Golder Associates

FOUNDATION INVESTIGATION AND DESIGN REPORT
OUTLET SEWER CROSSINGS
HIGHWAY 401 WIDENING FROM WEST OF SYDENHAM ROAD TO WEST OF MONTREAL STREET
KINGSTON, ONTARIO
G.W.P. 77-99-01

Submitted to:

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PART A

FOUNDATION INVESTIGATION REPORT
OUTLET SEWER CROSSINGS
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SYDENHAM ROAD TO WEST OF MONTREAL STREET
KINGTON, ONTARIO
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the detail design of the Highway 401 widening from four to six lanes, from west of Sydenham Road to west of Montreal Street in the City of Kingston, Ontario. Foundation engineering services are required for the following components under G.W.P. 77-99-01:

1. Northward widening of the existing Division Street overpass structure;
2. Investigation of instability and settlement along a section of the Division Street W-N/S Ramp;
3. Widening of high fill embankments in the vicinity of Little Cataraqui Creek, between Sydenham Road and Sir John A. MacDonald Boulevard;
4. Overhead signs; and
5. Outlet sewer crossings.

This report addresses the subsurface investigation carried out for the proposed outlet sewer crossings to be constructed at the following locations as part of this project:

1. Between the median and the south side of Highway 401 at the following locations;

   - Station 21+275
   - Station 21+425
   - Station 21+450 (Alternate Crossing Location)
   - Station 21+478
   - Station 21+740
   - Station 24+100
   - Station 24+810
   - Station 26+010

2. Beneath the embankment at Sydenham Road at the following locations;

   - Station 9+971 (north of Highway 401)
   - Station 10+029 (south of Highway 401)

The terms of reference for the original scope of work are outlined in the MTO's Request for Proposal (RFP) dated January 2005, in Section 6.8 of MRC's Technical Proposal and in Golder Associates' Scope Change letters dated December 11, 2006 and April 8, 2008 for this project.

2.0 SITE DESCRIPTION

The outlet sewers are to be installed along the Highway 401 corridor between Sydenham Road and Montreal Street and beneath the approach embankments which support Sydenham Road at the Highway 401 interchange.

The existing Highway 401 is a four-lane divided highway that trends northwest to southeast between Sydenhan Road and Division Street, and trends southwest to northeast between Division Street and Montreal Street. The regional slope in the vicinity of the site is downward to the south, toward Lake Ontario.

Highway 401 has been constructed on embankments at the proposed sewer crossing locations. The height of the embankments ranges from about 2 m to 6 m. The Highway 401 grade slopes downward from about Elevation 91 m at Station 21+275 to about Elevation 86 m at Station 21+478 and is relatively flat between Station 21+478 and Station 21+740. The highway grade is at about Elevation 90 m at Station 24+100, with the highway grade rising in the eastbound direction to about Elevation 109 m at Station 24+810 and sloping downwards to about Elevation 105 m at Station 26+010.

Sydenham Road has been constructed on a bridge approach embankment at the Highway 401 grade separation. Available information from a previous geotechnical investigation carried out in the immediate vicinity of the Sydenham Road interchange indicates bedrock outcrops at this location within the highway corridor.

3.0 INVESTIGATION PROCEDURES

3.1 Borehole Locations

The field work for this subsurface investigation was carried out between February and April 2007 and in May 2008 at which time a total of twenty-three boreholes (Boreholes 07-29 to 07-39, 07-41 to 07-50, 08-1 and 08-2) were put down at the locations of the proposed outlet sewer crossings.

The borehole locations were marked on the pavement and unpaved shoulder of Highway 401, marked on the pavement of Sydenham Road and staked at the toe of the embankment at the Sydenham Road interchange by members of Golder's technical staff. The station number at each borehole location was determined from survey stakes installed in the field by personnel from J.D. Barnes Surveying Ltd. The borehole designation, location and approximate ground surface elevation are summarized as follows:

Borehole Designation	Station	Borehole Location	Ground Surface Elevation (m)
07-29	21+275	East bound, inner lane	90.9[a]
07-30	21+275	East bound, south shoulder	90.7[a]
07-31	21+425	East bound, inner lane	86.7[a]
07-32	21+425	East bound, south shoulder	87.0[a]
08-1	21+450[1]	East bound, south shoulder	86.3[b]
08-2	21+450[1]	East bound, inner lane	86.4[b]
07-33	21+478	East bound, inner lane	86.0[a]
07-34	21+478	East bound, south shoulder	85.7[a]
07-35	21+740	East bound, south shoulder	85.6[a]
07-36	21+740	East bound, inner lane	85.7[a]
07-37	24+100	East bound, inner lane	90.1[a]
07-38	24+100	East bound, south shoulder	90.2[a]
07-39	24+810	East bound, inner lane	108.2[b]
07-41	24+810	East bound, south shoulder	108.7[b]

Borehole Designation	Station	Borehole Location	Ground Surface Elevation (m)
07-42	26+010	East bound, south shoulder	104.7[b]
07-43	26+010	East bound, inner lane	105.1[b]
07-44	26+010	South ditch	104.0[b]
07-45	Sydenham Road, north of Hwy 401 9+971	West Crest of Embankment	111.2[c]
07-46	Sydenham Road, north of Hwy 401 9+971	Near West Toe of Embankment	108.6[c]
07-47	Sydenham Road, north of Hwy 401 9+971	Near East Toe of Embankment	108.1[c]
07-48	Sydenham Road, south of Hwy 401 10+029	East Crest of Embankment	109.6[c]
07-49	Sydenham Road, south of Hwy 401 10+029	Near West Toe of Embankment	106.5[c]
07-50	Sydenham Road, south of Hwy 401 10+029	Near East Toe of Embankment	106.2[c]

Notes:

1- The Scope Change work plan was prepared using MRC Sketch 1; Drainage Profiles; Plate No. CONT WP 77-99-00; Sheet 181 dated September 9, 2006, which indicated sewer crossing locations at Station 21+425 and Station 21+478; An alternate crossing location at Station 21+450 is shown on MRC Median Sewer Outlet Profiles, Contract Sheet 195.

a - Ground surface elevation interpolated from the topographic survey provided by MRC on Drawings H6230XB01 and H6230XB02, dated January 10, 2006.

b - Ground surface elevation surveyed by J.D. Barnes Surveying Ltd.

c - Ground surface elevation surveyed by members of Golder's technical staff using a geodetic Elevation of 110.672 m for the brass Benchmark Station 00819680606 (E301281.351, N4904267.749). The elevation of the benchmark was provided by personnel from J.D. Barnes Surveying Ltd.

3.2 Borehole Investigation Program

Boreholes 07-29 through 07-45 were advanced using a CME-75 truck-mounted drill rig, Boreholes 07-46 to 07-50 were advanced using a CME-75 track-mounted drill and Boreholes 08-1 and 08-2 were advanced using a CME 55 truck-mounted drill rig, all supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario. Samples of the embankment materials and native overburden were obtained at generally 0.75 m to 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure.

The boreholes at Station 21+275 to Station 26+010 were advanced to depths varying from 4.1 m to 6.7 m below the ground surface, including rock coring where applicable, except for Borehole 07-44 (bedrock probe hole) which was advanced until refusal to auger penetration at a depth of 1.6 m below the ground surface. Bedrock core samples were obtained using 'NQ' coring equipment at the locations of Boreholes 07-39, 07-41, 07-42 and 07-43.

At Station 9+971 and Station 10+029, the boreholes were advanced until refusal to auger penetration and/or split spoon sampling was encountered. Bedrock core samples were obtained using 'NQ' coring equipment at all cored borehole locations (Boreholes 07-45 to 07-50). The boreholes were advanced to depths varying from 4.8 m to 9.1 m below the existing ground surface, including rock coring.

Piezometers were installed in Boreholes 07-38, 07-47 and 07-49 (at Station 24+100, Station 9+971 and Station 10+29) to permit monitoring of groundwater levels. The piezometers consist of 50 mm outside diameter PVC pipe with a 1.5 m long slotted tip surrounded with sand fill. All boreholes and the annulus around the peizometers above the sand pack were backfilled with a mixture of cuttings and bentonite gravel in accordance with Ontario Regulation 903. The piezometer installation details and water level readings are described on the Record of Borehole sheets following the text of this report.

The field work was supervised on a full time basis by members of Golder's technical staff, who located the boreholes in the field; arranged for the clearance of underground utilities; monitored the drilling, sampling and in situ testing operations; logged the boreholes and examined and cared for the soil and rock core samples. The samples were identified in the field, placed in appropriate labelled containers and transported to Golder's laboratory in Mississauga or Ottawa for further detailed visual examination and laboratory testing. Index and classification tests consisting of water content determinations, Atterberg limits testing and grain size distribution analyses were carried out on selected soil samples. All of the laboratory tests were carried out to MTO or ASTM Standards as appropriate. Point load testing were carried out on selected rock core samples.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geological Conditions

The site is located in the southern portion of the physiographic region of Southern Ontario known as the Napanee Plain, as delineated in *The Physiography of Southern Ontario*[1]. The Napanee Plain is flat to undulating, and is characterized by relatively shallow soil deposits overlying bedrock. Geologic mapping[2] indicates that the bedrock within the Napanee Plain consists of grey limestone/dolostone of the Gull River Formation (of the Trenton-Black River Group), which contains some shale partings and seams.

The overburden soils within the Napanee Plain generally consist of glacial till, although alluvium is present in river and stream valleys and, in the southern portion of the Plain, low-lying areas are typically covered with deposits of stratified clay. Water well records indicate that the average depth to bedrock within the Napanee Plain is approximately 2 m. However, in many areas, bedrock outcrops exist at ground surface, while deeper soil deposits (on the order of 10 m) are present in the northern and southern portion of the Plain, and within and adjacent to river valleys throughout the Plain.

4.2 Site Stratigraphy

Highway 401 has been constructed on an embankment at the proposed outlet sewer crossings. The proposed outlet sewer crossing from Station 21+275 to Station 21+478 are within an area of high fill embankment in the vicinity of Little Cataraqui Creek; crossing locations from Station 21+740 to Station 26+010 are located in an area where the road embankment is lower and is constructed over the native soils and/or limestone bedrock. At the Highway 401/Sydenham Road interchange, the proposed crossing locations at Station 9+971 and Station 10+029 are within the bridge approach embankment for Sydenham Road which is up to about 6 m high.

A total of twenty-three boreholes were advanced in the areas of the proposed sewer crossings at the locations shown on Drawings 1 to 8, as part of the subsurface investigation at this site between Sydenham Road and Montreal Street. The detailed subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ and laboratory testing are given on the Record of Borehole/Drillhole sheets and on Figures 1 to 11 which are included after the text of this report.

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[1] Chapman, L.J. and Putnam, D.F. *The Physiography of Southern Ontario.* Ontario Geological Survey Special Volume 2, Third edition, 1984.

[2] Map 2544, Ministry of Northern Development and Mines, 1991.

The stratigraphic boundaries shown on the borehole records are inferred from non continuous sampling and, therefore, represent transitions between soil types and bedrock rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations. The inferred subsurface stratigraphy at the sewer crossing locations are shown on Drawings 1 to 8 which follows the text of this report.

The following sections provide a more detailed description of the subsurface conditions encountered in the boreholes at each of the proposed pipe crossing locations.

4.3 Station 21+275

Borehole 07-29 was advanced through the pavement and encountered a 400 mm thick layer of asphalt. Granular fill materials consisting of sand and gravel to silty sand and gravel were encountered below the asphalt layer in Borehole 07-29 and at the ground surface at the location of Borehole 07-30. Standard Penetration Test ‘N’ values measured within the silty sand and gravel fill materials varied from 44 blows to 85 blows per 0.3 m of penetration suggesting that the relative density of the fill materials is dense to very dense. The water content of one sample of the silty sand and gravel fill was about 5 percent. The granular fill materials extend to depths of between 1.2 m and 1.4 m below the ground surface at the borehole locations.

The granular fill is underlain by limestone rockfill materials consisting of sand, gravel and cobble sized particles to depths of between about 2.7 m to about 2.9 m below the ground surface. The surface of the limestone rockfill was encountered at about Elevation 89.5 m in Boreholes 07-29 and 07-30. Organic materials were encountered at the base of the rockfill layer at a depth of about 2.8 m below ground surface at the location of Borehole 07-29. Standard Penetration Test (SPT) ‘N’ values measured within the limestone rockfill varied from 8 blows to 25 blows per 0.3 m of penetration suggesting that the relative density of the fill material is loose to compact. The results of a grain size distribution test carried out on a sample of the limestone rockfill is shown on Figure 1. The water contents of two samples of this rockfill material were 2 percent and 20 percent. Atterberg limit testing of a sample of the rockfill fines indicates that the tested sample had a liquid limit of about 31 percent and a plastic limit of about 18 percent with a corresponding plasticity index of 13 percent suggesting that the fine grained fraction of this material is a clayey silt of low plasticity (CL designation) as presented on Figure 2.

The limestone rockfill materials are underlain by sandy silt fill materials which contain trace to some clay, trace gravel and trace organics/rootlets. The surface of the sandy silt fill was encountered at about Elevation 88.0 m in Boreholes 07-29 and 07-30. The sandy silt fill material was encountered to a depth of about 4.4 m in Borehole 07-29 and to the bottom of Borehole 07-30 which was terminated at a depth of about 5.6 m below the ground surface. SPT ‘N’ values recorded within the sandy silt fill varied from 10 blows to 18 blows per 0.3 m of penetration suggesting that the relative density of the fill material is loose to compact. The water contents of two samples of this fill material were about 19 per cent and 24 per cent.

A lower layer of clayey silt fill materials was encountered below the sandy silt fill layer at about Elevation 86.5 m at the location of Borehole 07-29. The lower layer of clayey silt contains some sand and a trace of gravel. A SPT 'N' value of 7 blows per 0.3 m of penetration was measured within the clayey silt fill suggesting that the consistency of these fill materials is firm. Borehole 07-29 was terminated within the clayey silt fill materials at a depth of about 5 m below the ground surface. The water content of a sample of this fill material was about 24 percent

Boreholes 07-29 and 07-30 were dry on completion of drilling.

4.4 Station 21+425, Station 21+478 and Station 21+450 (Alternate Crossing Location)

Boreholes 07-31 and 07-32 were drilled at approximate Station 21+425 and Boreholes 07-33 and 07-34 were drilled at approximate Station 21+478 and Boreholes 08- and 08-2 were drilled at approximate Station 21+450.

Boreholes 07-31, 07-33 and 08-2 were advanced through the pavement and encountered a 275 mm to 400 mm thick layer of asphalt underlain by granular fill materials consisting of sand and gravel to a depth of about 1.1 m below the pavement surface. At the location of Boreholes 07-32, 07-34 and 08-1, the sand and gravel fill was encountered at ground surface and is underlain by embankment fill materials which are variable in composition from silty sand to sandy silt to sand and gravel to depths of between 0.9 m and 1.4 m below ground surface. Standard Penetration Test (SPT) 'N' values varying from 39 blows to 43 blows per 0.3 m of penetration were measured within the silty sand to sandy silt fill, indicating dense relative density; however, the upper layer of these materials was frozen at the time of the investigation and the recorded 'N' value may not be representative of the unfrozen condition. The water contents of three samples of this fill material varied from about 2 percent to 21 percent.

Limestone rockfill consisting of sand, gravel and cobble sized particles was encountered below the granular fill materials at a depth of about 0.9 m to 1.4 m below the ground surface, corresponding to Elevation 85.4 m to 85.6 m. The limestone rockfill layer extends to depths of between 3.8 m and 5.0 m corresponding to Elevation 82.5 m to 80.7 m at the borehole locations. Standard Penetration Test 'N' values varying from 4 blows to 35 blows per 0.3 m of penetration were measured in the rockfill indicating that this material is loose to dense. Standard Penetration Test 'N' values of 40 blows per 0.1 m of penetration and 60 blows per 0.08 m of penetration are considered to be the result of the sampler striking cobbles in the rockfill. The water content of eight samples of this fill material varied from about 1 percent to 7 percent. The results of grain size distribution tests carried out on three samples of the rockfill materials that were obtained with the 50 mm outside diameter split-spoon sampler are shown on Figure 1. Atterberg limits testing of one sample of the fine grained fraction of this fill indicated a liquid limit of about 14 percent and a plastic limit of about 10 percent, with a corresponding plasticity index of 4 percent, suggesting that the fine grained fraction of this fill material is a silt of low plasticity (ML designation) as presented on Figure 3.

A deposit of silty clay to clay was encountered below the limestone rockfill between about Elevation 80.7 m and Elevation 82.2 m at the borehole locations. The silty clay to clay deposit extends to a depth of at least 6.7 m below the ground surface, that is to Elevation 79.7 m, and was drilled for thicknesses ranging from 0.1 m to 2.6 m but was not fully penetrated at the borehole locations. Standard Penetration Test 'N' values measured within the silty clayey to clay deposit varied from 6 blows to 19 blows per 0.3 m of penetration suggesting that the consistency of the deposit varies from firm to very stiff. Refusal of penetration of the split spoon was encountered at a depth of 6.3 m corresponding to Elevation 80 m at the location of Borehole 08-1. The water contents of six samples of the silty clay to clay varied from about 19 percent to 40 percent. The results of grain size distribution tests carried out on samples of the silty clay to clay materials are shown on Figure 4. Atterberg limits testing of two samples gave liquid limit values of about 35 percent and 59 percent and plastic limit values of about 17 percent and 26 percent, with resulting plasticity indices of about 18 percent and 33 percent, respectively, suggesting that the material is a silty clay of intermediate plasticity to a clay of high plasticity (CI to CH designation) as presented on Figure 5.

Boreholes 07-31 to 07-34, 08-1 and 08-2 were dry on completion of drilling.

4.5 Station 21+740

Borehole 07-36 was advanced through the pavement and encountered a 400 mm thick layer of asphalt. Granular fill materials consisting of sand to sand and gravel were encountered below the asphalt layer and at the ground surface at the location of Borehole 07-35. The granular fill materials extend to depths of between 0.3 m and 1.7 m below the ground surface at the borehole locations. A Standard Penetration Test (SPT) 'N' value of 37 blows per 0.3 m of penetration was recorded in the sand to sand and gravel fill materials suggesting that the materials are dense. The result of a grain size distribution test carried out on a sample of sand fill is shown on Figure 6. The water content of one sample of the granular fill was about 10 percent.

The granular fill is underlain by fill materials consisting of clayey silt with some sand, encountered at about Elevation 84 m in Borehole 07-36 and about Elevation 85.3 m in Borehole 07-35. The clayey silt fill materials extend to depths of about 2.1 m to 2.9 m below the ground surface at the borehole locations. SPT 'N' values varying from 5 blows to 11 blows per 0.3 m of penetration was measured within the clayey silt fill suggesting that the materials are firm to stiff. The results of a grain size distribution test carried out on a sample of the clayey silt fill is shown on Figure 7. The water content of one sample of the clayey silt fill was about 40 percent. Atterberg limit testing of this sample of the fill indicated a liquid limit of about 29 percent and a plastic limit of about 16 percent, with a corresponding plasticity index of 13 percent, suggesting that the fill material is a clayey silt of low plasticity (CL designation) as presented on Figure 2.

An interbedded layer of sand and gravel fill material was encountered within the clayey silt fill at about Elevation 85 m in Borehole 07-35. The sand and gravel fill layer is about 0.5 m thick at the borehole location. A SPT 'N' value of 23 blows per 0.3 m of penetration was measured within the sand and gravel fill material suggesting that the materials is compact.

A deposit of clay with occasional layers of silt was encountered below the clayey silt fill at about Elevation 82.7 m to 83.6 m. Boreholes 07-35 and 07-36 were terminated within the clay deposit at a depth of about 5 m below the ground surface. SPT 'N' values varying from 5 blows to 20 blows per 0.3 m of penetration was measured within the clay deposit suggesting that this material is firm to very stiff. The results of grain size distribution tests carried out on samples of the clay materials are shown on Figure 4. The water contents of two samples of the clay were about 36 per cent and 37 percent. Atterberg limit testing of these two samples gave liquid limit values of about 63 percent and 62 percent and plastic limit values of 28 percent and 29 percent, with resulting plasticity indices of 35 percent and 33 percent respectively, suggesting that the material is a clay of high plasticity (CH designation), as shown on Figure 5.

Boreholes 07-35 and 07-36 were dry on completion of drilling.

4.6 Station 24+100

Borehole 07-37 and 07-38 were put down through the pavement and encountered a 100 mm to 200 mm thick layer of asphalt. The asphalt layer is underlain by granular fill materials consisting of sand and gravel and sand. The sand and gravel and sand fill materials extend to depths of 0.8 m to 1.4 m below the ground surface that is between Elevation 89.3 m to Elevation 88.8 m.

One Standard Penetration Test (SPT) 'N' value of 67 blows per 0.3 m of penetration was measured within the sand fill suggesting that this fill material is very dense. The water content of one sample of the granular fill materials was about 10 percent.

Limestone rockfill consisting of sand, gravel and cobble sized particles was encountered below the sand fill materials at depths of about 0.8 m and 1.4 m below the ground surface in Boreholes 07-37 and 07-38, respectively corresponding to Elevations 89.3 m and 88.8 m, respectively. The limestone rockfill layer extends to depths of about 2.9 m and 4.4 m below ground surface in the two boreholes. SPT 'N' values varying from 5 blows to 15 blows per 0.3 m of penetration were measured in the rockfill indicating that this material is loose to compact. The results of a grain size distribution test carried out on a sample of the rockfill materials that was obtained with the

50 mm outside diameter split-spoon sampler is shown on Figure 1. The water contents of two samples of this fill material were about 4 percent and 8 percent.

A layer of sandy silt fill was encountered below the rockfill at about Elevation 85.8 m in Borehole 07-38. The sandy silt contains a trace to some clay and a trace of gravel. Borehole 07-38 was terminated within the sandy silt fill at a depth of about 5.3 m below the ground surface, corresponding to Elevation 84.9 m. A SPT 'N' value of 4 blows per 0.3 m of penetration was measured within the sandy silt fill materials suggesting that the materials are very loose.

A deposit of silty clay containing trace to some sand and trace organics was encountered beneath the rockfill materials at about Elevation 87.2 m at the location of Borehole 07-37. Borehole 07-37 was terminated within the silty clay deposit at about 5 m below the ground surface, corresponding to Elevation 85.1 m. SPT 'N' values measured within the silty clay varied from 3 blows to 11 blows per 0.3 m of penetration suggesting that the deposit is soft to stiff. The results of a grain size distribution test carried out on one sample of the silty clay materials is shown on Figure 4. The water content of a sample taken from the deposit was about 40 percent. Atterberg limit testing of this sample indicates a liquid limit of about 49 percent and plastic limit of about 24 percent and a plasticity index of 25 percent, suggesting that the material is a clay of intermediate plasticity (CI designation), as shown on Figure 5.

Boreholes 07-37 and 07-38 were dry on completion of drilling. The water level measured in the piezometer screened within the limestone rockfill and the sandy silt fill materials encountered in Borehole 07-38 is summarized below.

Depth to Groundwater	***Groundwater Level Elevation***	***Date***
4.7 m	85.3 m	May 30, 2007

It should also be noted that the groundwater level at the site is expected to fluctuate with seasonal variations in precipitation and snow melt.

4.7 Station 24+810

Borehole 07-39 was advanced through the pavement and encountered a 200 mm thick layer of asphalt. Granular fill materials consisting of sand and gravel were encountered below the asphalt layer and at the ground surface at the location of Borehole 07-41. The granular fill materials extend to depths of between 2.2 m and 2.6 m below the ground surface at the borehole locations. Standard Penetration Test (SPT) 'N' values measured within the granular fill varied from 11 blows to 92 blows per 0.3 m of penetration suggesting that the materials are compact to very dense. The results of grain size distribution test carried out on two samples of the granular fill materials are shown on Figure 8. The water contents of three samples of the sand and gravel fill materials varied from about 2 percent to 10 percent. Atterberg limit testing of one sample of the granular fill materials indicated a liquid limit of about 28 percent, plastic limit of about 15 per cent and a plasticity index of 13 percent, suggesting that the fine grained fraction of the material is a clayey silt of low plasticity (CL designation), as shown on Figure 2.

Limestone bedrock was encountered beneath the fill materials in both boreholes at depths of approximately 2.2 m and 2.6 m below the existing ground surface corresponding to about between Elevation 106.5 m and 105.6 m, respectively. Borehole 07-39 and Borehole 07-41 were advanced into the bedrock using rock coring methods. The bedrock core samples obtained consist of grey slightly weathered to fresh, thinly bedded limestone containing occasional black shale seams. The Total Core Recovery (TCR) measured on the core samples ranged between 96 percent and 100 percent; Solid Core Recovery (SCR) was between 69 percent and 94 percent and Rock Quality Designation (RQD) was between 52 percent and 85 percent. Point load strength tests in the axial and diametral directions were carried out on selected samples of the rock core from Borehole 07-39 and Borehole 07-41. The point load strength index values are shown on Record of Drillhole 07-39 and 07-41 and the point load test results are summarized in Table 1. The approximate unconfined compression strength (UCS) values estimated from the results of the point load testing varied from 78 MPa (axial) to 94 MPa (diameteral). These values indicate that the rock is strong to very strong based on the rock strength classification presented in the *Canadian Foundation Engineering Manual*[3]. Boreholes 07-39 and 07-41 were terminated within the limestone bedrock at depths of about 5.5 m and 4.3 m below the ground surface, respectively.

The groundwater levels were not recorded in Boreholes 07-39 and 07-41 upon completion of drilling; overburden samples were dry to moist.

4.8 Station 26+010

Borehole 07-43 was advanced through the pavement and encountered a 400 mm thick layer of asphalt. Granular fill materials consisting of sand with variable proportion of gravel were encountered below the asphalt layer and at the ground surface at the location of Borehole 07-42. The granular fill materials extend to depths of 1.4 m and 1.8 m below the ground surface at the borehole locations. The lower portion of the granular fill at the location of Borehole 07-42 contains some clayey silt interlayers. An interbedded layer of clayey silt fill material was encountered within the granular fill at about Elevation 104.5 in Borehole 07-42. The clayey silt layer contains some sand, trace gravel and is about 0.6 m thick at the borehole location. A Standard Penetration Test (SPT) ‘N’ value of 11 blows per 0.3 m of penetration was measured in the lower sub-unit of the granular fill suggesting that the materials are compact. The water content of one sample of the granular fill was about 11 percent.

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[3] Canadian Foundation Engineering Manual, 4th Edition, 2006, Canadian Geotechnical Society.

Clayey silt fill was encountered at the ground surface at the location of Borehole 07-44, and extending to refusal to auger penetration at a depth of about 1.6 m below the ground surface (Elevation 102.4 m).

Limestone bedrock was encountered beneath the fill materials at depths of approximately 1.4 m to 1.8 m below the existing ground surface in Boreholes 07-42 and 07-43 corresponding to about Elevations 103.3 m and 103.4 m and refusal was encountered in Borehole 07-44 at Elevation 102.4 m, as noted above. The bedrock core samples consist of grey thinly bedded limestone containing occasional black shale seams. The upper approximately 1 m of the bedrock core sample retrieved in both boreholes is fractured resulting in poor core recovery. The Total Core Recovery (TCR) measured on the core samples below the upper 1 m was between 95 percent and 100 percent; Solid Core Recovery (SCR) the bedrock was between 65 percent and 89 percent and Rock Quality Designation (RQD) of the bedrock was between 57 percent and 77 percent. Point load strength tests in the axial and diametral directions were carried out on selected samples of the rock core from Borehole 07-42 and Borehole 07-43. The point load strength index values are shown on Record of Drillhole 07-42 and 07-43 and the point load test results are summarized in Table 1. The approximate unconfined compression strength (UCS) values estimated from the results of the point load testing varied from 101 MPa (axial) to 122 MPa (diameteral). These values indicate that the rock is strong to very strong. Boreholes 07-42 and 07-43 were terminated within the limestone bedrock at depths of about 4.6 m and 4.1 m below the ground surface, respectively.

The groundwater levels were not recorded in Boreholes 07-42 to 07-44 upon completion of drilling; overburden samples were moist or the ground was frozen.

4.9 Station 9+971 (Sydenham Road, North of Highway 401)

Borehole 07-45 was put down through the pavement and encountered a 130 mm thick layer of asphalt underlain by about 170 mm of sand and gravel fill. The granular fill is underlain by fill materials which are variable in composition from silty sand and gravel to limestone rockfill to sandy silt. Standard Penetration Test (SPT) 'N' values measured in the fill varied from about 11 blows to 33 blows per 0.3 m of penetration suggesting that the fill materials are compact to dense. Laboratory testing on three samples of the fill materials indicated water contents varying from about 2 percent to about 15 percent.

About 100 mm of topsoil was encountered at the ground surface at the locations of Boreholes 07-46 and 07-47 underlain by clayey silt fill materials extending to depths of 1.5 m and 1.8 m below the ground surface. Standard Penetration Test (SPT) 'N' values measured in the clayey silt fill varied from about 6 blows to 15 blows per 0.3 m of penetration suggesting that the fill materials are firm to very stiff. The water contents of two samples of the fill materials were about 23 percent and 39 percent.

A deposit of sand and silt till was encountered below the clayey silt fill materials at about elevation 107.5 m and 106.6 m in Boreholes 07-45 and 07-47, respectively. Two SPT 'N' values measured in the till were 14 blows and 20 blows per 0.3 m of penetration suggesting that the till materials are compact. The water contents of two samples of the till materials were about 8 percent and about 13 percent. Refusal to penetration of the split spoon was encountered at about Elevation of 105.7 m at the location of Borehole 07-47.

Limestone bedrock was encountered beneath the fill materials at the location of Borehole 07-46 and beneath the sand and silt till deposit at the locations of Boreholes 07-45 and 07-47. The elevation of the surface of the bedrock varied between about Elevation 105.7 m and 106.9 m. Bedrock core samples were obtained in all three boreholes and consisted of grey thinly bedded limestone containing occasional black shale seams and calcite inclusions. The bedrock core samples retrieved from Borehole 07-46 are fractured and contain weathered zones and soil infilling whereas the core samples from Boreholes 07-45 and 07-47 show less evidence of fracturing except in the upper approximately 0.5 m of Borehole 07-45. Typically, TCR values range from 76 percent to 100 percent, SCR values range from about 70 percent to 98 percent and RQD values range from zero per cent to 92 percent. Point load strength tests in the axial and diametral directions were carried out on selected samples of the rock core from Borehole 07-45 to 07-47. The point load strength index values are shown on Record of Drillhole sheets and the point load test results are summarized in Table 1. The approximate unconfined compression strength (UCS) values estimated from the results of the point load testing varied from 162 MPa (axial) to 55MPa (diameteral). These values indicate that the rock is strong to very strong. The boreholes were terminated within the limestone bedrock at depths between about 4.8 m and 7.6 m below the ground surface.

A standpipe piezometer was installed and screened within the limestone bedrock in Borehole 07-47 and the water levels measured in the piezometer are summarized as follows:

Depth to Groundwater	*Groundwater Level Elevation*	*Date*
5.0 m	103.1 m	May 3, 2007
5.0 m	103.1 m	May 30, 2007

It should also be noted that the groundwater level at the site is expected to fluctuate with seasonal variations in precipitation and snow melt.

4.10 Station 10+029 (Sydenham Road, South of Highway 401)

Borehole 07-48 was put down through the pavement and encountered a 200 mm thick layer of asphalt underlain by about 700 mm of granular fill consisting of sand and gravel. The granular fill is underlain by fill materials which are variable in composition from limestone rockfill to clayey silt with some sand and a trace of gravel. Standard Penetration Test (SPT) 'N' values measured in the limestone rockfill varied from about 10 blows to about 49 blows per 0.3 m of penetration suggesting that these fill materials are compact to dense. Standard Penetration Test (SPT) 'N' values measured in the clayey silt fill varied from about 13 blows to about 17 blows per 0.3 m of penetration suggesting that these fill materials are stiff to very stiff. The water content measured on one rockfill sample was about 2 percent and on one clayey silt sample was about 18 percent.

About 100 mm of topsoil was encountered at the ground surface at the locations of Boreholes 07-49 and 07-50 underlain by clayey silt fill materials. The clayey silt fill materials contains some sand, a trace of gravel, a trace of organic material and occasional wood and limestone fragments. The clayey silt fill layer extends to depths of between 1.5 m and 2.4 m below the ground surface. Refusal to penetration of the split spoon was encountered at about Elevation 104 m at Borehole 07-49. Standard Penetration Test (SPT) 'N' values measured in the clayey silt fill varied from 12 to 14 blows per 0.3 m of penetration suggesting that the fill materials are stiff. The water contents of three samples of the fill materials varied from about 21 percent to about 32 percent.

A 0.2 m to 0.9 m thick deposit of silty clay till was encountered below the clayey silt fill materials at about Elevations 105.0 m and 104.7 m in Boreholes 07-48 and 07-50, respectively. SPT 'N' values measured in the till varied from 9 blows to 21 blows per 0.3 m of penetration indicating that the till materials are stiff to very stiff. The water contents of two samples of the till materials were about 20 percent and about 29 percent. The results of a grain size distribution test carried out on a sample of the till are shown on Figure 9. Atterberg limit testing of one sample of the till indicated a liquid limit of about 49 percent, plastic limit of about 25 percent and a plasticity index of 24 percent, suggesting that the material is a silty clay of medium plasticity (CI designation), as shown on Figure 10.

A deposit of sand and silt till materials was encountered below the silty clay till layer at about Elevation 104.1 m and Elevation 104.5 m in Boreholes 07-48 and 07-50, respectively. Standard Penetration Test 'N' values measured in the sand and silt till varied from 14 blows to 65 blows per 0.3 m of penetration indicating that the relative density of the materials is compact to very dense. The water contents of two samples of the till materials were about 9 percent and 20 percent. The results of a grain size distribution test carried out on a sample of the till are shown on Figure 11.

Limestone bedrock was encountered beneath the fill materials at the location of Borehole 07-49 and the till deposit at the locations of Boreholes 07-48 and 07-50. The elevation of the surface of the bedrock varied between about Elevation 102.5 m and 104.1 m. The bedrock core samples were obtained in all three boreholes and consisted of grey thinly bedded limestone containing occasional black shale seams and calcite inclusions. In Boreholes 07-48 to 07-50 the Total Core Recovery (TCR) measured on the core samples ranged between 33 percent and 100 percent; Solid Core Recovery (SCR) was between 65 percent and 100 percent and Rock Quality Designation (RQD) of the bedrock was between 38 and 100 percent. Point load strength tests in the axial and diametral directions were carried out on selected samples of the rock core from Borehole 07-48, 07-49 and 07-50. The point load strength index values are shown on Record of Drillhole 07-48 through 07-50 and the point load test results are summarized in Table 1. The approximate unconfined compression strength (UCS) values estimated from the results of the point load testing varied from 144 MPa (axial) to 33 MPa (diameteral). These values indicate that the rock is medium strong to very strong. The boreholes were terminated within the limestone bedrock at depths between about 5.7 m and 9.1 m below the ground surface.

A standpipe piezometer was installed and screened within the limestone bedrock in Borehole 07-49 and the water levels measured in the piezometer are summarized as follows.

Depth to Groundwater	*Groundwater Level Elevation*	*Date*
3.5 m	103.0 m	May 3, 2007
3.8 m	102.7 m	May 30, 2007

It should also be noted that the groundwater level at the site is expected to fluctuate with seasonal variations in precipitation and snow melt.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Dave Walters, Ph.D., P.Eng. and reviewed by Ms. Anne Poschmann, P.Eng., and a Principal of Golder Associates. Mr. Fintan J. Heffernan, P.Eng., a Senior Consultant and Mr. Jorge Costa, P.Eng. and Principal of Golder Associates, both Designated MTO Contacts for Golder, conducted independent reviews of the report.

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PART B
FOUNDATION DESIGN REPORT
OUTLET SEWER CROSSINGS
HIGHWAY 401 WIDENING FROM WEST OF SYDENHAM ROAD TO WEST OF MONTREAL STREET
KINGSTON, ONTARIO
G.W.P. 77-99-01

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the sewer crossings proposed to be installed as part of the Highway 401 widening project from west of Sydenham Road to west of Montreal Street, in Kingston, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at the proposed sewer crossing sites. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible sewer crossing alternatives. As such, where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

Stratigraphic sections at the proposed sewer crossing locations are shown on Drawings 1 to 8. The existing grade shown on the drawings were taken from the topographic survey provided by MRC on Drawings H6230XB01 and H6230XB02, dated January 10, 2006. The ground surface elevations at the borehole locations at Station 21+450 and where the design invert alignment for the outlet sewers are located near or at the interface of the embankment fill and the limestone bedrock (Station 24+810 and Station 26+010) were surveyed by personnel from J.D. Barnes Surveying Ltd. Members of Golder's technical staff surveyed the ground surface elevation at the borehole locations at approximate Station 9+971 and Station 10+029 (Sydenham Road). The measured survey data indicate that borehole ground surface elevations interpreted from Drawings H6230XB01 and H6230XB02 varied from about 0.1 m to 0.2 m in elevation compared to the field measurements. Therefore, the interpolated borehole ground surface elevation from the topographic survey drawings at crossing locations where the sewer pipe is completely within rockfill or soil fill materials (i.e. Station 21+275, 21+425, 21+478, 21+740 and 24+100) is sufficiently accurate to provide the designers with the required information to assess the feasible sewer crossing alternatives.

The details of the proposed sewer crossings were provided on an undated untitled drawing (6230 – Sewer Profile) received May 16, 2007. It is understood that this untitled drawing is referred to as Median Sewer Outlet Profiles, Contract Sheet 195. It should be noted that the initial list of crossing locations included one sewer crossing at Station 21+425 and one sewer crossing at Station 21+478. The drawing received on May 17, 2007, indicated an alternate sewer crossing location at Station 21+450.

A summary of the subsurface conditions encountered in the boreholes at the depth zone where the sewers are to be advanced is as follows:

Sewer Crossing Location (Station)	Approximate Pipe Invert Elevation (m) (m)	Sewer Pipe Diameter (mm)	Approximate Depth of Cover (m) (m)	Anticipated Subsurface Conditions At Design Sewer Pipe Level
21+275	88.8 – 88.9	300	1.5 – 1.6	Fill materials consisting of loose to compact limestone rockfill (Borehole 09-29 and 07-30); boreholes dry; highway in embankment.
21+425 21+450 21+478	82.7 – 82.8	300	3.1	Fill materials consisting of loose to compact limestone rockfill at median (Boreholes 07-31, 07-33 and 08-2); either loose to compact limestone rockfill or silty clay to clay at the highway shoulder (Boreholes 07-32, 07-34 and 08-1); boreholes dry; highway in embankment.
21+740	83.2 – 83.4	300	2.0 – 2.1	Fill materials consisting of firm to stiff clayey silt (Boreholes 07-35 and 07-36); boreholes dry.
24+100	87.2 – 87.4	375	2.3 – 2.6	Fill materials consisting of loose to compact limestone rockfill (Boreholes 07-37 and 07-38); groundwater level at Elevation 85.3 m on May 30, 2007 in Borehole 07-38; highway in embankment.
24+810	106.3 – 106.5	300	1.4 – 2.1	Fill materials consisting of compact to very dense sand and gravel at median (Borehole 07-39) to stiff clayey silt overlying limestone bedrock at the highway shoulder (Borehole 07-41). (Note that pipe invert is located at about the interface of the fill and the bedrock at the highway shoulder). Boreholes dry during soil drilling.
26+010	102.7 - 102.8	300	1.7 – 2.0	Strong to very strong limestone bedrock (Borehole 07-43 and 07-42); interface of sand and gravel fill and the bedrock surface at outlet (Borehole 07-44). (Note that pipe obvert is located at about the interface of the bedrock with the overlying sand fill materials below the pavement).
9+971	101.5 - 102	1200	2.4 - 8 2	Note: boreholes located about 6 m north of Station 9+971. Strong to very strong limestone bedrock; obvert of sewer about 3 m to 3.8 m below bedrock surface (Boreholes 07-45 to 07-47); groundwater level at Elevation 103.1 m on May 30, 2007 in Borehole 07-47.
10+029	101.3 - 102	1200	1.5 – 7.0	Note: boreholes located about 6 m south of Station 10+029. Strong to very strong limestone bedrock; obvert of sewer about 1 m to 1.2 m below bedrock surface at centre of road to west of embankment west toe (Boreholes 07-48 and 07-49) and at about the bedrock interface at the embankment east toe (Borehole 07-50); groundwater level at Elevation 102.7 m on May 30, 2007 in Borehole 07-49.

6.2 Pipe Material Options

The results of the geotechnical investigation indicates that portions of the highway embankment fills consist of rockfill of cobble sizes (60 mm to 200 mm) which may damage a concrete sewer pipe if directly jacked/rammed into these fill materials. Therefore, a steel casing is suggested to be installed during the creation of the bore. A reinforced concrete pipe or high density polyethylene (HDPE) pipe may be used as the carrier sewer pipe installed inside the steel casing. Grout should be injected in the annular space between the carrier pipe and the steel casing. From an installation perspective, the concrete pipe class or the required dimensional ratio for the HDPE pipe must be selected to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces

6.3 Pipe Installation Methods

It is understood that the Contractor will be responsible for choosing the method and equipment for pipe installation. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible pipe installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A, Foundation Investigation Report, of this report.

Installation methods for the sewer pipe includes conventional open cut trenching or trenchless technology. Open cut trenching across the active highway includes pavement structure demolition and restoration; trench excavation and excavation sidewall support; pipe installation; and trench backfilling. The open cut method offers the best control of gradient and alignment of the sewers, reduced potential for delays resulting from encountering obstructions and least risk of damage to the active highway. The major disadvantages with open cut installation of the sewer pipes are the requirement for lane closures resulting in traffic disruption, large excavations for deep installations, pavement reconstruction and the potential for post construction settlement. Post construction settlement may be minimize by using unshrinkable fill to backfill the trench.

Therefore, the sewer crossings beneath Highway 401 and the embankments at Sydenham Road at the grade separation with Highway 401 are currently proposed to be installed by trenchless technology in order to minimize traffic disruption. Trenchless technology covers a wide range of methods of installing the sewers, such as "jack and bore" and pipe ramming which would not adversely affect the overall stability of the highway embankment during pipe installation without open cut excavation between the start point and the end point.

Jack and bore is a method of forming a near horizontal bore from a jacking/drive pit; the boring is typically done with a rotating cutter head and the casing is jacked essentially simultaneously to support the sidewalls of the bore. Spoil from the tunnel excavation is removed at the jacking pit, and the new pipe is then installed within the casing. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. Jack and bore is generally suitable for penetrating through most soil conditions. However, deflection and/or refusal to penetration of the casing can occur if large obstructions such as cobbles, boulders and limestone rockfill are encountered along the alignment of the bore.

The excavation at the face of the bore in "jack and bore" operations can be accomplished by many methods either by man-entry or by remote control methods. The excavation equipment using remote methods can consist of either a cutting head driven from the drive pit with an auger for removal of the spoil or a full-face cutting head with slurry spoil transport system. In "man-entry" operations, the excavation at the face can be done using manual hand mining methods or using mechanical methods. Construction specification for the installation of the outlet sewer by jacking and boring is given in Ontario Provincial Standard Specification (OPSS) 416.

Pipe ramming involves the use of a percussive hammer to advance a steel casing with a cutting shoe attached at the front end of the casing. The casing is generally advanced open-ended and the soil within the casing is typically removed after the casing has been driven the entire length of the installation, thereby reducing the potential for ground loss into the casing. Pipe ramming methods are also better suited for penetrating through potential obstructions such as cobbles, boulders and limestone rockfill rather than jack and bore installation method. However, deflection and/or refusal to penetration of the casing can still occur if large obstructions are encountered, and vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a "plug" of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. This could be controlled by stopping the operation and removing spoil from within the pipe before advancing further.

The size of the entrance pit for the methodologies described above is controlled by the equipment size and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. However, the right-of-way access in the median at the Highway 401 Kingston area sites is only about 6 m in the length direction of the pit. This restricted work area would favour the smaller pit size required for pipe ramming.

The following sections of this report discusses the various construction method options that may be considered for the installation of the sewers; jack and bore methodology is also included in the construction method options notwithstanding the larger pit size requirements. Due to the varying ground surface conditions encountered at the crossing locations and the possibility of insufficient work area in the median, the discussion of construction method options for the sites has been divided into the following four categories:

1. Outlet sewers to be installed within rockfill;

2. Outlet sewers to be installed within soil fill materials;

3. Outlet sewers to be installed at the interface of the overburden soils and bedrock; and

4. Outlet sewers to be installed entirely within the limestone bedrock.

6.3.1 Pipe Installed Within Rockfill Materials

Based on the available pipe invert information provided by MRC and the results of the subsurface investigation, the sewers proposed to be installed at approximate Station 21+275, 21+425, 21+450 (alternate crossing location), Station 21+478 and Station 24+100 are anticipated to be within limestone rockfill, which contains zones of loose materials. Jack and bore operations could be obstructed if there are large pieces of limestone or cobbles within the limestone rockfill and could deflect the path of the bore/casing at the locations of pipes to be installed within the rockfill materials.

If the diameter of the casings is large enough to permit man entry (about 0.9 m to 1.2 m in diameter), it would be possible to remove obstructions at the leading edge of the bore during jack and bore operations using manual excavation methods after removal of the cutter head/auger. However, this process would result in a delay in the installation operations and the loose materials could run into an unsupported face with associated subsidence of the overlying materials which could lead to settlement of the pavement.

If loss of ground into the casing is experienced during the installation of the sewers by either jack and bore or pipe ramming methods, ground surface settlement could be compensated for by pressure grouting of the soils around the pipes/casings.

The risks of ground surface settlement can be reduced by installing the sewers at these sites by pipe ramming installation methods or eliminated by installing the pipes using open cut methods.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with the sewer installation methods is presented in Table 2 following the text of this report. Based on the above, installing the sewers in open cut is considered to be the installation method with the least construction risk. However, this option may not be preferable from a traffic disruption standpoint. If a trenchless installation method is selected, pipe ramming is considered better suited for installing the sewers through the rockfill materials.

Ground movements should be monitored during pipeline installation using jack and bore or pipe ramming methods to confirm permissible ground surface movement (i.e. settlement/heave) tolerances are not exceeded, as discussed in Section 6.4.4.

6.3.2 Pipe Installed Within Soil Fill Materials

The proposed alignment for the sewer proposed to be installed at Station 21+740 is anticipated to be installed through claycy silt fill materials The sewer at this site could be installed using jack and bore or pipe ramming methods.

During jack and bore operations, the cutting head should be maintained at the appropriate distance ahead of the leading edge of the casing or retracted into the casing to permit a balance between jacking pressure, casing advancement and fill conditions as well as to minimize the potential for ground loss into the excavation with associated subsidence of the overlying materials which could lead to settlement of the pavement. Ground movements should be monitored during pipeline installation to confirm permissible ground surface movement (i.e. settlement/heave) tolerances are not exceeded

6.3.3 Pipe Installed at Interface of Overburden and Bedrock

The design invert alignment for the outlet sewer to be installed at approximate Station 24+810 and Station 26+010 are located near or at the interface of the embankment soil fill and limestone bedrock. Pipes installed at the design alignment are anticipated to encounter a combination of fill materials and bedrock.

At Station 24+810, the invert of the casing may encounter the bedrock in the vicinity of the shoulder and where this happens, the casing will tend to deflect upward at the bedrock interface during jack and bore or pipe ramming. As a result, maintaining the correct alignment/gradient of casings is anticipated to be extremely difficult if not impossible due to the mixed subsurface conditions and therefore jack and bore or pipe ramming methods are not considered to be suitable for the installation of the sewer at this site unless the vertical alignment of the pipe is changed. If the vertical alignment of the sewer can be raised by about 0.2 m to 0.3 m at the location of Station 24 + 810 such that the casing is installed entirely within the fill materials, then the sewer may be installed using either jack and bore or pipe ramming.

In the alternative, if the vertical alignment of the sewer at this site can not be raised to be installed entirely within the fill, then the pipe would be best suited to be installed by open cut method for the section outside the south shoulder of the highway.

At Station 26+010, the obvert of the pipe in the section between the median and the south shoulder is just below the surface of the bedrock and the bedrock is interpreted to dip below the invert of the pipe between the south shoulder and the ditch. Based on the bedrock coring carried out at Boreholes 07-42 and 07-43, the limestone bedrock at Station 26+010 is strong to very strong and the upper 1 m of the bedrock is moderately to highly fractured. This upper portion of the bedrock may have been broken/fractured during blasting carried out for the construction of Highway 401.

Augering equipment that is typically used for jack and bore operations in overburden soils would likely encounter refusal to penetration within the limestone bedrock and therefore this construction methodology is not considered suitable for installation of the sewer at this site. Similarly, pipe ramming is not considered to be a suitable alternative for installing the sewer unless the sewer invert level can be changed. Raising the invert level to be at or above the bedrock surface would require a raise of at least 0.5 m which would reduce the cover over the sewer to about 1.2 m. This is considered adequate for pipe ramming through clayey to sandy fill materials.

The use of hand tunnelling/mining methods to install the sewer at Station 26+010 has been considered. However, for this location, this installation procedure is expected to be difficult to implement and to have a high risk of ground loss from the overlying granular fill materials. The proposed pipe diameter (300 mm) would not permit man-entry for hand mining work; thus 0.9 m to 1.2 m diameter casing would be required. The use of a such a liner would not allow for adequate cover to be maintained. Therefore, the invert of the pipe has to be lowered either partially or fully into the bedrock. For partial lowering the invert would lie within variable soil fill materials and these fill materials that form the crown of such hand-mined crossings could not stand unsupported during the difficult process of breaking out and removing the limestone rock present at the invert level, thus precluding the use of liner plate for temporary support. Use of a jacked steel liner would limit access for breaking and removing the limestone bedrock.

A hooded shield could be considered, as it would provide crown support and allow excavation of the fill above the rock providing better access for removal of the rock. If this alternative is considered, rock splitting and/or drilling equipment would be anticipated to be required to permit removal of the bedrock for this method. Suitable control of the excavation face should be carried out to prevent loss of ground into the casing and associated ground surface settlements. To maintain face stability and minimize ground movements it is recommended that mining operations continue non-stop once started. If it is necessary to stop tunnelling operations for any reason, the face should be completely supported by breasting boards. Such face support should be pre-cut and assembled prior to the start of tunnelling so that it can be readily installed, if required. Given the subsurface conditions at this site and the risks associated with hand mining procedures in these conditions, it is recommended that the sewer vertical alignment be lower to be fully within the bedrock as discussed in Section 6.3.4.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with these installation methods is presented in Table 3 following the text of this report. Based on the above, raising the invert elevation of the sewer and installing the casing entirely in the fill materials is considered to be the trenchless installation method with the least construction risk at Station 24 + 810.

At Station 26 +010, the vertical alignment cannot be raised to allow for installation of the outlet sewer using hand mining, pipe ramming or jack and bore methods. Therefore, lowering the vertical alignment and using rock boring is the appropriate method of installing the sewer at this site.

6.3.4 Pipe Installed Within Limestone Bedrock

The design alignments for the 1200 mm diameter sewers at Station 9 +921 and Station 10+029 (Sydenham Road) are located within the limestone bedrock. Bedrock coring at these sewer crossing locations indicate that the limestone bedrock is typically strong to very strong with inclusions of medium strong rock at the location of Borehole 07-48.

The sewers at these crossings could be installed using a rock boring machine. This method typically involves the drilling of a pilot hole, in the order of 0.3 m in diameter, and enlarging the pilot hole to the required size by one or more reaming passes. The selection of the equipment is dependent on the type of the bedrock, the strength of the bedrock and the depth of the fractured zone below the surface of the rock. Consultation with contractors is needed to confirm that this methodology can be used to achieve the required diameter of 1.2 m minimum and provide at least 2 m of rock cover above the obvert of the culvert.

At Station 10+029 (Sydenham Road on the south side of Highway 401), the obvert at the east outlet of the sewer is near the interface of the bedrock and the sand and silt till overburden. As discussed above, consideration may be given to lowering the alignment at Station 10+029 to maintain the obvert of the sewer pipe at least 2 m below the surface of the bedrock, if a rock boring machine is selected to construct the excavation.

The use of rock boring machines typically requires a working area of approximately 3 m by 10 m in plan area, extending approximately 1 m below the invert of the installation. Excavation of the bedrock for these working pits will require the use of hoe ramming and/or line drilling with controlled blasting. A discussion of the requirements for ground vibration monitoring and control of blasting operations is included in Section 6.4.2 of this report.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with these installation methods is presented in Table 4 following the text of this report. Based on the above, installing the sewers using a rock boring machine is considered to be the most suitable technique for the ground conditions at these sites.

6.3.5 Preferred Installation Methods

The preferred installation methods for the outlet sewer are summarized as follows:

Sewer Crossing Location (Station)	Approximate Pipe Invert Elevation (m)	Anticipated Subsurface Conditions At Design Sewer Pipe Level	Preferred Installation Method
21+275	88.8 – 88.9	Fill materials consisting of loose to compact limestone rockfill (Borehole 09-29 and 07-30); boreholes dry; highway in embankment.	Pipe ramming

Sewer Crossing Location (Station)	Approximate Pipe Invert Elevation (m)	Anticipated Subsurface Conditions At Design Sewer Pipe Level	Preferred Installation Method
21+425 21+450 21+478	82.7 – 82.8	Fill materials consisting of loose to compact limestone rockfill at median (Boreholes 07-31, 07-33 and 08-2); either loose to compact limestone rockfill or silty clay to clay at the highway shoulder (Boreholes 07-32, 07-34 and 08-1); boreholes dry; highway in embankment.	Pipe ramming
21+740	83.2 – 83.4	Fill materials consisting of firm to stiff clayey silt (Boreholes 07-35 and 07-36); boreholes dry.	Pipe ramming
24+100	87.2 – 87.4	Fill materials consisting of loose to compact limestone rockfill (Boreholes 07-37 and 07-38); groundwater level at Elevation 85.3 m on May 30, 2007 in Borehole 07-38; highway in embankment.	Pipe ramming
24+810	106.3 – 106.5	Fill materials consisting of compact to very dense sand and gravel at median (Borehole 07-39) to stiff clayey silt overlying limestone bedrock at the highway shoulder (Borehole 07-41). (Note that pipe invert is located at about the interface of the fill and the bedrock at the highway shoulder). Boreholes dry during soil drilling.	Pipe ramming with raised invert elevation (or Jack & Bore)
26+010	102.7 - 102.8	Strong to very strong limestone bedrock (Borehole 07-43 and 07-42); interface of sand and gravel fill and the bedrock surface at outlet (Borehole 07-44). (Note that pipe obvert is located at about the interface of the bedrock with the overlying sand fill materials below the pavement).	Rock bore with lowered pipe invert elevation
9+971	101.5 - 102	Note: boreholes located about 6 m north of Station 9+971. Strong to very strong limestone bedrock; obvert of sewer about 3 m to 3.8 m below bedrock surface (Boreholes 07-45 to 07-47); groundwater level at Elevation 103.1 m on May 30, 2007 in Borehole 07-47.	Rock Bore
10+029	101.3 - 102	Note: boreholes located about 6 m south of Station 10+029. Strong to very strong limestone bedrock; obvert of sewer about 1 m to 1.2 m below bedrock surface at centre of road to west of embankment west toe (Boreholes 07-48 and 07-49) and at about the bedrock interface at the embankment east toe (Borehole 07-50); groundwater level at Elevation 102.7 m on May 30, 2007 in Borehole 07-49.	Rock Bore

Potential alternative sewer installation methods and relative costs were discussed with Marathon Drilling Company, Earth Boring Company Limited and Cruickshank Construction Kingston to arrive at the preferred methods noted above. However, it should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in Part A, Foundation Investigation Report, of this report. A Special Provision combing OPSS 415, OPSS 416 and OPSS 450 which allows the contractor to determine the most appropriate method of installation by trenchless technology while required to meet specific performance criteria, is provided in Appendix A.

6.4 Design and Construction Considerations

6.4.1 Excavation and Groundwater/Surface Water Control

Excavations will be required for the jacking and receiving pits for trenchless installation methods, or for the working platform for the rock boring machine and for any installations carried out using open cut methods. The excavations are anticipated to be extended through variable fill materials, including limestone rockfill, and native soils consisting of silty clay to clayey silt till. At some sites such as Sydenham Road and Station 26+010, the excavations will extend into strong to very strong limestone containing shale seams and calcite inclusions.

Excavation should be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act (OHSA) for Construction Projects. The fill materials and any firm to stiff native soils are classified as Type 3 soil, according to the OHSA. Very stiff to hard portions of the native soils would be classified as Type 1 or 2 soil. Temporary excavations (i.e. those which are only open for a relatively short period) within these overburden soils should be made with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V) assuming that appropriate groundwater control is carried out.

Groundwater was not encountered on completion of the overburden drilling at Station 21+275 to Station 26+010. The water level in the piezometer installed at Station 24+00 was measured at Elevation 85.3 m on May 30, 2007. The water level measured in the piezometers installed at Sydenham Road (Station 9+971 and Station 10+029) were at about Elevation 103.1 m and 102.7 m, respectively, on May 30, 2007.

Seepage from zones of perched water within the fill materials should be expected particularly where granular zones are intercepted in the excavation. Where the overburden materials at the crossing locations are predominantly fine-grained in nature, the seepage through these deposits is expected to be minor and pumping from well filtered sumps located at the base of the excavation should provide sufficient control of surface water and any "perched" groundwater. Increased seepage flows will occur in areas where predominantly granular fill and rockfill materials are encountered. Shallower side slopes may be required to minimize surficial sloughing if the construction is carried out at times of high "perched" water levels.

The entry and exit pits for jack and bore, pipe ramming or rock boring installation methods are anticipated to be located in the area of existing median ditches or in low-lying areas. All surface water, including water within existing ditches, should be directed away from the open excavations.

6.4.2 Blasting

If open cut sewer installation methods are carried out, the excavation into the limestone bedrock will require the use of hoe ramming and/or line drilling with controlled blasting. Due to the potential impacts of ground vibrations and flyrock on the existing structures and utilities as well as traffic and lane closures impacts during blasting operations, including the bridge structure at Sydenham Road (Station 9+971 and Station 10+029), it is recommended that a Special Provision for the control of all blasting operations, as presented in Appendix B, be included in the Contract Documents to address the following:

- The requirements, procedure and extent of a pre-blast survey. This would include all structures within a radius of about 100 m of the blasting operations, as well as notification to all individuals working or living within 500 m.
- Submission of a blast proposal by the blasting contractor or their blast consultant detailing the blast methodology, including drill hole patterns, hole size and depths, size of blasts, explosive and initiation product details, as well as all blast control procedures. Blast control procedures would include details on controlling flyrock, temporary road and bridge closures, blast signalling and site clearing procedures, as well as procedures to deal with debris clean-up. The blasting plan must also specifically address the methods to be used around the existing Sydenham Road bridge structure with specific reference to the line drilling required (i.e. describe hole diameters, depths and hole spacing to be used). This submission would be required prior to the commencement of any blasting operations.
- The requirement for trial blasts at a sufficient distance from the bridge structure to demonstrate that the vibration criteria can be met. Modifications to the blasting plan and additional trials will be required until it is demonstrated that the specified criteria can be met.
- The requirements for ground and air vibration monitoring by an independent blasting consultant during the blasting operations. This would include details on instrumentation, number and location of monitoring sites, blast recording and reporting procedures, and procedures to be followed in the event of excessive vibration readings.

It is recommended that ground vibration levels be limited to 50 mm/s peak particle velocity for the existing Sydenham Road bridge structure and other adjacent services and/or buildings. Continuous monitoring of all blasting operations would dictate when changes to the blast procedures become necessary to meet these limits and how close to the adjacent structures blasting could be carried out.

6.4.3 Temporary Excavation Support

Temporary roadway protection may be required at the entry and exit pit work areas at the crossing locations if sufficient space is not available to permit open cut excavations. Based on the subsurface conditions at the crossing locations and the likely excavation geometry, it is anticipated that a soldier pile and lagging system using anchors or rakers to provide lateral support would be suitable. The lagging should be backed with filter cloth to prevent loss of fines in areas where the temporary shoring intercepts zones of perched water conditions.

In areas where bedrock is located at or near the base of the excavations (Station 24+810, 26+010, (9+971 and 10+029), the soldier piles may need to be socketed into the limestone bedrock. Pre-drilled holes created by rock coring or churn drilling would be required to socket the soldier piles into the bedrock and the annulus around the pile should be backfilled with concrete. Alternatively, support to the soldier pile and lagging walls may be provided by internal bracing, anchors or rakers. The internal bracing/raker/anchor support should be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system.

The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision (SSP)105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SSP105S19.

6.4.4 Instrumentation and Monitoring

An instrumentation and monitoring program is recommended at pipe crossing locations in order to:

- Document the effects of the sewer installation on the overlying roadways, adjacent structures or services lines/pipes;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground condition;
- Verify the Contractor's compliance with the settlement limits imposed in the Contract; and
- Allow adjustments to be made to the sewer installation methods such that the settlement limits established are not exceeded.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the road must be read remotely and the use of electromagnetic distance measuring (EDM) equipment reading reflectors installed on the highway is recommended. A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation.

In addition, the installation of in-ground settlement points, consisting of a sleeved iron bars, set 1.5 m to 1.8 m below ground surface, above each crossing at accessible locations (e.g. highway shoulders) should be also considered. The elevation of the top of the bar would be read using conventional precision levelling equipment. The in-ground monitoring points provide the best measure of the ground settlement affects of tunnelling, as they are unaffected by frost heave, thaw settlement or the bridging action of the pavement structure.

All monitoring points should be read at least three times (on separate days) before the start of sewer/culvert installation to establish a pre-construction baseline. All points behind the face of the excavation and those within 10 m of the front of the face should be read every 4 hours over the duration of the tunnel drives. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months.

A settlement monitoring plan consistent with the requirements in the "Appendix: Settlement Monitoring Guideline – Tunnelling" of MTO's "Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application", should be established as part of the Contract Administration for construction. A copy of the "Guideline for Foundation Engineering – Tunnelling Speciality for Corridor Encroachment Permit Application" is provided in Appendix C of this report.

6.4.5 Grouting

A program of post-installation grouting should be specified to fill any voids or loose zones created during pipe installation, as included in the Specification for sewer installation via trenchless technology presented in Appendix A. For any installations at which the settlement monitoring indicates that pavement settlement has occurred, or where signs of ground loss have been noted, provision should be made for a program of compensation grouting above the pipe installation.

7.0 CLOSURE

This Foundation Investigation and Design Report was prepared by Dave Walters, Ph.D., P.Eng. and reviewed by Ms. Anne Poschmann, P.Eng. and a Principal of Golder Associates. Mr. Fintan J. Heffernan, P.Eng., a Senior Consultant and Mr. Jorge Costa, P.Eng. and a Principal of Golder Associates, both Designated MTO Contacts for Golder, conducted independent reviews of the report.

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TABLE 1
POINT LOAD TEST ON ROCK CORE SAMPLES
HIGHWAY 401 WIDENING FROM WEST OF SYDENHAM ROAD TO WEST OF MONTREAL STREET
KINGSTON, ONTARIO
G.W.P. 77-99-01

Borehole Number	Sample Number	Sample Depth (m)	Test Type	Core Length (mm)	Core (2) Diameter (mm)	Equivalent Diameter (mm)	Ram Pressure (kPa)	Load (P) (kN)	Is Axial (MPa)	Is Diametral (MPa)	**Is (50mm)** (MPa)	**Approx. (1) UCS** (MPa)
07-39	3	4.9-5.2	D	150.00	46.11	93.84	11,720.00	11.11		5.226	5.039	116
07-39	3	4.9-5.2	A	41.90	46.11	49.60	7,540.00	7.15	2.906		2.895	67
07-41	1	2.3-2.6	D	65.71	47.02	62.72	8,620.00	8.17		3.696	4.093	94
07-41	1	2.3-2.6	A	22.05	47.02	36.33	5,440.00	5.16	3.907		3.384	78
07-42	1	2.9-3.0	D	149.93	45.99	93.70	10,820.00	10.26		4.850	6.434	148
07-42	1	2.9-3.0	A	32.76	45.99	43.80	7,300.00	6.92	3.608		3.399	78
07-43	2	3.7-4.1	D	64.93	46.27	61.85	10,880.00	10.31		4.818	5.302	122
07-43	2	3.7-4.1	A	35.64	46.27	45.82	10,100.00	9.57	4.560		4.385	101
07-45	2	5.6-6.0	D	66.00	46.99	62.84	9,220.00	8.74		3.958	4.387	101
07-45	2	5.6-6.0	A	34.55	46.99	45.47	16,020.00	15.19	7.347		7.040	162
07-46	2	3.7-3.9	D	79.70	46.91	68.99	5,560.00	5.38		2.444	2.374	55
07-46	2	3.7-3.9	A	38.92	46.91	48.21	13,640.00	12.93	5.563		5.405	124
07-47	3	5.3-5.6	D	55.18	47.07	57.51	8,500.00	8.06		3.637	3.539	81
07-47	3	5.3-5.6	A	38.11	47.07	47.79	9,940.00	9.42	4.126		4.015	92
07-48	1	6.8-6.9	D	110.51	47.04	81.36	14,680.00	13.92		6.289	6.119	141
07-48	2	7.7-8.0	D	94.86	47.06	75.39	11,340.00	10.75		4.854	4.724	109
07-48	2	7.7-8.0	A	39.22	47.08	48.49	12,780.00	12.12	5.153		5.016	115
07-48	2	7.7-8.0	D	54.33	47.08	57.07	9,140.00	8.66		3.909	3.805	88

TABLE 1 (CONT'D)
POINT LOAD TEST ON ROCK CORE SAMPLES
HIGHWAY 401 WIDENING FROM WEST OF SYDENHAM ROAD TO WEST OF MONTREAL STREET
KINGSTON, ONTARIO
G.W.P. 77-99-01

Borehole Number	Sample Number	Sample Depth (m)	Test Type	Core Length (mm)	Core [(2)] Diameter (mm)	Equivalent Diameter (mm)	Ram Pressure (kPa)	Load (P) (kN)	Is Axial (MPa)	Is Diametral (MPa)	**Is (50mm)** (MPa)	**Approx.**[(1)] **UCS** (MPa)
07-48	3	8.9-9.1	A	34.13	46.92	45.15	13,880.00	13.16	6.454		6.272	144
07-48	3	8.9-9.1	D	113.11	46.92	82.20	3,420.00	3.24		1.473	1.431	33
07-49	1	2.9-3.1	D	67.55	46.98	63.57	9,580.00	9.08		4.115	4.001	92
07-49	1	2.9-3.1	A	33.02	46.98	44.44	12,460.00	11.81	5.981		5.815	134
07-49	3	5.2-5.4	A	47.27	47.20	53.30	13,080.00	12.40	4.365		4.253	98
07-49	3	5.2-5.4	D	122.98	47.20	85.97	7,960.00	7.55		3.387	3.300	76
07-50	3	5.8-6.2	D	77.52	47.14	68.21	9,320.00	8.84		3.976	3.872	89
07-50	3	5.8-6.2	A	32.99	47.14	44.50	9,620.00	9.12	4.606		4.485	103
07-50	3	5.8-6.2	D	88.35	47.14	72.82	9,840.00	9.33		4.198	4.088	94
07-50	3	5.8-6.2	A	40.91	47.14	49.55	10,260.00	9.73	3.961		3.858	89

(1) Is_{50} x C (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-6

(2) Actual distance between point load cones at time of failure

Checked by: DLW
Reviewed by JMAC

TABLE 2
EVALUATION OF SEWER INSTALLATION METHODS
PIPE CROSSINGS WITHIN LIMESTONE ROCKFILL AND SOIL FILL
STATION 21+275, 21+425, 21+450, 21+478, 21+740, 24+100, AND POSSIBLE STATION 24+810

Installation Method	*NS*[1]	*Advantages*	*Disadvantages*	*Estimated Costs/m of Sewer Installation*	*Risk/Consequences*
Open Cut Installations (OPSS 410)		Best control of gradient and alignment of sewers. Reduced potential for delays resulting from encountering obstructions. Least risk of damage to active highway.	Requires lane closures and pavement reconstruction. Large excavations required for deep installations	$250.00/m	Increased traffic disruption.
Jack and Bore Installation (OPSS 416)	NS[1] at Station 21+275, 21+425, 21+450, 21+478, and 24+100	Sewer can be installed without lane closures resulting in minimal traffic disruption.	Large work area required for jacking pit. Obstructions (e.g. cobbles, boulders and rockfill) may deflect and/or halt bore. Greatest risk of ground subsidence of highway; particularly if obstructions that slow installation procedures and/or require man-entry to remove are encountered.	$1,000.00/m	Risk of encountering refusal on obstructions within fill particularly where man entry to remove obstructions is not possible. Obstructions can result in deflection of the casing resulting in misalignment of sewer. Potential for loss of ground into casing particularly if cohesionless materials are encountered. Risk of ground surface subsidence increases with decreasing cover.
Pipe Ramming Installation		Minimal traffic disruption. Less risk of subsidence above pipe alignment than jack and bore installation methods. Better suited for penetrating through potential obstructions such as cobbles, boulders and limestone rockfill than jack and bore methods.	Large obstructions can deflect casing. Potential for heaving at ground surface.	$2,000.00/m	Obstructions can cause deflection of casing resulting in misalignment of sewer. Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining. Vibration from pipe ramming may be experienced by the users of the highway.

TABLE 2 CONT'D
EVALUATION OF SEWER INSTALLATION METHODS
PIPE CROSSINGS WITHIN LIMESTONE ROCKFILL AND SOIL FILL
STATION 21+275, 21+425, 21+450, 21+478, 21+740, 24+100, AND POSSIBLE STATION 24+810

Installation Method	*NS[1]*	*Advantages*	*Disadvantages*	*Relative Costs*	*Risk/Consequences*
Tunnelling Installation (OPSS 415)	NS[1] at Station 21+275, 21+425, 21+450, 21+478, and 24+100	Minimal traffic disruption. Smaller work area required compared to jack and bore methods.	Obstructions in the fill may deflect and/or halt bore. -Requires larger diameter casing for man-entry in hand mining techniques -Short tunnel sections may not be readily attractive to mining contractors, resulting in higher costs -Equipment may not be readily available locally	$6,000.00/m	Risk of encountering refusal on obstructions within fill.

NS[1]: Not considered a suitable installation alternative for certain crossings.

Compiled By: DLW

Reviewed By: ASP

TABLE 3
EVALUATION OF SEWER INSTALLATION METHODS
PIPE CROSSINGS AT INTERFACE OF OVERBURDEN AND BEDROCK
STATION 24+810 AND 26+010

Installation Method	*NS*[1]	*Advantages*	*Disadvantages*	*Estimated Costs/m of sewer installation*	*Risk/Consequences*
Open Cut Installations (OPSS 410)		Best control of gradient and alignment of sewers. Reduced potential for delays resulting from encountering obstructions. Least risk of damage to active highway.	Requires lane closures and pavement reconstruction. Large excavations required for deep installations	$250.00/m	Increased traffic disruption.
Hand Tunnelling Methods		Minimal traffic disruption. Ability to control alignment in mixed face conditions	Slow installation requiring continual man-entry into casings. Casings would need to be considerably larger than the pipe size to permit man-entry. Very difficult to carry out rock excavation while maintaining stability of excavation face in fill materials. Potential for loss of ground into casing leading to ground surface subsidence.	$4,000.00/m	Potential for instability of excavation and associated ground subsidence particularly during removal of bedrock at crossing invert.
Jack and Bore or Pipe Ramming Installation (OPSS 416)	X		Inability to maintain design alignment and gradient with mixed face conditions (bedrock and overburden). Potential for encountering refusal due to bedrock		

NS[1]: Not considered a suitable installation alternative for certain crossings/subsurface conditions.

Compiled By: DLW
Reviewed By: ASP

TABLE 4
EVALUATION OF CULVERT INSTALLATION METHODS
PIPE CROSSINGS WITHIN LIMESTONE BEDROCK
STATION 9+971 AND 10+029 (SYDENHAM ROAD)

Installation Method	*NS[1]*	*Advantages*	*Disadvantages*	*Estimated Costs/m of sewer installation*	*Risk/Consequences*
Open Cut Installations (OPSS 421)		Ability to install culvert at correct gradient and alignment.	Large excavations required for deep installations. Limestone bedrock is strong to very strong and blasting will likely be required. (Note that temporary detour lanes or closure of Sydenham Road and subsequent pavement reconstruction will be required).	$250.00/m	Increased traffic disruption. Controlled blasting required to limit damage to nearby structures/facilities including the Sydenham Road bridge over Highway 401.
Rock Bore Installation		Culverts can be installed without road closures resulting in minimal traffic disruption. Rock boring machine can penetrate through strong to very strong bedrock.	Difficulties may be encountered maintaining bore stability for services located less than 1 m below the surface of the bedrock (i.e. near upper, fractured portion of bedrock).	$4,000.00/m	Potential for collapse of crown of bore in areas where the culverts are located in close proximity to the upper fractured portion of the rock.
Jack and Bore or Pipe Ramming Installation (OPSS 416)	X		Inability to advance casing into strong to very strong limestone bedrock.		

NS[1]: Not considered a suitable installation alternative for this subsurface condition.

Compiled By: DLW

Reviewed By: ASP

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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.) drive open 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, 60° 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
I_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 = σ'_p/σ'_{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 = $\tan\delta$
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 0.6 m
Thinly bedded	60 mm 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	1 - 3 m
Moderately close	0.3 - 1 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

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 from 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 and infillings are also noted.

Abbreviations

B - Bedding
FO - Foliation/Schistosity
CL - Cleavage
SH - Shear Plane/Zone
VN - Vein
F - Fault
CO - Contact
J - Joint
FR - Fracture
MF - Mechanical Fracture
∥ - 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

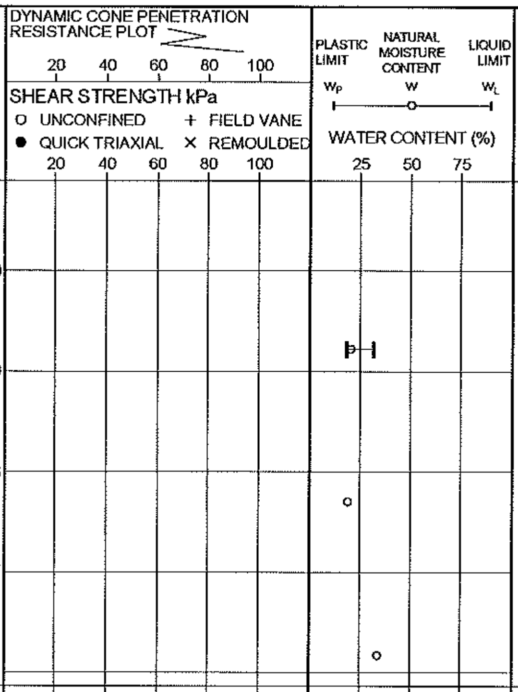
Golder Associates

RECORD OF BOREHOLE No 07-29

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4903945.5 ;E 302260.7
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE February 28, 2007
CHECKED BY KG

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
90.9	GROUND SURFACE											
0.0	ASPHALT											
90.5	Sand and gravel (FILL) Grey Moist											
90.1 0.8	Silty sand and gravel (FILL) Very dense Brown and grey Moist		1	SS	85		90					
89.5 1.4	Limestone Rockfill with sand and gravel, contains cobbles (FILL) Compact Brown to grey Moist to damp		2	SS	20		89		42	28	20	10
			3	SS	20							
	Organics at 2.89 m depth						88					
88.0 2.9	Sandy silt, trace clay and gravel (FILL) Loose to compact Light brown Moist		4	SS	18		87					
			5	SS	10							
86.5 4.4	Clayey silt, some sand, trace gravel (FILL) Firm Grey and brown Moist		6	SS	7		86					
85.9 5.0	End of Borehole											



Notes:

1. Borehole dry upon completion of drilling.

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 07-30

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4903933.9 ;E 302256.7
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE February 26, 2007
CHECKED BY KG

SOIL PROFILE

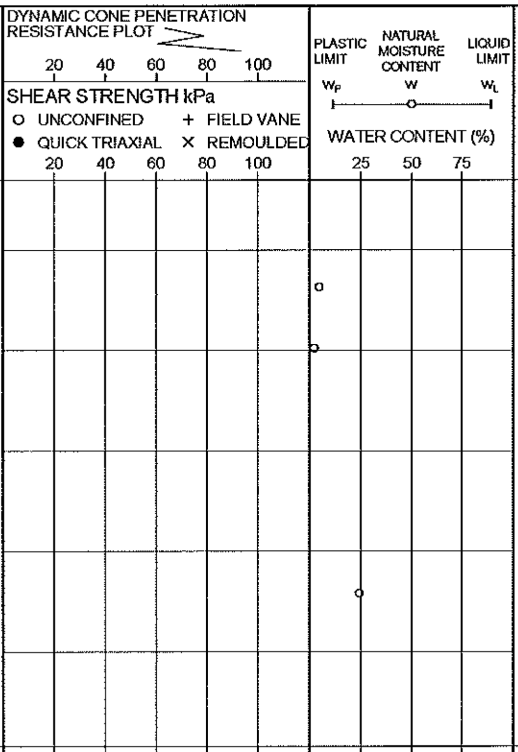
ELEV DEPTH	DESCRIPTION	STRAT PLOT
90.7	GROUND SURFACE	
0.0	Sand and gravel (FILL) Grey	▨
0.2	Silty sand and gravel, occasional cobbles (FILL) Loose to dense Grey and brown Moist	▨
89.5 1.2	Limestone Rockfill with sand and gravel, contains cobbles (FILL) Loose to compact Grey and brown Moist to damp	▨
88.0 2.7	Sandy silt, some clay, trace gravel and rootlets (FILL) Compact Brown Moist	▨
85.1 5.6	End of Borehole Notes: 1. Borehole dry upon completion of drilling.	

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	44
2	SS	25
3	SS	8
4	SS	11
5	SS	10
6	SS	10
7	SS	18

GROUND WATER CONDITIONS

ELEVATION SCALE: 90, 89, 88, 87, 86



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

+³, X³: Numbers refer to Sensitivity
O³% STRAIN AT FAILURE

MIS-MTO 001 05111031.GPJ GAL-MISS.GDT 7/22/08

RECORD OF BOREHOLE No 07-31

1 OF 1 **METRIC**

PROJECT 05-1111-031

W.P. 77-99-01

LOCATION N 4903892.0 ;E 302400.6

ORIGINATED BY DM

DIST Eastern HWY 401

BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE February 28, 2007

CHECKED BY KG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
86.7	GROUND SURFACE													
86.7 0.0	ASPHALT	■												
86.4 0.3	Sand and gravel (FILL) Very dense Brown Moist	▩	1	SS	60/0.08		86							
85.7 1.0	Limestone Rockfill with sand and gravel, contains cobbles (FILL) Loose to compact Grey and brown Moist to damp	▩	2	SS	17		85							
		▩	3	SS	7		84							
		▩	4	SS	5		83							
82.9 3.8	SILTY CLAY to CLAY, trace sand and gravel Firm to stiff Brown Moist	▥	5	SS	7									
		▥	6	SS	9		82							
81.7 5.0	End of Borehole Notes: 1. Borehole dry upon completion of drilling.													

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

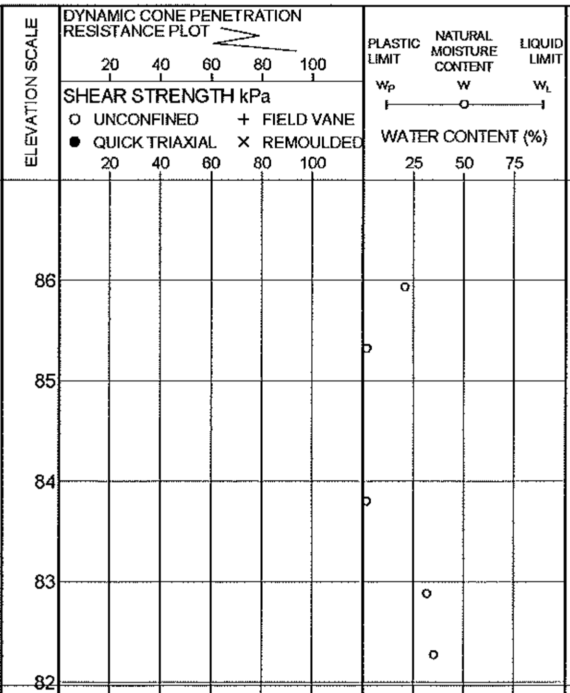
$O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 07-32

1 OF 1 **METRIC**

PROJECT	05-1111-031				
W.P.	77-99-01	LOCATION	N 4903881.2 ;E 302396.8	ORIGINATED BY	DM
DIST	Eastern HWY 401	BOREHOLE TYPE	Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers	COMPILED BY	KG
DATUM	Geodetic	DATE	February 26, 2007	CHECKED BY	KG

SOIL PROFILE			SAMPLES					REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
87.0	GROUND SURFACE										
0.0	Sand and gravel (FILL) Grey	▨									
0.1	Silty sand to sandy silt, some clay, trace gravel, organics (FILL) Dense Brown and grey Frozen	▨	1	SS	39						
85.6 1.4	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Loose to compact Grey and brown Moist to dry	▨	2	SS	12			61	30	7	2
		▨	3	SS	6						
		▨	4	SS	9						
83.2 3.8	SILTY CLAY to CLAY, trace sand, gravel and rootlets Firm to very stiff Brown and grey Moist	▧	5	SS	8						
		▧	6	SS	19						
82.0 5.0	End of Borehole Notes: 1. Borehole dry upon completion of drilling.										



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

RECORD OF BOREHOLE No 07-33

1 OF 1 **METRIC**

PROJECT 05-1111-031

W.P. 77-99-01 LOCATION N 4903872.6 ;E 302449.9 ORIGINATED BY DM

DIST Eastern HWY 401 BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers COMPILED BY KG

DATUM Geodetic DATE February 28, 2007 CHECKED BY KG

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
86.0	GROUND SURFACE					
0.0	ASPHALT					
85.6 0.4	Sand and gravel (FILL) Very dense Brown-grey	1	SS	40/0.10		85
85.0 1.0	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Loose to dense Brown and grey Moist to dry	2	SS	33		84
		3	SS	15		83
		4	SS	8		82
		5	SS	10		
		6	SS	4		81
81.1 5.0	SILTY CLAY to CLAY Brown End of Borehole					

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L

WATER CONTENT (%) 25 50 75

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Notes:

1. Borehole dry upon completion of drilling.

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

RECORD OF BOREHOLE No 07-34

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4903861.9 ;E 302446.1
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE February 26, 2007
CHECKED BY KG

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 25 50 75
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
85.7	GROUND SURFACE						
0.0	Sand and gravel (FILL) Grey Moist	▨					
84.9 0.8	Silty sand to sandy silt (FILL) Dense Brown to grey Moist	▨	1	SS	43		85
84.5 1.2	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Loose to compact Brown and grey Moist to dry	▨	2	SS	19		84
			3	SS	9		83
			4	SS	11		82
			5	SS	7		
			6	SS	6		81
80.7 5.0	SILTY CLAY to CLAY, trace gravel Stiff Brown Moist	▨	7	SS	13		
80.1 5.6	End of Borehole Note: 1. Borehole dry upon completion of drilling.						

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

PROJECT 05-1111-031

RECORD OF BOREHOLE No 07-35

1 OF 1 **METRIC**

W.P. 77-99-01

LOCATION N 4903779.8 ;E 302695.0

ORIGINATED BY DM

DIST Eastern HWY 401

BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE March 1, 2007

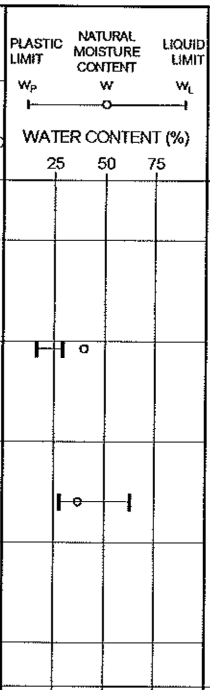
CHECKED BY KG

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
85.6	GROUND SURFACE									
0.0 85.3	Sand and gravel (FILL) Grey									
85.0 0.6	Clayey silt, some gravel, trace organics, trace rootlets (FILL) Brown and grey Moist					85				
84.5 1.1	Sand and gravel (FILL) Brown and grey Compact Moist	1	SS	23						
		2	SS	11		84	1	20	43	36
	Clayey silt, some sand, trace gravel, trace organics (FILL) Frim to stiff Brown and grey Moist	3	SS	6		83				
82.7 2.9	CLAY, trace sand, occasional silt layers Stiff Brown Moist	4	SS	14			0	2	36	62
						82				
		5	SS	10						
		6	SS	9		81				
80.6 5.0	End of Borehole Notes: 1. Borehole dry upon completion of drilling.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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

UNIT WEIGHT γ kN/m³



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

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PROJECT 05-1111-031 **RECORD OF BOREHOLE No 07-36** 1 OF 1 **METRIC**

W.P. 77-99-01 LOCATION N 4903769.1 ;E 302691.2 ORIGINATED BY DM

DIST Eastern HWY 401 BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers COMPILED BY KG

DATUM Geodetic DATE March 1, 2007 CHECKED BY KG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	WATER CONTENT (%) 25 50 75	γ kN/m³	GR	SA	SI	CL
85.7	GROUND SURFACE													
0.0	ASPHALT	■												
85.3	Sand and gravel (FILL)	▩												
85.0 0.7	Sand, trace gravel (FILL) Dense Brown Moist	▩	1	SS	37		85		o		2	88	5	5
		▩	2	SS	5		84							
84.0 1.7	Clayey silt, some sand, trace gravel and organics (FILL) Firm Brown and grey Damp	▩												
83.6 2.1	CLAY, trace sand, occasional silt layers Firm to very stiff Brown Moist	▨	3	SS	9		83		⊢o—⊣		0	2	39	59
		▨	4	SS	20									
		▨					82							
		▨	5	SS	13									
		▨	6	SS	5		81							
80.7 5.0	End of Borehole Notes: 1. Borehole dry upon completion of drilling.													

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

RECORD OF BOREHOLE No 07-37

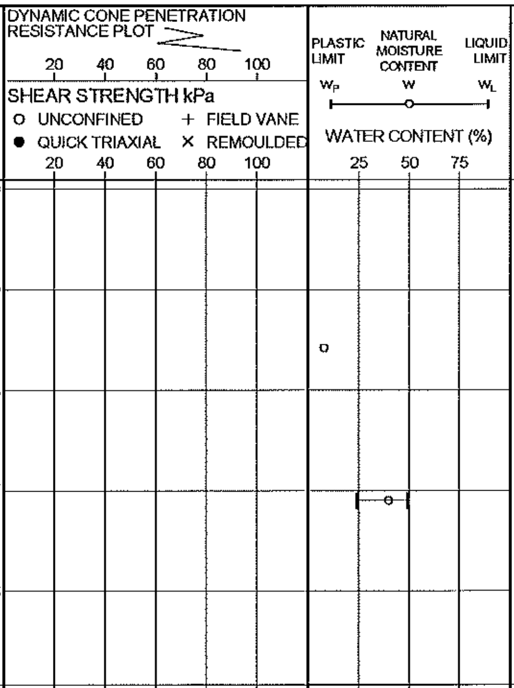
1 OF 1 **METRIC**

PROJECT 05-1111-031			ORIGINATED BY DM
W.P. 77-99-01	LOCATION N 4903227.0 ;E 304971.3		COMPILED BY KG
DIST Eastern HWY 401	BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers		CHECKED BY KG
DATUM Geodetic	DATE March 7, 2007		

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
90.1	GROUND SURFACE										
0.0 0.1	ASPHALT					90					
	Sand and gravel (FILL) Brown and grey										
89.3 0.8	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Compact Brown Moist	1	SS	26		89					
		2	SS	15				28	50	11	11
						88					
		3	SS	11							
87.2 2.9	SILTY CLAY, trace to some sand and organics Soft Grey and brown Moist	4	SS	3		87		0	7	38	55
86.3 3.8	SILTY CLAY, trace to some sand, trace organics and rootlets Firm Grey to black Moist	5	SS	6		86					
85.7 4.4	SILTY CLAY, trace to some sand Stiff Grey and brown Moist	6	SS	11							
85.1 5.0	End of Borehole										

Notes:

1. Borehole dry upon completion of drilling.

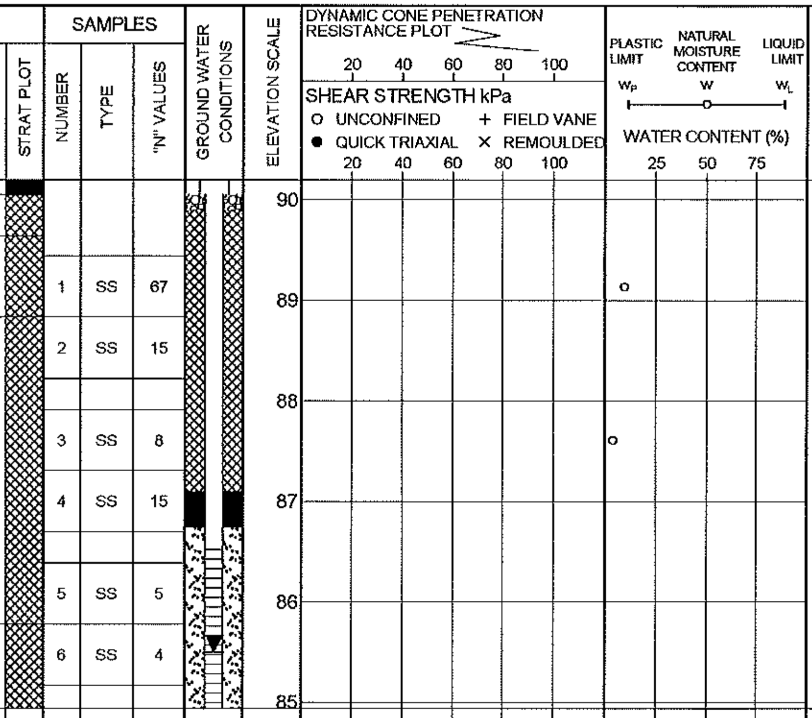


$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 07-38

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4903213.5 ;E 304970.1
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE March 7, 2007
CHECKED BY KG



ELEV / DEPTH	DESCRIPTION
90.2	GROUND SURFACE
0.0	ASPHALT
0.2	Sand and gravel (FILL) Grey
89.6 / 0.6	Sand, some gravel, trace clay and silt (FILL) Very dense Brown Moist
88.8 / 1.4	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Loose to compact Grey and brown Moist to dry
85.8 / 4.4	Sandy silt, trace to some clay, trace gravel (FILL) Very loose Brown Moist
84.9 / 5.3	End of Borehole

SAMPLES NUMBER	TYPE	"N" VALUES
1	SS	67
2	SS	15
3	SS	8
4	SS	15
5	SS	5
6	SS	4

UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL

Notes:

1. Borehole dry upon completion of drilling.

2. Water level in piezometer measured on May 30, 2007 at 4.7m (Elevation 85.3 m) below ground surface.

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

PROJECT 05-1111-031

RECORD OF BOREHOLE No 07-39

1 OF 1 **METRIC**

W.P. 77-99-01

LOCATION N 4903367.6 ;E 305651.4

ORIGINATED BY DM

DIST Eastern HWY 401

BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE March 8, 2007

CHECKED BY KG

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75

UNIT WEIGHT γ kN/m³

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE / SHEAR STRENGTH	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL	REMARKS
108.2	GROUND SURFACE														
0.0	ASPHALT	■													
0.2	Sand and gravel, trace to some silt, trace to some clay (FILL) Dense to very dense Grey and brown Moist to dry						108								
			1	SS	56		107		o						
			2	SS	48				o		50	42	4	4	
							106								
105.6			3	SS	92										
2.6	LIMESTONE (Bedrock) Bedrock cored from 2.66 m to 5.53 m depth. Refer to Record of Drillhole 07-39		4	RC NQ	REC 96%		105								RQD = 57%
			5	RC NQ	REC 100%		104								RQD = 85%
			6	RC NQ	REC 97%		103								RQD = 83%
102.7 5.5	End of Borehole Note: 1. Groundwater conditions not recorded.														

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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-39

SHEET 1 OF 1

LOCATION: N 4903367.6 ;E 305651.4
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: March 8, 2007
DRILL RIG: CME-75
DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break	BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	COLOUR % RETURN / FLUSH	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.3 m (5 10 15 20)	DISCONTINUITY DATA B Angle (0 90 180 270)	DISCONTINUITY DATA DIP w.r.t. CORE AXIS (0 30 60 90)	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	Diametral Point Load Index (MPa) (2 4 6)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-39		105.54																	
3		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh to slightly weathered, strong to very strong, thinly bedded		2.66	4		100														
4					5		100														
5				102.67 5.53	6		100														
		End of Drillhole																			
6																					
7																					
8																					
9																					
10																					
11																					
12																					

DEPTH SCALE
1 : 50

LOGGED: DM
CHECKED: KG

Golder Associates

RECORD OF BOREHOLE No 07-41

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic
LOCATION N 4903356.9 ;E 305658.3
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
DATE February 23, 2007
ORIGINATED BY DM
COMPILED BY KG
CHECKED BY KG

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
108.7	GROUND SURFACE													
0.0	Sand and gravel, trace to some silt, trace to some clay (FILL) Compact Grey and brown Moist						108							
			1	SS	23									
			2	SS	11		107				48	32	12	8
106.5 2.2	LIMESTONE (Bedrock) Bedrock cored from 2.16 m to 4.27 m depth. Refer to Record of Drillhole 07-41		3	RC NQ	REC 100%		106				RQD = 67%			
			4	RC NQ	REC 98%		105				RQD = 52%			
104.4 4.3	End of Borehole Note: 1. Groundwater conditions not recorded.													

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

PROJECT: 05-1111-031
LOCATION: N 4903356.9 ;E 305658.3
INCLINATION: -90° AZIMUTH: —

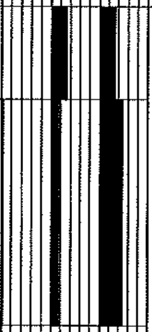
RECORD OF DRILLHOLE: 07-41

DRILLING DATE: February 23, 2007
DRILL RIG: CME-75
DRILLING CONTRACTOR: Marathon Drilling Ltd.

SHEET 1 OF 1
DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA θ Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-41		106.54																	
		LIMESTONE (BEDROCK) containing occasional shale seams and fresh calcite inclusions Strong to very strong, thinly bedded Near vertical fracture between depths of 2.6 m and 2.7 m		2.16	3		100														
3					4		100														
4				104.43 4.27																	
		End of Drillhole																			
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: KG

RECORD OF BOREHOLE No 07-42

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4904065.3 ;E 306627.1
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE March 9, 2007
CHECKED BY KG

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100
SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED: 20, 40, 60, 80, 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 25, 50, 75
UNIT WEIGHT γ kN/m³

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
104.7	GROUND SURFACE							
0.0	Sand and gravel (FILL) Grey to brown							
0.2	Clayey silt, some sand, trace gravel (FILL) Brown and grey Moist					104		
103.9 0.8	Sand, some gravel, some clayey silt (FILL) Compact Brown Moist	1	SS	11			o	
103.3 1.4	LIMESTONE (Bedrock) Bedrock cored from 1.42 m to 4.57 m depth. Refer to Record of Drillhole 07-42	2	RC NQ	REC 47%		103		RQD = 0%
		3	RC NQ	REC 100%		102		RQD = 77%
		4	RC NQ	REC 95%		101		RQD = 57%
100.1 4.6	End of Borehole Note: 1. Groundwater conditions not recorded.							

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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-42

SHEET 1 OF 1

LOCATION: N 4904065.3 ;E 306627.1

INCLINATION: -90° AZIMUTH: —

DRILLING DATE: March 9, 2007

DRILL RIG: CME-75

DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE m/n(m)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-42		103.33																	
2		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh, strong to very strong, thinly bedded		1.37	2		100														
3					3		100														
4		Vertical fracture between depths of 4.14 m to 4.57 m		100.13	4		100														
5		End of Drillhole		4.57																	
6																					
7																					
8																					
9																					
10																					
11																					

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: KG

Golder Associates

RECORD OF BOREHOLE No 07-43

1 OF 1 **METRIC**

PROJECT 05-1111-031

W.P. 77-99-01

LOCATION N 4904072.2 ;E 306622.6

ORIGINATED BY DM

DIST Eastern HWY 401

BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers

COMPILED BY KG

DATUM Geodetic

DATE March 12, 2007

CHECKED BY LCC

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	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				
105.1	GROUND SURFACE										
0.0	ASPHALT	■					105				
104.7 0.4	Sand and gravel (FILL) Brown and grey Frozen	▨					104				
103.4 1.8	LIMESTONE (Bedrock) Bedrock cored from 1.75 m to 4.14 m depth. Refer to Record of Drillhole 07-43	▨	1	RC NQ	REC 47%		103				RQD = 0%
		▨	2	RC NQ	REC 100%		102				RQD = 68%
101.0 4.1	End of Borehole Note: 1. Groundwater conditions not recorded.						101				

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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-43

SHEET 1 OF 1

LOCATION: N 4904072.2 ;E 306622.6

INCLINATION: -90° AZIMUTH: —

DRILLING DATE: March 12, 2007

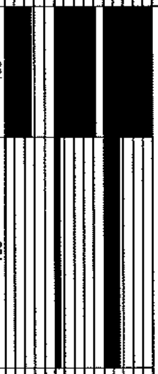
DRILL RIG: CME-75

DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU - Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN - Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE m/n(m)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-43		103.35																	
2 3 4	NQ Rotary Coring, Uncased	LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh, very strong, thinly bedded Highly fractured and broken core between depths of 1.75 m and 2.28 m Moderately fractured between depths of 2.28 m and 2.61 m		1.75 100.96 4.14	1 2		100 100														
		End of Drillhole																			
5 6 7 8 9 10 11																					



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: LCC

Golder Associates

RECORD OF BOREHOLE No 07-44

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4904058.2 ;E 306631.2
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY KG
DATUM Geodetic
DATE March 9, 2007
CHECKED BY KG

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
104.0	GROUND SURFACE										
0.0	Clayey silt, trace sand, trace gravel (FILL) Brown	▨					103				
102.4 1.6	Auger Refusal End of Probehole Note: 1. Groundwater conditions not recorded.										

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

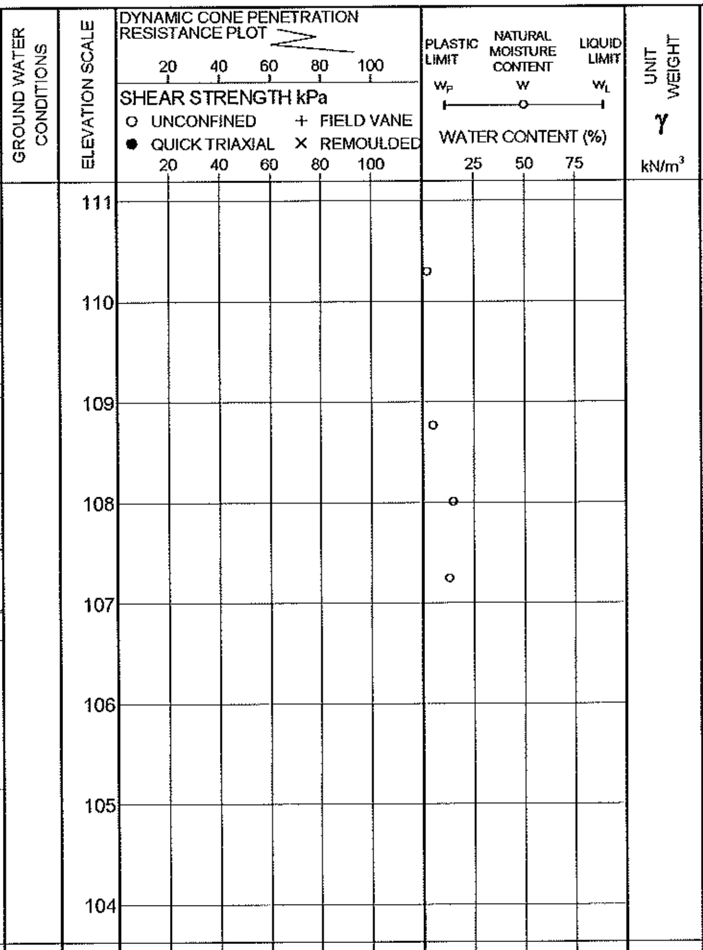
Golder Associates

RECORD OF BOREHOLE No 07-45

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4904155.2 ;E 301263.2
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY DW
DATUM Geodetic
DATE March 28, 2007
CHECKED BY LCC

SOIL PROFILE		SAMPLES			REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	
111.2	GROUND SURFACE				
0.0	ASPHALT				
	Sand and gravel (FILL)				
0.3	Silty sand and gravel (FILL) Dense Grey	1	SS	33	
109.8 / 1.4	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Compact Grey	2	SS	30	
		3	SS	11	
108.3 / 2.9	Sandy silt, some gravel, trace clay (FILL) Compact Grey	4	SS	18	
107.5 / 3.7	SAND and SILT, trace to some clay, trace gravel (TILL) Compact Light brown Moist	5	SS	20	
106.9 / 4.3	LIMESTONE (Bedrock) Bedrock cored from 4.27 m to 7.57 m depth. Refer to Record of Drillhole 07-45	6	RC NQ	REC 84%	RQD = 0%
		7	RC NQ	REC 98%	RQD = 74%
		8	RC NQ	REC 98%	RQD = 92%
103.6 / 7.6	End of Borehole Notes: 1. Borehole dry upon completion of drilling.				



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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-45

SHEET 1 OF 1

LOCATION: N 4904155.2 ;E 301263.2

INCLINATION: -90° AZIMUTH: —

DRILLING DATE: March 28, 2007

DRILL RIG: CME-75

DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR - Shear
VN - Vein
CJ - Conjugate

BD - Bedding
FO - Foliation
CO - Contact
OR - Orthogonal
CL - Cleavage

PL - Planar
CU - Curved
UN - Undulating
ST - Stepped
IR - Irregular

PO - Polished
K - Slickensided
SM - Smooth
Ro - Rough
MB - Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DISCONTINUITY DATA DIP w.r.t. CORE AXIS 0 30 60 90	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-45		106.93																	
		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh to slightly weathered, very strong, thinly bedded - Fractured between depths of 5.33 m and 5.38 m		4.27	6		100														
5					7		0														
6																					
7				103.63 7.57	8		0														
		End of Drillhole																			
8																					
9																					
10																					
11																					
12																					
13																					
14																					

DEPTH SCALE
1 : 50

Golder Associates

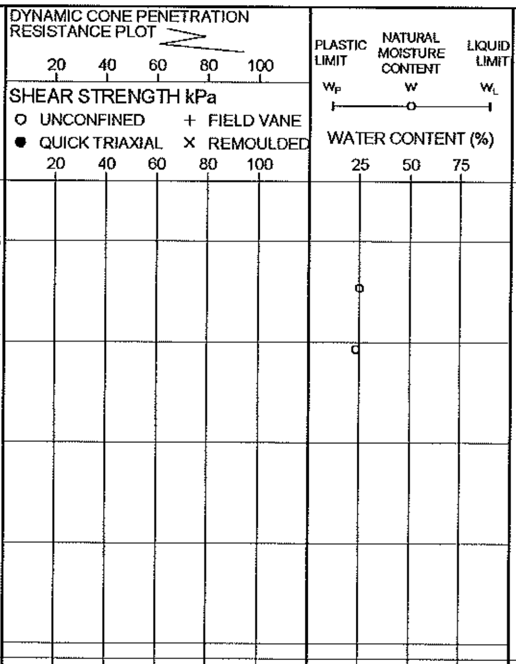
LOGGED: DM
CHECKED: LCC

RECORD OF BOREHOLE No 07-46

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
LOCATION N 4904167.9 ;E 301243.2
ORIGINATED BY DM
DIST Eastern HWY 401
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
COMPILED BY DW
DATUM Geodetic
DATE April 9, 2007
CHECKED BY LCC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES				
108.6	GROUND SURFACE							
0.1	Organic matter TOPSOIL							
	Clayey silt, some sand, trace gravel (FILL) Very stiff Brown					108		
		1	SS	15				
106.8		2	SS	20/0.15		107		
1.8	LIMESTONE (Bedrock)	3	RC NQ	REC 76%				RQD = 0%
	Bedrock cored from 1.82 m to 3.86 m depth.	4	RC NQ	REC 92%		106		RQD = 79%
	Refer to Record of Drillhole 07-46	5	RC NQ	REC 90%		105		RQD = 17%
103.9		6	RC NQ	REC 91%		104		RQD = 27%
4.8	End of Borehole Note: 1. Groundwater conditions not recorded.							



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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-46

SHEET 1 OF 1

LOCATION: N 4904167.9 ;E 301243.2

INCLINATION: -90° AZIMUTH: —

DRILLING DATE: April 9, 2007
DRILL RIG: CME-75
DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU - Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN - Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	COLOUR % RETURN / FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-46		106.78																	
2		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Moderately to slightly weathered, strong to very strong, thinly bedded - Weathered and broken between 2.06 and 2.16 m -Soil infill between 2.82 and 2.87 m - Lost water between 2.87 and 3.28 m		1.82	3		100														
					4		80														
3				104.74	5		0														
4		-Fresh		3.86 103.85	6		0														
5		End of Drillhole		4.75																	
6																					
7																					
8																					
9																					
10																					
11																					

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: LCC

Golder Associates

RECORD OF BOREHOLE No 07-47

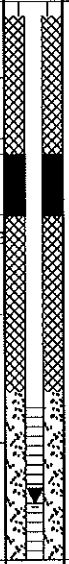
1 OF 1 **METRIC**

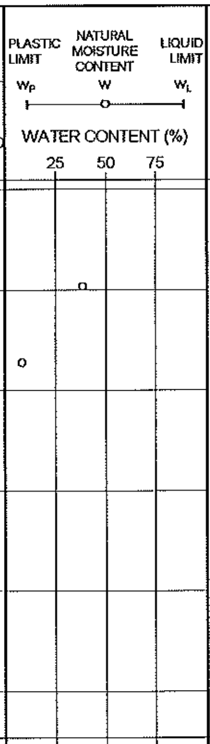
PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic

LOCATION N 4904166.0 ;E 301292.1
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
DATE April 10-11, 2007

ORIGINATED BY DM
COMPILED BY DW
CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLES NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
108.1	GROUND SURFACE				108	
8.0 0.1	Organic matter TOPSOIL					
	Clayey silt, some sand, trace gravel, occasional rootlets (FILL) Firm Brown and grey	1	SS	6	107	
106.6 1.5	SAND and SILT, trace to some clay, trace gravel (TILL) Compact Light brown Moist	2	SS	14	106	
		3	SS	11/0.13		
105.7 2.4	LIMESTONE (Bedrock) Bedrock cored from 2.41 m to 5.56 m depth. Refer to Record of Drillhole 07-47	4	RC NQ	REC 89%	105	RQD = 61%
		5	RC NQ	REC 99%	104	RQD = 77%
		6	RC NQ	REC 100%	103	RQD = 65%
102.5 5.6	End of Borehole					





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

UNIT WEIGHT γ kN/m³

Notes:

1. Water level in piezometer measured on May 3, 2007 at 5 m (Elevation 103.1 m) below ground surface.

2. Water level in piezometer measured on May 30, 2007 at 5 m (Elevation 103.1 m) below ground surface.

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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-47

SHEET 1 OF 1

LOCATION: N 4904166.0 ;E 301292.1

INCLINATION: -90°   AZIMUTH: ---

DRILLING DATE: April 10-11, 2007

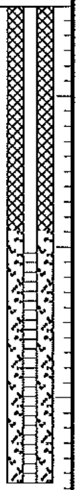
DRILL RIG: CME-75

DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	COLOUR / % RETURN FLUSH	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-47		105.69																	
		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh to slightly weathered, strong to very strong, thinly bedded -Near vertical fracture between depths of 4.8 m and 4.9 m		2.41	4		100														
3																					
					5		100														
4																					
5					6		0														
				102.54 5.56																	
		End of Drillhole																			
6																					
7																					
8																					
9																					
10																					
11																					
12																					



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DM

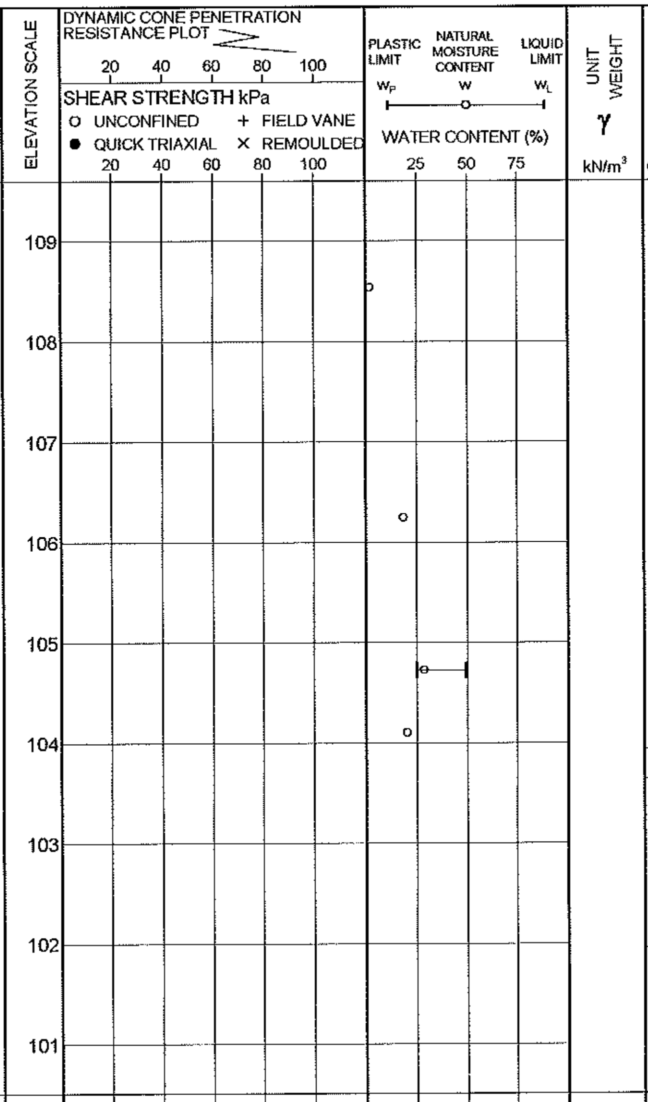
CHECKED: LCC

RECORD OF BOREHOLE No 07-48

1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic
LOCATION N 4904107.3 ;E 301277.1
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
DATE April 11, 2007
ORIGINATED BY DM
COMPILED BY DW
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		GR SA SI CL
109.6	GROUND SURFACE						
0.0	ASPHALT						
0.2	Sand and gravel (FILL)						
108.7 0.9	Limestone Rockfill, with sand and gravel, trace silt, contains cobbles (FILL) Compact to dense Grey Dry		1	SS	49		
			2	SS	10		
			3	SS	16		
106.7 2.9	Clayey silt, some sand, trace gravel, trace organic matter rootlets (FILL) Stiff to very stiff Brown and grey		4	SS	13		
			5	SS	17		
105.0 4.6	SILTY CLAY to CLAYEY SILT, trace sand (TILL) Stiff to very stiff Brown		6	SS	21		0 2 61 37
104.1	SAND and SILT (TILL) Compact Brown Moist		7	SS	14		
5.7	LIMESTONE (Bedrock) Bedrock cored from 5.66 m to 9.09 m depth. Refer to Record of Drillhole 07-48		8	RC NQ	REC 33%		RQD = %
			9	RC NQ	REC 85%		RQD = 38%
			10	RC NQ	REC 98%		RQD = 62%
100.5 9.1	End of Borehole Note: 1. Groundwater conditions not recorded.						



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

PROJECT: 05-1111-031

LOCATION: N 4904107.3 ;E 301277.1

INCLINATION: -90° AZIMUTH: —

RECORD OF DRILLHOLE: 07-48

DRILLING DATE: April 11, 2007

DRILL RIG: CME-75

DRILLING CONTRACTOR: Marathon Drilling Ltd.

SHEET 1 OF 1

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	FLUSH	COLOUR % RETURN	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.3 m (5 10 15 20)	DISCONTINUITY DATA B Angle (0 90 180 270)	DISCONTINUITY DATA DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	Diametral Point Load Index (MPa) (2 4 6)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-48		103.94																		
		LIMESTONE (BEDROCK) Highly weathered strong to very strong thinly bedded		5.66	8			100														
6					9			D														
		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh to slightly weathered, medium strong to very strong, thinly bedded		103.08 6.52																		
7																						
8					10			D														
9		End of Drillhole		100.51 9.09																		
10																						
11																						
12																						
13																						
14																						
15																						

MIS-RCK 004 05111031.GPJ GAL-MISS.GDT 7/22/08

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: DM

CHECKED: LCC

Golder Associates

RECORD OF BOREHOLE No 07-49

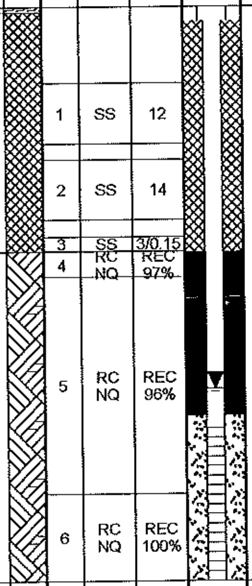
1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic

LOCATION N 4904104.1 ;E 301240.5
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
DATE April 12, 2007

ORIGINATED BY DM
COMPILED BY DW
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
106.5	GROUND SURFACE						
0.0 0.1	TOPSOIL, ORGANIC matter Clayey silt				106		
	Clayey silt, some sand, occasional limestone fragments, occasional wood fragments (FILL) Stiff Brown	1	SS	12		o	
		2	SS	14	105		
		3	SS	3/0.15			
104.1 2.4	LIMESTONE (Bedrock)	4	RC NQ	REC 97%	104		RQD = 65%
	Bedrock cored from 2.44 m to 5.72 m depth. Refer to Record of Drillhole 07-49	5	RC NQ	REC 96%	103 102		RQD = 90%
		6	RC NQ	REC 100%	101		RQD = 93%
100.8 5.7	End of Borehole						



DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75
UNIT WEIGHT γ kN/m³
GR SA SI CL

Notes:

1. Water level in piezometer measured on May 3, 2007 at 3.5 m (Elevation 103.0 m) below ground surface.

2. Water level in piezometer measured on May 30, 2007 at 3.8 m (Elevation 102.7 m) below ground surface.

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

PROJECT: 05-1111-031

RECORD OF DRILLHOLE: 07-49

SHEET 1 OF 1

LOCATION: N 4904104.1 ;E 301240.5

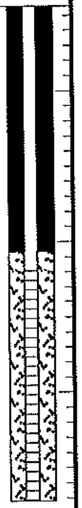
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: April 12, 2007
DRILL RIG: CME-75
DRILLING CONTRACTOR: Marathon Drilling Ltd.

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN - Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE m/n(m)	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.3 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Continued from borehole log 07-49		104.06																	
3 4 5		Grey, LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh, strong to very strong, thinly bedded -Fractured with soil infill		2.44	4 5 6		100 100 100														
				100.78																	
6		End of Borehole		5.72																	
7 8 9 10 11 12																					



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: LCC

MIS-RCK 004 05111031.GPJ GAL-MISS.GDT 7/22/08

Golder Associates

RECORD OF BOREHOLE No 07-50

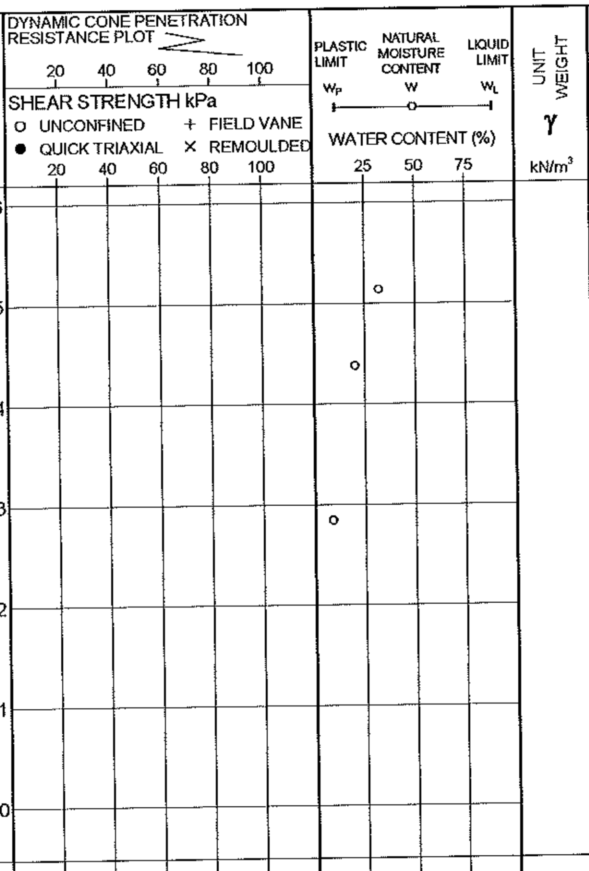
1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic

LOCATION N 4904102.8 ;E 301298.7
BOREHOLE TYPE Track-Mounted C.M.E. 75, 200mm O.D. Hollow Stem Augers
DATE April 12, 2007

ORIGINATED BY DM
COMPILED BY DW
CHECKED BY LCC

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
106.2	GROUND SURFACE						
0.0 0.1	TOPSOIL, ORGANIC matter, clayey silt Dark brown					106	
	Clayey silt, some sand, trace gravel, rootlets, friable (FILL) Stiff Brown Moist	1	SS	13		105	
104.7 1.7	SILTY CLAY to CLAYEY SILT, with sand, trace gravel (TILL) Stiff to hard Brown and grey	2	SS	9		104	
	SAND and SILT, trace to some clay, trace gravel (TILL) Dense to very dense Brown and grey Moist	3	SS	37			
		4	SS	65		103	5 45 39 11
102.5 3.7	LIMESTONE (Bedrock) Bedrock cored from 3.66 m to 6.72 m depth. Refer to Record of Drillhole 07-50	5	RC NQ	REC 100%			RQD = 46%
		6	RC NQ	REC 85%		102	RQD = 84%
		7	RC NQ	REC 99%		101	RQD = 86%
99.5		8	RC NQ	REC 100%		100	RQD = 100%
6.7	End of Borehole Note: 1. Groundwater conditions not recorded.						



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

RECORD OF DRILLHOLE: 07-50

PROJECT: 05-1111-031
LOCATION: N 4904102.8 ;E 301298.7
INCLINATION: -90° AZIMUTH: —

DRILLING DATE: April 12, 2007
DRILL RIG: CME-75
DRILLING CONTRACTOR: Marathon Drilling Ltd.

SHEET 1 OF 1
DATUM: Geodetic

JN - Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO- Foliation	CU- Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

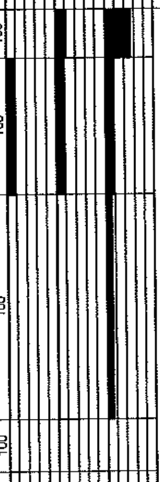
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE min/(m)	FLUSH COLOUR % RETURN
		Continued from borehole log 07-50		102.54			
		LIMESTONE (BEDROCK) containing occasional shale seams and calcite inclusions Fresh to slightly weathered, strong to very strong, thinly bedded -Fracture between depths of 3.6 m and 3.7 m		3.66	5		100
4					6		100
5							
					7		100
6							
				99.48	8		100
		End of Borehole		6.72			
7							
8							
9							
10							
11							
12							
13							

RECOVERY: TOTAL CORE % (80 60 40 20); SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.3 m (5 10 15 20)

DISCONTINUITY DATA: B Angle (0 90 180 270); DIP w.r.t. CORE AXIS (0 30 60 90); TYPE AND SURFACE DESCRIPTION; Jr; Ja; Jn

HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); Diametral Point Load Index (MPa) (2 4 6); RMC -Q' AVG.

NOTES WATER LEVELS INSTRUMENTATION



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: DM
CHECKED: LCC

Golder Associates

RECORD OF BOREHOLE No 08-1

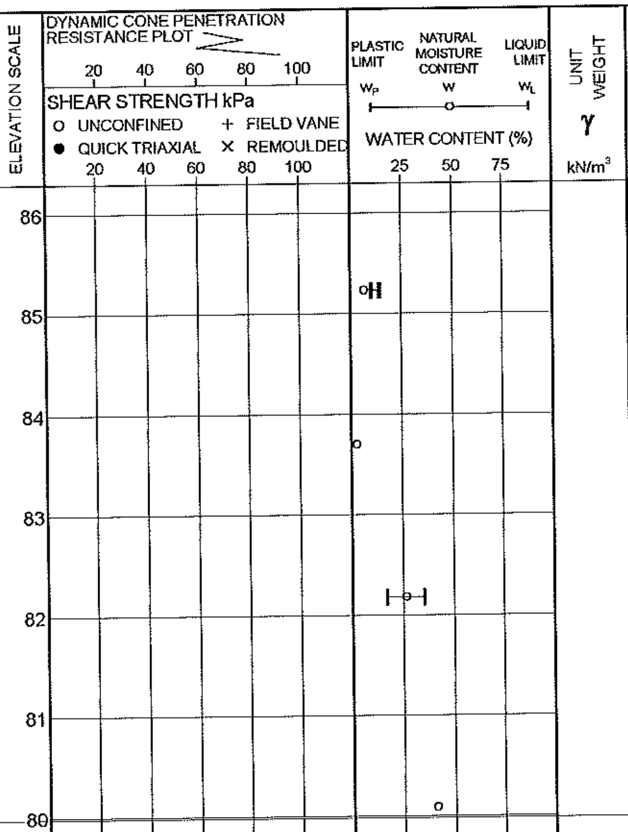
1 OF 1 **METRIC**

PROJECT 05-1111-031
W.P. 77-99-01
DIST Eastern HWY 401
DATUM Geodetic

LOCATION N 4903873.2 ;E 302420.2
BOREHOLE TYPE Truck-Mounted C.M.E. 55, 108 mm I.D. Hollow Stem Augers
DATE May 6, 2008

ORIGINATED BY SB
COMPILED BY DW
CHECKED BY DW

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES		GR	SA	SI	CL
86.3	GROUND SURFACE								
0.0	Sand and gravel (FILL) Brown and grey								
85.4 0.9	Limestone rockfill with sand and gravel, trace silt, contains cobbles (FILL) Loose to compact Grey and brown Moist	1	SS	27		28	54	13	5
		2	SS	13					
		3	SS	7					
		4	SS	7					
82.5 3.8	SILTY CLAY to CLAY, trace to some sand, trace gravel Firm to very stiff Brown Moist to wet	5	SS	6		5	17	59	19
		6	SS	16					
80.0	Refusal on Split Spoon	7	SS						
6.3	END OF BOREHOLE								



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

Golder Associates

RECORD OF BOREHOLE No 08-2

1 OF 1 **METRIC**

PROJECT 05-1111-031			ORIGINATED BY SB
W.P. 77-99-01	LOCATION N 4903879.4 ;E 302422.6		COMPILED BY DW
DIST Eastern HWY 401	BOREHOLE TYPE CME-55, 108 mm I.D. Hollow Stem Augers, Automatic Hammer		CHECKED BY DW
DATUM Geodetic	DATE May 6, 2008		

SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
86.4	GROUND SURFACE	
0.0	Asphalt	■
0.2	Sand with gravel, trace clay, occasional cobbles (FILL) Brown to grey Moist	▨
85.3 1.1	Limestone rockfill with sand and gravel, trace silt, contains cobbles (FILL) Loose to dense Grey and brown Moist	▨
82.3 4.1	SILTY CLAY to CLAY, trace to some sand, trace gravel Firm to very stiff Brown Moist to wet	▨
79.7 6.7	END OF BOREHOLE	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	35				
2	SS	13	75	20	4	1
3	SS	7				
4	SS	12				
5	SS	25				
6	SS	19	0	5	49	46
7	SS	11				

GROUND WATER CONDITIONS

ELEVATION SCALE: 86, 85, 84, 83, 82, 81, 80

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa
- o UNCONFINED
- + FIELD VANE
- ● QUICK TRIAXIAL
- × REMOULDED

20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT W_L

WATER CONTENT (%): 25 50 75

UNIT WEIGHT γ kN/m^3

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

MINISTRY OF TRANSPORTATION, ONTARIO

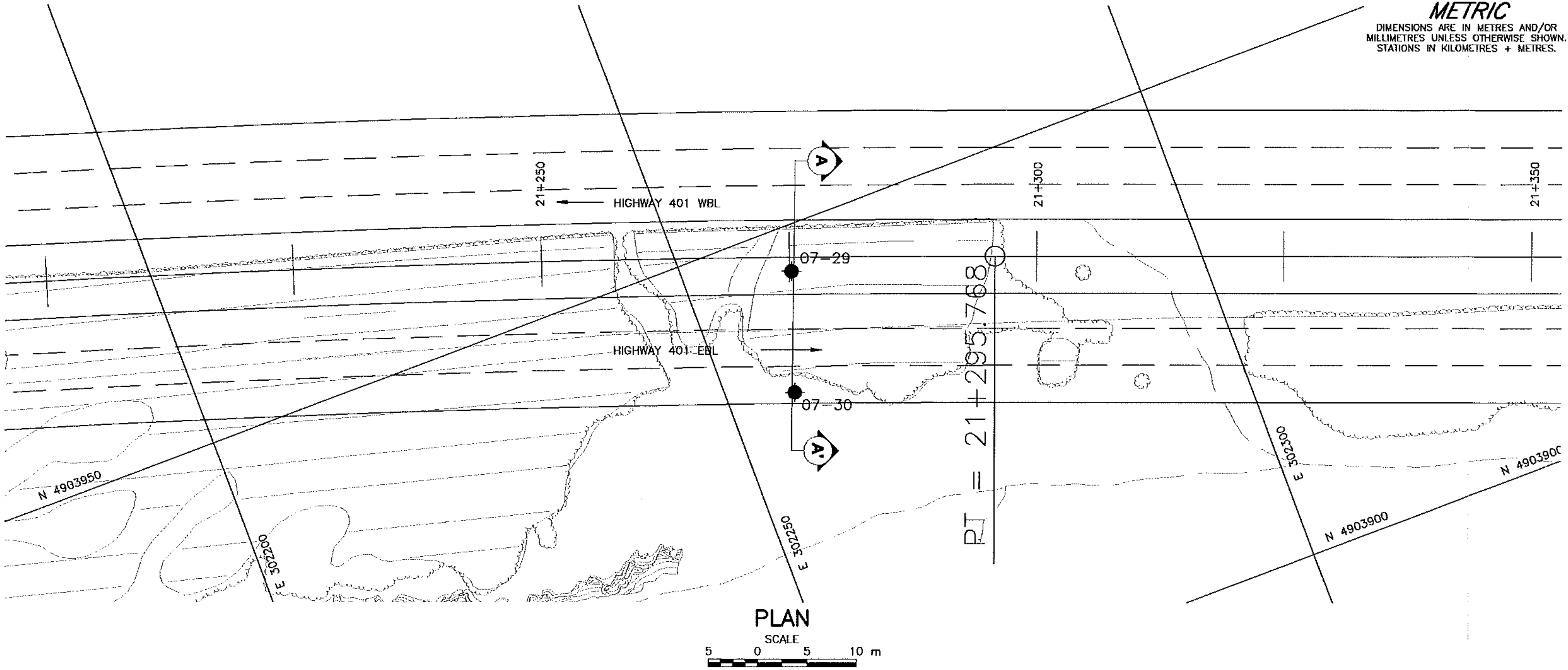
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

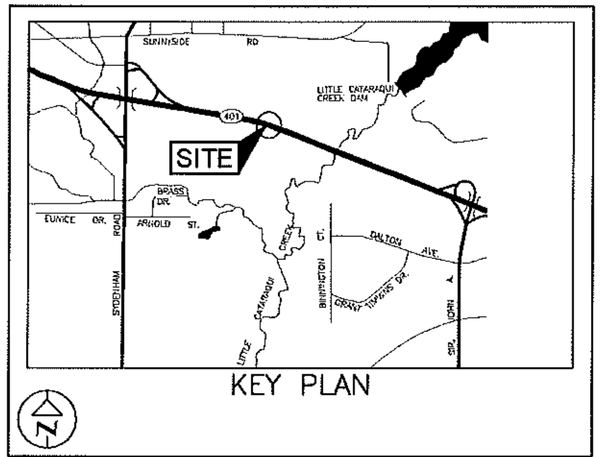
CONT No.
WP No.77-99-01

SHEET

HIGHWAY 401 STN 21+275 BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



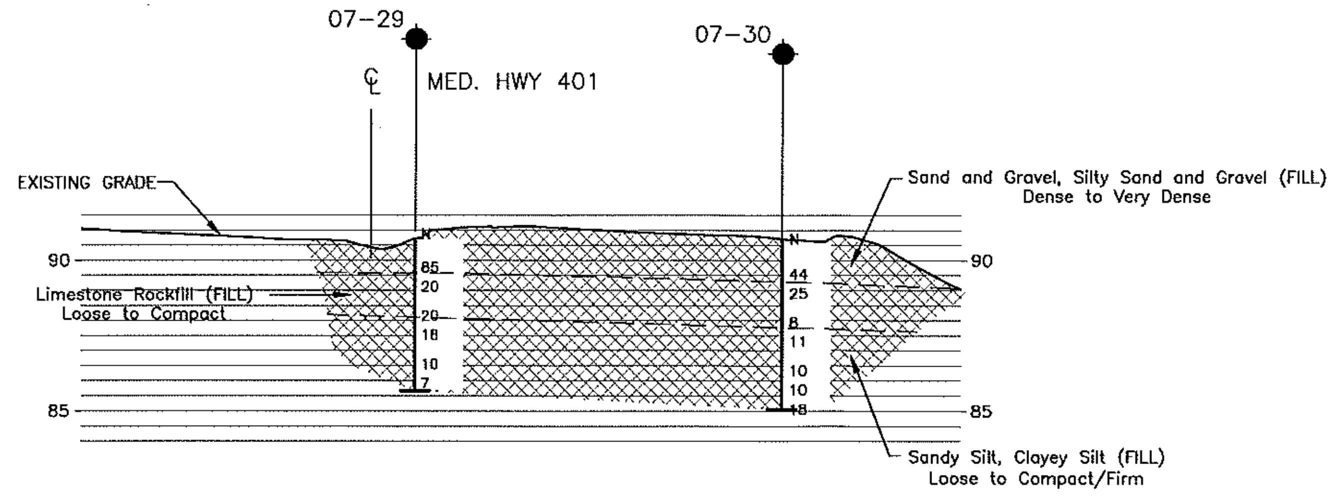


KEY PLAN

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-29	90.9	4903945.5	302260.7
07-30	90.7	4903933.9	302256.7



A–A' SECTION AT STN 21+275

SCALE
2.5 0 2.5 5 m

NOTES

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

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

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

REFERENCE

Base plans provided in digital format by McCormick Rankin Corporation, Drawing Nos. H6230XA01.dwg,H6230XB01.dwg, H6230XB02.dwg, H6230XB03.dwg, H6230XB04.dwg, H6230XM01.dwg, H6230Xn01-2.dwg, received January 10, 2006

NO.	DATE	BY	REVISION

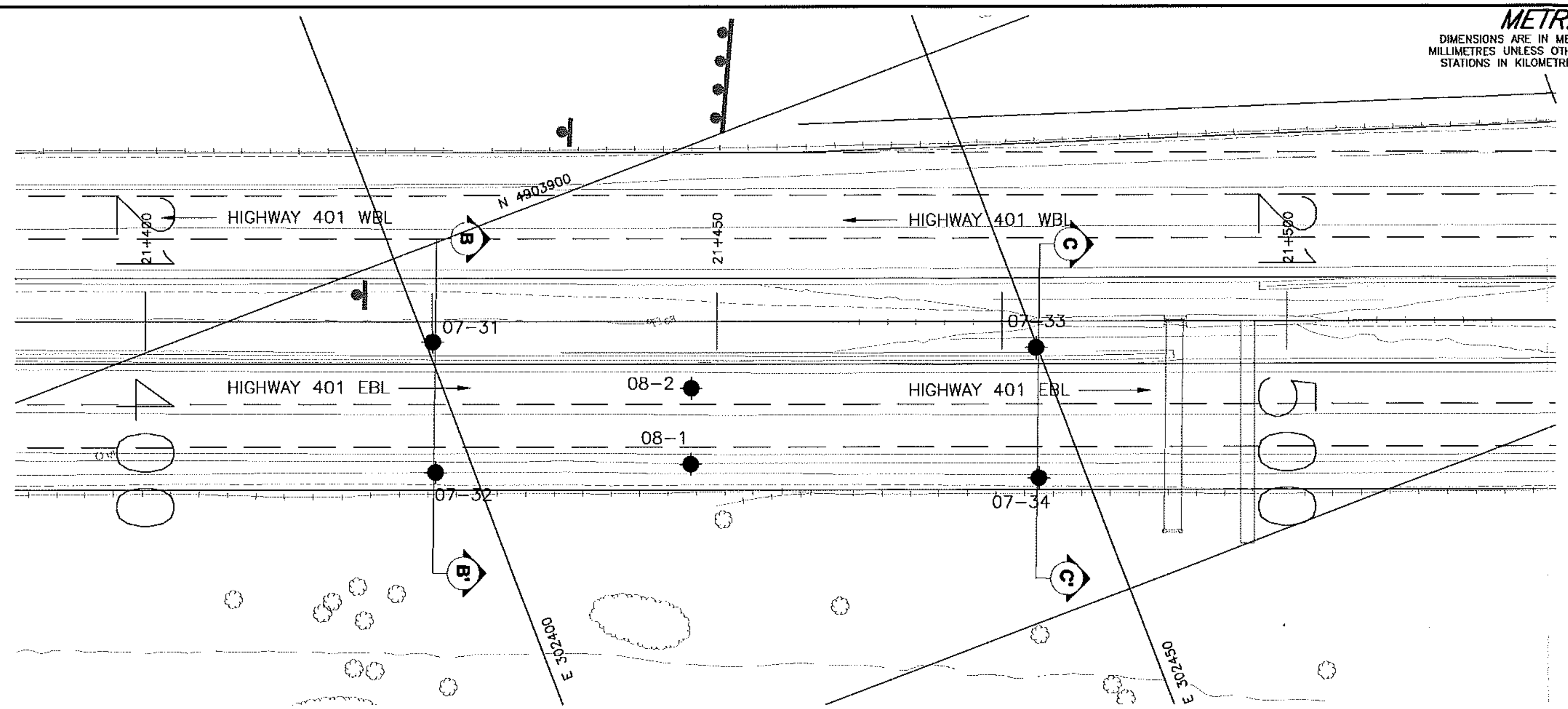
Geocres No. 31C-181

HWY. 401		PROJECT NO. 05-1111-031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22-Jul-2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 1

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-C0- Outlet Sewer\0511103100001.dwg

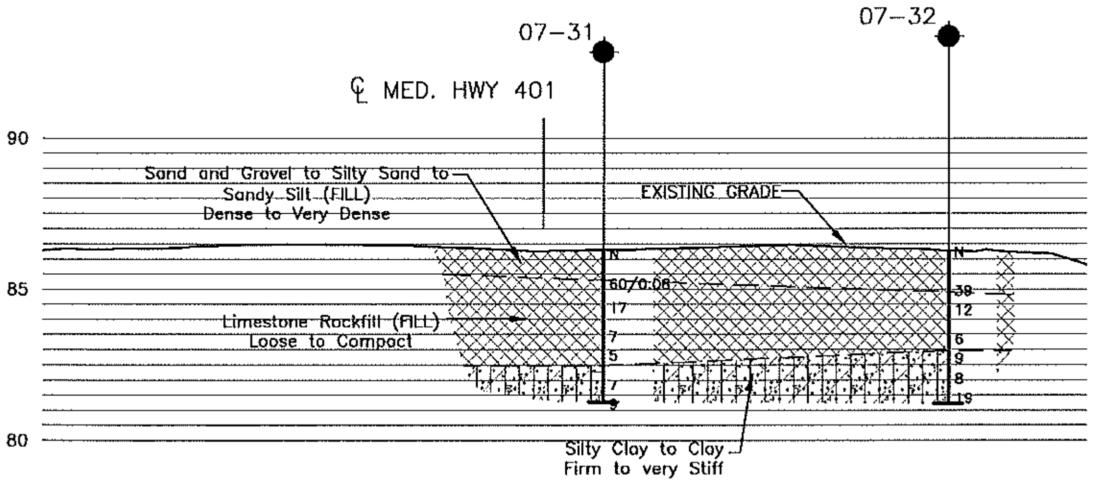
MINISTRY OF TRANSPORTATION, ONTARIO

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



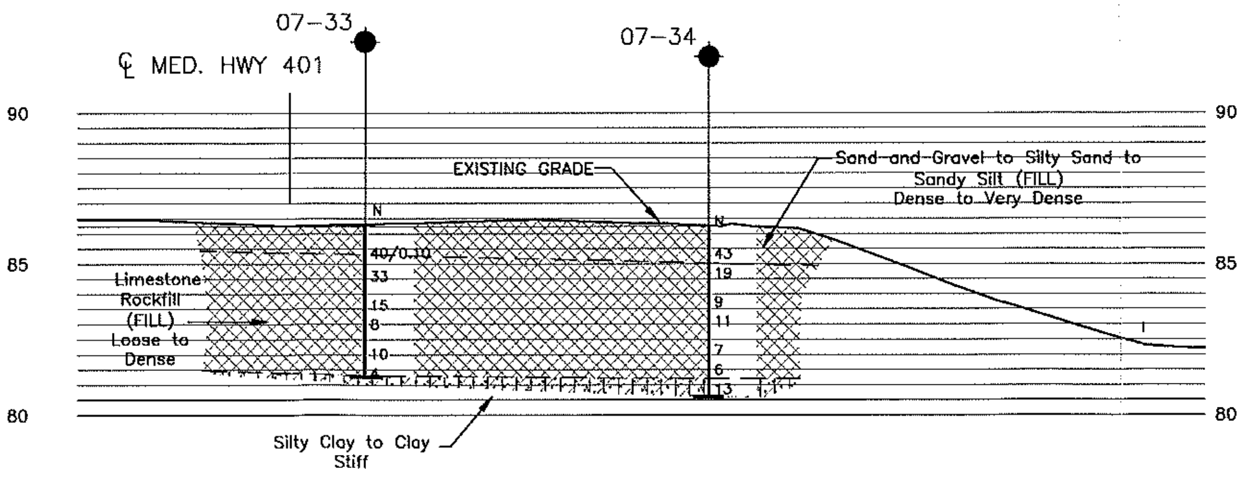
PLAN

SCALE
5 0 5 10 m



B-B' SECTION AT STN 21+425

SCALE
2.5 0 2.5 5 m



C-C' SECTION AT STN 21+478

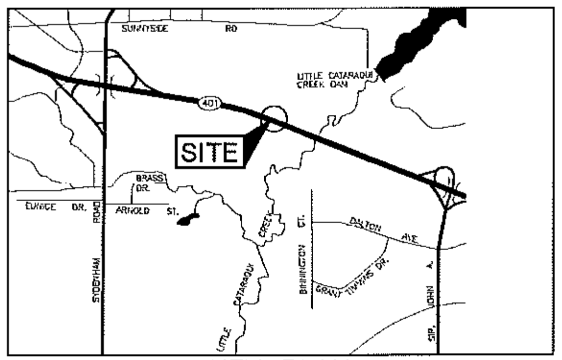
SCALE
2.5 0 2.5 5 m

CONT No. 2A
WP No. 77-99-01

SHEET

HIGHWAY 401 STN 21+450 AND STN 21+478 BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

LEGEND

●	Borehole – Current Investigation
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-31	86.5	4903892.0	302400.6
07-32	86.5	4903881.2	302396.8
07-33	87.2	4903872.6	302449.9
07-34	86.7	4903861.9	302446.1

NOTES

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

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

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

REFERENCE

Base plans provided in digital format by McCormick Rankin Corporation, Drawing Nos. H6230XA01.dwg,H6230XB01.dwg, H6230XB02.dwg, H6230XB03.dwg, H6230XB04.dwg, H6230XM01.dwg, H6230Xn01-2.dwg, received January 10, 2006

NO.	DATE	BY	REVISION

Geocres No. 31C-181

HWY. 401		PROJECT NO. 05-1111-031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22-Jul-2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 2a

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-ED- Outlet Sewer\0511110031ED02A.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

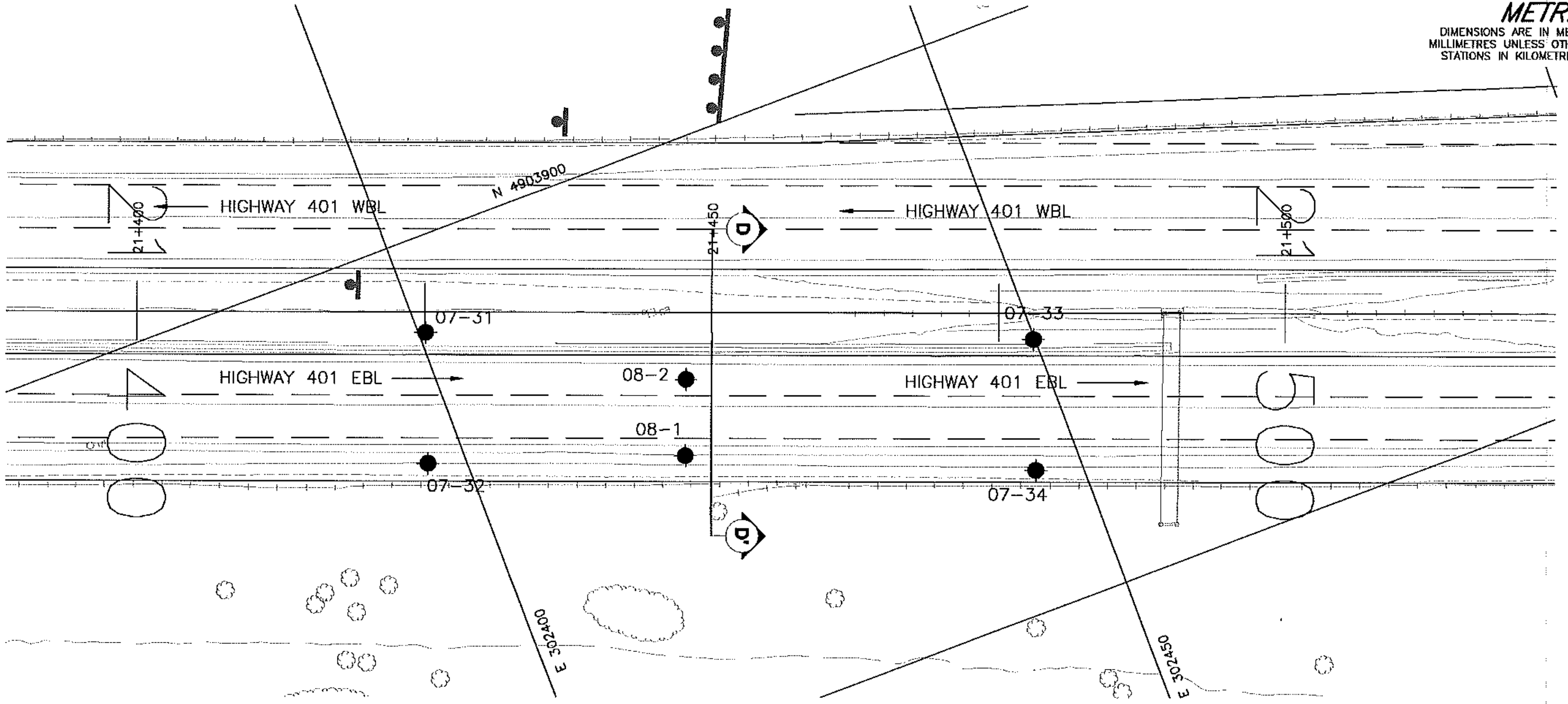
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.77-99-01

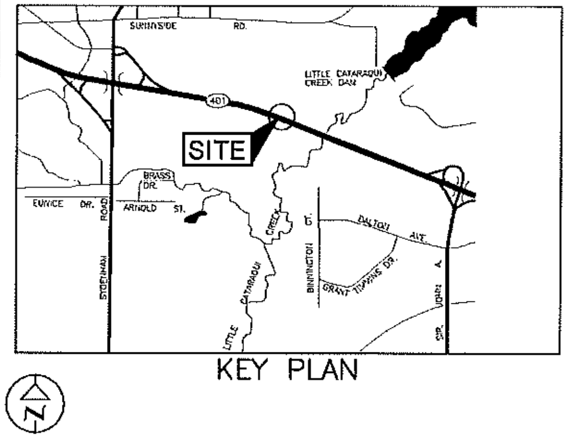
HIGHWAY 401 STN 21+450
(ALTERNATE CROSSING LOCATION)
BOREHOLE LOCATIONS AND
SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

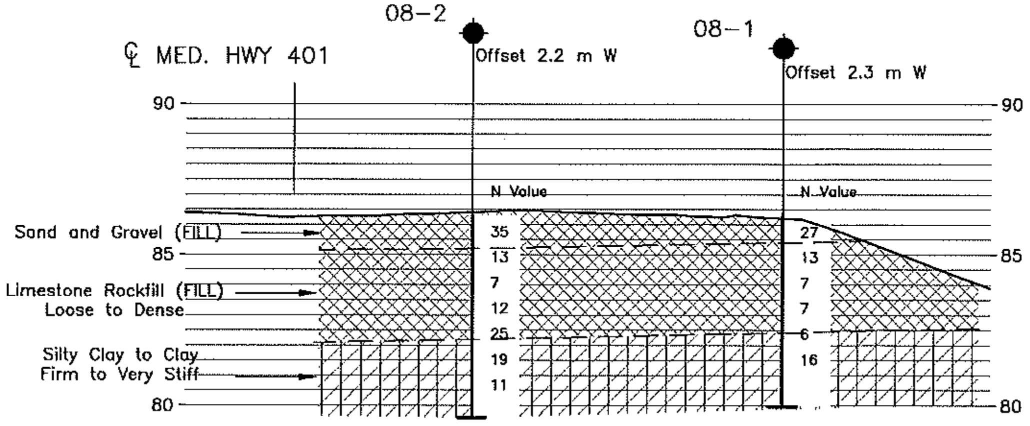


KEY PLAN

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-31	86.7	4903892.0	302400.6
07-32	87.0	4903881.2	302396.8
07-33	86.0	4903872.6	302449.9
07-34	85.7	4903861.9	302446.1
08-1	86.3	4903873.9	302418.0
08-2	86.4	4903880.1	302420.4



D–D'

SECTION AT STN 21+450
(ALTERNATE CROSSING LOCATION)

SCALE
2.5 0 2.5 5 m

NOTES

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REFERENCE

Base plans provided in digital format by McCormick Rankin Corporation, Drawing Nos. H6230XA01.dwg,H6230XB01.dwg, H6230XB02.dwg, H6230XB03.dwg, H6230XB04.dwg, H6230XM01.dwg, H6230Xn01-2.dwg, received January 10, 2006

NO.	DATE	BY	REVISION

Geocres No. 31C-181

HWY. 401		PROJECT NO. 05-1111-031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22-Jul-2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 2b

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MPC, Kingston, Ontario)\-ED- Outlet Sewer\05111031ED02B.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

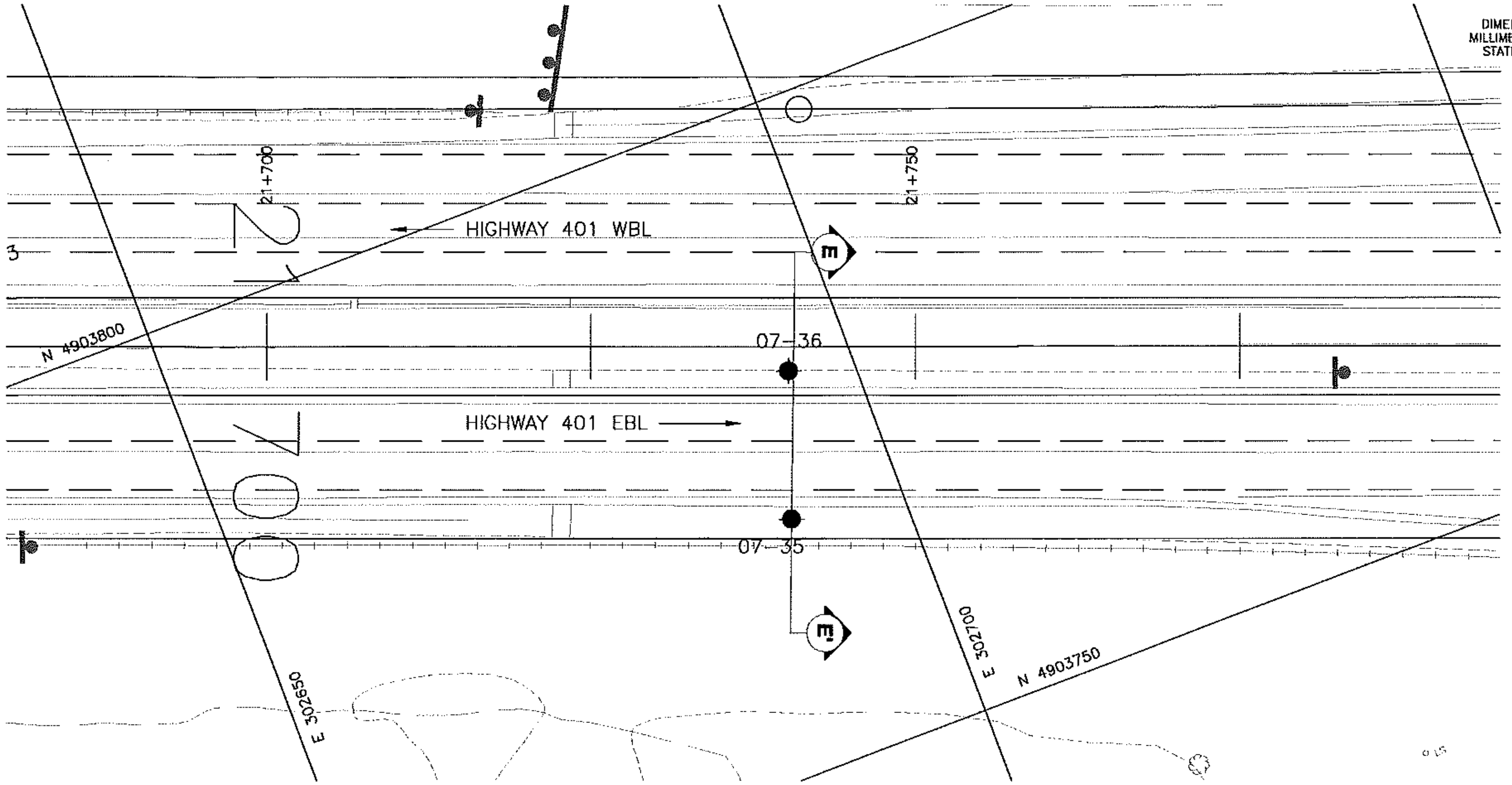
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.77–99–01

SHEET

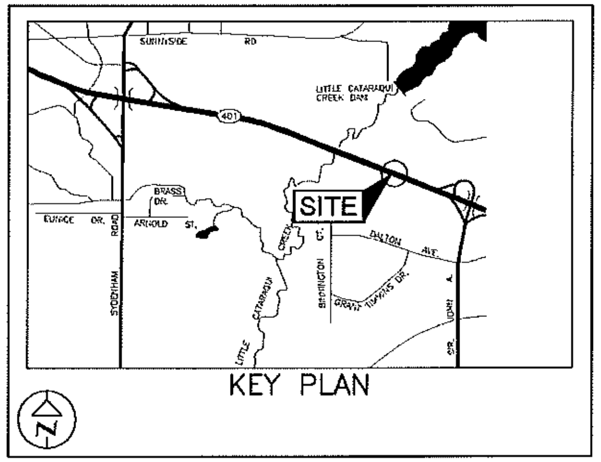
HIGHWAY 401 STN 21+740
BOREHOLE LOCATIONS AND
SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
5 0 5 10 m



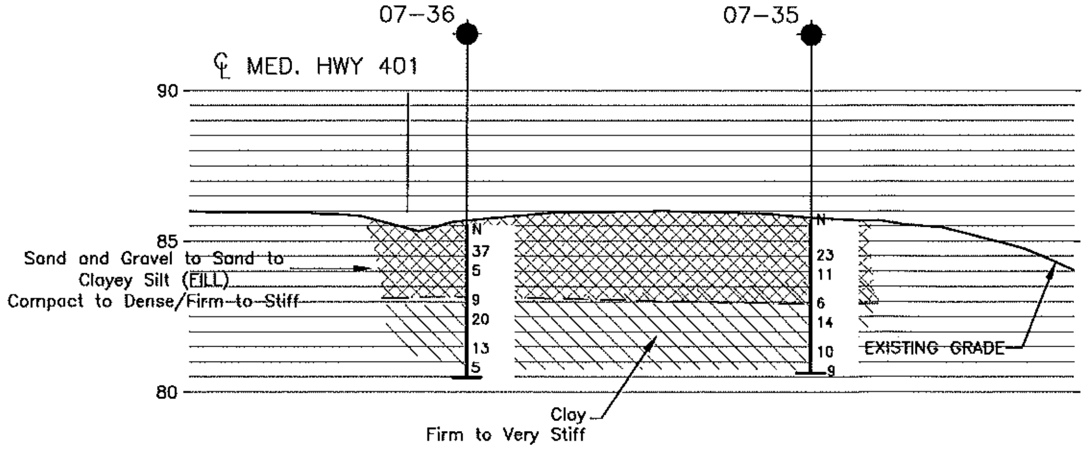
KEY PLAN

LEGEND

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
07–35	85.6	4903779.8	302695.0
07–36	85.7	4903769.1	302691.2



E–E' SECTION AT STN 21+740

SCALE
2.5 0 2.5 5 m

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No. 31C–181

HWY. 401		PROJECT NO. 05–1111–031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22–Jul–2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 3

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-E0- Outlet Sewer\05111031ED003.dwg

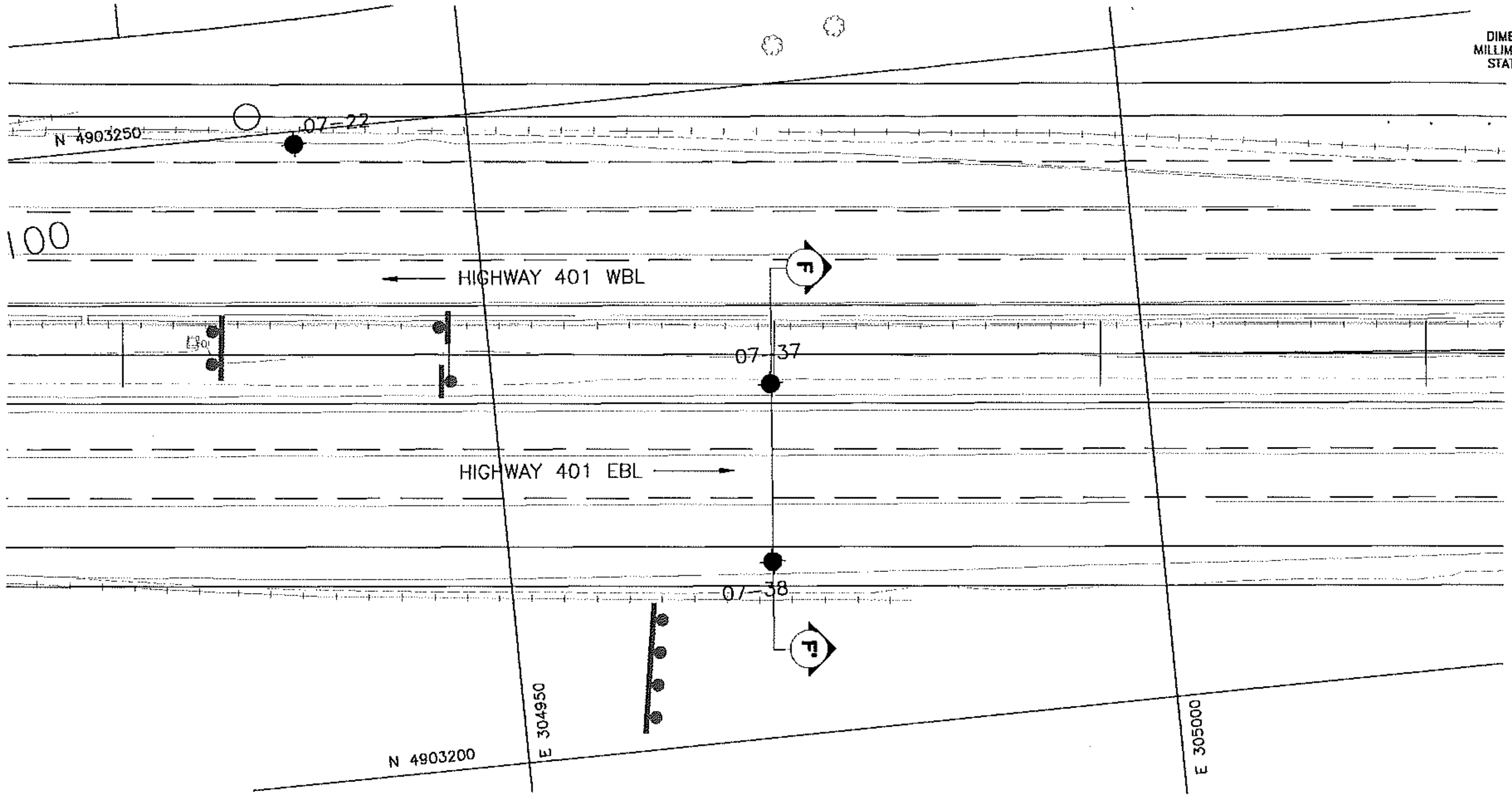
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.77–99–01

SHEET

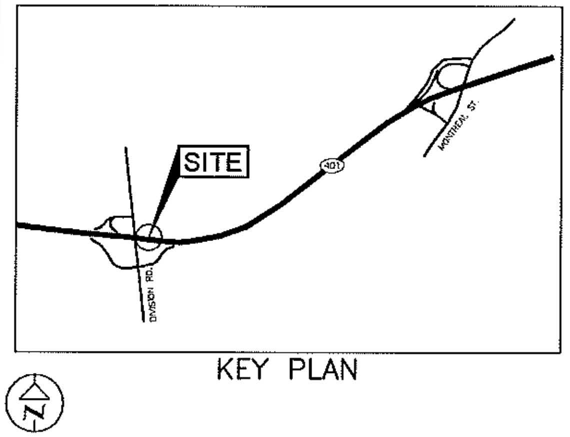
HIGHWAY 401 STN 24+100 BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
5 0 5 10 m

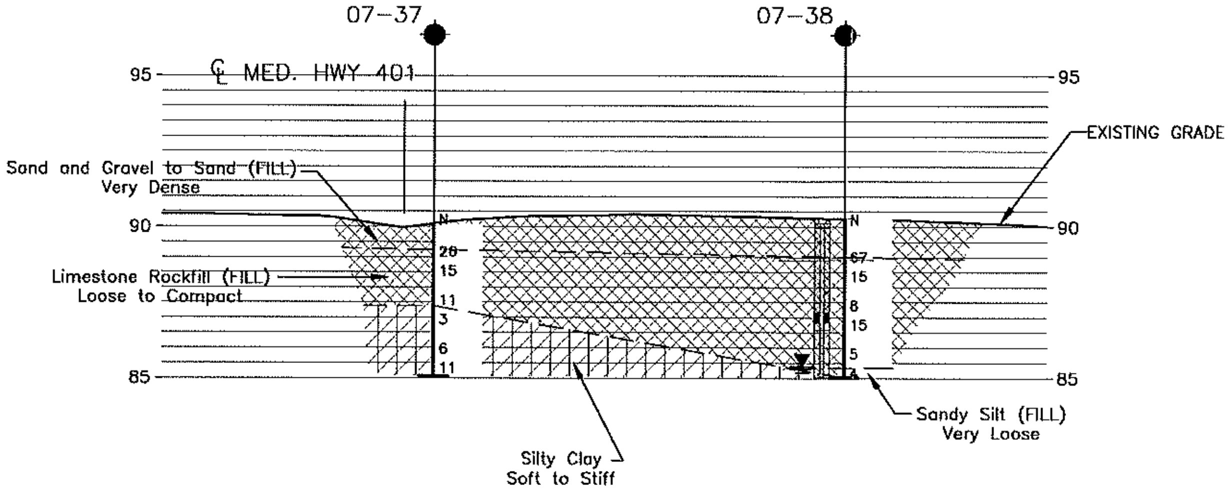


KEY PLAN

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▼ WL in piezometer, measured on May 30, 2007

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
07–37	90.1	4903227.0	304971.3
07–38	90.2	4903213.5	304970.1



F–F' SECTION AT STN 24+100

SCALE
2.5 0 2.5 5 m

NOTES

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No. 31C–181

HWY. 401		PROJECT NO. 05–1111–031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22–Jul–2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 4

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-ED- Outlet Sewer\051111031ED004.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

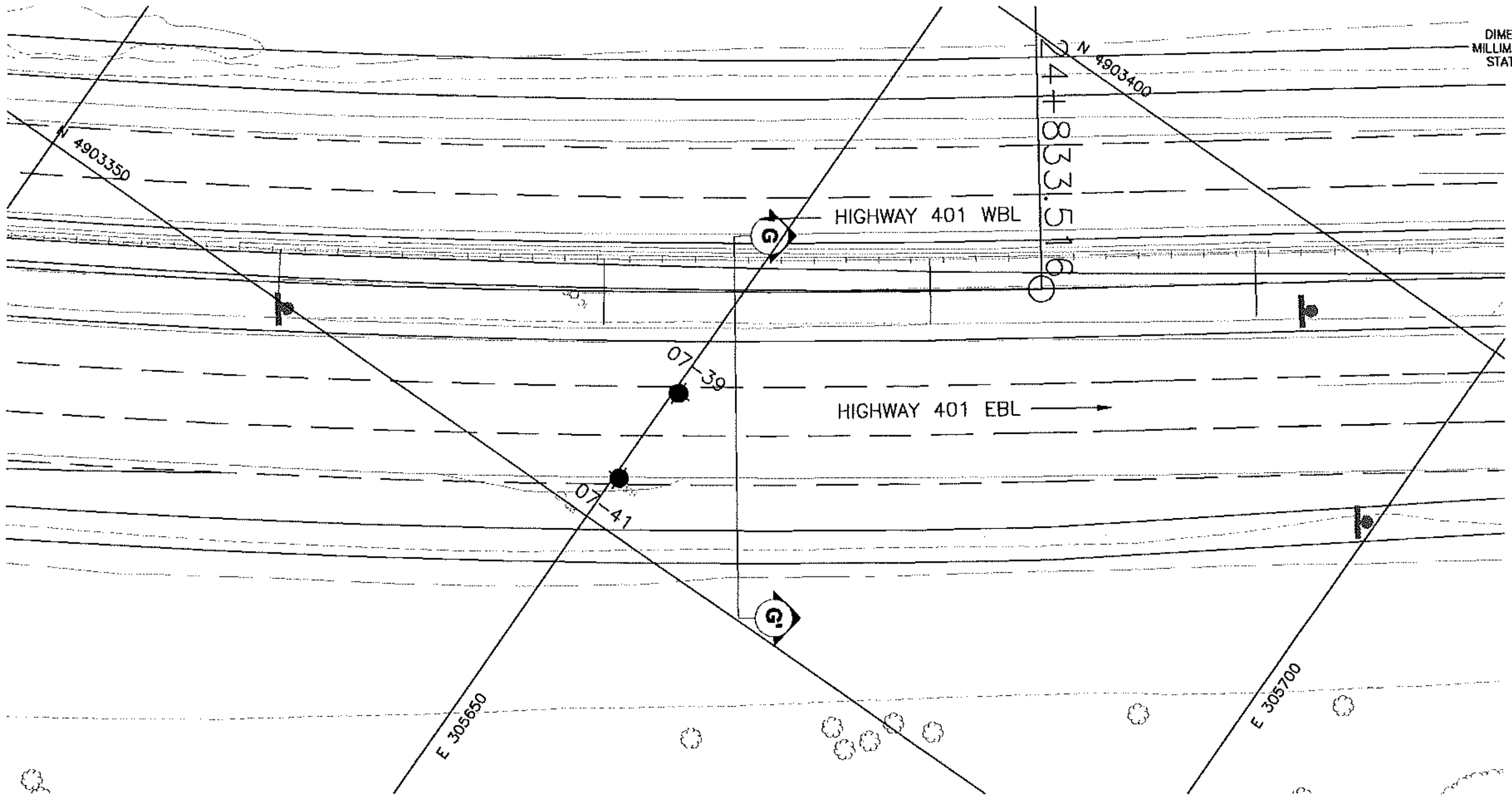
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.77–99–01

SHEET

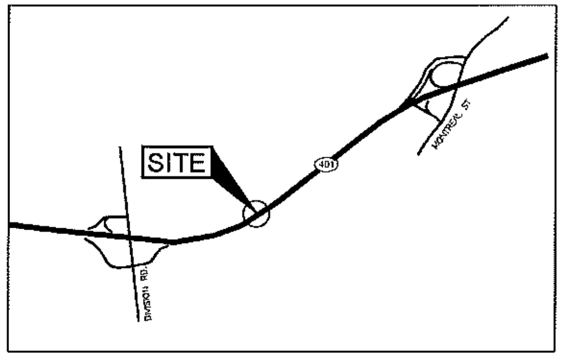
HIGHWAY 401 STN 24+810
BOREHOLE LOCATIONS AND
SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
5 0 5 10 m

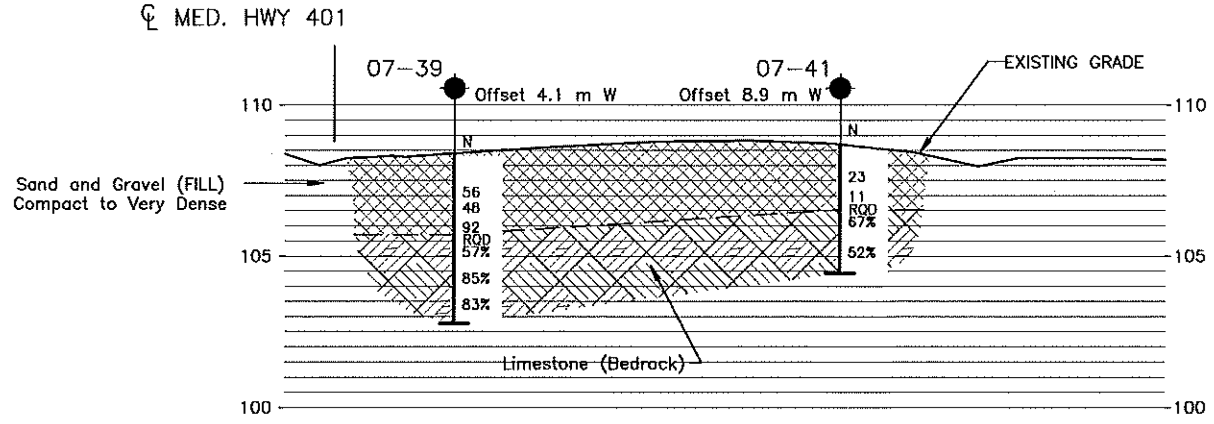


KEY PLAN

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
07–39	108.2	4903361.7	305643.5
07–41	108.7	4903353.8	305650.4



G–G' SECTION AT STN 24+810

SCALE
2.5 0 2.5 5 m

NOTES

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No. 31C–181

HWY. 401		PROJECT NO. 05–1111–031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22–Jul–2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 5

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-ED- Outlet Sewer\0511110031ED005.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

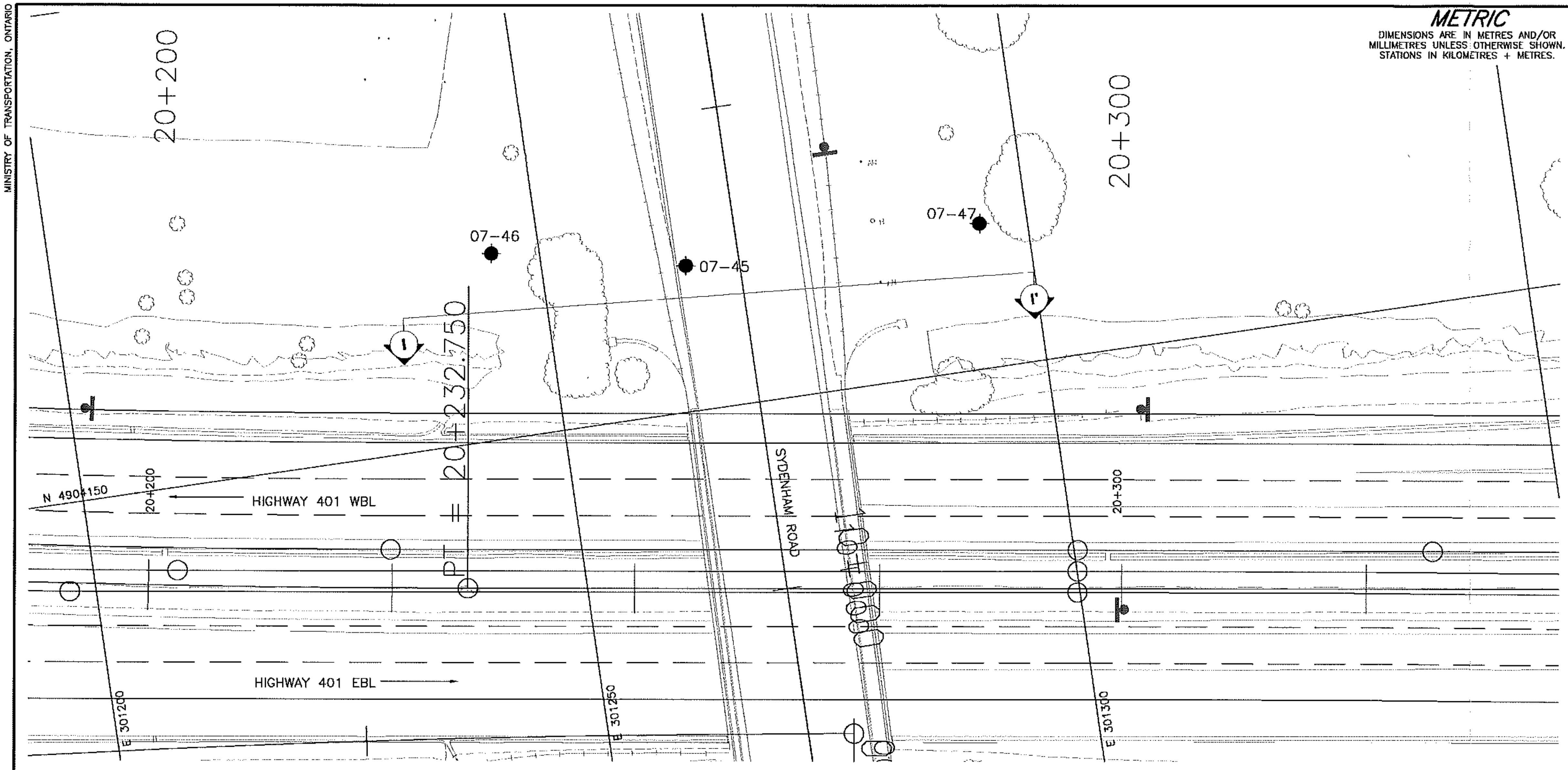
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 77-99-01

HIGHWAY 401
SYDENHAM ROAD CROSSING STN 9+971
BORHOLE LOCATIONS AND
SOIL STRATA

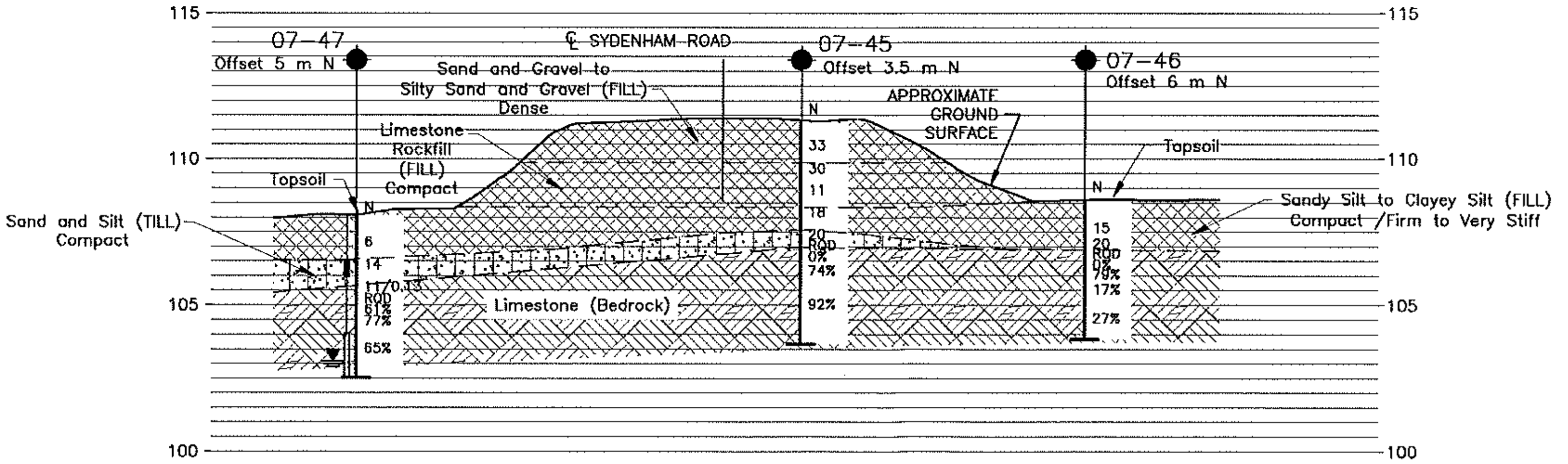
SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

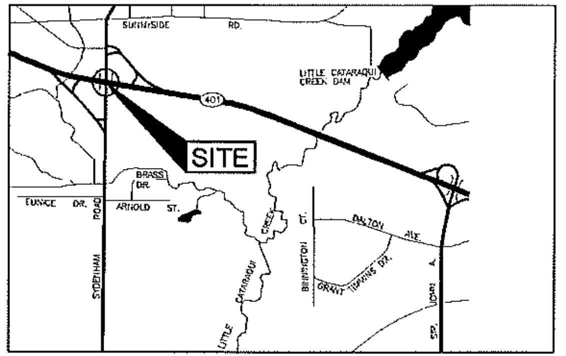
SCALE 5 0 5 10 m



I-I'

SECTION AT SYDENHAM ROAD STN 9+971
(SYDENHAM ROAD, NORTH OF HWY 401)

SCALE 2.5 0 2.5 5 m



KEY PLAN

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on May 30, 2007

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-45	111.2	4904164.9	301264.8
07-46	108.6	4904169.1	301245.1
07-47	108.1	4904164.8	301295.1

NOTES

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No. 31C-181

HWY. 401		PROJECT NO. 05-1111-031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22-Jul-2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 7

PLOT DATE: July 22, 2008

MINISTRY OF TRANSPORTATION, ONTARIO

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

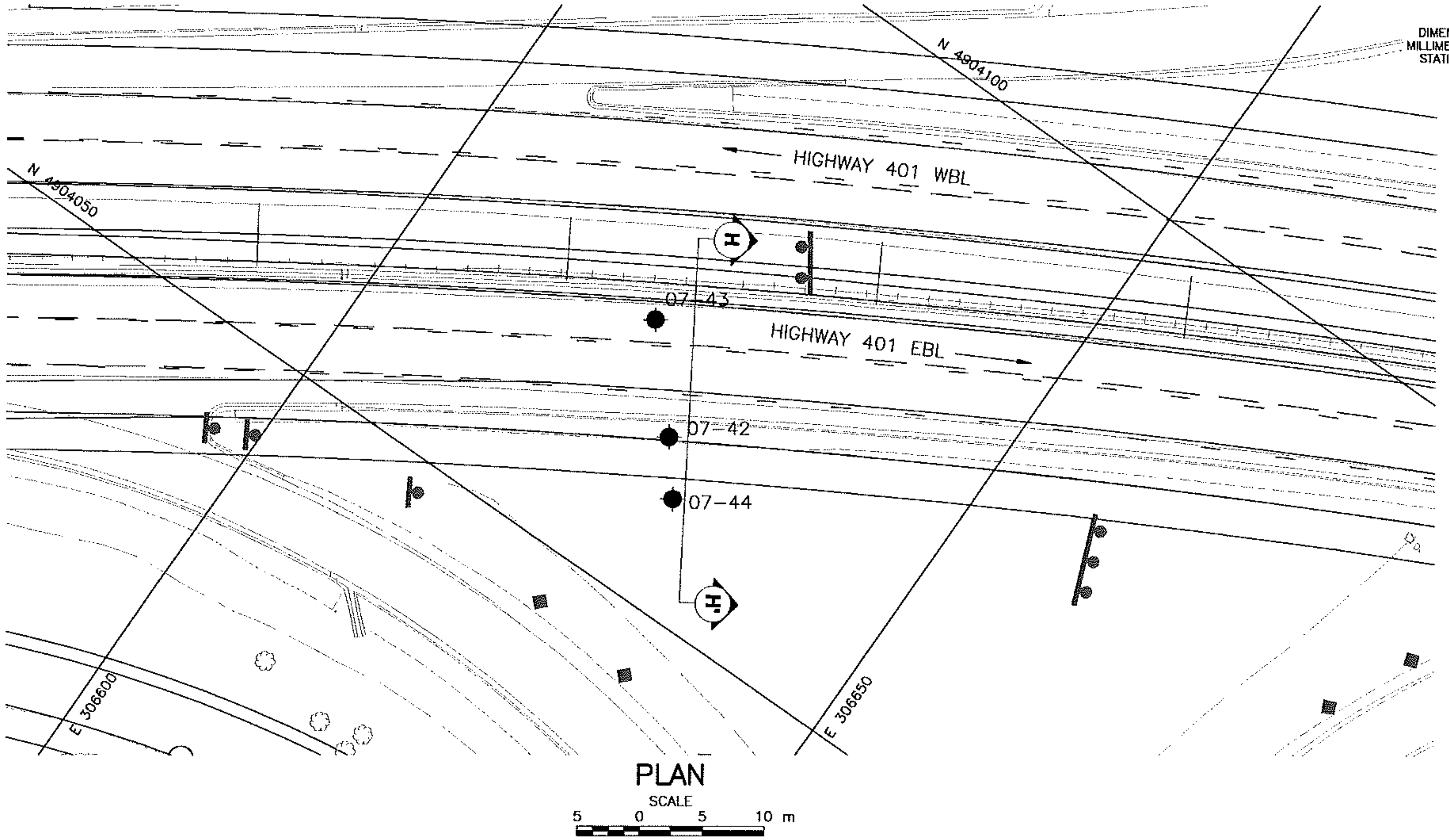
CONT No.
WP No. 77-99-01

SHEET

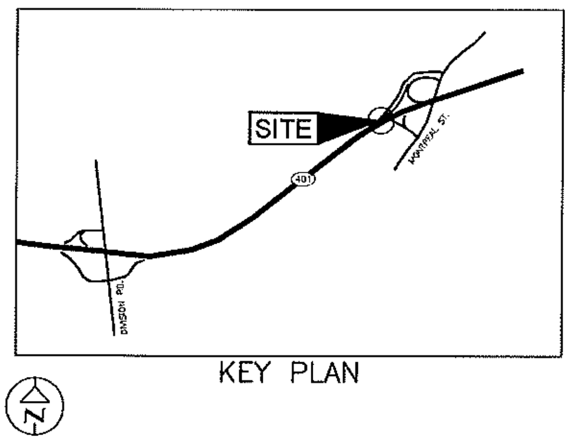
HIGHWAY 401 STN 26+010
BOREHOLE LOCATIONS AND
SOIL STRATA

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

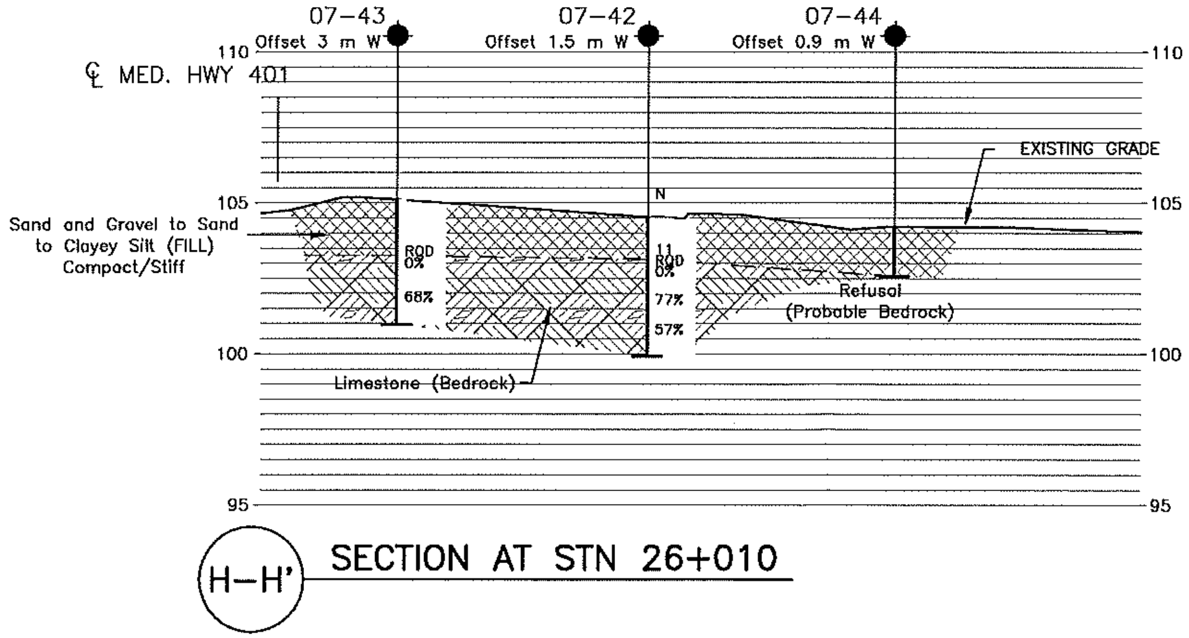


KEY PLAN

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-42	104.7	4904062.7	306627.0
07-43	105.1	4904069.8	306620.7
07-44	104.0	4904058.8	306630.1



H–H' SECTION AT STN 26+010

SCALE
2.5 0 2.5 5 m

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REFERENCE

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NO.	DATE	BY	REVISION

Geocres No. 31C-181

HWY. 401		PROJECT NO. 05-1111-031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22-Jul-2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 6

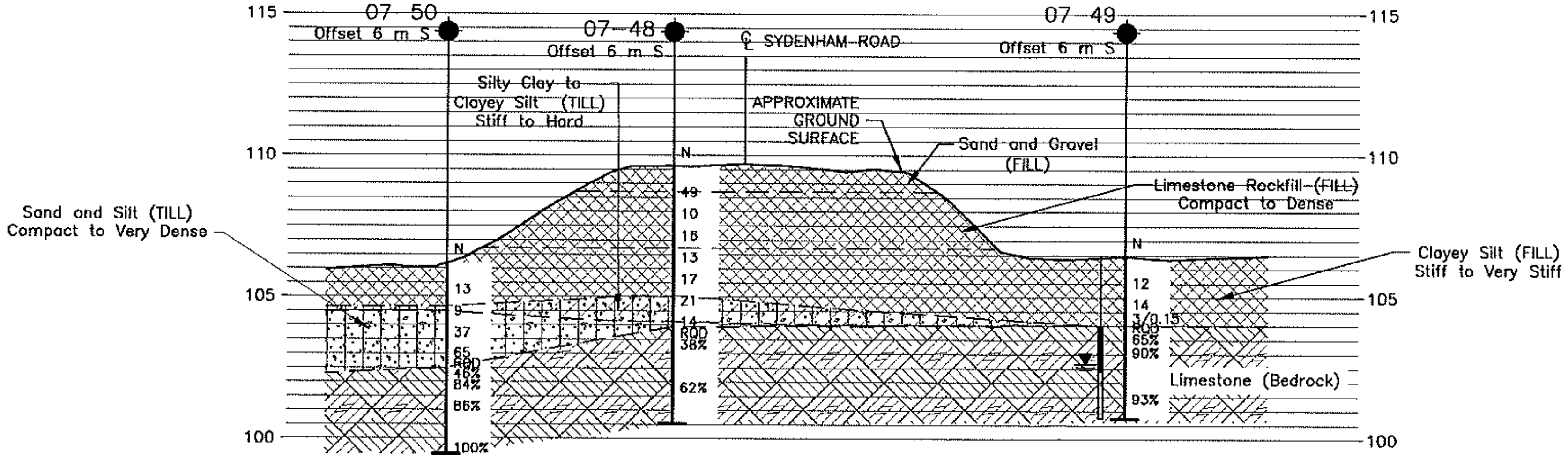
PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MRC, Kingston, Ontario)\-ED- Outlet Sewer\05111031ED006.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

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

PLAN

SCALE
5 0 5 10 m



SECTION AT SYDENHAM ROAD STN 10+029
(6 m SOUTH OF PROPOSED CROSSING)
(SYDENHAM ROAD, SOUTH OF HWY 401)

J–J'

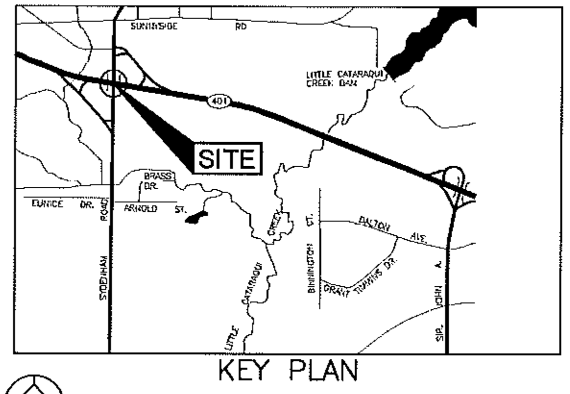
SCALE
2.5 0 2.5 5 m

CONT No.
WP No. 77–99–01

HIGHWAY 401
SYDENHAM ROAD CROSSING STN 10+029
BORDEHOLE LOCATIONS AND
SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

LEGEND

●	Borehole – Current Investigation
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on May 30, 2007

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
07–48	109.6	4904096.3	301275.5
07–49	106.5	4904096.2	301243.3
07–50	106.2	4904096.4	301291.3

NOTES

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NO.	DATE	BY	REVISION

Geocres No. 31C–181

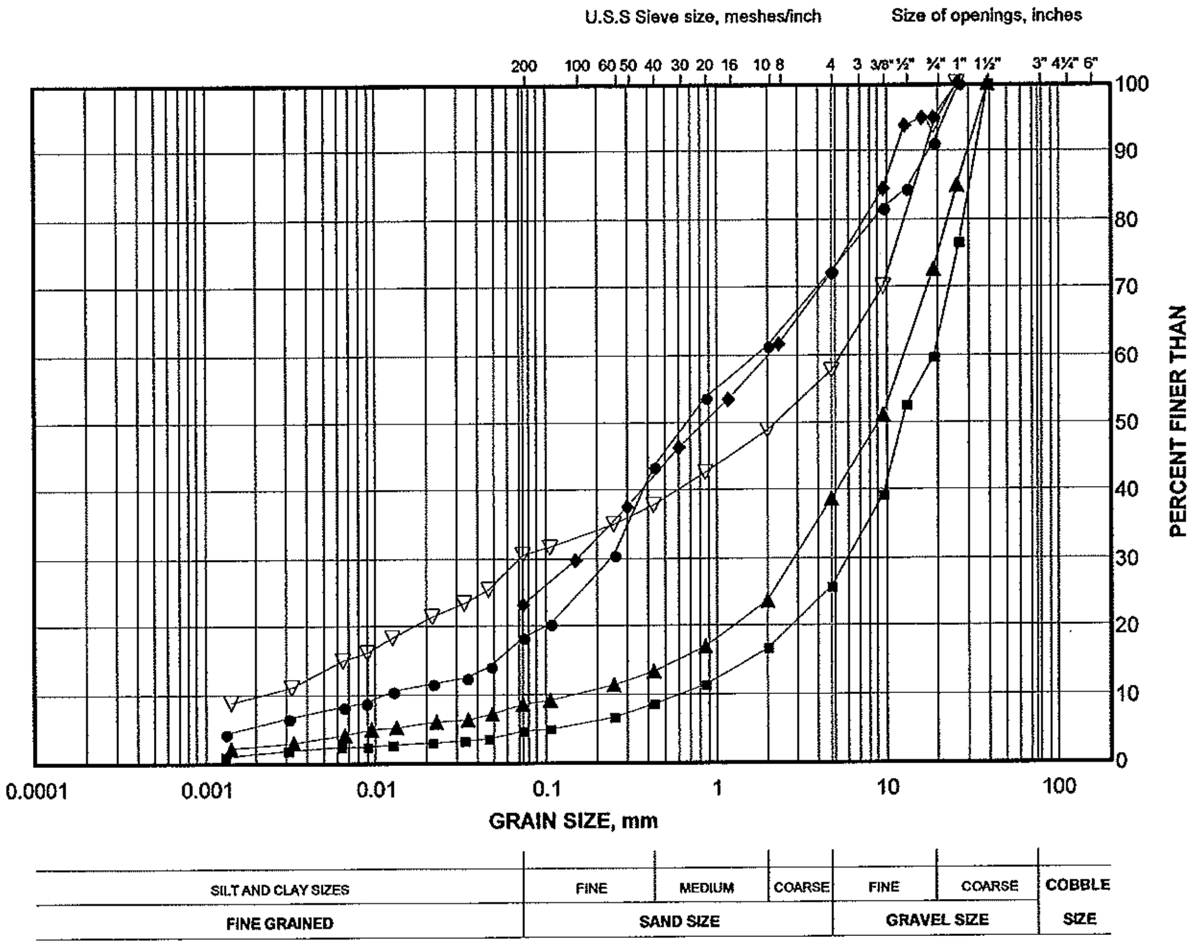
HWY. 401		PROJECT NO. 05–1111–031	DIST.
SUBM'D. DW	CHKD. DW	DATE: 22–Jul–2008	SITE:
DRAWN: MSM/DD	CHKD.	APPD.	DWG. 8

PLOT DATE: July 22, 2008
FILENAME: T:\Projects\2005\05-1111-031 (MPC, Kingston, Ontario)\-ED- Outlet Sewer\0511111031ED008.dwg

GRAIN SIZE DISTRIBUTION

Limestone Rockfill

FIGURE 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	08-1	1	85.2
■	08-2	2	84.5
◆	07-37	2	88.4
▲	07-32	2	85.3
▽	07-29	2	89.2

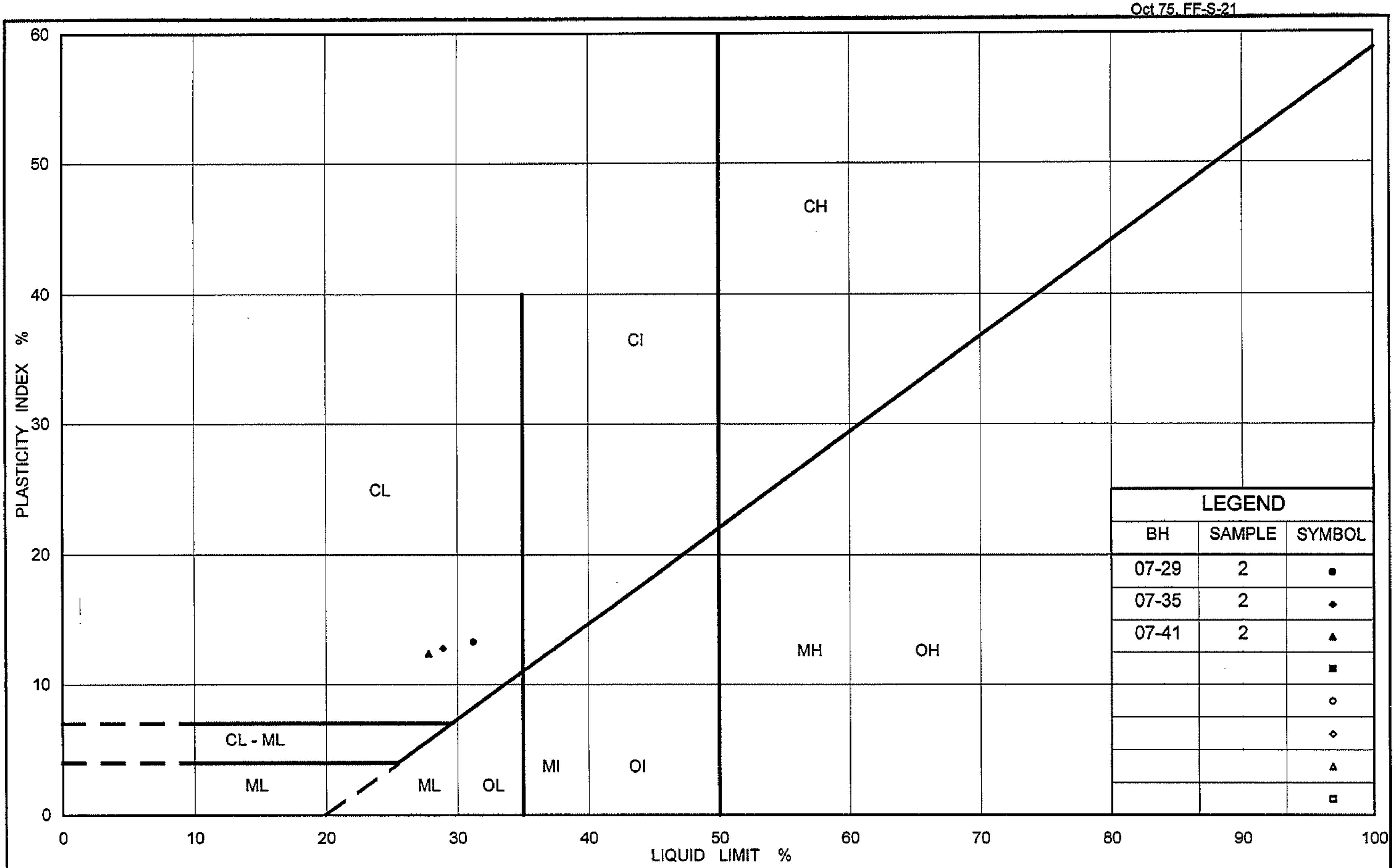
Project Number: 05-1111031

Checked By: ____________

Golder Associates

Date: 17-Jul-08

Oct 75. FF-S-21



Ministry of Transportation

Ontario

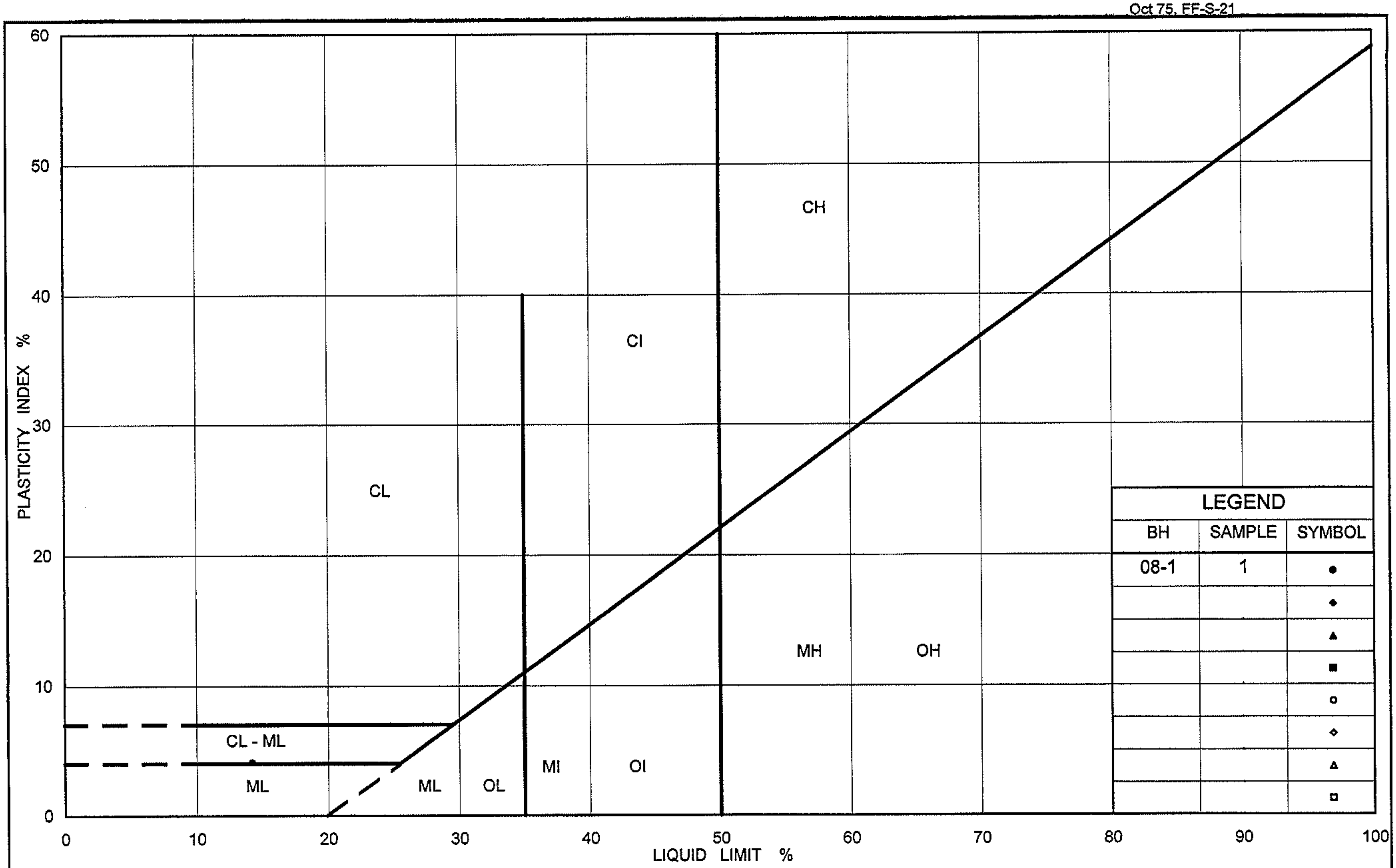
PLASTICITY CHART
Clayey Silt Fill

Figure No. 2

Project No. 05-1111-031

Checked By:

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silt

Figure No. 3

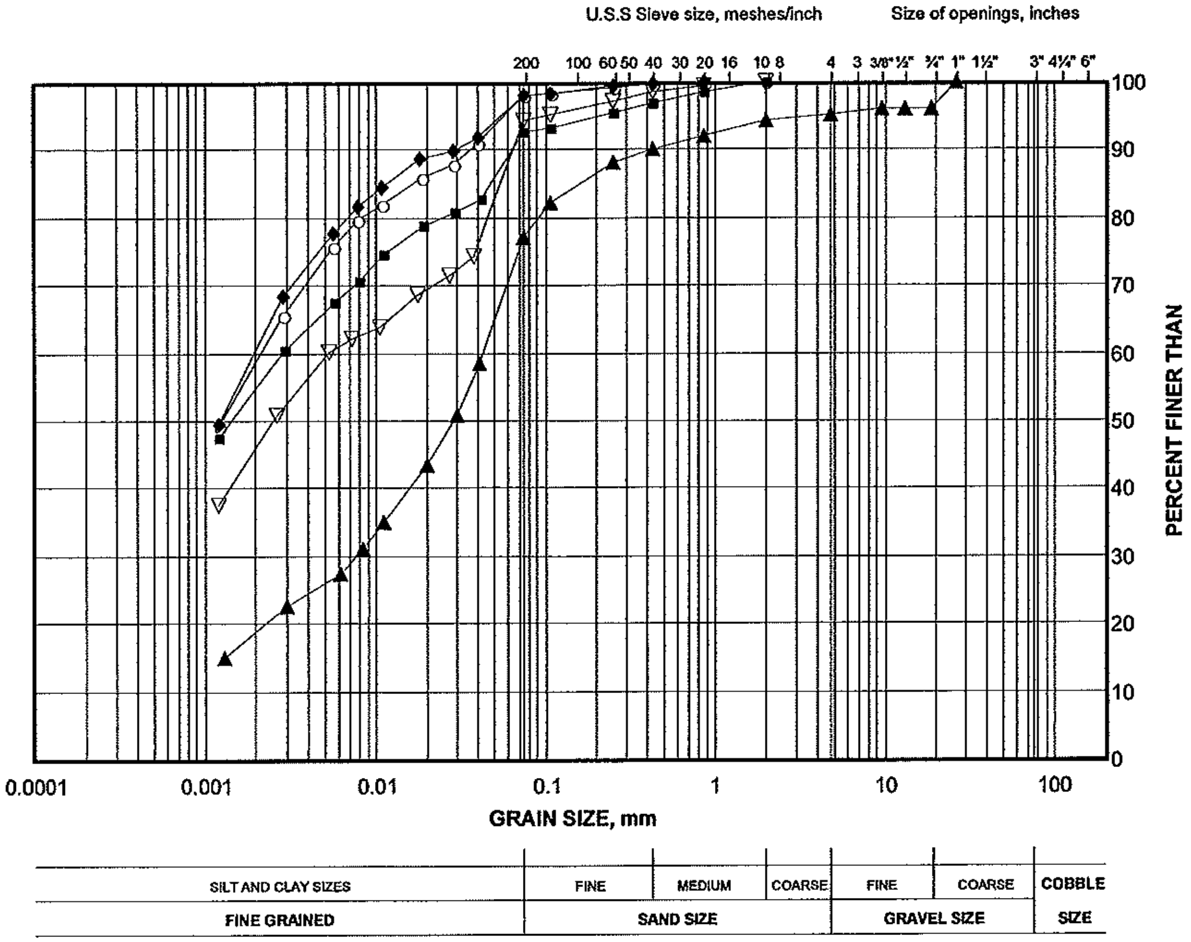
Project No. 05-1111-031

Checked By:

GRAIN SIZE DISTRIBUTION

Silty Clay to Clay

FIGURE 4



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-36	3	83.1
■	07-37	4	86.9
◆	07-35	4	82.4
▲	08-1	5	82.2
▽	08-2	6	81.4

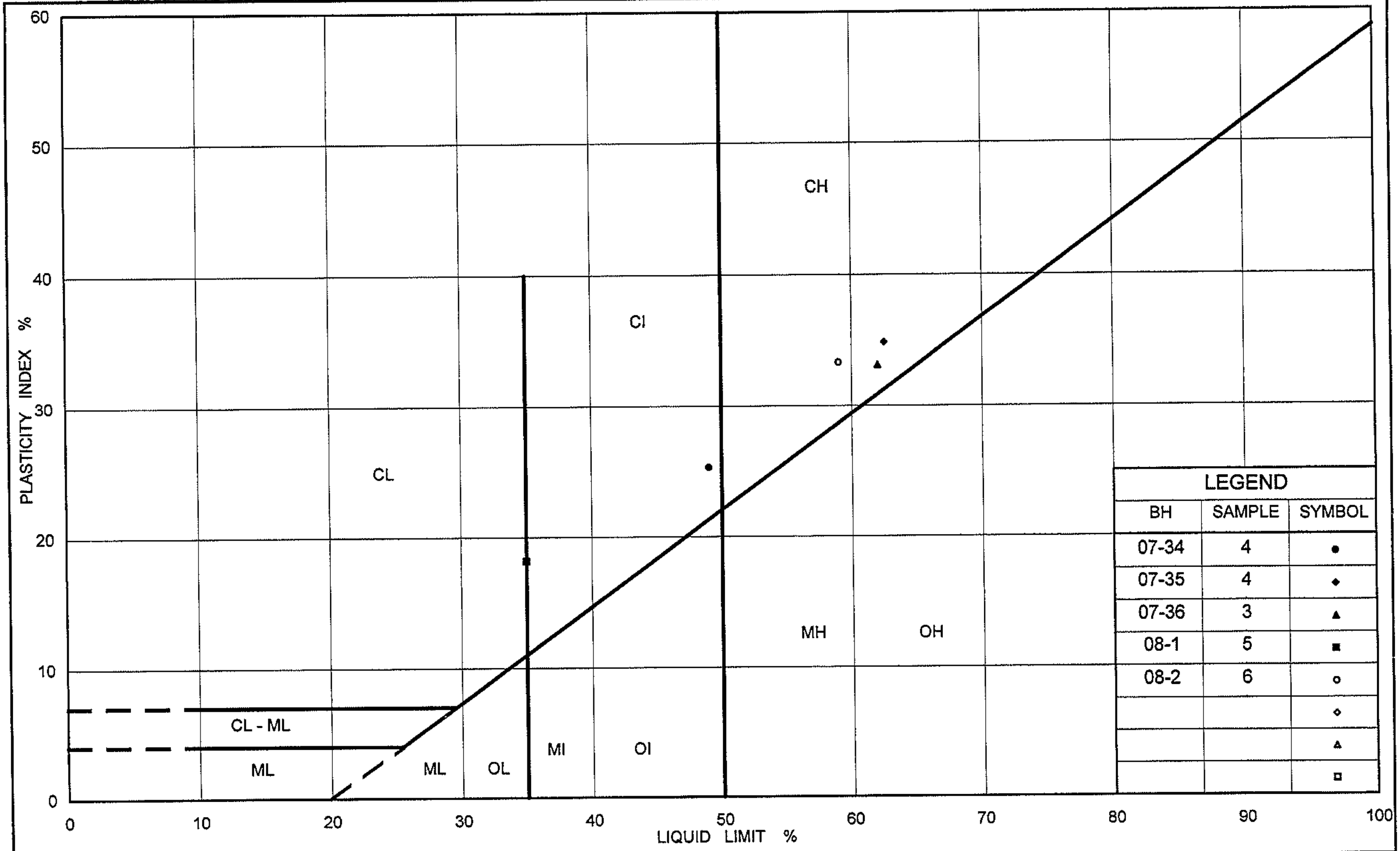
Project Number: 05-1111-031

Checked By: ______________

Golder Associates

Date: 16-Jul-08

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay to Clay

Figure No. 5

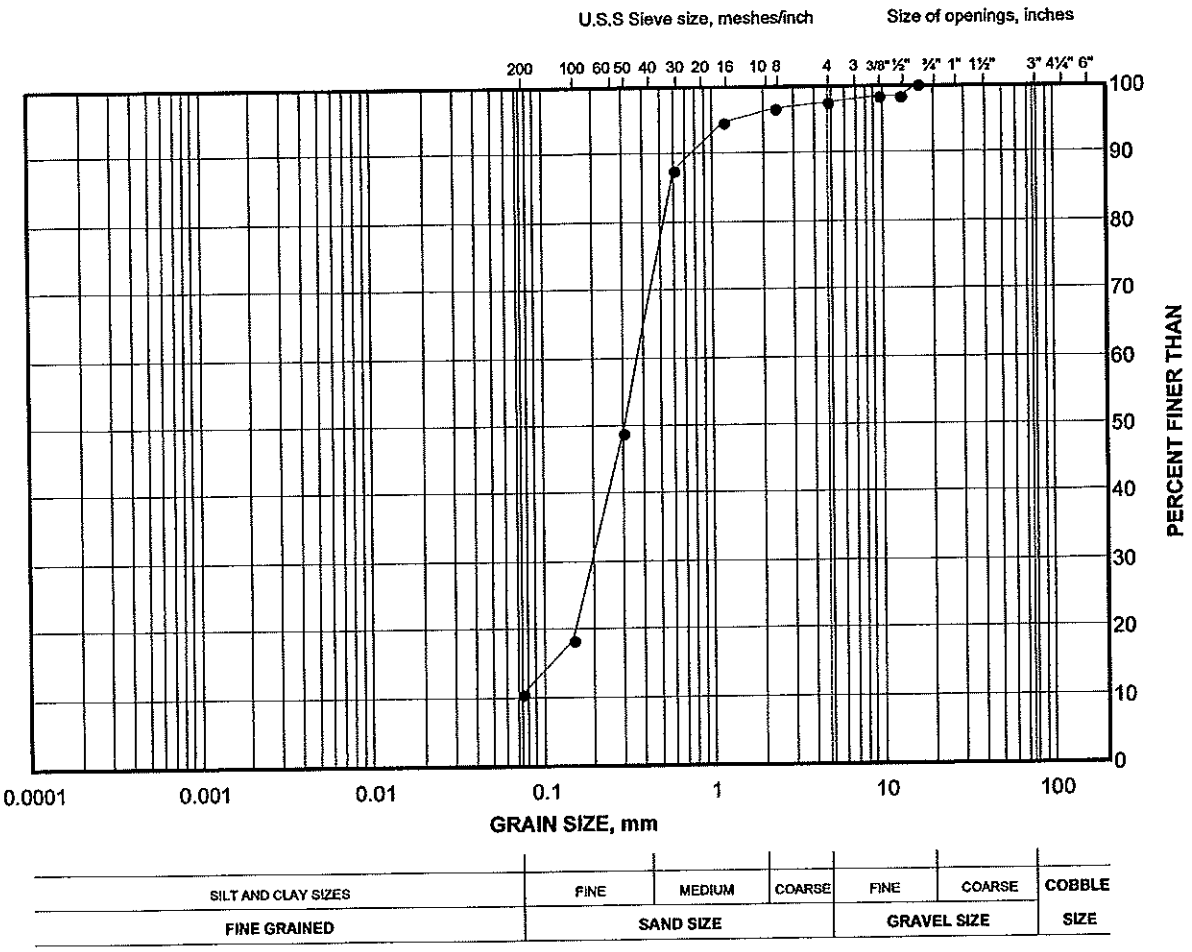
Project No. 05-1111-031

Checked By:

GRAIN SIZE DISTRIBUTION

Sand Fill

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-36	1	84.6

Project Number: 05-1111-031

Checked By:

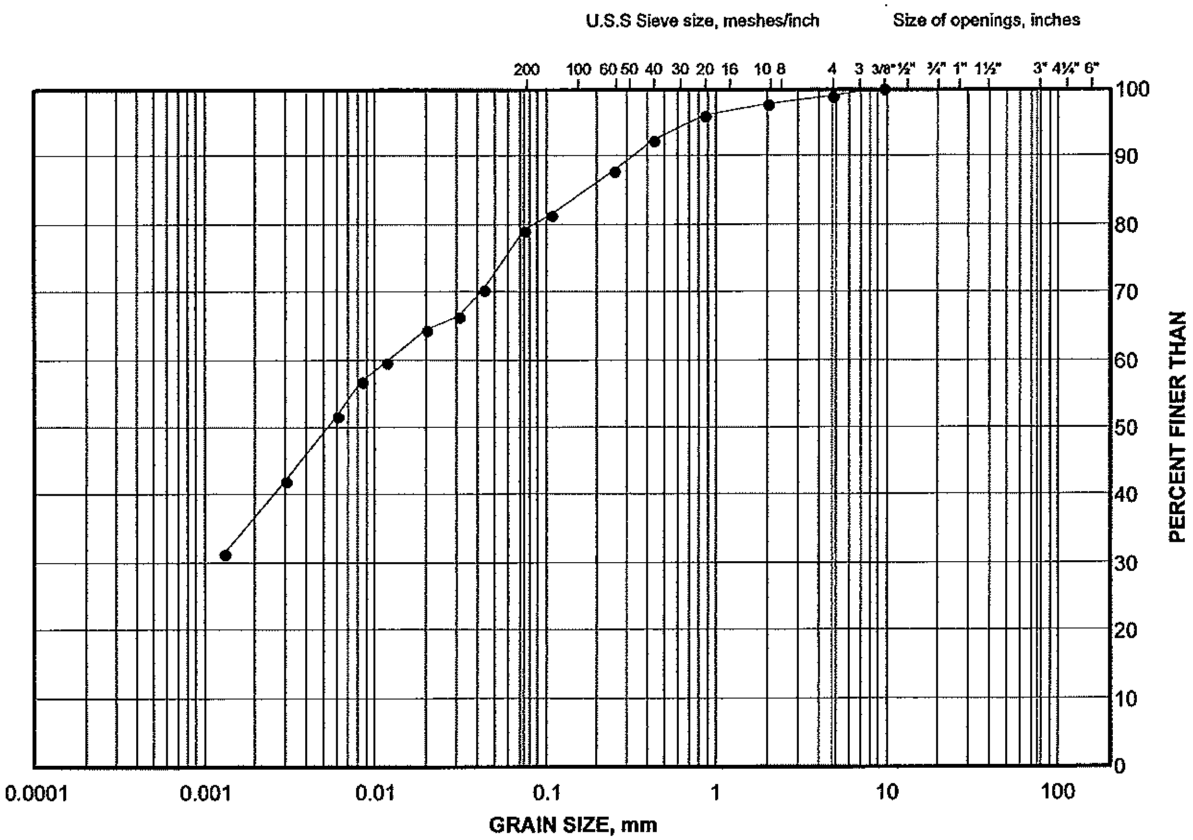
Golder Associates

Date: 16-Jul-08

GRAIN SIZE DISTRIBUTION

Clayey Silt Fill

FIGURE 7



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-35	2	83.9

Project Number: 05-1111-031

Checked By: DW

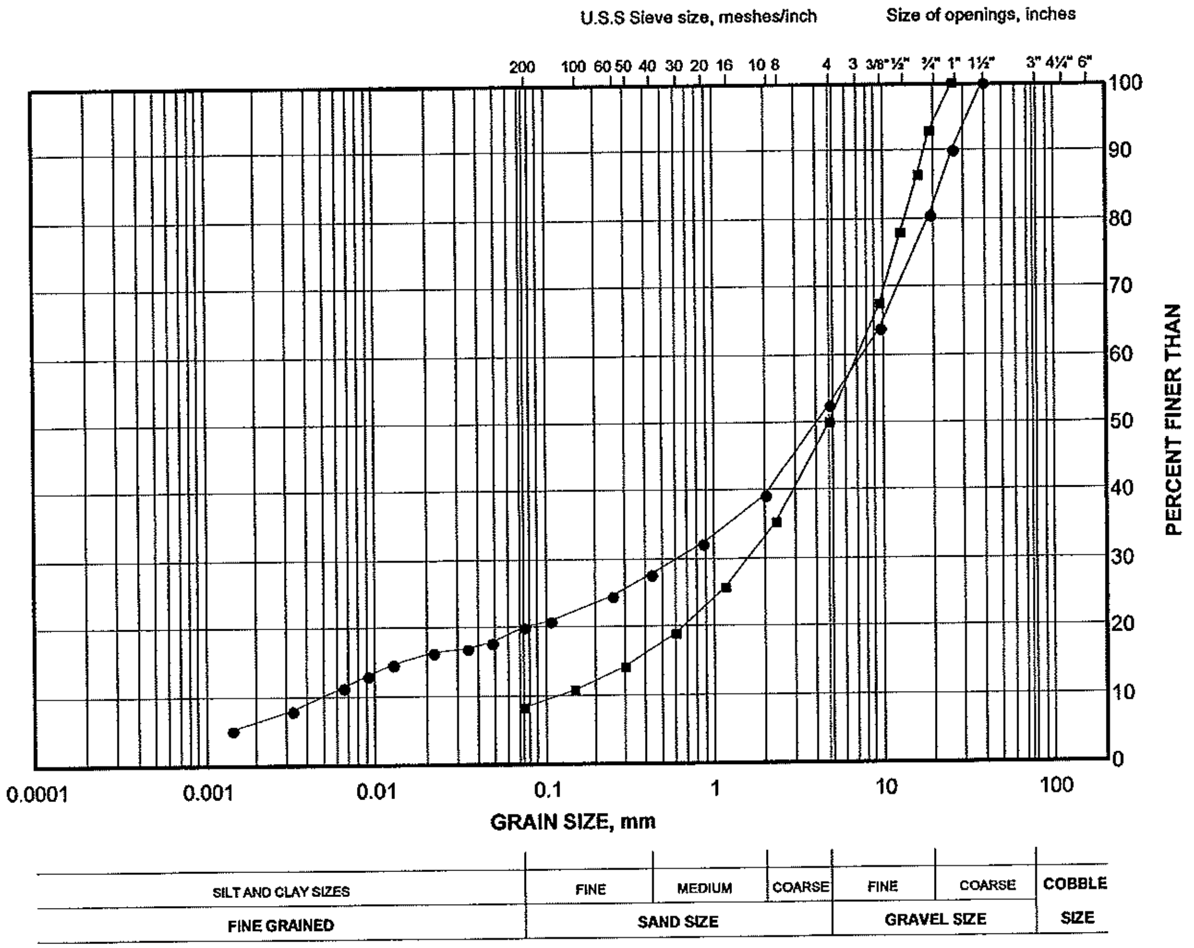
Golder Associates

Date: 16-Jul-08

GRAIN SIZE DISTRIBUTION

Silty Sand and Gravel Fill

FIGURE 8



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-41	2	107.0
■	07-39	2	106.5

Project Number: 05-1111-031

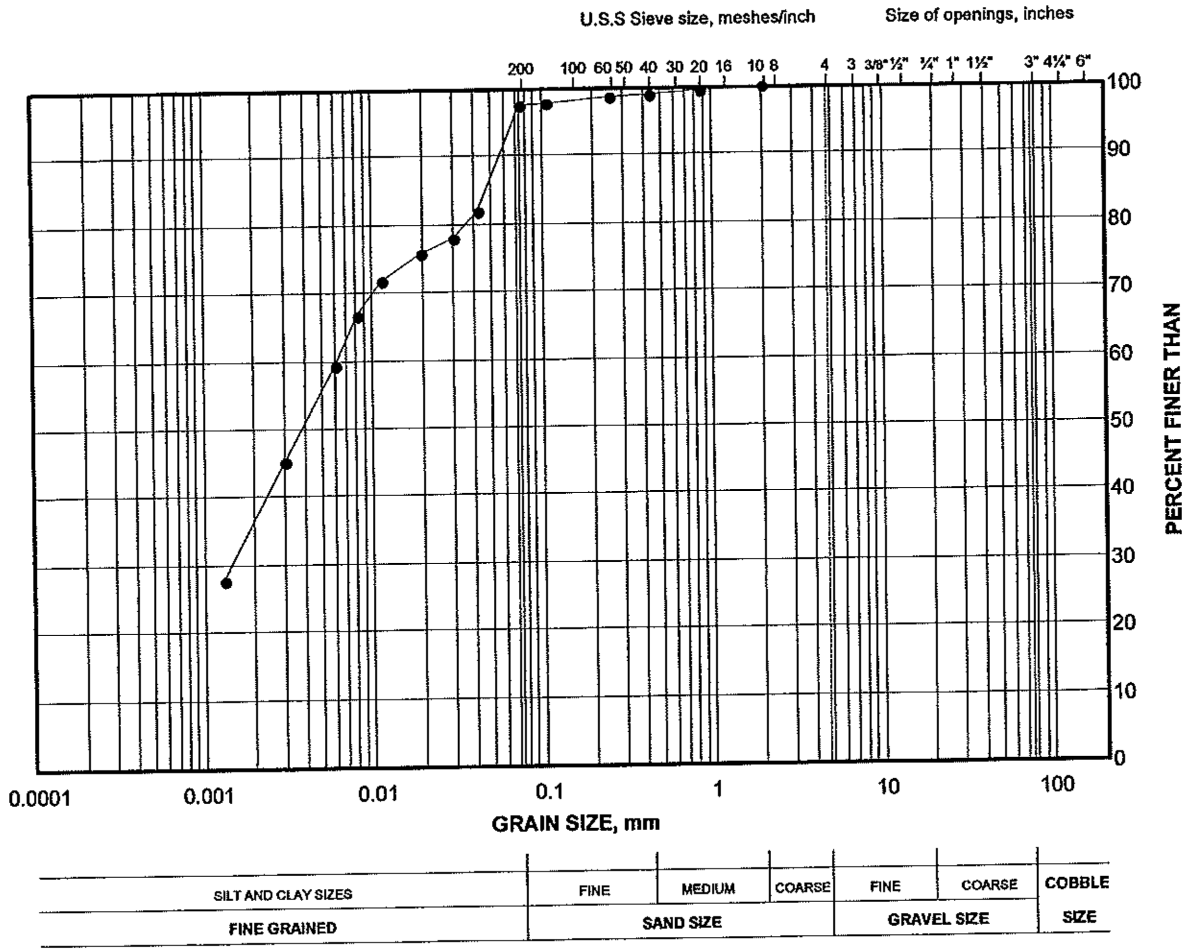
Checked By:

Golder Associates

Date: 16-Jul-08

GRAIN SIZE DISTRIBUTION
Silty Clay Till

FIGURE 9



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-48	6	104.7

Project Number: 05-1111-031

Checked By: __________

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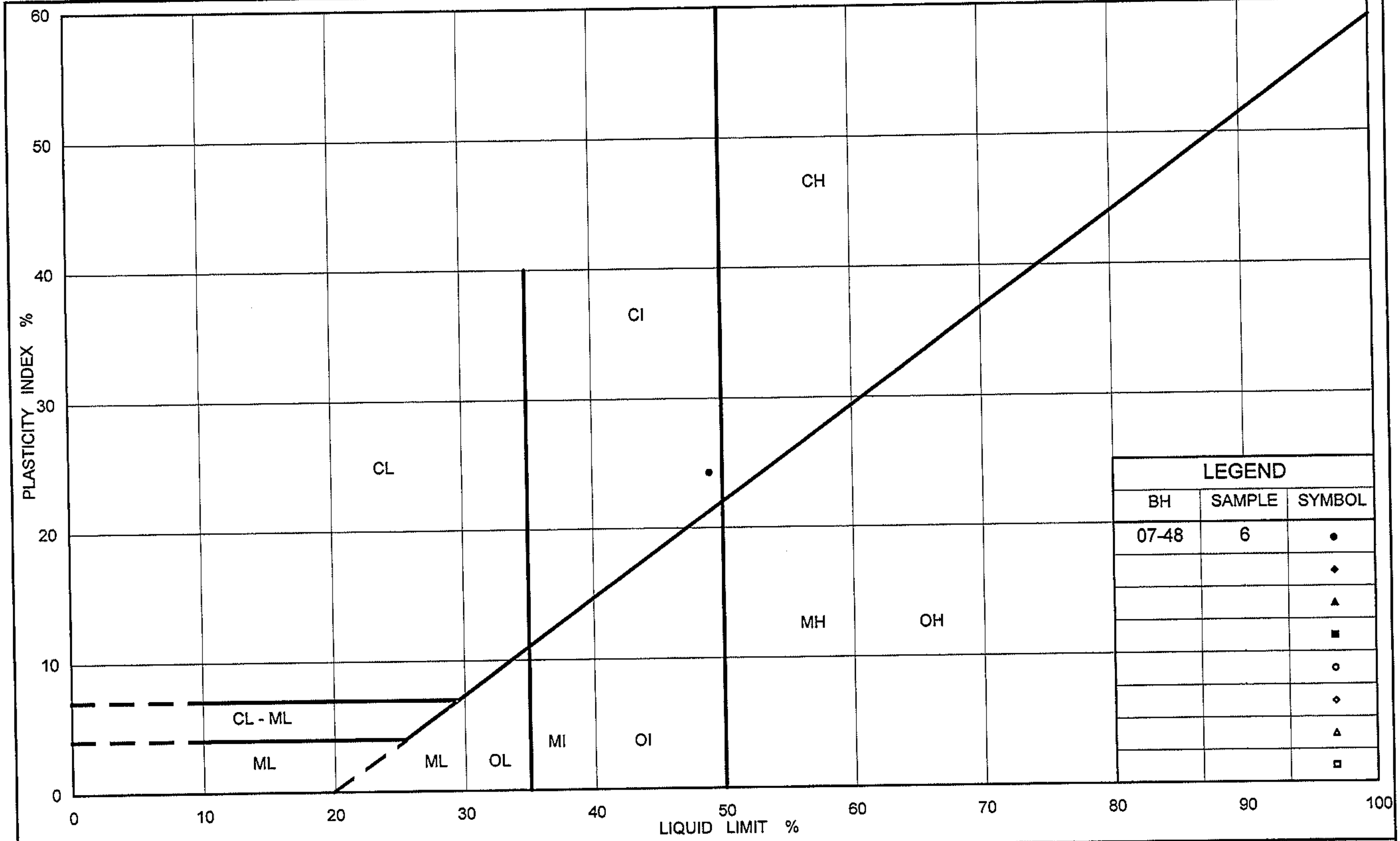
Date: 16-Jul-08

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART

Silty Clay Till

Figure No. 10

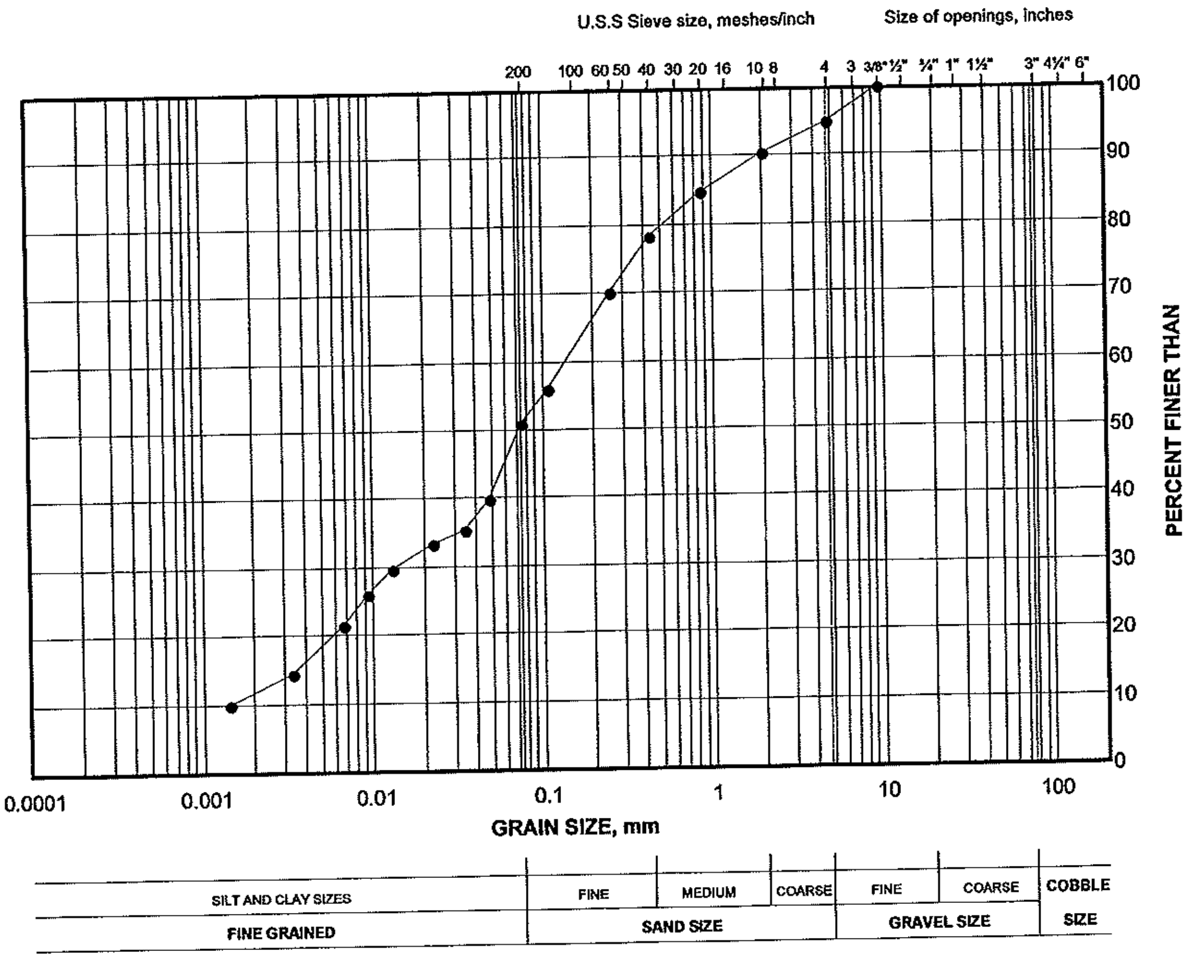
Project No. 05-1111-031

Checked By:

GRAIN SIZE DISTRIBUTION

Sand and Silt Till

FIGURE 11



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-50	4	102.8

Project Number: 05-1111-031

Checked By:

Golder Associates

Date: 16-Jul-08

APPENDIX A
Special Provision
Draft Specification for Sewer Installation Via Trenchless Technology

DRAFT SPECIFICATION FOR SEWER INSTALLATION VIA TRENCHLESS TECHNOLOGY

Special Provision

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) are deleted and replaced with the following:

1. Scope

This specification covers the general requirements for the installation of sewers by trenchless methods.

The Contractor shall determine the most appropriate method of installation. Specifications for Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Foundations Investigation Report GEOCRES NO. 31C-181.

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 504	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 507	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut
OPSS 514	Trenching, Backfilling, and Compaction
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 538	Support Systems
OPSS 539	Protection Schemes

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe

MTO Specifications

Form 1820	Concrete Pipe
Form 1840	Polyethylene Pipe
SP 105S19	Construction Specification for Protection Systems

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or “Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.
Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipelines, conduits, cable, or ducts.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

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

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, rockfill or fill, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Tunnelling: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined above such as Auger Jack & Boring, Pipe Ramming, Directional Drilling or using hand mining methods

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the presence of fill materials which vary in composition from clayey silt with gravel, to sandy silt, to sand and gravel, limestone rockfill consisting of sand, gravel and cobble sized particles, and hard layers of rock (limestone with shale seams) as identified in the geotechnical information. The subsurface conditions at/along the various sewer crossing alignments are presented in "Foundation Investigation Report, Outlet Sewer Crossings, Highway 401 Widening From West of Sydenham Road to West of Montreal Street, Kingston, Ontario, G.W.P. 77-99-01, by Golder Associates Ltd. Reference No. 05-1111-031-5 Rev. 2, GEOCRES No. 31C-181).

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one (1) week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable; and
- Design assumption and material data when materials other than those specified are proposed for use.
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages;

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe jacking procedures, including methodology to handle obstructions and preventing soil cave-in.; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method

- The methods to be employed to monitor and maintain the alignment of the installation;

4.02 Site Survey

Prior to commencing the work, the Contractor shall, at each sewer pipe location, layout the alignment and install settlement monitoring points.

4.03 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each sewer installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavation
Jacking/Ramming/Directional Drilling of Casing/Liner
Excavation and Dewatering
Installation of Sewer
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the sewer pipe at each location, the Contractor shall submit to the Contract Administrator a **final** Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the sewer pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Sewer Pipe

The sewer pipes shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Parging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per MTO Form 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 Mpa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per MTO Form 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per MTO Form 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per MTO Form 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of explosives or rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of sewer pipe installation to be used by the Contractor shall be submitted to the Contract Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The sewer pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the sewer pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or "dog-leg" shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor's sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Schemes

The construction of all protection schemes shall be according to OPSS 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 504.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet sewer pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the sewer pipe path shall be according to OPSS 514.

7.01.09 Support Systems

Support systems shall be according to OPSS 538.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in SP105S19.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular zones and rockfill materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that limestone rockfill in cobble and boulder sizes should be anticipated at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the sewer pipe and passing of water from the median end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 507.

7.01.16 Supervision

A qualified individual, who is experienced in the construction of sewer pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the presence and varying density of rockfill and the presence of mixed face conditions including inclination of hard layers of rock (limestone, limey shale, etc.).

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the presence of rockfill, mixed face conditions and hard layers of rock (limestone, limey shale, etc.) within the pipe alignment and shall be suitable to advance through such obstructions and address the potential for deflection off these obstruction and/or layers.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. Tunnelling in the bedrock will encounter hard layers of rock (limestone, limey shale, etc) at a relatively flat angle with the tunnel alignment. The selection of the tunnelling method in the fill, rockfill, mixed face conditions or in the bedrock should consider the presence and inclination of obstructions and hard rock layers with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

Tunnels excavated in rock shall be supported in a manner that prevents scaling and ravelling of the rock and also protects the rock from weathering or deterioration.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand as shown on the Contract Drawings.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Two times per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsection 4.02, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.

  If the Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

No construction shall take place until all the following conditions are satisfied:

- The cause of the settlement has been identified.
- The Contractor submits a corrective/preventive plan.
- Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the sewer pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of sewer installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for providing all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of primary liners, supply and installation of the sewers, site restoration and for all other work necessary to complete the sewer as specified.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections into the sewer system shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for installation of sewers.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

APPENDIX B
Non-Standard Special Provision
Controlled Blasting and Vibration Monitoring at Foundation Locations and Permanent Rock Cuts – Item No.

CONTROLLED BLASTING and VIBRATION MONITORING at Foundation Locations and Permanent Rock Cuts – Item No.

Non-Standard Special Provision

Scope of Work

Work under this item is for the complete removal of rock using controlled blasting techniques by appropriate controlled drilling and blasting at locations indicated in the contract and disposal of rock material. This includes all rock removal required at the proposed entry and/or exit pits for jack and bore, pipe ramming or rock tunnel boring operations for installation of sewers under Highway 401 or Sydenham Road, Kingston, Ontario.

Construction

The use of explosives shall follow the general specifications outlined in the latest version of OPSS 120.

Drilling equipment shall consist of the following:

> A hydraulic track drill or equivalent capable of drilling the required controlled blasting holes accurately and uniformly across the top of the rock cut excavation, or other suitable equipment, given the site conditions.

Removal shall be carried out in such a manner to minimize disturbance to any surrounding rock (or adjacent soil) beyond the excavation limits.

All material resulting from the operation shall be managed in accordance with OPSS 180 specified elsewhere in the contract.

All costs associated with the management of materials are deemed to be included in the contract unit price.

Monitoring and Reporting

Ground and air vibration monitoring is required during the blasting operations. Ground vibration levels should be limited to the maximum peak particle velocity values provided in Table 1 in OPSS 120 for adjacent services, bridges and buildings (i.e. 50 mm/s for frequencies greater than 40 Hz).

The Contractor shall submit the following information to the Contract Administrator at least 3 weeks in advance of rock excavation.

- Blast Contractor: contractor must be fully qualified, experienced and capable of working at depths with approved Ministry of Labour safety devices. A statement of experience is required;

- An outline of the requirements, procedure, and extent of the pre-blast survey required;

- Proposal prepared by blast contractor or blast consultant detailing the blast methodology, including drill hole patterns, hole size and depths, size of blasts, explosive and initiation product details, as well as all blast control procedures. Blast control procedures would include details on controlling flyrock, temporary road closures, blast signalling and site clearing procedures, as well as procedures to deal with debris clean-up; and

- Details on instrumentation, number and location of monitoring sites, blast recording and reporting procedures, and procedures to be followed in the event of excessive vibration readings.

Instrumentation or monitoring ground and air vibration effects from the blasting should be set up in accordance with the International Society of Explosives Engineers field practice guidelines (1999).

A minimum of 80 percent half barrels (drill hole traces) should be visible on the cut face after scaling is completed.

Measurement of Payment

The measurement for payment shall be by Plan Quantity, as may be revised by Adjusted Plan Quantity of the volume or rock in m^3 measured in-place.

Basis of Payment

Payment at the contract price for the above noted tender item includes full compensation for all labour, equipment and materials to do the required work.

APPENDIX B
Non-Standard Special Provision
Controlled Blasting and Vibration Monitoring at Foundation Locations and Permanent Rock Cuts – Item No.

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Measurement of Payment

The measurement for payment shall be by Plan Quantity, as may be revised by Adjusted Plan Quantity of the volume or rock in m^3 measured in-place.

Basis of Payment

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APPENDIX C
Guidelines for Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application

Guidelines For Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application

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These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

Table 1: Complexity ratings for tunnelling specialty services

Highway Classification	Tunnel Excavation Diameter (ϕ)					
	≤ 1 m		>1 m & ≤ 2 m		>2 m	
	Minimum Overburden Cover * (m)					
	$\geq 3\phi$ (or 1.5 m whichever is greater)	$< 3\phi$ (or 1.5 m whichever is greater)	$\geq 3\phi$	$< 3\phi$ (or 1.5 m whichever is greater)	$\geq 3\phi$	$< 3\phi$ (or 1.5 m whichever is greater)
Kings Highway	**Low**	**Medium**	**Medium**	**High**	**High**	**High**
400 Series Freeway	**Medium**	**High**	**High**	**High**	**High**	**High**

*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

Minimum requirements for Subsurface Investigation and Recommendations

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

Minimum Laboratory Testing Requirements:

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

Borehole Log Preparation and Foundation Drawing:

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

Minimum Requirements for the Foundation Investigation and Design Report:

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD)and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative rosts; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments. .

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

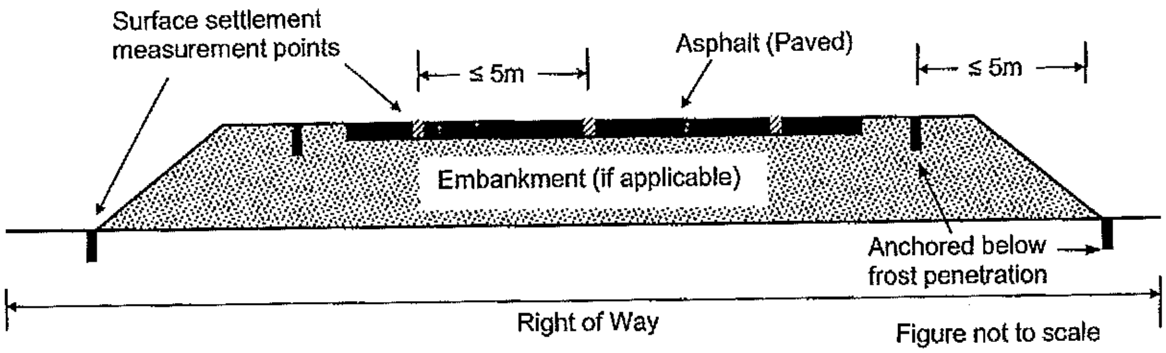

Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.