

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
W-N RAMP HWY 403 UNDER QEW WESTBOUND
QUEEN ELIZABETH WAY/HIGHWAY 403 IMPROVEMENTS
OAKVILLE, ONTARIO**

W.O. 09-20007, SITE No. 10-284-1

Geocres Number: 30M5-298

Report to

McCormick Rankin

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation conducted for the proposed new structure which will carry westbound Queen Elizabeth Way (QEW) over Highway 403 W-N Ramp in the Town of Oakville, Ontario. This investigation is part of the QEW/Highway 403 Improvements project, from Trafalgar Road to Winston Churchill Boulevard.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

The information collected in the course of the investigation and presented in this report is intended for preliminary design purposes only. Additional site investigation, field testing and engineering analysis will be required at the detailed design phase. The extent of the additional investigation will depend on the final location and General Arrangement (GA) of the structure.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin (MRC), under the Ministry of Transportation Ontario (MTO) Work Order Number 09-20007.

A previous foundation investigation report was completed in 1978 for the existing ramp structure located 5 m south of the proposed structure. The title of the report is as follows:

Foundation Investigation Report for W-N Ramp HWY 403 Under QEW, District 4,
(Hamilton), W.P. 159-75-06, Geocres 30M05-117, Site 10-284, dated February
1978

The Record of Borehole sheets for four boreholes (BH 1, 2, 3 and 4) drilled during the previous investigation have been used in the preparation of this report and are included in Appendix A.

2 SITE DESCRIPTION

The site is located on the QEW approximately 500 m east of the existing Ford Drive underpass structure. At this location the QEW has both a horizontal and vertical curvature and consists of 6 lanes of traffic, three EB lanes and three WB lanes. This general area has a gentle slope to the south and west towards Joshua Creek. The lands surrounding the site are primarily undeveloped fields in the adjacent MTO right-of-way. There are commercial developments further to the north east and residential developments further to the southeast. The proposed structure will be located directly to the north of the existing WB QEW structure at this location.

The site lies within the South Slope physiographic region, characterized by glacially deposited overburden overlying shale bedrock of the Queenston and Dundas Formations of the upper Ordovician age.

A photograph included in Appendix D shows the site of the proposed structure.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on May 30 and 31, 2013. Two boreholes were drilled at this proposed structure site, identified as 13-25 and 13-26. Borehole 13-25 was drilled near the west abutment and Borehole 13-26 was drilled near the east abutment. The borehole depths ranged from 6.1 m to 7.6 m. Four boreholes which were drilled during the previous investigation (No. 1, No. 2, No. 3, and No. 4) have also been included in this report. The Record of Borehole sheets for both the current investigation and previous investigation are included in Appendix A.

The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix E. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole sheets.

The borehole locations were marked in the field and utility clearances were obtained prior to commencement of drilling operations.

The drilling was carried out using a CME 55 track-mounted drill rig. A combination of solid stem augers and NQ coring techniques were used to advance the boreholes. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The recovered soil and bedrock samples were logged in the field and

processed for transport to Thurber's laboratory in Oakville, Ontario for further examination and testing.

Groundwater conditions were observed in the open boreholes during the drilling operations, prior to coring. A standpipe piezometer, consisting of 19mm diameter PVC pipe with slotted screen, was installed in each borehole drilled at this structure site. The installation details of the piezometers are summarised in Table 3-1.

Table 3-1. Piezometer Installation Details

Borehole	Tip Position		Borehole Completion and Piezometer Installation Details
	Depth (m)	Elev. (m)	
13-25	6.1	140.2	Sand filter from 6.1 to 4.3 m, then bentonite holeplug from 4.3 m to surface.
13-26	7.6	140.2	Sand filter from 7.6 to 5.8 m, then bentonite holeplug from 5.8 m to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determinations. Selected samples were also subjected to grain size distribution analyses (sieve and hydrometer). The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

Point load tests were conducted on selected portions of the rock cores. The UCS values of the rock were assessed from the point load data and these values are reported on the borehole logs (as average UCS per run).

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A, and the Borehole Location and Soil Strata Drawing in Appendix E. An overall description of the stratigraphy based on the conditions encountered in the boreholes is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The stratigraphy encountered in the boreholes generally consists of a thin layer of topsoil overlying layers of sand fill and native silty clay, which is underlain by reddish brown shale bedrock. The boreholes drilled during the previous investigation only encountered silty clay overlying the shale bedrock. More detailed descriptions of the individual strata encountered at the proposed structure site are presented below.

5.1 Topsoil

A thin layer of topsoil (100 mm thick) was encountered at the surface in both boreholes drilled during the current investigation. The topsoil thickness may vary between and beyond borehole locations and the data is not intended for the purpose of estimating quantities.

5.2 Fill

A layer of sand fill, some gravel to gravelly and some silt was encountered below the topsoil in both boreholes drilled during the current investigation. The sand fill was 0.7 m thick in both boreholes, with the lower boundary encountered at a depth of 0.8 m (Elev. 147.0 and 145.5 m).

SPT N-values of 18 and 21 blows for 300 mm of penetration were recorded, indicating a compact relative density. A moisture content of 5% was measured.

Laboratory grain size distribution analysis was carried out on one sample of the fill. The results of this test are summarized below and are presented on the corresponding Record of Borehole sheet included in Appendix A and the grain size distribution curve is presented on Figure B1 of Appendix B.

Gravel %	22
Sand %	62
Silt and Clay %	16

5.3 Silty Clay

A layer of native silty clay, trace sand and trace shale fragments was encountered at the surface in the four boreholes drilled during the previous investigation and below the sand fill in the two boreholes from the current investigation. The thickness of the silty clay ranged from 0.7 m to 2.4 m, with the lower boundary encountered at depths of 1.5 m to 2.4 m (Elev. 143.2 to 145.4 m).

SPT N-values recorded in the silty clay ranged from 14 to 45 blows for 300 mm of penetration, indicating a stiff to hard consistency. In general, the stiffness of the silty clay increased with depth. Moisture contents ranged from 11 to 24%.

Laboratory grain size distribution analysis was carried out on two samples of the silty clay (one from the previous investigation and one from the current investigation). The results of these tests are summarized below and are presented on the corresponding Record of Borehole sheets included in Appendix A and the grain size distribution curve for the sample from the current investigation is presented on Figure B2 in Appendix B.

Gravel %	0
Sand %	4 to 8
Silt %	65 to 69
Clay %	27

Two samples of the silty clay (from the previous investigation) underwent Atterberg Limits testing. The results of these tests are presented on the corresponding Record of Borehole sheets included in Appendix A and indicate that the silty clay exhibits intermediate plasticity with a plastic limit of 20 and a liquid limit of 37.

5.4 Shale Bedrock

Reddish brown, thinly bedded shale was encountered below the native silty clay and was proven by coring in both boreholes advanced during the current investigation and in two boreholes from the previous investigation (No. 2 and No. 3). Boreholes No. 1 and No. 4 penetrated the bedrock with augers. The shale was observed to have frequent hard limestone interbeds up to 300 mm thick. The shale bedrock was highly weathered near the bedrock surface and slightly weathered to fresh within 1 to 1.5 m of the soil-bedrock interface.

The depths and elevations at which bedrock was encountered at the borehole locations are summarized in Table 5-1.

Table 5-1. Depths and Elevations of Bedrock Surface

Foundation Element	Borehole	Bedrock Surface	
		Depth (m)	Elevation (m)
West Abutment	13-25	1.5	144.8
	3 ⁽¹⁾	2.1	143.8
	4 ⁽¹⁾	2.4	143.2
East Abutment-	13-26	2.4	145.4
	1 ⁽¹⁾	2.1	145.4
	2 ⁽¹⁾	2.1	144.8

Note: (1) Geocres 30M05-117, Site 10-284

Total Core Recovery (TCR) in the bedrock typically ranged from 70 and 100%, indicating good core recovery. A TCR value of 41% was recorded in Borehole No. 2 from the previous investigation. The Rock Quality Designation (RQD) values ranged from 13 to 82%, indicating a variable rock quality ranging from very poor to good. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to 4.

Average unconfined compression strength (UCS) of the shale, interpreted from point load tests conducted on intact cores, ranged from 3 to 16 MPa, indicating a very weak to weak rock strength. The UCS of selected limestone interbeds ranged from 93 to 193 MPa, indicating a strong to very strong rock strength.

5.5 Groundwater Levels

Water levels were observed in the open boreholes during the current investigation prior to starting the coring operations, where water was added to the borehole. A standpipe piezometer was installed in each borehole drilled during the current investigation, within the shale bedrock. The water levels measured in the open boreholes and piezometers are summarized below.

Table 5-2. Groundwater Depths and Elevations

Borehole	Date of Reading	Water Level		Comment
		Depth (m)	Elev. (m)	
13-25	May 30, 2013	Dry	N/A	Prior to coring
	June 7, 2013	5.5	140.8	Piezometer
	June 26, 2013	5.5	140.8	Piezometer
13-26	May 30, 2013	Dry	N/A	Prior to coring
	June 7, 2013	4.8	143.0	Piezometer
	June 26, 2013	4.4	143.4	Piezometer

It should be noted that the groundwater levels are short term and are susceptible to seasonal fluctuations. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of significant and/or prolonged precipitation events.

6 MISCELLANEOUS

Borehole locations were selected and established in the field by Thurber Engineering Ltd. Surveyors from MMM Group provided co-ordinates and the ground surface elevations at the boreholes drilled.

DBW Drilling Ltd. from Ajax, Ontario supplied a track mounted CME 55 drill rig and conducted the drilling, sampling and in-situ testing operations.

Overall planning and supervision of the field program was conducted by Ms. Lindsey Blaine, P.Eng.. The field investigation was supervised by Mr. George Azzopardi of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

Interpretation of the data and preparation of the report were carried out by Ms. Lindsey Blaine, P.Eng. and Mr. Alastair Gorman, P.Eng.. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Lindsey Blaine, P.Eng.
Geological Engineer

Alastair Gorman, P.Eng.
Senior Foundations Engineer



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



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents preliminary foundation recommendations to assist the design team to select and design a suitable foundation system for the new overpass.

Our understanding of the project, based on the GA, consists of:

- the proposed structure will carry westbound Queen Elizabeth Way (QEW) traffic over Highway 403
- the proposed structure will carry four lanes of traffic and will comprise of 30.0, 44.0 and 30.0 m spans
- the proposed structure will have a conventional abutment with concrete wingwalls at the east abutment (Elev. 147.4 m) and RSS walls at the west abutment (Elev. 145.4 m).

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

8 STRUCTURE FOUNDATION

The stratigraphy identified in the preliminary investigation generally consists of a thin layer of topsoil overlying sand fill followed by native silty clay which is underlain by shale bedrock. The short term groundwater levels measured in the piezometers was at Elev. 140.8 to 143.4 m.

In the preparation of the preliminary foundation design recommendations, consideration was given to the following foundation types:

- Spread footings bearing on shale bedrock

- Spread footings bearing on engineered fill
- Steel H-piles socketed into bedrock
- Augered caissons socketed into bedrock

A comparison of the foundation alternative, based on advantages and disadvantages of each is included in Appendix C.

8.1 Spread Footings Bearing on Shale Bedrock

Highway 403 is constructed in a cut at the proposed structure location. Due to the shallow depth of overburden, spread footings founded on shale bedrock are considered feasible to support the structural loads.

As interpreted from the boreholes, spread footing should be founded on undisturbed shale bedrock at or below elevation 144.0 and 144.9 m at the west and east abutments, respectively. Based on the previous investigation, footings at the piers could be founded below elevation 143.0 m. However, the existing grade may be lower and all footings must be placed at least 0.5 m below the bedrock surface. The elevations presented are the highest recommended founding elevations and must be reviewed during the detail design based on the final bridge arrangement and results of the site investigation and field testing to be completed at that time.

For preliminary design, footings founded on undisturbed shale bedrock should be designed using a factored geotechnical resistance at ULS of 1000 kPa. This value includes a resistance factor of 0.5 as per Table 6.1 of the CHBDC. The SLS condition will not govern design of footings founded on bedrock.

The geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be adjusted as shown in the CHBDC (2006) Clauses 6.7.3 and 6.7.4. During detail design, the geotechnical resistance must also be reviewed taking account of the position of the footing relative to the forward slope.

8.2 Spread Footings on Engineered Fill

If higher founding elevations are required, than those provided in Section 8.1, spread footings could be constructed on an engineered fill pad consisting of Granular 'A' material. This option would be suitable for abutment footings which may be perched within the approach embankment and above the existing bedrock surface elevation.

For preliminary design, footings founded on engineered fill should be designed using a factored resistance at ULS of 900 kPa and a SLS of 350 kPa.

The engineered fill must bear on undisturbed native soil at or below elevation 145.5 and 147.0 at the west and east abutments, respectively. The Granular 'A' pad must be placed in 150 mm lifts and compacted to 100% standard proctor maximum dry density (SPMDD) at optimum moisture content $\pm 2\%$. The geometry of the fill pad must conform to the general requirements shown in Figure 1.

The geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be adjusted as shown in the CHBDC (2006) Clause 6.7.3 and 6.7.4. During detailed design, the geotechnical resistance must also be reviewed taking account of the position of the footing relative to the forward slope.

8.3 Steel H-Piles Socketed into Bedrock

Since bedrock is shallow at this site, driven H-piles would typically not be considered cost effective or practical from a foundation point of view. Piles socketed into the bedrock could be used to provide axial geotechnical resistance and to accommodate the design of an integral abutment, if required.

However, since integral abutment design is not being considered, H-pile design recommendations have not been developed.

8.4 Augered Caissons Socketed into Bedrock

Drilled shaft foundations socketed into shale bedrock are not considered appropriate for this site and have not been developed further.

8.5 Abutment Design Considerations

From a geotechnical perspective, the conditions at this site are considered to be suitable for conventional or semi-integral abutment design, principally due to the shallow depth to bedrock.

8.6 Frost Cover

The design depth of frost penetration at this site is 1.2m. It is recommended that all footings be provided with a minimum of 1.2 m of earth cover above the underside of the pile cap or footing. Frost protection is also required for footings founded on shale bedrock.

8.7 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended foundation for the abutments and piers consists of spread footings bearing on undisturbed shale bedrock.

9 DEWATERING

Excavation for spread footings at the elevations given in Section 8.1 are not expected to penetrate below the groundwater level. However, if deeper excavations are required they may penetrate below the groundwater level and some seepage into the excavation may occur. However, due to the relatively low permeability of the shale, the volumes are expected to be small, similarly, minor seepage from the fill may be encountered and surface water flow may enter the excavations.

Given the small volumes of water that are expected, it is considered that pumping from sumps will be adequate for dewatering excavations at this site. The exposed shale at the base of the foundation excavation must be protected from deterioration with a concrete slab within 24 hours of completion of the excavation.

In the case of sockets drilled in the bedrock for deep foundations, pumping accumulated from the sockets prior to concreting will be adequate, in conjunction with cleaning all loosened material from the socket.

10 APPROACH EMBANKMENTS

Based on the current and previous boreholes drilled at this site, the approach embankments will be constructed over foundation soils consisting of stiff to very stiff native silty clay and shale bedrock. The embankment foundation soils are considered to provide adequate stability if constructed at a side slope of 2H:1V or RSS wall using SSM or granular fill.

Constructing the approach embankments with cohesive fill may be possible but will be dependent on the mechanical properties of the material. An embankment constructed of cohesive material will typically not perform as well as an embankment constructed using SSM or granular fill and will require flatter side slopes which will extend the footprint of the embankment.

Preliminary analysis indicates that settlement of the foundation soils under the imposed embankment loading is expected to be less than 25 mm. Considering the competency of the foundation soils the settlement will be essentially completed when construction of the fill is completed.

Further settlement analysis and the global, internal and surficial stability of the approach embankment fills should be further evaluated during the detailed design phase. Additionally, permanent drainage and slope protection requirements must be addressed during the detailed design.

11 ROADWAY PROTECTION

Excavation support systems may be required for temporary roadway protection during foundation construction where stable slopes cannot be maintained. The temporary excavation support system should be designed and constructed in accordance with OPSS 539. In general, the lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539. The feasibility of installing protection systems should be assessed once further subsurface investigation is carried out during detailed design.

12 CONSTRUCTION CONCERNS

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

- The shale bedrock exposed at the footing base must be concreted within 24 hours after the bedrock surface has been properly prepared and is free of loose debris to prevent softening and deterioration
- Excavation must not undermine the footings of any portion of the existing QEW W-N ramp structure that is still in service

13 INVESTIGATION FOR DETAIL DESIGN

During the detailed design phase of the project, additional site investigation and field testing will be required. The scope and results of this investigation must be reviewed at that time based on the final GA to determine they meet the current Ministry requirements and if additional investigation and analysis is necessary. In particular, subsurface conditions at the pier foundations must be investigated.

14 CLOSURE

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

Thurber Engineering Ltd.

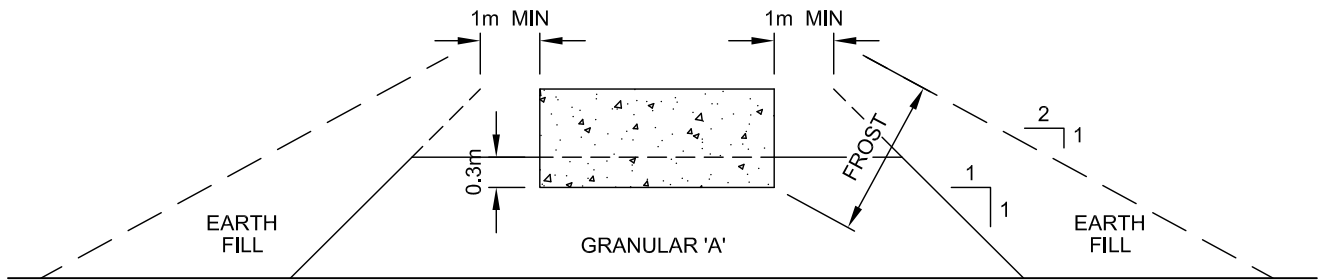
Report prepared by:
Stephen Peters, P.Eng.
Project Engineer

Report reviewed by:
Alastair Gorman, P.Eng.
Senior Foundations Engineer

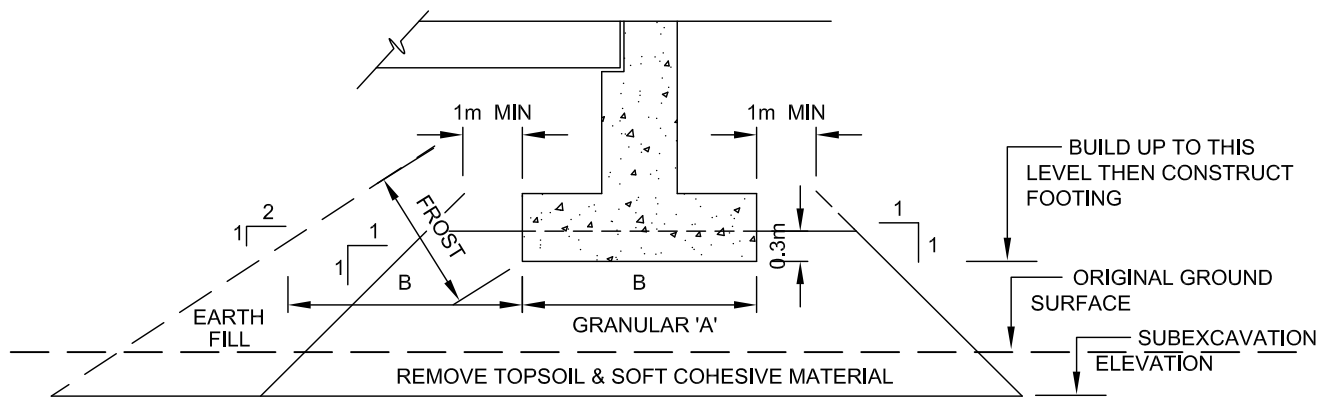


Report reviewed by:
P.K. Chatterji, P.Eng., Ph.D.
Review Principal





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:

SBP

DRAWN:

MFA

APPROVED:

AEG

DATE:

OCTOBER 2013

SCALE:

N.T.S.

DRAWING No.

FIGURE 1

Appendix A
Record of Borehole Sheets

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

SYMBOLS AND TERMS USED ON TEST HOLE LOGS

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 naked eye

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

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROX. SPT ⁽¹⁾ "N" VALUE
Very Soft	< 10	< 2
Soft	10 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	> 200	> 30

(1) Standard Penetration Test – the number of blows from a 63.5kg hammer falling through 0.76m to advance a 60 degree truncated cone 0.3m

TERMS DESCRIBING DENSITY(COHESIONLESS SOILS)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

HIERARCHY OF SOIL STRENGTH PREDICTION

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

LEGEND FOR TEST HOLE LOGS

 Shelby Tube
 A – Casing
  SPT
  Grab/Auger sample
  Core
  No Recovery

- MC – Moisture Content (% by Weight) as determined by sample



Water Level

C _{vane}	Shear Strength Determination by Field Insitu Vane
C _{pen}	Shear Strength Determination by Pocket Penetrometer
C _{lab}	Shear Strength Determination using a Laboratory Vane Apparatus
C _u	Undrained Shear Strength determined by Unconfined Compression Test
AS/GS/BS	Auger Sample/Grab Sample/ Block Sample
SS	Split-spoon
SC	Soil core
AED	Oedometer test
TXL	Triaxial test

RECORD OF BOREHOLE No 13-25

1 OF 1

METRIC

W.P. _____ LOCATION N 4 817 756.1 E 290 730.4 ORIGINATED BY GA
 HWY 403/QEW BOREHOLE TYPE Solid Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2013.05.30 - 2013.05.31 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
146.3								20	40	60	80	100						
0.0	TOPSOIL: (100mm)																	
0.1	Gravelly SAND , some silt Compact Brown Damp (FILL)		1	SS	18		146										22 62 16 (SI+CL)	
145.5																		
0.8	Silty CLAY , trace sand Hard Reddish Brown		2	SS	41		145											
144.7																		
1.5	SHALE , highly weathered, thinly bedded, reddish brown		3	SS	77		144											
	Start coring at 3.0m Slightly weathered to fresh, thinly bedded, occasional limestone interbeds Soft zone (300mm) at 3.0m		1	RUN			143										RUN #1 TCR=100% SCR=92% RQD=82% UCS=3MPa (Average)	
	Limestone interbeds (25mm thick) at 3.5m, 3.7m Horizontal fractures (25mm thick) at 3.1m, 3.2m, 3.4m, 3.6m, 3.7m, 3.8m, 4.3m Limestone interbeds (25mm thick) at 4.6m, 4.9m, 5.5m, 5.6m, 5.9m, 6.0m and (125mm) at 5.1m		2	RUN			142										RUN #2 TCR=100% SCR=97% RQD=67% UCS=13MPa (Average)	
	Horizontal fractures (25mm thick) at 4.6m, 4.9m, 5.0m, 5.2m, 5.3m, 5.4m, 5.6m, 5.7m, 5.9m, 6.1m						141											
140.2																		
6.1	END OF BOREHOLE AT 6.1m. BOREHOLE OPEN TO 6.1m AND WATER LEVEL AT 3.9m UPON COMPLETION OF CORING. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) June 7/13 5.5 140.8 June 26/13 5.5 140.8																	

ONTMT4S 1184.GPJ 2012TEMPLATE(MTO).GDT 8/8/13

RECORD OF BOREHOLE No 13-26

1 OF 1

METRIC

W.P. _____ LOCATION N 4 817 820.0 E 290 765.6 ORIGINATED BY GA
 HWY 403/QEW BOREHOLE TYPE Solid Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2013.05.30 - 2013.05.30 CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
147.8								20	40	60	80	100					
0.0	TOPSOIL: (100mm)																
0.1	SAND , some gravel, some silt Compact Brown Damp (FILL)		1	SS	21												
147.0							147										
0.8	Silty CLAY , trace sand, trace shale fragments Very Stiff to Hard		2	SS	27												0 4 69 27
			3	SS	45		146										
145.4			4	SS	50/ 0.150												
2.4	SHALE , highly weathered, thinly bedded, reddish brown						145										
							144										
	Start coring at 4.6m Slightly weathered to fresh, thinly bedded, reddish brown, occasional limestone interbeds Limestone interbeds (25mm thick) at 4.5m, 5.4m Highly broken zone (125mm) at 5.8m Soft zone (300mm) at 4.5m Horizontal fractures (25mm thick) at 4.9m, 5.2m, 5.6m, 5.7m Limestone interbeds (25mm thick) at 6.0m, 6.1m, 6.4m, 6.5m, 6.7m, 6.8m, 6.9m, 7.0m and (100mm) at 7.3m Horizontal fractures from 6.4m to 7.0m		1	RUN			143										RUN #1 TCR=100% SCR=83% RQD=60% UCS=8MPa (Average)
							142										
			2	RUN			141										RUN #2 TCR=100% SCR=93% RQD=72% UCS=16MPa (Average)
140.2																	
7.6	END OF BOREHOLE AT 7.6m. BOREHOLE OPEN TO 7.6m AND WATER LEVEL AT 2.7m UPON COMPLETION OF CORING. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) May 30/13 4.8 143.0 Jun 26/13 4.4 143.4																

ONTMT4S 1184.GPJ 2012TEMPLATE(MTO) GDT 8/8/13

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 1

W P 159-75-06 LOCATION N 15 805 696 E 953 919 Co-ords. ORIGINATED BY P.J.S.
DIST 4 HWY Q.E.W. BOREHOLE TYPE Solid Auger COMPILED BY P.J.S.
DATUM Geodetic DATE December 22, 1977 CHECKED BY R.S.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
484.1	Ground Level													
0.0	SILTY CLAY TRACE OF SAND Very Stiff To Hard		1	SS	15		480							
477.1			2	SS	60									
7.0	QUEENSTON SHALE BEDROCK		3	SS	100/12"									
	Red To Grey Red		4	SS	100/9"									
468.9			5	SS	100/5"		470							
15.2	End Of Borehole		6	SS	50/13"									
	Note: W.L. Not Established													

RECORD OF BOREHOLE No 2

W P 159-75-06 LOCATION N 15 805 618 E 953 900 Co-ords. ORIGINATED BY P.J.S.
DIST 4 HWY Q.E.W. BOREHOLE TYPE Solid Augers, NX Casing and NXL Core COMPILED BY P.J.S.
DATUM Geodetic DATE December 15, 1977 CHECKED BY R.S.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100		
482.2	Ground Level													
0.0	SILTY CLAY TRACE OF SAND Very Stiff To Hard		1	SS	14		480							
475.2			2	SS	47									
7.0	QUEENSTON SHALE BEDROCK		3	SS	100/14"									
	Red To Grey Red		4	NXL	80% Rec									RQD = 33
	Fine Texture		5	NXL	41% Rec		470							RQD = 13
	Soft And Fissile		6	NXL	81% Rec									RQD = 29
	With Thin Bedding		7	NXL	81% Rec									RQD = 38
	Including A Few Thin Shaly Limestone Beds		8	NXL	85% Rec		460							RQD = 30
			9	NXL	97% Rec									RQD = 73
			10	NXL	87% Rec		450							RQD = 73
			11	NXL	100% Rec									RQD = 75
440.3	End Of Borehole													
41.9	Note: W.L. Not Established													

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF BOREHOLE No 3

W P 159-75-06 LOCATION N 15 805 486 E 953 872 Co-ords. ORIGINATED BY P.J.S.
DIST 4 HWY Q.E.W. BOREHOLE TYPE Solid Auger, B Casing and BXL Core COMPILED BY P.J.S.
DATUM Geodetic DATE December 14, 1977 CHECKED BY R.S.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
478.8	Ground Level																
0.0	SILTY CLAY TRACE OF SAND Very Stiff		1	SS	15												
471.8	To Hard		2	SS	38												
7.0	QUEENSTON SHALE BEDROCK		3	SS	100/10"		470										
	Red To Grey Red Fine Texture Soft And Fissile With Thin Bedding Including A Few Thin Shaly Limestone Beds		4	BXL Core	97% Rec		460										RQD = 30
			5	BXL Core	70% Rec		450										RQD = 46
			6	BXL Core	100% Rec		440										
	Limestone Bed 21'-21'7"																
	Shaly Limestone 33'-34'		7	BXL Core	100% Rec												RQD = 65
436.5	End Of Borehole																
42.3	Note: W.L. Not Established																

RECORD OF BOREHOLE No 4

W P 159-75-06 LOCATION N 15 805 407 E 953 858 Co-ords. ORIGINATED BY P.J.S.
DIST 4 HWY Q.E.W. BOREHOLE TYPE Solid Auger COMPILED BY P.J.S.
DATUM Geodetic DATE December 22, 1977 CHECKED BY R.S.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
477.7	Ground Level																
0.0	SILTY CLAY TRACE OF SAND Very Stiff To Hard		1	SS	15		470										0 8 65 27
469.7			2	SS	58												
8.0	QUEENSTON SHAILE BEDROCK		3	SS	100/9"												0 2 68 30
	Red To Grey Red		4	SS	100/6"												
			5	SS	75/4"		460										
457.5			6	SS	75/3"												
20.2	End Of Borehole																
	Note: W.L. Not Established																

+3, x5 : Numbers refer to
Sensitivity

20
15
10

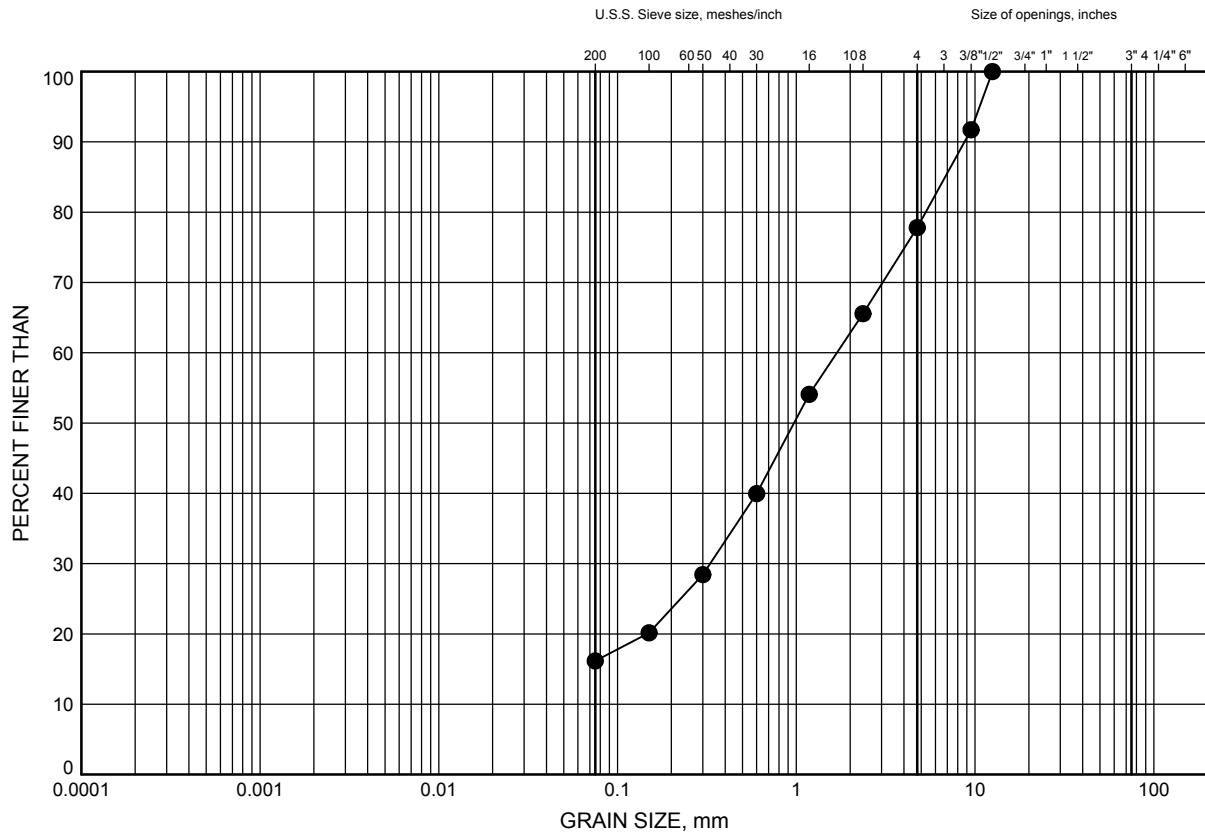
5 (%) STRAIN AT FAILURE

Appendix B
Laboratory Test Results

QEW and Hwy 403
GRAIN SIZE DISTRIBUTION

FIGURE B1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-25	0.30	145.97

Date August 2013
W.P.

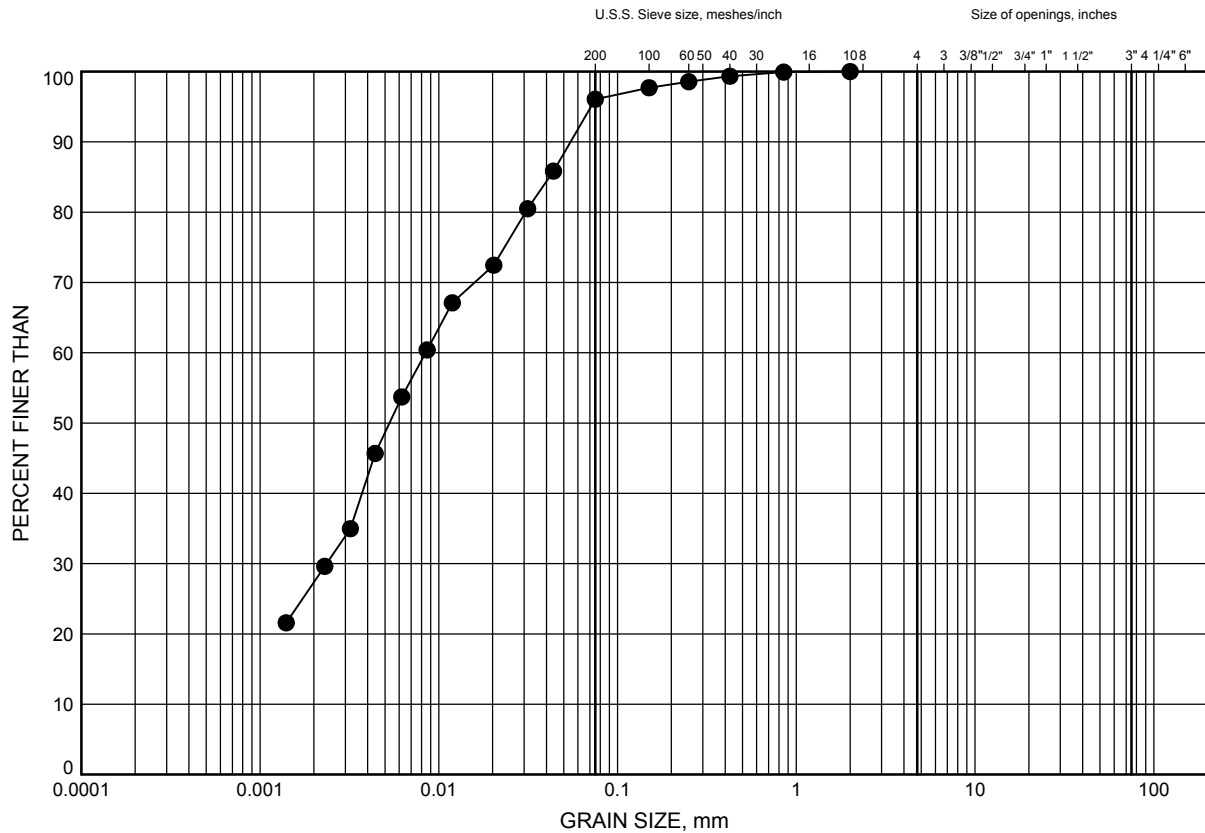


Prep'd SBP
Chkd.

QEW and Hwy 403
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)
●	13-26	1.07	146.73

Date August 2013
W.P.



Prep'd SBP
Chkd.

Appendix C
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

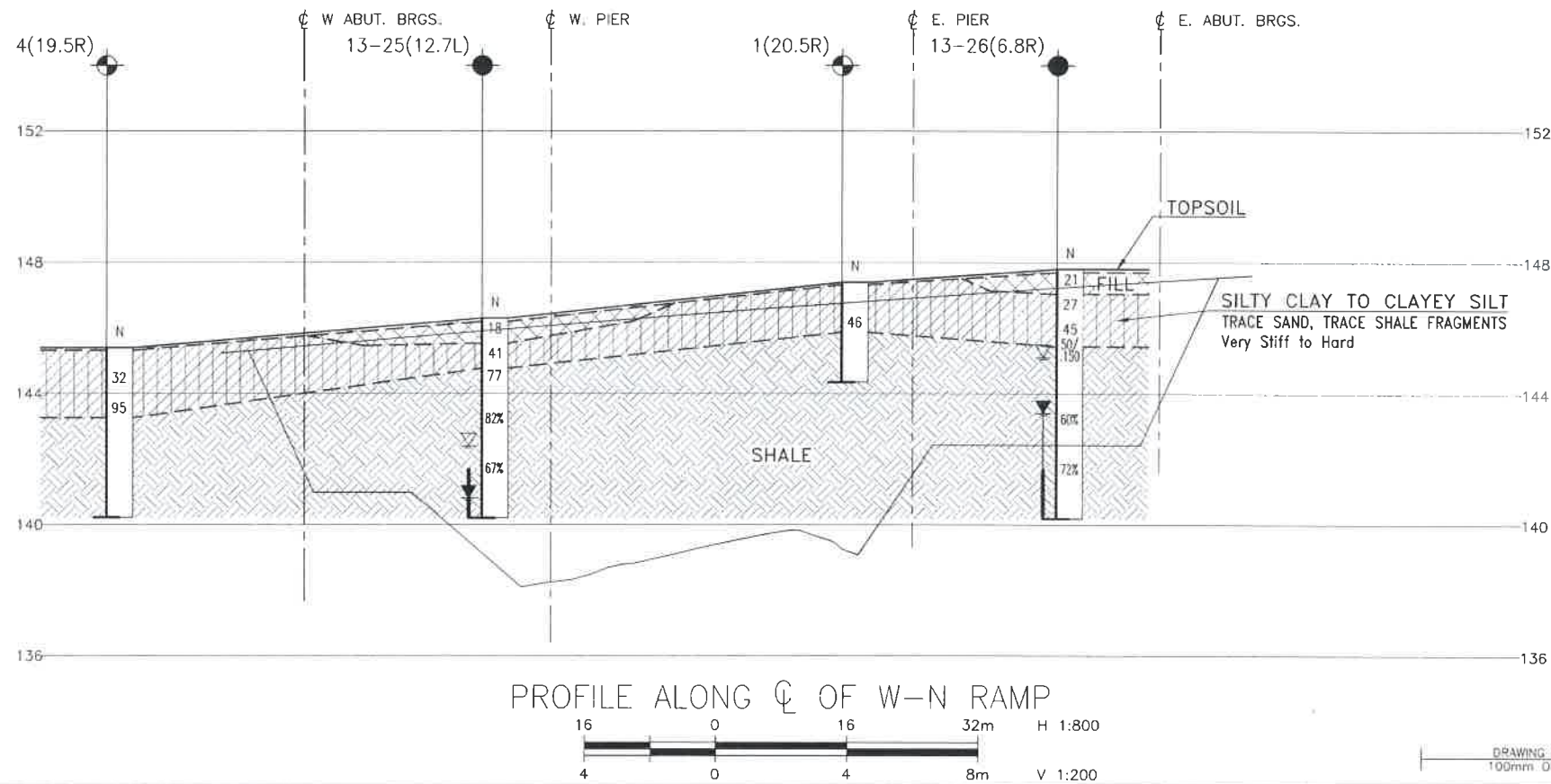
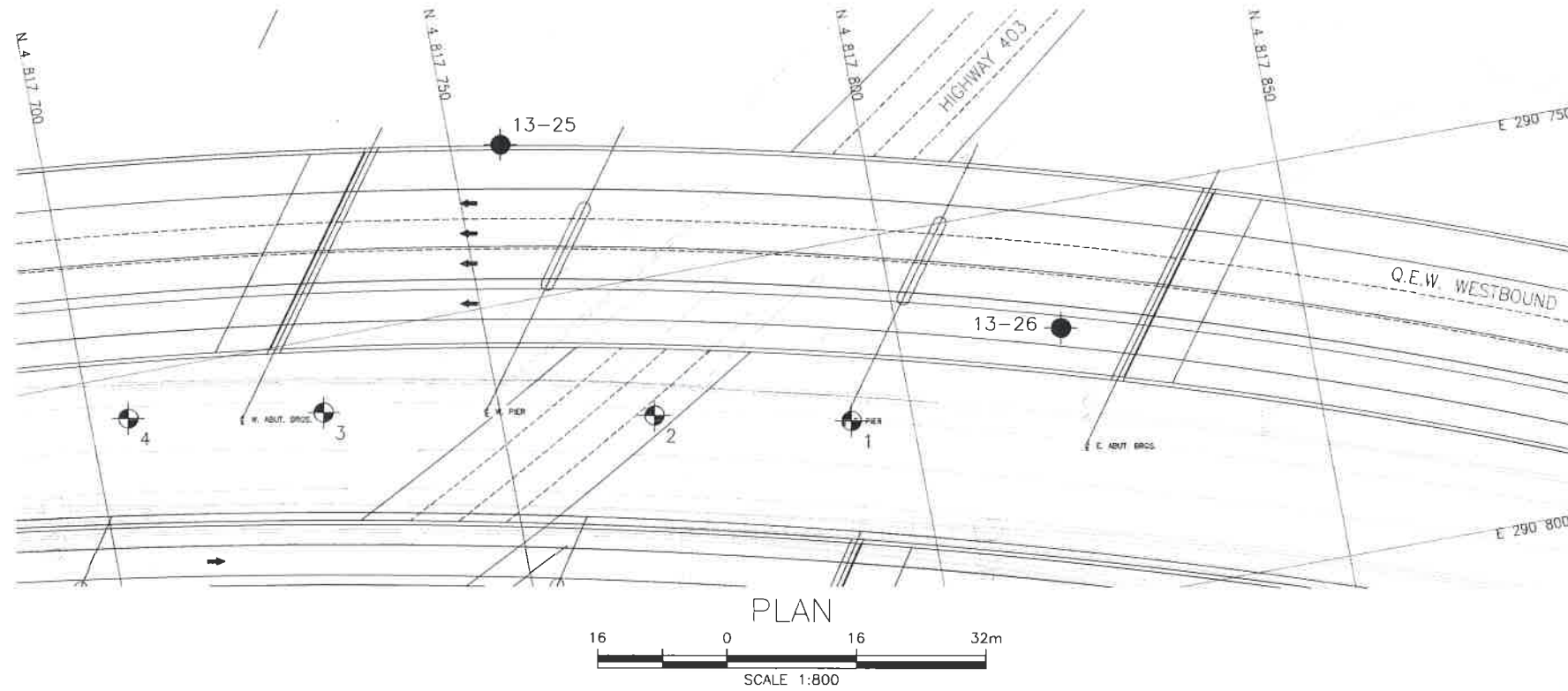
Spread Footing on Shale Bedrock	Spread Footing on Engineered Fill	Steel H-Piles on Shale Bedrock
<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Economical to install ii. Accommodates perched abutment. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance available by socketing piles into bedrock. ii. Provide uplift and overturning resistance iii. Installation less influenced by weather and groundwater than spread footings. iv. Permits integral abutment design v. Comparatively short abutment possible
<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation ii. Ineffective for resistance to uplift or overturning. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation ii. Lower geotechnical resistance than spread footings on bedrock iii. Ineffective for resistance to uplift or overturning. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to spread footings. ii. Difficultly in unwatering, cleaning and inspecting bases iii. Pre-drilling required for installation of socketed piles. iv. Potential for difficulty in drilling through hard limestone interbeds
RECOMMENDED	FEASIBLE	NOT RECOMMENDED

Appendix D
Site Photographs



Photograph 1 – Existing structure carrying WB QEW over HWY 403

Appendix E
Borehole Locations and Soil Strata Drawing

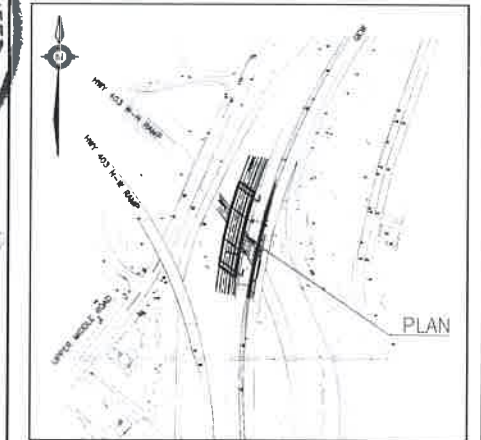


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
WP No

W-N RAMP HWY 403
UNDER Q.E.W. WESTBOUND
BOREHOLE LOCATIONS AND SOIL STRATA



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
13-25	146.3	4 817 756.1	290 730.4
13-26	147.8	4 817 820.0	290 765.6

-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. 30M5-298

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SBP	CHK AEG	CODE
DRAWN	MFA	CHK SBP	SITE
LOAD	DATE	AUG 2013	
STRUCT	DWG	1	

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING