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Highway 427 Expansion – Package 1A (100% Submission)
Hwy 427 NBL and SBL Bridges over Rainbow Creek (Bridges 11A/11B)

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1. INTRODUCTION

This report provides foundation recommendations for the design and construction of the proposed bridges to carry northbound lane (NBL) and southbound lane (SBL) of Highway 427 over Rainbow Creek. 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 recently completed geotechnical investigation by Thurber Engineering. Reference has also been made to available subsurface information from previous investigations documented in the reports listed below:

1. GEOCRE 30M13-168: Preliminary Foundation Investigation and Design Report, Rainbow Creek Bridges (NBL and SBL), 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. 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 General Arrangement (GA) drawings H427-D-H-1A-STR-B11A-DWG-600-A and H427-D-H-1A-STR-B11B-DWG-700-A dated March 16, 2018. A revised highway profile has been proposed between Zenway Boulevard and Langstaff Road in April 2018, which results in an approximate 2 m grade raise at the Rainbow Creek crossing.

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

The site is located approximately 550 m south of Langstaff Road and 400 m north of the terminus of Rainbow Creek Drive in the City of Vaughan, Ontario.

The proposed bridges will be located within the flood plain of the Rainbow Creek. The ground surface within the flood plain varies from approximately Elev. 175.6 to 177.5. South of the creek, the valley floor is approximately 20 to 25 m wide and the ground surface rises quickly to Elev. 183.5. North of the creek, the valley floor extends for approximately 50 m to 80 m and the ground surface rises gently to the north to Elev. 183. At the proposed crossing location, Rainbow Creek varies in width from about 4 to 7 m and flows in a direction from west to east.

The creek banks are moderately to densely vegetated with tall trees and shrubs. Some commercial and light industrial development areas are present along the main roads near the site.

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

3. GEOTECHNICAL INVESTIGATION

The current field investigation at this site was conducted between May 30 and June 9, 2017, and consisted of drilling and sampling six (6) boreholes, designated as Boreholes RC17-01 to RC17-06. Boreholes RC17-01, RC17-04 and RC17-06 were located along the proposed south abutments, and Boreholes RC17-02, RC17-03

and RC17-05 were advanced along the proposed north abutments. The boreholes were drilled to depths ranging from 12.6 m to 18.4 m.

The ground surface elevations for the boreholes were derived from a topographic drawing (Base Plan) provided by WSP/MMM. The coordinate system MTM NAD 83, Zone 16 was used to establish locations of the boreholes. The Record of Borehole sheets and approximate locations of the boreholes shown on the Borehole Locations and Soil Strata Drawing are included in Appendix D.

Track mounted CME 55 drill rigs, supplied by Landshark Drilling Ltd. of Ontario, were used to advance the boreholes. Soil samples were obtained at selected intervals using a 50mm nominal diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT) procedures as per ASTM D1586. Four boreholes were advanced to bedrock and the bedrock was confirmed by a minimum of 3 m coring using NQ-sized coring equipment. 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 and therefore these measurements were considered not reliable. Standpipe piezometers were installed in Boreholes RC17-01 to RC17-03 and RC17-05. Boreholes without piezometers were decommissioned as per O.Reg. 903.

4. SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the “Borehole Locations and Soil Strata” drawings included in Appendix A. The subsurface information documented in the reports from 2009 (Geocres No. 30M13-168) and from 2015 (Geocres 30M13-216) was reviewed and relevant borehole information was incorporated into this report and included in Appendix C.

In general, the subsurface conditions at the site consist of a layer of surficial clayey silt overlying clayey silt to silty clay till grading to sand and silt till which is underlain by a lower layer of clayey silt to silty clay till followed by shale bedrock. Occasional cobbles and boulders were reported in the till deposits. The groundwater level monitored in Borehole S-5 on the south valley slope was at 4.5 to 4.9 m below the ground surface or Elevation 177. Water level monitored in Borehole S-9 located within the flood plain was at 0.5 m below the ground surface or Elevation 175.5. Artesian conditions were encountered in piezometers with screens installed in the lower cohesive till. The measured short-term groundwater levels were at 0.8 m and 0.6 m above the ground surface in RC17-01 and RC17-02, respectively.

Detailed descriptions of individual strata are presented below.

4.1 Topsoil

Topsoil was encountered in all boreholes except RC17-04. Topsoil thickness varies from 50 to 100 mm.

4.2 Clayey Silt

A surficial deposit of brown clayey silt with trace to some sand and trace gravel was encountered in all six boreholes either beneath the topsoil or from the ground surface. Trace organic matter (rootlets) were noted in the deposit. The base of the clayey silt ranged from depths of 0.7 m to 1.5 m (Elev. 176.8 to 174.4). The SPT-N values ranged from 0 to 10 blows per 0.3 m of penetration indicating a very soft to stiff consistency.

4.3 Upper Clayey Silt to Silty Clay Till

Brown to grey clayey silt to silty clay till was encountered underlying the surficial clayey silt in all boreholes advanced in the current investigation. The depth to the base of the cohesive till ranged from 4.0 to 5.2 m or

Elevation 170.6 to 173.5. SPT-N values recorded in the cohesive till ranged from 8 to 82 blows per 0.3 m of penetration indicating a firm to hard consistency.

Glacial tills inherently contain cobbles and boulders, which should be expected to be present within the deposit.

4.4 Sand and Silt Till

A grey sand and silt till was encountered underneath the cohesive till. The cohesionless till was 3.5 to 6.7 m in thickness and extended to depths ranging from 7.6 to 11.5 m (Elev. 164.5 to 169.9). The SPT-N values ranged typically from 91 blows for 0.3 m of penetration to 100 blows for 100 mm penetration, indicating a very dense relative density.

A discontinuous layer of sandy clayey silt till approximately 1.3 m thick was encountered embedded in the sand and silt till in Borehole RC17-05 at 7.2 m depth (Elev. 169.0 to 167.7). A SPT-N value of 78 blows for 0.3 m of penetration was obtained in this layer.

Glacial tills inherently contain cobbles and boulders, which should be expected to be present within the deposit.

4.5 Lower Clayey Silt to Silty Clay Till

A layer of grey clayey silt to silty clay till was encountered underlying the cohesionless till in all boreholes in the current investigation. Where penetrated, the depth to the bottom of the lower cohesive till ranged from 12.4 to 15.2 m or Elevation 160.6 to 164.6. Boreholes RC17-05 and RC17-06 were terminated within this layer at 15.3 m and 12.6 m depth, respectively. SPT-N values recorded in the lower cohesive till ranged from 45 blows per 0.3 m of penetration to 100 blows for 125 mm penetration, indicating a hard consistency.

Glacial tills inherently contain cobbles and boulders, which should be expected to be present within the deposit.

4.6 Shale Bedrock

Grey shale bedrock of the Georgian Bay Formation was encountered in Boreholes RC17-01 to RC17-04 at depths from 12.4 to 15.2 m (Elev. 160.6 to 164.6). Typically, the upper zone of the shale bedrock was described as highly weathered and highly fractured beneath which the shale becomes moderately weathered to fresh, thinly bedded with occasional strong limestone interbeds. Occasional clay seams were noted at various depths in the shale bedrock.

Total Core Recovery (TCR) of the bedrock ranged from 89% to 100%. Solid Core Recovery (SCR) ranged from 55% to 100%. The Rock Quality Designation (RQD) values ranged typically from 67% to 93% indicating fair to excellent rock quality. Fracture Index (FI) of the rock cores indicating frequency of natural fractures per 0.3 m of core run, ranged from 0 to greater than 10, typically from 1 to 4.

The depths to bedrock and bedrock elevations encountered in the boreholes are summarized in the Table 1 below.

Table 1 – Depths and Elevations of Bedrock Surface

Borehole	Depth to Bedrock below Ground Surface (m)	Bedrock Elevation (m)
RC17-01	12.4	164.6
RC17-02	15.2	160.6
RC17-03	14.7	161.1
RC17-04	13.6	162.7

4.7 Groundwater Levels

Water levels measured in the piezometers installed during the current investigation and from the previous investigations by others are summarized in Table 2 below.

Table 2 – Piezometer Details and Groundwater Level Measurements

Borehole	Measurement Date	Water Level (m)		Screen Location (m)		Native Material at Screen
		Depth	Elevation	Depth	Elevation	
RC17-01	June 19, 2017	-0.8*	177.8	9.2-10.7	167.8-166.3	Lower Clayey Silt Till
	June 29, 2017	-0.7*	177.7			
	Oct 24, 2017	-0.3*	177.3			
RC17-02	June 19, 2017	-0.6*	176.4	14.3-15.8	161.5-160.0	Lower Clayey Silt Till/Shale
	June 29, 2017	-0.7*	176.5			
	Oct 18, 2017	-0.2*	176.0			
RC17-03 (S)	June 28, 2017	0.6	175.2	1.5-3.0	174.3-172.8	Upper Clayey Silt Till
	Oct 18, 2017	1.9	173.9			
RC17-03 (D)	June 28, 2017	-0.4*	176.2	9.2-10.7	166.6-165.1	Clayey Silt Till
	Oct 18, 2017	0.0	175.8			
RC17-05 (S)	June 19, 2017	0.7	175.5	1.5-3.0	174.7-173.2	Upper Clayey Silt Till
	June 28, 2017	0.5	175.7			
	Oct 18, 2017	2.9	173.3			
RC17-05 (D)	June 19, 2017	0.0	176.2	7.6-9.1	168.6-167.1	Sand and Silt Till to Clayey Silt Till
	June 28, 2017	-0.1*	176.3			
	Oct 18, 2017	0.7	175.5			
S5	April 24, 2009	4.4	177.2	9.2-10.7	172.4-170.9	Sand and Silt Till
	May 13, 2009	4.4	177.2			
	May 21, 2009	4.6	177.0			
	June 15, 2009	4.7	176.9			
	July 09, 2009	4.9	176.7			
S9	May 13, 2009	1.2	174.8	6.1-7.6	169.9-168.4	Sand and Silt Till
	May 21, 2009	0.9	175.1			
	June 15, 2009	0.5	175.4			
	July 09, 2009	0.5	175.5			

* 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 within the till.

Within the creek flood plain, the groundwater levels measured in the standpipe piezometers were up to 0.8 m and 0.6 m above ground surface at the proposed south and north abutments, respectively, indicating artesian groundwater conditions in the lower cohesive till.

At the crest of the south valley slope, the groundwater was approximately 4.4 to 4.9 m below the ground surface (Elevations 177.2 to 176.7) as measured in piezometer installed in sand and silt till in Borehole S5. The groundwater monitored in a piezometer installed in the sand and silt till in Borehole S9 drilled within the flood plain was between 0.5 m and 1.2 m below the ground surface (Elevations 175.5 to 174.8).

The preliminary General Arrangement drawing indicates a 100-year flood level at Elevation 175.97 and a regional storm level at Elevation 177.19.

4.8 Corrosion and Sulphate Test Results

Soil samples of the native soil collected from selected boreholes were submitted for analytical testing of corrosivity parameters and sulphate. The laboratory certificates of analyses are presented in Appendix B. The results of the analytical tests are summarized in Table 3.

Table 3 – Analytical Test Results

Parameter Tested	Unit	17-02	17-03	17-04	17-05
		SS8	SS5	SS4	SS3
Moisture	%	13.1	11.1	15.5	11.8
Corrosivity Index	-	8	8	8	4
pH	-	9.12	8.72	8.67	8.72
Soil Redox Potential	mV	227	256	242	283
Sulphide	%	0.07	0.07	0.14	< 0.02
Chloride	µg/g	36	13	5.4	18
Sulphate	µg/g	110	160	160	120
Electrical Conductivity	µS/cm	173	103	208	171
Resistivity	ohms.cm	5780	9710	4810	5850

5. PROJECT DESCRIPTION

Based on the GA drawings, Highway 427 extension is proposed to be carried over Rainbow Creek by two single span bridges (NBL and SBL) with span lengths of 49.4 m and 47.7 m, respectively. The SBL bridge will be approximately 30.2 m and 32.2 m wide at the south and north abutments, and the NBL bridge will be 32.5 m and 34.7 m wide at the south and north abutments, respectively.

The proposed H-pile foundations are to be constructed through the RSS fill to facilitate the integral abutments ("false abutments"). The undersides of the abutment stems are shown at approximate elevation 177.3 and 177.4 at the south and north abutments, respectively. The design grade of the bridge deck is indicated at approximate Elev. 184.2 to 184.4. The height of the approach embankments along the highway centreline will be approximately 7.5 to 8.5 m above the Rainbow Creek flood plain at the north and south abutments. RSS walls up to 8.5 m in height are proposed to retain the embankment fill at abutment locations.

6. GEOTECHNICAL RECOMMENDATIONS

6.1 Foundation Design

The GA drawings for the Rainbow Creek Bridges indicate that the twin structures will be supported on integral abutments with a single row of vertical HP 360x174 steel piles at both abutments.

6.1.1 Spread Footings

Shallow spread footings founded on native soils or engineered fill pad are not considered suitable for supporting the bridge abutments at this site due to the presence of low strength cohesive soils extending to significant depths and relatively deep excavation and associated construction dewatering required to reach competent founding stratum. Accordingly, this option has not been developed further.

6.1.2 Driven H-Piles

Based on the available subsurface information, supporting the proposed bridges on steel H-piles driven to refusal in the very dense/hard till or on shale bedrock is feasible for this site. The recommendations and discussion on

design and construction of driven H-piles are presented below.

6.1.2.1 Axial Pile Resistance

The available borehole information indicates that piles could be driven to refusal within the very dense sand and silt till or hard clayey silt till. For an HP 360x174 pile, estimated pile tip elevations and values of geotechnical resistances are provided in Table 4 below. The recommended pile tip elevation assumes that piles will be driven a minimum 3 m into the very dense or hard (i.e. SPT-N greater than 100 blow) till. Deeper penetration in the till may be required at individual pile locations as variation of soil conditions is anticipated between and beyond investigated locations.

Table 4 – Axial Geotechnical Resistances for HP 360x174

Location	Reference Boreholes	Pile Tip Elevation (m)	Founding Stratum	Factored ULS (kN)	Factored SLS (kN)
SBL Structure					
South Abutment	RC17-01, RC17-06	167.0	Hard Clayey Silt Till	1400	1100
		164.6	Shale Bedrock	3000	3000
North Abutment	RC17-02, RC17-05	167.0	Very Dense Sand and Silt Till	1400	1100
		160.6	Shale Bedrock	3000	3000
NBL Structure					
South Abutment	RC17-04, RC-1	167.0	Hard Clayey Silt Till	1400	1100
		162.7	Shale Bedrock	3000	3000
North Abutment	RC17-03, S7	167.0	Hard Clayey Silt Till	1400	1100
		161.1	Shale Bedrock	3000	3000

The values of geotechnical resistances at SLS provided above correspond to up to 25 mm of settlement.

If steel H-piles are to be driven to bedrock, the piles will need to penetrate approximately 8.2 to 10.6 m of very dense and hard till (mostly through materials with SPT-N>100) to reach bedrock. Pile installation may require pre-augering (i.e. loosening of soils) to facilitate pile driving.

6.1.3 Lateral Pile Resistance

The lateral resistance in the cohesionless soils may be calculated using 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:

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

$$D = \text{pile width in metres (0.378 m for HP 360x174)}$$

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

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

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

The geotechnical lateral resistance acting on a 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 HP 360x174)

The above equations and parameters provided in Table 5 below 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 – Geotechnical Design Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m ³)	n_h (kN/m ³)	K_p	S_u (kPa)
	Top	Bottom				
NBL North Abutment (S7 and RC17-3)						
Clayey Silt – firm	175.8	174.5	9.0 (*)	-	-	30
Clay & Silt Till – v. stiff/hard	174.5	171.5	10.0 (*)	-	-	100
Silt & Sand Till – dense/v. dense	171.5	170.0	11.0 (*)	5,500	3.5	-
Silt & Sand Till – v. dense	170.0	164.0	11.5 (*)	10,000	3.9	-
Clayey Silt Till – Hard	164.0	161.1	11.5 (*)	-	-	300
SBL North Abutment (RC17-02 and RC17-05)						
Clayey Silt – firm	176.0	174.5	9.0 (*)	-	-	30
Clay & Silt Till – v. stiff/hard	174.5	172.0	10.0 (*)	-	-	100
Silt & Sand Till – dense/v. dense	172.0	170.5	11.0 (*)	5,500	3.5	-
Silt & Sand Till – v. dense	170.5	164.5	11.5 (*)	10,000	3.9	-
Clayey Silt Till – Hard	164.5	160.6	11.0 (*)	-	-	300
NBL South Abutment (RC-1 and RC17-04)						
Clayey Silt – firm	176.0	175.0	9.0 (*)	-	-	30
Clayey Silt Till – v. stiff/hard	175.0	172.0	10.0 (*)	-	-	100
Silt & Sand Till – dense/v. dense	172.0	170.5	11.0 (*)	5,500	3.5	-
Silt & Sand Till – v. dense	170.5	168.0	11.5 (*)	10,000	3.9	-
Clayey Silt Till – Hard	168.0	162.7	11.5 (*)	-	-	300
SBL South Abutment (RC17-01 and RC17-06)						
Clayey Silt – firm	177.5	176.0	9.0 (*)	-	-	30
Clayey Silt Till – v. stiff/hard	176.0	173.0	10.0 (*)	-	-	100
Silt & Sand Till – v. dense	173.0	168.5	11.5 (*)	10,000	3.9	-
Clayey Silt Till – Hard	168.5	164.6	11.5 (*)	-	-	300

Note (*): Submerged unit weights

The modulus of subgrade reaction and ultimate lateral resistance should be reduced based on the pile spacing to account for group effect. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 6. Intermediate values may be obtained by linear interpolation.

Table 6 – Subgrade Reaction Reduction Factors for Pile Spacing

Loading 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

6.1.4 H-Pile Installation

Artesian groundwater conditions were encountered in Boreholes RC17-01 and RC17-02 in the piezometers with tips installed in the lower clayey sandy silt till. The water levels were measured 0.6 m and 0.8 m above the existing ground surface or at Elev. 177.8 and Elev. 176.4, respectively. To prevent upward migration of fines along the pile shaft to the surface, piles should be installed through a granular fill pad approximately 500 mm thick consisting of OPSS Granular A or B Type II. The granular pad should be installed as part of the subgrade preparation for the RSS false abutment.

Pile driving must be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance (2 times the design load at ULS) should be specified by the designer. The Hiley formula need not be used until the piles are within 2 m of the design tip elevation. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS103-11 using an ultimate resistance of 'R' kN per pile". 'R' must have a minimum value of twice the design load at ULS, but must not exceed twice the factored ULS resistance at each foundation element.

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.

6.1.5 Pile Tips

To prevent pile damage when setting the piles in the very dense/hard till or if cobbles or boulders are encountered, piles should be equipped with proper tip protection. Care must be used when driving piles to very dense/hard till with cobbles and boulders or to shale bedrock to avoid overdriving and damage to the piles.

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.

6.2 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.

6.3 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 OPSS 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 OPSS 3101.150.

6.4 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 added.

Earth pressure coefficients for backfill to the abutment wall are dependent on properties of the granular fill used as the backfill. Typical values are shown in Table 7 below.

Table 7 – 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

The active and passive earth pressure factors in Table 7 are ultimate values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code (CHBDC).

6.5 Seismic Considerations

Based on the encountered subsurface conditions from the previous investigation, Site Class C should 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 0.110 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 8 may be used:

Table 8 – 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

** After Woods

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

6.6 Approach Embankments and Reinforced Soil System (RSS)

6.6.1 General

The GA drawing indicates that reinforced soil system (RSS) for false abutments and wingwalls will be installed at both structures. It should be noted that no structural loading is applied to the RSS system in the case of false abutment. The RSS walls will be up to 8.5 m high above the existing ground at abutments, and taper in height at wingwall locations.

The RSS walls will be designed to “High Performance” and “High Appearance” at this site. To provide an acceptable performance, the RSS mass should be founded on competent soils or on engineered fill. Uniform and competent subgrade conditions within the entire footprint of the RSS mass will be critical for performance of the RSS walls.

The existing soils at the abutments and approach embankments consist of a surficial layer of very soft to firm clayey silt underlying the topsoil or extending from ground surface to a depth of as much as 1.5 m. The surficial clayey silt is underlain by very stiff clayey silt till. Subgrade preparation for RSS construction will involve removal of topsoil and very soft to firm clayey silt within the RSS footprint and replace with well compacted granular material.

The approach embankments in the order of 7.5 to 8.5 m in height qualify as high fill. To meet MTO's Embankment Settlement Criteria for Design (March 2, 2010) as per PA Schedule 15-2, a waiting period of minimum 2 months should be allowed after backfilling the structure for embankment settlement to take place prior to final paving and approach slab construction.

It is understood that the proposed RSS walls will become partially submerged during high water level periods in the floodplain. The designer of these RSS walls must carefully address the following aspects which include but are not limited to:

- Erosion and scour protection of the RSS walls during and after flood events
- Type of backfill material and control of migration of fines
- Reinforcement strength, facing connection strength and pullout resistance of reinforcement under submerged conditions
- Lateral stability of the RSS walls, including sliding and overturning
- Durability of the reinforcing strips against potential corrosion under submerged conditions

6.6.2 Geotechnical Resistances

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 frost depth in 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 the stiff to very stiff clayey silt till should be designed for a Factored Geotechnical Resistance at ULS of 350 kPa and a Factored Geotechnical Reaction at SLS of 250 kPa. The highest founding elevation for RSS walls at each abutment are summarized in Table 9. If required, higher RSS base elevations may be achieved by placing engineered fill between the RSS base and the highest founding elevation. The resistance values assume that the length of RSS wall reinforcement will extend for a distance equal at least 70% height behind the wall face.

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

The RSS mass must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base on native clayey silt till and engineered fill may be estimated using ultimate friction coefficients of 0.4 and 0.55, respectively.

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

Table 9 – Highest Founding Elevation for RSS Walls

RSS Wall Location	Reference Boreholes	Highest Founding Elevation (m)
NBL North Abutment	RC17-03, S7, S9	174.5
NBL South Abutment	RC17-04, RC-1	175.0
SBL North Abutment	RC17-02, RC17-05	174.5
SBL South Abutment	RC17-01, RC17-06	175.5

6.6.3 Subgrade Preparation

Topsoil and very soft to soft surficial clayey silt, disturbed soils and deleterious materials within the RSS footprint 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 work should be carried out in accordance with OPSS.PROV 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.

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.

6.6.4 Predicted Settlement

The primary consolidation settlements of the foundation soils were estimated to be in the range of 40 to 50 mm under approximately 8.5 m high 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 15 to 25 mm at this site will occur after construction.

6.6.5 Approach Embankment Stability

Limit equilibrium slope stability analysis was performed to assess the stability of the approach embankments and RSS retaining walls using the commercially available program Slope/w, employing the Morgenstern-Price method of analysis. The results of the analysis are shown in Figures E1 through E6 included in Appendix E.

The results of the analysis indicate a Factor of Safety of greater than 1.3 under the short-term conditions and greater than 1.5 under long-term conditions. The approach embankments will be stable at side slopes inclined at 2H:1V or flatter.

6.6.6 Approach Embankment Construction

It is understood that the contractor's intention is to reuse the excavated soils from the site as embankment fill. Embankments constructed with earth fill compacted as per OPSS.PROV 501 will have stable side slopes at inclinations not steeper than 2H:1V. Careful selection and/or treatment of the earth fill prior to reuse will be required.

Slope face treatment/surficial erosion protection should be in general accordance with OPSS.PROV 804. Erosion protection should be provided along any soil surfaces that may be in contact with the creek flow. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

6.7 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 surficial very soft to soft clayey silt within the depth of excavation and any cohesionless soils below the groundwater table may be classed as Type 4 soil.

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

The water level in open boreholes during the current and previous investigations varied with the shallower level noted at Elev. 175.5. The bases of temporary excavations for construction of RSS walls will be located near or below the water levels in the creek. In addition, perched groundwater may be present at shallower levels. Given the consistency and relatively low permeability of the clayey silt till, groundwater control measures such as perimeter ditches and pumping from filtered sumps may be effective to remove any accumulation of water from the excavation base. The possibility exists that additional pumps may be required if localized zones of high volume of perched groundwater are encountered.

The granular engineered fill pad for RSS walls should be constructed in the dry. Clayey silt subgrade should be covered as soon as practical upon exposure and be protected from any disturbances that will likely weaken the material.

6.8 Erosion and Scour Protection

Slope face treatment/surficial erosion protection should be in general accordance with OPSS.PROV 804. Erosion protection should be provided along any soil surface that may be in contact with the creek flow.

Design of the erosion and scour 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 at the abutment locations as per OPSS 511 where creek water is likely to be in contact.

The Meander Belt Width Report, the Technical Design Brief for Fluvial Designs, and the erosion and scour protection measures shown on the structure design drawings have been reviewed from a geotechnical perspective and are generally consistent with the above geotechnical recommendations. For detailed design of the erosion and scour protection, please refer to design report H427-1-ENV-REP-007.

6.9 Corrosion and Sulphate Attack Potential

The results of the analytical tests for soil corrosivity and sulphate content conducted on the samples collected near the water course 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 moderate.
- Appropriate protection measures are recommended if metal structural elements are used.

6.10 Construction Concerns

Potential construction concerns include, but not necessarily limited to:

- Pile installation may encounter cobbles and boulders inherently present in the till deposits, which may result in pile misalignment and/or damages to the pile;
- Pre-augering will be required to install H-piles to bedrock if this foundation option is selected;
- The sequence of pile installation and approach embankment/RSS wall construction should be carefully considered to not induce excessive lateral pile movement.



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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


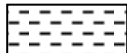



C_{pen} Shear Strength Determination by Pocket Penetrometer

- (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.

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

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

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
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 RC 17-01

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 395.5 E 293 791.2 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.08 - 2017.06.09 CHECKED BY AMP

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						
177.0	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL: (50mm)							20 40 60 80 100						
176.3	Clayey SILT , trace to some sand, trace gravel, trace organics (rootlets) Soft to Very Stiff Brown Moist		1	SS	3									
0.7	Clayey SILT , trace to some sand, trace gravel Very Stiff Brown to Grey Moist (TILL)		2	SS	19		176							
			3	SS	27		175							
			4	SS	30		174							
			5	SS	22									
							173							
172.8	SILT and SAND , trace gravel, occasional cobbles Very Dense Grey Moist (TILL)		6	SS	103/ 0.275		172							
4.2			7	SS	60/ 0.075		171							
			8	SS	100/ 0.125		170							
							169							
168.5	Clayey SILT , sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		9	SS	101/ 0.225		168							5 28 51 16
8.5														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC 17-01

2 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 395.5 E 293 791.2 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.08 - 2017.06.09 CHECKED BY AMP

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				
	Continued From Previous Page						20	40	60	80	100	20	40	60		GR SA SI CL
164.6	Clayey SILT , sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		10	SS	101/ 0.275											
12.4	SHALE moderately weathered to fresh, thinly bedded, grey, weak: (Georgian Bay Formation) Highly broken zone (50mm) at 12.4m, (150mm) at 12.5m and (50mm) at 12.7m Clay seam (75mm) at 12.8m Sub-vertical fracture (50mm) at 13.1m Limestone interbed (50mm) at 13.4m Broken zone (50mm) at 15.1m		1	RUN											FI >10 >10 4 3 3 0 0 0 2 4	RUN #1 TCR=100% SCR=67% RQD=67% RUN #2 TCR=100% SCR=93% RQD=93%
161.5			2	RUN												
15.5	END OF BOREHOLE AT 15.5m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.06.19 -0.8 177.8 2017.06.29 -0.7 177.7 2017.10.24 -0.3 177.3 "-" Above ground surface															

ONTMT4S MTO-19484.GPJ 2017TEMPLATE(MTO).GDT 11/29/17

RECORD OF BOREHOLE No RC 17-02

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 439.7 E 293 783.3 ORIGINATED BY TM
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.30 - 2017.05.31 CHECKED BY AMP

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						
175.8	GROUND SURFACE							20	40	60	80	100		
0.0	TOPSOIL: (50mm) Clayey SILT , trace silt, trace organics, rootlets Very Soft Brown Moist		1	SS	0		175							
175.0														
0.8	Clayey SILT , trace sand, trace gravel Very Stiff Brown Moist (TILL)		2	SS	18		174							
			3	SS	21		173							
			4	SS	27		172							
			5	SS	22		171							
171.2			6	SS	50/ 0.100		170							
4.6	SAND and SILT , trace to some gravel, trace to some clay Very Dense Grey Wet (TILL)													
			7	SS	50/ 0.125		169							
			8	SS	50/ 0.125		168							
			9	SS	50/ 0.125		167							
							166							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC 17-02

2 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 439.7 E 293 783.3 ORIGINATED BY TM
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.05.30 - 2017.05.31 CHECKED BY AMP

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				
	Continued From Previous Page							20 40 60 80 100				
								○ UNCONFINED + FIELD VANE				
								● QUICK TRIAXIAL × LAB VANE				
								WATER CONTENT (%)				
								20 40 60				
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				
								W _P W W _L				

ONTMT4S MTO-19484.GPJ 2017TEMPLATE(MTO).GDT 11/29/17

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

RECORD OF BOREHOLE No RC 17-03

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 434.8 E 293 834.3 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.02 - 2017.06.05 CHECKED BY AMP

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						
175.8	GROUND SURFACE						20	40	60	80	100					
0.0	TOPSOIL: (100mm) Clayey SILT , trace sand, trace gravel, rootlets Firm Brown Moist		1	SS	3											
0.1				2	SS	6										
174.4																
1.4	Clayey SILT , trace to some sand, trace gravel Very Stiff to Hard Brown Moist (TILL)		3	SS	26											
			4	SS	36											
			5	SS	24											
			6	SS	82											
170.6	SAND and SILT , trace to some gravel, trace to some clay, occasional cobbles Very Dense Grey Moist (TILL)		7	SS	101/ 0.275											
5.2																
			8	SS	91											
167.1	Clayey SILT , some sand to sandy, trace to some gravel, occasional cobbles Hard Grey Moist to Wet (TILL)		9	SS	102/ 0.225											
8.7																

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE						SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	<div>GROUND WATER CONDITIONS</div>	DYNAMIC CONE PENETRATION RESISTANCE PLOT							<div>NATURAL MOISTURE CONTENT</div> <div>PLASTIC LIMIT LIQUID LIMIT</div> <div>w_P w_L</div> <div>WATER CONTENT (%)</div>	UNIT WEIGHT <div>γ</div> kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
							<div>SHEAR STRENGTH kPa</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>									
							<div>20 40 60 80 100</div> <div>20 40 60</div>									
	Continued From Previous Page															
164.0 11.8	Clayey SILT, some sand to sandy, trace to some gravel, occasional cobbles Hard Grey Moist to Wet (TILL)		10	SS	102		165									
	Silty CLAY, trace to some sand, trace gravel Hard Grey Moist (TILL)		11	SS	56		164									
							163									
			12	SS	79		162									
							161									
161.1 14.7	SHALE moderately weathered to fresh, thinly bedded, weak with medium strong to strong limestone interbeds, grey: (Georgian Bay Formation) Limestone interbed (50mm) at 15.0m Limestone interbed (175mm) at 16.0m and (100mm) at 16.9m Vertical fracture (50mm) at 16.3m and (200mm) at 16.5m		1	RUN			160									
158.7 17.1	END OF BOREHOLE AT 17.1m. Piezometer installation consists of 50mm (deep) and 25mm (shallow) diameter Schedule 40 PVC pipes with 1.52m slotted screens. DEEP WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.06.28 -0.4 176.2 2017.10.18 0.0 175.8 SHALLOW WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.06.28 0.6 175.2 2017.10.18 1.9 173.9 "- Above ground surface						159									

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RC 17-04

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bldges N 4 849 390.4 E 293 813.4 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone/HQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.06.08 - 2017.06.08 CHECKED BY AMP

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						
176.3	GROUND SURFACE													
0.0	Clayey SILT , some sand, trace gravel, trace organics (rootlets) Firm Brown Moist		1	SS	4		176							
			2	SS	6		175							
174.8	Clayey SILT , with sand, trace gravel Very Stiff Brown to Grey Moist (TILL)		3	SS	28		174							
1.5			4	SS	26		173							
			5	SS	17		172							
172.0	SILT and SAND , trace to some clay, trace to some gravel, occasional cobbles Dense to Very Dense Grey Moist (TILL)		6	SS	40		171							
4.3			7	SS	50/ 0.075		170							
			8	SS	103/ 0.200		169							
167.8	Clayey SILT , some sand to sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		9	SS	101/ 0.125		168							
8.5							167							

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RC 17-05

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 436.0 E 293 758.3 ORIGINATED BY TM
 HWY 427 BOREHOLE TYPE Hollow Stem Augers/Tricone COMPILED BY AN
 DATUM Geodetic DATE 2017.06.01 - 2017.06.01 CHECKED BY AMP

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 w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)				
176.2	GROUND SURFACE																
0.0	TOPSOIL: (100mm)																
0.1	Clayey SILT , trace sand, trace gravel, occasional cobbles Firm to Stiff Brown Moist		1	SS	4		176						○				
			2	SS	10		175						○				
174.8																	
1.4	Clayey SILT , trace to some sand, trace gravel, occasional cobbles Very Stiff Brown Moist (TILL)		3	SS	28		174						○				
			4	SS	23								○				
			5	SS	25		173						○				
							172						○				
			6	SS	37		171						○				
171.0																	
5.2	SAND and SILT , trace to some clay, trace gravel Very Dense Grey Wet (TILL)		7	SS	100/ 0.100		170						○				
169.0																	
7.2	Clayey silt with sand, trace gravel between 7.2m and 8.5m depth (TILL)		8	SS	78		169						○				
							168										
167.7																	
8.5			9	SS	61/ 0.100		167						○				

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RC 17-06

1 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 390.7 E 293 765.8 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.09 - 2017.06.09 CHECKED BY AMP

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					
177.5	GROUND SURFACE												
0.0	TOPSOIL: (100mm)												
0.1	Clayey SILT , trace to some sand, trace gravel, trace rootlets Very Soft Brown Moist		1	SS	1								
176.8													
0.7	Silty CLAY , trace to some sand, trace gravel Stiff Brown Moist (TILL)		2	SS	8								
			3	SS	14								
			4	SS	14								
			5	SS	22								
173.5													
4.0	SAND and SILT , trace to some clay, trace gravel, occasional cobbles Very Dense Grey Moist (TILL)		6	SS	101/ 0.250								
			7	SS	102/ 0.225								
169.9													
7.6	Clayey SILT , some sand to sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		8	SS	100/ 0.225								
			9	SS	45								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

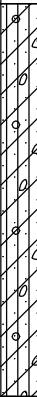
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC 17-06

2 OF 2

METRIC

W.P. _____ LOCATION HWY 427 DB - Rainbow Creek Bridges N 4 849 390.7 E 293 765.8 ORIGINATED BY KK
 HWY 427 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.06.09 - 2017.06.09 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
	Continued From Previous Page							20	40	60	80	100				
	Clayey SILT , some sand to sandy, trace gravel, occasional cobbles Hard Grey Moist (TILL)		10	SS	104/ 0.200		167									
							166									
164.9	Shale fragments		11	SS	101/ 0.250		165									
12.6	END OF BOREHOLE AT 12.6m. BOREHOLE BACKFILLED WITH BENTONITE GROUT TO SURFACE.															

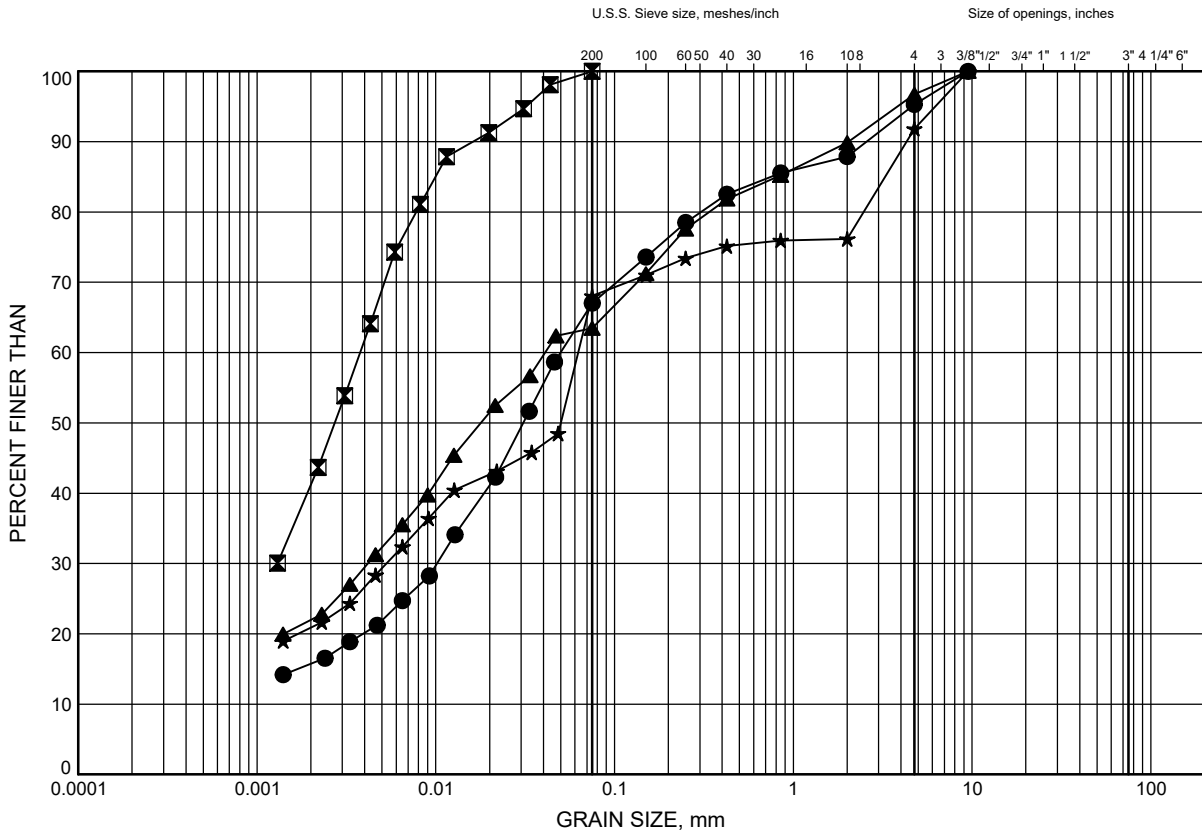
Appendix B
Laboratory Test Results – Current Investigation

HWY 427 DB - Rainbow Creek Bridges

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILT, some clay to clayey (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC 17-01	9.3	167.7
⊠	RC 17-03	12.5	163.3
▲	RC 17-04	3.4	172.9
★	RC 17-05	13.8	162.4

Date September 2017
W.P.



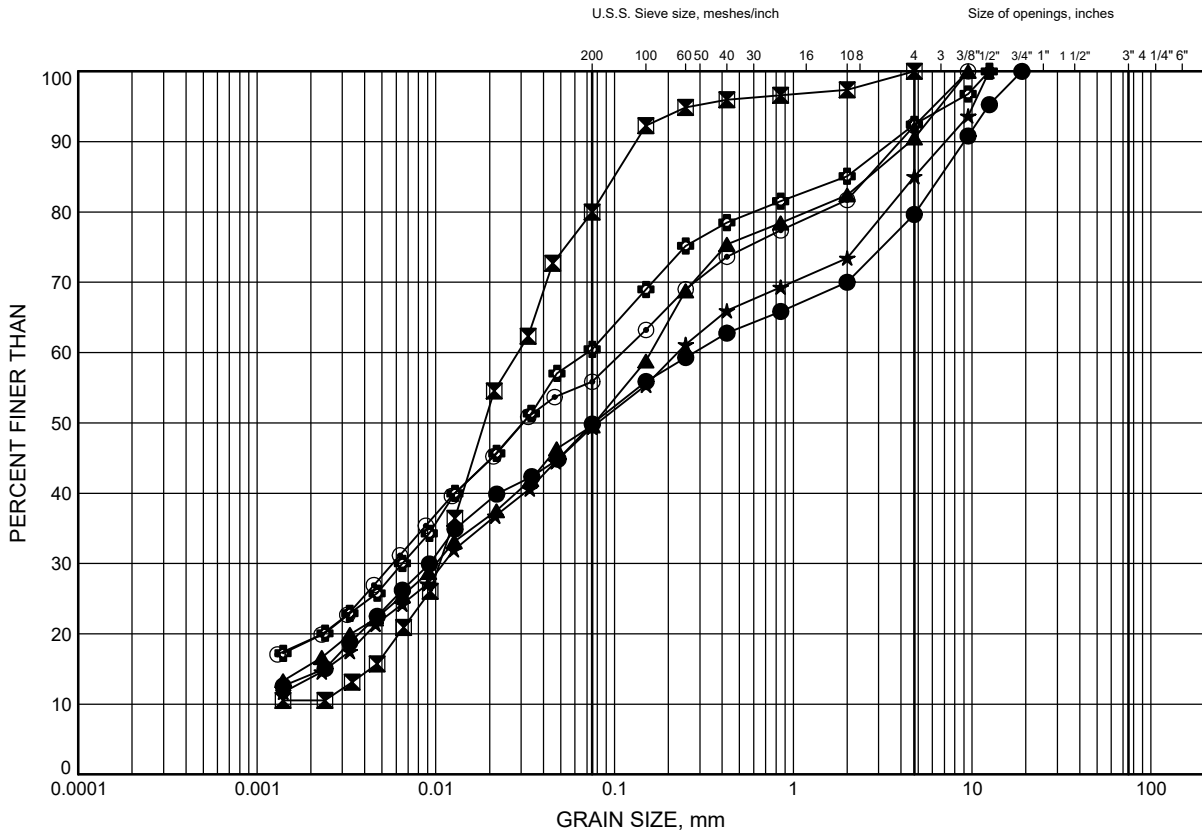
Prep'd AN
Chkd. KS

HWY 427 DB - Rainbow Creek Bridges

GRAIN SIZE DISTRIBUTION

FIGURE B2

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)
●	RC 17-02	4.7	171.1
⊠	RC 17-02	10.8	165.0
▲	RC 17-03	6.3	169.5
★	RC 17-04	6.2	170.1
⊙	RC 17-05	7.9	168.3
⊕	RC 17-06	7.9	169.6

Date September 2017
W.P.

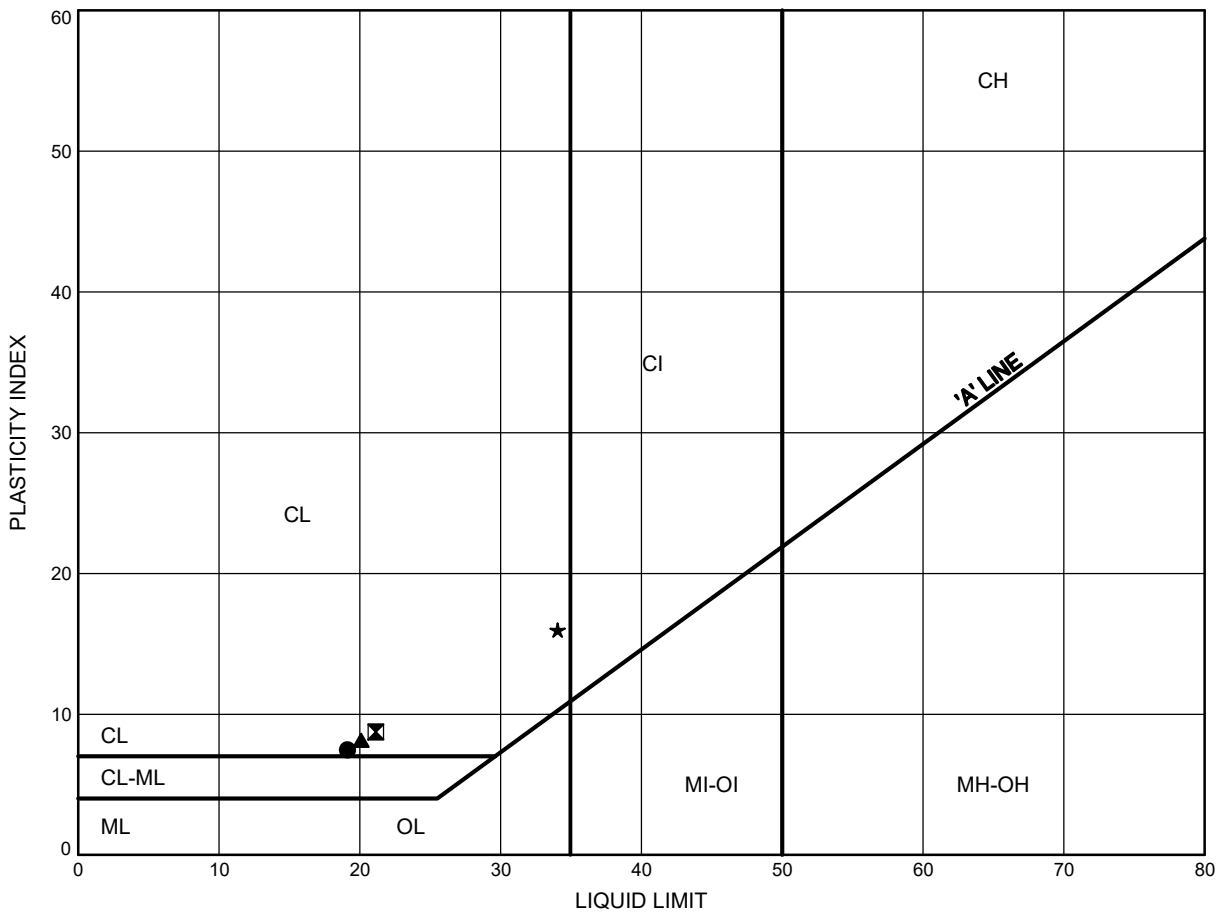


Prep'd AN
Chkd. KS

HWY 427 DB - Rainbow Creek Bridges
ATTERBERG LIMITS TEST RESULTS

FIGURE B3

SILT, some clay to clayey (TILL)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC 17-01	2.6	174.4
⊠	RC 17-02	2.6	173.2
▲	RC 17-04	3.4	172.9
★	RC 17-06	1.1	176.4

Date September 2017
 W.P.



Prep'd AN
 Chkd. KS

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.
CA14375-JUN17
Corrosivity

Sample ID	Unit	RC 17-02 SS8	RC 17-03 SS5	RC 17-05 SS3	RC 17-04 SS4B
Sample Date/Time		30-May-17 17:00	01-Jun-17 17:04	N/A	N/A
Temperature Upon Receipt	°C	3.0	3.0	3.0	3.0
Corrosivity Index	none	8	8	4	8
Soil Redox Potential	mV	227	256	283	242
Sulphide	%	0.07	0.07	< 0.02	0.14
% Moisture (wet wt)		13.1	11.1	11.8	15.5
pH	no unit	9.12	8.72	8.72	8.67
Chloride	µg/g	36.0	13.0	18.0	5.4
Sulphate	µg/g	110	160	120	160
Conductivity	uS/cm	173	103	171	208
Resistivity (calculated)	ohms.cm	5780	9710	5850	4810

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.

Appendix C

Record of Borehole Sheets - Previous Investigations

METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WO No. 05-20012



SHEET

HIGHWAY 427 EXTENSION
RAINBOW CREEK BRIDGES
BOREHOLE LOCATIONS



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE

2 0 2 4 km

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- Standard Penetration Test Value
- Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on May 13, 2009.
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S4	182.5	4849365.1	293793.2
S5	181.6	4849359.1	293821.4
S6	177.6	4849472.0	293764.4
S7	175.8	4849440.3	293806.1
S8	175.8	4849407.4	293777.1
S9	176.0	4849460.9	293829.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Preliminary Design Report.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

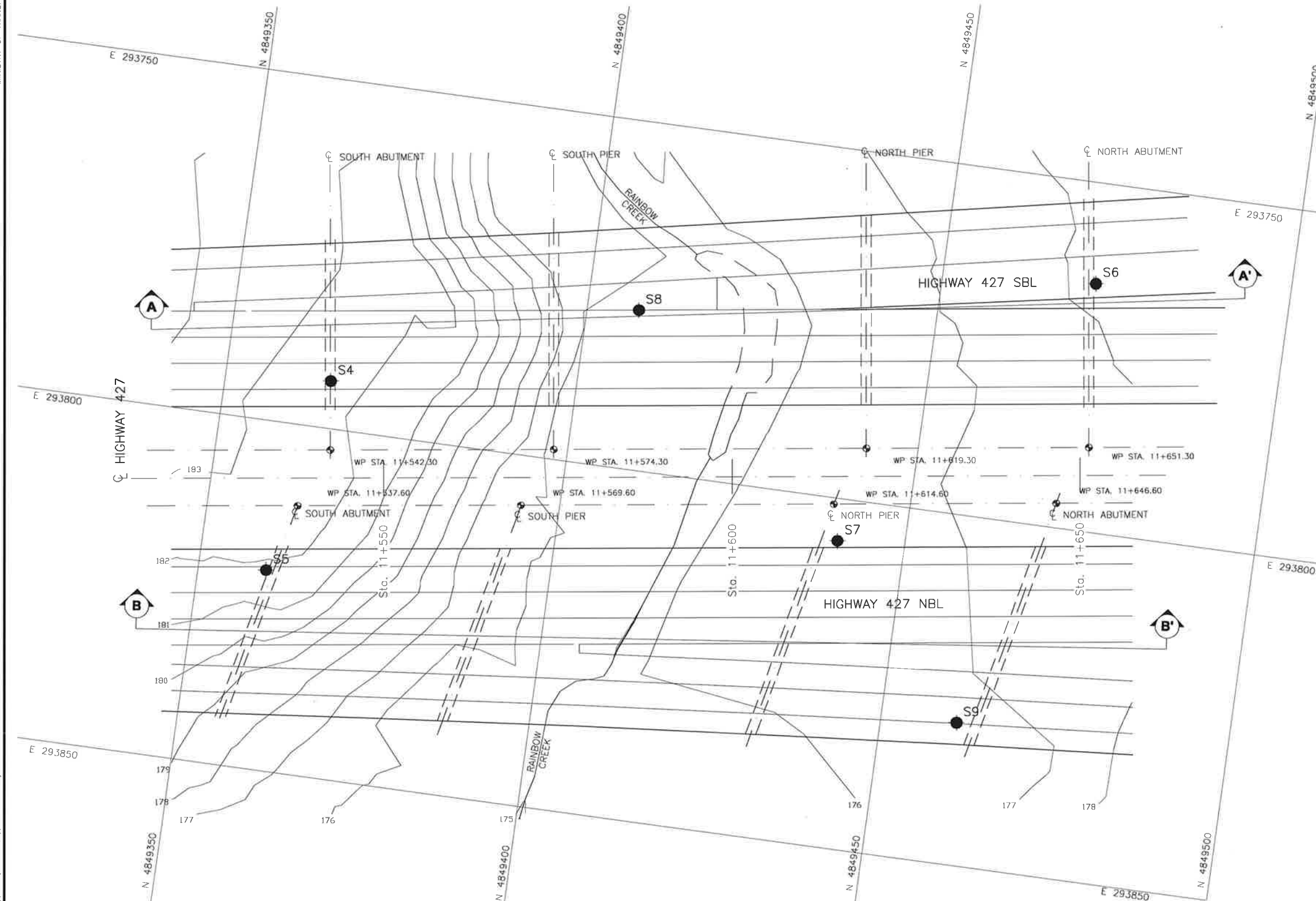
The complete Preliminary Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MRC (Drawing "rainbow_ga.dwg", received May 15, 2009).



PLAN
SCALE
6 0 6 12 m



PROJECT 06-1111-012

RECORD OF BOREHOLE No S4

1 OF 2 **METRIC**

W.O. 05-20012

LOCATION N 4849365.1 E 293793.2

ORIGINATED BY DD

DIST Central HWY 427

BOREHOLE TYPE 200 mm Outside Diameter Hollow Stem Augers

COMPILED BY VA

DATUM Geodetic

DATE February 27, 2009

CHECKED BY SMM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV	DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
182.5	0.0	GROUND SURFACE						20 40 60 80 100	20 40 60 80 100					
		TOPSOIL						○ UNCONFINED + FIELD VANE						
		CLAYEY SILT, some sand, trace to some gravel (TILL), containing rootlets to a depth of 0.6 m and containing oxidation zones to a depth of 5.2 m	1	SS	5		182	● QUICK TRIAXIAL × REMOULDED						
		Firm to hard	2	SS	22		181							
		Brown to grey	3	SS	25		180							
		Moist to wet	4	SS	35		179							
			5	SS	24		178							
			6	SS	21		177							
			7	SS	21		176							
		Auger grinding at a depth of 5.2 m	8	SS	11		175							
			9	SS	31		174							
173.8	8.7	SAND and SILT, some gravel, trace clay, containing cobbles below 11.4 m depth (TILL)	10	SS	37		173							
		Dense to very dense	11	SS	109		172							
		Grey	12	SS	106		171							
		Wet					170							
		Auger grinding at a depth of 11.4 m					169							
169.2	13.3	CLAYEY SILT with sand, some gravel (TILL)	13	SS	113									
		Hard												
		Grey												
		Wet												
168.3	14.2	END OF BOREHOLE												

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

Continued Next Page

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>06-1111-012</u>		RECORD OF BOREHOLE No S4				2 OF 2 METRIC							
W.O. <u>05-20012</u>		LOCATION <u>N 4649365.1 :E 293793.2</u>				ORIGINATED BY <u>DD</u>							
DIST <u>Central</u> HWY <u>427</u>		BOREHOLE TYPE <u>200 mm Outside Diameter Hollow Stem Augers</u>				COMPILED BY <u>VA</u>							
DATUM <u>Geodetic</u>		DATE <u>February 27, 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					
	— CONTINUED FROM PREVIOUS PAGE —												
	NOTES: 1. Water level in open borehole at a depth of 6.0 m below ground surface (Elev. 176.5 m) upon completion of drilling. 2. Borehole backfilled with bentonite.												

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

PROJECT 06-1111-012		RECORD OF BOREHOLE No S5		1 OF 2 METRIC	
W.O. 05-20012	LOCATION N 4849359.7, E 293821.4	ORIGINATED BY DD			
DIST Central HWY 427	BOREHOLE TYPE 200 mm, Outside Diameter Hollow Stem Augers	COMPILED BY VA			
DATUM Geodetic	DATE February 26, 2009	CHECKED BY SMM <i>SM</i>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N° VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× REMOULDED	20						40	60	80
181.8 0.0	GROUND SURFACE																			
0.1	TOPSOIL																			
	CLAYEY SILT, some sand, trace gravel (TILL), containing rootlets and oxidation zones to a depth of 2.1 m Stiff to hard Brown to grey Moist		1	SS	8									○						
			2	SS	23									○						
			3	SS	33									○						
			4	SS	44									○						
			5	SS	63									○						
	Grey below a depth of 3.8 m		6	SS	31									○						
			7	SS	31									○						
			8	SS	37									○						
			9	SS	48									○						
172.9 8.7	Auger grinding below a depth of 8.5m SAND and SILT, some gravel, trace clay, containing cobbles (TILL) Dense to very dense Grey Wet Auger grinding from depth of 9.7 m to 10.7 m		10	SS	39									○						
			11	SS	139									○		14 39 41 6				
	Auger grinding from depth of 11.9 m to 12.5 m		12	SS	00/0.0									○						
	Auger grinding from depth of 13.4 m to 13.7 m		13	SS	02/0.1									○						
167.6 14.0	END OF BOREHOLE																			

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

Continued Next Page

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

PROJECT 06-1111-012		RECORD OF BOREHOLE No S5		2 OF 2 METRIC	
W.O. 05-20012		LOCATION N 4849359.7 :E 293821.4		ORIGINATED BY DD	
DIST Central HWY 427		BOREHOLE TYPE 200 mm Outside Diameter Hollow Stem Augers		COMPILED BY VA	
DATUM Geodetic		DATE February 26, 2009		CHECKED BY SMM <i>SM</i>	

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 —														
	NOTES: 1. A 50 mm diameter monitoring well was installed at a depth of 10.7 m (Elev.170.9 m) Water level measurements Date Depth Elev. On Completion 6.0 m 175.6 m April 24, 2009 4.4 m 177.2 m May 13, 2009 4.4 m 177.2 m May 21, 2009 4.6 m 177.0 m June 15, 2009 4.7 m 176.9 m July 09, 2009 4.9 m 176.7 m													

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

PROJECT 06-1111-012

RECORD OF BOREHOLE No S6

1 OF 1 **METRIC**

W.O. 05-20012

LOCATION N 4849472.0, E 293764.4

ORIGINATED BY PKS

DIST Central HWY 427

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY VA

DATUM Geodetic

DATE March 13, 2009

CHECKED BY SMM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N° VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
177.6 0.0	GROUND SURFACE		1	SS	6		○ UNCONFINED + FIELD VANE		w _p w w _L			GR SA SI CL	
176.9 0.7	CLAYEY SILT, some sand, trace gravel (TILL) Stiff to hard Brown to grey Moist becoming wet below a depth of 1.2 m		2	SS	9		● QUICK TRIAXIAL x REMOULDED		20 40 60 80 100 10 20 30				
			3	SS	44								
			4	SS	65								
	Grey below a depth of 3.0 m		5	SS	35								
			6	SS	63								
			7	SS	47								
171.8 5.8	Augers grinding at a depth of 5.5 m												
	SAND and SILT, some gravel, trace clay, containing cobbles (TILL) Very dense Grey Wet		8	SS	100								
			9	SS	100/0.2								
168.3 9.3	END OF BOREHOLE	10	SS	100/0.1							3 33 66 9		
NOTES: 1. Water level in open borehole at a depth of 3.0 m below ground surface (Elev. 174.7 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

PROJECT <u>06-1111-012</u>		RECORD OF BOREHOLE No S7		1 OF 1 METRIC	
W.O. <u>05-20012</u>	LOCATION <u>N 4849440.3 E 293806.1</u>	ORIGINATED BY <u>PKS</u>			
DIST <u>Central</u> HWY <u>427</u>	BOREHOLE TYPE <u>108 mm Diameter Solid Stem Augers</u>	COMPILED BY <u>VA</u>			
DATUM <u>Geodetic</u>	DATE <u>March 13, 2009</u>	CHECKED BY <u>SMV</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	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								20	40	60						
175.8	GROUND SURFACE															
0.0	CLAYEY SILT with sand, trace gravel Firm Brown Moist to wet		1	SS	4	▽										
174.9			2	SS	15											
0.9	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff to hard Brown to grey below a depth of 1.8 m Wet		3	SS	48											
			4	SS	49											
			5	SS	42											
			6	SS	00/0.2											
			7	SS	84											
170.0	SAND and SILT, trace to some gravel, trace clay (TILL) Very dense Grey Wet		8	SS	00/0.2										6 32 51 11	
5.8			9	SS	00/0.1											
167.1	CLAYEY SILT, trace sand (TILL) Hard Grey Wet		10	SS	00/0.1										0 2 83 15	
8.7																
166.5																
9.3	END OF BOREHOLE															
NOTES: 1. Water level in open borehole at a depth of 0.9 m below ground surface (Elev. 174.9 m) upon completion of drilling. 2. Borehole backfilled with bentonite.																

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

PROJECT 06-1111-012 RECORD OF BOREHOLE No S8 1 OF 1 METRIC

W.O. 05-20012 LOCATION N 4849407.4 E 293777.1 ORIGINATED BY PKS

DIST Central HWY 427 BOREHOLE TYPE 108 mm Diameter Solid Stem Augers COMPILED BY VA

DATUM Geodetic DATE March 12, 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						
175.8 0.0	GROUND SURFACE Silty SAND, trace gravel, trace clay, containing rootlets Loose Brown Moist		1	SS	5										
			2	SS	9		175								
174.3 1.5	CLAYEY SILT with sand, trace gravel (TILL) Hard Grey Wet		3	SS	62		174								
			4	SS	58		173								
			5	SS	122		172								
172.1 3.7	SAND and SILT, some gravel, trace clay, containing cobbles (TILL) Very dense Grey Wet Augers grinding at depths of 3.7 m and 4.4 m		6	SS	00/0.2		171								
			7	SS	00/0.1		170								
169.5 6.3	END OF BOREHOLE NOTES: 1. Water level in open borehole at a depth of 0.9 m below ground surface (Elev.176.7m) upon completion of drilling. 2. Borehole backfilled with bentonite.		8	SS	00/0.1										

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

PROJECT 06-1111-012

RECORD OF BOREHOLE No S9

1 OF 1 **METRIC**

W.O. 05-20012

LOCATION N 4849460.9 : E 293829.6

ORIGINATED BY PKS

DIST Central HWY 427

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

COMPILED BY VA

DATUM Geodetic

DATE March 16, 2009

CHECKED BY SMY

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 × REMOULDED							WATER CONTENT (%)
176.0 0.0	GROUND SURFACE CLAYEY SILT, some sand, trace gravel, containing rootlets Firm Brown Moist		1	SS	4										
175.3 0.7	CLAYEY SILT, trace to some sand, trace gravel (TILL) Very stiff Brown to grey Moist to wet below a depth of 1.5 m Grey below a depth of 2.1 m		2	SS	22		175								
			3	SS	27		174								
			4	SS	22										2 7 56 35
			5	SS	23		173								
			6	SS	22		172								
171.4 4.6	SAND and SILT, trace to some gravel, trace clay, containing cobbles (TILL) Very dense Grey Wet Augers grinding at depths of 5.8 m and 8.8 m		7	SS	00/0.1									7 40 44 9	
			8	SS	00/0.1	170									
168.2 7.9	END OF BOREHOLE NOTES: 1. A 50 mm diameter monitoring well was installed at a depth of 7.6 m (Elev.168.4 m) Water level measurements Date Depth Elev. On Completion 1.2 m 174.8 m April 24, 2009 3.6 m 172.4 m May 13, 2009 1.2 m 174.8 m May 21, 2009 0.9 m 175.1 m June 15, 2009 0.5 m 175.4 m July 09, 2009 0.5 m 175.5 m		9	SS	00/0.2	169									

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

RECORD OF BOREHOLE No RC-1

1 of 1

METRIC

G.W.P. _____ LOCATION _____ Coords: 4 849 387.2 N; 293 839.4 E ORIGINATED BY F.P.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE November 06, 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					
175.7	Ground Surface												
0.0	CLAYEY SILT, some sand, containing rootlets		1	SS	8								
175.1	Firm					175							
0.6	Brown and grey Moist												
	SILTY CLAY, trace sand, trace gravel		2	SS	19								1 8 51 40
	Very stiff Brown Moist		3	SS	19	174							
173.5	(TILL)												
2.2	SANDY SILT to SILTY SAND, some clay, trace to some gravel, containing clayey silt seams		4	SS	34	173							
	Dense to very dense Grey Moist		5	SS	50/8cm								
	(TILL)		6	SS	54	172							9 38 41 12
			7	SS	83	171							First groundwater strike at 4.6m
	containing cobbles and/or boulder below a depth of 5.3m		8	SS	50/15cm	170							
			9	SS	50/10cm	169							18 33 38 11
						168							
						167							
166.1	End of borehole		11	SS	105								
9.6	Water level noted during drilling												
	Notes: 1. Groundwater was not encountered inside the borehole upon completion of drilling. 2. No cave-in was noted in the borehole upon extraction of hollow stem augers. 3. The borehole was backfilled with betonite grout.												

RECORD OF BOREHOLE No RC-2 1 of 1 METRIC

G.W.P. _____ LOCATION _____ Coords: 4 849 442.0 N; 293 736.3 E ORIGINATED BY D.W.
 DIST Central HWY 427 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY N.L.
 DATUM Geodetic DATE October 15, 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							
								20 40 60 80 100							
								○ UNCONFINED + FIELD VANE							
								● QUICK TRIAXIAL × LAB VANE							
177.3	Ground Surface							20 40 60 80 100							
177.1	TOPSOIL		1	SS	6		177								
0.2	CLAYEY SILT, some sand, trace organics, containing rootlets		2	SS	8		176								
175.8	Firm Brown Moist														
1.5	CLAYEY SILT, some sand, trace gravel, containing sand seams		3	SS	22		175								
	Very stiff Grey Wet (TILL)		4	SS	24										2 21 51 26
174.4	SAND, some silt, trace clay		5	SS	21		174								0 81 13 6
173.6	Compact Grey Moist														First groundwater strike at 3.2m
3.7	SANDY SILT, some gravel, some clay containing clayey silt seams		6	SS	34		173								12 31 41 16
	Dense to very dense Grey Moist (TILL)		7	SS	75/8cm		172								Auger grinding between depths of 4.4m and 6.1m Sampler bouncing
	containing cobbles and/or boulder between depths of 4.5m and 6.1m		8	SS	75/15cm		171								Sampler bouncing
			9	SS	115/28cm		170								18 31 38 13
			10	SS	111		168								
167.7	End of borehole														
9.6	Notes: 1. Groundwater measured at a depth 3.4m below ground surface (Elev. 173.9m) upon completion of drilling. 2. The borehole caved in to a depth of 3.5m below ground surface (Elev. 173.8m) upon extraction of hollow stem augers.														

Appendix D
Borehole Locations and Soil Strata Drawings

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



THURBER ENGINEERING LTD.



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
RC 17-01	177.0	4 849 395.5	293 791.2
RC 17-02	175.8	4 849 439.7	293 783.3
RC 17-03	175.8	4 849 434.8	293 834.3
RC 17-04	176.3	4 849 390.4	293 813.4
RC 17-05	176.2	4 849 436.0	293 758.3
RC 17-06	177.5	4 849 390.7	293 765.8
RC-1	175.7	4 849 387.2	293 839.4
S4	182.5	4 849 365.1	293 793.2
S5	181.6	4 849 359.7	293 821.4
S6	177.6	4 849 472.0	293 764.4
S7	175.8	4 849 440.3	293 806.1
S8	175.8	4 849 407.5	293 777.2
S9	176.0	4 849 460.9	293 829.6

-NOTES-

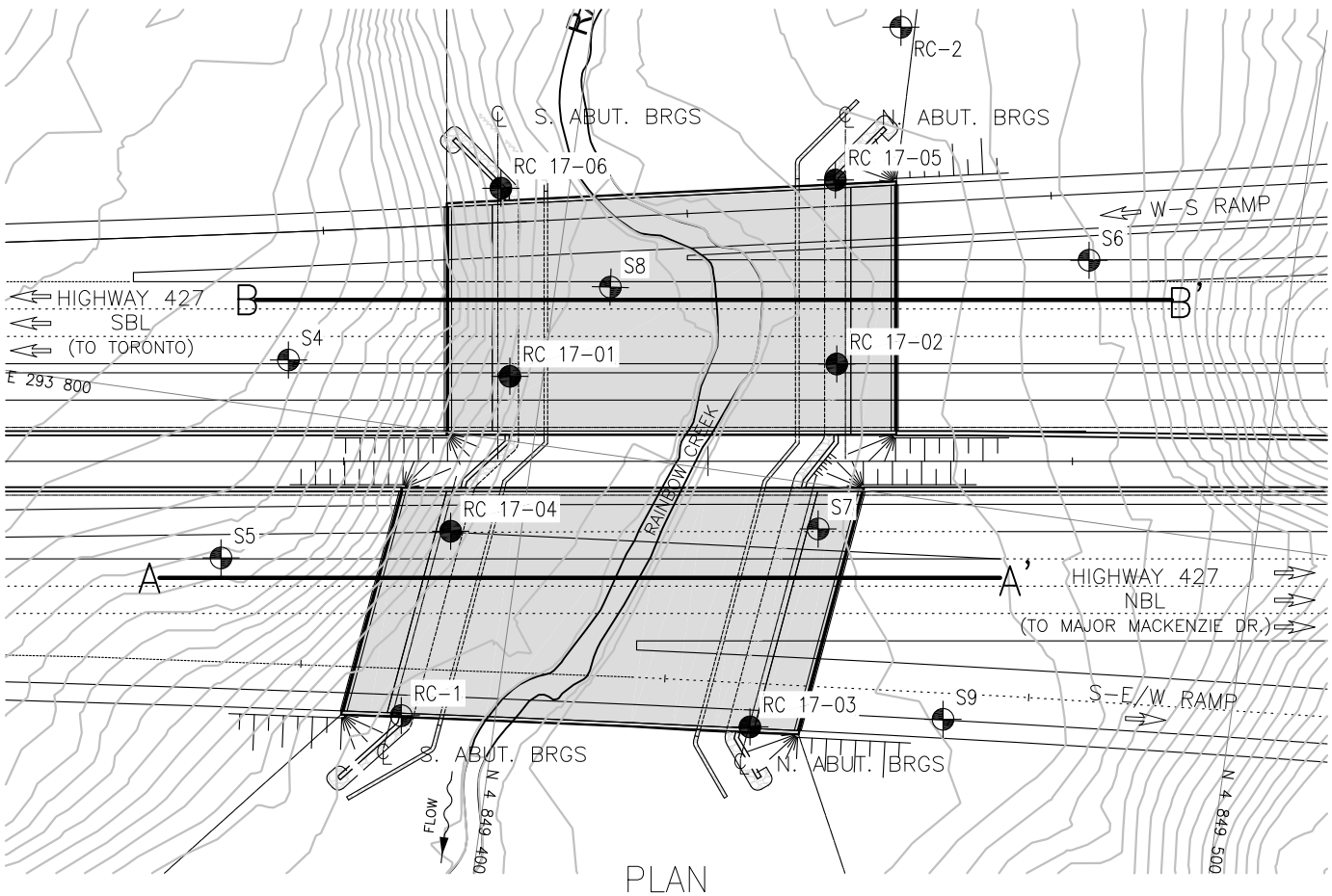
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRIS No.

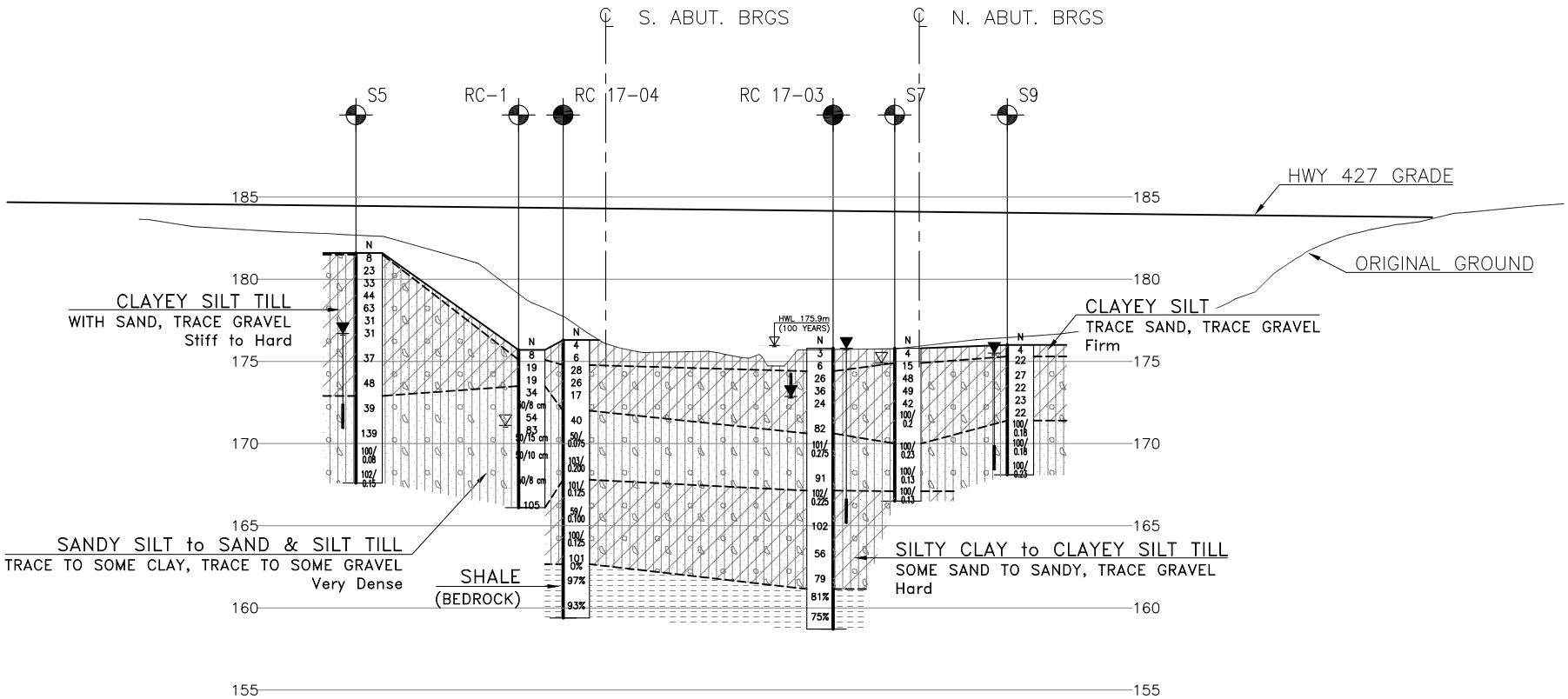
TITLE
HWY 427 EXPANSION
HWY 427 NBL RAINBOW CREEK OVERPASS

BOREHOLE LOCATIONS AND SOIL STRATA

PROJECT ID.	STAGE IDENTIFIER	DESIGN PACKAGE NUMBER	DISCIPLINE	STRUCTURE NUMBER	DOCUMENT TYPE	DRAWING NUMBER	REVISION NUMBER
H427-D	H	1A	STR	B11A	DWG	601	A

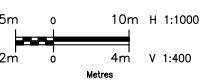


PLAN



PROFILE ALONG A-A'

SCALE :



DESIGNED	K. SHI	KS	19/05/15
DRAWN	A. NOOR	AN	19/05/15
CHECKED	K. SHI	KS	19/05/15
APPROVED	J. LEE	JL	19/05/15
LEAD ENGINEER	P. BAMFORTH	PB	19/05/15
PROJ. MGR			
NAME (PRINT)		INIT.	DATE



FILENAME: H:\Drafting\19000\19484\1ED19484-PLPR-HWY 427 OverRainbowCreek.dwg
PLOT DATE: 5/16/2019 11:16 AM

NO.	DATE	REVISIONS	BY	CHK	LEAD ENG.	PROJ. MGR.
A	19/05/15	100% SUBMISSION TO CA	AN	KS	JL	PB

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
RC 17-01	177.0	4 849 395.5	293 791.2
RC 17-02	175.8	4 849 439.7	293 783.3
RC 17-03	175.8	4 849 434.8	293 834.3
RC 17-04	176.3	4 849 390.4	293 813.4
RC 17-05	176.2	4 849 436.0	293 758.3
RC 17-06	177.5	4 849 390.7	293 765.8
RC-1	175.7	4 849 387.2	293 839.4
S4	182.5	4 849 365.1	293 793.2
S5	181.6	4 849 359.7	293 821.4
S6	177.6	4 849 472.0	293 764.4
S7	175.8	4 849 440.3	293 806.1
S8	175.8	4 849 407.5	293 777.2
S9	176.0	4 849 460.9	293 829.6

-NOTES-

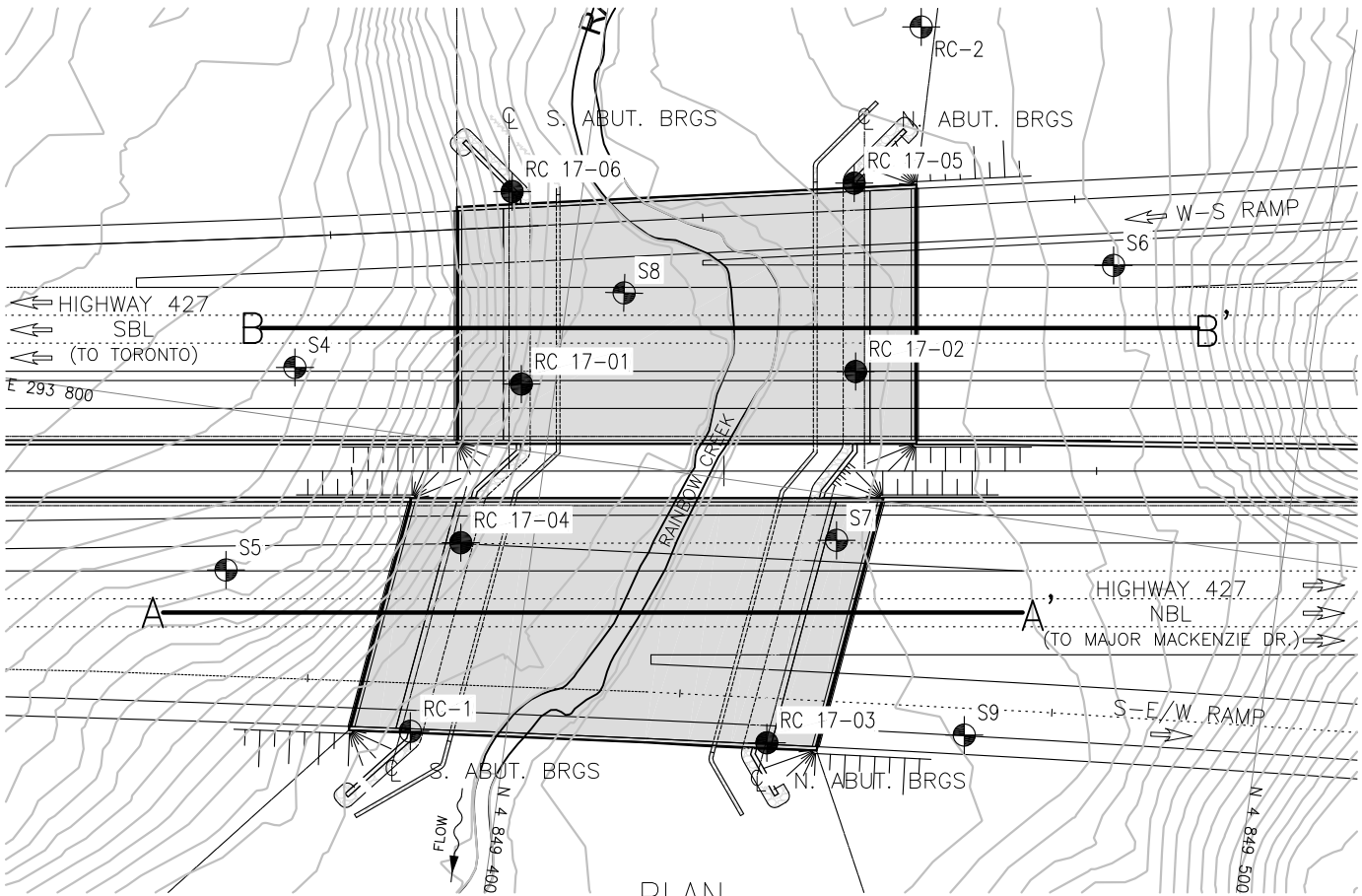
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No.

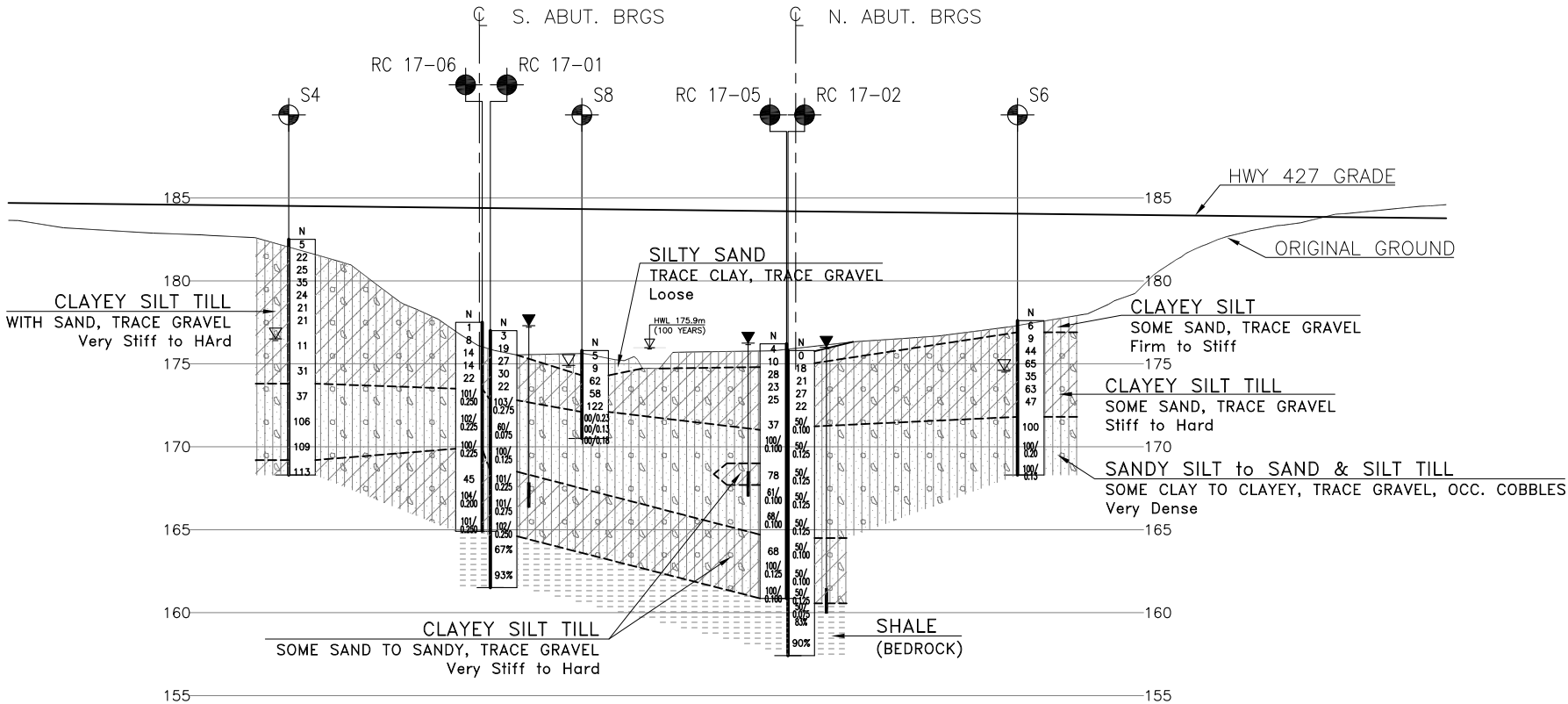
HWY 427 EXPANSION
HWY 427 SBL RAINBOW CREEK OVERPASS

BOREHOLE LOCATIONS AND SOIL STRATA

PROJECT ID.	STAGE IDENTIFIER	DESIGN PACKAGE NUMBER	DISCIPLINE	STRUCTURE NUMBER	DOCUMENT TYPE	DRAWING NUMBER	REVISION NUMBER
H427-D	H	1A	STR	B11B	DWG	701	A

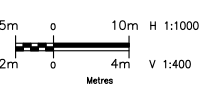


PLAN



PROFILE ALONG B-B'

SCALE :



DESIGNED	K. SHI	KS	19/05/15
DRAWN	A. NOOR	AN	19/05/15
CHECKED	K. SHI	KS	19/05/15
APPROVED LEAD ENGINEER	J. LEE	JL	19/05/15
APPROVED PROJ. MANAGER	P. BAMFORTH	PB	19/05/15
NAME (PRINT)		INIT.	DATE



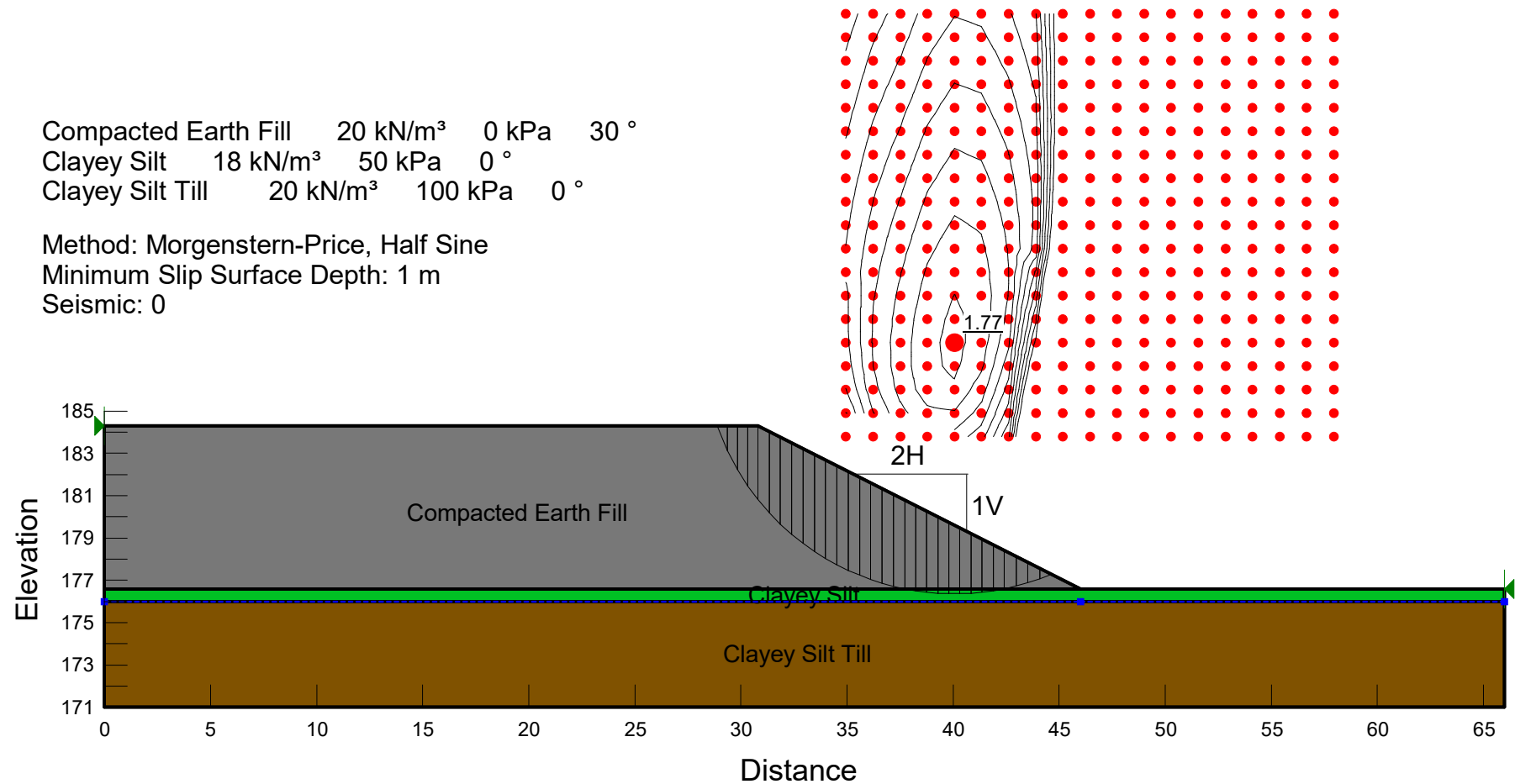
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PLOT DATE: 5/16/2019 11:17 AM

NO.	DATE	REVISIONS	BY	CHK	LEAD ENG.	PROJ. MGR.
A	19/05/15	100% SUBMISSION TO CA	AN	KS	JL	PB

Appendix E
Stability Analysis Output for Approach Embankments

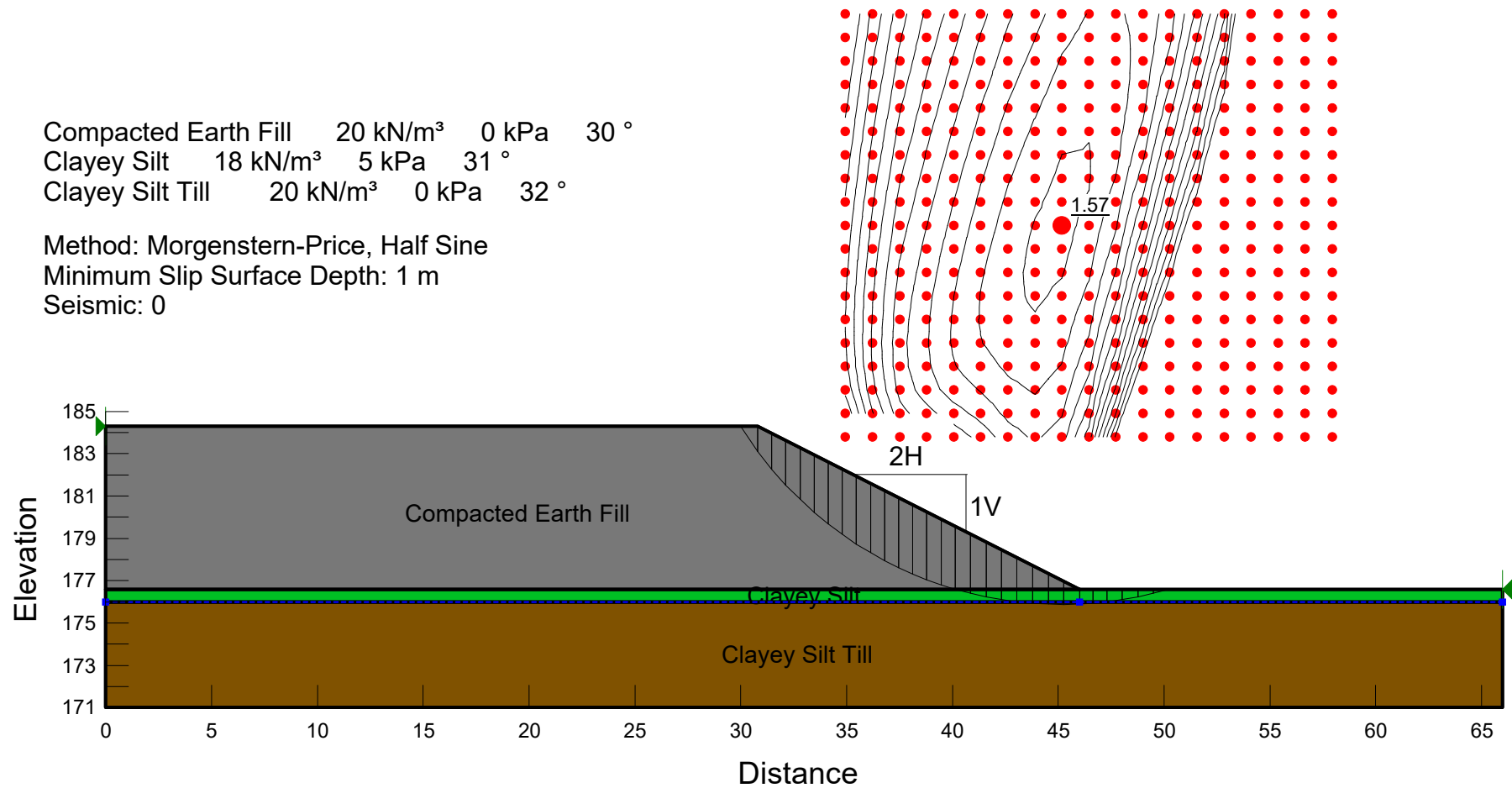
CRITICAL APPROACH EMBANKMENT SECTION SHORT-TERM CONDITION

FIGURE E1



CRITICAL APPROACH EMBANKMENT SECTION LONG-TERM CONDITION

FIGURE E2



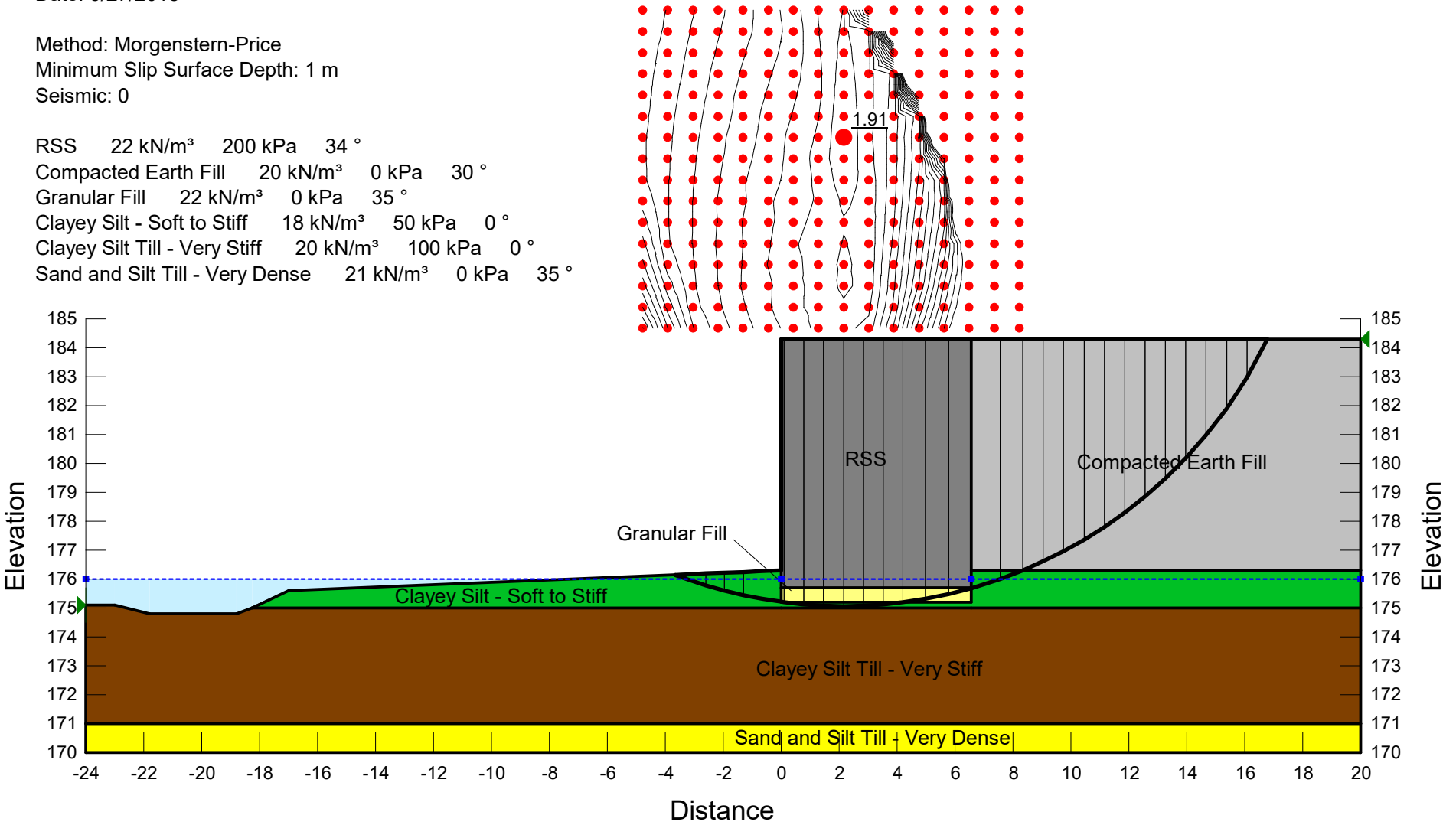
**CRITICAL RSS LONGITUDINAL SECTION
SHORT-TERM CONDITION**

FIGURE E3

File Name: Rainbow Creek North RSS Wall Longitudinal Section (Short -Term).gsz
Last Edited By: Geoff Lay
Date: 6/27/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

RSS	22 kN/m ³	200 kPa	34 °
Compacted Earth Fill	20 kN/m ³	0 kPa	30 °
Granular Fill	22 kN/m ³	0 kPa	35 °
Clayey Silt - Soft to Stiff	18 kN/m ³	50 kPa	0 °
Clayey Silt Till - Very Stiff	20 kN/m ³	100 kPa	0 °
Sand and Silt Till - Very Dense	21 kN/m ³	0 kPa	35 °



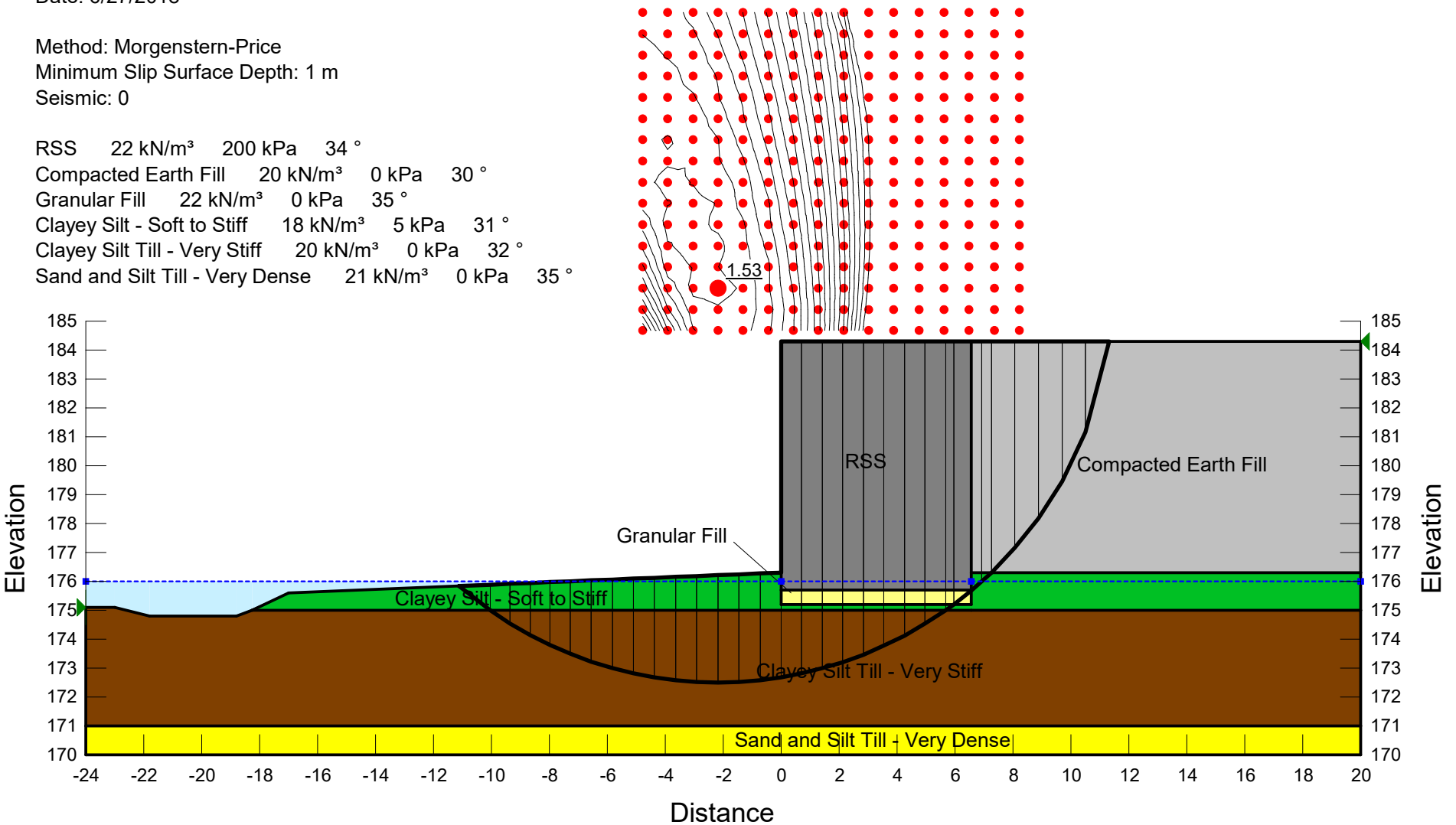
**CRITICAL RSS LONGITUDINAL SECTION
LONG-TERM CONDITION**

FIGURE E4

File Name: Rainbow Creek North RSS Wall Longitudinal Section (Long -Term).gsz
Last Edited By: Geoff Lay
Date: 6/27/2018

Method: Morgenstern-Price
Minimum Slip Surface Depth: 1 m
Seismic: 0

RSS	22 kN/m ³	200 kPa	34 °
Compacted Earth Fill	20 kN/m ³	0 kPa	30 °
Granular Fill	22 kN/m ³	0 kPa	35 °
Clayey Silt - Soft to Stiff	18 kN/m ³	5 kPa	31 °
Clayey Silt Till - Very Stiff	20 kN/m ³	0 kPa	32 °
Sand and Silt Till - Very Dense	21 kN/m ³	0 kPa	35 °



CRITICAL RSS TRANSVERSE SECTION SHORT-TERM CONDITION

FIGURE E5

File Name: Rainbow Creek North RSS Wing Wall Transverse Section (Short -Term).gsz

Last Edited By: Geoff Lay

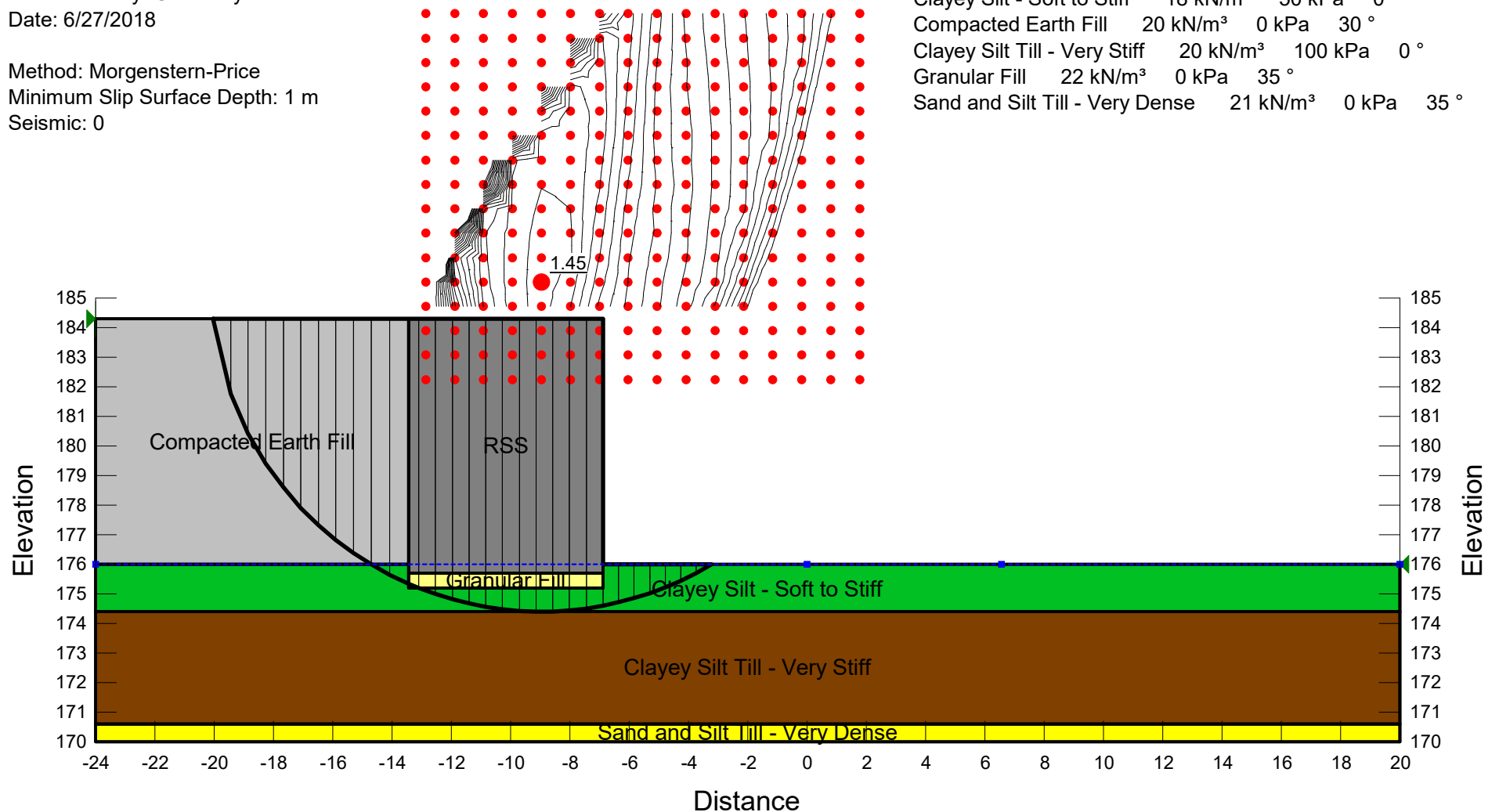
Date: 6/27/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

RSS	22 kN/m ³	200 kPa	34 °
Clayey Silt - Soft to Stiff	18 kN/m ³	50 kPa	0 °
Compacted Earth Fill	20 kN/m ³	0 kPa	30 °
Clayey Silt Till - Very Stiff	20 kN/m ³	100 kPa	0 °
Granular Fill	22 kN/m ³	0 kPa	35 °
Sand and Silt Till - Very Dense	21 kN/m ³	0 kPa	35 °



CRITICAL RSS TRANSVERSE SECTION LONG-TERM CONDITION

FIGURE E6

File Name: Rainbow Creek North RSS Wing Wall Transverse Section (Long -Term).gsz

Last Edited By: Geoff Lay

Date: 6/27/2018

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Seismic: 0

RSS	22 kN/m ³	200 kPa	34 °
Clayey Silt - Soft to Stiff	18 kN/m ³	5 kPa	31 °
Compacted Earth Fill	20 kN/m ³	0 kPa	30 °
Clayey Silt Till - Very Stiff	20 kN/m ³	0 kPa	32 °
Granular Fill	22 kN/m ³	0 kPa	35 °
Sand and Silt Till - Very Dense	21 kN/m ³	0 kPa	35 °

