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Highway 427 Expansion
Langstaff Road Underpass (Structure B13)

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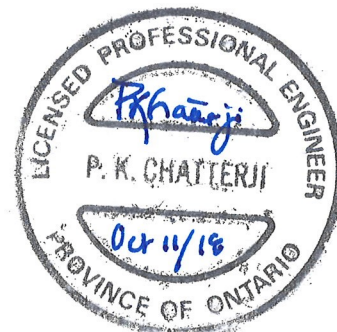
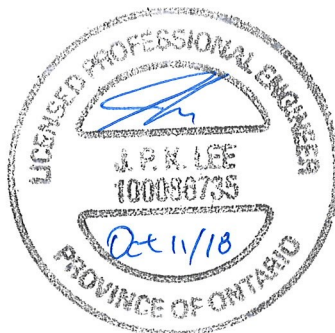
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1. INTRODUCTION

This report presents the results of a foundation investigation and provides foundation recommendations for the design and construction of the proposed bridges to carry Langstaff Road over the new Highway 427. The project is part of the proposed 6.6 km long extension of Highway 427 from Highway 7 to Major Mackenzie Drive in the City of Vaughan, Ontario.

Recommendations on the foundation aspects of the bridge design presented in this report were based on the interpretation of the subsurface information obtained during the current foundation investigation by Thurber Engineering (Thurber) as well as previous investigations at the site. The results of the previous investigations are presented in the reports listed below:

- GEOCRE 30M13-177: Preliminary Foundation Investigation and Design Report, High Fill Embankments, Highway 427 Extension from Highway 7 to Major Mackenzie Drive, Ministry of Transportation, Ontario, W.O. 05-20012, dated August 2009, prepared by Golder Associates.
- GEOCRE 30M13-216: Preliminary Foundation Investigation and Design Report, Highway 427 Expansion Project, Extension from Highway 7 to Major Mackenzie Drive, City of Vaughan, Ontario, W.O. 18, dated March 2016, prepared by Peto MacCallum Ltd.

Foundation recommendations presented in this report were prepared based on the General Arrangement (GA) drawing H427-D-F-4-STR-B13-DWG-600-A, dated January 31, 2018.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION, GEOLOGY BACKGROUND AND PROJECT DESCRIPTION

The site is located immediately north of the current Langstaff Road alignment approximately 1 km west of Highway 27 and 500 m north of Rainbow Creek in Vaughan. There are several industrial properties currently present at the site.

The site is situated within the Peel Plain physiographic region the subsurface condition in which generally comprises clayey silt to silty clay of Halton till with interlayers of sand and silt. Localized recent deposits of sands, silts and soft clays formed in small glacial meltwater ponds throughout the region may be encountered near the river and creek valleys. The site is underlain by shale bedrock of the Georgian Bay Formation with siltstone and limestone interlayers.

Based on the GA drawing, the proposed underpass structure is a two-span bridge with integral abutment configuration and the foundation of the pier supported on spread footing. The side slopes and foreslopes of the approach embankments are proposed to have a slope inclination of 2H:1V.

3. GEOTECHNICAL INVESTIGATION

The current field investigation at the proposed bridge site was conducted between May 10 and May 23, 2017, and consisted of advancing six (6) boreholes, designated as Boreholes LR17-01 to LR17-06 to depths ranging between 9.8 m and 27.7 m.

Borehole coordinates and ground surface elevations were provided by CJV. The Record of Borehole sheets (which includes the approximate locations in MTM NAD 83, Zone 10 coordinates) and the Borehole Locations and Soil Strata Drawing are included in Appendix A and Appendix D, respectively.

Truck mounted Mobile B57 drill rigs supplied by Landshark Drilling Inc. of Brantford, Ontario, were used to advance the boreholes. Soil samples were obtained at selected intervals using a 50 mm nominal inner diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT) procedures as per ASTM D1586. The

bedrock was confirmed by a minimum of 3 m coring using NQ-sized coring in four boreholes. All rock cores were logged, and Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and Fracture Indices (FI) were determined.

Groundwater conditions were observed in the open boreholes throughout the drilling operations and measured upon completion of drilling. However, since water was used during the drilling operations these measurements were considered not reliable. Standpipe piezometers were installed in four Boreholes (LR 17-02 to LR 17-05). The other two boreholes were backfilled as per O. Reg. 903. The piezometers will be decommissioned by Project Co. following final round of water level measurements as per O. Reg. 903.

Six borehole logs are available from the previous investigations. Boreholes S12, S13, S14 and S14A from the 2009 report and Boreholes LR-1 and LR-2 from the 2016 report are enclosed in Appendix C.

4. SUBSURFACE CONDITIONS

A general description of the stratigraphy is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description which was prepared for interpretation of the site conditions. Subsurface soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions at the site generally consist of a layer of surficial silty clay overlying a relatively thick deposit of clayey silt to silty clay till over shale bedrock. Asphalt and fill layers were encountered from ground surface at the borehole locations. In some boreholes, silty sand to sand till was encountered above shale bedrock and discontinuous sand layers were encountered in the cohesive till. Occasional auger grinding, hard augering, and/or split spoon bouncing were noted in the till deposits which are indications of presence of cobbles and/or boulders as expected to be present in till deposits of southern Ontario.

More descriptions of the subsurface conditions at the site are presented below.

4.1 Asphalt

Asphalt was encountered at the ground surface in the boreholes advanced through the parking lots of the existing industrial facilities (Boreholes LR 17-01 to LR 17-04). The thickness of the asphalt ranged from 50 to 75 mm.

4.2 Topsoil

Topsoil was encountered at the ground surface in Boreholes LR 17-06. The thickness of the topsoil was 75 mm.

4.3 Fill

A 0.3 to 0.9 m thick layer of cohesionless fill (gravelly sand to silty sand to sandy silt fill) was encountered in Boreholes LR 17-01 to 17-05. This cohesionless fill was underlain by 1.0 to 1.1 m of cohesive fill (clayey silt to silty clay fill) in boreholes LR 17-01, 17-03, and 17-04. The fill extended to depths ranging between 1.5 m and 1.6 m (Elev. 187.6 and 186.4 m). The SPT-N values within the cohesionless fill ranged from 7 to 34 blows per 0.3 m of penetration indicating a loose to dense relative density. The SPT-N values within the cohesive fill ranged from 5 to 8 blows per 0.3 m of penetration indicating a firm consistency.

4.4 Surficial Silty Clay

A 0.8 m thick deposit of silty clay was encountered in Borehole LR 17-06. The deposit extended to 0.9 m depth (Elev. 186.8 m). An SPT-N value of 7 blows per 0.3 m of penetration was measured in the deposit indicating a firm consistency.

4.5 Clayey Silt to Silty Clay Till

Clayey silt to silty clay till was encountered below the fill in all boreholes except LR 17-06 where it was encountered underlying surficial silty clay. The till extended to a maximum depth of 23.9 m (Elev. 164.0 m) in the boreholes.

SPT-N values within the cohesive till ranged from 8 blows per 0.3 m penetration to 80 blows per 0.125 m of penetration indicating a stiff to hard (predominantly very stiff to hard) consistency.

Glacial tills inherently contain cobbles and boulders.

4.6 Sand

Sand (also described as “sand to silty sand” in previous investigations) was encountered within the clayey silt to silty clay till in Borehole LR 17-03 at a depth of 18.3 m. The thickness of the sand was 1.5 m in the borehole and it extended to a depth of 19.8 m (Elev. 168.1 m).

An SPT-N value of 22 blows per 0.3 m penetration was recorded within the sand indicating a compact relative density.

4.7 Sand and Silt Till

A 1.1 m thick deposit of sand and silt till was encountered below the clayey silt to silty clay till in Borehole LR 17-04 and extended to a depth of 23.2 m (Elev. 165.0 m).

An SPT-N value of 80 blows per 0.3 m penetration was recorded within the deposit indicating a very dense relative density.

Glacial tills inherently contain cobbles and boulders.

4.8 Shale Bedrock

Grey shale bedrock of the Georgian Bay Formation was confirmed by coring in Boreholes LR 17-02 to LR 17-05. The bedrock surface was encountered at depths ranging between 23.2 and 23.9 m (Elev. 165.0 and 164.0 m). In general, the TCR ranged from 45 to 100%, and the SCR and RQD values ranged typically between 0 and 90%, and 0 and 73%, respectively. The RQD values indicate a very poor to good rock quality.

4.9 Groundwater Levels

Water levels measured in the piezometers installed during the current investigation are summarized in Table 4.1.

Table 4.1 – Piezometer Details and Groundwater Level Measurements

Borehole	Measurement Date	Water Level (m)		Screen Depth (m)	Native Material at Screen
		Depth	Elevation		
LR 17-02	August 8, 2017	5.5	182.7	19.8 – 22.9	Clayey Silt/Silty Clay Till
LR 17-03 (S)	August 9, 2017	0.5	187.4	4.0 – 7.0	Clayey Silt/Silty Clay Till
LR 17-03 (D)	August 9, 2017	3.6	184.3	7.6 – 9.1	Clayey Silt/Silty Clay Till (Sand and Silt seam)
LR 17-04	August 8, 2017	5.5	182.7	21.4 – 22.9	Clayey Silt/Silty Clay Till/ Sand and Silt Till
	Oct 25, 2017	5.4	182.8		
LR 17-05	August 9, 2017	3.7	184.2	22.0 – 23.5	Clayey Silt/Silty Clay Till

(S) denotes Shallow piezometer, (D) denotes Deep piezometer.

The above groundwater levels represent relatively short-term readings and seasonal fluctuations of the groundwater level are to be expected. The groundwater level may be at higher elevations after the spring snowmelt or after periods of heavy rainfall. Perched water may be present at higher levels in lenses or zones of more permeable sands and silts within the till.

4.10 Corrosion and Sulphate Test Results

Soil samples collected from selected boreholes were submitted for analytical testing of corrosivity parameters and sulphate content. The laboratory certificates of analyses are presented in Appendix B. The results of the analytical tests are summarized in Table 4.2.

Table 4.2 – Corrosion and Sulphate Test Results

Parameter Tested	Unit	LR17-03	LR17-05
		SS2	SS3
Moisture	%	18.5	7.3
Corrosivity Index	-	1.0	7.5
pH	-	7.90	8.67
Soil Redox Potential	mV	172	243
Sulphide	%	< 0.02	0.06
Chloride	µg/g	710	24
Sulphate	µg/g	29	50
Electrical Conductivity	µS/cm	725	121
Resistivity	ohms.cm	1380	8260

5. GEOTECHNICAL RECOMMENDATIONS

5.1 Foundation Design

5.1.1 Spread Footings

Spread footings are considered a feasible foundation option to support the pier and may be designed using the axial geotechnical resistances at the factored ULS and factored SLS provided in Table 5.1, assuming a minimum footing width of 3 m.

Table 5.1 – Geotechnical Resistances at ULS and SLS for Spread Footings

Location (Reference Borehole)	Highest Founding Elevation (m)	Founding Stratum	Factored ULS (kPa)	Factored SLS (kPa)
Center Pier (LR 17-03 & LR 17-04)	179.7	Very Stiff to Hard Silty Clay to Clayey Silt Till	400	300

The factored Geotechnical Resistance at SLS refers to settlement not exceeding 25 mm. The value of 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 factored Geotechnical Resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The geotechnical resistance quoted above is for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as indicated in Clause 6.10.3 and Clause 6.10.4 of the CHBDC (2014).

5.1.1.1 Lateral Resistance

The lateral resistance of the footings against sliding may be computed using an unfactored friction coefficient of 0.45 for cast-in-place concrete founded on very stiff to hard clayey silt to silty clay till. This value of friction coefficient is an ultimate value and requires some degree of sliding movement to fully mobilize.

5.1.1.2 Subgrade Preparation for Spread Footings

After the foundation excavation reaches the design subgrade level, the exposed surface should be inspected to

confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, disturbed soils and deleterious materials within the foundation footprint should be removed and backfilled with mass concrete. The work should be carried out as per OPSS 902 and construction must be carried out in the dry.

Once the subgrade is prepared, the construction traffic and equipment must not travel on the subgrade. It is recommended that a 100 mm thick layer of mass concrete be placed as soon as practicable to protect the footing subgrade.

5.1.2 Driven H-Piles

Based on the available subsurface information, supporting the proposed bridges on steel H-piles driven to refusal in hard till or shale bedrock is feasible. The recommendations and discussion on design and construction of driven H-piles are presented below. Cobbles and boulders generally exist within the till deposits in the project area.

5.1.2.1 Axial Pile Resistance

The axial resistances of a HP360x174 steel pile driven to refusal in hard till or shale bedrock were assessed based on the subsurface conditions encountered at the abutment and pier locations. The estimated axial geotechnical resistances as well as the recommended pile tip elevations are summarized in Table 5.2.

Table 5.2 - Geotechnical Resistances for HP360x174

Location (Reference Borehole)	Approximate Pile Tip Elevation (m)	Founding Stratum	Factored ULS (kN)	Factored SLS (kN)
West Abutment (LR-1 & LR 17-02)	175.0 or below	Very stiff to hard Till	1400	1100
	164.6	Refusal in Hard Till or on Shale Bedrock	2800	2400
Center Pier (LR 17-03 & LR 17-04)	164.5 to 165.0	Refusal in Hard Till or on Shale Bedrock	2800	2400
East Abutment (LR-2 & LR 17-05)	175.0 or below	Very stiff to hard Till	1400	1100
	164.0 to 164.2	Refusal in Hard Till or on Shale Bedrock	2800	2400

The factored geotechnical resistance at SLS provided above corresponds to up to 25 mm of settlement.

The factored geotechnical resistance at ULS was assessed assuming a consequence factor of 1 (Typical), and a resistance factor of 0.4 (Typical degree of understanding of the subsurface conditions), as per CHBDC (2014). The factored geotechnical resistance at SLS was assessed assuming a resistance factor of 0.8 for typical degree of understanding of the subsurface conditions.

5.1.2.2 Lateral Pile Resistance

The geotechnical lateral resistance acting on a HP360x174 pile in cohesive soils may be calculated using 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 in metres (0.378 m for HP360x174)

The lateral resistance acting on a HP360x174 pile in cohesionless soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

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

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

Where:

$$z = \text{depth of embedment of pile (m)}$$

$$D = \text{pile width in metres (0.378 m for HP360x174)}$$

$$n_h = \text{coefficient related to soil relative density (kN/m}^3\text{)}$$

$$\gamma' = \text{effective unit weight (kN/m}^3\text{)}$$

$$K_p = \text{passive earth pressure coefficient}$$

The above equations and parameters provided in Table 5.3 may be used to analyze the interaction between a pile and the surrounding soil. Lateral pressures obtained from analysis must not exceed the ultimate lateral resistance.

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} , can be obtained from the expression, $P_{ult} = p_{ult} L D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

Table 5.3 – Geotechnical Design Parameters for Lateral Pile Resistance

Foundation Location	Soil Unit	Elevation (m)		γ' (kN/m³)	n_h (kN/m³)	K_p	S_u (kPa)
		Top	Bottom				
West Abutment	South Side (LR-1)						
	Clayey Silt/Silty Clay Till	187.8	184.5	20	-	-	100
	Clayey Silt/Silty Clay Till	184.5	180.8	10 (*)	-	-	80
	Clayey Silt/Silty Clay Till	180.8	170.3	11 (*)	-	-	120
	Sand	170.3	168.8	11 (*)	5,500	3.2	-
	Clayey Silt/Silty Clay Till	168.8	167.2	12 (*)	-	-	250
	Sand and Silt	167.2	164.8	12 (*)	10,000	3.5	-
	North Side (LR17-02)						
	Clayey Silt/Silty Clay Till	187.4	183.5	20	-	-	120
	Clayey Silt/Silty Clay Till	183.5	171.0	11 (*)	-	-	200
	Clayey Silt/Silty Clay Till	171.0	164.6	12 (*)	-	-	250
Pier	South Side (LR17-03)						
	Silty Clay	187.4	186.4	20	-	-	50
	Clayey Silt/Silty Clay Till	186.4	184.0	20	-	-	120
	Clayey Silt/Silty Clay Till	184.0	179.0	10 (*)	-	-	90
	Clayey Silt/Silty Clay Till	179.0	173.0	11 (*)	-	-	150
	Clayey Silt/Silty Clay Till	173.0	169.6	10 (*)	-	-	80
	Silty Sand	169.6	168.1	11 (*)	4,500	3.1	-
	Clayey Silt/Silty Clay Till	168.1	164.5	12 (*)	-	-	250
	North Side (LR17-04)						
	Clayey Silt	187.8	186.7	20	-	-	50
	Clayey Silt/Silty Clay Till	186.7	183.0	20	-	-	100
	Clayey Silt/Silty Clay Till	183.0	180.0	10 (*)	-	-	100
	Clayey Silt/Silty Clay Till	180.0	173.0	11 (*)	-	-	200

Foundation Location	Soil Unit	Elevation (m)		γ' (kN/m ³)	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
	Clayey Silt/Silty Clay Till	173.0	166.1	11 (*)	-	-	120
	Silty Sand	166.1	165.0	12 (*)	10,000	3.5	-
East Abutment	South Side (LR-2)						
	Clayey Silt/Silty Clay Till	187.4	184.5	20	-	-	100
	Clayey Silt/Silty Clay Till	184.5	182	10 (*)	-	-	80
	Clayey Silt/Silty Clay Till	182	173.5	10 (*)	-	-	120
	Clayey Silt/Silty Clay Till	173.5	170.4	10 (*)	-	-	90
	Silty Sand	170.4	169	11 (*)	5,000	3.2	-
	Clayey Silt/Silty Clay Till	169	164.2	11 (*)	-	-	250
	North Side (LR17-05)						
	Clayey Silt/Silty Clay Till	187.0	184.2	20	-	-	100
	Clayey Silt/Silty Clay Till	184.2	180.5	10 (*)	-	-	80
	Clayey Silt/Silty Clay Till	180.5	170.0	11 (*)	-	-	120
	Clayey Silt/Silty Clay Till	170.0	164.0	12 (*)	-	-	250

Note (*): Submerged Unit Weight

The modulus of subgrade reaction and 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 Table 5.4. Intermediate values may be obtained by linear interpolation.

Table 5.4 - Subgrade Reaction Reduction Factors for Pile Spacing

Condition	Pile Spacing, Centre to Centre	Reduction Factor
Pile group oriented perpendicular to direction of loading	4D	1.0
	1D	0.5
Pile group oriented parallel to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

5.1.2.3 H-Pile Installation

Pile driving must be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance (two times the design load at ULS) should be specified by the structural designer.

For the case of piles driven to very stiff to hard till at Elev. 175 or below, it is anticipated that there will be relaxation on the pile capacity due to the Highway 427 cut excavation of 5 to 6 m soils in front of the abutments. To account for the potential loss of capacity, the Hiley test must achieve an ultimate pile resistance (R) of 3,640 kN and pile tips driven down to EL. 175.0 m or lower (approximately 6 m below the Hwy 427 mainline grade). PDA testing must be conducted on at least 10% of the piles at each abutment in accordance with OPSS 903 (3 tests on 3 piles at each abutment) to verify pile resistance during retapping after completion of the cut excavation.

The piles may encounter refusal on the cobbles and/or boulders that may be present in the till deposit above the design tip elevations. The pile installation equipment should be capable of penetrating through the cobbles and boulders. Oversize materials (e.g. greater than 75 mm nominal diameter) should not be used for any new fill which the piles will be driven through.

5.1.2.4 Pile Tips

To prevent structural damages to the piles when setting them in the very dense/hard till/shale bedrock or if cobbles or boulders are encountered, piles should be equipped with tip protection. All driven H-piles should be fitted with pile tip protection as per OPSS.PROV 903 and OPSD 3000.100 (Type I H-Pile Driving Shoe).

Care must be taken when driving piles to very dense/hard till with cobbles and boulders or to bedrock to avoid overdriving and damage to the piles. If pile damage or misalignment occurs, PDA testing may be required to assess the pile capacity and integrity. Consideration should be given to using Titus Steel (Standard H-point) or approved equivalent for the remaining piles at this site.

5.2 Frost Protection

The design depth of frost penetration at this site is 1.2 m. All pile caps and footing bases should be provided with 1.2 m of earth cover or an equivalent thickness of synthetic insulation.

5.3 Backfill to Abutments

Backfill to the abutment walls should be Granular A or Granular B Type II material meeting the requirements of OPSS. PROV 1010. The backfill should be in accordance with OPSS 902 and placed to the extent shown in OPSD 3101.150.

Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501. The design of the abutment should incorporate a subdrain as shown in OPSD 3101.150.

5.4 Lateral Earth Pressure

Lateral earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are 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
γ	=	unit weight of retained soil (kN/m ³)
H	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be applied in the design.

Earth pressure coefficients for backfill to the abutment walls are dependent on properties of the granular fill used as the backfill. Typical values are shown in Table 5.5.

Table 5.5 – Coefficients of Lateral Earth Pressure

Loading Condition	OPSS Granular A or B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At-rest (Restrained Wall)	0.43	-	0.47	-

Loading Condition	OPSS Granular A or B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Passive	3.7	-	3.3	-

* For wing walls

5.5 Seismic Considerations

Based on the encountered subsurface conditions, Site Class C may be assumed to evaluate the seismic site response, as per Table 4.1, Clause 4.4.3.2 of the CHBDC 2014.

The peak ground acceleration, PGA, for a 2% in 50-year probability of exceedance at this site is 0.11 g as per the National Building Code of Canada 2015 (NBCC 2015).

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 5.6 may be used:

Table 5.6 – Earth Pressure Coefficients for Earthquake Loading

Loading Condition	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.31	0.35
Passive (K_{PE})	3.5	3.1
At-rest (K_{OE})**	0.57	0.62

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

** After Woods

Given the low seismic ground motions and the presence of very stiff to hard clayey silt to silty clay till, the potential for liquefaction is considered low at this site.

5.6 Approach Embankments and Reinforced Soil System (RSS)

5.6.1 General

The GA drawing indicates that reinforced earth systems (RSS) for false abutments and wingwalls will be installed at the abutments. The drawing shows the RSS walls up to 7 m at the west and east abutments. It should be noted that no structural loading is applied to the RSS system in the case of false abutments. The RSS walls will be designed to “High Performance” and “High Appearance” at this site.

The existing soils at the abutments and approach embankments generally consist of surficial fill layers (loose to dense gravelly sand/sandy silt/silty sand and firm cohesive silty clay) beneath the paved surfaces and firm silty clay beneath topsoil in the unpaved areas. These surficial layers extend to 0.9 m to 1.6 m below existing ground surface and are underlain by very stiff to hard clayey silt to silty clay till.

The construction of the Langstaff Road Underpass bridge will require the placement of up to 3.5 m of fill at the west approach and up to 3 m at the east approach. The construction of the Highway 427 underpass will require excavation to approximately 5 m below the existing ground surface. The total height of the approach embankments will be up to approximately 8.5 m above the highway design grade. The side slopes of the approach embankment will be at an inclination of 2H:1V.

5.6.2 Subgrade Preparation

Topsoil and any soft surficial clayey silt/silty clay, loose fill, disturbed soils and deleterious materials within the footprint of the approach embankments should be removed and replaced with suitable granular material compacted as per OPSS.PROV 501. The exposed subgrade surface should be proof rolled and inspected to confirm that the subgrade is suitable and uniformly competent.

The groundwater table is anticipated to be drawn down upon completion of excavation for the permanent cut prior to constructing the RSS walls. The work should be carried out in accordance with OPSS 902 and wall construction must be carried out in the dry. Once the subgrade is prepared, the construction traffic and equipment should not travel on the subgrade.

The RSS walls should be founded on a minimum 500 mm thick layer of bedding material conforming to OPSS Granular A requirements to form a uniform subgrade. Engineered fill placed under the RSS mass to achieve the design founding level should be compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered fill layer should extend at least 500 mm beyond the limits of the RSS mass.

5.6.3 Geotechnical Resistance

As per MTO RSS Design Guidelines, the minimum soil cover to the underside of the levelling pad shall be at least 800 mm, or 40% of the actual frost depth for the area, whichever is greater. The minimum soil cover to the top of the levelling pad shall be at least 500 mm.

The RSS walls founded on very stiff clayey silt to silty clay till at the highest elevation of 183.5 m should be designed for a factored geotechnical resistance at ULS of 300 kPa and a factored geotechnical resistance at SLS of 200 kPa.

The recommended geotechnical resistances are for vertical concentric loading. The effects of load inclination and eccentricity need to be considered in accordance with CHBDC.

The RSS mass must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base native clayey silt till and engineered fill may be estimated using an ultimate friction coefficient of 0.35 and 0.55, respectively.

The internal stability or structural integrity of the RSS walls should be analysed by the supplier/designer of the proprietary product selected for this site.

5.6.4 Approach Embankment Stability

Slope stability analyses were carried out to assess the global stability of the approach embankments/RSS walls using the commercially available program Slope/W, employing Morgenstern-Price method of analysis.

For a RSS wall with a reinforcing strip length equal to 70% times its height, and RSS wall base at Elev. 183.5 m, satisfactory factors of safety greater than 1.3 for short-term condition and 1.5 for long-term condition were computed as shown in Appendix E. The approach embankments will be stable at side slopes inclined at 2H:1V or flatter.

5.6.5 Approach Embankment Settlement

The settlements of the foundation soils were estimated to be less than 25 mm under the approach embankments. Significant percentage of the estimated settlements will occur during embankment construction and within first two months following the completion of the embankment construction.

Embankment settlement due to fill compression is estimated to 0.5% of the fill height for granular fill or earth fill compacted to 100% of their SPMDD at a moisture content within 2% of optimum. Approximately 50% of the total fill compression (or 0.25% of the fill height) will occur during construction and the remaining 50% or approximately

10 mm at this site will occur after construction. After backfilling the structure, a waiting period of a minimum 1 month should be allowed for embankment settlement to take place prior to construction of approach slab and final paving.

5.7 Excavation and Dewatering

Excavation at this site will be carried out mainly in the very stiff clayey silt to silty clay till and should be carried out in accordance with OPSS.PROV 206.

All excavations should be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the cohesive till within the depth of excavation may be classed as Type 3 soil.

The excavation and backfilling for foundations should be carried out in accordance with OPSS 902.

Deep piezometers installed in the cohesive till measured groundwater levels between Elev. 182.7 and 184.3 m. A shallow piezometer installed in Borehole LR 17-03 measured a water level at Elev. 187.4 m, likely representing perched groundwater. These water levels are above the base of excavation for construction of RSS walls and the pier footings. However, given the consistency and relatively low permeability of the clayey silt to silty clay till, groundwater control measures such as perimeter ditches and pumping from filtered sumps inside the cofferdam should be adequate to lower the groundwater table to below the base of excavation. The possibility exists that additional pumps may be required if localized zones of high volume of perched groundwater are encountered.

All pile caps and spread footings should be constructed in the dry.

5.8 Corrosion and Sulphate Attack Potential

The results of the analytical tests for corrosivity and sulphate content conducted on the soil samples indicate the following:

- The potential for sulphate attack on structural concrete from the surrounding soil is negligible based on the generally low concentration of sulphate in the samples tested.
- The potential for corrosion on metal elements of the structure is considered to be mild to severe.
- Appropriate protection measures are recommended if metal structural elements are used.

5.9 Construction Concerns

Potential construction concerns include, but not necessarily limited to:

- The driven steel H-pile installation in the glacial till may result in pile misalignment and/or damages at the pile tip due to the presence of cobbles and/or boulders. The piling contractors should be warned of the associated risks.
- All pile caps and pier footings should be constructed in the dry. The clayey silt to silty clay subgrade should be covered/protected as soon as practical upon exposure and be protected from any disturbances that will likely weaken the material.
- The temporary excavation for RSS walls and pier foundations may extend below the groundwater level within the cohesive till. Therefore, water inflow into the excavation should be expected. The water inflow may be handled by pumping from filtered sumps.

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

Appendix A

Record of Borehole Sheets – Current Investigation

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

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


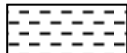



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (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>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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.				
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 LR 17-01

1 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 908.3 E 293 672.1 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.05.23 - 2017.05.23 CHECKED BY ME

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT 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							
188.0	GROUND SURFACE														
0.0	ASPHALT: (50mm)														
187.4	Gravelly SAND, trace silt, trace clay Loose Brown Moist (FILL)		1	SS	7										
0.6	Clayey SILT, some sand, trace gravel Firm Brown Moist (FILL)		2	SS	5										
186.4	Clayey SILT to Silty CLAY, some sand to sandy, trace gravel, occasional cobbles Stiff to Very Stiff Brown Moist (TILL)		3	SS	16										
1.6			4	SS	14										
			5	SS	17										
			6	SS	15										
			7	SS	10										
			8	SS	17										
178.2															
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 LR 17-02

1 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 929.8 E 293 687.9 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.19 - 2017.05.22 CHECKED BY ME

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							
188.2	GROUND SURFACE							20	40	60	80	100						
0.0 0.1	ASPHALT: (75mm)																	
	Silty SAND , trace clay, trace organics Loose Dark Brown Moist (FILL)		1	SS	10		188											
187.4																		
0.8			2	SS	12		187											
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles and boulders Stiff to Hard Brown Moist (TILL)																	
			3	SS	21		186											
			4	SS	19		185											
			5	SS	20		184											
			6	SS	18		183											
			7	SS	30		182											
			8	SS	38		181											
			9	SS	24		180											
							179											

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 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No LR 17-02

2 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 929.8 E 293 687.9 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.19 - 2017.05.22 CHECKED BY ME

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	20	40	60			
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles and boulders Stiff to Hard Brown Moist (TILL)		10	SS	80/ 0.125		178										
	Refusal on suspected boulder at 10.2m						177										
	Becoming grey		11	SS	32												
							176										
			12	SS	27		175										
							174										
			13	SS	41		173										
							172										
			14	SS	31		171										
							170										
			15	SS	39		169										
			16	SS	42												

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 (%) STRAIN AT FAILURE

METRIC

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No LR 17-03

2 OF 4

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 909.4 E 293 731.5 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.15 - 2017.05.16 CHECKED BY ME

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													
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel Very Stiff to Stiff Grey Wet (TILL)		10	SS	28		177							
							176							
			11	SS	29		175							
							174							
			12	SS	24		173							
							172							
			13	SS	16		171							
							170							
			14	SS	8		169							
							168							
169.6 18.3	SAND , some silt, trace gravel, trace clay Compact Grey Wet		15	SS	22									7 76 11 6
168.1 19.8														

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

RECORD OF BOREHOLE No LR 17-03

3 OF 4

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 909.4 E 293 731.5 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.15 - 2017.05.16 CHECKED BY ME

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE					w _p w w _L				
							● QUICK TRIAXIAL × LAB VANE										
							20	40	60	80	100	20	40	60			
	Continued From Previous Page		16	SS	39												
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel Hard Grey Wet (TILL)																
166.6																	
166.4	150mm sand layer at 21.3m																
21.5			17	SS	36												
164.5			18	SS	54												
23.4																	
	SHALE highly to slightly weathered, thinly laminated, weak with medium strong limestone interbeds, grey: (Georgain Bay Formation) Highly fractured/weathered zone (150mm) at 23.4m and (150mm) at 24.0m Limestone interbed (100mm) at 23.4m and 23.8m Sub-vertical fracture (150mm) at 23.4m and 23.8m Clay zone (100mm) at 24.6m and (175mm) at 25.5m Limestone interbed (125mm) at 25.8m Limestone interbed (125mm) at 26.6m Clay zone (125mm) at 26.7m and (100mm) at 27.4m		1	RUN													
			2	RUN													
			3	RUN													
160.4																	
27.5	END OF BOREHOLE AT 27.5m. Piezometer installation consists of 25mm and 50mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. SHALLOW 50mm MONITORING WELL INSTALLED IN A SECOND BOREHOLE LOCATED 2.0m NORTH OF THE SAMPLED BOREHOLE. DEEP (25mm) WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.08.09 3.6 184.3																

Continued Next Page

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

METRIC

[illegible]

RECORD OF BOREHOLE No LR 17-04

2 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 934.7 E 293 728.7 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.17 - 2017.05.18 CHECKED BY ME

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																
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Hard Brown Moist (TILL)		10	SS	31		178									0 21 52 27	
							177										
			11	SS	35		176										
							175										
			12	SS	27		174										
							173										
			13	SS	45		172										
							171										
			14	SS	21		170										
							169										
			15	SS	12												
			16	SS	22												

Continued Next Page

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

RECORD OF BOREHOLE No LR 17-04

3 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 934.7 E 293 728.7 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.17 - 2017.05.18 CHECKED BY ME

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT			LIQUID LIMIT	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			W _P W W _L WATER CONTENT (%)			
							20 40 60 80 100	20 40 60				GR SA SI CL		
166.1	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Very Stiff Brown Moist (TILL)		17	SS	27		168						11 45 34 10	
22.1			SAND and SILT , some clay, some gravel Very Dense Grey Moist (TILL)	18	SS		80	166						
165.0														
23.2	SHALE highly to slightly weathered, thinly laminated, very weak to weak with strong limestone interbeds, grey: (Georgian Bay Formation) Clay seam (275mm) at 23.2m Sub-vertical fracture at 23.9m Highly fractured zone (175mm) at 24.4m Clay seam at 24.9m Limestone layer (100mm) at 25.1m Vertical fracture (150mm) at 27.2m		1	RUN		165							RUN #1 TCR=100% SCR=71% RQD=25% RUN #2 TCR=87% SCR=67% RQD=30% RUN #3 TCR=100% SCR=73% RQD=40% UCS=7.3MPa (Shale) UCS=50.4MPa (Limestone)	
160.8							161							
27.4	END OF BOREHOLE AT 27.4m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.08.08 5.5 182.7 2017.10.25 5.4 182.8													

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

RECORD OF BOREHOLE No LR 17-05

1 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 947.0 E 293 766.0 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.11 - 2017.05.12 CHECKED BY ME

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W _p W W _L	WATER CONTENT (%)				
187.9	GROUND SURFACE													
0.0	Gravelly SAND , trace silt, occasional asphalt fragments Compact Brown Moist (FILL)		1	SS	11									
187.0	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Stiff to Hard Brown Moist to Wet (TILL)		2	SS	18									
			3	SS	19									
			4	SS	19									
			5	SS	21									
			6	SS	16									
			7	SS	12									
			8	SS	31									
			9	SS	23									

Continued Next Page

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

RECORD OF BOREHOLE No LR 17-05

2 OF 3

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 947.0 E 293 766.0 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.11 - 2017.05.12 CHECKED BY ME

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Very Stiff Grey Wet (TILL)		10	SS	27		177							
							176							
			11	SS	18		175							
							174							
			12	SS	32		173							
							172							
			13	SS	11		171							
							170							
			14	SS	26		169							
							168							
			15	SS	34									

Continued Next Page

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

METRIC

+³, ×³: Numbers refer to Sensitivity

ONTMT4S MTO-19484.GPJ 2017TEMPLATE(MTO).GDT 12/5/17

RECORD OF BOREHOLE No LR 17-06

1 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 936.4 E 293 788.3 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.05.10 - 2017.05.10 CHECKED BY ME

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							PLASTIC LIMIT w _P NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)		
187.7	GROUND SURFACE							20	40	60	80	100					
0.0 0.1	TOPSOIL: (75mm)							20	40	60	80	100					
	Silty CLAY , trace sand, trace gravel Firm to Very Stiff Brown Moist		1	SS	7		187										
186.8																	
0.9	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional cobbles Stiff to Very Stiff Brown to Grey Moist (TILL)		2	SS	15		186										
			3	SS	18												
			4	SS	22		185										
			5	SS	23		184										
							183										
	Becoming grey		6	SS	14												
							182										
			7	SS	14		181										
							180										
			8	SS	23												
							179										
			9	SS	20												
177.9							178										
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 LR 17-06

2 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Underpass N 4 849 936.4 E 293 788.3 ORIGINATED BY CAR
 HWY 427 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.05.10 - 2017.05.10 CHECKED BY ME

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 8.5m AND DRY. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S MTO-19484.GPJ 2017TEMPLATE(MTO).GDT 12/5/17

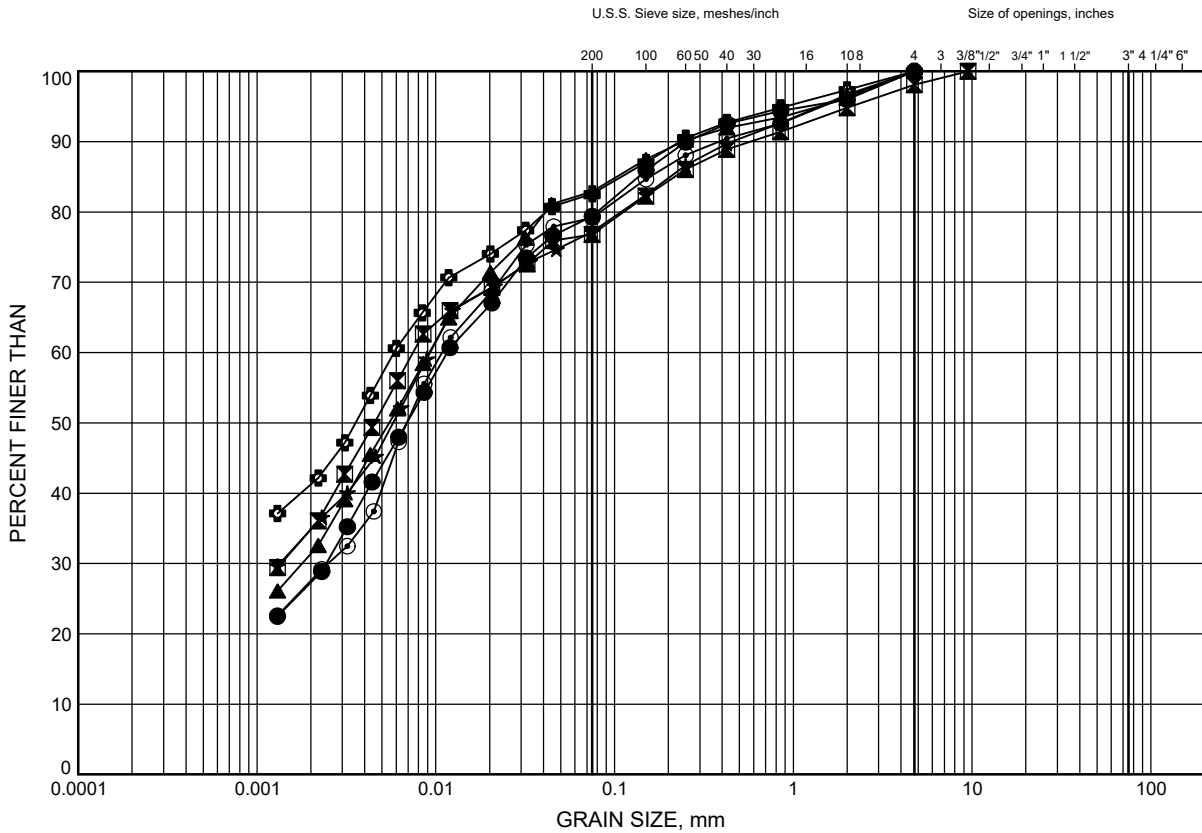
Appendix B

Geotechnical and Analytical Laboratory Test Results – Current Investigation

Langstaff Road Underpass GRAIN SIZE DISTRIBUTION

FIGURE B1

Clayey SILT to Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-02	20.9	167.3
⊠	LR 17-03	3.4	184.5
▲	LR 17-03	15.5	172.4
★	LR 17-04	4.1	184.1
⊙	LR 17-04	10.2	178.0
⊕	LR 17-05	1.8	186.1

Date December 2017
W.P.

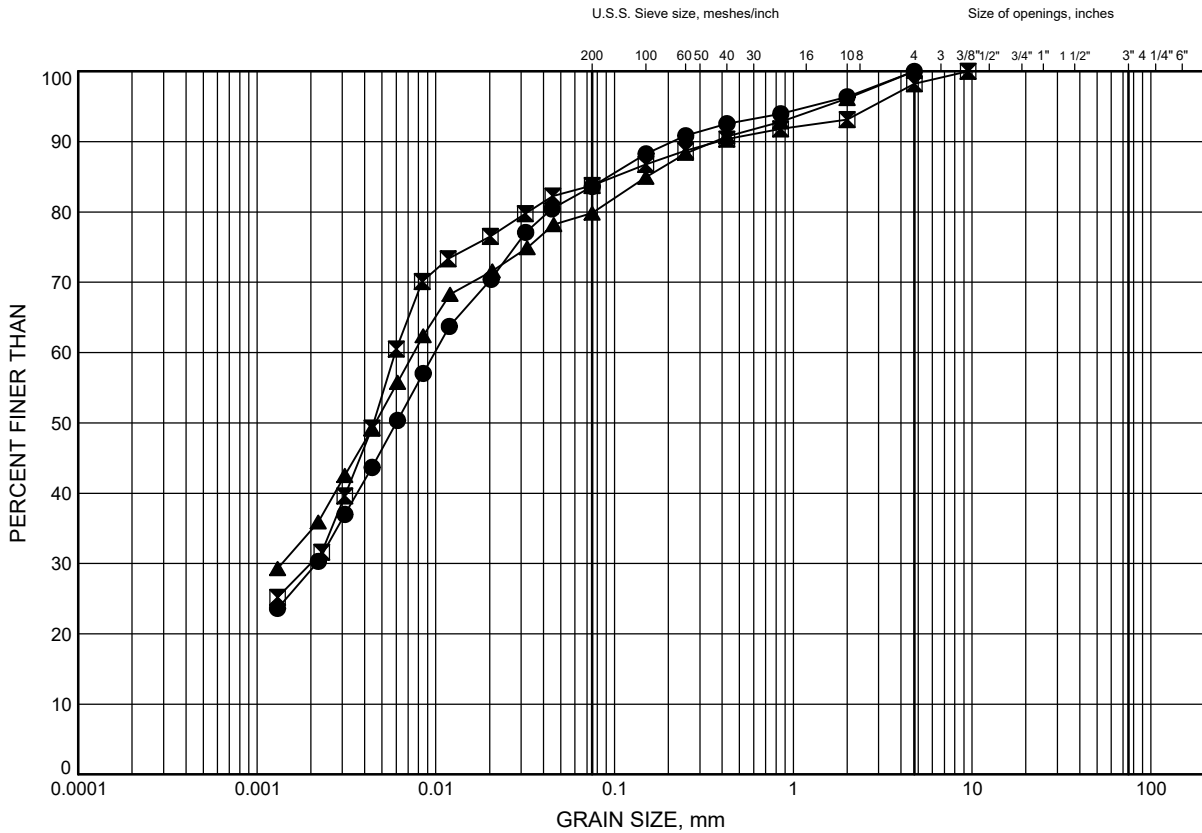


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Chkd. GRL

Langstaff Road Underpass GRAIN SIZE DISTRIBUTION

FIGURE B2

Clayey SILT to Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-05	9.4	178.5
⊠	LR 17-05	20.1	167.8
▲	LR 17-06	6.4	181.3

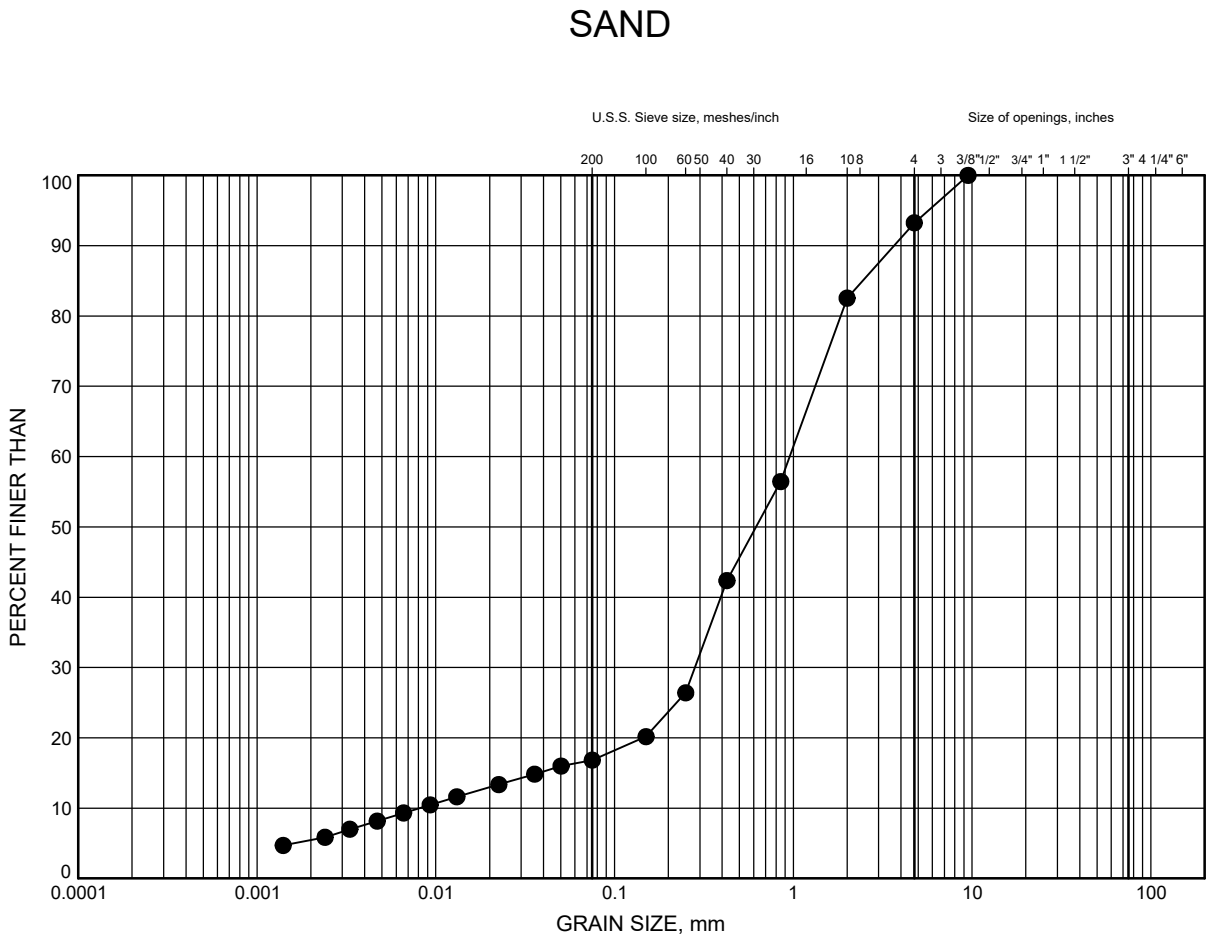
Date December 2017
W.P.



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Chkd. GRL

Langstaff Road Underpass GRAIN SIZE DISTRIBUTION

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-03	18.7	169.2

Date November 2017
W.P. _____

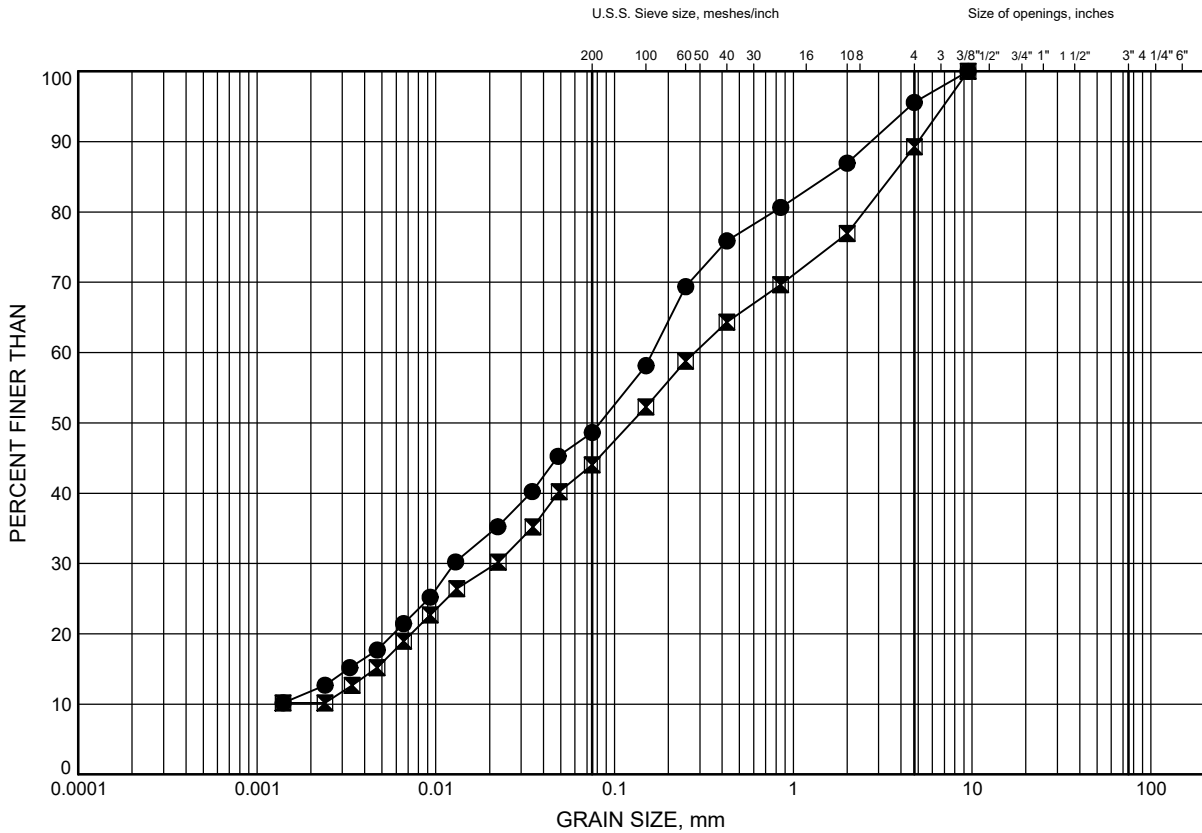


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Chkd. GRL

Langstaff Road Underpass GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND and SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-03	7.9	180.0
⊠	LR 17-04	22.4	165.8

Date December 2017
W.P.

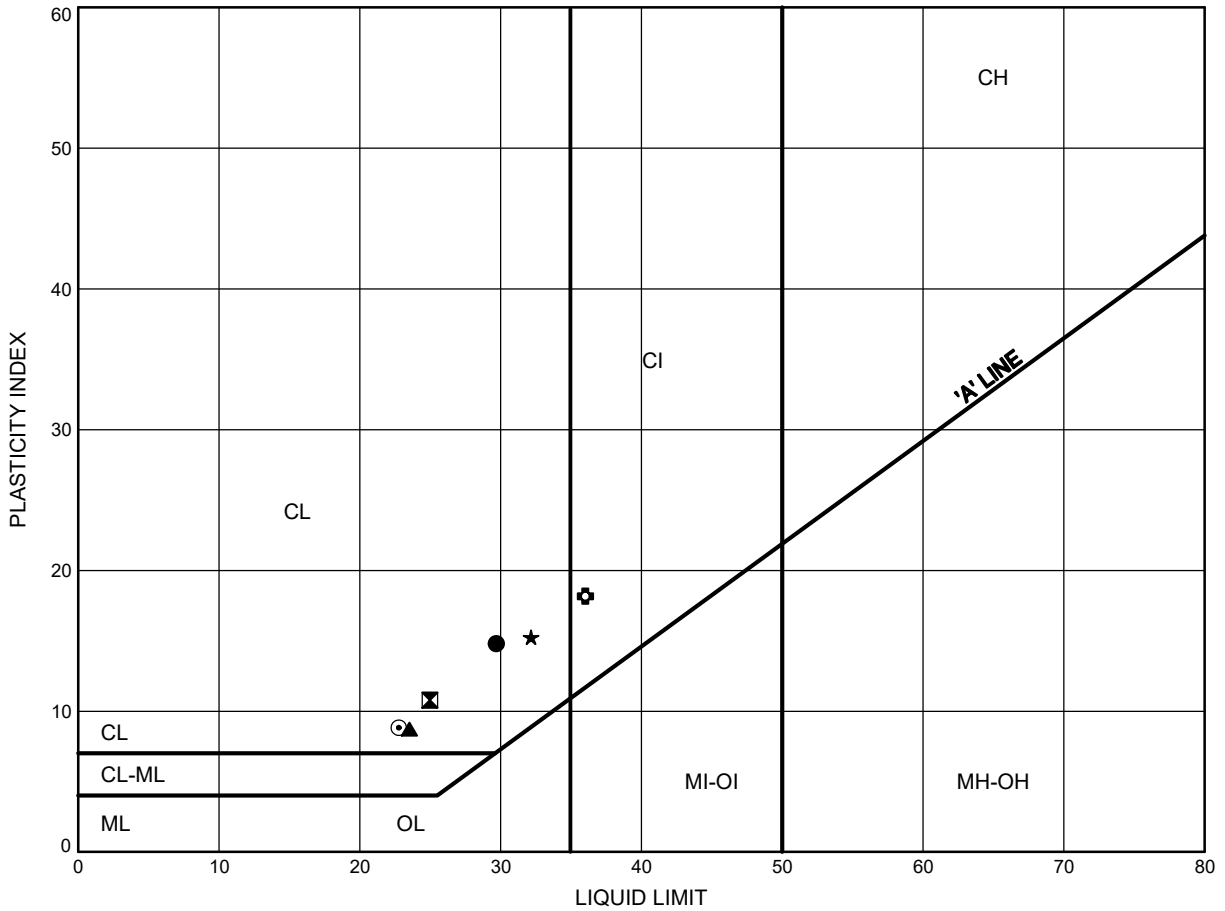


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Langstaff Road Underpass
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Clayey SILT to Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-01	2.6	185.4
⊠	LR 17-02	7.2	181.0
▲	LR 17-03	15.5	172.4
★	LR 17-04	4.1	184.1
⊙	LR 17-04	10.2	178.0
⊕	LR 17-05	1.8	186.1

Date December 2017
 W.P.

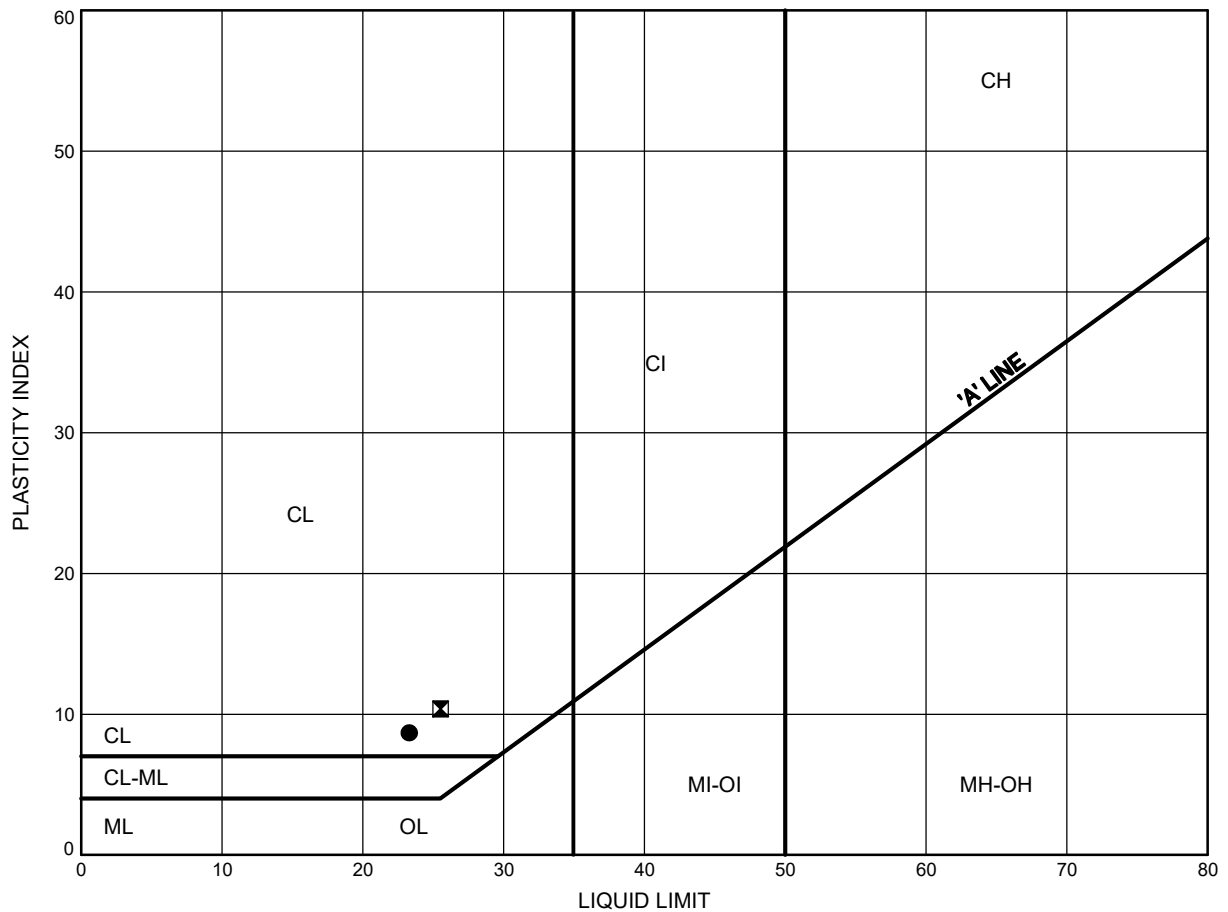


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Langstaff Road Underpass
ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Clayey SILT to Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-05	9.4	178.5
⊠	LR 17-06	6.4	181.3

Date December 2017
 W.P.

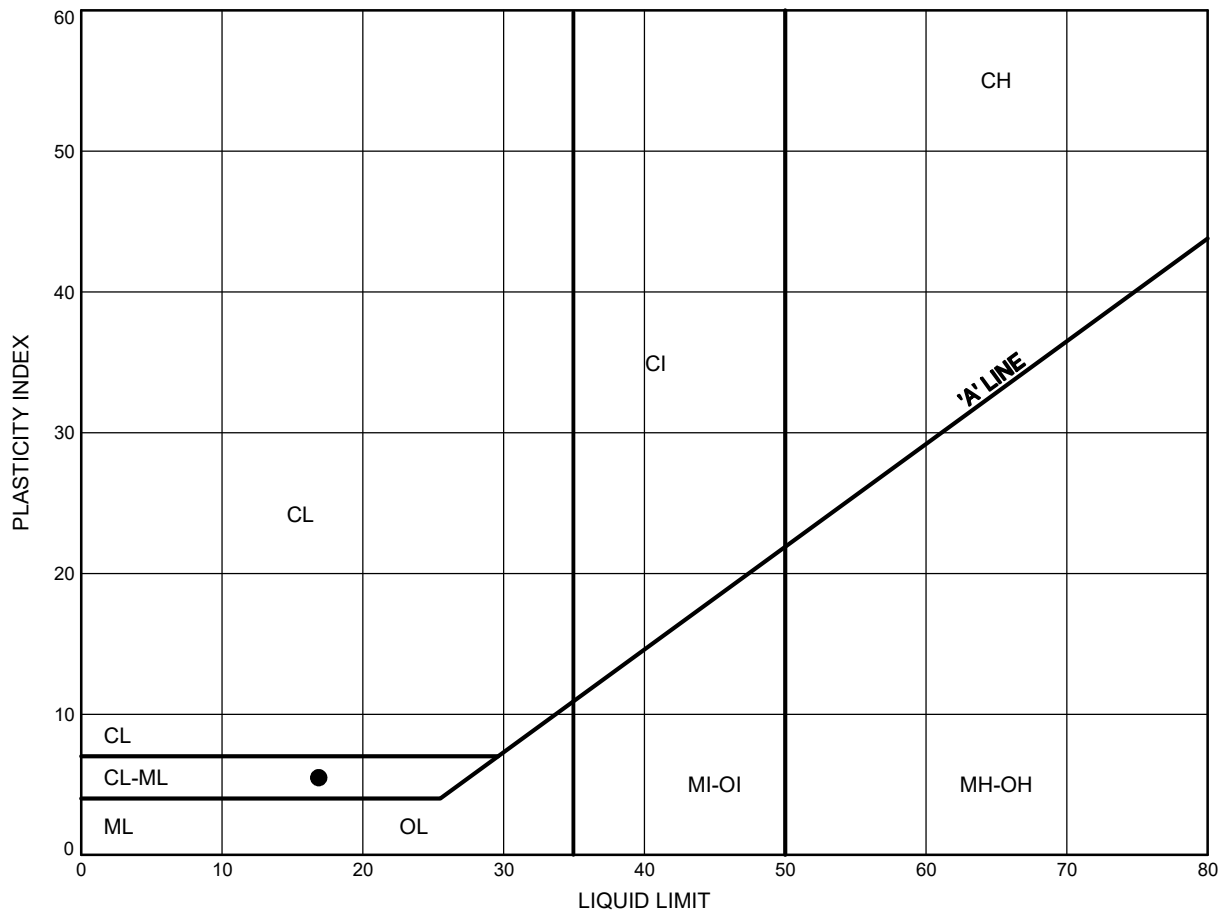


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Langstaff Road Underpass
ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SAND and SILT TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LR 17-03	7.9	180.0

Date December 2017
 W.P.



Prep'd AN
 Chkd. GRL



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Thurber Engineering Ltd.

Attn : Mohammad Egtesadi

103, 2010 Winston Park Drive
Oakville, ON
L6H 5R7,

Phone: 905-829-8666 x 263

Fax:

Project : PO#12307 Hwy 427

01-June-2017

Date Rec. : 26 May 2017

LR Report: CA14821-MAY17

Reference: PO#12307 Mohammad Egtesadi

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: LR17-03 SS2	6: LR17-05 SS3
Sample Date & Time					15-May-17	11-May-17
Temperature Upon Receipt [°C]	---	---	---	---	8.0	8.0
Corrosivity Index [none]	01-Jun-17	17:27	01-Jun-17	17:27	1.0	7.5
Soil Redox Potential [mV]	29-May-17	14:52	30-May-17	10:34	172	243
Sulphide [%]	01-Jun-17	12:41	01-Jun-17	12:55	< 0.02	0.06
% Moisture (wet wt) [%]	30-May-17	18:23	31-May-17	12:01	18.5	7.3
pH [no unit]	30-May-17	07:51	31-May-17	09:02	7.90	8.67
Chloride [µg/g]	31-May-17	04:30	01-Jun-17	11:43	710	24
Sulphate [µg/g]	31-May-17	04:30	01-Jun-17	11:43	29	50
Conductivity [uS/cm]	30-May-17	07:51	31-May-17	09:02	725	121
Resistivity (calculated) [Ohms.cm]	30-May-17	07:51	31-May-17	09:42	1380	8260

Appendix C

Record of Borehole Sheets - Previous Investigations

RECORD OF BOREHOLE No S12

1 OF 2 **METRIC**

PROJECT 06-1111-012

W.O. 05-20012

LOCATION N 4849869.7 : E 293699.8

ORIGINATED BY CR

DIST Central HWY 427

BOREHOLE TYPE 200 mm Outside Diameter Hollow Stem Augers

COMPILED BY PKS/VA

DATUM Geodetic

DATE March 26, 2009

CHECKED BY SMW *SMW*

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						
187.5	GROUND SURFACE							20 40 60 80 100	10 20 30					
0.0	ASPHALT							○ UNCONFINED + FIELD VANE						
0.4	Silty sand, some gravel (FILL) Compact Brown to grey Moist		1	SS	29		187	● QUICK TRIAXIAL x REMOULDED						
	Clayey silt, trace gravel, trace sand, containing rootlets (FILL) Stiff to very stiff Brown Moist		2	SS	13		186							
186.1	SILTY CLAY, trace gravel, trace sand (TILL) Hard Brown Moist		3	SS	32		185							
1.5			4	SS	30		184							
			5	SS	32		183							
			6	SS	37		182							
182.9	CLAYEY SILT, some sand, trace gravel, containing cobbles (TILL) Very stiff to hard Grey Moist		7	SS	25		181							
4.6			8	SS	22		180							
			9	SS	26		179							
			10	SS	42		178							
			11	SS	31		177							
			12	SS	51		176							
			13	SS	35		175							
							174							
							173							

Augers grinding at 11.4 m depth

1 18 58 23

Continued Next Page

+ 3, x 3,

Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

PROJECT 06-1111-012				RECORD OF BOREHOLE No S12				2 OF 2 METRIC						
W.O. 05-20012				LOCATION N 4849869.7 E 293699.8				ORIGINATED BY CR						
DIST Central HWY 427				BOREHOLE TYPE 200 mm Outside Diameter Hollow Stem Augers				COMPILED BY PKS/A						
DATUM Geodetic				DATE March 26, 2009				CHECKED BY SMM/SJA						
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 x REMOULDED						
— CONTINUED FROM PREVIOUS PAGE —														
	CLAYEY SILT, some sand, trace gravel, containing cobbles (TILL) Very stiff to hard Grey Moist		14	SS	39		172							
							171							
170.1							170							
17.4	SAND, trace gravel, trace silt, trace clay Compact Grey Wet Augers grinding between 17.6 m and 18.0 m depth		15	SS	12		169							
168.6							168							
18.9	SILTY CLAY, some sand, trace gravel (TILL) Hard Grey Wet		16	SS	155		167							
			17	SS	112		166							
166.6							165							
20.9	CLAYEY SILT, trace gravel, trace sand, containing cobbles (TILL) Hard Grey Wet Augers grinding between 22.1 m and 22.5 m depth		18	SS	102									
164.4			19	SS	00/0.1									
23.1	END OF BOREHOLE													
NOTES: 1. A 50 mm diameter monitoring well was installed at a depth of 18.9 m (Elev. 168.6 m). Water level measurements Date Depth Elev. On Completion 5.2 m 182.3 m May 13, 2009 6.9 m 180.6 m June 15, 2009 6.7 m 180.8 m July 09, 2009 6.3 m 181.3 m 2. At 18.3 m depth (Elev. 169.2 m) 1.2 m of sand was up inside the augers during drilling due to "blowing" sands.														

MIS-MTO 001 06-1111-012.GPJ GAL-MISS.GDT 8/5/09 SAC/DD

RECORD OF BOREHOLE No S13

1 OF 3 **METRIC**

PROJECT 06-1111-012

W.O. 05-20012

LOCATION N 4849885.0 E 293730.1

ORIGINATED BY CR

DIST Central HWY 427

BOREHOLE TYPE 200 mm Outside Diameter Hollow Stem Augers

COMPILED BY PKS/VA

DATUM Geodetic

DATE March 30 & 31, 2009

CHECKED BY SMM

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 ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED						
187.7	GROUND SURFACE						20 40 60 80 100								
-0.9	ASPHALT														
0.2	Silty sand, some gravel (FILL)		1	SS	15										
186.9	Compact Brown Moist														
0.8	Clayey silt, some sand, trace gravel (FILL) Very stiff Brown Moist		2	SS	12										
	SILTY CLAY, trace sand, trace gravel (TILL) Stiff to hard Brown Moist		3	SS	29										
			4	SS	27										
			5	SS	35										
			6	SS	31										
183.1	CLAYEY SILT, some sand, trace gravel, containing cobbles (TILL) Very stiff to hard Grey Moist Augers grinding at 5.2 m depth		7	SS	21										
4.6			8	SS	22										
			9	SS	43										
	Augers grinding at 6.4 m depth		10	SS	43										
			11	SS	55										
			12	SS	48										
174.0	Silty SAND, trace gravel Very dense Grey Wet		13	SS	59										
13.7															

Continued Next Page

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

PROJECT 06-1111-012 **RECORD OF BOREHOLE No S13** **2 OF 3 METRIC**
W.O. 05-20012 **LOCATION** N 4849885.0 :E 293730.1 **ORIGINATED BY** CR
DIST Central **HWY** 427 **BOREHOLE TYPE** 200 mm Outside Diameter Hollow Stem Augers **COMPILED BY** PKS/VA
DATUM Geodetic **DATE** March 30 & 31, 2009 **CHECKED BY** SMM *SM*

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 C	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED						
— CONTINUED FROM PREVIOUS PAGE —															
172.5	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Wet		14	SS	28		172								
15.2							171								
							170								
170.0	SAND, trace to some silt, trace gravel Compact Grey Wet		15	SS	22		169							1 87 9 3	
17.7							168								
							167								
167.9	CLAYEY SILT, some sand, trace gravel (TILL) Hard Grey Wet Augers grinding at 21.0 m depth Augers grinding at 22.0 m depth		16	SS	199		166								
19.8							165								
							164								
							163								
							162								
163.9	SHALE (BEDROCK) Grey		17	SS	80		161								
23.8							160								
							159								
							158								
160.2	END OF BOREHOLE		20	SS	00/0.05										
27.5															

Continued Next Page

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

MIS-MTO 001 06-1111-012.GPJ GAL-MISS.GDT 8/5/09 SAC/DD



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




PROJECT <u>06-1111-012</u>		RECORD OF BOREHOLE No S14		2 OF 2 METRIC	
W.O. <u>05-20012</u>		LOCATION <u>N 4849893.4 :E 293775.6</u>		ORIGINATED BY <u>CR</u>	
DIST <u>Central</u> HWY <u>427</u>		BOREHOLE TYPE <u>200 mm Outside Diameter Hollow Stem Augers</u>		COMPILED BY <u>PKS/VA</u>	
DATUM <u>Geodetic</u>		DATE <u>April 2, 2009</u>		CHECKED BY <u>SMM</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			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								20 40 60 80 100	20 40 60 80 100	10 20 30								

— CONTINUED FROM PREVIOUS PAGE —																
	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to hard Brown Moist		14	SS	12		172									
								171								
170.0								170								
17.7	Silty SAND, trace to some silt, trace gravel, trace clay Dense Grey Wet						170									
169.3																
18.4	SILTY CLAY, some sand, trace gravel (TILL) Hard Grey Wet		15	SS	46		169									
168.8																
18.9	END OF BOREHOLE															
NOTES: 1. Water level in open borehole at a depth of 17.7 m below ground surface (Elev. 170.0 m) upon completion of drilling. 2. An additional borehole was drilled adjacent to Borehole S14; See Record of Borehole S14A for details. 3. Borehole backfilled with bentonite.																

MIS-MTO 001 06-1111-012.GPJ GAL-MISS.GDT 8/5/09 SAC/DD

PROJECT <u>06-1111-012</u>		RECORD OF BOREHOLE No S14A		2 OF 2 METRIC	
W.O. <u>05-20012</u>	LOCATION <u>N 4849893.4 :E 293776.6</u>	ORIGINATED BY <u>JEB</u>			
DIST <u>Central</u> HWY <u>427</u>	BOREHOLE TYPE <u>200 mm Outside Diameter Hollow Stem Augers</u>	COMPILED BY <u>PKS/VA</u>			
DATUM <u>Geodetic</u>	DATE <u>April 13, 2009</u>	CHECKED BY <u>SMV</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p W W _L				
								○ UNCONFINED + FIELD VANE	WATER CONTENT (%)					
							● QUICK TRIAXIAL x REMOULDED	20 40 60 80 100	20 40 60 80 100			10 20 30	GR SA SI CL	
— CONTINUED FROM PREVIOUS PAGE —														
							172							
							171							
							170							
							169							
167.9 19.8	Unsampler, see Record of Borehole S14 for stratigraphy above a depth of 19.8 m.						168							
	SILTY CLAY, trace gravel, trace sand (TILL) Very stiff to hard Grey Moist		1	SS	22		167							
165.9 21.8	SAND and SILT, some gravel, trace clay (TILL) Dense to very dense Grey Wet		2	SS	33		166							
							165							
164.0 23.7	SHALE (BEDROCK) Grey		3	SS	70		164							
163.2 24.5	END OF BOREHOLE		4	SS	10/0/10									
	NOTES: 1. Water level in open borehole at a depth of 21.8 m below ground surface (Elev. 165.9 m) upon completion of drilling. 2. Borehole backfilled with bentonite.													

MIS-MTO-001 06-1111-012.GPJ CAL-MISS.GDT 8/5/09 SAC/DD

RECORD OF BOREHOLE No LR-1															1 of 2		METRIC			
G.W.P.			LOCATION			Coords: 4 849 889.6 N; 293 691.2 E			ORIGINATED BY			D.W.								
DIST			HWY			427			BOREHOLE TYPE			Continuous Flight Hollow Stem Augers			COMPILED BY			N.L.		
DATUM			Geodetic						DATE			September 28, 2015			CHECKED BY			A.V.		
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
187.9	Ground Surface							20	40	60	80	100								
187.8	TOPSOIL		1	SS	4															
0.1	CLAYEY SILT, trace to some sand, trace gravel																			
	Stiff to hard Brown becoming grey below 3.8m Moist		2	SS	17															
	(TILL)		3	SS	22															
			4	SS	23															
			5	SS	24															
			6	SS	15															
			7	SS	19															
			8	SS	14															
			9	SS	20															
	rock fragments at a depth 7.8m																			
			10	SS	20															
			11	SS	24															
			12	SS	24															
			13	SS	38															
172.9	Cont'd																			

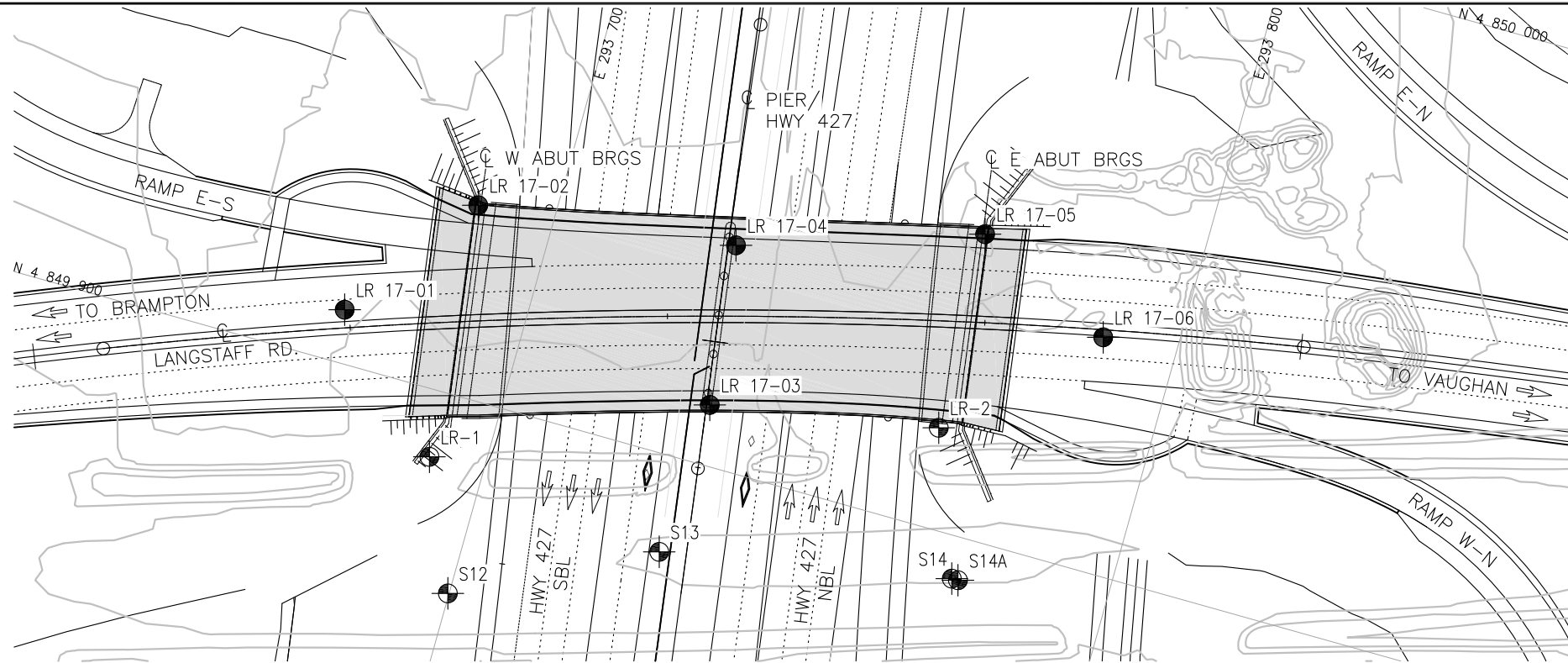
RECORD OF BOREHOLE No LR-1															2 of 2		METRIC			
G.W.P.			LOCATION			Coords: 4 849 889.6 N; 293 691.2 E			ORIGINATED BY			D.W.								
DIST			HWY			427			BOREHOLE TYPE			Continuous Flight Hollow Stem Augers			COMPILED BY			N.L.		
DATUM			Geodetic						DATE			September 28, 2015			CHECKED BY			A.V.		
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
172.9								20	40	60	80	100								
15.0	CLAYEY SILT, trace to some sand, trace gravel		14	SS	24															
	Stiff to hard Brown becoming grey below 3.8m Moist																			
	(TILL)		15	SS	33															
170.3	SAND, trace silt																			
17.6	Very dense Grey Wet		16	SS	61															
168.8	CLAYEY SILT, some sand, trace gravel																			
19.1	Hard Grey Moist		17	SS	60/3cm															
	(TILL)																			
167.2	SAND and SILT, some clay, trace gravel																			
20.7	Very dense Grey Moist		18	SS	103															
	(TILL)																			
164.8	End of borehole Split spoon sampler refusal		19	SS	70/5cm															
23.1																				
	Water level noted during drilling																			
	Water level measured upon completion																			
	Note: 1. Groundwater level measured at a depth of 9.1m below ground surface (Elev. 178.8) upon completion of drilling.																			

RECORD OF BOREHOLE No LR-2															1 of 2		METRIC		
G.W.P.		LOCATION				Coords: 4 849 915.7 N; 293 767.2 E				ORIGINATED BY					D.W.				
DIST		Central		HWY 427		BOREHOLE TYPE				Continuous Flight Hollow Stem Augers				COMPILED BY		N.L.			
DATUM		Geodetic		DATE		September 29, 2015				CHECKED BY					A.V.				
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 (%)		
188.1	Ground Surface		1	SS	22	188													
0.0	SAND and GRAVEL																		
187.4	Compact Brown Moist (FILL)		2	SS	20		187												
0.7	CLAYEY SILT, some to with sand, trace gravel																		
	Stiff to very stiff Brown becoming grey below 3.1m Moist (TILL)		3	SS	22														
			4	SS	24														
			5	SS	22														
			6	SS	15														
			7	SS	12														
			8	SS	19														
			9	SS	20														
			10	SS	27														
			11	SS	24														
		12	SS	22															
		13	SS	25															
173.1	Cont'd					174													

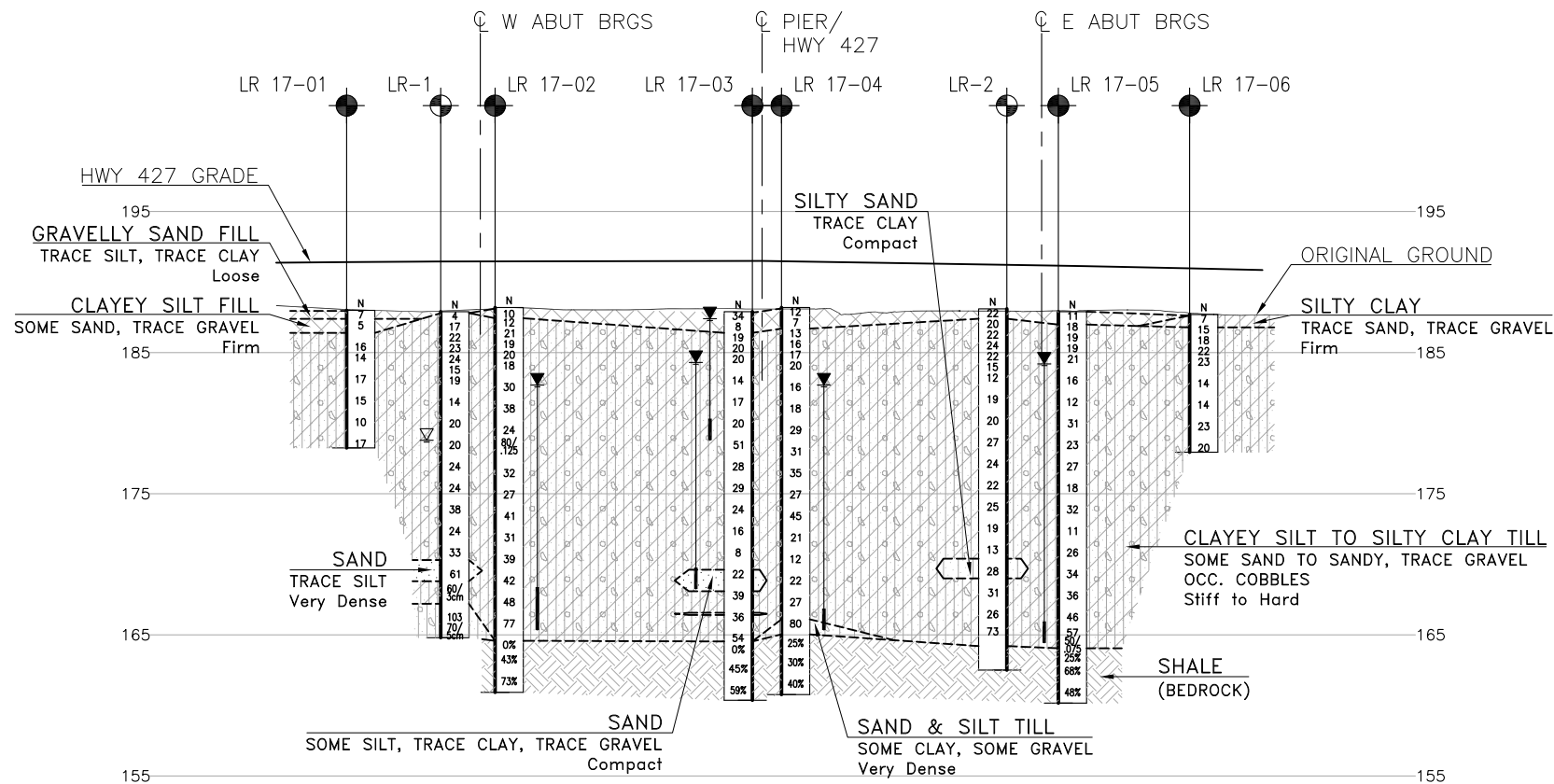
RECORD OF BOREHOLE No LR-2															2 of 2		METRIC	
G.W.P.		LOCATION				Coords: 4 849 915.7 N; 293 767.2 E				ORIGINATED BY					D.W.			
DIST		Central		HWY 427		BOREHOLE TYPE				Continuous Flight Hollow Stem Augers				COMPILED BY		N.L.		
DATUM		Geodetic		DATE		September 29, 2015				CHECKED BY					A.V.			
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 (%)	
173.1	(Cont'd)		14	SS	19	173												
15.0	CLAYEY SILT, trace sand, trace gravel																	
	Stiff to very stiff Grey Moist (TILL)		15	SS	13													
			16	SS	28													
170.4	SILTY SAND, trace clay																	
17.7	Compact Grey Moist		17	SS	31													
	CLAYEY SILT, some sand, some gravel		18	SS	26													
	Very stiff to hard Grey Moist (TILL)		19	SS	73													
			20	SS	70/8cm													
164.2	SHALE BEDROCK																	
23.9	Highly weathered Grey		21	SS	100/8cm													
162.5	End of borehole due to auger refusal																	
25.6	Water level noted during drilling																	

Appendix D

Borehole Locations and Soil Strata Drawing



PLAN



PROFILE ALONG C/L LANGSTAFF ROAD

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



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
LR 17-01	188.0	4 849 908.3	293 672.1
LR 17-02	188.2	4 849 929.8	293 687.9
LR 17-03	187.9	4 849 909.4	293 731.5
LR 17-04	188.2	4 849 934.7	293 728.7
LR 17-05	187.9	4 849 947.0	293 766.0
LR 17-06	187.7	4 849 936.4	293 788.3
LR-1	187.9	4 849 889.6	293 691.2
LR-2	188.1	4 849 915.7	293 767.2
S12	187.5	4 849 869.7	293 699.8
S13	187.7	4 849 885.0	293 730.1
S14	187.7	4 849 893.4	293 775.6
S14A	187.7	4 849 893.4	293 776.6

-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.

TITLE
HWY 427 EXPANSION
HIGHWAY 427 AT LANGSTAFF ROAD
UNDERPASS

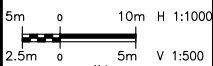
BOREHOLE LOCATIONS AND SOIL STRATA

PROJECT ID.	STAGE IDENTIFIER	DESIGN PACKAGE NUMBER	DISCIPLINE	STRUCTURE NUMBER	DOCUMENT TYPE	DRAWING NUMBER	REVISION NUMBER
H427-D	N	4	STR	B1.3	DWG	601	B

FILENAME: H:\Drafting\19000\19484\TED19484-PLR-HWY 427 OverLangstaff Rd.dwg
PLOTDATE: 5/23/2018 4:09 PM

NO.	DATE	REVISIONS	BY	CHK	LEAD DES.	PROJ. MAN.
B	18/05/25	90% SUBMISSION TO CA	AN	KS	JL	JL
A	18/04/27	90% SUBMISSION TO CA	AN	KS	JL	JL

SCALE :



DESIGNED	A. PIASIK	AP	18/05/25
DRAWN	A. NOOR	AN	18/05/25
CHECKED	K. SHI	KS	18/05/25
APPROVED LEAD ENGINEER	J. LEE	JL	18/05/25
APPROVED PROJ. MANAGER	J. LEE	JL	18/05/25
NAME (PRINT)	INIT.	DATE	



Appendix E

Stability Analysis Output for Approach Embankments

LANGSTAFF UNDERPASS EMBANKMENT SECTION SHORT-TERM CONDITION

File Name: Langstaff W Abutment Longitudinal Stability TSA RSS.gsz

Last Edited By: Geoff Lay

Date: 1/17/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill 21 kN/m³ 0 kPa 35 °

Sand Fill 20 kN/m³ 0 kPa 30 °

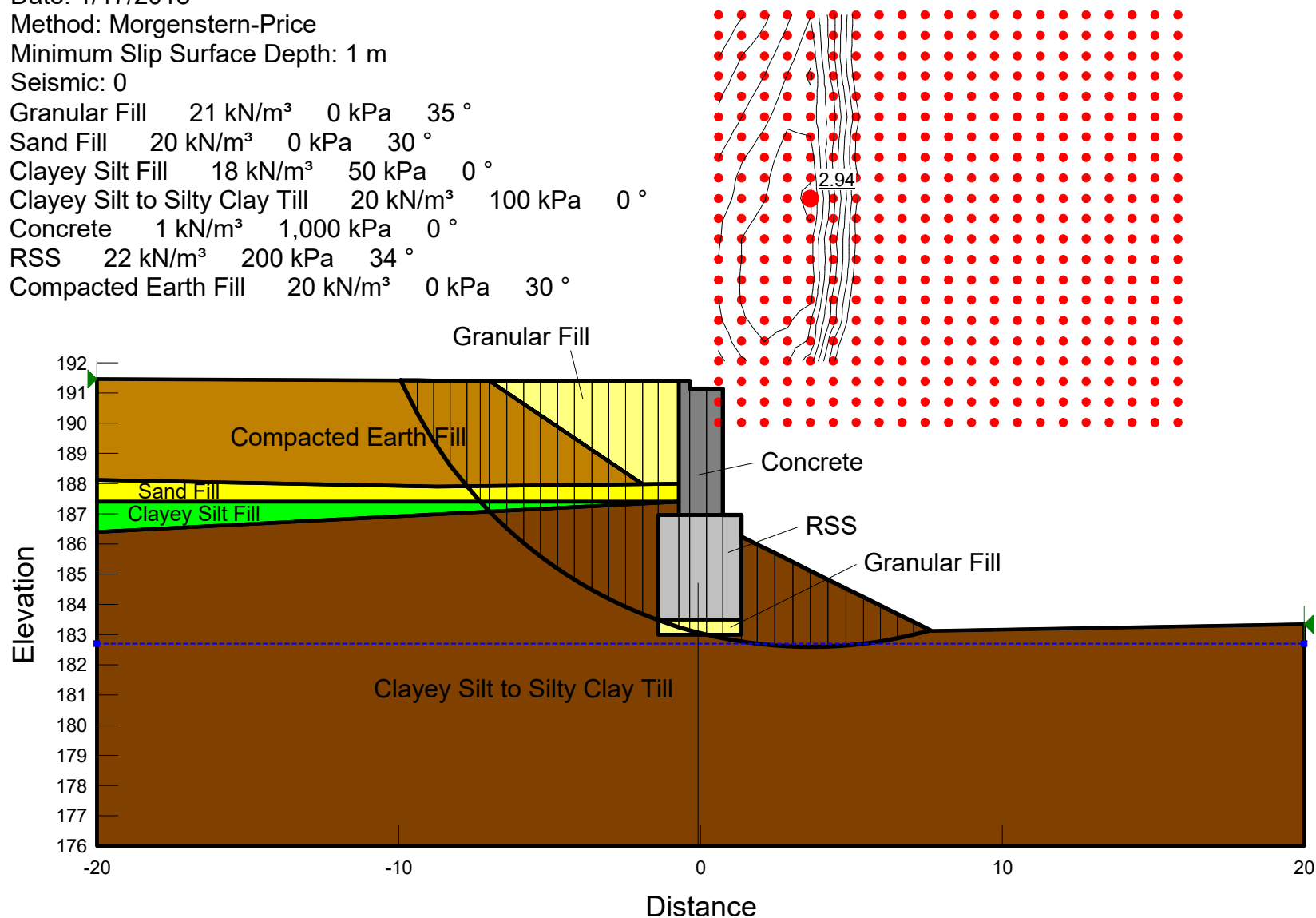
Clayey Silt Fill 18 kN/m³ 50 kPa 0 °

Clayey Silt to Silty Clay Till 20 kN/m³ 100 kPa 0 °

Concrete 1 kN/m³ 1,000 kPa 0 °

RSS 22 kN/m³ 200 kPa 34 °

Compacted Earth Fill 20 kN/m³ 0 kPa 30 °



LANGSTAFF UNDERPASS EMBANKMENT SECTION LONG-TERM CONDITION

File Name: Langstaff W Abutment Longitudinal Stability ESA.gsz

Last Edited By: Geoff Lay

Date: 1/9/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

Granular Fill 21 kN/m³ 0 kPa 35 °

Sand Fill 20 kN/m³ 0 kPa 30 °

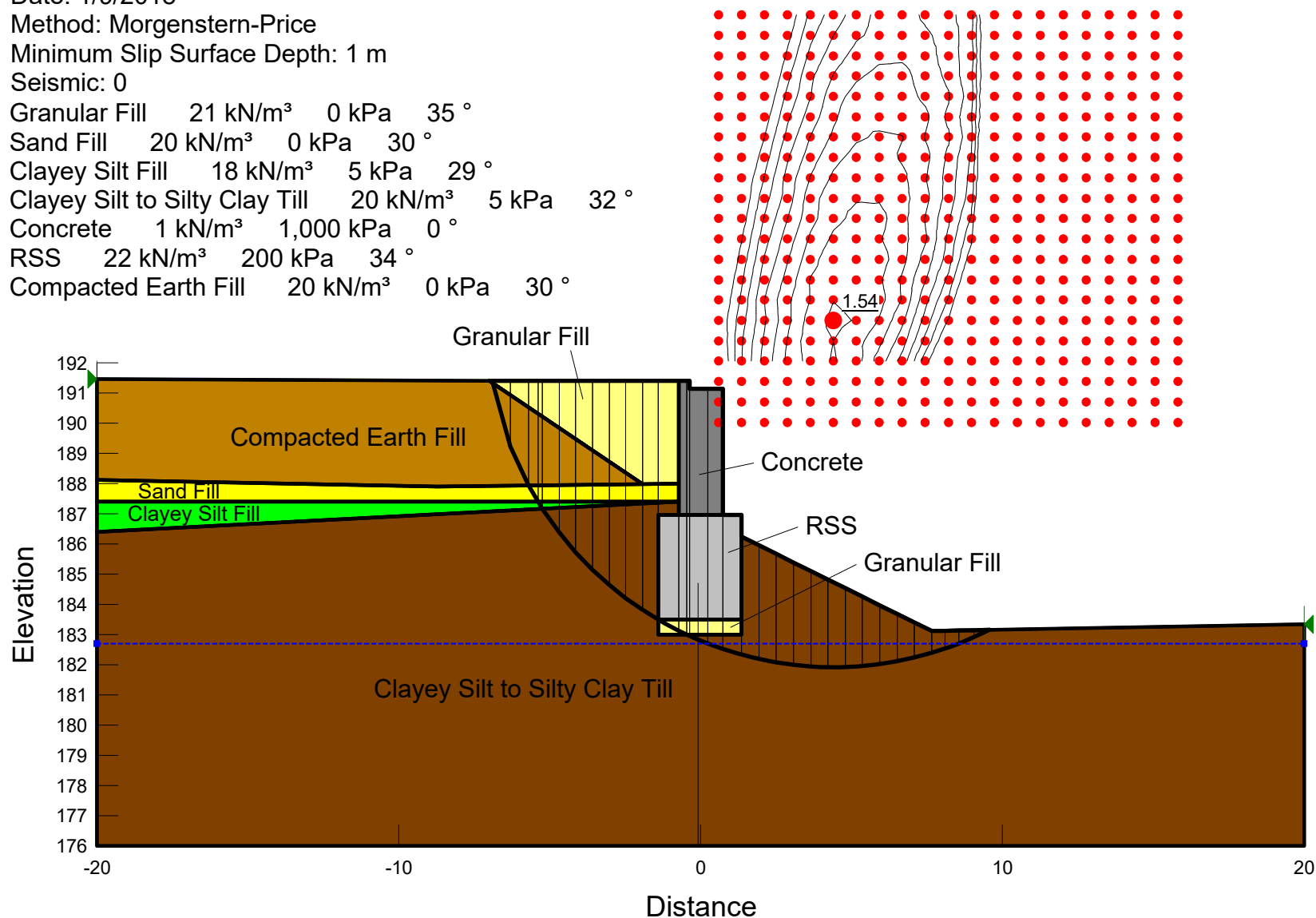
Clayey Silt Fill 18 kN/m³ 5 kPa 29 °

Clayey Silt to Silty Clay Till 20 kN/m³ 5 kPa 32 °

Concrete 1 kN/m³ 1,000 kPa 0 °

RSS 22 kN/m³ 200 kPa 34 °

Compacted Earth Fill 20 kN/m³ 0 kPa 30 °



LANGSTAFF UNDERPASS EMBANKMENT SECTION SEISMIC CONDITION

File Name: Langstaff W Abutment Longitudinal Stability TSA Seismic.gsz

Last Edited By: Geoff Lay

Date: 1/17/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0.055g

Granular Fill 21 kN/m³ 0 kPa 35 °

Sand Fill 20 kN/m³ 0 kPa 30 °

Clayey Silt Fill 18 kN/m³ 50 kPa 0 °

Clayey Silt to Silty Clay Till 20 kN/m³ 100 kPa 0 °

Concrete 1 kN/m³ 1,000 kPa 0 °

RSS 22 kN/m³ 200 kPa 34 °

Compacted Earth Fill 20 kN/m³ 0 kPa 30 °

