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DETAIL FOUNDATION INVESTIGATION REPORT
REHABILITATION OF THE ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00, AGREEMENT NO. 3006-E-0049
MINISTRY OF TRANSPORTATION, ONTARIO
– SOUTHWESTERN REGION

Submitted to:

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (Morrison Hershfield) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a detail foundation investigation at the site of the proposed rehabilitation of the Argyle Street South Bridge on the former Highway 6 over the Grand River in Caledonia, Ontario. The location of the bridge is shown on the Site Location Plan, Figure 1.

Consideration is being given to complete a rehabilitation of the existing bridge and foundations that would be suitable for a five to ten year period with the potential for full rehabilitation or the construction of a replacement structure to follow.

The purpose of the detail foundation investigation is to determine the subsurface soil, rock and groundwater conditions at the bridge site by drilling boreholes and carrying out in-situ tests and laboratory tests on selected samples. The terms of reference for the work are outlined in Golder's Total Project Management (TPM) for Detail Design Services proposal P61-3174 dated December 11, 2006. The work was carried out in accordance with our Quality Control of TPM Services Plan, Agreement No. 3006-E-0049, dated February 13, 2007 (updated July 11, 2007).

Morrison Hershfield provided Golder with drawings for the existing bridge. The existing MTO foundation investigation report available for the area of the site through Geocres (Geocres No. 30M4-101) was reviewed together with the April 1927 design drawings for the existing bridge. Bedrock is exposed in the riverbed at the existing bridge. The borehole data for the area of the site, including the results of previous investigations available for the dam and Canadian National Railway (CNR) bridge located approximately 600 metres upstream of the site, the recent Imperial Oil pipeline crossing of the Grand River approximately 1.6 kilometres upstream of the site and the recently constructed forcemain immediately downstream of the site, indicate that at least the upper 4 to 5 metres of the rock is highly weathered and fractured with gypsum seams and some cavities attributed to gypsum solutioning. Rock Quality Designations (RQDs) in this zone range from 0 to 20 per cent and are typically zero. In addition, existing borehole data indicate that approximately 3.5 metres of fill has been placed in the existing bridge approaches.

2.0 SITE DESCRIPTION

The existing bridge, constructed circa 1927, is a two lane, nine span structure carrying the north-south directions of Argyle Street pedestrian and road traffic over the Grand River. The bridge is a designated heritage structure which was rehabilitated in 1984. Each span of the existing structure is about 22 metres long, for a total length of approximately 198.5 metres. The bridge is about 7 metres wide. In 2002, vehicle weight limits were posted since the bridge was found to be in an advanced state of deterioration that limited the load carrying capacity of the structure. Site photographs are provided in Appendix B.

Based on the design drawings available for the existing bridge and our observations during the field investigation, the existing structure is founded on spread footings bearing on the rock surface.

The existing deck surface is at about elevation 191.2 metres. The water level in the Grand River was at about elevation 185.7 metres during the current field investigation. All elevations in this report are referenced to geodetic datum.

3.0 INVESTIGATION PROCEDURES

The preliminary foundation investigation at the site conducted by Golder was reviewed in conjunction with the preparation of this report. This information is identified as follows:

- Geocres No. 30M4-101 and Golder Report No. 021-3233 entitled "Preliminary Foundation Investigation and Design, Rehabilitation or Replacement of the Argyle Street South Bridge Over the Grand River, Highway 6, Caledonia, Site 9-2, GWP 3805-01-00" dated April 1, 2004, revised May 3, 2004.

The records of the pertinent boreholes and related laboratory test results from the above noted report are attached to this report in Appendix A for reference purposes. The borehole locations are shown on Figure 1. Selected photographs of the rock cores obtained during the previous and current investigation are provided in Appendix B.

During the previous investigation, boreholes 1 and 2 were drilled adjacent to the bridge abutments to depths of 17.1 and 17.4 metres, respectively. Boreholes 3 and 4 were drilled at the approaches to depths of 6.9 metres. Boreholes 5 through 8 were drilled from the bridge at or near to various pier locations to depths varying from 14.3 to 17.3 metres below the existing bridge deck. Boreholes 6 and 8 were drilled through the existing pier footings.

The field work for the current investigation was carried out between April 30 and June 21, 2007 with a CME-45 drill rig mounted on skids supplied and operated by a specialist drilling contractor. The boreholes, numbered 101 to 106, were drilled through or near the existing pier footings to depths varying from 15.7 to 17.3 metres below the existing bridge deck. Boreholes 101, 102, 103 and 104 were drilled from the west sidewalk while boreholes 105 and 106 were drilled from the east sidewalk. The skid mounted rig was moved to the various locations with a winch and a boom truck.

All of the boreholes were backfilled and abandoned in compliance with MTO and Ontario Regulation 128/03 recommended procedures. The pier footings were backfilled with premixed concrete and the sidewalks were patched with quick set, high strength concrete.

The field work was supervised on a full-time basis by a senior member of our engineering staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations and logged the boreholes. The soil and rock samples were identified in the field, placed in labeled containers and transported to our laboratory in London, Ontario for further examination. The rock cores were sent to our Mississauga laboratory where they were logged in detail by a geologist who is familiar with the geology of the area. In addition, the total core recovery (TCR), solid core recovery (SCR) and RQD were measured and unconfined compressive strength testing was carried out on four NQ size samples of the gypsiferous rock. The results of the field and laboratory testing from the current investigation are shown on the Record of Borehole sheets and on the Figures in Appendix C.

The cored length of bedrock at each borehole location is tabulated below:

Borehole Number	Component of Structure	Borehole Location		Collar Elevation (m)	Overburden or Concrete/Rock Interface		Cored Length (m)
		Northing (m)	Easting (m)		Elevation (m)	Depth (m)	
101	Pier 1	4 770 440.9	267 966.2	191.15	183.96	7.19	11.10
102	Pier 3	4 770 399.0	267 951.7	191.40	183.96	7.44	9.03
103	Pier 5	4 770 357.1	267 937.3	191.43	183.93	7.50	9.48
104	Pier 8	4 770 292.3	267 915.0	191.23	184.71	6.52	11.93
105	Pier 6	4 770 330.8	267 939.1	191.34	183.84	7.50	9.69
106	Pier 4	4 770 373.0	267 953.7	191.48	184.04	7.44	10.40
1	South Abutment	4 770 263.3	267 921.1	189.69	183.65	6.04	11.06
2	North Abutment	4 770 467.2	267 971.4	190.23	184.59	5.64	11.76
3	North Approach	4 770 478.9	267 978.8	190.07	-	-	-
4	South Approach	4 770 251.9	267 912.7	190.86	-	-	-
5	Between Piers 3 & 4	4 770 387.3	267 947.7	191.42	184.59	6.83	8.87
6	Pier 7	4 770 313.9	267 922.9	191.27	184.44	6.83	9.52
7	Between Piers 5 & 6	4 770 342.4	267 944.4	191.44	184.89	6.55	7.71
8	Pier 2	4 770 415.8	267 968.9	191.23	183.85	7.38	11.14

Boreholes 3 and 4 were approach boreholes and, thus, were not cored.

In addition, a survey of the bridge was conducted to determine the current profile along the bridge and to estimate the post construction settlements. These findings are summarized in Table I and on Figures 4 and 5. The settlements were estimated from a comparison of the survey data and the original bridge design drawings.

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Surficial Geology

The surficial soil deposits are comprised of the Wentworth Till sheet, a sandy silt to clayey silt till deposit with irregular interbeds of silty to sandy deposits. This till sheet was transported in a southwestward direction across the Caledonia area by glaciers that emanated from the Lake Ontario basin. This direction of glacial movement is indicated by the numerous elongate northeast to southwest orientated drumlin ridges comprised of till that dot the area as shown on Figure 2. The advance of the glacial ice associated with the deposition of the till also scoured the bedrock surface, greatly influencing the present bedrock surface topography that underlies the area.

Much of the area within the Grand River Valley was inundated by post glacial ponds that deposited a blanket of glaciolacustrine clayey silt and silty clay over much of the low areas. These deposits comprise the Haldimand Clay Plains that are characteristic of the Grand River Valley. The clay sequence may also contain local interbedded zones of silt and sand. Locally, the drumlin ridges tend to protrude through the clay.

The main drainage courses which pass through the region, such as the Grand River, contain recent alluvial deposits of clays, silts and sands associated with the stream channels and adjacent flood plains. In the area of the site, the Grand River Valley is fully incised through the overburden to expose the underlying rock in the riverbed.

4.2 Bedrock Geology

The site is underlain by Silurian-age dolomite, shaley dolomite and shale of the Salina Formation. The Salina Formation hosts the gypsum deposits of the Grand River Valley. The Salina Formation is underlain by the Guelph Formation. The strata are near flat lying with a gentle southward dip of approximately 0.5 per cent.

The Salina Formation consists of six members (Members A, B, C, E, F and G). The D Member (halite salt strata of the Salina Formation) was not deposited in this area. The C Member is present in the area of the site. The regional bedrock geology is shown on Figure 3.

4.3 Site Stratigraphy

The detailed subsurface soil, rock, surface water and groundwater conditions encountered at the borehole locations, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A2. The stratigraphic boundaries shown on the borehole sheets and Drawing 1 are inferred from non-continuous sampling and observation of limited core recovery and, therefore, may represent transitions between soil and rock types rather than exact planes of geological change. Subsurface conditions will vary between and beyond the borehole locations.

In summary, the subsoils at the abutments and approaches generally consist of variable thicknesses of pavements, fill and topsoil materials to between elevation 186 and 189 metres. These deposits are underlain by generally thin deposits of sand and gravel, sandy silt, silt, clayey silt and sand over the bedrock. At the pier locations, the bedrock is exposed below about 0.4 to 0.6 metres of water and/or thin sandy silt deposits. The bedrock surface was encountered at elevations between 183.6 and 184.9 metres at the borehole locations.

Locations and elevations of the borings, together with the interpreted stratigraphical profiles, are shown on the attached Drawing 1.

Detailed descriptions of the subsurface conditions encountered in the boreholes put down during both phases of the investigation (October/November 2003 – preliminary design and April/May 2007 – detail design) are provided in the following sections.

4.3.1 Pavement and Concrete

Boreholes 5, 8, and 101 through 106 were advanced through the existing 140 to 200 millimetre thick concrete sidewalks. Boreholes 6, 8, 103, 105 and 106 were cored through the concrete footings of the existing bridge piers. The footings were 790 to 1430 millimetres thick. The underside of footings was at approximately elevation 183.8 to 184.4 metres. Possible concrete was encountered but not recovered in borehole 101. Laboratory testing of the concrete cores indicated compressive strengths of 23 to 50 megapascals with an average of about 36 megapascals.

A 100 millimetre thick paving stone layer was encountered at the surface of borehole 2. Boreholes 3 and 4 encountered about 150 and 200 millimetres of asphalt at the north and south approaches, respectively.

4.3.2 Fill and Topsoil

A 430 millimetre thick fill layer of cobbles and boulders was encountered from elevation 185.3 metres over the possible concrete pier footing in borehole 101. A 160 millimetre thick layer of sandy silt fill was encountered at elevation 185.4 metres over the concrete pier foundation in borehole 105. Possible rock fill was encountered at elevation 185.3 metres but not recovered in borehole 102.

At the north approach, the asphalt was underlain by about 1.1 metres of granular base materials over 1.4 metres of firm clayey silt fill and 0.3 metres of topsoil. At the south approach, the asphalt was underlain by about 0.7 meters of granular base materials. At boreholes 1 and 2, advanced adjacent to the south and north abutments, respectively, layers of compact silty sand and sandy silt fill and stiff to hard clayey silt fill were encountered to depths of about 3.5 to 4.1 metres below ground surface or approximately elevation 186.2 metres. Also, 0.8 metres of silty sand fill with concrete, wood, gravel, cobbles and boulders was encountered over the concrete pier foundation in borehole 8. Standard penetration testing in the fill/topsoil materials indicated N values between 5 and 36 blows per 0.3 metres penetration. The fill materials had water contents of about 5 to 37 per cent with an average of about 15 per cent. Figure A-1 in Appendix A2 shows a gradation curve for the sandy silt fill materials recovered from borehole 4.

4.3.3 Sand and Gravel

A 1.5 metre thick layer of dense sand and gravel was encountered at elevation 186.1 metres beneath the fill materials in borehole 2. The sand and gravel deposit had a single N value of 37 blows per 0.3 metres penetration and a water content of about 9 per cent.

4.3.4 Clayey Silt

A 0.6 metre thick layer of stiff clayey silt was encountered at elevation 187.2 metres beneath the topsoil in borehole 3. The clayey silt deposit had a single N value of 9 blows per 0.3 metres and a water content of about 32 per cent.

4.3.5 Silt

Beneath the sandy silt in borehole 1 and the fill in borehole 4, silt layers 0.3 to 1.6 metres thick were encountered at elevation 185.3 metres and 186.7 metres, respectively, above the bedrock. The silt layer in borehole 1 had standard penetration test N values of 37 blows per 0.3 metres penetration and 70 blows per 150 millimetres penetration. The water contents were about 11 and 17 per cent.

4.3.6 Sand

Beneath the clayey silt, borehole 3 encountered a 0.9 metre thick sand deposit at about elevation 186 metres over the layers of sandy silt material. The sand deposit had a standard penetration test N value of 22 blows per 0.3 metres penetration based on a single standard penetration test. The water content of the sand sample collected was about 18 per cent.

4.3.7 Sandy Silt

Beneath the fill in borehole 1 at elevation 186.2 metres and in boreholes 3 and 4 at elevations 185.7 and 186.4 metres, respectively, deposits of compact to dense sandy silt were encountered. Where fully penetrated in borehole 1, the sandy silt layer was about 0.9 metres thick. Boreholes 3 and 4 were terminated at a depth of 6.9 metres in dense sandy silt layers after exploring those layers for some 2.4 metres. Also, a 0.3 metre thick deposit of sandy silt was encountered at elevation 184.9 metres over the bedrock in the river bed at borehole 5. The sandy silt layers had standard penetration test N values of 22 to 49 blows per 0.3 metres penetration and water contents between about 8 and 22 per cent. Figure A-2 in Appendix A2 shows a gradation curve for the sandy silt recovered from borehole 1.

4.3.8 Bedrock

A Golder geologist, who is familiar with the geology of the Caledonia area, logged the rock cores from boreholes 101 to 106 as well as boreholes 1, 2, 5, 6, 7 and 8 from the preliminary foundation investigation. These boreholes were drilled to characterize the founding conditions for the existing and proposed bridge abutments and piers. The rock was continuously cored with a swivel type double tube NQ size wire line core barrel, except for a 1 metre interval in borehole 2 where two standard penetration test samples were obtained in the rock. The core was carefully removed from the barrel following each run and care was taken to identify machine breaks, which are not counted in the SCR and the RQD values. Detailed descriptions of the bedrock are provided on the Record of Borehole sheets and the bedrock stratigraphy is shown on Drawings 1, 2 and 3. The following is a brief summary of the rock conditions.

The rock cores consisted of beds of gypsum, shale, dolostone and mudstone as detailed on the Record of Borehole sheets. The predominant rock strata have been identified as:

- Unit 1 - Shale to Dolomitic shale
- Unit 2 - Dolostone/Gypsiferous Dolostone
- Unit 3 - Gypsum
- Unit 4 - Gypsiferous Mudstone

and these units are shown on Drawings 1, 2 and 3.

Recovery in the upper weathered portions of the boreholes was very low, which is typical of the area, and attributed to gypsum dissolution, normally characterized by voids and/or vuggy intervals. Poor recovery is not attributed to the drilling techniques. No sudden loss of drill pressure or other evidence of large voids in the rock was noted during drilling and coring.

In order to estimate the extent of the highly weathered/solutioned upper bedrock zone, depths from inferred top of bedrock to rock with TCR greater than 80 per cent at each borehole are tabulated below:

Borehole Number	***Location***	***Bedrock Surface Elevation (m)***	***Approximate Elevation of >80% Total Core Recovery (m)***	***Inferred Thickness of Highly Weathered/ Solutioned Upper Bedrock (m)***
101	Pier 1	183.96	177.0	7.0
102	Pier 3	183.96	178.7	5.3
103	Pier 5	183.93	180.3	3.6
104	Pier 8	184.71	180.1	4.6
105	Pier 6	183.84	180.2	3.6
106	Pier 4	184.04	180.3	3.7
1	South Abutment	183.65	180.2	3.5
2	North Abutment	183.59	177.3	6.3
5	Between Piers 3 & 4	184.59	179.5	5.1
6	Pier 7	184.44	180.2	4.2
7	Between Piers 5 & 6	184.89	178.8	6.1
8	Pier 2	183.85	178.6	5.3

Dolomitic Shale (Unit 1)

Two distinct beds of dolomitic shale were encountered in the boreholes. The upper bed was encountered from elevation 180.7 to 184.7 metres in all boreholes in which rock was cored. The upper dolomitic shale bed was slightly to completely weathered, light to dark grey, and was encountered beneath the silt in borehole 1, beneath the sandy silt in borehole 5, and beneath the concrete footings of the existing bridge piers in boreholes 6, 8, 101, 102, 103, 105 and 106, beneath the dolostone in boreholes 2, 6, and 7 and beneath the dolostone boulders in borehole 104. The upper dolomitic shale was highly fractured and classified as weak to moderately strong. The RQD measured in the upper dolomitic shale ranged from 0 to 60 per cent, but was generally less than 20 per cent, with only 30 per cent of the runs having RQDs of greater than zero. The measured TCR values of the upper dolomitic shale ranged from 0 to 100 per cent and the SCR ranged from 0 to 80 per cent. The upper dolomitic shale is considered to be within the weathered/solutioned zone. It is considered that this bed originally contained significant amounts of gypsum and would probably have been originally described as gypsiferous dolostone.

A bed of lower dolomitic shale was encountered between elevations 173.2 and 175.8 metres below the lower gypsum in boreholes 1 and 2. The lower dolomitic shale bed was fresh, grey, medium strong and thinly laminated. The RQD measured on the lower dolomitic shale ranged from 8 to 33 per cent with TCR values ranging from 75 to 87 per cent and SCR values ranging from 50 to 95 per cent.

Shale (Unit 1)

A bed of slightly weathered to fresh, blue-grey, fine grained, weak shale to gypsiferous mudstone was encountered in borehole 104 beneath the dolomitic shale. An intact sample of the weak shale to gypsiferous mudstone had a compressive strength of 22 megapascals based on the results of the compressive strength testing. These results are presented on Figure C-1 of Appendix C. This material has a water content of 5 per cent and a unit weight of 23.1 kilonewtons per cubic metre.

A bed of green shale was encountered in borehole 106 beneath the dolomitic shale. Beds of fresh, grey, medium strong non-dolomitic/calcareous shale were encountered in borehole 1 beneath strata of dolomitic shale, gypsum and dolostone. A bed of grey shale to light grey dolomitic shale was encountered beneath the dolostone in borehole 8.

The measured TCR values of the shale ranged from 59 to 100 per cent, the SCR ranged from 0 to 83 per cent and the RQD ranged from 0 to 77 per cent. Typically, the shale beds were present between elevations 180.1 and 181.1 metres and marked the transition zone between the weaker solutioned zone and the underlying stronger, more intact rock.

Dolostone (Unit 2)

Dolostone boulders were encountered on the riverbed at borehole 104. Beneath the mudstone in borehole 102, a bed of slightly weathered to fresh, greenish brown and white, weak to moderately strong dolostone was encountered. Beds of slightly weathered to fresh, light brown, laminated, vuggy dolostone were encountered beneath the sand and gravel and beneath the gypsum in borehole 2, the upper dolomitic shale in borehole 6 and beneath the cobbles and boulders in borehole 7. The dolostone was classified as strong in borehole 2 and medium strong in borehole 7. Dolostone fragments were recovered in borehole 6.

The measured TCR values of the dolostone ranged from 0 to 100 per cent, the SCR ranged from 0 to 100 per cent and the RQD ranged from 0 to 75 per cent. Within the weathered/solutioned upper bedrock zone, the RQD measured 0 to 43 per cent with SCR values less than 30 per cent and TCR values of less than 57 per cent.

Gypsiferous Dolostone (Unit 2)

A bed of slightly weathered to fresh, grey-brown to grey-brown and white to light brown, weak to moderately strong gypsiferous dolostone was encountered beneath the shale in borehole 1, the gypsum in boreholes 1, 5, 6 and 8, dolomitic shale in boreholes 5, 6, 7, 8, 101 and 103, beneath the dolostone in borehole 102, beneath the gypsiferous mudstone in boreholes 104 and 105, and beneath the shale in borehole 106.

Based on the recoveries obtained in the boreholes, the upper solutioned zone in the gypsiferous dolostone is above elevation 175.6 to 180.8 metres. The measured TCR values of the upper solutioned zone ranged from 22 to 57 per cent, the SCR ranged from 3 to 43 per cent and the RQD ranged from 0 to 43 per cent. Only one run had an RQD of greater than zero. Below elevation 175.6 to 180.8 metres, the intact rock had TCR values of 83 to 100 per cent, SCR values of 42 to 90 per cent and RQD values of 32 to 83 per cent.

The results of laboratory testing indicate compressive strengths of 24 to 25 megapascals for intact samples of the gypsiferous dolostone. The unit weight varied between 22.6 and 23.3 kilonewtons per cubic metre. The results of the unconfined compression tests are presented on Figures C-2 and C-3. Water contents of 4 and 9 per cent were measured on samples of the gypsiferous dolostone.

Gypsum and Shaley Dolostone (Unit 3)

A bed of fresh, white, medium strong, nodular to coliform gypsum and strong, fresh, light brown, laminated shaley dolostone with nodular gypsum was encountered between beds of gypsiferous dolostone in borehole 8. TCR, SCR and RQD values of 96, 50 and 41 per cent, respectively were measured in the core from this material.

Gypsum (Unit 3)

Beds of weak to medium strong gypsum were encountered beneath the shale, dolostone and dolomitic shale in borehole 1 and beds of strong gypsum were found beneath the dolomitic shale and dolostone in borehole 2. Nodular gypsum with dolomitic shaley partings or bands was encountered beneath the dolostone in boreholes 5 and 6.

The measured TCR values of the gypsum ranged from 59 to 100 per cent, the SCR ranged from 0 to 95 per cent and the RQD ranged from 0 to 67 per cent.

Gypsiferous Mudstone (Unit 4)

Beneath the dolomitic shale, a bed of slightly weathered to fresh, grey to grey-brown to grey-brown and white, weak to moderately strong gypsiferous mudstone was encountered in boreholes 102 to 105. The mudstone in boreholes 102 and 103 is within the upper solutioned bedrock zone. TCR, SCR, and RQD values of 45 to 75 per cent, 20 to 48 per cent and 13 to 47 per cent, respectively, were measured in this zone. The mudstone encountered within boreholes 104 and 105 is considered to be intact rock with measured TCR values of 78 to 100 per cent, SCR values of 42 to 85 per cent and RQD values of 20 to 68 per cent.

An intact sample of the gypsiferous mudstone had a compressive strength of 28 megapascals as shown on Figure C-4. The unit weight of the gypsiferous mudstone is 24.7 kilonewtons per cubic metre and the water content is 4.0 per cent.

4.4 Groundwater Conditions

During the previous investigation, piezometers were sealed in boreholes 1 and 2 to permit the monitoring of the groundwater levels in the overburden soils and in the bedrock at the abutments. The measured water levels ranged from elevation 185.2 to 186.9 metres with higher piezometric levels observed in the deeper bedrock installations. An upward vertical hydraulic gradient has been assumed. The results of the analytical testing carried out on the groundwater sample obtained from borehole 2 are detailed in Appendix A. The analytical testing indicated a pH value of 7.58 and a sulphate concentration of 1330 milligrams per litre.

The Grand River water level was noted to vary from elevation 185.6 to 185.7 metres between April 30 and May 2, 2007 during the drilling of boreholes 101 to 103. The encountered water depths are summarized in the following table. Long-term groundwater levels of 185 and 186 metres have been inferred in the overburden and bedrock, respectively. It should be noted that the groundwater level and the river levels are subject to seasonal fluctuations.

Borehole Number and Installation	***Ground/ Sidewalk Surface Elevation (m)***	***Encountered Groundwater/ River Water Surface Elevation (m)***	***River Water Depth (m)***	***Measured Water Level Elevations***	
				October 3, 2003 (m)	***October 31, 2003 (m)***
101	191.15	185.74	0.44	-	-
102	191.40	185.73	0.46	-	-
103	191.43	185.61	0.43	-	-
104	191.23	-	-	-	-
105	191.34	-	-	-	-
106	191.48	-	-	-	-
1 - shallow	189.69	-	-	185.88	185.24
1 - deep	189.69	-	-	186.34	186.22
2 - shallow	190.23	-	-	186.85	185.41
2 - deep	190.23	-	-	185.48	185.51

4.5 Structure Settlement

The post construction settlement estimated from the current survey data and the 1927 design drawings are provided in Table I together with the related rock parameters for the founding stratum. These data indicate average foundation settlements of up to 94 millimetres with differential settlements of as much as 80 millimetres at individual piers or abutments.

Figure 4 provides a plot of the estimated settlements along the profile of the bridge and Figure 5 presents a frequency histogram of the transverse differential settlement of foundation units.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by Lantech Drilling Services Inc., an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. David Mitchell. The routine laboratory testing was carried out at Golder's London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates.

The unconfined compressive strength testing was carried out in Golder's Mississauga laboratory under the direction of Dr. P. Dittrich, P.Eng. In addition to also being a participant in the MTO Soil and Aggregate Proficiency Program, the Mississauga laboratory is a MTO registered laboratory in the Specialty of Soil and Rock Including Testing for Foundation Engineering - Low and High Complexity.

This report was prepared by Ms. Dirka U. Prout, P. Eng. under the direction of the Project Manager, Mr. Philip R. Bedell, P. Eng. This report was reviewed by Mr. Fintan J. Heffernan, P. Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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TP/DB/DUP/PRB/FJH/cr
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TABLE I

SUMMARY OF ESTIMATED FOUNDATION SETTLEMENTS AND ROCK DATA

Rehabilitation of the Argyle Street South Bridge
Former Highway 6, Caledonia, Site 9-2
GWP 3147-06-00

		SETTLEMENT				ROCK PARAMETERS - FOUNDING STRATUM		
FOUNDATION UNIT	BOREHOLE	West Side (mm)	East Side (mm)	Average (mm)	Differential (mm)	TCR %	SCR %	RQD %
North Abutment	2	55	98	77	+43	21	9	0
Pier 1	101	131	117	124	-14	37	4	2
Pier 2	8	95	140	117	+45	49	34	0
Pier 3	102	85	85	85	0	53	5	0
Pier 4	106	104	94	99	-10	64	8	0
Pier 5	103	159	84	121	-75	68	16	10
Pier 6	105	140	60	100	-80	69	6	0
Pier 7	6	30	60	45	+30	47	20	8
Pier 8	104	49	74	62	+25	49	6	2
South Abutment	1	30	15	23	-15	44	17	3

NOTES:
1. Differential settlements: + denotes tilt to the east; - denotes tilt to the west.
2. Table to be read in conjunction with accompanying report.

Prepared By: PRB
Checked By: DUP

TABLE II

COMPARISON OF FOUNDATION REHABILITATION MEASURES

Rehabilitation of the Argyle Street South Bridge
Former Highway 6, Caledonia, Site 9-2
GWP 3147-06-00

REMEDIATION OPTION	FEASIBILITY	ADVANTAGES	DISADVANTAGES	ESTIMATED COSTS	RISKS/ CONSEQUENCES
Do nothing with settlement monitoring in conjunction with structural inspections	Suitable for short-term provided that the risk of additional foundation deformation is deemed acceptable	• Cheapest alternative • Simple to implement • Provides warning system for gradual failure • Provides insight into settlement characteristics of foundation	• Does not remediate the deteriorated bedrock on which the footings are constructed thus allowing foundation to deteriorate with time • May not provide warning of sudden catastrophic failure • Unsuitable as a medium to long term rehabilitation strategy unless measures are put in place to stabilize foundations • Should monitoring reveal Scenario 3 to be the actual settlement behaviour, socially accepted probabilities of failure may be approached for the ten year period	• Costs are predictable • Settlement survey costs about $2,000 per event not including structural inspection or traffic protection	• Monitoring may not detect rapid deterioration leading to catastrophic failure of the structure even if alarm levels incorporated into monitoring system • Depending on settlement characteristics, cracking leading to closure of bridge may occur
Pressure grouting of upper solutioned bedrock zone	Suitable for short, medium and long term	• Improves geotechnical resistance of bedrock in solutioned zone • Original footings can be retained • Suitable medium to long term strategy if bridge in service for over 10 years	• Cofferdam construction and provision of a staging area is necessary • Uncertainty involved in effectiveness of grouting as grout may not fill all voids/fractures • Potential to impact groundwater supplies or Grand River ecosystem if grout escapes into sensitive pathways • Chemical grouts are likely to be more effective but more expensive than cement grouts • Pre, during and post remediation monitoring advisable	• Costs are very variable depending on the success of the initial trial(s) • $220,000 to $250,000 per pier/abutment footing exclusive of cofferdam and staging area construction	• Grout may not permeate all fractures/void resulting in untreated or poorly treated areas resulting in increased remediation costs or failure if such areas are not detected • Grout may escape and impact surface and groundwater; clean up costs unquantifiable
Micropiles socketed in competent bedrock	• Suitable for short, medium and long-term • Preferred technical solution	• Loads transferred to a competent stratum • Suitable medium to long term strategy if bridge in service for over 10 years • Depending on the method of installation selected at the pier locations, construction of pile caps, a cofferdam and staging area/platform within the water are not necessary	• Costly and unpopular decision if structure is not retained beyond 10 years • Installation of micropiles through existing piers from bridge deck possible but unlikely to be implemented due to the economic and social costs of bridge closure	• Costs are relatively predictable • $150,000 to $180,000 per footing (depending on the type of installation); cost estimate does not include cofferdam construction, pile caps, provision of a staging area or handling and disposal of drill cuttings	• Previously undetected voids/cavities can be intercepted during construction which can increase costs • This option should be carefully weighed against future plans for the structure to ensure compatibility

NOTES:

1. Costs are very preliminary estimates and are intended to provide a comparison between alternatives rather than actual construction costs.
2. Table to be read in conjunction with accompanying report.

Prepared By: DUP
Checked By: PRB

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u,s_u kPa	c_u,s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. General

π	3.1416
in x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_{w)}$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
l_p	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p)/I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u,s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

Notes:
1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2
* density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING STATE

Fresh: no visible sign of weathering.

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.
Completely weathered: rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing-
Very thickly bedded	>2 m
Thickly bedded	0.6 m to 2m
Medium bedded	0.2 m to 0.6m
Thinly bedded	60 m to 0.2 m
Very thinly- bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	< 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	> 3 m
Wide	I – 3 m
Moderately close	0.3 – I m
Close	50 – 300 mm
Very close	< 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	> 60 mm
Coarse Grained	2 – 60 mm
Medium Grained	60 microns – 2 mm
Fine Grained	2 – 60 microns
Very Fine Grained	< 2 microns

Note: *Grains >60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)
The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)
The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)
The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varies front 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of' the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to (W.R.T.) Core Axis

The angle of the discontinuity relative to the axis (length) of the core, In a vertical borehole a discontinuity with a 90' angle is horizontal.

Description and Notes

An abbreviated description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces

Abbreviations

B – Bedding
FO - Foliation Schistosity
CL - Cleavage
SH - Shear Plane Zone
VN - Vein
F - Fault
CO - Contact
J - Joint
FR - Fracture
M F - Mechanical Fracture
II - Parallel To
⊥ - Perpendicular To

P - Polished
S - Slickensided
SM - Smooth
R - Ridged / Rough
ST - Stepped
PL - Planar
FL - Flexured
UE - Uneven
W - Wavy
C - Curved

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London, Ontario

RECORD OF BOREHOLE No 101

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770440.9 ;E 267966.2
ORIGINATED BY DJM
DIST ____ HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE April 30, 2007 - May 1, 2007
CHECKED BY ____

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.15	SIDEWALK SURFACE											
0.00 0.15	CONCRETE						191					
							190					
							189					
							188					
							187					
							186					
185.74	Water Surface											
5.41	WATER											
185.30 5.85	FILL, cobbles and boulders						185					
184.87 6.28	POSSIBLY CONCRETE (Very Poor Recovery)		1	CORE	NQ			13	0	0		
183.96 7.19	Moderately weathered, light grey, high porosity, moderately strong, DOLOMITIC SHALE, highly fractured.		2	CORE	NQ		184	40	0	0		
182.66 8.49	Slightly weathered, thinly bedded, light grey, fine grained, moderately strong, DOLOMITIC SHALE, highly fractured.		3	CORE	NQ		183 182	70	11	11		
181.61 9.54	Moderately weathered, thinly bedded, light grey, fine grained, weak to moderately strong, DOLOMITIC SHALE, highly fractured.		4	CORE	NQ		181	26	0	0		
			5	CORE	NQ			50	10	0		
179.99 11.16	Slightly weathered, thinly bedded, greenish grey, weak DOLOMITIC SHALE, highly fractured.		6	CORE	NQ		180 179	33	8	0		
178.47 12.68	Slightly weathered, brownish grey, weak to moderately strong gypsiferous DOLOSTONE, Gypsum occurs as beds, bands and nodules, highly fractured/ broken core.		7	CORE	NQ		178	22	3	0		
176.95 14.20	Fresh, whitish brown mainly intact, cohesive, moderately strong, gypsiferous DOLOSTONE (>70% gypsum)		8	CORE	NQ		177	98	88	68		

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L
WATER CONTENT (%)
10 20 30

Continued Next Page

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

$\circ^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 101

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770440.9 ;E 267966.2
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE April 30, 2007 - May 1, 2007
CHECKED BY

SOIL PROFILE · SAMPLES · GROUND WATER CONDITIONS · ELEVATION SCALE · DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 · SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 · PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L · WATER CONTENT (%) 10 20 30 · UNIT WEIGHT γ kN/m³ · REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
		8	CORE	NQ	176	98	88	68
175.42 15.73	Slightly weathered to fresh, whitish brown to dark grey, fine grained, Gypsiferous DOLOSTONE transition to DOLOMITIC SHALE	9	CORE	NQ	175	93	77	70
173.90 17.25	END OF BOREHOLE				174			

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 102

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770399.0 ;E 267951.7
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE May 1, 2007
CHECKED BY

SOIL PROFILE · SAMPLES · GROUND WATER CONDITIONS · ELEVATION SCALE · DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 · SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 · PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L · WATER CONTENT (%) 10 20 30 · UNIT WEIGHT γ kN/m³ · REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
191.40	SIDEWALK SURFACE						
0.00	CONCRETE						
0.17							
185.73	Water Surface						
5.67	WATER						
185.27 6.13	POSSIBLY ROCK FILL OR CONCRETE						
6.43	CONCRETE	1	CORE	NQ	84	0	0
183.96 7.44	Slightly weathered with some oxidation on surfaces, dark grey, fine grained, weak, DOLOMITIC SHALE, highly fractured						
183.29 8.11	Slightly weathered with some oxidation on surfaces, dark grey, fine grained, weak, DOLOMITIC SHALE, highly fractured	2	CORE	NQ	37	10	0
181.77 9.63	Slightly to moderately weathered with some oxidation on surfaces, dark grey, fine grained, weak DOLOMITIC SHALE, highly fractured	3	CORE	NQ	40	5	0
180.24 11.16	Slightly weathered, dark grey brown, weak to moderately strong, MUDSTONE with Gypsum laminae and nodules.	4	CORE	NQ	75	48	47
178.72 12.68	Slightly weathered to fresh, greenish brown and white, weak to moderately strong, DOLOSTONE with Gypsum nodules (>40% gypsum).	5	CORE	NQ	83	68	52
177.20 14.20	Fresh, grey-brown and white, fine grained, Gypsiferous DOLOSTONE (>70% gypsum)	6	CORE	NQ	100	85	60

ELEVATION SCALE 191 190 189 188 187 186 185 184 183 182 181 180 179 178 177

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 102 2 OF 2 METRIC

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770399.0 ;E 267951.7
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE May 1, 2007
CHECKED BY

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.67		▦	6	CORE	NQ		176	100	85	60			
15.73	END OF BOREHOLE												

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 103 1 OF 2 METRIC

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770357.1 ;E 267937.3
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE May 2, 2007
CHECKED BY

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.43	SIDEWALK SURFACE												
0.00 0.15	CONCRETE						191						
							190						
							189						
							188						
							187						
							186						
185.61	Water Surface												
5.82 185.18	WATER												
6.25	CONCRETE		1	CORE	NQ		185	92	0	0			
183.93			2	CORE	NQ		184	88	0	0			
7.50 183.33	Slightly to moderately weathered, grey, fine grained, some vugs, weak, DOLOMITIC SHALE, highly fractured.												
8.10	Slightly to moderately weathered, grey, fine grained, weak, DOLOMITIC SHALE, highly fractured.		3	CORE	NQ		183	65	32	20			
181.80							182						
9.63	Slightly to moderately weathered, grey, fine grained, weak, DOLOMITIC SHALE to Gypsiferous MUDSTONE (>50% gypsum), highly fractured to rubbly, sharp contact with cohesive gypsiferous mudstone.		4	CORE	NQ		181	45	20	13			
180.27													
11.16	Slightly weathered to fresh, dark greyish brown with transition to greenish grey, fine grained, weak, DOLOMITIC SHALE. Gypsum occurs as laminae and nodules.		5	CORE	NQ		180	100	70	60			
178.75							179						
12.68	Fresh, greyish brown and white, weak to moderately strong, Gypsiferous DOLOSTONE (>60% gypsum). Gypsum occurs as laminae and nodules.		6	CORE	NQ		178	100	78	72			
177.23													
14.20	Fresh to slightly weathered, some vugs, grey-brown and white, weak to moderately strong, Gypsiferous DOLOSTONE (>60% gypsum).		7	CORE	NQ		177	100	62	55			

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

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RECORD OF BOREHOLE No 103

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00 LOCATION N 4770357.1 ;E 267937.3 ORIGINATED BY DJM
DIST HWY 6 BOREHOLE TYPE ROTARY DRILLING & Nw CASING COMPILED BY WDF
DATUM GEODETIC DATE May 2, 2007 CHECKED BY

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.70	Gypsum occurs as nodules.	▦	7	CORE	NQ		176	100	62	55			
15.73	END OF BOREHOLE												

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

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RECORD OF BOREHOLE No 104

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00 LOCATION N 4770292.3 ;E 267915.0 ORIGINATED BY DJM
DIST HWY 6 BOREHOLE TYPE ROTARY DRILLING & Nw CASING COMPILED BY WDF
DATUM GEODETIC DATE May 7, 2007 CHECKED BY

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30

SOIL PROFILE			SAMPLES										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.23	SIDEWALK SURFACE												
0.00	CONCRETE	▨											
0.20							191 190 189 188 187						
185.97	River Bed												
5.26 185.38	DOLOSTONE BOULDER and washout	▦	1	CORE	NQ		186	0	0	0			
5.85 184.71	Grey, moderately strong DOLOSTONE BOULDER	▦	2	CORE	NQ		185	81	0	0			
6.52 183.91	Moderately weathered, light grey, weak, DOLOMITIC SHALE, washout and broken core.	▦	3	CORE	NQ		184	37	0	0			
7.32 183.18	Moderately weathered, light grey, weak, DOLOMITIC SHALE, broken core.	▦	4	CORE	NQ			48	0	0			
8.05 181.66	Moderately to highly weathered, broken and rubbly core, light grey, weak, DOLOMITIC SHALE, core is very broken.	▦	5	CORE	NQ		183 182	52	3	0			
9.57 180.14	Moderately to slightly weathered, dark grey to green, fine grained, weak, DOLOMITIC SHALE with a 100mm Gypsum nodules, core is highly fractured.	▦	6	CORE	NQ		181	50	17	7			
11.09 178.61	Slightly weathered to fresh, fine grained, blue-grey, weak, SHALE to Gypsiferous MUDSTONE (<25% gypsum). Gypsum occurs as laminae and nodules.	▦	7	CORE	NQ		180 179	100	77	58	○	23.1	UC
12.62 177.09	Slightly weathered to fresh, grey-brown and white, weak to moderately strong, Gypsiferous MUDSTONE (>50% gypsum), occasional vuggy spots. Gypsum occurs as nodules.	▦	8	CORE	NQ		178	85	85	68	○	24.7	UC
14.14	Slightly weathered, grey-brown and white, weak, Gypsiferous MUDSTONE (>80% gypsum), highly fractured. Gypsum occurs as nodules.	▦	9	CORE	NQ		177	78	42	20			

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 104

2 OF 2

METRIC

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770292.3 ;E 267915.0
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE May 7, 2007
CHECKED BY

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 | PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
		9	CORE	NQ	176	78	42	20
175.56 15.67	Fresh, laminated, brown and white interbeds of dolostone and gypsum, some vugs near basal, moderately strong Gypsiferous DOLOSTONE (>50% gypsum). Gypsum occurs as laminae and nodules.	10	CORE	NQ	175	100	92	78
174.04 17.19	END OF BOREHOLE							

+ 3, × 3: Numbers refer to Sensitivity
○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 105

1 OF 2

METRIC

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770330.8 ;E 267939.1
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE May 8, 2007
CHECKED BY

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 | PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
191.34	SIDEWALK SURFACE							
0.00 0.14	CONCRETE				191 190 189 188 187 186			
185.43	River Bed							
5.91	FILL, Sandy silt, Brown							
6.07	CONCRETE	1	CORE	NQ	185	100	0	0
		2	CORE	NQ	184	87	0	0
183.84 7.50	Slightly to moderately weathered, grey, fine grained, weak, DOLOMITIC SHALE, highly fractured.							
183.20 8.14	Slightly to moderately weathered, light grey, top 300mm of run is vuggy, some clay infill of fractures near basal, weak, DOLOMITIC SHALE, highly fractured.	3	CORE	NQ	183 182	82	8	0
181.68 9.66	Slightly to moderately weathered, dark grey, weak, DOLOMITIC SHALE, highly fractured and broken core.	4	CORE	NQ	181	28	5	0
180.15 11.19	Slightly weathered to fresh, grey with white gypsum nodules, weak to moderately strong, Gypsiferous MUDSTONE (>50% gypsum). Gypsum occurs as nodules.	5	CORE	NQ	180 179	87	72	65
178.63 12.71	Slightly weathered to fresh, greyish brown, vuggy porosity, moderately strong, Gypsiferous DOLOMITE (~50% gypsum). Gypsum occurs as nodules.	6	CORE	NQ	178	95	85	67
177.11 14.23	Fresh, grey-brown with white gypsum nodules, moderately strong, Gypsiferous DOLOMITE (>70% gypsum) to GYPSUM (bottom	7	CORE	NQ	177	100	87	67

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity
○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 105

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00 LOCATION N 4770330.8 ;E 267939.1 ORIGINATED BY DJM
DIST HWY 6 BOREHOLE TYPE ROTARY DRILLING & Nw CASING COMPILED BY WDF
DATUM GEODETIC DATE May 8, 2007 CHECKED BY

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.58	400mm of core). Gypsum occurs as laminae and nodules.	7	CORE	NQ	176	100	87	67		
15.76	END OF BOREHOLE									

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 106

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00 LOCATION N 4770373.0 ;E 267953.7 ORIGINATED BY DJM
DIST HWY 6 BOREHOLE TYPE ROTARY DRILLING & Nw CASING COMPILED BY WDF
DATUM GEODETIC DATE June 21, 2007 CHECKED BY

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.48	SIDEWALK SURFACE								
0.00 0.15	CONCRETE								
185.38	River Bed								
6.10 184.04	CONCRETE	1	CORE	NQ	100	67	50		
		2	CORE	NQ	92	80	72		
7.44 183.37	Slightly to moderately weathered, grey, fine grained, highly fractured, weak, DOLOMITIC SHALE								
8.11 181.85	Slightly to moderately weathered, grey, fine grained, highly fractured, weak, DOLOMITIC SHALE	3	CORE	NQ	27	10	0		
9.63 180.54	Slightly to moderately weathered, grey/green, fine grained, highly fractured, weak, DOLOMITIC SHALE	4	CORE	NQ	60	17	0		
10.94 180.20	Green SHALE								
11.28 178.80	Slightly weathered, light brown with white gypsum nodules, laminated, cohesive, weak to moderately strong, Gypsiferous DOLOSTONE (~50% gypsum)	5	CORE	NQ	97	88	83	23.3	UC
12.68 177.28	Slightly weathered, light brown with white gypsum nodules, cohesive, weak to moderately strong, Gypsiferous DOLOSTONE (~50% gypsum)	6	CORE	NQ	97	80	50		
14.20	Fresh to slightly weathered, light brown with white gypsum nodules, cohesive, weak to moderately strong, Gypsiferous DOLOSTONE	7	CORE	NQ	83	60	52		

Elevation scale: 191, 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 106

2 OF 2 **METRIC**

PROJECT 07-1130-023-0

G.W.P. 3147-06-00 LOCATION N 4770373.0 ;E 267953.7 ORIGINATED BY DJM

DIST ____ HWY 6 BOREHOLE TYPE ROTARY DRILLING & Nw CASING COMPILED BY WDF

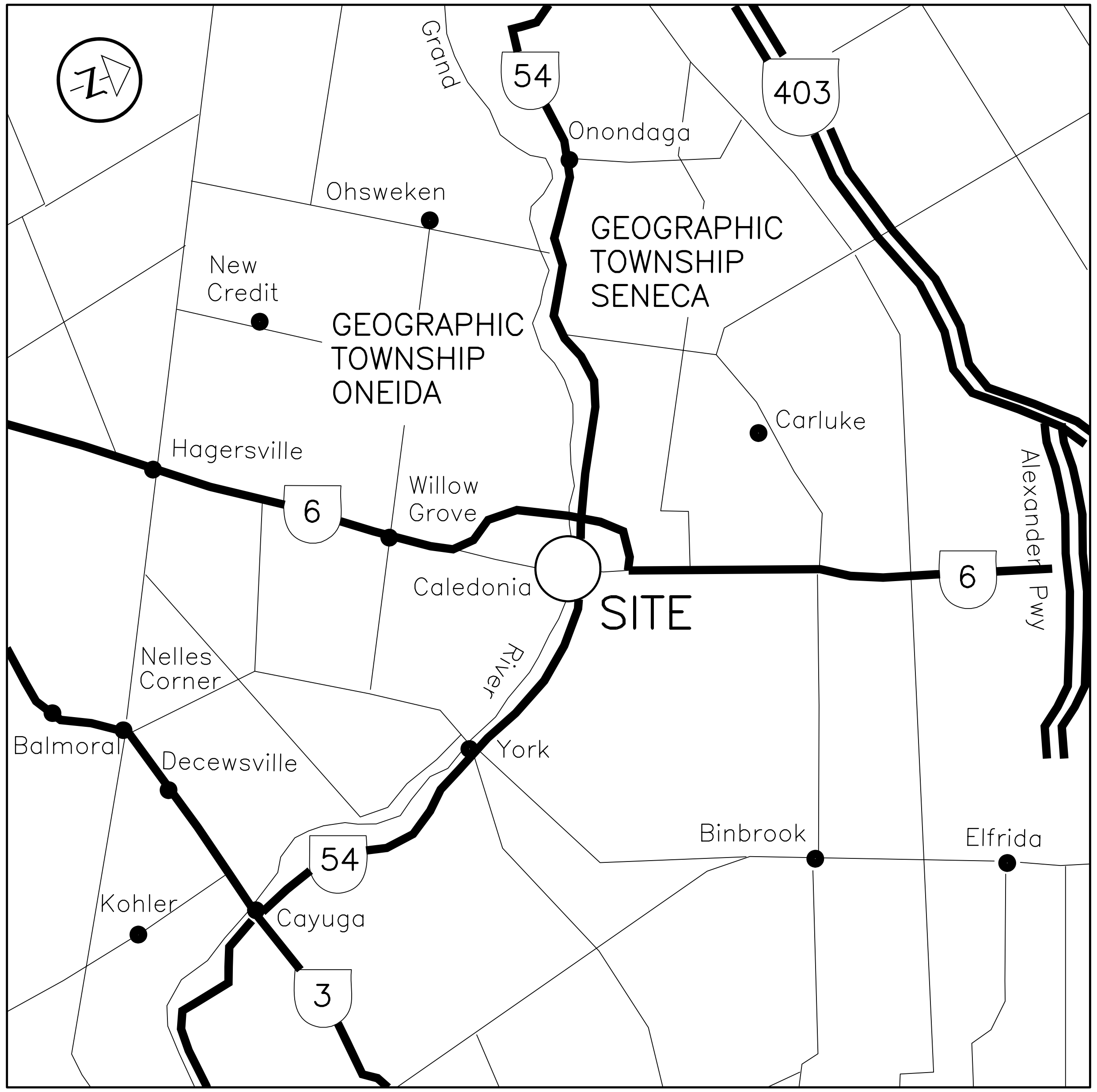
DATUM GEODETIC DATE June 21, 2007 CHECKED BY ____

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100			PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)			
	(~50% gypsum)		7	CORE	NQ		176	83	60	52	○	22.6	UC
175.75 15.73	Slightly weathered, light brown with white gypsum nodules, cohesive, weak to moderately strong, Gypsiferous DOLOSTONE (~50% gypsum)		8	CORE	NQ		175	98	90	77			
174.23 17.25	END OF BOREHOLE												

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

$\circ^{3\%}$ STRAIN AT FAILURE

ON_MTO 0711300230.GPJ LDN_MTO.GDT 1/3/08



NOTE

THIS DRAWING IS APPROXIMATE ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

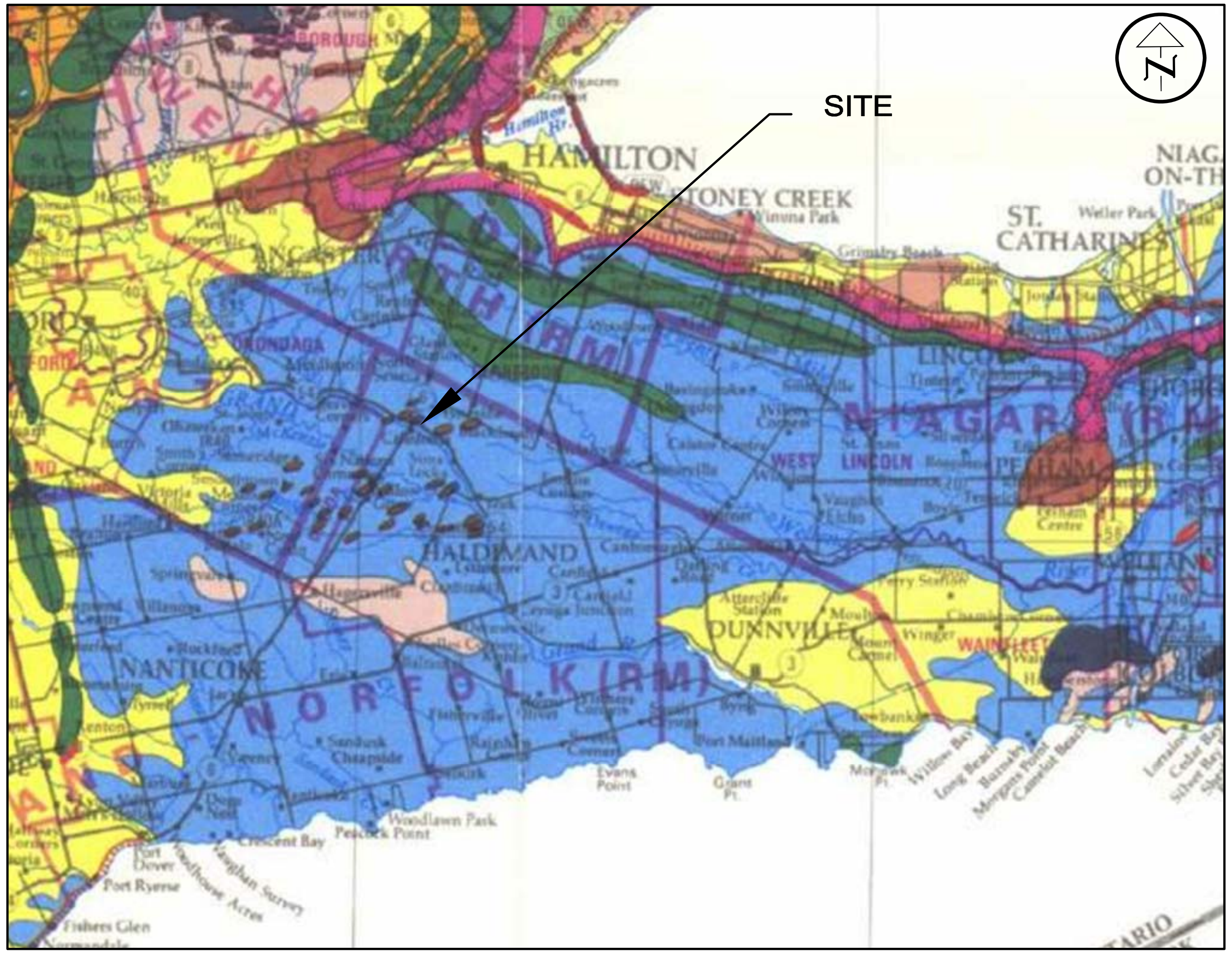
PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
SITE LOCATION PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-0	FILE No. 0711300230-R01001.DWG	
		SCALE N.T.S.	REV. 0
CADD	WDF	Nov. 15/07	**FIGURE 1**
CHECK			

Drawing file: 0711300230-R01001.dwg Jan 03, 2008 - 2:18pm



LEGEND

🟩	Till Moraine
🟥	Kame Moraine
🟩	Till Plain (drumlinized)
●	Drumlins
🟩	Till Plain (undrumlinized)
🟩	Bevelled Till Plain
🟩	Shallow Till and Rock Ridges
☐	Bare Rock Ridges and Shallow Till
🟦	Clay Plain
🟨	Sand Plain
╱	Esker
🟧	Spillway
╌	Beaches and Shorecliffs
🟪	Escarpment
▨	Limestone Plain
🟫	Shale Plain
⬛	Peat and Muck
━	International Boundary
─·─	Interprovincial Boundary
━	County, District, Regional or District Municipal Boundary
─	Township Boundary, surveyed
╌	Township Boundary, unsurveyed
═	Multilane Highway
━	King's Highway
─	Secondary Highway

NOTE

THIS DRAWING IS APPROXIMATE ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

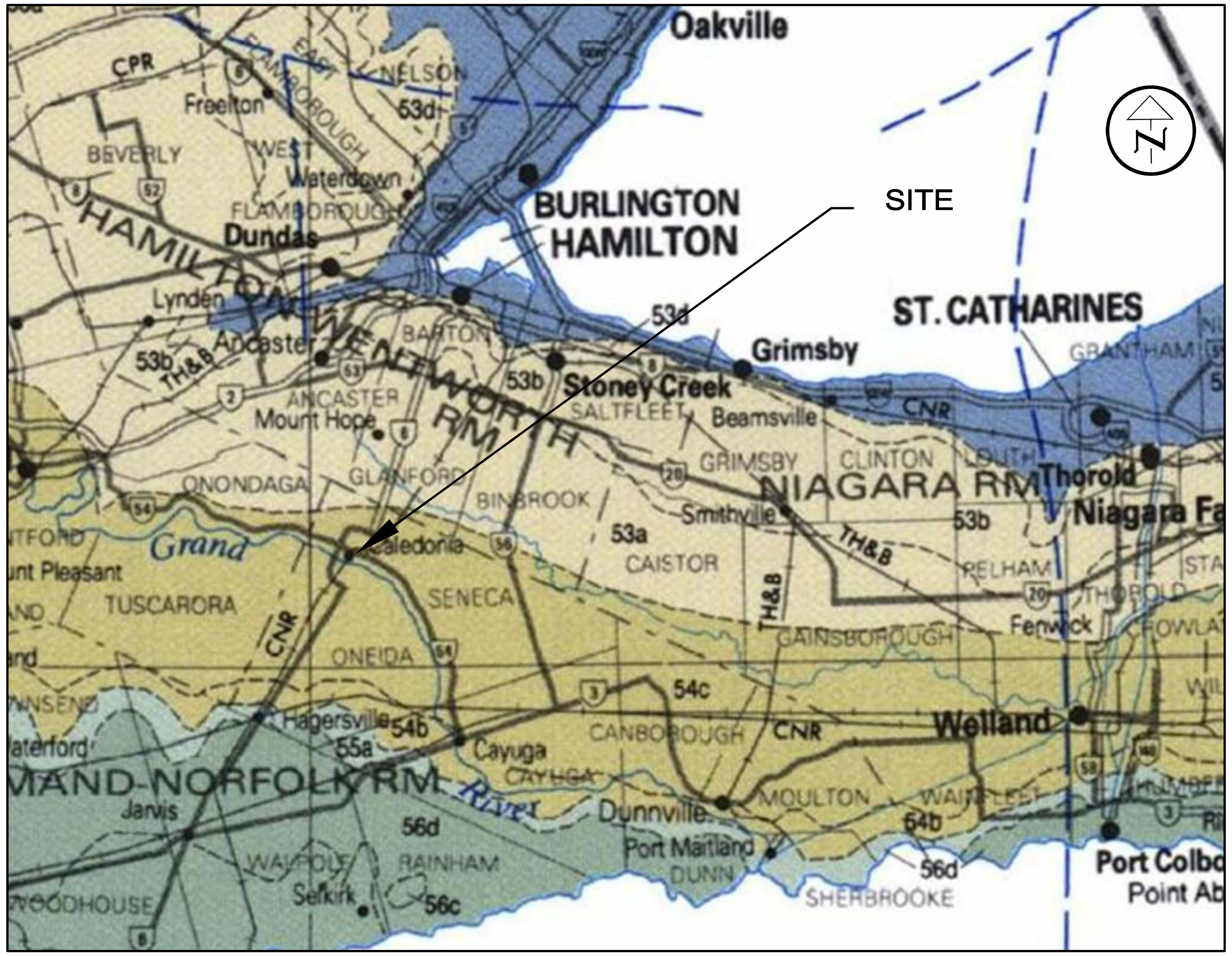
PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
REGIONAL PHYSIOGRAPHY

Golder Associates
LONDON, ONTARIO

PROJECT No.		07-1130-023-0	FILE No.	0711300230-R01002
			SCALE N.T.S.	REV. 0
CADD	WDF	NOV. 15/07	FIGURE 2	
CHECK				

Drawing file: 0711300230-R01002.dwg   Jan 03, 2008 - 2:19pm



LEGEND[a]

PHANEROZOIC[b]

PALEOZOIC

SILURIAN

UPPER SILURIAN

54	**Limestone, dolostone, shale, sandstone, gypsum, salt** 54a Bass Islands Fm. 54b Bertie Fm. 54c Salina Fm. 54d Kenogami River Fm. (Upper Silurian to Lower Devonian)

MIDDLE AND LOWER SILURIAN

53	**Sandstone, shale, dolostone, siltstone** 53a Guelph Fm. 53b Lockport Fm. 53c Amabel Fm. 53d Clinton Gp.; Cataract Gp. 53e Thornloe Fm.; Earlton Fm. 53f Wabi Gp. 53g Attawapiskat Fm. 53h Ekwan River Fm. 53i Severn River Fm.

NOTE

THIS DRAWING IS APPROXIMATE ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

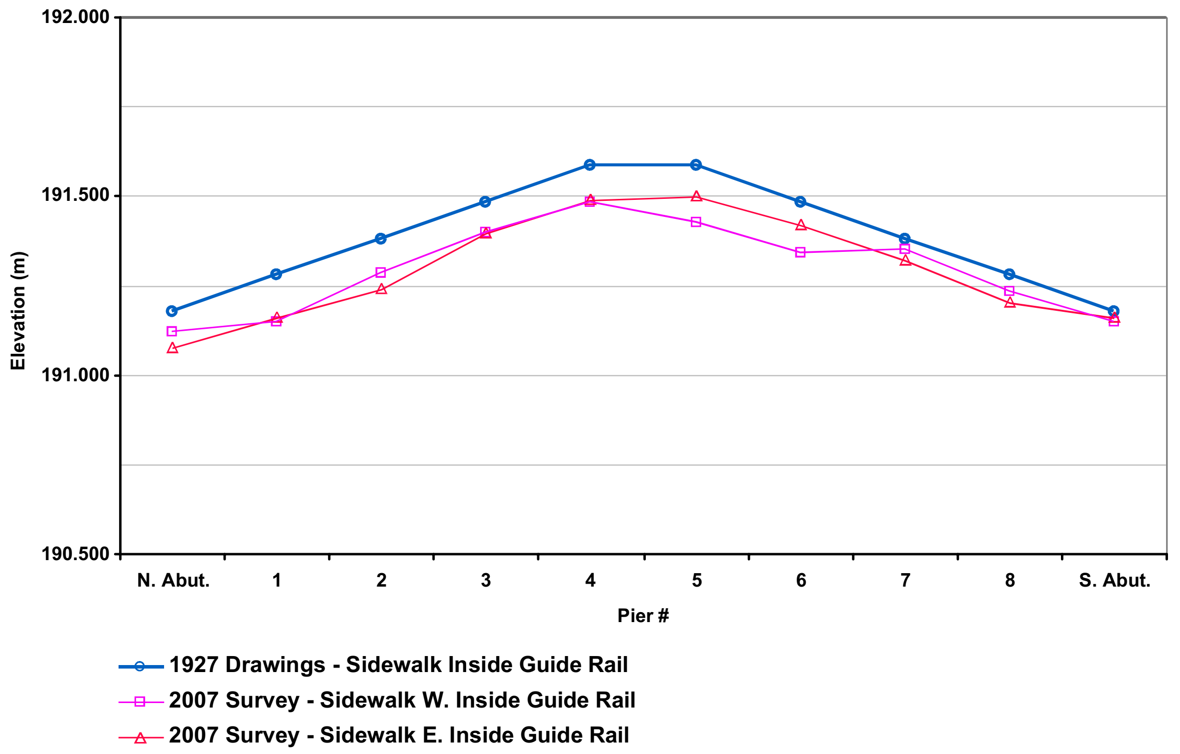
PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
REGIONAL BEDROCK GEOLOGY

Golder Associates
LONDON, ONTARIO

PROJECT No.		021-3233	FILE No.	0711300230-R01003.DWG
			SCALE N.T.S.	REV. 0
CADD	WDF	NOV. 15/07	FIGURE 3	
CHECK				

Drawing file: 0711300230-R01003.dwg   Jan 03, 2008 - 2:20pm



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NOTE

THIS DRAWING IS APPROXIMATE ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

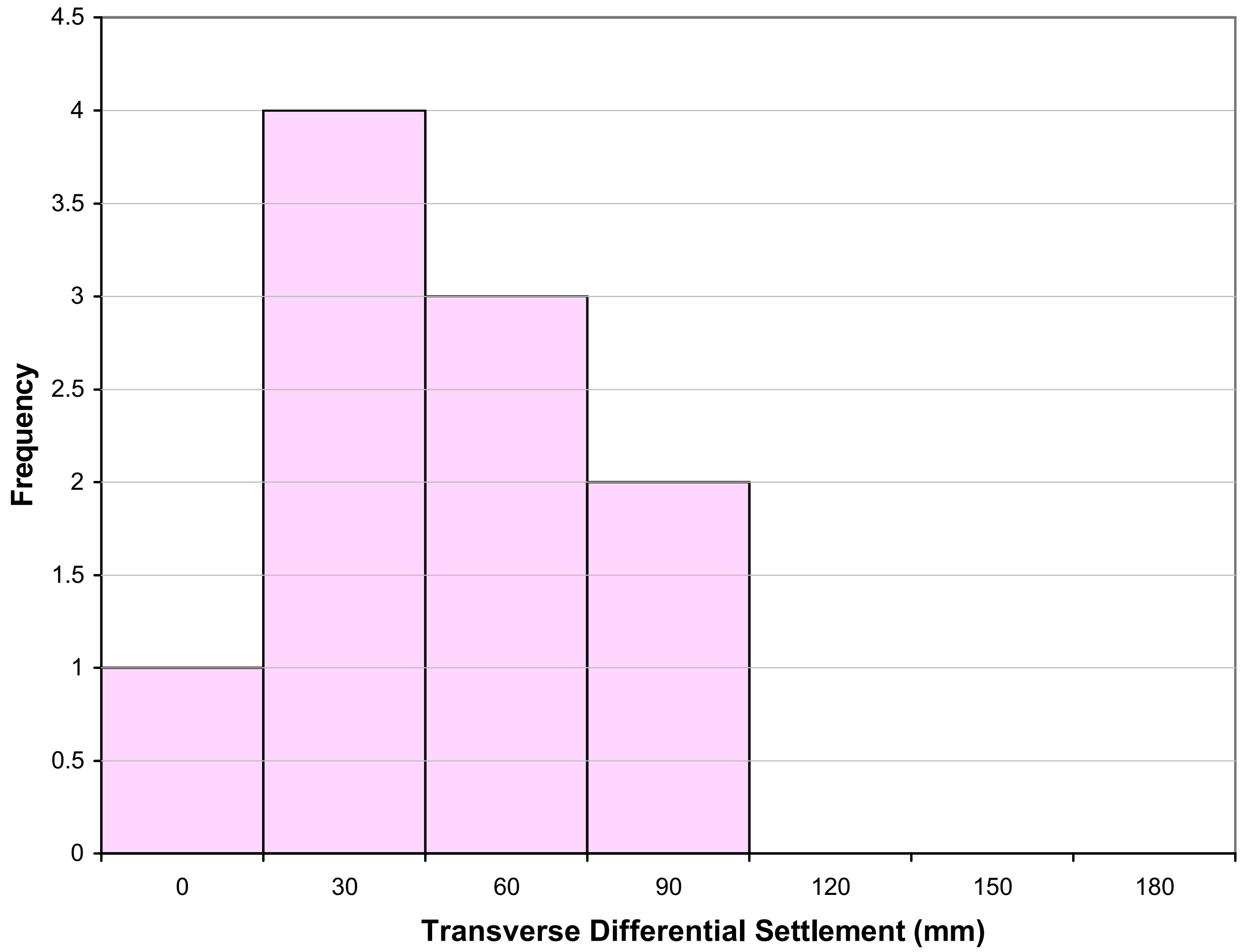
PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE

SIDEWALK SETTLEMENT

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-0		FILE No. 0711300230-R01004.DWG	
			SCALE N.T.S.	REV. 0
CADD	WDF	DEC. 18/07	FIGURE 4	
CHECK				



Drawing file: 0711300230-R01005.dwg Jan 03, 2008 - 2:24pm

NOTE

THIS DRAWING IS APPROXIMATE ONLY AND IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE

TRANSVERSE DIFFERENTIAL SETTLEMENT

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-0		FILE No. 0711300230-R01005.DWG	
			SCALE N.T.S.	REV. 0
CADD	WDF	DEC. 18/07	FIGURE 5	
CHECK				

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

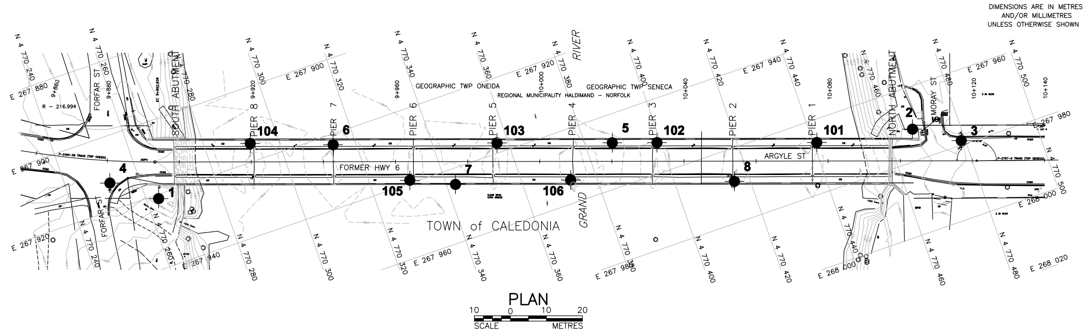
DIST HWY 6
CONT. No.
WP No. 3147-06-00

SHEET

ARGYLE STREET STRUCTURE

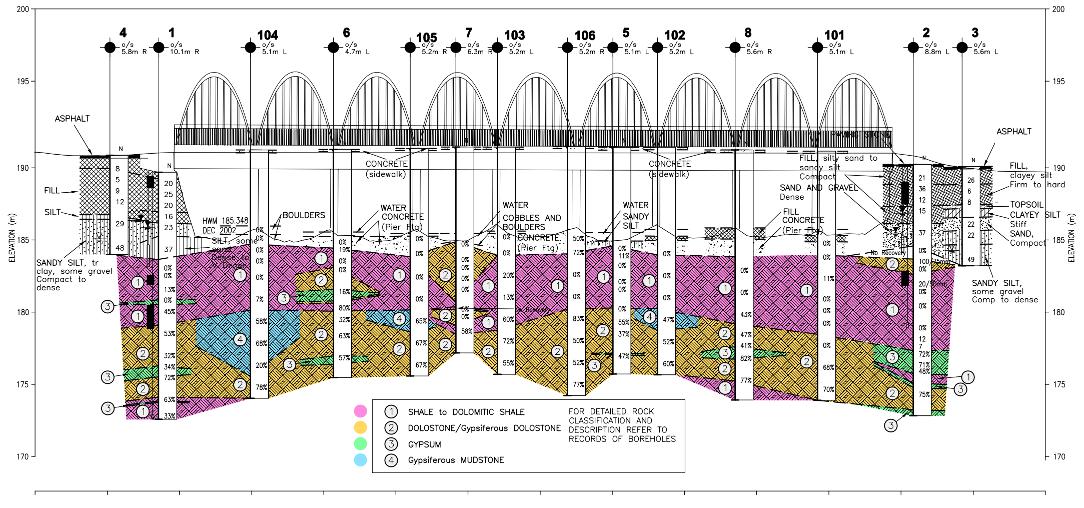
BOREHOLE LOCATIONS & SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



PLAN

SCALE 10 0 10 20 METRES

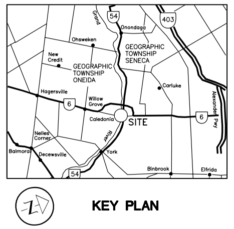


① SHALE to DOLOMITIC SHALE
② DOLOSTONE/Gypsiferous DOLOSTONE
③ GYPSUM
④ Gypsiferous MUDSTONE

FOR DETAILED ROCK CLASSIFICATION AND DESCRIPTION REFER TO RECORDS OF BOREHOLES

PROFILE

HORZ. SCALE 10 0 10 20
VERT. SCALE 2.5 0 2.5 5



KEY PLAN

LEGEND

● Borehole
Seal
Piezometer
N Blows/0.3m (Std. Pen. Test, 475 j/blow)
100% Rock Quality Designation (RQD)
▼ WL in piezometer OCT. 31, 2003.
▽ WL during drilling

No.	ELEVATION (metres)	CO–ORDINATES	
		NORTHING	EASTING
1	189.69	4 770 263.3	267 921.1
2	190.23	4 770 467.2	267 971.4
3	190.07	4 770 478.9	267 978.8
4	190.86	4 770 251.9	267 912.7
5	191.42	4 770 387.3	267 947.7
6	191.27	4 770 313.9	267 922.9
7	191.44	4 770 342.4	267 944.4
8	191.23	4 770 415.8	267 968.9
101	191.15	4 770 440.9	267 966.2
102	191.40	4 770 399.0	267 951.7
103	191.43	4 770 357.1	267 937.3
104	191.23	4 770 292.3	267 915.0
105	191.34	4 770 330.8	267 939.1
106	191.48	4 770 373.0	267 953.7

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REFERENCE

Drawing supplied by Morrison Hershfield entitled; Bridge Site Plan Bridge Crossing at the King's Highway 6 and Grand River
wp 3805–01–00 etr 143–6 plan date feb / 03

NO.	DATE	BY	REVISION

Geocres No. 30M4–111

HWY. No. 6		PROJECT NO.: 07–1130–023–0	DIST.
SUBM'D. PRB	CHKD: DUP	DATE: DEC 2007	SITE: 9–2
DRAWN: WDF	CHKD. DUP	APPD.	DWG. 1

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

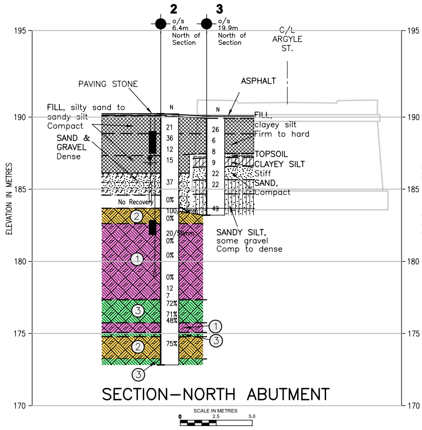
DIST HWY 6
CONT. No.
WP No. 3147-06-00

SHEET

ARGYLE STREET STRUCTURE

SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



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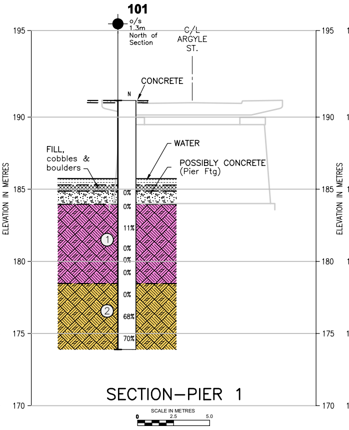
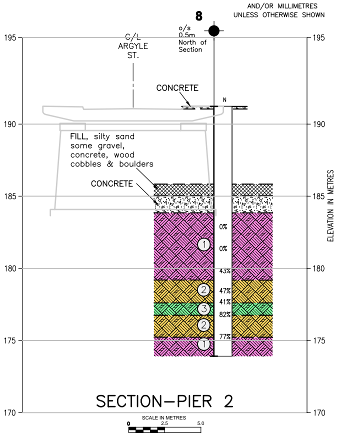
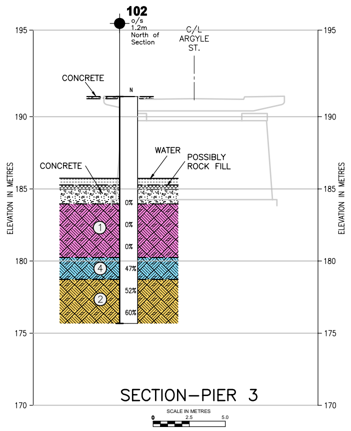


SECTION–PIER 1



SECTION–PIER 2



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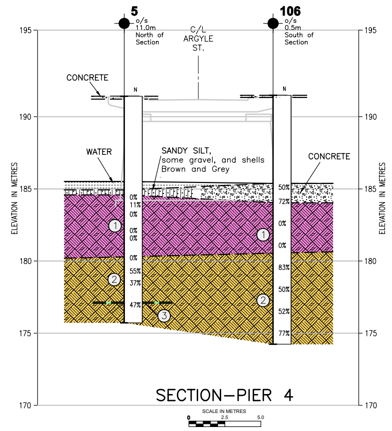
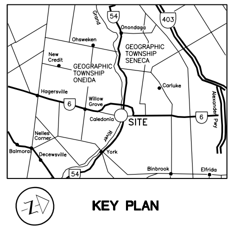


SECTION–PIER 4

① SHALE to DOLOMITIC SHALE
② DOLOSTONE/Gypsiferous DOLOSTONE
③ GYPSUM
④ Gypsiferous MUDSTONE

FOR DETAILED ROCK CLASSIFICATION AND DESCRIPTION REFER TO RECORDS OF BOREHOLES



KEY PLAN

LEGEND

● Borehole
Seal
Piezometer
N Blows/0.3m (Std. Pen. Test, 475 j/blow)
100% Rock Quality Designation (RQD)
▼ WL in piezometer OCT. 31, 2003.
▽ WL during drilling

No.	ELEVATION (metres)	CO–ORDINATES	
		NORTHING	EASTING
2	190.23	4 770 467.2	267 971.4
3	190.07	4 770 478.9	267 978.8
5	191.42	4 770 387.3	267 947.7
8	191.23	4 770 415.8	267 968.9
101	191.15	4 770 440.9	267 966.2
102	191.40	4 770 399.0	267 951.7
106	191.48	4 770 373.0	267 953.7

NOTES

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

REFERENCE

Drawing supplied by Morrison Hershfield entitled; Bridge Site Plan Bridge Crossing at the King's Highway 6 and Grand River
wp 3805–01–00 etr 143–6 plan date feb / 03

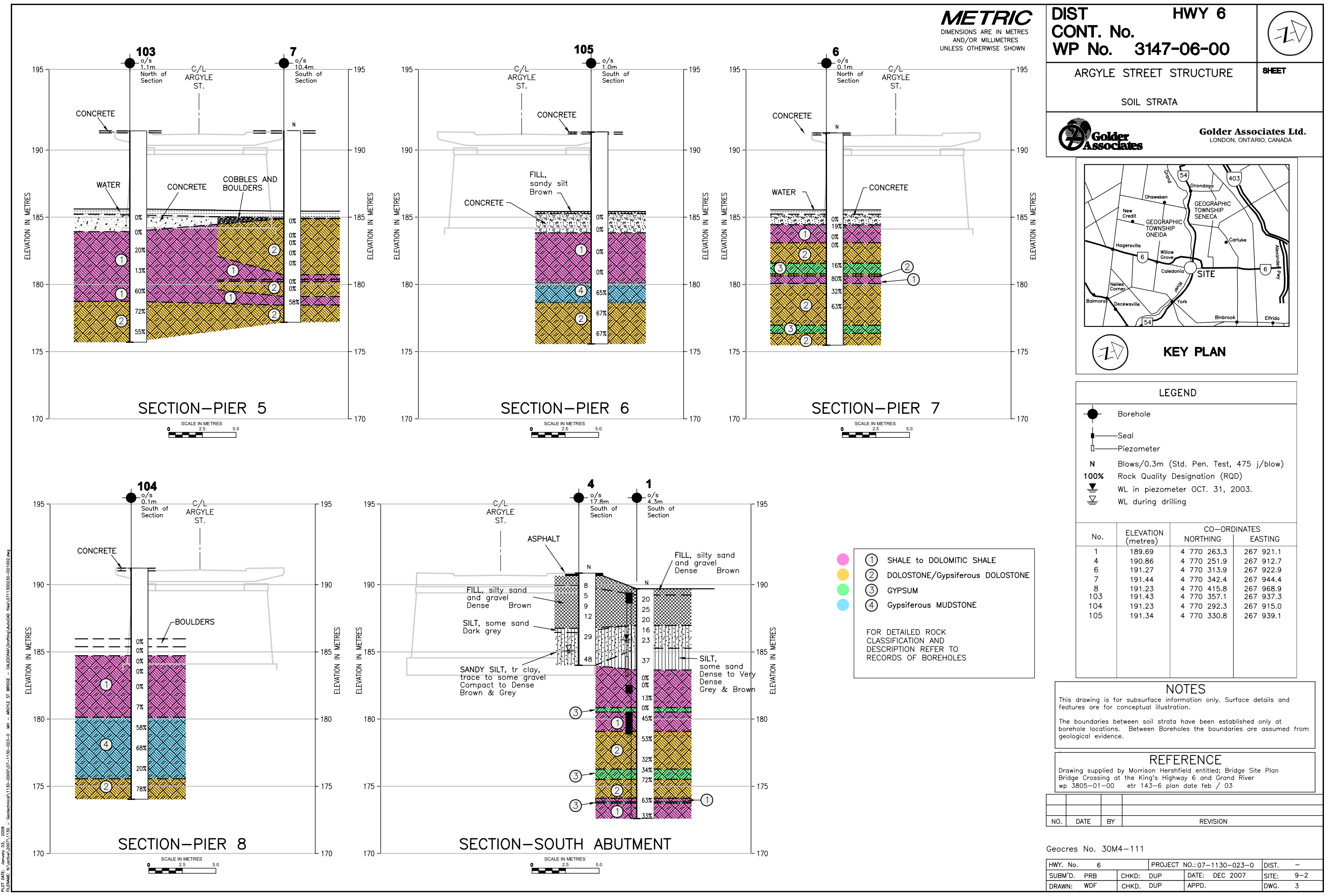
NO.	DATE	BY	REVISION

Geocres No. 30M4–111

HWY. No. 6		PROJECT NO.: 07–1130–023–0	DIST.
SUBM'D. PRB	CHKD: DUP	DATE: DEC 2007	SITE: 9–2
DRAWN: WDF	CHKD. DUP	APPD.	DWG. 2

APPENDIX A

RESULTS OF PREVIOUS INVESTIGATION
GEOCRES NO. 30M4-101
(GOLDER ASSOCIATES LTD. REPORT NO. 021-3233)



N Blows/0.3m (Std. Pen. Test, 475 j/blow)
100% Rock Quality Designation (RQD)
▼ WL in piezometer OCT. 31, 2003.
▽ WL during drilling

No.	ELEVATION (metres)	CO–ORDINATES NORTHING	EASTING
1	189.69	4 770 263.3	267 921.1
4	190.86	4 770 251.9	267 912.7
6	191.27	4 770 313.9	267 922.9
7	191.44	4 770 342.4	267 944.4
8	191.23	4 770 415.8	267 968.9
103	191.43	4 770 357.1	267 937.3
104	191.23	4 770 292.3	267 915.0
105	191.34	4 770 330.8	267 939.1

① SHALE to DOLOMITIC SHALE
② DOLOSTONE/Gypsiferous DOLOSTONE
③ GYPSUM
④ Gypsiferous MUDSTONE

FOR DETAILED ROCK CLASSIFICATION AND DESCRIPTION REFER TO RECORDS OF BOREHOLES

NOTES

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

REFERENCE

Drawing supplied by Morrison Hershfield entitled; Bridge Site Plan Bridge Crossing at the King's Highway 6 and Grand River wp 3805-01-00 etr 143-6 plan date feb / 03

NO.	DATE	BY	REVISION

Geocres No. 30M4-111

HWY. No. 6		PROJECT NO.: 07-1130-023-0	DIST. –
SUBM'D. PRB	CHKD: DUP	DATE: DEC 2007	SITE: 9-2
DRAWN: WDF	CHKD. DUP	APPD.	DWG. 3

APPENDIX A1

RECORDS OF PREVIOUS BOREHOLES

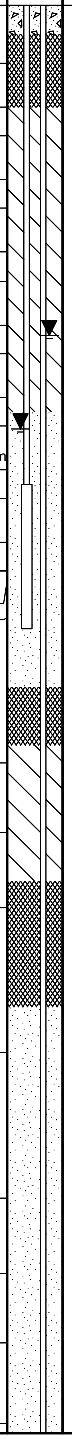
Golder Associates
London, Ontario

RECORD OF BOREHOLE No 1

1 OF 2 **METRIC**

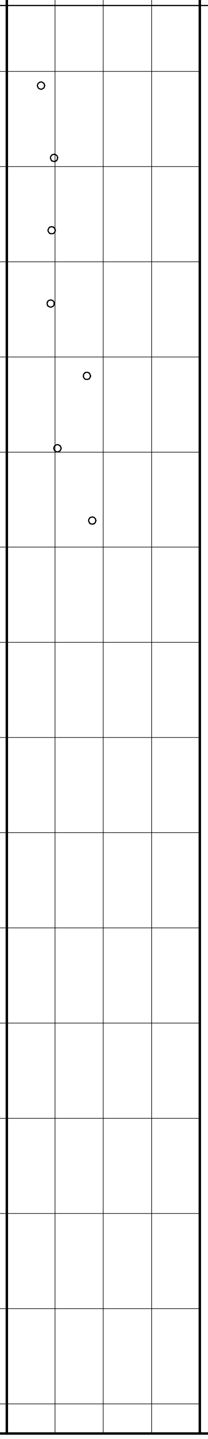
PROJECT 07-1130-023-0
G.W.P. 3147-06-00
DIST
HWY 6
DATUM GEODETIC
LOCATION N 4770263.3 ;E 267921.1
BOREHOLE TYPE POWER AUGER, SOLID STEM & Nw CASING
DATE October 1, 2003 - October 2, 2003
ORIGINATED BY DJM
COMPILED BY WDF
CHECKED BY DJM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
189.69	GROUND SURFACE							
0.00	(FILL), silty sand and gravel, with asphalt and topsoil Dark brown							
189.23 0.46	(FILL), sandy silt some gravel, trace asphalt Compact Brown	1	SS	20				
		2	SS	25				
		3	SS	20				
186.95 2.74	(FILL), sandy silt, trace gravel, roots and brick Compact Brown	4	SS	16				
186.18 3.51	SANDY SILT, trace clay, some gravel Compact Brown	5	SS	23				15 42 34 9
185.27 4.42	SILT, some sand, some rock fragments, Dense to very dense Grey and brown	6	SS	70/ 150mm				
		7	SS	37				
		~~8~~	~~SS~~					
183.65 6.04	Light grey to dark grey DOLOMITIC SHALE, moderate to low recovery as cylindrical core and angular, broken fragments. Surfaces are slightly weathered with brown stains.	9	CORE	30/ 0mm NQ	67	40	0	
		10	CORE	NQ	23	10	0	
		11	CORE	NQ	58	35	13	
181.09 8.60	Grey, fresh, medium strong non-dolomitic/calcareous SHALE							
8.84 180.52	White, fresh, medium-strong GYPSUM, with shaley laminae	12	CORE	NQ	59	0	0	
9.17	Grey, fresh, medium strong non-dolomitic/calcareous SHALE	13	CORE	NQ	93	53	45	
179.08 10.61	Light brown, fresh, medium strong, laminated gypsiferous DOLOSTONE. Gypsum occurs as nodules and laminae.	14	CORE	NQ	100	63	53	
		15	CORE	NQ	77	42	32	
176.28 13.41	White. fresh, medium strong GYPSUM with dolomitic shale laminae.	16	CORE	NQ	72	38	34	
175.52 14.17	Light brown, fresh, medium strong laminated, vuggy gypsiferous DOLOSTONE. Gypsum occurs as nodules and laminae.	17	CORE	NQ	95	90	72	



ELEVATION SCALE: 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178, 177, 176, 175

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100



UNIT WEIGHT γ kN/m³

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 1

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770263.3 ;E 267921.1
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE POWER AUGER, SOLID STEM & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 1, 2003 - October 2, 2003
CHECKED BY DJM

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
		17	CORE	NQ		95	90	72
174.11 15.58	Grey SHALE grading to light brown grey DOLOMITIC SHALE. Fresh, medium strong.	18	CORE	NQ	174	100	90	63
15.94	Vuggy GYPSUM, weak, slightly weathered.							
	Grey, medium strong, thinly laminated DOLOMITIC SHALE with gypsum laminae and nodules	19	CORE	NQ	173	75	50	33
172.59 17.10	END OF BOREHOLE							

Water level in Deep installation at elev. 186.34m OCT. 3, 2003.
Water level in Shallow installation at elev. 185.88m OCT. 3, 2003.

Water level in Deep installation at elev. 186.22m OCT. 31, 2003.
Blockage in Shallow installation at elev. 185.24m OCT. 31, 2003.

Abandoned Oct. 31, 2003.

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

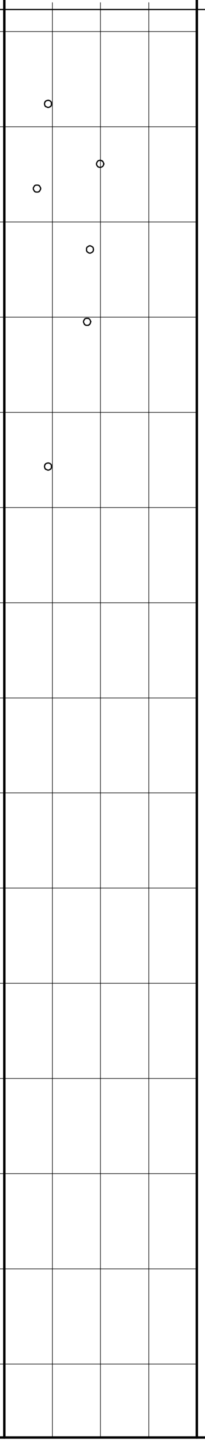
RECORD OF BOREHOLE No 2

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770467.2 ;E 267971.4
ORIGINATED BY DJM
DIST
HWY 6
BOREHOLE TYPE POWER AUGER, HOLLOW STEM & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 2, 2003 - October 3, 2003
CHECKED BY DJM

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
190.23	PAVEMENT SURFACE							
	PAVING STONE							
0.15	(FILL), sand, fine to medium				190			
	(FILL), sandy silt, trace clay, some gravel, trace bricks Compact Brown	1	SS	21	189			
188.86 1.37	(FILL), clayey silt, trace sand, some gravel, cinder layers Stiff to hard Brown and black	2	SS	36	188			
		3	SS	12				
187.33 2.90	(FILL), sandy silt, trace clay, some gravel, cinders and topsoil Compact Brown	4	SS	15	187			
186.12 4.11	SAND AND GRAVEL, trace silt Dense Brown	5	SS	37	186 185			
184.59 5.64	NO RECOVERY Probably Dolostone, light brown	6	CORE	NQ	184	0	0	0
183.68 6.55	Light brown, stained, very vuggy DOLOSTONE. Recovered as broken core and angular fragments.	7	SS	100/ 75mm				
		8	CORE	NQ	183	51	30	0
182.61 7.62	Grey, medium strong, massive to thinly laminated DOLOMITIC SHALE. Weathered surfaces, low recovery.	9	SS	20/ 50mm	182			
		10	CORE	NQ	181	24	12	0
180.60 9.63	HIghly weathered grey, medium strong, massive to thinly laminated DOLOMITIC SHALE. Weathered surfaces, low recovery.	11	CORE	NQ	180	17	0	0
		12	CORE	NQ	179	0	0	0
178.31 11.92	Completely weathered grey DOLOMITIC SHALE with gypsum nodules recovered from split spoon samples.	13	SS	12	178			
		14	SS	7				
177.34 12.89	Interbedded white, strong, fresh, coliform GYPSUM and strong, fresh, light brown, laminated SHALEY DOLOSTONE with nodular gypsum.	15	CORE	NQ	177	100	95	72
		16	CORE	NQ	176	100	100	71
175.75 14.48	Grey, fresh, medium strong DOLOMITIC SHALE	17	CORE	NQ		87	95	48



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+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 2

2 OF 2 **METRIC**

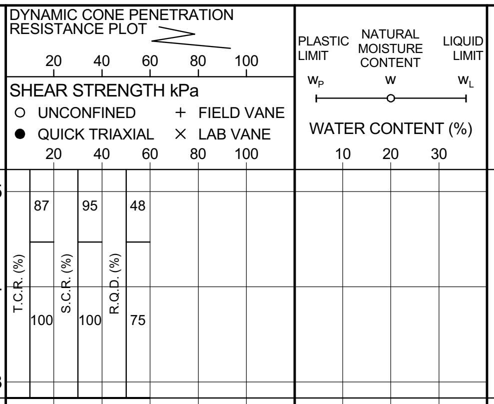
PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770467.2 ;E 267971.4
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE POWER AUGER, HOLLOW STEM & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 2, 2003 - October 3, 2003
CHECKED BY DJM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES							
175.08 15.15	White, slightly weathered, strong GYPSUM					175					
15.45	Light brown-grey, laminated, vuggy, slightly weathered, strong DOLOSTONE with gypsum nodules.	17	CORE	NQ			87	95	48		
		18	CORE	NQ		174	100	100	75		
173.24 16.99	White, strong, slightly weathered, GYPSUM					173					
172.83 17.40	END OF BOREHOLE										

Water level in Deep installation at elev. 185.48m OCT. 3, 2003.
Water level in Shallow installation at elev. 186.85m OCT. 3, 2003.

Water level in Deep installation at elev. 185.51m OCT. 31, 2003.
Water level in Shallow installation at elev. 185.41m OCT. 31, 2003.

Abandoned Oct. 31, 2003.



+ ³, × ³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

Golder Associates
London, Ontario

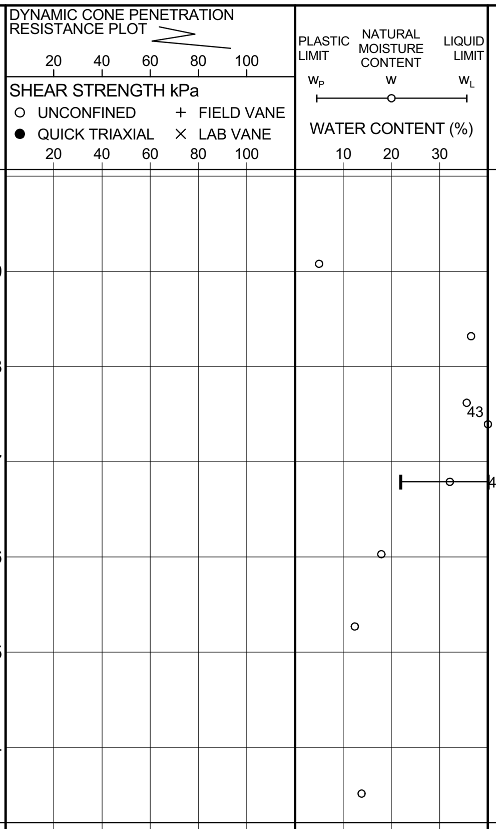
RECORD OF BOREHOLE No 3

1 OF 1 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770478.9 ;E 267978.8
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE POWER AUGER, SOLID STEM (UNCASED)
COMPILED BY WDF
DATUM GEODETIC
DATE October 3, 2003
CHECKED BY DJM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES					
190.07	PAVEMENT SURFACE								
0.00	ASPHALT								
0.15	(FILL), silty sand and crushed gravel Compact Grey	1	SS	26		189			
188.85 1.22	(FILL), clayey silt, trace sand, mottled Firm Brown and grey	2	SS	6		188			
		3	SS	8			43		
187.48 2.59	TOPSOIL, clayey Stiff Black					187			
187.17 2.90	CLAYEY SILT, trace sand Stiff Brown	4	SS	9			42		0 12 65 23
186.56 3.51	SAND, fine, some silt, trace gravel Compact Brown	5	SS	22		186			
185.65 4.42	SANDY SILT, some gravel Compact Brown	6	SS	22		185			
184.68 5.39	SANDY SILT, with angular gravel, cobbles Dense Brown				∇	184			
		7	SS	49					
183.21 6.86	END OF BOREHOLE								

Water level encountered at elev. 184.28m OCT. 3, 2003.



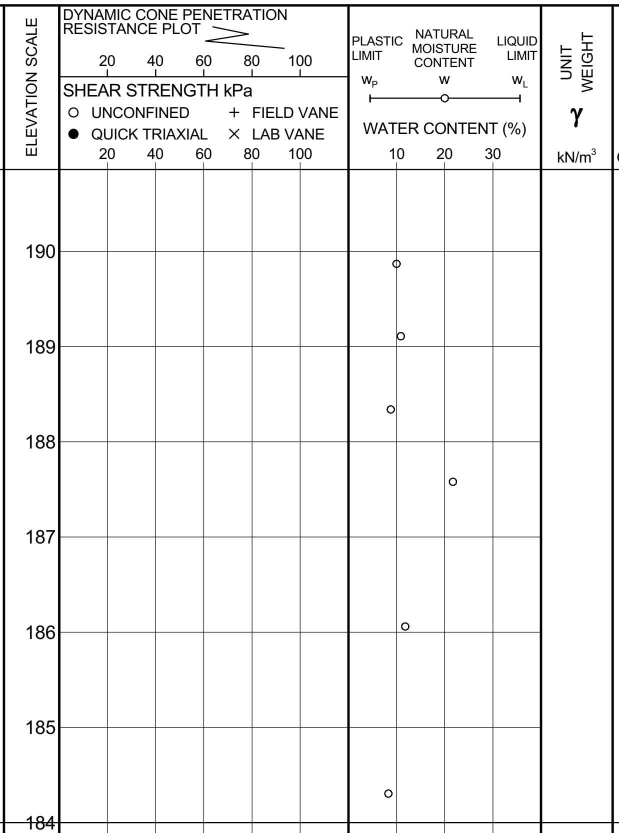
+ ³, × ³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 4

1 OF 1 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
DIST ____ HWY 6
DATUM GEODETIC
LOCATION N 4770251.9 ;E 267912.7
BOREHOLE TYPE POWER AUGER, SOLID STEM (UNCASED)
DATE October 3, 2003
ORIGINATED BY DJM
COMPILED BY WDF
CHECKED BY DJM

SOIL PROFILE		SAMPLES				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
190.86	PAVEMENT SURFACE								
0.00	ASPHALT								
0.20	(FILL), silty sand and crushed gravel Dense Grey								
189.95 0.91	(FILL), sandy silt, trace to some clay, trace gravel and brick Loose to compact Brown	1	SS	8					
		2	SS	5					
		3	SS	9					
		4	SS	12		3	40	44	13
186.75 4.11	SILT, some sand, trace organic material Dark grey								
186.44 4.42	SANDY SILT, trace clay, trace gravel Compact Brown	5	SS	29					
185.37 5.49	SANDY SILT, trace clay, some gravel, with cobbles Dense Brown and grey				∇				
		6	SS	48					
184.00 6.86	END OF BOREHOLE Water level encountered at elev. 185.07m OCT. 3, 2003.								



$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 5

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
DIST ____ HWY 6
DATUM GEODETIC
LOCATION N 4770387.3 ;E 267947.7
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
DATE October 27, 2003 - October 28, 2003
ORIGINATED BY DJM
COMPILED BY WDF
CHECKED BY DJM

SOIL PROFILE		SAMPLES					
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
191.42	SIDEWALK SURFACE						
0.00	CONCRETE						
0.20							
185.51	Water Surface						
5.91	WATER						
184.93 6.49	SANDY SILT, some gravel and shells Brown and grey						
184.59 6.83	Grey, moderately strong, slightly to highly weathered DOLOMITIC SHALE	1	CORE	NQ	66	0	0
		2	CORE	NQ	49	20	11
		3	CORE	NQ	27	7	0
		4	CORE	NQ	60	15	0
		5	CORE	NQ	40	9	0
180.29 11.13	Light brown-grey, fresh, moderately strong, gypsiferous DOLOSTONE. Gypsum occurs as laminae and nodules	6	CORE	NQ	39	8	0
		7	CORE	NQ	94	70	55
		8	CORE	NQ	83	53	37
177.16 14.35	White, medium strong, fresh, nodular GYPSUM with dolomitic shaley partings.	9	CORE	NQ	89	70	47
	Light brown grey, fresh, moderately						

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GROUND WATER CONDITIONS
ELEVATION SCALE 191 190 189 188 187 186 185 184 183 182 181 180 179 178 177
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT w LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 5

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770387.3 ;E 267947.7
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 27, 2003 - October 28, 2003
CHECKED BY DJM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)
175.72	strong, gypsiferous DOLOSTONE. Gypsum occurs as laminae and nodules	9	CORE	NQ	176	89	70	47
15.70	END OF BOREHOLE							

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

ON_MTO 0711300230.GPJ LDN_MTO.GDT 1/3/08

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 6

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770313.9 ;E 267922.9
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 28, 2003 - October 29, 2003
CHECKED BY DJM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
191.27	SIDEWALK SURFACE								
0.00 0.15	CONCRETE				191 190 189 188 187 186				
185.55	Water Surface								
5.72 185.23	WATER								
6.04 184.44	CONCRETE	1	CORE	NQ	185	63	32	0	37.4 MPa
6.83	Grey, moderately strong, slightly weathered DOLOMITIC SHALE. Moderate to low recovery in the form of cylindrical core and angular fragments.	2	CORE	NQ	184	68	28	19	
183.10		3	CORE	NQ		36	20	0	
8.17 181.58	Very low recovery of angular, vuggy DOLOSTONE fragments.	4	CORE	NQ	183 182	7	0	0	
9.69 180.78	White, medium strong, fresh nodular GYPSUM with dolomitic shaley partings.	5	CORE	NQ	181	78	31	16	
10.49 10.64 180.07	Light brown-grey. fresh, medium strong, gypsiferous DOLOSTONE. Gypsum occurs as nodules.								
11.20	Grey, fresh, medium strong DOLOMITIC SHALE	6	CORE	NQ	180	100	80	80	
	Light brown-grey, fresh, medium strong, gypsiferous, laminated DOLOSTONE.	7	CORE	NQ	179	83	68	32	
176.97		8	CORE	NQ	178	97	83	63	
14.30 176.37	White and light brown, fresh, medium strong, nodular GYPSUM with some dolomitic shale bands.	9	CORE	NQ	177	95	80	57	

Continued Next Page

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

ON_MTO 0711300230.GPJ LDN_MTO.GDT 1/3/08

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 6

2 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770313.9 ;E 267922.9
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 28, 2003 - October 29, 2003
CHECKED BY DJM

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
14.90	Light brown-grey, fresh, medium strong, laminated , gypsiferous DOLOSTONE. Gypsum occurs as beds, bands and nodules.		9	CORE	NQ		176	95	80	57			
175.48 15.79	END OF BOREHOLE												

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 7

1 OF 1 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770342.4 ;E 267944.4
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 30, 2003 - October 31, 2003
CHECKED BY DJM

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.44	SIDEWALK SURFACE												
0.00	CONCRETE												
0.18							191 190 189 188 187 186						
185.45 5.99	Water Surface WATER												
184.93 6.55	COBBLES AND BOULDERS Light brown, fresh to medium strong, laminated, vuggy DOLOSTONE. Low recovery in the form of angular fragments.						185						
			1	CORE	NQ		184	29	0	0			
			2	CORE	NQ			9	0	0			
			3	CORE	NQ		183	40	7	0			
			4	CORE	NQ		182	57	0	0			
181.75 9.69	Very low recovery of angular, vuggy DOLOSTONE fragments.		5	CORE	NQ		181	24	16	0			
180.71 10.73	Grey, moderately strong, finely laminated DOLOMITIC SHALE.												
180.38 11.06	-- No Recovery --		6	CORE	NQ			0	0	0			
11.23	Grey to light brown-grey gypsiferous DOLOSTONE. Poor recovery, broken core.		7	CORE	NQ		180	44	7	0			
179.10 12.34	Grey, moderately strong, finely laminated DOLOMITIC SHALE.						179						
178.46 12.98	Light brown-grey, fresh, strong, laminated, gypsiferous DOLOSTONE. Gypsum occurs as laminae and nodules.		8	CORE	NQ		178	85	71	58			
177.18 14.26	END OF BOREHOLE												

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 8

1 OF 2 **METRIC**

PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770415.8 ;E 267968.9
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 31, 2003 - November 1, 2003
CHECKED BY DJM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
191.23	SIDEWALK SURFACE								
0.00	CONCRETE				191				
0.18					190				
					189				
					188				
					187				
185.84	Ground Surface				186				
5.39	FILL, silty sand some gravel, concrete, wood, cobbles and boulders Brown								
185.06 6.17	CONCRETE	1	CORE	NQ	185	100	100	55	22.7 MPa
						90	85	80	50.3 MPa
183.85 7.38	Light grey to dark grey, laminated DOLOMITIC SHALE. Moderate to low recovery as cylindrical core and angular broken core fragments. Surfaces are slightly weathered.	2	CORE	NQ	184	80	30	19	33.5 MPa
		3	CORE	NQ	183 182	32	3	0	
		4	CORE	NQ	181	10	3	0	
179.19 12.04	Light brown, fresh, medium strong, gypsiferous DOLOSTONE. Gypsum occurs as nodules and laminae.	5	CORE	NQ	180 179	57	43	43	
		6	CORE	NQ	178	80	47	47	
177.61 13.62	White, fresh, medium strong, nodular to coliform GYPSUM and strong, fresh, light brown, laminated SHALEY DOLOSTONE with nodular gypsum.	7	CORE	NQ	177	96	50	41	
176.75 14.48	Light brown, fresh, medium strong, laminated, vuggy, gypsiferous	8	CORE			95	88	82	

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 8

2 OF 2 **METRIC**

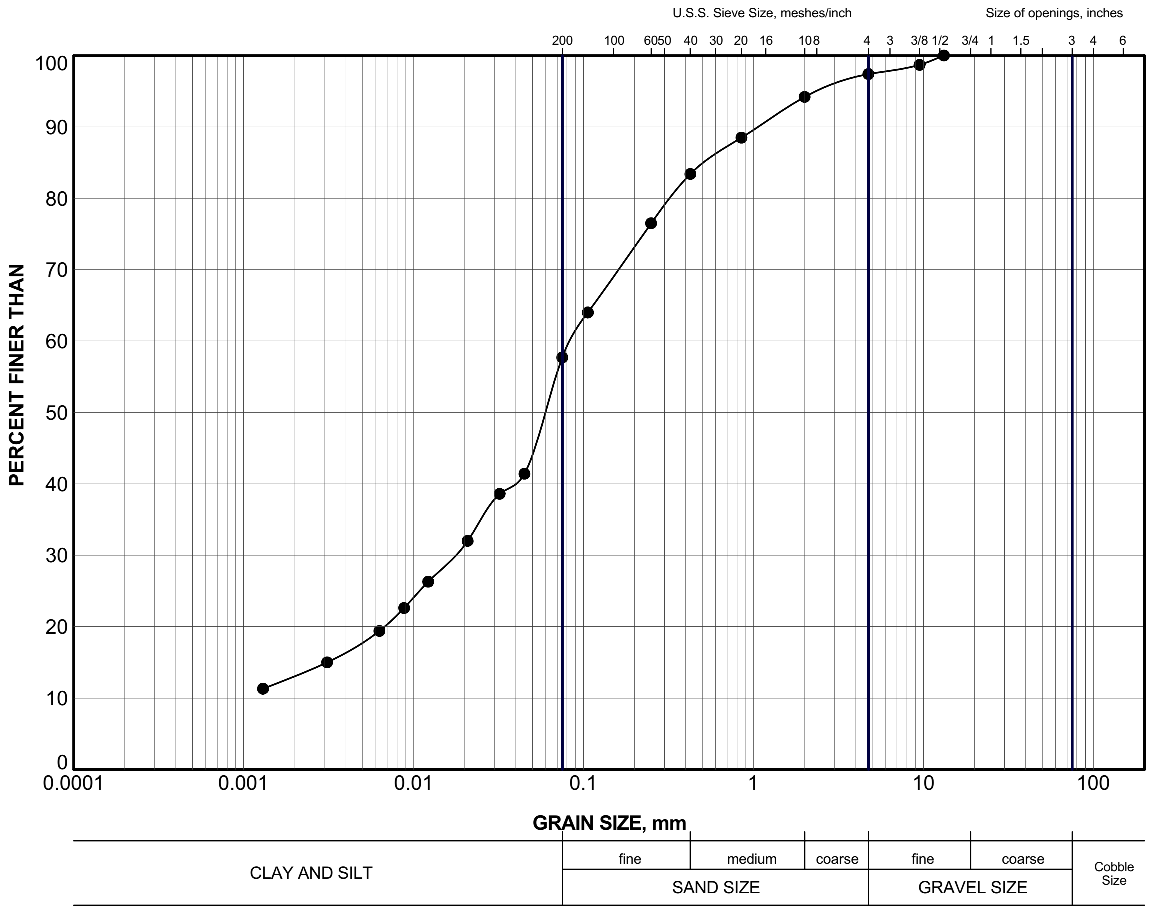
PROJECT 07-1130-023-0
G.W.P. 3147-06-00
LOCATION N 4770415.8 ;E 267968.9
ORIGINATED BY DJM
DIST HWY 6
BOREHOLE TYPE ROTARY DRILLING & Nw CASING
COMPILED BY WDF
DATUM GEODETIC
DATE October 31, 2003 - November 1, 2003
CHECKED BY DJM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	T.C.R. (%)	S.C.R. (%)	R.Q.D. (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	DOLOSTONE. Gypsum occurs as nodules and laminae.	8	CORE	NQ	176	95	88	82	
175.23 16.00	Grey SHALE grading to light grey DOLOMITIC SHALE. Fresh, medium strong, occasional vugs. Nodular gypsum 16.82m to 19.92m depth.	9	CORE	NQ	175	97	83	77	
173.92 17.31	END OF BOREHOLE				174				

$+^3, \times^3$: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

APPENDIX A2

LABORATORY TEST DATA



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	4	4	187.6

PROJECT

ARGYLE STREET SOUTH
BRIDGE OVER THE GRAND RIVER IN CALEDONIA
GWP 3805-01-00

TITLE

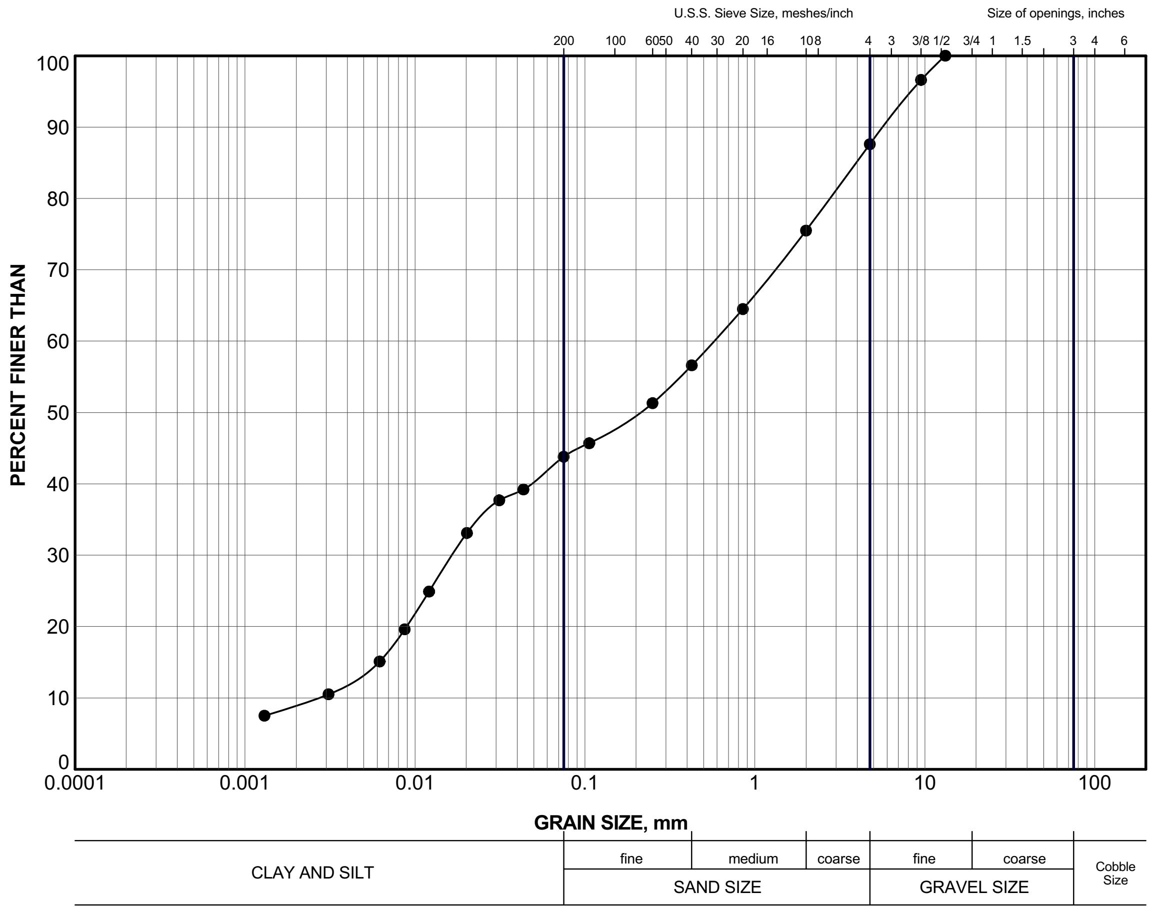
GRAIN SIZE DISTRIBUTION

FILL, sandy silt

Golder Associates
LONDON, ONTARIO

PROJECT No.		021-3233	FILE No.	021-3233MTO.GPJ
			SCALE N/A	REV.
DRAWN	WDF	12/12/03	**FIGURE A-1**	
CHECK	AMH	12/12/03		

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	1	5	185.8

PROJECT

ARGYLE STREET SOUTH
BRIDGE OVER THE GRAND RIVER IN CALEDONIA
GWP 3805-01-00

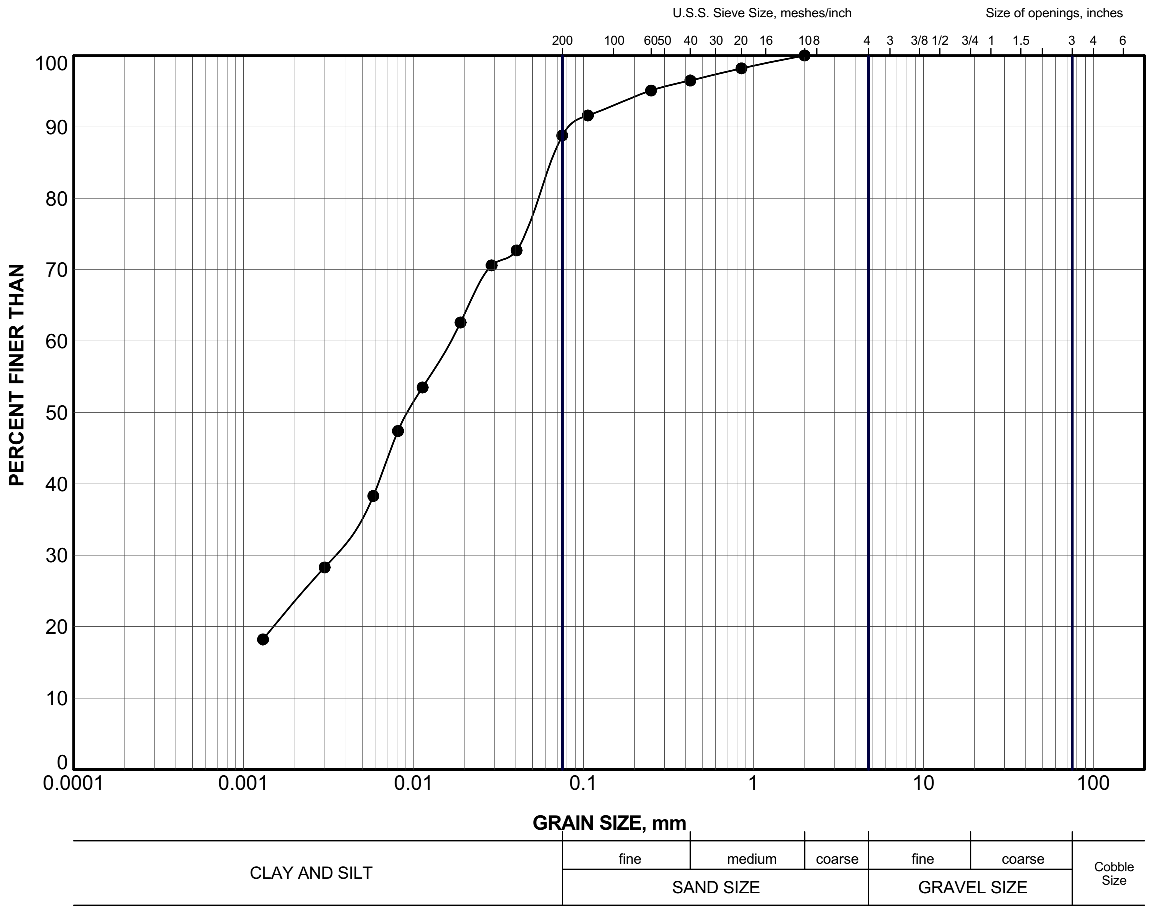
TITLE

GRAIN SIZE DISTRIBUTION
SANDY SILT

Golder Associates
LONDON, ONTARIO

PROJECT No.	021-3233	FILE No.	021-3233MTO.GPJ
		SCALE	N/A REV.
DRAWN	WDF	12/12/03	
CHECK	AMH	12/12/03	

FIGURE A-2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	3	4	186.8

PROJECT

ARGYLE STREET SOUTH
BRIDGE OVER THE GRAND RIVER IN CALEDONIA
GWP 3805-01-00

TITLE

GRAIN SIZE DISTRIBUTION
CLAYEY SILT

Golder Associates
LONDON, ONTARIO

PROJECT No.	021-3233	FILE No.	021-3233MTO.GPJ
		SCALE	N/A REV.
DRAWN	WDF	12/12/03	
CHECK	AMH	12/12/03	

FIGURE A-3

PSC

ANALYTICAL SERVICES

CERTIFICATE OF ANALYSIS

Attention: MR. STAN LOOMIS
Client Name: Golder Associates Ltd. (London)
Address: 500 Nottinghill Road
London, ON
N6K 3P1
Telephone: 519-471-9600
FAX: 519-471-4707

Laboratory Work Order: 109983

This Certificate of Analysis is for the following:

Sample Received on: 31-Oct-2003	Reported on: 4-Nov-2003
Client Reference:	The report contains the following sections:
Purchase Order:	Section: 1. Case Narrative
Quotation No.:	2. Analytical Results
	3. Methodology Summary
	4. Certificate of Quality Control
	5. Hold Time Report

Results for solids samples are corrected for moisture and reported as dry weight.

We are proud to be Accredited by: Standard Council of Canada (SCC) / CAEAL to ISO 17025 (#1799)
New York State (#11730)

Water samples are discarded 4 weeks after the results have been reported. Solid samples are retained for 3 months. Storage for longer periods requires prior arrangement with the laboratory.

Reviewed and Authorized by

[illegible]
Project Manager

NOTE: The enclosed results relate only to the sample or item as received by the laboratory.

This report may be reproduced in full. Reproduction of a partial report must have the written authorization of the laboratory.

CERTIFICATE OF ANALYSIS - SECTION 1

CASE NARRATIVE

Attention: MR. STAN LOOMIS
ient Name: Golder Associates Ltd. (London)
Address: 500 Nottinghill Road
London, ON
N6K 3P1
Telephone: 519-471-9600
FAX: 519-471-4707

Laboratory Work Order: 109983

Sample(s) Received on: 31-Oct-2003 Reported on: 4-Nov-2003

imple Shipment Receipt and Login:

Temperature on receipt was 12.6°C. The maximum allowable temperature is 10°C according to Canadian regulations or guidance documents. Samples submitted to the laboratory soon after sampling are exempt, provided that cooling has been initiated. Cooling is not required for certain situations such as: Waste for classification or specific matrices or tests such as PCB in oil.

There are no other notable comments.

imple Analysis:

No exceptions were noted during analysis.

eneral Comments:

None.

CERTIFICATE OF ANALYSIS - SECTION 2

ANALYTICAL RESULTS

Client:(1093) Golder Associates Ltd. (London). London
Reported: 4-Nov-2003
Page: 1 of 1

Attention: MR. STAN LOOMIS
Client Reference:
Work Order: 109983
Purchase Order:
Date Received: 31-Oct-2003
Sample Type: Liquid

Sample #	Test	Result	Units	EQL	Comment
03-A036202	Sample Description: 021-3233 BH2		Date & Time Sampled: 31-Oct-2003		
	pH Value	7.58	pH units	0.1	
	Sulphate as SO4	1330	mg/L	2	

EQL Estimated Quantitation Limit
Refer to the cover page for a list of report contents.

CERTIFICATE OF ANALYSIS - SECTION 3

METHODOLOGY SUMMARY

Client:(1093) Golder Associates Ltd. (London). London
Reported: 4-Nov-2003
Page: 1 of 1

Attention: MR. STAN LOOMIS
Client Reference:
Work Order: 109983
Purchase Order:
Date Received: 31-Oct-2003
Sample Type: Liquid

Test	Methodology, Reference	Instrument	Analyst
pH Value	Electrometric Measurement EPA SW846 9040A	Orion pH/ISE Meter 710A	C. Lanaus
Sulphate as SO4	Automated Methyl Thymol Blue Colorimetry EPA SW846 9036	Technicon AA II - SO4	A.Ivanovic

Test procedures are based on the above references.
EXPLANATION OF CODES:
EPA - US Environmental Protection Agency
SM - Standard Methods for the Analysis of Waters and Wastewater
MOE - Ontario Ministry of the Environment
P__ - Philip Analytical Services Location

CERTIFICATE OF ANALYSIS - SECTION 4

CERTIFICATE OF QUALITY CONTROL

Client: Golder Associates Ltd (London)
Contact: MR. STAN LOOMIS

Date Reported: 4 Nov-2003
Work Order: 109983

Matrix: Liquid

Client Reference:

			Process Blank		Process % Recovery			Matrix Spike					Duplicate			
Parameter	EQL	Units	Result	Upper Limit	Result	Lower Limit	Upper Limit	Spike ID	Result	Target	Lower Limit	Upper Limit	Duplicate ID	Original Result	Duplicate Result	QC Flag
pH Value	0.1	pH units			100.12	98.0	102.0						03-A036216	8.65	8.64	
pH Value	0.1	pH units			100.50	98.0	102.0						03-A036164	7.90	7.92	
pH Value	0.1	pH units			100.75	98.0	102.0						03-A036160	7.31	7.33	
pH Value	0.1	pH units			100.75	98.0	102.0						03-A035987	8.22	8.24	
Sulphate as SO4	2	mg/L	1.	2	95.65	85.0	115.0	03-F036043	65.	60.	48.	72.	03-F036043	24.	23.	

QC Flag(s) pertain to B-Process Blank, R-Process % Recovery, S-Matrix Spike and/or D-Duplicate NA Denotes Not Applicable
When two values exist for the same Spike ID and parameter it indicates the performance of a Matrix Spike (MS) and Matrix Spike Duplicate (MSD).

Refer to the cover page for a list of report contents.

CERTIFICATE OF ANALYSIS - SECTION 5

HOLD TIME REPORT

ONTARIO CONTAMINATED SITES

Client:(1093) Golder Associates Ltd. (London), London Reported: 4-Nov-2003

Attention: MR. STAN LOOMIS
Client Reference:
Work Order: 109983

Purchase Order:
Date Received: 31-Oct-2003
Sample Type: Liquid

The OMOEE Guidance Document on Contaminated Sites (May 1996) requires all soils for organic parameters be analyzed within 60 days. No criteria is specified for inorganic tests on soils. This reference may or may not be applicable to the samples reported.

03-A036202 Sample Type: Liquid Date Sampled: 31-Oct-2003

Analytical Tests	Date Analyzed	Hold Time (in days)	Actual Time (in days)	Exceeded	Comment
pH Value	1-Nov-2003	14	1		
Sulphate as SO4	4-Nov-2003	30	4		

When the sampling date is not supplied, the hold time is calculated from the date received.
Refer to the cover page for a list of report contents.

APPENDIX B

PHOTOGRAPHS

PHOTOGRAPHS

Photo 1

Photo 2 Borehole No. 2 – Split spoon in rock
Elevation 178.31m to 177.85m.

PHOTOGRAPHS

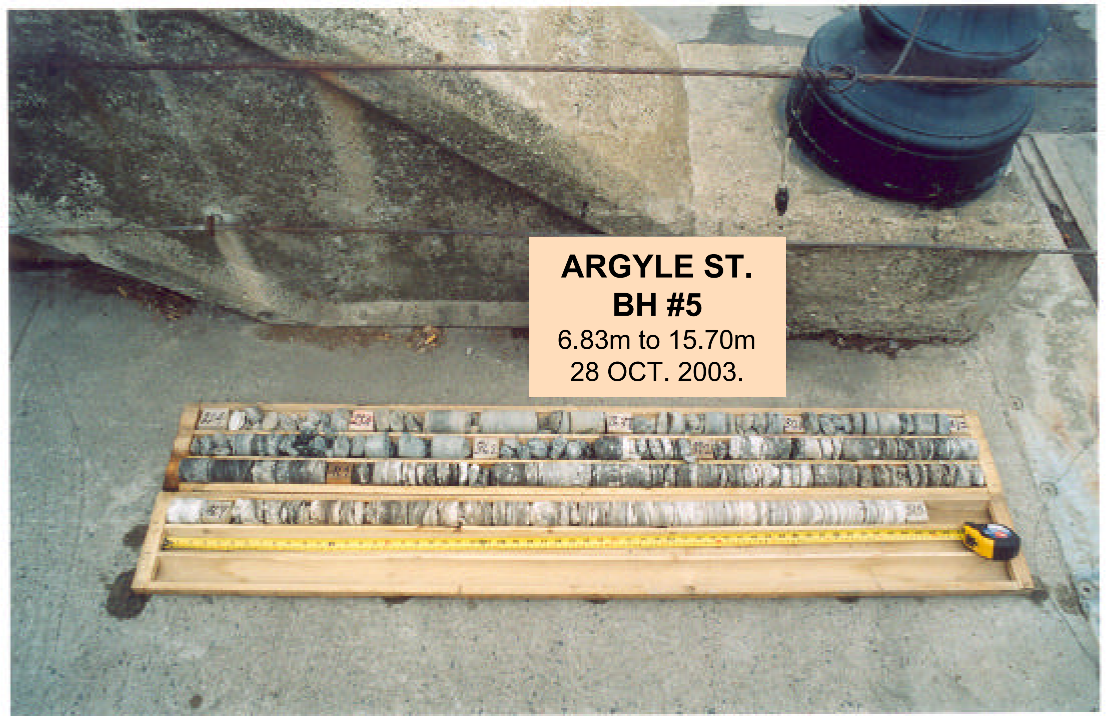


Photo 3 Borehole No. 5 – Rock core
Elevation 184.59m to 175.72m.

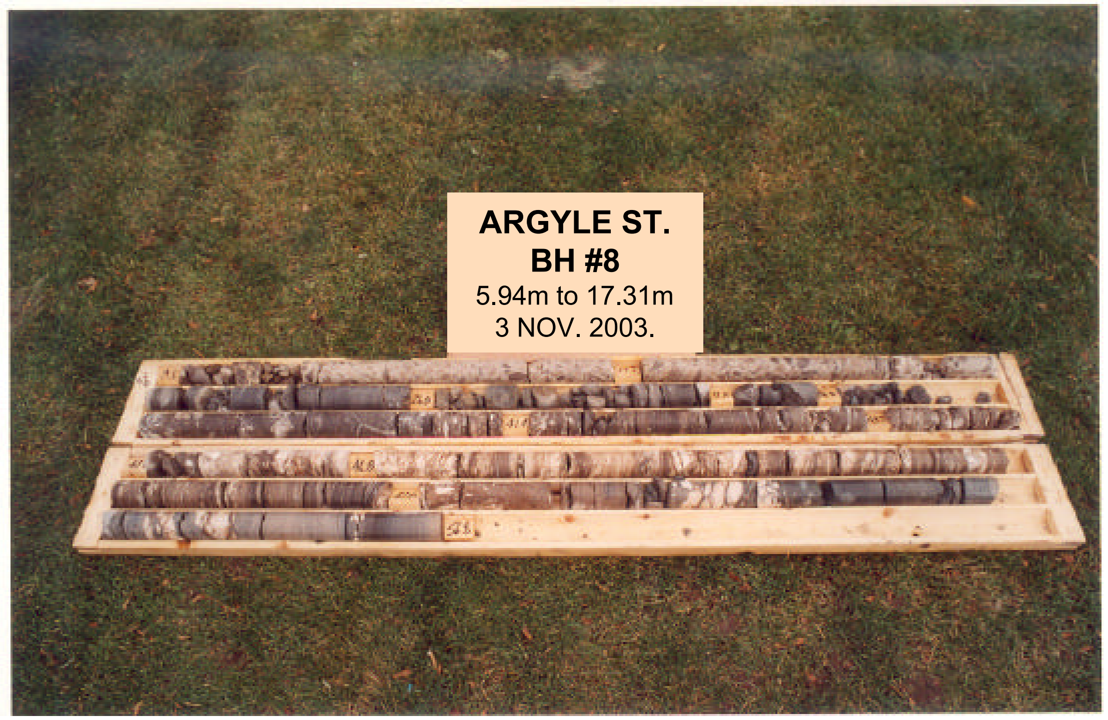


Photo 4 Borehole No. 8 – Rock core. Note concrete.
Elevation 185.29m to 173.92m.

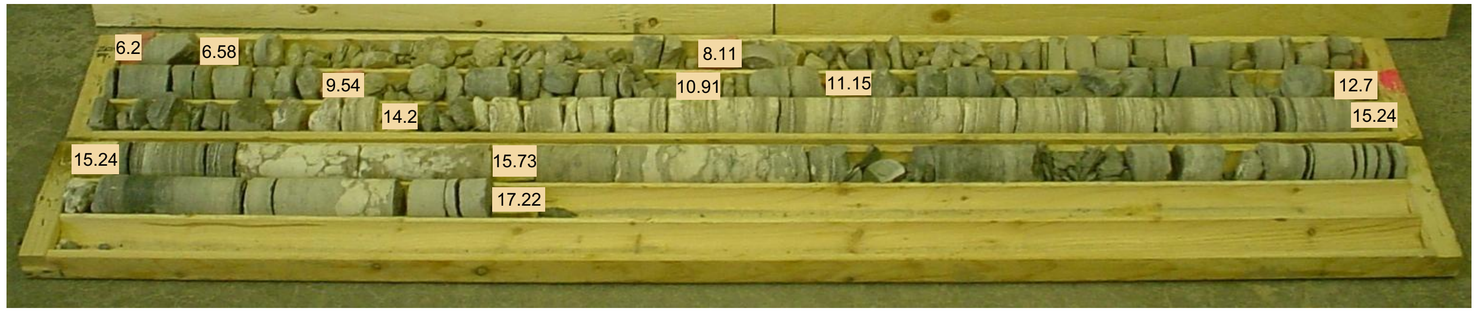


Photo 5: Borehole No. 101 – Rock Core. Possible concrete to approximate elevation 184.0 metres. Elevation 184.87 metres to 173.93 metres.

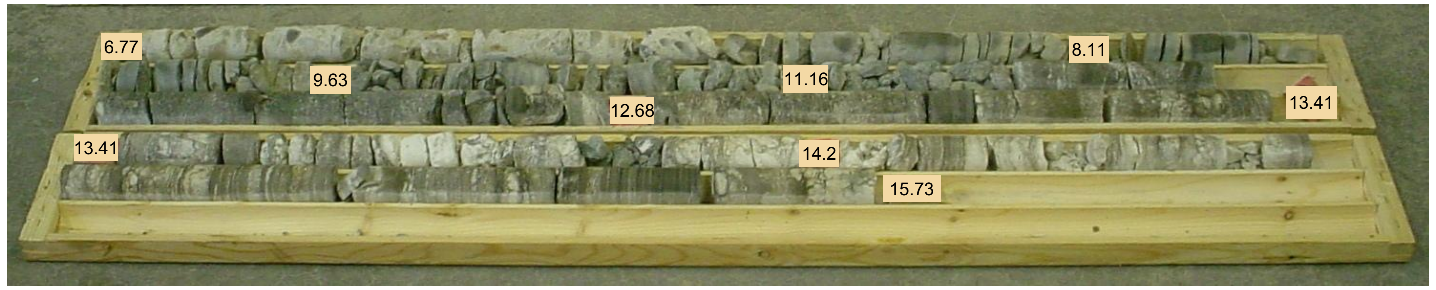


Photo 6: Borehole No. 102 – Rock Core. Concrete to approximate elevation 184.0 metres. Elevation 184.63 metres to 175.67 metres.

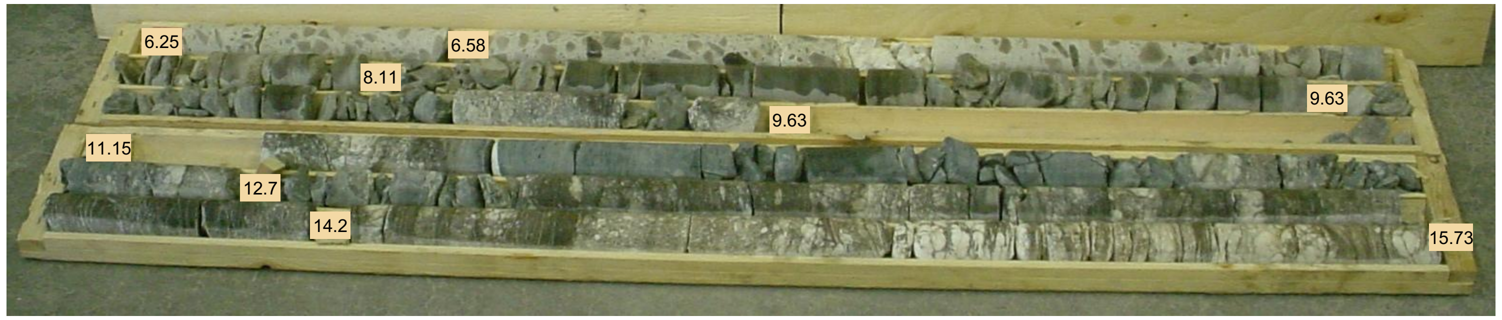


Photo 7: Borehole No. 103 – Rock Core. Concrete to approximate elevation 183.9 metres. Elevation 185.18 metres to 175.70 metres.

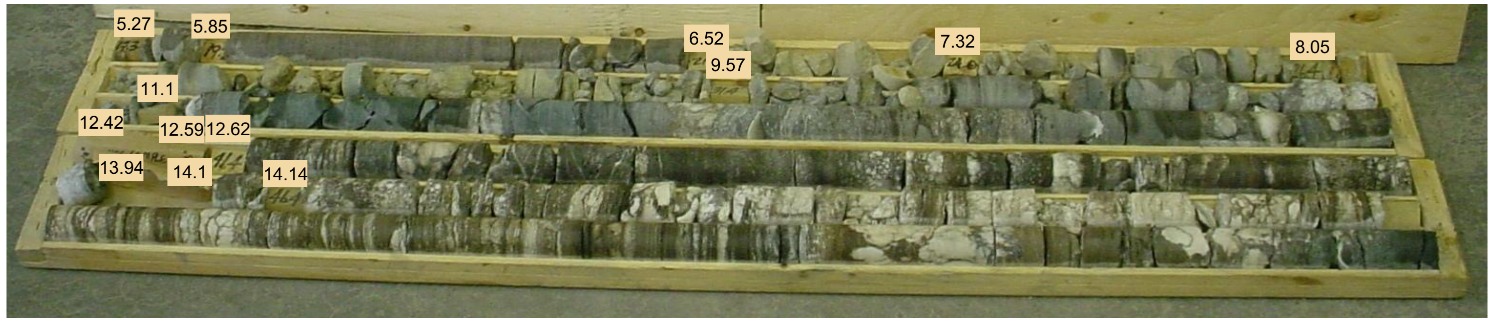


Photo 8: Borehole No. 104 – Rock Core. Elevation 185.96 metres to 194.04 metres.

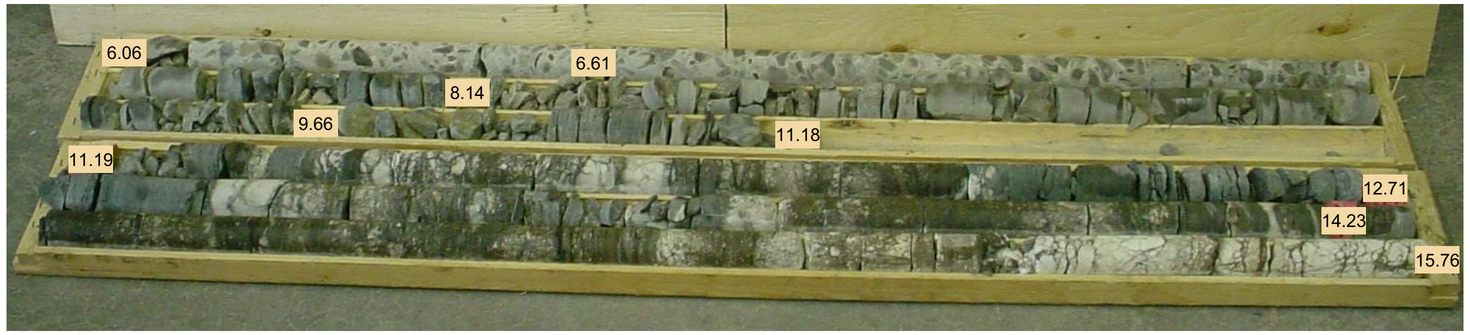


Photo 9: Borehole No. 105 – Rock Core. Concrete to approximate elevation 183.8 metres. Elevation 185.27 metres to 175.58 metres.

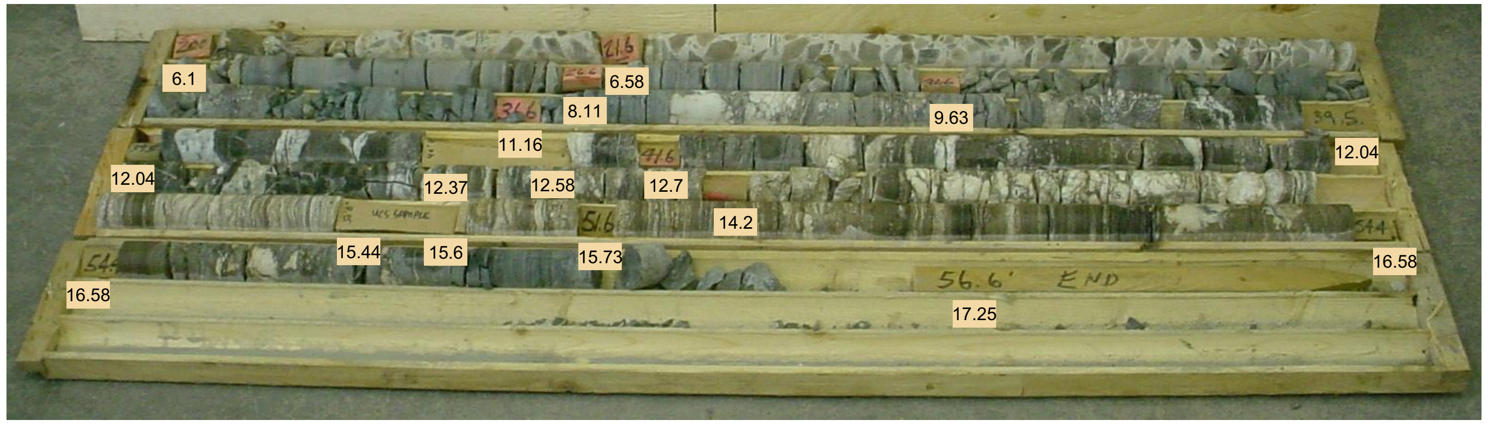


Photo 10: Borehole No. 106. Concrete to approximate elevation 186.0 metres. Elevation 185.38 metres to 174.23 metres.

APPENDIX C

LABORATORY TEST DATA

UNCONFINED COMPRESSION TEST (UC)

SAMPLE IDENTIFICATION

PROJECT NUMBER	07-1130-0023	SAMPLE NUMBER	-
BOREHOLE NUMBER	104	SAMPLE DEPTH, m	12.4-12.6

TEST CONDITIONS

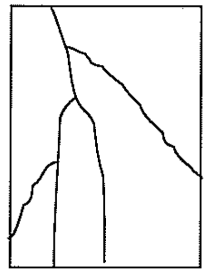
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.08

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	9.80	WATER CONTENT, (specimen) %	5.10
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m^3	23.11
SAMPLE AREA, cm^2	17.50	DRY UNIT WT., kN/m^3	21.99
SAMPLE VOLUME, cm^3	171.48	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	404.26	VOID RATIO	0.20
DRY WEIGHT, g	384.64		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	21.6

REMARKS:

DATE: 7/15/2007

FIGURE C-1

UNCONFINED COMPRESSION TEST (UC)

SAMPLE IDENTIFICATION

PROJECT NUMBER	07-1130-0023	SAMPLE NUMBER	-
BOREHOLE NUMBER	106	SAMPLE DEPTH, m	12.4-12.5

TEST CONDITIONS

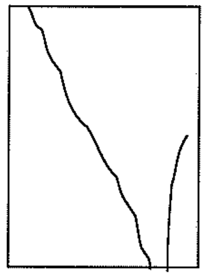
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.14

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	10.10	WATER CONTENT, (specimen) %	4.40
SAMPLE DIAMETER, cm	4.72	UNIT WEIGHT, kN/m^3	23.33
SAMPLE AREA, cm^2	17.50	DRY UNIT WT., kN/m^3	22.35
SAMPLE VOLUME, cm^3	176.72	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	420.62	VOID RATIO	0.18
DRY WEIGHT, g	402.89		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	25.4

REMARKS:

DATE: 7/15/2007

FIGURE C-2

Golder Associates

UNCONFINED COMPRESSION TEST (UC)

SAMPLE IDENTIFICATION

PROJECT NUMBER	07-1130-0023	SAMPLE NUMBER	-
BOREHOLE NUMBER	106	SAMPLE DEPTH, m	15.4-15.6

TEST CONDITIONS

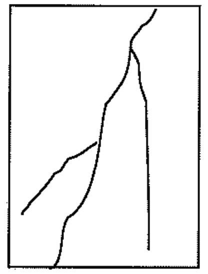
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.07

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	9.72	WATER CONTENT, (specimen) %	9.10
SAMPLE DIAMETER, cm	4.70	UNIT WEIGHT, kN/m^3	22.59
SAMPLE AREA, cm^2	17.35	DRY UNIT WT., kN/m^3	20.70
SAMPLE VOLUME, cm^3	168.64	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	388.52	VOID RATIO	0.28
DRY WEIGHT, g	356.11		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	24.4

REMARKS:

DATE: 7/15/2007

FIGURE C-3

Golder Associates

UNCONFINED COMPRESSION TEST (UC)

SAMPLE IDENTIFICATION

PROJECT NUMBER	07-1130-0023	SAMPLE NUMBER	-
BOREHOLE NUMBER	104	SAMPLE DEPTH, m	13.9-14.1

TEST CONDITIONS

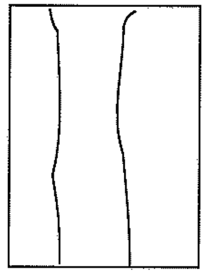
MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.14

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	10.06	WATER CONTENT, (specimen) %	4.00
SAMPLE DIAMETER, cm	4.70	UNIT WEIGHT, kN/m^3	24.71
SAMPLE AREA, cm^2	17.35	DRY UNIT WT., kN/m^3	23.76
SAMPLE VOLUME, cm^3	174.54	SPECIFIC GRAVITY, assumed	2.70
WET WEIGHT, g	439.87	VOID RATIO	0.11
DRY WEIGHT, g	422.95		

VISUAL INSPECTION

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	28.2

REMARKS:		DATE:	7/15/2007

FIGURE C-4

APPENDIX D

SETTLEMENT RISK ANALYSIS REPORT

Golder Associates Ltd.

309 Exeter Road, Unit #1
London, Ontario, Canada N6L 1C1
Telephone: (519) 652-0099
Fax: (519) 652-6299

SETTLEMENT RISK ANALYSIS REPORT
REHABILITATION OF THE ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00, AGREEMENT NO. 3006-E-0049
MINISTRY OF TRANSPORTATION, ONTARIO
– SOUTHWESTERN REGION

Submitted to:

Morrison Hershfield Limited
Consulting Engineers
235 Yorkland Boulevard, Suite 600
Toronto, Ontario
M2J 1T1

DISTRIBUTION:

8 Copies - Morrison Hershfield Limited
2 Copies - Golder Associates Ltd.

December 20, 2007 07-1130-023-1

TABLE OF CONTENTS

SECTION PAGE

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (Morrison Hershfield) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a settlement risk analysis in conjunction with the design of the proposed rehabilitation of the Argyle Street South Bridge over the Grand River in Caledonia, Ontario. The location of the bridge is shown on the Site Location Plan, Figure 1.

The existing bridge has experienced settlement at the piers and abutment since its original construction in 1927. The ground conditions and an evaluation of the cause(s) of foundation settlement are described in more detail in a separate report Geocres No. 30M4-111, titled “Detail Foundation Investigation And Design Report, Rehabilitation Of The Argyle Street South Bridge, former Highway 6, Caledonia, Site 9-2, GWP 3147-06-00, Agreement No. 3006-E-0049, Ministry Of Transportation, Ontario – Southwestern Region”, prepared by Golder Associates, Ltd., September, 2007 (Golder 2007). Consideration is currently being given to completing a rehabilitation of the existing bridge and foundations that would be suitable for a five to ten year period with the potential for full rehabilitation or the construction of a replacement structure to follow.

The purpose of the risk analysis is to estimate the potential for continued settlement of the bridge piers and abutments to adversely affect the performance of the bridge structure. The terms of reference for the work are outlined in Golder's Total Project Management (TPM) for Detail Design Services proposal P61-3174 dated December 11, 2006. The work was carried out in accordance with our Quality Control of TPM Services Plan, Agreement No. 3006-E-0049, dated February 13, 2007 (updated July 11, 2007).

2.0 EXISTING BRIDGE STRUCTURE

2.1 Superstructure Configuration

Morrison Hershfield provided Golder with the April 1927 design drawings for the existing bridge. The existing bridge, constructed circa 1927, is a two lane, nine span structure carrying the north-south directions of Argyle Street pedestrian and road traffic over the Grand River. The bridge is a designated heritage structure which was rehabilitated in 1984. Each span of the existing structure is about 22 metres long, for a total length of approximately 198.5 metres. The bridge is about 8 metres wide in the roadway area and about 12 m wide between the sidewalk handrails. In 2002, vehicle weight limits were posted since the bridge was found to be in an advanced state of deterioration that limited the load carrying capacity of the structure. Site photographs are provided in the aforementioned report.

2.2 Foundation Conditions

Based on the design drawings available for the existing bridge and observations made during the field investigation, the existing structure is founded on spread footings bearing on the bedrock surface. The existing deck surface is at about elevation 191.2 metres. The water level in the Grand River was at about elevation 185.7 metres during the current field investigation. All elevations in this report are referenced to geodetic datum.

Because of visually observable distortion in the structure, a survey of elevations along the bridge structure was carried out. This survey is described in greater detail in the Detail Foundation Investigations and Design Report (Golder 2007). The post construction settlements estimated from the current survey data and the 1927 design drawings are provided in Table I, below. These data indicate total settlements, Δ, of up to 159 mm on one side of the pier foundation, average pier foundation settlements of up to 124 millimetres, with transverse differential settlements (one side of a pier to the other side) of as much as 80 millimetres at individual piers or abutments. Figure 2 provides a plot of the estimated settlements along the profile of the bridge and Figure 3 presents a frequency histogram of the transverse differential settlement of foundation units.

Although the pier footings are supported on weathered and weak rock that has had gypsum removed by dissolution, the foundation analysis (Golder 2007) concluded that there is sufficient resistance currently offered by the surficial bedrock to adequately support the piers under the currently applied loads, albeit with some apparent post construction settlements. However, the dolomitic shale and dolostone rock on which the piers are founded are susceptible to some potential ongoing deterioration. These effects are expected to be time dependent and will cause a reduction in geotechnical bearing resistance with time. Similarly, it was concluded that a potential exists for ongoing gypsum dissolution causing additional structure movements. No sinkholes or solution cavities were observed during the drilling investigations carried out on site.

The Detail Foundation Investigation and Design Report (Golder 2007) concluded that based on the available borehole information and experience with sites in the surrounding area, the potential for significant sinkhole and solution cavity formation in the bedrock in the zone of influence of the existing foundations within the proposed five to ten year design life is insignificant.

Table I. Summary of Estimated Post-Construction Foundation Settlements

Pier #	Estimated Total Settlement West Side, Δ (mm)	Estimated Total Settlement East Side, Δ (mm)	Transverse Differential Settlement (mm)	Maximum Longitudinal Differential Settlement (mm)
North Abutment	55	98	43	
				76
1	131	117	14	
				36
2	95	140	45	
				54
3	85	85	0	
				19
4	104	94	10	
				55
5	159	84	75	
				24
6	140	60	80	
				111
7	30	60	30	
				19
8	49	74	25	
				59
South Abutment	30	15	15	

3.0 SITE GEOLOGY AND STRATIGRAPHY

Detailed descriptions of the subsurface conditions at the site are provided within the Detail Foundation Investigation And Design Report (September, 2007). A brief summary of these conditions is provided within this report for reference purposes, to allow an understanding of the mechanisms of settlement, and the inferences made regarding the probable mechanisms of future settlement.

The surficial soil deposits are comprised of the Wentworth Till sheet, a sandy silt to clayey silt till deposit with irregular interbeds of silty to sandy deposits. The advance of the glacial ice associated with the deposition of the till also scoured the bedrock surface, greatly influencing the present bedrock surface topography that underlies the area. In the area of the bridge site, the Grand River Valley is fully incised through the overburden to expose the underlying rock in the riverbed.

The site is underlain by Silurian-age dolomite, shaley dolomite and shale of the Salina Formation. The Salina Formation hosts the gypsum deposits of the Grand River Valley. The Salina Formation is underlain by the Guelph Formation. The strata are near flat lying with a gentle southward dip of approximately 0.5 per cent. The Salina Formation consists of six members (Members A, B, C, E, F and G). The D Member (halite salt strata of the Salina Formation) was not deposited in this area.

In summary, the subsoils at the abutments and approaches generally consist of variable thicknesses of pavements, fill and topsoil materials to between elevation 186 and 189 metres. These deposits are underlain by generally thin deposits of sand and gravel, sandy silt, silt, clayey silt and sand over the bedrock. At the pier locations, the bedrock is exposed below about 0.4 to 0.6 metres of water and/or thin sandy silt deposits. The bedrock surface was encountered at elevations between 183.6 and 184.9 metres at the borehole locations.

The rock cores obtained at the site consisted of beds of gypsum, shale, dolostone and mudstone. The predominant rock strata have been identified as:

- Unit 1 - shale to dolomitic shale
- Unit 2 - Dolostone/Gypsiferous Dolostone/Shaley Dolostone
- Unit 3 - Gypsum
- Unit 4 - Gypsiferous Mudstone

Recovery in the upper weathered portions of the boreholes was very low, which is typical of the area, and attributed to gypsum dissolution, normally characterized by voids and/or vuggy intervals. Poor recovery was not attributed to the drilling techniques. No sudden loss of drill pressure or other evidence of large voids in the rock was noted during drilling and coring.

The Grand River water level was noted to vary from elevation 185.6 to 185.7 metres between April 30 and May 2, though such levels are subject to significant seasonal fluctuations. Analytical testing following investigations conducted at the site indicated a groundwater pH value of 7.58 and a sulphate concentration of 1330 milligrams per litre.

4.0 SETTLEMENT RISK ANALYSIS

Rehabilitation of the existing Argyle Street (formerly Highway 6) bridge foundations has been planned as a short-term strategy for the crossing at this location. The proposed design service life of the short-term rehabilitation for the current structure is five to ten years. In separate studies concerning the future of this structure beyond the short-term future, the feasibility of an extensive rehabilitation or bridge replacement will be considered. There are three options under consideration for addressing the existing bridge foundations in the short term: do nothing except monitor the bridge, pressure grouting of the bedrock beneath the foundations, and installing micropiles to support the foundations on more competent rock found at lower elevations. A quantitative risk analysis was carried out in order to assist with decisions regarding the efficacy of completing foundation and bridge temporary and permanent repair options at various future time intervals. This risk analysis used data available at the time this report was prepared related to settlement, bridge conditions, and the thresholds of displacement at which damage to the structure of differing degrees could be expected based on structural analyses completed by Morrison Hershfield.

4.1 Characteristics of Bridge Settlement

The time-rate of settlement data available to complete a risk analysis is limited to only the initial bridge design and construction data as compared to the survey data gathered during the recent site investigations (Golder 2007). This results in a time period of some 80 years between known (or reasonably estimated) foundation elevations. Therefore, a number of simplifying assumptions were necessary to characterize the probable future settlement behaviour based on these measurements and plausible settlement mechanisms.

During subsurface investigations carried out at the site, no large solution cavities were found within a total of 121.7 m of coring through bedrock. Although the absence of relatively large solution cavities at borehole locations does not eliminate the potential for solution cavities to exist elsewhere, given that the majority of coring was completed at the foundation locations, it is reasonable to conclude that the probability of such solution cavities existing and being of a sufficient size to result in total foundation collapse is negligible.

The characteristics of the bedrock strata as found in the core samples indicate that the bedrock is composed of laterally extensive, though relatively thin, gypsum layers or laminae and nodules of gypsum within the shale, dolomitic shale, and dolostone rock formations. While cumulatively, the gypsum made up a significant proportion of the total rock mass, relatively large and laterally discontinuous zones of gypsum that might be subject to future dissolution were not identified during the investigations. These conditions suggest that the removal of gypsum and the subsequent compression of the remaining rock mineral matter is likely a relatively gradual process without a significant potential for sudden collapse.

4.2 Structure Settlement Performance Thresholds

Morrison Hershfield completed a structural analysis of the existing bridge design and determined two modes of potential settlement-induced damage. These are:

1. Transverse differential settlement of an individual pier (δ_{trans}) – for example, the west side of a pier settles more than the east side of the pier. This differential settlement thus results in a rotational torque, or “twist”, angle of the bridge deck, compounded if the adjacent pier supporting the other end of the span also settles but in a different rotational direction (θ).

2. Longitudinal settlement of adjacent piers (δ_{long}) – for example, Pier 5 settles in relation to Pier 6, causing the supporting beams and deck to tilt in a north to south direction.

It is understood that should total transverse differential settlement exceed about 175 mm, or a twist angle of about 0.82 degrees, the extreme fibre stresses in the deck beams may result in structural cracking. Though this structural cracking is considered by the structural analysis to not result in ultimate or catastrophic failure of the bridge span, it is of a magnitude that would lead to road closure due to sufficient concern regarding the structural integrity of the bridge and initiate subsequent repairs. In this case, then, the “failure” may be more representative of a serviceability failure rather than ultimate failure. The mode of failure arising from longitudinal settlement is of an ultimate-failure nature in that beyond a limit of about 305 mm of differential settlement between adjacent piers, the deck beams may slip from their bearings and off the piers. These modes of displacement are illustrated on Figure 5.

While these thresholds represent a useful means by which to evaluate the potential risk of damage to the structure from continued settlement, these thresholds are deterministic in nature (i.e., no uncertainty has been associated with these singular threshold values, e.g., probability of failure increasing as movement increases). Ranges of the structural performance thresholds for various assumptions of dimensional or material variability were not provided by Morrison Hershfield.

4.3 Settlement Performance Simulation

To complete a time-based analysis of future risks, some estimate of the time rate of settlement and its uncertainty was necessary. As previously discussed, there exist only two instances of known (or reasonably estimated) elevation data for the bridge piers, separated by a period of some 80 years. This intervening period was used to define the average rate of settlement for each of the measured pier and abutment locations, resulting in a total of 20 average rate of settlement values. It is presently uncertain whether the average rate of settlement exhibited at each measurement location is representative of a relatively smooth and continuous rate of settlement or a pattern of settlement in which long periods of stability are interrupted by relatively rapid, albeit small magnitude, settlements that occur in a single or series of “steps” to accumulate to the observed total values. Therefore, three different scenarios regarding the settlement patterns were considered:

1. A continuous, normal distribution of settlement rate was used to represent the time rate of settlement as shown in Figure 4 based on all measurements and assessed differential settlement. It was considered that use of a continuous distribution could reasonably represent low probability, relatively high rates of settlement that may not be adequately captured by the distribution of the limited measured data set (“extrapolated”). A mean value of 1.1 mm per year and standard deviation of 0.5 mm per year was used for simulating the cumulative settlement in repetitive estimates of settlement over given time periods. This continuous distribution was applied independently to each side of the individual pier foundation units, ignoring potential spatial correlations. This assumes a random, independent settlement process at each location.

2. Normal distributions of settlement rate were assigned to each side of the individual piers assuming that each side of the individual piers would settle at a mean annual rate equal to its total settlement divided by 80 years with a standard deviation of 0.25 mm/year (half the value for the combined data of all piers). This approach is based on an assumption that those piers that have settled at the highest rates will continue to settle at the highest rates (i.e. the rates of settlement are spatially correlated). For example, if one pier is located in a section of the riverbed exposed to greater flows of water that have the potential to dissolve and remove gypsum more rapidly than in other areas, this pier may settle at a higher rate than others.

3. Each side of the individual piers was assumed to have undergone its estimated settlement in one event (worst case) over the course of the 80 years since the structure was built. This approach also assumes spatial correlation of settlement rates similar to Scenario 2 described above in that those piers that have experienced the worst settlement will experience the worst settlement in the future. It is understood that the structure, however, does not exhibit distress that might be consistent with such rapid settlements and, therefore, that this scenario may be less probable than Scenarios 1 or 2.

The future settlement performance of the structure foundations was simulated using stochastic methods (e.g. Monte Carlo simulation) and the probabilistic settlement rate characterization as described above using a total of 10,000 trials for each assumption of settlement performance described above for the 5 and 10 year periods of interest. The simulated settlement values were then applied to each side (east and west) of each pier for simulated 5 or 10 year periods, thus allowing simulation of east-to-west differential settlement of each pier and the north-to-south differential settlement between piers for these two time periods. East-to-west differential settlements were converted into “twist” angles to which the deck and supporting frames may be subject by transverse rotations at adjacent piers (see Figure 5). All calculated settlements were added to current estimates of settlement, therefore describing the cumulative effect of such settlements between 2007 and the future date (2012 or 2017), not just the incremental effects, because structural behavior will be determined by cumulative (not incremental) effects. The maximum twist angles and differential settlements amongst all piers were simulated.

The overall results of this simulation using Scenarios 1 and 2 are illustrated on Figures 6 and 7 in which cumulative probability distributions (percentile charts) are used to describe the potential for Scenarios 1 and 2. Scenario 3 is not illustrated because of the step-function nature of the distribution. Figure 7 illustrates the cumulative probability of north-to-south differential settlement from pier to pier for Scenarios 1 and 2. For example, there is a 90% probability that the maximum differential settlement between any two piers will be less than about 115 mm within the next 5 years or less than about 120 mm in the next 10 years for Scenario 1. The "twist" angle cumulative distribution summary shown in Figure 6 illustrates that the maximum angle ranges between about 0.40 and 0.65 degrees for the two assessed time periods for Scenario 1. Characteristic values of settlement and angular "twist" of the deck are provided in Table II, below.

Table II. Summary of Performance Simulation Results

Deformation Mode	**Maximum (of 10000)**	**Minimum (of 10000)**	**Mean**	**Standard Deviation**	**Structural Criteria**
SCENARIO 1 *5 Year Period*					
Max. δ_{long} (mm)	125	97	111	3	*305*
Max. Δ (mm)	173	156	164	2	--
Max. θ (degrees)	0.60	0.43	0.52	0.02	*0.82*
Max. δ_{trans} (mm)	128	92	110	5	*175*
10 Year Period					
Max. δ_{long} (mm)	138	84	111	7	*305*
Max. Δ (mm)	191	151	170	5	--
Max. θ (degrees)	0.68	0.34	0.52	0.05	*0.82*
Max. δ_{trans} (mm)	145	73	110	10	*175*
SCENARIO 2 *5 Year Period*					
Max. δ_{long} (mm)	117	105	111	2	*305*
Max. Δ (mm)	170	160	164	1	--
Max. θ (degrees)	0.53	0.44	0.48	0.01	*0.82*
Max. δ_{trans} (mm)	113	93	103	2	*175*
10 Year Period					
Max. δ_{long} (mm)	124	99	111	3	*305*
Max. Δ (mm)	178	160	168	2	--
Max. θ (degrees)	0.54	0.36	0.45	0.02	*0.82*
Max. δ_{trans} (mm)	114	77	96	5	*175*
SCENARIO 3 *5 Year Period*					
Max. δ_{long} (mm)	251	81	111	8	*305*
Max. Δ (mm)	318	159	160	11	--
Max. θ (degrees)	1.18	0.31	0.52	0.05	*0.82*
Max. δ_{trans} (mm)	250	65	111	10	*175*
10 Year Period					
Max. δ_{long} (mm)	251	81	113	17	*305*
Max. Δ (mm)	2318	159	164	22	--
Max. θ (degrees)	1.27	0.28	0.53	0.09	*0.82*
Max. δ_{trans} (mm)	270	59	113	18	*175*

NOTE: Values shown above are to nearest mm; however, these values should only be considered as statistical indicator values and can not be considered to be precise predications of future events.

4.4 Conclusions

The probabilistic settlement performance results are summarized in Table II for the full range of deformation simulations. For example, for Scenario 1 the longitudinal differential settlement is estimated to be 123 mm or less, and the “twist” angle about 0.60^{o} or less (transverse settlement of 128 mm or less) given a probability of these values being exceeded of 10^{-4} for the simulated 5 year period. For the 10 year simulation period, the longitudinal and transverse differential settlement corresponding to a probability of being exceeded equal to 10^{-4} are about 136 mm and 145 mm, respectively. For Scenario 2 the differential settlement and “twist” angle values corresponding to a probability of being exceeded of 10^{-4} are on the order of 5 to 15% less than those for Scenario 1. For both Scenarios 1 and 2, these values are well below the structural thresholds provided by Morrison Hershfield. The probability of any threshold criteria being exceeded in Scenarios 1 and 2 is less than 10^{-5}. Scenario 3 is the most critical, indicating that the maximum transverse differential settlement threshold may be exceeded with a corresponding probability equal to about 7x10^{-3} for the 5 year time period and about 1 order of magnitude greater for the 10 year period. The probability of exceeding the catastrophic mode of failure for Scenario 3 is considered to be less than 10^{-5} for both time periods.

While the results summarized in Table II encompass the full simulated performance range, they do not adequately illustrate the small values of risk that are accepted by society for performance of engineered structures or some forms of transportation. Table III, below, provides some reference values for accepted annual probabilities of failure for various conditions. Based on the available information, threshold criteria, and reasonable, albeit simplifying assumptions, for the two time periods evaluated, the probability of catastrophic failure of the Argyle Street bridge is estimated to be well below the values indicated in Table III for foundation failure, by several orders of magnitude. These risk acceptability thresholds, however, must also take into account the duration of interest. Thus, for an annual risk threshold of 10^{-4}, the thresholds for a 5 year duration would be 5x10^{-4} and 10^{-3} for a 10 year duration. Using the available limited information and methods described above, it has been estimated that the foundation settlement is near what may be considered a societal acceptable annual probability of failure for the serviceability mode (transverse differential settlement) should it continue to settle for a total of 5 years or more into the future for the worst-case scenario (Scenario 3). It is understood that this mode of “failure” identified by Morrison Hershfield, however, constitutes closure of the bridge rather than catastrophic structural failure based on the provided thresholds and is more appropriately compared to the societal acceptance thresholds for financial loss. In this case, the societal acceptance for annual losses in the vicinity of $20 million is on the order of 5x10^{-3} and, when related to the project durations under examination, the risk of failure for any of the examined scenarios is less by one half to one order of magnitude.

As noted previously, these probabilities of failure are based on deterministic thresholds of structural performance. It is recommended that the structural performance criteria be evaluated with respect to potential uncertainty in as-built structural dimensions that may affect the catastrophic mode of failure resulting from longitudinal differential settlement (deck beams slipping from supports). Furthermore, it is recommended that the structural performance criteria for transverse differential settlement (“twist”) be examined with respect to potential uncertainty in concrete and reinforcement strength and condition. It is understood that these as-built conditions will be measured during planned work on the bridge to be conducted within the next 5 years. Should the probability of structural failure or cracking (corresponding to the identified modes of displacement) based on the review of the as-built conditions, be considered equal to 10^{-4} or greater for threshold criteria values equal to or less than those defined in the paragraph above, the combined probability of failure from both sources of uncertainty (geotechnical and structural) should be reexamined.

The choice of when to rehabilitate the existing bridge foundations within the five to ten year period under consideration should be made by MTO considering the results presented above. It is recommended that MTO undertake a prudent course of action and complete a more detailed examination of the uncertainty associated with the structural performance thresholds based on measurements of the as-built conditions associated with both modes of failure. It is understood that this work will be undertaken within the next 5 years and that the structure settlements will be monitored through this duration. This will reduce the uncertainty associated with this analysis for defining failure thresholds for all modes of displacement. This may be particularly important if the probability of serviceability failure (unplanned road closure for repairs) being close to 1 in 1,000 for the 5 year period and 1 in 100 for the 10 year period approaches levels considered unacceptable by the MTO.

Table III. Examples of Societal Acceptance of Annual Probability of Failure (Risk)

	Approximate Societal Acceptable Annual Probability of Failure	
Category of Failure	**Low End of Range$^{1, 3}$**	**High End of Range$^{2, 3}$**
Mine Pit Slopes	2x10^{-2}	2x10^{-1}
Foundations	1x10^{-3}	1x10^{-2}
Dams	5x10^{-5}	2x10^{-4}
Commercial Aviation	1x10^{-6}	2x10^{-6}
$2 M Financial Cost	2x10^{-2}	8x10^{-2}
$20 M Financial Cost	5x10^{-3}	2x10^{-2}
$200 M Financial Cost	1x10^{-3}	8x10^{-3}
Potential For 1 Fatality	1x10^{-3}	1x10^{-2}
Potential For 10 Fatalities	1x10^{-4}	1x10^{-2}
Potential For 100 Fatalities	1x10^{-6}	1x10^{-3}

NOTES: 1. Low end of range represents published values of societal accepted risks; 2. High end of range represents published values of risks that are marginally accepted by society; 3. Values compiled from Whitman (1984); Nielson, Hartford and MacDonald (1994); and US FHWA (2001); 4. Financial cost values expressed in current 2007 Canadian dollars.

5.0 CLOSURE

This report was prepared by Dr. Storer Boone, P.Eng., with the technical oversight of Dr. William Roberds, the Project Manager, Mr. Philip R. Bedell, P. Eng. and the MTO Designated Contact Mr. Fintan J. Heffernan, P.Eng. This report presents the results of a technical risk analysis associated with potential foundation settlement of the Argyle Street Bridge over the Grand River in Caledonia, Ontario. The magnitudes of risk are associated only with the identified mechanism of settlement due to continued dissolution of gypsum from beneath the bridge foundations and addresses no other potential cause of structural or foundation failure. Furthermore, although the magnitude of risk has been technically quantified, this quantification is based on limited information and may need to be reviewed and revised as additional information becomes available. While it is considered that the results of this work represent a useful aid to decisions regarding rehabilitation of the structure, it can not be considered a guarantee that foundation failure and its consequent effects will not occur at the site within the identified time periods of study. Decisions made by Morrison Hershfield and the Ministry of Transportation Ontario as may be aided by this report must be made with the understanding of the limitations of this study.

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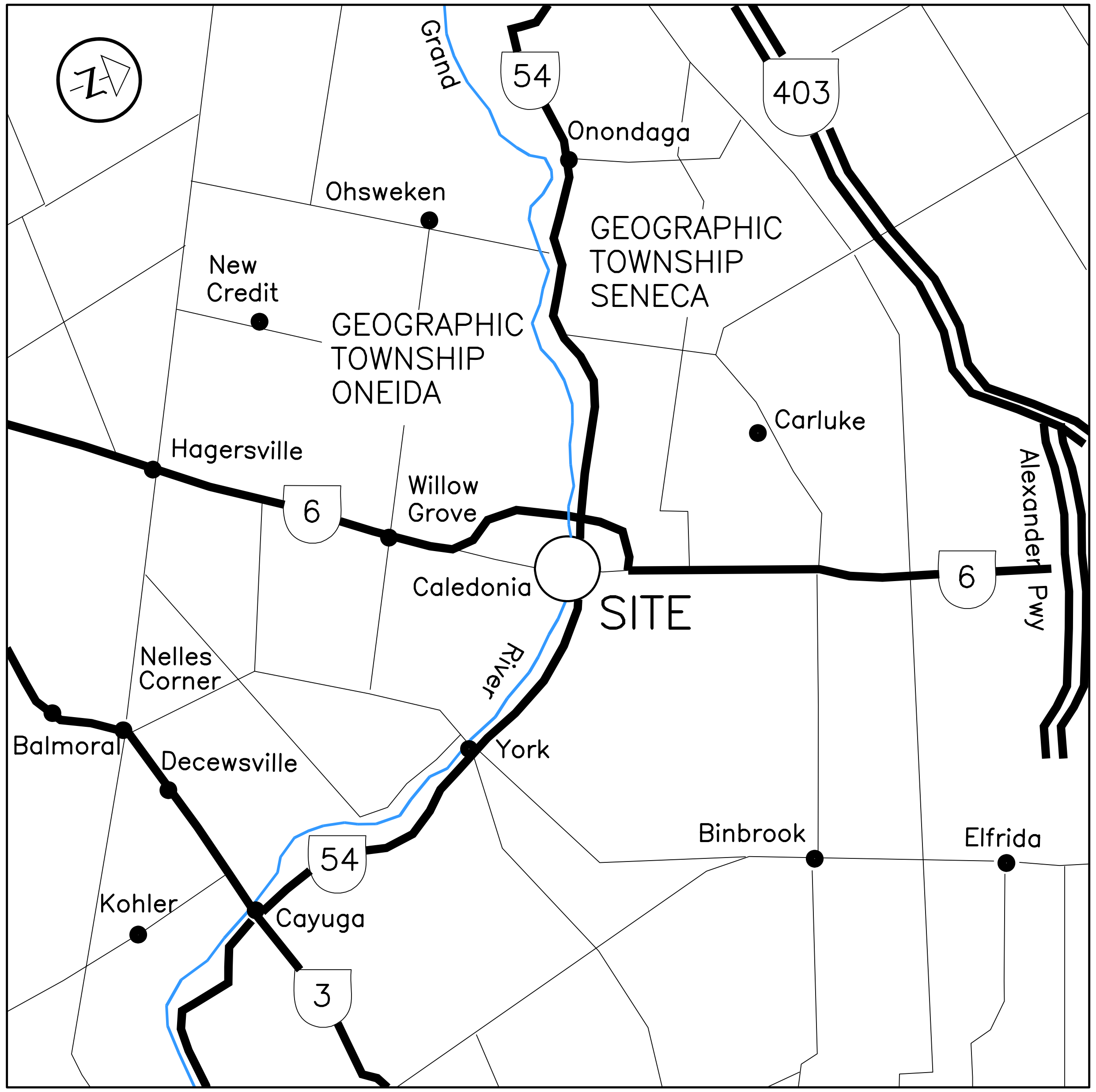

NOTE

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PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
SITE LOCATION PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-1		FILE No.	0711300231-R01001.DWG
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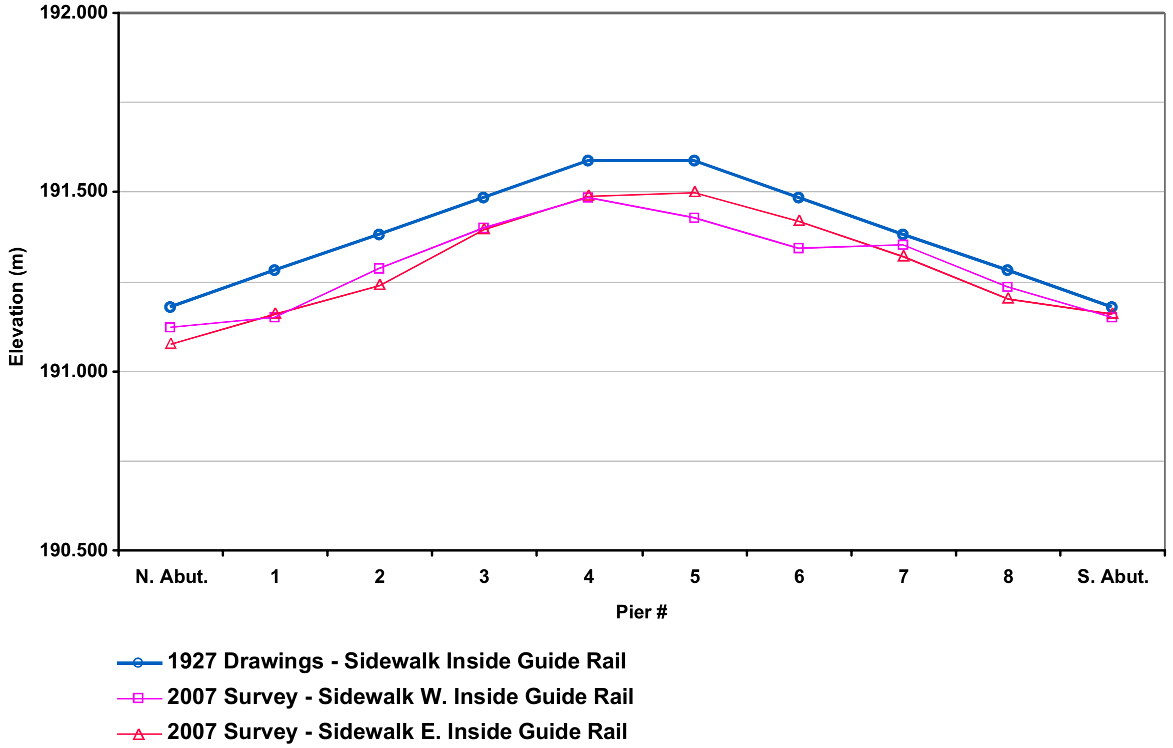

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PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
SIDEWALK SETTLEMENT

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-1		FILE No.	0711300231-R01002.DWG
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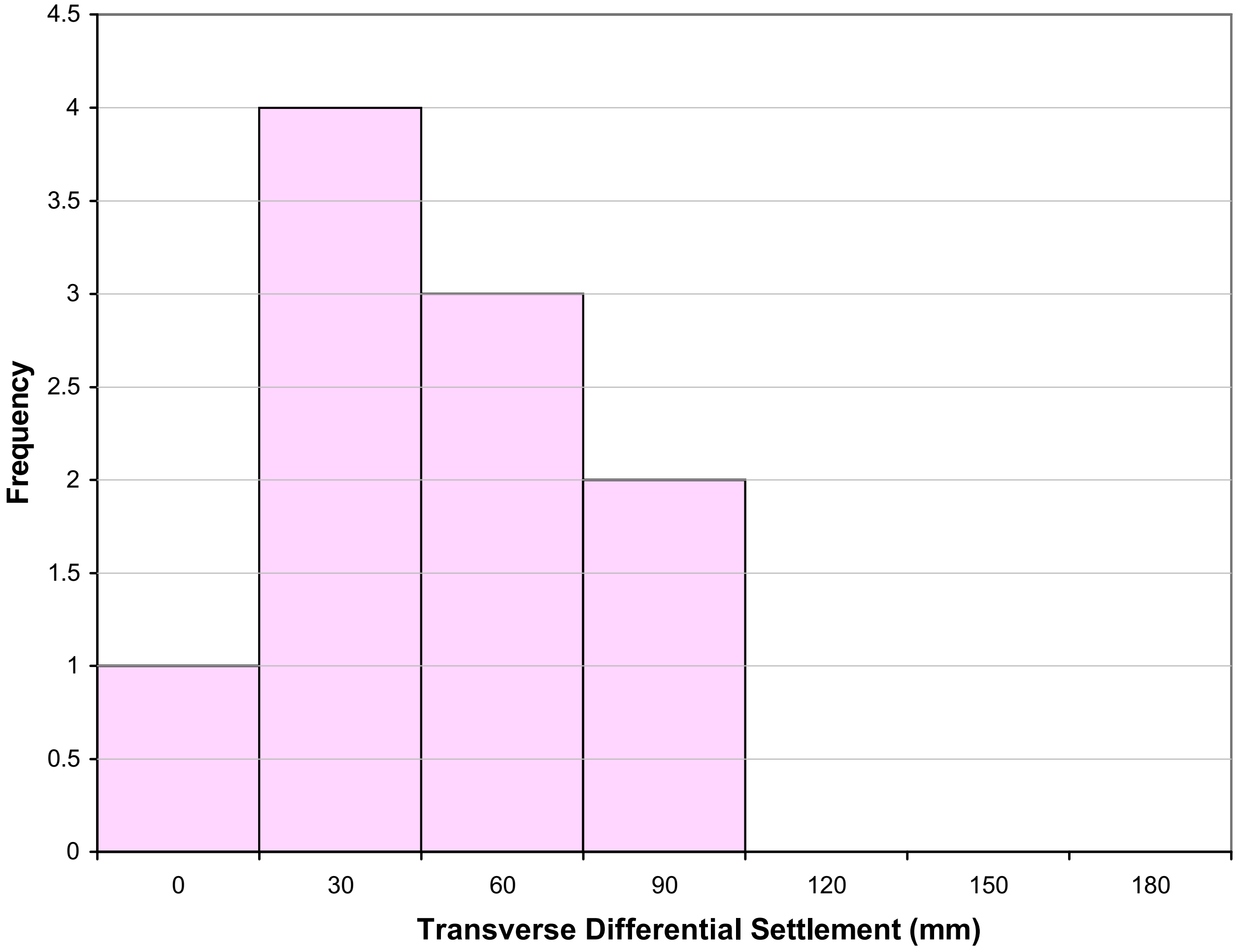

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PROJECT
ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA, SITE 9-2
GWP 3147-06-00

TITLE
TRANSVERSE DIFFERENTIAL SETTLEMENT

Golder Associates
LONDON, ONTARIO

PROJECT No.	07-1130-023-1	**FILE No.** 0711300231-R01003.DWG	
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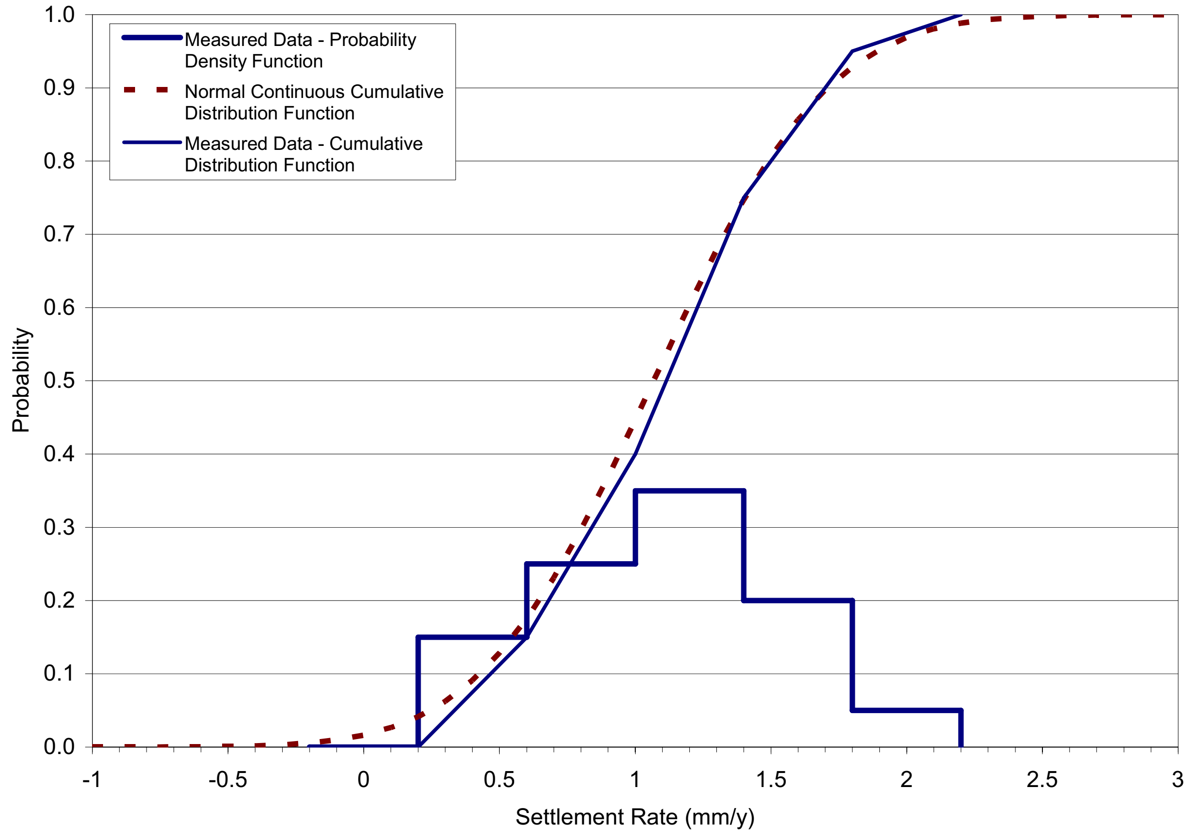

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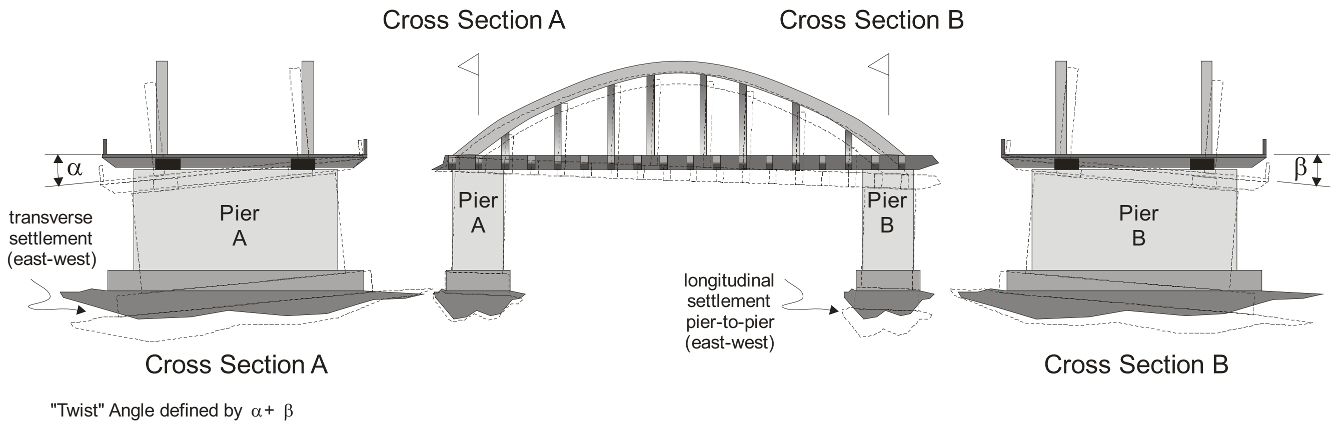
PROJECT NO: 07-1130-023-1

Characteristic Time Rates of Settlement

ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA
GWP 3147-06-00

FIGURE
4



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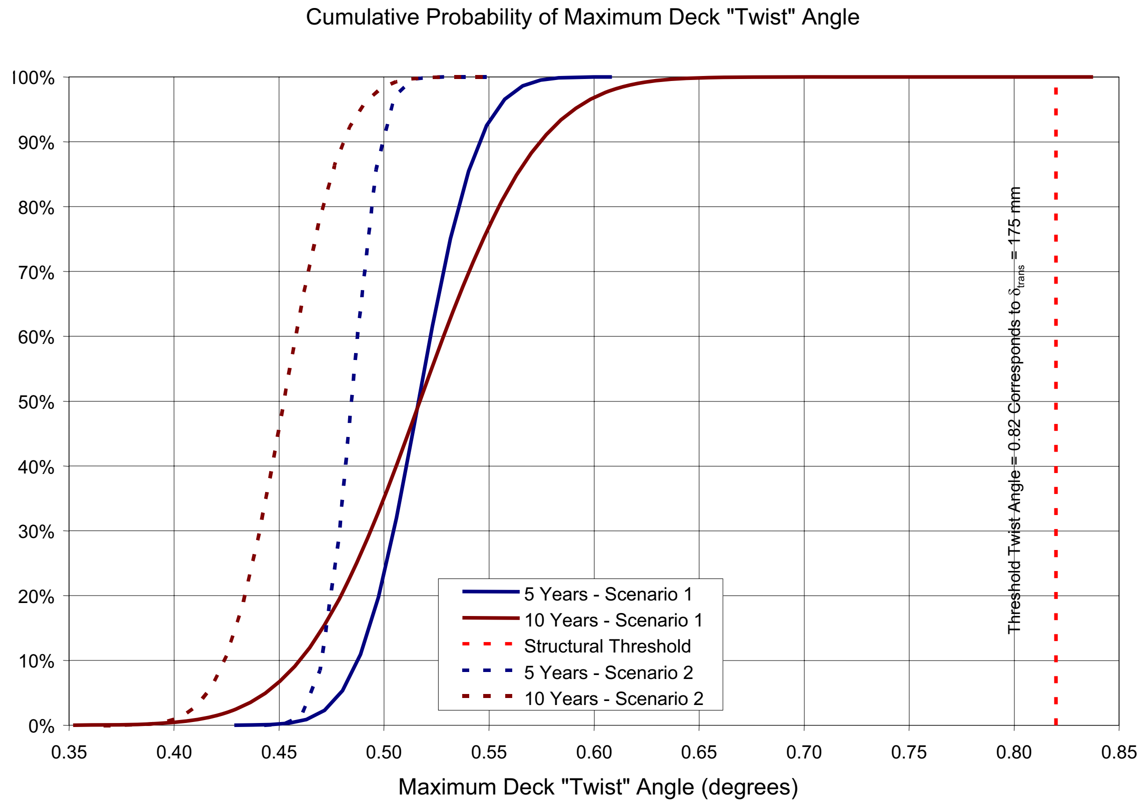
PROJECT NO: 07-1130-023-1

Modes of Differential Settlement

ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA
GWP 3147-06-00

FIGURE
5



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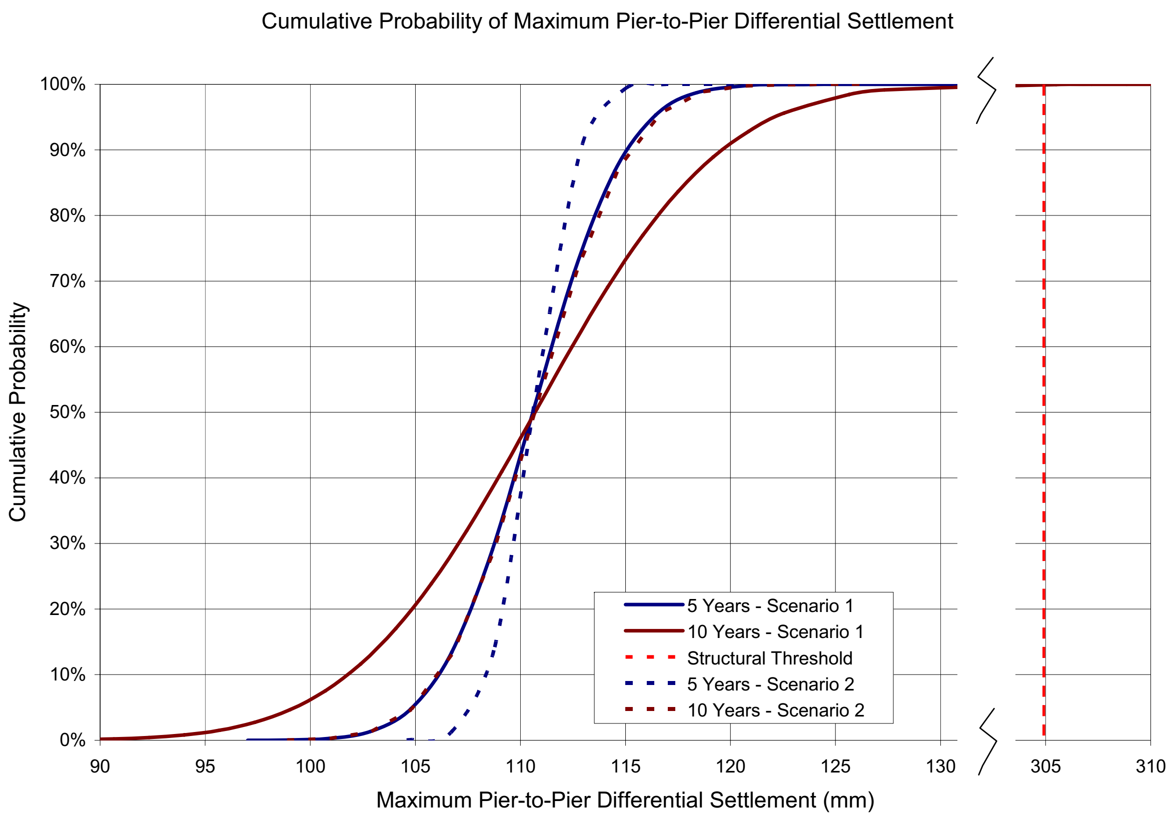
PROJECT NO: 07-1130-023-1

Cumulative Probability Distribution of Maximum “Twist” Angle

ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA
GWP 3147-06-00

FIGURE
6



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PROJECT NO: 07-1130-023-1

Cumulative Probability Distribution of Maximum Longitudinal Differential Settlement

ARGYLE STREET SOUTH BRIDGE
FORMER HIGHWAY 6, CALEDONIA
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FIGURE 7