PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 401 STRUCTURE REPLACEMENT
CPR OVERPASS
HALTON REGION, ONTARIO
G.W.P. 2188-10-00, SITE No. 10-20/1&2

GEOCRES Number: 40P8-228

Report to

AECOM

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

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation carried out at the location of the proposed replacement of the existing Highway 401 Overpass Bridge at Canadian Pacific Railway (CPR) crossing. This investigation was carried out in support of the preliminary design, environmental assessment and planning for the bridge rehabilitation. These works are part of the project involving preliminary design for Highway 401 Structure Rehabilitation from Trafalgar Road westerly to Halton Region boundary in Halton Region.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location and soil strata drawings, records of boreholes, stratigraphic profile and cross sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained from the present investigation and selected data from previous investigation.

Thurber was retained by AECOM to carry out the foundation investigation at this site on behalf of the Ministry of Transportation Ontario (MTO) under Consultant Assignment No. 2012-E-0016.

2 SITE DESCRIPTION

The site is located approximately midway between 1st line and 2nd line/Twiss Road along Highway 401 in the Regional Municipality of Halton, Ontario. The terrain in the general area is relatively flat and well forested to the north and south. Two large water ponds each measuring approximately 500 m by 150 m in plan exist within about 300 m south of the existing bridge.

The existing overpass bridge carries Highway 401 eastbound (EB) and westbound (WB) traffic over the CPR railway tracks on a single span structure with a span of 18 m and an approximately 25.7 degree skew angle.

The site lies in the physiographic region known as Flamborough Plain, which is bounded by the Galt Moraine on the northwest and by the silts and sands of glacial Lake Warren on the south. The

Plain slopes gently to the south towards Lake Ontario. The surface topography in the area is typically characterized by glacially derived drumlins with overburden soil consisting of glacial till and sand and gravel. The Silurian bedrock underlying the area belongs to the Gasport Member, characterized by thick-bedded, blue-grey, crinoidal limestone to dolostone, of the Lockport Formation.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at this site consisted of four (4) sampled boreholes advanced from the existing pavement grade behind abutments and three (3) sampled boreholes advanced from the highway road shoulder and the ground surface beyond the existing embankment footprint. The field work was carried out from June 2 to 10 and July 17 to 20, 2014. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawings attached in Appendix D. Historical borehole information from the original investigation is attached in Appendix C.

For the present investigation, the planned borehole locations were staked and/or marked in the field by Thurber. Utility clearance was obtained at all borehole locations prior to drilling. Borehole location data including northing, easting and surface elevation was derived from GA drawings provided by AECOM to Thurber.

Walker Drilling Ltd. of Barrie, Ontario supplied and operated a truck-mounted D-90 drill rig and continuous flight hollow stem augers to advance the boreholes through embankment fill and native soils. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with the Standard Penetration Testing (SPT).

Upon auger refusal on bedrock, NQ-sized coring equipment was used to obtain a minimum 3 m of rock core in the boreholes drilled near the existing abutments. All rock cores were logged, and properties including Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and Fracture Indices (FI) were determined where applicable.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Groundwater levels in the open boreholes were measured upon completion of drilling. Standpipe piezometers were installed in Boreholes 14-10 and 14-11 to permit monitoring of the groundwater levels. The standpipe piezometer typically consists of 19 mm diameter Schedule 40 PVC pipes with 1.5 m long slotted screen positioned in the soil strata where groundwater fluctuations are to be monitored. The sand screen surrounded the pipe and extended at least 0.3 m above the slotted screen. Bentonite holeplug seals were placed above the sand screen in each installation to seal the annular space. Following the final water level reading, the piezometers were decommissioned in general accordance with MOE Regulation 903.

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

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets attached in Appendix A. Selected soil samples were subjected to gradation analysis. The results of this testing program are presented on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

Selected rock cores were subjected to Point Load Test (PLT). Unconfined compressive strengths (UCS) of the rock cores correlated from the PLT results are shown on the Record of Borehole sheets in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil and rock stratigraphy are presented in these sheets and on the Borehole Locations and Soil Strata drawings in Appendix D. A general description of the stratigraphy based on the current and historical boreholes is given in the following paragraphs. The factual information established at the borehole locations governs any interpretation of site conditions.

In general, the subsurface conditions below the existing embankment fill consist of a relatively thin layer of native silty sand which overlies a thick sand deposit directly above the bedrock.

5.1 Asphalt Pavement

Boreholes RC14-01 to RC14-04 were advanced from the top of pavement level. Thickness of the asphalt encountered in the boreholes varied from 75 to 88 mm.

5.2 Concrete

Concrete was encountered below the asphalt pavement in Boreholes RC14-01 to RC14-04. The concrete was about 0.5 m thick.

5.3 Fill

Existing embankment fill encountered beneath the concrete was characterized as sand and gravel with varying gradation. Thickness of the sand and gravel fill encountered in the boreholes ranged from 1.8 to 8.1 m with the base of the sand and gravel fill at elevations varying from 294.5 to 301.2 m. Silty sand fill was encountered only in Borehole 14-09. Thickness of the silty sand fill was 7.0 m with the base of the layer at elevation 294.2 m.

Standard Penetration Tests (SPT) conducted within the existing fill gave ‘N’ values ranging from 17 to 59 blows per 0.3 m penetration, indicating compact to very dense relative densities. The measured natural moisture contents of the fill samples ranged from about 4 to 13%.

Results of grain size analyses conducted on selected fill samples are presented in Figures B1a and B1b, and are summarized as follows:

	Sand and Gravel Fill	Silty Sand Fill
Gravel	25 to 52%	2 to 13%
Sand	31 to 58%	59 to 63%
Silt & Clay	11 to 18%	-
Silt	-	17 to 26%
Clay	-	7 to 13%

5.4 Topsoil

Topsoil was encountered in Boreholes 14-10 and 14-11 drilled from the existing ground surface. Thickness of the topsoil encountered was about 120 mm.

5.5 Silty Sand

A thin layer of native silty sand was encountered below the embankment fill in Boreholes RC14-01 to RC14-04 and below the topsoil in Boreholes 14-10 and 14-11. The silty sand contains some clay. Thickness of the silty sand layer ranged from 1.3 to 3.0 m with the base of the layer at elevations varying from 292.4 to 295.6 m.

Standard Penetration Tests (SPT) conducted within the silty sand produced ‘N’ values ranging from 9 to 27 blows per 0.3 m penetration, indicating a loose to compact relative density. The measured natural moisture contents of the samples ranged from 4 to 17%.

Results of grain size analyses conducted on selected silty sand samples are presented in Figure B2, and are summarized as follows:

Gravel	0 to 4%
Sand	46 to 69%
Silt	18 to 40%
Clay	10 to 14%

5.6 Sand

A layer of gravelly sand to sand was encountered underlying the silty sand layer except in Borehole 14-09 where sand was encountered beneath the fill. Borehole 14-09 was terminated within the sand layer. Thickness of the sand layer ranged from 2.3 to 11.6 m with the base of the layer at elevations varying from 283.3 to 290.1 m. The sand layer contains cobbles in Boreholes RC14-01and RC14-03 near the bedrock surface.

Standard Penetration Tests (SPT) conducted within the sand deposit produced ‘N’ values ranging from 10 to 89 blows per 0.3 m penetration, indicating compact to very dense relative densities. Two ‘N’ values for SPT conducted near bedrock surface recorded 50 blows for zero to 0.15 m penetration, which is assumed to reflect the presence of cobbles. The measured natural moisture contents of the sand samples ranged from about 2 to 26%.

Results of grain size analyses conducted on selected sand samples are presented in Figures B3a and B3b, and are summarized as follows:

	Sand	Gravelly Sand
Gravel	0 to 15%	24 to 34%
Sand	74 to 89%	52 to 66%
Silt & Clay	7 to 11%	10 to 16%

5.7 Sandy Silt

A layer of sandy silt was encountered below the gravel sand to sand in Boreholes 14-10 and 14-11. The sandy silt contains trace clay. Both boreholes were terminated in the sandy silt layer upon refusal at elevations 285.3 m and 287.7 m.

Standard Penetration Tests (SPT) conducted within the sandy silt produced ‘N’ values ranging from 7 to 15 blows per 0.3 m penetration, indicating a loose to compact relative density. SPT ‘N’ values of 72 blows per 0.3 m penetration and 100 blows for 0.05 m penetration were recorded upon refusal on probable bedrock. The measured natural moisture contents of the samples ranged from 4 to 23%.

Results of grain size analyses conducted on selected silty sand samples are presented in Figure B4, and are summarized as follows:

Gravel	0%
Sand	29 to 32%
Silt	63 to 65%
Clay	5 to 6%

5.8 Bedrock

Bedrock was encountered in Boreholes RC14-01 to RC14-04 below the sand layer and proven by a minimum 3 m of coring. The bedrock was generally described as slightly weathered to fresh, fine to medium grained, porous, and brown to grey/beige coloured dolostone.

Total Core Recovery (TCR) of the bedrock was generally between 88 and 100%. Rock Quality Designation (RQD) values ranged from 48 to 97% indicating fair to excellent rock quality. The RQD values generally increase with depth below the bedrock surface except in Borehole RC14-02 where an RQD value of 23% was recorded in Run 2. Fracture Index (FI) of the rock cores typically ranged from 0 to 5 except in Borehole RC14-02 where higher FI values greater than 5 to 10 were recorded which is consistent with the low RQD values in the same borehole. The following table summarizes the depth to bedrock and the bedrock surface elevations encountered in the boreholes.

Foundation Element	Borehole	Depth to Bedrock below Top of Pavement (m)	Bedrock Elevation (m)
West Abutment	RC14-01	19.8	283.3
	RC14-03	19.2	284.0
East Abutment	RC14-02	15.2	288.0
	RC14-04	15.2	288.0

The unconfined compressive strengths (UCS) of the intact rock cores, estimated from the results of point load tests (PLT) conducted on the rock core samples, range between 34 and 105 MPa, indicating medium strong to very strong intact rock. The UCS values are included on the Record of Borehole sheets in Appendix A.

5.9 Groundwater Conditions

Groundwater conditions were observed in the open boreholes upon completion of drilling. The measured groundwater levels in the open boreholes are presented in the table below.

Borehole	**Date**	**Conditions**	**Groundwater Level**	
			Depth (m)	**Elevation (m)**
RC14-01	June 6, 2014	Open Borehole	8.8	294.3
RC14-02	June 4, 2014		11.3	291.9
RC14-03	June 10, 2014		10.4	292.8
RC14-04	June 9, 2014		10.4	292.9
14-10	July 25, 2014	Piezometer	3.0	291.7
	July 28, 2014		3.4	291.3
	Aug. 11, 2014		3.1	291.6
14-11	July 25, 2014	Piezometer	3.1	291.9
	July 28, 2014		3.5	291.5
	Aug. 11, 2014		3.0	292.0

It should be noted that all groundwater observations at this site are short term. The groundwater levels are expected to fluctuate seasonally and after severe weather events.

6 MISCELLANEOUS

The drilling and sampling equipment was supplied and operated by Walker Drilling Ltd. of Barrie, Ontario. A truck-mounted D-90 drill rig was used for the duration of the investigation.

Traffic protection during the drilling operation was provided by Direct Traffic Management Inc. of Hamilton, Ontario.

The field work was supervised on a full time basis by Mr. George Azzopardi of Thurber Engineering Ltd. Overall supervision of the field program was conducted by Mr. Weiss Mehdawi, P.Eng.

The report was prepared by Mr. Keli Shi, P. Eng., and reviewed by Mr. Alastair E. Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

K. L. SHI
100141639
Aug.14/2014

Keli Shi, P.Eng.
Geotechnical Engineer

A. E. GORMAN
Aug 14/14

Alastair E. Gorman, P.Eng.
Associate, Senior Foundations Engineer

P. K. CHATTERJI
Aug 14/14

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

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides an interpretation of the geotechnical data in the factual report and presents preliminary foundation design recommendations to assist the design team in the selection and design of a suitable foundation system for the Highway 401 CPR Overpass Bridge.

Based on the preliminary information provided by AECOM, it is understood that the existing 18 m span CPR Overpass Bridge will be replaced by a 27 m long span. Based on the preliminary general arrangement (GA) drawing, the existing bridge abutments are supported on pile foundations.

Deck width of the new Highway 401 roadway carried by the overpass bridge will be about 48.9 m. Reinforced soil systems (RSS) wingwalls are proposed for the widened approach embankments. Fill height of the existing approach embankments is in the order of 8 to 9 m. Grade raise of approximately 0.5 m is proposed at the overpass bridge.

The discussion and recommendations presented in this report are based on the information provided by AECOM and on the factual data obtained during the course of current investigation.

8 STRUCTURE FOUNDATION

In general, the stratigraphy below the existing bridge approach embankments consists of a thin layer of compact silty sand underlain by a thick deposit of sand layer overlying dolostone bedrock. The highest groundwater measured in the piezometers was at elevation 292.0 m or 2.7 m below the top of railway tracks.

Based on the subsurface conditions, initial consideration was given to supporting the replacement bridge on spread footings on native soil or engineered fill, driven steel H-piles, and augered caissons. A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix F.

Recommendations for design of the feasible foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation scheme from a geotechnical perspective is recommended.

8.1 Spread Footings on Native Soil

Based on the subsurface conditions encountered at this site, the use of spread footings to support the abutments is considered feasible from a geotechnical perspective. Spread footings should be founded on compact to dense native silty sand to sand. Table 8.1 summarizes the recommended founding elevations at the abutment locations.

Table 8.1 – Recommended Founding Elevations for Spread Footings

Foundation Element	Borehole No.	Recommended Highest Founding Elevation (m)	Bearing Stratum
West Abutment	RC14-01	294.5	Compact Silty Sand
	RC14-03	294.5	Compact to Dense Sand
	14-10	292.5	Compact Gravelly Sand
East Abutment	RC14-02	294.5	Dense Gravelly Sand
	RC14-04	293.0	Dense Sand
	14-11	288.0	Compact Sandy Silt

The following geotechnical resistances are recommended for design of spread footings founded on the undisturbed, compact to dense native soils shown above, assuming a minimum 2 m wide footing subjected to vertical concentric loading:

- Factored Geotechnical Resistance at ULS = 400 kPa
- Geotechnical Resistance at SLS = 250 kPa

Where eccentric or inclined loads are applied, the resistances used in design must be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

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

The lateral resistance developed along the base of concrete footings founded on compact to dense silty sand to sand may be computed using an ultimate friction coefficient of 0.5.

Excavation and backfilling for the footings must be in accordance with OPSS 902.

Construction of a footing will require excavation extending to or possibly below the groundwater level and is not recommended.

8.2 Spread Footings on Engineered Fill

The design founding levels may be raised by placing the footings on engineered fill constructed over the native cohesionless soils. The base of the engineered fill pad must be placed at or below the founding levels provided in Table 8.1. The engineered fill must consist of OPSS Granular ‘A’ placed in 150 mm lifts and compacted to 100% of its SPMDD at ±2% of optimum moisture content. The fill pad should extend laterally at least 1.0 m beyond the edge of footing.

Provided a minimum footing width of 2 m is maintained, footings bearing on an engineered fill pad at least 2.0 m thick may be designed for the following values:

- Factored Geotechnical Resistance at ULS = 900 kPa
- Geotechnical Resistance at SLS = 350 kPa

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

Construction of an engineered fill pad for spread footing will require excavation extending to or possibly below the groundwater level and is not recommended.

8.3 Steel H-Pile Foundations

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

8.3.1 Axial Resistance

It is recommended that H-piles be driven to refusal on bedrock. Cobbles were encountered immediately above the bedrock surface in Boreholes RC14-01 and RC14-03. It is possible that some piles may meet refusal on cobbles above the bedrock surface.

The anticipated pile tip elevations and factored geotechnical resistances at ULS for HP 310x110 piles driven to bedrock are presented in Table 8.2. The geotechnical resistance of piles at the west abutment has been reduced considering piles potentially encountering refusal above the bedrock surface.

Table 8.2 – Anticipated Pile Tip Elevation and Recommended Geotechnical Resistance for H-Piles

Foundation Element	Borehole No.	Anticipated Pile Tip Elevation	Factored Geotechnical Resistance at ULS (kN)
West Abutment	RC14-01 RC14-03	283.3 to 284.0	1,800
East Abutment	RC14-02 RC14-04	288.0	2,000

The geotechnical resistance at SLS will not govern for piles founded on bedrock.

8.3.2 Pile Tips

Pile tip protection is recommended for driven H-piles to prevent pile damage when setting the piles on bedrock or if cobbles are encountered. The tips of all driven H-piles must be fitted with rock points from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent.

8.3.3 Pile Installation

Pile installation should be in accordance with OPSS 903. The foundation drawing should include the note "Piles to be driven to bedrock".

8.3.4 Pile Lateral Resistance

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

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

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

Where z = depth of embedment of pile (m)

D = pile width or diameter (m)

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

γ' = effective unit weight (kN/m^3)

K_p = coefficient of passive lateral earth pressure

The parameters recommended for use with the above equations are provided in Table 8.3.

Table 8.3 – Soil Parameters for Lateral Pile Resistance

Location	Soil Unit	Elevation (m)		γ' (kN/m^3)	n_h (kN/m^3)	K_p
		Top	Bottom			
West Abutment	Silty Sand	294.5*	292.9	10	3,500	3.3
	Sand	292.9	Bedrock (283.3)	11	5,000	3.7
East Abutment	Silty Sand	294.5*	293.0	10	3,500	3.3
	Sand	293.0	Bedrock (288.0)	11	5,000	3.7

Note: * Assumed elevation at pile head.

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the 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}, may be obtained from the expression, $P_{ult} = p_{ult} \, L \, D$. This represents the ultimate load at which geotechnical failure of the pile occurs and will not support any additional load at greater displacement.

According to the CHBDC Clause C6.8.7.1 and Table C6.4, lateral resistance for steel HP310 x 110 piles embedded in compact to dense cohesionless soils should be limited to 120 kN and 50 kN under ULS (factored) and SLS conditions, respectively.

The coefficient 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 8.4. Intermediate values may be obtained by linear interpolation.

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

Table 8.4 – Subgrade Reaction Reduction Factors for Pile Spacing

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

8.4 Caissons / Drilled Shafts

Caisson installation at this site would extend through cohesionless soils below the groundwater table and require the use of a permanent liner to support the caisson sidewalls. Sealing of the caisson liner into the bedrock to prevent inflow of water and cohesionless soils may be problematic. In addition, cobbles are present within the sand layer, which may obstruct excavation and advancement of the liner. The use of caissons is therefore not recommended.

8.5 Downdrag

In view of the soil conditions at this site, downdrag on the piles is not considered to be an issue.

8.6 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles driven to bedrock are the preferred foundation option.

8.7 Frost Cover

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

9 EXCAVATION AND DEWATERING

All excavations must be carried out in accordance with OPSS 902 and the requirements of the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the approach fill and native silt/sand within the depth of excavation may be classified as Type 3 soils above the water table and Type 4 soils below the water table. Flatter slopes may be required at locations where water seepage affects surficial stability.

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

It is understood that bridge replacement will be carried out in stages to maintain the highway traffic at all times. Roadway protection will be required to facilitate staging. Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. Protection of the railway tracks should follow the AREMA guideline.

The design of any roadway protection or dewatering system that may be required is the responsibility of the Contractor. All shoring systems should be designed by a professional engineer experienced in such design.

10 RETAINED SOIL SYSTEMS (RSS)

Based on the preliminary design information provided by AECOM, both abutments will have RSS wingwalls. The RSS walls will be stepped up at a slope of 2H: 1V along the approaches away from the abutments.

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

As per MTO’s RSS Design Guidelines, the underside of the levelling pad must be placed at least 0.5 m (40% of frost depth) below finished grade in front of the wall.

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

The borehole information indicates that the soil conditions at the wall base levels will generally comprise existing embankment fill and compact native silty sand. Walls founded on the above materials should be designed for a Factored Geotechnical Resistance at ULS of 320 kPa and a Geotechnical Reaction at SLS of 200 kPa.

The above geotechnical resistance values are estimated for a horizontal ground surface in front of the wall and may have to be reduced for ground surface sloping down in front of the wall.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC 2006 Section 6.7. The resistance values assume that the RSS wall reinforcement will extend a distance behind the wall face of approximately 70% of the wall height.

A minimum 500 mm thick layer of bedding material conforming to OPSS Granular “A” requirements should be provided under the RSS mass to provide a uniform subgrade condition. Engineered fill placed under the RSS mass to achieve the design founding level should consist of OPSS Granular “A” compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered fill pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip. Any topsoil and soft/loose fill or native material should be stripped from the footprint of the RSS. All disturbed and new embankment fill must be compacted in accordance with OPSS 501. Suggested text for a NSSP addressing these issues is included in Appendix E.

The reinforced earth block must also be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall on native silty sand and engineered granular fill may be estimated using ultimate friction coefficients of 0.45 and 0.55, respectively. The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

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

11 EMBANKMENT WIDENING

Widening of the approach embankments will be required to accommodate the replacement structure. Based on the preliminary design information provided by AECOM, the approach embankments will be widened to the south of the existing embankments.

When placing new fill against the existing embankment, benching will be required for the existing embankment slopes in accordance with OPSD 208.010.

The widened portions of embankments with the existing fill height of 8 to 9 m are anticipated to be stable at standard side slope inclination of 2H: 1V. A mid-height berm comprising a 2 m wide bench should be incorporated along the length of embankments with fill heights exceeding 8 m.

12 LATERAL EARTH PRESSURES

Backfill to the abutment walls must be in accordance with OPSS 902 and must consist of Granular A or Granular B Type II. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

Earth pressures acting on the structure 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: p_h = horizontal pressure on the wall at depth h (kPa)

K = coefficient of lateral earth pressure (see Table 12.1)

γ = unit weight of retained soil (see Table 12.1)

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

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are given in Table 12.1.

The coefficients provided in Table 12.1 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).

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or Granular B Type II.

Table 12.1 – Coefficients of Lateral Earth Pressure (K)

Loading Condition	**Earth Pressure Coefficient (K)**			
	OPSS Granular A or Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m^3		**OPSS Granular B Type I $\phi = 32°$, $\gamma = 21.2$ kN/m^3**	
	Horizontal Backfill	**Sloping Backfill (2H:1V)**	**Horizontal Backfill**	**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.

13 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design in accordance with the CHBDC for a design earthquake with 475-year return period:

Velocity Related Seismic Zone	0
Zonal Velocity Ratio	0.05
Acceleration Related Seismic Zone	1
Zonal Acceleration Ratio	0.05
Peak Ground Acceleration	0.04 g

The soil profile type at this site has been classified as Type I. Therefore, according to Clause 4.4.6.1 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. For the design of retaining walls, the coefficients of lateral earth pressure in Table 13.1 may be used.

Table 13.1 – Earth Pressure Coefficient for Earthquake Loading

Loading Condition	**Earth Pressure Coefficient (K) for Earthquake Loading**			
	Granular A or Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		**OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3**	
	Horizontal Backfill	**Sloping Backfill (2H:1V)**	**Horizontal Backfill**	**Sloping Backfill (2H:1V)**
Active (K_{AE})*	0.29	0.42	0.32	0.51
At-rest (K_{OE})**	0.46	-	0.51	-
Passive (K_{PE})*	3.5	-	3.1	-

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

** After Woods (1973).

In view of the velocity related seismic zone of zero, the foundation soils at the site are assessed as not being prone to liquefaction.

14 EROSION PROTECTION

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

15 CONSTRUCTION CONCERNS

During construction, the Contract Administrator (CA) should employ an experienced geotechnical engineer to observe foundation construction activities and to provide advice to the CA regarding any issues that need to be referred to the design team.

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

Protection of the Existing Structure and Roadway Remaining in Service

During the staged replacement of the existing structure, portions of the existing structure and travelled lanes must remain in service. The Contractor must provide adequate protection, e.g. shoring, to ensure that the performance of the existing foundations is not compromised and the roadway is protected.

Pile Installation

If piles are meeting refusal at higher elevations than anticipated, the issue should be referred to the design team for comment.

Excavation and Dewatering

Any excavation carried out below the prevailing groundwater level runs a significant risk of being destabilized due to the inflow of groundwater. Adequate shoring and groundwater control measures must be in place to maintain the stability of the excavation and to prevent loss of ground under the structure or embankment. If the selected foundation option requires excavation below the groundwater level, it is advisable to obtain a Permit to Take Water (PTTW) prior to dewatering.

16 INVESTIGATION FOR DETAIL DESIGN

During the detail design phase, the designers must review the available geotechnical information to determine if it is adequate to support the proposed design. If there are information gaps at the final foundation locations or in the approach embankments, additional investigation must be carried out in accordance with MTO standards.

17 CLOSURE

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

THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER
K. L. SHI
100141639
Aug.14, 2014
PROVINCE OF ONTARIO

Keli Shi, P.Eng.
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
Aug 14/14
PROVINCE OF ONTARIO

Alastair E. Gorman, P.Eng.
Associate, Senior Foundation Engineer

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 14/14
PROVINCE OF ONTARIO

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

Appendix A

Record of Borehole Sheets

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-01

1 OF 3

METRIC

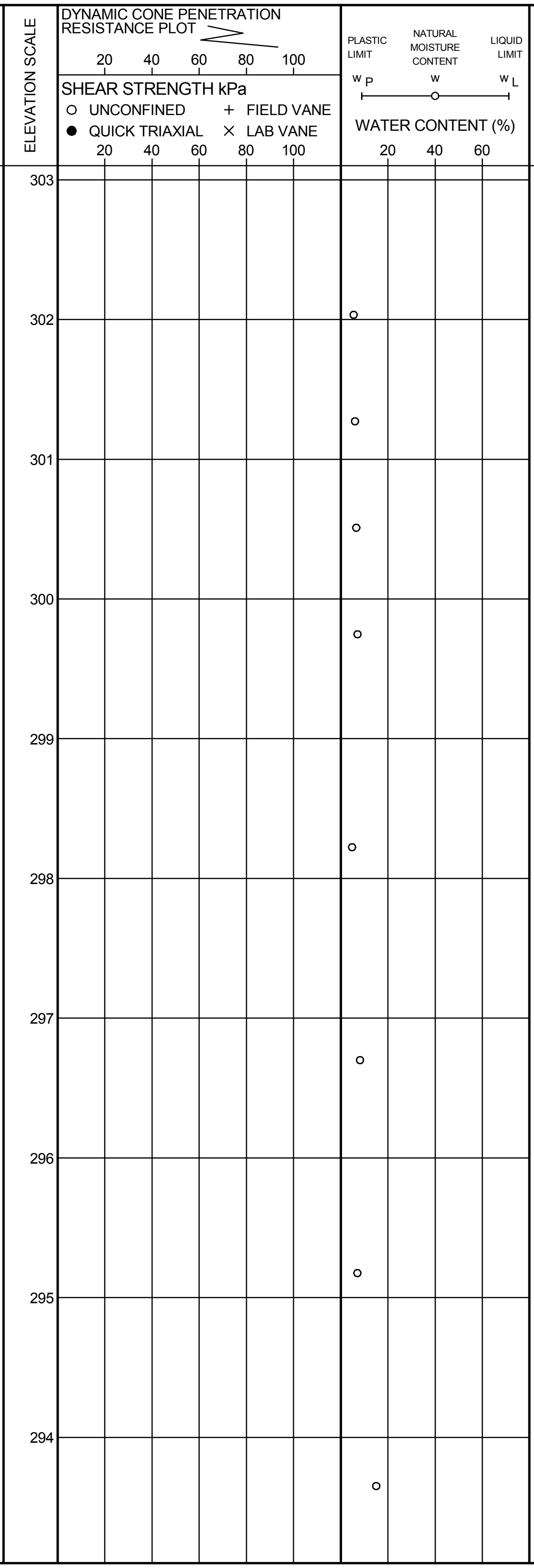
GWP# 2188-10-00	LOCATION CPR Overpass N 4 815 694.3 E 263 354.7		ORIGINATED BY GA
HWY 401	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2014.06.04 - 2014.06.06		CHECKED BY KS

SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
303.1		
0.0	**ASPHALT:** (88mm)	
0.1	**CONCRETE**	
302.5 0.6	Sandy **GRAVEL** to **SAND** and **GRAVEL**, some silt Compact to Very Dense Brown Dry (FILL)	
294.4 8.7	Silty **SAND**, some clay Compact Brown Moist	

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
1	SS	47						
2	SS	59			52	31	17 (SI+CL)	
3	SS	28						
4	SS	36						
5	SS	24			42	42	16 (SI+CL)	
6	SS	21						
7	SS	33	▽					
8	SS	27						



REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-01 2 OF 3 METRIC

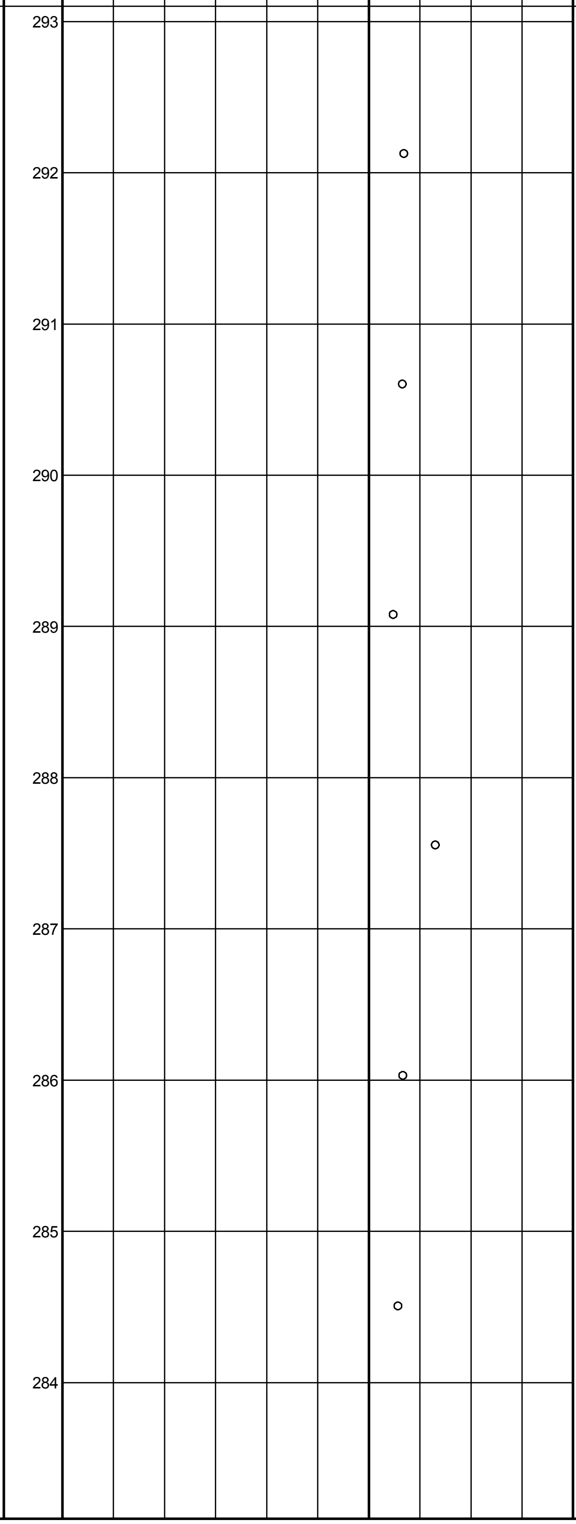
GWP# 2188-10-00
LOCATION CPR Overpass N 4 815 694.3 E 263 354.7
ORIGINATED BY GA
HWY 401
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2014.06.04 - 2014.06.06
CHECKED BY KS

SOIL PROFILE			SAMPLES						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page								
292.9							293		
10.2	**SAND**, trace silt, trace gravel Compact to Dense Brown Moist to Wet								
			9	SS	27		292		
			10	SS	37		291		8 85 7 (SI+CL)
			11	SS	43		290 289		
			12	SS	18		288		
			13	SS	16		287 286		
			14	SS	50/ 0.150		285		
	Cobbles (19.2m to 19.8m)						284		
283.3								FI	
19.8	**BEDROCK**, dolostone, porous								RUN #1

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L
WATER CONTENT (%)
20 40 60



+ 3 , × 3 : Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC14-01

3 OF 3

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 694.3 E 263 354.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.06.04 - 2014.06.06	CHECKED BY	KS

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

Continued From Previous Page

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	BEDROCK, dolostone, porous, fine grained, slightly weathered to fresh, brown						283	4 5	TCR=88% SCR=75% RQD=48% UCS=60MPa (Average)
			1	RUN				2	
	Voids from 19.9m to 20.1m Horizontal joints from 19.8m to 21.2m							2	
							282	5	
	Sub-vertical joint (100mm) at 21.0m Highly broken zone (100mm) at 21.1m							0	RUN #2 TCR=100% SCR=92% RQD=92% UCS=89MPa (Average)
			2	RUN				1	
	Horizontal joints at 21.7m, 22.2m, 22.3m						281	1	
280.5								2	
22.6	END OF BOREHOLE AT 22.6m. BOREHOLE OPEN TO 22.6m AND WATER LEVEL AT 8.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.								

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

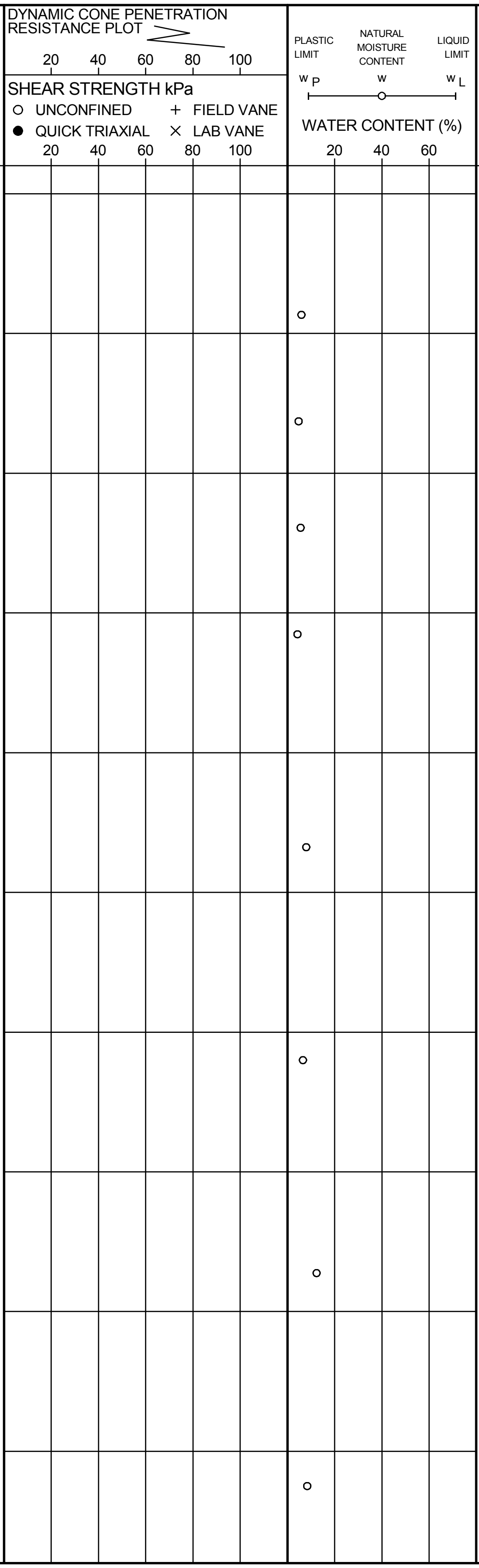
RECORD OF BOREHOLE No RC14-02

1 OF 2

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 710.7 E 263 399.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.06.02 - 2014.06.04	CHECKED BY	KS

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
303.2								
0.0	**ASPHALT:** (75mm)							
0.1	**CONCRETE**							
302.6 0.6	**SAND** and **GRAVEL** to Gravelly **SAND**, some silt Very Dense to Compact Brown Dry to Moist (FILL)	1	SS	47				
		2	SS	57				
		3	SS	43	43	41	16 (SI+CL)	
		4	SS	52				
		5	SS	28				
		6	SS	28	25	58	17 (SI+CL)	
296.0 7.2	Silty **SAND**, some clay Compact Brown Moist	7	SS	17	0	56	30	14
294.5 8.7	Gravelly **SAND** to some gravel, trace to some silt Dense to Compact Brown Wet	8	SS	47				



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+ 3 , × 3 : Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-02

2 OF 2

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 710.7 E 263 399.4	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.06.02 - 2014.06.04	CHECKED BY	KS

ELEV DEPTH	DESCRIPTION (Continued From Previous Page)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
						293		
		9	SS	51				
					∇	292		
						291		
		10	SS	19				
						290		
		11	SS	41				32 52 16 (SI+CL)
						289		
288.0						288	FI	
15.2	**BEDROCK**, dolostone, porous, fine grained, slightly weathered to fresh, beige/grey	1	RUN				>5 >10 >5	RUN #1 TCR=100% SCR=78% RQD=48% UCS=65MPa (Average)
	Highly broken zone: 175mm at 15.5m 100mm at 15.9m					287	1 1	
	Horizontal joints from 15.3m to 16.6m	2	RUN			286	>5 >5 5	RUN #2 TCR=100% SCR=95% RQD=23% UCS=34MPa (Average)
284.9	Horizontal joints 16.8m to 18.0m					285	5 1	
18.3	END OF BOREHOLE AT 18.3m. BOREHOLE OPEN TO 18.3m AND WATER LEVEL AT 11.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.4m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

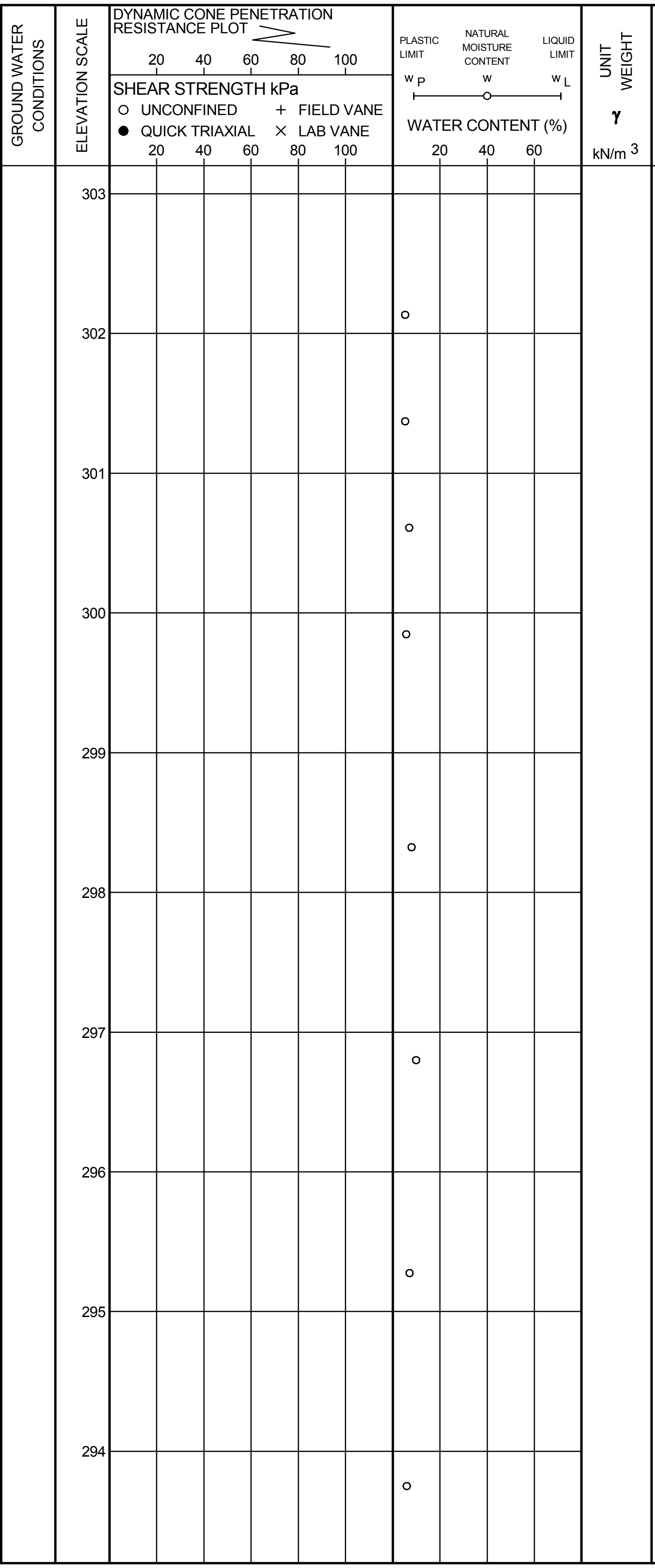
+ 3, × 3: Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC14-03

1 OF 3 **METRIC**

GWP# 2188-10-00
LOCATION CPR Overpass N 4 815 672.2 E 263 380.7
ORIGINATED BY GA
HWY 401
BOREHOLE TYPE Hollow Stem Augers/NQ Coring
COMPILED BY AN
DATUM Geodetic
DATE 2014.06.10 - 2014.06.10
CHECKED BY KS

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
303.2								
0.0	**ASPHALT:** (75mm)							
0.1	**CONCRETE**							
302.6 0.6	**SAND** and **GRAVEL**, some silt Dense to Compact Brown Dry (FILL)	1	SS	46	49	35	16 (SI+CL)	
		2	SS	40				
		3	SS	48				
		4	SS	33	50	35	15 (SI+CL)	
		5	SS	24				
297.1 6.1	Silty **SAND**, some clay Compact Reddish Brown Moist	6	SS	15	2	69	18	11
295.6 7.6	**SAND**, some silt, some gravel Compact to Very Dense Brown Moist to Wet	7	SS	20				
		8	SS	29				



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+ 3, × 3: Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC14-03

2 OF 3

METRIC

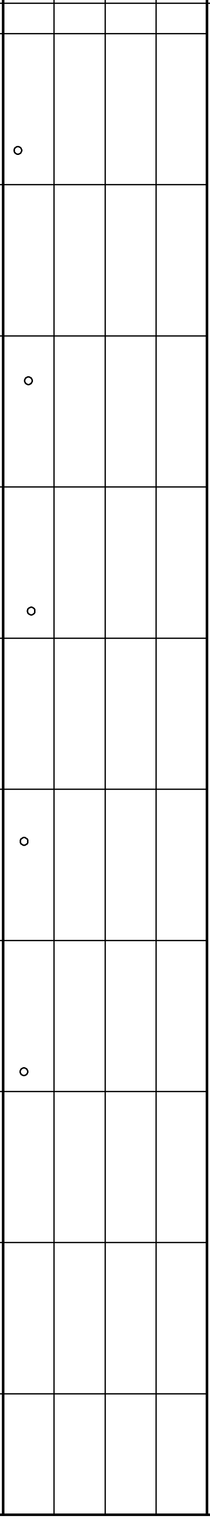
GWP# 2188-10-00	LOCATION CPR Overpass N 4 815 672.2 E 263 380.7	ORIGINATED BY GA
HWY 401	BOREHOLE TYPE Hollow Stem Augers/NQ Coring	COMPILED BY AN
DATUM Geodetic	DATE 2014.06.10 - 2014.06.10	CHECKED BY KS

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					∇	293		
		9	SS	35				15 74 11 (SI+CL)
						292		
						291		
		10	SS	36				
						290		
		11	SS	39				
						289		
						288		
		12	SS	89				
						287		
		13	SS	84				
						286		
						285		
	Cobbles (18.3m to 19.2m)	~~14~~	~~SS~~	~~50/~~ 0.0				
284.0							FI	
19.2	**BEDROCK**, dolostone, porous, slightly weathered to fresh, fine to medium grained, mottled beige/grey					284	2 1	RUN #1 TCR=88% SCR=88% RQD=73% UCS=79MPa (Average)

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100



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+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-03

3 OF 3

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 672.2 E 263 380.7	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.06.10 - 2014.06.10	CHECKED BY	KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Horizontal joints at 19.2m, 19.3m, 19.6m, 19.9m, 20.3m, 20.6m		1	RUN			283			1 1	
	Highly broken zone (75mm) at 20.7m									1 4	RUN #2 TCR=100% SCR=85% RQD=78% UCS=88MPa (Average)
	Horizontal joints at 20.8m, 20.9m, 21.1m, 21.2m, 21.3m, 21.6m		2	RUN			282			4 0 1	
280.9							281			0	
22.3	END OF BOREHOLE AT 22.3m. BOREHOLE OPEN TO 22.3m AND WATER LEVEL AT 10.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.										

$+^3, \times^3$: Numbers refer to Sensitivity

$\overset{20}{15 \oplus 5}_{10}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-04

1 OF 2

METRIC

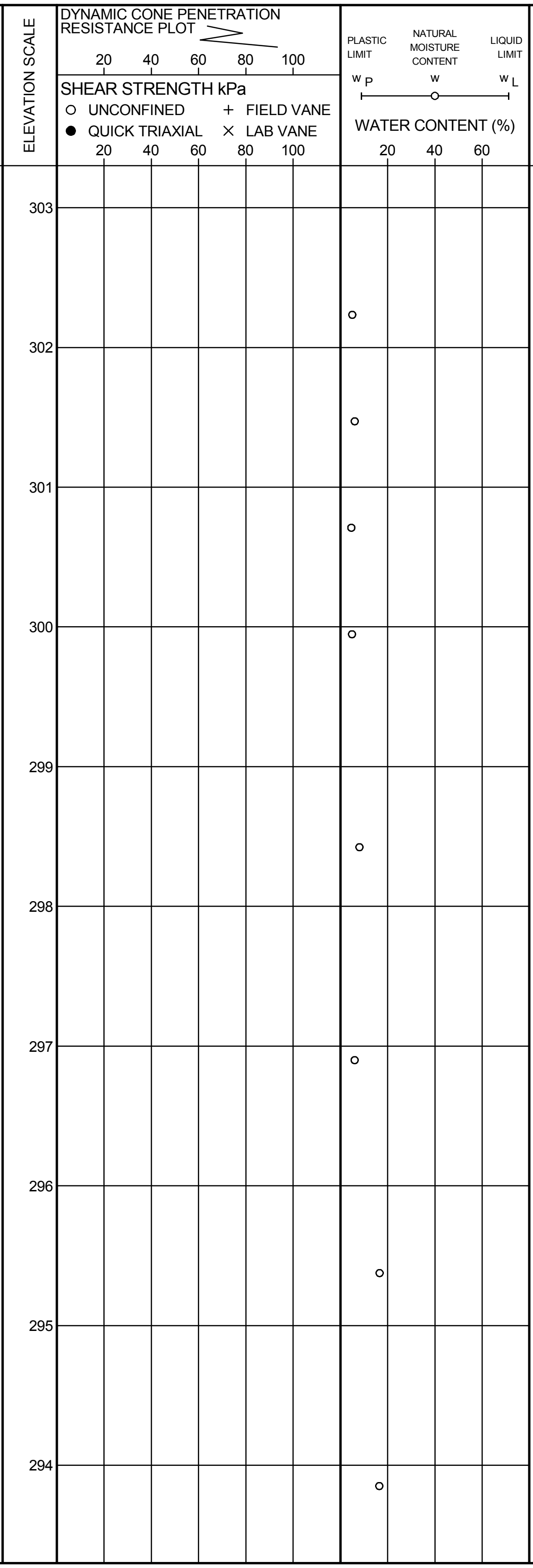
GWP# 2188-10-00	LOCATION CPR Overpass N 4 815 687.7 E 263 422.9		ORIGINATED BY GA
HWY 401	BOREHOLE TYPE Hollow Stem Augers/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2014.06.09 - 2014.06.09		CHECKED BY KS

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
303.3	
0.0	**ASPHALT:** (75mm)
0.1	**CONCRETE**
302.7 0.6	**SAND** and **GRAVEL**, some silt Dense to Compact Brown Dry (FILL)
296.1 7.2	Silty **SAND**, some clay Compact Brown Moist

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	42				
2	SS	30				
3	SS	44				
4	SS	42	40	42	18 (SI+CL)	
5	SS	28				
6	SS	33				
7	SS	20	0	64	24	12
8	SS	16				



UNIT WEIGHT γ kN/m³

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+ 3, × 3 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No RC14-04 2 OF 2 METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 687.7 E 263 422.9	ORIGINATED BY	GA
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.06.09 - 2014.06.09	CHECKED BY	KS

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR SA SI CL
	Continued From Previous Page										
293.1											
10.2	**SAND**, trace silt, trace gravel Dense to Very Dense Moist to Wet					∇	293				
			9	SS	39				○		
							292				
							291				
			10	SS	37				○		10 82 8 (SI+CL)
							290				
			11	SS	51				○		
							289				
288.1										FI	
15.2	**BEDROCK**, dolostone, porous, slightly weathered to fresh, fine grained, brown/beige						288			3 2	RUN #1 TCR=100% SCR=88% RQD=75% UCS=80MPa (Average)
			1	RUN						2	
							287			2	
	Horizontal joints at 15.4m, 15.7m, 15.9m, 16.2m, 16.3m									1	
	Vertical joint at: 100mm at 16.1m 125mm at 16.4m									1 0	RUN #2 TCR=100% SCR=98% RQD=97% UCS=105MPa (Average)
			2	RUN			286			0	
	Horizontal joints at 16.8m									0	
285.0										0	
18.3	END OF BOREHOLE AT 18.3m. BOREHOLE OPEN TO 18.3m AND WATER LEVEL AT 10.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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Ministry of Transportation
Ontario

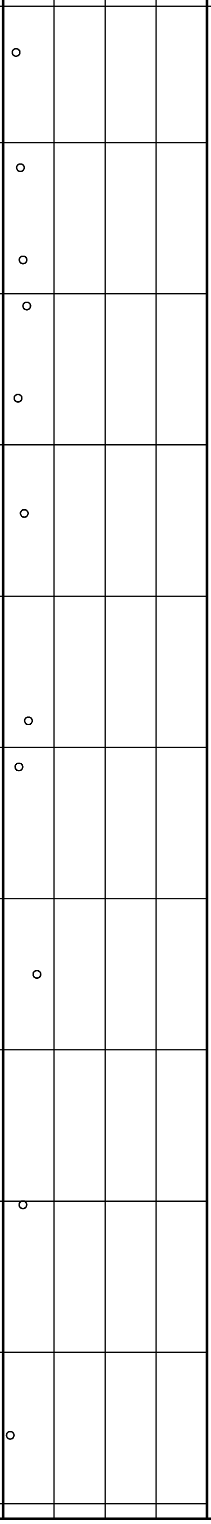
THURBER

RECORD OF BOREHOLE No 14-09

1 OF 2 **METRIC**

GWP# 2188-10-00
LOCATION CPR Overpass N 4 815 658.3 E 263 347.0
ORIGINATED BY BST
HWY 401
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2014.07.20 - 2014.07.20
CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
302.9														
0.0	**SAND** and **GRAVEL**, trace to some silt Dense to Compact Brown Moist (FILL)		1	SS	31						45	44	11 (SI+CL)	
							302							
			2	SS	28									
301.1			3	SS	26		301							
1.8	Silty **SAND**, trace to some gravel, trace to some clay Dense to Compact Brown Moist (FILL)													
			4	SS	38						13	63	17	7
							300							
			5	SS	17									
							299							
			6	SS	30		298							
							297							
			7	SS	20						2	59	26	13
							296							
			8	SS	32		295							
294.1														
8.8	**SAND**, trace gravel, trace fines Dense to Compact Brown Moist						294							
			9	SS	46									
							293							



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

ONTMT4S 3896A.GPJ 2012TEMPLATE(MTO).GDT 8/6/14

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-09

2 OF 2

METRIC

GWP# 2188-10-00
LOCATION CPR Overpass N 4 815 658.3 E 263 347.0
ORIGINATED BY BST
HWY 401
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2014.07.20 - 2014.07.20
CHECKED BY MEF

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
	Trace silt		10	SS	18		292		○		0	89	11 (SI+CL)	
291.3 11.6	END OF BOREHOLE AT 11.6m. BOREHOLE OPEN TO 9.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPUG AND CUTTINGS TO SURFACE.													

ONTMT4S 3896A.GPJ 2012TEMPLATE(MTO).GDT 8/6/14

+ 3, × 3: Numbers refer to Sensitivity

20
15 ⊕ 5
10
(%) STRAIN AT FAILURE

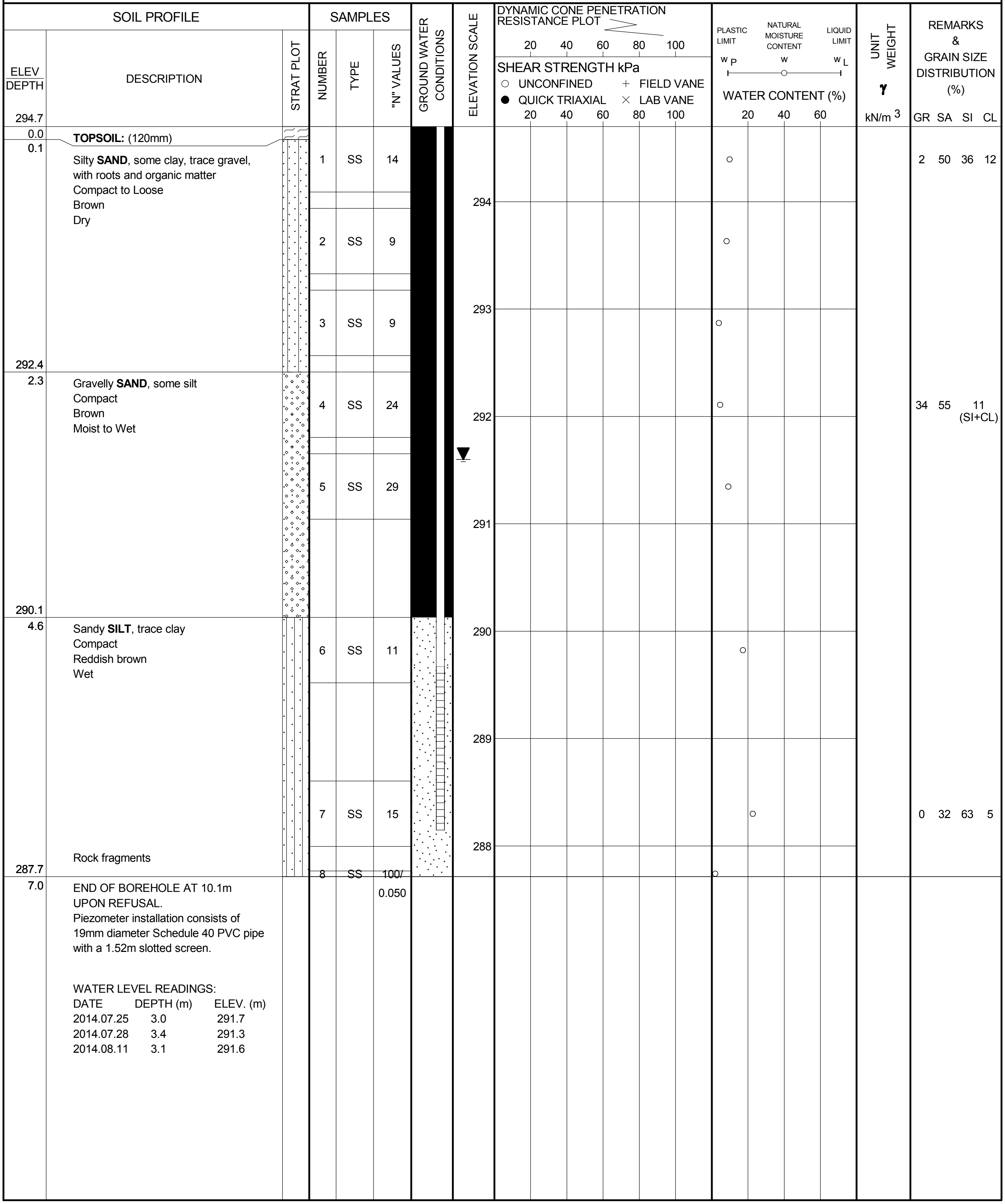
Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-10

1 OF 1 **METRIC**

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 649.6 E 263 396.0	ORIGINATED BY	JAG
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.07.17 - 2014.07.17	CHECKED BY	MEF



ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
294.7									
0.0	**TOPSOIL:** (120mm)								
0.1	Silty **SAND**, some clay, trace gravel, with roots and organic matter Compact to Loose Brown Dry	1	SS	14		2	50	36	12
		2	SS	9					
		3	SS	9					
292.4 2.3	Gravelly **SAND**, some silt Compact Brown Moist to Wet	4	SS	24		34	55	11 (SI+CL)	
		5	SS	29					
290.1 4.6	Sandy **SILT**, trace clay Compact Reddish brown Wet	6	SS	11					
		7	SS	15		0	32	63	5
	Rock fragments	8	SS	100/ 0.050					
287.7 7.0	END OF BOREHOLE AT 10.1m UPON REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.								

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2014.07.25	3.0	291.7
2014.07.28	3.4	291.3
2014.08.11	3.1	291.6

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ◆ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

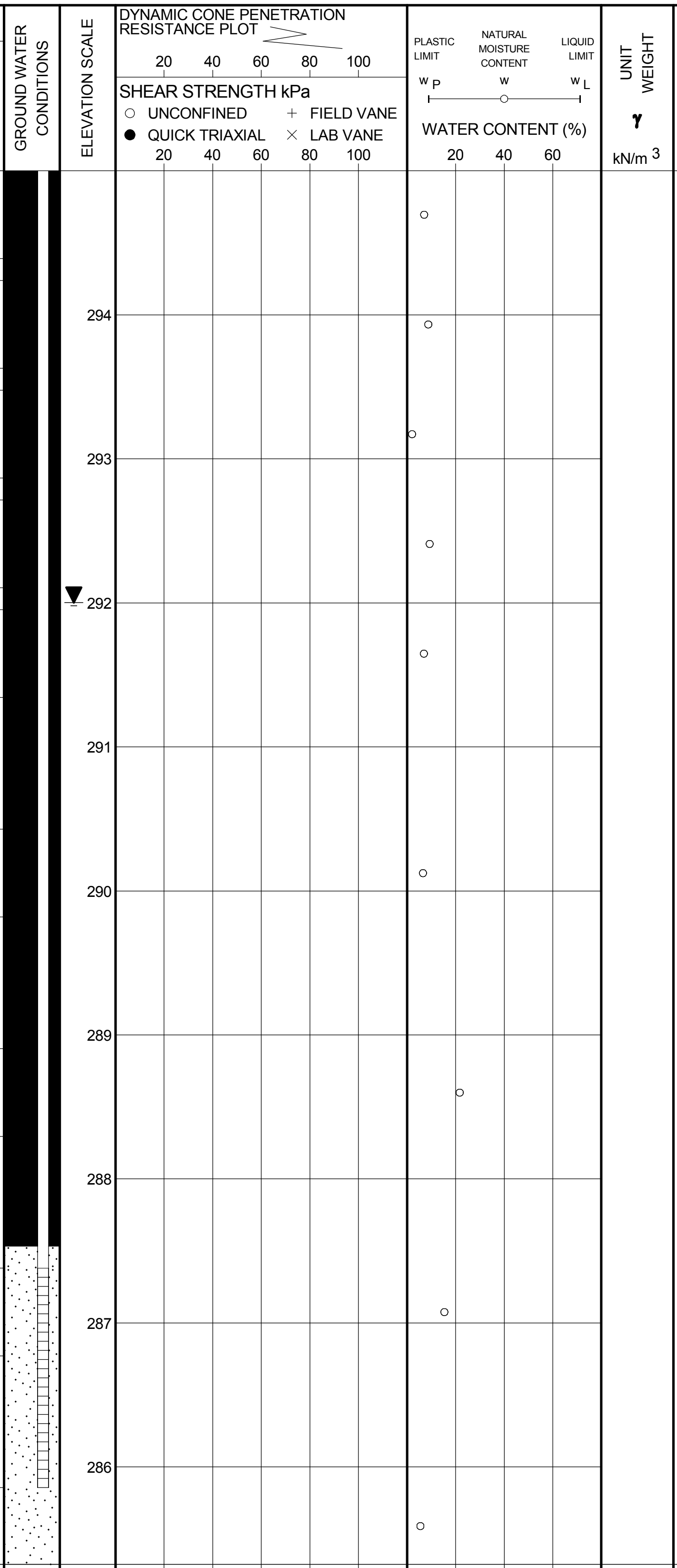
RECORD OF BOREHOLE No 14-11

1 OF 2

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 674.5 E 263 454.2	ORIGINATED BY	JAG
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.07.18 - 2014.07.18	CHECKED BY	MEF

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
295.0								
0.0	**TOPSOIL:** (120mm)							
0.1	Silty **SAND**, trace to some clay, trace gravel Compact Brown Moist	1	SS	17	4	46	40	10
		2	SS	12				
293.6 1.4	Gravelly **SAND**, trace to some silt Compact Brown Moist	3	SS	23				
		4	SS	10	24	66	10 (SI+CL)	
		5	SS	12				
		6	SS	15				
288.9 6.1	Sandy **SILT**, trace clay Loose to Compact Reddish Brown Wet	7	SS	7	0	29	65	6
		8	SS	13				
	Rock fragments	9	SS	72				
285.3 9.7	END OF BOREHOLE AT 9.7m UPON REFUSAL.							



Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 14-11

2 OF 2

METRIC

GWP#	2188-10-00	LOCATION	CPR Overpass N 4 815 674.5 E 263 454.2	ORIGINATED BY	JAG
HWY	401	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.07.18 - 2014.07.18	CHECKED BY	MEF

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ^{3}	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.07.25 3.1 291.9 2014.07.28 3.5 291.5 2014.08.11 3.0 292.0										

+ 3, × 3: Numbers refer to Sensitivity

20
15 ◐ 5
10
(%) STRAIN AT FAILURE

ONTMT4S 3896A.GPJ 2012TEMPLATE(MTO).GDT 8/14/14

Appendix B

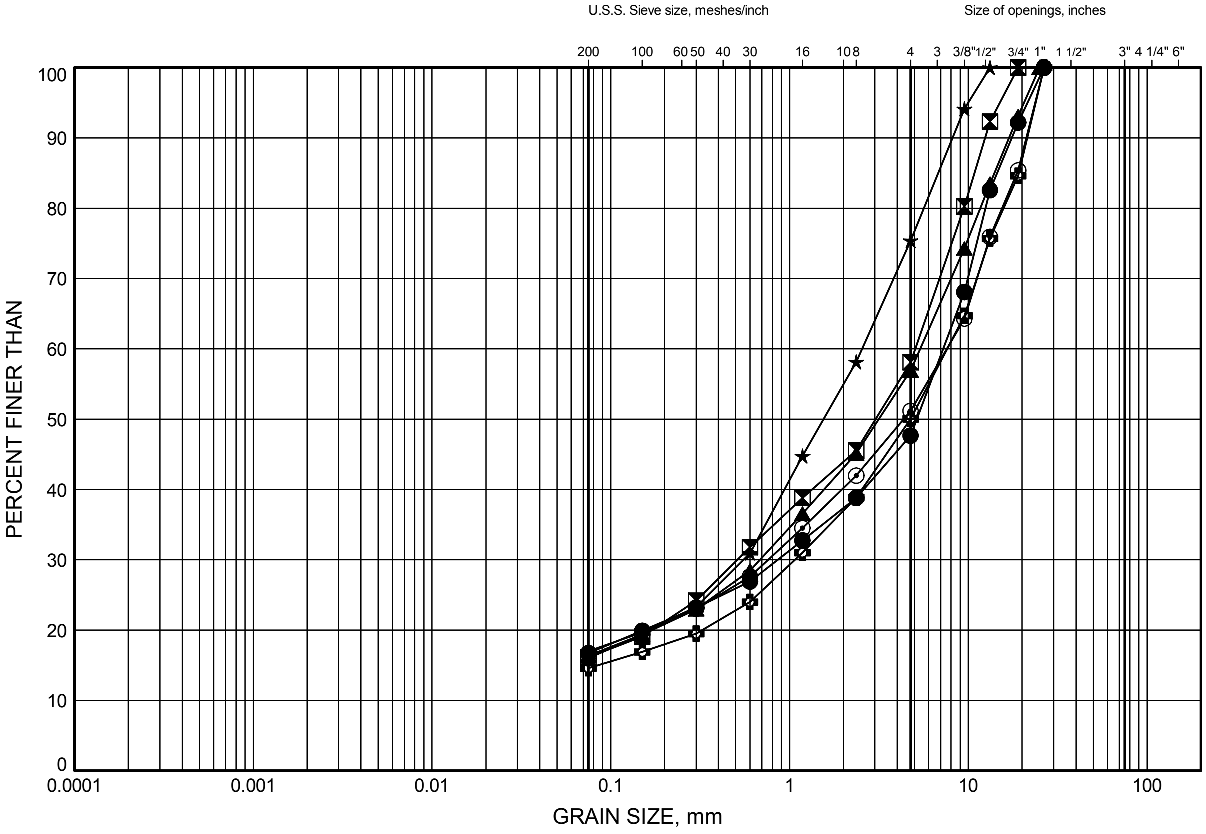
Laboratory Test Results

CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B1a

SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC14-01	1.83	301.27
☒	RC14-01	4.88	298.22
▲	RC14-02	2.59	300.61
★	RC14-02	6.40	296.80
⊙	RC14-03	1.07	302.13
✚	RC14-03	3.35	299.85

Date July 2014

GWP# 2188-10-00

THURBER

Prep'd MFA

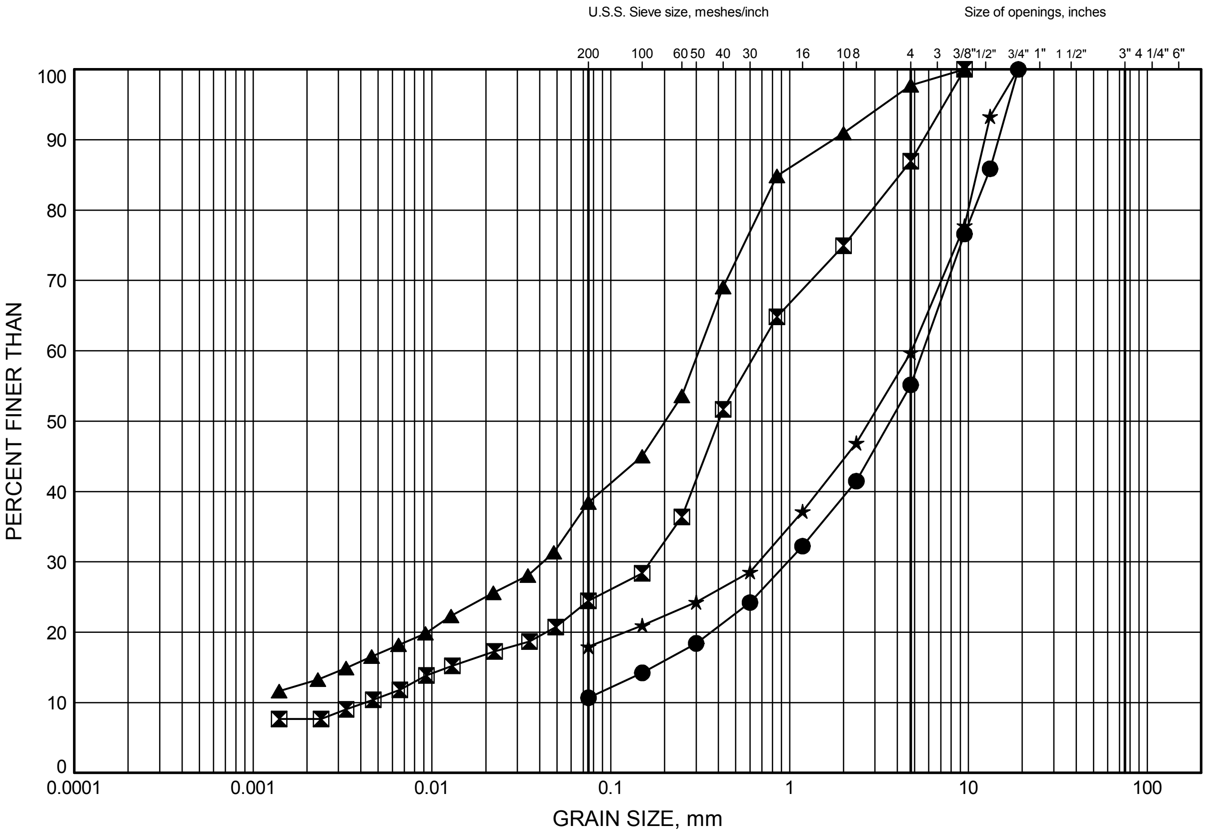
Chkd. KS

CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B1b

SAND & GRAVEL FILL / SILTY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-09	0.30	302.70
☒	14-09	2.59	300.41
▲	14-09	6.40	296.60
★	RC14-04	3.35	299.95

Date July 2014

GWP# 2188-10-00

THURBER

Prep'd MFA

Chkd. KS

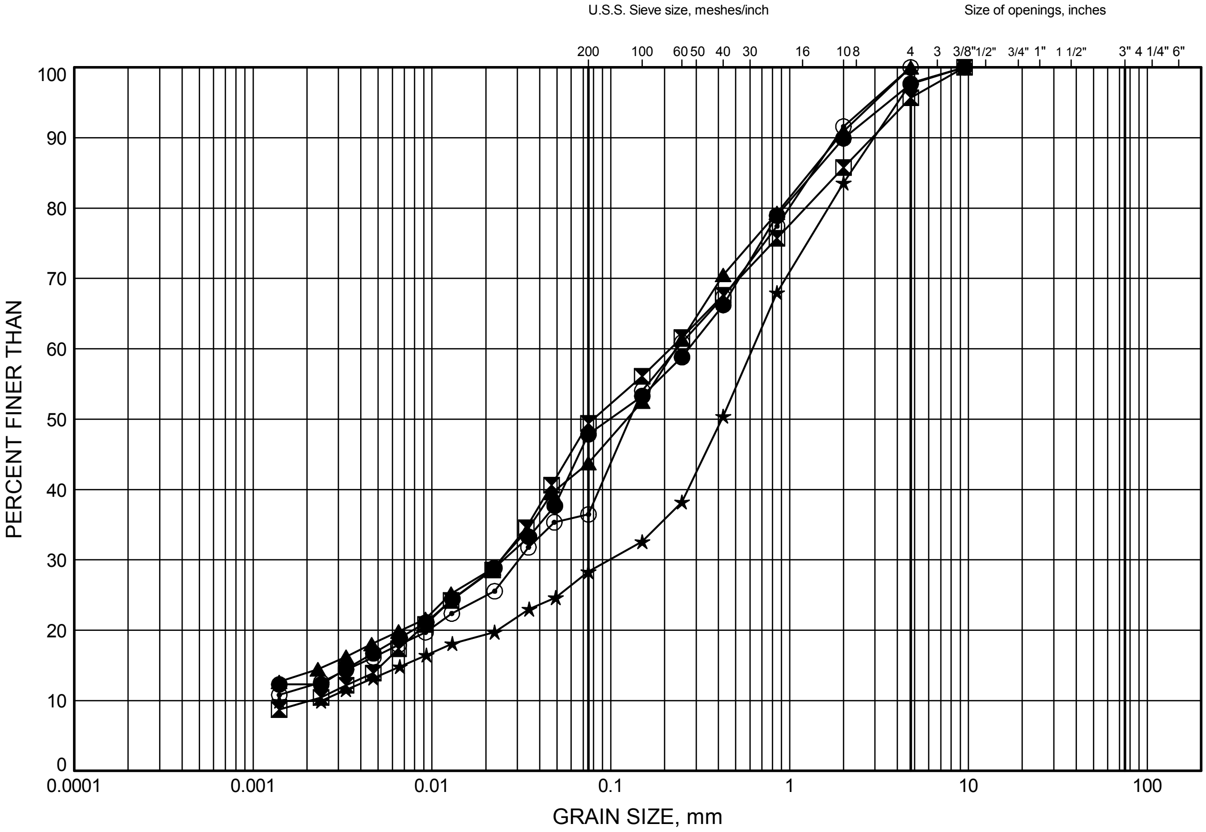
GRAIN SIZE DISTRIBUTION - THURBER 3896A.GPJ 7/30/14

CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-10	0.30	294.40
⊠	14-11	0.30	294.70
▲	RC14-02	7.92	295.28
★	RC14-03	6.40	296.80
⊙	RC14-04	7.92	295.38

Date July 2014

GWP# 2188-10-00

THURBER

Prep'd MFA

Chkd. KS

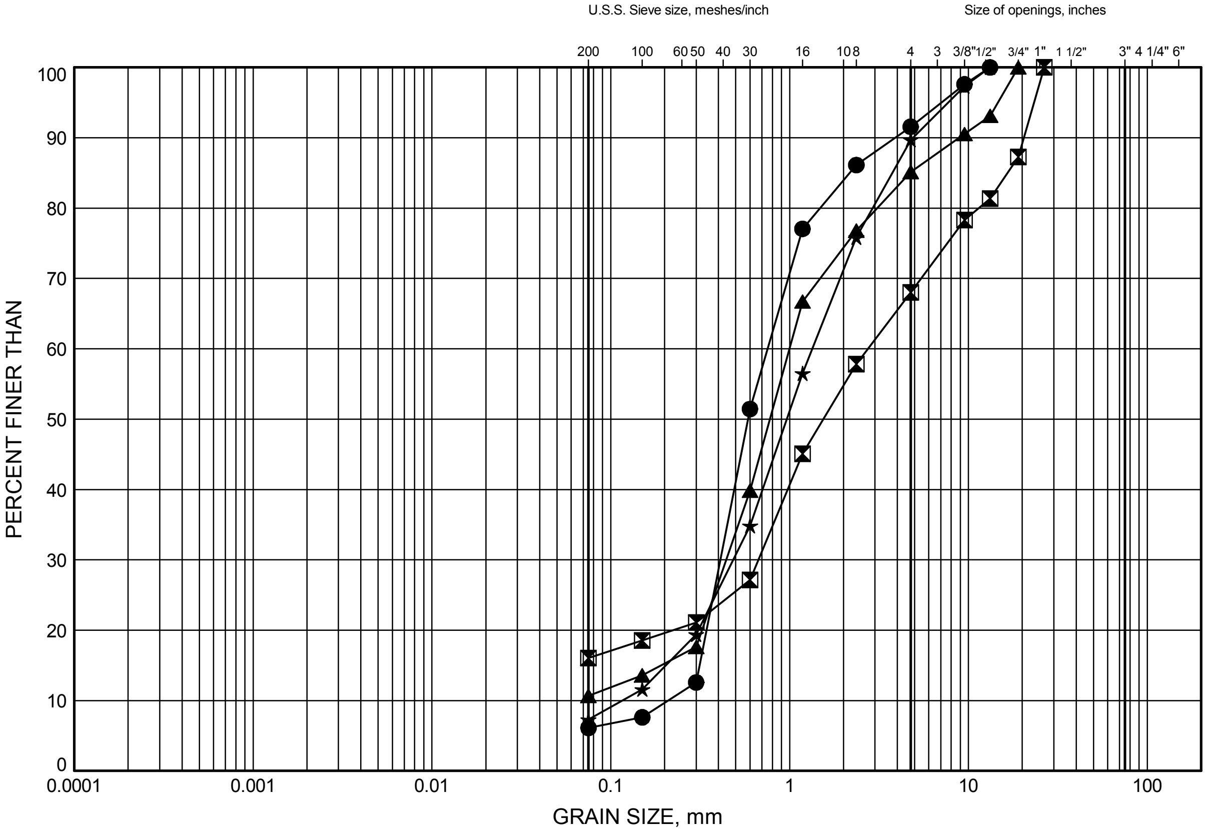
GRAIN SIZE DISTRIBUTION - THURBER 3896A.GPJ 7/30/14

CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B3a

Gravelly SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC14-01	12.50	290.60
☒	RC14-02	14.02	289.18
▲	RC14-03	10.97	292.23
★	RC14-04	12.50	290.80

GRAIN SIZE DISTRIBUTION - THURBER 3896A.GPJ 7/30/14

Date July 2014

GWP# 2188-10-00

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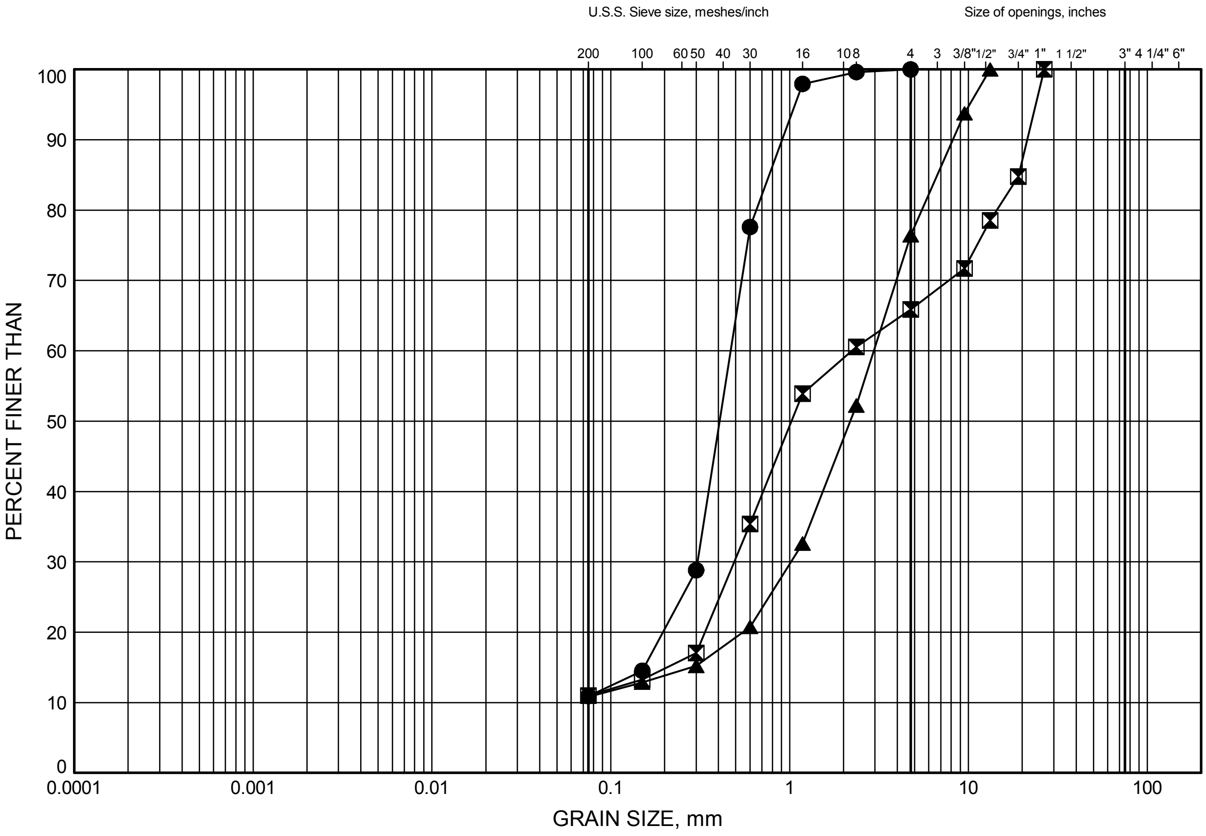
CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B3b

Gravelly SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-09	10.97	292.03
☒	14-10	2.59	292.11
▲	14-11	2.59	292.41

GRAIN SIZE DISTRIBUTION - THURBER 3896A.GPJ 7/30/14

Date July 2014

GWP# 2188-10-00

THURBER

Prep'd MFA

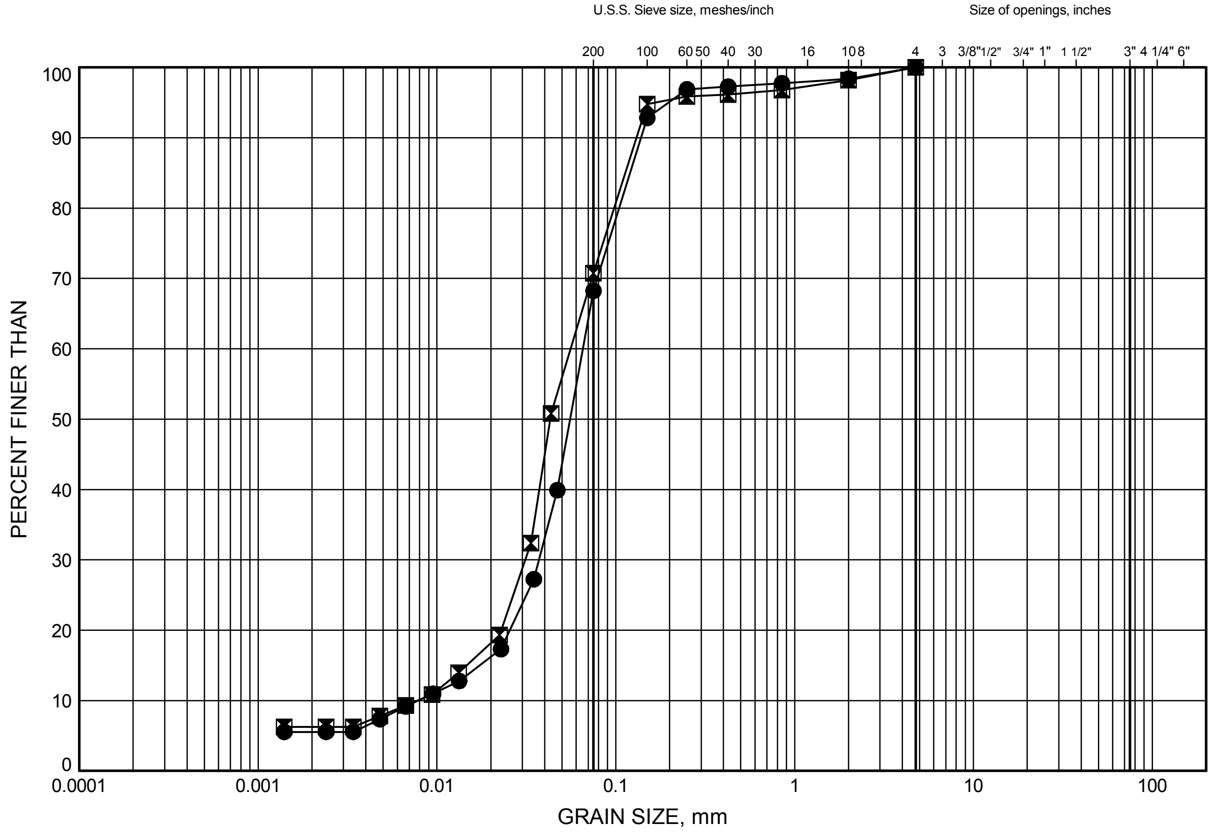
Chkd. KS

CPR Overpass

GRAIN SIZE DISTRIBUTION

FIGURE B4

Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-10	6.40	288.30
☒	14-11	6.40	288.60

Date July 2014

GWP# 2188-10-00

THURBER

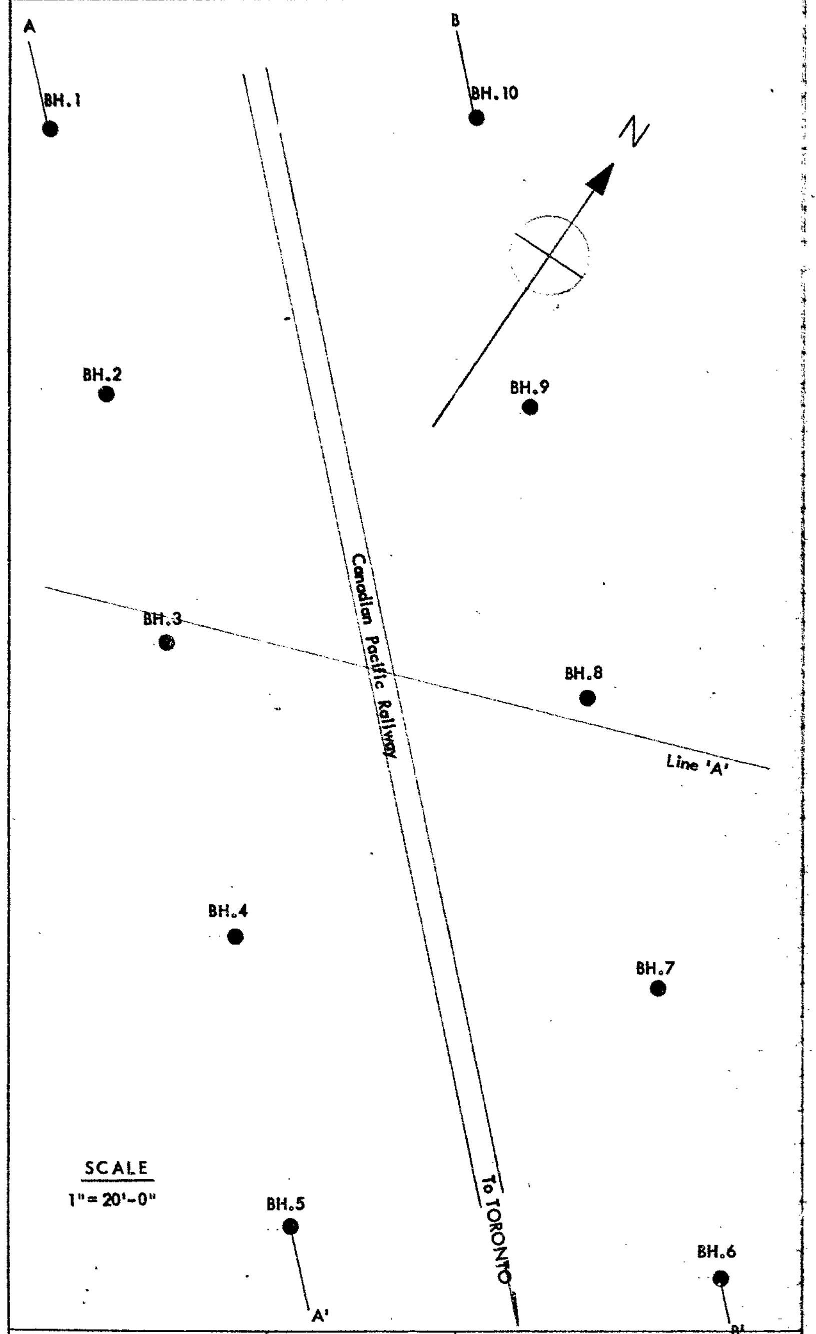
Prep'd MFA

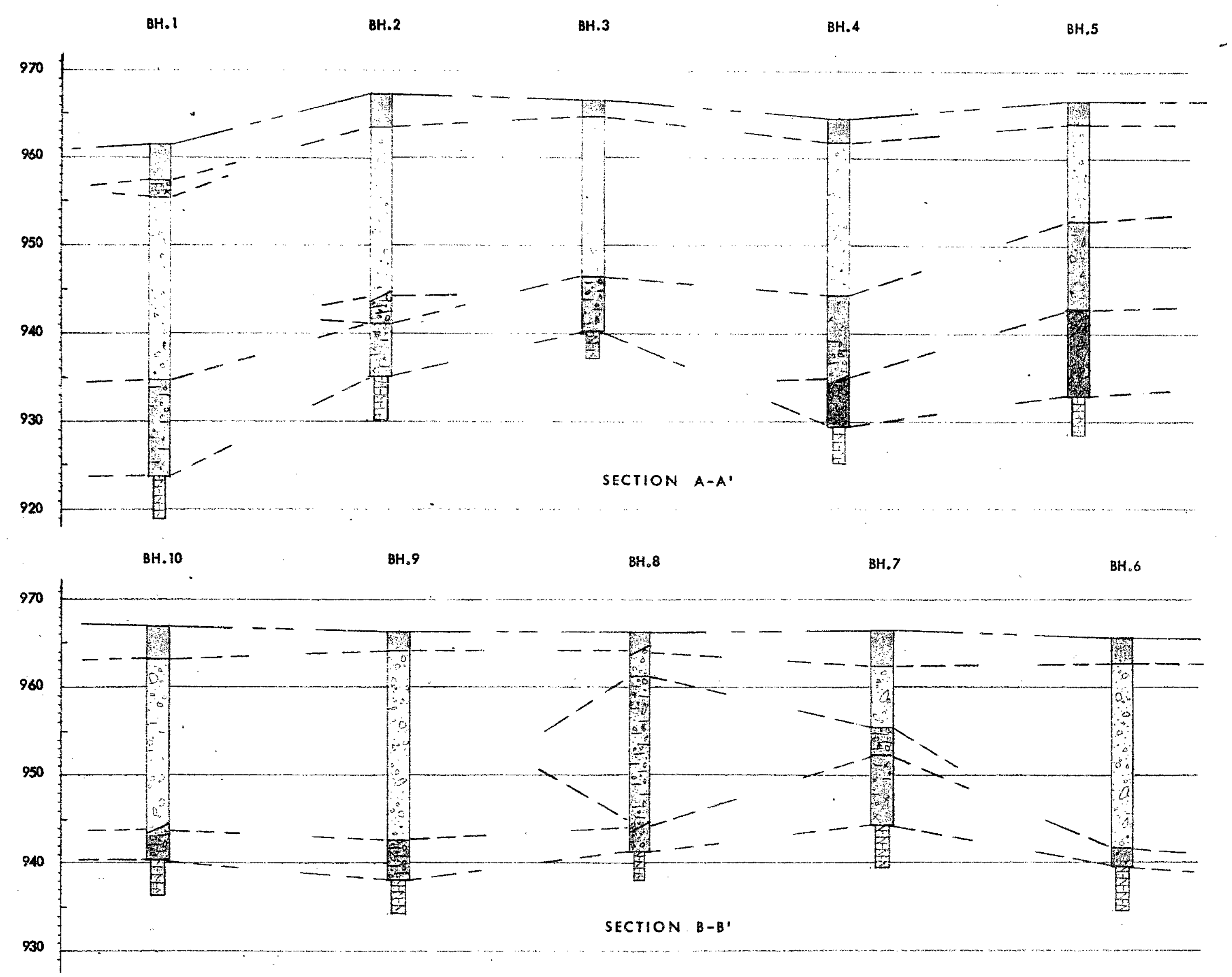
Chkd. KS

GRAIN SIZE DISTRIBUTION - THURBER 3896A.GPJ 7/30/14

Appendix C

Historical Borehole Information





LEGEND

- ▨ SAND
- ▨ SAND & GRAVEL
- ▨ GRAVEL
- ▨ GRAVELLY CLAYS
- ▨ TILL
- ▨ BEDROCK (Lockport Dolomite)

SCALE

Horizontal 1" = 20'-0"
Vertical 1" = 10'-0"

This sketch is an approximate copy of a section of plan N° E-2906-1 supplied by D.H.O.

Drawn by BA Date 11 Sept. 1957
Scale As Indicated

Project C.P.R. Overhead, Bridge N° 11, Highway 401
Title Borehole Plan & Sections
Drg. No. 1 Order No. T.246/57

UNIVERSAL
GEOTECHNIQUE
LIMITED

G9 500-6-54 United Stationery Co.

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57
CLIENT Department of Highways, Ontario.
BOREHOLE NO. BH.1 DIAMETER 2-1/2" CASING 2-1/2"
BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

FORM G-1A 500 UNITED STATIONERY Co. Ltd.

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	961.4			Zero			
Firm brown fine to coarse SAND. Little clay and some organic matter.			● 1			12	Damp. Low to medium dry strength.
				4'-0"	Water Seepage		
Firm brown very sandy CLAY with fine rounded GRAVEL and black organic concentrations.			● 2			6	Wet. Medium to high dry strength.
				6'-0"	Free Water		
Dense brown fine to coarse SAND and fine subrounded GRAVEL, little clay.			● 3			39	Wet. Medium dry strength.
Firm do			● 4			23	do
Dense do			● 5			33	do
Firm brown fine to coarse subrounded to subangular SAND.			● 6			21	Wet. No dry strength.
				26'-6"			
Dense reddish brown calcareous clayey SAND & GRAVEL. Gravel generally fine subangular to subrounded.			● 7			30	Wet. Medium dry strength.
Firm reddish brown calcareous clayey silty fine SAND.			● 8			22	do
				37'-6"			
White grey to grey porous dolomite, jointed. Joints generally parallel to core length and slightly stained. Solution cavities exhibit secondary crystallization. Rock weathered and somewhat broken. Gasport member of the Lockport formation.							37'-6" to 42'-6" Core Recovery 56%
		End of Borehole		42'-6"			

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ■ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

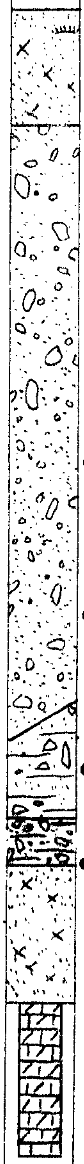
PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.2 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

FORM G-1A 500 UNITED STATIONERS Co. Limited

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	967.2			Zero			
Loose brown fine silty SAND with little organic matter.			● 1			7	Damp. No dry strength.
				3'-9"			
Dense brown fine to coarse SAND with fine to medium subangular to subrounded GRAVEL.			● 2			37	do
Very dense do			● 3			57	do
Dense do			● 4			29	do
do			● 5			45	Moist. No dry strength.
Hard brown calcareous very sandy gravelly CLAY. Gravel angular to subangular.			● 6			35	Moist. Medium to high dry strength.
				26'-0"			
Very stiff reddish brown clayey sand and gravel.							
Dense reddish brown calcareous silty clayey fine SAND.			● 7	27'-6"		29	Wet Medium dry strength.
				32'-0"			
White grey to grey porous dolomite. Some jointing at 45° to core length. Exhibits partly refilled solution cavities and fossiliferous horizons. (Crinoids and brachiopods). Broken rock 31' to 32'. Weathered rock 32' to 37'. Gasport member of the Lockport formation.							32'-0" to 37'-0" Core Recovery 50%.
		End of Borehole		37'-0"			

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.3 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See plan INCLINATION Vertical BEARING ——

FORM G-1A 500 UNITED STATIONERY CO Limited

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.6			Zero			
Loose brown fine to medium SAND with gravel. Some organic matter.			● 1	2'-0"		8	Damp No dry strength.
Dense brown fine to coarse SAND and fine to medium subrounded GRAVEL.			● 2			37	do
do			● 3			32	do
do			● 4			38	do
				Free Water ▼			
Firm do with clayey concentrations			● 5			26	Wet. Low to medium dry strength.
				18'-6"			
Firm brown medium to coarse SAND with fine gravel.			● 6	20'-0"		23	Wet No dry strength.
Hard reddish brown calcareous very sandy gravelly CLAY. Gravel subangular to subrounded.			● 7			31	Wet. Medium to high dry strength.
				26'-3"			
White grey porous dolomite with partly refilled solution cavities. Fossiliferous horizons. (Crinoids). Gasport member of Lockport formation.				29'-3"			26'-3" to 29'-3" Core Recovery 92%
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

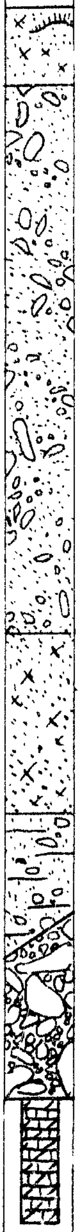
BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.4 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ——

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	964.5			Zero			
Loose brown fine silty SAND with some organic matter.			● 1			7	Damp. No dry strength.
				2'-5"			
Firm brown fine to coarse SAND with fine subangular to subrounded GRAVEL.			● 2			16	do
do			● 3			19	do
do			● 4			19	Moist No dry strength.
do With little clay.			● 5			16	Wet. Low dry strength.
do			● 6			15	do
				20'-0"			
Firm reddish brown fine calcareous silty SAND.			● 7			18	do
				25'-9"			
Hard reddish brown calcareous very sandy gravelly CLAY, gravel fine to medium subangular to subrounded.			● 8			35	do
Dense GRAVEL with fragments of badly weathered dolomite.			● 9			47	
				35'-0"			
Light grey porous dolomite. Exhibits partly refilled solution cavities and fossiliferous horizons (Crinoids). Fairly sound rock. Gasport member of the Lockport formation.							35'-0" to 39'-0" Core Recovery 75%
				39'-0"			
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.5 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

FORM G-1A 500
United Stationery Co. Ltd

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.6			Zero			
Loose brown fine silty SAND. Traces of organic matter.			● 1			5	Damp. No dry strength.
				2'-7"			
Loose brown fine to coarse SAND and fine to medium GRAVEL, subangular to subrounded.			● 2			7	do
Firm do			● 3			19	do
do With little clay.			● 4			28	Moist. Low dry strength.
				Free Water ▼			
				13'-8"			
Firm brown to reddish brown fine to coarse SAND with fine to medium gravel, subangular to subrounded. Little clay.			● 5			19	Wet. Low dry strength.
do			● 6			19	do
				23'-9"			
Dense fine to medium GRAVEL. Fragments of weathered dolomite.			● 7			53	
do			● 8			49	
				33'-7"			
Greyish white to grey porous dolomite. Partly filled solution cavities. Rock weathered and broken. Gasport member of the Lockport formation.							33'-7" to 38'-0" Core Recovery 33%.
				38'-0"			
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.6 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	965.7			Zero			
Loose brown silty fine SAND with little organic matter.			● 1			8	Damp. No dry strength.
				3'-0"			
Firm brown fine to coarse SAND and fine to medium GRAVEL, subangular to subrounded.			● 2			18	do
Dense do			● 3			34	do
				Free Water ▼			
Loose do With clayey concentrations			● 4			14	Wet Medium dry strength.
Dense do With little clay.			● 5			45	Wet. Low to medium dry strength.
				24'-0"			
Very dense reddish brown calcareous fine silty SAND.			● 6			66	do
				26'-0"			26'-0" to 31'-0" Core Recovery 93%
Greyish white to grey porous dolomite. Exhibits partly filled solution cavities. Sound rock. Gasport member of the Lockport formation.							
				31'-0"			
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

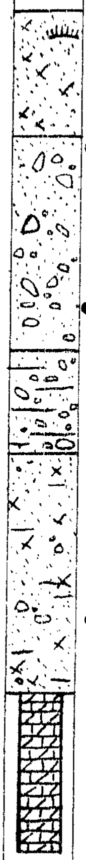
BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.7 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.4			Zero			
Loose brown fine silty SAND with little organic matter.			● 1			10	Damp No dry strength.
				4'-0"			
Dense brown fine to coarse SAND and fine to medium GRAVEL, subangular to subrounded.			● 2			37	do
Firm do			● 3			12	do
				11'-0"	Free Water	▼	
Stiff yellow brown sandy gravelly CLAY. Gravel subangular to subrounded.			● 4				
Firm purplish brown silty fine SAND with little clay and occasional fine to medium subangular to rounded gravel.			● 5	14'-3"		27	Wet. Low to medium dry strength.
Dense do			● 6			44	
				22'-0"			
Grey somewhat porous dolomite. Occasional stained jointing at about 15° to core length. Some solution cavities. Gasport member of the Lockport formation.							22'-0" to 27'-0" Core Recovery 87%.
		End of Borehole		27'-0"			

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

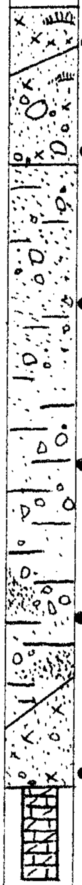
BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.8 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———



DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.2			Zero			
Loose brown fine silty SAND with little organic matter.			● 1			6	Damp Low dry strength,
Firm brown fine silty SAND with fine to medium subangular to rounded gravel. Little organic matter.			● 2	5'-0"		13	do
Dense brown fine to coarse clayey SAND with fine to medium subangular to subrounded gravel.			● 3			37	Moist. High dry strength.
Stiff reddish brown to light brown sandy gravelly CLAY. Gravel fine to medium, subangular to rounded.			● 4			13	do
Very Stiff do With sandy concentrations.			● 5			29	do
Dense reddish brown fine silty SAND with some gravel.			● 6	25'-0"		43	Wet. Low dry strength.
Greyish white to grey somewhat porous dolomite. Stained jointing at about 30° to core length. Exhibits fossiliferous horizons (Crinoids). Broken rock. Gasport member of the Lockport formation.				28'-0"			25'-0" to 28'-0" Core Recovery 55%.
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL **GEOTECHNIQUE** LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

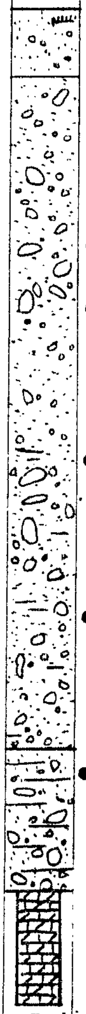
PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH.9 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING ———

FORM G-1A 500 UNITED STATIONERY CO. Limited

DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.3			Zero			
Loose brown silty fine to medium SAND with fine gravel. Traces of organic matter.			● 1	2'-1"		6	Damp. No dry strength.
Dense brown fine to coarse SAND and fine to medium subangular to subrounded GRAVEL.			● 2			39	do
do			● 3			37	do
do			● 4			33	do
				Free Water ▼			
Firm do With little clay.			● 5			16	Wet. Low dry strength.
do			● 6			16	do
				23'-9"			
Stiff light brown to reddish brown sandy gravelly CLAY. Gravel fine to medium, subangular to subrounded.			● 7			14	Wet. Medium to high dry strength.
				28'-3"			
Greyish white to grey porous dolomite. Exhibits partly filled solution cavities and fossiliferous horizons (Crinoids and brachiopods). Gasport member of the Lockport formation.							28'-3" to 32'-0" Core Recovery 89%.
		End of Borehole		32'-0"			

SCALE : 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

UNIVERSAL GEOTECHNIQUE LIMITED

SOIL MECHANICS LABORATORY

BOREHOLE LOG

PROJECT C.P.R. Overhead, Bridge N° 11, Highway 401, Nassagaweya Twp. ORDER NO. T.246/57

CLIENT Department of Highways, Ontario.

BOREHOLE NO. BH. 10 DIAMETER 2-1/2" CASING 2-1/2"

BOREHOLE LOCATION See Plan INCLINATION Vertical BEARING —

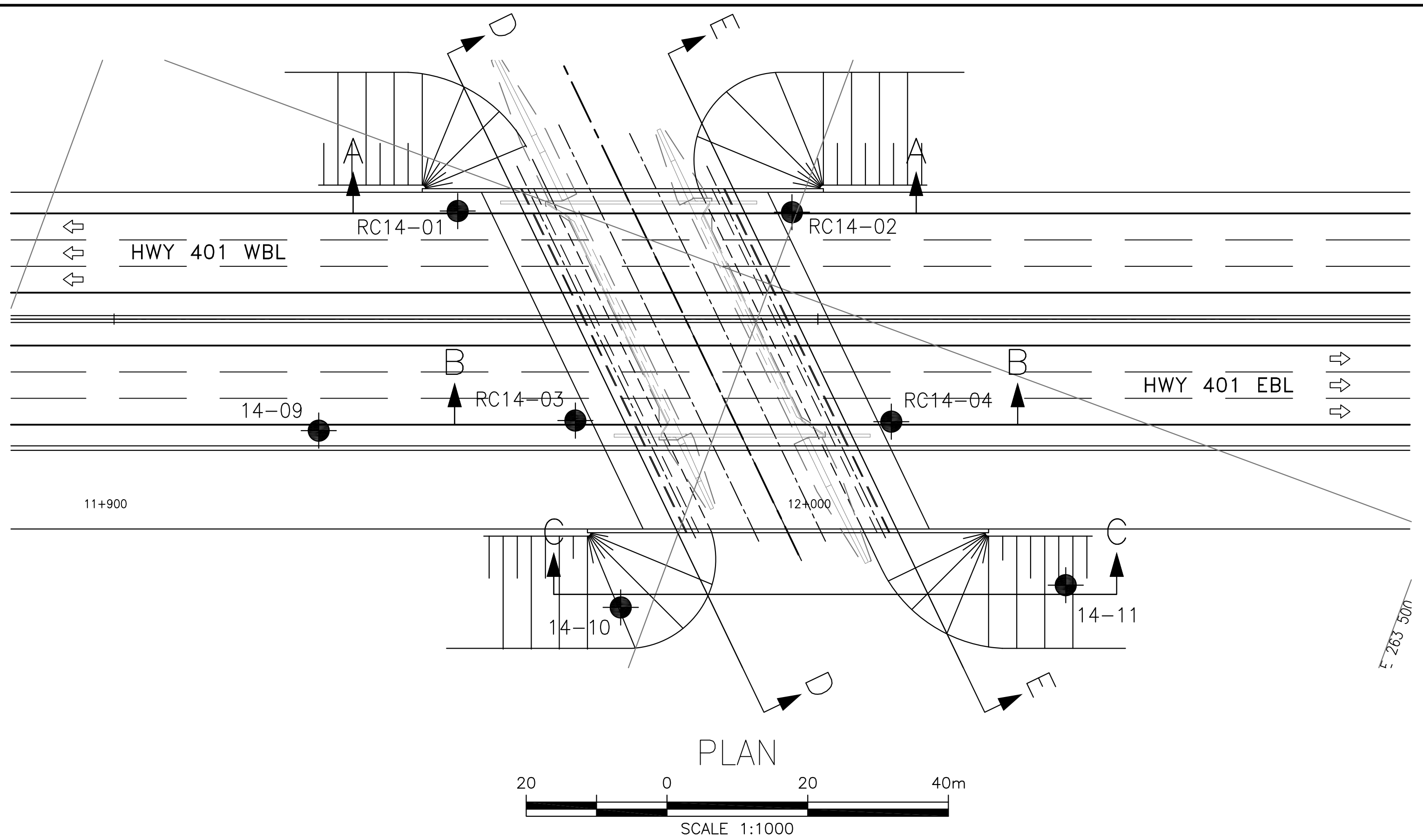
DESCRIPTION OF STRATA	ELEVATION	LEGEND	SAMPLE	DEPTH	THICKNESS	N	REMARKS
	966.9			Zero			
Loose brown SAND with fine gravel. Traces of organic matter.			● 1	1'-10"		5	Damp No dry strength.
Cavity.				4'-0"			
Firm brown fine to coarse SAND and fine to medium gravel, subangular to subrounded.			● 2			12	do
Dense do			● 3			30	do
do			● 4	10'-6"		31	Moist. No dry strength.
Firm do With clayey concentrations.			● 5			25	Moist. Low to medium dry strength.
do Little clay.			● 6			16	Wet Low dry strength.
Stiff reddish brown calcareous sandy gravelly CLAY. Gravel fine to medium, subangular to rounded.			● 7	26'-6"		14	Wet. Medium to high dry strength.
Greyish white porous dolomite with fossiliferous horizons. Extensive solution cavities partly filled. Exhibits secondary crystallization. Some jointing at 30° and perpendicular to core length, slight staining. Sound rock. Gasport member of the Lockport formation.				30'-6"			26'-6" to 30'-6" Core Recovery 92%
		End of Borehole					

SCALE: 1" = 5'-0" ● DISTURBED SAMPLE ▮ UNDISTURBED SAMPLE

Appendix D

Borehole Locations and Soil Strata Drawings

MINISTRY OF TRANSPORTATION, ONTARIO



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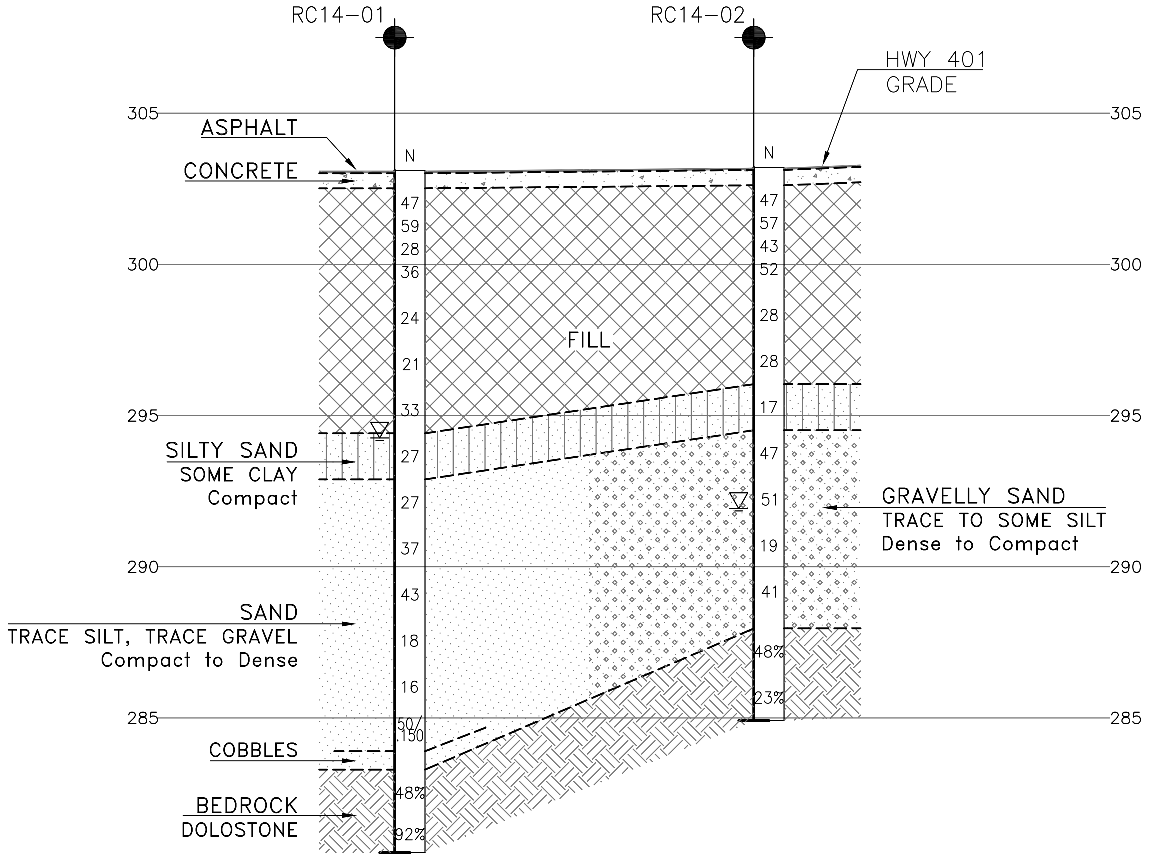
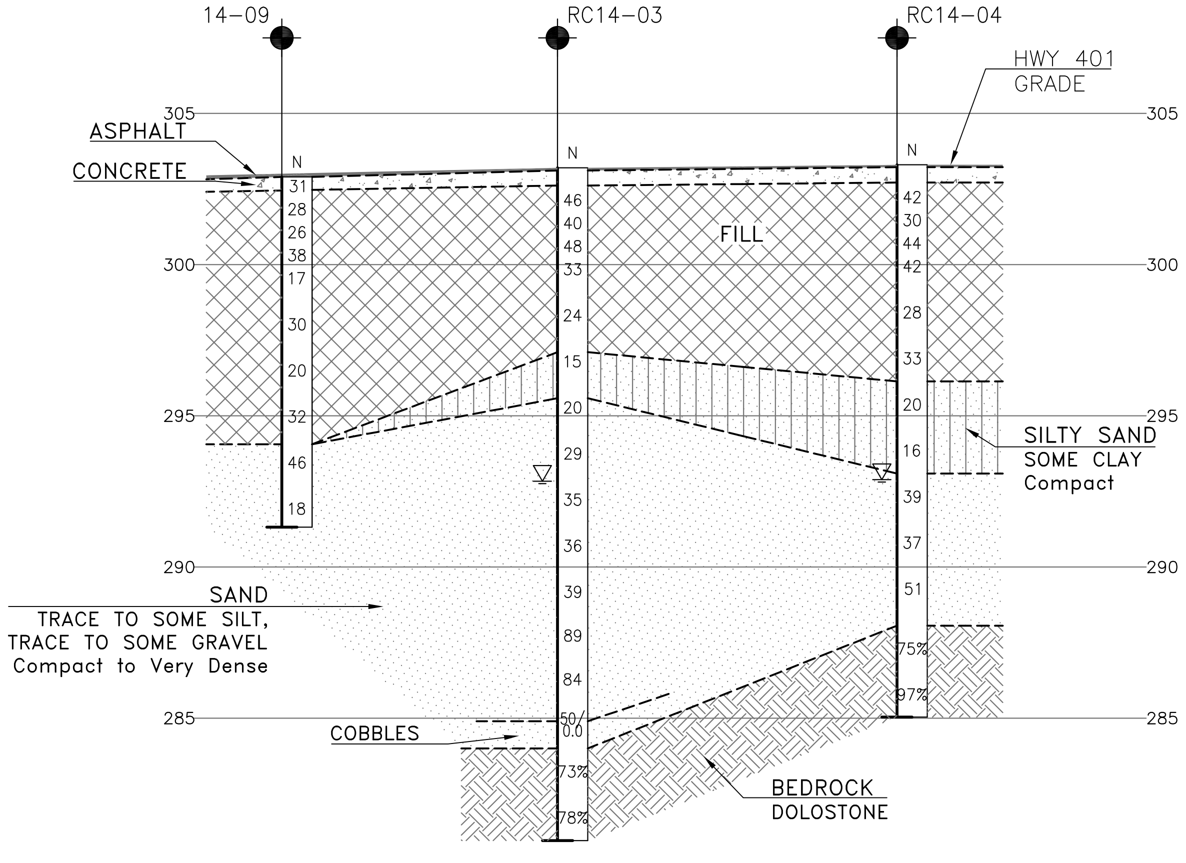


PROFILE A–A



PROFILE B–B

20 0 20 40m H 1:1000

5 0 5 10 V 1:250

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
Aug 14/14
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 14/14
PROVINCE OF ONTARIO

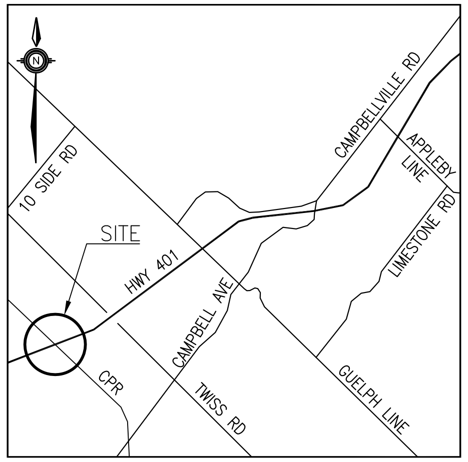
CONT No
WP No 2188-10-00

SHEET

HIGHWAY 401
CPR OVERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

AECOM

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
∇	Water Level
▼	Head Artesian Water
┃	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RC14–01	303.1	4 815 694.3	263 354.7
RC14–02	303.2	4 815 710.7	263 399.4
RC14–03	303.2	4 815 672.2	263 380.7
RC14–04	303.3	4 815 687.7	263 422.9
14–09	302.9	4 815 658.3	263 347.0
14–10	294.7	4 815 649.6	263 396.0
14–11	295.0	4 815 674.5	263 454.2

-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. 40P8-228

REVISIONS	DATE	BY	DESCRIPTION

DESIGN KS	CHK AEG	CODE	LOAD	DATE JUL 2014
DRAWN AN	CHK KS	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\19\5438\96\ted3896–Plan&Profile(RailwayCrossing).dwg
PLOTDATE: 8/20/2014 10:41 AM

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 2188-10-00

HIGHWAY 401
CPR OVERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

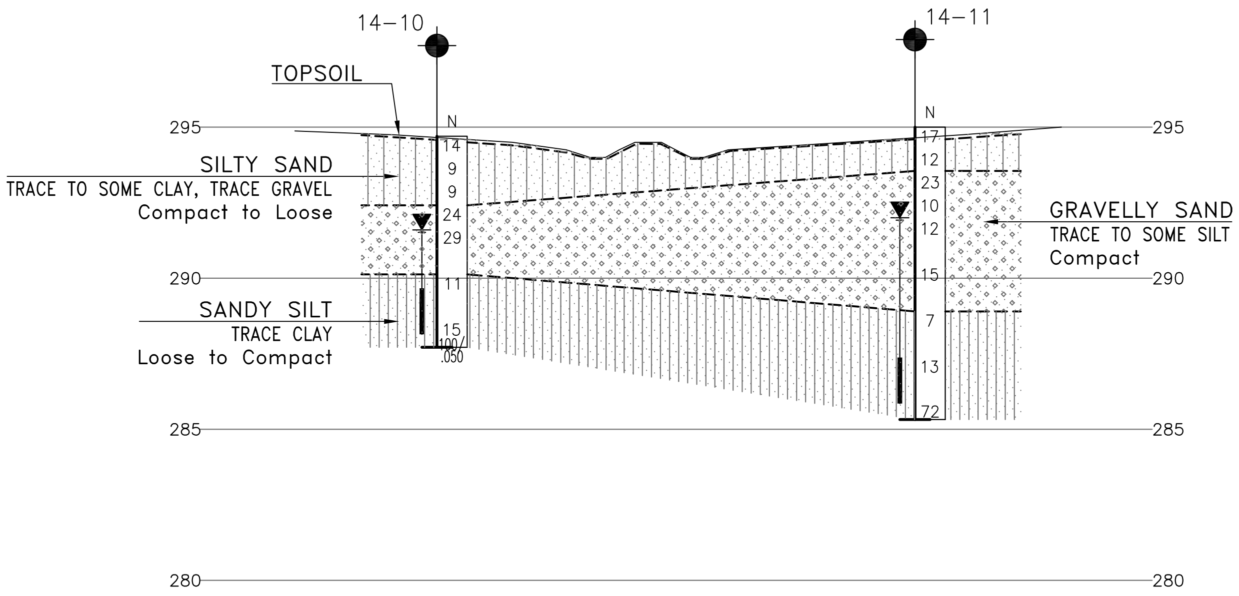
SHEET

AECOM

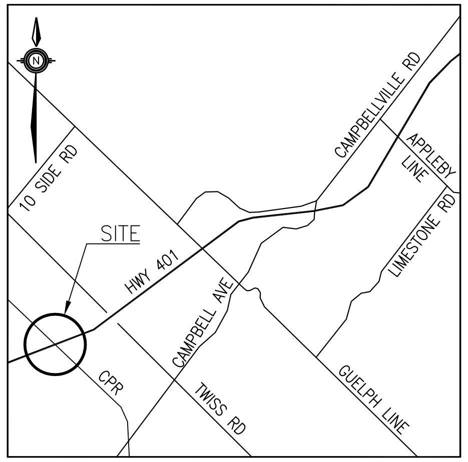
THURBER ENGINEERING LTD.

A. E. GORMAN
Aug 14/14

P. K. CHATTERJI
Aug 14/14



PROFILE C-C



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▼	Head Artesian Water
ǀ	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RC14-01	303.1	4 815 694.3	263 354.7
RC14-02	303.2	4 815 710.7	263 399.4
RC14-03	303.2	4 815 672.2	263 380.7
RC14-04	303.3	4 815 687.7	263 422.9
14-09	302.9	4 815 658.3	263 347.0
14-10	294.7	4 815 649.6	263 396.0
14-11	295.0	4 815 674.5	263 454.2

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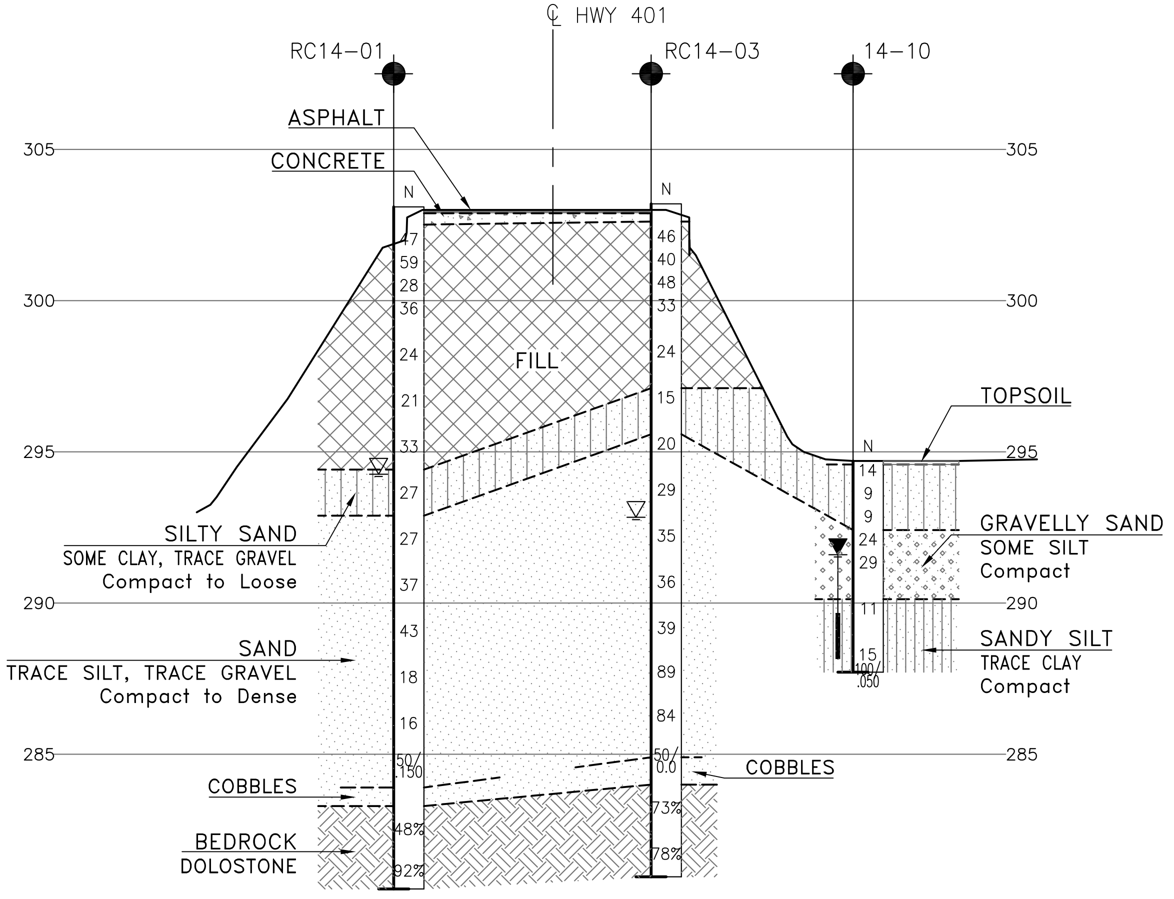
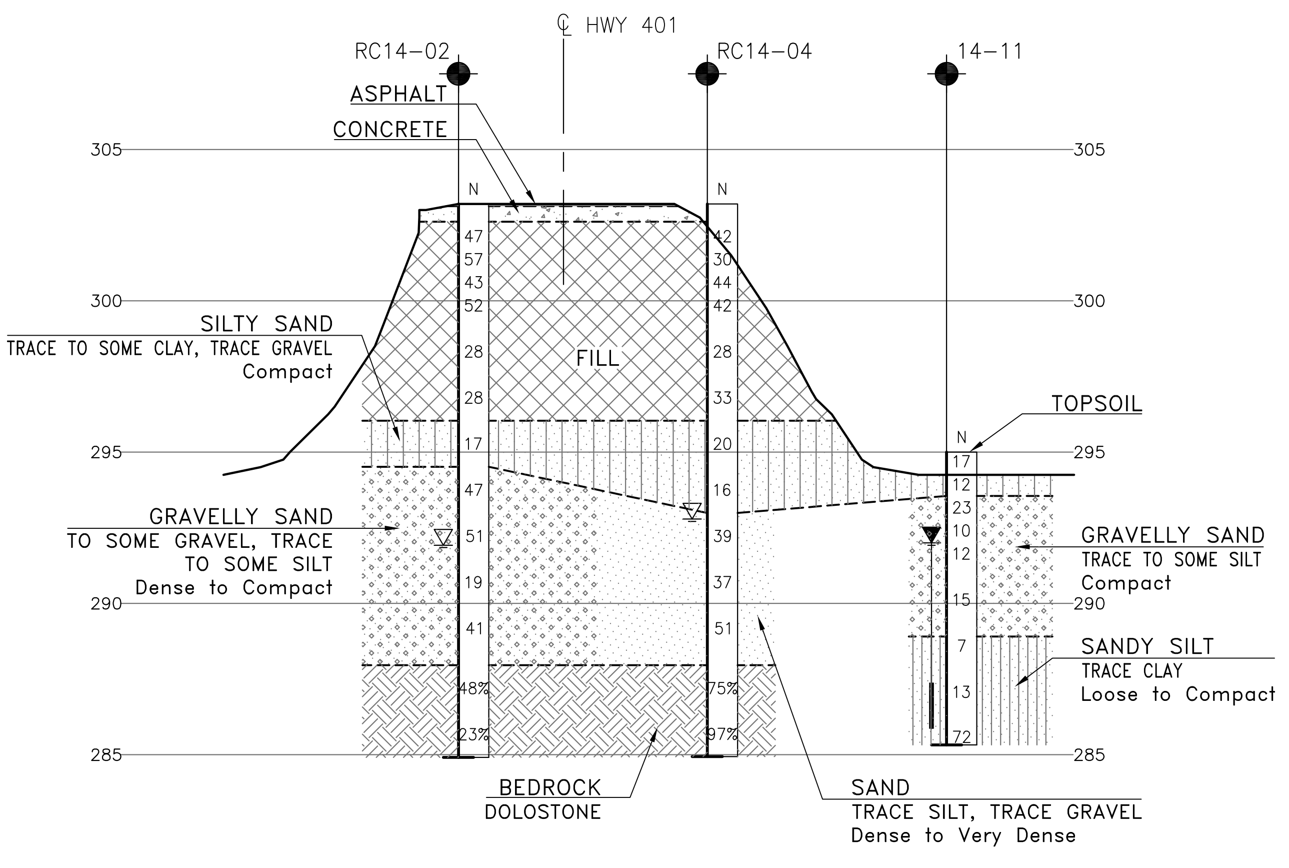
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 40P8-228



SECTION D-D



SECTION E-E

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5 0 5 10 V 1:250

REVISIONS	DATE	BY	DESCRIPTION

DESIGN KS	CHK AEG	CODE	LOAD	DATE JUL 2014
DRAWN AN	CHK KS	SITE	STRUCT	DWG 2

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PLOTDATE: 8/20/2014 10:41 AM

Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS.PROV 1010
- OPSD 208.010

2. Suggested Text for NSSP on "Preparation of Subgrade and Engineered Fill Pad for RSS"

Any topsoil, soft/loose native soil or disturbed fill should be stripped from the footprint of the RSS. A minimum 500 mm thick layer of bedding material conforming to OPSS Granular "A" requirements should be provided under the RSS mass to provide a uniform subgrade condition. Engineered fill placed under the RSS mass to achieve the design founding level should consist of OPSS Granular "A" compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered fill pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

Appendix F

Foundation Comparison

THURBER

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Engineered Fill	Driven H-Piles on/in Bedrock	Caissons / Drilled Shafts
Advantages: i. Ease of construction. ii. Lower cost than deep foundations. ***Disadvantages:*** i. Excavation may require temporary shoring. ii. Potential disturbance to the existing foundations under service. iii. Dewatering may be required, depending on depth of excavation. iv. Low resistance available. **FEASIBLE BUT NOT RECOMMENDED**	***Advantages:*** i. Generally less costly construction than deep foundation elements. ii. Higher geotechnical resistance than native soils. iii. Allows use of perched abutments. ***Disadvantages:*** i. Cost of engineered fill placement. ii. Potential disturbance to the existing footings under service. iii. Deeper excavation may be required compared to footings on native soils. iv. Dewatering may be required, depending on depth of excavation. **NOT RECOMMENDED**	***Advantages:*** i. Piles will develop high geotechnical resistance on bedrock. ii. Installation of piles could continue in freezing weather. iii. Allows integral abutment design. iv. Requires less excavation than footings. ***Disadvantages:*** i. Higher unit costs than footings. ii. Possibility that cobbles and boulders may be encountered in existing fill. iii. Piles at west abutment may encounter refusal on cobbles above bedrock surface to result in a lower axial capacity. **RECOMMENDED**	***Advantages:*** i. High resistance is available for caissons founded on bedrock. ii. Construction of caissons could continue in freezing weather. ***Disadvantages:*** i. Higher cost than footings. ii. Temporary liners will be required to install caissons in cohesionless sands/silts below groundwater level. iii. Difficulty in sealing liners at bedrock surface. iv. Possibility of cobbles and boulders being encountered during augering and liner installation. v. Difficulty in cleaning and inspecting bases. **NOT RECOMMENDED**