April 21, 2014

MICROPILE FOUNDATION DESIGN REPORT

DESIGN OF MICROPILE FOUNDATIONS FOR LITTLE EAST RIVER BRIDGES NO. 1 TO 4 AND RAGGED CREEK BRIDGE, SITE NOs. 44-174 TO 44-178
HIGHWAY 592
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5265-07-00

Submitted to:
Morrison Hershfield Limited
Suite 600, 235 Yorkland Blvd.
Toronto, Ontario
M2J 1T1

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REPORT

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LITTLE EAST RIVER BRIDGES NO. 1 TO 4 AND RAGGED CREEK BRIDGE, SITE NOs. 44-174 TO 44-178

HIGHWAY 592

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5265-07-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the design of the micropile foundation systems for the replacement of Little East River Bridges No. 1 to No. 4 (Sites No. 44-174 to 44-177) and Ragged Creek Bridge (Site No. 44-178) on Highway 592.

Based on the General Arrangement (GA) drawings provided by MH on November 6, 2013 for Little East River Bridges No. 1 to 4 and on August 23, 2013 for Ragged Creek Bridge, the proposed bridges will consist of single-span, pre-cast girder structures with a span length of 12.6 m.

This report provides a summary of the subsurface conditions encountered at each bridge site.

2.0 SITE DESCRIPTION

The five bridge sites are located along Highway 592 crossing Little East River and Ragged Creek in the Township of Perry, Ontario. The detailed site description is presented in the following Foundation Investigation and Design Reports (FIDRs).

- Ministry of Transportation, Ontario. 2013a. Foundation Investigation and Design Report, Little East River Bridge No. 1, Site No. 44-174, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5265-07-01, Geocres No. 31E-330, prepared by Golder Associates Ltd.
- Ministry of Transportation, Ontario. 2013b. Foundation Investigation and Design Report, Little East River Bridge No. 2, Site No. 44-175, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5266-07-01, Geocres No. 31E-331, prepared by Golder Associates Ltd.
- Ministry of Transportation, Ontario. 2013c. Foundation Investigation and Design Report, Little East River Bridge No. 3, Site No. 44-176, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5267-07-01, Geocres No. 31E-332, prepared by Golder Associates Ltd.
- Ministry of Transportation, Ontario. 2013d. Foundation Investigation and Design Report, Little East River Bridge No. 4, Site No. 44-177, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5268-07-01, Geocres No. 31E-333, prepared by Golder Associates Ltd.
- Ministry of Transportation, Ontario. 2013e. Foundation Investigation and Design Report, Ragged Creek Bridge, Site No. 44-178, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5269-07-01, Geocres No. 31E-334, prepared by Golder Associates Ltd.

In general, the topography along Highway 592 consists of rolling terrain, with the lower elevation areas occupied by lakes, low-lying swamps containing areas of standing water and sparsely to densely populated tree covered areas. Land use in some areas consists of residential/recreational communities. The existing bridges are single-span rigid frame structures with span lengths of 6.1 m. The bridge sites and associated approach embankments are situated on relatively flat, sparsely treed areas, surrounded by residential/recreational properties to the north and south.

3.0 INVESTIGATION PROCEDURES

The foundation investigation field work for the proposed bridge structures was carried out between April 29 and June 6, 2013. The detailed investigation procedure and the results of the investigation are presented in the respective FIDRs (MTO, 2013a to 2013e) for each site.

A total of 21 boreholes and three Dynamic Cone Penetration Tests (DCPTs) were advanced at the location of the proposed bridge foundation footprints and approach embankments. A summary of the respective boreholes advanced at each bridge site is presented below.

Bridge Site	Number of Boreholes	Number of DCPTs
Little East River Bridge No. 1	5	0
Little East River Bridge No. 2	4	0
Little East River Bridge No. 3	4	1
Little East River Bridge No. 4	4	1
Ragged Creek Bridge	4	1

The Borehole Locations and Soil Strata drawing for each of the bridge sites is included in Appendix A. The Record of Borehole and Drillhole sheets and laboratory testing results carried out on selected soil samples and bedrock cores for each investigated area are included in the respective FIDRs (MTO, 2013a to 2013e).

In addition to the laboratory testing carried out on soil samples and bedrock cores, groundwater samples were collected by MH during the foundation investigation and were submitted for analytical testing for parameters associated with corrosion aggressiveness (i.e. pH, sulphate, chloride and electrical resistivity). The results of the analytical testing are included in Appendix B.

4.0 SUMMARY OF SUBSURFACE CONDITIONS

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during the foundation investigations are presented in Part A of the FIDRs (MTO, 2013a to 2013e) for each site.

The following sections provide brief descriptions of the subsurface conditions at each bridge site.

4.1 Little East River Bridge No. 1

The as-drilled borehole locations and the soil stratigraphy for this site are shown on Drawing A1 in Appendix A.

A layer of asphalt between about 25 mm and 90 mm thick was encountered at the ground surface at the proposed abutment locations.

A 2.2 m to 3.7 m thick fill deposit comprised of sand and gravel to gravelly sand to sand was encountered below the asphalt layer. Pieces of wood were encountered within the fill deposit at the location of the north abutment and are inferred to be remnants of a corduroy roadbed. Standard Penetration Testing (SPT) ‘N’-values in the fill deposit at the abutment locations generally range from 6 blows to 20 blows per 0.3 m of penetration, indicating a loose to compact relative density.

A 0.8 m thick layer of organic sand was encountered underlying the fill deposit at the proposed north abutment. An SPT 'N'-value of 5 blows per 0.3 m of penetration was measured within this layer, indicating a loose relative density.

The organic sand is underlain by a 2.6 m thick deposit of silt and sand. The SPT 'N'-values measured within this deposit range from 4 blows to 8 blows per 0.3 m of penetration, indicating a loose relative density.

A 1.3 to 2.6 m thick clayey silt deposit was encountered underlying the silt and sand deposit and organic sand at the south and north abutment, respectively. The SPT 'N'-values measured within this deposit range from 3 blows to 7 blows per 0.3 m of penetration, suggesting a soft to firm consistency.

The clayey silt deposit is in turn underlain by a deep deposit of sand and gravel to sandy gravel with a thickness of up to 19.2 m to the termination depth of drilling. Inference from a DCPT advanced at the location of the south abutment suggests that the sand and gravel to sandy gravel deposit extends to a depth of at least 25.4 m below ground surface. Cobbles and boulders were encountered at various depths throughout this deposit with boulder sizes up to about 0.7 m thick. The SPT 'N'-values measured within the sand and gravel to sandy gravel deposit typically range from 16 blows to 36 blows per 0.3 m of penetration, suggesting a compact to dense relative density.

During the drilling operations at the abutments, artesian groundwater conditions were noted when advancing the casing between depths of about 5.2 m and 22.3 m below ground surface. The groundwater levels measured in the open boreholes upon completion of drilling range from about 1.0 m below ground surface to 0.8 m above ground surface. A standpipe piezometer installed at the north approach embankment and screened within the sand and gravel to sandy gravel deposit measured a groundwater level at about 0.1 m above ground surface prior to decommissioning.

4.2 Little East River Bridge No. 2

The as-drilled borehole locations and the soil stratigraphy for this site are shown on Drawing A2 in Appendix A.

A layer of asphalt between about 30 mm to 40 mm thick was encountered at the ground surface at the proposed abutment locations.

A 2.2 m to 3.0 m thick fill deposit comprised of sand to sand and gravel was encountered below the asphalt layer. The SPT 'N'-values measured within the fill deposit range from 4 blows to 20 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

An upper deposit of sand and gravel was encountered below the fill deposit and contains a 2.1 m thick layer of silt to clayey silt in the borehole at the south abutment. The thickness of the overall sand and gravel deposit is between 5.8 m and 6.5 m. Cobbles and boulders were encountered within the lower portions of this deposit, between the depths of about 7.4 m and 8.5 m below ground surface. The SPT 'N'-values measured within the overall sand and gravel deposit generally range from 3 blows to 70 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

The upper sand and gravel deposit is underlain by a 8.3 m to 12.2 m thick deposit of silt and sand to sand. Cobbles were encountered between the depths of 19.5 m and 20.9 m below ground surface in the borehole at the south abutment. The SPT 'N'-values measured within the silt and sand to sand deposit range from 5 blows to 18 blows per 0.3 m of penetration, indicating a loose to compact relative density.

A 7.3 m thick lower deposit of sand and gravel was encountered below the silt and sand to sand deposit at the proposed north abutment. Cobbles and boulders were encountered between the depths of 19.4 m and 21.3 m as well as between 21.7 m and 24.4 m below ground surface. SPT 'N'-values of 17 blows and 54 blows per 0.3 m of penetration were measured within this deposit, indicating a compact to very dense relative density.

Granitic gneiss bedrock was encountered in the borehole at the proposed south abutment underlying the silt and sand to sand deposit and confirmed by bedrock coring. The bedrock surface was encountered at a depth of about 20.9 m below ground surface.

The groundwater level measured in the open boreholes upon completion of drilling ranges from about 2.1 m to 2.2 m below ground surface. A standpipe piezometer installed at the north abutment and screened within the upper sand and gravel deposit measured a groundwater level at between about 2.0 m and 2.7 m below ground surface prior to decommissioning.

4.3 Little East River Bridge No. 3

The as-drilled borehole locations and the soil stratigraphy for this site are shown on Drawing A3 in Appendix A.

A layer of asphalt between 25 mm to 50 mm thick was encountered at the ground surface at the proposed abutment. A 0.5 m thick layer of asphalt fragments were encountered below the asphalt at the south abutment.

A 1.7 m to 3.0 m thick fill deposit comprised of sand and gravel to silt and sand was encountered below the layer of asphalt/asphalt fragments. The SPT 'N'-values measured within the fill deposit range from 4 blows to 41 blows per 0.3 m of penetration, indicating a very loose to dense relative density.

A 2.6 m to 3.4 m thick deposit of organic sand was encountered underlying the fill deposit at the location of the proposed abutments. The SPT 'N'-values measured within this deposit range from 3 blows to 5 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

The organic sand is underlain by a 6.1 m to 6.9 m thick deposit of silt. At the south abutment, the silt deposit is underlain by a 1.6 m thick pocket of gravelly sand at a depth of 11.7 m below ground surface. The SPT 'N'-values measured within the silt deposit and sand pocket range from 0 blows (weight of hammer) to 6 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

A 2.3 m to 3.8 m thick clayey silt with sand deposit was encountered below the silt deposit at the abutments. The SPT 'N'-values measured within this deposit range from 0 blows (weight of hammer) to 8 blows per 0.3 m of penetration, suggesting a very soft to firm consistency.

The clayey silt with sand deposit is in turn underlain by a deep deposit of gravelly sandy silt to sand and gravel with thicknesses ranging from about 14 m to 16.3 m to the termination depth of drilling. Inference from a DCPT advanced at the location of the south abutment suggests that the gravelly sandy silt to sand and gravel deposit extends to a depth of at least 32.1 m. Cobbles and boulders were encountered at various depths throughout this deposit with boulder sizes up to 0.5 m thick.

The groundwater levels measured in the open boreholes upon completion of drilling range from about 1.3 m to 2.3 m below ground surface. A standpipe piezometer installed at the south abutment and screened within the organic sand deposit measured a groundwater levels between about 1.9 m and 2.4 m below ground surface prior to decommissioning.

4.4 Little East River Bridge No. 4

The as-drilled borehole locations and the soil stratigraphy for this site are shown on Drawing A4 in Appendix A.

A layer of asphalt/asphalt fragments between about 300 mm to 460 mm thick was encountered at the ground surface at the proposed abutment locations.

A 0.9 m to 1.2 m thick fill deposit comprised of sand and gravel to sand was encountered below the layer of asphalt/asphalt fragment. The SPT 'N'-values measured within the fill deposit are 9 blows and 10 blows per 0.3 m of penetration, indicating a loose relative density.

At the north abutment, a 1.6 m thick pocket of organic silt was encountered underlying the fill deposit. The SPT 'N'-values measured within the organic silt pocket are 2 blows and 3 blows per 0.3 m of penetration, indicating a very loose relative density.

A deep deposit of silt to sand was encountered underlying the fill deposit at the south abutment and the organic silt at the north abutment. In general, the silt to sand deposit is comprised of an upper portion of silt and sand to silty sand to a depth of 1.3 m below ground surface and a lower portion of silt to sandy silt. The thickness of the silt to sand deposit ranges from 20.8 m to 21.7 m. The SPT 'N'-values measured within the overall silt to sand deposit range from 0 blows (weight of hammer) to 26 blows per 0.3 m of penetration, indicating a very loose to compact relative density. The silty sand to silt and sand upper portion of the deposit may be described as very loose to loose and the silt to sandy silt lower portion of the deposit may be described as very loose to compact.

The silt to sand deposit is underlain by a deposit of sand and gravel with thicknesses ranging from about 7.3 m to 7.9 m to the termination depth of drilling. Inference from a DCPT advanced at the north abutment suggests that the sand and gravel deposit extends to a depth of at least 38 m below ground surface. Cobbles were encountered within the silt to sandy silt deposit at the the south abutment between depths of 26.5 m and 27.4 m below ground surface. The SPT 'N'-values measured within the deposit range from about 12 blows to 34 blows per 0.3 m of penetration, indicating a compact to dense relative density.

The groundwater levels measured in the open boreholes upon completion of drilling range from about 1.2 m to 1.6 m below ground surface. A standpipe piezometer installed at the south abutment and screened within the silt to sand deposit measured a groundwater level between about 1.5 m and 2.2 m below ground surface prior to decommissioning.

4.5 Ragged Creek Bridge

The as-drilled borehole locations and the soil stratigraphy for this site are shown on Drawing A5 in Appendix A.

A layer of asphalt between about 75 mm to 480 mm thick was encountered at the ground surface at the proposed abutment locations.

A 1.7 m to 2.1 m thick fill deposit comprised of sand and gravel to sand was encountered underlying the asphalt. The SPT 'N'-values measured within the fill deposit generally range from 2 blows to 15 blows per 0.3 m of penetration, indicating a very loose to compact relative density, with SPT 'N'-values up to 27 m blows per 0.3 m of penetration recorded within the upper portion of the fill immediately underlying the asphalt layer, indicating a compact relative density.

The fill deposit is underlain by a 0.8 m to 1.5 m thick deposit of organic silt. The SPT 'N'-values measured within this deposit range from 2 blows to 4 blows per 0.3 m of penetration, indicating a very loose relative density.

A deep deposit comprised of silt to sand was encountered underlying the organic silt deposit with thicknesses ranging from about 27.4 m to 28.1 m to the termination depth of drilling. Inference from a DCPT advanced at the location of the north abutment suggests that the silt to sand deposit extends to a depth of at least 32 m below ground surface. The SPT 'N'-values measured within the silt to sand deposit range from 1 blow to 20 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The groundwater levels measured in the open boreholes upon completion of drilling range from about 1.7 m to 1.8 m below ground surface. A standpipe piezometer installed at the south abutment and screened within the silt to sand deposit measured a groundwater between about 1.8 m and 2.0 m below ground surface prior to decommissioning.

5.0 CLOSURE

This report was prepared by Mr. Matt Soderman, E.I.T., and was reviewed by Mr. Christopher Ng, P.Eng., a geotechnical engineer and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.

Report Signature Page

Matt Soderman, E.I.T.
Geotechnical Engineering Group

Christopher Ng, P.Eng.,
Geotechnical Engineer, Associate

Jorge M. A. Costa, P. Eng.,
Designated MTO Contact, Principal

MAS/CN/JMAC/

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PART B

MICROPILE FOUNDATION DESIGN REPORT

LITTLE EAST RIVER BRIDGES NO. 1 TO 4 AND RAGGED CREEK BRIDGE, SITE NOs. 44-174 TO 44-178

HIGHWAY 592

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5265-07-00

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides engineering micropile foundation design recommendations for the proposed Little East River Bridges No. 1 to No. 4 (Sites Nos. 44-174 to 44-177) and Ragged Creek Bridge (Site No. 44-178) on Highway 592. The recommendations have been developed based on the results of the factual geotechnical data obtained from the boreholes advanced during the foundation investigation at each bridge site (as summarized in Sections 3.0 and 4.0) and discussions with Morrison Hershfield (MH) and a micropile installation contractor during the design process.

6.1 General

It is understood that the proposed bridges at each site will consist of single-span, pre-cast girder structures with a span length of 12.6 m. Soil bonded micropiles have been selected as the preferred foundation alternative for the support of the structures for the following reasons:

- Ease of construction given the subsurface soil and groundwater conditions;
- Potential for least disturbance to the existing adjacent structures during construction;
- Bedrock was not encountered to the termination depths of the majority of the boreholes drilled;
- Presence of cobbles and boulders within the sand and gravel deposits;
- High groundwater level and/or artesian conditions relative to the excavation to the underside of the pile cap;
- Narrow right-of-way available to allow for stage construction; and,
- Presence of an overhead Hydro line along the highway,

Based on the layout details shown on the General Arrangement (GA) drawings, a total of 32 micropiles (two rows of eight micropiles at each abutment) are required to provide support for each structure and all micropiles are proposed to be installed vertically.

6.2 Design Method

The micropile design was carried out in accordance with the FHWA/NHI Micropile Design and Construction Reference Manual, Publication No. FHWA NHI-05-039 (FHWA/NHI, 2005). The geotechnical/foundation aspects of the foundation design were evaluated using the Canadian Foundation Engineering Manual, 4th Edition (CFEM, 2006).

6.3 Types of Micropile

There are two main types of micropiles: solid central reinforcing bar micropiles and hollow-core central reinforcing bar micropiles. The solid bar micropile system is typically constructed by advancing a hole into the overburden and/or bedrock using a steel casing and down-the-hole (DTH) hammer attached to control drill rods. Upon completion of drilling to the design tip depth, the DTH hammer and drill rods are removed from the casing and a solid steel reinforcing bar is lowered to the bottom of the borehole and grouted in place as the casing is raised up to the length required to achieve the design axial capacity and satisfy requirements for lateral capacity, if needed. The hollow-core bar micropile system is typically constructed by drilling a hollow steel bar with a sacrificial drill bit into the overburden, and of itself serves as the drill-string during drilling, and is grouted in place as the drilling advances by flushing grout through the hollow bar. A casing may also be installed either before or after this process to address structural requirements for lateral capacity, if needed.

Given the presence of very loose to compact non-cohesive deposits and high groundwater level and/or artesian conditions at the bridge sites, there are risks associated with base heave and potential loss of ground during the drilling of hole for micropile installation. Following several discussions with MH and a micropile contractor to consider the risk for base heave/ground loss and the practicality of construction of the different types of micropiles at these sites, hollow-core bar micropiles are considered the preferred micropile type for the support of the structures given their ease of construction and potential for least disturbance to foundation soils.

The advantages, disadvantages, relative costs and risks/consequences of the different types of micropiles as applicable to the conditions at these sites are summarized in Table 1.

6.4 Basis for Micropile Design

6.4.1 Design Loads

The following design loads (per micropile) have been provided by MH:

Site	Factored Axial Design Load at Ultimate Limits State (ULS) per Micropile
Little East River Bridge No. 1	450 kN
Little East River Bridge No. 2	480 kN
Little East River Bridge No. 3	450 kN
Little East River Bridge No. 4	400 kN
Ragged Creek Bridge	410 kN

6.4.2 Micropile Section Detail

Various micropile sections considered for analyses are comprised of the following components:

Steel Casing	
Size	**Grade**
273 mm OD x 13.8 mm (10-3/4” x 0.545”)	F_y = 552 MPa (80 ksi)
273 mm OD x 16.5 mm (10-3/4” x 0.625”)	F_y = 552 MPa (80 ksi)

Central Reinforcing Bar		
Type of Central Bar	**Size**	**Grade**
Solid Bar	57 mm (#18, 2-1/4”)	F_y = 520 MPa (75 ksi)
Hollow-Core Bar	73 mm OD, 56 mm ID (73/56)	F_y = 555 MPa (80 ksi)
Hollow-Core Bar	103 mm OD, 78 mm ID (103/78)	F_y = 572 MPa (83 ksi)

Final Structural Grout
f'_c = 30 MPa
f'_c = 35 MPa

Following the structural evaluation/analysis of the micropile group behaviour under the design axial, lateral and moment combinations as carried out by MH, the following micropile design was selected:

Component	Properties
Steel Casing	API-N80 (threaded) 273 mm OD x 13.8 mm (10-3/4” x 0.545”) F_y = 552 MPa (80 ksi) 1.6 mm casing section loss (per side) to be considered due to corrosion potential
Central Reinforcing Bar	Con-Tech Systems CTS/TITAN Bar 103/78 (or equivalent) F_y = 572 MPa (83 ksi)
Final Structural Grout	Water/Cement ratio (by weight) < 0.45 f'_c = 35 MPa
Uncased Length	175 mm diameter drill bit An enlargement factor of 1.5 and 1.4 is assumed as the bond zone (D_b) for non-cohesive soil and cohesive soil, respectively.

6.4.3 Grout-to-Ground Bond Ultimate Strength

The following grout-to-ground bond ultimate strengths, α_{bond}, were selected based on Table 5-3 in FHWA NHI-05-039 for Type B micropiles (pressure grouted through casing) which are understood to be applicable to hollow bar flush grouted micropiles (Type E).

Site	Soil Type	Elevation		Grout-to-Ground Bond Ultimate Strength, α_{bond}
		From	To	
Little East River Bridge No. 1	Compact to Very Dense Sand and Gravel	314.3 m	297.1 m	240 kPa
Little East River Bridge No. 2	Loose to Dense Sand and Gravel	319.3 m	317.7 m	180 kPa
	Loose to Compact Sand	317.7 m	302.1 m	120 kPa
Little East River Bridge No. 3	Very Loose to Loose Silt to Very Soft to Firm Clayey Silt	320.5 m	309.1 m	35 kPa
	Compact to Dense Sand and Gravel	309.1 m	294.1 m	180 kPa

Site	Soil Type	Elevation		Grout-to-Ground Bond Ultimate Strength, α_{bond}
		From	To	
Little East River Bridge No. 4	Very Loose Silt and Sand	320.5 m	315.0 m	90 kPa
	Compact Silt and Sand	315.0 m	304.1 m	180 kPa
Ragged Creek Bridge	Very Loose to Compact Silt to Sand	315.1 m	293.4 m	120 kPa

6.4.4 Length of Micropiles

Using the design loads, micropile material properties and grout-to-ground bond ultimate strengths as described in Sections 6.4.1 through 6.4.3, the procedures outlined in FHWA NHI-05-039 were followed to establish the required lengths for the micropiles to satisfy the geotechnical design requirement for a Factor of Safety of 2.5, as outlined below. It is noted that a Factor of Safety of 2.5 has been selected for the geotechnical design of the micropiles at these sites given the variable subsurface conditions, the fact that micropiles will be soil bonded and given the uncertainties associated with the actual bond zone diameter created by the 175 mm diameter bit.

Site	Elevation of Underside of Pile Cap / Tremie Plug	Cased Length [1] / Casing Tip Elevation	Uncased Length / Micropile Tip Elevation	Total Length of Micropile Below Tremie Plug
Little East River Bridge No. 1	319.3 m / 317.8 m	4.5 m / 313.3 m	5.7 m / 307.6 m	10.2 m
Little East River Bridge No. 2	322.7 m / 321.5 m	3.5 m / 318.0 m	12.0 m / 306.0 m	15.5 m
Little East River Bridge No. 3	322.2 m / 321.0 m	3.5 m / 317.5 m	15.0 m / 302.5 m	18.5 m
Little East River Bridge No. 4	325.2 m / 324.0 m	3.0 m / 321.0 m	10.0 m / 311.0 m	13.0 m
Ragged Creek	316.7 m / 315.5 m	3.0 m / 312.5 m	10.5 m / 302.0 m	13.5 m

Note: 1. Minimum cased length to be confirmed by structural analysis.

Given the method for which the micropiles will be installed, the diameter of the uncased length/bond zone is estimated to be between about 245 mm and 263 mm (i.e. 1.4 to 1.5 times the diameter of drill bit). Based on the GA drawings provided by MH, given that the pile cap is in firm contact with the ground and that the minimum spacing between the piles in the micropile group is greater than three micropile diameters (i.e. $s > 3D_b$) and considering that the micropiles will be bonded into non-cohesive soils, a reduction factor on the factored geotechnical axial resistance at Ultimate Limits States (ULS) for group effects is not required.

If the minimum cased lengths indicated above are modified based on the results of the structural assessment, the total length of the micropile will increase as the uncased length must remain unchanged to satisfy the geotechnical design requirements.

The geotechnical reaction at Serviceability Limits States (SLS) for 25 mm of settlement will be greater than or equal to the factored geotechnical axial resistance at ULS; the SLS conditions does not apply.

6.4.5 Recommendations for Lateral Micropile Analysis

The P-y curves to be used by MH for the assessment of the micropile group(s) under the combined design loads (i.e. including axial loads, lateral loads and bending moments) are provided in Table C1 and in Figures C1 to C5, inclusive, in Appendix C. The P-y curves were generated using the commercially available program LPILE Plus (version 5.0) developed by Ensoft Inc. The soil parameters and geotechnical model used in the analysis are presented below.

Soil Type	Elevation		Bulk Unit Weight, γ	Undrained Shear Strength, s_u	Strain Factor, ε_{50}	Effective Angle of Internal Friction, φ	P-y Modulus [1]	LPILE Soil Model
	From	To						
Little East River Bridge No. 1 – South Abutment								
Loose to Compact Silt and Sand	317.8 m	316.9 m	18 kN/ m^3	--	--	30°	10,000 kPa/m	API Sand – O'Neill
Soft to Firm Clayey Silt	316.9 m	314.3 m	17 kN/ m^3	25 kPa	0.02	--	--	API Clay – O'Neill
Compact to Dense Sand and Gravel	Below 314.3 m		20 kN/ m^3	--	--	34°	20,000 kPa/m	API Sand – O'Neill
Little East River Bridge No. 1 – North Abutment								
Compact to Dense Sand and Gravel	Below 317.8 m		20 kN/ m^3	--	--	34°	20,000 kPa/m	API Sand – O'Neill
Little East River Bridge No. 2 – South Abutment								
Very loose Silt	321.5 m	320.8 m	17 kN/ m^3	--	--	27°	3,500 kPa/m	API Sand – O'Neill
Stiff Clayey Silt	320.8 m	319.9 m	17 kN/ m^3	30 kPa	0.01	--	--	API Clay – O'Neill
Loose to Compact Sand to Sand and Gravel	320.8 m	305.5 m	20 kN/ m^3	--	--	32°	15,000 kPa/m	API Sand – O'Neill
Little East River Bridge No. 2 – North Abutment								
Loose to Compact Sand to Sand and Gravel	321.5 m	309.4 m	20 kN/ m^3	--	--	32°	15,000 kPa/m	API Sand – O'Neill
Compact to Dense Sand and Gravel	Below 309.4 m		20 kN/ m^3	--	--	34°	20,000 kPa/m	API Sand – O'Neill
Little East River Bridge No. 3 – South and North Abutment								
Loose Organic Sand	321.0 m	320.5 m	16 kN/ m^3	--	--	27°	1,000 kPa/m	API Sand – O'Neill
Very Loose to Loose Silt to Gravelly Sand	320.5 m	313.6 m	17 kN/ m^3	--	--	28°	3,500 kPa/m	API Sand – O'Neill
Firm Clayey Silt with Sand	313.6 m	309.1 m	18 kN/ m^3	25 kPa	0.02	--	--	API Clay – O'Neill
Compact to Dense Sand and Gravel	Below 309.1 m		20 kN/ m^3	--	--	34°	20,000 kPa/m	API Sand – O'Neill

Soil Type	Elevation From	Elevation To	Bulk Unit Weight, γ	Undrained Shear Strength, s_u	Strain Factor, ε_{50}	Effective Angle of Internal Friction, φ	P-y Modulus [1]	LPILE Soil Model
Little East River Bridge No. 4 – South and North Abutment								
Very Loose Silt to Sand	324.0 m	315.0 m	19 kN/ m^3	--	--	29°	5,000 kPa/m	API Sand – O'Neill
Compact Silt to Sand	315.0 m	304.1 m	19 kN/ m^3	--	--	32°	15,000 kPa/m	API Sand – O'Neill
Compact to Dense Sand and Gravel	Below 304.1 m		20 kN/ m^3	--	--	34°	20,000 kPa/m	API Sand – O'Neill
Ragged Creek Bridge – South and North Abutment								
Very Loose to Loose Silt to Sand	315.5 m	295.0 m	18 kN/ m^3	--	--	28°	3,500 kPa/m	API Sand – O'Neill
Compact Silt to Sand	Below 295.0 m		19 kN/ m^3	--	--	32°	15,000 kPa/m	API Sand – O'Neill

Note: 1. For non-cohesive soils below groundwater table.

It should be noted that micropile behaviour in a group configuration is influenced by the spacing between the individual pile elements. The pile-soil-pile interaction can result in the lateral capacity of a pile group being less than the sum of the lateral capacities of the individual piles comprising the group (i.e. group efficiency of less than 1), depending on the pile spacing relative to the orientation of the loading.

Based on the GA drawing, the proposed spacing between the micropiles varies between 1,200 mm and 1,700 mm (center-to-center) in the same row of micropiles, as shown on Figure 2. The proposed centre-to-centre spacing between the front and back row of micropiles is 1,000 mm. For lateral loads applied perpendicular and parallel to axis of the bridge structure, the P-y curves representing the lateral resistance of the soils as presented on Figures C1 to C5, inclusive, should be modified to account for the pile spacing in the group configuration (i.e. $s < 6D_b$). If the proposed micropile geometry, spacing or arrangement of the micropiles is revised, modifications to the P-y curves will be required.

For lateral loads applied perpendicular to axis of the bridge structure, the P-y curves representing the lateral resistance of the soils should be modified according to the 'p-multipliers' (P_m) provided below.

Pile Row	Multiplier, P_m
Front Row[1]	0.8
Second Row	0.4
Third and Subsequent Rows	0.3

Note: 1. The front row is the furthest row in the pile group from the application of the lateral load (see Figure 3)

The micropiles should be designed so that bending moments are negligible within the uncased length of the lower section of the micropile. In this regard, the cased length(s) indicated in Section 6.4.4 are minimums and may have to be modified based on the structural assessment and design requirements. The P-y curves presented on Figures C1 to C5, inclusive, are therefore only provided for the cased section.

6.5 Design and Installation Considerations

6.5.1 Corrosion Protection Requirements

Samples of the groundwater were collected at each site by MH during the foundation investigation and were submitted for analytical testing (i.e. pH, sulphate, chloride, electrical conductivity and resistivity). The analytical test results are included in Appendix B and are summarized below:

Site / Sample Number	pH	Sulphate (mg/L or ppm)	Chloride (mg/L or ppm)	Electrical Conductivity µS/cm	Electrical Resistivity ohm.cm
Little East River Bridge No. 1 (Sample 1)	6.43	7.9	60.3	304 [a]	3290 [b]
Little East River Bridge No. 2 (Sample 3)	7.68	33.4	319	1550	645
Little East River Bridge No. 3 (Sample 4)	5.69	<1.0	475	1540	649
Little East River Bridge No. 4 (Sample 5)	7.01	0.27	3.26	210	4760
Ragged Creek Bridge (Sample 6)	6.98	19.3	69.6	405	2470

Note: a. Electrical conductivity is a measured field parameter (by MH) from water sample from spring outlet pipe.
b. Resistivity is calculated (by MH) from electrical conductivity.

Based on the test results and guidelines provided in FHWA NHI-05-039, the water samples from Little East River Bridges No. 2 and 3 and Ragged Creek Bridge are classified as having a strong corrosion potential. As a result, in accordance with Section 5.14 of FHWA NHI-05-039, a minimum steel section loss of 1.6 mm per side of the micropile casing is required and has been included in the foundation design. The structural assessment and design should also take this into consideration. Corrosion protection of the central bar is typically afforded by epoxy coating combined with grout cover. Therefore, proper centering of the central bar by means of centralizers will be required during construction to ensure uniform grout cover around the central bar.

6.5.2 Buckling

Assessments of the potential for buckling along the cased length of the micropile at each bridge were carried out and the results are presented below.

Site	Unsupported Length[1]	Design Load	Critical Buckling Load, P_{cr}	Soil Modulus, E_s, Along Unsupported Length	Limiting Lateral Reaction Soil Modulus, E_s^{LIMIT}
Little East River Bridge No. 1	4.5 m	450 kN	18,000 kN	5 MPa	0.45 MPa
Little East River Bridge No. 2	3.5 m	480 kN	19,500 kN	2 MPa	0.45 MPa
Little East River Bridge No. 3	3.5 m	450 kN	19,500 kN	3 MPa	0.45 MPa

Site	Unsupported Length[1]	Design Load	Critical Buckling Load, P_{cr}	Soil Modulus, E_s, Along Unsupported Length	Limiting Lateral Reaction Soil Modulus, E_s^{LIMIT}
Little East River Bridge No. 4	3.0 m	400 kN	22,500 kN	3 MPa	0.45 MPa
Ragged Creek Bridge	3.0 m	410 kN	22,500 kN	3 MPa	0.45 MPa

Note: 1. Unsupported length is conservatively assumed to be equal to the cased length.

Given that that the critical buckling load is greater than the design load and that the limiting lateral reaction soil modulus is less than the assumed elastic modulus of soils, the geotechnical capacity and structural strength of the micropile will control the micropile capacity and therefore, buckling does not need to be considered further for the micropile design.

6.5.3 Combined Axial Compression and Bending of Cased Length

Additional compressive loads (i.e. above the axial compression design load) due to the combination of lateral loads and/or bending moments imposed on the pile group(s) will need to be considered in the evaluation of the structural capacity of the cased section of the micropiles. It is understood that MH will evaluate the effects of these additional stresses on the structural capacity of the micropiles as part of the lateral pile group analysis. It should be noted that if there are any additional compressive stresses that increase the compression loads above those indicated in Section 6.4.1, the geotechnical axial resistance of the micropile will need to be re-evaluated.

6.5.1 Recommendations for Micropile Connection at Pile Cap

The connection between the top of the micropiles and the pile caps should be designed to transfer compression loads as well as any lateral loads and bending moments, as necessary. It is recommended that the casings and hollow core central reinforcing bars be extended into the pile cap to accommodate the load and moment transfer in a manner similar to that illustrated on Figure 4. It is understood that the required dimensions and thicknesses of embedment and bearing plate will be determined by MH.

6.6 Micropile Installation/Technical Specification

All micropiles should be installed in accordance with the Non-Standard Special Provision (NSSP) “Technical Specification for Grouted Micropiles” included in Appendix D. This NSSP was developed for this project in accordance with the guidelines recommended by the Deep Foundation Institute (DFI, 2004), the Federal Highway Administration and the National Highway Institute (FHWA-NHI, 2005) and prepared following the Ontario Provincial Standard (OPS) format.

7.0 CLOSURE

This report was prepared by Mr. Christopher Ng, P.Eng., a geotechnical engineer and Associate with Golder, and was reviewed by Mr. J. Paul Dittrich, P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, conducted an independent quality control review of the report.

Report Signature Page

Christopher Ng, P.Eng.,
Geotechnical Engineer, Associate

J. Paul Dittrich, P.Eng.,
Senior Geotechnical Engineer, Principal

Jorge M. A. Costa, P. Eng.,
Designated MTO Contact, Principal

CN/JPD/JMAC/

n:\active\2011\1111\11-1111-0149 mh - highway 592 - huntsville\reporting\micropile design\final\11-1111-0149-7 rpt 14apr21 highway 592 micropile design.docx

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Deep Foundation Institute (DFI). 2011. Guide to Drafting Specification for High Capacity Drilled and Grouted Micropiles for Structural Support. Prepared by the Joint Micropile Committee of the Deep Foundation Institute and ADSC: The International Association of Foundation Drilling.

Federal Highway Administration – National Highway Institute (FHWA/NHI), 2005. Micropile Design and Construction Reference Manual. Publication No. FHWA NHI-05-039.

Ministry of Transportation, Ontario. 2013a. Foundation Investigation and Design Report, Little East River Bridge No. 1, Site No. 44-174, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5265-07-01, Geocres No. 31E-330, prepared by Golder Associates Ltd.

Ministry of Transportation, Ontario. 2013b. Foundation Investigation and Design Report, Little East River Bridge No. 2, Site No. 44-175, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5266-07-01, Geocres No. 31E-331, prepared by Golder Associates Ltd.

Ministry of Transportation, Ontario. 2013c. Foundation Investigation and Design Report, Little East River Bridge No. 3, Site No. 44-176, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5267-07-01, Geocres No. 31E-332, prepared by Golder Associates Ltd.

Ministry of Transportation, Ontario. 2013d. Foundation Investigation and Design Report, Little East River Bridge No. 4, Site No. 44-177, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5268-07-01, Geocres No. 31E-333, prepared by Golder Associates Ltd.

Ministry of Transportation, Ontario. 2013e. Foundation Investigation and Design Report, Ragged Creek Bridge, Site No. 44-178, Highway 592 – Replacement of Six Structures, GWP 5265-07-00; WP 5269-07-01, Geocres No. 31E-334, prepared by Golder Associates Ltd.

Commercial Software:

LPILE Plus (Version 5.0) by Ensoft Inc.

TABLES

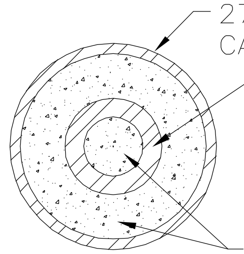
Table 1: Evaluation of Micropile Alternatives

Foundation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks / Consequences
Hollow-Core Central Reinforcing Bar Micropiles	1	■ Hollow bar serves dual function as the drilling string during micropile installation and central bar reinforcement upon completion of drilling. ■ Continuous grout flush through hollow bar while drilling stabilizes the hole and eliminates the need for casing advancement to the tip of micropile. ■ Allows for simultaneous drilling and grouting of micropiles eliminating the need to 'trip' in and out of hole. ■ Higher rate of production than solid central bar micropile installation. ■ Actual diameter of bond zone may be much larger than diameter of drill bit depending on soil type and extent of grout permeation into foundation soil(s). ■ High groundwater levels and non-cohesive overburden deposits are more suited to hollow-core bar installation in terms of minimizing ground disturbance. ■ Cobbles and boulder can be penetrated provided that appropriate drill bits are used.	■ Diameter of the micropile bond zone is not precisely known and limited to the known and relatively small diameter of the drill bit plus the adjacent grouted soil zone of the hole.	■ Higher material cost for hollow bar system.	■ Eliminates potential for base heave and ground loss during micropile installation; lower risk of disturbance to adjacent structures. ■ Shorter construction period as compared to solid central bar micropile installation.

Table 1: Evaluation of Micropile Alternatives

Foundation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks / Consequences
Solid Central Reinforcing Bar Micropiles	2	■ More commonly used than hollow-core bar micropiles. ■ Diameter of bond zone is known and is typically larger than that of a hollow-core bar and can be up to 300 mm in diameter.	■ Drilling mud will be required to balance groundwater pressures and minimize basal heave and ground loss. ■ Requires casing advancement during drilling to full depth of micropile and the partial removal of casing after the installation of central bar and grouting. ■ Down-the-hole (DTH) hammer drilling to penetrate cobbles and boulders present in the overburden may disturb grout in adjacent micropiles.	■ Higher labour cost due to the construction sequence.	■ Potential for unbalanced head in casing during removal of drill string and DTH hammer may result in base heave, possible loss of ground and potential settlement of adjacent structure(s). ■ Longer construction period due to the construction sequence for micropiles and the provision for partial curing of micropiles prior to the use of down-the-hole hammer in adjacent locations.

FIGURES



CASED MICROPILE
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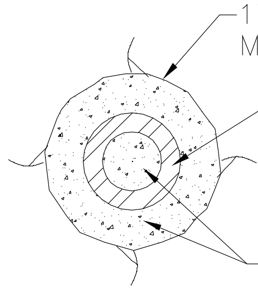

UNCASED MICROPILE
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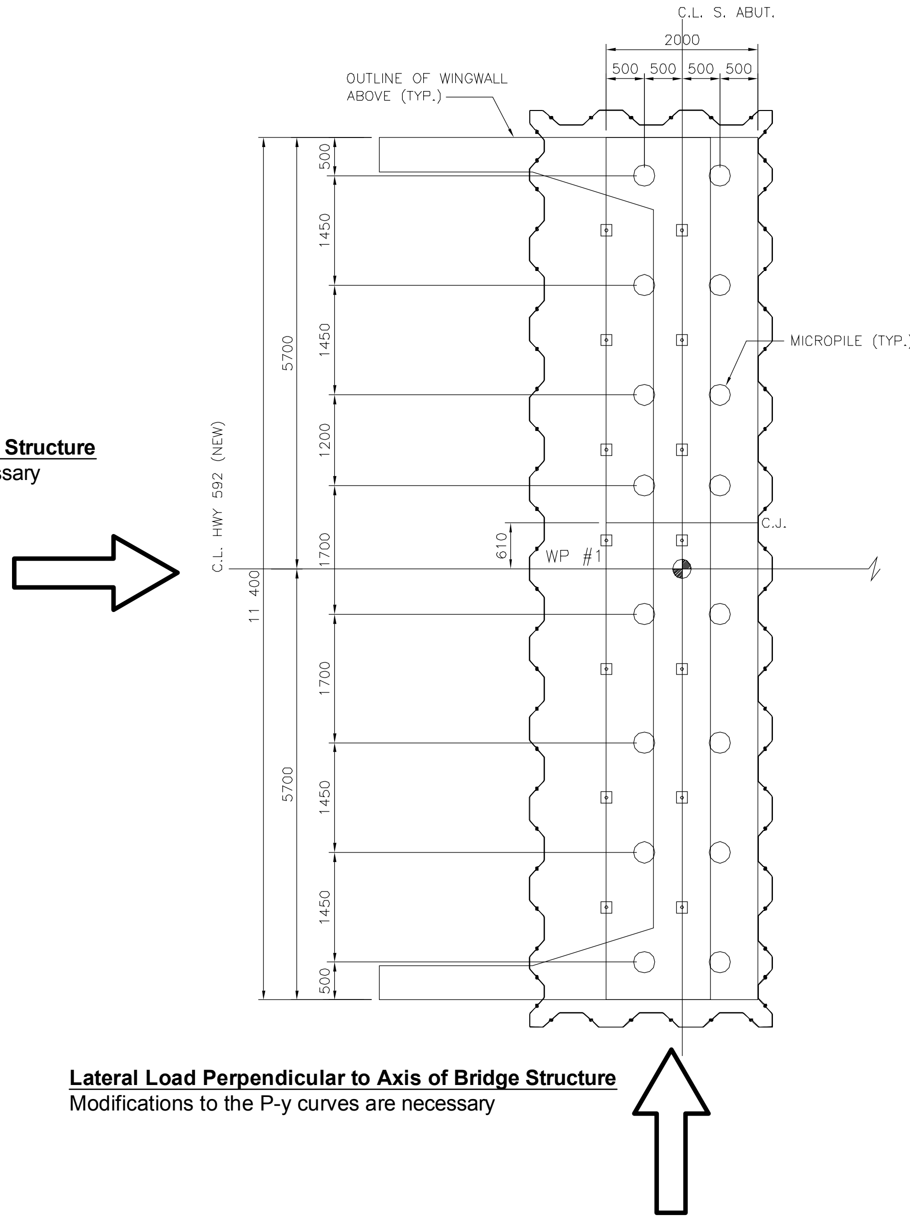
FILE No. FIGURE 1 (Section Details).dwg	CHECK CN	HIGHWAY 592	FIGURE **1**
PROJECT No. 11-1111-0149 REV. A	REVIEW JPD/JMAC		

PLOT DATE: March 12, 2014
FILENAME: T:\Projects\2011\11-1111-0149 (MH, Huntsville)\-MA- Micropile Design\FIGURE 1 (Section Details).dwg



Lateral Load Parallel to Axis of Bridge Structure
Modifications to the P-y curves are necessary

Lateral Load Perpendicular to Axis of Bridge Structure
Modifications to the P-y curves are necessary

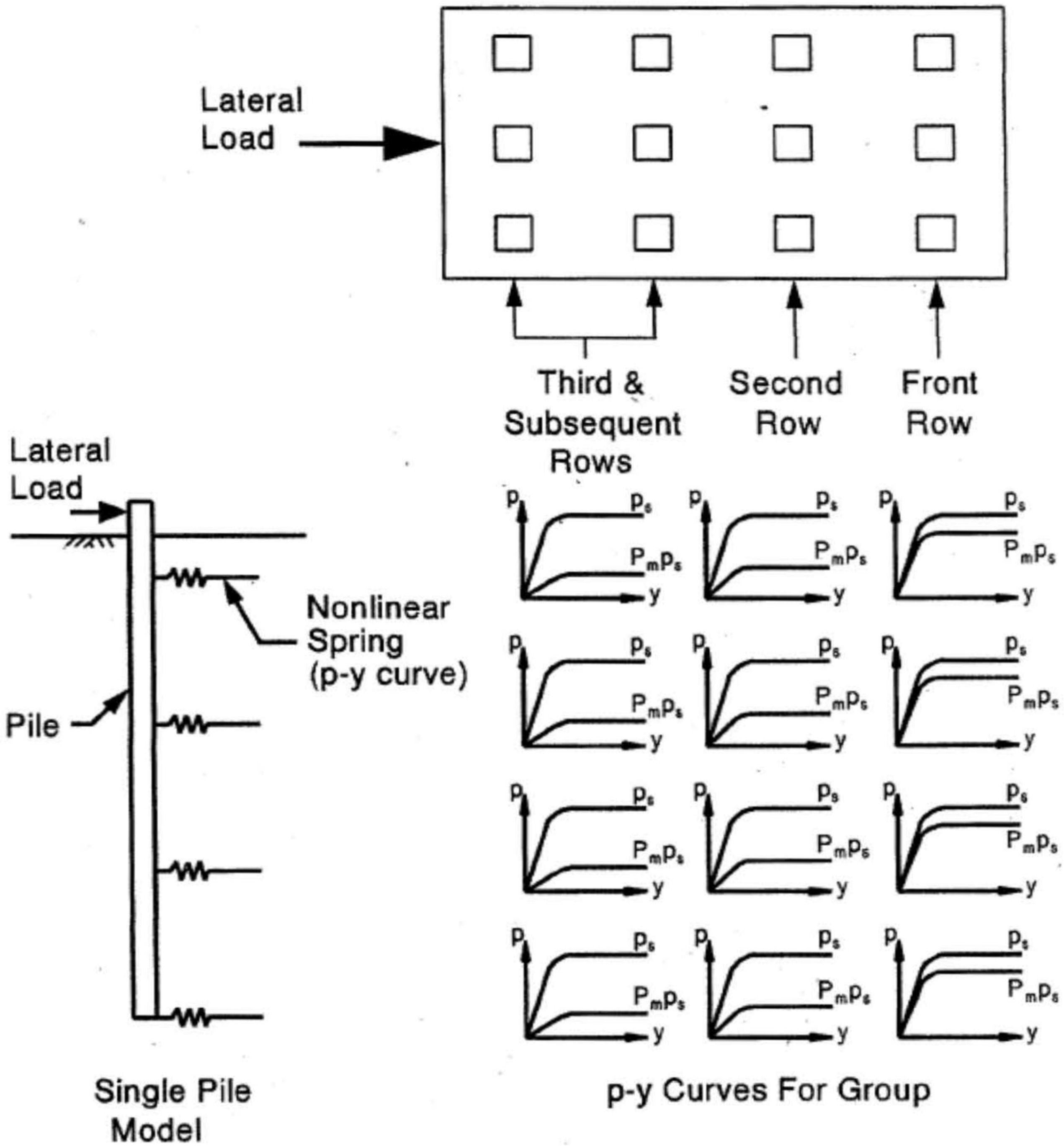
REFERENCES:

1. PLAN OBTAINED FROM DIGITAL FILE PROVIDED BY MORRISON HERSHFIELD FILE No. 094.dwg, RECEIVED DECEMBER 4, 2013.

Golder Associates
Mississauga, Ontario, Canada

FILE No. FIGURE 2 (Lateral Loading).dwg		SCALE 1:100	TITLE
PROJECT No. 11-1111-0149	REV. A	DATE Dec. 2013	**SCHEMATIC OF PILE GROUP LATERAL LOADING DIRECTION**
		DESIGN	
		CAD JFC	
		CHECK CN	HIGHWAY 592
		REVIEW JPD/JMAC	FIGURE 2

PLOT DATE: December 18, 2013
FILENAME: T:\Projects\2011\11-1111-0149 (MH, Huntsville)\-MA- Micropile Design\FIGURE 2 (Lateral Loading).dwg



p_s = p-y Curve for Single Pile

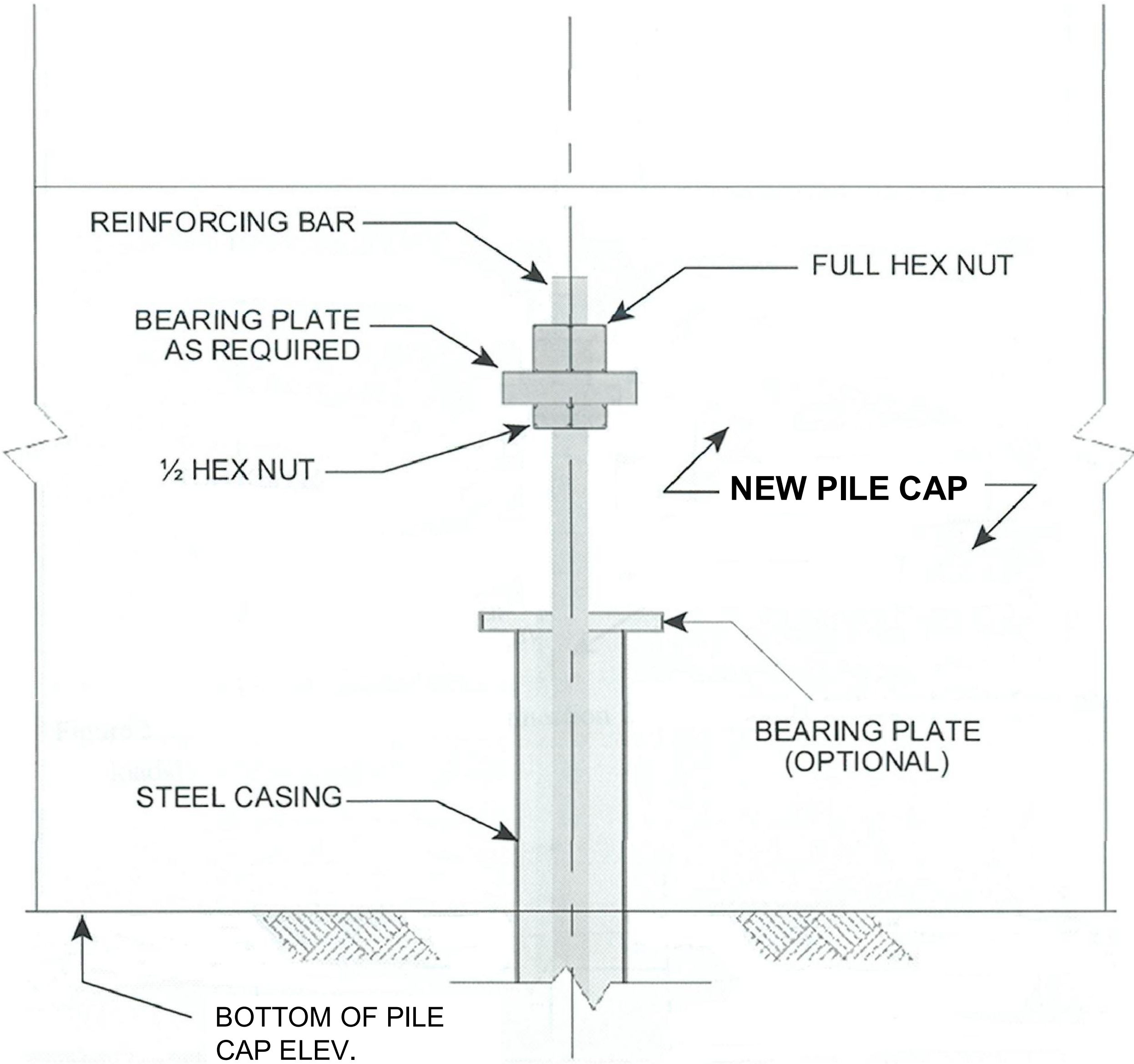
P_mp_s = p-y Curve for Pile in Group

(ADAPTED FROM FHWA/NHI 2005, FIGURE 5-21)

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	P-MULTIPLIER CONCEPT FOR LATERAL GROUP ANALYSIS
DATE	Dec. 2013		
DESIGN			
CAD	JFC		
FILE No. FIGURE 3 (Multiplier).dwg	CHECK	CN	HIGHWAY 592
PROJECT No. 11-1111-0149 REV. A	REVIEW	JPD/JMAC	FIGURE 3

PLOT DATE: December 18, 2013
FILENAME: T:\Projects\2011\11-1111-0149 (MH, Huntsville)\-MA- Micropile Design\FIGURE 3 (Multiplier).dwg



(ADAPTED FROM FHWA/NHI 2005, FIGURE 5-12)

Golder Associates Mississauga, Ontario, Canada	SCALE AS SHOWN DATE Dec. 2013 DESIGN CAD JFC	TITLE	**SCHEMATIC OF MICROPILE CONNECTION DETAIL**
FILE No. FIGURE 4 (Connection).dwg	CHECK CN	HIGHWAY 592	FIGURE 4
PROJECT No. 11-1111-0149 REV. A	REVIEW JPD/JMAC		

APPENDIX A

Borehole Locations and Soil Strata Drawings – Little East River Bridges No. 1 to 4 and Ragged Creek Bridge

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–5125
WP No. 5265–07–01

HIGHWAY 592
LITTLE EAST RIVER BRIDGE #1
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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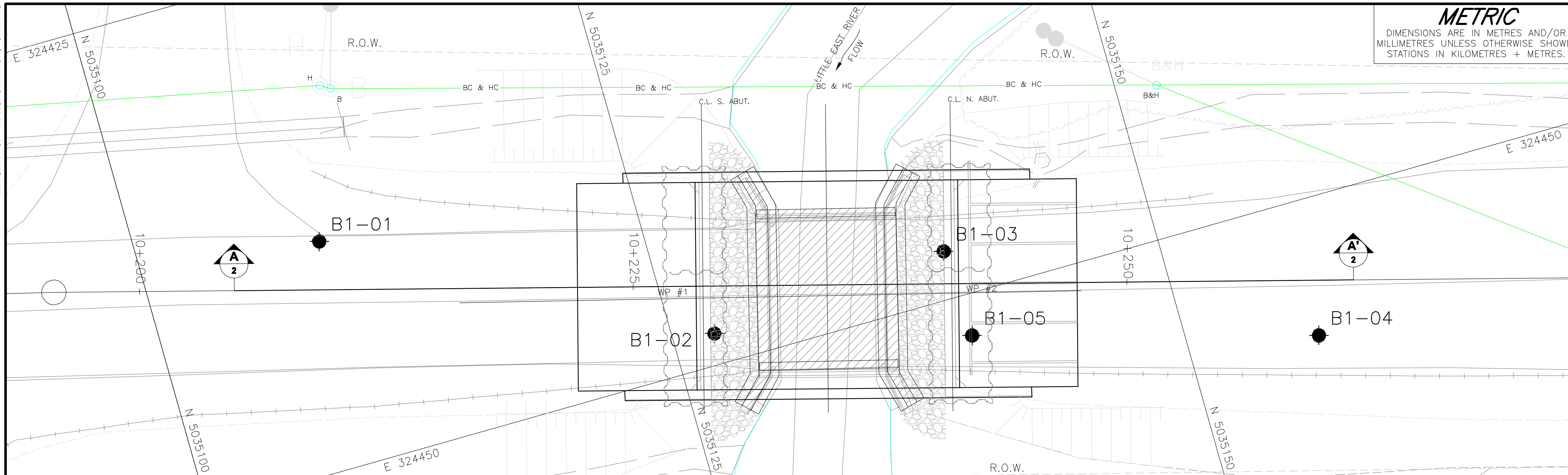

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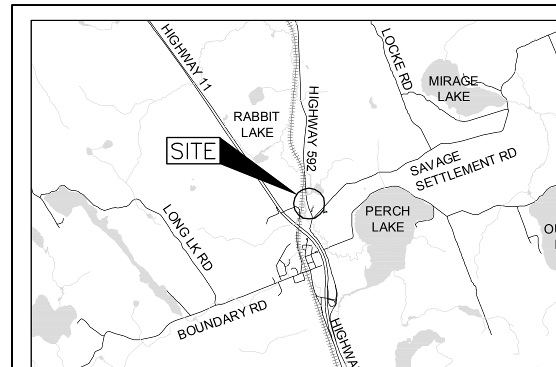


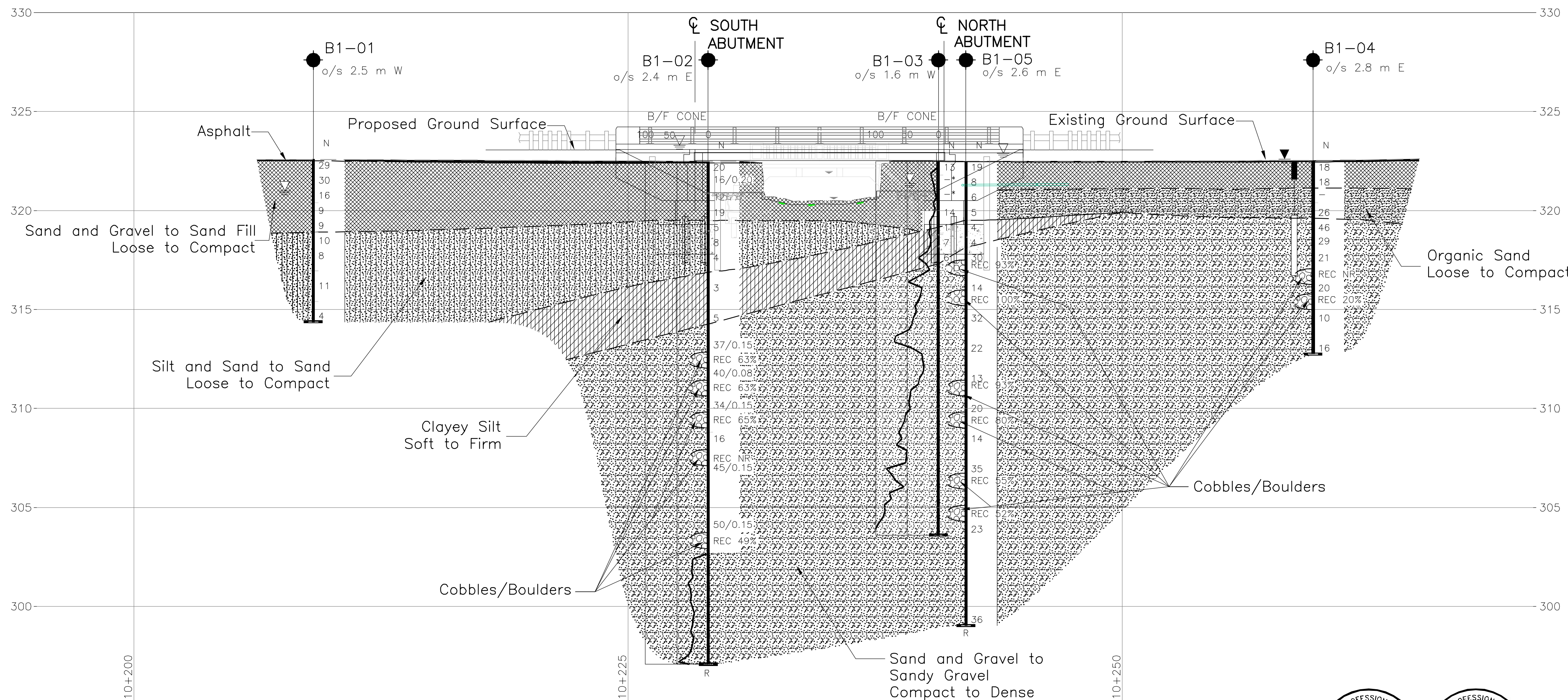
KEY PLAN
SCALE 1.2 0 1.2 2.4 km

LEGEND

●	Borehole – Current Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
REC	Total core recovery
▼	WL in piezometer, measured on May 14, 2013
▽	WL upon completion of drilling
R	Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
B1–01	322.6	5035109.1	324438.5
B1–02	322.5	5035127.1	324448.4
B1–03	322.5	5035139.4	324447.6
B1–04	322.5	5035156.5	324456.9
B1–05	322.5	5035139.6	324452.1



CENTRELINE PROFILE
SCALE 2.5 0 2.5 5 m

NOTES

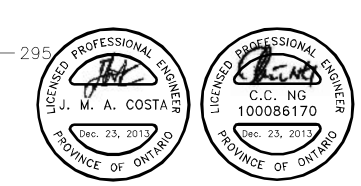
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing file nos. X1114246_44–174_44–175_44–176align.dwg, x1114246_44177align.dwg, x1114246_44178_44166align.dwg and X1114246_44–174_44–175_44–176base.dwg, x1114246_44177base.dwg and x1114246_44178_44166base.dwg, received June 11, 2013 and General Arrangement Plan and Profile file no. 44174–01.dwg, received November 07, 2013.



NO.	DATE	BY	REVISION

Geocres No. 31E–330

HWY. 592		PROJECT NO. 11–1111–0149	DIST.
SUBM'D. AV	CHKD. TVA	DATE: Dec. 2013	SITE: 44–174
DRAWN: JFC	CHKD.	APPD. CN/JMAC	DWG. 2

MINISTRY OF TRANSPORTATION, ONTARIO

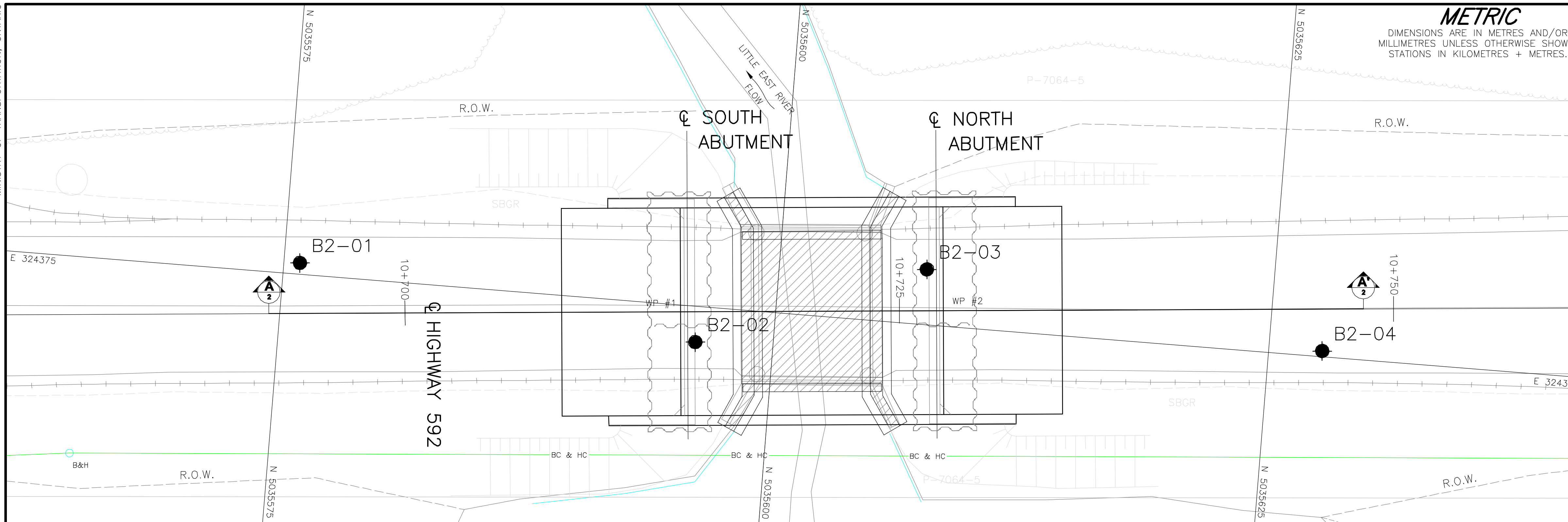
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2014–5125
WP No. 5266–07–01

HIGHWAY 592
LITTLE EAST RIVER BRIDGE #2
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN
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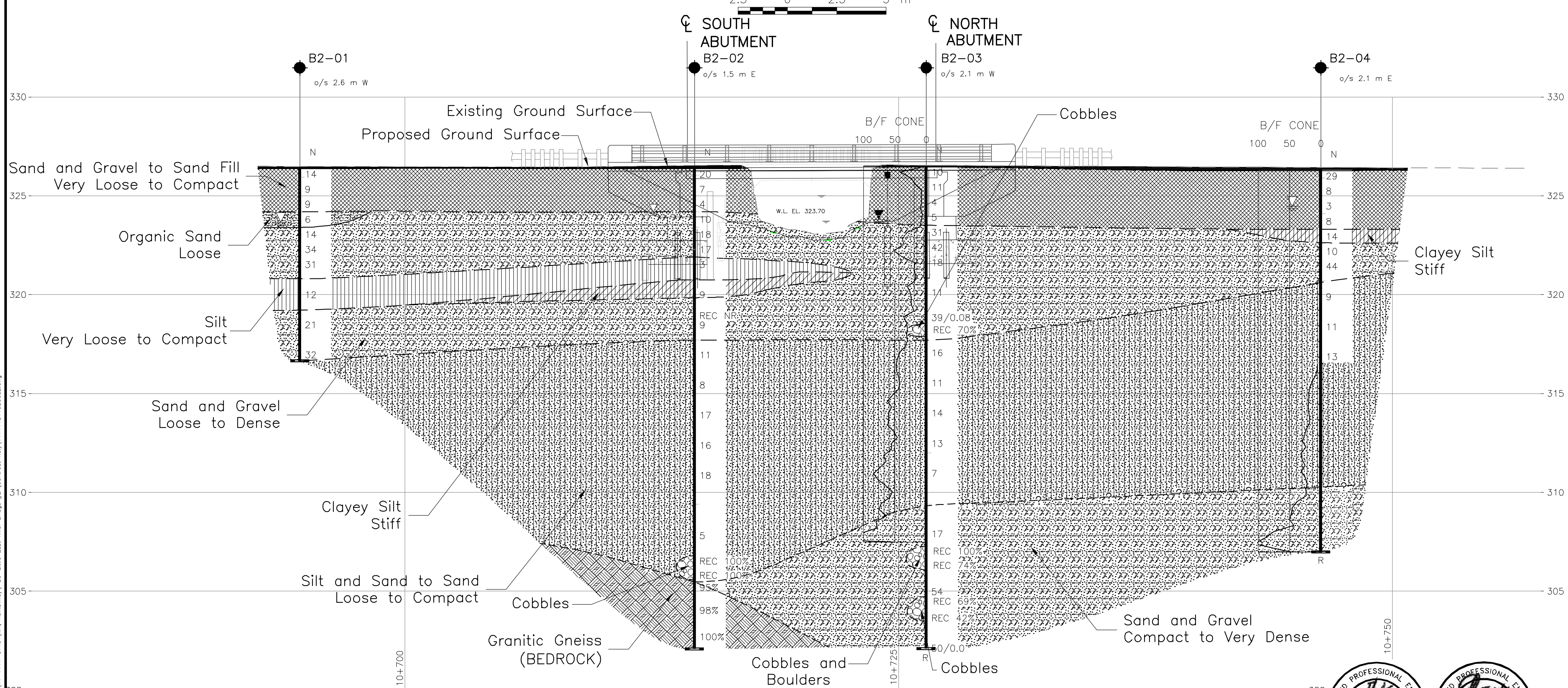

A-A' 2 CENTRELINE PROFILE
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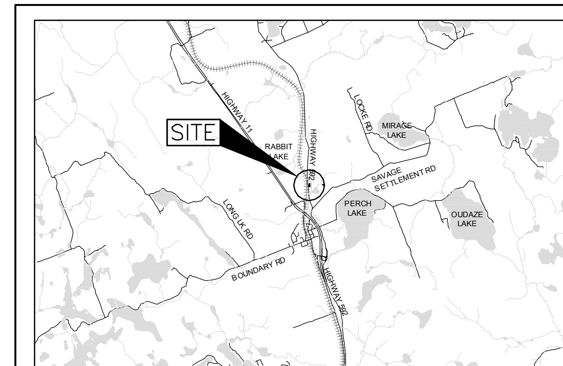

KEY PLAN
SCALE 2 0 2 4 km

LEGEND

●	Borehole – Current Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
REC	Total core recovery
▼	WL in piezometer, measured on June 26, 2013
▽	WL upon completion of drilling
R	Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
B2–01	326.4	5035575.8	324374.4
B2–02	326.4	5035596.1	324376.8
B2–03	326.5	5035607.5	324372.2
B2–04	326.3	5035627.7	324374.7

NOTES

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REFERENCE

Base plans provided in digital format by MH, drawing file nos. X1114246_44-174_44-175_44-176align.dwg, x1114246_44177align.dwg, x1114246_44178_44166align.dwg and X1114246_44-174_44-175_44-176base.dwg, x1114246_44177base.dwg and x1114246_44178_44166base.dwg, received June 11, 2013 and General Arrangement Plan and Profile file no. 44175–01.dwg, received November 7, 2013.

LICENSED PROFESSIONAL ENGINEER J. M. A. COSTA Dec. 23, 2013 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER C.C. NG 100086170 Dec. 23, 2013 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31E–331

HWY. 592		PROJECT NO. 11–1111–0149	DIST.
SUBM'D. AV	CHKD. CN	DATE: Dec. 2013	SITE: 44–175
DRAWN: JFC	CHKD. TVA	APPD.	DWG. 2

PLOT DATE: April 2, 2014

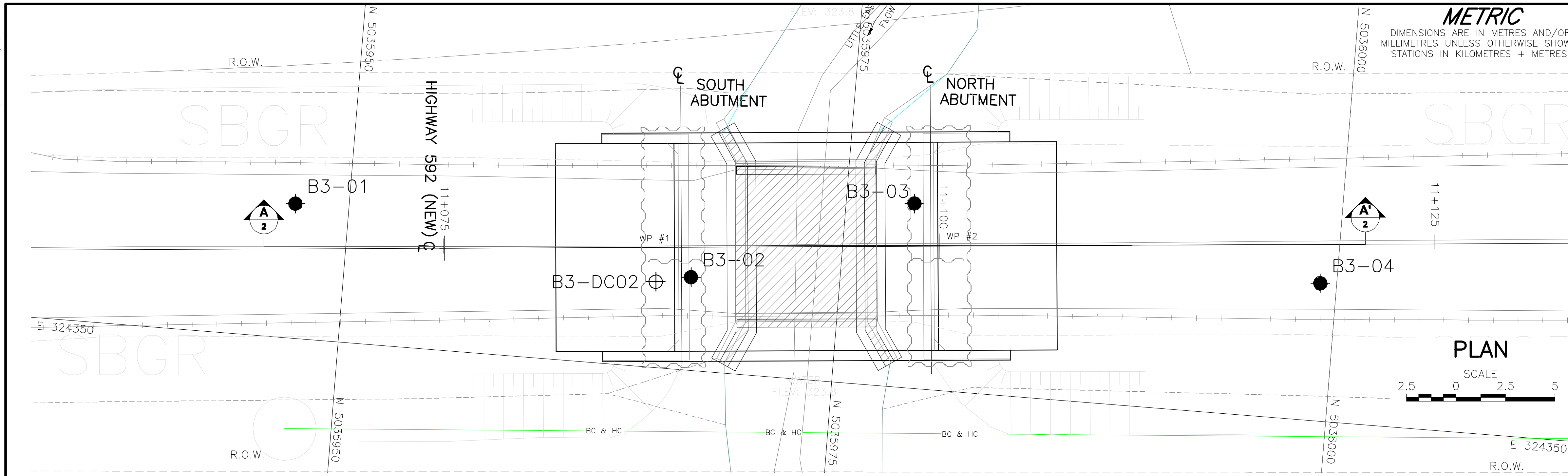
CONT No. 2014–5125
WP No. 5267–07–01

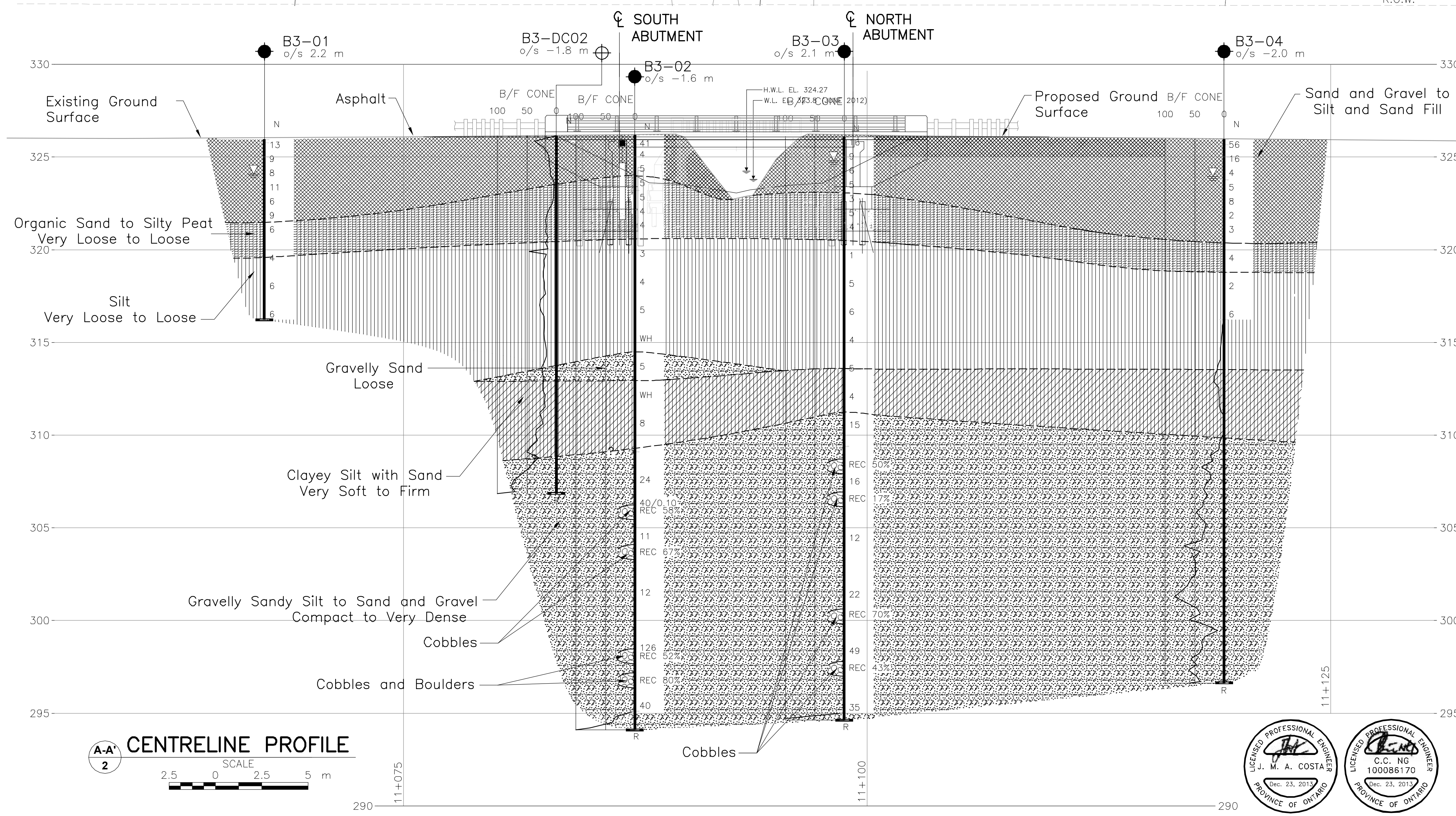
HIGHWAY 592
LITTLE EAST RIVER BRIDGE #3
BOREHOLE LOCATIONS AND SOIL STRATA

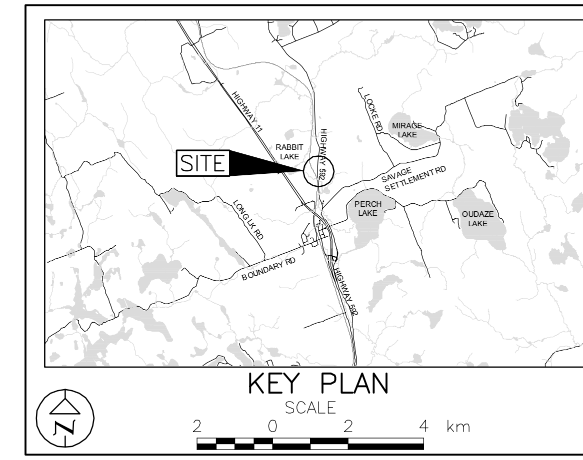
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.







LEGEND

●	Borehole – Current Investigation
⊕	Dynamic Cone Penetration Test
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
REC	Recovery
▼	WL in piezometer, measured on June 26, 2013
▽	WL upon completion of drilling
R	Refusal

BOREHOLE CO–ORDINATES			
No.	ELEVATION	NORTHING	EASTING
B3–01	326.0	5035947.3	324343.2
B3–02	326.2	5035967.5	324345.3
B3–03	326.1	5035978.4	324340.7
B3–04	326.0	5035999.2	324343.1
B3–DC02	326.2	5035965.7	324345.7

NOTES

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The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing file nos. X1114246_44–174_44–175_44–176align.dwg, x1114246_44177align.dwg, x1114246_44178_44166align.dwg and X1114246_44–174_44–175_44–176base.dwg, x1114246_44177base.dwg and x1114246_44178_44166base.dwg, received June 11, 2013 and General Arrangement file Plan and Profile no. 44176–01.dwg, received November 7, 2013.

NO.	DATE	BY	REVISION

Geocres No. 31E–332

HWY. 592	PROJECT NO. 11–1111–0149		DIST.
SUBM'D. AV	CHKD. CN	DATE: Dec. 2013	SITE: 44–176
DRAWN: JFC	CHKD. TVA	APPD.	DWG. 2

LICENSED PROFESSIONAL ENGINEER J. M. A. COSTA Dec. 23, 2013 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER C.C. NG 100086170 Dec. 23, 2013 PROVINCE OF ONTARIO

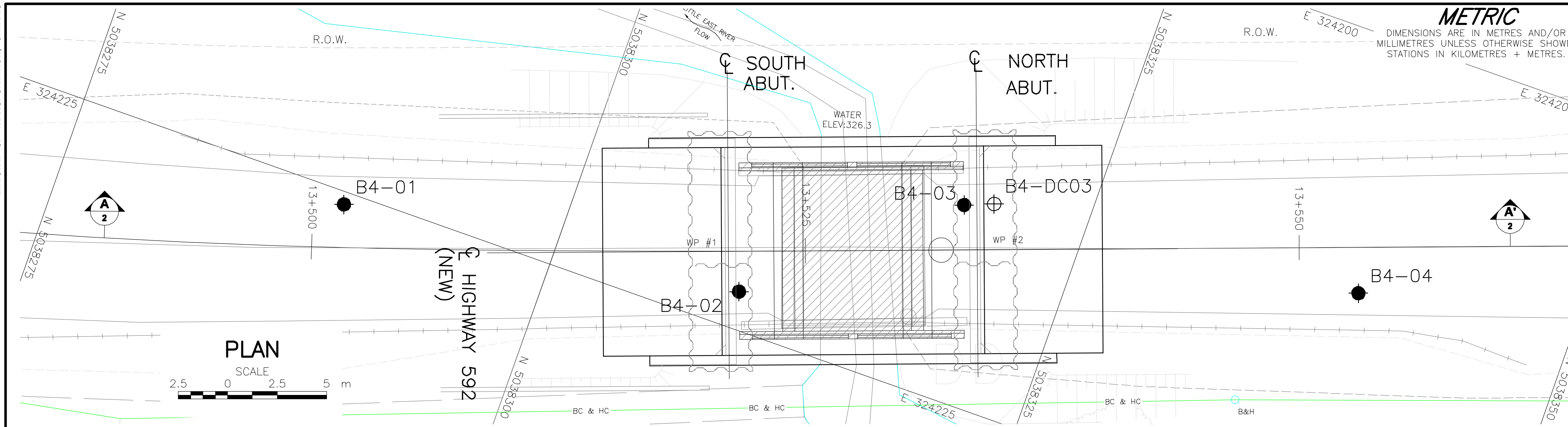
CONT No. 2014–5125
WP No. 5268–07–01

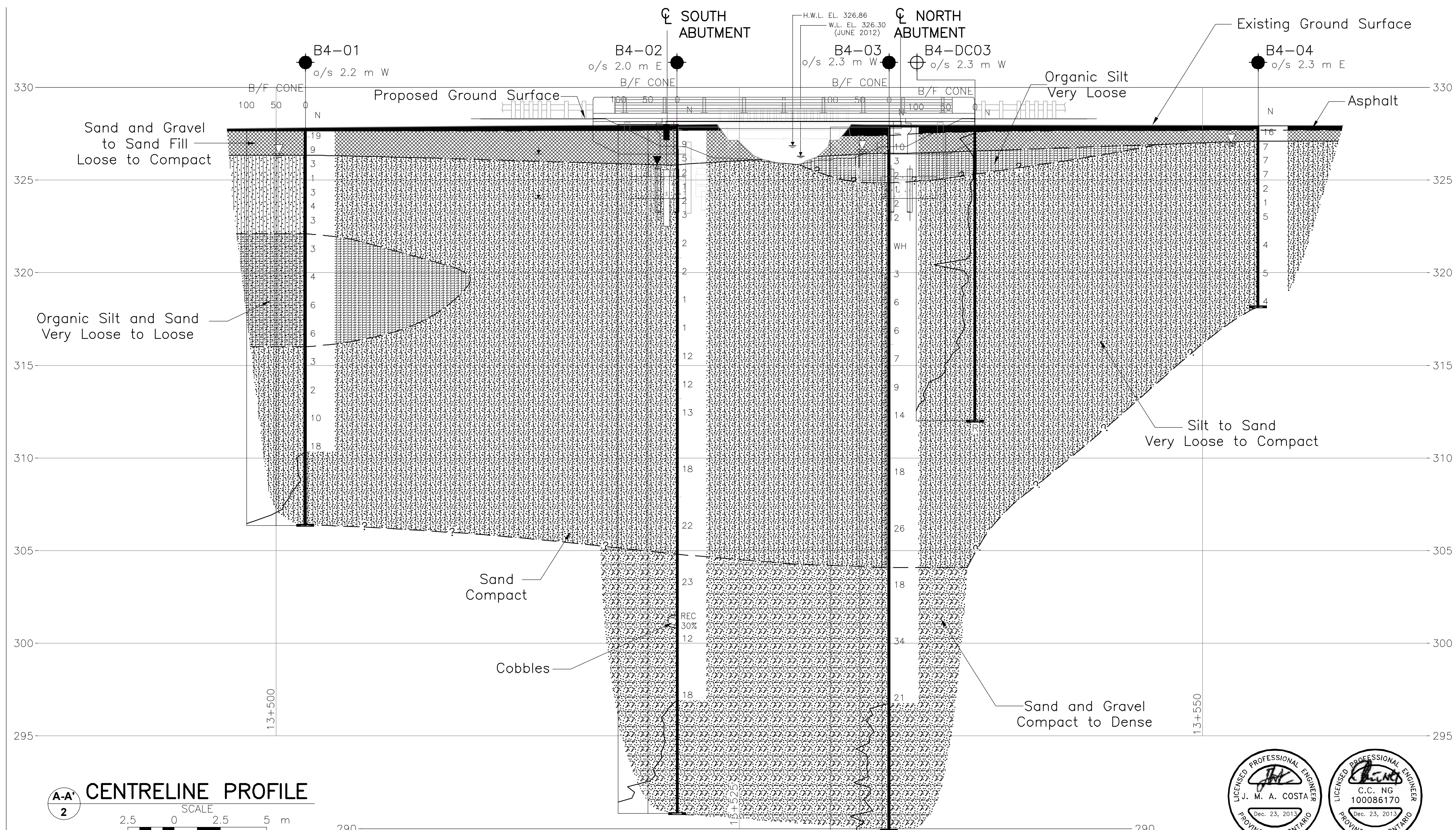
HIGHWAY 592
LITTLE EAST RIVER BRIDGE #4
BOREHOLE LOCATIONS AND SOIL STRATA

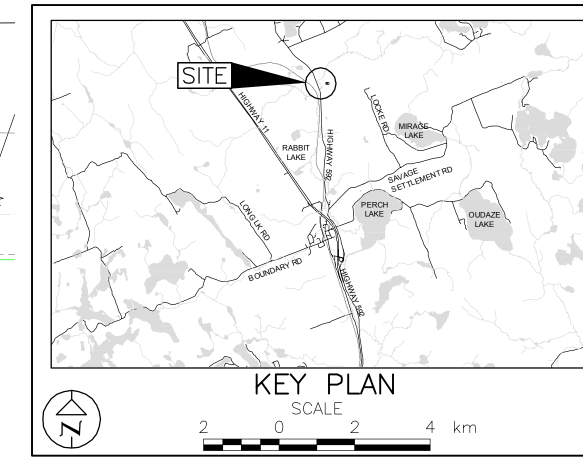
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.







LEGEND

- ● Borehole – Current Investigation
- ⊕ Dynamic Cone Penetration Test
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- REC Total core recovery
- ▼ WL in piezometer, measured on June 26, 2013
- ▽ WL upon completion of drilling
- R Refusal

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
B4–01	327.7	5038289.2	324225.6
B4–02	328.0	5038309.5	324223.1
B4–03	327.9	5038318.8	324215.2
B4–04	327.9	5038339.1	324212.7
B4–DC03	327.9	5038320.2	324214.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing file nos. X1114246_44–174_44–175_44–176align.dwg, x1114246_44177align.dwg, x1114246_44178_44166align.dwg and X1114246_44–174_44–175_44–176base.dwg, x1114246_44177base.dwg and x1114246_44178_44166base.dwg, received June 11, 2013 and General Arrangement Plan and Profile file no. 44177–01.dwg, received November 7, 2013.

J. M. A. COSTA — LICENSED PROFESSIONAL ENGINEER — Dec. 23, 2013 — PROVINCE OF ONTARIO

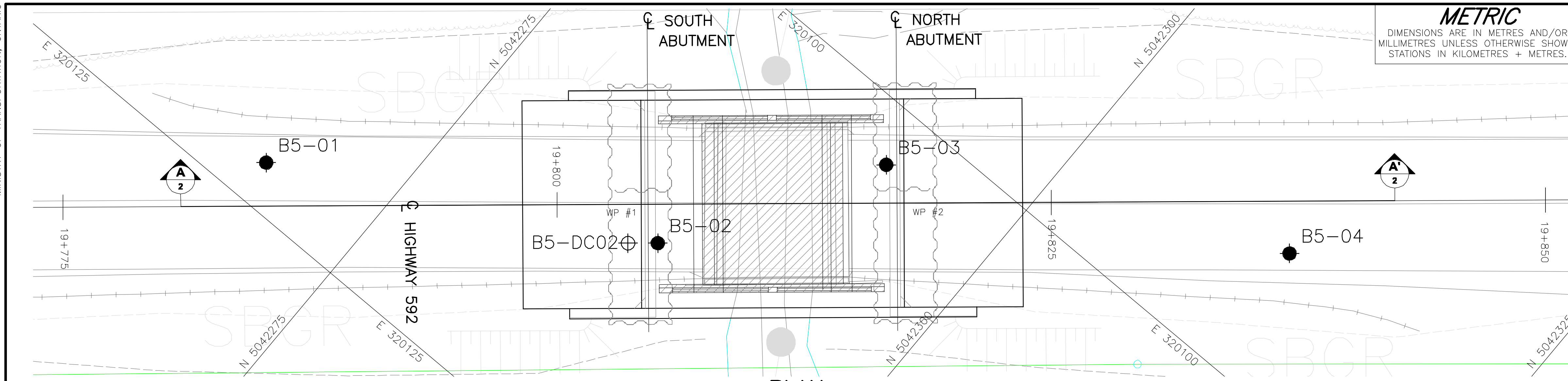
C.C. NG 100086170 — LICENSED PROFESSIONAL ENGINEER — Dec. 23, 2013 — PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31E–333

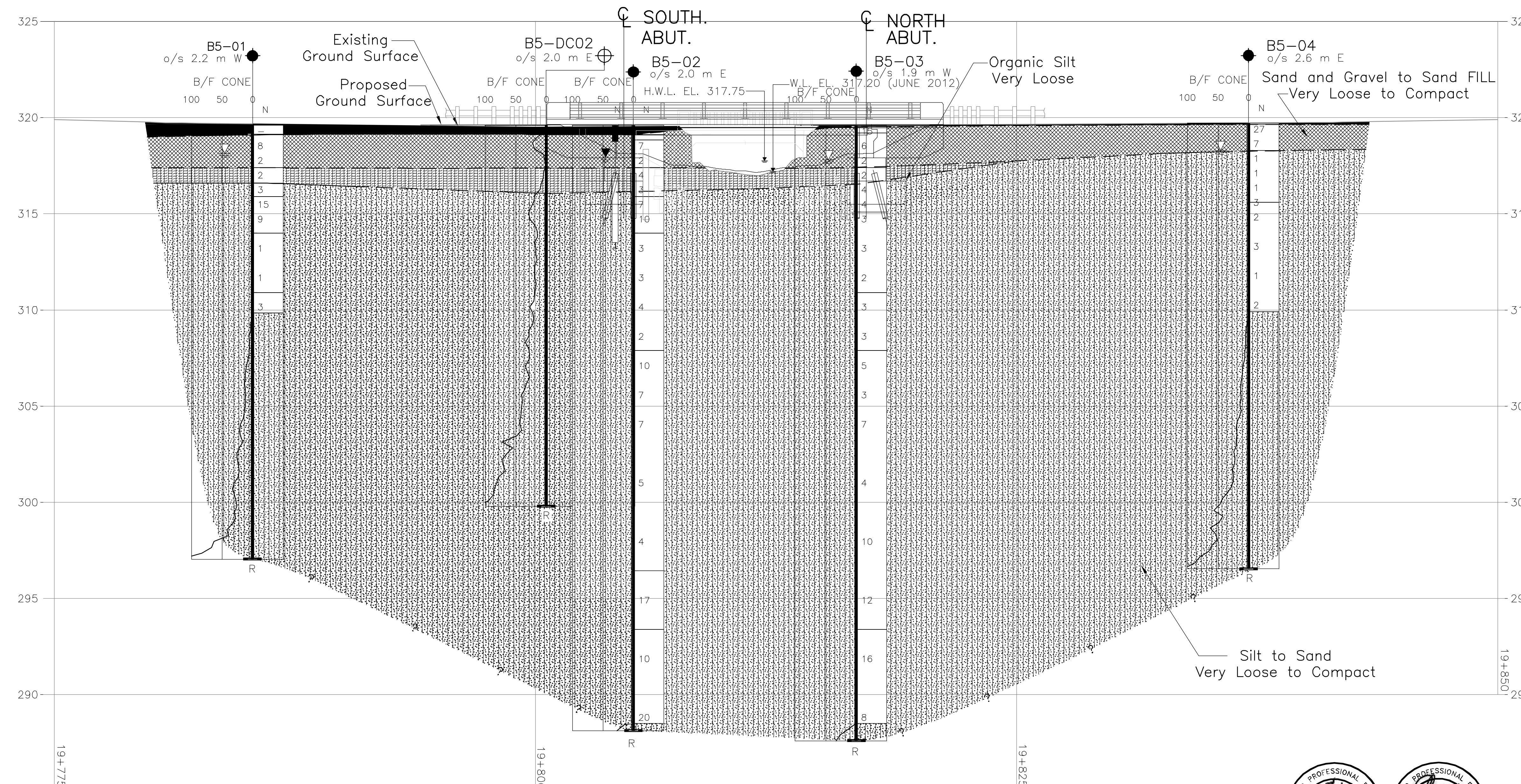
HWY. 592	PROJECT NO. 11–1111–0149	DIST.
SUBM'D. AV	CHKD. CN	DATE: Dec. 2013	SITE: 44–177
DRAWN: JFC	CHKD.	APPD.	DWG. 2

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.



PLAN

SCALE 2.5 0 2.5 5 m



CENTRELINE PROFILE

A-A'

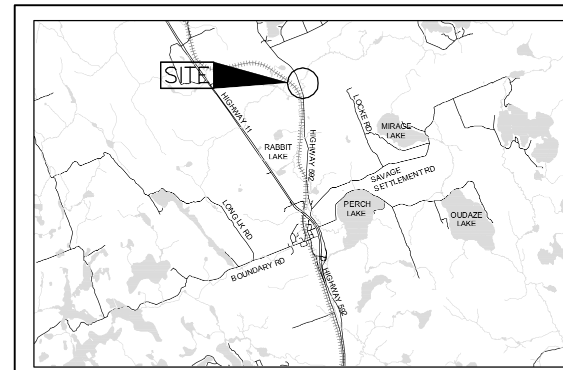
SCALE 2.5 0 2.5 5 m

CONT No.
WP No. 5269-07-01

SHEET

HIGHWAY 592
RAGGED CREEK BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE 2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- Dynamic Cone Penetration Test
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on June 21, 2013
- WL upon completion of drilling
- R — Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
B5-01	319.6	5042269.0	320122.8
B5-02	319.6	5042286.8	320113.2
B5-03	319.6	5042293.1	320102.8
B5-04	319.7	5042311.6	320093.1
B5-DC02	319.6	5042285.6	320114.2

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MH, drawing file nos. X1114246_44-174_44-175_44-176align.dwg, x1114246_44177align.dwg, x1114246_44178_44166align.dwg and X1114246_44-174_44-175_44-176base.dwg, x1114246_44177base.dwg and x1114246_44178_44166base.dwg, received June 11, 2013 and General Arrangement Plan and Profile file no. 44178-01.dwg, received August 26, 2013.

LICENSED PROFESSIONAL ENGINEER J. M. A. COSTA Dec. 23, 2013 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER C.C. NG 100086170 Dec. 23, 2013 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31E-334

HWY. 592	PROJECT NO. 11-1111-0149		DIST.
SUBM'D. AV	CHKD. CN	DATE: Jan. 2014	SITE: 44-178
DRAWN: JFC	CHKD. TVA	APPD.	DWG. 2

APPENDIX B

Analytical Laboratory Test Results

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: **MORRISON HERSHFIELD**
2440 DON REID DRIVE
OTTAWA, ON K1H1E1
(613) 739-2910

ATTENTION TO: **Adel Chowdhury**

PROJECT NO: **1114246**

AGAT WORK ORDER: **13T730457**

MICROBIOLOGY ANALYSIS REVIEWED BY: **Inesa Alizarchyk, Inorganic Lab Supervisor**

WATER ANALYSIS REVIEWED BY: **Sofka Pehlyova, Senior Analyst**

DATE REPORTED: **Jun 30, 2013**

PAGES (INCLUDING COVER): **7**

VERSION*: **1**

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Certificate of Analysis

AGAT WORK ORDER: 13T730457

PROJECT NO: 1114246

CLIENT NAME: MORRISON HERSHFIELD

ATTENTION TO: Adel Chowdhury

Microbiological Analysis (water)

DATE RECEIVED: 2013-06-24

DATE REPORTED: 2013-06-30

			SAMPLE DESCRIPTION:	Sample 1
			SAMPLE TYPE:	Water
			DATE SAMPLED:	6/19/2013
Parameter	**Unit**	**G / S**	**RDL**	**4499821**
Escherichia coli	CFU/100mL	0	1	ND
Total Coliforms	CFU/100mL	0	1	ND
Heterotrophic Plate Count	CFU/1mL		10	ND

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to SDWA - Microbiology

4499821 ND - Not Detected.
Sample analysis performed past holding time. Review data with discretion.

Certified By:

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Certificate of Analysis

AGAT WORK ORDER: 13T730457

PROJECT NO: 1114246

CLIENT NAME: MORRISON HERSHFIELD

ATTENTION TO: Adel Chowdhury

Inorganic Chemistry (Water)

DATE RECEIVED: 2013-06-24

DATE REPORTED: 2013-06-30

			SAMPLE DESCRIPTION:	Sample 1
			SAMPLE TYPE:	Water
			DATE SAMPLED:	6/19/2013
Parameter	**Unit**	**G / S**	**RDL**	**4499821**
pH	pH Units		NA	6.43
Total Hardness (as CaCO3)	mg/L		10	45
Alkalinity (as CaCO3)	mg/L		5	24
Fluoride	mg/L		0.05	<0.05
Chloride	mg/L		0.10	60.3
Nitrate as N	mg/L		0.05	1.00
Nitrite as N	mg/L		0.05	<0.05
Sulphate	mg/L		0.10	7.88
Turbidity	NTU		0.5	<0.5

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By: Sofia Pehlyova

Results relate only to the items tested and to all the items tested

Certificate of Analysis

AGAT WORK ORDER: 13T730457

PROJECT NO: 1114246

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: MORRISON HERSHFIELD

ATTENTION TO: Adel Chowdhury

pH, Resistivity, EC, SO4 & Cl (Water)

DATE RECEIVED: 2013-06-24

DATE REPORTED: 2013-06-30

			SAMPLE DESCRIPTION:	Sample 2		Sample 3	Sample 4		Sample 5	Sample 6
			SAMPLE TYPE:	Water		Water	Water		Water	Water
			DATE SAMPLED:	6/19/2013		6/19/2013	6/19/2013		6/19/2013	6/19/2013
Parameter	**Unit**	**G / S**	**RDL**	**4499823**	**RDL**	**4499835**	**4499838**	**RDL**	**4499840**	**4499843**
Electrical Conductivity	uS/cm		2	484	2	1550	1540	2	210	405
Resistivity	ohms.cm			2070		645	649		4760	2470
pH	pH Units		NA	6.57	NA	7.68	5.69	NA	7.01	6.98
Chloride	mg/L		0.50	111	1.0	319	475	0.10	3.26	69.6
Sulphate	mg/L		0.10	26.1	1.0	33.4	<1.0	0.10	0.27	19.3

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By: Sofia Pehlyova

Results relate only to the items tested and to all the items tested

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: MORRISON HERSHFIELD | **AGAT WORK ORDER: 13T730457**

PROJECT NO: 1114246 | **ATTENTION TO: Adel Chowdhury**

Microbiology Analysis

RPT Date: Jun 30, 2013			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Microbiological Analysis (water)															
Escherichia coli	1	4499821	ND	ND	NA	< 1	NA			NA			NA		
Total Coliforms	1	4499821	ND	ND	NA	< 1	NA			NA			NA		
Heterotrophic Plate Count	1	4499821	ND	ND	NA	< 10	NA			NA			NA		

Comments: ND - Not Detected, ; NA - % RPD Not Applicable
NA - Not Applicable

Certified By:

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: MORRISON HERSHFIELD | **AGAT WORK ORDER: 13T730457**

PROJECT NO: 1114246 | **ATTENTION TO: Adel Chowdhury**

Water Analysis

RPT Date: Jun 30, 2013			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Inorganic Chemistry (Water)															
pH	4499129		7.32	7.52	2.7%	NA	97%	90%	110%	NA			NA		
Alkalinity (as CaCO3)	4499129		309	312	0.9%	< 5	96%	80%	120%	NA			NA		
Fluoride	4496096		<0.25	<0.25	0.0%	< 0.05	95%	90%	110%	90%	90%	110%	102%	80%	120%
Chloride	4496096		43.4	42.9	1.1%	< 0.10	91%	90%	110%	94%	90%	110%	96%	80%	120%
Nitrate as N	4496096		<0.25	<0.25	0.0%	< 0.05	93%	90%	110%	96%	90%	110%	97%	80%	120%
Nitrite as N	4496096		<0.25	<0.25	0.0%	< 0.05	NA	90%	110%	103%	90%	110%	108%	80%	120%
Sulphate	4496096		249	250	0.2%	< 0.10	92%	90%	110%	98%	90%	110%	92%	80%	120%
Turbidity	1		2.8	2.6	7.4%	< 0.5	99%	90%	110%	NA			NA		

Comments: Turbidity Analysis: Sample was submitted and analyzed past holding time. The result should be reviewed with discretion.

pH, Resistivity, EC, SO4 & Cl (Water)															
Electrical Conductivity	4499129		877	878	0.1%	< 2	103%	80%	120%	NA			NA		

Comments: NA signifies Not Applicable.

Certified By: Sofia Pehlyova

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Method Summary

CLIENT NAME: MORRISON HERSHFIELD **AGAT WORK ORDER: 13T730457**

PROJECT NO: 1114246 **ATTENTION TO: Adel Chowdhury**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Microbiology Analysis			
Escherichia coli	MIC-93-7010	EPA 1604	Membrane Filtration
Total Coliforms	MIC-93-7010	EPA 1604	Membrane Filtration
Heterotrophic Plate Count	MIC-93-7020	SM 9215C	Spread Plate
Water Analysis			
pH	INOR-93-6000	SM 4500-H+ B	PC TITRATE
Total Hardness (as CaCO3)	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Alkalinity (as CaCO3)	INOR-93-6000	SM 2320 B	PC TITRATE
Fluoride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Nitrate as N	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Nitrite as N	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Turbidity	INOR-93-6044	SM 2130 B	NEPHELOMETER
Electrical Conductivity	INOR-93-6000	SM 2510 B	PC TITRATE
Resistivity		SM 2510 B	EC METER
pH	INOR-93-6000	SM 4500-H+ B	PC TITRATE
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH

Coordinate SR-8

AGAT Laboratories

5835 Coopers Avenue
Mississauga, ON
L4Z 1Y2
www.agatlabs.com · webearth.agatlabs.com

P: 905.712.5100 · F: 905.712.5122 · TF: 800.856.6261

Chain of Custody Record

Laboratory Use Only

Arrival Temperature: 5/6/6

AGAT WO #:

Lab Temperature: 4.7/5.3/4.9

Notes: 13T730457

Client Information

Company: Morrison Hershfield
Contact: Adel Chowdhury
Address: 2440 Don Reid Dr
Ottawa, ON
Phone: 613-668-6248 Fax:
Project: 1114246 PO:
AGAT Quotation #: 27358

Please note, if quotation number is not provided, client will be billed full price for analysis.

Regulatory Requirements

☐ Regulation 153/04 (reg. 511 Amend.)
Table ____ Indicate one
☐ Ind/Com
☐ Res/Park
☐ Agriculture
Soil Texture (check one) ☐ Coarse ☐ Fine

☐ Sewer Use
Region ____ Indicate one
☐ Sanitary
☐ Storm

☐ Regulation 558
☐ CCME
☐ Other (specify)
☐ Prov. Water Quality Objectives (PWQO)
☐ None

Turnaround Time Required (TAT) Required*

Regular TAT
☑ 5 to 7 Working Days

Rush TAT (please provide prior notification)
Rush Surcharges Apply
☐ 3 Working Days
☐ 2 Working Days
☐ 1 Working Day

OR

Date Required (Rush surcharges may apply):

*TAT is exclusive of weekends and statutory holidays

Invoice To

Same: Yes ☑ No ☐
Company:
Contact:
Address:

Is this a drinking water sample? (potable water intended for human consumption) ☐ Yes ☐ No
If "Yes", please use the *Drinking Water Chain of Custody Form*

Is this submission for a **Record of Site Condition**? ☐ Yes ☐ No

Legend Matrix

GW Ground Water O Oil
SW Surface Water P Paint
SD Sediment S Soil

Report Information – reports to be sent to:

1. Name: Adel Chowdhury
Email: AChowdhury@morrisonhershfield.com
2. Name:
Email:

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Comments Site/Sample Information	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl- ☐ CN- ☐ EC ☐ FOC ☐ Cr+6- ☐ SAR ☐ NO3/NO2 ☐ N-Total ☐ Hg ☐ pH	Nutrients: ☐ TP ☐ NH3 ☐ TKN ☐ NO3 ☐ NO2 ☐ NO3/NO2	VOC: ☐ VOC ☐ THM ☐ BTEX	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	Sewer Use	Resis., Cond., Sulphate(?)	pH	Turb., Alka, Hardness	Anions(?)	Micro bio
Sample 1	June 19			3					✓													✓	✓	✓	✓
Sample 2	June 19			2																	✓	✓			
Sample 3	June 20			2																	✓	✓			
Sample 4	"			2																	✓	✓			
Sample 5	"			2																	✓	✓			
Sample 6	"			2																	✓	✓			

Samples Relinquished By (Print Name and Sign): Adel Chowdhury [signature] 21/6/13 3:29 PM
Date/Time:
Samples Relinquished By (Print Name and Sign):
Date/Time:

Samples Received By (Print Name and Sign): Marilynn Desrosiers [signature]
Date/Time: June 21/13 3:30pm
Samples Received By (Print Name and Sign): Shazmin [signature] June 22/2013 10:00am
Date/Time:

Pink Copy - Client
Yellow Copy - AGAT
White Copy - AGAT

Page 1 of 1

Nº: 193022

APPENDIX C

P-y Curves for Lateral Analysis

P-y CURVES FOR LATERAL ANALYSIS

LITTLE EAST RIVER BRIDGE NO. 1 - NORTH ABUTMENT

FIGURE C1-1

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
Depth (z) *	z= 0.1 m		z= 0.5 m		z= 1.0 m		z= 1.5 m		z= 2.0 m		z= 2.5 m	
Elevation	317.7 m		317.3 m		316.8 m		316.3 m		315.8 m		315.3 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	0.74	0.00038	3.73	0.00038	7.45	0.00038	11.27	0.00038	15.08	0.00038	18.89
	0.00076	1.41	0.00076	7.15	0.00076	14.19	0.00076	21.95	0.00076	29.66	0.00076	37.34
	0.00114	1.96	0.00114	10.02	0.00114	19.74	0.00114	31.55	0.00114	43.31	0.00114	54.98
	0.00152	2.37	0.00152	12.27	0.00152	23.98	0.00152	39.80	0.00152	55.70	0.00152	71.49
	0.00190	2.65	0.00190	13.94	0.00190	27.03	0.00190	46.61	0.00190	66.63	0.00190	86.62
	0.00228	2.85	0.00228	15.13	0.00228	29.14	0.00228	52.04	0.00228	76.05	0.00228	100.24
	0.00265	2.98	0.00265	15.96	0.00265	30.55	0.00265	56.26	0.00265	84.00	0.00265	112.30
	0.00303	3.06	0.00303	16.51	0.00303	31.47	0.00303	59.48	0.00303	90.58	0.00303	122.82
	0.00341	3.11	0.00341	16.89	0.00341	32.07	0.00341	61.89	0.00341	95.96	0.00341	131.88
	0.00379	3.15	0.00379	17.13	0.00379	32.46	0.00379	63.67	0.00379	100.29	0.00379	139.60
	0.00417	3.17	0.00417	17.30	0.00417	32.70	0.00417	64.98	0.00417	103.75	0.00417	146.12
	0.00455	3.18	0.00455	17.40	0.00455	32.86	0.00455	65.94	0.00455	106.49	0.00455	151.57
	0.01024	3.20	0.01024	17.60	0.01024	33.13	0.01024	68.41	0.01024	116.00	0.01024	175.41
	0.28324	3.20	0.28324	17.60	0.28324	33.13	0.28324	68.42	0.28324	116.20	0.28324	176.47
	0.55624	3.20	0.55624	17.60	0.55624	33.13	0.55624	68.42	0.55624	116.20	0.55624	176.47
	0.82924	3.20	0.82924	17.60	0.82924	33.13	0.82924	68.42	0.82924	116.20	0.82924	176.47

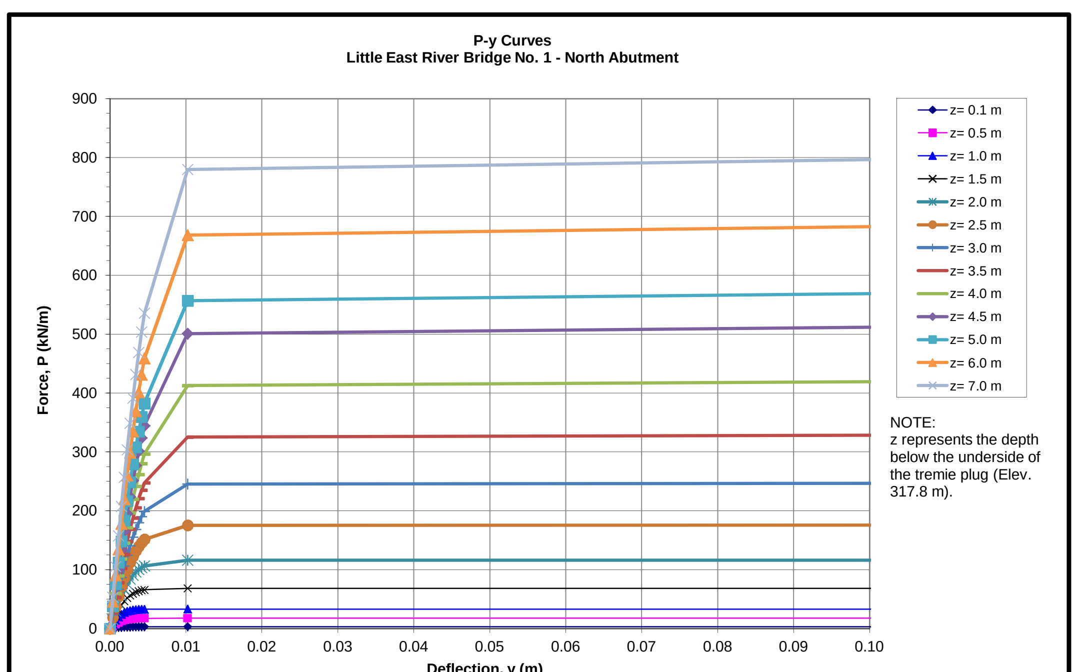
Description												
Depth (z) *	z= 3.0 m		z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 6.0 m	
Elevation	314.8 m		314.3 m		313.8 m		313.3 m		312.8 m		311.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	22.69	0.00038	26.49	0.00038	30.28	0.00038	34.08	0.00038	37.87	0.00038	45.44
	0.00076	45.00	0.00076	52.64	0.00076	60.27	0.00076	67.88	0.00076	75.42	0.00076	90.51
	0.00114	66.59	0.00114	78.15	0.00114	89.68	0.00114	101.14	0.00114	112.38	0.00114	134.85
	0.00152	87.16	0.00152	102.74	0.00152	118.24	0.00152	133.60	0.00152	148.45	0.00152	178.14
	0.00190	106.46	0.00190	126.16	0.00190	145.73	0.00190	165.05	0.00190	183.38	0.00190	220.06
	0.00228	124.31	0.00228	148.22	0.00228	171.95	0.00228	195.27	0.00228	216.97	0.00228	260.36
	0.00265	140.61	0.00265	168.78	0.00265	196.75	0.00265	224.12	0.00265	249.02	0.00265	298.83
	0.00303	155.32	0.00303	187.76	0.00303	220.02	0.00303	251.46	0.00303	279.40	0.00303	335.28
	0.00341	168.45	0.00341	205.13	0.00341	241.68	0.00341	277.21	0.00341	308.01	0.00341	369.61
	0.00379	180.06	0.00379	220.89	0.00379	261.71	0.00379	301.30	0.00379	334.78	0.00379	401.74
	0.00417	190.24	0.00417	235.08	0.00417	280.11	0.00417	323.72	0.00417	359.69	0.00417	431.63
	0.00455	199.09	0.00455	247.77	0.00455	296.91	0.00455	344.47	0.00455	382.75	0.00455	459.30
	0.01024	245.65	0.01024	325.38	0.01024	413.09	0.01024	501.14	0.01024	556.82	0.01024	668.18
	0.28324	249.23	0.28324	334.47	0.28324	432.19	0.28324	533.96	0.28324	593.29	0.28324	711.95
	0.55624	249.23	0.55624	334.47	0.55624	432.19	0.55624	533.96	0.55624	593.29	0.55624	711.95
	0.82924	249.23	0.82924	334.47	0.82924	432.19	0.82924	533.96	0.82924	593.29	0.82924	711.95

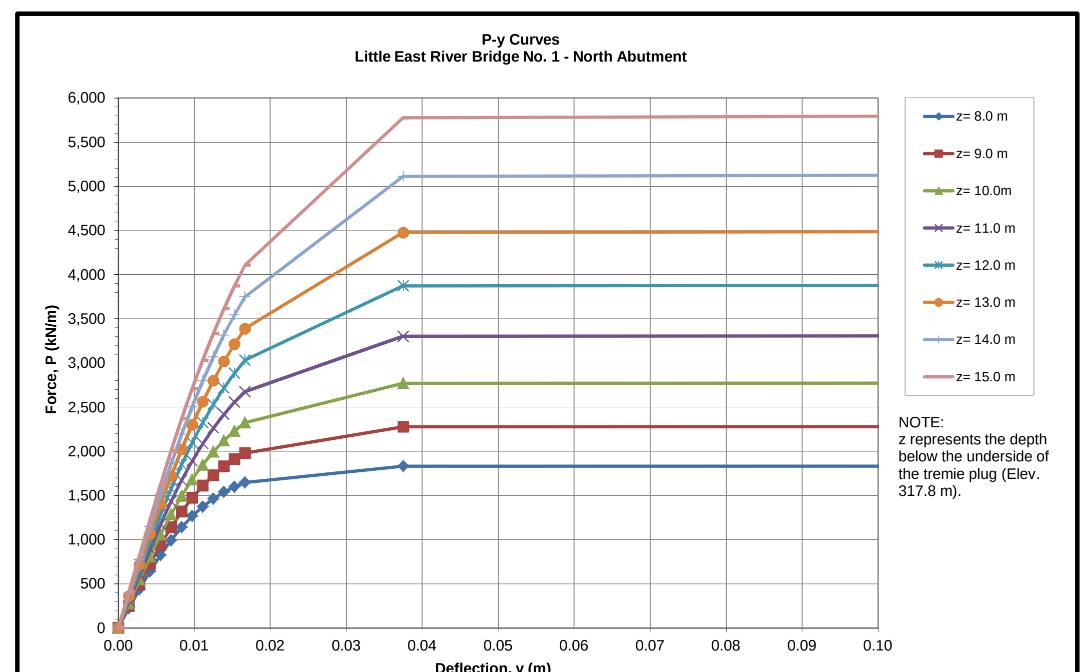
Description												
Depth (z) *	z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0m		z= 11.0 m		z= 12.0 m	
Elevation	310.8 m		309.8 m		308.8 m		307.8 m		306.8 m		305.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	53.01	0.00139	221.14	0.00139	249.01	0.00139	276.87	0.00139	304.71	0.00139	332.55
	0.00076	105.59	0.00278	435.97	0.00278	492.21	0.00278	548.36	0.00278	604.42	0.00278	660.42
	0.00114	157.33	0.00417	638.87	0.00417	724.32	0.00417	809.51	0.00417	894.46	0.00417	979.22
	0.00152	207.83	0.00556	825.47	0.00556	941.02	0.00556	1056.10	0.00556	1170.74	0.00556	1285.01
	0.00190	256.74	0.00694	992.92	0.00694	1139.20	0.00694	1284.91	0.00694	1430.01	0.00694	1574.53
	0.00228	303.76	0.00833	1139.91	0.00833	1317.07	0.00833	1493.80	0.00833	1669.89	0.00833	1845.29
	0.00265	348.63	0.00972	1266.48	0.00972	1474.04	0.00972	1681.70	0.00972	1888.98	0.00972	2095.61
	0.00303	391.16	0.01111	1373.65	0.01111	1610.49	0.01111	1848.48	0.01111	2086.69	0.01111	2324.57
	0.00341	431.21	0.01250	1463.12	0.01250	1727.59	0.01250	1994.77	0.01250	2263.20	0.01250	2531.97
	0.00379	468.70	0.01389	1536.95	0.01389	1826.95	0.01389	2121.75	0.01389	2419.28	0.01389	2718.17
	0.00417	503.57	0.01528	1597.26	0.01528	1910.47	0.01528	2230.98	0.01528	2556.12	0.01528	2884.02
	0.00455	535.85	0.01667	1646.15	0.01667	1980.12	0.01667	2324.21	0.01667	2675.20	0.01667	3030.71
	0.01024	779.55	0.03750	1831.93	0.03750	2279.06	0.03750	2770.01	0.03750	3302.04	0.03750	3872.05
	0.28324	830.61	1.03750	1837.28	1.03750	2291.69	1.03750	2796.06	1.03750	3350.36	1.03750	3954.62
	0.55624	830.61	2.03750	1837.28	2.03750	2291.69	2.03750	2796.06	2.03750	3350.36	2.03750	3954.62
	0.82924	830.61	3.03750	1837.28	3.03750	2291.69	3.03750	2796.06	3.03750	3350.36	3.03750	3954.62

Description						
Depth (z) *	z= 13.0 m		z= 14.0 m		z= 15.0 m	
Elevation	304.8 m		303.8 m		302.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00139	360.37	0.00139	388.20	0.00139	416.01
	0.00278	716.37	0.00278	772.27	0.00278	828.13
	0.00417	1063.81	0.00417	1148.27	0.00417	1232.61
	0.00556	1398.94	0.00556	1512.58	0.00556	1625.97
	0.00694	1718.52	0.00694	1862.04	0.00694	2005.14
	0.00833	2020.00	0.00833	2194.05	0.00833	2367.50
	0.00972	2301.50	0.00972	2506.62	0.00972	2710.97
	0.01111	2561.84	0.01111	2798.35	0.01111	3034.02
	0.01250	2800.50	0.01250	3068.46	0.01250	3335.66
	0.01389	3017.50	0.01389	3316.69	0.01389	3615.37
	0.01528	3213.37	0.01528	3543.27	0.01528	3873.13
	0.01667	3388.99	0.01667	3748.80	0.01667	4109.26
	0.03750	4476.74	0.03750	5112.74	0.03750	5776.73
	1.03750	4608.82	1.03750	5312.97	1.03750	6067.06
	2.03750	4608.82	2.03750	5312.97	2.03750	6067.06
	3.03750	4608.82	3.03750	5312.97	3.03750	6067.06

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 317.8 m).
The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149
Prepared By: AV
Checked By: CN/JPD/JMAC

P-y CURVES FOR LATERAL ANALYSIS
LITTLE EAST RIVER BRIDGE NO. 1 - SOUTH ABUTMENT

FIGURE C1-2

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description														
Depth (z) *	z= 0.1 m		z= 0.5 m		z= 1.0 m		z= 1.5 m		z= 2.0 m		z= 2.5 m		z= 3.0 m	
Elevation	317.7 m		317.3 m		316.8 m		316.3 m		315.8 m		315.3 m		314.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	0.37	0.00038	1.88	0.00011	3.52	0.00011	4.24	0.00011	4.97	0.00011	5.69	0.00011	6.14
	0.00076	0.73	0.00076	3.64	0.00341	11.08	0.00341	13.36	0.00341	15.64	0.00341	17.92	0.00341	19.35
	0.00114	1.03	0.00114	5.20	0.00683	13.96	0.00683	16.83	0.00683	19.70	0.00683	22.57	0.00683	24.38
	0.00152	1.29	0.00152	6.51	0.01024	15.98	0.01024	19.27	0.01024	22.56	0.01024	25.84	0.01024	27.90
	0.00190	1.49	0.00190	7.56	0.01365	17.59	0.01365	21.21	0.01365	24.83	0.01365	28.44	0.01365	30.71
	0.00228	1.64	0.00228	8.38	0.01706	18.95	0.01706	22.85	0.01706	26.74	0.01706	30.64	0.01706	33.08
	0.00265	1.76	0.00265	9.00	0.02048	20.14	0.02048	24.28	0.02048	28.42	0.02048	32.56	0.02048	35.16
	0.00303	1.84	0.00303	9.45	0.02389	21.20	0.02389	25.56	0.02389	29.92	0.02389	34.28	0.02389	37.01
	0.00341	1.90	0.00341	9.78	0.02730	22.17	0.02730	26.72	0.02730	31.28	0.02730	35.84	0.02730	38.70
	0.00379	1.94	0.00379	10.02	0.03071	23.05	0.03071	27.79	0.03071	32.53	0.03071	37.27	0.03071	40.24
	0.00417	1.97	0.00417	10.19	0.03413	23.88	0.03413	28.79	0.03413	33.69	0.03413	38.60	0.03413	41.68
	0.00455	1.99	0.00455	10.31	0.03754	24.65	0.03754	29.72	0.03754	34.78	0.03754	39.85	0.03754	43.03
	0.01024	2.04	0.01024	10.59	0.04095	25.37	0.04095	30.59	0.04095	35.81	0.04095	41.02	0.04095	44.30
	0.28324	2.04	0.28324	10.60	0.10920	35.19	0.10920	42.42	0.10920	49.65	0.10920	56.88	0.10920	61.43
	0.55624	2.04	0.55624	10.60	0.20475	35.19	0.20475	42.42	0.20475	49.65	0.20475	56.88	0.20475	61.43
	0.82924	2.04	0.82924	10.60	0.27300	35.19	0.27300	42.42	0.27300	49.65	0.27300	56.88	0.27300	61.43

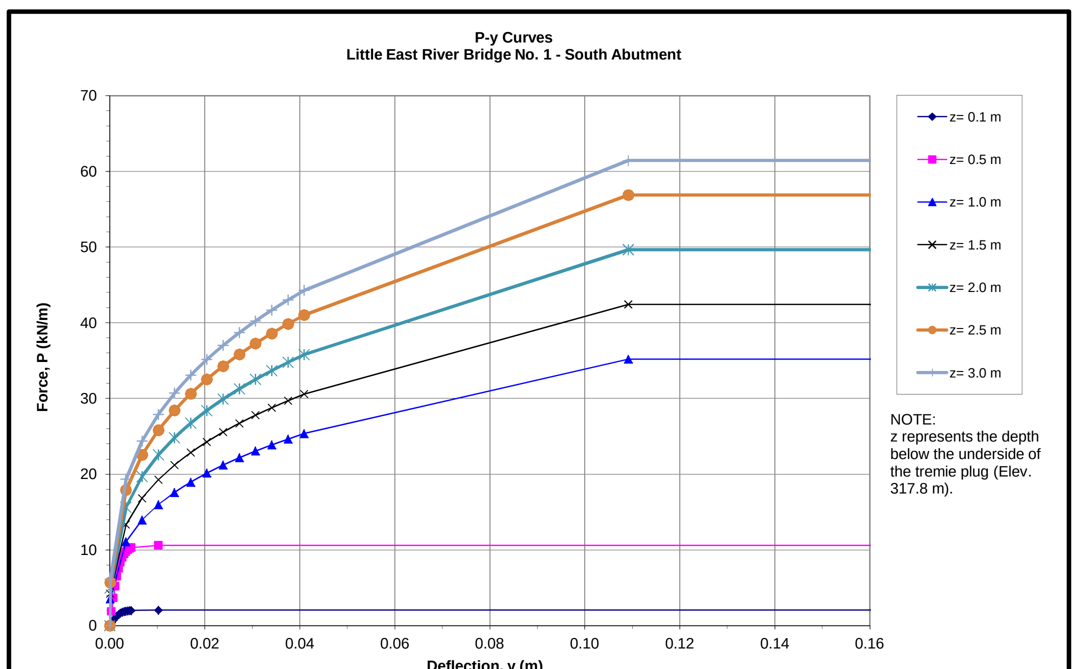
Description												
Depth (z) *	z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 6.0 m		z= 7.0 m	
Elevation	314.3 m		313.8 m		313.3 m		312.8 m		311.8 m		310.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	20.24	0.00038	24.06	0.00038	27.87	0.00038	31.67	0.00038	39.25	0.00038	46.82
	0.00076	39.73	0.00076	47.51	0.00076	55.23	0.00076	62.91	0.00076	78.05	0.00076	93.14
	0.00114	57.84	0.00114	69.82	0.00114	81.62	0.00114	93.31	0.00114	115.98	0.00114	138.47
	0.00152	74.10	0.00152	90.54	0.00152	106.64	0.00152	122.51	0.00152	152.65	0.00152	182.36
	0.00190	88.27	0.00190	109.38	0.00190	129.98	0.00190	150.20	0.00190	187.72	0.00190	224.44
	0.00228	100.30	0.00228	126.17	0.00228	151.42	0.00228	176.16	0.00228	220.92	0.00228	264.38
	0.00265	110.28	0.00265	140.86	0.00265	170.83	0.00265	200.21	0.00265	252.05	0.00265	301.94
	0.00303	118.40	0.00303	153.52	0.00303	188.19	0.00303	222.26	0.00303	280.98	0.00303	336.96
	0.00341	124.92	0.00341	164.29	0.00341	203.55	0.00341	242.30	0.00341	307.62	0.00341	369.34
	0.00379	130.09	0.00379	173.34	0.00379	216.98	0.00379	260.34	0.00379	331.98	0.00379	399.07
	0.00417	134.14	0.00417	180.88	0.00417	228.64	0.00417	276.46	0.00417	354.09	0.00417	426.16
	0.00455	137.29	0.00455	187.10	0.00455	238.68	0.00455	290.77	0.00455	374.03	0.00455	450.70
	0.01024	147.54	0.01024	212.73	0.01024	288.76	0.01024	374.28	0.01024	501.78	0.01024	612.16
	0.28324	147.71	0.28324	213.68	0.28324	292.07	0.28324	382.89	0.28324	518.81	0.28324	635.30
	0.55624	147.71	0.55624	213.68	0.55624	292.07	0.55624	382.89	0.55624	518.81	0.55624	635.30
	0.82924	147.71	0.82924	213.68	0.82924	292.07	0.82924	382.89	0.82924	518.81	0.82924	635.30

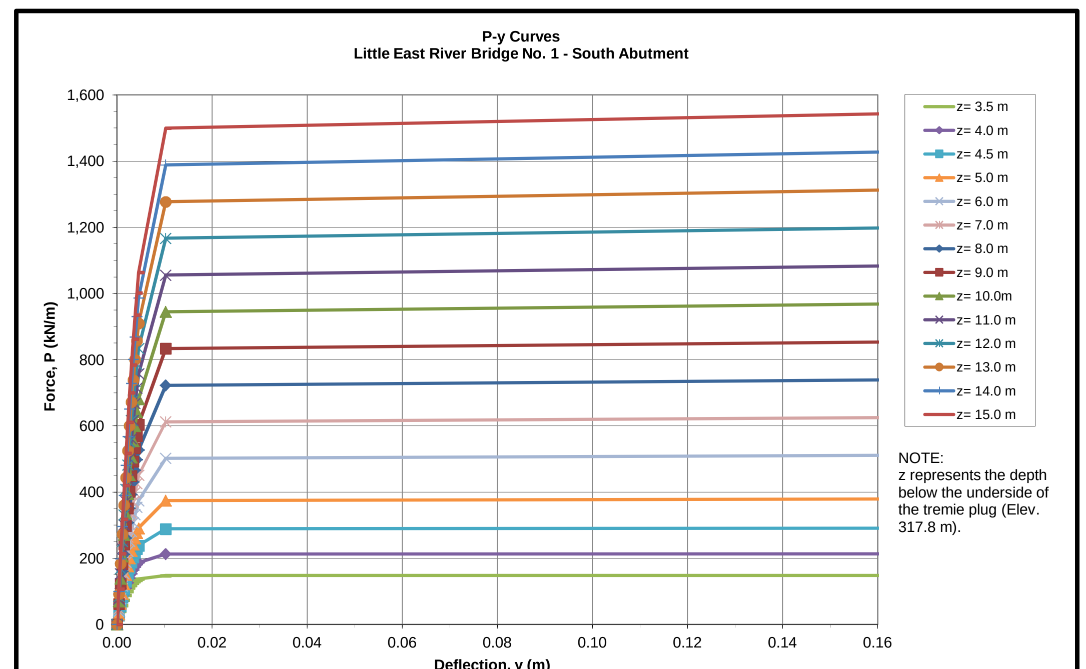
Description										
Depth (z) *	z= 8.0 m		z= 9.0 m		z= 10.0m		z= 11.0 m		z= 12.0 m	
Elevation	309.8 m		308.8 m		307.8 m		306.8 m		305.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	54.40	0.00038	61.97	0.00038	69.54	0.00038	77.12	0.00038	84.69
	0.00076	108.23	0.00076	123.31	0.00076	138.40	0.00076	153.49	0.00076	168.57
	0.00114	160.95	0.00114	183.43	0.00114	205.91	0.00114	228.39	0.00114	250.87
	0.00152	212.07	0.00152	241.77	0.00152	271.47	0.00152	301.16	0.00152	330.86
	0.00190	261.14	0.00190	297.84	0.00190	334.53	0.00190	371.22	0.00190	407.91
	0.00228	307.81	0.00228	351.24	0.00228	394.66	0.00228	438.07	0.00228	481.48
	0.00265	351.80	0.00265	401.65	0.00265	451.49	0.00265	501.32	0.00265	551.15
	0.00303	392.91	0.00303	448.85	0.00303	504.78	0.00303	560.69	0.00303	616.60
	0.00341	431.03	0.00341	492.70	0.00341	554.36	0.00341	616.00	0.00341	677.64
	0.00379	466.12	0.00379	533.15	0.00379	600.17	0.00379	667.17	0.00379	734.17
	0.00417	498.20	0.00417	570.22	0.00417	642.22	0.00417	714.21	0.00417	786.19
	0.00455	527.35	0.00455	603.97	0.00455	680.58	0.00455	757.18	0.00455	833.77
	0.01024	722.81	0.01024	833.63	0.01024	944.57	0.01024	1055.60	0.01024	1166.68
	0.28324	752.33	0.28324	869.73	0.28324	987.38	0.28324	1105.21	0.28324	1223.18
	0.55624	752.33	0.55624	869.73	0.55624	987.38	0.55624	1105.21	0.55624	1223.18
	0.82924	752.33	0.82924	869.73	0.82924	987.38	0.82924	1105.21	0.82924	1223.18

Description						
Depth (z) *	z= 13.0 m		z= 14.0 m		z= 15.0 m	
Elevation	304.8 m		303.8 m		302.8 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.00000	0.00	0.00000	0.00	0.00000	0.00
	0.00038	92.26	0.00038	99.84	0.00038	107.41
	0.00076	183.66	0.00076	198.74	0.00076	213.83
	0.00114	273.34	0.00114	295.82	0.00114	318.30
	0.00152	360.55	0.00152	390.25	0.00152	419.94
	0.00190	444.59	0.00190	481.28	0.00190	517.96
	0.00228	524.89	0.00228	568.29	0.00228	611.70
	0.00265	600.97	0.00265	650.79	0.00265	700.61
	0.00303	672.51	0.00303	728.41	0.00303	784.31
	0.00341	739.27	0.00341	800.90	0.00341	862.52
	0.00379	801.16	0.00379	868.14	0.00379	935.12
	0.00417	858.16	0.00417	930.13	0.00417	1002.09
	0.00455	910.36	0.00455	986.93	0.00455	1063.51
	0.01024	1277.81	0.01024	1388.98	0.01024	1500.17
	0.28324	1341.25	0.28324	1459.41	0.28324	1577.64
	0.55624	1341.25	0.55624	1459.41	0.55624	1577.64
	0.82924	1341.25	0.82924	1459.41	0.82924	1577.64

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 317.8 m).
The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149
Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

P-y CURVES FOR LATERAL ANALYSIS
LITTLE EAST RIVER BRIDGE NO. 2 - NORTH ABUTMENT

FIGURE C2-1

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
*Depth (z) **	z= 0.1 m		z= 0.5 m		z= 1.0 m		z= 1.5 m		z= 2.0 m		z= 2.5 m	
Elevation	321.4 m		321.0 m		320.5 m		320.0 m		319.5 m		319.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	0.56	0.0004	2.81	0.0004	5.61	0.0004	8.47	0.0004	11.32	0.0004	17.03
	0.0008	1.08	0.0008	5.44	0.0008	10.80	0.0008	16.59	0.0008	22.35	0.0008	33.83
	0.0011	1.53	0.0011	7.74	0.0011	15.26	0.0011	24.06	0.0011	32.82	0.0011	50.20
	0.0015	1.89	0.0015	9.64	0.0015	18.86	0.0015	30.69	0.0015	42.52	0.0015	65.96
	0.0019	2.17	0.0019	11.15	0.0019	21.62	0.0019	36.37	0.0019	51.30	0.0019	80.93
	0.0023	2.37	0.0023	12.30	0.0023	23.66	0.0023	41.10	0.0023	59.09	0.0023	95.01
	0.0027	2.52	0.0027	13.15	0.0027	25.11	0.0027	44.95	0.0027	65.88	0.0027	108.09
	0.0030	2.63	0.0030	13.77	0.0030	26.14	0.0030	48.02	0.0030	71.69	0.0030	120.14
	0.0034	2.70	0.0034	14.21	0.0034	26.84	0.0034	50.44	0.0034	76.61	0.0034	131.12
	0.0038	2.75	0.0038	14.52	0.0038	27.33	0.0038	52.31	0.0038	80.72	0.0038	141.05
	0.0042	2.78	0.0042	14.73	0.0042	27.65	0.0042	53.75	0.0042	84.13	0.0042	149.96
	0.0046	2.80	0.0046	14.89	0.0046	27.88	0.0046	54.85	0.0046	86.93	0.0046	157.90
	0.0102	2.85	0.0102	15.23	0.0102	28.33	0.0102	58.16	0.0102	98.16	0.0102	205.40
	0.2832	2.85	0.2832	15.23	0.2832	28.33	0.2832	58.20	0.2832	98.54	0.2832	210.64
	0.5562	2.85	0.5562	15.23	0.5562	28.33	0.5562	58.20	0.5562	98.54	0.5562	210.64
	0.8292	2.85	0.8292	15.23	0.8292	28.33	0.8292	58.20	0.8292	98.54	0.8292	210.64

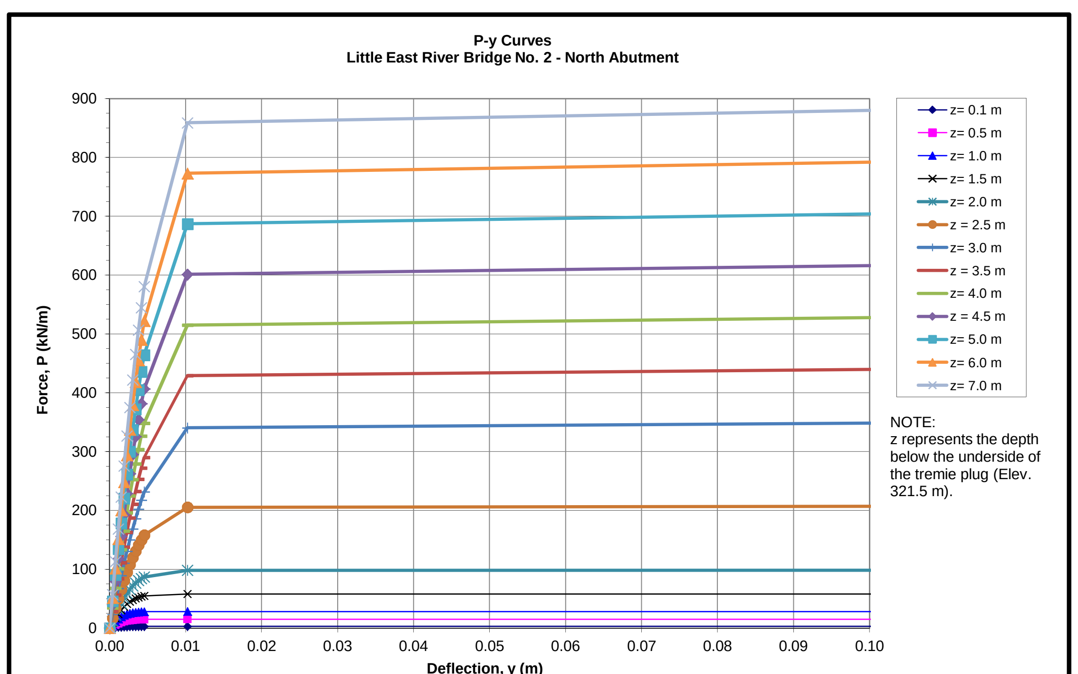
Description												
*Depth (z) **	z= 3.0 m		z= 3.5 m		z= 4.0 m		z= 4.5 m		z= 5.0 m		z= 6.0 m	
Elevation	318.5 m		318.0 m		317.5 m		317.0 m		316.5 m		315.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	22.72	0.0004	28.40	0.0004	34.08	0.0004	39.76	0.0004	45.44	0.0004	51.12
	0.0008	45.27	0.0008	56.59	0.0008	67.91	0.0008	79.22	0.0008	90.54	0.0008	101.86
	0.0011	67.46	0.0011	84.35	0.0011	101.22	0.0011	118.09	0.0011	134.96	0.0011	151.84
	0.0015	89.16	0.0015	111.50	0.0015	133.80	0.0015	156.10	0.0015	178.40	0.0015	200.70
	0.0019	110.20	0.0019	137.85	0.0019	165.42	0.0019	192.99	0.0019	220.56	0.0019	248.13
	0.0023	130.46	0.0023	163.25	0.0023	195.90	0.0023	228.55	0.0023	261.20	0.0023	293.85
	0.0027	149.84	0.0027	187.56	0.0027	225.08	0.0027	262.59	0.0027	300.10	0.0027	337.61
	0.0030	168.25	0.0030	210.69	0.0030	252.83	0.0030	294.97	0.0030	337.10	0.0030	379.24
	0.0034	185.64	0.0034	232.55	0.0034	279.06	0.0034	325.57	0.0034	372.08	0.0034	418.59
	0.0038	201.95	0.0038	253.10	0.0038	303.72	0.0038	354.34	0.0038	404.96	0.0038	455.58
	0.0042	217.18	0.0042	272.30	0.0042	326.76	0.0042	381.22	0.0042	435.68	0.0042	490.14
	0.0046	231.31	0.0046	290.16	0.0046	348.19	0.0046	406.22	0.0046	464.25	0.0046	522.28
	0.0102	340.36	0.0102	429.39	0.0102	515.27	0.0102	601.14	0.0102	687.02	0.0102	772.90
	0.2832	364.63	0.2832	461.31	0.2832	553.57	0.2832	645.83	0.2832	738.09	0.2832	830.35
	0.5562	364.63	0.5562	461.31	0.5562	553.57	0.5562	645.83	0.5562	738.09	0.5562	830.35
	0.8292	364.63	0.8292	461.31	0.8292	553.57	0.8292	645.83	0.8292	738.09	0.8292	830.35

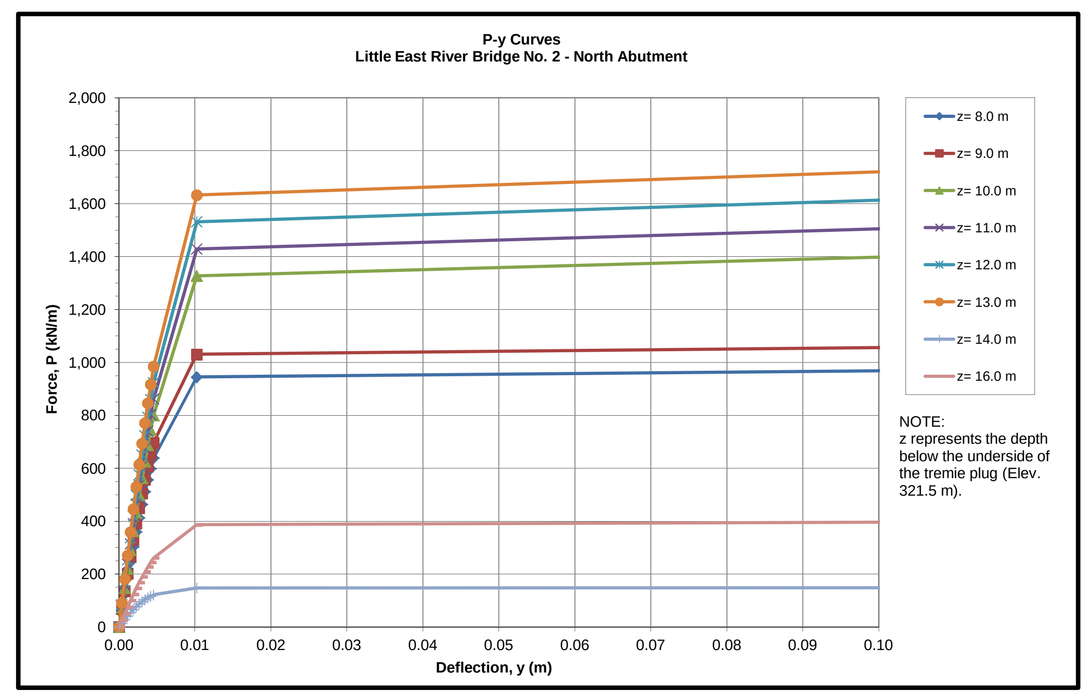
Description												
*Depth (z) **	z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m	
Elevation	314.5 m		313.5 m		312.5 m		311.5 m		310.5 m		309.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	56.80	0.0004	62.48	0.0004	68.16	0.0004	73.88	0.0004	79.56	0.0004	85.25
	0.0008	113.18	0.0008	124.49	0.0008	135.81	0.0008	147.42	0.0008	158.76	0.0008	170.10
	0.0011	168.71	0.0011	185.58	0.0011	202.45	0.0011	220.30	0.0011	237.24	0.0011	254.19
	0.0015	223.00	0.0015	245.30	0.0015	267.60	0.0015	292.18	0.0015	314.65	0.0015	337.13
	0.0019	275.70	0.0019	303.27	0.0019	330.84	0.0019	362.77	0.0019	390.67	0.0019	418.58
	0.0023	326.50	0.0023	359.14	0.0023	391.79	0.0023	431.79	0.0023	465.00	0.0023	498.21
	0.0027	375.13	0.0027	412.64	0.0027	450.15	0.0027	498.98	0.0027	537.36	0.0027	575.74
	0.0030	421.38	0.0030	463.52	0.0030	505.66	0.0030	564.12	0.0030	607.51	0.0030	650.91
	0.0034	465.10	0.0034	511.61	0.0034	558.13	0.0034	627.02	0.0034	675.25	0.0034	723.48
	0.0038	506.20	0.0038	556.82	0.0038	607.44	0.0038	687.51	0.0038	740.40	0.0038	793.28
	0.0042	544.60	0.0042	599.06	0.0042	653.52	0.0042	745.48	0.0042	802.83	0.0042	860.17
	0.0046	580.32	0.0046	638.35	0.0046	696.38	0.0046	800.83	0.0046	862.43	0.0046	924.03
	0.0102	858.78	0.0102	944.65	0.0102	1030.53	0.0102	1326.93	0.0102	1429.00	0.0102	1531.07
	0.2832	922.61	0.2832	1014.87	0.2832	1107.13	0.2832	1542.56	0.2832	1661.22	0.2832	1779.87
	0.5562	922.61	0.5562	1014.87	0.5562	1107.13	0.5562	1542.56	0.5562	1661.22	0.5562	1779.87
	0.8292	922.61	0.8292	1014.87	0.8292	1107.13	0.8292	1542.56	0.8292	1661.22	0.8292	1779.87

Description								
*Depth (z) **	z= 13.0 m		z= 14.0 m		z= 15.0 m		z= 16.0 m	
Elevation	308.5 m		307.5 m		306.5 m		305.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	90.93	0.0004	14.18	0.0004	19.87	0.0004	25.56
	0.0008	181.44	0.0008	28.10	0.0008	39.55	0.0008	50.93
	0.0011	271.13	0.0011	41.53	0.0011	58.84	0.0011	75.92
	0.0015	359.60	0.0015	54.28	0.0015	77.58	0.0015	100.35
	0.0019	446.48	0.0019	66.17	0.0019	95.61	0.0019	124.06
	0.0023	531.43	0.0023	77.10	0.0023	112.79	0.0023	146.92
	0.0027	614.13	0.0027	87.02	0.0027	129.04	0.0027	168.81
	0.0030	694.30	0.0030	95.89	0.0030	144.27	0.0030	189.62
	0.0034	771.71	0.0034	103.74	0.0034	158.45	0.0034	209.30
	0.0038	846.17	0.0038	110.63	0.0038	171.55	0.0038	227.79
	0.0042	917.51	0.0042	116.61	0.0042	183.57	0.0042	245.07
	0.0046	985.63	0.0046	121.76	0.0046	194.55	0.0046	261.14
	0.0102	1633.14	0.0102	147.62	0.0102	270.12	0.0102	386.45
	0.2832	1898.53	0.2832	149.36	0.2832	282.40	0.2832	415.17
	0.5562	1898.53	0.5562	149.36	0.5562	282.40	0.5562	415.17
	0.8292	1898.53	0.8292	149.36	0.8292	282.40	0.8292	415.17

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 321.5 m).
The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149
Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

P-y CURVES FOR LATERAL ANALYSIS

LITTLE EAST RIVER BRIDGE NO. 2 - SOUTH ABUTMENT

FIGURE C2-2

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
Depth (z) *	z= 0.1 m		z= 0.5 m		z= 1.0 m		z= 1.5 m		z= 2.0 m		z = 2.5 m	
Elevation	321.4 m		321.0 m		320.5 m		320.0 m		319.5 m		319.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	0.66	0.0001	4.15	0.0001	5.00	0.0004	12.38	0.0004	18.09	0.0004	23.79
	0.0008	1.31	0.0017	13.08	0.0017	15.75	0.0008	24.28	0.0008	35.89	0.0008	47.35
	0.0011	1.95	0.0034	16.48	0.0034	19.85	0.0011	35.32	0.0011	53.12	0.0011	70.46
	0.0015	2.55	0.0051	18.87	0.0051	22.72	0.0015	45.21	0.0015	69.53	0.0015	92.92
	0.0019	3.12	0.0068	20.77	0.0068	25.01	0.0019	53.80	0.0019	84.94	0.0019	114.53
	0.0023	3.64	0.0085	22.37	0.0085	26.94	0.0023	61.06	0.0023	99.21	0.0023	135.16
	0.0027	4.13	0.0102	23.77	0.0102	28.63	0.0027	67.07	0.0027	112.24	0.0027	154.67
	0.0030	4.57	0.0119	25.03	0.0119	30.14	0.0030	71.93	0.0030	124.01	0.0030	172.99
	0.0034	4.96	0.0137	26.17	0.0137	31.51	0.0034	75.82	0.0034	134.52	0.0034	190.06
	0.0038	5.31	0.0154	27.21	0.0154	32.77	0.0038	78.89	0.0038	143.82	0.0038	205.85
	0.0042	5.62	0.0171	28.19	0.0171	33.94	0.0042	81.29	0.0042	151.98	0.0042	220.37
	0.0046	5.89	0.0188	29.10	0.0188	35.04	0.0046	83.14	0.0046	159.09	0.0046	233.63
	0.0102	7.36	0.0205	29.95	0.0205	36.07	0.0102	89.08	0.0102	196.63	0.0102	325.76
	0.2832	7.49	0.0546	41.54	0.0546	50.02	0.2832	89.18	0.2832	199.55	0.2832	341.09
	0.5562	7.49	0.1024	41.54	0.1024	50.02	0.5562	89.18	0.5562	199.55	0.5562	341.09
	0.8292	7.49	0.1365	41.54	0.1365	50.02	0.8292	89.18	0.8292	199.55	0.8292	341.09

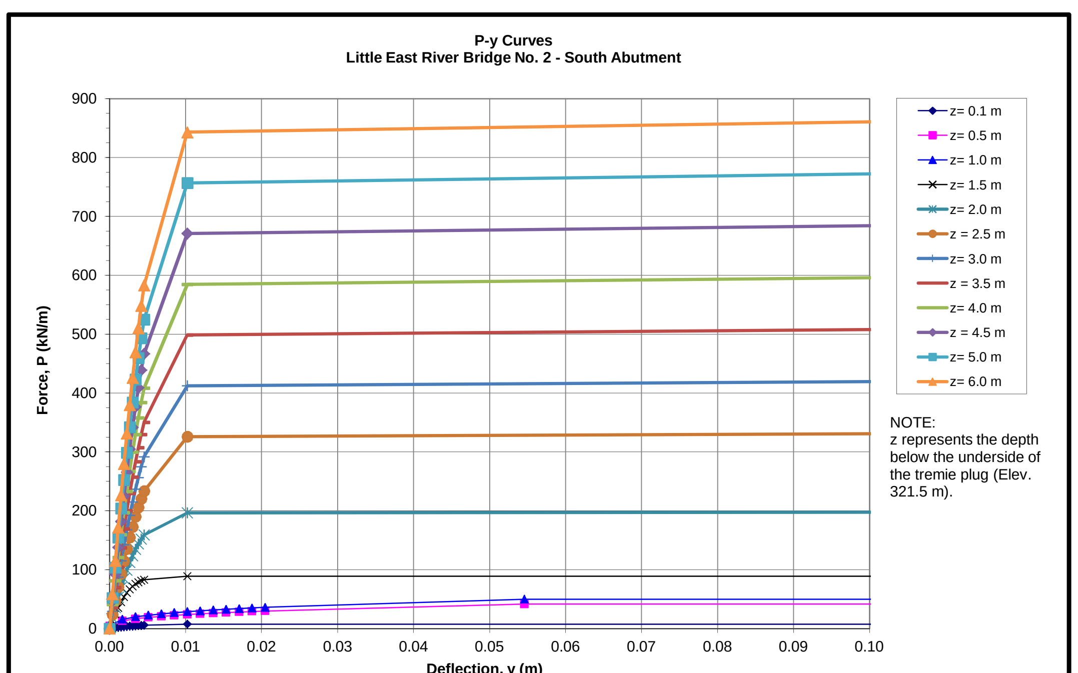
Description												
Depth (z) *	z= 3.0 m		z = 3.5 m		z= 4.0 m		z = 4.5 m		z= 5.0 m		z= 6.0 m	
Elevation	318.5 m		318.0 m		317.5 m		317.0 m		316.5 m		315.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	29.47	0.0004	35.15	0.0004	40.83	0.0004	46.51	0.0004	52.19	0.0004	57.87
	0.0008	58.67	0.0008	69.99	0.0008	81.31	0.0008	92.63	0.0008	103.95	0.0008	115.27
	0.0011	87.34	0.0011	104.22	0.0011	121.10	0.0011	137.97	0.0011	154.84	0.0011	171.72
	0.0015	115.24	0.0015	137.55	0.0015	159.86	0.0015	182.17	0.0015	204.48	0.0015	226.78
	0.0019	142.15	0.0019	169.74	0.0019	197.33	0.0019	224.92	0.0019	252.50	0.0019	280.08
	0.0023	167.88	0.0023	200.58	0.0023	233.26	0.0023	265.93	0.0023	298.60	0.0023	331.26
	0.0027	192.30	0.0027	229.88	0.0027	267.44	0.0027	304.99	0.0027	342.52	0.0027	380.06
	0.0030	215.28	0.0030	257.52	0.0030	299.72	0.0030	341.91	0.0030	384.08	0.0030	426.25
	0.0034	236.77	0.0034	283.41	0.0034	330.01	0.0034	376.58	0.0034	423.14	0.0034	469.69
	0.0038	256.72	0.0038	307.50	0.0038	358.23	0.0038	408.93	0.0038	459.61	0.0038	510.28
	0.0042	275.13	0.0042	329.78	0.0042	384.38	0.0042	438.94	0.0042	493.47	0.0042	547.99
	0.0046	292.02	0.0046	350.28	0.0046	408.47	0.0046	466.62	0.0046	524.74	0.0046	582.84
	0.0102	412.31	0.0102	498.63	0.0102	584.83	0.0102	670.94	0.0102	757.00	0.0102	843.03
	0.2832	433.76	0.2832	526.30	0.2832	618.76	0.2832	711.17	0.2832	803.54	0.2832	895.89
	0.5562	433.76	0.5562	526.30	0.5562	618.76	0.5562	711.17	0.5562	803.54	0.5562	895.89
	0.8292	433.76	0.8292	526.30	0.8292	618.76	0.8292	711.17	0.8292	803.54	0.8292	895.89

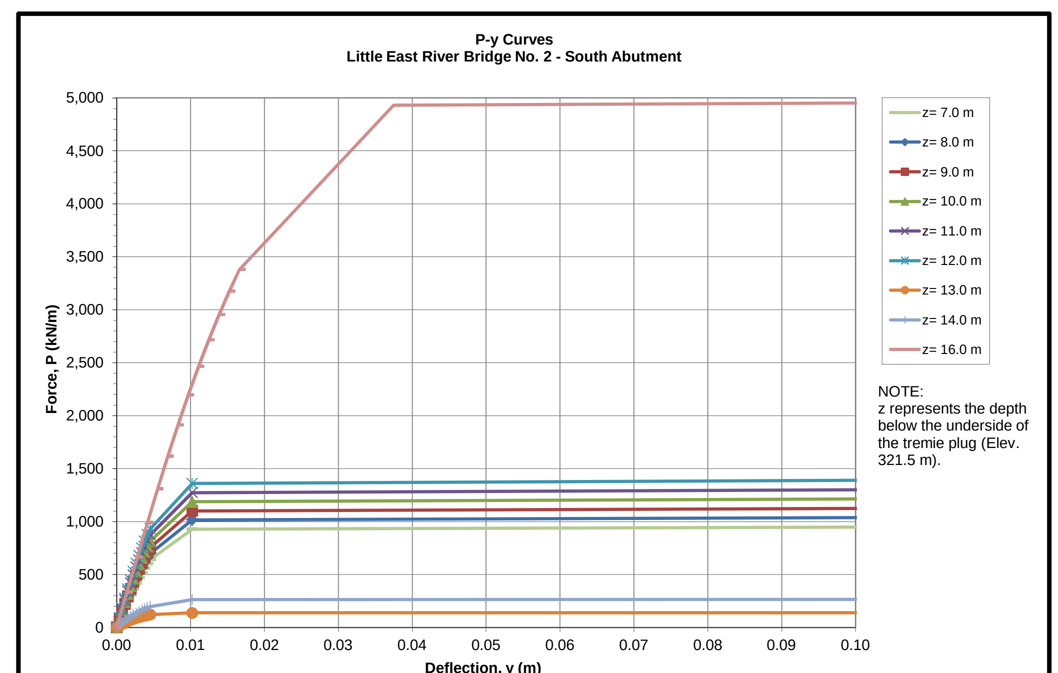
Description												
Depth (z) *	z= 7.0 m		z= 8.0 m		z= 9.0 m		z= 10.0 m		z= 11.0 m		z= 12.0 m	
Elevation	314.5 m		313.5 m		312.5 m		311.5 m		310.5 m		309.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	63.56	0.0004	69.24	0.0004	74.92	0.0004	80.60	0.0004	86.28	0.0004	91.96
	0.0008	126.59	0.0008	137.90	0.0008	149.22	0.0008	160.54	0.0008	171.86	0.0008	183.18
	0.0011	188.59	0.0011	205.46	0.0011	222.33	0.0011	239.20	0.0011	256.07	0.0011	272.95
	0.0015	249.09	0.0015	271.39	0.0015	293.69	0.0015	315.99	0.0015	338.30	0.0015	360.60
	0.0019	307.65	0.0019	335.23	0.0019	362.80	0.0019	390.38	0.0019	417.95	0.0019	445.52
	0.0023	363.92	0.0023	396.58	0.0023	429.24	0.0023	461.90	0.0023	494.55	0.0023	527.21
	0.0027	417.59	0.0027	455.11	0.0027	492.64	0.0027	530.16	0.0027	567.68	0.0027	605.20
	0.0030	468.41	0.0030	510.57	0.0030	552.73	0.0030	594.88	0.0030	637.03	0.0030	679.18
	0.0034	516.23	0.0034	562.77	0.0034	609.30	0.0034	655.83	0.0034	702.36	0.0034	748.88
	0.0038	560.94	0.0038	611.59	0.0038	662.24	0.0038	712.88	0.0038	763.52	0.0038	814.16
	0.0042	602.50	0.0042	657.00	0.0042	711.50	0.0042	765.99	0.0042	820.47	0.0042	874.95
	0.0046	640.93	0.0046	699.01	0.0046	757.08	0.0046	815.14	0.0046	873.20	0.0046	931.26
	0.0102	929.03	0.0102	1015.00	0.0102	1100.96	0.0102	1186.91	0.0102	1272.85	0.0102	1358.79
	0.2832	988.23	0.2832	1080.55	0.2832	1172.87	0.2832	1265.17	0.2832	1357.47	0.2832	1449.77
	0.5562	988.23	0.5562	1080.55	0.5562	1172.87	0.5562	1265.17	0.5562	1357.47	0.5562	1449.77
	0.8292	988.23	0.8292	1080.55	0.8292	1172.87	0.8292	1265.17	0.8292	1357.47	0.8292	1449.77

Description								
Depth (z) *	z= 13.0 m		z= 14.0 m		z= 15.0 m		z= 16.0 m	
Elevation	308.5 m		307.5 m		306.5 m		305.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	15.24	0.0004	20.94	0.0004	26.63	0.0014	333.82
	0.0008	30.11	0.0008	41.64	0.0008	53.01	0.0028	664.97
	0.0011	44.30	0.0011	61.85	0.0011	78.90	0.0042	990.85
	0.0015	57.53	0.0015	81.35	0.0015	104.08	0.0056	1309.04
	0.0019	69.62	0.0019	99.96	0.0019	128.34	0.0069	1617.35
	0.0023	80.45	0.0023	117.54	0.0023	151.52	0.0083	1913.87
	0.0027	89.99	0.0027	133.98	0.0027	173.49	0.0097	2197.02
	0.0030	98.27	0.0030	149.20	0.0030	194.15	0.0111	2465.56
	0.0034	105.36	0.0034	163.17	0.0034	213.43	0.0125	2718.60
	0.0038	111.36	0.0038	175.89	0.0038	231.30	0.0139	2955.59
	0.0042	116.40	0.0042	187.39	0.0042	247.77	0.0153	3176.27
	0.0046	120.59	0.0046	197.72	0.0046	262.85	0.0167	3380.68
	0.0102	138.41	0.0102	262.34	0.0102	369.07	0.0375	4932.69
	0.2832	139.14	0.2832	270.40	0.2832	387.45	1.0375	5262.98
	0.5562	139.14	0.5562	270.40	0.5562	387.45	2.0375	5262.98
	0.8292	139.14	0.8292	270.40	0.8292	387.45	3.0375	5262.98

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 321.5 m).
The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149

Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

P-y CURVES FOR LATERAL ANALYSIS

LITTLE EAST RIVER BRIDGE NO. 3 - SOUTH AND NORTH ABUTMENTS

FIGURE C3

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
Depth (z) *	z = 0.1 m		z = 0.5 m		z = 1.0 m		z = 1.5 m		z = 2.0 m		z = 2.5 m	
Elevation	320.9 m		320.5 m		320.0 m		319.5 m		319.0 m		318.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	0.04	0.0004	0.50	0.0004	1.16	0.0004	1.83	0.0004	2.49	0.0004	3.16
	0.0008	0.08	0.0008	1.00	0.0008	2.30	0.0008	3.63	0.0008	4.97	0.0008	6.30
	0.0011	0.11	0.0011	1.47	0.0011	3.39	0.0011	5.40	0.0011	7.41	0.0011	9.41
	0.0015	0.15	0.0015	1.93	0.0015	4.41	0.0015	7.11	0.0015	9.80	0.0015	12.48
	0.0019	0.19	0.0019	2.35	0.0019	5.34	0.0019	8.75	0.0019	12.14	0.0019	15.50
	0.0023	0.23	0.0023	2.75	0.0023	6.18	0.0023	10.30	0.0023	14.39	0.0023	18.46
	0.0027	0.26	0.0027	3.10	0.0027	6.93	0.0027	11.76	0.0027	16.57	0.0027	21.34
	0.0030	0.30	0.0030	3.42	0.0030	7.59	0.0030	13.11	0.0030	18.64	0.0030	24.13
	0.0034	0.33	0.0034	3.71	0.0034	8.15	0.0034	14.36	0.0034	20.62	0.0034	26.83
	0.0038	0.37	0.0038	3.96	0.0038	8.63	0.0038	15.51	0.0038	22.49	0.0038	29.43
	0.0042	0.40	0.0042	4.18	0.0042	9.04	0.0042	16.55	0.0042	24.25	0.0042	31.92
	0.0046	0.44	0.0046	4.37	0.0046	9.38	0.0046	17.49	0.0046	25.90	0.0046	34.31
	0.0102	0.85	0.0102	5.36	0.0102	10.88	0.0102	23.59	0.0102	39.46	0.0102	57.22
	0.2832	1.29	0.2832	5.43	0.2832	10.95	0.2832	24.43	0.2832	43.08	0.2832	66.93
	0.5562	1.29	0.5562	5.43	0.5562	10.95	0.5562	24.43	0.5562	43.08	0.5562	66.93
	0.8292	1.29	0.8292	5.43	0.8292	10.95	0.8292	24.43	0.8292	43.08	0.8292	66.93

Description												
Depth (z) *	z = 3.0 m		z = 3.5 m		z = 4.0 m		z = 4.5 m		z = 5.0 m		z = 6.0 m	
Elevation	318.0 m		317.5 m		317.0 m		316.5 m		316.0 m		315.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	3.82	0.0004	4.48	0.0004	5.15	0.0004	5.81	0.0004	6.47	0.0004	7.80
	0.0008	7.63	0.0008	8.96	0.0008	10.28	0.0008	11.61	0.0008	12.93	0.0008	15.58
	0.0011	11.41	0.0011	13.41	0.0011	15.39	0.0011	17.38	0.0011	19.36	0.0011	23.33
	0.0015	15.16	0.0015	17.83	0.0015	20.47	0.0015	23.11	0.0015	25.75	0.0015	31.02
	0.0019	18.86	0.0019	22.21	0.0019	25.50	0.0019	28.79	0.0019	32.07	0.0019	38.65
	0.0023	22.50	0.0023	26.53	0.0023	30.47	0.0023	34.40	0.0023	38.33	0.0023	46.19
	0.0027	26.08	0.0027	30.80	0.0027	35.38	0.0027	39.94	0.0027	44.50	0.0027	53.63
	0.0030	29.58	0.0030	35.00	0.0030	40.21	0.0030	45.40	0.0030	50.58	0.0030	60.95
	0.0034	32.99	0.0034	39.12	0.0034	44.95	0.0034	50.75	0.0034	56.55	0.0034	68.15
	0.0038	36.32	0.0038	43.16	0.0038	49.60	0.0038	56.00	0.0038	62.40	0.0038	75.20
	0.0042	39.54	0.0042	47.10	0.0042	54.15	0.0042	61.14	0.0042	68.13	0.0042	82.11
	0.0046	42.66	0.0046	50.95	0.0046	58.59	0.0046	66.15	0.0046	73.72	0.0046	88.84
	0.0102	75.94	0.0102	95.12	0.0102	109.91	0.0102	124.17	0.0102	138.44	0.0102	166.96
	0.2832	95.95	0.2832	130.16	0.2832	151.89	0.2832	171.80	0.2832	191.71	0.2832	231.54
	0.5562	95.95	0.5562	130.16	0.5562	151.89	0.5562	171.80	0.5562	191.71	0.5562	231.54
	0.8292	95.95	0.8292	130.16	0.8292	151.89	0.8292	171.80	0.8292	191.71	0.8292	231.54

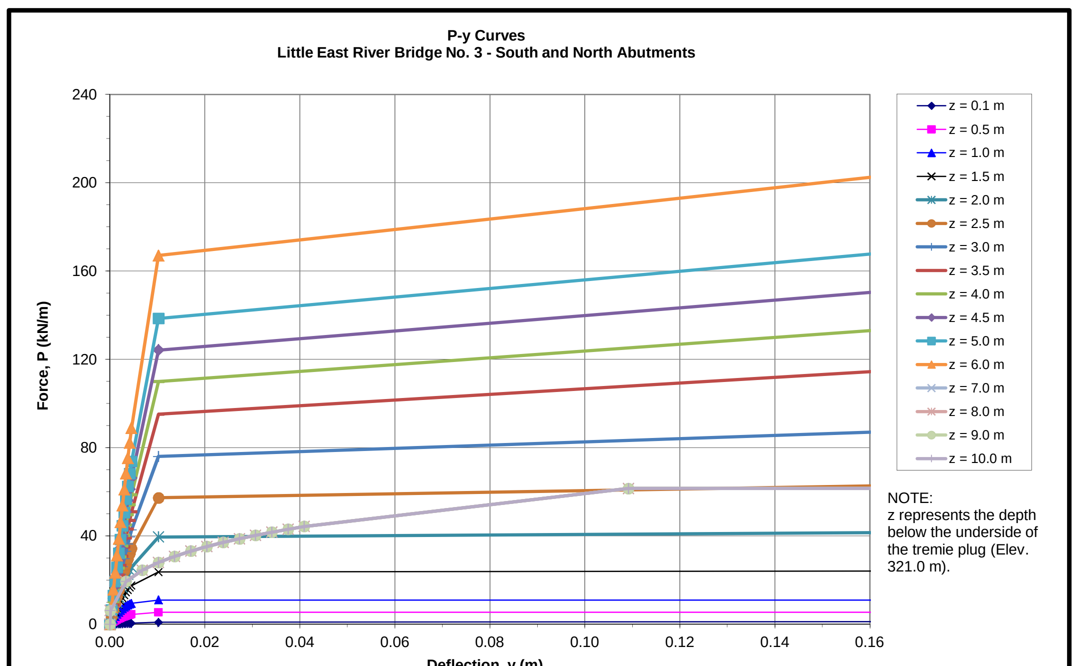
Description												
Depth (z) *	z = 7.0 m		z = 8.0 m		z = 9.0 m		z = 10.0 m		z = 11.0 m		z = 12.0 m	
Elevation	314.0 m		313.0 m		312.0 m		311.0 m		310.0 m		309.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0001	6.14	0.0001	6.14	0.0001	6.14	0.0001	6.14	0.0004	35.92	0.0004	43.50
	0.0034	19.35	0.0034	19.35	0.0034	19.35	0.0034	19.35	0.0008	71.32	0.0008	86.53
	0.0068	24.38	0.0068	24.38	0.0068	24.38	0.0068	24.38	0.0011	105.73	0.0011	128.60
	0.0102	27.90	0.0102	27.90	0.0102	27.90	0.0102	27.90	0.0015	138.72	0.0015	169.31
	0.0137	30.71	0.0137	30.71	0.0137	30.71	0.0137	30.71	0.0019	169.93	0.0019	208.29
	0.0171	33.08	0.0171	33.08	0.0171	33.08	0.0171	33.08	0.0023	199.09	0.0023	245.24
	0.0205	35.16	0.0205	35.16	0.0205	35.16	0.0205	35.16	0.0027	226.03	0.0027	279.93
	0.0239	37.01	0.0239	37.01	0.0239	37.01	0.0239	37.01	0.0030	250.63	0.0030	312.21
	0.0273	38.70	0.0273	38.70	0.0273	38.70	0.0273	38.70	0.0034	272.90	0.0034	342.01
	0.0307	40.24	0.0307	40.24	0.0307	40.24	0.0307	40.24	0.0038	292.86	0.0038	369.30
	0.0341	41.68	0.0341	41.68	0.0341	41.68	0.0341	41.68	0.0042	310.61	0.0042	394.12
	0.0375	43.03	0.0375	43.03	0.0375	43.03	0.0375	43.03	0.0046	326.30	0.0046	416.55
	0.0410	44.30	0.0410	44.30	0.0410	44.30	0.0410	44.30	0.0102	415.58	0.0102	562.08
	0.1092	61.43	0.1092	61.43	0.1092	61.43	0.1092	61.43	0.2832	424.16	0.2832	582.15
	0.2048	61.43	0.2048	61.43	0.2048	61.43	0.2048	61.43	0.5562	424.16	0.5562	582.15
	0.2730	61.43	0.2730	61.43	0.2730	61.43	0.2730	61.43	0.8292	424.16	0.8292	582.15

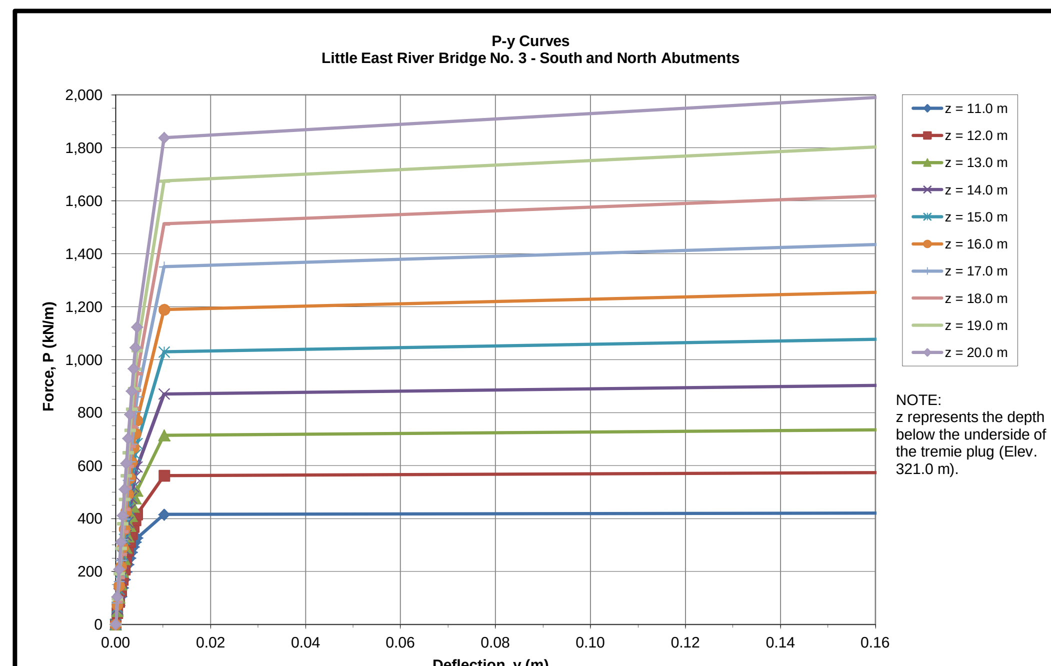
Description																
Depth (z) *	z = 13.0 m		z = 14.0 m		z = 15.0 m		z = 16.0 m		z = 17.0 m		z = 18.0 m		z = 19.0 m		z = 20.0 m	
Elevation	308.0 m		307.0 m		306.0 m		305.0 m		304.0 m		303.0 m		302.0 m		301.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	51.09	0.0004	58.67	0.0004	66.26	0.0004	73.84	0.0004	81.42	0.0004	89.00	0.0004	96.59	0.0004	104.17
	0.0008	101.71	0.0008	116.88	0.0008	132.05	0.0008	147.21	0.0008	162.37	0.0008	177.53	0.0008	192.68	0.0008	207.83
	0.0011	151.41	0.0011	174.18	0.0011	196.92	0.0011	219.66	0.0011	242.38	0.0011	265.09	0.0011	287.80	0.0011	310.50
	0.0015	199.76	0.0015	230.13	0.0015	260.45	0.0015	290.74	0.0015	321.00	0.0015	351.24	0.0015	381.47	0.0015	411.69
	0.0019	246.40	0.0019	284.37	0.0019	322.24	0.0019	360.06	0.0019	397.82	0.0019	435.56	0.0019	473.27	0.0019	510.96
	0.0023	291.01	0.0023	336.55	0.0023	381.95	0.0023	427.25	0.0023	472.48	0.0023	517.65	0.0023	562.79	0.0023	607.89
	0.0027	333.33	0.0027	386.41	0.0027	439.28	0.0027	492.01	0.0027	544.64	0.0027	597.19	0.0027	649.68	0.0027	702.12
	0.0030	373.17	0.0030	433.72	0.0030	493.99	0.0030	554.08	0.0030	614.02	0.0030	673.86	0.0030	733.62	0.0030	793.32
	0.0034	410.41	0.0034	478.32	0.0034	545.90	0.0034	613.24	0.0034	680.40	0.0034	747.43	0.0034	814.36	0.0034	881.20
	0.0038	444.98	0.0038	520.12	0.0038	594.88	0.0038	669.35	0.0038	743.61	0.0038	817.71	0.0038	891.68	0.0038	965.56
	0.0042	476.88	0.0042	559.08	0.0042	640.85	0.0042	722.31	0.0042	803.52	0.0042	884.55	0.0042	965.43	0.0042	1046.20
	0.0046	506.14	0.0046	595.18	0.0046	683.79	0.0046	772.06	0.0046	860.06	0.0046	947.87	0.0046	1035.50	0.0046	1123.00
	0.0102	714.51	0.0102	870.69	0.0102	1029.30	0.0102	1189.55	0.0102	1350.91	0.0102	1513.05	0.0102	1675.75	0.0102	1838.86
	0.2832	751.63	0.2832	930.13	0.2832	1115.86	0.2832	1307.45	0.2832	1503.87	0.2832	1704.32	0.2832	1908.16	0.2832	2114.89
	0.5562	751.63	0.5562	930.13	0.5562	1115.86	0.5562	1307.45	0.5562	1503.87	0.5562	1704.32	0.5562	1908.16	0.5562	2114.89
	0.8292	751.63	0.8292	930.13	0.8292	1115.86	0.8292	1307.45	0.8292	1503.87	0.8292	1704.32	0.8292	1908.16	0.8292	2114.89

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 321.0 m).

The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149
Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

P-y CURVES FOR LATERAL ANALYSIS

LITTLE EAST RIVER BRIDGE NO. 4 - SOUTH AND NORTH ABUTMENTS

FIGURE C4

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
*Depth (z) **	z = 0.1 m		z = 0.5 m		z = 1.0 m		z = 1.5 m		z = 2.0 m		z = 2.5 m	
Elevation	323.9 m		323.5 m		323.0 m		322.5 m		322.0 m		321.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	0.19	0.0004	0.95	0.0004	1.89	0.0004	2.84	0.0004	3.79	0.0004	4.74
	0.0008	0.38	0.0008	1.88	0.0008	3.75	0.0008	5.66	0.0008	7.56	0.0008	9.46
	0.0011	0.56	0.0011	2.79	0.0011	5.56	0.0011	8.43	0.0011	11.29	0.0011	14.14
	0.0015	0.73	0.0015	3.67	0.0015	7.28	0.0015	11.13	0.0015	14.96	0.0015	18.78
	0.0019	0.90	0.0019	4.50	0.0019	8.91	0.0019	13.74	0.0019	18.55	0.0019	23.35
	0.0023	1.05	0.0023	5.28	0.0023	10.42	0.0023	16.25	0.0023	22.06	0.0023	27.84
	0.0027	1.20	0.0027	6.01	0.0027	11.81	0.0027	18.64	0.0027	25.46	0.0027	32.23
	0.0030	1.33	0.0030	6.68	0.0030	13.07	0.0030	20.91	0.0030	28.74	0.0030	36.52
	0.0034	1.45	0.0034	7.30	0.0034	14.21	0.0034	23.04	0.0034	31.89	0.0034	40.70
	0.0038	1.56	0.0038	7.85	0.0038	15.22	0.0038	25.03	0.0038	34.91	0.0038	44.74
	0.0042	1.65	0.0042	8.35	0.0042	16.11	0.0042	26.87	0.0042	37.78	0.0042	48.65
	0.0046	1.74	0.0046	8.80	0.0046	16.89	0.0046	28.58	0.0046	40.51	0.0046	52.42
	0.0102	2.25	0.0102	11.48	0.0102	21.16	0.0102	41.30	0.0102	65.20	0.0102	91.17
	0.2832	2.30	0.2832	11.78	0.2832	21.53	0.2832	43.87	0.2832	73.92	0.2832	111.68
	0.5562	2.30	0.5562	11.78	0.5562	21.53	0.5562	43.87	0.5562	73.92	0.5562	111.68
	0.8292	2.30	0.8292	11.78	0.8292	21.53	0.8292	43.87	0.8292	73.92	0.8292	111.68

Description												
*Depth (z) **	z = 3.0 m		z = 3.5 m		z = 4.0 m		z = 4.5 m		z = 5.0 m		z = 6.0 m	
Elevation	321.0 m		320.5 m		320.0 m		319.5 m		319.0 m		318.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	5.69	0.0004	6.63	0.0004	7.58	0.0004	8.53	0.0004	9.48	0.0004	11.37
	0.0008	11.36	0.0008	13.25	0.0008	15.15	0.0008	17.04	0.0008	18.93	0.0008	22.72
	0.0011	17.00	0.0011	19.85	0.0011	22.68	0.0011	25.52	0.0011	28.36	0.0011	34.03
	0.0015	22.59	0.0015	26.40	0.0015	30.18	0.0015	33.95	0.0015	37.72	0.0015	45.27
	0.0019	28.13	0.0019	32.90	0.0019	37.62	0.0019	42.32	0.0019	47.02	0.0019	56.43
	0.0023	33.60	0.0023	39.34	0.0023	44.98	0.0023	50.61	0.0023	56.23	0.0023	67.48
	0.0027	38.98	0.0027	45.71	0.0027	52.27	0.0027	58.80	0.0027	65.33	0.0027	78.40
	0.0030	44.27	0.0030	51.98	0.0030	59.46	0.0030	66.89	0.0030	74.32	0.0030	89.18
	0.0034	49.45	0.0034	58.16	0.0034	66.54	0.0034	74.85	0.0034	83.17	0.0034	99.81
	0.0038	54.52	0.0038	64.24	0.0038	73.50	0.0038	82.69	0.0038	91.88	0.0038	110.25
	0.0042	59.45	0.0042	70.19	0.0042	80.34	0.0042	90.38	0.0042	100.42	0.0042	120.50
	0.0046	64.26	0.0046	76.03	0.0046	87.03	0.0046	97.91	0.0046	108.79	0.0046	130.55
	0.0102	118.15	0.0102	145.55	0.0102	167.46	0.0102	188.39	0.0102	209.32	0.0102	251.19
	0.2832	157.15	0.2832	210.34	0.2832	244.97	0.2832	275.59	0.2832	306.21	0.2832	367.45
	0.5562	157.15	0.5562	210.34	0.5562	244.97	0.5562	275.59	0.5562	306.21	0.5562	367.45
	0.8292	157.15	0.8292	210.34	0.8292	244.97	0.8292	275.59	0.8292	306.21	0.8292	367.45

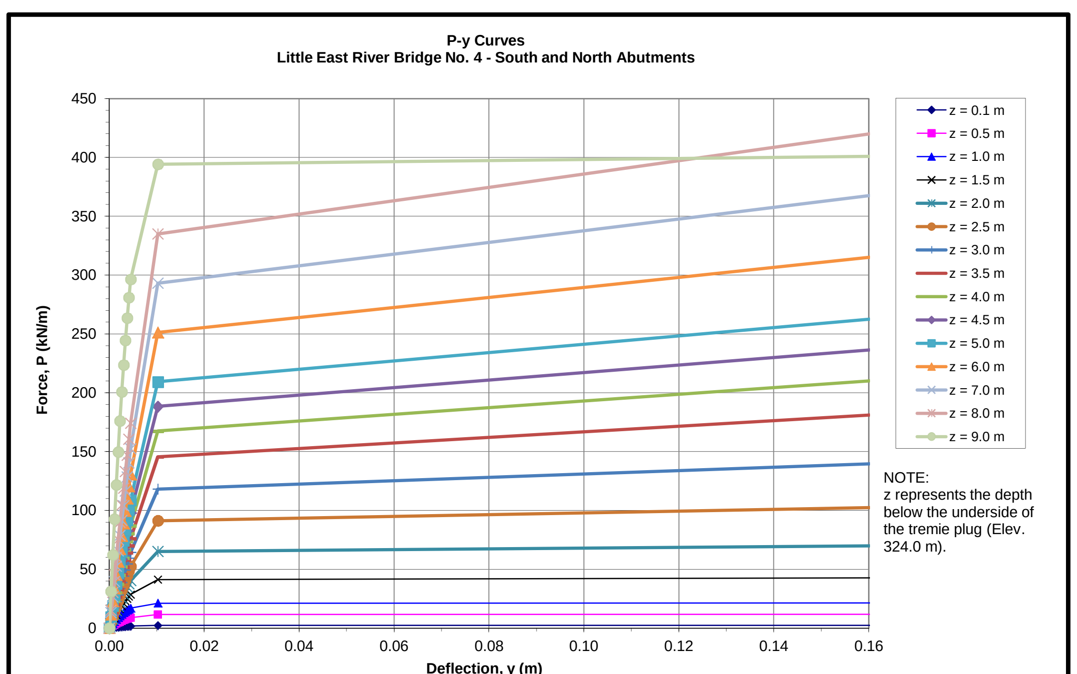
Description												
*Depth (z) **	z = 7.0 m		z = 8.0 m		z = 9.0 m		z = 10.0 m		z = 11.0 m		z = 12.0 m	
Elevation	317.0 m		316.0 m		315.0 m		314.0 m		313.0 m		312.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	13.27	0.0004	15.16	0.0004	31.35	0.0004	37.05	0.0004	42.73	0.0004	48.41
	0.0008	26.51	0.0008	30.29	0.0008	62.33	0.0008	73.80	0.0008	85.11	0.0008	96.42
	0.0011	39.70	0.0011	45.37	0.0011	92.59	0.0011	109.95	0.0011	126.80	0.0011	143.66
	0.0015	52.81	0.0015	60.36	0.0015	121.80	0.0015	145.23	0.0015	167.49	0.0015	189.76
	0.0019	65.83	0.0019	75.23	0.0019	149.69	0.0019	179.39	0.0019	206.89	0.0019	234.39
	0.0023	78.72	0.0023	89.97	0.0023	176.05	0.0023	212.23	0.0023	244.76	0.0023	277.29
	0.0027	91.47	0.0027	104.54	0.0027	200.70	0.0027	243.55	0.0027	280.88	0.0027	318.22
	0.0030	104.05	0.0030	118.91	0.0030	223.54	0.0030	273.23	0.0030	315.11	0.0030	356.99
	0.0034	116.44	0.0034	133.07	0.0034	244.52	0.0034	301.16	0.0034	347.32	0.0034	393.49
	0.0038	128.63	0.0038	147.00	0.0038	263.64	0.0038	327.29	0.0038	377.46	0.0038	427.63
	0.0042	140.59	0.0042	160.67	0.0042	280.94	0.0042	351.59	0.0042	405.48	0.0042	459.38
	0.0046	152.31	0.0046	174.07	0.0046	296.49	0.0046	374.06	0.0046	431.41	0.0046	488.75
	0.0102	293.05	0.0102	334.91	0.0102	394.20	0.0102	543.16	0.0102	626.43	0.0102	709.70
	0.2832	428.69	0.2832	489.93	0.2832	406.54	0.2832	578.24	0.2832	666.89	0.2832	755.53
	0.5562	428.69	0.5562	489.93	0.5562	406.54	0.5562	578.24	0.5562	666.89	0.5562	755.53
	0.8292	428.69	0.8292	489.93	0.8292	406.54	0.8292	578.24	0.8292	666.89	0.8292	755.53

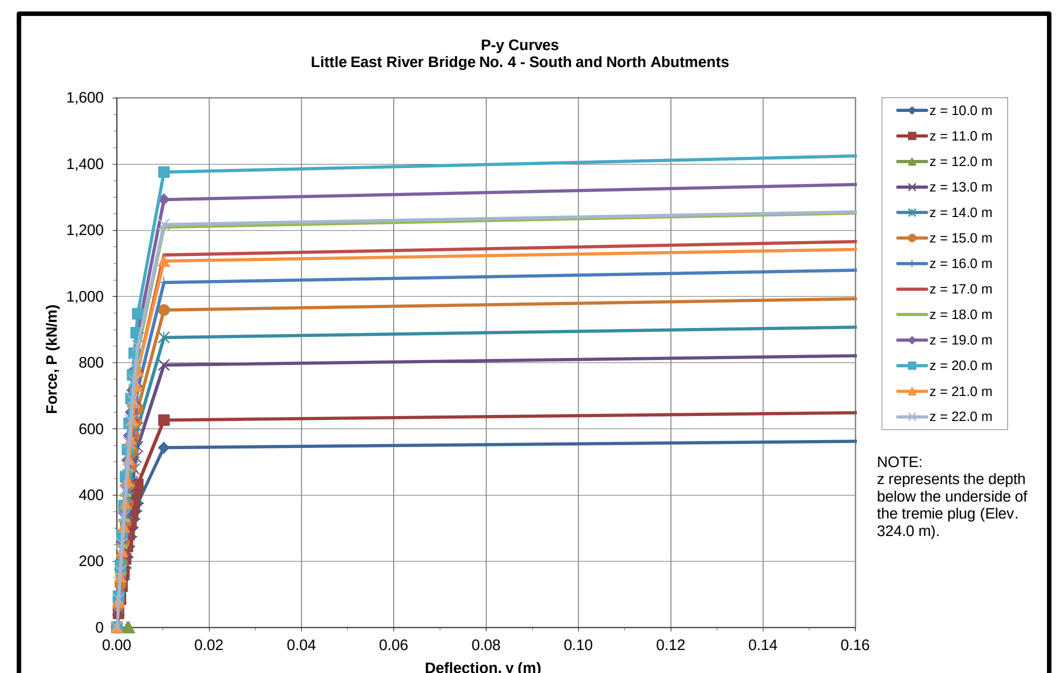
Description										
*Depth (z) **	z = 13.0 m		z = 14.0 m		z = 15.0 m		z = 16.0 m		z = 17.0 m	
Elevation	311.0 m		310.0 m		309.0 m		308.0 m		307.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	54.09	0.0004	59.77	0.0004	65.45	0.0004	71.13	0.0004	76.81
	0.0008	107.74	0.0008	119.05	0.0008	130.36	0.0008	141.68	0.0008	152.99
	0.0011	160.51	0.0011	177.37	0.0011	194.22	0.0011	211.08	0.0011	227.93
	0.0015	212.02	0.0015	234.28	0.0015	256.55	0.0015	278.81	0.0015	301.07
	0.0019	261.90	0.0019	289.40	0.0019	316.90	0.0019	344.40	0.0019	371.90
	0.0023	309.83	0.0023	342.36	0.0023	374.89	0.0023	407.43	0.0023	439.96
	0.0027	355.55	0.0027	392.89	0.0027	430.22	0.0027	467.56	0.0027	504.89
	0.0030	398.88	0.0030	440.76	0.0030	482.65	0.0030	524.53	0.0030	566.42
	0.0034	439.66	0.0034	485.82	0.0034	531.99	0.0034	578.16	0.0034	624.32
	0.0038	477.80	0.0038	527.97	0.0038	578.15	0.0038	628.32	0.0038	678.49
	0.0042	513.28	0.0042	567.17	0.0042	621.07	0.0042	674.97	0.0042	728.87
	0.0046	546.09	0.0046	603.43	0.0046	660.78	0.0046	718.12	0.0046	775.46
	0.0102	792.96	0.0102	876.23	0.0102	959.49	0.0102	1042.76	0.0102	1126.02
	0.2832	844.17	0.2832	932.82	0.2832	1021.46	0.2832	1110.10	0.2832	1198.74
	0.5562	844.17	0.5562	932.82	0.5562	1021.46	0.5562	1110.10	0.5562	1198.74
	0.8292	844.17	0.8292	932.82	0.8292	1021.46	0.8292	1110.10	0.8292	1198.74

Description										
*Depth (z) **	z = 18.0 m		z = 19.0 m		z = 20.0 m		z = 21.0 m		z = 22.0 m	
Elevation	306.0 m		305.0 m		304.0 m		303.0 m		302.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	82.49	0.0004	88.17	0.0004	93.85	0.0004	77.61	0.0004	85.19
	0.0008	164.30	0.0008	175.61	0.0008	186.93	0.0008	154.55	0.0008	169.63
	0.0011	244.79	0.0011	261.64	0.0011	278.50	0.0011	230.15	0.0011	252.61
	0.0015	323.34	0.0015	345.60	0.0015	367.86	0.0015	303.80	0.0015	333.47
	0.0019	399.40	0.0019	426.90	0.0019	454.40	0.0019	374.96	0.0019	411.60
	0.0023	472.49	0.0023	505.03	0.0023	537.56	0.0023	443.16	0.0023	486.48
	0.0027	542.23	0.0027	579.57	0.0027	616.90	0.0027	508.02	0.0027	557.72
	0.0030	608.30	0.0030	650.19	0.0030	692.07	0.0030	569.26	0.0030	624.98
	0.0034	670.49	0.0034	716.66	0.0034	762.82	0.0034	626.67	0.0034	688.05
	0.0038	728.66	0.0038	778.83	0.0038	829.01	0.0038	680.14	0.0038	746.81
	0.0042	782.76	0.0042	836.66	0.0042	890.56	0.0042	729.64	0.0042	801.23
	0.0046	832.81	0.0046	890.15	0.0046	947.49	0.0046	775.22	0.0046	851.34
	0.0102	1209.29	0.0102	1292.55	0.0102	1375.82	0.0102	1107.43	0.0102	1217.20
	0.2832	1287.39	0.2832	1376.03	0.2832	1464.67	0.2832	1170.57	0.2832	1287.06
	0.5562	1287.39	0.5562	1376.03	0.5562	1464.67	0.5562	1170.57	0.5562	1287.06
	0.8292	1287.39	0.8292	1376.03	0.8292	1464.67	0.8292	1170.57	0.8292	1287.06

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 324.0 m).
The P-y curves have been generated based on the following assumptions:

1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149

Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

P-y CURVES FOR LATERAL ANALYSIS
RAGGED CREEK BRIDGE - SOUTH AND NORTH ABUTMENTS

FIGURE C5

SUMMARY OF P-y CURVES FOR A 10 3/4" (273 mm) DIAMETER CASING

Description												
Depth (z) *	z = 0.1 m		z = 0.5 m		z = 1.0 m		z = 1.5 m		z = 2.0 m		z = 2.5 m	
Elevation	315.4 m		315.0 m		314.5 m		314.0 m		313.5 m		313.0 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	0.13	0.0004	0.66	0.0004	1.32	0.0004	1.99	0.0004	2.65	0.0004	3.32
	0.0008	0.26	0.0008	1.32	0.0008	2.63	0.0008	3.96	0.0008	5.29	0.0008	6.62
	0.0011	0.39	0.0011	1.96	0.0011	3.91	0.0011	5.91	0.0011	7.91	0.0011	9.91
	0.0015	0.52	0.0015	2.58	0.0015	5.14	0.0015	7.82	0.0015	10.50	0.0015	13.17
	0.0019	0.64	0.0019	3.18	0.0019	6.31	0.0019	9.68	0.0019	13.04	0.0019	16.39
	0.0023	0.75	0.0023	3.75	0.0023	7.41	0.0023	11.47	0.0023	15.52	0.0023	19.56
	0.0027	0.86	0.0027	4.28	0.0027	8.43	0.0027	13.20	0.0027	17.95	0.0027	22.67
	0.0030	0.96	0.0030	4.79	0.0030	9.38	0.0030	14.84	0.0030	20.30	0.0030	25.73
	0.0034	1.05	0.0034	5.25	0.0034	10.25	0.0034	16.41	0.0034	22.58	0.0034	28.71
	0.0038	1.13	0.0038	5.68	0.0038	11.03	0.0038	17.89	0.0038	24.77	0.0038	31.62
	0.0042	1.21	0.0042	6.07	0.0042	11.74	0.0042	19.28	0.0042	26.88	0.0042	34.45
	0.0046	1.28	0.0046	6.42	0.0046	12.37	0.0046	20.58	0.0046	28.90	0.0046	37.19
	0.0102	1.75	0.0102	8.81	0.0102	16.21	0.0102	31.13	0.0102	48.43	0.0102	66.92
	0.2832	1.81	0.2832	9.17	0.2832	16.66	0.2832	33.84	0.2832	56.92	0.2832	85.91
	0.5562	1.81	0.5562	9.17	0.5562	16.66	0.5562	33.84	0.5562	56.92	0.5562	85.91
	0.8292	1.81	0.8292	9.17	0.8292	16.66	0.8292	33.84	0.8292	56.92	0.8292	85.91

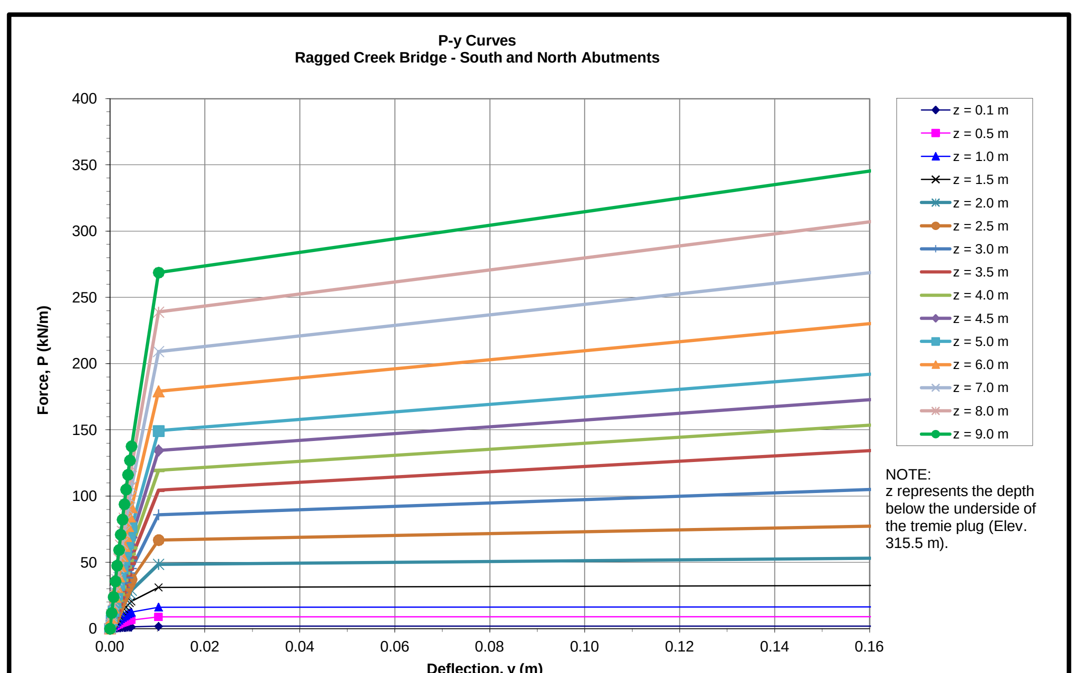
Description												
Depth (z) *	z = 3.0 m		z = 3.5 m		z = 4.0 m		z = 4.5 m		z = 5.0 m		z = 6.0 m	
Elevation	312.5 m		312.0 m		311.5 m		311.0 m		310.5 m		309.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	3.98	0.0004	4.64	0.0004	5.31	0.0004	5.97	0.0004	6.63	0.0004	7.96
	0.0008	7.95	0.0008	9.28	0.0008	10.60	0.0008	11.93	0.0008	13.26	0.0008	15.91
	0.0011	11.90	0.0011	13.90	0.0011	15.88	0.0011	17.87	0.0011	19.86	0.0011	23.83
	0.0015	15.83	0.0015	18.49	0.0015	21.14	0.0015	23.78	0.0015	26.42	0.0015	31.71
	0.0019	19.73	0.0019	23.06	0.0019	26.35	0.0019	29.65	0.0019	32.94	0.0019	39.53
	0.0023	23.58	0.0023	27.59	0.0023	31.53	0.0023	35.47	0.0023	39.41	0.0023	47.29
	0.0027	27.38	0.0027	32.07	0.0027	36.65	0.0027	41.23	0.0027	45.81	0.0027	54.97
	0.0030	31.13	0.0030	36.49	0.0030	41.71	0.0030	46.92	0.0030	52.14	0.0030	62.56
	0.0034	34.82	0.0034	40.86	0.0034	46.70	0.0034	52.54	0.0034	58.38	0.0034	70.05
	0.0038	38.43	0.0038	45.17	0.0038	51.62	0.0038	58.07	0.0038	64.52	0.0038	77.43
	0.0042	41.97	0.0042	49.40	0.0042	56.46	0.0042	63.51	0.0042	70.57	0.0042	84.69
	0.0046	45.43	0.0046	53.56	0.0046	61.21	0.0046	68.86	0.0046	76.51	0.0046	91.81
	0.0102	85.93	0.0102	104.53	0.0102	119.47	0.0102	134.40	0.0102	149.33	0.0102	179.20
	0.2832	120.80	0.2832	158.81	0.2832	181.49	0.2832	204.18	0.2832	226.87	0.2832	272.24
	0.5562	120.80	0.5562	158.81	0.5562	181.49	0.5562	204.18	0.5562	226.87	0.5562	272.24
	0.8292	120.80	0.8292	158.81	0.8292	181.49	0.8292	204.18	0.8292	226.87	0.8292	272.24

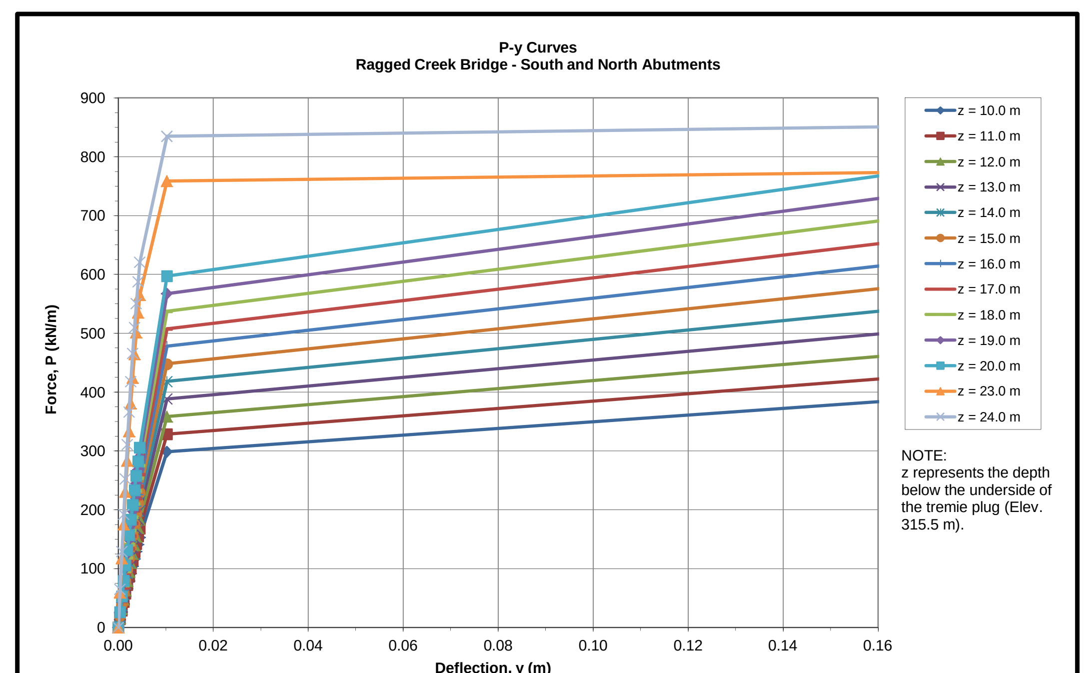
Description												
Depth (z) *	z = 7.0 m		z = 8.0 m		z = 9.0 m		z = 10.0 m		z = 11.0 m		z = 12.0 m	
Elevation	308.5 m		307.5 m		306.5 m		305.5 m		304.5 m		303.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	9.29	0.0004	10.61	0.0004	11.94	0.0004	13.27	0.0004	14.59	0.0004	15.92
	0.0008	18.56	0.0008	21.21	0.0008	23.86	0.0008	26.51	0.0008	29.16	0.0008	31.81
	0.0011	27.80	0.0011	31.77	0.0011	35.74	0.0011	39.71	0.0011	43.68	0.0011	47.65
	0.0015	36.99	0.0015	42.27	0.0015	47.56	0.0015	52.84	0.0015	58.13	0.0015	63.41
	0.0019	46.12	0.0019	52.71	0.0019	59.30	0.0019	65.89	0.0019	72.47	0.0019	79.06
	0.0023	55.17	0.0023	63.05	0.0023	70.94	0.0023	78.82	0.0023	86.70	0.0023	94.58
	0.0027	64.13	0.0027	73.30	0.0027	82.46	0.0027	91.62	0.0027	100.78	0.0027	109.94
	0.0030	72.99	0.0030	83.42	0.0030	93.84	0.0030	104.27	0.0030	114.70	0.0030	125.12
	0.0034	81.73	0.0034	93.40	0.0034	105.08	0.0034	116.75	0.0034	128.43	0.0034	140.10
	0.0038	90.33	0.0038	103.24	0.0038	116.14	0.0038	129.05	0.0038	141.95	0.0038	154.86
	0.0042	98.80	0.0042	112.91	0.0042	127.03	0.0042	141.14	0.0042	155.26	0.0042	169.37
	0.0046	107.11	0.0046	122.41	0.0046	137.72	0.0046	153.02	0.0046	168.32	0.0046	183.62
	0.0102	209.06	0.0102	238.93	0.0102	268.80	0.0102	298.66	0.0102	328.53	0.0102	358.40
	0.2832	317.61	0.2832	362.99	0.2832	408.36	0.2832	453.73	0.2832	499.10	0.2832	544.48
	0.5562	317.61	0.5562	362.99	0.5562	408.36	0.5562	453.73	0.5562	499.10	0.5562	544.48
	0.8292	317.61	0.8292	362.99	0.8292	408.36	0.8292	453.73	0.8292	499.10	0.8292	544.48

Description												
Depth (z) *	z = 13.0 m		z = 14.0 m		z = 15.0 m		z = 16.0 m		z = 17.0 m		z = 18.0 m	
Elevation	302.5 m		301.5 m		300.5 m		299.5 m		298.5 m		297.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
	0.0004	17.25	0.0004	18.57	0.0004	19.90	0.0004	21.23	0.0004	22.55	0.0004	23.88
	0.0008	34.46	0.0008	37.12	0.0008	39.77	0.0008	42.42	0.0008	45.07	0.0008	47.72
	0.0011	51.62	0.0011	55.59	0.0011	59.57	0.0011	63.54	0.0011	67.51	0.0011	71.48
	0.0015	68.70	0.0015	73.98	0.0015	79.26	0.0015	84.55	0.0015	89.83	0.0015	95.12
	0.0019	85.65	0.0019	92.24	0.0019	98.83	0.0019	105.42	0.0019	112.00	0.0019	118.59
	0.0023	102.46	0.0023	110.34	0.0023	118.23	0.0023	126.11	0.0023	133.99	0.0023	141.87
	0.0027	119.11	0.0027	128.27	0.0027	137.43	0.0027	146.59	0.0027	155.75	0.0027	164.91
	0.0030	135.55	0.0030	145.98	0.0030	156.41	0.0030	166.83	0.0030	177.26	0.0030	187.69
	0.0034	151.78	0.0034	163.45	0.0034	175.13	0.0034	186.81	0.0034	198.48	0.0034	210.16
	0.0038	167.76	0.0038	180.67	0.0038	193.57	0.0038	206.48	0.0038	219.38	0.0038	232.29
	0.0042	183.49	0.0042	197.60	0.0042	211.71	0.0042	225.83	0.0042	239.94	0.0042	254.06
	0.0046	198.92	0.0046	214.22	0.0046	229.53	0.0046	244.83	0.0046	260.13	0.0046	275.43
	0.0102	388.26	0.0102	418.13	0.0102	448.00	0.0102	477.86	0.0102	507.73	0.0102	537.60
	0.2832	589.85	0.2832	635.22	0.2832	680.60	0.2832	725.97	0.2832	771.34	0.2832	816.72
	0.5562	589.85	0.5562	635.22	0.5562	680.60	0.5562	725.97	0.5562	771.34	0.5562	816.72
	0.8292	589.85	0.8292	635.22	0.8292	680.60	0.8292	725.97	0.8292	771.34	0.8292	816.72

Description												
Depth (z) *	z = 19.0 m		z = 20.0 m		z =21.0 m		z = 22.0 m		z = 23.0 m		z = 24.0 m	
Elevation	296.5 m		295.5 m		294.5 m		293.5 m		292.5 m		291.5 m	
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
	0.0000	0.00	0.0000	0.00	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.00
	0.0004	25.21	0.0004	26.53	0.00	47.93	0.00	53.61	0.0004	59.29	0.0004	64.96
	0.0008	50.37	0.0008	53.02	0.00	95.31	0.00	106.60	0.0008	117.90	0.0008	129.20
	0.0011	75.45	0.0011	79.42	0.00	141.60	0.00	158.40	0.0011	175.20	0.0011	192.00
	0.0015	100.40	0.0015	105.68	0.00	186.33	0.00	208.46	0.0015	230.60	0.0015	252.75
	0.0019	125.18	0.0019	131.77	0.00	229.07	0.00	256.33	0.0019	283.59	0.0019	310.87
	0.0023	149.75	0.0023	157.64	0.00	269.51	0.00	301.63	0.0023	333.77	0.0023	365.93
	0.0027	174.08	0.0027	183.24	0.00	307.37	0.00	344.08	0.0027	380.83	0.0027	417.60
	0.0030	198.11	0.0030	208.54	0.00	342.51	0.00	383.51	0.0030	424.56	0.0030	465.64
	0.0034	221.83	0.0034	233.51	0.00	374.85	0.00	419.82	0.0034	464.85	0.0034	509.93
	0.0038	245.19	0.0038	258.10	0.00	404.37	0.00	452.99	0.0038	501.69	0.0038	550.46
	0.0042	268.17	0.0042	282.29	0.00	431.12	0.00	483.08	0.0042	535.15	0.0042	587.29
	0.0046	290.73	0.0046	306.04	0.00	455.21	0.00	510.21	0.0046	565.32	0.0046	620.53
	0.0102	567.46	0.0102	597.33	0.01	608.21	0.01	683.41	0.0102	758.98	0.0102	834.85
	0.2832	862.09	0.2832	907.46	0.28	628.12	0.28	706.29	0.2832	784.91	0.2832	863.91
	0.5562	862.09	0.5562	907.46	0.56	628.12	0.56	706.29	0.5562	784.91	0.5562	863.91
	0.8292	862.09	0.8292	907.46	0.83	628.12	0.83	706.29	0.8292	784.91	0.8292	863.91

NOTES: * Depth (z) is measured to be positive below the underside of the tremie plug (Elevation 315.5 m).
The P-y curves have been generated based on the following assumptions:
1. Micropiles are installed vertically (i.e. no inclination)
2. Only static loading conditions are applicable.
3. There are no pile group effects (i.e. analysis are based on a single micropile).





Date: April 2014
Project No: 11-1111-0149

Prepared By: AV
Checked By: CN/JPD/JMAC

Golder Associates

APPENDIX D

Non-Standard Special Provision – Technical Specification for Grouted Micropiles

<u>SUPPLY EQUIPMENT FOR INSTALLING MICROPILES</u> – Item No.
<u>PRE-PRODUCTION MICROPILE</u> – Item No.
<u>PRODUCTION MICROPILE</u> – Item No.
<u>PRODUCTION MICROPILE TESTING</u> – Item No.
<u>GROUT FOR MICROPILES</u> – Item No.

Non-Standard Special Provision April 2014

1.0 SCOPE

This Special Provision covers the requirements for the installation and testing of grout flush, hollow bar micropiles for five (5) replacement bridge structures (Little East River Bridges No. 1 to 4 and Ragged Creek Bridge) on Highway 592 in the Township of Perry, Ontario.

1.01 Qualifications of the Contractor

The minimum pre-qualification requirements of the micropile Contractor are specified as follows:

i. The Contractor shall be fully experienced in all aspects of grout flush, hollow bar micropile construction and with the execution of pile load tests. The Contractor shall demonstrate that he has successfully completed at least three grout flush, hollow bar micropile (3) projects in the previous five (5) years of similar scope, complexity and size.

ii. The micropile superintendent, micropile project manager and the foreman driller and grout operators responsible for installation of the micropile system must have micropile installation experience on at least three (3) successfully completed grout flush, hollow bar micropile projects over the past five (5) years. The Contractor shall provide resumes of key personnel who will be present full time on site (and will be substantially involved) and who will each have at least five (5) years of relevant experience. The personnel include the Quality Verification Engineer.

iii. The micropile work shall be carried out in whole by a specialist Contractor having the qualifications stated above.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, General and Construction:

OPSS 180	Management of Excess Material
OPSS 903	Deep Foundation
OPSS.PROV 904	Concrete Structures
OPSS 905	Steel Reinforcement for Concrete
OPSS 906	Structural Steel for Bridges

Ontario Provincial Standard Specifications, Material:

OPSS.PROV 1002	Aggregates – Concrete
OPSS 1301	Cementing Materials
OPSS 1302	Water
OPSS 1303	Admixtures for Concrete

OPSS.PROV 1350	Concrete – Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1442	Epoxy Coated Reinforcing Steel Bars for Concrete
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

Canadian Standards Association Standards, CSA:

A23.1-04/A23.2-09	Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practice for Concrete
A283-06	Qualification Code for Concrete Testing Laboratories
G30.18-09	Billet-Steel Bars for Concrete Reinforcement
G40.20-98/G40.21-04	General Requirements for Rolled or Welded Structural Quality Steel/Structural Quality Steels
W59-03(R2008)	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials Standards, ASTM:

A722/A722M-07	Uncoated High-Strength Bar for Prestressing Concrete
A252-10	Standard Specification for Welded and Seamless Steel Pipe Piles
C144-11	Standard Specification for Aggregate for Masonry Mortar
D1143M-07	Standard Test for Piles Under Static Axial Compressive Load
D1784-11	Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
D3689-07	Standard Test Methods for Deep Foundations Under Static Axial Tensile Load
D4380-84 (2006)	Standard Test Method for Density of Bentonite Slurries

American Welding Society (AWS):

D1.1/D1.1M:2004	Structural Welding Code - Steel
D1.4:2005	Structural Welding Code – Reinforcing Steel

American Society of Civil Engineers (ASCE):

ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations

International Organization for Standardization/International Electrotechnical Committee, ISO/IEC

DIS-17025:2005 General Requirements for the Competence of the Testing and Calibration Laboratories

Others:

Post Tensioning Institute Publications – Recommendations for Prestressed Rock and Soil Anchors – 2004.
Canadian Foundation Engineering Manual (CFEM), 4th Edition.
Federal Highway Administration Publication No. FHWA NHI–05-039: Micropile Design and Construction Reference Manual, December 2005 (FHWA 2005).

3.0 DEFINITIONS

For the purposes of this Non-Standard Special Provision, the following definitions apply:

Admixture means a substance added to the grout to either control bleed and/or shrinkage, improve flowability, reduce water content, retard setting time, or resist washout.

Alignment Load (AL) means a nominal load applied to a micropile during testing to keep the testing equipment correctly positioned.

Apparent Free Micropile Length means the length of micropile that is not bonded to the surrounding ground, as calculated from the elastic movement data during testing.

Bond Length means the length of the micropile that is bonded to the ground and capable of transferring the applied axial loads to the surrounding soil or rock.

Bond-Breaker means a sleeve placed over the reinforcement steel to prevent load transfer.

Casing means a steel pipe introduced during the drilling process to temporarily stabilize the drill hole and/or permanently reinforce the pile.

Centralizer means a device used to centrally locate the reinforcing element(s) within the casing and/or drillhole to ensure that minimum grout cover is provided.

Central Bar or Central Steel means steel reinforcing bars (solid or hollow-core) or pipes used to strengthen or stiffen the pile, excluding any left-in drill rod or casing.

Coupler means a device used to transmit load from one partial length of reinforcement to another.

Creep Movement means the movement that occurs during the creep test of a micropile under a constant load.

Design Engineer means the Engineer retained by the Contractor who produces the Working Drawings and designs the pile load test system(s).

Design Checking Engineer means the Engineer retained by the Contractor who checks the Working Drawings and the design of the pile load test system(s).

Design Load (DL) means the anticipated final maximum service load in the micropile. The design load includes appropriate factors to ensure that the overall structure has adequate capacity for its intended use.

Duplex Drilling means a drilling system involving the simultaneous rotation and advancement of (inner) drill rod and (outer) drill casing in which the cuttings from the inner drill rod exit the borehole via the annulus between the rod and the casing.

Elastic Movement means the recoverable movement measured during a micropile load test.

Encapsulation means a corrugated or deformed tube protecting the reinforcing steel against corrosion.

Engineer means a professional engineer, licensed by Professional Engineers, Ontario to practice in the Province of Ontario.

Flush Grout means a suitably thin Portland cement based grout that is injected through the micropile hollow-core central reinforcing bar during drilling.

Free (Unbonded) Length means the designed length of the micropile that is not bonded to the surrounding ground or grout during testing.

Low Mobility Grout means a low slump grout with a mix design that typically contains sand or a suitable admixture (thixotropic agent) in order to control its travel from its point of injection.

Micropile means a bored, cast-in-place pile containing steel reinforcement, designed to accept load (axial, bending or lateral) directly, and transfer it to an appropriate bearing stratum.

Maximum Test Load (TL) means the maximum load to which the micropile is subjected during testing.

Overburden means a non-lithified material, natural or placed, which normally requires cased drilling methods to provide an open drillhole to underlying strata.

Post-Grouting means the injection of additional grout into the load transfer length of a micropile after the primary grout has set.

Pre-Production Micropile means a sacrificial micropile that is not part of the final foundation system and is subjected to load testing to verify the design and installation procedures.

Primary/Structural Grout means a Portland cement based grout that is injected into the micropile hole prior to, during or after the installation of the reinforcement to provide the load transfer to the surrounding ground along the micropile and affords a degree of corrosion protection when the micropile is in compression.

Production Micropile means a micropile that forms part of the final foundation support system to a structure.

Proof Load Test means the incremental loading of a production micropile, recording the total movement at each increment.

Quality Verification Engineer (QVE) means an engineer who has a minimum of five (5) years experience in the field of design and/or installation of micropiling or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the Contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the Contract Documents and to issue Certificate(s) of Conformance.

Reinforcement Steel means the steel component(s) of the micropile which accepts and/or resists applied loadings. This includes the hollow-core central reinforcing bar and the permanent steel casing on this project.

Residual Movement means the non-elastic (non-recoverable) movement of a micropile measured during load testing.

Rotary Percussive Duplex (Concentric) means a drilling system involving the simultaneous rotation, percussion and advancement of an (inner) drill rod and an (outer) drill casing in which the cuttings from the inner drill rod exit the borehole via the annulus between rod and casing.

Rotary Percussive Duplex (Eccentric or Lost Crown) means a drilling system involving the simultaneous rotation, percussion and advancement of an (inner) drill rod combined with an eccentric underreaming bit and an (outer) drill casing in which the cuttings from the inner drill rod exit the borehole via the annulus between rod and casing. Previously called the Overburden Drilling Eccentric (ODEX) System.

Sheathing means a smooth or corrugated piping or tubing that protects the reinforcing steel against corrosion.

Spacer means a device used to separate elements of a multiple-element steel bar reinforcement.

Tremie Grouting means the placing of grout in a borehole via a grout pipe introduced to the bottom of the hole.

Ultimate Grout-To-Ground Bond Value means the estimated ultimate geotechnical unit grout-to-ground bond strength selected for use in design.

Verification Load Test means a pile load test performed to verify the design of the pile system and the construction methods proposed, prior to installation of production piles.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design Requirements

The Contractor shall be responsible for the design of the pile load testing set-up including the reaction system(s), the reaction piles/ground anchors and all loading frame connections.

The reaction piles/ground anchors and the reaction system(s) shall be designed to safely withstand the applied loads specified in the Contract Documents.

The design assumptions of the reaction piles/ground anchors, the reaction system(s) and all loading frame connections shall accurately represent the subsurface conditions prevalent at the site.

Except as specified herein, the reaction piles/ground anchors shall be designed in accordance with the design recommendations of the Post Tensioning Institute Recommendations for Prestressed Rock and Soil Anchors (2004).

4.02 Submission Requirements

4.02.01 Site Survey

One (1) week prior to commencing any work associated with the micropile operation, the Contractor shall submit to the Contract Administrator, a condition survey of property and structures that may be affected by the work. The survey shall include, but not be limited to, the locations and conditions of adjacent properties, buildings, underground structures, utility services and structures such as bridges at or adjacent to the site.

4.02.02 Working Drawings

At least three (3) weeks prior to the commencement of the micropile operations, the Contractor shall submit three (3) copies of the Working Drawings to the Contract Administrator for information purposes only. These Working Drawings shall bear the seal and signature of the Design and Checking Engineers.

Information to be shown on the Working Drawings shall describe and illustrate the complete details of the micropile installations for each stage of construction (including traffic staging), as well as the micropile testing equipment, test set-up, and reaction system(s) for the pre-production and production test micropile(s). The information on the Working Drawings shall include the following:

a) Plans, Elevations and Sections (at each of the south and north abutments)

- i. micropile spacing
- ii. orientation
- iii. minimum total micropile length
- iv. casing plunge length
- v. uncased bond length
- vi. design load
- vii. a unique identification number for each micropile
- viii. micropile components and details

b) Materials

i. physical properties of reinforcement steel (central bar and casing)
ii. physical properties of pile top attachment
iii. bond length grout materials and mix proportions
iv. corrosion protection material physical/mechanical properties

c) Micropile Installation

i. construction methods
ii. work restrictions
iii. schedule of major equipment resources
iv. sequence of pile installation and coordination of work
v. procedures for monitoring micropile installation
vi. type, number and location of pre-production load tests
vii. method of evaluation of load test results

d) Micropile Construction Details

i. Detailed description of the proposed construction procedures.
ii. Method of drilling the micropile holes and maintaining the stability of the holes, through artesian conditions, during the micropile installation.
iii. Method to be employed to penetrate the overburden, including cobbles and boulders, during the micropile installation.
iv. Detailed description of the drilling equipment and materials including drill bit/auger diameter and lengths, casing diameter and lengths, flush type, slurry materials or other materials to facilitate the construction of the micropile hole.
v. Method of verifying the lengths of micropile holes.
vi. Detailed description of the grout mixing procedure and the method of grout installation and placement. The description shall include the grout pressures and details of the grout mix design(s).

e) All design assumptions, loads, parameters and bond stresses used for the micropile load tests.

f) Testing records and evaluation when testing has been completed to assess bond stress and micropile movement.

4.02.03 Mill Certificates

The Contractor shall submit to the Contract Administrator at the time of delivery to the job site, one (1) copy of the certified mill test reports, indicating that the steel meets the requirements for the appropriate standards for casing and central bar reinforcement, plates and shapes. The ultimate strength, yield strength, elongation, and material properties composition shall be included. For steel pipe used as permanent casing, or core steel, the Contractor shall submit a minimum of two (2) representative coupon tests or mill certifications on each load delivered to the project.

Where mill test certificates originate from a mill outside Canada or the United States of America, the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

One copy of the stress-strain curves representative of the lots to be used shall be submitted to the Contract Administrator together with the mill test certificates detailed in OPSS 1440.

4.02.04 Grout

The Contractor shall submit to the Contract Administrator a suitable, site specific grout mix design(s), including details of all materials to be incorporated, and the procedure for mixing and placing the grout. This submittal shall include certified test results verifying the acceptability of the proposed mix design(s). The acceptability of the mixes will be further verified on site prior to production.

4.02.05 Installation Records

The Contractor shall submit micropile installation records, signed by the Quality Verification Engineer, to the Contract Administrator, within three (3) business days after each pile installation (including all test piles and production piles) is completed. The installation records shall include the following information:

a) Pile identification number and location;
b) Pile drilling duration, including date of installation and start and finish time;
c) Pile drilling observations, including nature of and variation in cuttings return, penetration rates for each 0.5 m of penetration, presence of cobbles or boulders or obstructions or voids, connections between holes;
d) Information on depth of drilling and soil types encountered, including description of strata, depth to water, etc.;
e) Sequence of installation;
f) Inclination and direction;
g) Final tip elevation;
h) Casing tip elevation;
i) Cut-off elevation;
j) Length and diameters of all components;
k) Bar length, spacers/coupler details;
l) Casing length, joint location details;
m) Description of unusual installation behaviour, conditions, voids, high grout takes;
n) Any deviations from the intended parameters, exceptions and “unusual” events;
o) Grout pressures attained, where applicable;
p) Grout mix proportions;
q) Grout quantities pumped, including depths were larger than normal grout takes occur;
r) Pile materials and dimensions;
s) Micropile test records, analysis and details;
t) As-built drawings showing the location of the piles, their depth and inclination, and details of their composition shall be submitted within thirty (30) calendar days of each pier completion.

4.02.06 Micropile Load Testing

The Contractor shall submit to the Contract Administrator details of the micropile load testing, three (3) weeks prior to construction. The details shall include the following:

a) Detailed description of the proposed load testing procedures.

b) Shop drawings and structural calculations for the design of the pile load testing, including reaction system(s). The structural calculations shall confirm that the materials will meet the specified load and movement criteria.

c) Detailed plans for the set-up method proposed for testing the pre-production and production micropiles including all necessary drawings and details to clearly describe the test method, means for providing reaction, equipment proposed including independent reference beams for measuring micropile head movement. Special attention shall be paid to ensuring safety and providing adequate structural stability of the reaction piles/ground anchors and loading frame connections.

d) Calibration reports for each test jack, pressure gauge, and master pressure gauge to be used. The calibration tests shall have been performed by an independent testing laboratory and tests shall have been performed within one (1) year of the date submitted. Testing shall not commence until the Contract Administrator has approved the jack, pressure gauge and master pressure gauge calculations.

4.02.07 Quality Control

4.02.07.01 Interim Inspections During Installation of Micropiles

The Quality Verification Engineer shall carry out Interim Inspections of the:

a) drilling and casing installation (including cleanliness of casing); and,
b) drilling and grouting with hollow-core central bar reinforcement steel (including depth, diameter and length of penetration).

The above shall be carried out for each individual micropile to verify that the works are constructed in general conformance with the Contract Documents and Working Drawings.

4.02.07.02 Certificate of Conformance

4.02.07.02.01 Pre-Production Micropile Tests

The Contractor shall submit, to the Contract Administrator, a Certificate of Conformance sealed, signed and dated by the Quality Verification Engineer (QVE) upon completion of all of the pre-production micropile testing. The certificate shall state that the pre-production micropiles have been installed and tested in general conformance with the Contract Documents and Working Drawings.

4.02.07.02.02 Production Micropile Tests

The Contractor shall submit, to the Contract Administrator, a Certificate of Conformance sealed, signed and dated by the Quality Verification Engineer (QVE) upon completion of each production micropile test. The certificate shall state that the production micropile has been installed and tested in general conformance with the Contract Documents and Working Drawings.

4.02.07.02.03 Production Micropiles

The Contractor shall submit, to the Contract Administrator, a Certificate of Conformance upon completion of all of the micropile installations. The certificate shall be sealed, signed and dated by the QVE. The certificate shall state that all of the production micropiles have been supplied and installed in general conformance with the Contract Documents and Working Drawings.

4.02.08 As-Constructed Drawings

As-constructed drawings shall be submitted to the Contract Administrator in a reproducible format prior to final acceptance of the work.

The as-constructed drawings shall be dated and bear the seal and signature of the Quality Verification Engineer.

5.0 MATERIALS

5.01 Water

Water for mixing grout shall be according to OPSS 1302.

5.02 Admixtures

Admixtures shall be according to OPSS 1303. Admixtures which control bleed, improve or control flowability, reduce water content, and retard set may be used in the grout only if the admixture manufacturer certifies that their use will not affect the required properties of the grout. Expansive admixtures shall only be added to the grout used for filling sealed encapsulations (if used). Accelerators and admixtures with chlorides shall not be permitted. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer's recommendations.

5.03 Cement

All cement shall be Type GU General Use hydraulic cement conforming to OPSS 1301.

5.04 Fillers

Inert fillers, such as sand, may be used in the grout in special situations (e.g., presence of large voids in the ground) to limit grout take and travel and only if the QVE certifies that their use will not affect the required properties of the grout.

5.05 Grout

The grout mix materials and procedures for placement and testing shall conform to OPSS 1301, OPSS 1302, OPSS 1303, OPSS 1350 and CSA A23.2-1B.

The Contractor shall provide a stable, homogenous neat cement grout or a sand-cement grout. The grout shall be free of any lumps and not contain any evidence of poor or incomplete mixing. The grout shall be mixed to the supplier's specification. The water/cement grout ratio of the thin/flush grout (by weight) shall not exceed 0.90. The water/cement ratio of the structural grout (by weight) shall not exceed 0.45. The structural grout shall have the following physical properties:

a) A minimum compressive strength of 25 MPa at 7 Days.
b) A minimum compressive strength of 35 MPa at 28 Days.
c) No segregation and a bleed of less than 2% when allowed to stand for 1 hour.

5.06 Reinforcement Steel

5.06.01 Central Bar

The central bar reinforcement steel shall be continuously threaded Titan Hollow Bar or approved equivalent, according to OPSS 1440 with minimum yield strength of 572 MPa.

5.06.02 Couplers

Couplers for the central bar reinforcement steel shall be as specified by the supplier of the central bar and shall develop at least 100% of the guaranteed minimum ultimate strength of the central bar.

5.06.03 Casing

The steel casing shall meet the requirements of ASTM A252-10, Grade 3 with minimum yield strength of 552 MPa.

New “Structural Grade” (a.k.a. “Mill Secondary”) steel pipe meeting the above but without Mill Certification is acceptable for use as permanent casing provided it is free from defects (dents, cracks, tears) and is accompanied by two (2) coupon tests per truckload confirming it meets the above requirements.

All casing joints shall be threaded or comprised of full penetration field welds. The casing joints shall develop at least the required compressive, tensile and/or bending strength used in the design of the micropile.

5.07 Plates and Shapes

Structural steel plates and shapes for pile top attachments shall be according to OPSS 906 Grade 300W.

5.08 Centralizers and Spacers

Centralizers shall be fabricated from schedule PVC pipe or tube, steel, or material that is non-detrimental to the reinforcement steel. Wood shall not be used.

6.0 EQUIPMENT

6.01 General

All equipment for the installation, testing and monitoring of the pre-production (verification) and production micropiles shall be suitable for the intended purposes and capable of working on the site under the prevailing access and clearance conditions.

The equipment used shall be capable of installing and grouting the micropiles to the prescribed depths or elevations without damage to the pile materials or to the adjacent structures.

6.02 Grouting Equipment

All grout mixers, pumps and hoses shall be of an adequate capacity and shall be sized to enable the grout to be pumped in one continuous operation, while keeping the grout in constant agitation prior to pumping, and to allow continuous grouting of an individual micropile with the final structural grout within one (1) hour.

A high speed, high shear, colloidal grout mixer with a gauge to measure the quantity of water discharged into the mixer shall be used. A paddle mixer is not acceptable.

The grout pump(s) shall be equipped with a pressure gauge to monitor grout pressures of at least 1 MPa or twice the actual grouting pressures used, whichever is greater.

6.03 Micropile Testing Equipment

The equipment shall be capable of loading the test piles to the maximum specified test load (TL) within the rated capacity.

The equipment shall be capable of loading the pile in increments so that the load on the pile can be increased or decreased in accordance with the test procedures outlined in the Contract Documents.

Dial gauges shall have at least a 75 mm travel and longer gauge stems or sufficient gauge blocks shall be provided to allow for greater travel where required. Gauges shall have precision of at least 0.02 mm.

Dial gauges shall allow the measurement of total micropile movement at every load increment to be read to the nearest 0.02 mm increment. The gauge shall have sufficient travel to record the total pile movement at Test Load without the need to reset at an interim point.

Loading equipment shall be calibrated within an accuracy of +/-2% immediately prior to use.

Current calibration curves, dated and bearing the seal and signature of an Engineer shall be provided for all gauges and jacks.

7.0 CONSTRUCTION

7.01 General

The Contractor shall be responsible for the material, fabrication, installation, testing and monitoring of the test micropiles and the production micropiles. In addition, for non-Owner designed reaction piles/ground anchors, the Contractor shall be responsible for design parameters and the design of the reaction piles/ground anchors.

The Contractor's attention is specifically drawn to the following details:

a) The drilling, grouting and micropile installation will be carried out immediately adjacent to the existing bridge abutments on Highway 592. The Contractor is alerted to the limited available working space within each construction staging of the replacement bridge structure as well as the presence of overhead Hydro line(s) within the right-of-way. The Contractor shall select construction techniques that will prevent settlement or heave of the existing structure during construction.

b) The Contractor is alerted that micropiles will be installed through cohesionless overburden soils containing cobble and boulder nests at Little East River Bridges No. 1 to No. 4 and may be present within these deposits at the Ragged Creek Bridge. Boulders up to 0.7 m in size were encountered during the foundation investigation. The factual information contained in the foundation investigation reports (that are available as specified elsewhere in the Contract) provide information on the subsurface conditions at the sites.

   The Contractor is also alerted that artesian groundwater conditions were encountered during the foundation investigation at Little East River Bridge No. 1 and that the cohesionless soils at all sites, subjected to conditions of unbalanced hydrostatic head, will result in basal heave and soil cave in.

   The Contractor shall select drilling and grouting methods and be prepared with suitable equipment and procedures (including the use of hollow-core central steel reinforcement bars, with sacrificial drill bits, to allow the simultaneous drilling and injection of grout during installation of the micropiles) to penetrate through the overburden soils containing cobbles and boulders, prevent basal heave and soil cave in and surface ground movement at the adjacent bridge structures so as to avoid causing an unacceptable level of disturbance as defined elsewhere in the Contract Documents.

The Contractor shall not proceed with the installation of production micropiles until the satisfactory completion of the pre-production load tests and until approval has been given by the Contract Administrator.

The Contractor shall control all drilling fluids, grout, water and drill cuttings during micropile installation and upon completion of the micropile installations shall clean up, and off-site dispose of all excess fluids and cuttings in accordance with the requirements of OPSS 180.

The Contractor shall comply with all environmental provisions as specified elsewhere in the Contract Documents.

7.02 Subsurface Conditions

A Foundation Investigation Report that describes the subsurface conditions at each bridge site for the project is available, as specified elsewhere in the Contract Documents. The Ministry warrants that the information provided in the Foundation Investigation Report can be relied upon with the following limitations and exceptions:

a) Any interpretation of data or opinions expressed in the reports is not warranted.

b) Although the raw measured data presented is warranted, the Contractor must satisfy itself as to the sufficiency of the information presented for the intended construction purpose and obtain any updating or additional information as required to facilitate the deep foundation works.

The Contractor is alerted that the micropiles will be installed through cohesionless overburden soils containing cobble and boulder nests at Little East River Bridges No. 1 to No. 4 and may be present within these deposits at the Ragged Creek Bridge. Boulders up to 0.7 m in size were encountered during the foundation investigation. The factual information contained in the Foundation Investigation Reports (that is available as specified elsewhere in the Contract Documents) provide information on the subsurface conditions at each site. Further, artesian groundwater conditions were encountered during the Foundation Investigation at Little East River Bridge No. 1.

7.03 Transportation, Handling, Storage

Casings and central bar reinforcement shall be transported, stored and handled in such a manner that damage and distortion is prevented and that the strength and integrity are maintained.

All materials, including cement, additives for grout and pile reinforcement steel (central bar and casing) shall be stored off-ground, under cover and protected against moisture and directly from the elements.

Lifting of any casings and bar reinforcement shall not cause excessive bending.

7.04 Installation of Micropiles

7.04.01 General

The Contractor shall install the micropiles in accordance with the diameter, orientation and length specified in the Contract Documents and as detailed on the Working Drawings.

The micropile installation technique shall be such that it is consistent with the geotechnical, logistical, environmental, and load carrying conditions of the project.

The micropiles will be installed in close proximity to each other near the foundation of the existing bridge structures. The Contractor shall carry out the drilling and grouting works in such a manner to prevent any damage to previously installed micropiles, to prevent any loss of ground, and to prevent ground movement at the existing bridge structures. The Contractor shall monitor movements of the existing structure during the installation of the micropiles from commencement and continue through to the end of substantial completion of the Contract. The Contractor shall adopt established method(s) of monitoring such as the use of monitoring pins or electronic devices, and record and report movements and readings in general on a weekly basis, and more frequently on a daily basis during active drilling and grouting operations, with copies forwarded to the Contract

Administrator. Where movements of 25mm are observed, the Contractor shall stop work and re-evaluate and modify the micropile installation and grouting method prior to continuing work.

The available working space is limited. The Contractor shall inspect the work area to ensure that adequate access and headroom are available for the proposed equipment and procedures for the micropile installation work.

7.04.02 Drilling

The Contractor shall employ drilling equipment and methods suitable for drilling through the anticipated subsurface conditions to be encountered and cause no damage or disruption to these conditions or any overlying or adjacent structure or service. The Contractor shall use steel casing during drilling and installation. Drilling shall be conducted under full head of water. Bentonite slurries to stabilize the holes are not permitted.

The upper cased sections of the micropiles shall be drilled using duplex drilling techniques with the cuttings returning up the inside of the casing. The lower uncased sections of the micropiles shall be installed using the hollow-core central reinforcing bars with sacrificial drill bits that allow the simultaneous drilling and injection of grout.

Drilling shall be conducted in a manner that does not result in significant loss of ground beyond the hole diameter. Disposed cuttings from the upper cased sections of the micropiles shall not exceed 110% of the theoretical borehole volume based on the outside diameter of the casing. Disposed cutting from the micropile installation/grouting process shall be collected at top of the upper cased sections of the micropiles to minimize the amount of chipping/cleaning required before the construction of the pile cap.

The Contractor shall determine and schedule all installation techniques such that there will be no interconnection or damage to previously installed micropiles.

7.04.03 Reinforcement Steel

7.04.03.01 General

Pile reinforcement steel (central bar and permanent casing) shall be installed as specified in the Contract Documents and detailed on the stamped Working Drawings.

7.04.03.02 Placement

The Contractor shall be responsible for determining the number of centering devices required. As a minimum, centralizers shall be provided at 3 m centre maximum spacing on the central bar reinforcement. The uppermost centralizer shall be located a maximum of 1.5 m from the top of the micropile. Centralizers shall permit the free flow of grout without misalignment of the reinforcement.

All pile top elevations shall be checked and adjusted to ensure all installed micropiles are installed to the planned elevations.

7.04.03.03 Connections

The pile reinforcement steel connections (splices and joints) shall be constructed to develop the required design strength of the pile section. The central bar reinforcement steel connections (splices) shall be constructed using mechanical connectors only. The casing connections shall be constructed using either mechanical connectors (e.g., threaded joints) or full penetration field welds.

The proposed pile splice/connection details shall be submitted to the Contract Administrator, for information purposes only, prior to use.

Reinforcement steel central bar connections shall not be in the same plane as casing connections/splices.

Secure lengths of casing and reinforcement steel central bar shall be joined in proper alignments and in such a manner that causes no eccentricity between the axes of the two joined lengths or the angle between them.

7.04.04 Grouting

7.04.04.01 General

The grout shall be installed as specified in the Contract Documents and as detailed on the stamped Working Drawings.

The Contractor shall provide systems and equipment to measure the grout quality, quantity and pumping pressure during the grouting operations.

During advancement of the hollow-core central reinforcement bar (with sacrificial drill bit), the Contractor shall continuously flush the hole using the thin flush grout. Flushing with water is not permitted.

Upon completion of drilling of the uncased section of the micropile to the design tip elevation, the Contractor shall inject the final structural grout from the lowest point of the drill hole until clean, pure structural grout flows from the top of the micropile (to be verified by specific gravity testing with a Baroid mud balance).

Subsequent to completion of grouting, all installation operations associated with completion of the micropile must ensure complete continuity of the grout column. The use of compressed air to directly pressurize the fluid grout is not permissible. The grout pressures and grout take volumes shall be controlled for each stage of each pile to prevent excessive heave or fracturing in the foundation soils or existing bridge structures. The entire micropile shall be grouted to the design cut-off level.

The grout within the micropiles shall be permitted to attain the minimum design strength prior to being loaded.

Any micropiles not installed according to the specifications shall be replaced, or otherwise remediated appropriately. The cost of replacement and any required foundation modifications are to be carried out at no additional cost to the Owner.

If necessary, the Contractor shall undertake cold weather protection requirements, preparation and protection in accordance with CSA CAN3-A23.1. The temperature of the grout during mixing and pumping shall be maintained between 10°C and 30°C.

7.04.04.02 Quality of Grout Mixture

7.04.04.02.01 General

Any grout mixture showing evidence of dampness, lumps, harden pieces, or contamination shall not be incorporated into the work.

The Contractor shall be responsible for testing of bleed, preparation and initial storage of grout cubes for determination of compressive strength, and delivery of the grout cubes to a testing laboratory designated by the Owner.

The Contractor shall employ staff from a testing company certified according to CSA A283 – Certification for Additional Tests 1B, by an organization accredited by the Standards Council of Canada, to carry out testing for bleed, making and curing of grout cubes and early strength determination.

Making of grout cubes for compressive strength test and testing of bleeding, shall be done on a level, vibration free surface.

The Contractor shall perform and record specific gravity testing using a Baroid mud balance following ASTM D4380-84 on the grout utilized for each and every micropile.

7.04.04.02.02 Bleed Requirements

The testing for bleed of the grout shall be according to CSA A23.2-1B.

Prior to the grouting operation, in the presence of the Quality Verification Engineer and the Contract Administrator, a trial batch shall be mixed and the grout tested for bleed, to ensure that the grout meets the requirements specified in the Contract Documents. The trial batch of grout shall not be used in the actual grouting operation unless it meets the requirements for bleed as specified herein.

During the grouting operation, bleeding measurements shall be performed on the grout sampled at the mixer. The measurements shall be performed and recorded at least once a day and as requested by the Contract Administrator.

The bleed test results shall be submitted to the Contract Administrator in writing at the end of each working day. The test results that indicate the grout is not meeting the requirements of the Contract Documents shall be reported immediately to the Contract Administrator and the grouting operation halted until the cause of the problem is identified and corrected.

7.04.04.02.03 Strength Requirements

Grout cubes shall be prepared as follows on site from the grout pumped into the micropile:

a) Three (3) sets of grout cubes, consisting of three (3) cubes each, shall be made each day the grouting operations are carried out.

b) The grout cubes shall be prepared and stored according to CSA A23.2-1B, and shall not be moved prior to demoulding.

c) The grout cubes shall be demoulded and transported to the laboratory within 24 hours ± 4 hours.

d) The grout cubes shall be transported in a sealed white opaque plastic bag containing at least 250 mL of water and maintained at a temperature between 15°C and 25°C.

e) Compressive strength testing shall be carried out on the grout cubes according to CSA A23.2-1B at 3, 7 and 28 days and the test results provided to the Contract Administrator.

f) The Contractor shall prepare and test additional grout cubes to determine when the grout has attained a compressive strength of 25 MPa.

7.05 Tolerances

The allowable tolerances are as follows:

a) Centreline of the installed micropiles shall not be more than 75 mm from that shown on the Contract Drawings.

b) Micropile hole alignment shall be within 2% of the total-length plan alignment.

c) Top elevation of micropiles shall be within +25 mm or -50 mm of maximum of the vertical design elevation.

d) Centreline of central bar reinforcement shall not be more than 19 mm from centerline of micropile casing.

7.06 Testing of Micropiles

7.06.01 General

Verification load tests shall be carried out on pre-production test micropile(s) and proof load tests shall be carried out on selected production micropiles. The micropile load testing shall be carried out according to the Working Drawings and as specified herein.

The Contractor shall provide to the Contract Administrator a minimum of three (3) Working Days notice of when the load tests will be carried out. The load tests shall be conducted at a time mutually acceptable to the Contractor and Contract Administrator.

The maximum load in the reaction piles/ground anchors shall not exceed 80% of the guaranteed minimum ultimate tensile strength of the central bar reinforcement.

The testing shall not be performed until after the grout in the micropiles (or reaction piles/ground anchors) has reached a minimum 7 days unconfined compressive strength of 25 MPa.

The load tests shall be closely monitored for the duration of the test by the Quality Verification Engineer and the test results recorded and submitted to the Contract Administrator.

7.06.02 Reaction System

The reaction system(s) for the pre-production and production micropile load tests shall be designed by the Contractor and shall be installed as detailed on the Working Drawings.

The Contractor shall determine the number of reaction piles (or ground anchors) required for proper execution of the axial compression load tests. The reaction piles or ground anchors shall be located no closer than 2 m to the micropile to be tested under axial compression conditions.

The Contractor shall make provisions, as appropriate and necessary, to ensure safety and structural stability of the reaction piles, ground anchors and their connection to the load frame and load apparatus.

7.06.03 Reference System, Testing Equipment and Procedures

The layout of the reference systems and testing equipment required for testing shall be as detailed on the Working Drawings and as specified herein.

The Contractor shall supply a suitable means for providing independent reference beams for measuring micropile head movement, jack, electronic load cell, dial gauges or electronic displacement transducers, anchor extension, and any other hardware necessary to carry out the load tests. A minimum of three (3) dial gauges or electronic displacement transducers and piano wire, is required. Dial gauges or displacement transducers shall have an accuracy of ±0.0254 mm (0.001 in). Load cells shall have an accuracy of ±2% of the maximum test load. The calibration curve between the jack pressure and the load shall be submitted to the Contract Administrator for information purposes.

All reference beams shall be independently supported with the support firmly embedded in the ground at a distance of not less than 2.5 m from the reaction system. Reference beams shall be sufficiently rigid to support instrumentation such that variations in readings do not occur.

All gauges, scales and reference points attached to the micropile (or reaction piles/ground anchors) shall be mounted so as to prevent movement relative to the micropile (or reaction piles/ground anchors) during the test.

The jacks shall be secured (with chains or other protective housing(s)) to provide adequate protection to personnel in the event of breakage of the micropile, ground anchor or loading system.

The Contractor shall perform the micropile load tests according to ASTM D-1143 and ASTM D-3689, superseded where applicable by the procedures specified in this Special Provision, and indicate the minimum following information:

a) Type and accuracy of apparatus for measuring load.

b) Type and accuracy of apparatus for applying load.

c) Type and accuracy of apparatus for measuring the micropile displacement.

d) Type and capacity of reaction load system, including sealed Working Drawings.

e) Hydraulic jack calibration report.

7.06.04 Pre-Production Micropile Load Tests

7.06.04.01 General

The Contractor shall perform pre-production load axial compression tests on sacrificial micropiles to verify the design assumptions and the appropriateness of the proposed construction procedures, prior to installation of production micropiles. In the pre-production axial compression micropile test, the micropile shall be subjected to an axial compressive load equal to 2.5 times the factored geotechnical axial resistance at Ultimate Limit States (ULS); but not necessarily to failure.

For the purposes of the pre-production axial compression load test, ground anchors or micropiles will be used to provide the tensile reaction.

After completion of the axial compression load test on the sacrificial micropiles, both of the ground anchors (reaction piles) shall be tested in tension to failure (if possible) so that the ultimate grout-to-ground bond can be assessed for design verification purposes.

The pre-production sacrificial micropile load tests with dead weight, or reaction piles/ground anchors shall be designed, constructed and tested by the Contractor and, based on the load test results, the design verified by the Contract Administrator prior to approval being given to the Contractor to start installation of the production micropiles. Approval to start production micropiles shall be given no later than three (3) Working Days after completion of all of the pre-production load tests.

7.06.04.02 Installation of Pre-Production Sacrificial Test Micropiles

The Contractor shall install five (5) micropile pre-production load test sections (consisting of one (1) central micropile and two (2) reaction piles/ground anchors) at the following sites:

- Little East River Bridge No. 1;
- Little East River Bridge No. 2;
- Little East River Bridge No. 3;
- Little East River Bridge No. 4; and,
- Ragged Creek Bridge.

The pre-production test piles and reaction piles will be installed near, but a minimum of 5 m away from, the proposed micropile group cap at locations selected by the Contract Administrator. Due to the variable subsurface conditions, the pre-production test piles are to be installed on the south side of the following bridge structures:

- Little East River Bridge No. 1;
- Little East River Bridge No. 2; and,
- Little East River Bridge No. 3.

The Contractor shall install and test one (1) micropile under axial compressive loading and both reaction piles under axial tensile loading at each test section location.

The Contractor shall employ the drilling and grouting methods, casing and other reinforcement details, and depth of embedment for the test micropiles identical to those to install the production micropiles, except where specified otherwise by the Contract Administrator. In this regard, the upper portion of the pre-production test micropile, down to approximately the same elevation as the underside of the tremie plug is to be free from the overburden soils by bond-breaker or other suitable method. The underside of the tremie plug at each of the test location is as follows:

- Little East River Bridge No. 1 – Elevation 317.8 m;
- Little East River Bridge No. 2 – Elevation 321.5 m;
- Little East River Bridge No. 3 – Elevation 321.0 m;
- Little East River Bridge No. 4 – Elevation 324.0 m; and,
- Ragged Creek Bridge – Elevation 315.5 m;

The details of the test pile set-up area (including any excavation, over-drilling and/or bond-breaker) shall be submitted to the Contract Administrator for information purposes only.

The Quality Verification Engineer shall be responsible for logging the holes for the pre-production micropiles to be tested and for the associated reaction piles (ground anchors). The subsurface conditions in terms of stratigraphy at the test locations are required for proper interpretations of the load test results. The Contractor shall also make provisions, as appropriate, to facilitate the Contract Administrator in carrying out his own logging of the holes for the pre-production sacrificial micropiles and the associated reaction piles.

Upon completion of the sacrificial, pre-production micropile load tests, and prior to demobilization from the site, the test section area is to be restored to near original conditions as per the direction of the Contract Administrator.

7.06.04.03 Test Procedures and Measurement

The Contractor shall load the tested micropile(s) to a minimum of 250% of the design load (DL) (i.e., 2.5 DL). The jack shall be positioned at the beginning of the tests such that unloading and repositioning of the jack during the test will not be required. The Contractor shall apply an Alignment Load (AL) to the piles prior to setting the movement recording devices. This Alignment Load shall be no more than 10% of the Design Load (i.e., 0.1 DL); dial gauges shall be zeroed at the first setting of the AL.

The Contractor shall carry out the axial compression load test by loading the micropile and recording the micropile head movement according to the load increments presented in Table 1. The axial design load and maximum axial test load (TL) for each of the sites shall be as follows:

- Little East River Bridge No. 2 – DL = 450 kN, TL = 1,125 kN;
- Little East River Bridge No. 2 – DL = 480 kN, TL = 1,200 kN;
- Little East River Bridge No. 3 – DL = 450 kN, TL = 1,125 kN;
- Little East River Bridge No. 4 – DL = 400 kN, TL = 1,000 kN; and,
- Ragged Creek Bridge – DL = 410 kN, TL = 1,025 kN.

The Contractor shall maintain each load increment minimum duration indicated in Table 1 or until the settlement rate is less than 1 mm/log cycle of time.

Table 1
Axial Micropile Compression Load Test Increments

Load	Minimum Hold Time (Minutes)
AL	-
0.15 DL	2.5
0.30 DL	2.5
0.50 DL	10
AL	10
0.15 DL	1
0.45 DL	1
0.60 DL	2.5
0.70 DL	2.5
0.80 DL	10
0.90 DL	10
1.00 DL	30
AL	10
0.15 DL	1
1.00 DL	1
1.15 DL	2.5
1.30 DL	2.5
1.50 DL	10
AL	10
0.25 DL	2.5
0.50 DL	2.5
0.75 DL	2.5
1.00 DL	10
1.25 DL	2.5
1.50 DL	2.5
1.75 DL	10
2.00 DL	60

Load	Minimum Hold Time (Minutes)
1.50 DL	5
1.00 DL	5
0.50 DL	5
AL	10
0.25 DL	2.5
0.50 DL	2.5
0.75 DL	2.5
1.00 DL	10
1.25 DL	2.5
1.50 DL	2.5
1.75 DL	10
2.00 DL	10
2.25 DL	10
2.50 DL	60
2.00 DL	5
1.50 DL	5
1.00 DL	5
0.50 DL	5
AL	10

AL = Alignment Load
DL = Design Load
TL = maximum test load = 2.5 DL unless failure occurs at a lower load increment

The Contractor shall carry out an axial tension load test on each of the reaction piles (ground anchors) following the completion of the pre-production micropile axial compression load test. The tension load tests shall be carried out in a manner to induce uplift failure of the reaction piles (ground anchor) to enable assessment of the ultimate value of the grout-to-ground bond.

Construction and installation procedures used for the grouted section of the tested reaction piles (ground anchors) shall be identical to those used for the grout-to-ground section of the pre-production and production micropiles and the grouted section shall be between or below the following elevations:

- Little East River Bridge No. 1 – below Elevation 313.3 m;
- Little East River Bridge No. 2 – between Elevations 317.7 m and 309.4 m;
- Little East River Bridge No. 3 – below Elevation 309.1 m;
- Little East River Bridge No. 4 – below Elevation 321.0 m; and,
- Ragged Creek Bridge – below Elevation 312.5 m.

The load increments and hold times for the uplift/axial tension load test shall be as shown in Table 2.

Table 2
Axial Reaction Pile (Ground Anchor) Tension Load Test Increments

Load	Minimum Hold Time (Minutes)
AL	-
0.15 TL	2.5
0.25 TL	2.5
AL	1

Load	Minimum Hold Time (Minutes)
0.15 TL	2.5
0.30 TL	2.5
0.50 TL	2.5
AL	1
0.15 TL	2.5
0.45 TL	2.5
0.60 TL	2.5
0.75 TL	2.5
AL	1
0.15 TL	2.5
0.45 TL	2.5
0.75 TL	2.5
0.90 TL	5.0
1.00 TL	5.0
0.75 TL	5.0
0.50 TL	5.0
0.25 TL	5.0
AL	5.0

AL = Alignment Load
TL = Maximum Test Load estimated to cause failure

The movement of the test pile (or reaction pile/ground anchor) shall be measured at each load increment. The load hold period shall be started as soon as the test load is applied. The pile movement shall be measured and recorded, with respect to a fixed reference, at 1, 2, 3, 4, 5 and 10 minutes, and at 10 minute increments thereafter (if applicable). For durations longer than 60 minutes, readings shall be taken at 30 minute intervals (if applicable).

7.06.04.04 Design Acceptance Criteria for Pre-Production Load Tests

The acceptance criteria for micropile pre-production load tests are:

a) Sustaining the axial compression design load (1.0 DL) with no more than 25 mm total vertical movement at the top of the pile, as measured relative to the top of the pile prior to the start of testing. If an Alignment Load is used, then the allowable movement will be reduced by multiplying by a factor of (DL-AL)/DL.

b) Creep rate at the end of the 2.5 DL increment on axial test micropiles not greater than 1 mm/log cycle time from 1 to 10 minutes or 2 mm/log cycle time from 6 to 60 minutes and having a linear or decreasing creep rate.

c) Failure does not occur at the 2.5 DL axial load where failure is defined as the slope of the applied load versus deflection (at end of load increment) curve exceeding 0.15 mm/kN.

d) Overall micropile alignment of all test micropiles within 2% of vertical. This is required given the close spacing of the micropiles to avoid interaction between or intersection of micropiles at depth.

e) The above is under the assumption that the test piles have been installed in accordance with the specifications and drawings to a proper standard of care.

7.06.05 Production Micropile Load Tests and Target Criteria

7.06.05.01 General

The Contractor shall carry out proof load tests (under axial compression conditions) on a minimum of one (1) production micropile at each abutment at each bridge site (i.e. a minimum of 10 proof load tests). The Contractor shall submit to the Contract Administrator a proposal recommending the production micropile(s) to be selected for testing, however, the final selection will be up to Contract Administrator.

The selected micropiles for proof testing will be tested no sooner than 7 days after installation to allow the grout to reach sufficient strength. It is noted that the use of adjacent vertical micropiles as reaction anchors is acceptable, provided that the minimum spacing requirements between the reaction piles and the test pile (as defined in Section 7.06.02) can be satisfied. The reaction system, including any reaction anchors, if necessary, is to be entirely designed by the Contractor and submitted to the Contract Administrator for information purposes.

The Contractor shall set-up the reaction frame and load test set-up, complete with jacks, load cells and gauges in a manner similar to the pre-production load tests. The Contractor shall repair any previously installed production micropiles that may have been damaged during the course of proof load testing to the approval of the Contract Administrator and at no cost to the Owner.

The Contractor shall carry out proof load testing in axial compression and loading in increments to 1.6 DL as shown in Table 3.

Table 3
Axial Production Micropile Load Test Increments

Load	Minimum Hold Time (Minutes)
AL	-
0.15 DL	2.5
0.30 DL	2.5
0.45 DL	2.5
0.60 DL	2.5
0.75 DL	2.5
0.85 DL	10*
0.95 DL	10*
1.00 DL	10*
1.30 DL	10*
1.60 DL	10*
1.00 DL	4
0.75 DL	4
0.50 DL	4
0.25 DL	4
AL	4

AL = Alignment Load
DL = Design Load as indicated in Section 7.06.04.03
* Hold until acceptance criterion for creep movement is satisfied as specified in Section 7.06.05.02 of this specification.

7.06.05.02 Target Criteria for Production Load Tests

The target criteria for proof load tests shall be as follows:

a) Total vertical movement at the top of the micropile shall not be greater than 25 mm (at 1.0 DL), as measured relative to the top of the micropile prior to the start of testing.

b) Creep rate at the end of the 1.00 DL and 1.60 DL load increments shall not be greater than 1 mm/log cycle of time.

c) Failure does not occur where failure is defined as the slope of the applied load versus deflection (at the end of load increments 1.00 DL and 1.60 DL) curve exceeding 0.15 mm/kN.

d) Overall micropile alignment of all production micropiles is within 2% of vertical.

7.07 Management of Excess Material

Management of excess material shall be according to OPSS 180.

7.08 As-Constructed Drawings

As-constructed drawings shall be prepared by the Contractor for Owner designed installations as follows:

a) For all work incorporated in the completed structure that required the submission of Working Drawings.

b) For all changes from the original Contract requirements.

The as-constructed drawings shall be submitted to the Contract Administrator in a reproducible format prior to final acceptance of the work.

The as-constructed drawings shall be dated and bear the seal and signature of the Quality Verification Engineer.

8.0 MEASUREMENT FOR PAYMENT

8.1 Pre-Production Micropile Testing

A count will be made of the number of pre-production micropiles that are load tested and satisfy the Contract requirements.

8.2 Production Micropile

Measurement will be made in metres of the micropiling left in place after cut-off.

8.3 Grouting

Measurement will be made in cubic metres of grout pumped into the subsurface during the installation of the micropiles.

8.4 Production Micropile Testing

A count will be made of the number of production micropiles that are load tested and satisfy the Contract requirements.

9.0 BASIS FOR PAYMENT

9.1 Supply Equipment for Installing Micropiles – Item

Payment at the Contract price for the above items shall be full compensation for all labour, equipment and material required to do the work.

It will be assumed, for payment purposes, that 20% of the work under this item has been completed when the satisfactory performance of the equipment has been demonstrated to the Contract Administrator by the installation of one (1) pre-production micropile and one (1) production micropile. The remaining 80% will be paid on the satisfactory completion of the installation.

9.2 Grout for Micropiles – Item

Payment at the Contract price for the above items shall be full compensation for all Labour, Equipment and Material required to do the work.

9.3 Pre-Production Micropile – Item

Payment at the Contract price for the above items shall be full compensation for all labour, load testing, equipment and material required to do the work.

No payment will be made for micropiles that fail the load test.

For pre-production micropiles that fail the load test, payment for any additional work directed by the Contract Administrator shall be made as Extra Work.

No payment will be made for additional work for pre-production micropiles that fail to meet the Design Acceptance Criteria for Pre-Production Load Tests.

9.4 Production Micropile – Item

Payment at the Contract price for the above items shall be full compensation for all labour, equipment and material required to do the work.

9.5 Production Micropile Testing – Item

Payment at the Contract price for the above tender item shall be full compensation for all labour, equipment and materials required to do the work.

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444