

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HWY 406 BEAVERDAMS ROAD UNDERPASS REHABILITATION
SITE 34-160, W.P. 2348-09-01, G.W.P. 2348-09-00
AND
HWY 58 RICHMOND STREET UNDERPASS REHABILITATION
SITE 34-280, W.P. 2377-09-01, G.W.P. 2365-09-00
CITY OF THOROLD, ONTARIO
P.O. 2010-E-0073**

GEOCRES No. 30M3-276

Report to

**McCormick Rankin,
A member of MMM Group Limited**

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

January 29, 2013
File: 19-1351-221

H:\19\1351\221 5 Bridges Rehab Welland\Reports & Memos\Richmond and Beaverdams\191351221 Hwy 406 Richmond and Beaverdams FIDR FINAL jan 13.doc

TABLE OF CONTENTS

SECTION		PAGE
PART 1	FACTUAL INFORMATION	
1	INTRODUCTION	1
2	PROJECT AND SITE DESCRIPTION	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1	Highway 406 - Beaverdams Road Underpass.....	3
5.1.1	Pavement Structure.....	3
5.1.2	Fill.....	4
5.1.3	Silty Clay	5
5.1.4	Bedrock.....	5
5.1.5	Water Levels.....	6
5.2	Highway 58 - Richmond Street Underpass	7
5.2.1	Topsoil	7
5.2.2	Pavement Structure.....	7
5.2.3	Silty Clay Fill.....	8
5.2.4	Silty Clay	8
5.2.5	Bedrock.....	9
5.3	Water Levels	10
6	MISCELLANEOUS	10
PART 2	ENGINEERING DISCUSSION AND RECOMMENDATIONS	
7	GENERAL.....	13
8	EVALUATION OF EXISTING FOUNDATIONS.....	14
8.1	Existing Foundations.....	14
8.1.1	Beaverdams Road Underpass	15
8.1.2	Richmond Street Underpass	15
8.2	Reassessment of Existing Foundations	16
8.2.1	Beaverdams Road Underpass	16
8.2.2	Richmond Street Underpass	17
9	LATERAL RESISTANCE	18
9.1	Driven Piles.....	18

9.2	Spread Footings.....	20
10	LATERAL EARTH PRESSURES	20
11	APPROACH EMBANKMENTS	21
12	ROADWAY PROTECTION.....	21
13	EXCAVATION AND BACKFILL	22
14	GROUNDWATER AND SURFACE WATER CONTROL.....	22
15	IMPACT ON EXISTING FOUNDATIONS.....	22
16	CONSTRUCTION CONCERNS	23

Appendices

Appendix A	Highway 406 - Beaverdams Road Underpass Record of Borehole Sheets – Current Investigation Laboratory Test Results – Current Investigation Borehole Logs – Previous Investigation Drawing titled “Borehole Locations and Soil Strata”
Appendix B	Highway 58 - Richmond Street Underpass Record of Borehole Sheets – Current Investigation Laboratory Test Results – Current Investigation Borehole Logs – Previous Investigation Drawing titled “Borehole Locations and Soil Strata”

FOUNDATION INVESTIGATION AND DESIGN REPORT
HWY 406 BEAVERDAMS ROAD UNDERPASS REHABILITATION
SITE 34-160, W.P. 2348-09-01, G.W.P. 2348-09-00
AND
HWY 58 RICHMOND STREET UNDERPASS REHABILITATION
SITE 34-280, W.P. 2377-09-01, G.W.P. 2365-09-00
CITY OF THOROLD, ONTARIO
P.O. 2010-E-0073

GEOCRES No. 30M3-276

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation carried out at the locations of the proposed rehabilitation of the Beaverdams Road Underpass at Highway 406 and the Richmond Street Underpass at Highway 58 in the City of Thorold, Ontario. This investigation was carried out as part of a consolidated assignment to rehabilitate or replace six (6) bridge structures at five (5) site locations.

The purpose of this investigation was to explore the subsurface conditions at the two sites and, based on the data obtained, to provide borehole location plans and soil strata drawings with stratigraphic profiles, records of boreholes, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed for each of the sites based on the data obtained from the present and previous investigations.

Thurber carried out the investigation as a foundation sub-consultant to McCormick Rankin, a member of MMM Group (MRC) under MTO Purchase Order No. 2010-E-0073.

2 PROJECT AND SITE DESCRIPTION

The existing Beaverdams Road Bridge is comprised of four (4) spans. The bridge carries Regional Road 67 (Beaverdams Rd) over Highway 406 in the City of Thorold (Thorold), The Regional Municipality of Niagara (Niagara Region). The lands surrounding the bridge structure are primarily agricultural and are relatively flat.

The existing Richmond Street Bridge is comprised of two (2) spans. The bridge carries Richmond St. over Highway 58 in Thorold, Niagara Region. The lands surrounding the bridge structure are

relatively flat and consist primarily of light residential zoning at three quadrants except for the northwest quadrant where the land is used for agricultural purposes.

From published geological information, the bridge sites are situated within the physiographic region known as the Iroquois Plain in the vicinity of the Niagara Escarpment which extends from the Niagara River to the Bruce Peninsula. In this area, a deposit of glaciolacustrine silty clay overlies dolostone bedrock of the Lockport Formation.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out during the period of April 9 to 18, 2012 and involved drilling and sampling four boreholes at the Beaverdams Road Bridge (identified as BR12-01 to BR12-04) and two boreholes at the Richmond Street Bridge (identified as RS12-01 and RS12-02). The borehole depths at Beaverdams Road ranged from 1.3 m to 14.3 m while the borehole depths at Richmond Street ranged from 19.1 m to 19.4 m.

In addition to the six boreholes drilled for the current investigation, three boreholes were previously drilled by MTO at each of the Beaverdams Road structure and Richmond Street structure. The borehole logs from the 1964 investigation at Beaverdams Rd are included in Appendix A and the borehole logs from the 1974 investigation at Richmond Street are included in Appendix B.

Solid stem augers and coring techniques were used to advance the boreholes through soil and bedrock. Soil samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Boreholes BR12-01, BR12-04, RS12-01 and RS12-02, were advanced a minimum of 2.7 m into bedrock by NXL size diamond coring. The remaining boreholes were terminated upon auger and/or split spoon refusal on boulders or probable bedrock.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. A piezometer, consisting of 19 mm diameter Schedule 40 PVC pipe with a 1.5 m slotted screen surrounded with filter sand, was installed in each of Boreholes BR12-01, BR12-04, RS12-01 and RS12-02.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, processed the soil and rock core samples in labelled containers and wooden core boxes, respectively, for transport to Thurber's laboratory for further examination and testing.

All rock cores were logged and Total Core Recovery (TCR), the Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendices A and B. At least 25% of the recovered soil samples were subjected to grain size distribution analysis. Atterberg Limits tests were carried out on selected samples of silty clay to determine the plasticity characteristics. The results of these tests are presented on the figures included in Appendices A and B.

Point load testing was carried out on selected rock cores retrieved from Boreholes BR12-01, BR12-04, RS12-01 and RS12-02. These results are presented on the Record of Borehole sheets (as estimated UCS) included in Appendices A and B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets included in Appendix A and Appendix B (from the current and previous investigations). Details of the encountered soil and rock stratigraphy are presented in these records and on the “Borehole Locations and Soil Strata” drawings included in Appendices A and B. The factual information at the borehole locations governs any interpretation of site conditions.

5.1 Highway 406 - Beaverdams Road Underpass

Three boreholes were previously drilled in the vicinity of the Beaverdams Road structure in 1964 (BH 1 to BH3) and four boreholes were drilled as part of the current investigation (BR12-01 to BR12-04). The borehole logs from 1964 indicate that the stratigraphy encountered in the boreholes consisted primarily of hard cohesive silt till with boulders at depth. Grey limestone bedrock was reported at 5.3 m depth (Elevation 174.5 m) in BH 3. The descriptions of the stratigraphy presented below are based on the current boreholes only.

In general, the subsurface at the site consists of pavement structure overlying fill which is underlain by a deposit of silty clay. The overburden is underlain by dolostone bedrock of the Lockport Formation.

5.1.1 Pavement Structure

A pavement structure consisting of asphalt overlying granular fill materials was encountered in the four boreholes drilled for the current investigation (BR12-01 to BR12-04). Asphalt was present at ground surface in boreholes drilled on the shoulder of Beaverdams Road (BR12-01 and BR12-04) and ramps to Highway 406 (BR12-02 and BR12-03). The thickness of the asphalt ranged from 75 to 275 mm. Concrete was

encountered below the asphalt in Boreholes BR12-02 and BR12-03. The thickness of the concrete ranged from 225 to 300 mm.

The granular fill encountered below the asphalt and/or concrete consisted of sand in Boreholes BR12-01 and BR12-04, and sand and gravel in Boreholes BR12-02 and BR12-03. The thickness of the granular fill ranged from 0.5 m to 1.2 m, with the lower boundary of the granular fill encountered at depths of 0.8 m to 1.4 m (Elevations 182.0 to 176.3 m).

SPT 'N' values recorded in the granular fill ranged from 17 to 32 blows per 0.3 m of penetration, indicating a compact to dense relative density. The moisture contents of samples of the granular fill ranged from 2 to 10 %.

It should be noted that the thickness of the pavement structure may vary between and beyond the borehole locations.

5.1.2 Fill

Fill was encountered below the pavement structure in all boreholes except for Borehole BR12-02. The fill generally consisted of silty clay, except in Borehole BR12-04 where a 0.8 m thick layer of sandy silt fill with trace clay was encountered between the pavement structure and the silty clay fill. The silty clay fill was brown and contained trace sand and asphalt fragments.

The thickness of the silty clay fill ranged between 0.5 and 2.6 m, with the lower boundary of the silty clay fill encountered at depths of 1.3 m to 4.0 m (Elevations 175.8 to 179.8 m).

SPT 'N' values recorded in the silty clay fill ranged from 6 to 24 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. A SPT 'N' value of 50 blows for 0.05 m was also recorded in the silty clay fill in Borehole BR12-04, indicating the presence of possible obstructions in the fill. The measured moisture contents of samples of the silty clay fill ranged between 18 and 24%.

Selected samples of the silty clay fill were subjected to grain size analysis, the results of which are summarized in the table below. These results are also presented on the Record of Borehole sheets included in Appendix A. Figure A1 in Appendix A illustrates the grain size distribution curves of these samples of the silty clay fill.

Soil Particles	Percentage (%)
Gravel	0
Sand	9
Silt	40 to 43
Clay	48 to 51

5.1.3 Silty Clay

A deposit of silty clay was encountered below the fill across the Beaverdams Road Bridge site, except in Borehole BR12-03 where the fill directly overlies bedrock. The silty clay contained trace to some sand and trace gravel.

The thickness of the silty clay layer ranged from 2.9 m to 4.4 m, with the lower boundary of the silty clay encountered at depths of 3.7 m to 8.4 m (Elevations 176.6 to 173.4 m).

SPT 'N' values recorded in the silty clay ranged from 31 blows for 0.3 m penetration to 100 blows for less than 0.3 m of penetration, indicating a hard consistency. In general, SPT 'N' values increased with depth. The measured moisture content of samples of the silty clay varied from about 12 to 19%.

Selected samples of the silty clay were subjected to gradation analysis and Atterberg Limits testing. The results of these tests are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix A. Figure A2 presents the grain size distribution curves for these samples, and Figure A3 illustrates the results of the Atterberg Limits tests on plasticity charts.

Soil Particles	Percentage (%)
Gravel	0
Sand	2 to 5
Silt	54 to 70
Clay	28 to 41

Index Property	Percentage (%)
Liquid Limit	28 to 34
Plasticity Index	11 to 15

The results of the Atterberg Limits tests indicate that the silty clay is generally low plastic with a group symbol of CL.

5.1.4 Bedrock

The overburden soils described above are underlain by bedrock which was proven by coring in Boreholes BR12-01 and BR12-04. Boreholes BR12-02 and BR12-03 were terminated upon auger and/or split spoon refusal on probable bedrock or boulders. The following table summarizes the depths and elevations of bedrock or auger refusal encountered at the borehole locations. The depths and elevations of bedrock or auger refusal encountered at the 1974 borehole locations are also included for reference.

Foundation Element	Borehole Number	Depth to Bedrock or Auger Refusal (m)	Elevation of Top of Bedrock or Auger Refusal on Boulders or Probable Bedrock (m)
West Abutment	BR12-01*	8.4	174.4
	BH 1	6.0	173.5
Pier 1	BR12-02	3.7	173.3
Pier 2	BH 3*	5.3	174.5
Pier 3	BR12-03	1.3	175.8
East Abutment	BR12-04*	6.9	176.6
	BH 2	4.4	175.9

*Bedrock proven by coring

Based on the rock cores from the current investigation, the bedrock was described as thinly bedded, grey, dolostone. The bedrock was highly weathered near the silty clay – bedrock interface in Borehole BR12-01 and became moderately weathered to fresh with depth. Occasional joints were observed in the bedrock cores. MTO Borehole BH 3 indicates the presence of solution cavities in the upper part of the bedrock.

Total Core Recovery (TCR) of the bedrock typically ranged from 80 to 100%, except for Runs 1, 2, and 3 in Borehole BR 12-01 where a mixture of infilling sand and rock fragments was encountered with the TCR ranging from 0 to 20%. The Rock Quality Designation (RQD) values generally ranged from 62 to 91%, indicating a fair to excellent rock quality. RQD values of 0% were recorded for Runs 2 and 3 of Borehole BR12-01. The Fracture Index (FI) of the rock, expressed as fractures or joints per 0.3 m of core, was generally less than 5, except for the multiple fractures observed in Runs 1, 2 and 3 in Boreholes BR 12-01.

Point load tests were carried out at regular intervals on selected rock cores. The estimated Unconfined Compressive Strength (UCS) of the bedrock as inferred from the point load tests ranged from 93 to 170 MPa, indicating a strong to very strong intact rock strength.

5.1.5 Water Levels

Standpipe piezometers were installed in selected boreholes to facilitate monitoring of the groundwater levels. The groundwater levels observed at the standpipe piezometers are summarized in the table below. The water levels observed in the open boreholes on completion of drilling have also been noted, and the water levels observed during the 1964 investigation are also included for reference.

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
BR12-01	July 16, 2012	10.0	172.8
BR12-04	July 16, 2012	6.6	176.9
BH 1	September 1964	4.1	175.4
BH 2	September 1964	3.1	177.2
BH 3	September 1964	2.3	177.6

All groundwater observations at this site are short term readings and the groundwater levels are expected to fluctuate seasonally and after severe climatic events.

5.2 Highway 58 - Richmond Street Underpass

Three boreholes were previously drilled in the vicinity of the Richmond Street structure in 1974 (BH 1 to BH3) and two boreholes were drilled as part of the current investigation (RS12-01 and RS12-02). The descriptions of the stratigraphy presented in the paragraphs below are based on the current boreholes and previous boreholes from 1974.

In general, the subsurface at the site consists of topsoil or pavement structure overlying cohesive fill which is underlain by a deposit of native silty clay. The overburden is underlain by dolostone bedrock of the Lockport Formation.

5.2.1 Topsoil

A thin layer of topsoil was encountered at the original ground surface in the three boreholes drilled during the 1974 investigation (BH 1 to BH3).

5.2.2 Pavement Structure

Pavement structure consisting of asphalt overlying granular fill was encountered in both boreholes from the current investigation (RS12-01 and RS12-02). The thickness of the asphalt ranged from 200 mm to 225 mm.

The granular fill encountered below the asphalt consisted of brown sand with some gravel and was found to be 1.2 m thick in both boreholes. The lower boundary of the granular fill was encountered at a depth of 1.4 m in both boreholes (Elevation 186.3 m). SPT 'N' values of 9 and 14 blows for 0.3 m penetration were recorded in the granular fill, indicating a loose to compact relative density. The moisture contents of samples of the granular fill ranged from 3 to 5%.

The thickness of the pavement structure may vary between and beyond the borehole locations.

5.2.3 Silty Clay Fill

Silty clay fill was encountered below the topsoil in Boreholes BH 1 to BH 3 and below the pavement structure in Boreholes RS12-01 and RS12-02. The silty clay fill contains trace to some sand and gravel and trace organics.

The thickness of the silty clay fill ranged from 0.9 m to 1.6 m in Boreholes BH 1 to 3, which were drilled near highway level and the silty clay fill was 5.9 m thick in Boreholes RS12-01 and RS12-02, which were drilled from the Richmond Street level. The lower boundary of the silty clay fill was encountered at depths of 0.9 m to 7.3 m (Elevations 178.9 to 180.5m).

SPT 'N' values recorded in the cohesive fill ranged from 5 to 21 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. The measured moisture contents of samples of the cohesive fill ranged between 18 and 25%.

Selected samples of the cohesive fill were subjected to gradation analysis and Atterberg Limits testing. The results of these tests are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix B. Figure B1 presents the grain size distribution curves for these samples, and Figure B3 illustrates the results of the Atterberg Limits tests on plasticity charts. These figures show the results of testing from the current investigation only while the 1974 test results are included in the tables below.

Soil Particles	Percentage (%)
Gravel	0 to 2
Sand	5 to 13
Silt	43 to 50
Clay	42 to 47

Index Property	Percentage (%)
Liquid Limit	37 to 39
Plasticity Index	18 to 21

The results of the Atterberg Limits tests indicate that the fill is generally medium plastic with a group symbol of CI.

5.2.4 Silty Clay

A deposit of native brown silty clay was encountered below the cohesive fill in all five boreholes. The silty clay contains trace sand and occasional gravel.

The thickness of the silty clay deposit ranged from 7.5 m to 9.1 m, with the lower boundary of the silty clay encountered at depths of 8.4 m to 16.4 m (Elevations 171.4 to 171.7 m).

SPT 'N' values recorded in the silty clay ranged from 19 to 51 blows for 0.3 m of penetration, indicating a very stiff to hard consistency. The measured moisture content varied from about 13 to 24%.

Selected samples of the silty clay were subjected to gradation analysis and Atterberg Limits testing. The results of these tests (from both the 1974 investigation and current investigation) are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix B. Figure B2 presents the grain size distribution curves for these samples, and Figure B4 illustrates the results of the Atterberg Limits tests on plasticity charts. These figures show the results of testing from the current investigation only.

Soil Particles	Percentage (%)
Gravel	0 to 4
Sand	2 to 13
Silt	38 to 66
Clay	18 to 55

Index Property	Percentage (%)
Liquid Limit	29 to 42
Plasticity Index	13 to 22

The results of the Atterberg Limits tests indicate that the silty clay has a low to intermediate plasticity with a group symbol of CL to CI.

5.2.5 Bedrock

The overburden soils described above are underlain by bedrock which was proven by coring in Boreholes BH-1, BH-2, RS12-01, and RS12-02. Bedrock was inferred by auger refusal at BH-3. The following table summarizes the depths and elevations at which bedrock was encountered at the borehole locations.

Foundation Element	Borehole Number	Depth to Bedrock or Auger Refusal (m)	Elevation of Top of Bedrock or Auger Refusal on Boulders or Probable Bedrock (m)
East Abutment	RS12-01*	16.4	171.4
	BH-2*	9.4	171.4
Pier	BH-3	8.4	171.4
West Abutment	RS12-02*	16.2	171.4
	BH-1*	9.2	171.7

*Bedrock proven by coring

The bedrock was described as thinly bedded, grey dolostone with occasional gypsum pockets and vugs. The dolostone was generally in a slightly weathered to fresh state. Occasional horizontal joints were observed in the bedrock cores.

Total Core Recovery (TCR) of the bedrock ranged from 97 to 100%. The Rock Quality Designation (RQD) values, where measured, ranged from 93 to 98%, indicating an excellent rock quality. The Fracture Index (FI) of the rock, expressed as fractures or joints per 0.3 m of core, ranged from 0 to 3.

Point load tests were carried out at regular intervals on selected rock cores. The estimated Unconfined Compressive Strength (UCS) of the rock as inferred from the point load tests ranged from 143 to 185 MPa, indicating a very strong intact rock strength.

5.3 Water Levels

Standpipe piezometers were installed in selected boreholes to facilitate monitoring of the groundwater levels. The groundwater levels observed at the standpipe piezometers are summarized in the table below. The water levels observed in the open boreholes on completion of drilling have also been noted.

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
RS12-01	July 16, 2012	9.8	178.0
RS12-02	July 16, 2012	10.5	177.2
BH 1	July 24, 1974	4.5	176.4
BH 2	July 26, 1974	2.0	178.8
BH 3	July 25, 1974	0.5	179.3

All groundwater observations at this site are short term readings and the groundwater levels are expected to fluctuate seasonally and after severe climatic events.

6 MISCELLANEOUS

Borehole locations were established in the field relative to the location of the existing structures. The ground surface elevations and coordinates at the borehole locations were surveyed by surveyors arranged by MRC upon completion of drilling.

Underground utility clearances were obtained for the borehole locations prior to drilling.

Elite Drilling Services of St. Catharines, Ontario supplied a truck-mounted CME-75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The field investigation was supervised by Mr. Stephane Loranger and Mr. Dave Ametrano of Thurber.

Geotechnical laboratory testing was carried out in Thurber's Toronto Area laboratory.

Overall planning and supervision of the field program was conducted by Mr. Luke Gilarski, E.I.T. and Mr. Sydney Pang, P.Eng. Interpretation of the data and preparation of the report was carried out by Mr. Luke Gilarski, E.I.T. and Ms. Lindsey Blaine, E.I.T.

The report was reviewed by Messrs. Sydney Pang, P.Eng. and P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

Report Preparation by:
Lindsey Blaine, E.I.T.
Project Manager



Report Reviewed by:
Sydney Pang, P.Eng.,
Associate, Senior Geotechnical Engineer



Report Reviewed by:
P. K. Chatterji, P.Eng.,
Review Principal, Designated MTO Contact

FOUNDATION INVESTIGATION AND DESIGN REPORT
HWY 406 BEAVERDAMS ROAD UNDERPASS REHABILITATION
SITE 34-160, W.P. 2348-09-01, G.W.P. 2348-09-00
AND
HWY 58 RICHMOND STREET UNDERPASS REHABILITATION
SITE 34-280, W.P. 2377-09-01, G.W.P. 2365-09-00
CITY OF THOROLD, ONTARIO
P.O. 2010-E-0073

GEOCRES No. 30M3-276

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides an interpretation of the geotechnical data in the factual report and presents foundation design recommendations for the two bridges to assist the design team in assessing whether the existing foundations are sufficient to accommodate revised loading conditions imposed by the rehabilitated structures.

Based on information provided by MRC, it is understood that the proposed rehabilitation will impose minimal additional loads (likely less than 10%) on the existing foundations. Results of evaluation of sub-structure loadings for the Richmond Street Underpass have been provided by MRC. Evaluation results for subsurface loadings of the Beaverdams Road structure are unavailable to Thurber at the time of preparation of this report. If the additional load is confirmed to be less than 10%, then the proposed rehabilitation works are not expected to impact the performance of the existing foundations provided that the foundations are structurally adequate.

Beaverdams Road Underpass

The existing bridge is a four-span, cast-in-place post-tensioned reinforced concrete deck structure with circular voids and with two abutments and three piers. The two centre spans measured about 29.7 m in length while the two approach spans are about 15.2 m each. The 6 to 7 m high approach fills carry Beaverdams Road over Highway 406. Information provided by MRC and from GEOCRES indicates that both abutments are founded on steel H-piles driven to refusal on bedrock, and the three piers are supported by square footings founded on bedrock. All pier pile caps are below the highway grade while the abutment pile caps are perched within the abutment fill. The forward and side slope inclinations were designed to be at 2H : 1V.

The proposed rehabilitation works include remediation of deteriorated concrete, new fascia, concrete parapet walls, new sidewalk, concrete deck overlay and reconstruction of abutment wingwalls to facilitate conversion to semi-integral abutments.

Richmond Street Underpass Bridge

The existing bridge is a double span, cast-in-place post tensioned reinforced concrete deck structure with rectangular voids, and with two abutments and a centre pier. The east and west spans measure about 36.6 m and 40.5 m in length, respectively. The 6 to 7 m high approach fills carry Richmond Street over Highway 58. Information provided by MRC and from GEOCREs indicate that all abutment and pier foundations are founded on HP 310 x 79 (12 BP 53) steel piles driven to refusal on bedrock. The pier pile cap is below the highway grade while the abutment pile caps are perched within the abutment fill. The forward and side slope inclinations were designed to be at 2H : 1V.

The proposed rehabilitation works include remediation of deteriorated concrete, new fascia, concrete parapet walls, sidewalks on both sides, concrete deck overlay and reconstruction of abutment wingwalls to facilitate conversion to semi-integral abutments.

8 EVALUATION OF EXISTING FOUNDATIONS

8.1 Existing Foundations

The following documents contain design information on the existing foundations.

- DHO report titled "Foundation Investigation - Proposed Bridge Overpass, County Road 23 and Highway 406, Township of Thorold, County of Welland, Ontario", District 4, W.P. 93-63, Site No. 34-160, Geocres No. 64-F-244C dated September 1964. (Reference 1).
- DHO / Swan Wooster Engineering drawings titled "General Layout, Bore Hole Location & Soil Strata, Foundation & Pier Details, Abutment & Wingwall Details", Beaver Dams Road U'Pass / Proposed Crossing at County Road No. 23", King's Highway No. 406, Dist. No.4, W.P. 93-63, Site No. 34-160, Twp 133-160-1-A to -4-A, 1964 to 1967 (Reference 2).
- MTC report titled "Preliminary Foundation Recommendations for A Proposed Structure At the Jct. of Existing Hwy. #58 and Proposed Richmond St. Extension", Town of Thorold, Regional Municipality of Niagara, Lot 34, District 4 (Hamilton)", W.P. 80-73-03, Site No. 34-280, Geocres No. 30M3-170 dated August 1974. (Reference 3).

- MTC drawings titled “General Plan, Footings”, Richmond Street Underpass at Confederation Heights, King’s Highway No. 58, Dist. No.4, Regional Municipality of Niagara, Town of Thorold, W.P. 80-73-03, Site No. 34-280, 1975 (Reference 4).

8.1.1 Beaverdams Road Underpass

Based on existing information, steel H-piles driven to bedrock have been used for foundation support to the existing abutments, and spread footings have been used to support the piers. The Foundation & Pier Details drawing show that 10 BP 42 pile (HP 250 x 62 equivalent) were used. The pile design capacity, depths and tip elevations have been converted into S.I. units and presented in the following Table 8.1.

Table 8.1: Foundation Information and Assessed Geotechnical Resistances

Foundation Information	East Abutment		West Abutment
Pile Depth	4.3 m		6.4 m
Pile Tip Elevation	175.1 m		172.5 m
Founding Materials	Dolostone bedrock*		
Design Pile Bearing Capacity (Working Stress Design)	550 kN [55 tons (imperial)] (from Foundation & Pier Details drawing)		
Pile Bearing Pressure Recommended in GEOCRETS report	48,265 kPa (7,000 psi)		
	East Pier	Centre Pier	West Pier
Footing Width	2 squared	2 squared	2 squared
Footing Length	footings each of 3.66 x 3.66 m	footings each of 3.66 x 3.66 m	footings each of 3.66 x 3.66 m
Founding Elevation	175.0 m	174.0 m	173.7 m
Founding Materials	Dolostone bedrock*		
Allowable Design Bearing Capacity (Working Stress Design)	Not available from drawings		
Footing Bearing Capacity Recommended in GEOCRETS report	• Bearing Capacity of about 400 to 600 kPa for footings on hard or dense soils • Not available for bedrock		

Notes *: A General Layout drawing for the existing bridge indicates that all driven H-piles and spread footings were to be founded on bedrock.

8.1.2 Richmond Street Underpass

Based on existing information, steel H-piles driven to bedrock have been used for foundation support to the existing structure. Partial pile driving data indicates that the 12 BP 53 (HP 310 x 79 equivalent) H-piles had been driven to refusal. The design pile load

had been quoted as 70 tons (imperial), or approximately 700 kN, per pile. The pile design capacity, depths and tip elevations have been converted into S.I. units and presented in the following Table 8.2.

Table 8.2: Foundation Information and Pile Capacities

Foundation Information	East Abutment	Pier	West Abutment
Pile Depth	12.8 to 13.1 m	6.7 to 7.0 m	12.5 to 13.1 m
Pile Tip Elevation	170.7 to 171.0 m	171.1 to 171.5 m	170.8 to 171.5 m
Founding Materials	Dolostone bedrock*		
Design Pile Bearing Capacity (Working Stress Design)	700 kN [70 tons (imperial)] (from Footings drawing)		
Pile Bearing Capacity Recommended in GEOCRE report	Not Specified Numerically		

Notes *: The General Plan for the existing bridge indicates that all H-piles were to be driven to bedrock.

8.2 Reassessment of Existing Foundations

Engineering analysis was conducted to estimate the geotechnical resistances for the existing piled foundations at the abutments, and the piled/footing foundations at the piers. The analysis was carried out based on the requirements stipulated in the CHBDC (2010) and with reference to the CFEM (4th Edition). Results of the analysis are presented in the following sub-sections. The pile depths, pile tip elevations, footing dimensions, founding elevations and materials are the same as those presented in Tables 8.1 and 8.2, and are therefore not repeated.

8.2.1 Beaverdams Road Underpass

The subsurface loading assessment for the Beaverdams Road structure was unavailable at the time of preparation of this report. Based on the available information on the design drawings, the following capacities are assessed.

Table 8.3: Assessed Design Pile and Geotechnical Resistances

Foundation Information	East Abutment		West Abutment
Factored Axial Pile Resistance at ULS of 10 BP 42 pile (Limit States Design)	1,040 kN		1,040 kN
Axial Pile Resistance at SLS (Limit States Design)	SLS conditions do not govern pile design on strong bedrock		
	East Pier	Centre Pier	West Pier
Factored Geotechnical Resistance at ULS of footings (Limit States Design)	3,500 kPa	3,500 kPa	3,500 kPa

Geotechnical Resistance at SLS of footings (25 mm settlement) (Limit States Design)	SLS conditions do not govern footing design on strong bedrock
----------------------------------------------------------------------------------------	---------------------------------------------------------------

The above assessment is based on the assumption that the bridge was constructed in accordance with the design drawings available to Thurber and that the piles at the abutments were indeed driven to refusal in bedrock. The above assessed value is based on the structural resistance of the pile assuming a steel yield strength of 250 MPa commonly adopted at and prior to the time of construction of the bridge, in conjunction with appropriate resistance factors. The actual geotechnical resistance of the bedrock exceeds this value. We have not considered the possibility of corrosion of the piles. If it is considered that there may be section loss due to corrosion, the value above should be reduced in proportion to the assumed loss of section area.

For footing assessment, the geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistances must be calculated as illustrated in the CHBDC Clause 6.7.3 and Clause 6.7.4.

According to MRC, there is no increase in the structure loads because the removals from the bridge balance the additional loads resulting from the rehabilitation. Therefore, the foundation performance of the abutments and piers is not expected to be impacted by the rehabilitation works provided that the foundations are structurally adequate.

8.2.2 Richmond Street Underpass

At the Richmond Street Underpass, assuming that the 12 BP 53 (HP 310 x 79) were driven to strong dolostone bedrock, the geotechnical resistance of the pile provided by the bedrock will be higher than the structural capacity of the pile. The available pile capacity should therefore be based on the structural capacity of the pile.

Based on information provided by MRC, using a steel yield strength of 250 MPa (1976), a resistance factor of 0.7 and a below ground reduction factor of 0.75, the factored axial capacity at ULS of an HP 310 x 79 pile is estimated to be 1,300 kN. The SLS condition does not govern design of piles bearing on strong bedrock. The actual geotechnical resistance of the bedrock will exceed this value. This assessment is based on the assumption that the bridge was constructed in accordance with the design drawings where the piles are to bear on bedrock.

We have not considered the possibility of corrosion of the piles. If it is considered that there may have been section loss due to corrosion, then the recommended resistance of 1,300 kN should be reduced in proportion to the assumed loss of section area. It is understood that the loss of section area has been estimated to be in the order of 10%.

According to MRC, the structure loads resulting from the rehabilitation are approximately 4.5% greater than the loads imposed by the existing structure. Given the modest load increase, the proposed rehabilitation works are not expected to impact the performance of the existing foundations provided that the foundations are structurally adequate.

9 LATERAL RESISTANCE

9.1 Driven Piles

For design, lateral soil resistance against standard pile sections can be assessed based on the method outlined in the CHBDC 2010.

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

Fill

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

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

Silty Clay

$$k_s = 125 \cdot C_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 0 \text{ between ground surface and } 1.5D$$

$$= 9 C_u \text{ (kPa) at and below a depth of } 1.5D$$

where n_h = coefficient related to soil density, kN/m^3

D = width of pile perpendicular to the load direction (m)

C_u = undrained shear strength (kPa).

z = depth of pile embedment (m)

For assessment of existing structures, the following parameter values may be assumed.

$$n_h = 2,500 \text{ kN/m}^3 \text{ (cohesionless fill)}$$

$$C_u = 40 \text{ kPa (firm – 'N' from 4 to 8 blows)}$$

$$C_u = 75 \text{ kPa (stiff – 'N' from 8 to 15 blows)}$$

$$C_u = 125 \text{ kPa (very stiff – 'N' from 15 to 30 blows)}$$

$$C_u = 200 \text{ kPa (hard – 'N' > 30 blows)}$$

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

For conventional abutments, the lateral resistance may be provided by battered piles.

For lateral soil-pile interaction analysis, the modulus of subgrade reaction (k_s) will have to be reduced if the adjacent pile spacing is less than the minimum value recommended in the CHBDC.

The spring constant, K , for analysis may be obtained by the expression, $K = k_s * L * D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance on any one segment of pile, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} * L * D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements.

For lateral soil/pile group interaction analysis, the modulus of subgrade reaction (k_s) may have to be reduced based on pile spacing.

Where a pile group is oriented **perpendicular** to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Perpendicular to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
4 D*	1.00
1 D*	0.50

* D is the width of the pile, and spacing is measured centre to centre

Where a pile group is oriented **parallel** to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Parallel to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
8 D	1.00
6 D	0.70
4 D	0.40
3 D	0.25

Intermediate values may be obtained by interpolation.

9.2 Spread Footings

Resistance to sliding of a cast-in-place concrete footing on the dolostone may be computed on the basis of an ultimate coefficient of friction of 0.8. The above is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.

10 LATERAL EARTH PRESSURES

Lateral earth pressures acting on the abutment walls and wingwalls may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K \cdot (\gamma h + q)$$

where: P_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 10.1)

γ = unit weight of retained soil (see Table 10.1)

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

Q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A and Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ, \gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	-	0.47	-	0.50	-
Passive (Movement towards soil mass)	3.7	-	3.3	-	3.0	-

11 APPROACH EMBANKMENTS

The existing approach embankment slopes at both the Richmond Street Underpass and Beaverdams Road Underpass sites are typically vegetated with grass. Available information indicates that these slopes have been designed to have an inclination of 2H : 1V. The forward slopes under the bridge decks are covered with concrete slope paving as indicated on the design drawings. There is no visual evidence to date of major distress associated with the approach slopes.

Currently available design information does not call for placement of new fill at the approach locations. It is anticipated that the approach slopes will remain stable under existing conditions.

Should placement of new approach fills and/or any alterations to the approach fill configuration be required, slope stability assessment will have to be carried out to confirm that the reconstructed slopes will remain stable with acceptable factors of safety.

12 ROADWAY PROTECTION

Roadway protection may be required during the course of the rehabilitation works. An item titled "Protection System" as per OPSS 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the shoring be specified on the contract drawings.

The design of roadway protection should be the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at both sites is a soldier pile and lagging wall. It is anticipated that the soldier piles will need to be extended into the very stiff silty clay underlying the approach fills to develop the required toe resistance. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

A temporary soldier pile and lagging wall may be designed using the parameters given below:

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
K_a	=	0.33 (approach fills)
	=	0.36 (silty clay)
K_p	=	3.0 (approach fills)
	=	2.7 (silty clay)

The designer of the roadway protection system should check whether the depth of pile is sufficient to provide base fixity.

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when

designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs.

13 EXCAVATION AND BACKFILL

Temporary excavations may be required during the course of the rehabilitation works. All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purpose of OHSA, the native soils and approach fills at both sites may be classified as Type 3 soils. It is anticipated that the excavations would not be carried out below the groundwater level.

Excavation and backfilling for foundation construction should be carried out with reference to the requirements in OPSS 902. Backfill to the abutments should consist of Granular A or Granular B Type II materials meeting the gradation and relevant requirements stipulated in OPSS 1010. Compaction procedures and equipment to be used adjacent to the existing structures must be in accordance with the relevant OPSS 501 requirements.

14 GROUNDWATER AND SURFACE WATER CONTROL

It is anticipated that the amount of perched water within the approach fills at the abutment locations would be limited. Groundwater from water-bearing sand and silt interlayers within the silty clay should also be minimal. For excavations at the abutment and pier locations, groundwater control will likely be limited to diverting surface runoff and sump pumping. Filtered sumps must be designed properly so that construction drainage water containing eroded soil and fines does not flow onto existing highways and roadways.

The design of unwatering systems for the excavations is the responsibility of the Contractor who is expected to retain dewatering specialists for this task.

15 IMPACT ON EXISTING FOUNDATIONS

The proposed rehabilitation works at the abutments and piers are largely structural (above ground) and therefore should not have significant adverse impacts on the existing foundation elements. However, it is considered prudent to carry out a pre-construction condition survey of the existing bridge, and a monitoring program during and shortly after construction to confirm that the existing foundations will not be adversely affected. Visual inspection should also be carried out periodically during construction.

16 CONSTRUCTION CONCERNS

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

Approach Fill Stability

The existing approach slopes at both the Richmond Street Underpass and Beaverdams Road Underpass sites are considered stable at an inclination of 2H : 1V. There is no visual evidence or report to date of major distress associated with the approach slopes. It is anticipated that the approach slopes will remain stable under existing conditions.

Should placement of new approach fills and/or any alterations to the approach fill configuration be required during the rehabilitation works, slope stability assessment and visual inspection will have to be carried out to confirm that the reconstructed slopes will remain stable throughout and after construction.

THURBER ENGINEERING LTD.



Report Preparation by:
Sydney Pang, P.Eng.,
Associate, Senior Foundations Engineer



Report Reviewed by:
P. K. Chatterji, P.Eng.,
Review Principal, Designated MTO Contact

Appendix A

Highway 406 – Beaverdams Road Underpass

19-1351-221

RECORD OF BOREHOLE No BR12-01

1 OF 2

METRIC

W.P. 2365-09-00 LOCATION N 4 772 841 6 E 326 140.5 Beaverdams Rd. Underpass ORIGINATED BY SLL
 HWY 406 BOREHOLE TYPE Solid Stem Augers/CME75/NXL Casing COMPILED BY AN
 DATUM Geodetic DATE 2012.04.11 - 2012.04.12 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	
182.8 0.0	ASPHALT: (225mm)											
0.2	SAND, some gravel Compact Brown Moist (FILL)		1	GS			182					
181.4			2	SS	17							
1.4	Silty CLAY, trace sand Firm to Very Stiff Brown (FILL)		3	SS	6		181					0 9 43 48
			4	SS	11		180					
	Asphalt fragments		5	SS	18							
178.8							179					
4.0	Silty CLAY, trace sand, trace gravel Hard Brown		6	SS	34		178					
							177					
			7	SS	31							0 2 70 28
							176					
			8	SS	85/ 0-200		175					
	Auger refusal at 8.4m and start coring											
174.4 8.4	Highly weathered to 11.3m, thinly bedded, grey, strong to very strong: DOLOSTONE BEDROCK						174					RUN #1 TCR=83% SCR=57% RQD=57%
	Infilling sand mixed with limestone fragments from 9.2m to 11.3m		1	RUN								
							173					RUN #2

Continued Next Page

+ 3 × 3

Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BR12-01

2 OF 2

METRIC

W.P. 2365-09-00 LOCATION N 4 772 841 6 E 326 140.5 Beavardams Rd. Underpass ORIGINATED BY SLL
HWY 406 BOREHOLE TYPE Solid Stem Augers/CME75/NXL Casing COMPILED BY AN
DATUM Geodetic DATE 2012.04.11 - 2012.04.12 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
	Continued From Previous Page													
			2	RUN			172						>10	TCR=20% SCR=0% RQD=0%
			3	RUN									>10	RUN #3 TCR=0% SCR=0% RQD=0%
	Becoming moderately weathered to fresh Sub-vertical joint from 11.8m to 12.1m		4	RUN			171						2	RUN #4 TCR=100% SCR=91% RQD=91% UCS=170MPa (Average)
	Rubble zone (100mm) at 12.3m												1	
	Horizontal joints at 12.9m, 13.0m, 13.2m		5	RUN			170						0	RUN #5 TCR=100% SCR=75% RQD=75% UCS=114MPa (Average)
													3	
			6	RUN			169						2	RUN #6 TCR=100% SCR=100% RQD=70% UCS=93MPa (Average)
168.5													0	
14.3	END OF BOREHOLE AT 14.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Jul.16/12 10.0 172.8													

RECORD OF BOREHOLE No BR12-02

1 OF 1

METRIC

W.P. 2365-09-00 LOCATION N 4 772 832.7 E 326 159.2 Beaverdams Rd. Underpass ORIGINATED BY DA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2012.04.18 - 2012.04.18 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE				w _p	w	w _L
177.0						20	40	60	80	100	20	40	60		
0.0	ASPHALT: (75mm)														
0.1	CONCRETE: (225mm)														
176.7															
0.3	SAND and GRAVEL, trace silt, trace clay		1	AS							○				
176.3	Brown Moist (FILL)		1	SS	56							○			
0.8	Silty CLAY, some sand, trace gravel														
	Hard Brown		2	SS	52						○				
			3	SS	57/ 0.100						○				
			4	SS	96						○				
173.4															
3.7	END OF BOREHOLE AT 3.7m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.3m, CONCRETE TO 0.1m, THEN ASPHALT TO SURFACE.														

RECORD OF BOREHOLE No BR12-03

1 OF 1

METRIC

W.P. 2365-09-00 LOCATION N 4 772 862.2 E 326 211.2 Beaverdams Rd. Underpass ORIGINATED BY DA
HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2012.04.18 - 2012.04.18 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
177.1														
0.0	ASPHALT: (100mm)						177							
0.1														
0.3	CONCRETE: (300mm)													
176.3	SAND and GRAVEL, trace silt, trace clay		1	AS										
0.8	Brown Moist (FILL)		1	SS	24		176							
175.8	Silty CLAY, some sand, some gravel													
1.3	Very Stiff Brown (FILL)													
END OF BOREHOLE AT 1.3m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.3m, CONCRETE TO 0.1m, THEN ASPHALT TO SURFACE.														

RECORD OF BOREHOLE No BR12-04

1 OF 2

METRIC

W.P. 2365-09-00 LOCATION N 4 772 882.5 E 326 232.4 Beaverdams Rd. Underpass ORIGINATED BY SLL
 HWY 406 BOREHOLE TYPE Solid Stem Augers/CME55/NXL Coring COMPILED BY AN
 DATUM Geodetic DATE 2012.04.12 - 2012.04.13 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	
183.5												
0.0	ASPHALT: (275mm)											
183.2												
0.3	SAND, some gravel Dense Brown Moist (FILL)		1	GS			183					
			2	SS	32							
182.0							182					
1.4	Sandy SILT, trace clay Compact Brown Moist (FILL)		3	SS	19							
181.3							181					
2.2	Silty CLAY, trace sand Very Stiff Brown (FILL)		4	SS	18							
			5	SS	50/ 0.050							
	Asphalt fragments						180					
179.8							179					
3.7	Silty CLAY, trace sand Hard Brown		6	SS	60							
							178					
							177					
			7	SS	100/ 0.200							
176.6							176					
6.9	Moderately weathered to fresh, thinly bedded, grey, strong to very strong: DOLOSTONE BEDROCK Horizontal joints at 6.9m, 7.0m, 7.3m, 7.5m, 7.6m, 7.7m		1	RUN								
	Horizontal joints at 8.2m, 8.3m, 8.4m, 8.6m, 8.9m, 9.3m, 9.6m		2	RUN								
	Vertical joint (50mm) at 8.6m						175					
	Horizontal joints at 9.9m, 10.0m, 10.1m, 10.2m		3	RUN			174					

Continued Next Page

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

RECORD OF BOREHOLE No BR12-04

2 OF 2

METRIC

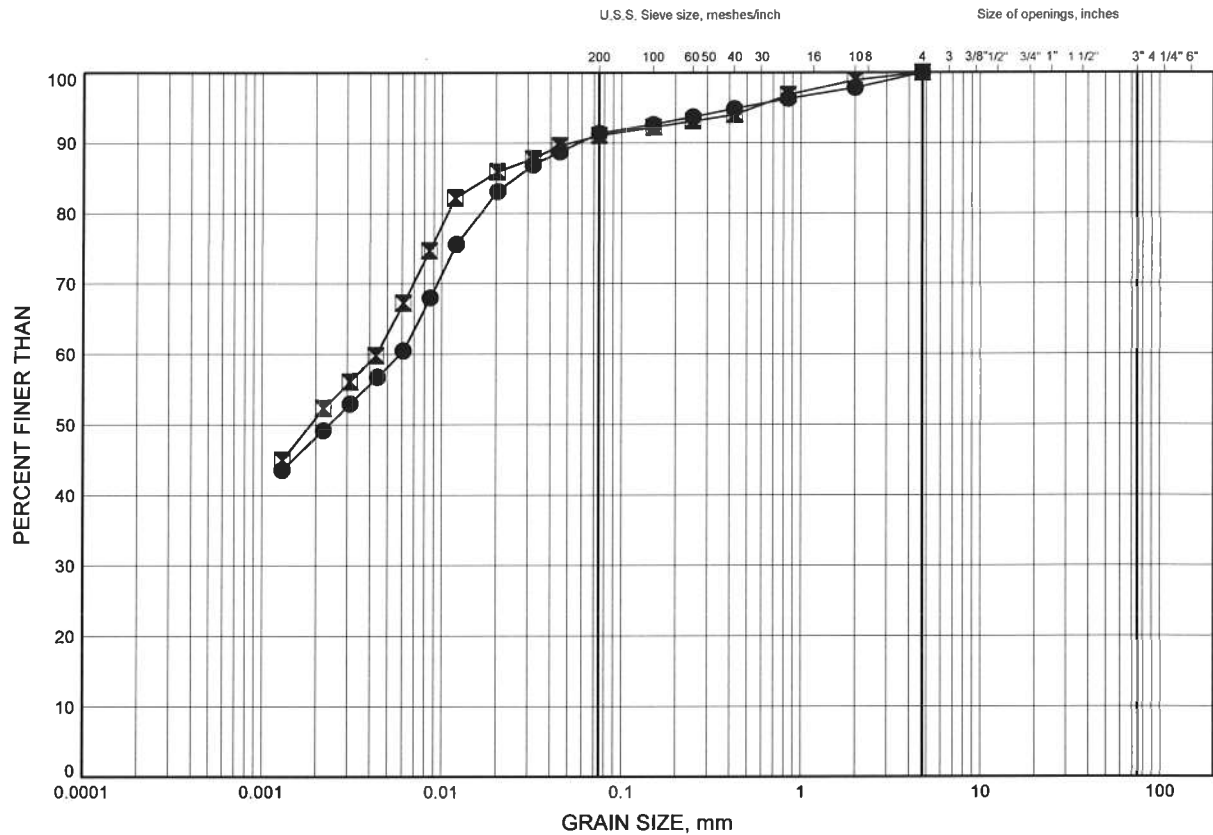
W.P. 2365-09-00 LOCATION N 4 772 882.5 E 326 232.4 Beaverdams Rd. Underpass ORIGINATED BY SLL
HWY 406 BOREHOLE TYPE Solid Stem Augers/CME55/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.12 - 2012.04.13 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page		4	RUN				20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	kN/m ³	GR SA SI CL RQD=81% UCS=111MPa (Average)
173.2													4	
10.3	END OF BOREHOLE AT 10.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Jul.16/12 6.6 176.9													

5 Bridges, Welland and St. Catharines
GRAIN SIZE DISTRIBUTION

FIGURE A1

SILTY CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BR12-01	1.83	180.96
✕	BR12-04	2.59	180.90

Date December 2012
 W.P.# 2365-09-00

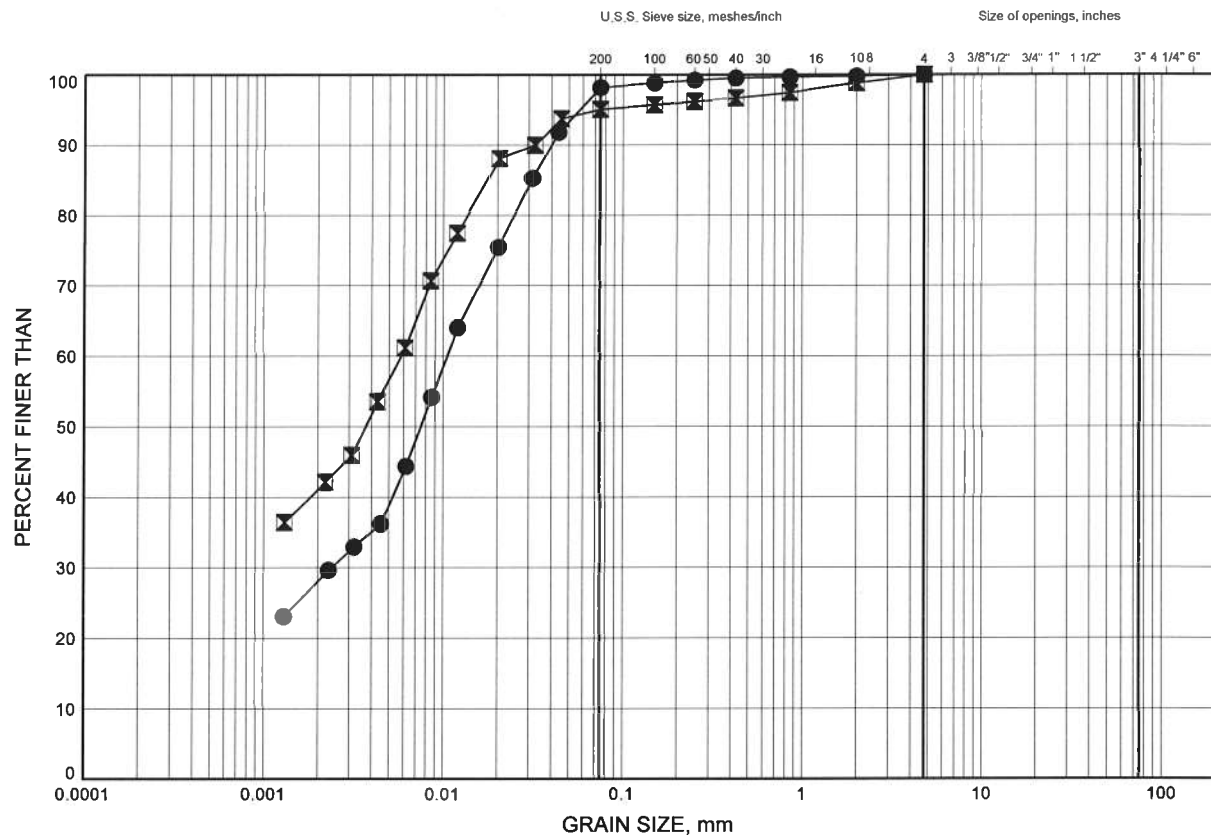


Prep'd AN
 Chkd. SKP

5 Bridges, Welland and St. Catharines
GRAIN SIZE DISTRIBUTION

FIGURE A2

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BR12-01	6.32	176.46
✕	BR12-04	4.80	178.69

Date: December 2012
W.P.#: 2365-09-00

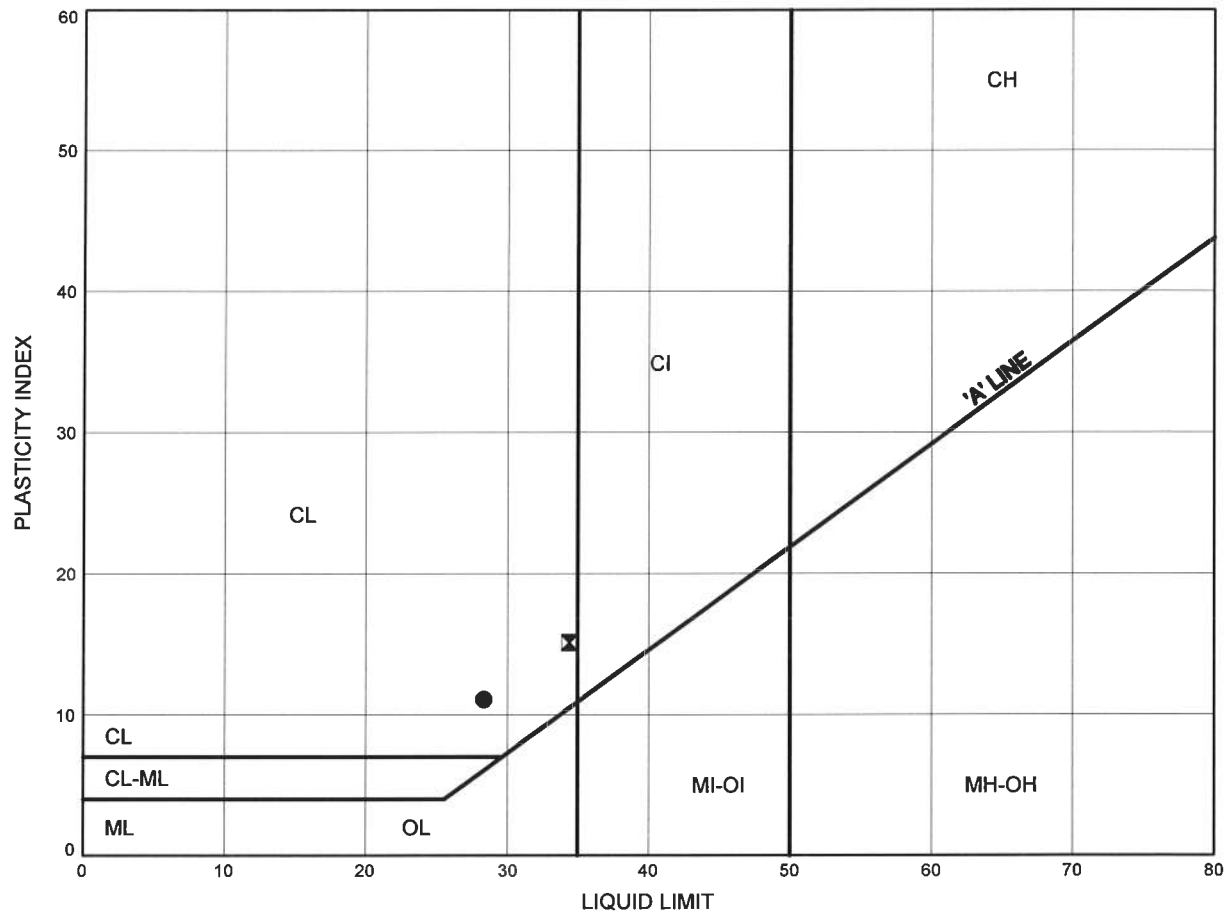


Prep'd: AN
Chkd.: SKP

5 Bridges, Welland and St. Catharines
ATTERBERG LIMITS TEST RESULTS

FIGURE A3

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BR12-01	6.32	176.46
⊠	BR12-04	4.80	178.69

Date December 2012
W.P.# 2365-09-00



Prep'd AN
Chkd. SKP

RECORD OF BOREHOLE No BR64-01

1 OF 1

METRIC

W.P. 93-63 LOCATION Beaverdams Rd. Underpass ORIGINATED BY WAT (DHO)
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY WAT (DHO)
 DATUM Geodetic DATE 1964.09.01 - 1964.09.23 CHECKED BY WAT (DHO)

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L		
179.5	Clayey SILT, crushed stone, roots (FILL)												
	Silty CLAY Hard Brown (TILL)		1	SS	12		179					20.7	
178.0	Silty CLAY, occasional gravel Hard Brown Moist (TILL)		2	SS	32*		178						
			3	TW	42*		177					20.6	*50mm Shelby Tube was reportedly driven
			4	TW	66*		176						
							175						
	Inferred cobbles and boulders		5	SS	50/ 0.100		174						
173.5			6	SS	50/ 0.050								
6.0	END OF BOREHOLE AT 6.0m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY AT 5.8m ONE AND A HALF HOURS AFTER COMPLETION, WATER LEVEL AT 4.1m AFTER 3 DAYS.												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BR64-02

1 OF 1

METRIC

W.P. 93-63 LOCATION Beaverdams Rd. Underpass ORIGINATED BY WAT (DHO)
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY WAT (DHO)
 DATUM Geodetic DATE 1964.09.01 - 1964.09.23 CHECKED BY WAT (DHO)

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT		
180.3 0.0	Clayey SILT , crushed stone (FILL)						180						
179.7 0.6	Silty CLAY Hard Brown (TILL)		1	SS	12		179						
			2	TW	38*		178						
			3	SS	66*		177						
	Inferred cobbles and boulders		4	SS	60/ 0.100		176						
175.9 4.4	END OF BOREHOLE AT 4.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY ON COMPLETION, WATER LEVEL AT 3.1m AFTER 3 DAYS.												

+ 3 x 3 : Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

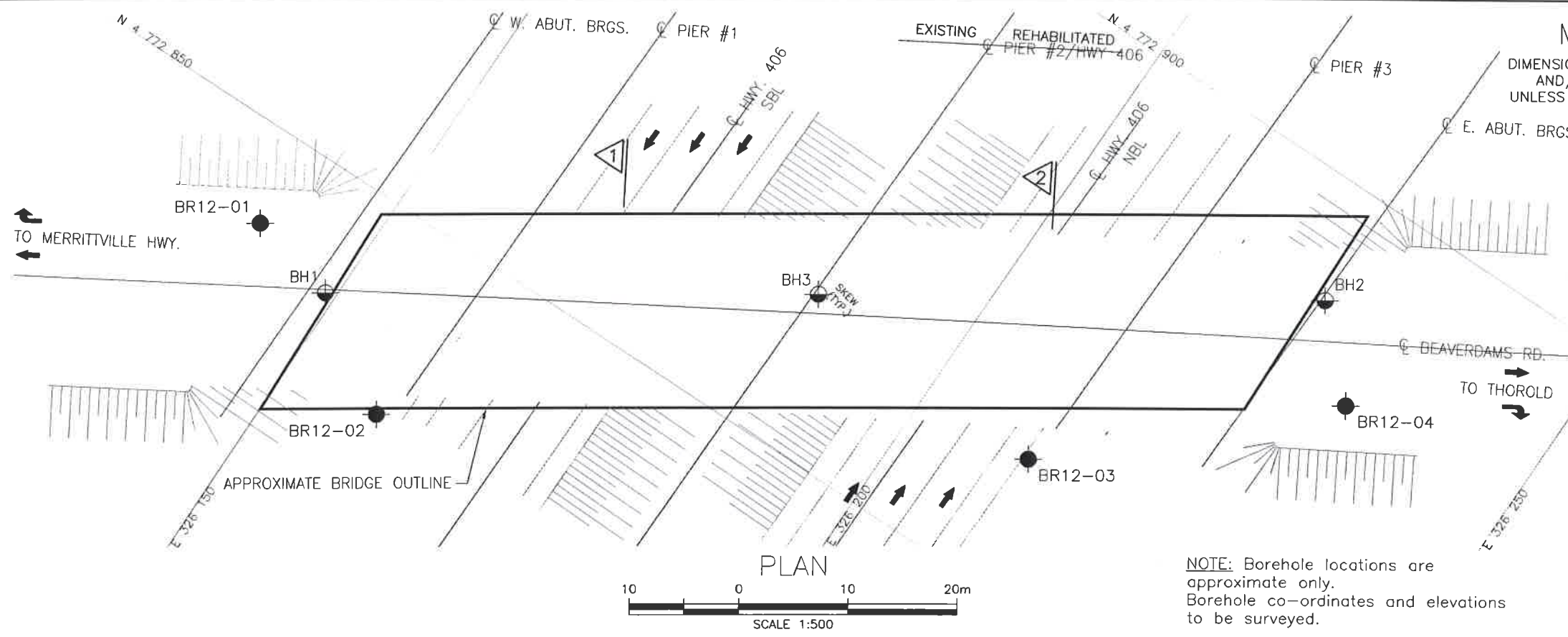
RECORD OF BOREHOLE No BR64-03

1 OF 1

METRIC

W.P. 93-63 LOCATION Beaverdams Rd. Underpass ORIGINATED BY WAT (DHO)
 HWY 406 BOREHOLE TYPE Solid Stem Augers/AX Core COMPILED BY WAT (DHO)
 DATUM Geodetic DATE 1964.09.01 - 1964.09.23 CHECKED BY WAT (DHO)

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
179.8														
0.0	CRUSHED STONE, silt, brown (FILL)													
179.2														
0.6	Silty CLAY Hard Brown (TILL)		1	SS	22		179							
			2	TW	35*		178							
			3	SS	42		177							
			4	TW	66*		176							
			5	SS	80		175							
174.5							174							
5.3	BEDROCK, grey limestone, solution cavities		1	RUN										
173.1														
6.7	END OF BOREHOLE AT 6.7m. BOREHOLE DRY ON COMPLETION, WATER LEVEL AT 2.2m AFTER 3 DAYS.													



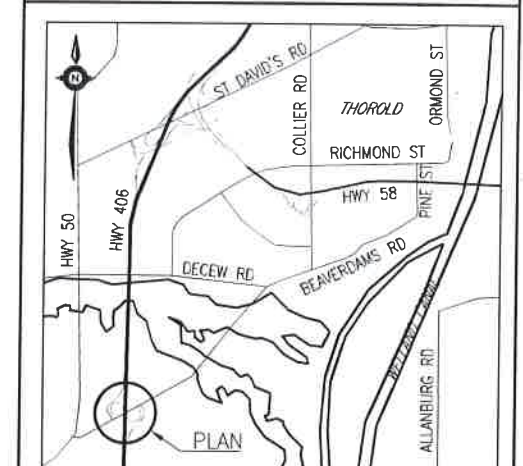
GWP No 2348-09-00
WP No 2348-09-01

HIGHWAY 406
BEAVERDAMS ROAD UNDERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

MRC
McCORMICK RANKIN
A member of MMM GROUP

THURBER ENGINEERING LTD.

SHEET



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
W	Water Level
HA	Head Artesian Water
P	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

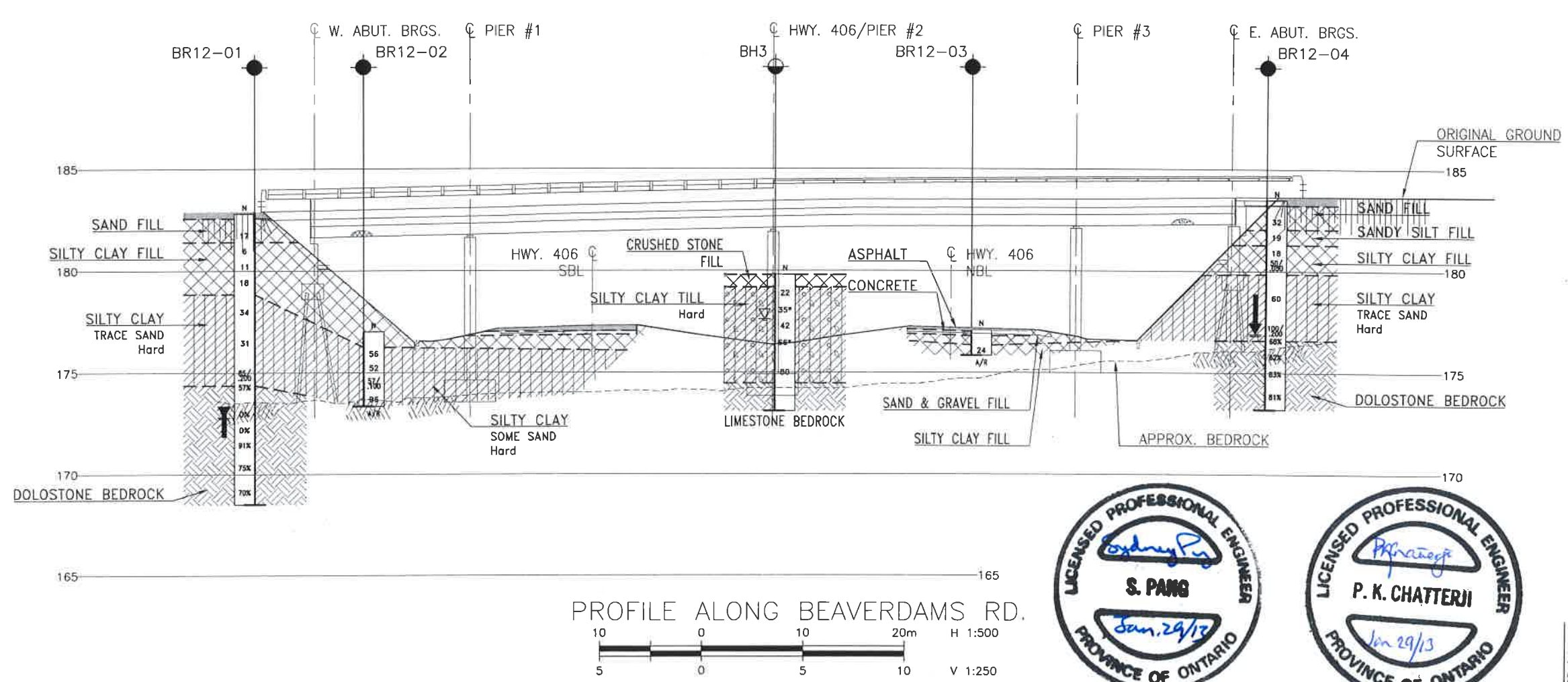
NO	ELEVATION	NORTHING	EASTING
BR12-01	182.8	4 772 841.6	326 140.5
BR12-02	177.0	4 772 832.7	326 159.2
BR12-03	177.1	4 772 862.2	326 211.2
BR12-04	183.5	4 772 882.5	326 232.4
BH1	179.5	N/A	N/A
BH2	180.3	N/A	N/A
BH3	179.8	N/A	N/A

N/A: Not Available

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

GEOCRES No. 30M3-276

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	PKG
DRAWN	MFA	CHK	SKP
SITE	34-160	STRUCT	JDWG
DATE	JAN. 2013		



Appendix B
Highway 58 – Richmond Street Underpass

RECORD OF BOREHOLE No RS12-01

1 OF 3

METRIC

W.P. 2365-09-00 LOCATION N 4 775 243.3 E 327 471.8 Richmond St. Underpass ORIGINATED BY SLL
HWY 58 BOREHOLE TYPE Solid Stem Augers/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.10 - 2012.04.11 CHECKED BY LPG

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						
187.8								20 40 60 80 100						
0.0	ASPHALT: (225mm)							20 40 60 80 100						
0.2	SAND, some gravel Compact Brown Moist (FILL)		1	GS			187							
			2	SS	14									
186.3														
1.4	Silty CLAY, trace sand, trace rootlets Stiff to Very Stiff Brown (FILL)		3	SS	17		186						0 5 50 45	
			4	SS	17									
			5	SS	9		185							
			6	SS	17		183							
	Wood fragments													
			7	SS	17		181						0 8 45 47	
180.5														
7.3	Silty CLAY, trace sand Very Stiff to Hard Brown		8	SS	24		180							
			9	SS	42		179							
							178							

Continued Next Page

+ 3, x 3

Numbers refer to
Sensitivity

20
15 5
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RS12-01

2 OF 3

METRIC

W.P. 2365-09-00 LOCATION N 4 775 243.3 E 327 471.8 Richmond SL Underpass ORIGINATED BY SLL
HWY 58 BOREHOLE TYPE Solid Stem Augers/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.10 - 2012.04.11 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			GR SA SI CL
			10	SS	33		177					
							176					
			11	SS	23		175					0 8 38 54
							174					
			12	SS	25		173					
							172					
			13	SS	38		171					
171.4							170					
16.4	Slightly weathered to fresh, thinly bedded, grey, very strong, with gypsum pockets: DOLOSTONE BEDROCK Horizontal joints at 16.9m, 17.1m, 17.2m, 17.3m Horizontal joints at 17.6m, 17.8m, 17.9m, 18.6m		1	RUN			169					
			2	RUN								
168.7												
19.1	END OF BOREHOLE AT 19.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.											

Continued Next Page

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

ONTMT-4S 1221.GPJ 12/3/12

METRIC

[illegible]

RECORD OF BOREHOLE No RS12-02

1 OF 3

METRIC

W.P. 2365-09-00 LOCATION N 4 775 199.3 E 327 393.1 Richmond St. Underpass ORIGINATED BY SLL
 HWY 58 BOREHOLE TYPE Solid Stem Augers/NXL Coring COMPILED BY AN
 DATUM Geodetic DATE 2012.04.09 - 2012.04.09 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
187.7								20 40 60 80 100								
0.0	ASPHALT: (200mm)															
0.2	SAND, some gravel Loose Brown Moist (FILL)		1	GS												
			2	SS	9											
186.3																
1.4	Silty CLAY, trace to some sand, trace gravel Firm to Very Stiff Brown (FILL)		3	SS	6											
			4	SS	11									2 13 43 42		
			5	SS	8											
			6	SS	13											
			7	SS	21											
180.3																
7.3	Silty CLAY, trace to some sand, trace rootlets, topsoil stained Very Stiff to Hard Grey		8	SS	19									0 6 52 42		
			9	SS	41											

Continued Next Page

+ 3, × 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RS12-02

2 OF 3

METRIC

W.P. 2365-09-00 LOCATION N 4 775 199.3 E 327 393.1 Richmond St. Underpass ORIGINATED BY SLL
HWY 58 BOREHOLE TYPE Solid Stem Augers/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.09 - 2012.04.09 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
	Continued From Previous Page												
	Becoming reddish brown		10	SS	45		177						
							176						
			11	SS	31		175						
							174						
			12	SS	24		173						
							172						
			13	SS	22		171						
							170						
							169						
171.4	Auger refusal on bedrock, start NW Casing at 16.2m												
16.2	Fresh, thinly bedded, grey, very strong: DOLOSTONE BEDROCK		1	RUN									
	Gypsum pockets at 16.4m, 16.6m, 16.9m												
	Horizontal joints at 16.8m, 17.1m, 17.7m												
	Horizontal joints at 18.3m, 19.0m, 19.1m, 19.2m		2	RUN									
	Gypsum pocket (50mm thick) at 18.6m												
168.2													
19.4	END OF BOREHOLE AT 19.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen												

Continued Next Page

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

RECORD OF BOREHOLE No RS12-02

3 OF 3

METRIC

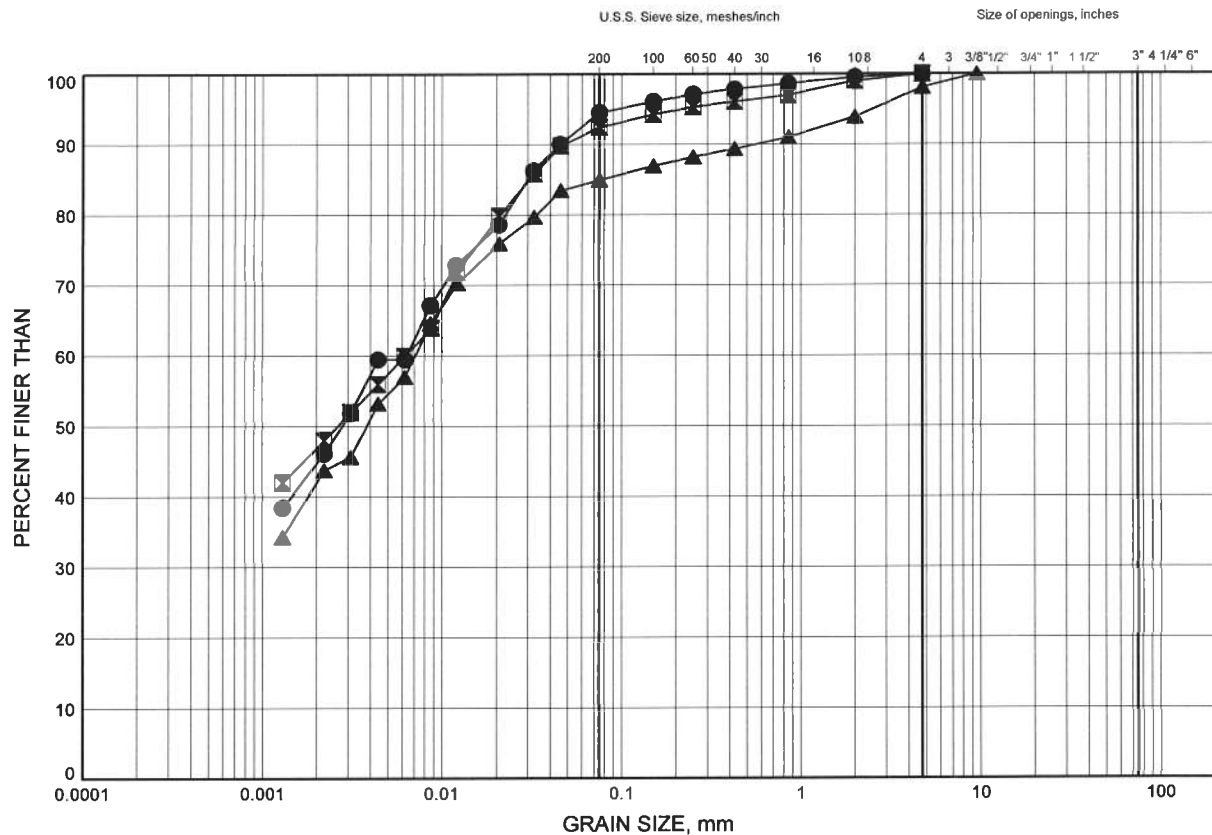
W.P. 2365-09-00 LOCATION N 4 775 199.3 E 327 393.1 Richmond St. Underpass ORIGINATED BY SLL
HWY 58 BOREHOLE TYPE Solid Stem Augers/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.09 - 2012.04.09 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L				
	Continued From Previous Page													
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Jul.16/12 10.5 177.2													

5 Bridges, Welland and St. Catharines
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)
●	RS12-01	1.83	185.96
■	RS12-01	6.40	181.38
▲	RS12-02	2.59	185.06

Date December 2012
W.P.# 2365-09-00

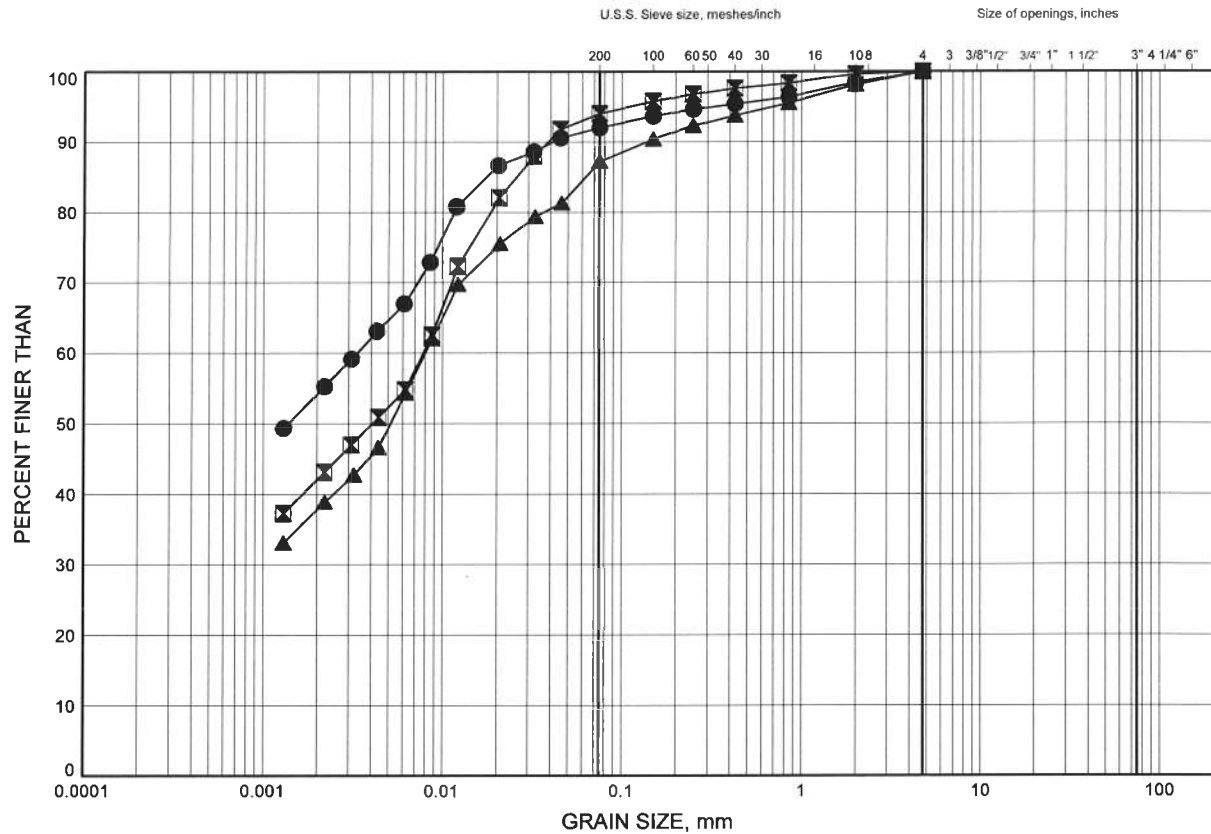


Prep'd AN
Chkd. SKP

5 Bridges, Welland and St. Catharines
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)
●	RS12-01	12.42	175.36
⊠	RS12-02	7.92	179.73
▲	RS12-02	13.94	173.71

Date December 2012

W.P.# 2365-09-00



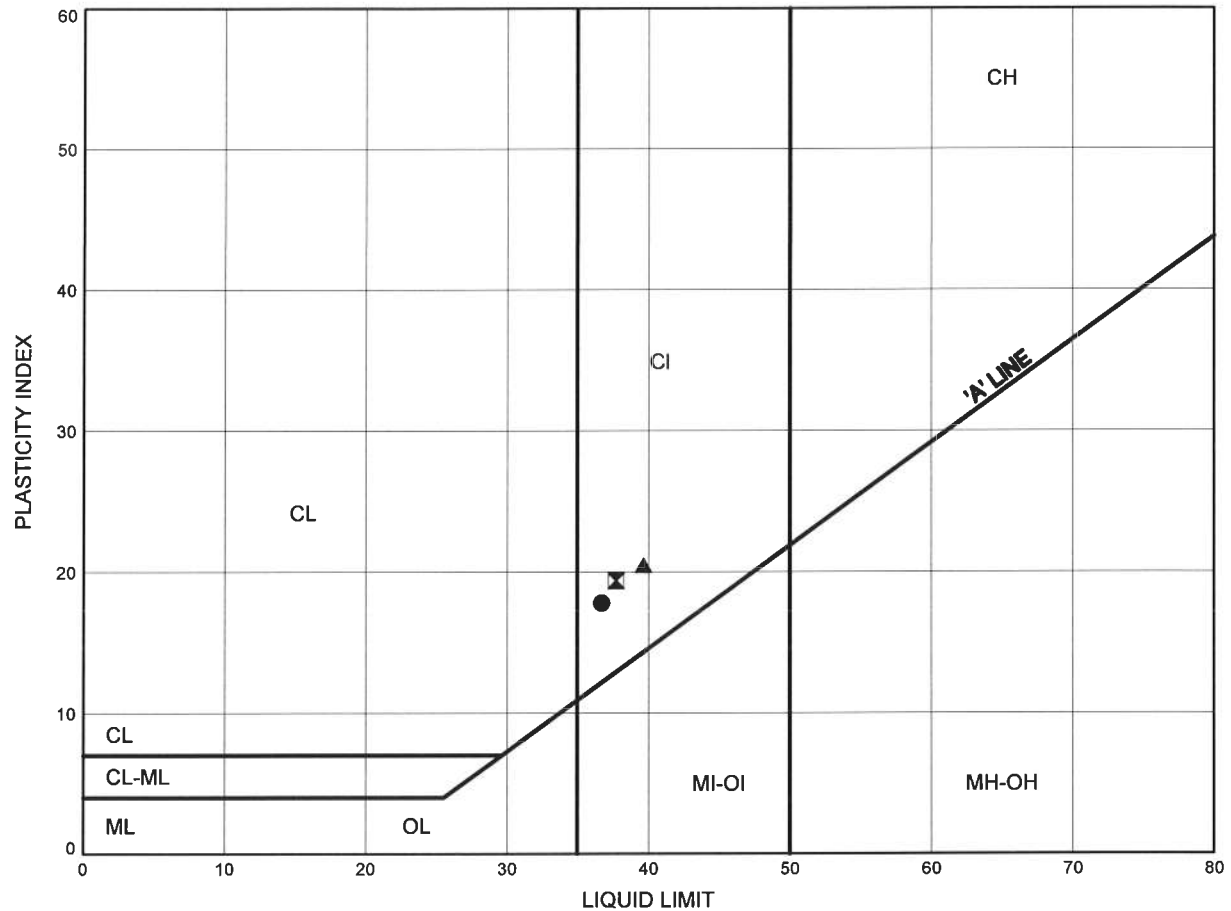
Prep'd AN

Chkd. SKP

5 Bridges, Welland and St. Catharines
ATTERBERG LIMITS TEST RESULTS

FIGURE B3

SILTY CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RS12-01	1.83	185.96
⊠	RS12-01	6.40	181.38
▲	RS12-02	2.59	185.06

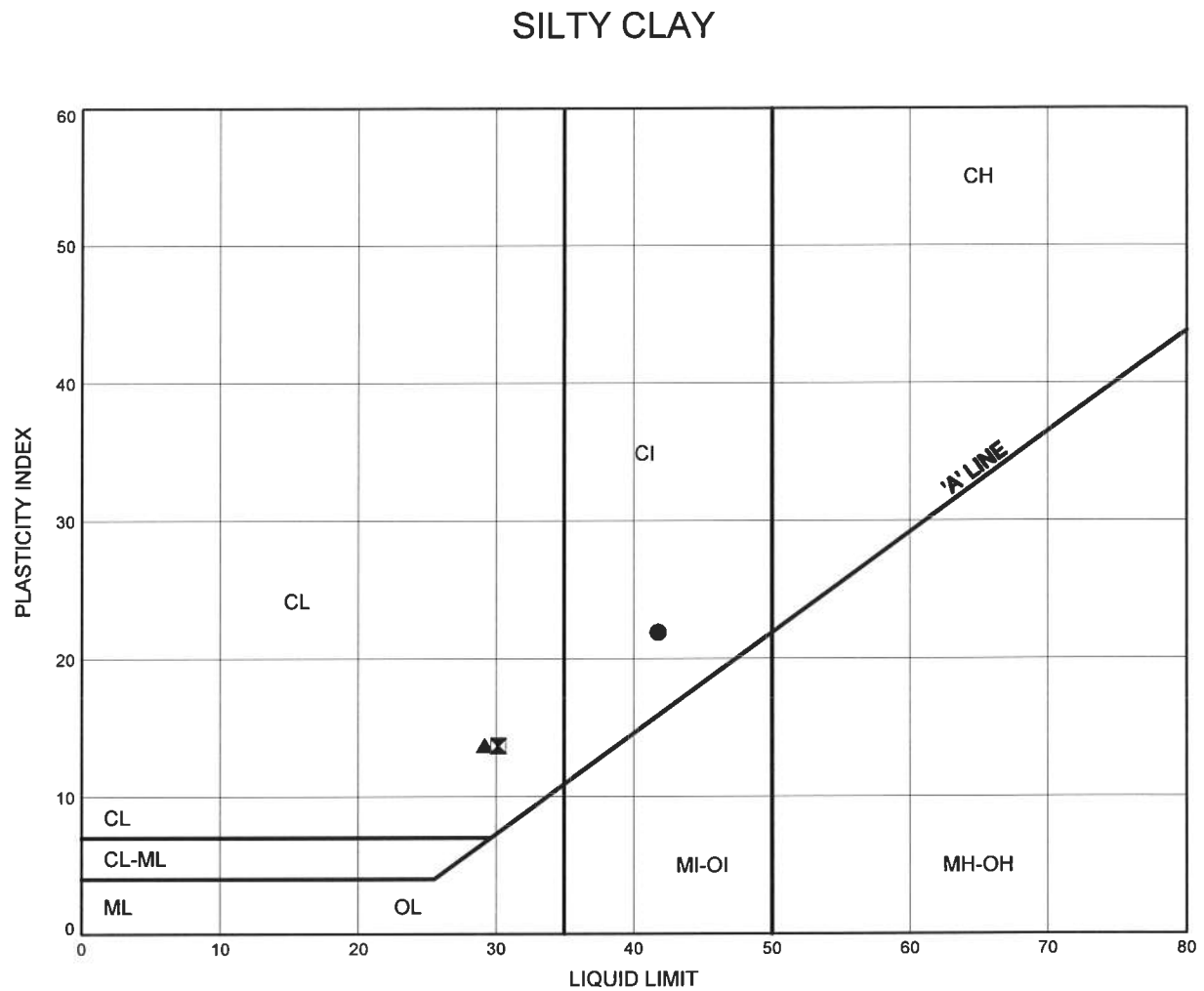
Date December 2012
W.P.# 2365-09-00



Prep'd AN
Chkd. SKP

5 Bridges, Welland and St. Catharines
ATTERBERG LIMITS TEST RESULTS

FIGURE B4



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RS12-01	12.42	175.36
⊠	RS12-02	7.92	179.73
▲	RS12-02	13.94	173.71

Date December 2012

W.P.# 2365-09-00



Prep'd AN




Chkd. SKP

RECORD OF BOREHOLE No RS74-01

1 OF 2

METRIC

W.P. 80-73-03 LOCATION Richmond St. Underpass ORIGINATED BY HS (DHO)
 HWY 58 BOREHOLE TYPE Solid Stem Augers/BXL Coring COMPILED BY NT (DHO)
 DATUM Geodetic DATE 1974.07.24 - 1974.07.24 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)					
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	W _P	W	W _L			
180.9 0.0	Silty CLAY with gravel, trace organics Firm to Stiff (FILL)		1	SS	9							○	19.3		
			2	SS	5										
179.5 1.4	Silty CLAY , trace of sand and gravel Very Stiff to Hard		3	TW	PH							○	20.4	6 8 51 35	
			4	TW	PH										○
			5	SS	46										○
			6	SS	33										○
			7	SS	33										○
			8	SS	37										○
			9	SS	25										○
171.7 9.2	Sandy silt layer														
	DOLOMITE BEDROCK		1	RUN										RUN #1 TCR=97%	

Continued Next Page

+ 3, × 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RS74-01

2 OF 2

METRIC

W.P. 80-73-03 LOCATION Richmond St. Underpass ORIGINATED BY HS (DHO)
 HWY 58 BOREHOLE TYPE Solid Stem Augers/BXL Coring COMPILED BY NT (DHO)
 DATUM Geodetic DATE 1974.07.24 - 1974.07.24 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100						W _P	W	W _L
	Continued From Previous Page																			
170.0																				
10.9	END OF BOREHOLE AT 10.9m.																			

RECORD OF BOREHOLE No RS74-02

1 OF 2

METRIC

W.P. 80-73-03 LOCATION Richmond St. Underpass ORIGINATED BY HS (DHO)
HWY 58 BOREHOLE TYPE Solid Stem Augers (BXL Coring) COMPILED BY NT (DHO)
DATUM Geodetic DATE 1974.07.26 - 1974.07.26 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	W _P	W	W _L		
180.8 0.0	Silly CLAY, with some sand, trace gravel, trace organics Firm to Stiff (FILL)		1	TW	PH							19.9		
179.2 1.6	Silly CLAY, trace sand and gravel Very Stiff to Hard		2	TW	PH							19.6		
			3	SS	45								0 3 62 35	
			4	SS	37									
			5	SS	35									
			6	SS	20								0 2 43 55	
			7	TW	PH							20.7		
			8	SS	33									
	Sandy silt layer													
171.4 9.4	DOLOMITE BEDROCK												RUN #1 TCR=100%	

Continued Next Page

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

RECORD OF BOREHOLE No RS74-02

2 OF 2

METRIC

W.P. 80-73-03 LOCATION Richmond St. Underpass ORIGINATED BY HS (DHO)
 HWY 58 BOREHOLE TYPE Solid Stem Augers (BXL Coring) COMPILED BY NT (DHO)
 DATUM Geodetic DATE 1974.07.26 - 1974.07.26 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
							20	40	60	80	100						
	Continued From Previous Page		1	RUN													
169.7																	
11.1	END OF BOREHOLE AT 11.1m.																

RECORD OF BOREHOLE No RS74-03

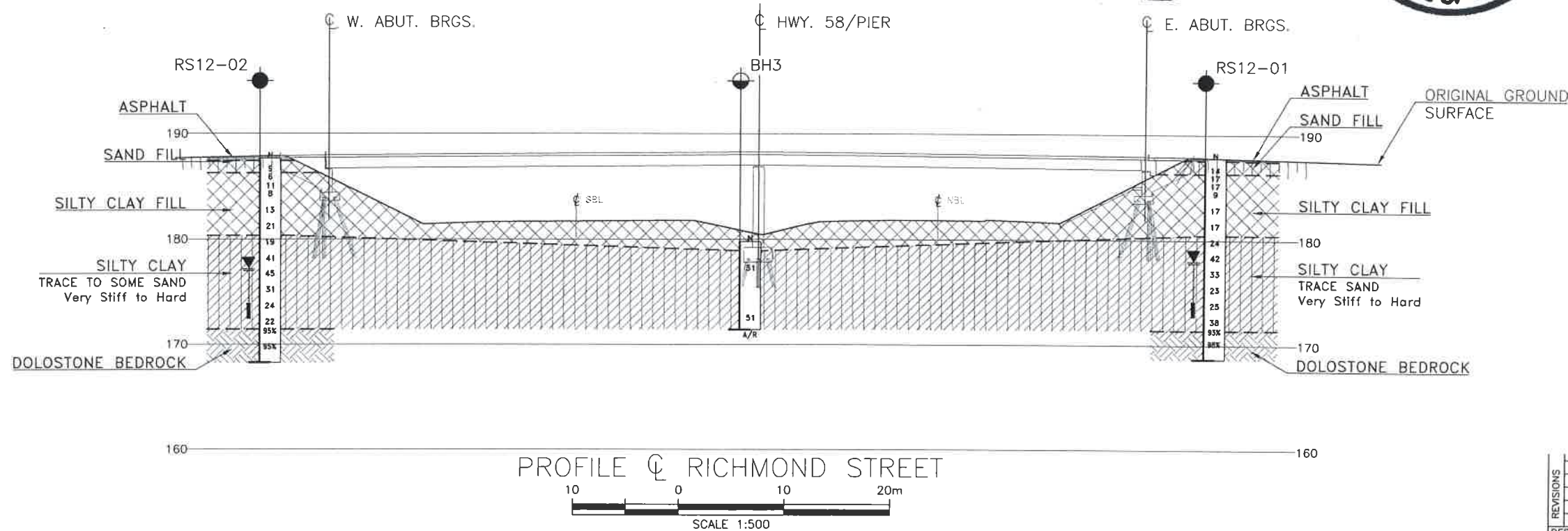
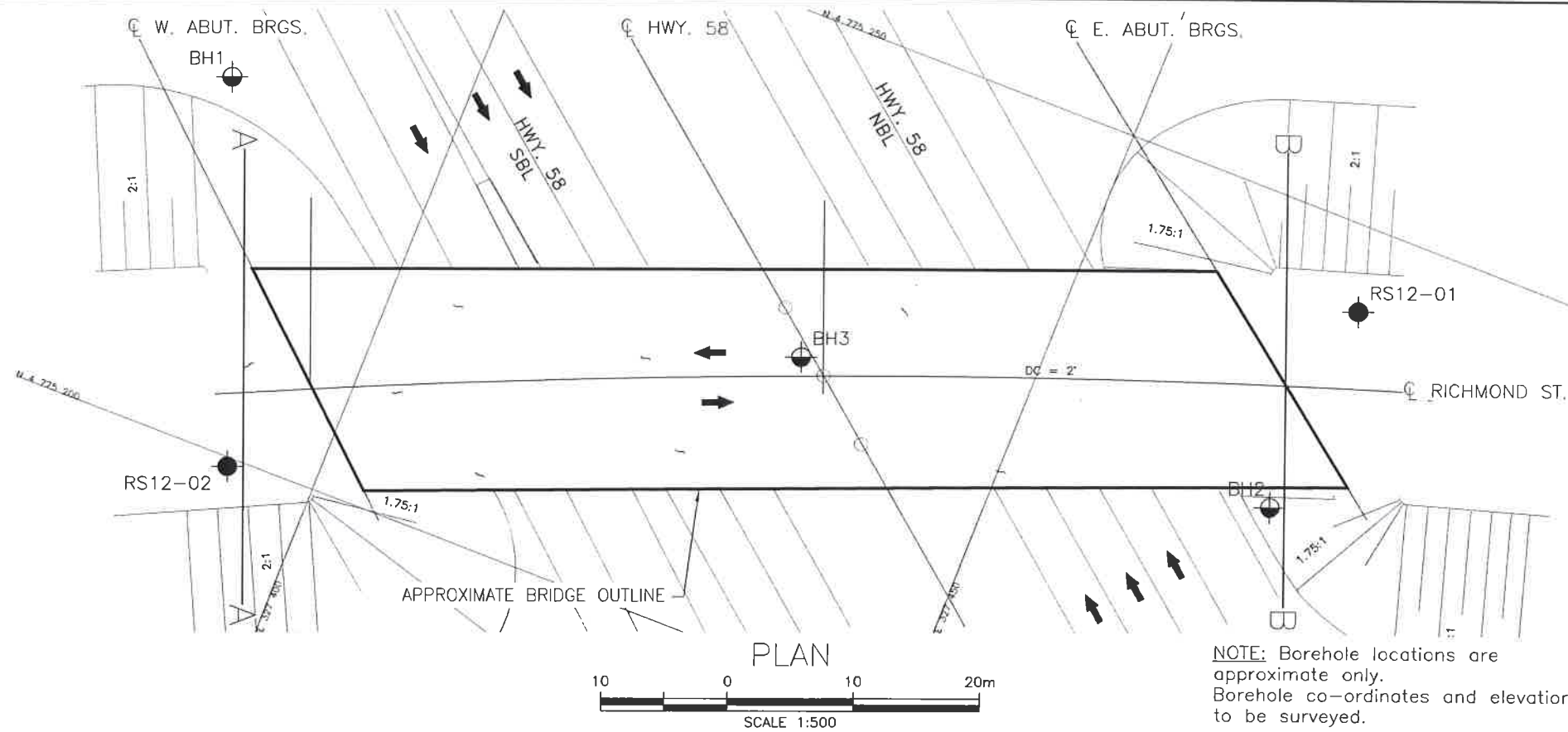
1 OF 1

METRIC

W.P. 80-73-03 LOCATION Richmond St. Underpass ORIGINATED BY HS (DHO)
HWY 58 BOREHOLE TYPE Solid Stem Augers COMPILED BY NT (DHO)
DATUM Geodetic DATE 1974.07.25 - 1974.07.25 CHECKED BY

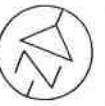
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE						● QUICK TRIAXIAL	× LAB VANE
179.8 0.0	Silty CLAY , trace gravel (FILL)		1	SS												
178.9 0.9	Silty CLAY , trace sand and gravel Stiff to Hard		2	SS			179									
			3	SS			178									0 3 51 46
			4	SS	31		177									
			5	SS												
			6	SS			176									
			7	SS			175									
			8	SS			174									
			9	SS	51											
171.4 8.4	END OF BOREHOLE AT 8.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK.															

ONTMT4S 1221.GPJ 12/4/12



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

CONT No
GWP No 2365-09-00
WP No 2377-09-01



HIGHWAY 58
RICHMOND STREET UNDERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

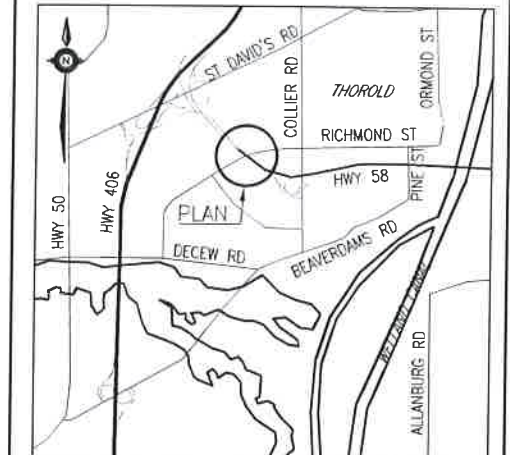
SHEET
57



McCORMICK RANKIN
A member of MMR GROUP



THURBER ENGINEERING LTD.



LEGEND

\bullet	Borehole (Current Investigation)
\circ	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
RS12-01	187.8	4 775 243.3	327 471.8
RS12-02	187.7	4 775 199.3	327 393.1
BH1	180.9	N/A	N/A
BH2	180.8	N/A	N/A
BH3	179.8	N/A	N/A
N/A: Not Available			

NOTES

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

GEOCRES No. 30M3-276

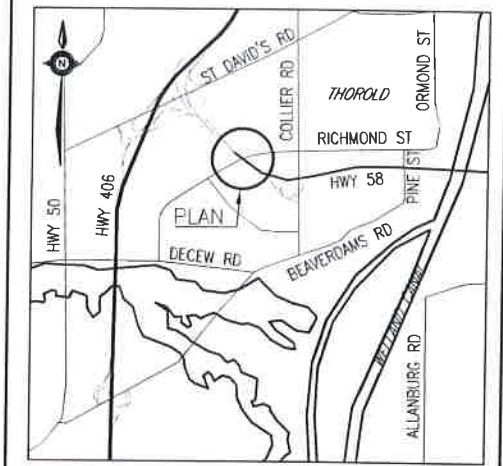
REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	PKC
DRAWN	MFA	CHK	SKP
SITE 34-280			
STRUCT			
DWG 2			
DATE JAN. 2013			

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

CONT No
GWP No 2365-09-00
WP No 2377-09-01

HIGHWAY 58
RICHMOND STREET UNDERPASS
BRIDGE REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
58



KEYPLAN

LEGEND

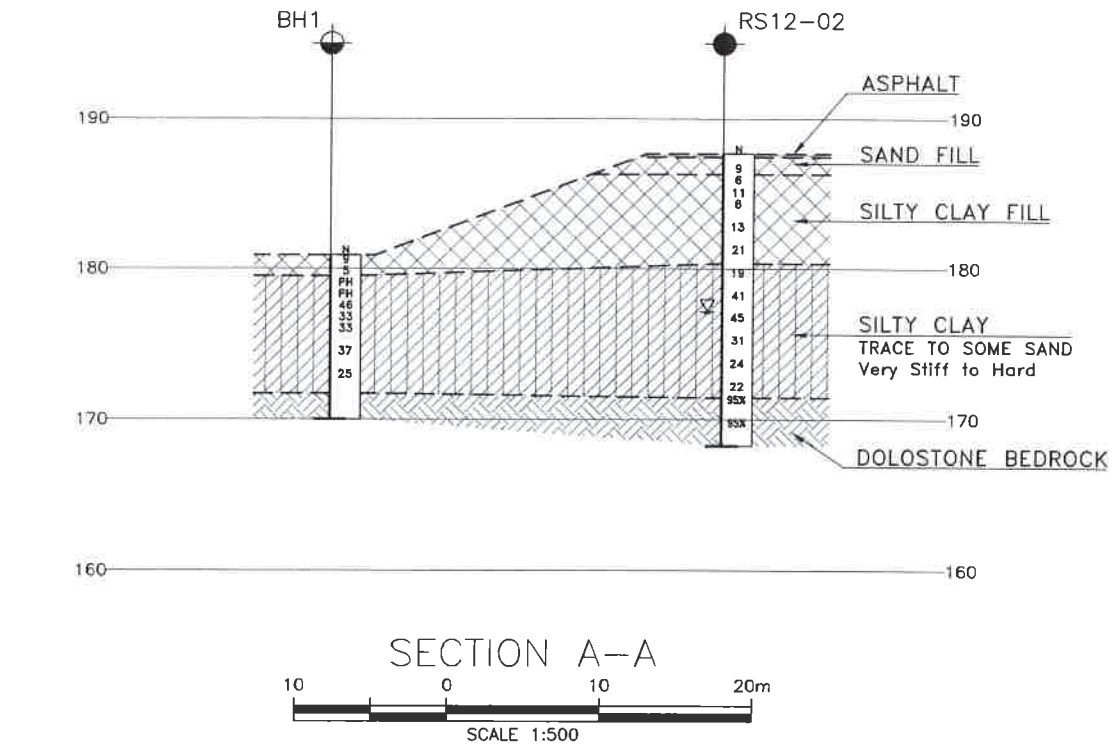
- ◆ Borehole (Current Investigation)
- ◊ Borehole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ↑ Head Artesian Water
- ⊥ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RS12-01	187.8	4 775 243.3	327 471.8
RS12-02	187.7	4 775 199.3	327 393.1
BH1	180.9	N/A	N/A
BH2	180.8	N/A	N/A
BH3	179.8	N/A	N/A
N/A: Not Available			

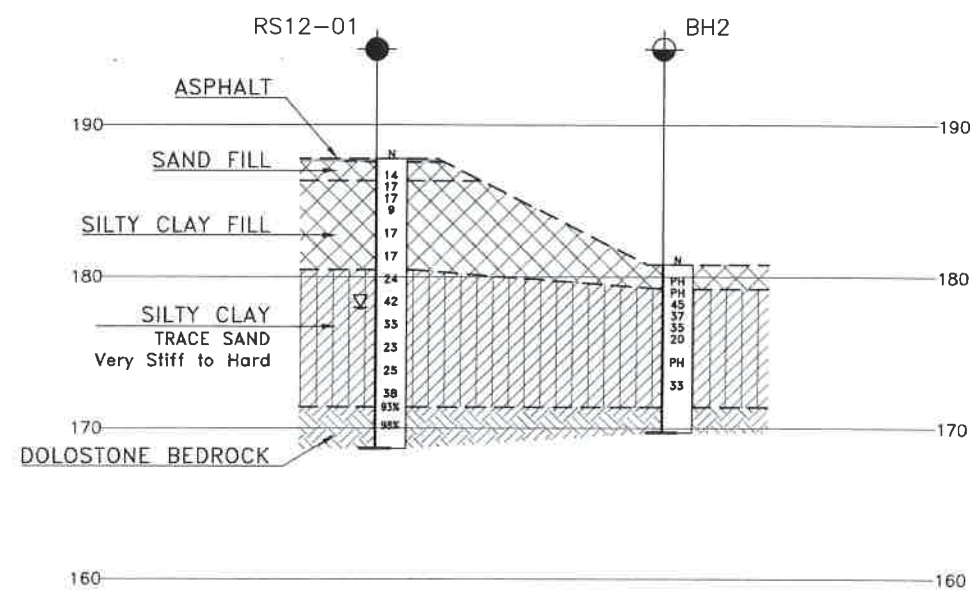
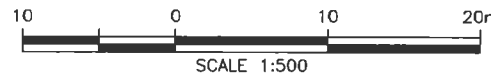
NOTES-

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

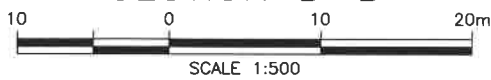
GEOCRES No. 30M3-276



SECTION A-A



SECTION B-B



NOTE: The locations of Boreholes BH1 to 3 are approximate only.



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	PKC
DRAWN	MFA	CHK	SKP
SITE 34-280			
STRUCT			
DWG 3			
DATE JAN. 2013			