DRAFT

FOUNDATION INVESTIGATION AND DESIGN REPORT
HARVIE AND BIG BAY POINT ROAD UNDERPASS STRUCTURE
NEW CROSSING – HIGHWAY 400
BARRIE, ONTARIO

Geocres Number:

Report to

HATCH

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PART 1: FACTUAL INFORMATION

1.0 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed Highway 400 Underpass structure at the new crossing of Harvie Road and Big Bay Point Road in Barrie, Ontario.

The proposed structure will cross Highway 400 between the existing interchanges at Mapleview Drive to the south and Essa Road to the north. The structure will accommodate the future widening of Highway 400 as well as a potential future interchange at the site.

The purpose of the investigation was to explore the subsurface conditions at the proposed underpass structure location and, based on the data obtained, to provide borehole logs, borehole location plans, stratigraphic profiles, and a written description of the subsurface conditions at the site.

Thurber carried out the investigation as a sub-consultant to Hatch who are preparing the detailed crossing design for The City of Barrie.

2.0 SITE DESCRIPTION

The proposed new crossing of Highway 400 will connect Harvie Road currently terminated to the west of Highway 400, to Big Bay Point Road currently ending at Fairview Road to the east of Highway 400.

At present, Highway 400 at the proposed crossing site conveys six lanes of traffic, with three lanes in each direction, separated by a steel box guiderail and approximately 1.0 m wide paved median shoulders in both directions. At the proposed structure location, one additional through lane enters into the Barrie ONroute Service Centre in the northbound direction.

Harvie Road is a paved two-lane rural roadway which is presently closed approximately 600 m west of Highway 400. Existing Big Bay Point Road east of Fairview Road is a two lane municipal roadway with gravel shoulders.

The site is located at the south end of Barrie in a largely vacant area surrounded by commercial/light industrial development and residential subdivisions. The lands to the northwest and northeast of the site are generally forested with the exception of the service centre. Earthworks have been carried out on the lands to the south of Harvie Road, and the property on the south side of Big Bay Point Road was formerly occupied by a large brewery, since demolished.

A small watercourse (Whiskey Creek) crosses under Highway 400 from the southwest to northeast at the structure location, eventually discharging into Kempenfelt Bay. The invert level of the existing culvert under Highway 400 falls from Elev. 282.3 at the inlet to Elev. 281.4 at the outlet. The roadway surface on the Highway 400 embankment is at approximate Elev. 291.2. Photographs of the existing embankment are provided in Appendix C.

The study area is located within the western extent of the Peterborough Drumlin Field physiographic region, a rolling till plain located north of the Oak Ridges Moraine. This region generally comprises sandy till drumlins or drumlinoid hills with sand, silt or clay deposits in the intervening lowlands. At the site, the surficial materials are expected to comprise glaciofluvial ice-contact sands, with localized glaciolacustrine silt and clay deposits to the west of Highway 400. The underlying bedrock is expected to lie at a depth in excess of 100 m.

3.0 SITE INVESTIGATION AND FIELD TESTING

The site investigation at the proposed underpass location was carried out in several stages during the period November 4, 2016 to February 22, 2017. Seven boreholes were drilled for the proposed foundation units, two boreholes were advanced in the approaches, and three boreholes were drilled for the associated wingwalls. The borehole designations and depths are summarized in Table 3.1.

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings provided in Appendix G.

Table 3.1 – Borehole Designations and Depths

Borehole Location	Borehole No.	Borehole Depth (m)
West Abutment	UP-01	20.0
	UP-02	33.8
Pier	UP-03	35.3
	UP-04	30.9
East Abutment	UP-05	26.2
	UP-06	23.0
	UP-09	9.6
West Approach	UP-07	9.6
East Approach	UP-08	9.6
Northeast Wingwall	RW-01	18.7
Northwest Wingwall	RW-02	6.1
Southwest Wingwall	RW-03	9.6

All borehole locations were cleared of utilities prior to commencement of drilling. The boreholes were repositioned as necessary in consideration of surface features, underground utilities, and site access. Of note were the numerous underground utilities and overhead wires present along the Harvie – Big Bay Point Road corridor, steep slopes and ravines associated with Whiskey Creek, prohibition to close the service centre entrance lane, no permission to access the lands south of Harvie Road, and a large off-limits area preserved for archeological study to the north of Harvie Road.

Hollow stem augers were used to advance the boreholes in the overburden, and soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Portable tripod drilling equipment was employed to advance Borehole RW-02 in a ditch area inaccessible to a conventional drill rig.

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 for transport to Thurber’s laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Monitoring wells (50mm diameter) and standpipe piezometers (19mm diameter) were installed and enclosed in filter sand in selected boreholes to permit groundwater level monitoring and sampling for the concurrent hydrogeological study. The details of the monitoring wells and piezometers are shown in Table 3.2.

Table 3.2 – Piezometer Details

Borehole	Piezometer Tip		Instrument Type	Slotted Screen Length (m)
	Depth (m)	Elevation (m)		
UP-01	20.0	269.5	50mm Well	3.0
UP-06	21.1	266.4	50mm Well	3.0
RW-01	18.7	266.5	19mm piezometer	1.5

The boreholes in which no wells/piezometers were installed were backfilled with bentonite and cuttings to the ground surface in general accordance with MOE Regulation 903.

4.0 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Selected samples were subjected to gradation analysis. The results of this testing program are shown on the Record of Borehole sheets and on the laboratory test result figures attached in Appendix B.

5.0 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy are presented in Appendix A and on the “Borehole Locations and Soil Strata” drawings in Appendix G. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general terms, the subsurface stratigraphy encountered in the boreholes consists of a surficial topsoil layer or pavement structure, overlying a layer of silt/sand fill or native silt/sand, underlain by a deep deposit of sand.

More detailed descriptions of the individual strata are presented below.

5.1 Pavement Structure

Asphalt pavement was encountered in Boreholes UP-03 and UP-04 drilled in the paved median of Highway 400. The pavement structure consisted of 225 and 200 mm of asphalt overlying granular material extending to depths of 1.5 and 0.8 m (Elev. 289.2 and 290.1). Measured moisture contents in the granular material ranged from 2 to 10%.

5.2 Topsoil

A topsoil or organic layer was encountered at the ground surface in all boreholes except Boreholes UP-03 and UP-04. The thickness of the topsoil layer ranged from 40 to 180 mm, locally 600 mm in Borehole UP-07. The topsoil thickness may vary between and beyond the borehole locations.

5.3 Fill

Existing embankment fill was encountered below the pavement structure in Boreholes UP-03 and UP-04 drilled on Highway 400. The fill consisted of silty sand with a trace of clay or gravel. SPT ‘N’ values obtained in the fill generally ranged from 22 to 51 blows/0.3 m, indicating a compact to very dense condition. One value of 3 blows/0.3 m was obtained at the base of the fill in Borehole UP-03, indicating a very loose condition. Moisture contents of 5 to 18% were measured in the sand fill. The lower boundary of the fill was encountered at depths of 8.7 and 5.6 m (Elev. 282.0 and 285.3).

Fill material was also encountered in Boreholes UP-05, UP-06, UP-08 and RW-01 located adjacent to the east side of Highway 400. The fill consisted of sand to silt with trace to some clay and/or gravel, locally clayey sandy silt. SPT ‘N’ values in this fill ranged from 2 to 16 blows/0.3 m, indicating a very loose to compact condition. One ‘N’ value of 32 blows/0.3 m was recorded in Borehole UP-06, indicating a dense condition. Moisture contents of 5 to 18% were measured in the fill. The lower boundary was encountered at depths of 1.5 to 3.1 m (Elev. 285.8 to 282.4).

The results of grain size distribution tests carried out on the fill are shown on Figure B1 in Appendix B and summarized below:

Gravel (%)	0 to 14	
Sand (%)	47 to 80	
Silt (%)	25 to 37	7 to 11
Clay (%)	4 to 25	

5.4 Sand and Silt

Cohesionless deposits varying in gradation from sand with some silt to silt with some sand were encountered below the topsoil and fill in Boreholes UP-01, UP-02, UP-07, and RW-01 to RW-03. The total thickness of these units ranged from 1.1 to 2.6 m, with a lower boundary at depths of 1.2 to 4.1 m.

SPT ‘N’ values of 4 to 61 blows/0.3 m were obtained in the sand/silt deposits, indicating a loose to dense relative density. Typically the ‘N’ values ranged from 4 to 7 blows/0.3 m (loose) immediately below the topsoil and from 14 to 22 blows/0.3 m (compact) below this level. Measured moisture contents ranged from 5 to 22%.

The results of grain size distribution tests carried out on the sands and silts are shown on Figure B2 in Appendix B and summarized below:

Gravel (%)	2 to 14
Sand (%)	49 to 71
Silt (%)	14 to 32
Clay (%)	4 to 17

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5.5 Sand

A deep deposit of sand was encountered below the topsoil, fill and upper sand/silt deposits in all boreholes at depths of 0.1 to 8.7 m (Elev. 287.1 to 281.1). This deposit typically consisted of fine to medium grained sand with trace silt and gravel; several zones graded to silty or gravelly sand. All boreholes were terminated in the sand at depths of 6.1 to 35.3 m (Elev. 249.8 to 279.5).

SPT ‘N’ values recorded in the sand deposit typically exceeded 50 blows/0.3 m penetration, indicating a very dense relative density. The upper 0.5 to 3.5 m of this unit was very loose to compact in Boreholes UP-02 to UP-05, UP-09, RW-01 and RW-02, and a locally deeper zone of compact to dense material (‘N’ values of 21 to 44 blows/0.3 m) was encountered to a depth of 19.2 m (Elev. 271.5) in Borehole UP-03. Boreholes UP-01 to UP-06 were terminated in the sand at depths of 20.0 to 35.3 m (Elev. 249.8 to 269.5) upon recording at least three ‘N’ values exceeding 100 blows/0.3 m.

Measured moisture contents in the sand generally ranged from 1 to 12%, increasing to about 18 to 24% below depths of 20 to 25 m. The results of grain size distribution tests carried out on sand samples are shown on Figures B3 to B6 included in Appendix B and also summarized below:

	Typical	Gravelly Zones	Silty Zones
Gravel (%)	0 to 5	29 to 35	0
Sand (%)	86 to 97	59 to 66	73 to 77
Silt & Clay (%)	3 to 14	5 to 6	23 to 27

5.6 Silt

A silt layer was encountered within the sand deposit in Borehole UP-05, between depths of 19.1 and 20.9 m. The silt was very dense as evidenced by a recorded 'N' value of 109 blows/0.3 m. A moisture content of 21% was measured.

The results of a grain size distribution test carried out on the silt are shown on Figure B7 included in Appendix B and also summarized below:

Gravel (%)	0
Sand (%)	5
Silt (%)	90
Clay (%)	5

5.7 Groundwater Levels

Groundwater conditions were observed in the boreholes during and upon completion of drilling, and water levels in the monitoring wells and piezometers were subsequently recorded. The groundwater depths and elevations observed in the open boreholes and measured in the wells/ piezometers after drilling are summarized in the following table.

Table 5.1 - Recorded Groundwater Depths and Elevations

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
UP-01	Nov. 10, 2016 Mar. 30, 2017	12.9 19.4	276.6 270.1	Upon completion In monitoring well
UP-02	Nov 17, 2016	3.2	280.4	Upon completion
UP-03	Feb. 22, 2017	9.3	281.4	Upon completion
UP-04	Feb. 17, 2017	6.4	284.5	Upon completion
UP-05	Nov. 09, 2016	13.0	273.8	Upon completion
UP-06	Nov. 07, 2016 Mar. 30, 2017	16.3 19.1	271.0 268.2	Upon completion In monitoring well
RW-01	Jan. 25, 2017 Mar. 30, 2017	15.8 17.0	269.4 268.2	Upon completion In piezometer
RW-03	Jan. 16, 2017	5.6	282.7	Upon completion

The above water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.

6.0 MISCELLANEOUS

Thurber Engineering positioned the boreholes in the field using a hand-held GPS unit, with consideration of site features and access limitations. The co-ordinates and ground elevations at the borehole locations, excepting the boreholes located on Highway 400, were subsequently determined by DFP Surveyors.

Walker Drilling of Utopia, Ontario supplied and operated the drilling and sampling equipment for the field program.

Full time supervision of the field activities, including obtaining utility clearances, was carried out by Ms. Eckie Siu and Mr. Stephane Loranger of Thurber Engineering. Overall supervision of the field program was performed by Mr. Mohamed Hosney, P.Eng. and Mr. Murray Anderson, P.Eng. of Thurber.

Interpretation of the field data and preparation of the report were performed by Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7.0 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist selection and design of the foundation system for the new Harvie Road – Big Bay Point Road underpass structure at Highway 400.

A new crossing of Highway 400 is planned, connecting Harvie Road from the west with Big Bay Point Road to the east of Highway 400. Based on the preliminary General Arrangement drawing, the new crossing will comprise a two span underpass structure with a total span length of 90 m and a width of 29.2 m. The structure will be designed to cross over the future widened Highway 400 consisting of six general purpose lanes and two HOV lanes. Highway 400 is presently a six lane highway with a steel box guiderail in the median.

Proposed finished grades on the structure will range from approximate elevation 299.5 at the west abutment to elevation 298.6 at the east abutment. The structure approach embankments will have a height in the order of 10 to 16 m. Grades on Highway 400 are near elevation 291.0 at the crossing.

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

The interpretation and recommendations are intended for the use of the design consultant and the City of Barrie, and shall not be relied upon by any other parties including the construction contractor, or used for any purposes other than development of the project design. Comments on construction methodology and equipment, where presented, are provided only to highlight those aspects that could affect the design of the project. Contractors must make their own assessment of the factual information presented in Part 1 of the report, and the implications on equipment selection, construction methodology, and scheduling.

8.0 FOUNDATION DESIGN

In general terms, the subsurface stratigraphy encountered at the underpass location consists of a surficial topsoil layer or pavement structure, overlying a layer of silt/sand fill or native silt/sand, underlain by a deep deposit of sand. The sand is typically very dense, locally very loose to compact within the upper 0.5 to 3.5 m of this unit. The groundwater level was measured at depths of 17.0 to 19.4 m in the monitoring wells/piezometers.

Based on the subsurface conditions at the site, consideration was given to supporting the structures using the following foundation types:

- Spread footings on native soil or engineered fill
- Driven steel H-piles
- Drilled shafts (caissons)

A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix D. Recommendations for feasible foundation alternatives are presented in the following sections. A foundation scheme preferred from a foundations perspective is then recommended.

8.1 Spread Footings on Native Soil

Based on the subsurface conditions encountered at this site, consideration may be given to supporting the proposed structure on spread footings founded in the native sand. However, the borehole information indicates that the depth to competent sand capable of supporting the structural loads varies significantly with location, and the required excavation depths are expected to make the use of spread footings impractical.

If employed, spread footings should be founded on the dense to very dense native sand at least 1.5 m below finished grade. The recommended geotechnical resistances for footings founded at or below the noted elevations are presented in Table 8.1.

The geotechnical resistances at SLS are based on an estimated settlement not exceeding 25 mm. This settlement should be essentially complete by the end of construction.

Table 8.1 – Recommended Geotechnical Resistances for Spread Footing Design

Foundation Unit	Borehole	Highest Founding Level	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Resistance at SLS (kPa)
West Abutment	UP-01	287.1	600	400
	RW-02	279.8	600	400
	UP-02	279.1	600	400
Pier	UP-03	278.5 272.5	500 600	300 400
	UP-04	283.3	600	400
East Abutment	UP-05	283.8	600	400
	UP-09	281.8 280.3	600 600	400 400
	UP-06	285.8	600	400

The resistance values are for a minimum 2 m wide footing subjected to vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with the CHBDC Clauses 6.10.2 to 6.10.4.

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

All footings should be provided with a minimum of 1.5 m of earth cover over the footing base as protection against frost action.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed surface conforms to the design requirements, has been adequately prepared to receive concrete, and consists of undisturbed native sand.

Founding surfaces should be protected from disturbance during construction. The exposed surface should be protected from deterioration by placing a minimum 75 mm thick working mat of concrete immediately following approval of the founding surface.

8.2 Spread Footings on Engineered Fill

Construction of spread footings on engineered fill placed over the dense to very dense sand may be considered for the abutments. Use of engineered fill at the pier is not recommended in view of the additional depth of excavation required for fill construction and the spatial constraints within the median of the existing highway.

The underside of the engineered fill pad should extend down to the higher elevations given for the foundation elements 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 and generally conforming to the geometry illustrated in Figure 1, Appendix E.

Provided a minimum footing width of 2 m is maintained, a footing bearing on the engineered fill may be designed for a concentric, vertical geotechnical resistance of 900 kPa at factored ULS and a geotechnical reaction of 350 kPa at SLS. The engineered fill pad should be at least 1.2 m thick at the east abutment to achieve these resistance values.

The resistance values are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clauses 6.10.2 to 6.10.4.

For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is not expected to exceed 25 mm. Differential settlements are not expected to exceed 20 mm across the width of the structure.

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

8.3 Driven Steel H-Pile Foundations

The soil 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 into the very dense sand deposit encountered at depths of 2.4 to 19.8 m in the boreholes. The piles will derive resistance through both skin friction along the pile shaft as well as end-bearing at the pile tip. The axial geotechnical resistances recommended for steel HP 310x110 piles driven to the design capacity in the very dense sand are as follows:

Factored Geotechnical Resistance at ULS = 1,600 kN

Geotechnical Resistance at SLS = 1,400 kN

The pile tip elevations will be controlled as described in Section 8.3.3 Pile Installation. For estimating purposes, the anticipated pile tip elevations are as follows:

Table 8.2 – Anticipated Pile Tip Elevations

Foundation Unit	Anticipated Pile Tip Elevation
West Abutment	270 North End 260 South End
Pier	260
East Abutment	268

8.3.2 Pile Tips

Pile tip protection should not be provided for driven H-piles at this site as the piles are expected to derive a large proportion of the geotechnical resistance through skin friction along the pile shaft. Care must be taken while driving the piles to avoid overdriving and damaging the pile when setting into the very dense sand.

8.3.3 Pile Installation

Pile installation should be in accordance with OPSS 903.

Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance should be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of “R” kN per pile”. “R” must have a value of two times the design load at ULS calculated by the structural engineer.

In view of the highly variable elevation at which refusal blow counts (SPT ‘N’ values greater than 100 blows/0.3 m) were obtained in the boreholes, the piles are likely to achieve the specified resistance at different elevations. Variable pile lengths and the need for additional splicing and/or cutting of piles must be anticipated during installation. Driving must be terminated before the pile is damaged by overdriving.

To facilitate pile installation, embankment fill through which piles may be driven must not contain oversize material, i.e. no particles exceeding 75 mm in size.

8.3.4 Downdrag

As the underlying soils consist primarily of dense to very dense cohesionless sands, downdrag on the piles is not an issue at this site.

8.3.5 Lateral Pile Resistance

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

$$k_s = n_h \, z / D \quad (kN/m^3)$$

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

Where z = depth of embedment along 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 above equations and recommended parameters in Table 8.3 below may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

Table 8.3 – Soil Parameters for Lateral Pile Design

Foundation Unit	Soil Type	Elevation (m)		γ' (kN/m^3)*	n_h (kN/m^3)	K_p
		Top	Bottom			
West Abutment	Fill	290	283	21	5,000	3.2
	Loose sand	283	280	20	3,000	3.0
	Dense sand	280	270	21	10,000	3.7
	Dense sand	270	250	11	6,500	3.7
Pier	Fill	290	283	21	5,000	3.2
	Compact sand	283	272	21	5,000	3.2
	Dense sand	272	270	21	10,000	3.7
	Dense sand	270	255	11	6,500	3.7
East Abutment	Fill	290	283	21	5,000	3.2
	Dense sand	283	270	21	10,000	3.7
	Dense sand	270	260	11	6,500	3.7

*Buoyant unit weight below the water table.

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.

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.

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

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

8.3.6 Integral Abutment Considerations

The ground conditions at this site are considered suitable for an integral abutment design. The use of H-piles at the abutments allows for the design of an integral abutment structure.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. The near surface native soils at this site are locally dense to very dense and the lateral resistance of a pile in this soil may not provide sufficient flexibility. In addition, the upper 3 m of the pile may lie within the compacted fill of the approach embankment. Accordingly, to provide the required flexibility in the piles, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP as specified by the integral abutment design procedures.

After the pile is driven, the space between the pile and the CSP should be filled with sand. An NSSP should be included in the contract drawings specifying the gradation of the sand according to Table 8.5.

Table 8.5 – Integral Abutment Sand Backfill Grading

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80% - 100%
425 µm	#40	40% - 80%
250 µm	#60	5% - 25%
150 µm	#100	0% - 6%

8.4 Drilled Shafts (Caissons)

The use of augered caissons founded in the dense to very dense native sand may be considered. It must be noted however that caisson installation will extend through cohesionless embankment fill (at the pier) and native sand, potentially below the groundwater table depending on the required caisson length. A temporary liner will be required to support the caisson sidewalls in the cohesionless deposits, and further measures such as the use of drilling mud and/or tremie concrete may be required where caissons extend below the water level.

Recommendations for caisson design are provided in the following sections.

8.4.1 Axial Capacity

The recommended axial geotechnical resistances for augered caissons of selected diameters and base levels are presented in Tables 8.6 and 8.7, below. In general, the values are based on very dense conditions existing along the full length of caisson shaft and at the base. Lower resistance values are provided for caissons at the pier in view of the compact to dense conditions identified above approximate Elev. 272 in Borehole UP-03.

The designer should evaluate the serviceability requirements to determine the appropriate SLS values (10 mm or 25 mm of permissible axial displacement) to use in design, as per the CHBDC 2014 Commentary C6.11.2.1.2.

Downdrag on the caisson is not considered to be an issue at this site.

Table 8.6 – Recommended Axial Resistances for Caisson Design at Abutments

Caisson Base Elevation	Factored Axial Resistance at ULS (kN)	Axial Resistance at SLS (kN) – 10 mm axial displacement	Axial Resistance at SLS (kPa) – 25 mm axial displacement
0.9 m diameter			
275	1700	1000	2000
270	2600	1400	2400
265	3300	1700	2700
1.2 m diameter			
275	2900	1400	2800
270	4400	1800	3200
265	5500	2300	3500
1.5 m diameter			
275	4400	1700	3500
270	6600	2300	4100
265	8100	3000	4700
1.8 m diameter			
275	6400	2100	4300
270	9300	2900	5000
265	11300	3600	5700

Table 8.7 – Recommended Axial Resistances for Caisson Design at Pier

Caisson Base Elevation	Factored Axial Resistance at ULS (kN)	Axial Resistance at SLS (kN) – 10 mm axial displacement	Axial Resistance at SLS (kPa) – 25 mm axial displacement
0.9 m diameter			
275	1100	600	1200
270	2400	900	1700
265	3000	1400	2400
1.2 m diameter			
275	1900	800	1700
270	4000	1200	2300
265	5000	1900	3200
1.5 m diameter			
275	2900	1000	2100
270	6200	1600	2900
265	7700	2400	4100
1.8 m diameter			
275	4100	1200	2600
270	8800	1900	3600
265	10800	2900	5000

8.4.2 Caisson Installation

Caisson installation must be in accordance with OPSS 903.

The caissons will generally be advanced through dense to very dense sand and sand fill, locally loose sand near the ground surface. The caisson drilling equipment supplied by Contractor must be capable of advancing through these materials and penetrating very dense material. Further, the potential exists for encountering obstructions in the existing embankment fill.

The sand and embankment fill are typically cohesionless, and a temporary steel liner will be required to support the caisson sidewalls in these materials. If the caissons extend below the groundwater level, anticipated near Elev. 270 at the site, additional measures such as the use of drilling mud and/or placement of concrete using tremie methods may be required to avoid hydraulic disturbance and heave at the caisson base. Temporary liners should be removed as the concrete is placed to enable the caisson to develop resistance along the shaft sidewalls.

8.4.3 Caisson Lateral Resistance

The geotechnical lateral resistance of a pile in cohesionless soil may be calculated using a coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as outlined in Section 8.3.5.

8.5 Recommended Foundation

From a geotechnical perspective, the preferred foundation option to support the underpass structure comprises steel H-piles driven to the design resistance in the very dense native sand underlying the site. The use of H-piles also enables integral abutment design. The use of augered caissons may be preferred at the pier in view of the narrow work zone available in the highway median.

9.0 FROST COVER

The depth of frost penetration at this site is 1.5 m. The base of footings or pile caps must be provided with a minimum of 1.5 m of earth cover as protection against frost action.

10.0 ABUTMENT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the abutments should consist of free-draining granular material conforming to OPS Granular A or B Type II specifications. The granular material should be placed to the extents shown in OPSD 803.010.

Heavy compaction equipment should not be used adjacent to the abutment walls. Compaction should be carried out in accordance with OPSS 501.

Earth pressures acting on the structure may be assumed to impose a triangular distribution 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:

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

Where:
- p = horizontal earth pressure on the wall at depth h (kPa)
- K = earth pressure coefficient (see table below)
- γ = unit weight of retained soil (see table below)
- h = depth below top of fill where pressure is computed (m)
- q = value of any surcharge (kPa)

The earth pressure coefficients are dependent on the material used as backfill. Recommended unfactored values are shown in Table 10.1. The at-rest coefficients should be employed for restrained walls. Active pressures should be used for any wingwalls or unrestrained walls.

Table 10.1 – Lateral Earth Pressure Coefficients

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	0.39*	0.31	0.47*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wing walls.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC.

In accordance with Clause 6.12.3 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 1.7 m for Granular A or Granular B Type II.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is generally preferred as it results in lower earth pressures acting on the wall. In the case of integral abutments, material with a lower passive pressure coefficient (e.g. Granular B, Type I) might be preferred as it results in lower forces acting on the ballast wall as the wall moves towards the soil mass.

The design of the abutment walls must incorporate measures such as weep holes to permit drainage of the backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

11.0 RETAINED SOIL SYSTEMS

Details of retaining walls to be employed for wingwalls or approach embankments have yet to be established. If required, the use of retained soil systems (RSS walls) is considered to be feasible at this site.

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.

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 soil conditions at the wall base levels are generally expected to comprise compact to very dense sand to sand and silt. Loose zones may be present locally, as identified in Boreholes UP-02 and UP-09, and existing fill may also be present at the founding level.

Based on the borehole data, the RSS walls should be founded on the native soils at or below the levels indicated in Table 11.1. Alternatively, the RSS may be constructed on granular engineered fill placed to raise the wall base level.

Table 11.1 – Highest Recommended Founding Levels for RSS Walls

Location	Boreholes	Highest Recommended Base Level
West Abutment	RW-02 UP-02 RW-03	283.7 279.0 287.7
East Abutment	RW-01 UP-05 UP-09 UP-06	282.4 284.4 282.5 285.8

Where the design founding level is above that indicated in Table 11.1, engineered fill should be used to raise the grade. 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.

The RSS walls should be founded below the level of all fill, topsoil, organic material, and very loose sand. Locally within the creek ravine (e.g., Borehole UP-02), the loose sand extends to depths of up to 4.5 m below the ravine base level. Full excavation of these loose deposits may not be practical. In these areas, sub-excavation of loose sand need not exceed a depth of 2.5 m below the existing ground surface.

Walls founded on engineered fill or compact to very dense native sand should be designed for a factored geotechnical resistance at ULS of 600 kPa. The computed geotechnical resistance at SLS is 250 kPa for 25 mm of settlement and 400 kPa for 40 mm of settlement. Settlement is expected to be essentially complete at the end of construction.

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 2014. The resistance values assume that the RSS wall reinforcement will extend a distance behind the wall face of approximately 70% of the wall height.

The RSS wall must also be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall on native sand or engineered fill may be estimated using an ultimate friction coefficient of 0.5 and 0.6, respectively. The internal stability of the RSS wall should be analysed by the supplier/designer of the proprietary product selected for this site.

The global stability of the RSS wall is dependent on the characteristics of the foundation soils, the geometry of the embankment and location of the RSS within the embankment. Considering the compact to very dense conditions of the native sand subgrade at the site, global stability of the RSS walls is not expected to be a concern. The stability should be confirmed when further details of the wall design are established.

12.0 SEISMIC CONSIDERATIONS

In accordance with the CHBDC, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the ground profile. The stratigraphy at this site generally consists of surficial fill and sand/silt deposits, underlain by dense to very dense sand to depths exceeding 30 m. As per Table 4.1, Clause 4.4.3.2 of the CHBDC, the site may be classified as Seismic Site Class C (very dense soil and soft rock).

Based on the National Building Code of Canada (NBCC 2015), the peak horizontal ground acceleration (PGA), corresponding to a design earthquake having a 2 percent probability of being exceeded in 50 years (i.e. 2,475 year return period) is 0.064 g at the site.

Based on review of the SPT data, seismically-induced liquefaction of foundation soils is not anticipated under the design earthquake.

13.0 APPROACH EMBANKMENTS

The foundation soils encountered below the proposed approach embankments generally consist of a layer of compact sand/ silt overlying dense sand. The maximum proposed embankment height will be approximately 16.0 m above the base of the existing creek channel.

Stability analyses were carried out for a maximum 16 m high fill embankments at the immediate approaches to the proposed underpass. The stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 7) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses. The slope model and geotechnical parameters used in the analysis, along with the analysis results, are presented on Figure F1 in Appendix F.

The minimum computed factor of safety against slope instability was approximately 1.5 for both short-term and long-term conditions. Global stability of the embankments with standard side slope inclinations of 2H:1V is therefore not expected to be an issue.

The estimated foundation settlement beneath the new embankment fill is expected to be in the order of 150 mm under the highest fill, and be essentially complete at the end of construction. Settlement due to compression of the compacted embankment fill under self-weight is expected to be a maximum of 80 mm, and be completed within one to two years after construction. The fill should be placed prior to pile installation to minimize potential deflection of the piles, and pavement construction should be delayed at least two months after embankment construction.

Embankment construction should be carried out in accordance with OPSS.PROV 206. Materials used to construct the embankments should comprise granular materials or Select Subgrade Material (SSM) in compliance with OPSS.PROV 1010, earth borrow as per OPSS 212, or on-site inorganic materials subject to geotechnical approval.

Mid-height berms comprising 2 m wide benches must be incorporated along the length of embankments with heights exceeding 8 m in earth fill. Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface, the existing earth or fill slope must be benched in accordance with OPSD 208.010.

Earth fill embankment slopes must be provided with erosion protection in accordance with OPSS.PROV 804. Design and implementation of the erosion protection works should include consideration of the surficial stability under heavy, prolonged rainfall and spring thaw conditions. Vegetation must be sufficiently established before the onset of winter. Use of granular sheeting may also be considered.

To minimize the erosion potential, surface water should be directed away from the embankment slopes and conveyed down the slope in appropriately designed drainage channels or storm sewers. In this regard, a curb and gutter system is recommended at the pavement edge. Consideration should also be given to adopting flatter slope inclinations in sections of high uninterrupted slopes to increase infiltration and reduce flow velocities.

14.0 EXCAVATION AND GROUNDWATER CONTROL

All excavation must be carried out in accordance with OPSS 902 and the Occupational Health and Safety Act (OHSA). For the purposes of assessing excavation slope requirements in compliance with the OHSA, the fill and upper loose to compact sand/silt deposits are classified as Type 3 soils. The underlying dense to very dense sand is classified as Type 2. Saturated cohesionless soils encountered within the creek may flow upon excavation and should be classified as Type 4 soils if flow diversion and/or dewatering in not provided.

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 and potential obstructions in the fill.

Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. Based on available subsurface information, a shoring system consisting of sheet piling or steel H-piles with timber lagging may be considered. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces.

Based on the water levels measured in the monitoring wells and piezometers, the groundwater level at the site is greater than 10 m below the ground surface and is not expected to impact foundation excavations, with the exception of caisson excavations extending below Elev. 270. However, Whiskey Creek appears to flow in a perched channel condition, and water should be anticipated during excavation at the ravine base. Provided the creek flow is diverted from the construction area, dewatering measures such as pumping from filtered sumps should be adequate to remove any accumulation of water in footing/pile cap excavations. All footings/pile caps must be constructed in the dry.

Selection of the equipment and methodology to excavate and prepare the subgrade is the responsibility of the Contractor. The design of the shoring and dewatering system that may be required is also the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.

15.0 CONSTRUCTION CONCERNS

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

- Driven steel H-piles may develop the design resistance or encounter refusal at varying depths in the very dense sand deposits at this site. If the pile tip elevations vary by more than 3 m from the predicted values, the design team should be notified and permitted to review the possible implications. Allowances for adjustments such as additional splicing should be made for potential varying pile lengths.

- Fill, organic deposits or very loose native soil may locally extend to greater depths than identified in the boreholes. Additional sub-excavation may therefore be required prior to footing and embankment construction or for engineered fill placement under RSS walls.

- Temporary steel liners will be required during construction to support the caisson sidewalls in the cohesionless fill and sand deposits. If the caissons extend below the groundwater level, additional measures such as the use of drilling mud and/or placement of concrete using tremie methods may be required to avoid hydraulic disturbance and heave at the caisson base.

- Excavation within the creek ravine may encounter perched water. Stream diversion and additional dewatering measures may be required to provide stable excavations and enable construction in the dry.

- An existing culvert passes under the alignment of the proposed bridge pier. Deep foundations for the pier should be positioned to avoid the existing culvert (to be abandoned), or pile/caisson installation operations will need to penetrate the culvert if left in place. Installation of roadway protection structures must also anticipate the presence of the culvert.

16.0 CLOSURE

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

Thurber Engineering Ltd.

Murray R. Anderson, P.Eng.
Senior Geotechnical Engineer

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

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

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

2. COMPLETE REPORT

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

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

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5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

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

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HKH/LG_Dec 2014

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction
1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

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.

<u>UNIFIED SOILS CLASSIFICATION</u>

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

RECORD OF BOREHOLE No UP-01

METRIC

W.P.		ORIGINATED BY	ES
HWY	400	COMPILED BY	AN
DATUM	Geodetic	CHECKED BY	MH
LOCATION	Harvie / Big Bay Point Road N 4 912 086.9 E 289 758.5		
BOREHOLE TYPE	Hollow Stem Augers		
DATE	2016.11.09 - 2016.11.10		

Column headings: SOIL PROFILE (ELEV/DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (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)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
289.5	GROUND SURFACE							
0.0 / 0.1	**TOPSOIL:** (60mm)							
	SAND and **SILT**, trace gravel, trace roots Loose to Very Dense Brown Moist	1	SS	6				
		2	SS	47				
		3	SS	61	8	53	39 (SI+CL)	
287.1 / 2.4	**SAND**, fine grained, trace silt, trace gravel Very Dense Light Brown Moist	4	SS	97				
		5	SS	93				
		6	SS	100/ 0.275				
		7	SS	100/ 0.250				
		8	SS	98				
		9	SS	101				

Elevation scale: 289, 288, 287, 286, 285, 284, 283, 282, 281, 280

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Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No UP-01

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 086.9 E 289 758.5 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.09 - 2016.11.10 CHECKED BY MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SAND, fine grained, trace silt, trace gravel Very Dense Light Brown Moist				279						
		10	SS	115		o		2	93	5 (SI+CL)	
					278						
		11	SS	109/ 0.250	277	o					
					276						
	Occasional black sand seam	12	SS	111		o					
					275						
		13	SS	102/ 0.250	274	o					
					273						
		14	SS	101/ 0.250		o		1	91	8 (SI+CL)	
					272						
		15	SS	104/ 0.275	271	o					
					270						
269.5		16	SS	100/		o					

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

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No UP-01

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 086.9 E 289 758.5
ORIGINATED BY	ES		
HWY	400	BOREHOLE TYPE	Hollow Stem Augers
COMPILED BY	AN		
DATUM	Geodetic	DATE	2016.11.09 - 2016.11.10
CHECKED BY	MH		

SOIL PROFILE: ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: 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
	Continued From Previous Page										
20.0	END OF BOREHOLE AT 20.0m. WATER LEVEL AT 12.9m UPON COMPLETION. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.03.30 19.4 270.1				0.200						

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

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

RECORD OF BOREHOLE No UP-02

METRIC

W.P. ____ LOCATION Harvie / Big Bay Point Road N 4 912 040.9 E 289 759.7 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.11 - 2016.11.17 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
283.6	GROUND SURFACE											
0.0	**TOPSOIL:** (50mm)											
	SAND and **SILT**, trace gravel, trace roots Loose Dark Brown Moist	1	SS	4								
						283						
282.4		2	SS	9								
1.2	**SAND**, trace gravel, trace silt Loose to Very Loose Brown Wet					282						
		3	SS	6								
		4	SS	3		281						
		5	SS	6	∇							
						280						
						279						
	Trace to some gravel Dense to Very Dense	6	SS	44					5	88	7 (SI+CL)	
						278						
		7	SS	66								
						277						
						276						
		8	SS	43								
						275						
		9	SS	53								
						274						

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
REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

RECORD OF BOREHOLE No UP-02

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 040.9 E 289 759.7 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.11 - 2016.11.17 CHECKED BY MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace gravel, trace silt Very Dense Brown Moist						273	
			10	SS	48			
							272	
			11	SS	76		271	
							270	
			12	SS	75		269	
	Some silt to silty		13	SS	74		268	
							267	
			14	SS	87		266	
			15	SS	54		265	
							264	

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.

Continued Next Page

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

RECORD OF BOREHOLE No UP-02

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 040.9 E 289 759.7 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.11 - 2016.11.17 CHECKED BY MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	SAND, fine grained, some silt to silty Very Dense Brown Wet	16	SS	71		0	86	14 (SI+CL)	
					263				
		17	SS	103/ 0.200	262				
					261				
		18	SS	72	260				
		19	SS	84	259				
					258				
		20	SS	71	257	0	77	23 (SI+CL)	
		21	SS	90	256				
					255				
		22	SS	100/ 0.225	254				

Column headings: 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

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-02

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 040.9 E 289 759.7	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.11.11 - 2016.11.17	CHECKED BY	MH

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, fine grained, trace gravel, trace to some silt Very Dense Brown Wet										
			23	SS	101/ 0.225		253		~20		
							252				
			24	SS	106/ 0.200				~20		
							251				
249.8			25	SS	100/ 0.250		250		~20		1 90 9 (SI+CL)
33.8	END OF BOREHOLE AT 33.8m. WATER LEVEL AT 3.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH GROUT TO 0.5m, THEN HOLEPLUG TO SURFACE.										

Legend: 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

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+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No UP-03

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 083.6 E 289 809.4 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.02.21 - 2017.02.22 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
290.7	GROUND SURFACE							
0.0	**ASPHALT:** (225mm)							
0.2	**SAND**, some gravel, trace silt Compact Brown Moist (FILL)		1	GS			290	
			1	SS	29			
289.2 / 1.5	Silty **SAND**, trace clay Dense to Very Dense Brown Moist (FILL)		2	SS	31		289	
			3	SS	51		288	
			4	SS	44		287	0 71 25 4
			5	SS	34		286	
			6	SS	31		285 / 284	
	Occasional wood fibres Very Loose		7	SS	3		283	0 69 24 7
282.0 / 8.7	**SAND**, trace silt, trace gravel Loose to Compact Brown Moist		8	SS	7	▽	282 / 281	5 87 8 (SI+CL)

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

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No UP-03

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 083.6 E 289 809.4 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.02.21 - 2017.02.22 CHECKED BY MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT
	SAND, trace silt, trace gravel Compact Brown Moist					
					280	
		9	SS	13		o
					279	
	Occasional black sand seams Compact to Dense	10	SS	32		o
					278	
					277	
		11	SS	31		o
					276	
		12	SS	27		o
					275	
					274	
		13	SS	21		o
					273	
		14	SS	44		o
					272	
					271	
	Some silt to silty Very Dense					

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

Chart headings: 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; STRAT PLOT; GROUND WATER CONDITIONS

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RECORD OF BOREHOLE No UP-03

METRIC

W.P. ____ LOCATION Harvie / Big Bay Point Road N 4 912 083.6 E 289 809.4 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.02.21 - 2017.02.22 CHECKED BY MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty Very Dense Brown Moist	15	SS	61		o	0 73 25 2
					270		
		16	SS	53	269	o	
					268		
					267		
		17	SS	72	266	o	
					265		
					264		
		18	SS	86	263	o	
					262		
					261		

Chart column headings: 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; STRAT PLOT; GROUND WATER CONDITIONS.

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+ 3, × 3: Numbers refer to Sensitivity

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

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THURBER

RECORD OF BOREHOLE No UP-03

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 083.6 E 289 809.4	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.02.21 - 2017.02.22	CHECKED BY	MH

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty Very Dense Brown Wet										
			19	SS	95		260		○		
							259				
			20	SS	102				○		
							258				
			21	SS	100/ 0.250		257		○		
							256				
255.4			22	SS	102/ 0.250				○		
35.3	END OF BOREHOLE AT 35.3m. WATER LEVEL AT 9.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.5m, CEMENT TO 0.2m, THEN ASPHALT TO SURFACE.										

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-04

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 054.1 E 289 814.8 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.02.13 - 2017.02.17 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS
290.9	GROUND SURFACE								
0.0	**ASPHALT:** (200mm)								
0.2	**SAND**, some gravel to gravelly, Brown, Moist		1	GS				○	
290.1 / 0.8	(FILL)						290		
	Silty **SAND**, trace gravel, Compact to Dense, Brown, Moist, (FILL)		1	SS	22			○	
			2	SS	22		289	○	
			3	SS	49		288	○	
			4	SS	42		287	○	
			5	SS	40		286	○	
285.3 / 5.6	**SAND**, trace silt, trace gravel, Loose, Brown, Moist						285		
			6	SS	9	▽	284	○	
	Very Dense		7	SS	60		283	○	
			8	SS	88		282 / 281	○	

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No UP-04

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 054.1 E 289 814.8
HWY	400	BOREHOLE TYPE	Hollow Stem Augers
DATUM	Geodetic	DATE	2017.02.13 - 2017.02.17
ORIGINATED BY	ES	COMPILED BY	AN
CHECKED BY	MH		

Continued From Previous Page

SAND, trace silt, trace gravel
Very Dense
Brown
Moist

Sample Number	Type	"N" Values	Water Content
9	SS	76	○
10	SS	87	○
11	SS	76	○
12	SS	80	○
13	SS	64	○
14	SS	84	○

Elevation scale: 280, 279, 278, 277, 276, 275, 274, 273, 272, 271

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (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

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Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

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THURBER

RECORD OF BOREHOLE No UP-04

METRIC

W.P.

LOCATION Harvie / Big Bay Point Road N 4 912 054.1 E 289 814.8

ORIGINATED BY ES

HWY 400

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY AN

DATUM Geodetic

DATE 2017.02.13 - 2017.02.17

CHECKED BY MH

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
	Continued From Previous Page												
	SAND, trace silt Very Dense Brown Moist		15	SS	77			o					
							270						
			16	SS	97			o					
							269						
							268						
							267						
	Loose (hydraulic disturbance)		17	SS	9			o		0	96	3	1
							266						
							265						
							264						
			18	SS	112			o					
							263						
							262						
			19	SS	103			o					
							261						

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No UP-04

METRIC

W.P.		ORIGINATED BY	ES
HWY	400	COMPILED BY	AN
DATUM	Geodetic	CHECKED BY	MH
LOCATION	Harvie / Big Bay Point Road N 4 912 054.1 E 289 814.8		
BOREHOLE TYPE	Hollow Stem Augers		
DATE	2017.02.13 - 2017.02.17		

ELEV DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SAND, trace silt Very Dense Brown Moist		20	SS	114		260		o		0	94	4	2
260.0 30.9	END OF BOREHOLE AT 30.9m. WATER LEVEL AT 6.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.													

Shear strength legend: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-05

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 102.9 E 289 867.9 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.08 - 2016.11.09 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
286.8	GROUND SURFACE						
0.0	**TOPSOIL:** (40mm)						
	SAND, trace to some gravel, some silt Loose to Compact Brown Moist (FILL)	1	SS	6		~6	
					286		
		2	SS	7		~4	9 80 11 (SI+CL)
		3	SS	14	285	~4	
284.4 2.4	**SAND**, trace silt Loose Light Brown Moist	4	SS	8		~2	
					284		
	Dense	5	SS	43		~2	
					283		
	Very Dense						
		6	SS	58	282	~2	
					281		
		7	SS	59		~2	0 96 4 (SI+CL)
					280		
					279		
		8	SS	77		~2	
					278		
		9	SS	59		~2	
					277		

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+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No UP-05

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 102.9 E 289 867.9	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.11.08 - 2016.11.09	CHECKED BY	MH

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ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace silt, occasional black sand seams Very Dense Light Brown Moist	10	SS	92		276	o	
		11	SS	86		275	o	
					∇	274		
		12	SS	104/ 0.250		273	o	
		13	SS	70		272	o	0 94 6 (SI+CL)
		14	SS	102/ 0.250		270	o	
		15	SS	101		268	o	
267.7 / 19.1	**SILT**, trace sand, trace clay Very Dense Brown Wet					267		

Legend: 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

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 UP-05

METRIC

W.P. ____ LOCATION Harvie / Big Bay Point Road N 4 912 102.9 E 289 867.9 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.08 - 2016.11.09 CHECKED BY MH

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILT, trace sand, trace clay; Very Dense; Brown; Wet	16	SS	109		~20	0	5	90	5
265.9 / 20.9	**SAND**, trace to some silt; Very Dense; Brown; Wet				266					
		17	SS	100/0.125	265	~20				
		18	SS	100/0.225	264	~20				
		19	SS	103/0.250	263, 262	~20				
260.6 / 26.2	END OF BOREHOLE AT 26.2m. WATER LEVEL AT 13.0m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.	20	SS	110/0.250	261	~20				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (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/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

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$+^3$, $\times^3$: Numbers refer to Sensitivity. 15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

ONTMT4S MTO-11398.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

THURBER

RECORD OF BOREHOLE No UP-06

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 064.9 E 289 869.2
HWY	407	BOREHOLE TYPE	Hollow Stem Augers
DATUM	Geodetic	DATE	2016.11.04 - 2016.11.07

ORIGINATED BY ES
COMPILED BY AN
CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.3	GROUND SURFACE					
0.0 / 0.1	**TOPSOIL:** (100mm)					
	SILT, some clay, some sand, trace roots, Loose, Brown, Moist (FILL)	1	SS	4	287	
286.5 / 0.8	Silty **SAND**, trace clay, trace gravel, Dense, Brown, Moist (FILL)	2	SS	32	286	
285.8 / 1.5	**SAND**, trace gravel, trace silt, occasional cobble, Dense to Very Dense, Light Brown, Moist	3	SS	32		
		4	SS	34	285	
		5	SS	37	284	
					283	
		6	SS	61	282	
		7	SS	52	281	
					280	
		8	SS	78	279	
		9	SS	61	278	0 91 9 (SI+CL)

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

Continued Next Page

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

ONTMT4S MTO-11398.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-06

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 064.9 E 289 869.2 ORIGINATED BY ES

HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.04 - 2016.11.07 CHECKED BY MH

Continued From Previous Page

SAND, trace gravel, trace silt
Very Dense
Light Brown
Moist

Sample Number	Type	"N" Values	Water Content	Remarks & Grain Size Distribution (%) GR SA SI CL
10	SS	107	o	
11	SS	100/ 0.275	o	
12	SS	105	o	2 92 6 (SI+CL)
13	SS	74	o	
14	SS	60	o	
15	SS	77	o	

Elevation scale: 277, 276, 275, 274, 273, 272, 271, 270, 269, 268

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

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 UP-06

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 064.9 E 289 869.2 ORIGINATED BY ES

HWY 407 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.04 - 2016.11.07 CHECKED BY MH

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)
	SAND, trace gravel, trace silt Very Dense Light Brown Moist	16	SS	100/ ~~0.250~~	267	~20
		17	SS	104/ 0.175	266	~20
264.3 23.0		18	SS	119/ 0.175	265	~20

END OF BOREHOLE AT 23.0m.
WATER LEVEL AT 16.3m UPON COMPLETION.
Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.03.30	19.1	268.2

Legend: 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

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No UP-07

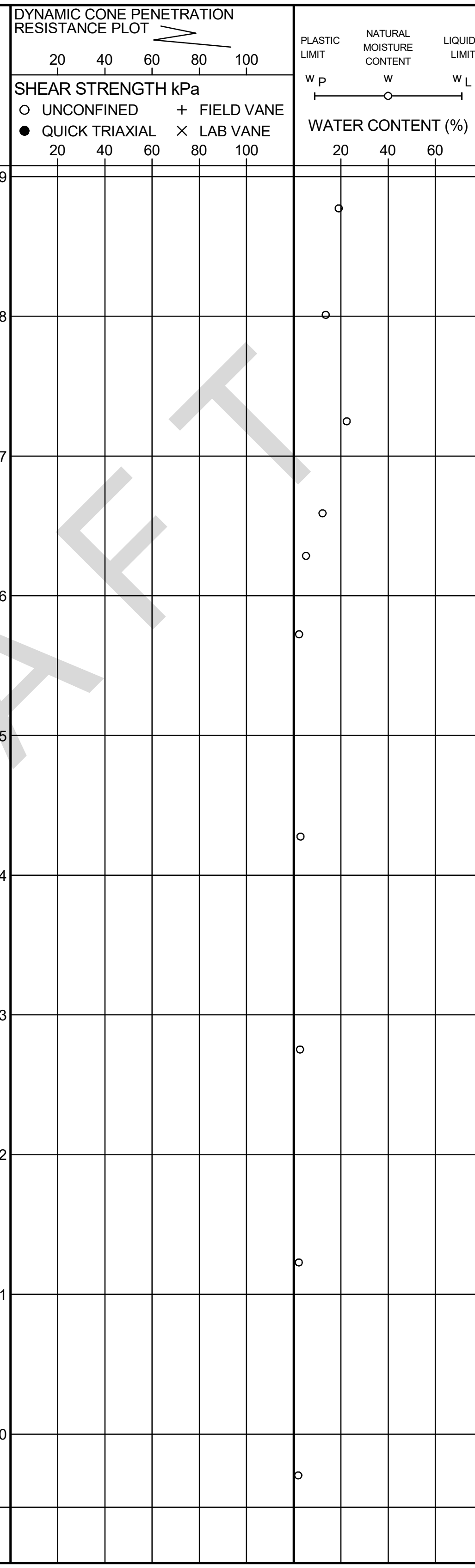
METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 055.4 E 289 733.9 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.10 - 2016.11.10 CHECKED BY MH

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
289.1	GROUND SURFACE								
0.0	**TOPSOIL** Very Loose Dark Brown Moist	1	SS	2	289				
288.5 / 0.6	Silty **SAND**, some clay, trace gravel Loose to Compact Brown to Light Brown Moist	2	SS	6	288	2	49	32	17
		3	SS	21					
287.1 / 2.0	**SILT**, some sand, trace gravel Compact Brown Moist	4	SS	53	287				
286.4 / 2.7	**SAND**, trace gravel, trace silt Very Dense Brown Moist	5	SS	61	286				
	Gravelly zone	6	SS	74	285	35	59	6 (SI+CL)	
		7	SS	76	284, 283				
		8	SS	81	282, 281				
279.5		9	SS	104	280	2	91	7 (SI+CL)	
9.6	END OF BOREHOLE AT 9.6m. BOREHOLE DRY UPON								



Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

UNIT WEIGHT γ kN/m 3

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DRAFT

RECORD OF BOREHOLE No UP-07

METRIC

W.P.
LOCATION Harvie / Big Bay Point Road N 4 912 055.4 E 289 733.9
ORIGINATED BY ES

HWY 400
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN

DATUM Geodetic
DATE 2016.11.10 - 2016.11.10
CHECKED BY MH

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-08

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 087.8 E 289 875.6 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.07 - 2016.11.07 CHECKED BY MH

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
287.0	GROUND SURFACE									
0.0	**TOPSOIL:** (50mm)									
	SAND and **SILT**, trace clay, trace roots Loose Dark Brown Moist (FILL)		1	SS	5					
			2	SS	8		286			0 55 37 8
			3	SS	6		285			
	Trace gravel, occasional wood fibres Compact		4	SS	16					
283.9 3.1	**SAND**, trace gravel, trace silt Dense to Very Dense Light Brown Moist		5	SS	33		284			
							283			
			6	SS	56		282			3 92 5 (SI+CL)
							281			
			7	SS	67		280			
			8	SS	75		279			
							278			
277.4			9	SS	101					2 92 6 (SI+CL)
9.6	END OF BOREHOLE AT 9.6m. BOREHOLE DRY UPON									

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 Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No UP-08

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 087.8 E 289 875.6 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.11.07 - 2016.11.07 CHECKED BY MH

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

DRAFT

+3, ×3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-09

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 084.3 E 289 861.2 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.01.20 - 2017.01.20 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
284.8	GROUND SURFACE						
0.0	**TOPSOIL:** (125mm)						
0.1	**SAND**, trace gravel, trace silt Very Loose to Compact Brown Moist	1	SS	5		o	
					284		
		2	SS	3		o	
					283		
		3	SS	1		o	
		4	SS	14		o	
					282		
	Dense to Very Dense						
		5	SS	36		o	
					281		
		6	SS	46	280	o	4 89 7 (SI+CL)
					279		
		7	SS	51		o	
					278		
		8	SS	53	277	o	
					276		
		9	SS	55		o	
275.2 / 9.6	END OF BOREHOLE AT 9.6m. BOREHOLE DRY UPON						

Continued Next Page

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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

+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S MTO-11398.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No UP-09

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 084.3 E 289 861.2	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.01.20 - 2017.01.20	CHECKED BY	MH

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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
	Continued From Previous Page										
	COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No RW-01

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 142.7 E 289 853.2 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.01.25 - 2017.01.25 CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
285.2	GROUND SURFACE						
0.0	**TOPSOIL:** (50mm)				285		
	SAND, some silt, trace gravel, trace roots and rootlets, Very Loose, Brown, Moist (FILL)	1	SS	2		o	
284.4 / 0.8	Clayey **SILT**, sandy, Stiff, Brown, Moist (FILL)	2	SS	14		o	0 47 28 25
284.0 / 1.2	**SAND**, trace to some gravel, trace silt, Compact, Brown, Moist (FILL)				284	o	
		3	SS	16		o	14 79 7 (SI+CL)
		4	SS	14	283	o	
282.4 / 2.8	Silty **SAND**, trace clay, trace gravel, occasional wood fibres, Compact, Grey to Dark Grey, Moist					o	
		5	SS	15	282	o	7 63 26 4
281.1 / 4.1	**SAND**, trace gravel, trace silt, Loose to Compact, Brown, Moist				281		
		6	SS	6	280	o	
	Cobble	~~7~~	~~SS~~	~~50/~~ 0.025	279		
					278		
		8	SS	31	277	o	
	Dense to Very Dense	9	SS	45	276	o	0 97 3 (SI+CL)

Column headings also include: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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.

Continued Next Page

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

DRAFT

ONTMT4S MTO-11398.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

RECORD OF BOREHOLE No RW-01

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 142.7 E 289 853.2	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.01.25 - 2017.01.25	CHECKED BY	MH

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, trace gravel, trace silt Dense to Very Dense Brown Moist				275		
		10	SS	53	274		
		11	SS	70	273		
					272		
		12	SS	56	271		
					270		
		13	SS	71	269		
	Silty	14	SS	63	268		
					267		
266.5 18.7		15	SS	42			0 76 22 2
	END OF BOREHOLE AT 18.7m. WATER LEVEL AT 15.8m UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.						

Column headings also shown: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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

Continued Next Page

+^{3}, ×^{3}: Numbers refer to Sensitivity

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

THURBER

RECORD OF BOREHOLE No RW-01

METRIC

W.P.		LOCATION	Harvie / Big Bay Point Road N 4 912 142.7 E 289 853.2	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.01.25 - 2017.01.25	CHECKED BY	MH

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 (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Continued From Previous Page										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.03.30	17.0	268.2

+ 3, × 3: Numbers refer to Sensitivity

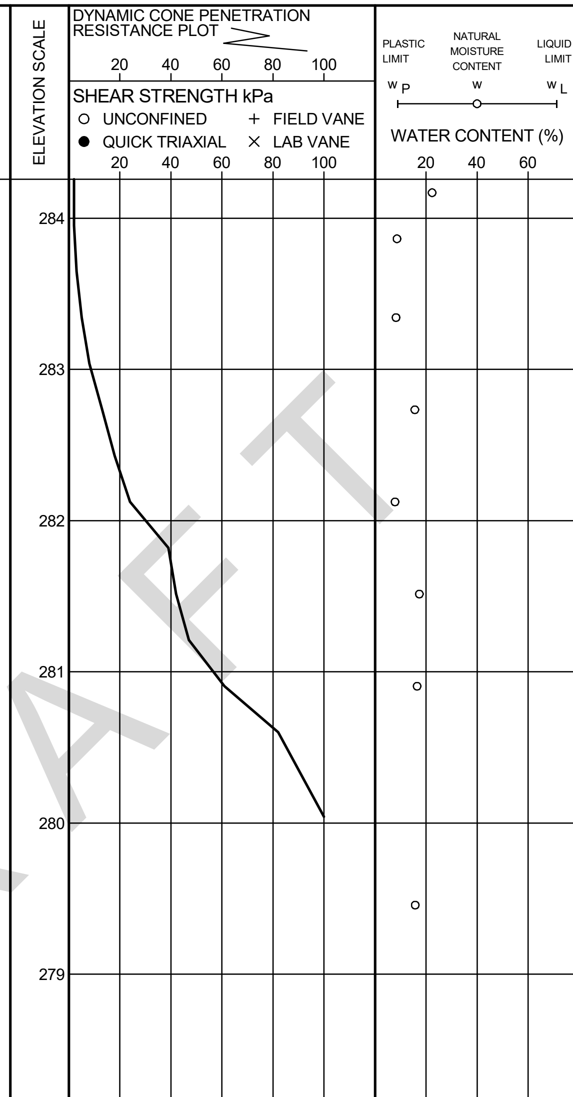
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RW-02

METRIC

W.P.		ORIGINATED BY	ES
LOCATION	Harvie / Big Bay Point Road N 4 912 069.9 E 289 775.1		
HWY	400	COMPILED BY	AN
BOREHOLE TYPE	Tripod/Dynamic Cone Penetration Test		
DATUM	Geodetic	CHECKED BY	MH
DATE	2017.02.02 - 2017.02.02		

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
284.3	GROUND SURFACE									
0.0	**TOPSOIL:** (180mm) Dark Brown									
0.2	**SAND**, some silt, some gravel, occasional wood fibres Loose to Compact Brown Moist	1	SS	7						
		2	SS	22			14	63	14	9
		3	SS	14						
282.3 / 2.0	**SAND**, trace to some gravel, trace silt Loose to Compact Brown Moist to Wet	4	SS	9						
		5	SS	9						
		6	SS	17						
	Dense to Very Dense	7	SS	48			4	93	3 (SI+CL)	
278.2 / 6.1	END OF BOREHOLE AT 6.1m. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.	8	SS	100/ 0.025						



+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No RW-03

METRIC

W.P.

LOCATION Harvie / Big Bay Point Road N 4 912 013.4 E 289 780.6

ORIGINATED BY ES

HWY 400

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY AN

DATUM Geodetic

DATE 2017.01.16 - 2017.01.16

CHECKED BY MH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.3	GROUND SURFACE						
0.0 / 0.1	**TOPSOIL:** (100mm)						
	SAND, some silt to silty, trace gravel; Loose to Compact; Brown; Moist	1	SS	6		288	
		2	SS	14		287	
		3	SS	15			8 71 15 6
286.0 / 2.3	**SILT**, some sand, trace gravel; Compact; Brown; Moist	4	SS	18		286	
285.6 / 2.7	**SAND**, trace to some gravel, trace silt; Compact; Brown; Moist	5	SS	28		285	
						284	
	Dense to Very Dense	6	SS	48			
					▽	283	
	Gravelly zone	7	SS	63		282	29 66 5 (SI+CL)
						281	
		8	SS	75		280	
		9	SS	61		279	
278.7 / 9.6	END OF BOREHOLE AT 9.6m. WATER LEVEL AT 5.6m UPON						

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

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 ⊕ 5 (20, 10) (%) STRAIN AT FAILURE

ONTMT4S MTO-11398.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

RECORD OF BOREHOLE No RW-03

METRIC

W.P. ______ LOCATION Harvie / Big Bay Point Road N 4 912 013.4 E 289 780.6 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.01.16 - 2017.01.16 CHECKED BY MH

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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ 3 , × 3 : Numbers refer to Sensitivity

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

Appendix B

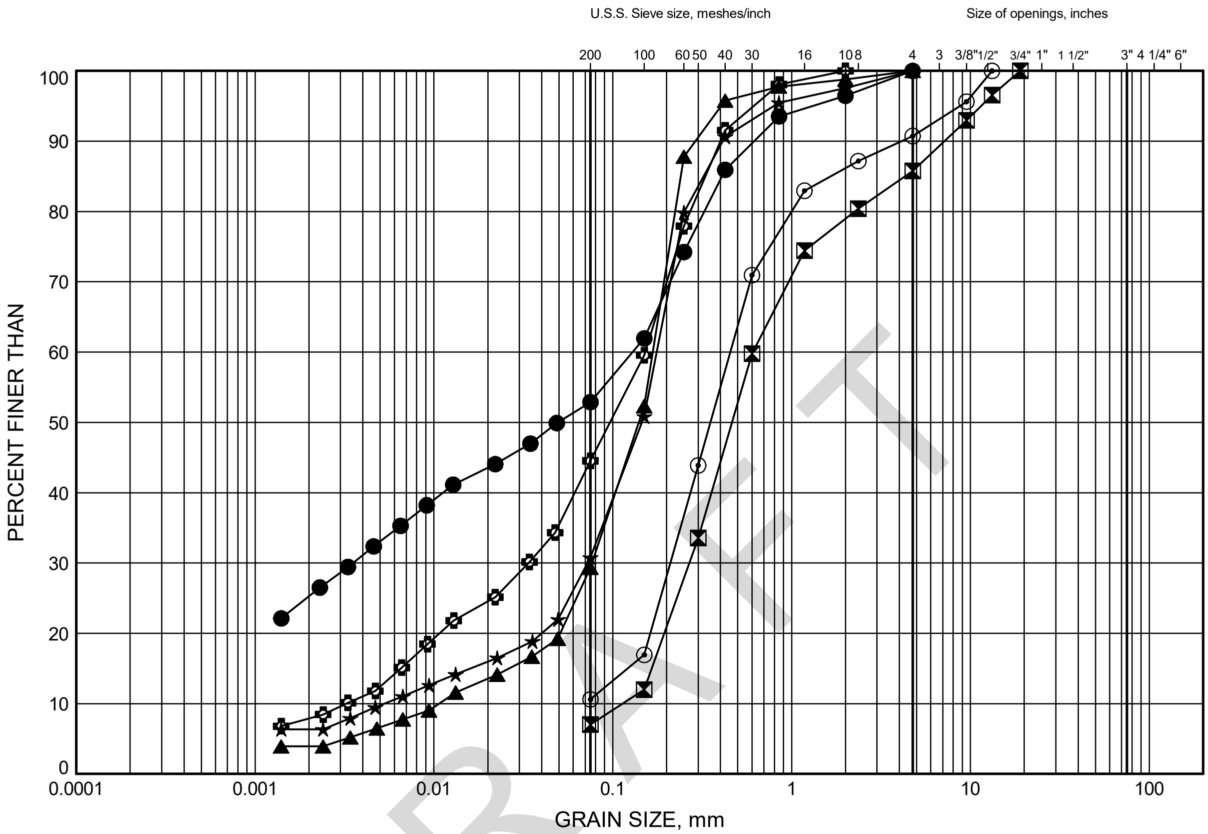
Laboratory Test Results

Harvie / Big Bay Point Road

GRAIN SIZE DISTRIBUTION

FIGURE B1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RW-01	0.97	284.21
⧗	RW-01	1.83	283.34
▲	UP-03	3.28	287.38
★	UP-03	7.85	282.81
⊙	UP-05	1.07	284.97
✣	UP-08	1.07	285.96

GRAIN SIZE DISTRIBUTION - THURBER MTO-11398.GPJ 3/27/17

Date March 2017

W.P.

THURBER

Prep'd MFA

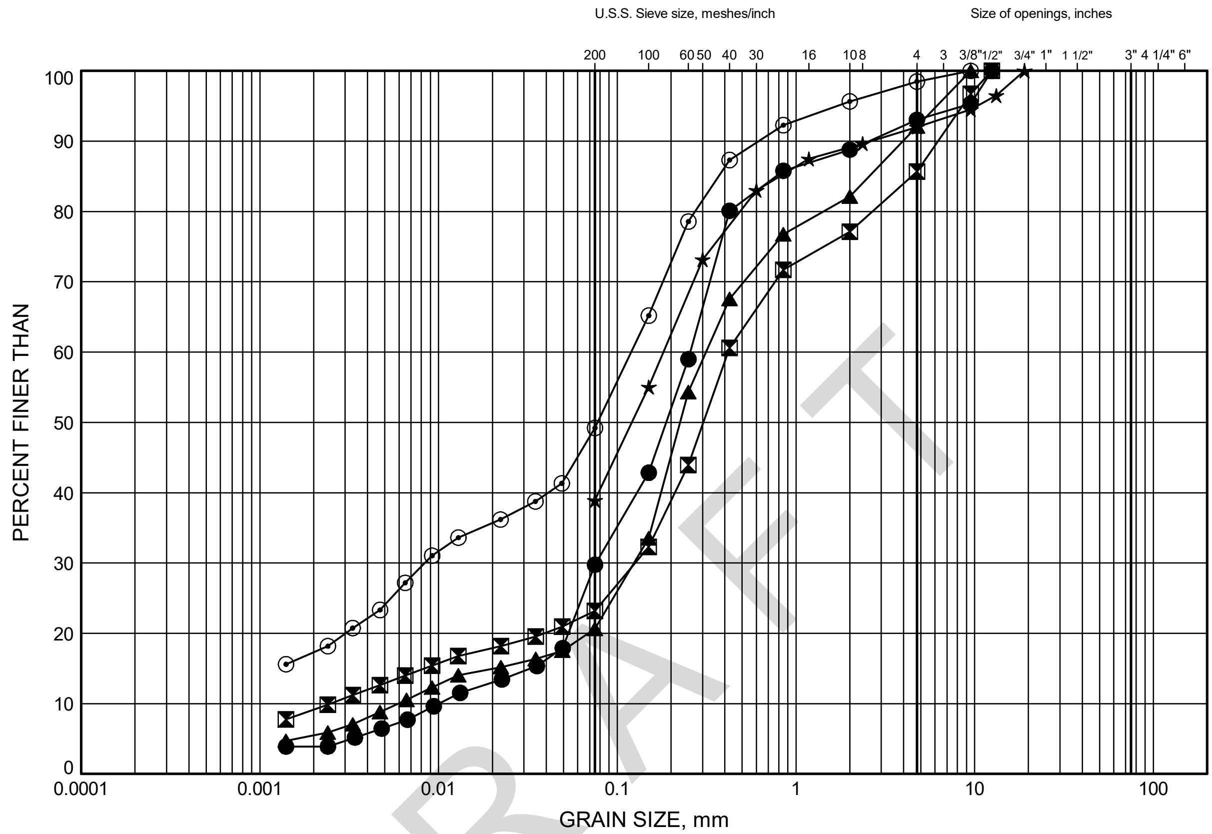
Chkd. MRA

Harvie / Big Bay Point Road

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND to SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RW-01	3.35	281.82
⧗	RW-02	0.91	283.34
▲	RW-03	1.83	286.50
★	UP-01	1.75	287.78
⊙	UP-07	1.07	288.01

GRAIN SIZE DISTRIBUTION - THURBER MTO-11398.GPJ 3/27/17

Date March 2017

W.P.

THURBER

Prep'd MFA

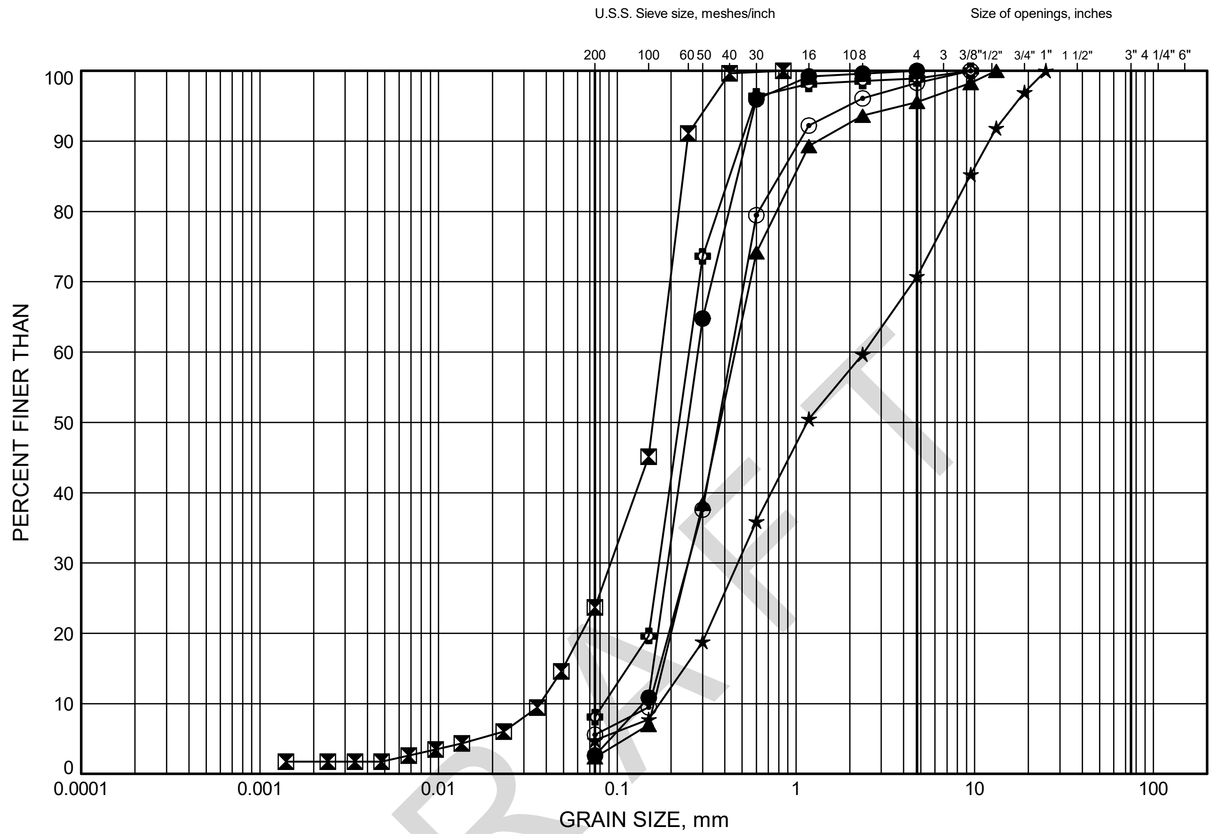
Chkd. MRA

Harvie / Big Bay Point Road

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RW-01	9.37	275.80
⧗	RW-01	18.52	266.66
▲	RW-02	4.80	279.46
★	RW-03	6.32	282.01
⊙	UP-01	10.90	278.64
✿	UP-01	16.97	272.57

GRAIN SIZE DISTRIBUTION - THURBER MTO-11398.GPJ 3/27/17

Date March 2017

W.P.

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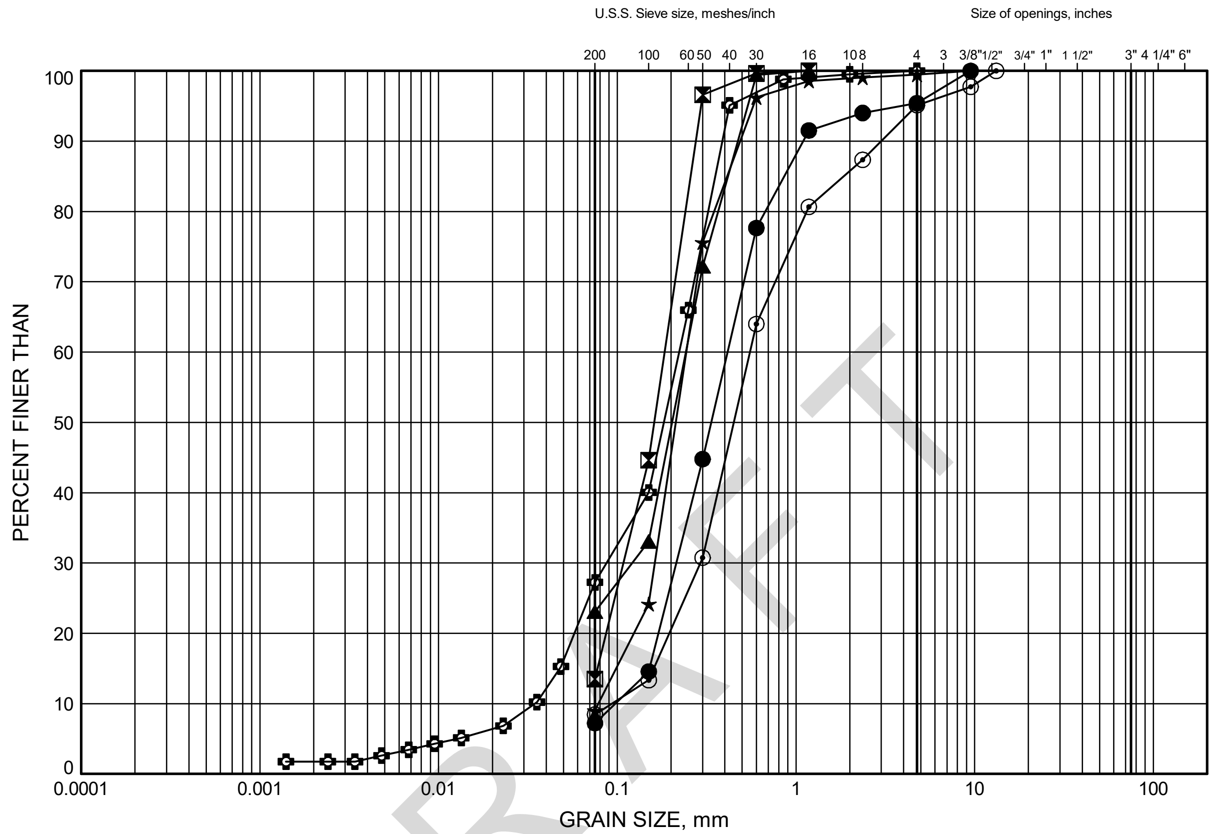
Harvie / Big Bay Point Road

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-02	4.88	278.70
⧗	UP-02	20.04	263.54
▲	UP-02	26.14	257.44
★	UP-02	33.66	249.92
⊙	UP-03	9.37	281.28
✿	UP-03	20.04	270.61

GRAIN SIZE DISTRIBUTION - THURBER MTO-11398.GPJ 3/27/17

Date March 2017

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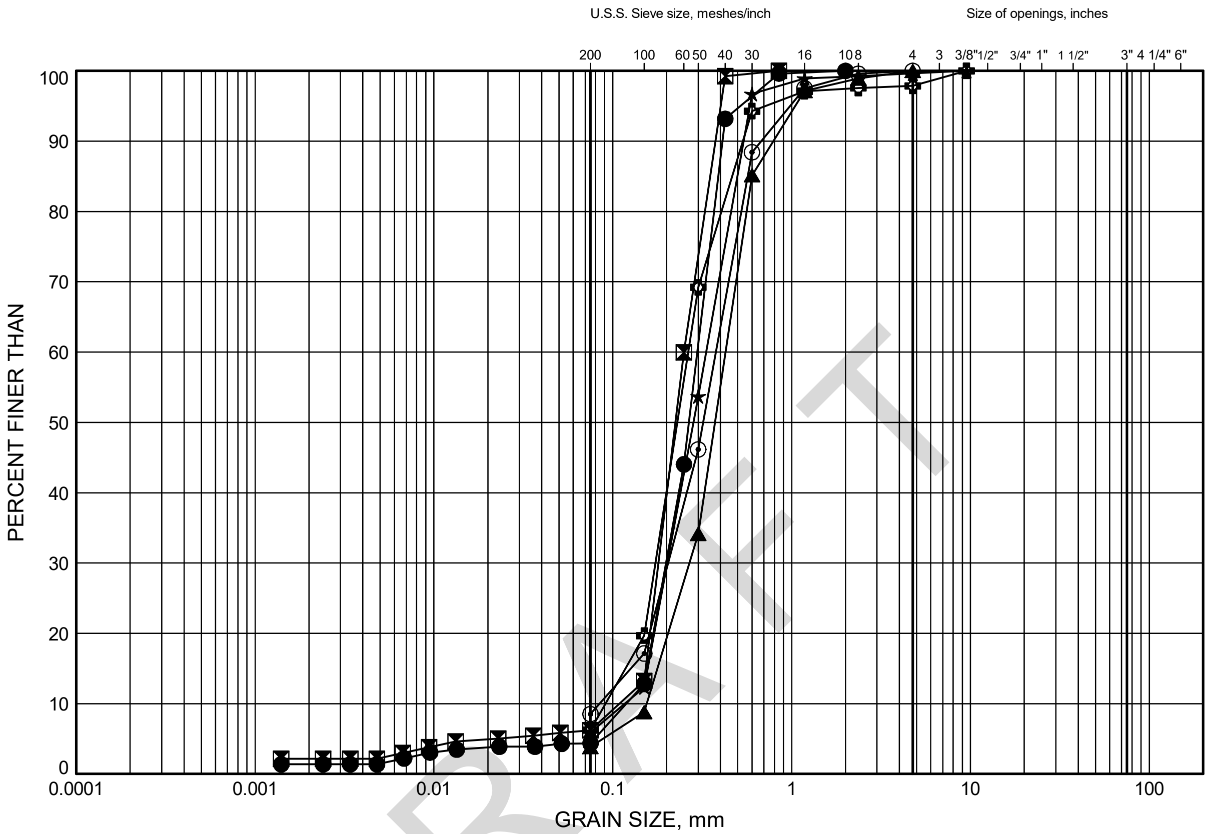
GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-04	24.69	266.17
⧗	UP-04	30.71	260.15
▲	UP-05	6.40	279.63
★	UP-05	15.47	270.57
⊙	UP-06	9.37	277.97
✿	UP-06	13.94	273.40

Date March 2017

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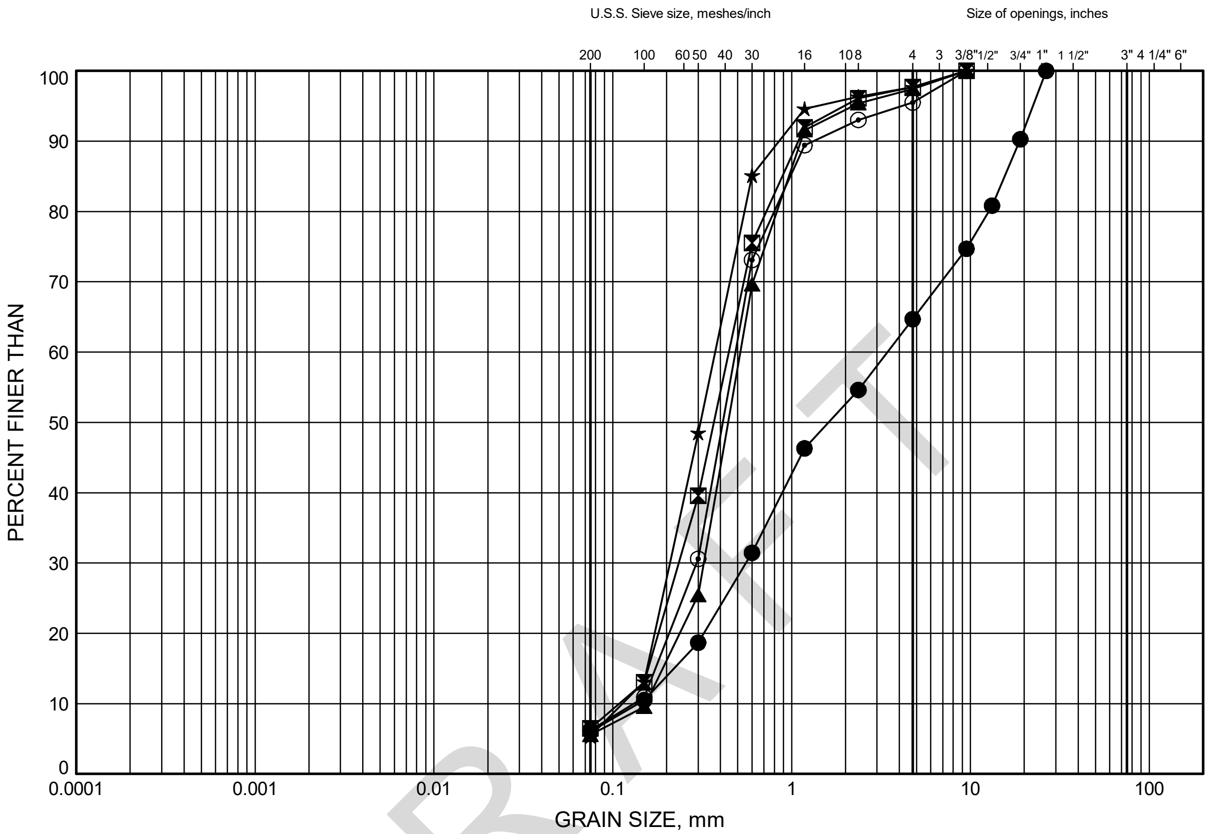
GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-07	4.80	284.28
⧗	UP-07	9.37	279.70
▲	UP-08	4.88	282.15
★	UP-08	9.37	277.65
⊙	UP-09	4.80	280.04

Date March 2017

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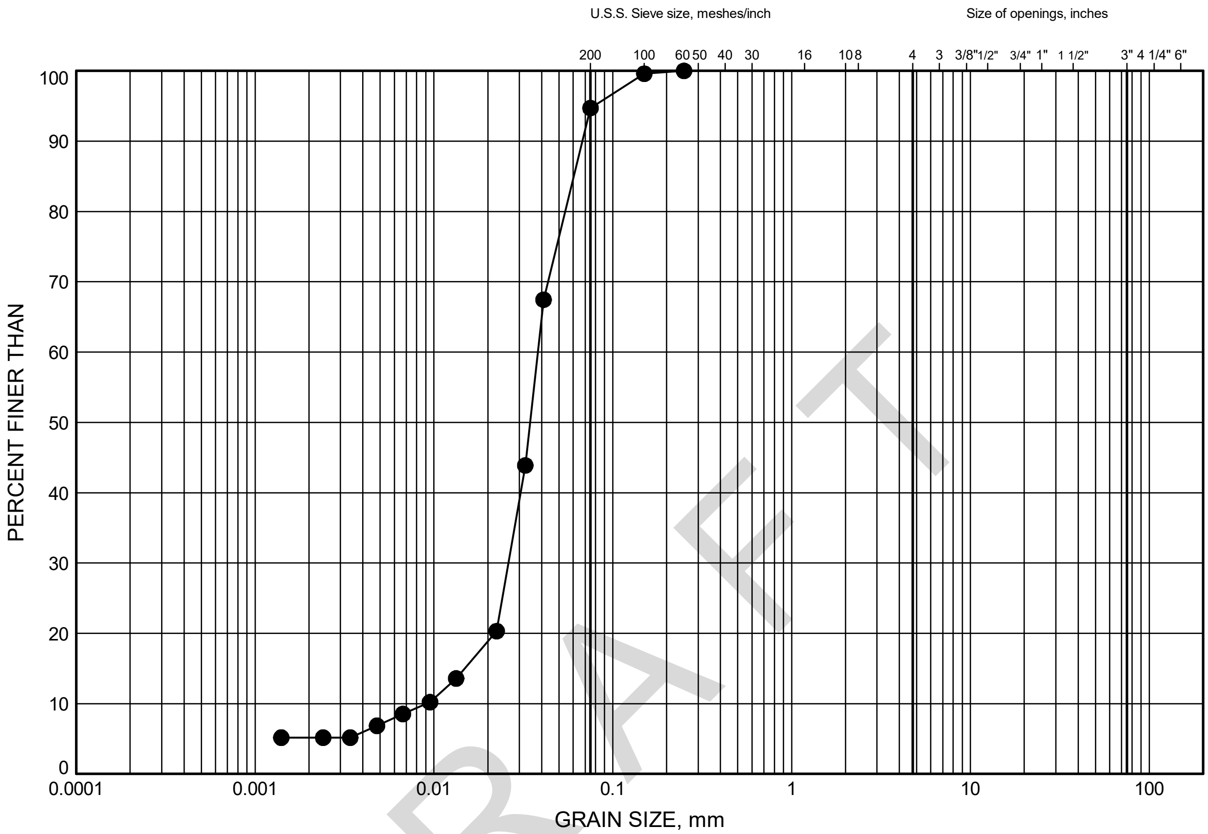
GRAIN SIZE DISTRIBUTION

FIGURE B7

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UP-05	20.04	265.99

Date March 2017

W.P.

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Chkd. MRA

Appendix C

Site Photographs

Photograph 1: Looking north towards west abutment location, in autumn

Photograph 2: Looking north towards west abutment location, in winter

Photograph 3: Looking southwest towards east abutment location, in autumn

Photograph 4: Looking south towards east abutment location, in winter

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Engineered Fill	Driven Piles	Caissons
Advantages: i. Ease of construction. ii. Relatively high resistance values are available at typically shallow depth at the abutments. iii. Lower cost than deep foundations. ***Disadvantages:*** i. Deep excavations are required at the pier and locally at the abutments. ii. Variable depth to competent material. iii. Does not allow use of integral abutment design.	***Advantages:*** i. Ease of construction. ii. Design founding level can be controlled. iii. Generally lower cost than deep foundations. ***Disadvantages:*** i. Additional cost of engineered fill placement. ii. Increased costs of shoring and roadway protection due to deeper excavation for fill placement.	***Advantages:*** i. Piles will develop high geotechnical resistance when driven into very dense sand. ii. Pile installation may continue in freezing weather. iii. May require less excavation than footing construction. iv. Allows use of integral abutments. ***Disadvantages:*** i. Higher unit cost than footings. ii. Possibility that piles will develop required resistance at variable depths. iii. Some piles may encounter refusal at shallower depth.	***Advantages:*** i. High resistance is available for caissons founded in very dense sand. ii. Minimizes width of working zone and roadway protection requirements in highway median. iii. Construction could continue in freezing weather. ***Disadvantages:*** i. Much higher cost than shallow footings. ii. Temporary steel liners will be required to install caissons through cohesionless soils. iii. Drilling mud or tremie methods may be required if caissons extend below groundwater table. iv. Difficulty in cleaning and inspecting bases.
FEASIBLE AT ABUTMENTS	**NOT RECOMMENDED**	**RECOMMENDED FOR ABUTMENTS**	**RECOMMENDED FOR PIER**

Appendix E

List of Standard Specifications and Special Provisions

1) The following Standard Specifications and Special Provisions are referenced in this report:

OPSS.PROV 206

OPSS 212

OPSS 501

OPSS 539

OPSS.PROV 804

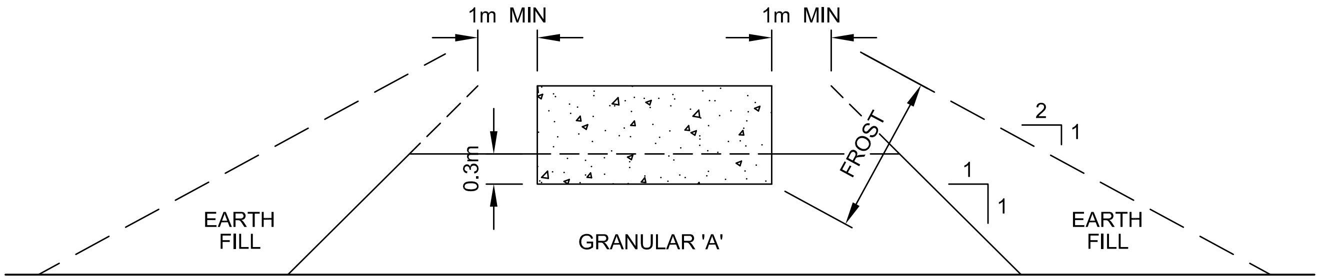
OPSS 902

OPSS 903

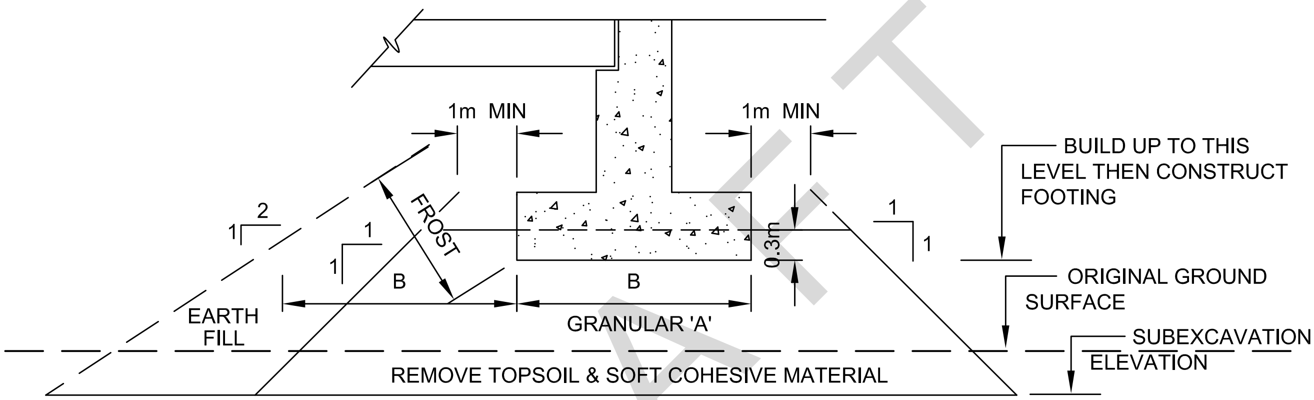
OPSS.PROV 1010

OPSD 208.010

OPSD 803.010



CROSS-SECTION



LONGITUDINAL SECTION

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ABUTMENT ON COMPACTED FILL
SHOWING GRANULAR 'A' CORE

THURBER ENGINEERING LTD.

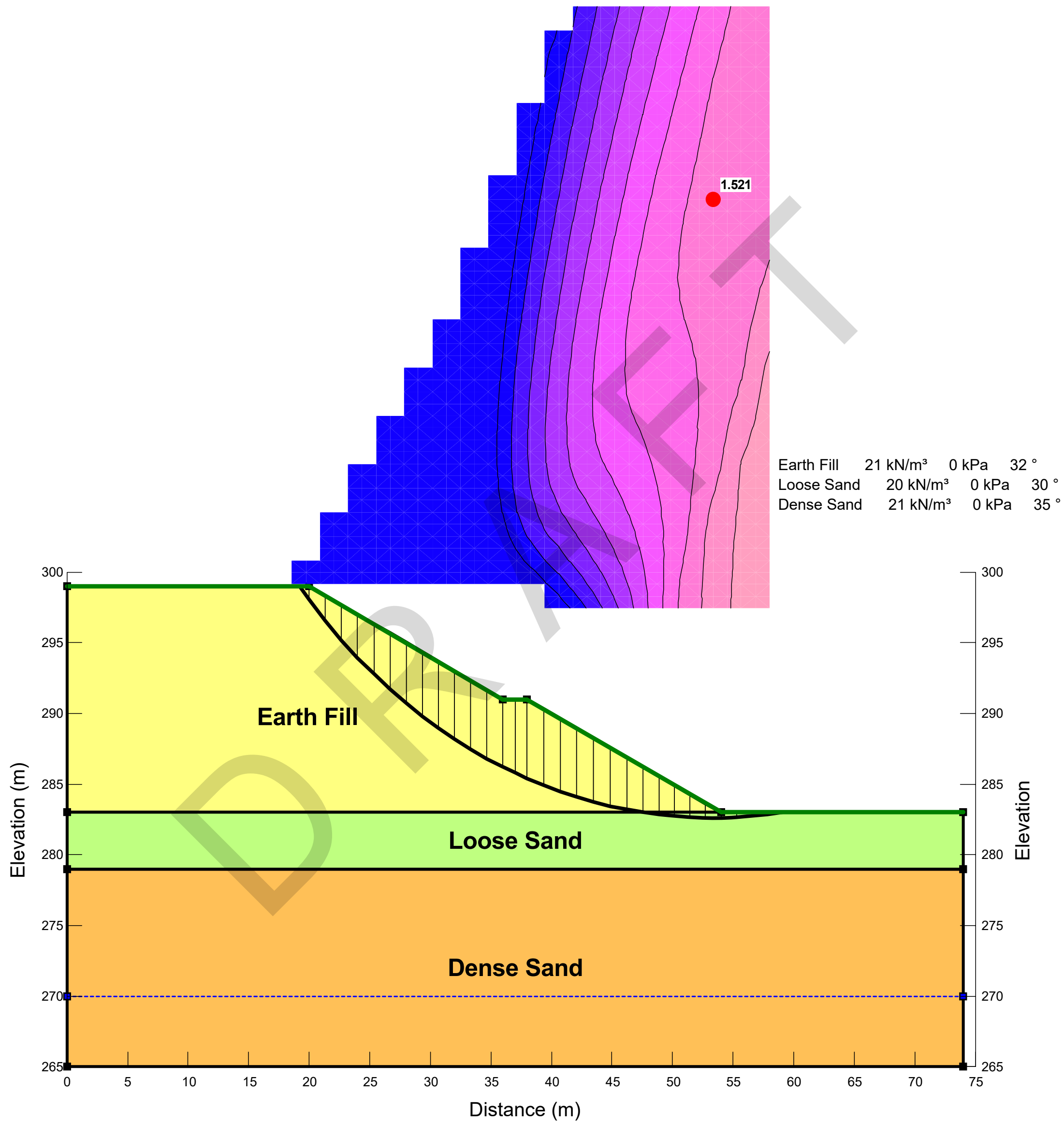
ENGINEER :	DRAWN :	APPROVED :
MRA	MFA	-
DATE :	SCALE :	DRAWING No.
MARCH 2015	N.T.S.	FIGURE 1

Appendix F

Slope Stability Analysis

HARVIE ROAD AND BIG BAY POINT ROAD
HWY 400 UNDERPASS
SLOPE STABILITY ANALYSIS

FIGURE F1



Date: April, 2017
File No.: 11398

Analysis By: MSH
Reviewed By: MRA

Appendix G

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No

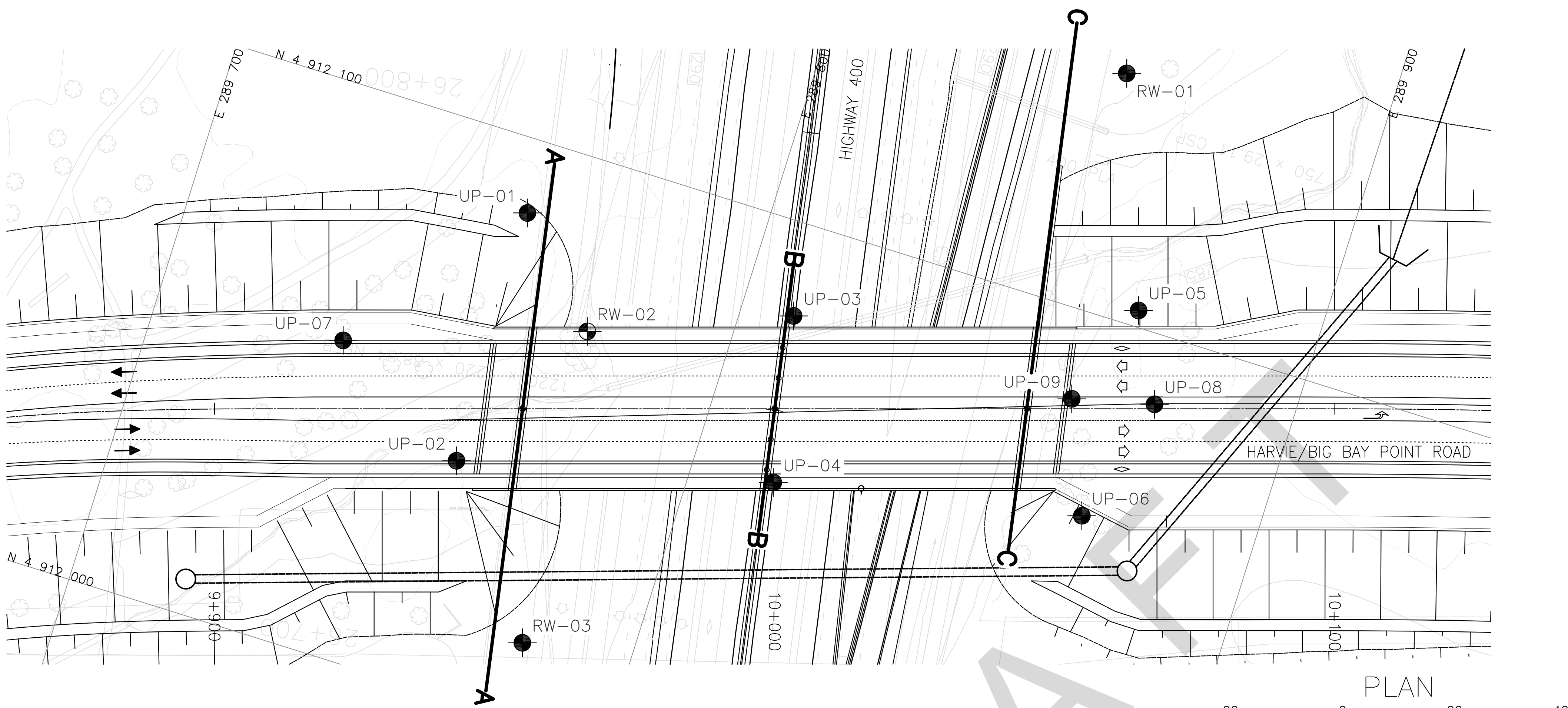
SHEET

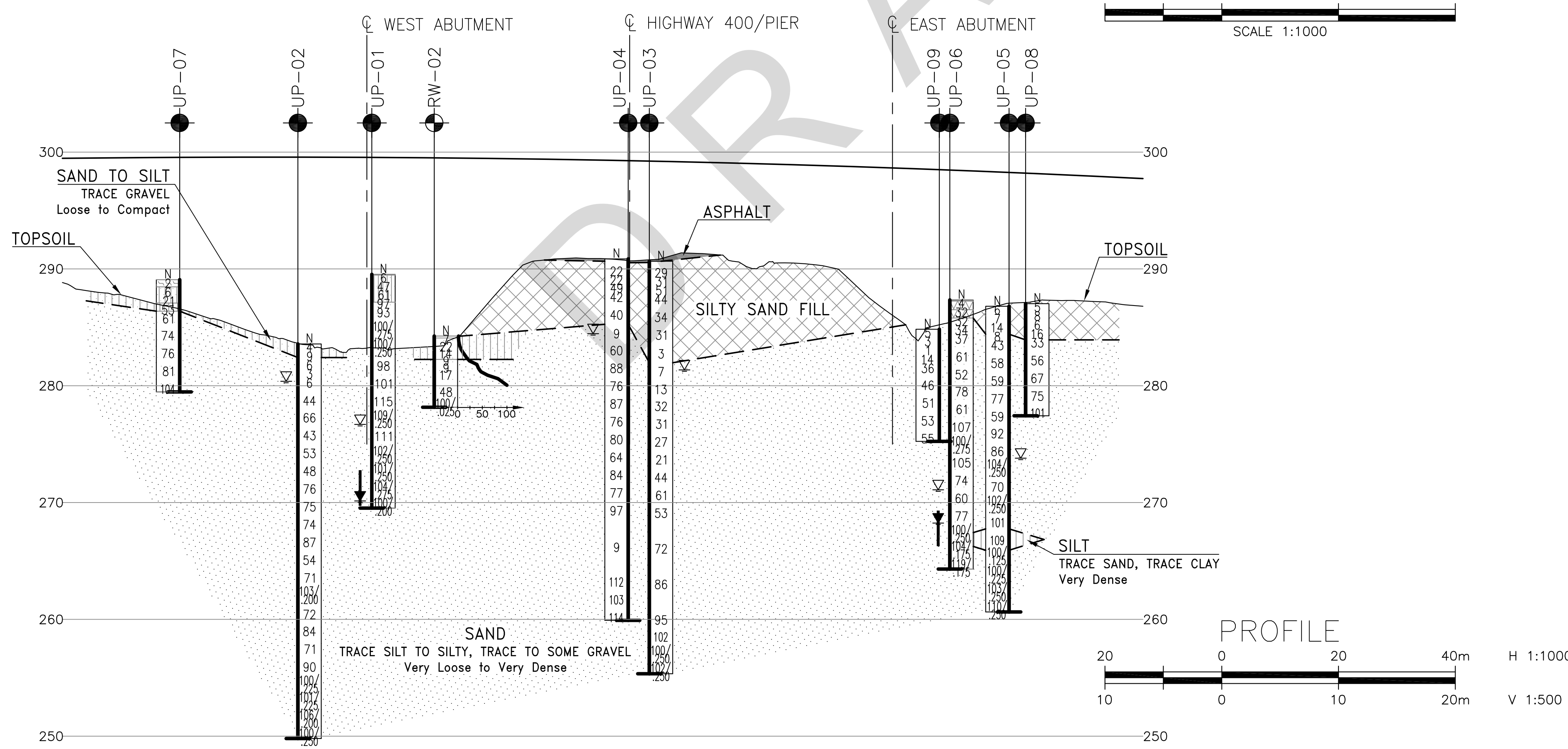
HIGHWAY 400 HARVIE/BIG BAY POINT ROAD UNDERPASS

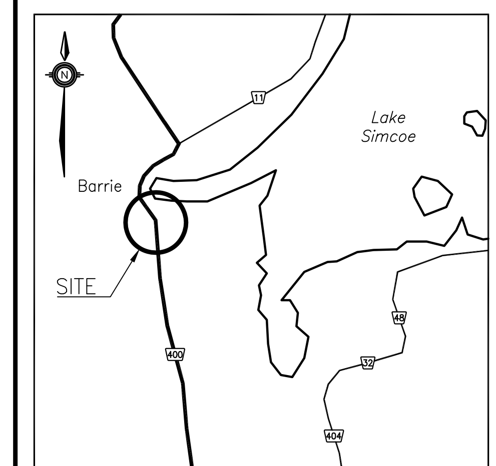
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH

THURBER ENGINEERING LTD.







KEYPLAN

LEGEND

Symbol	Description
●	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 During Drilling
▼	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RW-01	285.2	4 912 142.7	289 853.2
RW-02	284.3	4 912 069.9	289 775.1
RW-03	288.3	4 912 013.4	289 780.6
UP-01	289.5	4 912 086.9	289 758.5
UP-02	283.6	4 912 040.9	289 759.7
UP-03	290.7	4 912 083.6	289 809.4
UP-04	290.9	4 912 054.1	289 814.8
UP-05	286.8	4 912 102.9	289 867.9
UP-06	287.3	4 912 064.9	289 869.2
UP-07	289.1	4 912 055.4	289 733.9
UP-08	287.0	4 912 087.8	289 875.6
UP-09	284.8	4 912 084.3	289 861.2

-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.

REVISIONS	DATE	BY	DESCRIPTION

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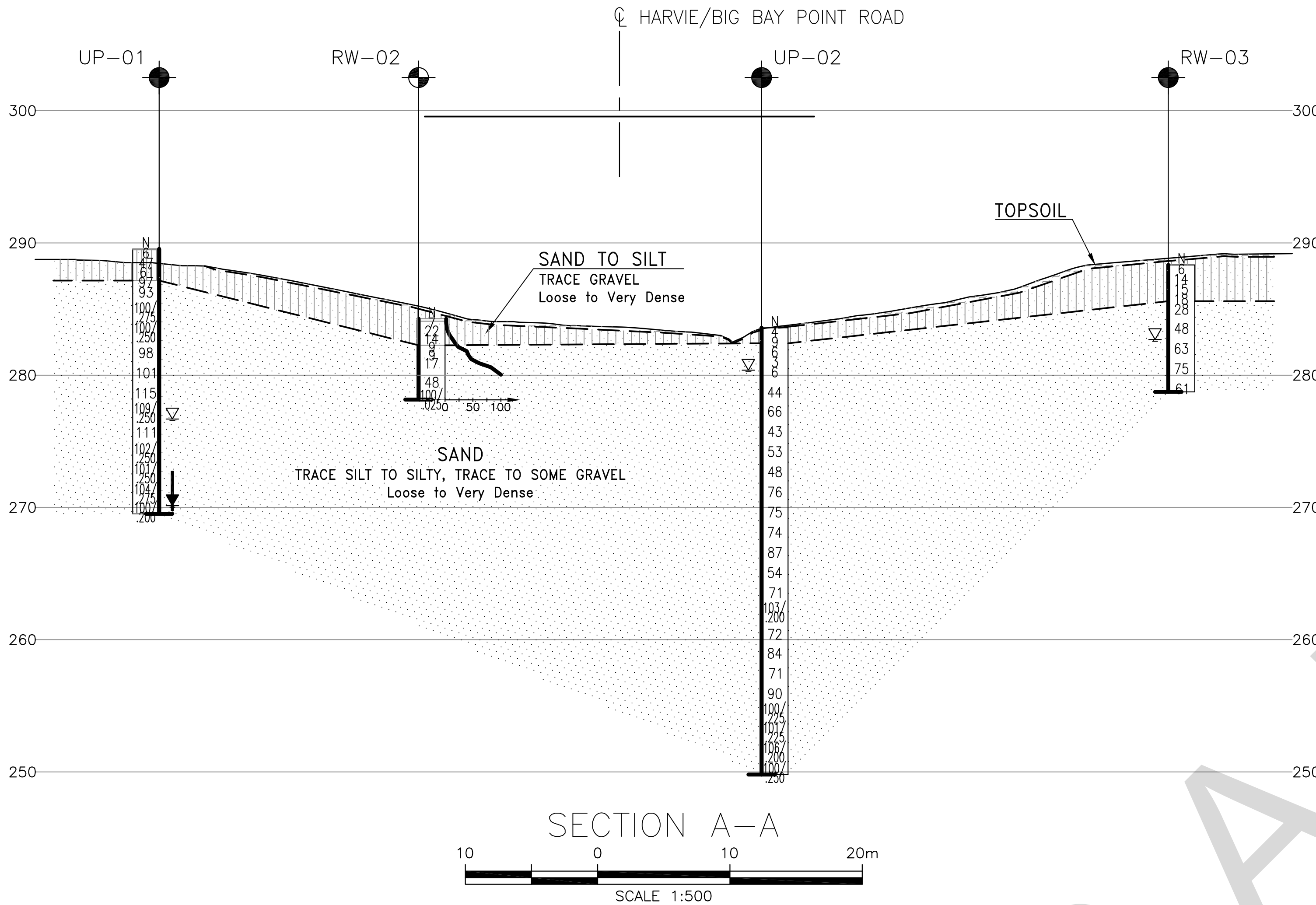
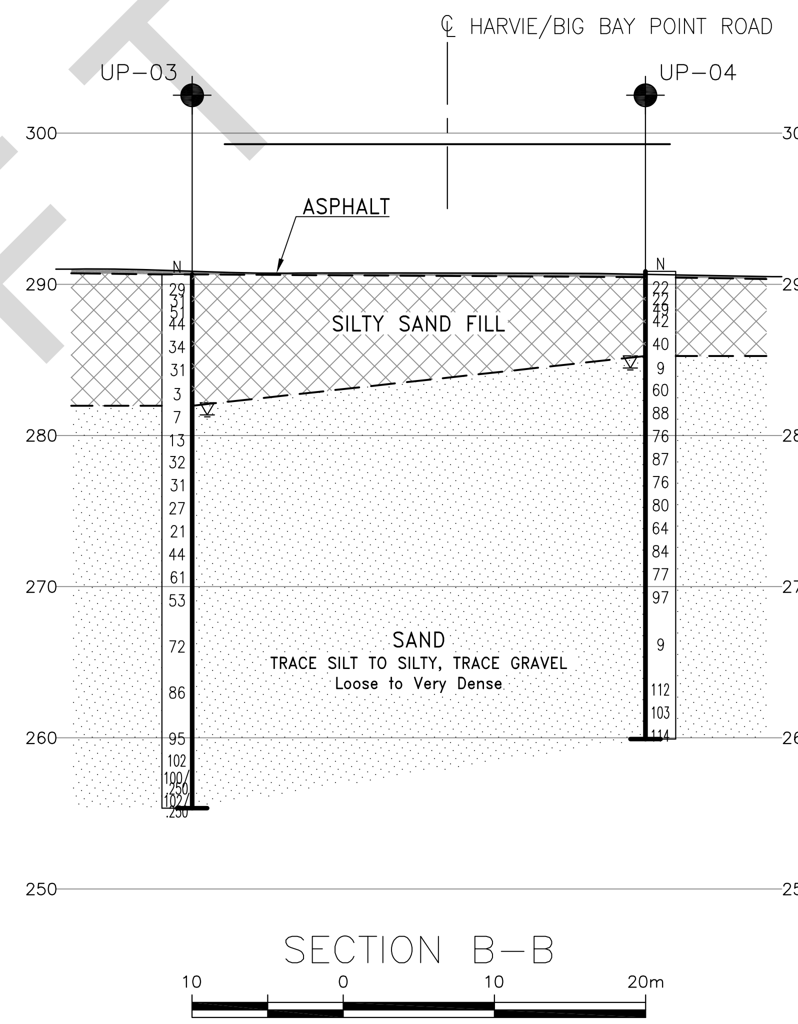
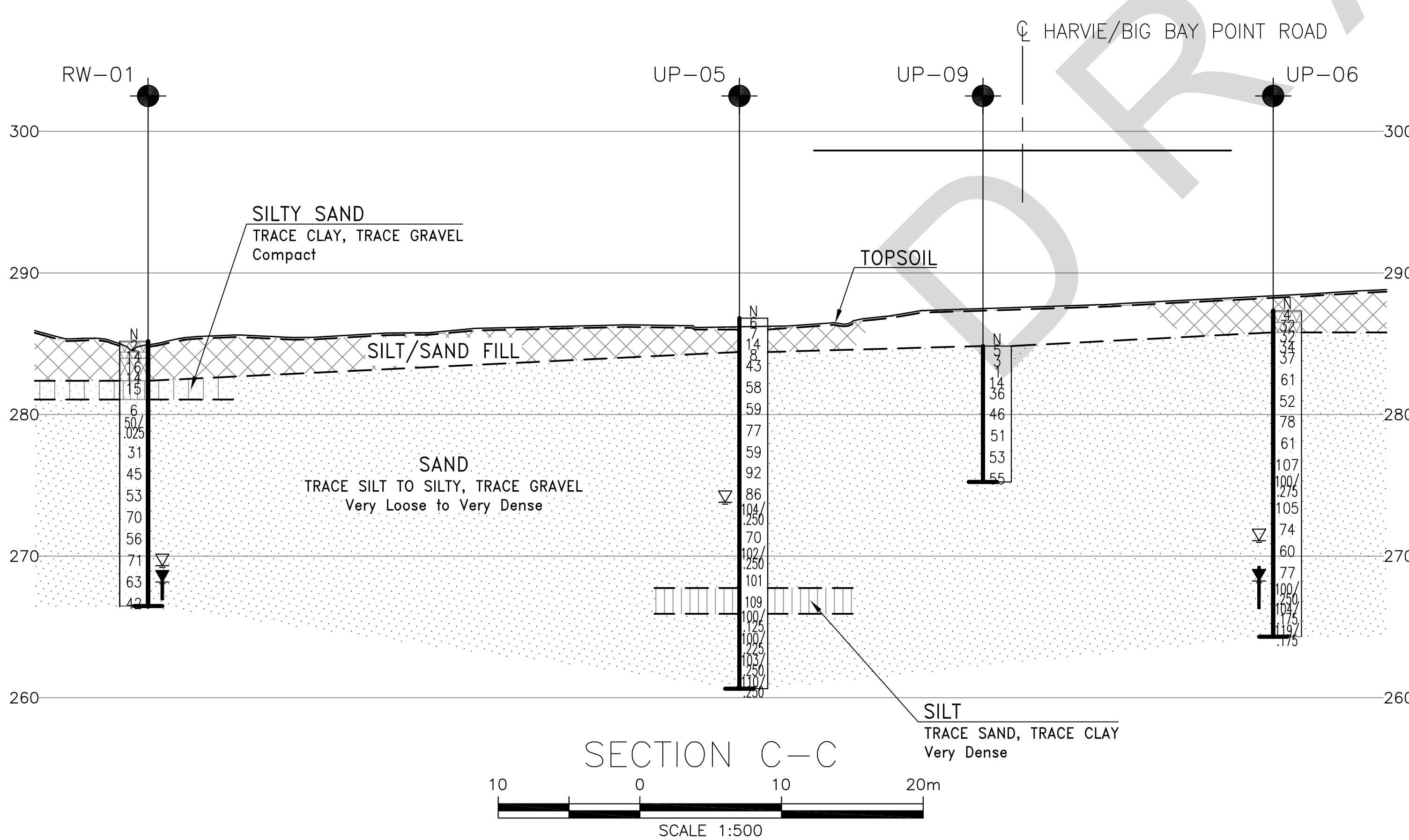






METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

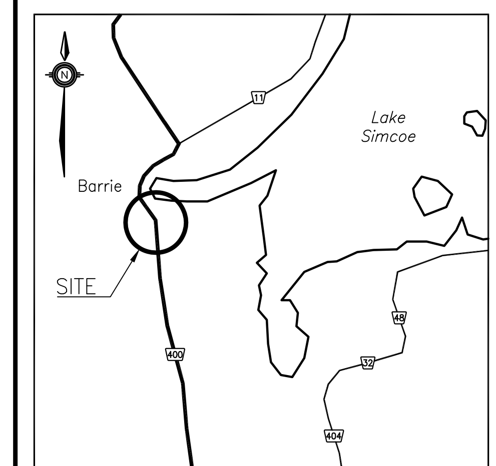
CONT No
WP No

SHEET

HIGHWAY 400
HARVIE/BIG BAY POINT ROAD
UNDERPASS
SOIL STRATA

HATCH

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

Symbol	Description
(Borehole symbol)	Borehole
(Borehole and Cone symbol)	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
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PH	Pressure, Hydraulic
(symbol)	Water Level During Drilling
(symbol)	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RW–01	285.2	4 912 142.7	289 853.2
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UP–06	287.3	4 912 064.9	289 869.2
UP–07	289.1	4 912 055.4	289 733.9
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UP–09	284.8	4 912 084.3	289 861.2

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1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
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GEOCRES No.

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