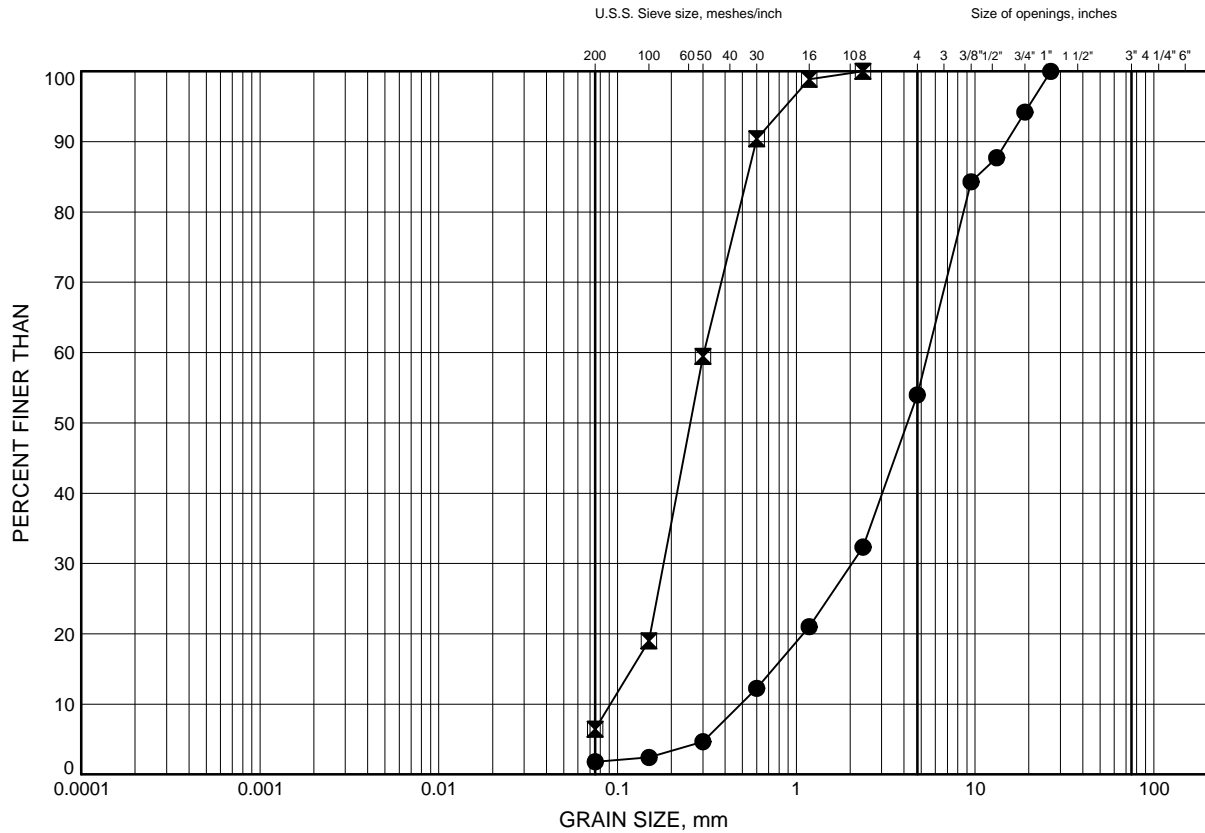


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND to SAND & GRAVEL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-01	15.40	204.00
⊠	UP-04	15.54	204.26

Date March 2015
W.P. _____

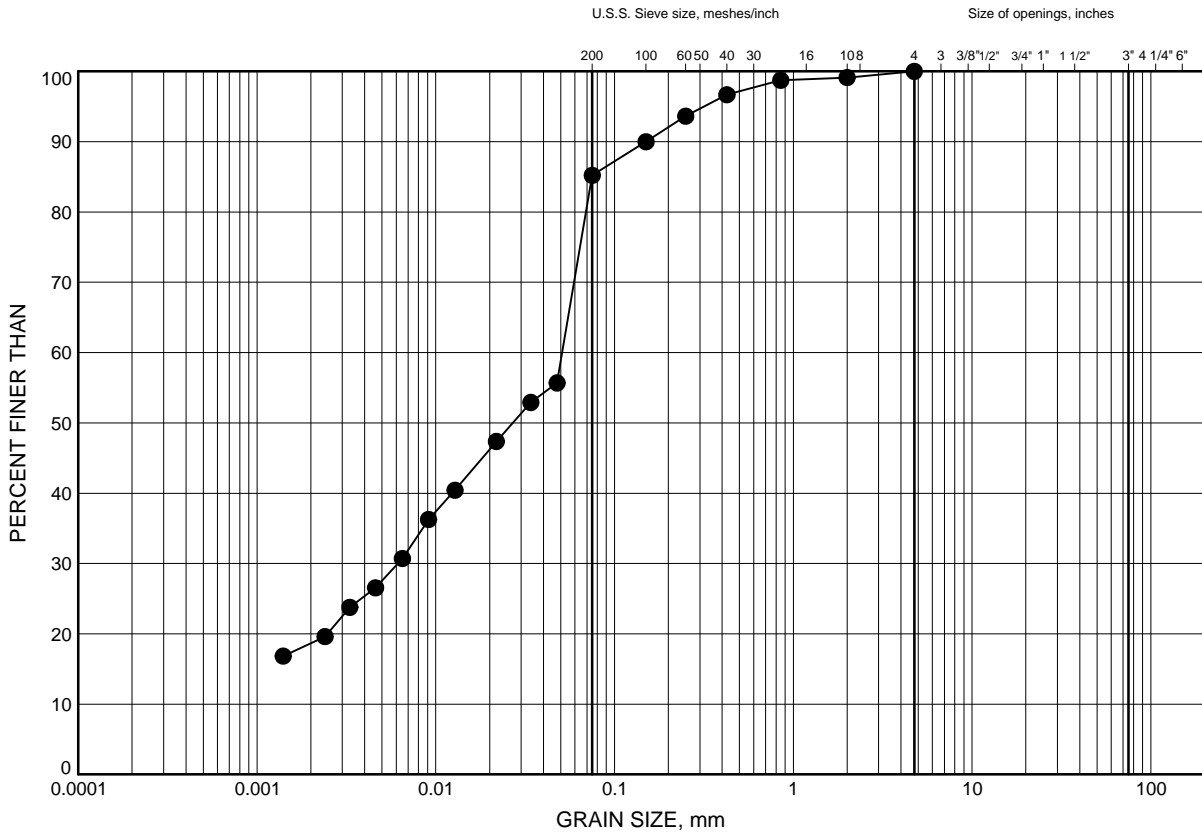


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
GRAIN SIZE DISTRIBUTION

FIGURE B7

Lower Clayey SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-05	18.44	200.06

Date March 2015
W.P. _____

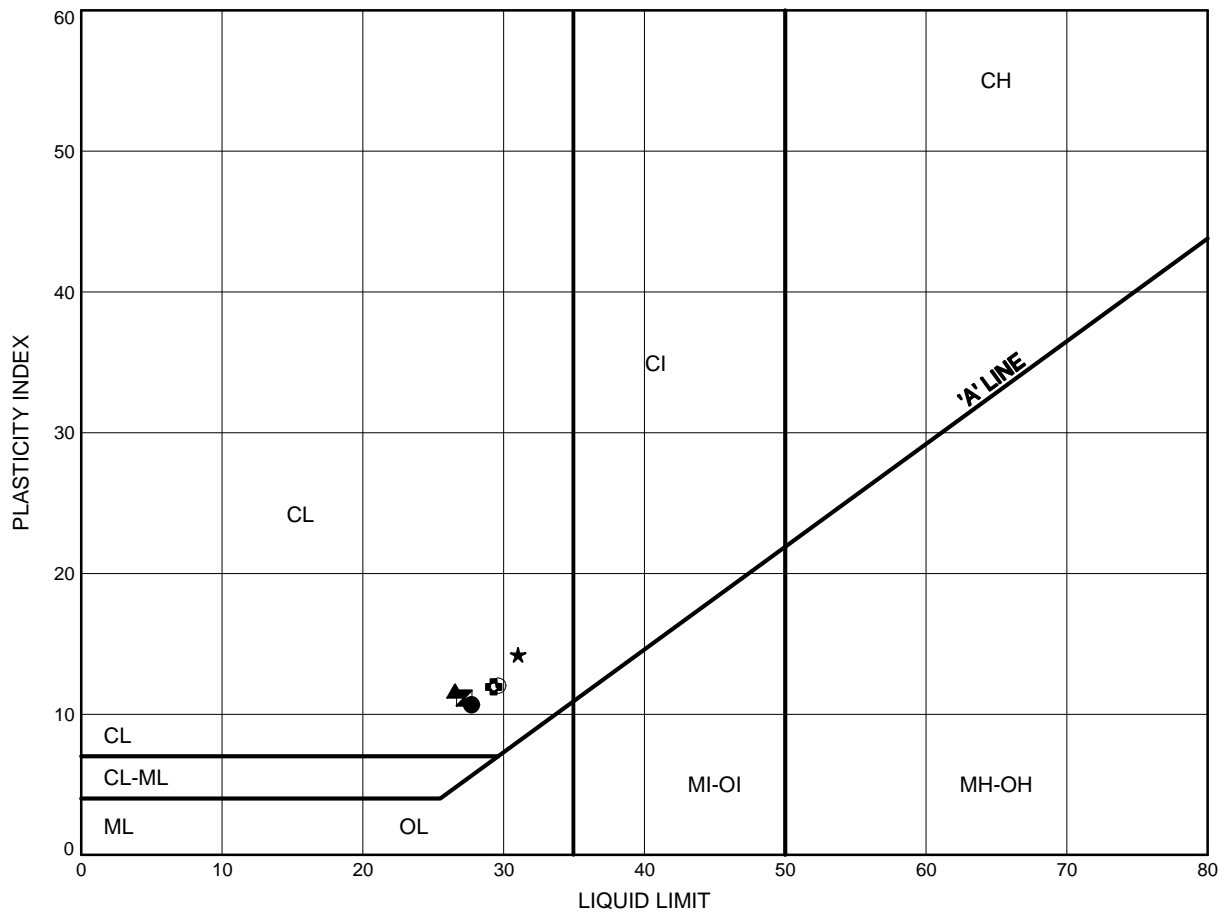


Prep'd AN
Chkd. MRA

New Tremaine Road I/C at Hwy 401
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Upper Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-01	2.59	216.81
⊠	UP-02	2.51	216.19
▲	UP-04	2.59	217.21
★	UP-05	1.07	217.43
⊙	UP-08	1.83	216.67
⊕	UP-09	1.83	217.57

Date March 2015
 W.P. _____

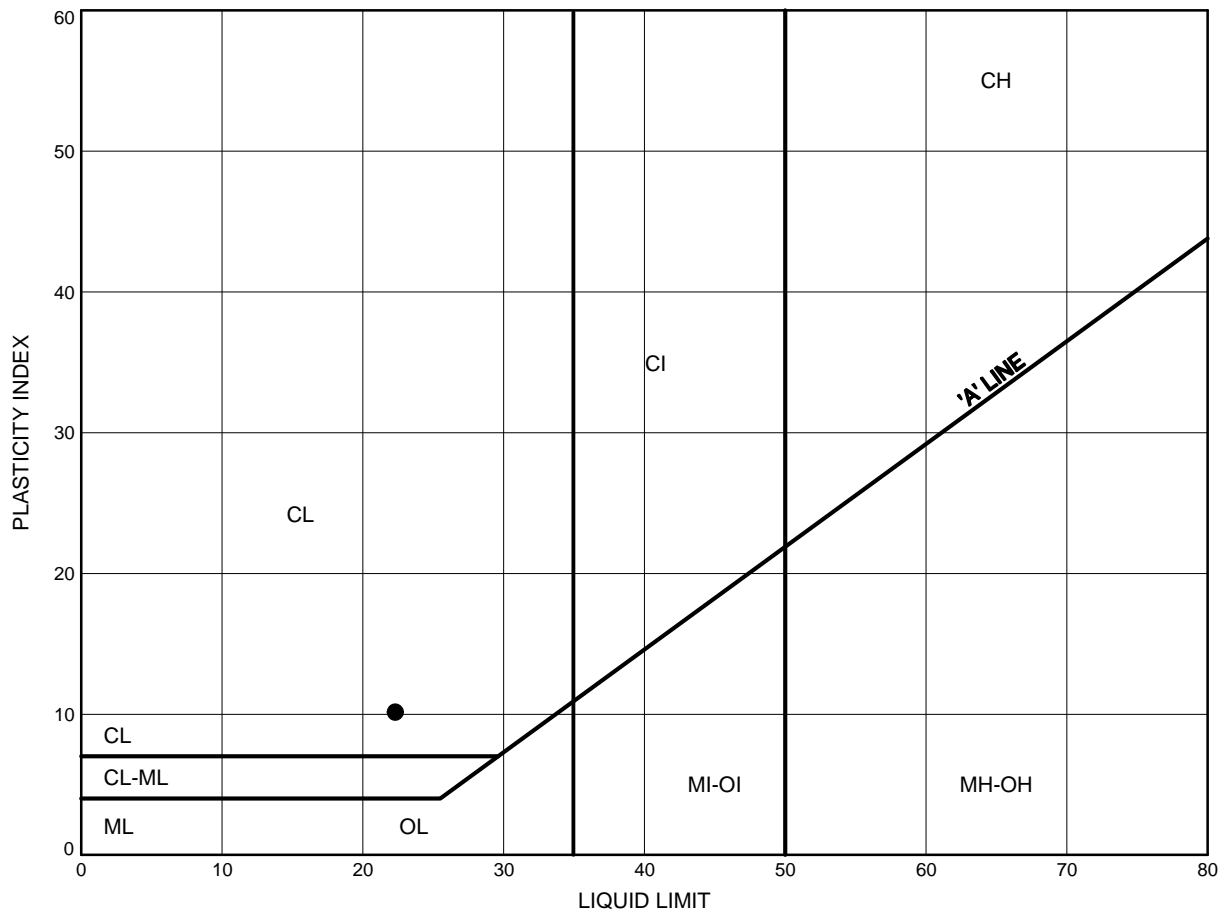


Prep'd AN
 Chkd. MRA

New Tremaine Road I/C at Hwy 401
ATTERBERG LIMITS TEST RESULTS

FIGURE B9

Upper SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-10	3.35	215.15

Date March 2015
 W.P. _____

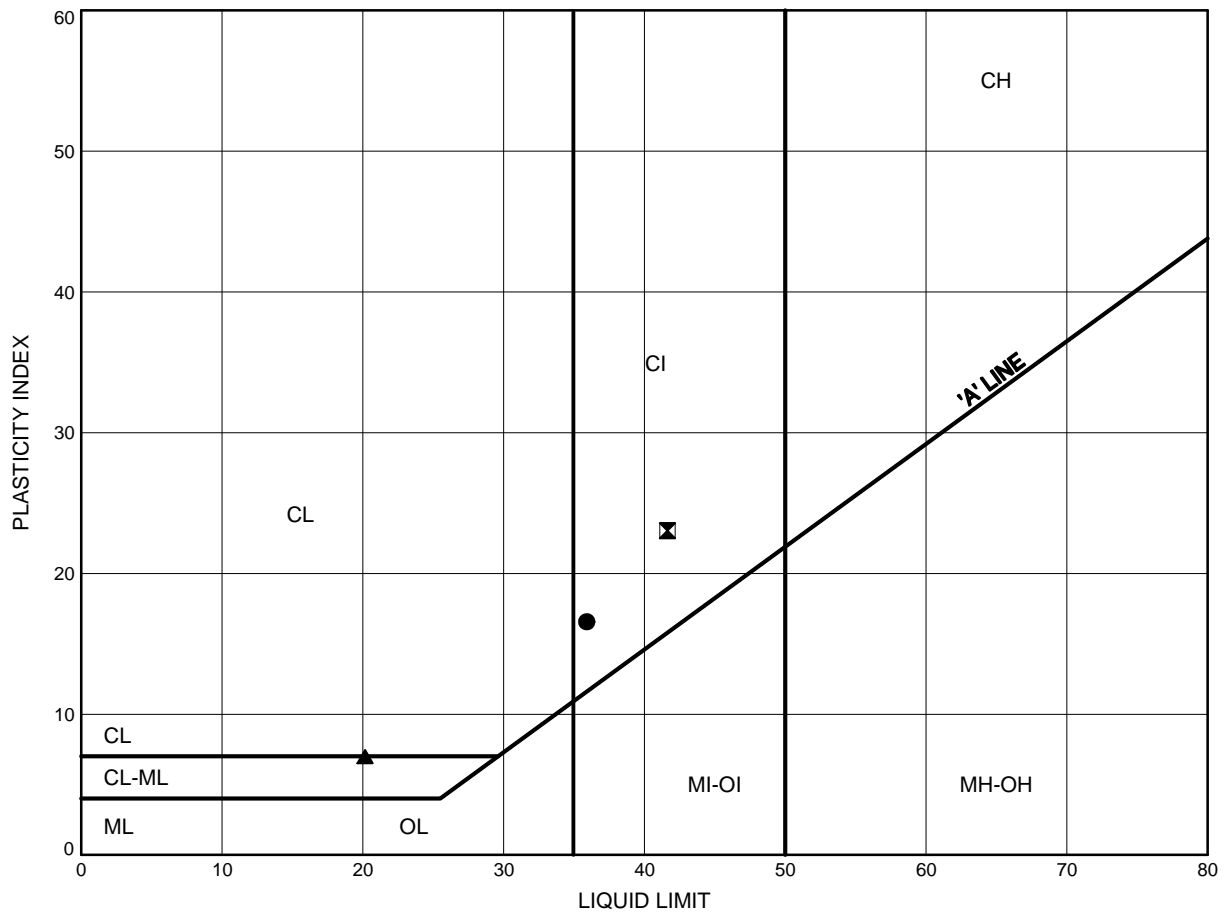


Prep'd AN
 Chkd. MRA

New Tremaine Road I/C at Hwy 401
ATTERBERG LIMITS TEST RESULTS

FIGURE B10

Middle Silty CLAY to Clayey SILT TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-02	12.50	206.20
⊠	UP-04	10.97	208.83
▲	UP-06	12.27	206.13

Date March 2015
 W.P. _____



Prep'd AN
 Chkd. MRA

Appendix C

Site Photographs



Photograph 1: Looking Northwest towards Underpass Location



Photograph 2 – Looking East at Underpass Location

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Engineered Fill	Driven Piles	Caissons
<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Less potential for construction impacts due to cobbles and boulders in the till. iii. Lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Relatively large footings may be required due to modest geotechnical resistance available at this site. ii. Does not allow use of integral abutment design. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Higher geotechnical resistance than footings on native soil. iii. Generally lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Additional cost of engineered fill placement. ii. Increased costs of shoring and roadway protection due to deeper excavation for fill placement. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Piles will develop high geotechnical resistance when driven to hard till or bedrock. ii. Pile installation may continue on freezing weather. iii. May require less excavation than footing construction. iv. Allows use of integral abutments. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost than footings. ii. Possibility that cobbles and boulders may be encountered in the till deposits. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High resistance is available for caissons founded in bedrock. ii. Construction could continue in freezing weather. iii. Minimizes construction area within highway median. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Much higher cost than shallow footings. ii. Possibility of encountering cobbles and boulders in the underlying soils. iii. Temporary steel liners will be required to install caissons through cohesionless soils below groundwater table. iv. Difficulty in cleaning and inspecting bases.
FEASIBLE	FEASIBLE	RECOMMENDED	FEASIBLE

Appendix E

List of Standard Specifications and Special Provisions

1) The following Standard Specifications and Special Provisions are referenced in this report:

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 212	Construction Specification for Earth Borrow
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 902	Construction Specification for Excavating and Backfilling – Structures
OPSS.PROV 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
SP 105S09	Amendment to OPSS 539

2) Suggested Wording for “NSSP – Caisson Excavation”

Caisson installation shall be in accordance with OPSS.PROV 903. The Contractor is further advised of the following:

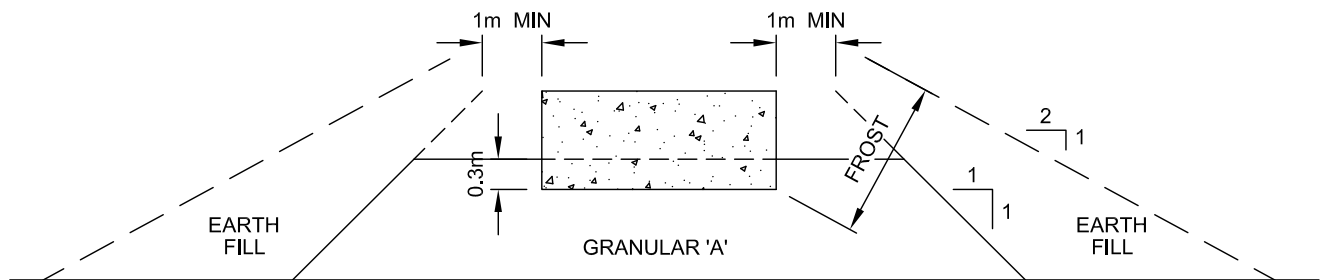
- The caissons will be advanced through successive deposits of stiff to very stiff silty clay till, compact to dense sand and silt, very stiff to hard clayey silt to silty clay till, compact to very dense silt and sand, and hard clayey silt till prior to contacting bedrock. The caisson drilling equipment supplied by the Contractor must be capable of advancing through these materials, penetrating very dense/hard material, and dislodging, removing or penetrating any obstructions such as cobbles, boulders, and rock fragments in the till deposits.
- In general, caisson excavation will take place below the measured groundwater level on site. Synthetic drilling slurry and/or installation of a steel liner sealed into the shale bedrock will be required to support the caisson sidewalls in the cohesionless sand and silt layers. The use of synthetic slurry and/or maintaining an adequate head of water in the liner during drilling will be required to avoid hydraulic disturbance and heave at the caisson base. Caisson liners extended to the weathered bedrock may either be removed as the concrete is placed (temporary) or can be left in place (permanent).
- The shale bedrock generally becomes harder/more sound with depth and contains hard siltstone or limestone interbeds. In addition, clay seams and highly fracture zones are present, particularly at the west end of the pier location. The presence of the hard layers, clay seams and fractured zones may impact auger production, and coring equipment may be required to penetrate hard layers during socketing of the caissons. The caisson drilling equipment selected by the contractor must be capable of advancing through shale of variable strength and quality.

3) Suggested Wording for “NSSP – Inspection of Caisson Excavation”

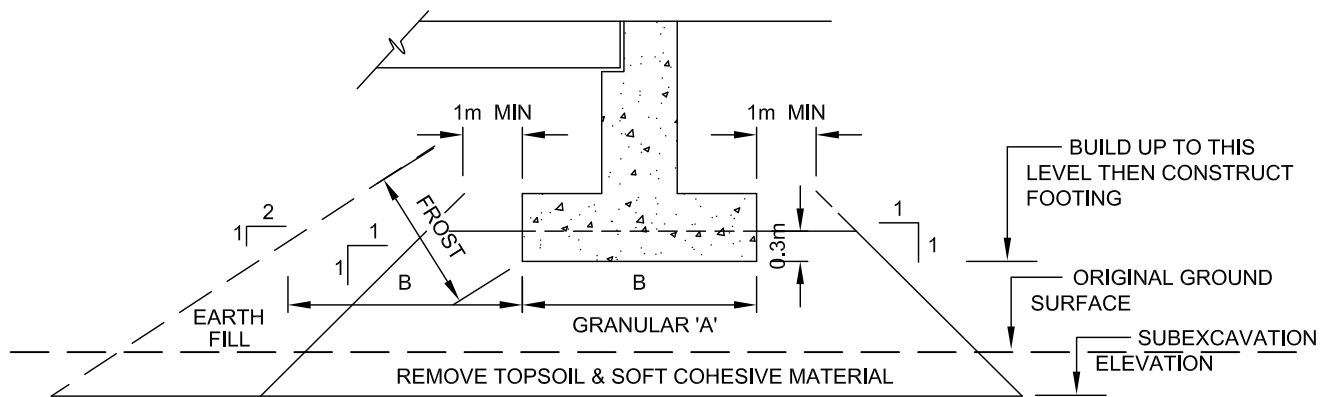
The Contractor shall use appropriate means such as a cleanout bucket, air lift, hydraulic pump, or other devices approved by the Engineer to clean the bottom of the excavation of all shafts. A clean-out bucket alone is not sufficient for final clean-out. The cleaning methods, inspection method, and any additional measures required to satisfy the acceptance criteria must be selected by the contractor to ensure direct contact between the concrete and undisturbed bedrock at the socket base. It is the Contractor’s responsibility to apply means necessary (such as air lift pump or hydraulic pump, etc.) to clean the socket base and sidewalls.

The bottom of the excavated shaft shall be inspected using a Shaft Inspection Device (SID), Shaft Quantitative Inspection Device (SQUID), down-hole camera (subject to adequate flushing of sediment), and/or an approved alternate to verify socket cleanliness and thickness of base sediment at the time of concreting. A minimum of 50 percent of the base of each shaft shall have less than 15mm of sediment at the time of concrete placement. The maximum depth of sediment or any debris at any place on the base of the shaft shall not exceed 40mm at the time of concrete placement.

A shaft inspection field report shall be submitted to the Engineer for acceptance prior to proceeding with construction. Concrete placement shall commence no later than 6 hours after acceptance of the excavation.



CROSS-SECTION



LONGITUDINAL SECTION

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ABUTMENT ON COMPACTED FILL
SHOWING GRANULAR 'A' CORE



THURBER ENGINEERING LTD.

ENGINEER :

MRA

DRAWN :

MFA

APPROVED :

-

DATE :

MARCH 2015

SCALE :

N.T.S.

DRAWING No.

FIGURE 1

Appendix F
Slope Stability Analyses

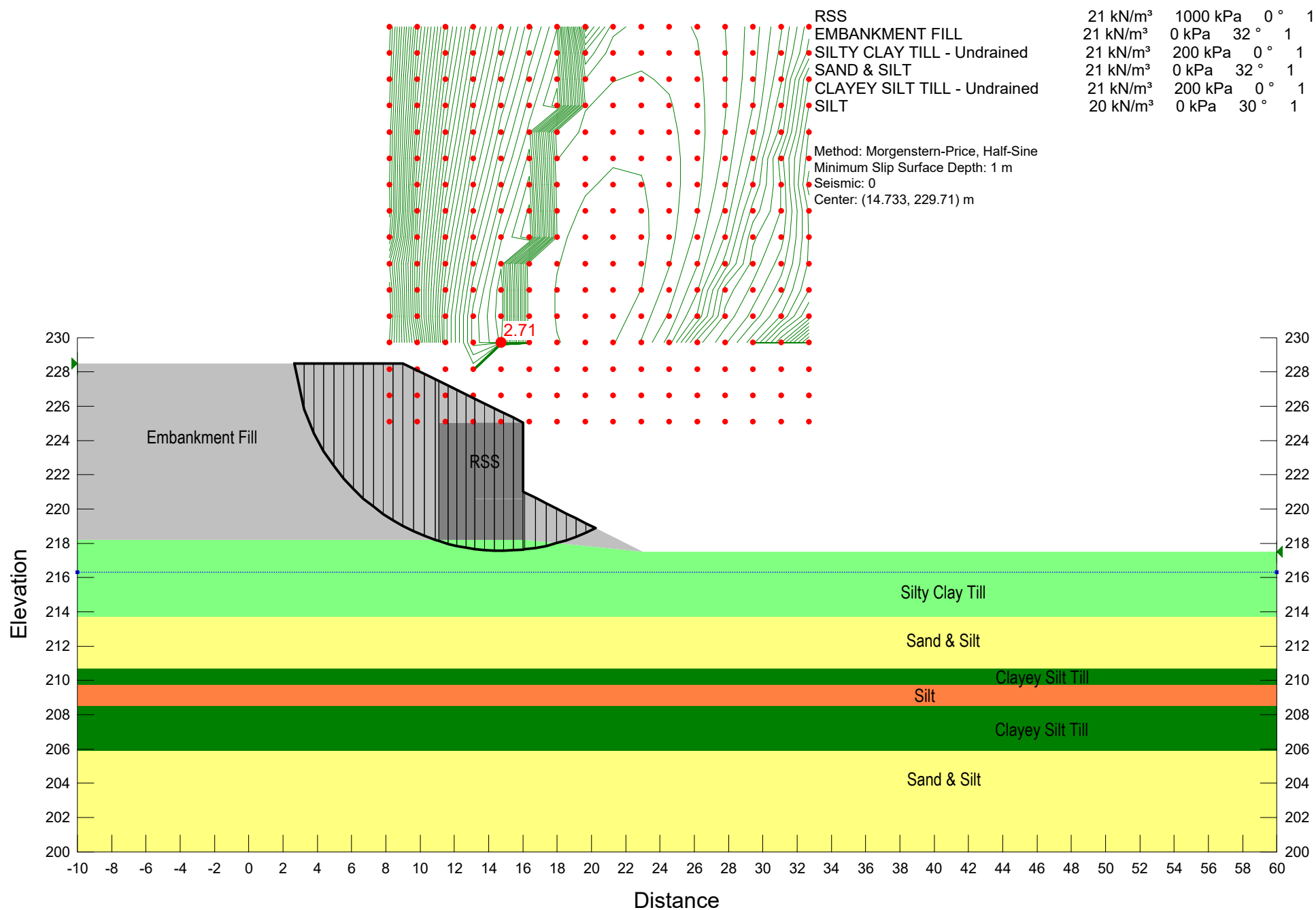


FIGURE F1

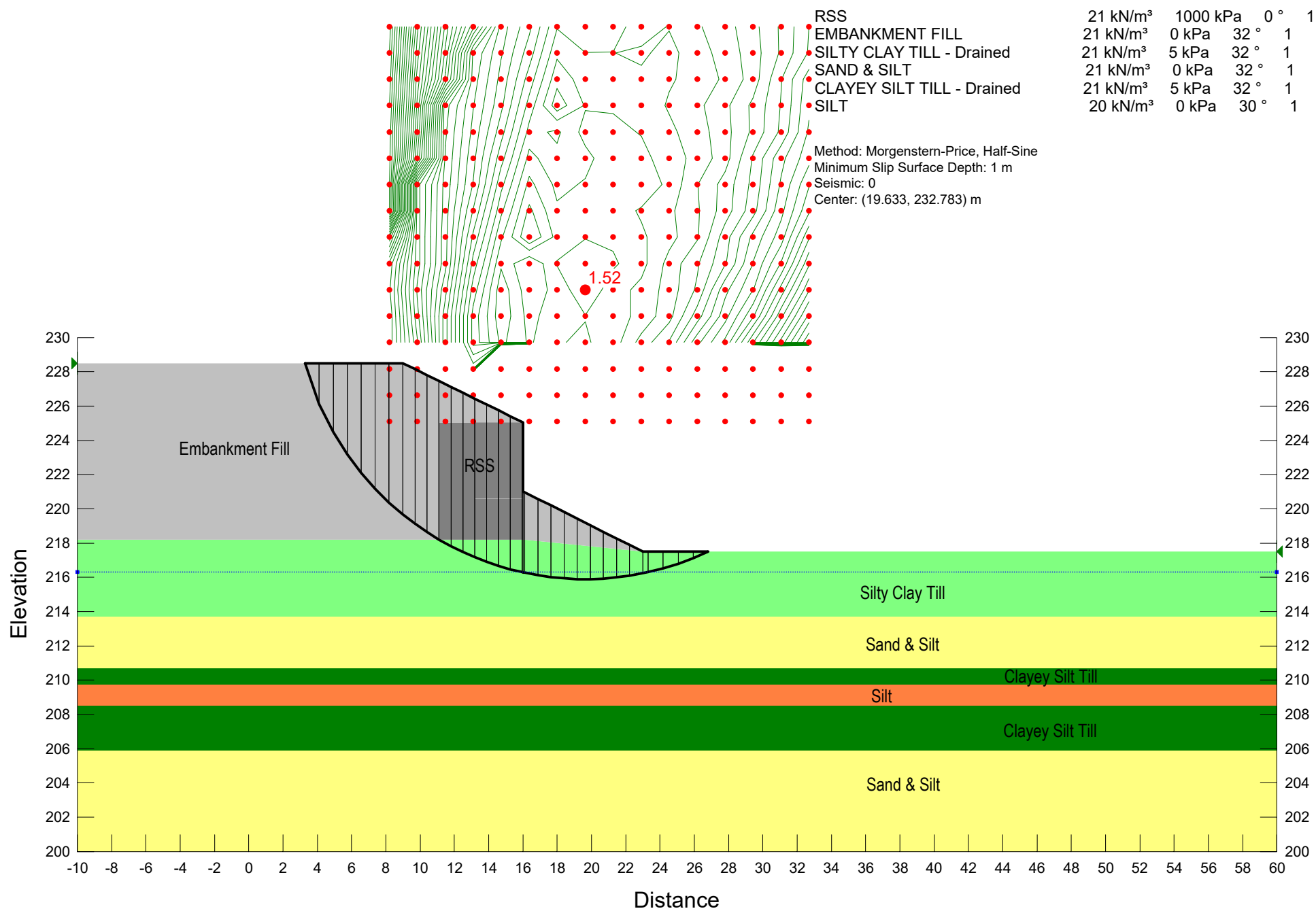


FIGURE F2

RSS
 EMBANKMENT FILL
 SILTY CLAY TILL - Undrained
 SAND & SILT
 CLAYEY SILT TILL - Undrained
 SILT

21 kN/m ³	1000 kPa	0°
21 kN/m ³	0 kPa	32°
21 kN/m ³	200 kPa	0°
21 kN/m ³	0 kPa	32°
21 kN/m ³	200 kPa	0°
20 kN/m ³	0 kPa	30°

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1 m
 Seismic: 0
 Center: (19.267, 234.783) m

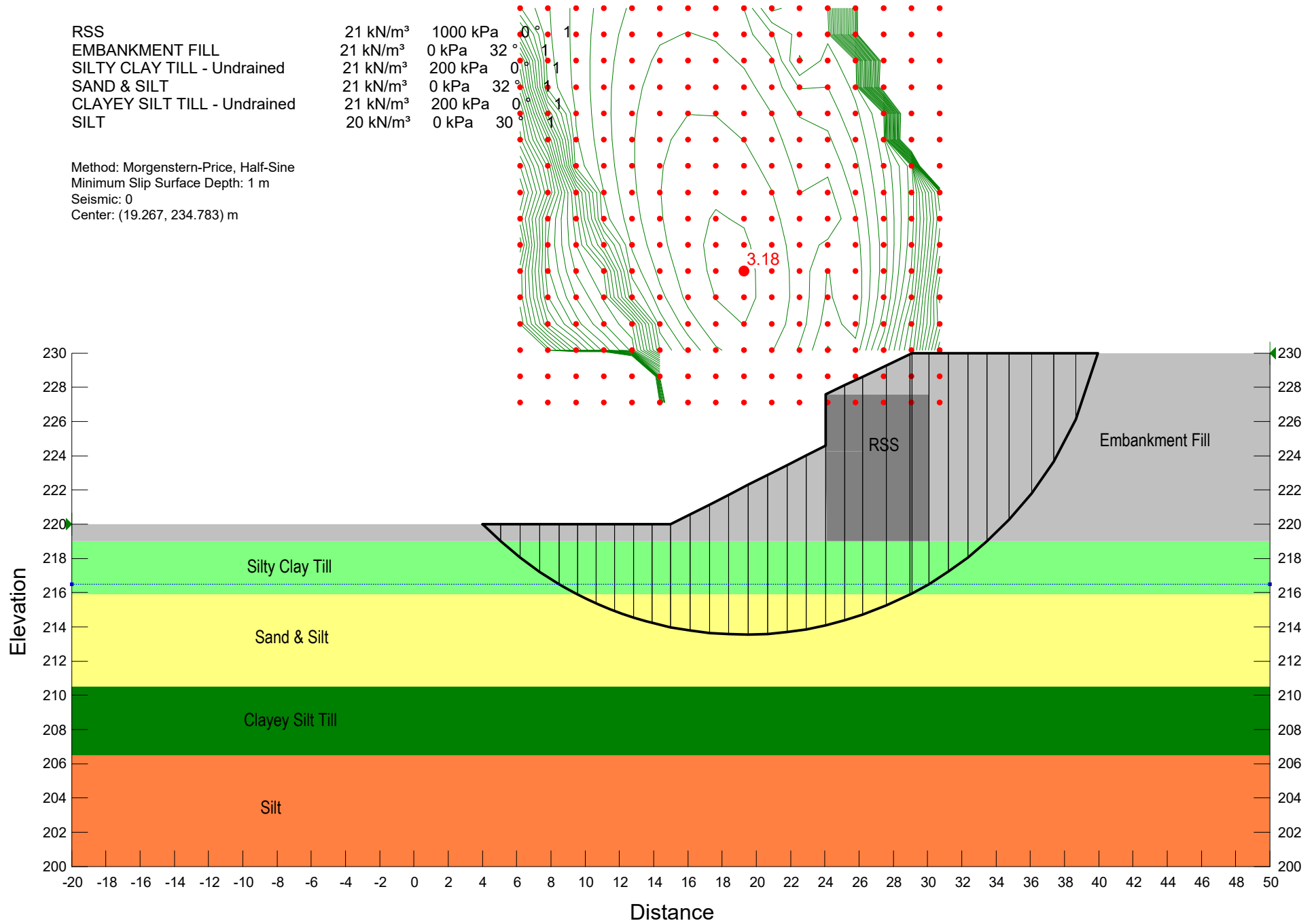


FIGURE F3

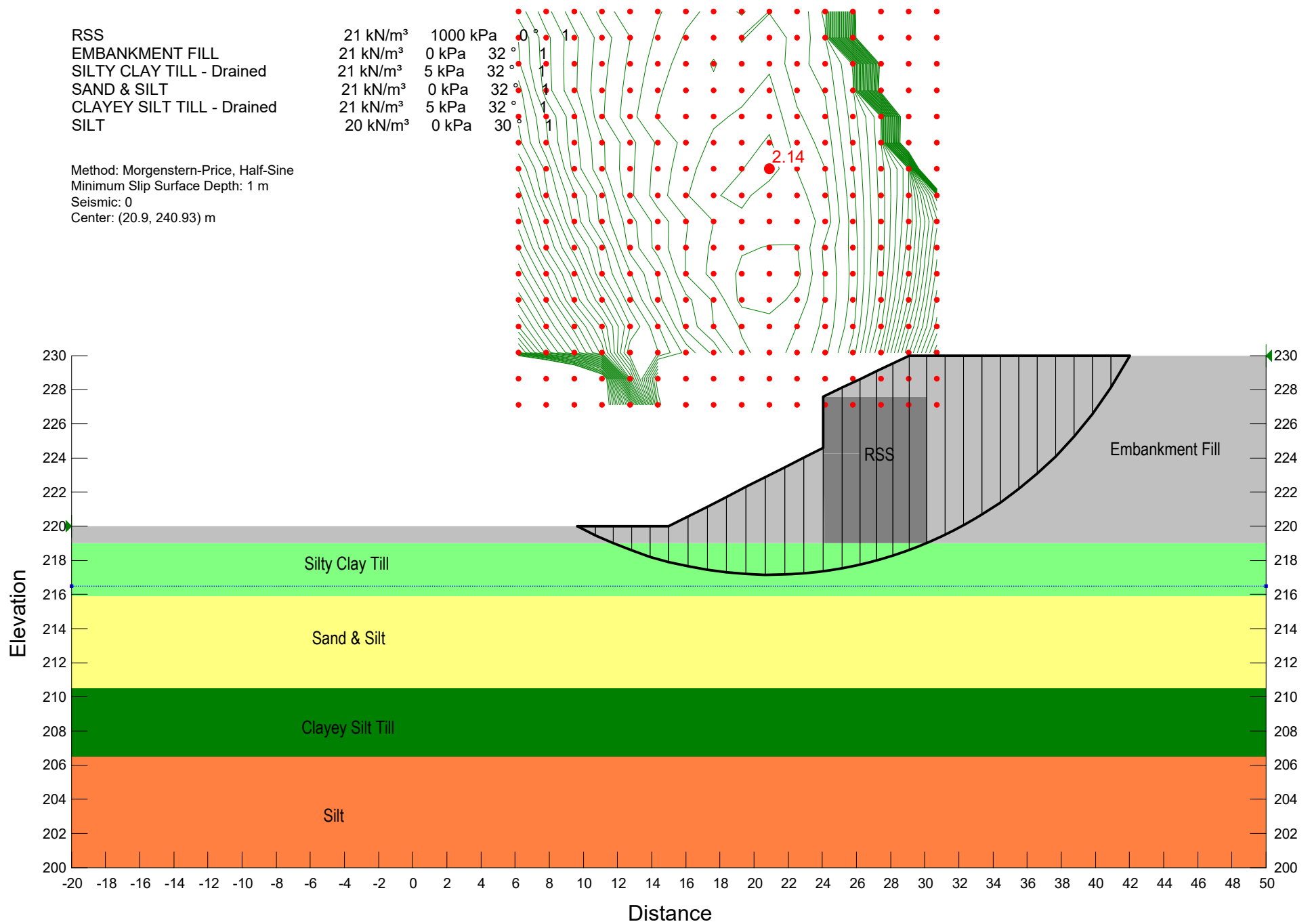


FIGURE F4

RSS
 EMBANKMENT FILL
 SILTY CLAY TILL - Undrained
 SAND & SILT
 CLAYEY SILT TILL - Undrained
 SILT

21 kN/m ³	1000 kPa	0°	1
21 kN/m ³	0 kPa	32°	1
21 kN/m ³	200 kPa	0°	1
21 kN/m ³	0 kPa	32°	1
21 kN/m ³	200 kPa	0°	1
20 kN/m ³	0 kPa	30°	1

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1 m
 Seismic: 0
 Center: (20.9, 236.32) m

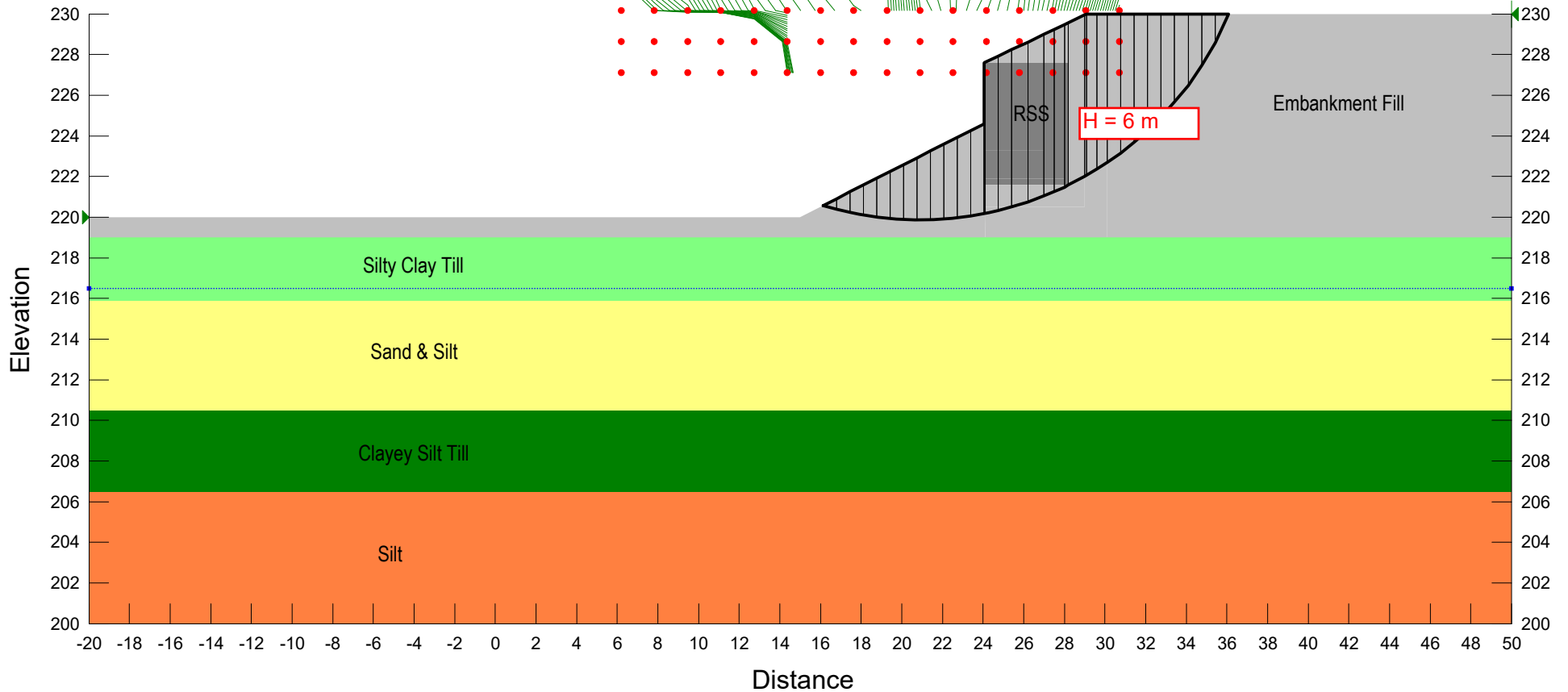
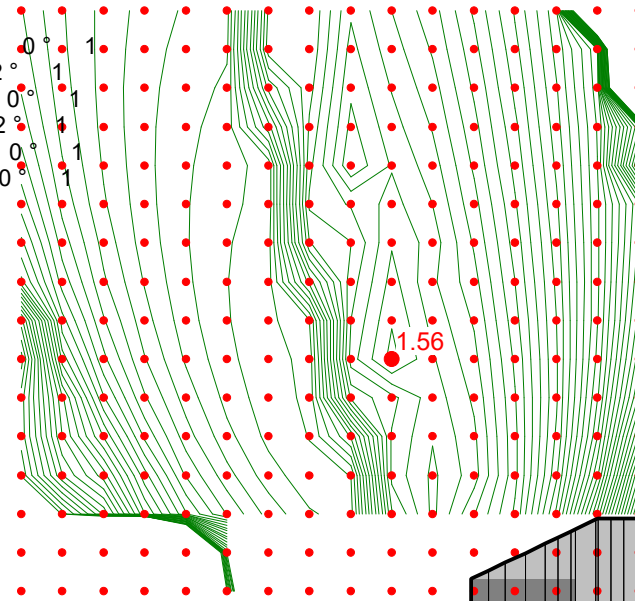


FIGURE F5

RSS
 EMBANKMENT FILL
 SILTY CLAY TILL - Drained
 SAND & SILT
 CLAYEY SILT TILL - Drained
 SILT

21 kN/m ³	1000 kPa	0 °
21 kN/m ³	0 kPa	32 °
21 kN/m ³	5 kPa	32 °
21 kN/m ³	0 kPa	32 °
21 kN/m ³	5 kPa	32 °
20 kN/m ³	0 kPa	30 °

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1 m
 Seismic: 0
 Center: (19.267, 236.32) m

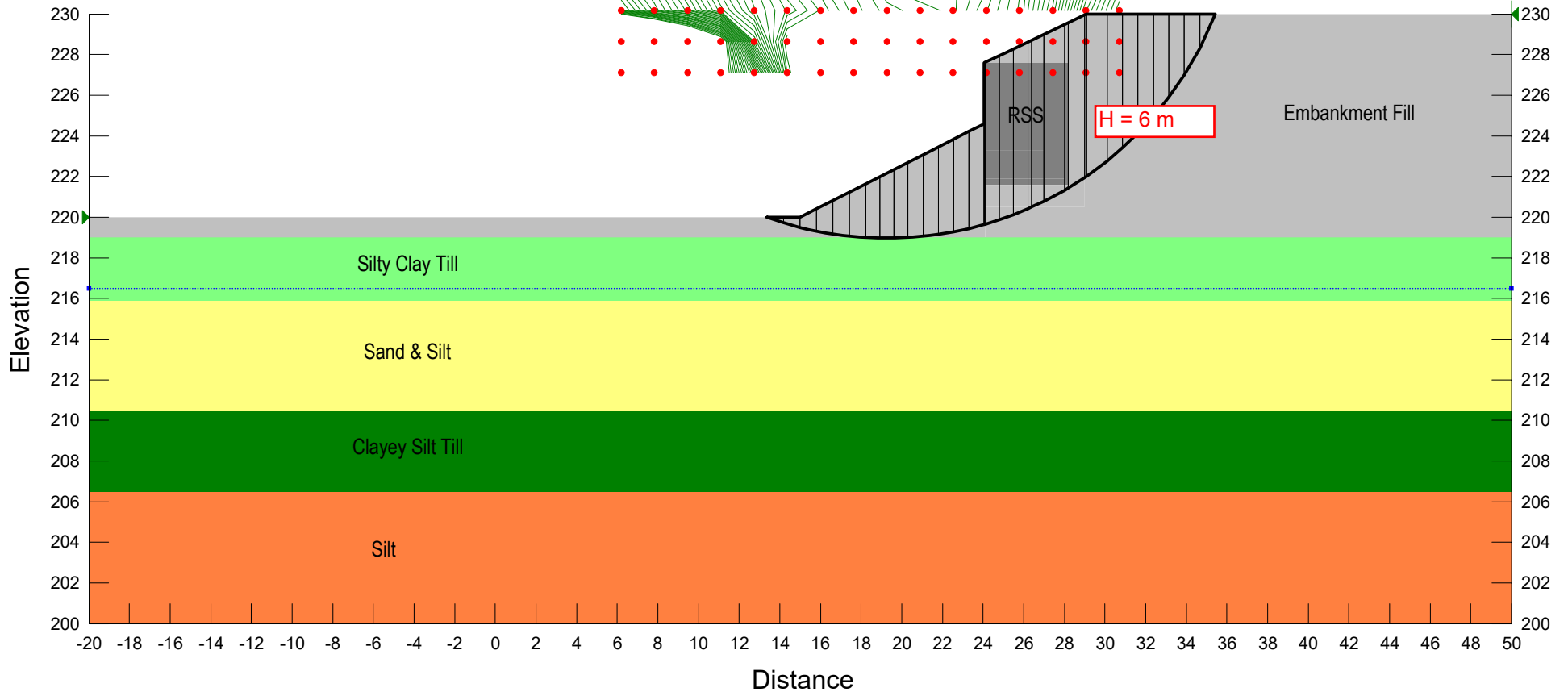
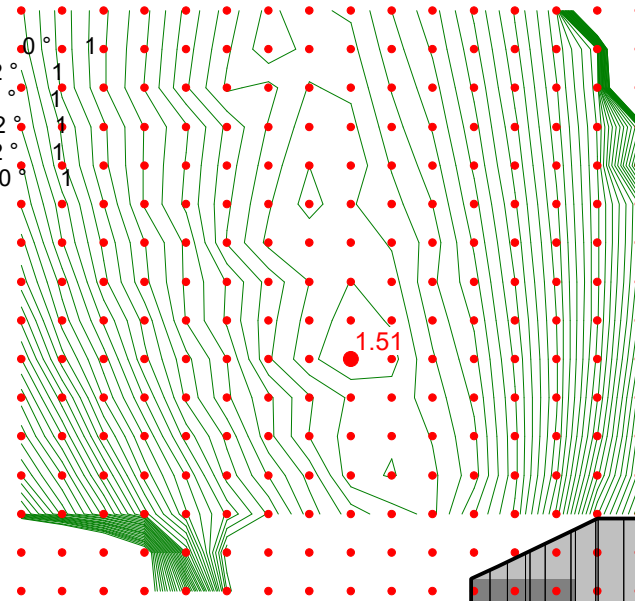
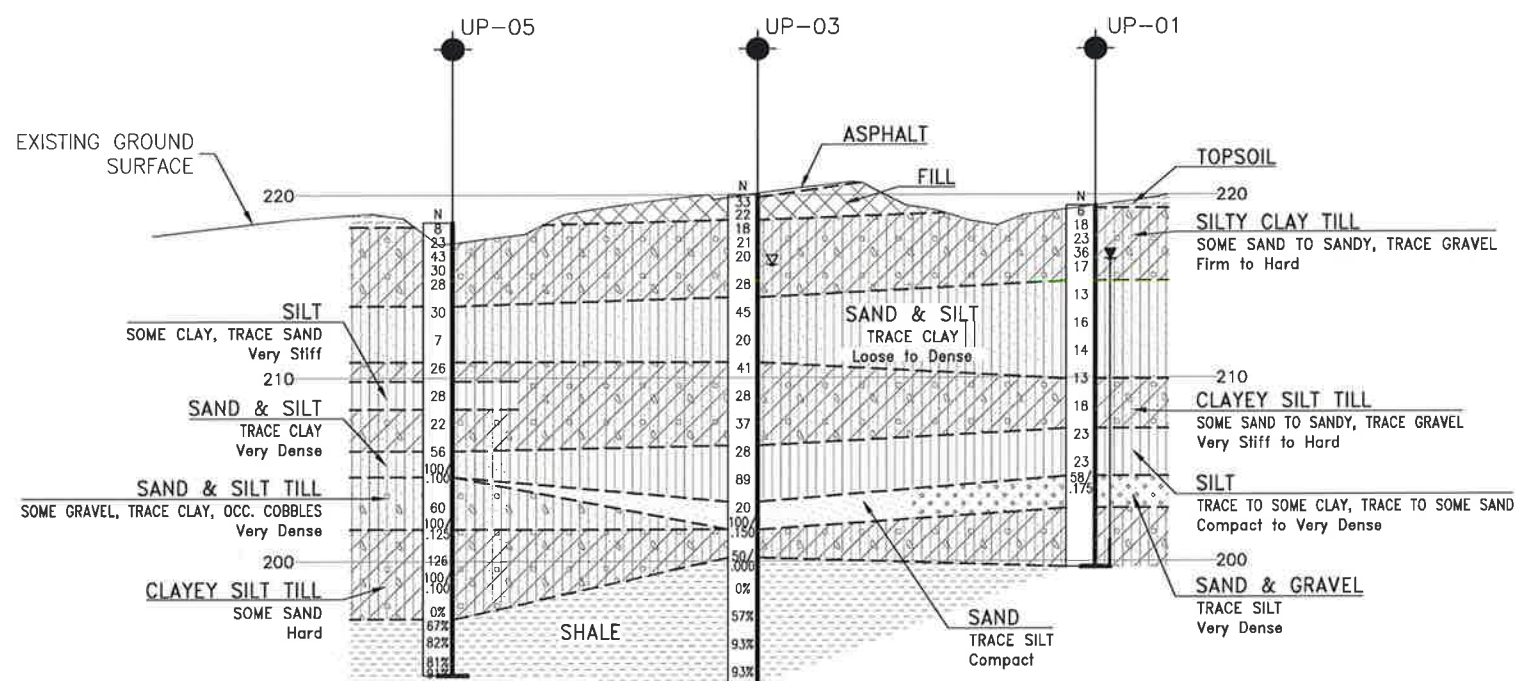


FIGURE F6

Appendix G
Borehole Locations and Soil Strata Drawings

PLAN



PROFILE ALONG A-A



H 1:1000

V 1:400

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No






WP No

NEW TREMAINE ROAD
UNDERPASS AT
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

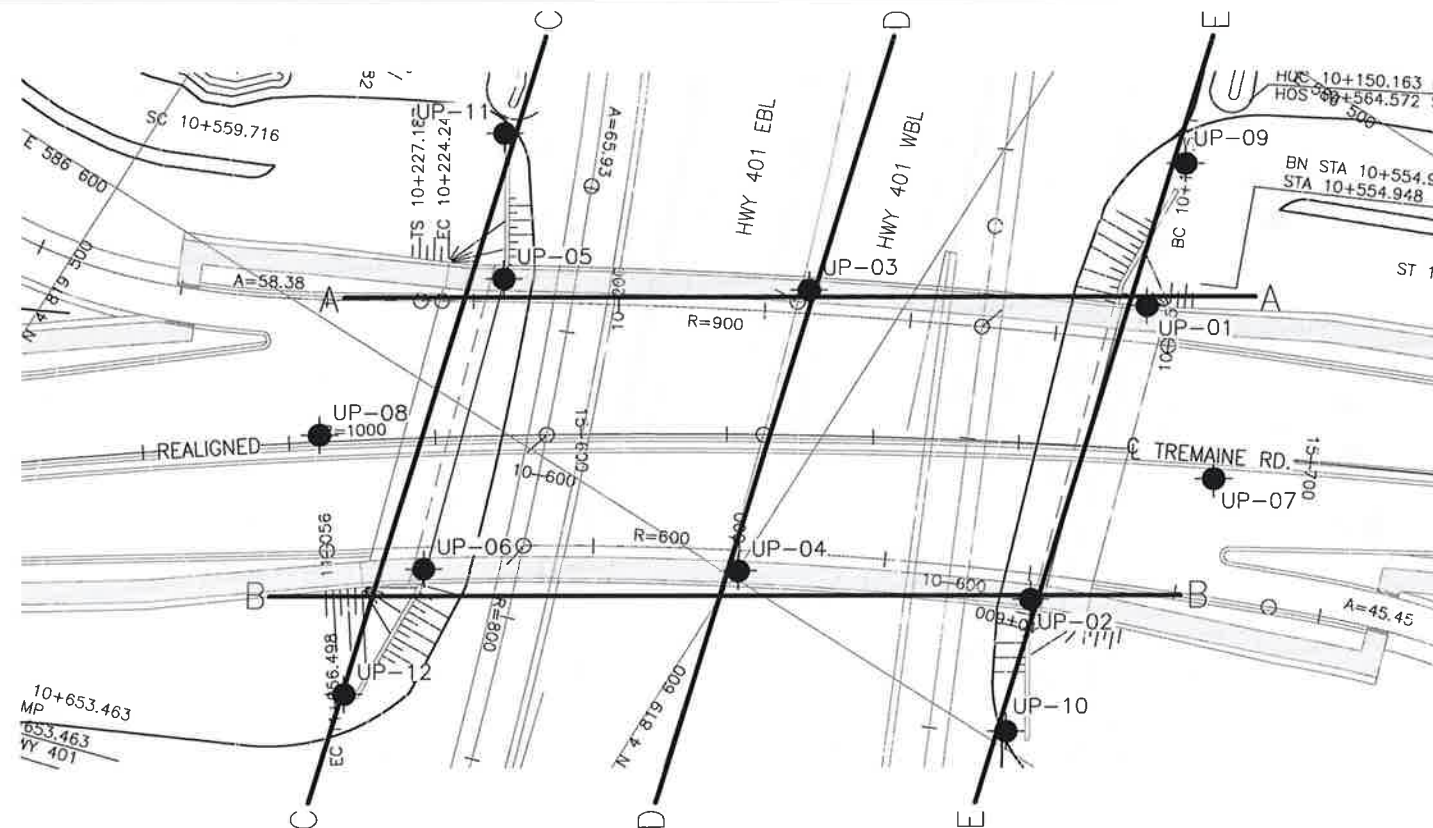
NO	ELEVATION	NORTHING	EASTING
UP-01	219.4	4 819 628.1	586 538.3
UP-02	218.7	4 819 636.2	586 580.8
UP-03	220.0	4 819 587.8	586 561.2
UP-04	219.8	4 819 600.2	586 598.9
UP-05	218.5	4 819 551.6	586 582.2
UP-06	218.4	4 819 563.6	586 621.7
UP-07	219.9	4 819 648.5	586 553.5
UP-08	218.5	4 819 541.7	586 613.8
UP-09	219.4	4 819 622.1	586 519.0
UP-10	218.5	4 819 643.0	586 597.9
UP-11	218.8	4 819 541.0	586 565.3
UP-12	218.2	4 819 563.5	586 642.1

-NOTES-

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

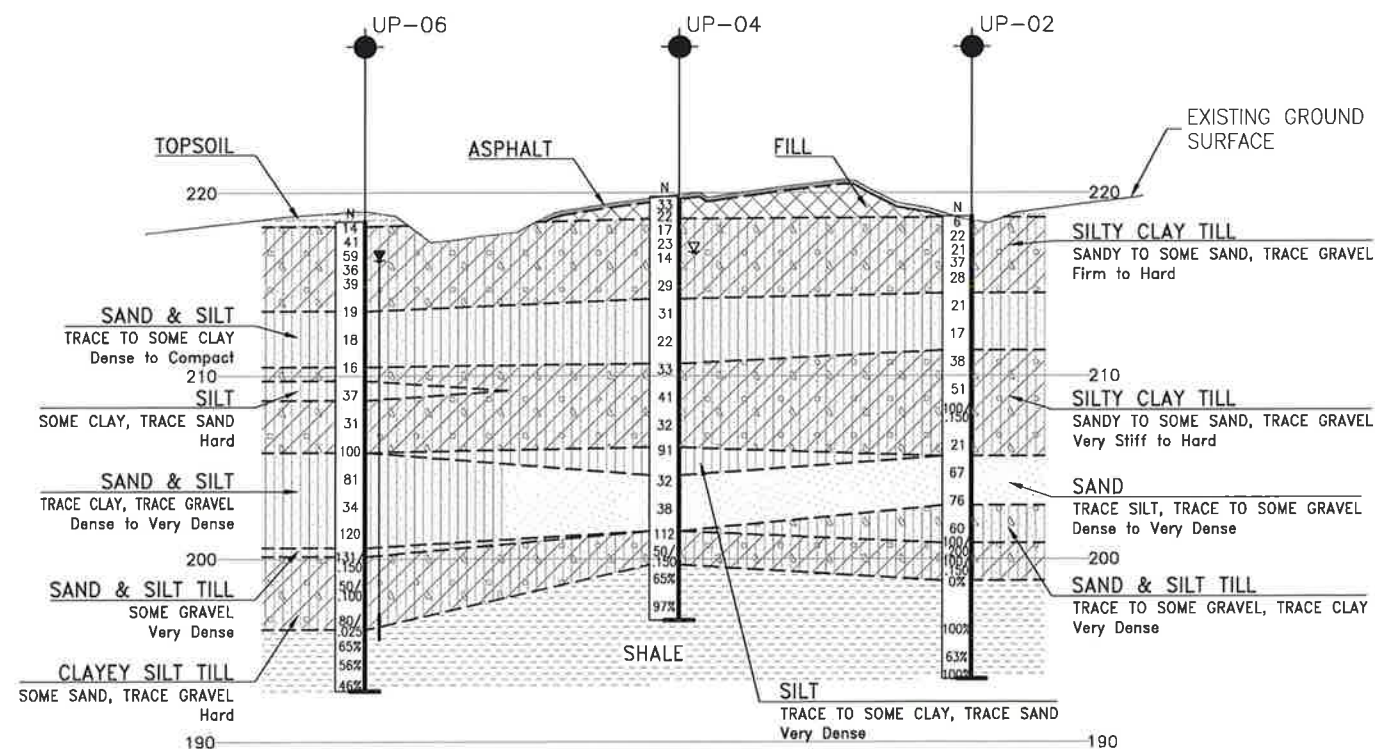
GEOCRES No. 30M12-391

[illegible]



PLAN

20 0 20 40m
SCALE 1:1000



PROFILE ALONG B-B

H 1:1000
V 1:400

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
WP No

NEW TREMAINE ROAD
UNDERPASS AT
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA








THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
UP-01	219.4	4 819 628.1	586 538.3
UP-02	218.7	4 819 636.2	586 580.8
UP-03	220.0	4 819 587.8	586 561.2
UP-04	219.8	4 819 600.2	586 598.9
UP-05	218.5	4 819 551.6	586 582.2
UP-06	218.4	4 819 563.6	586 621.7
UP-07	219.9	4 819 648.5	586 553.5
UP-08	218.5	4 819 541.7	586 613.8
UP-09	219.4	4 819 622.1	586 519.0
UP-10	218.5	4 819 643.0	586 597.9
UP-11	218.8	4 819 541.0	586 565.3
UP-12	218.2	4 819 563.5	586 642.1

-NOTES-

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

GEOCRES No. 30M12-391

[illegible]

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



CONT No
WP No
NEW TREMAINE ROAD
UNDERPASS AT
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN LEGEND

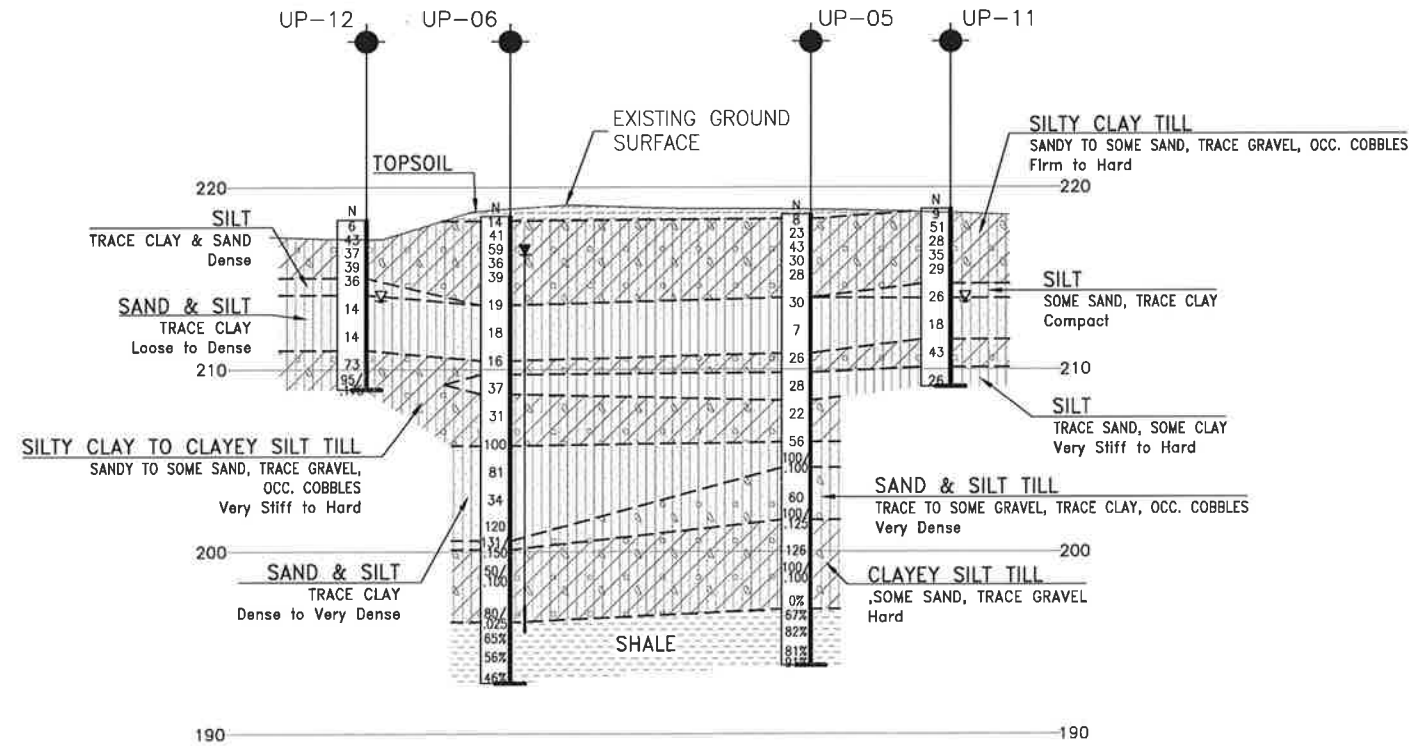
- Borehole
- ⊕ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level During Drilling
- ↑ Water Level in Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
UP-01	219.4	4 819 628.1	586 538.3
UP-02	218.7	4 819 636.2	586 580.8
UP-03	220.0	4 819 587.8	586 561.2
UP-04	219.8	4 819 600.2	586 598.9
UP-05	218.5	4 819 551.6	586 582.2
UP-06	218.4	4 819 563.6	586 621.7
UP-07	219.9	4 819 648.5	586 553.5
UP-08	218.5	4 819 541.7	586 613.8
UP-09	219.4	4 819 622.1	586 519.0
UP-10	218.5	4 819 643.0	586 597.9
UP-11	218.8	4 819 541.0	586 565.3
UP-12	218.2	4 819 563.5	586 642.1

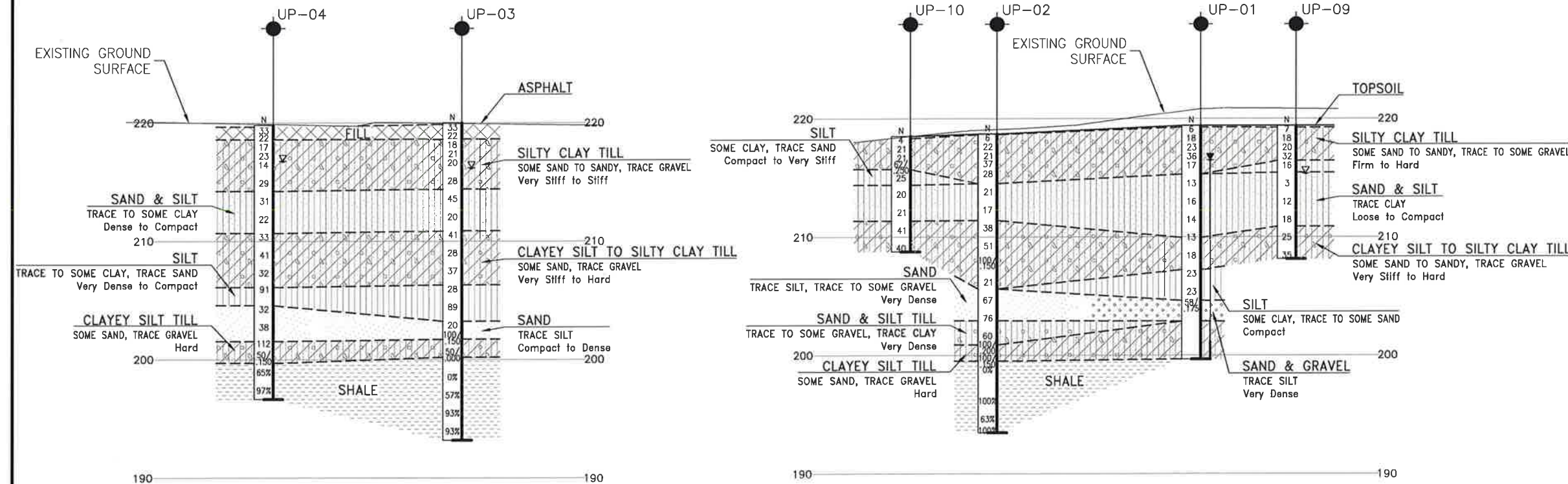
NOTES

- 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.

GEOCREs No. 30M12-391

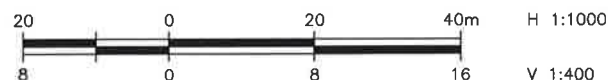


SECTION ALONG C-C



SECTION ALONG D-D

SECTION ALONG E-E



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KS	CHK MRA	CODE
DRAWN	AN	CHK KS	SITE
			STRUCT
			DWG 3
			DATE DEC 2016