

Prepared By: Matthew Boucher, P.Eng.
Keli Shi, P.Eng.
Reviewed By: Jason Lee, P.Eng.
P.K. Chatterji, P.Eng.
Prepared For: Peter Bamforth, P.Eng.
Tatiana Ojala, P.Eng.
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Highway 427 Expansion – Package 4A (100% Submission)
Langstaff Road Over Rainbow Creek

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Statement of Limitations and Conditions

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Appendix A	Record of Borehole Sheets – Current Investigation
Appendix B	Geotechnical and Analytical Laboratory Test Results – Current Investigation
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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 structure to carry Langstaff Road over Rainbow Creek (RC). 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 structure 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 which are presented in the reports listed below:

1. GEOCRETS 30M13-170: Preliminary Foundation Investigation and Design Report, Rainbow Creek Bridge on Langstaff Road, 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.
2. GEOCRETS 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.
3. GEOCRETS 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 information provided by WSP.

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 along the existing Langstaff Road alignment approximately 500 m west of proposed interchange of Langstaff Road and Highway 427 in Vaughan, Ontario.

The proposed structure will be located within the flood plain of Rainbow Creek. Rainbow Creek at the site is up to 7 m wide and the stream flows from north to south. The bottom of the creek is at approximately Elev. 178 m. The crests of the valley are up to about 7 m above the creek level.

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 structure will be a precast concrete arch culvert. The culvert will utilize precast concrete wingwalls and the side slopes of the approaches will be at a slope of 2H:1V.

3. GEOTECHNICAL INVESTIGATION

The current field investigation at the proposed bridge site was conducted between May 31 and June 7, 2017, and consisted of advancing four (4) boreholes, designated as Boreholes LC 17-01 to LC 17-04 to depths ranging between 12.5 m and 16.4 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 the appendices.

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 coring using NQ-sized coring equipment in all 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 two Boreholes (LC 17-02 and LC 17-03). The boreholes where piezometers were not installed were backfilled as per O.Reg. 903. The piezometers will be decommissioned by Project Co. after completion of all water level measurements as per O.Reg. 903.

Two borehole records are available from the previous investigations. Boreholes LRC-1 and LRC-3 from the 2016 report are enclosed in the appendices.

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 pavement structure overlying silty clay with occasional organic material, overlying a layer of clayey silt till, over a clayey silt deposit overlying a second layer of clayey silt to silty clay till. The overburden overlies shale bedrock of the Georgian Bay Formation. Occasional auger grinding, hard augering, and/or split spoon bouncing were noted during advancing the boreholes in the till deposit which are indications of the presence of cobbles and/or boulders as expected in till deposits.

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

4.1 Topsoil

Topsoil was encountered at the ground surface in Borehole LC 17-02 which was advanced beyond the road shoulder. The thickness of the topsoil was 150 mm.

4.2 Pavement Structure

Asphalt was encountered at the ground surface in the three boreholes advanced through Langstaff Road (LC 17-02, LC 17-03 and LC 17-04). The thickness of the asphalt was 150 mm in all three boreholes.

A 0.9 m to 1.2 m thick layer of cohesionless fill (gravelly sand to sand and gravel fill) was encountered beneath the asphalt in Boreholes LC 17-01, LC 17-03 and LC 17-04. The fill extended to depths of 1.1 m to 1.4 m (Elev. 179.9 m to 180.7 m). The SPT-N values within the cohesionless fill ranged from 12 to 73 blows per 0.3 m of penetration indicating a compact to very dense relative density.

The results of one grain size analysis are presented on Figure B1 in Appendix B.

4.3 Upper Silty Clay

A 1.2 m to 2.7 m thick deposit of silty clay with some sand to sandy, trace clay and occasional organic material was encountered in all four boreholes. In Borehole LC 17-02 the upper silty clay was encountered below the topsoil. In the other three boreholes the upper silty clay was encountered below the pavement structure. The upper silty clay extended to depths of 1.4 m to 3.8 m (Elev. 177.5 to 178.8 m).

The SPT-N values within the silty clay ranged from 2 to 8 blows per 0.3 m of penetration indicating a very soft to firm consistency.

The results of two grain size analyses are presented on Figure B2 and the results of Atterberg Limits testing are presented on Figure B6 in Appendix B.

4.4 Upper Clayey Silt Till

A 1.7 m to 2.6 m thick deposit of clayey silt till was encountered below the upper silty clay deposit in Boreholes LC 17-01, LC 17-02 and LC 17-04. The upper clayey silt till extended to depths ranging between 4.0 and 5.6 m (Elev. 176.2 and 175.7 m).

The SPT-N values within the till ranged from 43 blows per 0.3 m of penetration to 106 blows per 0.2 m penetration suggesting a hard consistency.

The results of a grain size analysis are presented on Figure B3 and the results of Atterberg Limits testing are presented on Figure B7 in Appendix B.

Glacial till inherently contains cobbles and boulders.

4.5 Silt

A 1.5 m thick deposit of silt was encountered underlying the upper silty clay in Borehole LC 17-03. The silt extended to a depth of 5.6 m (Elev. 176.2 m).

An SPT-N value of 4 blows per 0.3 m penetration was measured within the silt suggesting a loose relative density. It is suspected that hydraulic disturbance may have affected this SPT-N value.

4.6 Lower Silty Clay

A 3.1 to 4.6 m thick deposit of silty clay was encountered underlying the upper cohesive till deposit in all boreholes except LC 17-03 where it was encountered underlying the silt deposit. The lower silty clay contained trace to some sand and was described as layered or varved. The lower silty clay deposit extended to depths ranging between 7.2 to 10.2 m (Elev. 173.1 m to 171.6 m).

SPT-N values within the cohesive till ranged from 35 to 98 blows per 0.3 m penetration suggesting a hard consistency. One SPT-N value of 2 was recorded in Borehole LC 17-03, however it is suspected that hydraulic disturbance may have affected the SPT-N value.

The results of a grain size analysis are presented on Figure B4 and the results of Atterberg Limits testing are presented on Figure B8 in Appendix B.

4.7 Lower Clayey Silt to Silty Clay Till

A 1.8 m to 3.2 m thick deposit of clayey silt to silty clay till was encountered underlying the lower silty clay deposit in all boreholes. The lower cohesive till extended to depths ranging between 9.3 and 12.0 m (Elev. 171.0 and 169.4 m).

SPT-N values within the cohesive till ranged from 35 blows per 0.3 m penetration to 102 blows per 0.225 m of penetration indicating a hard consistency.

The results of a grain size analysis are presented on Figure B5 and the results of Atterberg Limits testing are presented on Figure B9 in Appendix B.

Glacial till inherently contains cobbles and boulders.

4.8 Shale Bedrock

Grey shale bedrock of the Georgian Bay Formation was confirmed by coring in all boreholes. The bedrock surface was encountered at depths ranging between 9.3 to 12.0 m (Elev. 171.0 and 169.8 m). In general, the TCR ranged from 86 to 100%, and the SCR and RQD values ranged typically between 33 and 97%, and 0 and 40%, respectively. The RQD values indicate a very poor to poor rock quality. Results of point load testing indicate an unconfined compressive strength ranging between 7 and 17 MPa for shale and ranging between 68 and 158 MPa for limestone interbeds.

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)		Native Material at Screen
		Depth (m)	Elevation (m)	
LC 17-02	July 10, 2017	-0.7*	180.4	Lower Cohesive Till
	Oct 18, 2017	-0.7*	180.4	
LC 17-03 (S)	Oct 25, 2017	0.2	181.6	Upper Silty Clay / Silt
LC 17-03 (D)	Oct 25, 2017	2.7	179.1	Lower Silty Clay / Lower Cohesive Till

* Groundwater level above ground surface, i.e. artesian condition

(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.

The General Arrangement drawing indicates a 100-year flood level at Elev. 179.8 m and a regional storm level at Elev. 181.0 m.

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 certificate of analysis is 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	LC 17-01	LC 17-03
		SS5	SS8
Moisture	%	14.2	13.6
Corrosivity Index	-	8.0	8.0
pH	-	8.72	8.51
Soil Redox Potential	mV	231	235
Sulphide	%	0.09	0.08
Chloride	µg/g	51	69
Sulphate	µg/g	190	150
Electrical Conductivity	µS/cm	261	272
Resistivity	ohms.cm	3830	3680

5. GEOTECHNICAL RECOMMENDATIONS

5.1 Foundation Design

5.1.1 Spread Footings

Spread footings are considered feasible foundation option to support the concrete arch culvert and may be designed using the axial geotechnical resistances at the factored ULS and SLS provided in Table 5.1. Geotechnical resistance values provided in the table assume a minimum footing width of 2 m. The actual footing width will be governed by the structural load demand.

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

Location	Reference Boreholes	Founding Elevation (m)	Founding Stratum	Factored ULS (kPa)	Factored SLS (kPa)
East Abutment	LC17-01, LC17-02 LRC-3	176.7	Hard Clayey Silt Till	550	325
West Abutment	LC17-03, LC17-04 LRC-1	174.2	Hard Silty Clay	450	300
		176.7	2.5 m thick engineered fill on hard Silty Clay(*)	750	350

* - This option assumes the excavation for the west footing will be extended to an elevation of 174.2 m and a 2.5 m thick engineered fill pad will be constructed up to an elevation of 176.7 m.

The Factored Geotechnical Reaction 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 Reaction 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).

Due to the high water table, a cofferdam will be required to facilitate footing construction and keep water out of the excavation.

5.1.2 Driven H-Piles

Due to the high water table and the variable subsurface conditions (e.g. lower SPT-N values at the northwest corner of structure), steel piles driven to bedrock is the preferred option to support the proposed arch culvert from a foundations perspective. The recommendations and discussion on design and construction of driven H-piles are presented below.

5.1.2.1 Axial Pile Resistance

The axial resistances of a steel HP310x110 pile driven to shale bedrock were assessed based on the subsurface conditions obtained at the proposed foundation locations. The estimated factored axial geotechnical resistances are summarized in Table 5.2 below.

Table 5.2 - Geotechnical Resistances for HP310x110

Location	Reference Boreholes	Anticipated Pile Tip Elevation (m)	Founding Stratum	Factored ULS (kN)	Factored SLS (kN)
East Abutment	LC17-01, LC17-02	169.4 to 170.4	Shale Bedrock	2,000	2,000
West Abutment	LC17-03, LC17-04	169.8 to 171.0	Shale Bedrock	2,000	2,000

The values of factored Geotechnical Resistance at SLS given above are for up to 25 mm of settlement. The value of Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.4 (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.

5.2 Lateral Pile Resistance

The geotechnical lateral resistance acting on a HP310x110 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 (0.31 m for HP310x110)

The lateral resistance acting on a 0.31 m for HP310x110 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:

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

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

Where: z = depth of embedment of pile (m)

D = pile width in metres
(0.31 m for HP310x110)

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

γ' = effective unit weight (kN/m^3)

K_p = 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/m^3), 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

Location	Soil Unit	Elevation (m)		γ' (kN/m^3)	n_h (kN/m^3)	K_p	S_u (kPa)
		Top	Bottom				
East Abutment	Clayey Silt Till – hard	177.0	176.0	11 (*)	-	-	300
	Silty Clay - hard	176.0	172.5	11 (*)	-	-	250
	Silty Clay/Clayey Silt Till - hard	172.5	169.4	11 (*)	-	-	300
West Abutment	Silt - loose	177.0	176.0	10 (*)	1,000	2.8	-
	Silty Clay - hard	176.0	172.5	11 (*)	-	-	250
	Silty Clay/Clayey Silt Till - hard	172.5	169.8	11 (*)	-	-	250

Note (*): Submerged Unit weights

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 <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

5.2.1 H-Pile Installation

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.

5.2.2 Pile Tips

To prevent structural damages to the piles when setting them in the very dense/hard till 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 from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent.

5.3 Culvert Wingwalls

5.3.1 Geotechnical Resistances

For a minimum 1.5 m wide wall base founded at Elev. 176.7, the following geotechnical resistances are recommended.

Table 5.5 – Highest Founding Levels of Retaining Walls

Wingwall	Reference Borehole	Founding Elevation (m)	Founding Material	Factored ULS (kPa)	Factored SLS (kPa)
NE wingwall	LC 17-01	176.7	Hard Clayey Silt Till	550	325
SE wingwall	LC 17-02	176.7	Hard Clayey Silt Till	550	325
NW wingwall	LC 17-03/LRC-1	176.7	Loose Silt/Stiff Clayey Silt Till	175	125
		174.7	2 m thick engineered fill pad on hard silty clay(*)	750	350
SW wingwall	LC 17-04	176.7	Hard Clayey Silt Till	550	325

* - This option assumes the excavation will be extended to an elevation of 174.7 m and a 2-m thick engineered fill pad will be constructed.

The factored geotechnical resistances provided above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistances should be modified as indicated in the CHBDC (2014) Clause 6.10.3 and Clause 6.10.4.

5.3.2 Lateral Resistance

The lateral resistance of the wall base against sliding may be computed using an unfactored friction coefficient of 0.4 for precast concrete founded on hard clayey silt till and 0.35 on loose silt/stiff clayey silt till. These values of friction coefficient are an ultimate value and require some degree of sliding movement to fully mobilize. A resistance factor of 0.6 should be applied for cohesive soils and 0.8 for cohesionless soils, as indicated in Table 6.2 in the CHBDC (2014).

5.3.3 Subgrade Preparation for Wingwalls

After the excavation reaches the design subgrade level, the exposed surface should be proof-rolled and 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 in accordance with OPSS.PROV 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 300-mm thick engineered fill pad consisting of OPSS.Prov 1010 Granular A or Granular B Type II compacted as per OPSS 501.

5.4 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.

5.5 Backfill to Culvert/Wingwalls

Backfill to the culvert/wingwalls should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS.PROV 1010.

All fills should be placed and compacted in accordance with OPSS.PROV 501. The backfill should be maintained equal on both sides of the culvert, with one side not exceeding the other by more than 500 mm. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction equipment to be used adjacent to retaining structures/culvert walls should be restricted in accordance with OPSS.PROV 501. The design of the culvert and wingwalls should incorporate appropriate drainage.

5.6 Lateral Earth Pressure

Lateral earth pressures acting on the structure and wingwalls 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 but generally are given by the expression:

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

where:

$$\begin{aligned} P_h &= \text{horizontal pressure on the wall at depth } h \text{ (kPa)} \\ K &= \text{earth pressure coefficient} \\ \gamma &= \text{unit weight of retained soil (kN/m}^3\text{)} \end{aligned}$$

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 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 5.6.

Table 5.6 – Coefficients of Lateral Earth Pressure

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or 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	-
Passive	3.7	-	3.3	-

* For wing walls

5.7 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 5.7 may be used:

Table 5.7 – 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.

5.8 Approach Embankments

5.8.1 General

The construction of the culvert structure will require up to 1.7 m of fill above the existing ground surface at the west approach and up to about 4 m at the east approach. The side slopes of the approach embankments will be at an inclination of 2H:1V.

5.8.2 Subgrade Preparation

Stripping of soft and compressible soil and existing topsoil should be subject to construction inspection and completed in accordance with OPSS.PROV 206 and OPSS 802. All topsoil and organic deposits encountered in areas where the existing ground slope is steeper than 3H:1V or within 75 m of the culvert structure must be stripped from under the proposed footprint of the embankment as per OPSS.PROV 206.

Following stripping/organic removal, the exposed subgrade should be backfilled with suitable earth/granular materials compacted as per OPSS.PROV 501. The work should be carried out in accordance with OPSS 902 and construction should be carried out in the dry. Once the subgrade is prepared the construction traffic and equipment should not travel on the subgrade.

5.8.3 Approach Embankment Stability

Based on the soil conditions and proposed embankment heights, stability issues are not anticipated for the embankments if constructed on properly prepared subgrade to the maximum embankment heights with 2H:1V side slopes.

5.8.4 Approach Embankment Settlement

The settlements of the foundation soils were estimated to be in the order of 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 2 months should be allowed for embankment settlement to take place prior to construction of approach slab and final paving.

5.9 Excavation and Dewatering

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 and the loose silt/very soft to soft silty clay (encountered in Borehole LC 17-03) may be classed as Type 4 soil.

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

The groundwater level measured varied between Elev. 181.6 and 179.1 m. which is above the base of excavation (Elev. 176.7 m) for construction of the culvert pile caps and wingwalls. Accordingly, a sheet pile or sand bag cofferdam around the excavations would be required for pile cap and wingwall construction. It is important to note that difficulty driving the sheet piles through the till soils should be anticipated. Given the consistency and relatively low permeability of the silty clay and sandy silt 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 the excavations. 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.

The comments regarding excavation procedures and dewatering requirements are provided for design guidance only. The construction methodology, interpretation of the factual data, and design of the shoring and dewatering system are the responsibility of the Contractor. We recommend that the Contractor retain an experienced dewatering contractor to design and install any dewatering systems. We also recommend that an engineer experienced in temporary shoring/cofferdam design be retained to design the temporary shoring/cofferdam system.

A temporary sheet pile cofferdam may be designed using the parameters given below:

γ	=	21 kN/m ³ (unit weight above groundwater level)
γ'	=	11 kN/m ³ (unit weight below groundwater level)
K_a	=	0.33 (coefficient of active earth pressure of embankment fill)
	=	0.37 (coefficient of active earth pressure of soft to firm silty clay)
	=	0.31 (coefficient of active earth pressure of hard silty clay and hard clayey silt to silty clay till)
K_p	=	3.0 (coefficient of passive earth pressure of embankment fill)
	=	2.7 (coefficient of passive earth pressure of soft to firm silty clay)
	=	3.3 (coefficient of passive earth pressure of hard silty clay and hard clayey silt to silty clay till)

5.10 Erosion and Scour Protection

Erosion protection should be provided in the areas of the culvert inlet and/or outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all embankment surface where creek water is likely to be in contact. Treatment at the outlets should be in accordance with OPSP 810.010.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

Culvert design drawings prepared by the structural designer and the water resources designer have been reviewed from a geotechnical perspective. The erosion and scour protection measures included in the culvert design drawings are generally consistent with the geotechnical recommendations provided above.

5.11 Corrosion and Sulphate Attack Potential

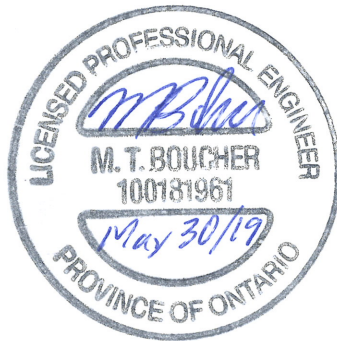
The results of the analytical tests for corrosivity and sulphate content conducted on the soil samples indicate the following:

- 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 moderate.
- Appropriate protection measures are recommended if metal structural elements are used.

5.12 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 wingwall footings should be constructed in the dry. The subgrade should be covered/protected as soon as practical upon exposure and be protected from any disturbances that will likely weaken the material.
- The excavation for the footings will extend below the groundwater level. Therefore, water inflow into the excavation should be expected and a cofferdam will be required. The water inflow within the cofferdam 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

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


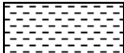



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No LC 17-01

1 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Over Rainbow Creek N 4 849 750.3 E 293 270.4 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.31 - 2017.05.31 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL
181.3	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (150mm)							20	40	60	80	100						
0.2	SAND and GRAVEL, trace silt, trace cobbles Very Dense Brown Moist (FILL)		1	SS	73		181							○				
			2	SS	60		180							○				40 54 6 (SI+CL)
179.9																		
1.4	Silty CLAY, some sand, trace gravel, occasional rootlets Soft to Firm Brown Moist		3	SS	5		179							○				
			4	SS	4									○				
			1	ST	TW		178							○				
177.5																		
3.8	Clayey SILT, sandy, trace gravel Hard Grey Moist to Wet (TILL)		5	SS	100/ 0.250		177							⊕				
							176											
175.8																		
5.5	Silty CLAY, trace sand, layered Hard Grey Moist		6	SS	67		175											
							174											
			7	SS	50		173							○				
172.6																		
8.7	Clayey SILT to Silty CLAY, some sand to sandy Hard Grey Moist (TILL)		8	SS	46		172							⊕				0 28 40 32

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No LC 17-02

1 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Over Rainbow Creek N 4 849 727.0 E 293 280.7 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.07 - 2017.06.07 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			SHEAR STRENGTH kPa											
179.7	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (150mm)							20	40	60	80	100							
0.2	Silty CLAY , sandy, trace gravel, trace organics Soft to Firm Brown Moist		1	SS	4		179												
			2	SS	5														
178.3																			
1.4	Clayey SILT , sandy, trace gravel, occasional cobbles Hard Grey Moist to Wet (TILL)		3	SS	48		178												
			4	SS	106/ 0.200		177												
			5	SS	101/ 0.200		176												
175.7																			
4.0	Silty CLAY , trace sand, layered Hard Grey Moist		6	SS	81		175												
							174												
			7	SS	35		173												
172.5																			
7.2	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel Hard Grey Moist (TILL)		8	SS	35		172												
							171												
170.4	Occasional shale fragments		9	SS	102/ 0.225														
9.3	SHALE highly to moderately weathered, thinly bedded, weak with strong limestone interbeds, grey: (Georgian Bay Formation)		1	RUN	0.225		170												

Continued Next Page

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		NATURAL MOISTURE CONTENT	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 w _P			w	LIQUID LIMIT w _L
								SHEAR STRENGTH kPa					WATER CONTENT (%)	
	Continued From Previous Page													
167.2	Vertical fracture (50mm) at 9.4m, 9.6m and (100mm) at 10.3m		2	RUN		169					5	RUN #2 TCR=100% SCR=80% RQD=40% UCS=14MPa (Shale)		
			Highly fractured zone (175mm) at 9.5m							6				
	Limestone interbed (125mm) at 9.5m, (25mm) at 9.8m, (50mm) at 9.9m and (75mm) at 10.1m	3	RUN		168					2	RUN #3 TCR=100% SCR=70% RQD=40% UCS=6.7MPa (Shale) UCS=67.7MPa (Limestone)			
	Sub-vertical fracture (25mm) at 10.4m									5				
	Vertical fracture (100mm) at 11.1m, (75mm) at 11.7m and (200mm) at 12.3m									8				
	Highly fractured zone (175mm) at 11.1m									7				
	Limestone interbed (75mm) at 11.1m, 11.3m, (250mm) at 12.0m and (175mm) at 12.3m									7				
					4									
					5									

END OF BOREHOLE AT 12.5m.
Piezometer installation consists of
25mm diameter Schedule 40 PVC pipe
with a 1.52m slotted screen.

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.07.10	-0.7	180.4
2017.10.18	-0.7	180.4

"-" Above ground surface

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S MTO-19484.GPJ 2017TEMPLATE(MTO).GDT 1/30/18

RECORD OF BOREHOLE No LC 17-03

2 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Over Rainbow Creek N 4 849 742.5 E 293 248.0 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.01 - 2017.06.01 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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					
171.6																	
10.2	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel, occasional shale fragments Hard Grey Moist (TILL)		10	SS	40		171										
169.8							170										
12.0	SHALE highly to moderately weathered, thinly bedded, weak with medium to very strong limestone interbeds, grey: (Georgian Bay Formation) Limestone interbed (75mm) at 12.1m and (125mm) at 12.4m Highly fractured zone (350mm) at 12.5m and (75mm) at 13.2m Sub-vertical fracture (50mm) at 12.5m and (100mm) at 13.0m Limestone interbed (200mm) at 13.8m Limestone interbed (50mm) at 15.0m, (75mm) at 15.3m and 16.0m Sub-horizontal fracture (75mm) at 15.8m		1	RUN			169										
			2	RUN			168										
							167										
			3	RUN			166										
165.4																	
16.4	END OF BOREHOLE AT 16.4m. Piezometer installation consists of two 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. DEEP WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.10.25 2.7 179.1 SHALLOW WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.10.25 0.2 181.6 * Possibly erroneous due to disturbance																

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

RECORD OF BOREHOLE No LC 17-04

1 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Over Rainbow Creek N 4 849 727.0 E 293 255.3 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.06 - 2017.06.06 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		W _p W W _L WATER CONTENT (%)			
181.8	GROUND SURFACE												
0.0	ASPHALT: (150mm)												
0.2	Gravelly SAND , trace silt, occasional cobbles Dense Brown Moist (FILL)												
180.7			1	SS	33								
1.1	Silty CLAY , some sand, trace gravel Firm Brown Moist												
			2	SS	7								
			3	SS	8								
178.8													
3.0	Clayey SILT , sandy, trace gravel Hard Brown Moist to Wet (TILL)		4	SS	43								
			5	SS	68								
176.2													
5.6	Silty CLAY , trace sand, layered Hard Grey Moist		6	SS	98								
			7	SS	48								
173.1													
8.7	Clayey SILT to Silty CLAY , some sand to sandy, trace gravel Hard Grey Moist (TILL)		8	SS	43								

Continued Next Page

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

RECORD OF BOREHOLE No LC 17-04

2 OF 2

METRIC

W.P. _____ LOCATION Langstaff Road Over Rainbow Creek N 4 849 727.0 E 293 255.3 ORIGINATED BY TF
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.06 - 2017.06.06 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						
	Continued From Previous Page							20 40 60 80 100						
								20 40 60 80 100						
171.0							171							
10.8	SHALE highly to moderately weathered, thinly laminated, weak with very strong limestone interbeds, grey: (Georgian Bay Formation) Limestone interbed (50mm) at 11.1m and 12.1m Sub-horizontal fracture (50mm) at 11.1m and 11.3m Sub-vertical fracture (25mm) at 12.0m Highly fractured zone (75mm) at 12.4m Sub-vertical fracture (25mm) at 12.6m, 12.7m and 13.3m Limestone interbed (25mm) at 12.6m, 13.1m and (75mm) at 13.3m Highly fractured zone (75mm) at 13.5m		1	RUN		170							FI 10 5 4 3 4 	

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

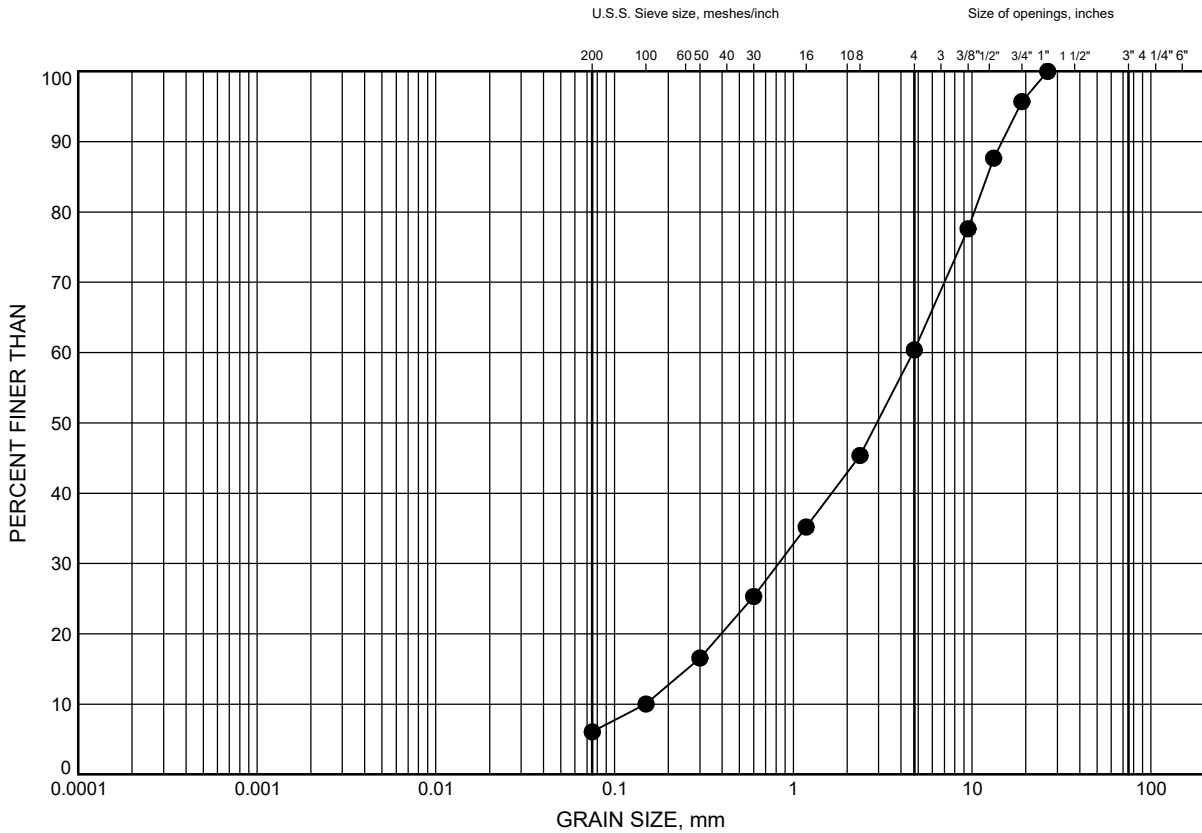
Appendix B

Geotechnical and Analytical Laboratory Test Results – Current Investigation

Langstaff Road Over Rainbow Creek
GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND to SAND and GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-01	1.1	180.2

Date January 2018
 W.P. _____

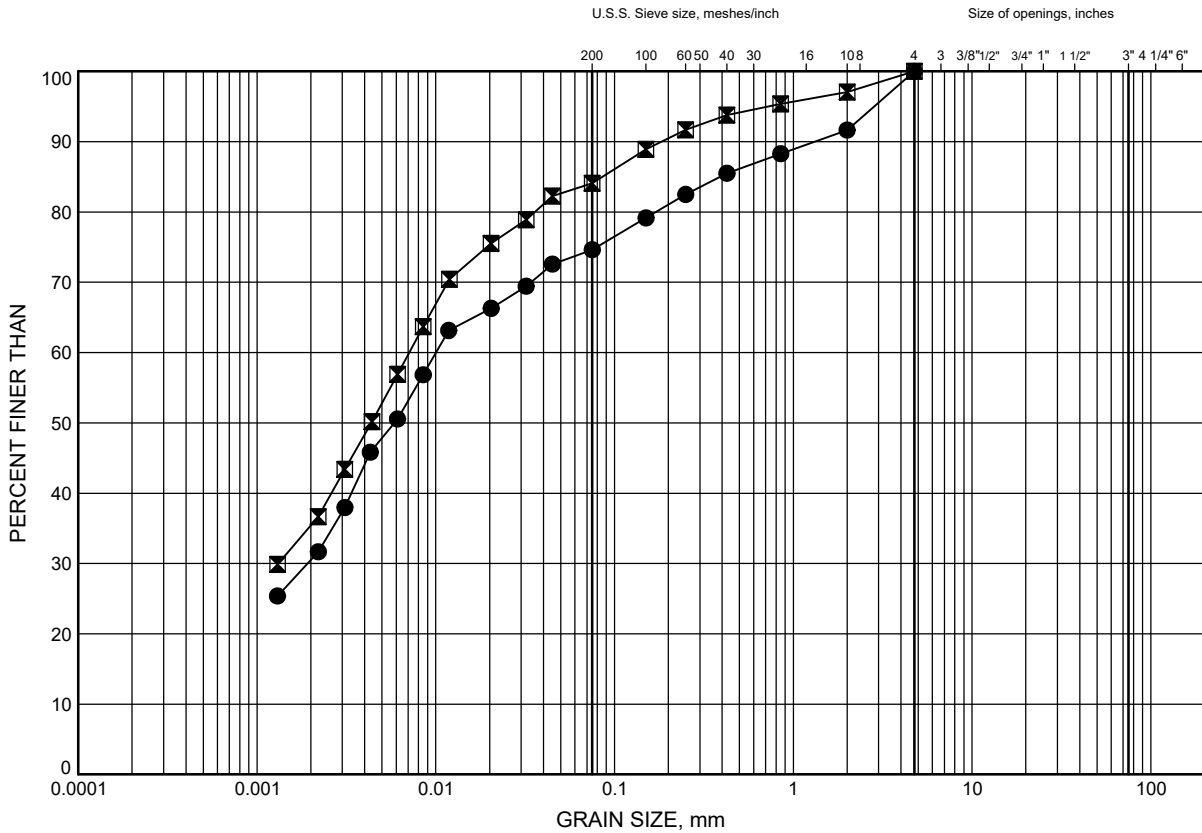


Prep'd AN
 Chkd. MTB

Langstaff Road Over Rainbow Creek GRAIN SIZE DISTRIBUTION

FIGURE B2

Upper Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-03	2.6	179.2
◻	LC 17-04	2.6	179.2

Date January 2018
W.P.

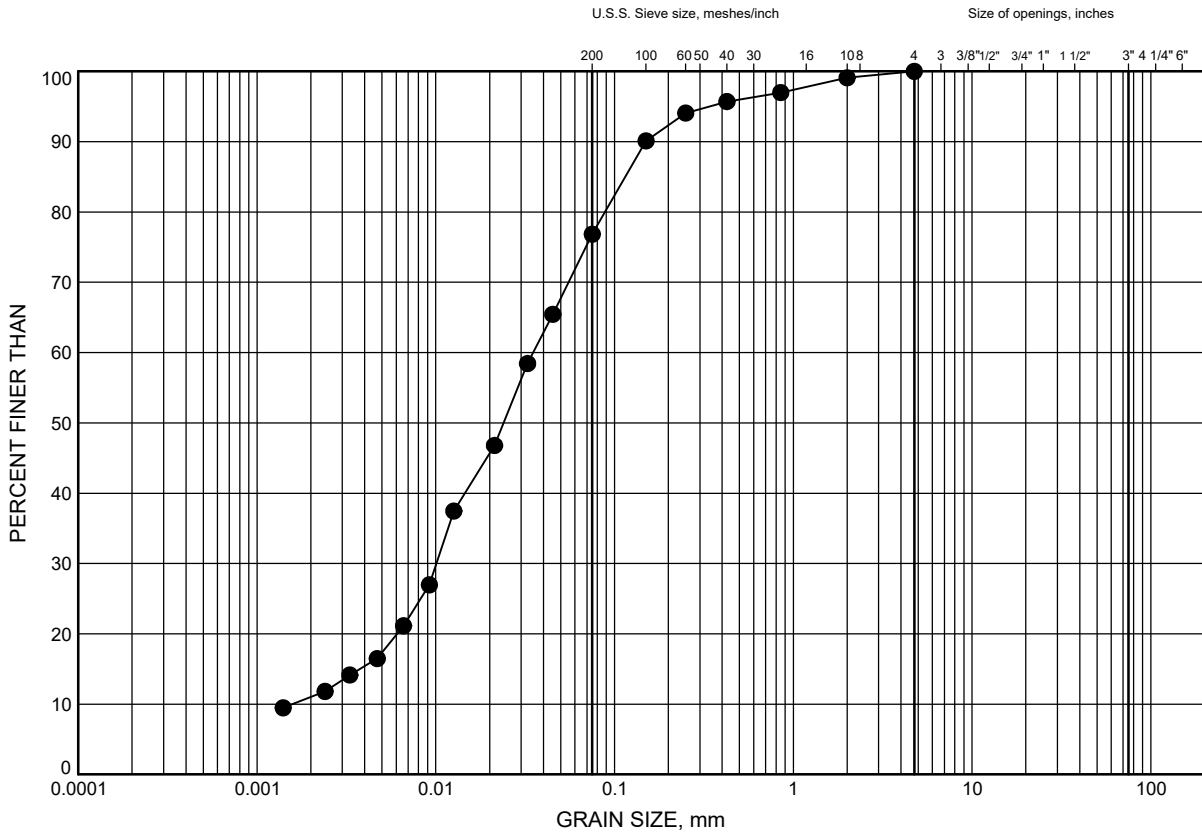


Prep'd AN
Chkd. MTB

Langstaff Road Over Rainbow Creek GRAIN SIZE DISTRIBUTION

FIGURE B3

Upper Clayey SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-02	3.2	176.5

Date January 2018
W.P. _____

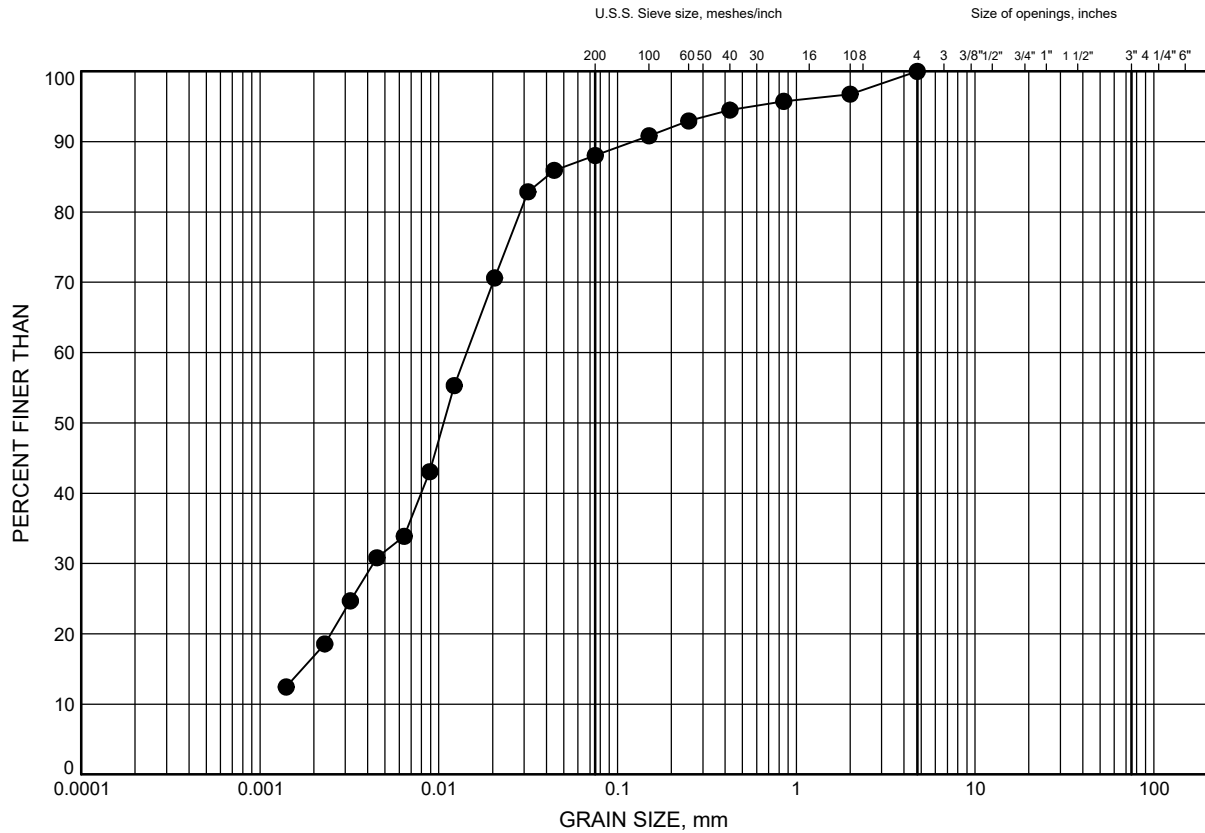


Prep'd AN
Chkd. MTB

Langstaff Road Over Rainbow Creek GRAIN SIZE DISTRIBUTION

FIGURE B4

Lower Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-03	6.4	175.4

Date January 2018
W.P.

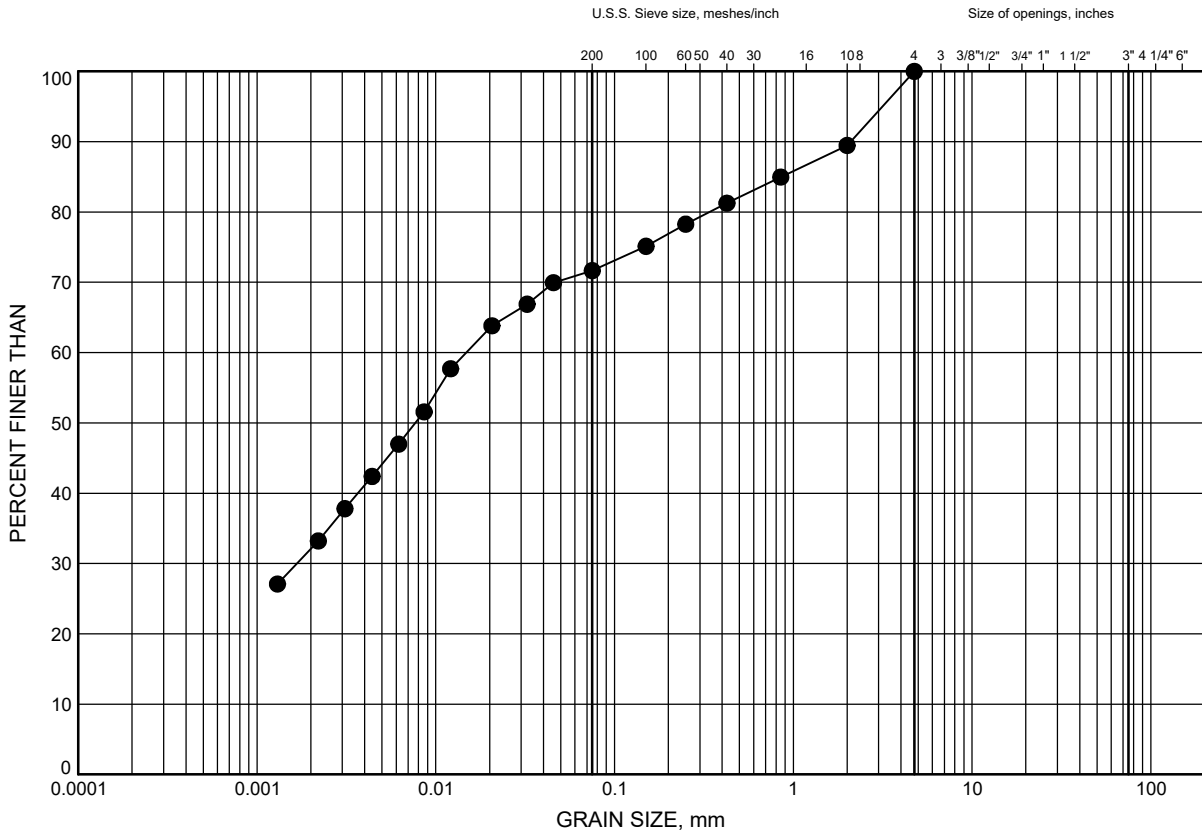


Prep'd AN
Chkd. MTB

Langstaff Road Over Rainbow Creek
GRAIN SIZE DISTRIBUTION

FIGURE B5

Lower 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)
●	LC 17-01	9.4	171.9

Date January 2018
W.P.

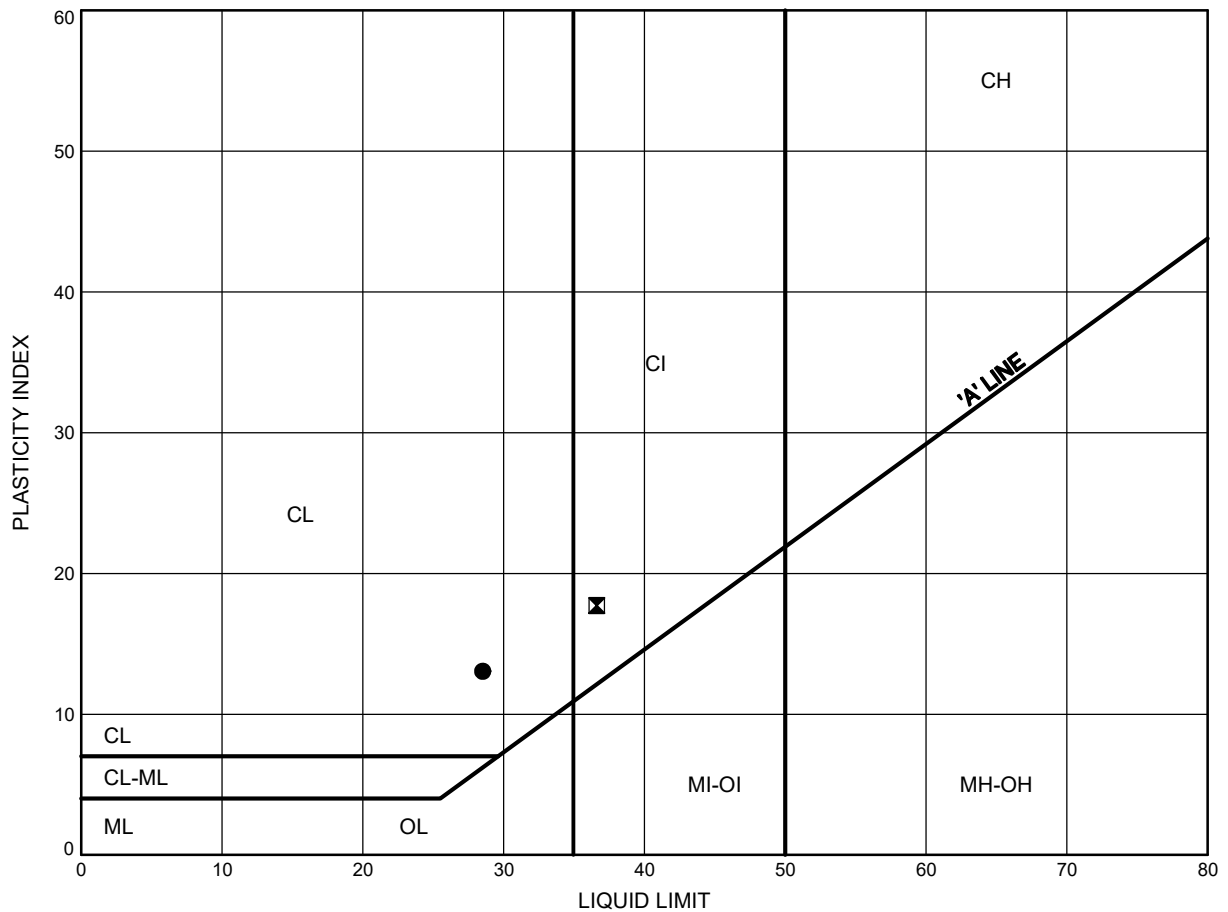


Prep'd AN
Chkd. MTB

Langstaff Road Over Rainbow Creek
ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Upper Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-03	2.6	179.2
⊠	LC 17-04	2.6	179.2

Date January 2018
 W.P.

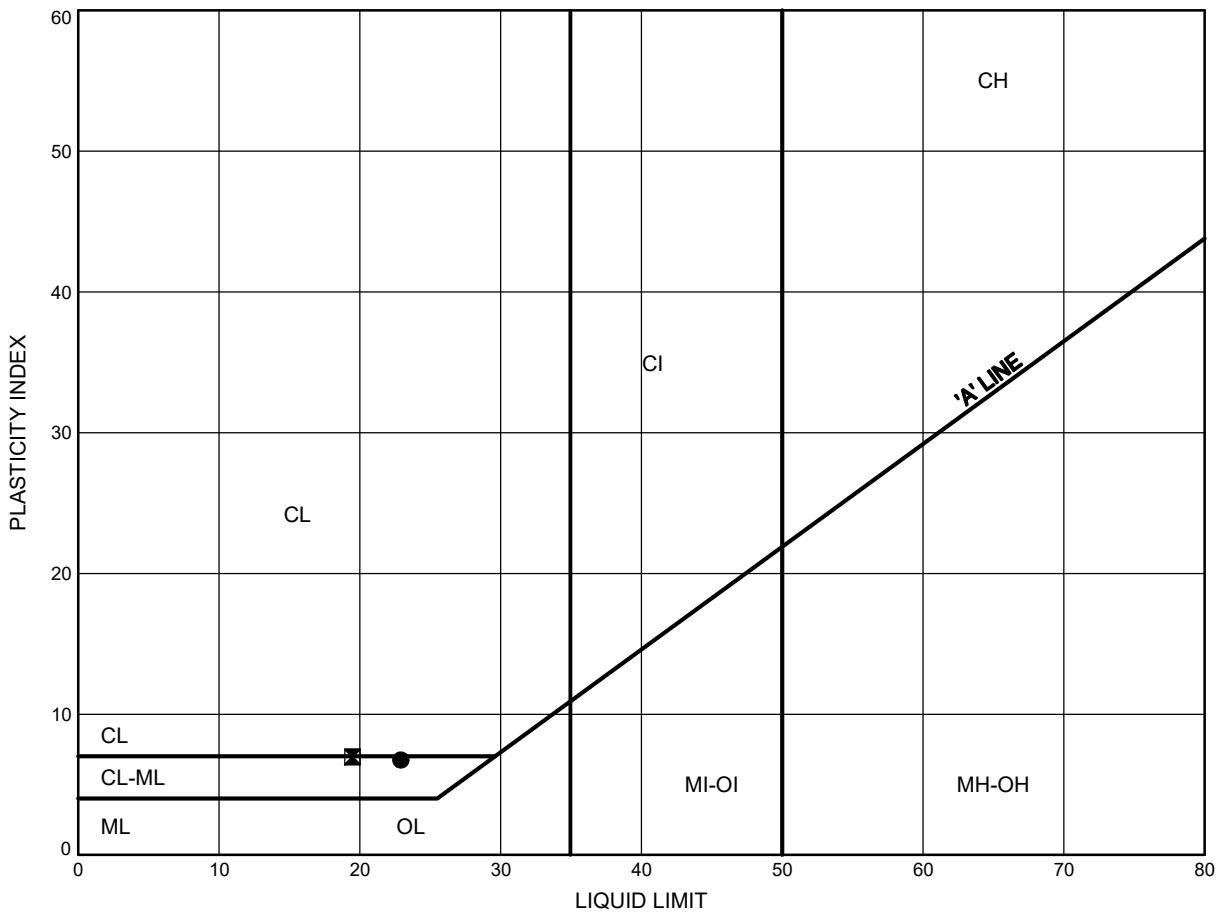


Prep'd AN
 Chkd. MTB

Langstaff Road Over Rainbow Creek
ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Upper Clayey SILT TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-01	4.9	176.4
⊠	LC 17-02	1.8	177.9

Date January 2018
 W.P.

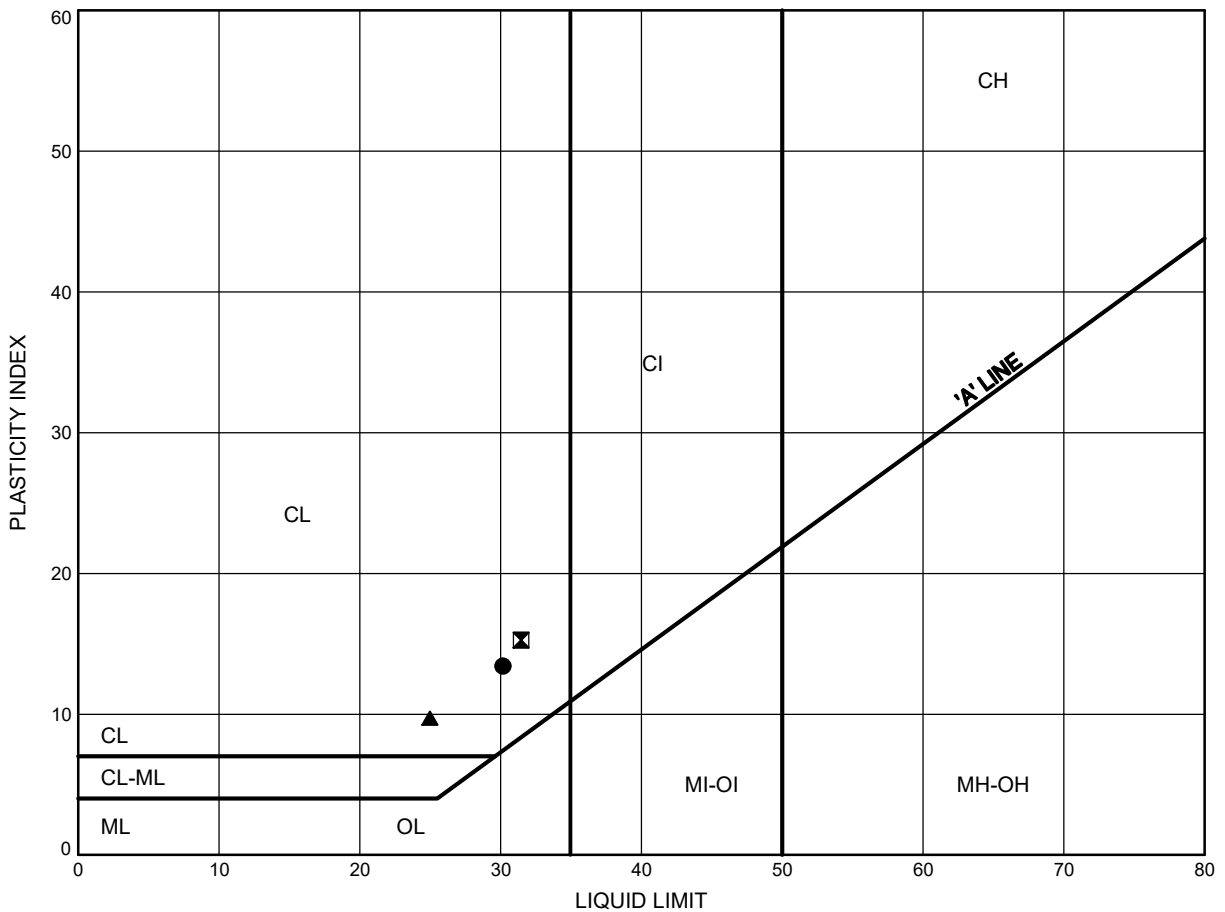


Prep'd AN
 Chkd. MTB

Langstaff Road Over Rainbow Creek
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Lower Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-02	6.4	173.3
⊠	LC 17-03	7.9	173.9
▲	LC 17-04	6.4	175.4

Date January 2018
 W.P.

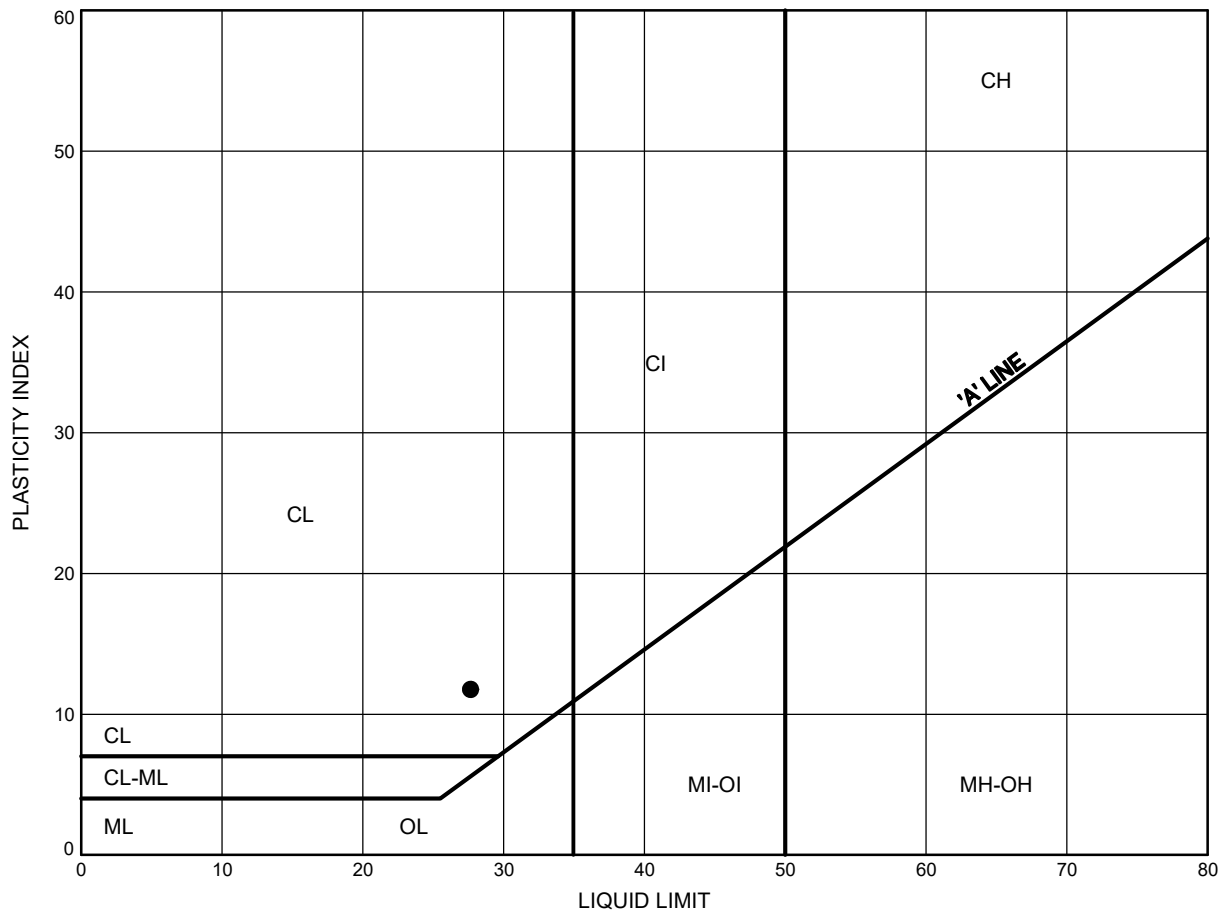


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Langstaff Road Over Rainbow Creek
ATTERBERG LIMITS TEST RESULTS

FIGURE B9

Lower Clayey SILT to Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LC 17-01	9.4	171.9

Date January 2018
 W.P.



Prep'd AN
 Chkd. MTB

Certificate of Analysis

SGS Canada Inc.
185 Concession St. Box 4300
Lakefield, Ont., Canada, K0L 2H0



Client
SGS LIMS Number
Analysis Package:

Attention: Mohammad Eghtesadi
Project#: 12307 Hwy 427
Thurber Engineering Ltd.
CA14376-JUN17
Corrosivity

Sample ID	Unit	LC 17-01 SS5	LC 17-03 SS8
Sample Date/Time		31-May-17 16:52	01-Jun-17 16:55
Temperature Upon Receipt	°C	3.0	3.0
Corrosivity Index	none	8	8
Soil Redox Potential	mV	231	235
Sulphide	%	0.09	0.08
% Moisture (wet wt)		14.2	13.6
pH	no unit	8.72	8.51
Chloride	µg/g	51	69
Sulphate	µg/g	190	150
Conductivity	uS/cm	261	272
Resistivity (calculated)	ohms.cm	3830	3680

Corrosivity Index is based on the AWWA
Corrosivity Scale according to AWWA C-105.
An index greater than 10 indicates the
soil matrix may be corrosive to cast iron alloys.

Deanna Edwards B.Sc., C.Chem
Project Specialist
Environment, Health and Safety

Data reported represents the sample submitted to SGS. Reproduction of this analytical report in full or in part is prohibited without prior written approval. Please refer to SGS General Conditions of Services located at http://www.sgs.com/terms_and_conditions_service.htm. (Printed copies are available upon request.). Test Method information available upon request. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.



SGS Canada Inc.

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - KOL 2H0

Phone: 705-652-2000 FAX: 705-652-6365

Project# 12307 Hwy 427

LR Report : CA14376-JUN17

Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank		RPD		LCS / Spike Blank			Matrix Spike / Reference Material		
						Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0258-JUN17												
Chloride	0.4	µg/g	<0.4		2	20	99	80	120	109	75	125
Sulphate	0.4	µg/g	<0.4		0	20	95	80	120	97	75	125
Carbon/Sulphur - QCBatchID: ECS0021-JUN17												
Sulphide	0.02	%	<0.02		NV	20	85	80	120			
Conductivity - QCBatchID: EWL0252-JUN17												
Conductivity	2	uS/cm	4		1	10	92	90	110	NA		
pH - QCBatchID: EWL0252-JUN17												
pH	0.05	no unit	NA		0		100			NA		

Appendix C

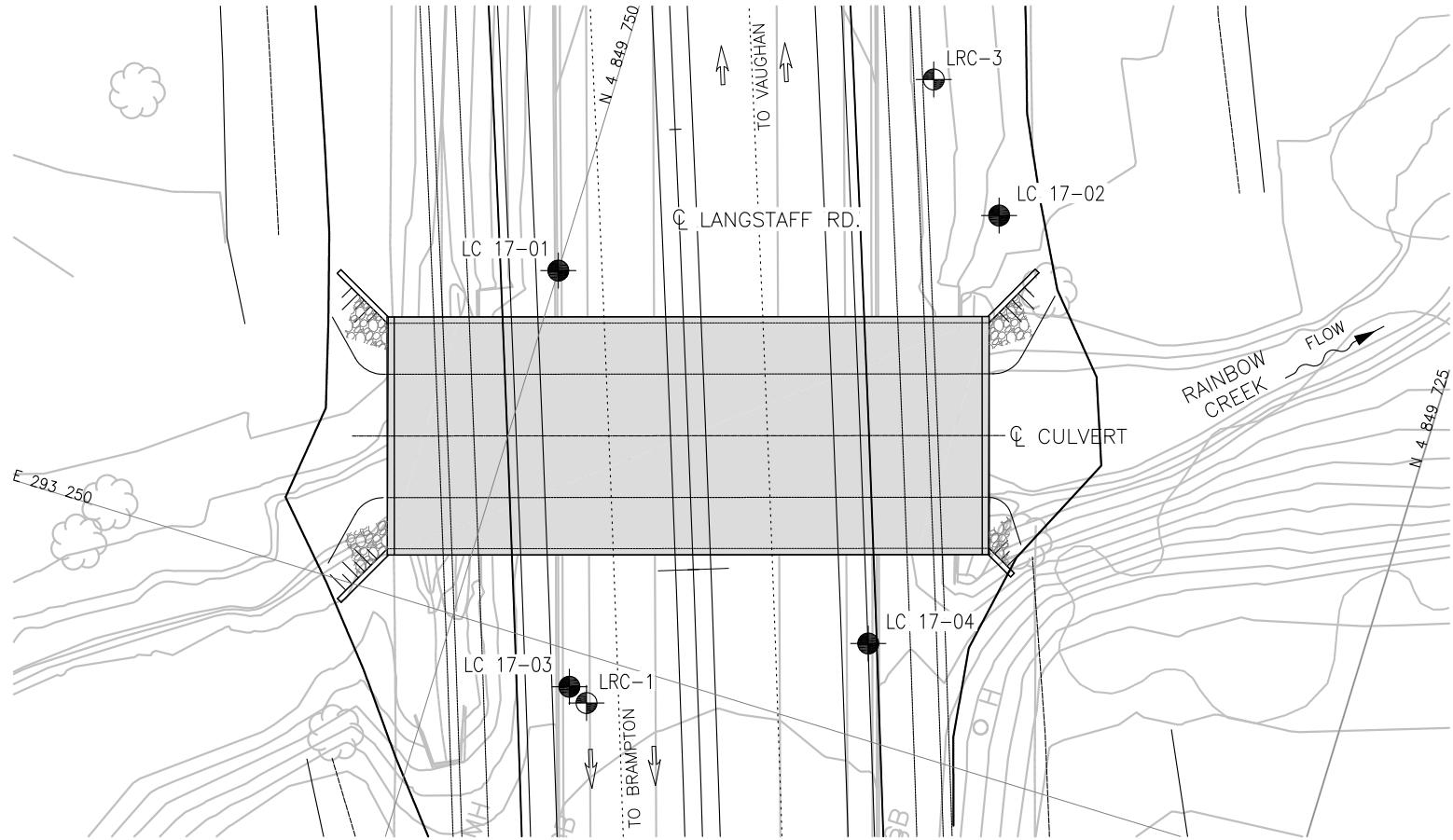
Record of Borehole Sheets and Laboratory Test Results - Previous Investigations

[illegible][illegible]

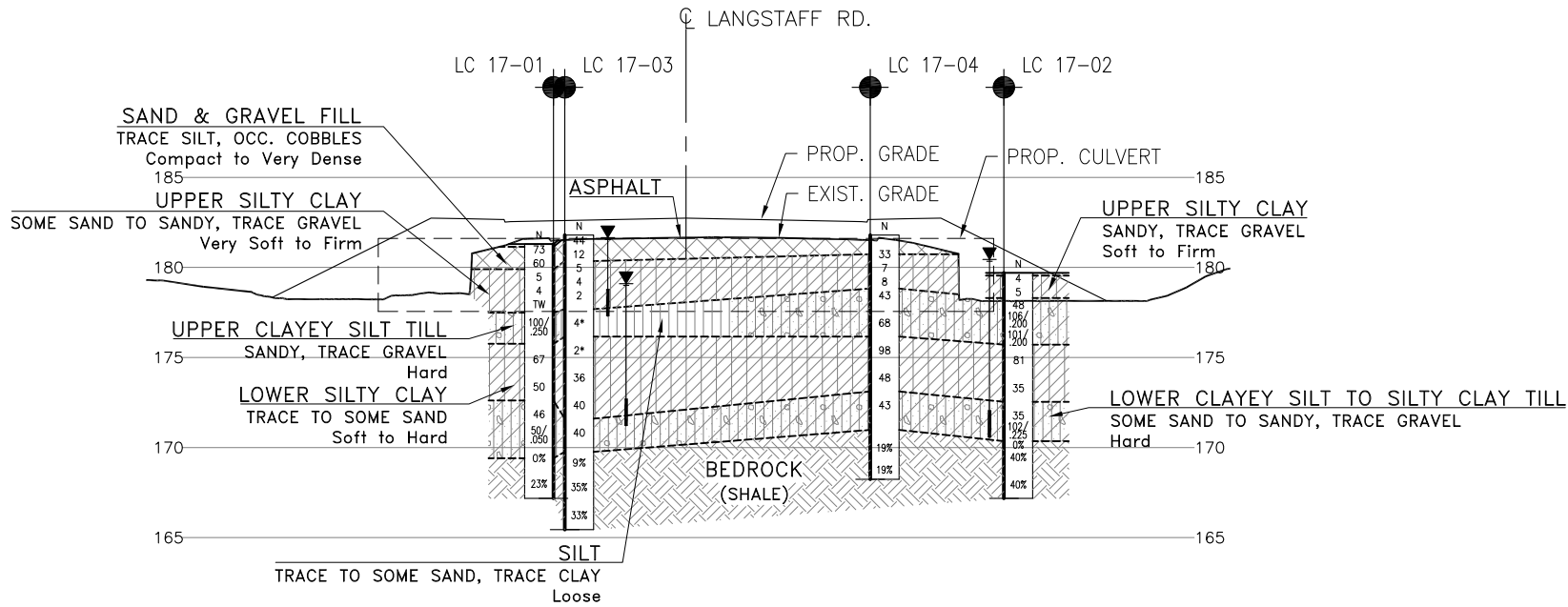
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Appendix D

Borehole Locations and Soil Strata Drawing

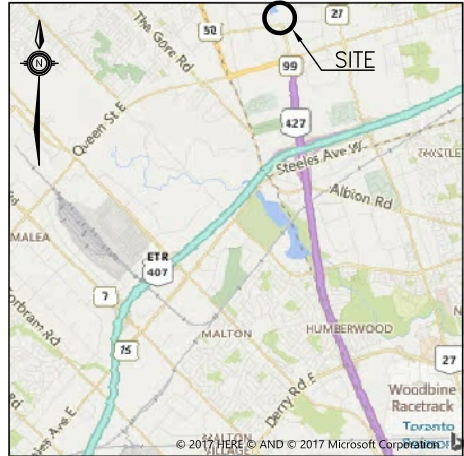


PLAN



SECTION ALONG CULVERT

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
LC 17-01	181.3	4 849 750.0	293 270.4
LC 17-02	179.7	4 849 727.0	293 280.7
LC 17-03	181.8	4 849 742.5	293 248.0
LC 17-04	181.8	4 849 727.0	293 255.3
LRC-1	181.9	4 849 741.3	293 247.4
LRC-3	179.9	4 849 732.8	293 287.0

-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.

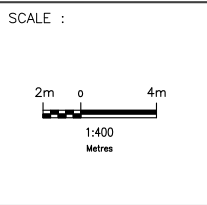
TITLE
HWY 427 EXPANSION
LANGSTAFF ROAD OVER RAINBOW CREEK
CULVERT

BOREHOLE LOCATIONS AND SOIL STRATA

PROJECT ID.	STAGE IDENTIFIER	DESIGN PACKAGE NUMBER	DISCIPLINE	STRUCTURE NUMBER	DOCUMENT TYPE	DRAWING NUMBER	REVISION NUMBER
H427-D	H	4A	STR	B12	DWG	501	A

FILENAME: H:\Drafting\19000\19484\1ED19484-PLR-HWY 427 LangstaffRd Over RainbowCreek.dwg
PLOT DATE: 5/30/2019 9:00 AM

NO.	DATE	REVISIONS	BY	CHK	LEO. DES.	PROJ. MGR.
A	19/05/30	100% SUBMISSION TO CA	MB	JL	JL	PB



DESIGNED	M. BOUCHER	MB	19/05/30
DRAWN	A. NOOR	AN	19/05/30
CHECKED	J. LEE	JL	19/05/30
APPROVED LEAD ENGINEER	J. LEE	JL	19/05/30
APPROVED PROJ. MANAGER	P. BAMFORTH	PB	19/05/30
NAME (PRINT)		INIT.	DATE

