



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
EAST HUMBER RIVER ARCH CULVERT
RETAINING WALLS
SITE NO. 37-94
HIGHWAY 400 WIDENING
YORK REGION, ONTARIO
G.W.P. 2539-04-00**

GEOCRES NO. 30M13-219

Report

to

SNC-Lavalin Inc.

Date: April 16, 2018
File: 15591



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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the design and construction of wingwalls as part of the proposed extension of the existing East Humber River Arch Culvert crossing under Highway 400 at King Township, Regional Municipality of York, Ontario. Thurber was retained by SNC Lavalin Inc. (SLI) to carry out the foundation investigation at this site on behalf of the Ministry of Transportation Ontario (MTO).

The purpose of the field investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole locations plan and soil strata drawing with stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained during the course of the present investigation.

During the preparation of this report and in addition to the boreholes drilled under the current assignment, reference has been made to information on subsurface conditions contained in earlier preliminary foundation investigation and design reports. The titles of these reports are listed as follows:

- Preliminary Foundation Investigation and Design Report, Humber River Arch Culvert Extension, Highway 400 Widening from North of Major Mackenzie Drive to South Canal

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Road, G.W.P. 222-97-00, Agreement No. 2005-A-000106, prepared by Golder Associates (Golder), dated May 2001; Geocres No. 30M13-51 (Reference 1).

- Final Foundation Investigation and Design Report, Proposed Humber River Arch Culvert Extension, Highway 400 Interim Widening, Vaughan, Ontario, G.W.P. 192-00-00, prepared by Amec, dated September 8, 2003; Geocres No. 30M13-156 (Reference 2).

2 SITE AND PROJECT DESCRIPTION

The site is located on Highway 400 approximately 1 km south of King Road (King City, Ontario) and approximately 1 km north of King Vaughan Road (Maple, Ontario). Highway 400 over the culvert is at an elevation of approximately 267 m. At this site, the Humber River flows from east to west under Highway 400 through the culvert. The areas surrounding the inlet and outlet of the culvert are generally moderately vegetated.

Based on the available drawings provided by SLI dated October 4, 2016, this project includes the proposed extension of the existing 72.7 m long East Humber River Culvert by approximately 8.3m on both sides of the highway. The existing arch culvert is founded on 2.4 m wide spread footings at approximate Elevation 252.4 m. The culvert extensions will be covered by new fill for highway platform widening up to a maximum thickness of approximately 6 m. The side slope of the new high fill will be 2H : 1V. As part of the earthwork required to extend the culvert and widen the highway, four wingwalls will be constructed (two at the inlet and two at the outlet) to support the new embankment fill. The length of the four wingwalls varies between a maximum length of about 28 m for the wingwall at the southwest quadrant to a minimum length of 9.6 m for the wingwall at the southeast quadrant.

From published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as South Slope of Oak Ridges Moraine. The South Slope of Oak Ridges Moraine generally consists of sandy materials (derived from glacial tills) overlying glacial tills. The soil deposit is underlain at deep depths by shale bedrock.

3 INVESTIGATION PROCEDURES

The site investigation for this project was carried out between October 17 and October 25, 2016

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during which time a total of four (4) boreholes denoted as Boreholes 16-01 to 16-04 were advanced to depths ranging from 10.2 m to 12.8 m.

Boreholes 16-01 and 16-03 were located to the north and south of the culvert outlet, respectively. Boreholes 16-02 and 16-04 were located to the north and south of the culvert inlet, respectively. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing provided in Appendix C. Borehole details are provided in Table 3.1 below.

Table 3.1 – Borehole Details

Borehole Number	Location	Approximate Ground Surface Elevation (m)	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
16-01	North of culvert outlet	255.5	12.8	242.7
16-02	North of culvert inlet	257.3	10.2	247.1
16-03	South of culvert outlet	256.8	12.2	244.6
16-04	South of culvert inlet	257.0	10.4	246.6

A mobile tripod drill rig was used throughout the field investigation. This rig operated in conjunction with B size casing that was advanced using the wash-boring method. The head of water inside the casing served the purpose of counteracting the upward hydrostatic pressure. In all boreholes, soil samples were obtained with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT). Dynamic Cone Penetration test was carried out at the bottom of Boreholes 16-02 and 16-04.

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Standpipe piezometers were installed in Boreholes 16-01 and 16-04 to permit monitoring of the groundwater levels at the site. Each piezometer consisted of a 25 mm diameter PVC pipe with a slotted screen sealed at a selected depth within the borehole. The boreholes in which no piezometer was installed were backfilled in general accordance with Ontario Regulation 903. Piezometer installation and borehole completion details are summarized in Table 3.2 below.



Table 3.2 – Piezometer and Borehole Completion Details

Borehole Number	Piezometer Tip Depth / Elevation (m)	Completion Details
16-01	9.0 / 246.5	Backfilled with filter sand from 12.0 m to 6.9 m, then bentonite holeplug and auger cuttings from 6.9 m to 0.15 m, then concrete to surface.
16-02	None installed	Backfilled with bentonite holeplug to surface.
16-03	None installed	Backfilled with bentonite holeplug to surface.
16-04	8.7 / 248.3	Backfilled with filter sand from 10.4 m to 7.5 m, then bentonite holeplug and auger cuttings 7.5 m to surface.

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

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to grain size distribution analysis (hydrometer and/or sieve analysis) and Atterberg Limits testing, where appropriate. Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the Borehole Location and Soil Strata Drawings in Appendix C. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the

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site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface stratigraphy encountered in the boreholes consists of surficial topsoil overlying interlayered sands and silts. The groundwater level varied from 0.2 m to 0.7 m below the existing ground surface. This soil stratigraphy is generally consistent with the stratigraphy reported in Reference 1 and 2. The description of each major stratigraphic layer is provided below.

5.1 Topsoil

A layer of surficial topsoil with a thickness ranging from 25 mm to 75 mm was encountered in all boreholes.

5.2 Silty Clay

A 0.75 m thick layer of silty clay, trace sand and trace gravel was encountered below the topsoil layer in Borehole 16-02. The base elevation of this layer was at Elevation 256.5 m. SPT 'N' values recorded in this silty clay was 14 blows per 0.3 m penetration indicating a stiff consistency. Measured moisture contents within this layer was 10%.

5.3 Silty Sand to Sand and Silt

Interlayered silty sand to sand and silt deposit with trace to some clay and trace gravel was encountered below the topsoil in Boreholes 16-01 and 16-03, below the silty clay layer in Borehole 16-02, and below the silty sand fill in Borehole 16-04. The thickness of these interlayers varied from 2.4 m to 3.3 m. The base of these layers was encountered at 3.0 m to 7.2 m depths (Elevations 248.3 to 253.7).

SPT 'N' values recorded in this deposit ranged from 10 blows per 0.3 m penetration to greater than 50 blows for less than 0.3 m, indicating a compact to very dense condition. A lower SPT "N" value of 7 blows per 0.3 m penetration were measured in a silty sand layer in Borehole 16-01, indicating a loose condition. Measured moisture contents within this layer varied between 10% and 22%.



The results of grain size distribution analyses carried out on selected samples of these deposits are presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	36 to 66
Silt	20 to 45
Clay	8 to 19

5.4 Gravelly Sand

A 1.5-m-thick layer of gravelly sand with trace silt and clay was encountered below the silty sand layer in Borehole 16-01. The base of this layer was encountered at 2.2 m depth (Elevation 253.3).

SPT 'N' values recorded in this gravelly sand layer varied from 17 to 18 blows per 0.3 m penetration indicating a compact condition. Measured moisture contents within this layer varied between 16% to 18%.

The results of grain size distribution analysis carried out on one sample of this soil is presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	25
Sand	67
Silt and Clay	8

5.5 Sand

Sand with trace to some silt and clay was encountered in all boreholes at Elevations ranging between 252.5 and 253.7 m. Boreholes 16-01, 16-03 and 16-04 were terminated within this sand at elevations ranging from 242.7 to 246.6 m. In Borehole 16-02, the base of the sand was encountered at Elevation 250.1 m. This deposit has a thickness varying from 3.1 m to greater than 9.2 m.



SPT 'N' values recorded in this deposit ranged from 13 blows per 0.3 m penetration to 76 blows for 0.3 m indicating a compact to very dense condition. A low SPT "N" value of 9 blows per 0.3m penetration was measured in Borehole 16-01, indicating a loose condition. Measured moisture contents within this layer varied between 10% and 22%.

The results of grain size distribution analyses carried out on selected samples of this deposit are presented on the Record of Borehole Sheets included in Appendix A and on Figure B3 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	81 to 94
Silt	8 to 16
Clay	3 to 4
Silt and Clay	6

5.6 Clayey Silt Till

A till deposit consisting of clayey silt with sand and trace gravel was found underlying the sand layer in Borehole 16-02. Borehole 16-02 was terminated within cohesive till at Elevation 247.0 m upon DCPT refusal.

SPT 'N' values recorded in this till deposit were greater than 50 blows per 0.3 m of penetration indicating a hard consistency. Glacial tills inherently contain cobbles and boulders. Measured moisture contents within the till layer varied between 10% and 15%.

The results of grain size distribution analyses and Atterberg Limits testing carried out on one sample of the clayey silt till is presented on the Record of Borehole Sheets included in Appendix A and on Figures B4 and B5 of Appendix B. The results of the grain size distribution analysis are summarized below:



Soil Particle	Percentage (%)
Gravel	0
Sand	19
Silt	61
Clay	20

The results of Atterberg Limits testing are summarized below:

Index Property	Percentage (%)
Plasticity Index	6
Liquid Limit	18

The results of the Atterberg Limits testing indicate the layer is of low to slight plasticity with a group symbol CL-ML.

5.7 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes 16-01 and 16-04 to monitor the groundwater level at the site. The groundwater levels measured in the open boreholes and in the piezometers are summarized in Table 5.6 below.

Table 5.6 – Groundwater Levels and Observations

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
16-01	15 November 2016	0.7 m below G.S.	254.8	Piezometer
16-02	19 October 2016	4.5 m below G.S.	252.8	Open hole
16-03	25 October 2016	Not recorded	-	Open hole
16-04	25 October 2016	3.1 m below G.S.	253.9	Piezometer
	15 November 2016	0.2 m below G.S.	256.8	

The groundwater levels above are short-term readings and are largely governed by the river water level. The latest readings suggest that the groundwater level measured in the piezometers was generally consistent with the river water level. Seasonal fluctuations of the groundwater level are also to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

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6 MISCELLANEOUS

Thurber marked and/or staked the borehole locations in the field and obtained buried utility clearances prior to drilling. The northing and easting co-ordinates and elevations of the boreholes have been provided by SNC-Lavalin.

Geotechnical laboratory testing was carried out at Thurber's MTO approved Toronto area laboratory.

Walker Drilling Ltd. supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation.

The field investigation was supervised on a full time basis by a member of Thurber's technical staff. Compilation of data and preparation of the report was carried out by Messrs. Mohamad Hosney, P.Eng. and Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., MTO designated principal contact.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist the design team in the design of the wingwalls associated with the proposed extension of the East Humber River Arch Culvert crossing Highway 400 at King Township, Regional Municipality of York, Ontario.

This foundation design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on the available cross sections and a General Arrangement (GA) drawing dated December 2016 provided by SLI, this project involves the extension of the existing East Humber River Arch Culvert at both the inlet and outlet. Fill material will be placed above the culvert extensions to widen the highway platform. The side slope of the new fill will be 2H : 1V and the maximum height of the new fill will be approximately 6 m. There is no grade raise proposed for Highway 400. The GA drawings show the proposed cantilevered concrete walls at all quadrants of the extended culvert.

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8 RETAINING WALL FOUNDATIONS

According to the GA drawings, the four wingwalls that will be constructed to retain the new embankment fill will be of the concrete cantilever type. The wall footings will be stepped upwards away from the river and founded on typically compact sands and silts at elevations vary between approximately 252.8 m and 254.6 m. Each wingwall is comprised of one to four segments with varying widths, lengths and heights. The retained heights of the wingwalls vary between approximately 1 m and 6 m. The length of each wall segment varies between 4.6 m to 9.6 m.

8.1 Structure Classification

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

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

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

8.2 Foundation Alternatives

This section discusses the feasible foundation alternatives, provides geotechnical design parameters and recommends a preferred foundation scheme.

Initial consideration was given to the following types of wall;

- Conventional concrete cantilever wall
- Concrete toe wall
- Gabion wall
- Retained Soil System (RSS) wall

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A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Table D1 in Appendix D.

Given the required retained height, surface topography, founding conditions and from a foundations technical and cost effectiveness perspective, it is considered that conventional concrete cantilever walls founded on the native, undisturbed compact sands and silts is a feasible foundation option at this site. Roadway protection systems are required for constructing the walls.

RSS walls will require sufficient space behind the wall to install the reinforcing strips which may need to extend laterally up to the order of 0.7 to 1.2 times the wall height. Moreover, submerged RSS walls, when subject to river overflow and flooding, will require effective scour and erosion control to prevent undermining of the wall. Fluctuation of the water level may also result in loss of fines behind the RSS system which may result in surface settlement. The RSS wall design, internal stability assessment and construction are usually carried out by proprietary suppliers. Since roadway protection systems are also required for construction, RSS walls may not be cost effective at this site. As such, RSS walls are not recommended at this site.

Concrete toe wall is limited to retained heights of less than 2 m and is therefore unsuitable for this site. A gabion wall is not suitable for the height of fill that needs to be retained and may undergo irregular deformation with time, thus requiring maintenance and/or reconstruction in the future. As such, a gabion wall is not recommended for use at this site.

8.3 Spread Footing Foundations

According to the GA drawings, the wingwalls will be supported on concrete spread footings. The founding elevations for the wingwalls vary between approximately 252.8 m and 254.6 m. The founding elevations and soil conditions at the four wingwalls are presented in the following table.

Retaining Wall	Borehole	Proposed Founding Elevation (m)	Typical Founding Soil Conditions
Northwest	16-01	253.4	Compact Silty Sand, Sand and Gravelly Sand (loose zones close to river)
	HR2		
Southwest	16-03	253.4 to 254.6	Compact Silty Sand and Sand (loose zones close to river)
	HR3		

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Northeast	16-02	253.4 to 254.6	Compact to dense Sands and Silts (loose zones close to river)
	90		
Southeast	16-04	253.8	Compact to dense Sands and Silts (loose zones close to river)
	HR1		

The following geotechnical capacities could be used for design of wingwall footings of 3.5 to 6.2 m in width founded at, or below, the elevations and on the subgrade quoted above:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 200 kPa.

The values of the Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads. From the GA drawing, the foundation depth of the footings was assumed to be at least 1.4m below ground surface. This minimum founding depth must be maintained for a horizontal distance equal to at least a footing width in front of the wall. The geotechnical resistances should be reviewed if the footing dimensions, foundation depth and/or founding elevations differ from that given above.

The geotechnical resistances presented above are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces/sliding resistance between the concrete footings and the undisturbed compact sands and silts subgrade should be calculated in accordance with the CHBDC 2014 assuming an unfactored coefficient of friction, $\tan \delta$, of 0.45.

The friction coefficient for base sliding was assessed assuming a factor of 0.85 for typical degree of understanding of the subsurface conditions.



The local and global stability of the wingwalls must be checked against various modes of failure including but not limited to sliding and overturning. In addition, wingwalls should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, traffic loadings and surcharge due to construction equipment.

Once the desired footing subgrade level is reached, careful inspection should be carried out by qualified personnel. Once the subgrade is approved, it is recommended that a working mat of mass concrete of the same class and strength as that of the footings be placed for protection prior to footing construction. Given that the footing subgrade at this site is water-bearing sands and silts that are more vulnerable to disturbance, it is recommended that a working slab with a minimum thickness of 150 mm be used. Any loose/softened or otherwise disturbed areas should be sub-excavated and backfilled with mass concrete quoted above. Footing construction and subgrade preparation must be carried out in the dry. Suggested wordings for an NSSP on footing subgrade preparation are provided in Appendix F.

For frost protection purposes, a minimum earth cover of 1.4 m must be maintained above the footings.

The lower portions of the retaining walls should be provided with scour and erosion protection.

9 WINGWALL BACKFILL AND LATERAL PRESSURES

The backfill to the wingwalls should be in accordance with OPSS 902. Any backfill to the wall should consist of Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

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

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

where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 9.1)

γ = unit weight of retained soil (see Table 9.1)

h = depth below top of fill where pressure is computed (m)



q = value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

Earth pressure coefficients for backfill to the retaining wall are dependent on the material used as backfill. Typical values are shown in Table 9.1.

Table 9.1 – Geotechnical Parameters of the Fill Materials

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

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

It is noted that this wall should be designed to retain a sloping backfill.

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

The factors in Table 9.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.



Prior to fill placement behind the wingwalls, the subgrade must be adequately prepared to receive the fill. Within widening areas, all vegetation, topsoil, organics, soft/loosened or wet soils should be sub-excavated. All subgrade should be inspected and approved prior to placing fill.

It is recommended that perforated sub-drains and weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the retaining walls. Reference should be made to OPSD 3102.100.

10 WINGWALL STABILITY ANALYSIS

Based on the embankment configurations provided by SLI, limit equilibrium stability analyses were carried out for representative cases. The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE and employing the Morgenstern-Price method of slices for limit equilibrium.

As per MTO practice, a minimum Factor of Safety (F.S.) of 1.3 is considered acceptable for maintaining global stability for a typical highway embankment.

The geotechnical parameters used in the stability analyses were determined from the in-situ testing conducted during the field investigation and/or estimated from soil index correlations.

Static stability analyses were carried out using drained shear strength parameters. A surcharge load of 12 kPa has been used in the analyses to simulate traffic loading. It is noted that the groundwater level has been assumed to be at the toe level of the embankment slopes. These parameters and the results of the stability analyses are shown on Figures E1 to E4 in Appendix E.

For the cases considered, a minimum factor of safety of 1.2 was estimated for the current conditions and factors of safety in the order of 1.3 to 1.4 were calculated for the cases after the construction of the wingwalls. The above results indicate that the global stability acceptance criterion outlined above are generally satisfied for the cases analysed.

11 EMBANKMENT FILLS

It is recommended that MTO approved Select Subgrade Material (SSM) or granular materials satisfying OPSS.PROV 1010 requirements be used for constructing the embankment fill



widening. Based on the above analyses, the permanent embankment slopes with retaining walls constructed using these materials will be stable at an inclination not steeper than 2H : 1V.

All embankment fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and OPSS.PROV 501 requirements.

It is also recommended that all permanent and temporary slope surfaces be vegetated and seeded in accordance with current MTO practice with reference to OPSS.PROV 804. It is important to note that slopes steeper than 2H : 1V will be subject to surficial instability which may include sloughing and gullyng. Surface runoff and precipitation must be prevented from flowing perpendicularly down any slope surface.

12 SETTLEMENT

Placement of the new fill will result in settlement of the existing sands and silts. Results of settlement analyses due to fill placement indicate that the estimated settlement would be up to 30mm. Much of that settlement is due to elastic compression of the soil which is anticipated to be completed by the end of construction. Post construction settlement should be considered negligible.

13 EXCAVATION, GROUNDWATER AND SURFACE WATER CONTROL

Excavation should not commence until the dewatering system is operational and effective. If groundwater lowering is required, the dewatering should be capable of maintaining the groundwater level at a minimum 0.5 m depth below the final excavation base level. It is noted that basal instability ("boiling") would occur if the dewatering is ineffective.

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill and native soils at this site are classified as Type 3 soils above the water level, and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils.

The piezometric readings indicate that the groundwater level is at approximate Elevations between 254.8 m and 256.8 m, or within 0.5 m below the existing ground surface. A river water level at approximate Elevation 255.3 m was shown on the GA drawing. The groundwater level is expected to be largely governed by the river water level.



Excavations for wingwall footing construction will extend below the groundwater level. Depending on the location and the time of construction, the depth of excavation could be up to the order of 2m below the water level. Dewatering measures will be required to facilitate footing construction in the dry. A combination of cofferdam enclosures and vacuum well points, in conjunction with sump pumping, will likely be required to maintain reasonably dry excavations during the course of retaining wall footing construction. Surface water must be directed away from the excavations at all times. Sandbagging may be required to redirect the surface flow from the river to minimize water ingress into the excavations.

OPSS.PROV 517 Construction Specification for Dewatering is provided in Appendix F and should be included in the contract documents.

One type of cofferdam enclosures that may be considered consists of interlocking steel sheet piles. The sheet piles must be supplemented by sump pumping within the enclosure. Vacuum well points may be required at some locations. It is anticipated that the following procedures may be required for pier construction.

- Install sheet pile cofferdam (enclosure)
- Dewater within the cofferdam
- Excavate to underside of the footing
- Construct the footing.

Responsibility for design of the cofferdam and dewatering system must remain the responsibility of the contractor. The design of cofferdams must take into consideration the maximum groundwater level and river water level that may likely be encountered during construction.

The following geotechnical parameters may be used for design of the temporary cofferdam (sheet pile enclosure):

$$\begin{aligned}\gamma &= 20 \text{ kN/m}^3 && \text{(bulk unit weight)} \\ \gamma' &= 10 \text{ kN/m}^3 && \text{(submerged unit weight below water level)} \\ K_a &= 0.33 && \text{(existing fill and native soils)} \\ K_p &= 3.0 && \text{(existing fill and native soils)}\end{aligned}$$

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.



Water discharged from the dewatering operations may not be suitable for direct discharge to the East Humber River. The contract documents must alert the contractor to this fact and include an item for treatment of the water to the satisfaction of TRCA, MOE, MNR, DFO or other agencies having jurisdiction prior to discharge into the river or any other water body.

14 STABILITY OF ROADWAY PROTECTION SYSTEM

Roadway protection will be required to retain the highway embankment behind the proposed retaining walls and backfill. An item titled "Protection System" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the roadway protection be specified on the contract drawings.

The design of roadway protection is the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at this site is an interlocking steel sheetpile wall. It is noted that a soldier pile and wood lagging wall would be suitable as temporary shoring purposes, but would not be able to provide partial groundwater cutoff. It is anticipated that the protection system will need to be extended through the existing highway embankment fill (clays silt fill based on previous investigation) into the underlying native sands and silts. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

An interlocking steel sheetpile wall may be designed using the geotechnical parameters and recommendations provided in Section 13 for the design of a cofferdam enclosure.

It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2014. The surcharge should include soil loadings above the retained soil and other loadings adjacent to the wall.

The designer of the roadway protection system should check whether the depth of the sheetpiles is sufficient to provide base fixity. All roadway protection systems should be designed by a Professional Engineer experienced in such designs.

15 SEISMIC CONSIDERATIONS

Based on the encountered soil conditions, this site is assessed as Site Class D for seismic site response in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC 2014. The peak ground acceleration, PGA, for a 2% in 50 years probability of exceedance at this site is 0.038 g as per the National Building Code of Canada (NBCC). The above PGA value should be modified by a site co-efficient of 1.29 based on Table 4.8 of the CHBDC.

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 14.1 may be used:

Table 15.1 – Earth Pressure Coefficients for Earthquake 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 (modified) $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.29	0.33
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.51	0.55

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

Given that the main deposit at the site location is typically compact sands and silts and in view of the potential for seismic activity in the area, liquefaction is not considered to be a concern at this site.

16 DESIGN FROST DEPTH

The depth of frost penetration at this site for design purposes is approximately 1.4 m.

17 ADJACENT STRUCTURES AND BURIED UTILITIES

The potential presence of buried utilities might in the vicinity of the retaining wall construction and the proposed embankment widening areas must be checked. It is recommended that the exact



locations and elevations of any these utilities be established by the designer, and compared with the extent of the potential work zones related to the widening activities. If necessary, relocation of and/or special protective measures for affected utilities may be required.

In addition, placement of new fill adjacent to the existing Highway 400 will induce foundation settlement that could result in pavement distress on the travelled lanes of the highway. Should this occur, remedial measures including temporarily re-paving the affected areas may be required.

If buried utilities are present in the vicinity of the new fill and construction areas, it is recommended that the following be carried out prior to the commencement of construction:

- Carry out pre-construction condition survey including documentation of any existing distress associated with the existing utilities. Any distress should be reported to and discussed with the structure/utility owner.
- Potential impact of fill placement and construction activities on the existing pavement surface of Highway 400 should be closely monitored.
- Daily visual inspection of the pavement surface must be carried out in the vicinity of the fill placement and construction areas. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the Contract Administrator for determining as to whether remedial action is required. Such action may include temporarily re-paving the affected areas.
- Implement a survey monitoring program to include ground settlement monitoring during installation of roadway protection/temporary retaining wall. The ground adjacent to the retained fills behind the roadway protection (temporary shoring) walls should be monitored for potential movement.

18 CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable wingwalls construction in the dry and prevent base boiling, sloughing and instability of the footing excavations.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.

Client: SNC-Lavalin Inc.

File No.: 15591

E file: H:\15000-15999\15591 East Humber Arch Culvert Extension Highway 400 Widening\Reports & Memos\FINAL\15591 Hwy 400 East Humber Arch Retaining Wall FINAL FIDR mar 18.docx

Date: April 16, 2018

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- The embankment slopes should be inspected after construction for surficial disturbance. Where necessary, remedial measures such as re-vegetation and/or placement of gravel sheeting may be required
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures. Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

19 CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Messrs. Mohamad Hosney, P.Eng. and Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Contact for MTO foundation projects.



THURBER ENGINEERING LTD.



Mohamad Hosney, P.Eng.
Geotechnical Engineer



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



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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


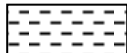



 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

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

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

RECORD OF BOREHOLE No 16-01

1 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 532.8 E 299 615.7 ORIGINATED BY OA
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.17 - 2016.10.18 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
255.5	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL: (25mm)		1	SS	10		255											
254.8	Silty SAND, trace gravel Compact Dark Brown Moist																	
0.7	Gravelly SAND, trace silt Compact Dark Grey Wet		2	SS	17		254											
			3	SS	18													
253.3																		
2.2	Silty SAND, trace gravel Compact Grey Wet		4	SS	12		253											
252.5			5	SS	9		252											
3.0	SAND, trace gravel, trace silt Loose to Compact Grey Wet																	
			6	SS	13		251											
249.9							250											
5.6	Silty SAND Loose Grey Wet		7	SS	7		249											
248.3																		
7.2	SAND, some silt, trace clay Compact to Dense Grey Wet		8	SS	18		248											
							247											
			9	SS	38		246											

Continued Next Page

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

RECORD OF BOREHOLE No 16-01

2 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 532.8 E 299 615.7 ORIGINATED BY OA
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.17 - 2016.10.18 CHECKED BY SKP

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					
	SAND , some silt, trace clay Dense Grey Wet						245						
			10	SS	44			20 40 60 80 100					
								20 40 60 80 100					
242.7			11	SS	40			20 40 60 80 100					
12.8	END OF BOREHOLE AT 12.8m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.11.15 0.7 254.8												

RECORD OF BOREHOLE No 16-02

1 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 562.1 E 299 708.3 ORIGINATED BY OA
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.18 - 2016.10.19 CHECKED BY SKP

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	
257.3	GROUND SURFACE					▽	257													
0.0	TOPSOIL: (50mm)		1	SS	14															
	Silty CLAY , trace sand, trace gravel, some organics and grass Stiff Brown Moist																			
256.5			2	SS	63			256									0	51	36	13
	SAND and SILT , some clay, trace gravel Very Dense to Compact Brown Moist		3	SS	63															
	Becoming wet		4	SS	17			255									0	48	38	14
	Trace wood pieces		5	SS	23			254												
253.2			6	SS	30			253												
4.1	SAND , some silt, some pieces of wood Dense Grey Wet						252													
			7	SS	35		251													
250.1							250													
7.2	Clayey SILT , some sand, trace gravel Hard Grey Wet (TILL)		8	SS	65											0	19	61	20	
							249													
			9	SS	54		248													
247.5																				
9.8	End of sampling at 9.8m and start																			

Continued Next Page

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Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02

2 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 562.1 E 299 708.3 ORIGINATED BY OA
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.18 - 2016.10.19 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)						
						20 40 60 80 100 20 40 60 80 100					20	40	60				
247.0	DCPT		10	SS	100/												
10.2	END OF BOREHOLE AT 10.2m UPON DCPT REFUSAL. WATER LEVEL AT 4.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.175												

RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 496.6 E 299 627.0 ORIGINATED BY RI
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.22 - 2016.10.25 CHECKED BY SKP

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		
256.8	GROUND SURFACE							20	40	60	80	100									
0.0	TOPSOIL: (75mm)							20	40	60	80	100									
0.1	Silty SAND , trace gravel, trace to some clay, with roots Compact to Very Dense Grey Moist		1	SS	31		256							○				4	52	30	14
			2	SS	50/ 0.150									○							
			3	SS	53		255							○							
			4	SS	19		254							○				6	66	20	8
253.7																					
3.0	SAND , trace clay, trace silt, trace gravel Dense to Compact Grey Wet		5	SS	33		253							○							
			6	SS	26		252							○							
							251														
			7	SS	18									○				0	88	8	4
							250														
			8	SS	33		249							○							
							248														
			9	SS	35									○							
							247														

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Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 496.6 E 299 627.0 ORIGINATED BY RI
 HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN
 DATUM Geodetic DATE 2016.10.22 - 2016.10.25 CHECKED BY SKP

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						20	40	60	80	100							
244.6	SAND, trace silt, trace gravel Dense to Very Dense Grey Wet	.					246											
			10	SS	55										○			
			11	SS	38										○			
12.2	END OF BOREHOLE AT 12.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																	

RECORD OF BOREHOLE No 16-04

1 OF 2

METRIC

W.P. 2539-04-00 LOCATION N 4 863 520.2 E 299 702.5 ORIGINATED BY RI
 HWY 400 BOREHOLE TYPE Tripod / Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.10.20 - 2016.10.20 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								20	40	60	80	100	W _P	W	W _L					
257.0	GROUND SURFACE																			
0.8	TOPSOIL: (25mm)																			
	Silty SAND , trace gravel		1	SS	35															
	Dense																			
	Brown																			
256.2	Moist																			
0.8	SAND and SILT , some clay, trace gravel		2	SS	34															
	Dense to Very Dense																			
	Brown																			
	Moist																			
	(TILL)																			
			3	SS	68															
254.7																				
2.3	Silty SAND , trace clay, trace gravel		4	SS	14															
	Compact																			
	Grey																			
	Wet																			
253.5			5	SS	10															
3.5	SAND , trace silt, trace gravel																			
	Dense to Very Dense																			
	Grey																			
	Wet																			
			6	SS	50															
			7	SS	37															
			8	SS	76															
								</												

Continued Next Page

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

RECORD OF BOREHOLE No 16-04

2 OF 2

METRIC

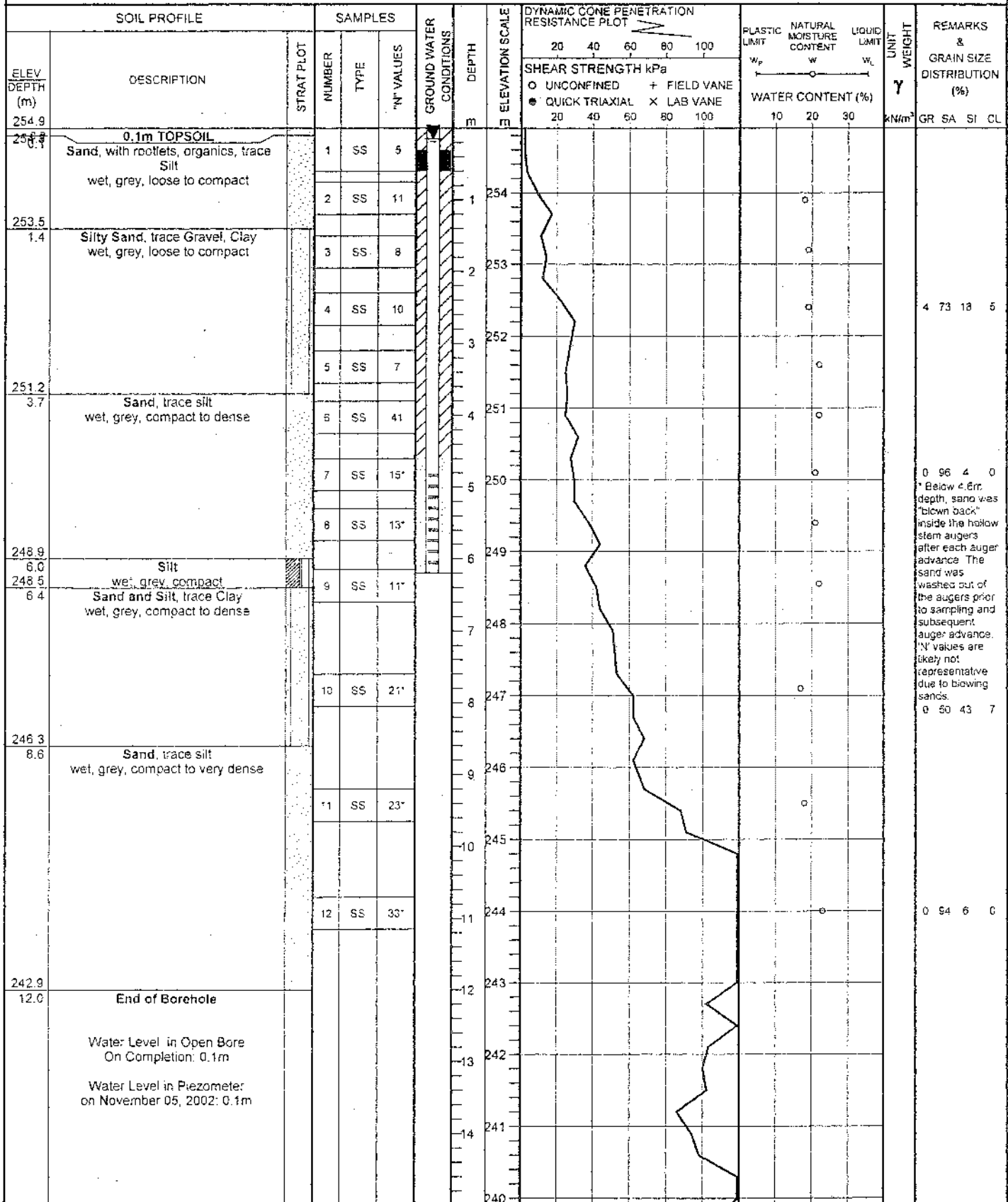
W.P. 2539-04-00 LOCATION N 4 863 520.2 E 299 702.5 ORIGINATED BY RI
 HWY 400 BOREHOLE TYPE Tripod / Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2016.10.20 - 2016.10.20 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					
246.6	DCPT																
10.4	END OF BOREHOLE AT 10.4m UPON DCPT REFUSAL. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.10.25 3.1 253.9 2016.11.15 0.2 256.8																

RECORD OF BOREHOLE No HR1



W.P. 192-00-00	LOCATION 4863532.7N 299710.2E	1 OF 2	ORIGINATED BY FPM
DIST HWY 400	BOREHOLE TYPE Hollow Stem Augering	COMPILED BY IH	
DATUM Geodetic	DATE 16 September 2002 - 16 September 2002	CHECKED BY AD	
PROJECT HWY 400 Widening, Vaughan, Ontario		JOB NO. TT22852	



Continued Next Page

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

RECORD OF BOREHOLE No HR1

2 OF 2

W.P. 192-00-00 LOCATION 4863532.7N 299710.2E ORIGINATED BY PPM
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Augering COMPILED BY IH
 DATUM Geodetic DATE 15 September 2002 - 16 September 2002 CHECKED BY AD
 PROJECT HWY 400 Widening, Vaughan, Ontario JOB NO. TT22852

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE				"N" VALUES	20						40
236.6	End of DCPT DCPT carried out about 2m east of borehole					16	239								
18.3						17	238								
						18	237								

RECORD OF BOREHOLE No HR2



W.P. 192-00-00 LOCATION 4863525.9N 299615.6E 1 OF 1 ORIGINATED BY IH
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Augering COMPILED BY IH
 DATUM Geodetic DATE 17 September 2002 - 17 September 2002 CHECKED BY AD
 PROJECT HWY 400 Widening, Vaughan, Ontario JOB NO. TT22852

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa						
254.6									20 40 60 80 100						
0.0	Silty Sand, with Gravel, trace clay, rootlets		1	SS	3				○ UNCONFINED + FIELD VANE						
254.0	damp, brown, very loose		2	SS	6		1		● QUICK TRIAXIAL × LAB VANE						0 93 7 0
0.6	Sand, trace silt		3	SS	47		2	253							
	wet, brown to grey, loose		4	SS	5*		3	252							
251.6							4	251							8 78 (14)
3.0	Silty Sand, trace Gravel, Clay		5	SS	9*		5	250							0 57 27 6
	wet, grey, loose to compact		6	SS	9*		6	249							* Below 2.3m depth, sand was "blown back" inside the hollow stem augers after each auger advance. The sand was washed out of the augers prior to sampling and subsequent auger advance. "N" values are likely not representative due to blowing sands
			7	SS	17*		7	248							
			8	SS	5*		8	247							
247.6			9	SS	6*		9	246							
7.0	Sand, trace Silt, Clay		10	SS	12*		10	245							1 83 10 6
	wet, grey, loose to compact		11	SS	20*		11	244							
243.3							12	243							
11.3	End of DCPT														
242.4	DCPT carried out about 2m west of borehole														
12.2	End of Borehole														
	Water Level in Open Bore On Completion : 1.2m September 18, 2002: 0.3m above augers November 05, 2002: 0.2 m above ground														

RECORD OF BOREHOLE No HR3

1 OF 1

W.P. 192-00-00 LOCATION 4863514.9N 299615.6E ORIGINATED BY IH
 DIST HWY 400 BOREHOLE TYPE Hollow Stem Augering COMPILED BY IH
 DATUM Geodetic DATE 17 September 2002 - 18 September 2002 CHECKED BY AD
 PROJECT HWY 400 Widening, Vaughan, Ontario JOB NO. TT22852

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION SCALE m	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE				SHEAR STRENGTH kPa		w_p	w	w_L		
254.7 0.0	Sand, with Gravel, some Organics, Rootlets		1	SS	3			20	40	60	80	100		
254.0 0.7	damp, brown to grey, very loose		2	SS	8			20	40	60	80	100		
253.3 1.4	Sand, with Gravel moist, grey, loose		3	SS	17			20	40	60	80	100		
	Sand, trace Silt wet, grey, loose to dense		4	SS	50			20	40	60	80	100		
			5	SS	6*			20	40	60	80	100		
			6	SS	7*			20	40	60	80	100		
250.3 4.4	Silty Sand, trace Clay wet, grey, loose to compact		7	SS	5*			20	40	60	80	100		
			8	SS	20*			20	40	60	80	100		
			9	SS	13*			20	40	60	80	100		
			10	SS	19*			20	40	60	80	100		
			11	SS	31*			20	40	60	80	100		
243.1 11.6	CLAYEY SILT, with Sand, trace gravel (TILL)							20	40	60	80	100		
242.5 12.2	moist, gray, hard							20	40	60	80	100		
242.0 12.7	End of DCPT							20	40	60	80	100		
	DCPT carried out about 2m west of borehole							20	40	60	80	100		
	End of Borehole							20	40	60	80	100		
	Water Level in Open Bore On Completion : 0.9 m							20	40	60	80	100		

PROJECT 001-1122F		RECORD OF BOREHOLE No 90		1 OF 2		METRIC										
W.P. 222-97-00		LOCATION N 4853549 E 2996599		ORIGINATED BY AZ												
DIST Central HWY 400		BOREHOLE TYPE 108mm I.D. Hollow Stem Augers		COMPILED BY LCC												
DATUM Geodetic		DATE October 16 & 17, 2000		CHECKED BY ASP												
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	T _N VALUES	20						40	60	80
255.0	GROUND SURFACE															
254.7	Topsoil (silty clay with organics)															
254.4	Silty Clay, trace organics Brown															
254.0	Silty Sand, trace gravel, trace clay, trace organics Compact to dense Brown to grey Wet below 1.5m depth 20mm layer of organics at about 1.5m depth		1	SS	47											
252.8			2	SS	12											
252.2	Sand, trace to some silt Compact to dense Brown becoming grey at 4.5m depth Wet		3	SS	13											
	SPT "N" values are considered to be impacted by blowing sands (See Note 1)		4	SS	3											
			5	SS	7											
			6	SS	8											
			7	SS	15											
			8	SS	12											
	Layer of grey sandy silt, trace clay encountered at 7.6m depth		9	SS	19											
			10	SS	20											
			11	SS	18											
242.5	Probably compact to dense sand															
241.5																
241.0																

Continued Next Page

+ 3 X 3

Numbers refer to
Sensitivity

0.3%

100% STRAIN AT FAILURE

ON MOT 001-1122F ON MOT 001 19/001

PROJECT <u>001-1122F</u>		RECORD OF BOREHOLE No 90		2 OF 2 METRIC	
W.P. <u>222-97-00</u>		LOCATION <u>N 4803549 # 299699</u>		ORIGINATED BY <u>AZ</u>	
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>105mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>LCC</u>	
DATUM <u>Geodetic</u>		DATE <u>October 16 & 17 2000</u>		CHECKED BY <u>ASP</u>	

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
	— CONTINUED FROM PREVIOUS PAGE —													
	Probably compact to dense sand													
238.2						239								
18.8	END OF BOREHOLE Notes: 1. Below about 2.5m depth, between 1.5m and 3.5m of sand was "blown back" inside the hollow stem augers after each auger advance. This material was washed out of the augers prior to sampling and subsequent auger advance. 2. Water level in open borehole at 1.5m depth (Elev. 253.5m) during drilling and at 1.1m depth (Elev. 253.9m) on completion of drilling. 3. Water level in piezometer at 0.2m depth (Elev. 254.5m) on January 18, 2001.													

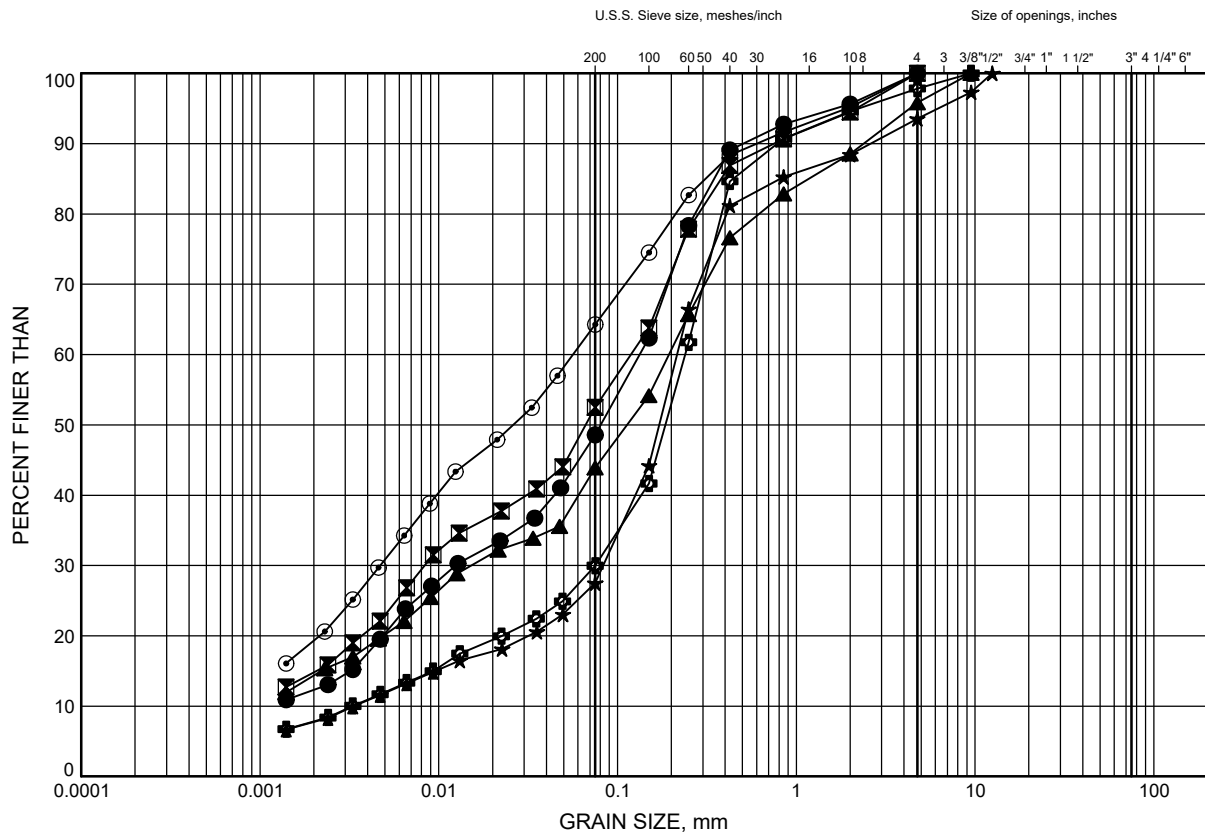


Appendix B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silty SAND to SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	1.1	256.2
⊠	16-02	2.6	254.7
▲	16-03	0.3	256.5
★	16-03	2.6	254.2
⊙	16-04	1.8	255.2
⊛	16-04	3.4	253.6

Date April 2018

W.P. 2539-04-00

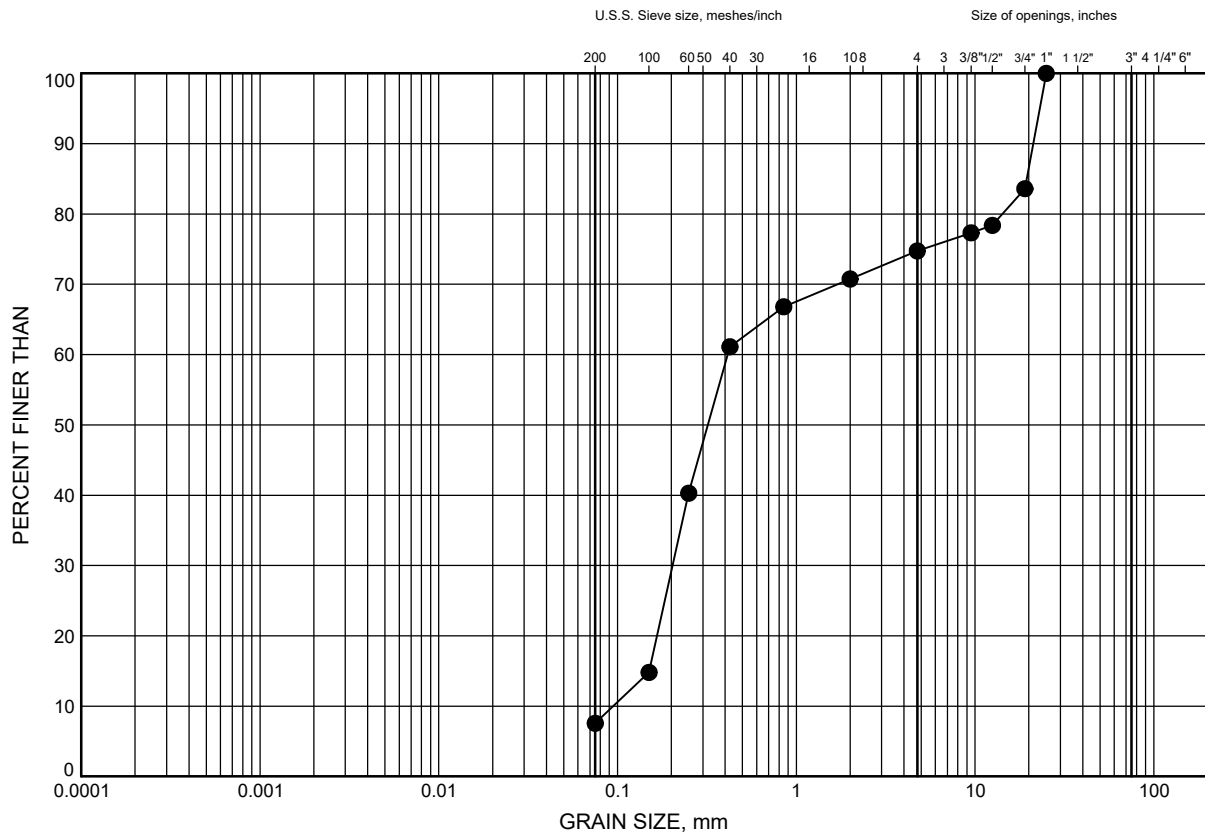


Prep'd AN

Chkd. MH

GRAIN SIZE DISTRIBUTION

Gravelly SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	1.8	253.7

Date April 2018

W.P. 2539-04-00

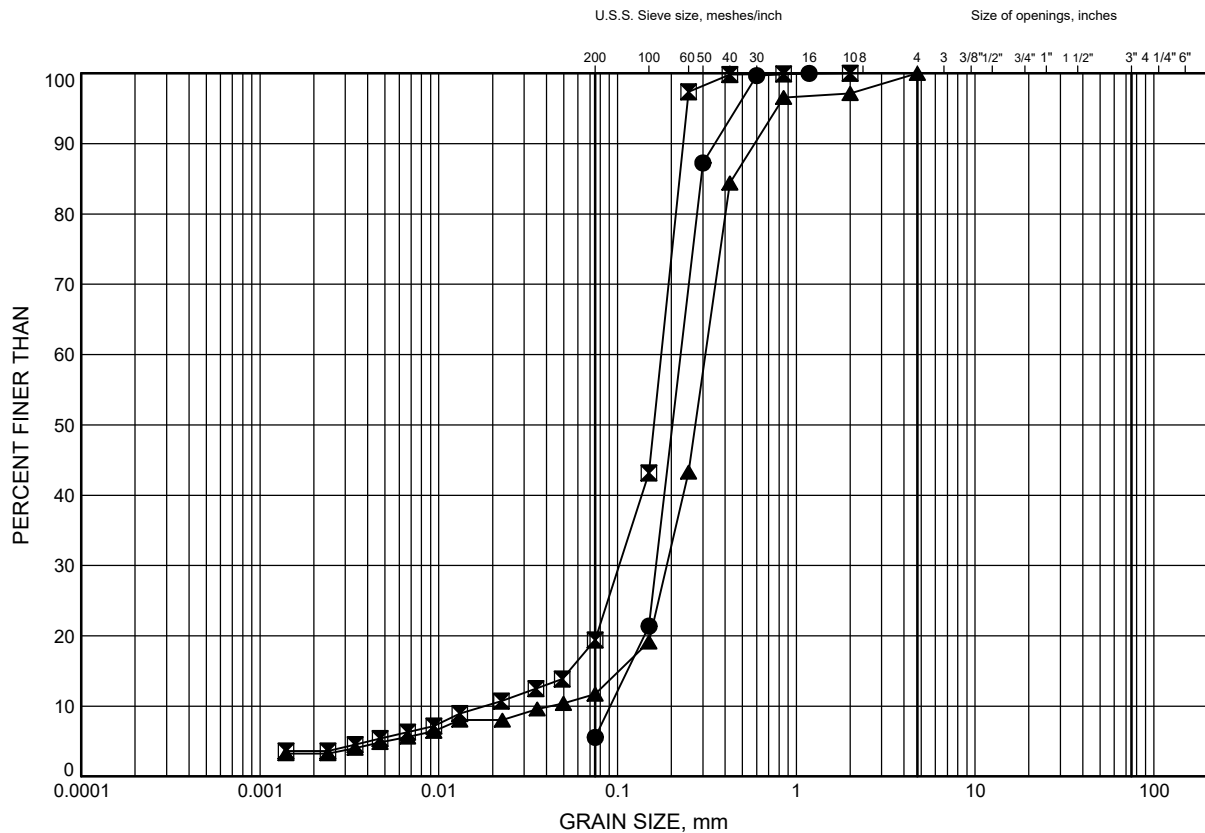


Prep'd AN

Chkd. MH

GRAIN SIZE DISTRIBUTION

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	3.4	252.1
◻	16-01	7.9	247.6
▲	16-03	6.4	250.4

Date April 2018

W.P. 2539-04-00

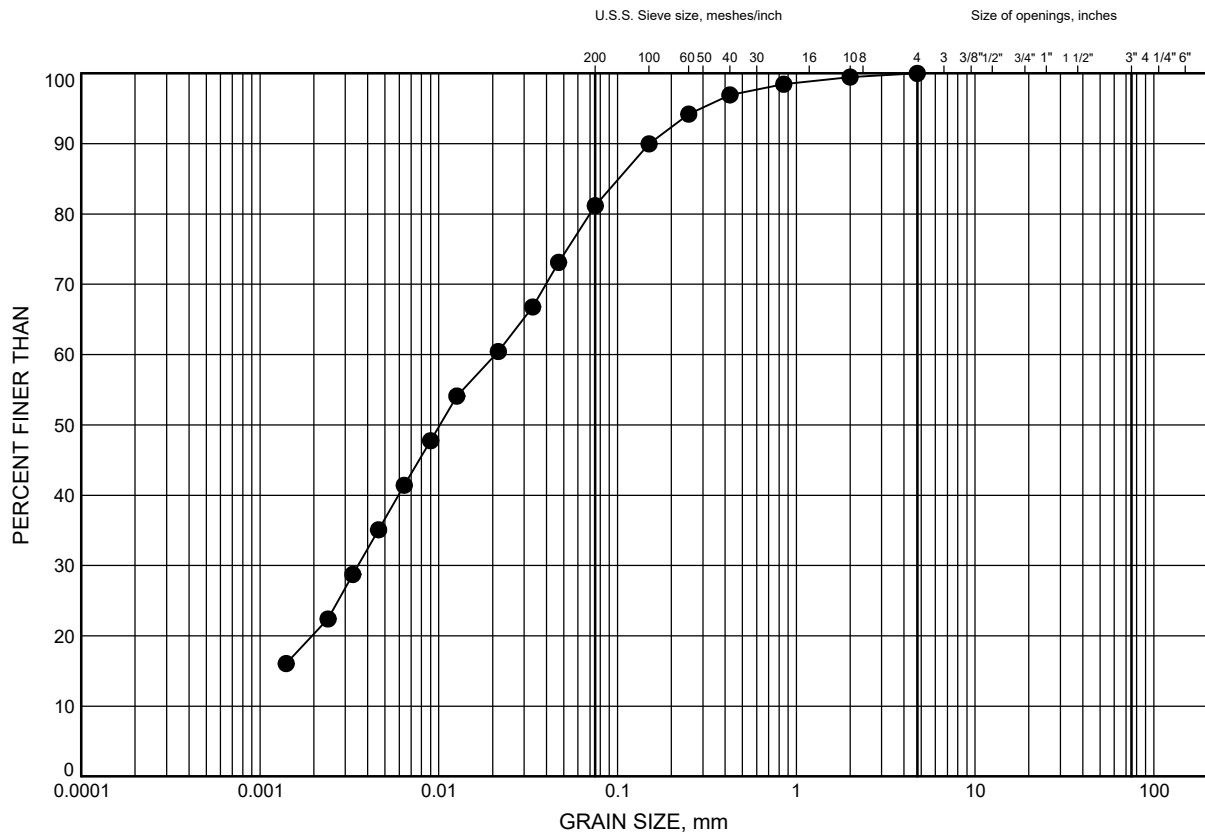


Prep'd AN

Chkd. MH

GRAIN SIZE DISTRIBUTION

Clayey SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	7.9	249.4

Date April 2018

W.P. 2539-04-00



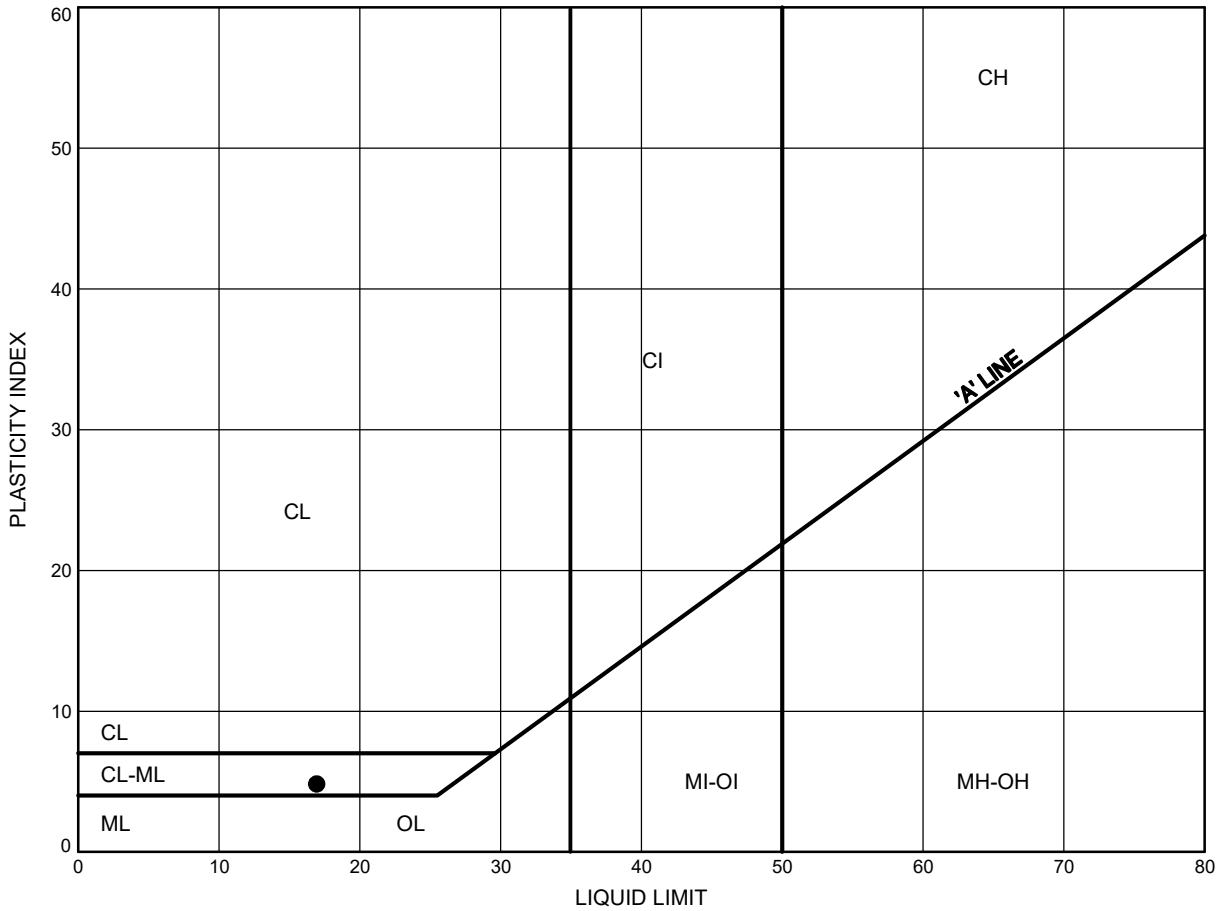
Prep'd AN

Chkd. MH

East Humber Arch Culvert Extension Highway 400 widening
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Clayey SILT TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	7.9	249.4

Date April 2018
W.P. 2539-04-00

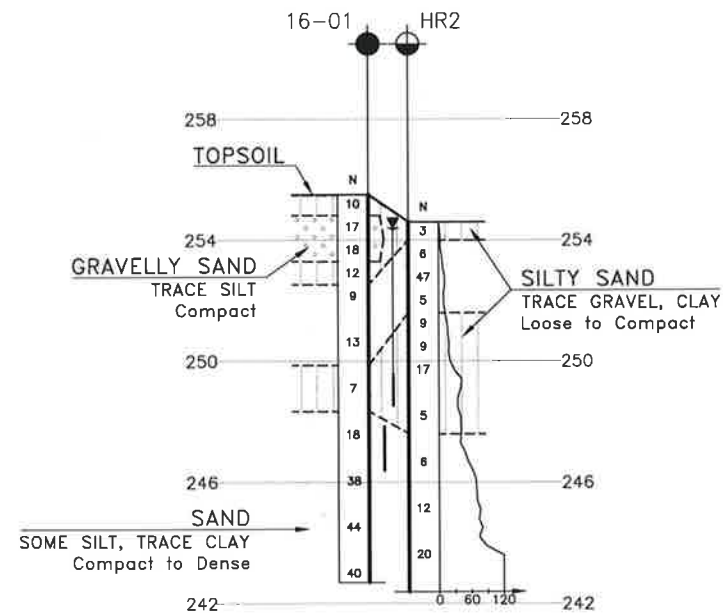


Prep'd AN
Chkd. MH

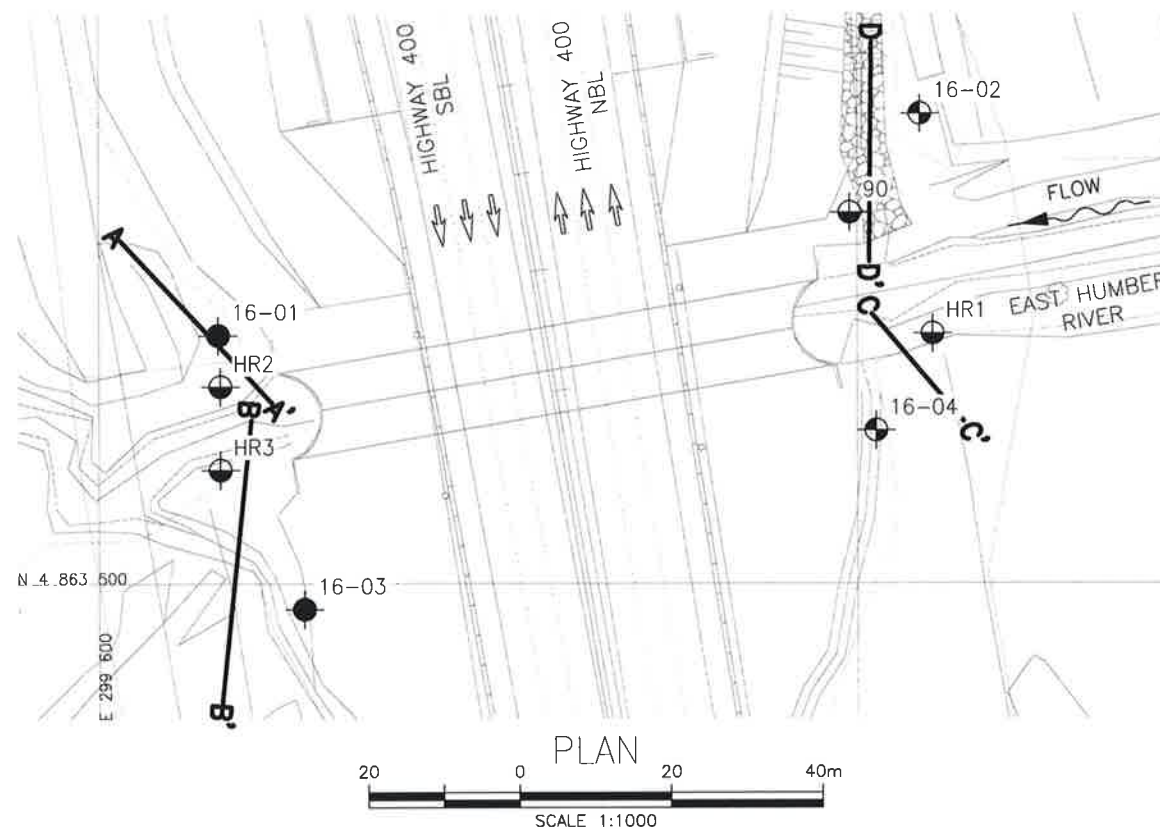


Appendix C

Drawings titled “Borehole Locations and Soil Strata”

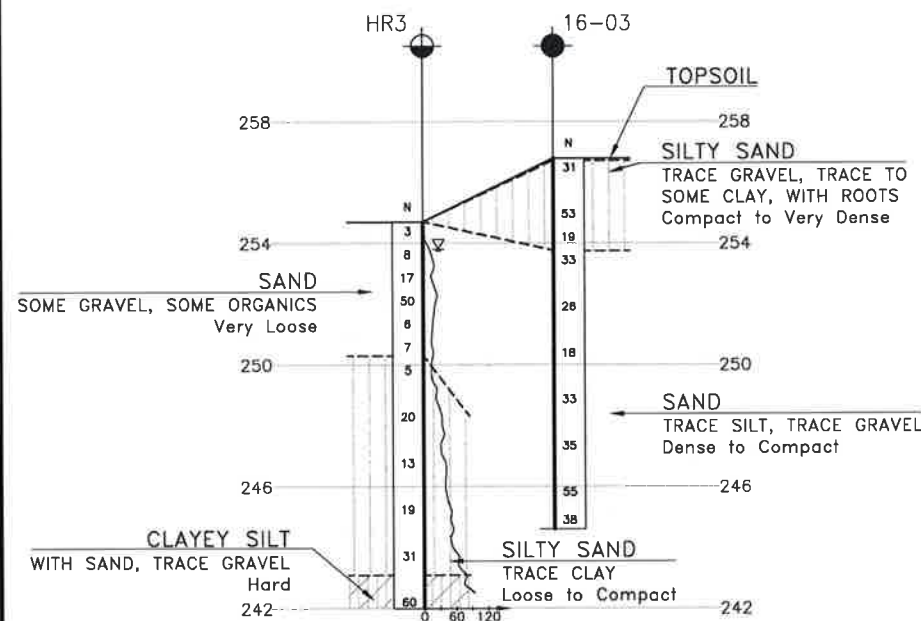


SECTION A-A'

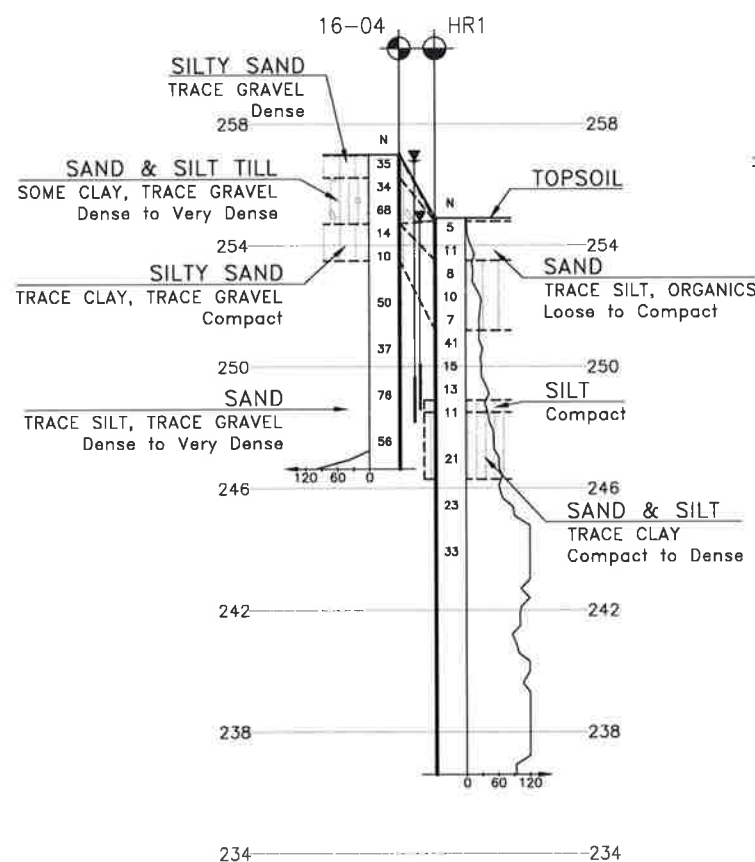


PLAN

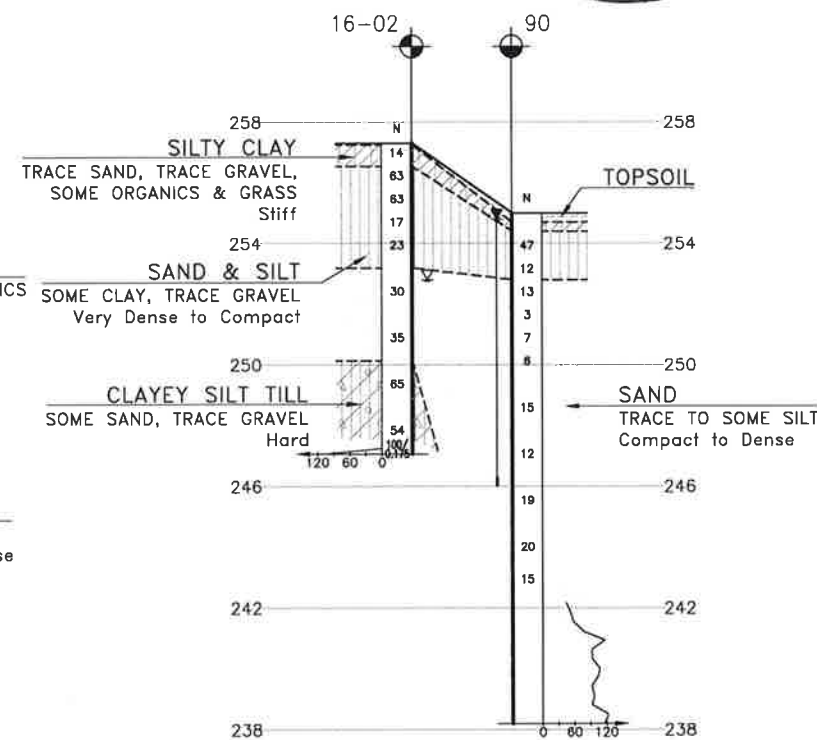
SCALE 1:1000



SECTION B-B'



SECTION C-C'



SECTION D-D'



H 1:1000

V 1:250

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



CONT No 2017-2001
WP No 2539-04-00

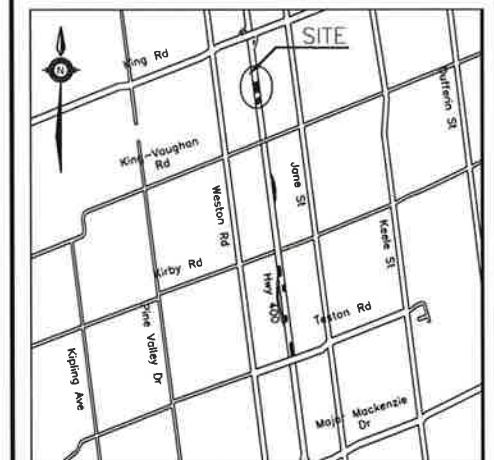
HIGHWAY 400
EAST HUMBER RIVER CULVERT
RETAINING WALLS
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET
532

SNC-LAVALIN

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- Borehole
- ⊕ Borehole & Cone
- ⊕ Borehole (Geocres No. 30M13-156)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ⬆ Head Artesian Water
- ⬆ Piezometer
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-01	255.5	4 863 532.8	299 615.7
16-02	257.3	4 863 562.1	299 708.3
16-03	256.8	4 863 496.6	299 627.0
16-04	257.0	4 863 520.2	299 702.5
90	255.0	4 863 549.0	299 699.0
HR1	254.9	4 863 533.0	299 710.0
HR2	254.6	4 863 526.0	299 616.0
HR3	254.7	4 863 515.0	299 616.0

-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. 30M13-219

DATE	BY	DESCRIPTION
DESIGN	MH	CHK SKP CODE
DRAWN	AN	CHK MH SITE 37-94
		LOAD
		DATE APR 2018
		JDWG R2-2



Appendix D

Foundation Comparison

TABLE D1 COMPARISON OF FOUNDATION ALTERNATIVES

Foundation Element	Concrete Cantilever Wall	Gabion Wall	Concrete Toe Wall	RSS Wall
Retaining Walls	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively cost effective for this type of application ii. Aesthetically compatible with the arch culvert and other structures along the highway iii. Can accommodate a wide range of retained heights <p>Disadvantages:</p> <ul style="list-style-type: none"> i. None compared with other available options 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relative ease of construction. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Unsuitable for retaining back slopes of the required heights ii. Relatively flexible, potentially allowing more lateral ground movement and irregular deformation with time iii. Aesthetic concerns with respect to general appearance. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Better general appearance than gabions. ii. Relatively stiffer than gabion wall. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Limited to retained heights of ≤ 2 m ii. Requires more detailed subgrade preparation and construction procedures than gabions iii. More sensitive to differential settlements. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Can be made aesthetically compatible with the surroundings. ii. Can readily cope with changing retained heights, founding depths and conditions <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Requires sufficient space behind the wall face (0.7 to 1.2 wall height) to install reinforcing strips ii. Submerged RSS walls require scour protection and erosion control; and may result in loss of fines iii. Proprietary suppliers and designers will be involved in the design and construction
	RECOMMENDED	NOT RECOMMENDED	FEASIBLE AT LOWER RETAINED HEIGHTS	NOT RECOMMENDED

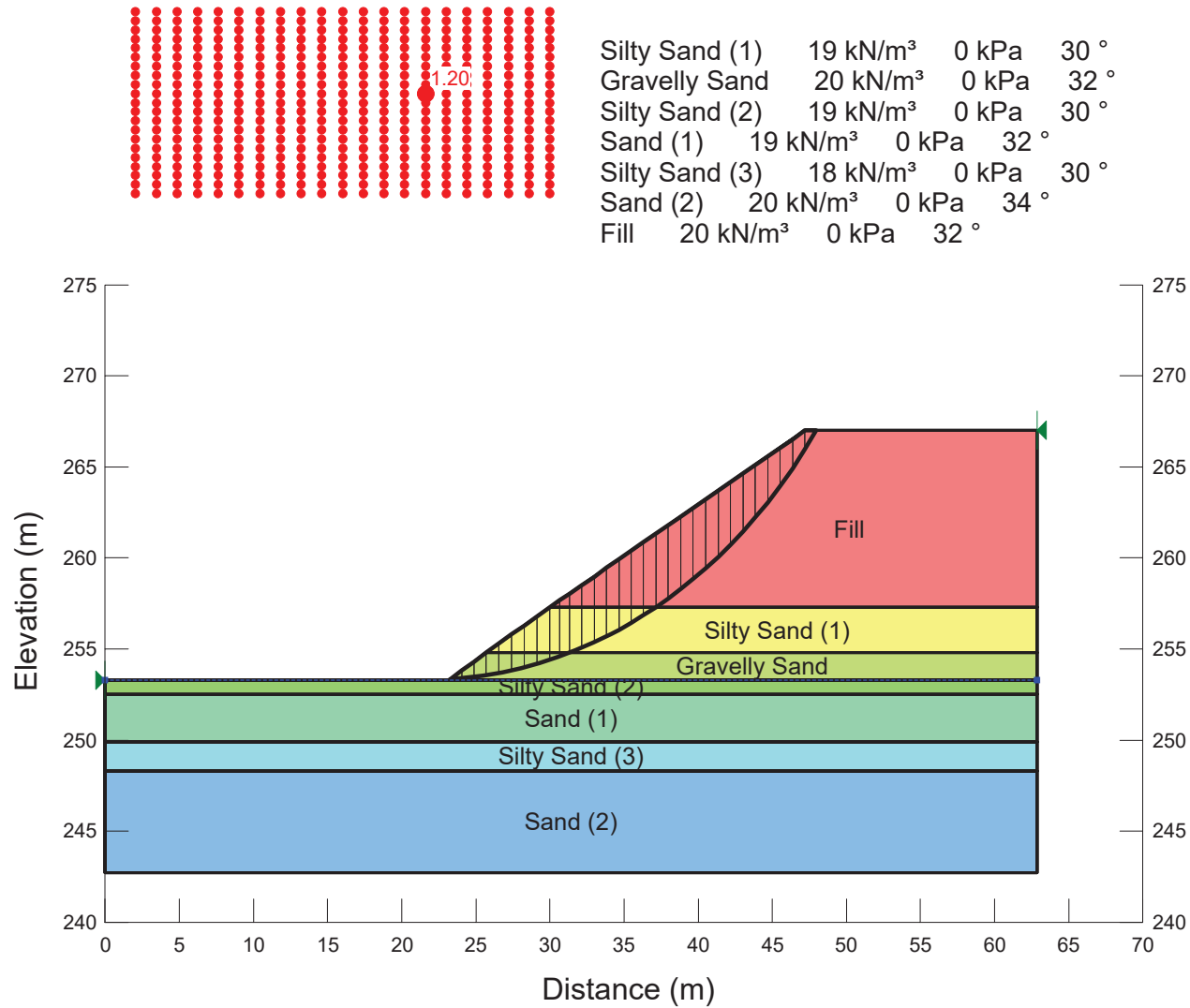


Appendix E

Slope Stability and Settlement Analyses Results

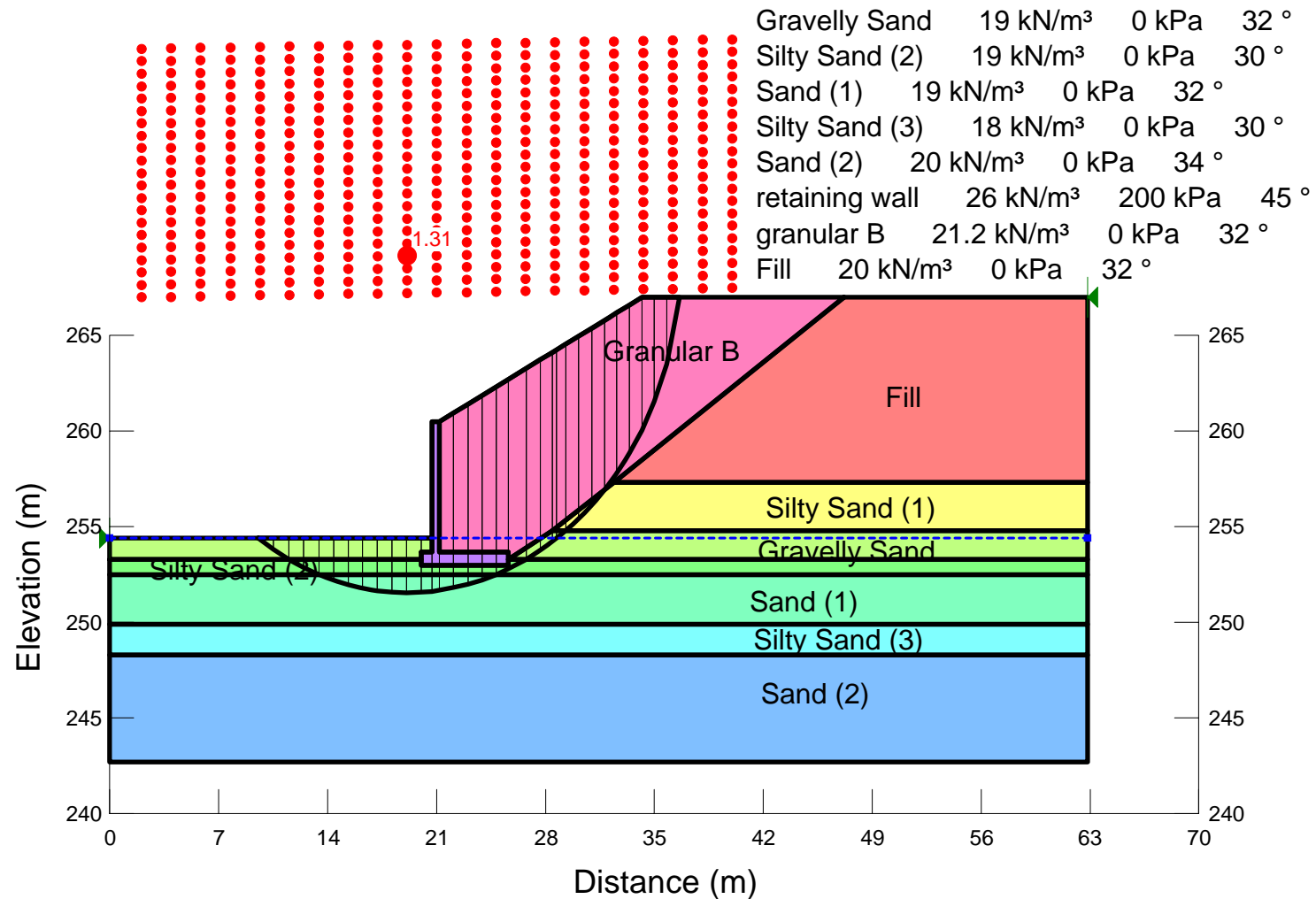
EAST HUMBER RIVER ARCH CULVERT EXTENSION HWY 400 WIDENING CURRENT CONDITIONS - WEST SIDE [DRAINED]

FIGURE E1



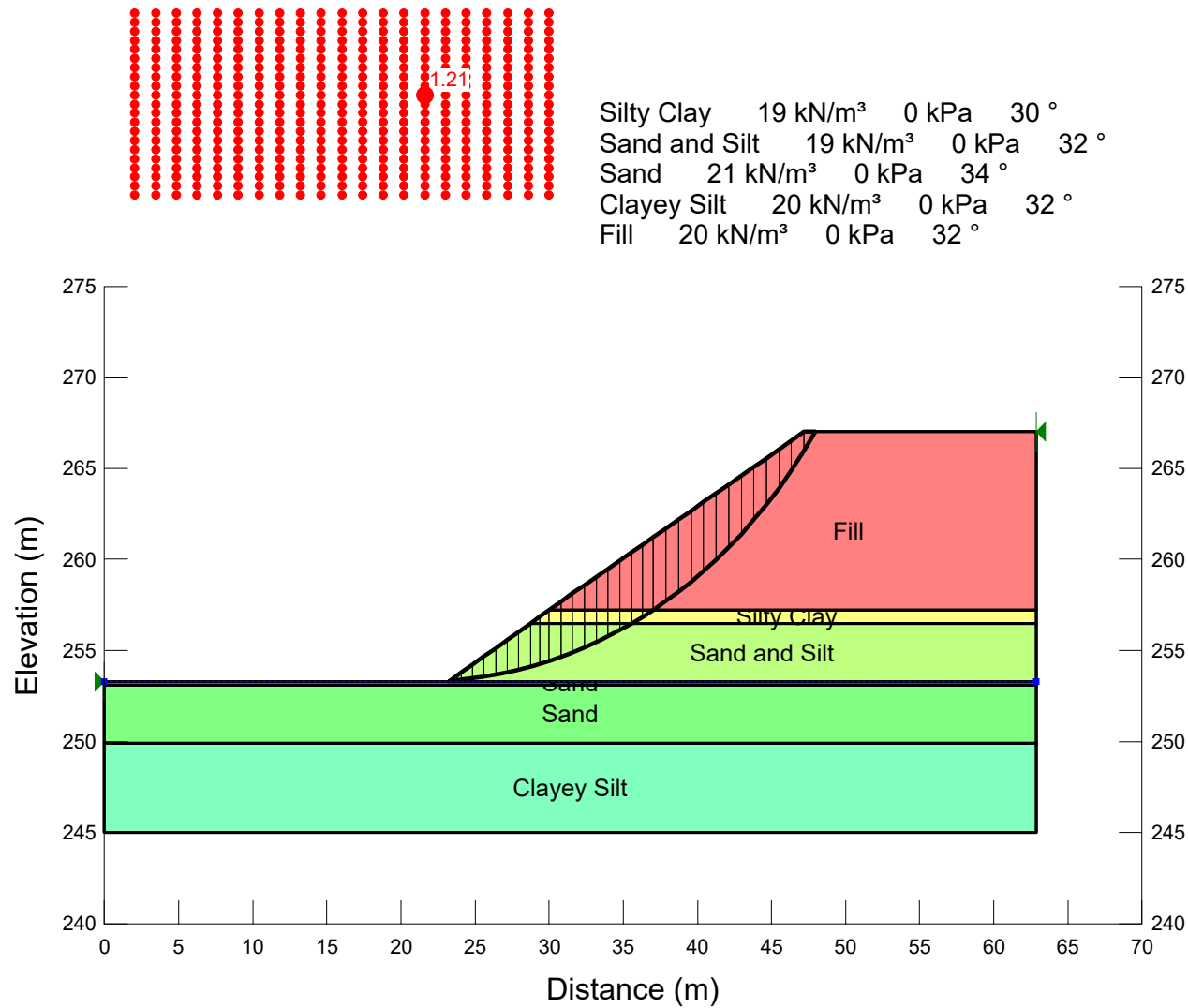
EAST HUMBER RIVER ARCH CULVERT EXTENSION HWY 400 WIDENING AFTER CONSTRUCTION OF WINGWALLS – WEST SIDE [DRAINED]

FIGURE E2



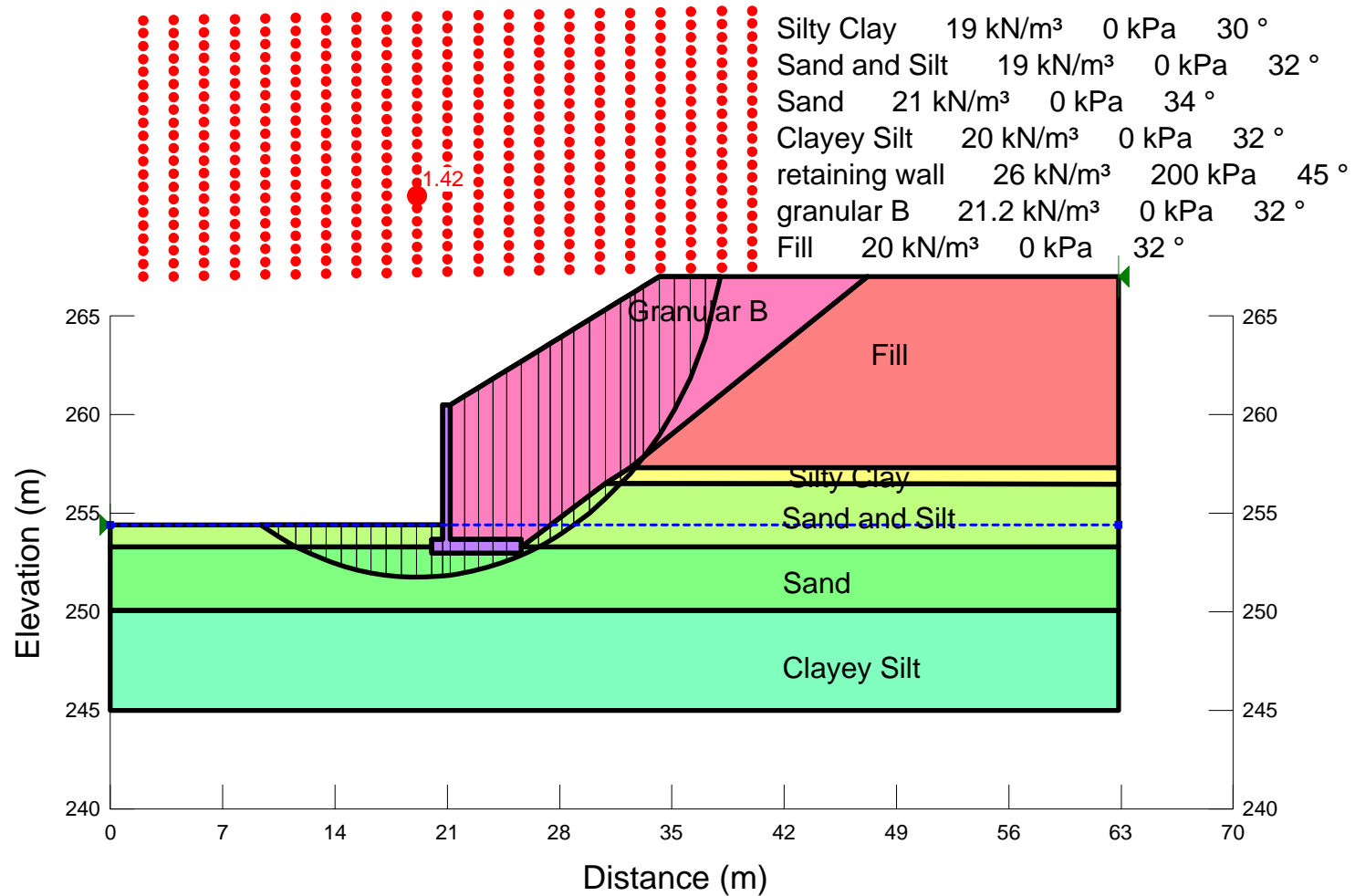
EAST HUMBER RIVER ARCH CULVERT EXTENSION HWY 400 WIDENING CURRENT CONDITIONS – EAST SIDE [DRAINED]

FIGURE E3



EAST HUMBER RIVER ARCH CULVERT EXTENSION HWY 400 WIDENING AFTER CONSTRUCTION OF WINGWALLS – EAST SIDE [DRAINED]

FIGURE E4





Appendix F

List of OPS and Suggested Wordings for NSSPs



1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS.PROV 903
- OPSS.PROV 804
- OPSS.PROV 902
- OPSS.PROV 517 and SP 517F01 – Amendment to OPSS.PROV 517
- OPSS.PROV 539
- OPSS.PROV 206
- OPSS.PROV.1010
- OPSD 3000.100
- OPSD 3102.100

2. Suggested Text for NSSP on “Footing Subgrade Preparation”

The Contractor is advised that the native, water-bearing sands and silts that will be exposed at the subgrade following sub-excavation can be negatively impacted when subject to construction traffic, freeze-thaw actions, ingress of surface water and/or fluctuations of the groundwater table. Once the desired footing subgrade level is reached, careful inspection should be carried out by qualified geotechnical personnel. Once the subgrade is approved, it is recommended that a working mat of mass concrete of the same class and strength as that of the footings be placed for protection prior to footing construction. The thickness of this working slab should be at least 150 mm. Any loose/softened or otherwise disturbed areas should be sub-excavated and backfilled with the same mass concrete quoted above. Footing construction and subgrade preparation must be carried out in the dry.

The Contractor shall be responsible for providing adequate site and subgrade drainage to maintain good trafficability on the subgrade for construction equipment. No additional compensation shall be made to the Contractor for carrying out his operation or construction activities to suit these conditions.



3. NSSP on “Amendment to OPSS.PROV 517 Construction Specification for Dewatering”

Special Provision

Amendment to OPSS 517, November 2016 and SP 517F01, July 2017

517.01 SCOPE

Under these tender items, the Contractor shall be responsible for the design of the dewatering scheme and all work necessary to control the flow of water into the excavation and to prevent disturbance of the founding material at East Humber River Arch (Site No. 37-94) including the wingwalls and Culvert No. 21 (Site No. 37-123/C). The Contractor shall ensure all construction is done in the dry and disposal of water shall conform to OPSS 518.

At East Humber River Arch (Site No. 37-94), dewatering for the construction of the footings and area outside the Temporary Flow Passage System is required. For Culvert No. 21 (Site No. 37-1203/C), dewatering for the construction of the base slab is required. This is different than the Temporary Flow Passage System and all work required for the Temporary Flow Passage System is covered under a separate tender item.

This specification covers the requirements for the design, operation, and removal of a dewatering of temporary flow passage system to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems

517.02 REFERENCES

Section 517.02 of OPSS 517 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 805 Temporary Erosion and Sediment Control Measures

517.03 DEFINITIONS

Section 517.03 of OPSS 517 is amended by the addition of the following:

Automatic Transfer Switch means an electrical device that transfers power supply to a backup power source when there is an outage of the primary power source.



Cofferdam means as defined in OPSS 539.

Cut-Off Wall means a below grade wall that restricts groundwater flow and/or supports excavations, typically using soil-bentonite or cement-bentonite.

Design Storm Return Period means the average number of years based upon probability, between the occurrences of a storm event of a certain severity or greater.

Dewatering System means the components required to control water to permit construction work to proceed under specified conditions, and may include a groundwater control system, impermeable barriers, pumps, and/or equipment to carry out unwatering.

Groundwater Control System means sump pumps, oversized excavations with perimeter ditches, deep wells or well points or other systems used to lower the groundwater table.

Plug means an impervious, natural, or constructed drainage work that blocks water.

Sediment means soil particles detached from an earth surface by erosion.

Sediment Control Measure means a measure to remove sediment from water prior to discharge to the natural environment and sewer systems.

Temporary Flow Control means temporary flow control devices, channels, pipes, and other materials used to convey or divert water past an area under construction.

Unwatering means the removal of ponded or flowing surface water.

Vegetated Discharge Area means a sloped, open area of land with existing vegetation suitable to prevent erosion.

Waterbody means as any permanent or intermittent, natural or constructed body of water including lakes, ponds, wetlands and watercourses, but does not include sewage works as defined in the Ontario Water Resources Act.

Watercourse means a stream, creek, river, or channel including ditches, in which the flow of water is permanent, intermittent, or temporary.



517.04 DESIGN AND SUBMISSION REQUIREMENTS

Subsections 517.04.01 and 517.04.02 of OPSS 517 are deleted in their entirety and replaced with the following:

517.04.01 Design Requirements

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work. The design of the system shall be sufficient to permit the work to be carried out as specified in the Contract Documents.

The design shall meet the requirements of the Contract Documents, and where a waterbody is present, shall include channel and inlet and outlet protection measures as required to protect the environment in the event of system failure or the design flow rate being exceeded.

The design shall not include the use of embankments and/or structures in public use, either existing or to be constructed as part of the Work, to control or stop water flow, unless approved by the Contract Administrator.

The design shall not result in displacement or damage to property, buildings, structures, utilities and other facilities adjacent to the Working Area, including from drawdown related settlement or other groundwater related effects.

The system shall be designed to prevent soil loss or erosion where water is removed, pumped, or discharged. The system shall be designed to prevent basal heave or instability.

Where the system involves the taking of water from a waterbody, the design shall maintain the flow of water and the natural functions of the waterbody upstream and downstream of the work area, and shall not interfere with other uses of the water.

517.04.2 Submission Requirements

Three (3) sets of Working Drawings for the dewatering system shall be submitted to the Contract Administrator at least 7 Days prior to commencement of the dewatering system installation, for information purposes only. Prior to submission of Working Drawings, the seals and signatures of a design Engineer and a design-checking Engineer shall be affixed on the Working Drawings verifying that the



drawings are consistent with the Contract Documents.

One person shall not perform both the design Engineer and design-checking Engineer roles for a system.

Where multi-discipline engineering work is depicted on the same Working Drawing and the design or design-checking Engineer or both are unable to seal and sign the Working Drawing for all aspects of the work, the drawing shall be sealed and signed by as many additional design and design-checking Engineers as necessary.

The following information and details shall be shown on the Working Drawings, where applicable:

- a) Plans, Elevations, and Details
 - i. Type of system(s).
 - ii. Design calculations demonstrating adequacy of the system and equipment.
 - iii. Design flow rate(s).
 - iv. Plan location, description, and dimensions of system components, including dams, cofferdams, cut-off walls, temporary channels, pipes, culverts, sewers, groundwater control systems employing wells and/or well points, sedimentation basins, tanks, pumps, power supply, and standby equipment.
 - v. Method of management of pumped water and plan location of all dewatering discharge points.
 - vi. Profile drawings shall extend through and immediately beyond the limits of the system.
 - vii. Water elevations upstream and downstream of the system at design flow rate.
 - viii. Dam height or crest elevation, cofferdam depth and tip elevation, cutoff wall depth or base elevation, pipe invert elevations, depths of wells and wellpoints, pump intake elevation, and sedimentation basin depth or base elevation.
 - ix. Plan location, elevation, and dimensions of environmental protection measures.
 - x. Pipe type, size, and length, pump capacity, and tank capacity.
 - xi. Material and construction standards to be used for the work.
 - xii. Method for establishing and monitoring construction site groundwater levels.
 - xiii. Criteria and method of removal of the system.
- b) Procedures for the system construction, operation, and maintenance, including daily start-up sequence where applicable, and operation shut down.
- c) Procedures for the removal of the system, including the removal sequence, and well decommissioning.
- d) Stand-by power or pumping system requirements and the use of automatic transfer switching, when required to protect the environment and the Work.



- e) A copy of the Permit to Take Water issued by the Ministry of the Environment and Climate Change or confirmation of registration of water taking for construction dewatering, if a permit or registration is required by provincial regulation.
- f) When applicable, a copy of the water taking report and discharge plan required by provincial regulation.
- g) A copy of any necessary permits for the discharge of water to a sanitary sewer, or stormwater sewer system, stormwater pond, or other facility.

517.04.3 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of 50 metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

517.04.2.1 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

- a) Dewatering of excavation for structure.
- b) Completion of excavation for foundation.
- c) Excavation for backfill and frost tapers.
- d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

517.07 CONSTRUCTION



Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

517.07.4 Dewatering Structure Excavation

517.07.4.1 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation of temporary flow control, if applicable, shall be as specified in the Contract

Documents.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When temporary flow control is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the temporary flow control during the seasonal shutdown period.

Temporary erosion and sediment control measures, including to control the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow control shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

517.07.4.2 Discharge of Water

Water from dewatering and unwatering operations shall be directed to a sediment control measure and/or



a vegetated discharge area 30 m away from waterbodies or as far away as practicable from the top of the bank of any waterbody, prior to discharge to the natural environment.

Equipment and materials shall not be used or stored in vegetated discharge areas.

The discharge of water to the natural environment shall not be directed across pavements, sidewalks, curb and gutter or similar hard surfaces except through appurtenances as specified in the Contract Documents.

517.07.4.3 Monitoring

The Contract Administrator shall be notified of any complaints and any action taken or proposed to be taken in response to complaints.

Daily external visual monitoring of the surrounding area and property and structures on the preconstruction survey, if applicable, for impacts such as settlement and erosion shall be completed. Any observed impacts shall be immediately reported to the Contract Administrator. When public safety, the environment, or property is impacted or potentially impacted, the design Engineer shall, without delay, make a full assessment and direct changes to the system to eliminate impacts or potential impacts. Any changes shall be documented according to the System Amendments subsection.

When a groundwater control system is observed to negatively impact water supplies obtained from any adequate sources that were in use prior to groundwater control system operation, then water shall be supplied to the affected water users. The water shall be equivalent in quantity and quality to the normal water takings of the users. Supply shall continue until the negative impacts on the water supplies are removed, or until Contract Completion, whichever occurs first.

517.07.4.4 System Amendments

When displacement or damage to embankments and/or structures, or property adjacent to the Working Area, occurs due to the operation of the system, or soil loss or erosion occurs where water is removed, pumped, or discharged, the dewatering system or temporary flow control shall be amended to stop the displacement, damage, soil loss, or erosion.

Amendments shall be submitted to the Contract Administrator within two Business Days of the system being amended, on revised Working Drawings bearing the seal and signature of the design Engineer and design- checking Engineer.

517.07.4.5 Removal

Dewatering system and temporary flow control components shall be removed when no longer



required. Removal of system components shall be according to the procedures specified on the Working Drawings, where applicable, and as specified in the Contract Documents.

Deactivation of temporary flow control shall be as specified in the Contract Documents.

Removal of temporary drainage work shall be according to OPSS 510.

Environmental protection measures and cut-off walls shall be removed, unless approved otherwise by the Contract Administrator.

Sedimentation basins and other excavations shall be backfilled with the original soil excavated, unless approved otherwise by the Contract Administrator. All disturbed areas shall be restored to an equivalent or better condition than existed prior to the commencement of construction.