THURBER ENGINEERING LTD.

MEMORANDUM

To: Mahfuz Alam, M.Eng., P.Eng.
AECOM

Date: September 16, 2016

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(Reviewed by P.K. Chatterji, P.Eng.)

File: 14515

PRELIMINARY FOUNDATION RECOMMENDATIONS
BOWEN ROAD UNDERPASS REPLACEMENT
QEW/BOWEN ROAD INTERCHANGE IMPROVEMENT
FORT ERIE, ONTARIO
G.W.P. 2482-04-00

INTRODUCTION

This memorandum presents preliminary foundation recommendations for the proposed replacement of the Queen Elizabeth Way (QEW) Bowen Road underpass structure in the Town of Fort Erie, Niagara Region, Ontario. The bridge replacement is a part of the QEW Bowen Road interchange improvement project.

A preliminary General Arrangement (GA) drawing, dated September 2008, provided by AECOM indicates that the new underpass consists of a two-span structure supported by one pier and two abutments. The drawing appears to illustrate the proposed integral abutments supported on piles socketted into bedrock and the pier supported on augered caissons founded on bedrock. The new bridge will be approximately 95.5 m in length and 11.6 m in width, and will intersect the QEW at a 40° skew. The immediate approaches to the bridge and the high fills at the east embankment are up to the order of 8 m in height. The Bowen Road Underpass will be designed to carry two lanes of traffic. The new bridge centreline will be in the order of 7 m to 10 m to the south of the existing bridge centreline.

It is understood that an underground Enbridge pipeline in the vicinity of the bridge will be relocated to the north side of the proposed bridge.

Record of Borehole sheets and a Borehole Location Plan are attached for reference.

SUBSURFACE CONDITIONS

A foundation investigation involving seven boreholes was carried out at the site in August 2016 to supplement preliminary boreholes completed in 2008. Three of the new boreholes were advanced to prove bedrock at the abutment and pier locations. The boreholes were also advanced to confirm the nature and extent of the existing approach fill.

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Based on the new boreholes drilled on Bowen Road, the subsurface conditions generally consist of a pavement structure with a 100 mm thick layer of asphalt overlying 200 mm to 600 mm of gravelly sand fill. The underlying approach embankment consists of up to 4.1 m of silty clay fill. The base of fill elevations at the boreholes ranges between 185.4 m and 185.8 m at the west approach, and between Elevations 185.3 m and 187.3 m at the east approach. The silty clay fill has a typically stiff to firm consistency. Below and beyond the fill, native firm to hard silty clay containing some sand and trace gravel was contacted at most locations. Layers of typically compact sand and silt containing some clay and trace to some gravel were also encountered below the fill or below the native silty clay. The above soil strata are underlain by grey shaley dolostone bedrock across the site. At the west approach, bedrock was encountered at 6.2 m to 6.7 m depths (Elevations 183.6 m to 183.7 m). Bedrock was encountered at 2.3 m (Elevation 183.7 m) below the QEW median. At the east approach, bedrock was encountered at 6.4 m to 8.1 m depths (Elevations 181.9 m to 182.7 m).

No free groundwater was observed in the open boreholes upon completion of drilling. Stabilized piezometric water levels are yet to be established. However, previous investigations at and in the vicinity of the site indicated that the groundwater level could be up to the order of Elevation 184m.

FOUNDATION ALTERNATIVES

Consideration was given to the following foundation types for the new abutments and piers:

- Steel H-piles socketted into bedrock
- Steel pipe piles
- Augered caissons (drilled shafts) socketted into bedrock
- Spread footings on bedrock
- Spread footings on native soils or engineered fill

Abutments

From a foundations perspective, an integral abutment design is feasible for this site as indicated on the preliminary GA drawing. Accordingly, a single row of steel H-piles will be required at each abutment. The depth to bedrock is up to the order of 6.7 m and 8.1 m at the west and east abutments, respectively. A minimum pile length of 5 m below the CSP (flexible zone) is typically considered. The required pile embedment depth below the CSP should be determined by the structural designer for satisfying base fixity and/or other structural requirements.

The preliminary GA drawing indicates that the underside of the abutment stems is at approximate Elevation 185 m. Based on the bedrock elevations outlined above, there is insufficient depth to accommodate the minimum pile length. Accordingly, the piles will need to be socketted into bedrock by installing and grouting them within pre-drilled holes. Driven piles are not suitable for this site due to the shallow bedrock.

If integral abutments are not used, augered caissons socketted into bedrock is a feasible foundation option.

Steel pipe piles cannot be used for integral abutments due to its high stiffness. If integral abutments are not considered, steel pipe piles socketted into bedrock may be used. Driven pipe piles are not suitable for this site due to the shallow bedrock.

Spread footings require large excavations within roadway protection systems. As such, spread footings are not considered feasible for supporting the abutments at this site and no foundation recommendations will be developed.

Pier

The preferred foundation option at the pier is augered caissons (drilled shafts) which can be designed to be structurally connected to the superstructure without a cap. This would eliminate the need for open excavation in conjunction with roadway protection and better cope with space restriction at the narrow QEW median.

Driven steel H-piles are not suitable for the pier due to the shallow bedrock. Steel H-piles socketted within bedrock may be feasible only if there is sufficient space and if it is cost effective to construct the pile cap. No foundation recommendations are currently being developed for this option.

Spread footings founded on bedrock is a technically feasible foundation option at the pier if there is sufficient space for a temporary excavation within roadway protection systems at the QEW median. The designer should evaluate the cost effectiveness of this option should it be considered.

STEEL H-PILES

The steel H-piles for supporting the integral abutments will need to be socketted into bedrock. The sockets should be pre-drilled and the socket base should be cleaned of loose and shattered rock. The pile should then be lowered into the socket and the remaining space grouted with 30 MPa concrete. A pre-drilled hole for commonly used H-piles (e.g. HP 310 x 110) are typically 600 mm in nominal diameter. The actual depth of sockets shall be designed to provide the required lateral resistances and base fixity. It is recommended that a minimum 3 m deep socket in the sound dolostone bedrock be used.

The recommended design founding elevations are as follows:

Table 1 – Design Socketted Pile Tip Elevations

Foundation Element	Borehole	Highest Pile Tip Elevation (m)
West abutment	16-02 08-02	180.7
East abutment	16-04 (north) 08-04 (south)	179.7 177.9

Axial Resistance

For steel H-piles grouted in rock sockets, the following axial design geotechnical resistances per pile may be used.

Table 2 – Design Pile Resistances

Pile Type	Factored Geotechnical Resistance at ULS (kN)
HP 310 x 110	2,000
HP 360 x 132	2,400

The geotechnical SLS condition does not govern pile design in rock.

The structural resistance of the pile must be checked by the structural designer. The piles shall also be designed to provide the required lateral resistance and base fixity.

Lateral Resistance

For integral abutments, the flexibility of the upper portion of the pile may be provided by a single corrugated steel pipe (CSP) system. Reference should be made to the integral abutment manual for details of this system.

For pile lateral resistance design below the flexible zone, soil-pile interaction analyses may be carried out using the coefficient of horizontal subgrade reaction values provided in Table 3 and in conjunction with the equations below.

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

<u>Cohesionless soils</u>

$k_s = n_h \cdot z / B$ (kN/m^3)

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

where
- p_{ult} = ultimate lateral resistance mobilized by a pile, kPa
- z = depth of embedment of pile, m
- B = pile width, m
- n_h = coefficient related to soil density, kN/m^3
- γ = total unit weight of fill, γ_T (above groundwater level), kN/m^3
- γ = submerged unit weight of soils, γ' (below groundwater level), kN/m^3
- K_p = passive earth pressure coefficient

Cohesive soils

$$k_s = 67\ C_u / B \quad (kN/m^3)$$
$$p_{ult} = 9\ C_u \quad (kPa)$$

where C_u = undrained shear strength of cohesive soils, kPa

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

Parameter values for lateral pile resistance are shown in Table 3 below.

Table 3 – Soil Parameters for Lateral Pile Resistance

Foundation Element	Elevation (m)	C_u (kPa)	Unit Weight (kN/m^3)	K_p	n_h (kN/m^3)	Soil Conditions
West Abutment	Underside of abutment to bedrock	75	20	-	-	Silty Clay to Silty Clay Till (firm to hard)
East Abutment	Underside of abutment to 182.5	-	10*	3.3	4,000	Sand and Silt (compact)
	182.5 to bedrock	200	20	-	-	Silty Clay Till (hard)

*Buoyant unit weight below the water table

For sockets formed within the dolostone bedrock, the ultimate passive force that can be mobilized by the embedded portion of a rock socket is given by:

$$P_p = 6 . C . D . L$$

where C = 2,000 kPa (equivalent Mohr-Coulomb cohesion based on Hoek and Brown rock mass classification)
D = rock socket diameter (m)
L = rock socket depth (m)

The structural designer should check whether a 3 m long socket is sufficient to provide base fixity.

After each pile is driven, the space between the pile and the CSP should be filled with sand. The gradation of the sand should be in accordance with Table 4 below.

Table 4 – Integral Abutment Sand 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%

Installation of the piles must be in accordance with OPSS 903.

AUGERED CAISSONS (DRILLED SHAFTS)

Augered caissons (drilled shafts) foundations formed through the soil strata and socketted into dolostone bedrock may be employed at the pier. Table 5 below presents the recommended founding elevations for the caissons. It is recommended that each rock socket be extended to at least two (2) times the socket diameter below the top of bedrock.

Table 5 - Founding Elevations for Augered Caissons

Foundation Element	Borehole	Caisson Diameter (m)	Assumed Design Bedrock Elevation (m)	Assumed Founding Elevation (m)
Pier	16-03 08-03	1.2	183.1 (lower)	180.7
		1.5		180.1

The following Table 6 presents factored geotechnical resistances calculated for typical 1.2 and 1.5 m diameter caissons associated with the following minimum socket depths within bedrock.

Table 6 - Vertical Geotechnical Resistance for Caisson Foundations

Caisson Diameter (m)	Minimum Socket Depth below Bedrock Surface (m)	Factored ULS (kN)
1.2	2.4 (2D)	4,000
1.5	3.0 (2D)	7,500

* D = caisson diameter

The SLS condition does not govern design of caisson in bedrock.

The minimum spacing between adjacent caissons should be as per the CHBDC 2014. The vertical resistance will not be significantly affected by the caisson spacing for caissons socketed within bedrock.

For lateral resistance design of caissons, soil-caisson interaction analyses may be carried out using the coefficient of horizontal subgrade reaction values provided in Table 3 for the sands and silts assuming the top of bedrock at Elevation 183 m, and in conjunction with the equations and method outlined above for lateral resistance of piles. For caisson analysis, D denotes the caisson diameter.

SPREAD FOOTINGS ON BEDROCK AT PIER

If spread footings founded on bedrock are considered at the pier, a Factored Geotechnical Resistance at ULS of 3,000 kPa may be used for design. The SLS condition does not govern design of footings founded on bedrock.

The top of bedrock elevations encountered at the borehole locations are summarized in Table 7. Any depressions in the bedrock surface should be brought up to the design founding level using mass concrete fill of the same class as the footing concrete.

Table 7 – Top of Bedrock Elevations at Borehole Locations

Foundation Element	Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
Pier	16-03	2.3	183.7
	08-03	1.9	183.1

The geotechnical resistance is based on a minimum 2.0 m wide footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC 2014.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.7 for cast-in-place concrete footings on bedrock.

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RSS ABUTMENTS

RSS systems may be used at both abutments provided that the levelling pad for the wall panels is formed directly on undisturbed native soils or on a pad of engineered fill. A Factored Geotechnical Resistance at ULS of 350 kPa and a Geotechnical Resistance at SLS of 225 kPa may be used for preliminary design.

NEW APPROACH EMBANKMENTS

The preliminary GA drawing indicates a grade raise of about 3 m at both approaches. As per MTO requirements, a mid-height bench with a minimum width of 2 m is typically required for approach fills that are 8 m or higher for maintenance purposes. It is anticipated that the mid-height bench will not be required for enhancing global stability. Detailed global stability analysis will be carried out once the actual design slope geometry is available. Considering the site and subsurface conditions, fills with a slope inclination not steeper than 2H : 1V are expected to remain stable.

The new fill will induce elastic settlements of the over-consolidated silty clay and the sands and silts. The magnitudes of these settlements are anticipated to be limited due to the soil conditions and shallow bedrock. Detailed settlement calculations will be carried out once the actual design slope geometry is available.

CLOSURE

The above preliminary foundation recommendations have been provided based on preliminary design information in order to allow the bridge design to proceed at this time. These recommendations may be subject to revision and elaboration as the design proceeds.

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

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

DISCONTINUITY SPACING

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

SYMBOLS

- CLAYSTONE
- SILTSTONE
- SANDSTONE
- COAL
- BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

<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			

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-01

METRIC

W.P. 2482-04-00 | LOCATION QEW/Bowen Rd. Underpass N 4 754 988.3 E 346 903.9 | ORIGINATED BY OA

HWY QEW | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.08.29 - 2016.08.29 | CHECKED BY RPR

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
189.8	GROUND SURFACE									
0.0 / 0.1	**ASPHALT:** (100mm)									
189.1 / 0.7	Gravelly **SAND** Compact Grey Moist (FILL)	1	SS	28		○				
	Silty **CLAY**, some sand, trace gravel Stiff to Firm Brown to Dark Brown Moist (FILL)	2	SS	9	189	○				
		3	SS	6	188	○				
		4	SS	5	187	○				
		5	SS	6	186	○	3	23	31	43
185.4 / 4.4	**SAND** and **SILT**, some clay, trace gravel Compact Dark Brown Moist	6	SS	19	185	○	8	40	35	17
					184					
183.6 / 6.2	END OF BOREHOLE AT 6.2m UPON REFUSAL ON BEDROCK. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN CONCRETE TO SURFACE.	7	SS	50/ 0.150		○				

Column headings also include: STRAT PLOT; 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 (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-02

METRIC

W.P. 2482-04-00
LOCATION QEW/Bowen Rd. Underpass N 4 754 990.1 E 346 916.0
ORIGINATED BY OA
HWY QEW
BOREHOLE TYPE Hollow Stem Augers/HQ Coring
COMPILED BY AN
DATUM Geodetic
DATE 2016.08.29 - 2016.08.29
CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.4	GROUND SURFACE							
0.0 / 0.1	**ASPHALT:** (100mm)							
189.9 / 0.5	Gravelly **SAND** Compact Grey Moist (FILL)	1	SS	15	190			
	Silty **CLAY**, some sand, trace gravel Stiff to Firm Brown Moist (FILL)	2	SS	8	189			
		3	SS	5				0 17 33 50
		4	SS	5	188			
		5	SS	7	187			
185.8 / 4.6	Silty **CLAY**, some sand, trace gravel Firm to Hard Brown Moist	6	SS	7	186 / 185			
	Coring started at 6.7m	7	SS	31	184			3 19 38 40
183.7 / 6.7	Shaley **DOLOSTONE**, slightly weathered, thinly bedded, grey, very strong to strong. Horizontal joints (25mm) at 7.1m, 7.2m, 7.3m, 7.4m and 7.5m	1	RUN		183		FI 6, 6, 1	RUN #1 TCR=100% SCR=100% RQD=17% UCS=144.8MPa (Limestone)
	Horizontal joints (25mm) at 7.8m, 7.9m, 8.0m, 8.1m, 8.3m, 8.7m, 8.8m, 8.9m and 9.2m	2	RUN		182		8, 5, 4, 4, 3	RUN #2 TCR=100% SCR=100% RQD=32% UCS=131.0MPa (Limestone)
	Horizontal joints (25mm) at 9.4m, 9.5m, 9.6m, 9.7m, 9.8m, 9.9m, 10.3m and 10.7m. Rubble zone (50mm) at 9.9m				181		5, 5	RUN #3 TCR=100% SCR=100%

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

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 16-02

METRIC

W.P.	2482-04-00	LOCATION	QEW/Bowen Rd. Underpass N 4 754 990.1 E 346 916.0	ORIGINATED BY	OA
HWY	QEW	BOREHOLE TYPE	Hollow Stem Augers/HQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.29 - 2016.08.29	CHECKED BY	RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Shaley **DOLOSTONE**, thinly bedded Grey Vertical joint (175mm) at 10.3m		3	RUN			180			3 3 1	RQD=50% UCS=85.7MPa (Limestone)
179.6 10.8	END OF BOREHOLE AT 10.8m. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. Piezometer installation consists of 50mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m)										

+³, ×³: Numbers refer to Sensitivity

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

ONTMT4S MTO-14515.GPJ 2015TEMPLATE(MTO).GDT 9/14/16

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-03

METRIC

W.P. 2482-04-00	LOCATION QEW/Bowen Rd. Underpass N 4 754 969.8 E 346 985.6	ORIGINATED BY OA
HWY QEW	BOREHOLE TYPE Hollow Stem Augers/HQ Coring	COMPILED BY AN
DATUM Geodetic	DATE 2016.08.30 - 2016.08.30	CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL / UNIT WEIGHT
186.0	GROUND SURFACE					
0.0	**TOPSOIL:** (25mm)					
185.3 / 0.7	Silty **CLAY**, some sand, trace gravel, occasional organics, roots and rootlets Firm Brown Moist	1	SS	8		
	SAND and **SILT**, some clay, trace gravel Compact to Dense Brown	2	SS	27	185	
		3	SS	47	184	4 39 37 20
183.7 / 2.3	Coring started at 2.3m Shaley **DOLOSTONE**, slightly weathered, thinly bedded, grey, very strong	1	RUN			RUN #1 TCR=100% SCR=100% RQD=17%
	Horizontal joints (25mm) at 3.0m, 3.2m, 3.6m, 3.7m and 4.3m	2	RUN		183, 182	RUN #2 TCR=100% SCR=100% RQD=70% UCS=148.3MPa (Limestone)
180.4 / 5.6	Horizontal joints (25mm) at 4.9m, 5.0m, 5.3m and 5.4m	3	RUN		181	RUN #3 TCR=100% SCR=100% RQD=94% UCS=126.6MPa (Limestone)
	END OF BOREHOLE AT 5.6m. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.					

FI (fracture index, m): 5, 4, 2, 3, 2, 1, 3, 0, 1, 2, 3, 1

Plot 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; STRAT PLOT; GROUND WATER CONDITIONS.

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

RECORD OF BOREHOLE No 16-04

METRIC

W.P.	2482-04-00	LOCATION	QEW/Bowen Rd. Underpass N 4 754 996.8 E 346 989.1	ORIGINATED BY	OA
HWY	QEW	BOREHOLE TYPE	Hollow Stem Augers/HQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.30 - 2016.08.30	CHECKED BY	RPR

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
190.8	GROUND SURFACE
0.0	**ASPHALT:** (100mm)
0.1	Gravelly **SAND** Compact Grey Moist (FILL)
190.1 / 0.7	Silty **CLAY**, some sand, trace gravel Firm Brown Moist (FILL)
186.8 / 4.0	Silty **CLAY**, some sand, trace gravel Soft Brown Moist
184.7 / 6.1	**SAND** and **SILT**, some clay Compact Brown Moist Coring started at 8.1m
182.7 / 8.1	Shaley **DOLOSTONE**, slightly weathered, thinly bedded, grey, very strong to strong Horizontal joints (25mm) at 8.2m, 8.3m, 8.4m, 8.5m, 8.8m and 9.0m Sub-horizontal joint (25mm) at 9.2m Horizontal joints (25mm) at 9.5m, 9.6m, 9.8m, 9.9m, 10.1m, 10.2m and 10.6m

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	14		
2	SS	7		
3	SS	5		
4	SS	4		0 18 36 46
5	SS	5		
6	SS	3		
7	SS	20		
8	SS	39		14 38 32 16
1	RUN		FI: 4, 3, 2	RUN #1 TCR=100% SCR=100% RQD=33% UCS=105.2MPa (Limestone)
2	RUN		1, 1	RUN #2 TCR=100% SCR=100% RQD=73% UCS=99.4MPa (Limestone)

ELEVATION SCALE: 190, 189, 188, 187, 186, 185, 184, 183, 182, 181

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 16-04

METRIC

W.P.	2482-04-00	LOCATION	QEW/Bowen Rd. Underpass N 4 754 996.8 E 346 989.1	ORIGINATED BY	OA
HWY	QEW	BOREHOLE TYPE	Hollow Stem Augers/HQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.08.30 - 2016.08.30	CHECKED BY	RPR

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Shaley **DOLOSTONE**, thinly bedded Grey Rubble zone (25mm) at 10.5m									3 2	
	Horizontal joints (25mm) at 10.9m and 11.1m		3	RUN			180			4 1 0	RUN #3 TCR=100% SCR=100% RQD=94% UCS=110.2MPa (Limestone)
179.2 11.6	END OF BOREHOLE AT 11.6m. Piezometer installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m)										

ONTMT4S MTO-14515.GPJ 2015TEMPLATE(MTO).GDT 9/14/16

+ 3 , × 3 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-05

METRIC

W.P. 2482-04-00	LOCATION QEW/Bowen Rd. Underpass N 4 754 999.5 E 347 004.1	ORIGINATED BY OA
HWY QEW	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2016.08.29 - 2016.08.29	CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
190.3	GROUND SURFACE									
0.0	**ASPHALT:** (100mm)									
0.1	Gravelly **SAND**, Compact, Grey, Moist (FILL)	1	SS	21	190					
189.8 / 0.5	Silty **CLAY**, trace sand, trace gravel, Stiff to Firm, Brown, Moist (FILL)	2	SS	9	189					
		3	SS	13						
		4	SS	6	188					
187.3 / 3.0	Silty **CLAY**, some sand, trace gravel, Firm, Brown, Moist	5	SS	6	187					
		6	SS	50	186		4	18	35	43
185.3 / 5.0	Gravelly **SAND**, some silt, Very Dense, Grey, Moist				185					
184.2 / 6.1	**SAND** and **SILT**, some clay, trace gravel, Compact, Brown, Wet	7	SS	17	184					
		8	SS	50/ 0.075	183		6	45	36	13
182.5 / 7.8	END OF BOREHOLE AT 7.8m UPON REFUSAL ON BEDROCK. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN CONCRETE TO SURFACE.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-06

METRIC

W.P. 2482-04-00 LOCATION QEW/Bowen Rd. Underpass N 4 755 002.8 E 347 044.2 ORIGINATED BY OA

HWY QEW BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2016.08.29 - 2016.08.29 CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
188.3	GROUND SURFACE									
0.0	**ASPHALT:** (100mm)									
188.0 / 0.1 / 0.3	Gravelly **SAND** Compact Grey Moist (FILL)	1	SS	22	188	~1				
	Silty **CLAY**, trace sand, trace gravel Very Stiff to Firm Brown Moist (FILL)	2	SS	7	187	~18				
		3	SS	15	186	~22				
		4	SS	7		~16				
185.3 / 3.0	Silty **CLAY**, trace sand, trace gravel Firm Brown to Grey Moist	5	SS	7	185	~24	0	10	34	56
184.2 / 4.1	**SAND** and **SILT**, some clay, some gravel Compact Brown Moist	6	SS	14	184 / 183	~7				
181.9		7	SS	50/ 0.150	182	~9	12	33	38	17
6.4	END OF BOREHOLE AT 6.4m UPON REFUSAL ON BEDROCK. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN CONCRETE TO SURFACE.									

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

+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 16-07

METRIC

W.P. 2482-04-00 | LOCATION QEW/Bowen Rd. Underpass N 4 754 971.0 E 347 088.6 | ORIGINATED BY OA

HWY QEW | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.08.29 - 2016.08.29 | CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)
184.0	GROUND SURFACE					
0.0	**TOPSOIL:** (25mm)					
	Silty **CLAY**, some sand, trace gravel Firm to Hard Brown Moist	1	SS	5		○
		2	SS	63	183	○
		3	SS	74	182	○
		4	SS	95/ 0.300		○
181.2 / 2.8	**SAND** and **SILT**, some clay, trace gravel Very Dense Grey Moist				181	
		5	SS	58		○
180.3 / 3.7	END OF BOREHOLE AT 6.2m UPON REFUSAL ON BEDROCK. NO FREE WATER IN BOREHOLE UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.					

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

+³, ×³: Numbers refer to Sensitivity

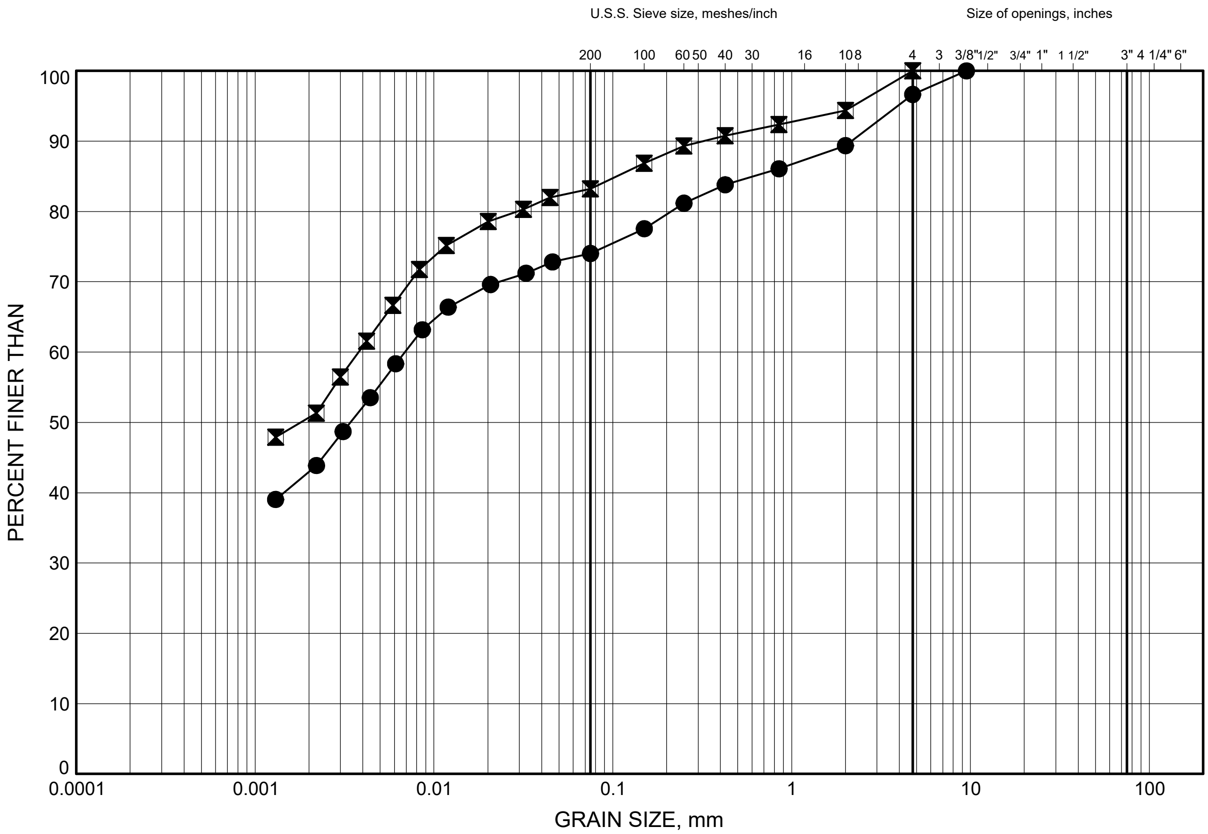
20 / 15 ◔ 5 / 10 (%) STRAIN AT FAILURE

QEW - Bowen Road Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	3.35	186.45
⧗	16-02	1.83	188.57

Date September 2016

W.P. 2482-04-00

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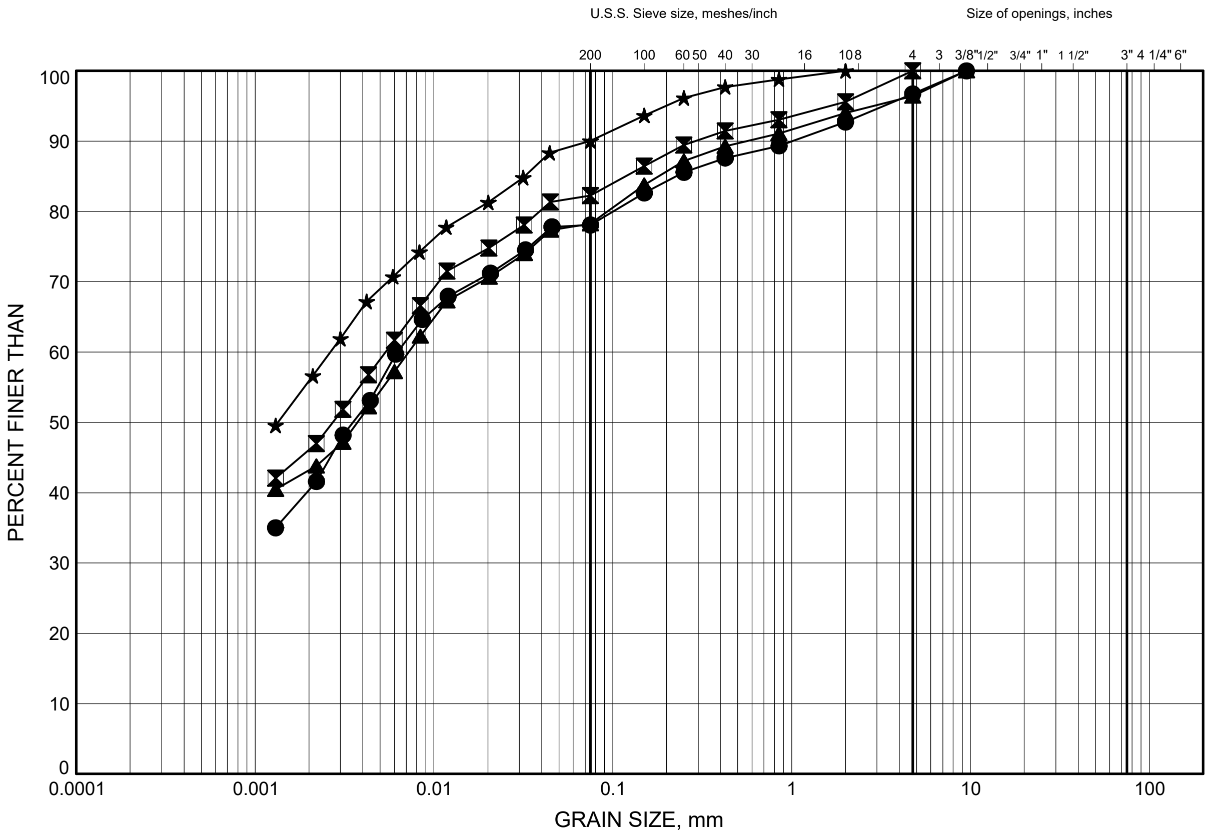
QEW - Bowen Road Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-02	6.40	184.00
⧗	16-04	2.59	188.21
▲	16-05	5.03	185.27
★	16-06	3.35	184.95

Date September 2016

W.P. 2482-04-00

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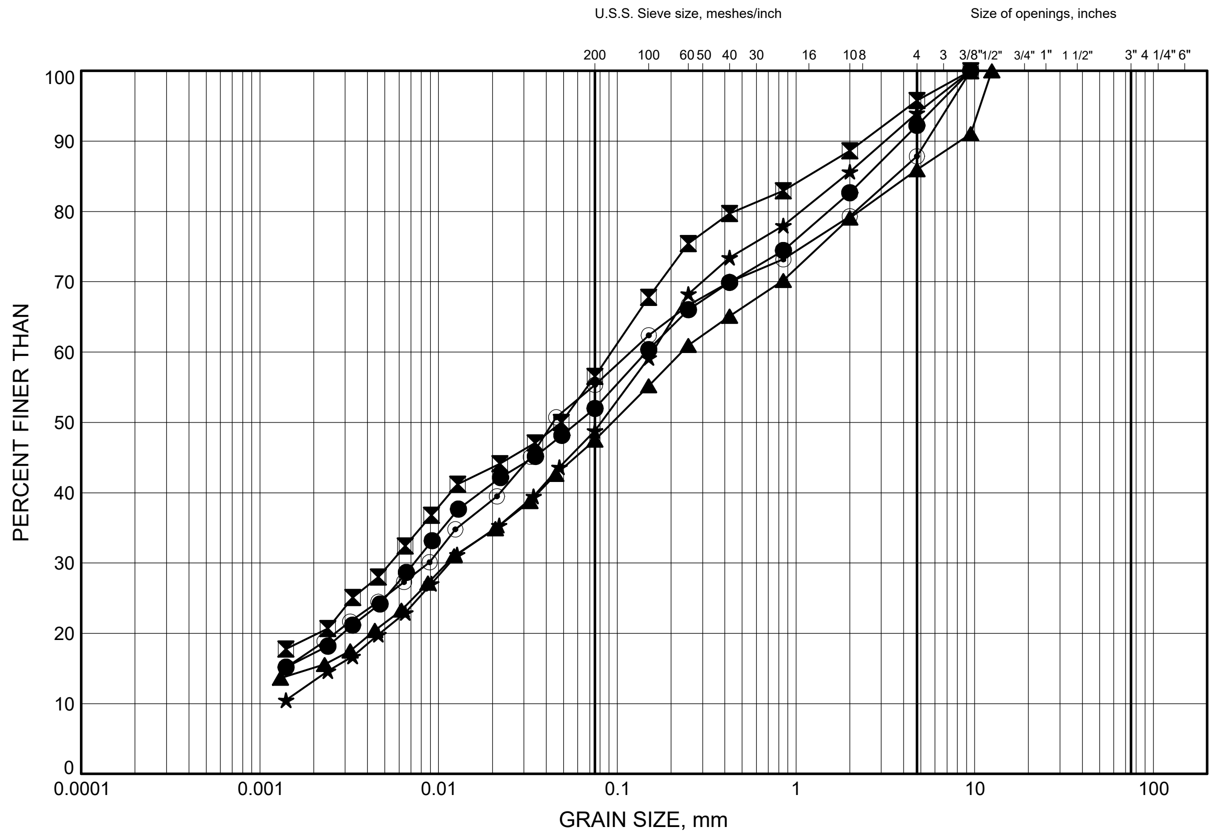
GRAIN SIZE DISTRIBUTION - THURBER MTO-14515.GPJ 9/13/16

QEW - Bowen Road Interchange

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND and SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	4.88	184.92
⧗	16-03	1.83	184.17
▲	16-04	7.92	182.88
★	16-05	7.73	182.57
⊙	16-06	6.25	182.05

Date September 2016

W.P. 2482-04-00

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GRAIN SIZE DISTRIBUTION - THURBER MTO-14515.GPJ 9/13/16

METRIC

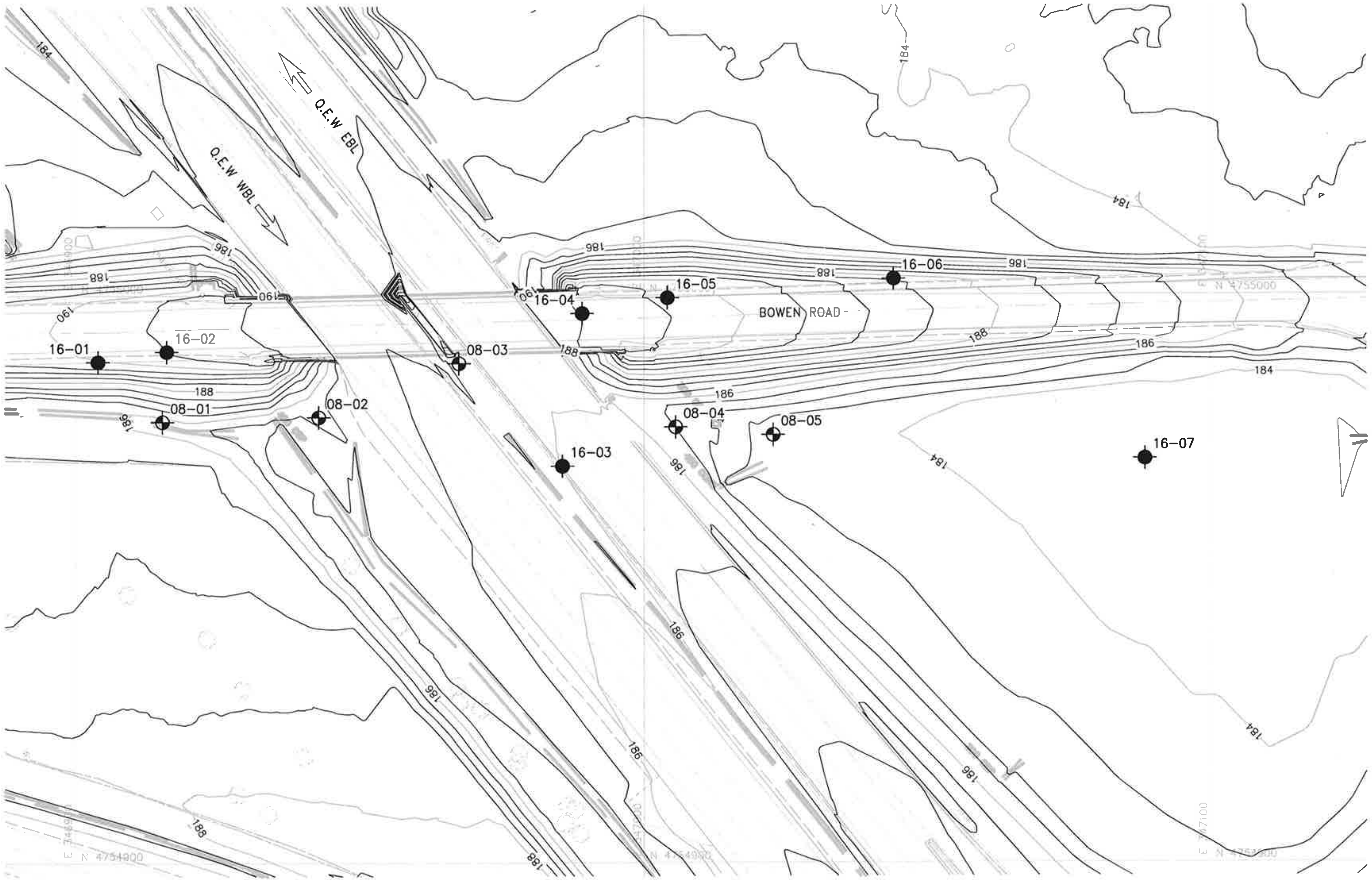
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 2482-04-00

SHEET

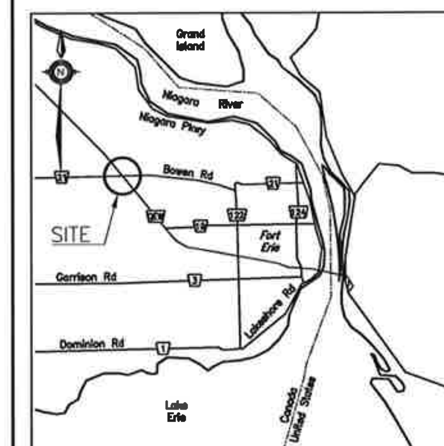
Q.E.W
BOWEN ROAD UNDERPASS
BOREHOLE LOCATIONS PLAN

THURBER ENGINEERING LTD.



PLAN

SCALE 1:800



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
16-01	189.8	4 754 988.3	346 903.9
16-02	190.4	4 754 990.1	346 916.0
16-03	186.0	4 754 969.8	346 985.6
16-04	190.8	7 754 996.8	346 989.1
16-05	190.3	4 754 999.5	347 004.1
16-06	188.3	7 754 002.8	347 044.2
16-07	184.0	4 754 971.0	347 088.6
08-01	185.7	4 754 977.7	346 915.2
08-02	185.3	4 754 978.5	346 942.7
08-03	185.0	4 754 988.0	346 967.3
08-04	184.0	4 754 976.7	347 005.6
08-05	185.0	4 754 975.3	347 022.8

-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

DESIGN RPR	CHK RPR	CODE	LOAD	DATE SEP 2016
DRAWN AN	CHK SKP	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\14000\14515\TED-14515-BoreholePlan.dwg
PLOTDATE: 9/15/2016 3:26 PM