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FOUNDATION
INVESTIGATION AND DESIGN REPORT
JACK AND BORE SEWER CROSSINGS
HIGHWAY 401 WIDENING
FROM 2.7 KM WEST OF HIGHWAY 38
EASTERLY TO HIGHWAY 15
W.P. 76-99-01

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PART A - FOUNDATION INVESTIGATION REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the installation of a series of sewers/culverts associated with the widening of Highway 401 from 2.7 km west of County Road 38 to Highway 15, in the vicinity of Kingston, Ontario.

This report addresses the subsurface investigations carried out for the proposed sewers/culvert crossings to be constructed at the following locations as part of this project:

- A 31 m long, 450 mm diameter sewer to be installed between the median and the south side of Highway 401 at Station 17+380; hereafter referred to as Crossing Location 1
- A 30 m long, 450 mm diameter sewer to be installed between the median and the south side of Highway 401 at Station 17+440; hereafter referred to as Crossing Location 2
- A 25 m long, 450 mm diameter sewer to be installed between the south side of Highway 401 and the median and a 29 m long, 600 mm diameter sewer to be installed between the median and north side of Highway 401 at approximately Station 18+020 to 18+040; hereafter referred to as Crossing Location 3&4
- A 47 m long, 825 mm diameter sewer to be installed beneath the N/S-E Ramp of the Highway 401 and County Road 38 Interchange (at approximately Highway 401 Station 18+190); hereafter referred to as Crossing Location 5
- A 34 m long, 450 mm diameter sewer to be installed between the median and the south side of Highway 401 at Station 18+850; hereafter referred to as Crossing Location 6
- A 53 m long, 1200 mm diameter sewer to be installed between the north and the south sides of Highway 401 at Station 19+015; hereafter referred to as Crossing Location 7
- A 30 m long, 375 mm diameter sewer to be installed between the median and the south side of Highway 401 at Station 19+510; hereafter referred to as Crossing Location 8
- A 17 m long, 600 mm diameter culvert to be installed beneath the E-N/S Ramp Highway 401 and County Road 38 Interchange (at approximately Highway 401 Station 17+870); hereafter referred to as Crossing Location 9

The terms of reference for this work are outlined in the MTO's Request for Proposal (RFP) and in Golder Associates' Proposal No. P31-1139, dated March 2003 and revised Proposal No. P31-1139 dated April 2, 2003.

2.0 SITE DESCRIPTION

The sewers/culverts are to be installed along the Highway 401 corridor between Collins Creek and Sydenham Road and beneath on and off-ramps off the Highway 401 and County Road 38 interchange.

The existing Highway 401 is a four-lane divided highway that trends northwest-southeast at the County Road 38 underpass site. The regional slope in the vicinity of the site is downward to the south, toward Lake Ontario.

The Highway 401 grade is at about Elevation 111 m to 112 m below the County Road 38 underpass structure, with the highway grade rising in the eastbound direction and sloping downward towards Collins Creek to the west.

Highway 401 has been constructed in cut through the bedrock in the immediate vicinity of the County Road 38 underpass structure. There are sporadic bedrock outcrops in the northeast and southeast quadrants of this interchange. The bedrock cut faces are between 2 m and 4 m high along the south side of Highway 401, and up to about 2.5 m high in the northwest quadrant of the Highway 401 – County Road 38 interchange. The exposed rock face at County Road 38 extends to approximately 400 m west of the interchange as the terrain slopes downward to Collins creek. The Highway 401 profile to the east of County Road 38 is relatively flat but rises slowly to the east. Bedrock outcrops also occur at the Sydenham Road interchange.

3.0 INVESTIGATION PROCEDURES

A field investigation was carried out at the site between the dates of November 17 and 21, 2003, at which time 18 boreholes were advanced at the locations of the proposed pipe crossing locations.

The boreholes locations were staked in the field by MTO personnel who provided Golder with the ground surface elevations and Stations and Offsets of the staked locations. At some locations, the staked locations could not be accessed by the drilling equipment or could not be drilled without closing portions of the Highway 401 and County Road 38 interchange. These boreholes were drilled at the closest locations to the staked borehole locations that were both accessible to the drill rig and would not require closures of portions of the interchange. The following table summarizes the locations of the boreholes drilled as part of the investigation.

Borehole Designation	Pipe Crossing Location	Station / Offset*	Ground Surface Elevation (m)
CU1-1	Site 1	17+380 / 32.0 m	89.0
CU1-2	Site 1	17+380 / 3.0 m	92.8
CU2-1	Site 2	17+440 / 31.5 m	92.0
CU2-2	Site 2	17+440 / -2.0 m	94.4
CU3-1	Site 3/4	18+040 / 22.0 m	111.9
CU3-2	Site 3/4	18+035 / 2.0 m	111.6
CU3-3	Site 3/4	18+030 / -20.5 m	111.3
CU5-1	Site 5	18+194 / 70.1 m	115.8
CU5-2	Site 5	18+188 / 100.2	113.2
CU6-1	Site 6	18+850 / 16.1 m	114.9
CU6-2	Site 6	18+850 / 1.5 m	114.9
CU7-1	Site 7	19+015 / 16 m	114.5
CU7-2	Site 7	19+015 / 1.5 m	114.9
CU7-3	Site 7	19+015 / -16.0 m	113.4
CU8-1	Site 8	19+510 / 16 m	113.7
CU8-2	Site 8	19+510 / 1.5 m	113.8
CU9-1	Site 9	17+870 / -35.5 m	107.9
CU9-2	Site 9	17+863 / -25 m	106.4

*Note – Positive offsets are to the right of centreline, negative offsets are to the left of centreline when facing the direction of increasing station.

The borehole locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to geodetic datum, are shown on Drawings 1 to 6.

3.1 Borehole Investigation Program

The boreholes were drilled using a bombardier-mounted drill rig supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. Samples of the overburden were obtained at 0.75 m to 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven with an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure.

The boreholes were typically advanced until refusal to auger penetration testing and/or split spoon sampling was encountered. Bedrock was cored using 'NQ' coring equipment at the locations of Boreholes CU2-2, CU3-2, CU5-1 and CU8-2. The boreholes were advanced to depths ranging from 0.6 m to 9.1 m below the existing ground surface (including rock coring where applicable).

The groundwater conditions in the open boreholes were observed during the drilling operations and piezometers were installed in three selected boreholes to permit monitoring of the groundwater level at these locations. The piezometers consist of a 25 mm outside diameter rigid PVC tubing with a 0.3 m long slotted tip installed in the boreholes. The slotted tip is surrounded by a sand filter and the remainder of the borehole is sealed with bentonite. The remaining boreholes were backfilled with bentonite mixed with soil cuttings. The piezometer installation details and water level readings are described on the Record of Borehole sheets that follow the text of this report.

The field work was coordinated by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground service locations, monitored the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil and rock samples. The samples were identified in the field, placed in appropriate labelled containers and transported to our Mississauga geotechnical laboratory where the samples underwent further detailed visual examination and appropriate laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate. Classification testing (water content, Atterberg Limits and grain size distribution analyses) was carried out on selected soil samples. Point load testing was performed on samples of the rock core.

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The site is located in 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, 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. Well records indicate that the average depth to bedrock within the Napanee Plain is approximately 2 m. However, in many areas, bedrock outcrops at ground surface, while deeper soil deposits (on the order of 10 m) are present in the northern portion of the Plain, and within and adjacent to river valleys throughout the Plain.

4.2 Site Stratigraphy

Much of the Highway 401 and County Road 38 Interchange has been constructed in cut through a limestone bedrock outcrop and bedrock outcrops are present in other areas along the Highway 401 alignment within the study area.

Eighteen boreholes were advanced in the areas of the proposed pipe crossings at the locations displayed on Drawings 1 to 6. The detailed subsurface soil, bedrock, and groundwater conditions encountered in the boreholes are given on the Record of Borehole / Drillhole sheets. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil and bedrock types rather than exact planes of geological change. Subsurface conditions will vary beyond the borehole locations. The inferred subsurface stratigraphy at Crossing Locations 1, 2, 3&4, 6, 7, and 8 based on the results of the borehole investigation are displayed on Drawings 7 and 8.

The following sections provide a summary of the subsurface conditions at each of the proposed pipe crossing locations.

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[1] Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario.* Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.

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

4.3 Crossing Location 1 – Approximate Station 17+380 – Approximate Pipe Invert Elevation – 89.8 m to 89.0 m

Surficial fill materials were encountered at the locations of Boreholes CU1-1 and CU1-2 drilled at Crossing Location 1. The fill materials varied in composition from clayey silt to silty clay and contained varying amounts of sand, gravel and limestone fragments that suggest that cobbles and boulders are present in the fill to a mixture of silty clay and limestone rockfill. The fill materials contained trace topsoil and rootlets in some areas. Standard Penetration Test (SPT) 'N' resistance values measured within the fill materials varied from 7 to 27 blows per 0.3 m of penetration. Refusal to auger penetration on an inferred piece of limestone rockfill was encountered at a depth of approximately 1.95 m at the location of Borehole CU1-2. The measured SPT 'N' values suggest that the fill materials are firm to very stiff consistency. The fill materials were encountered to depths of approximately 1.3 m and 2.3 m below ground surface at the locations of Boreholes CU1-1 and CU1-2 respectively. Gradations of the fill materials that were recovered in the 38 mm I.D. sampler are displayed on Figure A1. Laboratory testing of two samples of the fill materials indicates that the natural water content of the tested samples were 14 and 15 percent.

At the location of Borehole CU1-2, the fill materials are underlain by deposits of black, slightly organic silty clay containing some sand and trace gravel, and sandy silt containing trace clay gravel and organics. These deposits were encountered at elevations of approximately 90.5 m and 89.8 m, respectively. Atterberg Limit testing carried out on a sample of the silty clay deposit indicated that the sample tested had a natural water content of 17, a Plastic Limit of 19 and a Liquid Limit of 51. A SPT 'N' value of 5 blows per 0.3 m of penetration was measured within the silty clay deposit suggesting this deposit is firm. A SPT 'N' value of 8 blows per 0.3 m of penetration was measured within the sandy silt indicating this deposit is loose. These soils were encountered to a depth of approximately 3.8 m below ground surface.

A brown to grey, clayey silt till deposit containing some sand, trace gravel as well as cobbles was encountered beneath the fill materials at Borehole CU1-1. SPT 'N' values recorded within the clayey silt till varied from 26 blows to 53 blows per 0.3 m of penetration suggesting the clayey silt till is very stiff to hard. The clayey silt till was encountered to a depth of approximately 3 m below ground surface corresponding to an elevation of approximately 87.7 m. The natural water content of a sample of the clayey silt till was measured to be approximately 16 percent.

Deposits of silty sand till were encountered beneath the above noted deposits at depths of approximately 3 m to 3.8 m below ground surface corresponding to an elevation of approximately 86 m to 89 m. The silty sand till contains trace to some gravel, trace clay and is grey to brown in colour. Occasional cobbles were encountered within the till at the location of Borehole CU1-2 and cobbles and/or boulders are anticipated to be present throughout the till deposits at the site. SPT 'N' values measured within the silty sand till varied between 19 and 61 blows per 0.3 m of penetration indicating the till is compact to very dense.

Borehole CU1-2 encountered refusal to auger penetration at a depth of approximately 7.1 m below ground surface while Borehole CU1-1 was stopped at a depth of 3.7 m.

The water level in Borehole CU1-2 was at Elevation 85.7 m at the completion of drilling operations. Borehole CU1-1 was dry to Elevation 88 .4 m.

4.4 Crossing Location 2 – Approximate Station 17+440 – Approximate Pipe Invert Elevation – 91.6 m to 91.2 m

A surficial deposit of grey to black, silty clay containing some sand and organics was encountered at ground surface at the location of Borehole CU2-1. A SPT 'N' value of 3 blows per 0.3 m of penetration was measured within the silty clay suggesting this material is soft. The results of a gradation analysis carried out on a sample of this material is displayed on Figure A-2. The natural water content of the silty clay was measured to be approximately 35 percent. A deposit of grey silty clay containing some sand, trace gravel, rootlets and pockets of sand was encountered beneath the grey to black silty clay at an elevation of approximately 91.4 m. SPT 'N' values measured within the lower silty clay deposit varied from 10 blows to 46 blows per 0.3 m of penetration suggesting the consistency of this deposit is stiff to hard.

Surficial fill materials were encountered at the location of Borehole CU2-2. The fill materials varied in composition from silty sand to silty clay/organic silty clay containing varying amounts of gravel as well as pieces of limestone rockfill. SPT 'N' values measured within the fill materials varied from 9 blows per 0.3 m of penetration to 50 blows per 0.1 m of penetration. The higher SPT 'N' value is considered to be a result of the split spoon sampler encountering a cobble or limestone rockfill. The fill materials are considered to be firm to stiff or loose. Atterberg Limit testing carried out on a sample of the fill indicates that the tested sample had a Plastic Limit of 22, a Liquid Limit of 48 and a water content of 26 percent. The results of a gradation analysis carried out on a sample of the fill material is displayed on Figure A-3.

At the location of Borehole CU2-1, a deposit of silty sand till containing trace gravel was encountered beneath the silty clay at a depth of approximately 1.8 m below ground surface (corresponding to an elevation of approximately 90.2 m). Based on a SPT 'N' value of 46 measured within the silty sand till, this deposit is considered to be dense. A sample of the silty sand till had a natural water content of approximately 9 percent.

A deposit of silty clay till containing some sand and trace gravel was encountered beneath the fill materials at a depth of 2.3 m below ground surface at Borehole CU2-2 (corresponding to approximately Elevation 92.1 m). A resistance of 4 blows per 0.23 m of penetration was recorded within the silty clay till during Standard Penetration Testing before the split spoon encountered refusal. The consistency of the silty clay till deposit varies from soft to firm.

Although cobbles and boulders were not encountered in the silty clay till, this deposit is anticipated to contain cobbles and/or boulders.

Refusal to penetration to augering and split spoon sampling was encountered at approximate elevations of 90 m and 91.7 m (corresponding to depths of 2 m and 2.7 m below ground surface) at Boreholes CU2-1 and CU2-2, respectively.

Bedrock was confirmed by coring in Borehole CU2-2. The bedrock core samples obtained consisted of fresh to slightly weathered, grey, fine to medium grained, limestone containing occasional black shaley laminae and occasional vugs. The Total Core Recovery (TCR) of the bedrock was between 88 and 100 percent. Solid Core Recovery (SCR) and Rock Quality Designation (RQD) were both 0 percent in the uppermost 0.45 m of the core. Below an elevation of approximately 91.3 m, the SCR varied from 88 to 89 percent and the RQD varied from 57 to 70 percent indicating this portion of the rock mass is of fair to good quality.

Two point load strength tests, one axial and one diametral, were carried out on selected samples of the rock core from Borehole CU2-2. The point load strength index values are shown on Record of Drillhole CU2-2 and the point load test results are summarized in Table A1 in Appendix A. The approximate UCS (unconfined compression strength) values estimated from the results of point load testing varied from 122 MPa (axial) to 123 MPa (diametral). These values indicate that the rock strength is very strong according to the *Canadian Foundation Engineering Manual*[3]. Borehole CU2-2 was terminated at a depth of 6.0 m below ground surface in the limestone bedrock.

The water level in Borehole CU2-1 was at an elevation of approximately 90.5 m upon completion of drilling. Borehole CU2-2 was dry upon completion of drilling within the overburden soils.

4.5 Crossing Location 3/4 – Approximate Station 18+030 to 18+040 – Approximate Pipe Invert Elevations – 110 m to 109.7 m & 109.2 m to 108.8 m

Surficial fill materials were encountered at the locations of Boreholes CU3-1, CU3-2 and CU3-3. The fill materials consisted primarily of limestone rockfill containing varying amounts of sand and gravel, trace clay and pockets of clayey silt. Laboratory testing of a sample of the fill from Borehole CU3-2 indicates that the tested sample had a natural water content of approximately 10 percent.

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[3] *Canadian Foundation Engineering Manual.* Third Edition, 1992. Canadian Geotechnical Society., Technical Committee on Foundations.

SPT 'N' values measured within the fill materials at Borehole CU3-2 varied between 10 and 34 blows per 0.3 m of penetration indicating that the rockfill at that location is compact to dense. Boreholes CU3-1 and CU3-3 were located in close proximity to bedrock exposures and these boreholes were advanced to refusal at a shallow depth on the bedrock surface without sampling.

Grey limestone bedrock was encountered beneath the fill materials at depths of approximately 0.6 m to 1.4 m below existing ground surface. The elevation of the surface of the limestone bedrock varied between 110.2 m and 111.1 m at the borehole locations. The limestone bedrock was typically fresh to slightly weathered and contained occasional black shaley laminae. A 0.1 m thick shale interbed was encountered at a depth of approximately 3.3 m below ground surface corresponding to an elevation of 108.3 m.

The Total Core Recovery (TCR) of the bedrock was 100 percent. Solid Core Recovery (SCR) and Rock Quality Designation (RQD) were both 0 percent in the uppermost 0.45 m of the rock core. Below an elevation of approximately 109.8 m, the SCR varied from 76 to 93 percent and the RQD varied from 50 to 74 percent indicating the lower portion of the rock mass is of good to excellent quality.

Two point load strength tests, one axial and one diametral, were carried out on selected samples of the rock core from Borehole CU3-2. The point load strength index values are shown on Record of Drillhole CU3-2 and the point load test results are summarized in Table A1 in Appendix A. The approximate UCS (unconfined compression strength) values estimated from the results of point load testing varied from 101 MPa (axial) to 137 MPa (diametral). These values indicate that the rock strength is very strong according to the *Canadian Foundation Engineering Manual*[3]. Borehole CU3-2 was terminated within the limestone bedrock at a depth of 4.4 m below ground surface.

Boreholes CU3-1 to CU3-3 were dry upon completion of the overburden drilling.

4.6 Crossing Location 5 – Approximate Station 18+160 to 18+190 – (N/S-E Ramp Highway 401 and County Road 38 Interchange) – Approximate Pipe Invert Elevation – 112.3 m to 111 m

Limestone rockfill was encountered at ground surface at the location of Borehole CU5-1. SPT 'N' resistance values of between 5 and 10 blows per 0.3 m of penetration were recorded within the rockfill indicating that this material is loose to compact. The limestone rockfill was encountered to a depth of approximately 4.6 m below ground surface.

A silty clay deposit was encountered beneath the rockfill at an elevation of approximately 111.3 m at the location of Borehole CU5-1 and at ground surface (Elevation 113.2 m) at the location of

Borehole CU5-2. The silty clay deposit was brown in colour and contained trace to some sand and trace gravel. SPT 'N' values measured within the silty clay varied from 9 to 24 blows per 0.3 m of penetration suggesting that the consistency of the till deposit varies from stiff to very stiff. The water content of a sample of the silty clay was measured to be approximately 30 percent. The results of a gradation analysis of a sample of the silty clay is displayed on Figure A4.

A silty clay till deposit was encountered below the silty clay at an elevation of 110 m at the location of Borehole CU5-2. The till deposit contained some gravel and occasional cobbles and the till deposit is anticipated to also contain boulders. SPT 'N' values varying from 8 to 15 blows per 0.3 m of penetration were recorded within the silty clay till suggesting the consistency of this deposit varies from stiff to very stiff.

Refusal to penetration during augering and/or split spoon sampling was encountered at approximate elevations of 109.8 m and 109.7 m (corresponding to depths of 6 m and 3.5 m below ground surface) at Boreholes CU5-1 and CU5-2, respectively.

Bedrock was confirmed by coring in Borehole CU5-1. The bedrock core samples obtained consisted of consisted of fresh to slightly weathered, grey, fine to medium grained, limestone containing occasional black shaley laminae. A 0.1 m thick shale interbed was encountered at a depth of approximately 8.1 m corresponding to an elevation of 107.7 m.

The Total Core Recovery (TCR) of the bedrock was 100 percent. Solid Core Recovery (SCR) varied from 87 to 97 percent and Rock Quality Designation (RQD) varied from 63 to 83 percent indicating a rock mass of fair to good quality.

Two point load strength tests, one axial and one diametral, were carried out on selected samples of the rock core from Borehole CU5-1. The point load strength index values are shown on Record of Drillhole CU5-1 and the point load test results are summarized in Table A1 in Appendix A. The approximate UCS (unconfined compression strength) values estimated from the results of point load testing varied from 171 MPa (axial) to 69 MPa (diametral). These values indicate that the rock strength is strong to very strong according to the *Canadian Foundation Engineering Manual*. Borehole CU5-1 was terminated within the limestone bedrock at a depth of 9.1 m below ground surface.

Boreholes CU5-1 and CU5-2 were dry upon completion of the overburden drilling. The water level in a standpipe piezometer installed in the overburden at the location of Borehole CU5-2 was at a depth of 0.3 m below ground surface corresponding to an elevation of 112.9 m on December 13, 2003.

4.7 Crossing Location 6 – Approximate Station 18+850 – Approximate Pipe Invert Elevation – 112.9 m to 112.8 m

Fill materials were encountered at ground surface at the locations of both Boreholes CU6-1 and CU6-2. The fill materials encountered at ground surface at Borehole CU6-1 consisted of sand and gravel containing crushed asphalt that extend to a depth of approximately 0.6 m below existing ground surface. The remaining fill materials were typically comprised of silty clay/organic silty clay and contained varying amounts of sand, gravel and limestone pieces.

A SPT 'N' value of 23 blows per 0.3 m of penetration was measured within the granular fill materials indicating these fill materials are compact. SPT 'N' values recorded within the silty clay fill materials varied from 9 blows to 29 blows per 0.3 m of penetration; however the higher SPT 'N' value is considered to be a result of the split spoon encountering a large piece of gravel, a cobble or a limestone slab. Based on the SPT 'N' values and visual examination of the samples, the silty clay fill is considered to be firm to stiff. The fill materials were encountered to depths of approximately 1.5 m to 2.1 m below ground surface. Gradations of the fill materials are displayed on Figure A5. Laboratory testing of two samples of the fill materials indicates that the natural water content of the tested samples varied from approximately 4 to 38 percent. Atterberg Limit testing of sample of the fill indicates that the tested sample had a Plastic Limit of 27 and a Liquid Limit of 76.

A grey to brown, silty clay deposit containing trace to some sand and trace gravel was encountered beneath the fill materials at both boreholes drilled at this site. The elevation of the surface of the silty clay varied between approximately 112.8 m and 113.4 m at the locations of Borehole CU6-1 and CU6-2. SPT 'N' values measured within the silty clay varied from 7 to 21 blows per 0.3 m of penetration suggesting that the consistency of the silty clay deposit varies from firm to very stiff. Laboratory testing indicates that the natural water content of the silty clay deposit varies from 25 to 33 percent.

A silty clay till deposit containing varying amounts of sand and gravel was encountered below the silty clay at an elevation of 111.2 m and 111.6 m at the locations of Borehole CU6-1 and CU6-2, respectively. SPT 'N' values recorded within the silty clay till varied from 21 to 23 blows per 0.3 m of penetration suggesting the silty clay till typically has a very stiff consistency. Although cobbles and boulders were not encountered in the till at the borehole locations at this site, the till deposits are anticipated to contain cobbles and/or boulders. The natural water content of a sample of the silty clay till was 10 percent.

Refusal to penetration during augering and split spoon sampling was encountered at approximate elevations of 110.3 m and 110.9 m (corresponding to depths of 4.6 m and 4 m below ground surface) at Boreholes CU6-1 and CU6-2, respectively.

The water level in the open boreholes varied from approximately Elevation 111.2 m to 111.5 m upon completion of the drilling operations.

4.8 Crossing Location 7 – Approximate Station 19+015 – Approximate Pipe Invert Elevation 112.6 m to 112.3 m

Predominantly granular fill materials varying in composition from silty sand to sand and gravel were encountered at ground surface at the locations of Boreholes CU7-1 to CU7-3. SPT 'N' values measured within the granular fill materials varied from 22 to 32 blows per 0.3 m of penetration indicating these fill materials are compact to dense. The predominantly granular fill materials extend to depths of between 0.2 m and 0.75 m below ground surface at the borehole locations. The granular fill materials are underlain by silty clay fill materials that typically contain some sand, trace gravel and trace organics/rootlets. SPT 'N' values recorded within the silty clay varied from 7 blows to 16 blows per 0.3 m of penetration suggesting the consistency of these fill materials is firm to very stiff. The fill materials were encountered to depths of approximately 1.5 m to 2.1 m below ground surface. Gradations of the fill materials are displayed on Figure A6. Laboratory testing of samples of the fill materials indicates that the natural water content of the tested samples varied from approximately 4 to 33 percent. Atterberg Limit testing of a sample of the fill indicates that the tested sample had a Plastic Limit of 19 and a Liquid Limit of 46.

The fill materials are underlain by silty clay materials at each of the boreholes drilled at this site. The elevation of the surface of the silty clay varied between approximately 111.3 m and 113.4 m at the borehole locations. At the location of Borehole CU7-2, the uppermost 0.5 m of the silty clay deposit was grey-black and contained trace organics. The remainder of the silty clay deposit typically contained some sand, trace gravel and occasional sand seams. SPT 'N' values measured within the silty clay deposit varied between 9 blows and 25 blows per 0.3 m of penetration suggesting that the consistency of the silty clay is generally stiff to very stiff. Laboratory testing indicates that the natural water content of the silty clay deposit varies from 27 to 33 percent.

A brown silty clay till deposit containing some sand and trace gravel was encountered beneath the silty clay deposit at the locations of Boreholes CU7-2 and CU7-3. The silty clay till deposit contains cobbles and is anticipated to contain boulders. The surface of the till deposit was encountered at elevations of approximately 110.2 to 110.3 m.

Refusal to penetration during augering and split spoon sampling was encountered between approximate elevations of 108.4 m and 109.6 m (corresponding to depths of 4 m to 6.1 m below ground surface) at Boreholes CU7-1 to CU7-3.

The water level in Borehole CU7-2 was at an elevation of approximately 110.3 m upon completion of drilling. The other two boreholes were dry on completion of drilling. The water level in a standpipe piezometer installed at the location of Borehole CU7-3 was at a depth of 1.2 m below ground surface corresponding to an elevation of 112.2 m on December 13, 2003.

4.9 Crossing Location 8 – Approximate Station 19+510 – Approximate Pipe Invert Elevation – 111.7 m to 111.5 m

Fill materials were encountered at ground surface at the locations of Boreholes CU8-1 and CU8-2. The surficial fill materials at Borehole CU8-1 were comprised primarily of sand and contained some gravel and crushed asphalt and trace clay and rootlets. A SPT 'N' value of 14 blows per 0.3 m of penetration was recorded within the sand fill indicating that this material is compact. Laboratory testing of a sample of the sand fill indicated that the sample tested had a natural water content of approximately 12 percent.

Silty clay fill materials were encountered beneath the sand fill in Borehole CU8-1 and at ground surface at the location of Borehole CU8-2. The silty clay fill materials typically contained some sand, trace gravel and organics. SPT 'N' values recorded within the silty clay fill materials varied from 5 to 11 blows per 0.3 m of penetration suggesting these fill materials have a firm to stiff consistency. The results of a gradation analysis carried out on a sample of silty clay fill materials is displayed on Figure A7. Laboratory testing indicates that the natural water content of the silty clay fill varies from 18 to 28 percent. Atterberg Limit testing of a sample of the silty clay fill indicates that the tested sample had a Plastic Limit of 18 and a Liquid Limit of 35.

A thin layer of organic silty clay was encountered beneath the silty clay fill materials at an elevation of approximately 112.6 m in Borehole CU8-2.

A deposit of silty clay till containing some sand and trace gravel (including limestone pieces) was encountered beneath the fill materials and organic silty clay deposit. Although cobbles and boulders were not encountered in the silty clay till at this site, this deposit is anticipated to contain cobbles and boulders. The elevation of the surface of the silty clay till varied between approximately 112.2 and 112.5 m at the borehole locations. Based on a SPT 'N' value of 11 blows per 0.3 m of penetration measured within the silty clay till, this deposit is considered to be stiff. Laboratory testing indicates that the natural water content of the silty clay till deposit varies from 25 to 29 percent. A gradation of the silty clay till is displayed on Figure A8.

Refusal to penetration during augering and split spoon sampling was encountered at approximate elevations of 111.9 m and 111.8 m (corresponding to depths of 1.8 m and 2 m below ground surface) at Boreholes CU8-1 and CU8-2, respectively.

Bedrock was confirmed by coring in Borehole CU8-2. The bedrock core samples obtained consisted of fresh, grey, fine to medium grained, limestone containing occasional black shaley laminae. A 0.1 m thick interbed of weak, black shale was encountered within the limestone at a depth of approximately 3.9 m corresponding to an elevation of approximately 109.9 m.

The Total Core Recovery (TCR) of the bedrock was 100 percent. Solid Core Recovery (SCR) varied from 58 to 93 percent and Rock Quality Designation (RQD) varied from 22 to 65 percent indicating a rock mass of very poor to fair quality.

Two point load strength tests, one axial and one diametral, were carried out on selected samples of the rock core from Borehole CU8-2. The point load strength index values are shown on Record of Drillhole CU5-1 and the point load test results are summarized in Table A1 in Appendix A. The approximate UCS (unconfined compression strength) values estimated from the results of point load testing varied from 141 MPa (axial) to 69 MPa (diametral). These values indicate that the rock strength is strong to very strong according to the *Canadian Foundation Engineering Manual.* Borehole CU8-2 was terminated within the limestone bedrock at a depth of 9.1 m below ground surface.

The open boreholes were dry upon completion of drilling within the overburden soils.

4.10 Crossing Location 9 – Approximate Station 17+865 to 17+880 – (E-N/S Ramp Highway 401 and County Road 38 Interchange) – Approximate Pipe Invert Elevation – 107 m to 106.7 m

Sand to sand and gravel fill materials containing some crushed asphalt, limestone pieces and silt were encountered at ground surface at the location of Borehole CU9-1. SPT 'N' resistance values of 11 blows per 0.3 m of penetration were recorded within the granular fill materials indicating that these materials are compact. The granular fill materials were encountered to a depth of approximately 1.3 m below ground surface. The natural water content of a sample of the granular fill was measured to be approximately 5 percent.

A deposit of very stiff, silty clay containing some sand and trace gravel was encountered at ground surface at the location of Borehole CU9-2. A SPT 'N' value of 16 blows per 0.3 m of penetration was measured within the silty clay deposit.

A deposit of silty clay containing trace sand and occasional gravel and sand/sandy silt seams was encountered beneath the fill materials and silty clay deposit. The elevation of the surface of the silty clay deposit varied from 105.6 m at Borehole CU9-2 to 106.6 m at Borehole CU9-1. SPT 'N' values measured within the clay deposit varied from 10 blows to 26 blows per 0.3 m of penetration suggesting the consistency of the silty clay varies from stiff to very stiff. The natural water content of the silty clay deposit varied from 24 to 38 percent. Atterberg Limit testing of a sample of the silty clay from Borehole CU9-1 indicates that the tested sample had a Plastic Limit of 24 and a Liquid Limit of 63. The results of gradation analyses of the silty clay deposit are displayed on Figure A9.

A silty clay with sand till deposit containing some gravel was encountered below the silty clay at an elevation of 100.6 m at the location of Borehole CU9-2. A SPT 'N' value of 7 blows per 0.3 m of penetration was measured within the silty clay till suggesting this deposit is firm.

Refusal to penetration during augering and/or split spoon sampling was encountered at an elevation of approximately 100.0 m (corresponding to a depth of 6.4 m below ground surface) at Borehole CU9-2; while Borehole CU9-2 was terminated at a depth of 6.7 m.

Boreholes CU9-1 and CU9-2 were dry upon completion of the drilling operations. The water level in a standpipe piezometer installed at the location of Borehole CU9-1 was at a depth of 1.7 m below ground surface corresponding to an elevation of 106.2 m on December 13, 2003.

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PART B

FOUNDATION DESIGN REPORT
JACK AND BORE SEWER CROSSINGS
HIGHWAY 401 WIDENING
FROM 2.7 KM WEST OF HIGHWAY 38
EASTERLY TO HIGHWAY 15
W.P. 76-99-01

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides foundation design recommendations for the culvert/sewer crossings proposed to be installed by jack and bore methods as part of the Highway 401 widening project from 2.7 km west of County Road 38 to Highway 15, in the vicinity of Kingston, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at the proposed pipe crossing sites. The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible pipe 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.

Sections displaying accurate elevations of existing ground surface and proposed sewer profiles were not available at the time of preparation of the draft version for this report. We understand that, in the period between the preparation of the draft and final versions of this report, a decision was made to install the sewers at Pipe Crossing Locations 5 and 9 using conventional open cut installation methods. Sections at the remaining sewer crossing locations (Pipe Crossing Locations 1, 2, 3/4, 6, 7 and 8) were provided to us by GGG personnel and this report includes stratigraphic sections at these sites.

5.2 Pipe Information

MTO currently proposes to install a series of concrete sewers/culverts using jack and bore installation methods at the locations identified in the following table. For reference, the proposed crossing locations have been identified in this report as Pipe Crossing Location 1 to Pipe Crossing Location 9.

Station/ Offset	*Jack and Bore Length (m)*	*Pipe Type*
17+380 o/s 3m Rt.-34m Rt. (Pipe Crossing Location 1)	31	Concrete sewer 450 mm diameter
17+440 o/s 0m Rt.-30m Rt. (Pipe Crossing Location 2)	30	Concrete sewer 450 mm diameter
18+040 o/s 24m Rt.-18+030 o/s 1m Rt. (Pipe Crossing Location 3)	27	Concrete sewer 450 mm diameter
18+030 o/s 1m Lt.-18+020 o/s 28m Lt. (Pipe Crossing Location 4)	35	Concrete sewer 600 mm diameter
N/S – E Ramp 18+163 o/s 9m Rt.-18+188 o/s 32m Lt. (Pipe Crossing Location 5)	47	Concrete sewer 825 mm diameter

Station/ Offset	*Jack and Bore Length (m)*	*Pipe Type*
18+850 o/s 1m Rt.-18+850 o/s 33m Rt. (Pipe Crossing Location 6)	32	Concrete sewer 600 mm diameter
19+015 o/s 24.25m Lt.-19+015 o/s 30.75m Rt. (Pipe Crossing Location 7)	55	Concrete culvert 1200 mm diameter
19+510 o/s 1m Rt.-31m Rt. (Pipe Crossing Location 8)	30	Concrete sewer 375 mm diameter
E-N/S Ramp 17+865 o/s 22m Lt.-17+877 o/s 35 m Lt. (Pipe Crossing Location 9)	17	Concrete culvert 600 mm diameter

Based on information provided by The Greer Galloway Group Inc. (GGG), the following table summarizes the approximate pipe invert elevations and cover above the sewer/culvert. The table also provides a summary of the subsurface conditions encountered at the approximate pipe level during the subsurface investigation (i.e. the subsurface conditions through which the pipe is to be advanced).

Pipe Crossing Location	*Approximate Pipe Invert Elevation (m)*	*Approximate Depth of Cover (m)*	*Anticipated Subsurface Conditions At Design Pipe Level*
1	89 - 89.8	3.9	Fill materials consisting of firm to very stiff silty clay/clayey silt containing or mixed with limestone rockfill to slightly organic clay to native deposits comprised of slightly organic silty clay and sandy silt. Note: Refusal to auger penetration was encountered at a depth of about 1.9 m in the fill materials at the original location of Borehole CU1-2
2	91.2 - 91..6	2.8	Silty clay fill containing cobbles and limestone pieces overlying silty clay till overlying limestone bedrock at median to soft to stiff clayey silt/silty clay at outlet
3	109.7 - 110	1.2	Strong to very strong limestone bedrock (Note: Pipe obvert is located very close to interface with overlying fill materials)
4	108.8 – 109.2	3.3	Strong to very strong limestone bedrock
5	111 - 112.3	1	Loose limestone rockfill to stiff to very stiff silty clay
6	112.8 - 112.9	1.2	Stiff clay fill containing limestone pieces to firm to very stiff silty clay
7	112.3 - 112.6	1.1	Fill materials comprised of compact to dense sand and gravel to firm to very stiff silty clay overlying stiff to very stiff, native silty clay
8	111.5 – 111.7	2.7	Mixed face conditions consisting of silty clay till and strong to very strong limestone bedrock
9	106.7 - 107	0.5	Mixed soil face of compact sand to sand and gravel fill materials overlying stiff to very stiff silty clay

5.3 Pipe Installation Methods

The culverts/sewers crossings beneath Highway 401 and the ramps of the Highway 401 and County Road 38 interchange are currently proposed to be installed by jack and bore installation methods. Jack and boring is a method of forming a near horizontal bore from a drive pit with a rotating cutter head and simultaneously jacking a casing to support the sidewalls of the bore. The following sections of this report discusses the suitability of installing the sewers/culverts using jack and bore methods and discuss various construction method options that may be considered for the installation of the sewers/culverts. Due to the varying ground surface conditions encountered at the crossing locations, the discussion of construction method options for the sites has been divided into the following three categories:

- Sewers/culverts to be installed within fill materials and native overburden soils;
- Sewers/culverts to be installed at the interface of the overburden soils and bedrock; and
- Sewers/culverts to be installed entirely within the limestone bedrock.

5.3.1 Pipes Installed Within Fill Materials And Native Overburden Soils

Based on the available pipe invert information provided by GGG and the results of the subsurface investigation, the sewers/culverts proposed to be installed at Pipe Crossing Locations 1 (approximate Station 17+380), 5 (N/S–E Ramp (approximate Station 18+170)), 6 (approximate Station), 7 (approximate Station 19+015), and 9 (E-N/S ramp (approximate Station 17+870)) are anticipated to be installed through fill materials and/or native overburden soils varying in composition from silty clay to sandy silt and/or till comprised of silty sand to silty clay.

The fill materials at the location of Pipe Crossing Location 5 consisted of limestone rockfill and the fill materials at many of the other crossing locations were noted to contain cobbles and/or pieces of limestone/limestone rockfill. Cobbles were encountered within the native till deposits and these deposits are anticipated to also contain boulders. Refusal to auger penetration was encountered within the fill materials at Borehole CU1-2 at the approximate level of the proposed pipe. The presence of limestone rockfill, cobbles or large pieces of limestone within the fill materials, and/or cobbles and boulders within the till deposits will obstruct the jack and bore operations and could deflect the path of the bore/casing at the locations of pipes to be installed within the fill materials and/or native soils. Where the casings are large enough to permit man entry, it would be possible to remove obstructions at the leading edge of the bore using manual excavation methods after removal of the cutterhead/auger. However, this process would result in a delay in the installation operations and could increase ground loss into the casing, with associated subsidence of the overlying materials and consequent pavement settlement. This risk is greatest at Pipe Crossing 5 where loose to compact rockfill is anticipated below the existing ramp. Such material could run into an unsupported face. Indeed, at the location of Pipe Crossing 5, there is considered to be a high risk of creating a void above the pipe if jack and bore procedures are used or if auger removal is necessary for manual removal of obstructions.

The design depth of cover between the top of the sewers/culverts and the road surfaces at Pipe Crossing Locations 6, 7, and 9 is understood to be in the order of 1.5 m or less. The depth of cover above a casing installed for the jack and boring operations will be even less. The potential for subsidence of the pavement and possible creation of sinkholes to surface is increased in areas where limited cover is present above the jack and bore alignment particularly where the casing will be located near the granular materials of the highway pavement structure. The culvert at Pipe Crossing Location 7 is 1200 mm diameter and has a design cover of approximately 1 m. A cross section displaying the pipe alignment at Pipe Crossing Location 9 was not available to us at the time or preparation of this report but based on the available information, the depth of cover at this site is understood to be only about 0.5 m. The casings required to install these pipes are anticipated to extend into the granular pavement structure and the top of the casings for Pipe Crossing Locations 6, 7 and 9 are all anticipated to be located less than 1 m below the surface of the pavement. If possible, the culverts at these locations should be lowered to reduce the potential for ground surface deformations during pipe installation using trenchless methods. Alternatively, consideration could also be given to replacing the culvert at Pipe Crossing Location 7 with two or more smaller diameter culverts installed at the same design invert elevation to increase the ratio of cover to pipe diameter so that at least about a half pipe diameter distance is maintained between the top of the casing and the underside of the granular road bed materials.

As described above, due to the potential for encountering cobbles, boulders, and limestone rockfill/large pieces of limestone within the fill materials, there are risks associated with encountering obstructions that could lead to refusal of, or deflect the alignment, of the jack and bore operations. In addition, the potential for ground subsidence to occur is greater in areas where relatively limited cover is present above the casings and where cohesionless rock fill or granular pavement base materials are present above the crown of the casing. These risks can reduced by installing the sewers/culverts at these sites by pipe ramming installation techniques or eliminated by installing the pipes using open cut methods.

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 than jack and bore installation techniques. 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.

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.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with these installation methods is presented in Table 1 following the text of this report. Based on the above, installing the culverts/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 to better suited for installing the sewers/culverts through the fill materials and overburden soils particularly at sites where there is relatively limited cover above the sewers/culverts. At Pipe Crossing Locations 5, 7 and 9, the use of conventional jack and bore installation methods are not considered suitable due to the limited cover above the crossings (Pipe Crossing Locations 7 and 9) or the presence of limestone rockfill (Pipe Crossing Location 5).

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.

5.3.2 Pipes Installed At Interface Of Overburden And Bedrock

The design alignment for the sewers to be installed at Pipe Crossing Location 2 (Approximate Station 17+440) and Pipe Crossing Location 8 (Approximate Station 19+510) are located at or near the interface of the overburden soils and limestone bedrock. Pipes installed at the design alignment are anticipated to encounter a combination of soil and bedrock. The casing for the installation 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 these methods are not considered to be suitable for the installation of sewers/culverts at this site unless the vertical alignments of the pipes are changed.

If the vertical alignment of the sewers at this site can not be raised or lowered to be installed either entirely within the bedrock or entirely within the overburden soils, the sewers at these sites would be best suited to be installed by open cut. The use of hand tunnelling/mining methods to install the culverts/sewers has been considered. However, for these locations, this installation procedure is expected to be difficult to implement and to have a high risk of ground loss. The proposed pipe diameters would not permit man-entry for hand mining work; thus the casing diameters would need to be increased to about 0.9 m to 1.2 m in size. The 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 needs to 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. Further, filter fabric, straw and other packing materials should be available on site to contain any localized occurrences of flowing ground.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with these installation methods is presented in Table 2 following the text of this report. Based on the above, installing the culverts/sewers in open cut is considered to be the installation method with the least construction risk. If open cut installations are not possible, installation of the sewers/culverts using hand mining/tunnelling methods is considered to be the only trenchless method suitable for the ground conditions at these sites; however, as noted above, this method carries with it ground support risks and is anticipated to be much more expensive than a conventional jack and bore crossing.

5.3.3 Pipes Installed Within Limestone Bedrock

The Highway 401 alignment at this crossing site was constructed in a cut through limestone bedrock and bedrock exposures are present on both sides of the highway at this site. The design alignments for the 450 mm to 600 mm diameter sewers to be installed at Crossing Location 3/4 (Approximate Station 18+020 to 18+040) are located entirely within the limestone bedrock. Based on the bedrock coring carried out at Borehole CU3-2, the limestone bedrock at this site strong to very strong and the upper 0.5 m of the bedrock is 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 conventional jack and boring is not considered suitable for installation of the sewers at this site. Similarly, pipe ramming is not considered to be a suitable alternative for installing the sewers.

The sewers at this site could be installed using a rock boring machine. This method involves the drilling of a pilot hole, typically 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 reaming equipment is dependent on the type and strength of the bedrock.

At the location of proposed Pipe Crossing 3 (i.e. the sewer crossing the eastbound lanes of the 401), the proposed sewer is located within 1 m of the surface of the bedrock. Typically, maintaining the obvert of the crossing at least a 1 m or one pipe diameter, which ever is greater, below the surface of the bedrock is preferred to reduce risks of instability of the bore. Therefore, if possible, it is recommended that consideration be given to lowering the alignment of Pipe Crossing 3.

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. Bedrock outcrops extending above the level of the Highway 401 pavement structure are present in the immediate vicinity of the north and south limits of Pipe Crossing Location 3/4 and blasting may be required to permit construction of the required work areas if sufficient space is not available for installing the rock boring machine in the median of the highway at this location.

Alternatively, the sewers could be installed by conventional open cut methods. Excavation of the bedrock 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 5.4.2 of this report.

A summary comparison of the advantages, disadvantages, relative costs and risks associated with these installation methods is presented in Table 3 following the text of this report. Based on the above, installing the culverts/sewers using a rock boring machine is considered to be the most suitable technique for the ground conditions at this site.

5.4 Design And Construction Considerations

5.4.1 Excavation and Groundwater / Surface Water Control

Excavations will be required for the jacking and receiving pits for trenchless installation methods 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 predominantly of silty clay and sandy silt to silty clay till. At some sites, the excavations may extend into strong to very strong limestone containing interbeds of shale.

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 Activities. The fill materials and any firm to stiff or loose to compact native soils are classified as Type 3 soil, according to the OHSA. Very stiff to hard or dense portions of the till deposits 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.

The groundwater level measured in piezometers installed during the subsurface investigation varied between 0.3 m and 1.7 m below ground surface. Seepage from zones of perched water within the fill materials and native soils should be expected particularly where granular zones are intercepted in the excavation. As the overburden soils at the site are predominantly fine-grained in nature, the seepage through these deposits is expected to be minor and pumping from wellfiltered 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 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 ditches or in low-lying areas. All surface water, including water within existing ditches, should be directed away from the open excavations.

5.4.2 Blasting

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 during blasting operations, including the bridge structure at Pipe Crossing Location 3/4, it is recommended that a separate Special Provision for the control of all blasting operations be prepared. The Special Provision should include, but not be limited to 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 signaling 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 County Road 38 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.

We recommend limiting ground vibration levels to 50 mm/s peak particle velocity for the existing County Road 38 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.

5.4.3 Temporary Excavation Support

Temporary roadway protection may be required in areas where sufficient space is not available to permit the exit and entry pit work areas to be developed within open cuts. Based on the subsurface conditions at the site 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 required excavations, the soldier piles would likely need to be socketed into the limestone bedrock. Rock coring or churn drilling would be required to socket the soldier piles into the bedrock.

Support to the soldier pile and lagging walls may be provided by internal bracing, anchors or rakers. The internal bracing / raker / anchor support must 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 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01.

5.4.4 Instrumentation And Monitoring

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

- Document the effects of sewer installation on the overlying roadways;
- 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 pipe 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 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 ± 1 mm of the actual elevation.

In addition, the installation of in-ground settlement points, consisting of a sleeved iron bars, set 1.2 m to 1.5 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 twice (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.

5.4.5 Grouting

For all pipes that are large enough to permit man-entry, a program of post-installation grouting should be specified to fill any voids or loose zones created during the pipe installation. 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.

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TABLES

TABLE 1

EVALUATION OF SEWER/CULVERT INSTALLATION METHODS
PIPE CROSSINGS WITHIN FILL AND/OR OVERBURDEN SOILS
CROSSING LOCATIONS 1, 5, 6, 7, AND 9

Installation Method	*NS*	*Advantages*	*Disadvantages*	*Relative Costs*	*Risks/Consequences*
Open Cut Installations		Best control on gradient and alignment of sewers/culverts. Reduced potential for delays resulting from encountering obstruction. Least risk of damage to active highway.	Requires lane closures and pavement reconstruction. Large excavations required for deep installations.	Least expensive installation method for shallow installations.	Increased traffic disruption. Traffic disruptions at Crossings 5 and 9 on ramps may not be as severe and staged open cut operations may mitigate traffic disruptions at these locations.
Jack and Bore Installation	NS at Crossings 5,7,9	Sewers/culverts can be installed without lane closures resulting in minimal traffic disruption.	Obstructions (e.g. cobbles/boulders or limestone rockfill) may deflect and/or stop bore. Greatest risk of ground subsidence of highway; particularly for crossings with limited cover or if obstructions that slow installation procedures and/or require man-entry to remove are encountered.	Less expensive than pipe ramming.	Risk of encountering refusal on obstructions within fill and till particularly for smaller casings where man entry to remove obstructions is not possible. Obstructions can result in deflection of casing resulting in misalignment of sewer/culvert. Potential for loss of ground into casing particularly if cohesionless materials 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/or limestone rockfill than jack and bore techniques.	Large obstructions can deflect casing. Potential for heaving at ground surface particularly for relatively shallow installations.	Most expensive installation method for these crossings.	Obstructions can cause deflection of casing resulting in gradient/alignment of sewer/culvert. Large cobbles and/or boulders stop penetration of casing requiring hand mining.

NS: Not considered a suitable installation alternative for this project

TABLE 2

EVALUATION OF SEWER/CULVERT INSTALLATION METHODS PIPE CROSSINGS AT INTERFACE OF OVERBURDEN AND BEDROCK PIPE CROSSING LOCATIONS 2 AND 8

Installation Method	*NS*	*Advantages*	*Disadvantages*	*Relative Costs*	*Risks/Consequences*
Open Cut Installations		Ability to install sewers and culverts at correct gradient and alignment.	Requires lane closures and pavement reconstruction. Large excavations required for deep installations. Blasting may be required.	Least expensive installation method for shallow installations.	Increased traffic disruption.
Jack and Bore Installation Pipe Ramming Installation	X		Inability to maintain design alignment and gradient with mixed bedrock and face conditions. Potential for encountering refusal due to bedrock.		Risk of encountering refusal or not being able to install casing on correct alignment.
Micro-Tunneling Machines	X		Inability to maintain design alignment and gradient with mixed bedrock and face conditions.		Risk of not being able to install casing on correct alignment.
Hand Tunneling 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 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.	Most expensive installation method. Significantly more expensive than conventional jack and bore installation.	Potential for instability of excavation and associated ground subsidence particularly during removal of bedrock at crossing invert.

NS: Not considered a suitable installation alternative for this project

TABLE 3

EVALUATION OF SEWER/CULVERT INSTALLATION METHODS
PIPE CROSSINGS WITHIN LIMESTONE BEDROCK
PIPE CROSSING LOCATIONS 3 AND 4

Installation Method	*NS*	*Advantages*	*Disadvantages*	*Relative Costs*	*Risks/Consequences*
Open Cut Installations		Ability to install sewers and culverts at correct gradient and alignment.	Requires lane closures and pavement reconstruction. Limestone bedrock is strong to very strong and blasting will likely required.	Less expensive than rock bore installation method for shallow installations.	Increased traffic disruption. Controlled blasting required to limit damage to nearby structures/facilities including the County Road 38 bridge over Highway 401.
Jack and Bore Installation Pipe Ramming Installation	X		Inability to advance casing into strong to very strong limestone bedrock.		
Rock Bore Installation		Sewers/culverts can be installed without lane 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, highly fractured portion of bedrock). Blasting may be required to construct work area of approximately 3 m by 10 m necessary for rock boring machine.	More expensive than open cut installation methods.	Potential for collapse of top/sidewalls of bore in areas where pipes are located in close proximity to upper, highly fractured portion of rock.

NS: Not considered a suitable installation alternative for this project

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
DO	Drive open
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 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):
An electronic cone penetrometer with a 60° conical tip and a projected 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	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 test (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
ln 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
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma\text{-}u$)
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 ($\gamma' = \gamma\text{-}\gamma_w$)
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

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(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 $= \sigma'_p/\sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
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

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	P - Polished
FO - Foliation/Schistosity	S - Slickensided
CL - Cleavage	SM - Smooth
SH - Shear Plane/Zone	R - Ridged/Rough
VN - Vein	ST - Stepped
F - Fault	PL - Planar
CO - Contact	FL - Flexured
J - Joint	UE - Uneven
FR - Fracture	W - Wavy
MF - Mechanical Fracture	C - Curved
∥ - Parallel To	
⊥ - Perpendicular To	

Golder Associates

RECORD OF BOREHOLE No CU1-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4905401.9 ;E 298707.4
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 17, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
89.0	GROUND SURFACE												
0.0	Silty Clay to Clayey Silt, some sand, trace to some gravel, trace topsoil and rootlets (FILL) Firm to very stiff Brown Moist		1	SS	7			○		4	24	41	31
			2	SS	27		88						
87.7 / 1.3	Clayey Silt with sand, trace gravel, occasional cobbles (TILL) Very stiff to hard Brown to grey Moist		3	SS	26			○					
							87						
			4	SS	53								
86.0 / 3.1	Silty Sand, trace gravel and clay (TILL) Very dense Grey Moist		5	SS	57		86	○					
85.3 / 3.7	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
REMARKS & GRAIN SIZE DISTRIBUTION (%)

Notes:

1. Open borehole dry upon completion of drilling operations

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

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RECORD OF BOREHOLE No CU1-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4905426.5 ;E 298722.8
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 21, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.8	GROUND SURFACE						
0.0	Mixture of Silty Clay with sand and gravel and limestone rock fill, contains cobbles and/or boulders. Firm to stiff. Brown. Moist. (Fill)	1	SS	11	92		
		2	SS	9	91	o	27 26 27 20
90.5 / 2.3	Refusal to auger penetration encountered at 1.9 m depth. Borehole moved 1 m East and redrilled. Silty Clay, some sand, trace gravel, slightly organic. Firm. Black. Moist	3	SS	5	90	o (with plastic/liquid limit range)	
89.8 / 3.1	Sandy Silt, trace clay, gravel and organics. Loose. Black. Moist to wet	4	SS	8		o	
89.0 / 3.8	Silty Sand, trace to some gravel, trace clay, occasional cobbles, contains zones of silty clay (TILL). Compact to very dense. Brown. Moist	5	SS	19	89		
		6	SS	60	88	o	
					87		
		7	SS	61	86		
85.7 / 7.1	End of Borehole						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Notes:

1. Auger and spoon refusal at 7.1 m depth (Elev. 85.7 m)
2. Water level in open borehole at Elev. 87.6 m upon completion of drilling operations

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

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RECORD OF BOREHOLE No CU2-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic
LOCATION N 4905369.7 :E 298755.8
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 17, 2003
ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT (%)	GR	SA	SI	CL
92.0	GROUND SURFACE									
0.0	Silty Clay with sand, trace organics, gravel and rootlets Soft Grey and black Moist to wet	1	SS	3		~35	3	29	41	27
91.4 0.6	Silty Clay, some sand, trace gravel, trace rootlets and sand pockets Stiff to hard Grey Moist	2	SS	10	91					
		3	SS	46		~15				
90.2 2.0	Silty Sand, trace clay and gravel, occasional cobbles (TILL) Very dense Grey Moist				90					
	End of Borehole									

Notes:

1. Auger and spoon refusal at 2.0 m depth (Elev. 90.0 m)
2. Water level at Elev. 90.5 m upon completion of drilling operations

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 (%) 20 40 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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RECORD OF BOREHOLE No CU2-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4905396.5 ;E 298775.8
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 21, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.4	GROUND SURFACE						
0.0	Silty Sand, trace clay, gravel, organics and rootlets (FILL) Loose Dark brown Moist	1	SS	5	94		
93.6 / 0.8	Silty Clay to Organic Silty Clay, some sand, trace gravel (FILL) Stiff Dark brown and black Moist	2	SS	9		W_P–w–W_L plotted	8 20 37 35
92.9 / 1.5	Silty Clay, some sand, trace gravel, contains limestone cobbles and/or boulders (FILL) Firm Brown Moist	3	SS	50/0.10	93		
92.1		4	SS	4/0.23	92	w plotted	
91.7 / 2.7	Silty Clay, some sand, trace gravel (TILL) Soft to firm Grey Moist to wet						
	Limestone (Bedrock) For coring details see Record of Drillhole CU2-1						
88.4 / 6.0	End of Borehole						

Notes:

1. Auger and spoon refusal at 2.7 m depth (Elev. 91.7 m)
2. Borehole dry upon completion of drilling in overburden

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
UNIT WEIGHT γ kN/m³

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

RECORD OF DRILLHOLE: CU2-2

PROJECT: 03-1111-016

LOCATION: N 4905396.5 ;E 298775.8

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 21, 2003

DRILL RIG: CME 75

DRILLING CONTRACTOR: Marathon

SHEET 1 OF 1

DATUM: Geodetic

Legend: FR/FX-FRACTURE, F-FAULT, SM-SMOOTH, FL-FLEXURED, BC-BROKEN CORE, CL-CLEAVAGE, J-JOINT, R-ROUGH, UE-UNEVEN, MB-MECH. BREAK, SH-SHEAR, P-POLISHED, ST-STEPPED, W-WAVY, B-BEDDING, VN-VEIN, S-SLICKENSIDED, PL-PLANAR, C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	RECOVERY (TOTAL CORE %, SOLID CORE %)	R.Q.D %	FRACT. INDEX PER 0.3	DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION)	HYDRAULIC CONDUCTIVITY K, cm/sec	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
				91.70										
3	NQ Coring	LIMESTONE (BEDROCK), styolitic with occasional black shaley laminae Fresh to slightly weathered Strong to very strong Fine to medium grained Occasional vugs		2.70	1		100							
4					2		100				Weathering on vugs B-UE, PL, SM			
5					3		100							
6		End of Drillhole		88.40 6.00										

Depth scale markings: 7, 8, 9, 10, 11, 12

DEPTH SCALE

1 : 50

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LOGGED: PKS

CHECKED:

Golder Associates

RECORD OF BOREHOLE No CU3-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904999.5 E 299226.9
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 19, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
111.9	GROUND SURFACE										
0.0	Limestone Rockfill with sand and gravel, trace silt and clay, contains cobbles (FILL)										
111.2 0.8	End of Borehole Notes: 1. Auger and spoon refusal at 0.8 m depth (Elev. 111.1 m) 2. Open borehole dry upon completion of drilling operations 3. No sampling carried out at this location						111				

MISS_MTO 03-1111-016 JACK AND BORE.GPJ ON_MOT.GDT 17/12/03

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

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

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RECORD OF BOREHOLE No CU3-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic
LOCATION N 4905018.4 :E 299235.3
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 20, 2003
ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
111.6	GROUND SURFACE										
0.0	Limestone Rockfill with sand and gravel, trace silt and clay, contains cobbles (FILL) Compact to dense Grey Moist		1	SS	10		111				
			2	SS	34				o		
110.2 / 1.4	Limestone (Bedrock) For coring details see Record of Drillhole CU3-2										
107.2 / 4.4	End of Borehole										

Notes:

1. Auger and spoon refusal at 1.4 m depth (Elev. 110.2 m)
2. Open borehole dry upon completion of drilling operations in overburden

+ ³, X ³: Numbers refer to Sensitivity   O ³% STRAIN AT FAILURE

RECORD OF DRILLHOLE: CU3-2

PROJECT: 03-1111-016
LOCATION: N 4905018.4 ;E 299235.3
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 20, 2003
DRILL RIG: CME 75
DRILLING CONTRACTOR: Marathon

DATUM: Geodetic

FR/FX-FRACTURE, F-FAULT, SM-SMOOTH, FL-FLEXURED, BC-BROKEN CORE, CL-CLEAVAGE, J-JOINT, R-ROUGH, UE-UNEVEN, MB-MECH. BREAK, SH-SHEAR, P-POLISHED, ST-STEPPED, W-WAVY, B-BEDDING, VN-VEIN, S-SLICKENSIDED, PL-PLANAR, C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	RQD %	FRACT. INDEX PER 0.3	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
				110.20												
	NQ Coring	LIMESTONE (BEDROCK), styolitic with occasional black shaley laminae Fresh to slightly weathered Strong to very strong Fine to medium grained		1.40	1		100						BC			
2					2		100									
3		0.1 m thick black SHALE bed at 3.3 m depth			3		100						B-UE, PL, SM			
4				107.20 4.40												
		End of Drillhole														

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: PKS
CHECKED:

Golder Associates

RECORD OF BOREHOLE No CU3-3

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4905039.0 ;E 299245.7
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 18, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

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, X REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
111.3	GROUND SURFACE										
0.0	Limestone Rockfill with sand and gravel, trace silt and clay, contains cobbles (FILL)						111				
110.8 / 0.6	End of Borehole										

Notes:

1. Auger and spoon refusal at 0.6 m depth (Elev. 110.7 m)
2. Open borehole dry upon completion of drilling operations
3. No sampling carried out at this location

MISS_MTO 03-1111-016 JACK AND BORE.GPJ ON_MOT.GDT 17/12/03

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

Golder Associates

RECORD OF BOREHOLE No CU5-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904868.3 ;E 299331.4
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 19, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
115.8	GROUND SURFACE										
0.0	Limestone Rockfill Loose to compact Wet		1	SS	5						
			2	SS	7		115				
			3	SS	6		114				
			4	SS	8		113				
			5	SS	10		112				
111.2 4.6	Silty Clay, some sand, trace gravel Stiff Brown Moist to wet		6	SS	9		111				
							110				
109.8 6.0	Limestone (Bedrock) For coring details see Record of Drillhole CU5-1										
106.7 9.1	End of Borehole Notes: 1. Auger refusal at 6.0 m depth (Elev. 109.8 m) 2. Open borehole dry on completion of drilling										

Shear strength legend: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; X REMOULDED. Scales: 20 40 60 80 100.

Water content: PLASTIC LIMIT W_P; NATURAL MOISTURE CONTENT W; LIQUID LIMIT W_L. Scale: 20 40 60.

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

RECORD OF DRILLHOLE: CU5-1

PROJECT: 03-1111-016

LOCATION: N 4904868.3 ;E 299331.4

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 19, 2003

DRILL RIG: CME 75

DRILLING CONTRACTOR: Marathon

DATUM: Geodetic

FR/FX-FRACTURE F-FAULT SM-SMOOTH FL-FLEXURED BC-BROKEN CORE
CL-CLEAVAGE J-JOINT R-ROUGH UE-UNEVEN MB-MECH. BREAK
SH-SHEAR P-POLISHED ST-STEPPED W-WAVY B-BEDDING
VN-VEIN S-SLICKENSIDED PL-PLANAR C-CURVED

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION
		109.80			
6	LIMESTONE (BEDROCK), styolitic with occasional black shaley laminae Fresh to slightly weathered Strong to very strong Fine to medium grained	6.00	1	100	
7					B-UE, PL, SM
8	0.1 m thick black SHALE bed at 8.1 m depth		2	80	
9	End of Drillhole	106.70 9.10			

Column headings: DEPTH SCALE METRES; DRILLING RECORD; DESCRIPTION; SYMBOLIC LOG; ELEV. DEPTH (m); RUN No.; PENETRATION RATE (m/min); FLUSH COLOUR % RETURN; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT INDEX PER 0.3; DISCONTINUITY DATA (DIP w.r.t CORE AXIS; TYPE AND SURFACE DESCRIPTION); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}); DIAMETRAL POINT LOAD INDEX (MPa); NOTES WATER LEVELS INSTRUMENTATION

Depth scale: 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: PKS

CHECKED:

Golder Associates

RECORD OF BOREHOLE No CU5-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904843.4 ;E 299309.2
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 19, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
113.2	GROUND SURFACE													
0.0	Silty Clay, trace to some sand Stiff to very stiff Brown and grey Moist					▼	113							
			1	SS	9		112		o		0	6	56	38
			2	SS	24									
111.0 2.2	Silty Clay with sand, some gravel, occasional cobbles (TILL) Stiff to very stiff Brown Wet						111							
			3	SS	15				o					
			4	SS	8		110							
109.7 3.5	End of Borehole													

Shear strength legend: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; X REMOULDED. Scales: 20 40 60 80 100 (DCPT and shear strength); 20 40 60 (water content).

Notes:

1. Auger and spoon refusal at 3.5 m depth (Elev. 109.7 m)
2. Open borehole dry upon completion of drilling operations
3. Water level in piezometer at Elevation 112.9 m on December 13, 2003

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

Golder Associates

RECORD OF BOREHOLE No CU6-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904632.9 ;E 299951.9
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 17, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
114.9	GROUND SURFACE						
0.0	Sand and Gravel, some crushed asphalt (FILL) Compact Brown and black Moist	1	SS	23		o	
114.3 / 0.6	Silty Clay, some sand, trace gravel and limestone pieces (FILL) Firm Grey Moist	2	SS	29	114		7 23 39 31
113.4 / 1.5	Silty Clay, some sand, trace gravel Firm to very stiff Grey Moist	3	SS	7	113	o	
		4	SS	18	112		
		5	SS	20		o	
111.2 / 3.7	Silty Clay with sand, trace gravel (TILL) Very stiff Brown Moist to wet	6	SS	23	111		
110.3 / 4.6	End of Borehole						

Notes:

1. Auger and spoon refusal at 4.6 m depth (Elev. 110.3 m)
2. Water level at Elev. 111.5 m upon completion of drilling operations

Legend: 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³

+ 3, X 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No CU6-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904646.2 ;E 299958.0
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 20, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
114.9	GROUND SURFACE					
0.0	Organic Silty Clay, some sand, trace gravel and rootlets (FILL) Firm Brown and black Moist	1	SS	6		
114.3 / 0.6	Silty Clay, trace to some sand, trace limestone gravel and organics (FILL) Stiff Brown and grey Wet	2	SS	9	114	
		3	SS	9	113	0 4 33 63
112.8 / 2.1	Silty Clay, trace sand and gravel Very stiff Brown Moist	4	SS	21	112	
111.6 / 3.4	Silty Clay, some sand and gravel (TILL) Very stiff to hard Grey Moist	5	SS	21		
		6	SS	4/0.05	111	
110.9 / 4.0	End of Borehole					

Notes:

1. Auger and spoon refusal at 4.0 m depth (Elev. 110.9 m)
2. Water level at Elev. 111.2 m upon completion of drilling operations

Column headings: SOIL PROFILE; STRAT PLOT; 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, X REMOULDED, 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

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

Golder Associates

RECORD OF BOREHOLE No CU7-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904564.0 ;E 300101.8
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 17, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
114.5	GROUND SURFACE				
0.0	Sand and Gravel, including crushed limestone and asphalt, trace silt (FILL) Dense Brown and black Moist	1	SS	32	
113.7 0.8	Silty Clay, some sand, trace gravel and organics (FILL) Stiff Brown and grey Moist	2	SS	12	3 12 54 31
		3	SS	11	
112.4 2.1	Silty Clay, some sand, trace gravel Very stiff to stiff Brown and grey Moist	4	SS	20	
		5	SS	25	
		6	SS	14	
		7	SS	12	
108.4 6.1	End of Borehole				

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (114, 113, 112, 111, 110, 109); 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 (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Notes:

1. Auger and spoon refusal at 6.1 m depth (Elev. 108.4 m)
2. Open hole dry upon completion of drilling operations

MISS_MTO 03-1111-016 JACK AND BORE.GPJ ON_MOT.GDT 17/12/03

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

Golder Associates

RECORD OF BOREHOLE No CU7-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904579.8 ;E 300109.1
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 20, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
114.9	GROUND SURFACE								
0.0 / 0.2	Silty Sand, trace clay (FILL), Loose, Brown, Wet	1	SS	7					
	Silty Clay, some sand, trace gravel (FILL), Firm to stiff, Brown, Wet	2	SS	8	~24 (with plastic/liquid limits plotted)	3	10	57	30
113.4 / 1.5	Silty Clay, trace sand, gravel and organics, Stiff, Grey and black, Moist	3	SS	9					
112.9 / 2.0	Silty Clay, trace to some sand, Stiff to very stiff, Brown to brownish-grey, Moist	4	SS	18	~25				
		5	SS	21					
		6	SS	19	~24				
110.3 / 4.6	Silty Clay, some sand, trace to some gravel, occasional cobbles (TILL), Very stiff, Brown, Moist to wet	7	SS	50/0.08					
109.6 / 5.3	End of Borehole								

Notes:

1. Auger and spoon refusal at 5.3 m depth (Elev. 109.6m)
2. Water level at Elev. 110.3 m after completion of drilling operations

Legend: 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 (%) 20, 40, 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL. Elevation scale: 114, 113, 112, 111, 110.

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

MISS_MTO 03-1111-016 JACK AND BORE.GPJ ON_MOT.GDT 17/12/03

Golder Associates

RECORD OF BOREHOLE No CU7-3

METRIC

PROJECT 03-1111-016			ORIGINATED BY PKS
W.P. 76-99-01	LOCATION N 4904593.0 ;E 300115.2		COMPILED BY KG
DIST 42 HWY 401	BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger		CHECKED BY KN
DATUM Geodetic	DATE Nov. 18, 2003		

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
113.4	GROUND SURFACE					
0.0	Sand and Gravel, including crushed asphalt (FILL) Compact Brown Moist	1	SS	22	113	
112.8 / 0.6	Silty Clay, trace to some sand, trace gravel and rootlets (FILL) Firm to very stiff Grey Moist	2	SS	7	112	
		3	SS	16		0 8 45 47
111.3 / 2.1	Silty Clay, some sand, trace gravel, contains occasional sand seams Very stiff Brown to brownish-grey Moist	4	SS	24	111	
110.2 / 3.2	Silty Clay, some sand and gravel (TILL) Very stiff Brown Moist	5	SS	22	110	
		6	SS	3/0.05		
109.4 / 4.0	End of Borehole					

Chart column headings: STRAT PLOT; GROUND WATER CONDITIONS; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³

Notes:

1. Auger and spoon refusal at 4.0 m depth (Elev. 109.4 m)
2. Open hole dry upon completion of drilling operations
3. Water level in piezometer at Elevation 112.2 m on December 13, 2003

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

Golder Associates

RECORD OF BOREHOLE No CU8-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904356.8 ;E 300551.3
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 18, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
113.7	GROUND SURFACE						
0.0	Sand, some gravel including crushed asphalt, trace clay and rootlets (FILL) Compact Brown and black Moist	1	SS	14		w ≈ 12	
113.1 / 0.6	Silty Clay, some sand, trace gravel and organics (FILL) Stiff Brown Moist	2	SS	11	113		
112.2 / 1.8	Silty Clay, some sand, trace gravel (TILL) Stiff Brown Moist	3	SS	4/0.10	112	w ≈ 25	4 14 64 18
	End of Borehole						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Notes:

1. Auger and spoon refusal at 1.8 m depth (Elev. 111.9 m)
2. Open borehole dry upon completion of drilling operations

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

Golder Associates

RECORD OF BOREHOLE No CU8-2

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic

LOCATION N 4904373.0 :E 300558.7
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 20, 2003

ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
113.8	GROUND SURFACE					
0.0	Silty Clay, some sand, trace gravel, rootlets and organics (FILL) Firm Brown Moist	1	SS	5		
113.2 / 0.6	Silty Clay, some sand, trace gravel (FILL) Firm Brown Moist	2	SS	6	113	1 9 53 37
112.6 / 1.3	Organic Silty Clay	3	SS	11	112	
111.8 / 2.0	Silty Clay, some sand, trace gravel, including limestone fragments (TILL) Stiff Brown Moist to wet					
	Limestone (Bedrock) For coring details see Record of Drillhole CU8-2					
108.8 / 5.0	End of Borehole					

Notes:

1. Auger refusal at 2 m depth (Elev. 111.8 m)
2. Open borehole dry upon completion of drilling in overburden

Column headings: SOIL PROFILE; STRAT PLOT; 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, X REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

RECORD OF DRILLHOLE: CU8-2

SHEET 1 OF 1

PROJECT: 03-1111-016

LOCATION: N 4904373.0 ;E 300558.7

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: Nov. 20, 2003

DRILL RIG: CME 75

DRILLING CONTRACTOR: Marathon

DATUM: Geodetic

FR/FX-FRACTURE, F-FAULT, SM-SMOOTH, FL-FLEXURED, BC-BROKEN CORE, CL-CLEAVAGE, J-JOINT, R-ROUGH, UE-UNEVEN, MB-MECH BREAK, SH-SHEAR, P-POLISHED, ST-STEPPED, W-WAVY, B-BEDDING, VN-VEIN, S-SLICKENSIDED, PL-PLANAR, C-CURVED

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	COLOUR % RETURN FLUSH	TOTAL CORE %	SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
				111.80												
2	NQ Coring	LIMESTONE (BEDROCK), styolitic with occasional black shaley laminae Fresh to slightly weathered Strong to very strong Fine to medium grained		2.00	1		100						BC			
3					2		100						B-UE, PL, SM			
4		0.1 m thick weak black SHALE bed at 3.9 m depth			3		100									
5				108.80 5.00												
		End of Drillhole														

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: PKS

CHECKED:

MISS_ROCK 03-1111-026JACK AND BORE ROCK LOGS.GPJ GAL-CANADA.GDT 17/12/03 KG

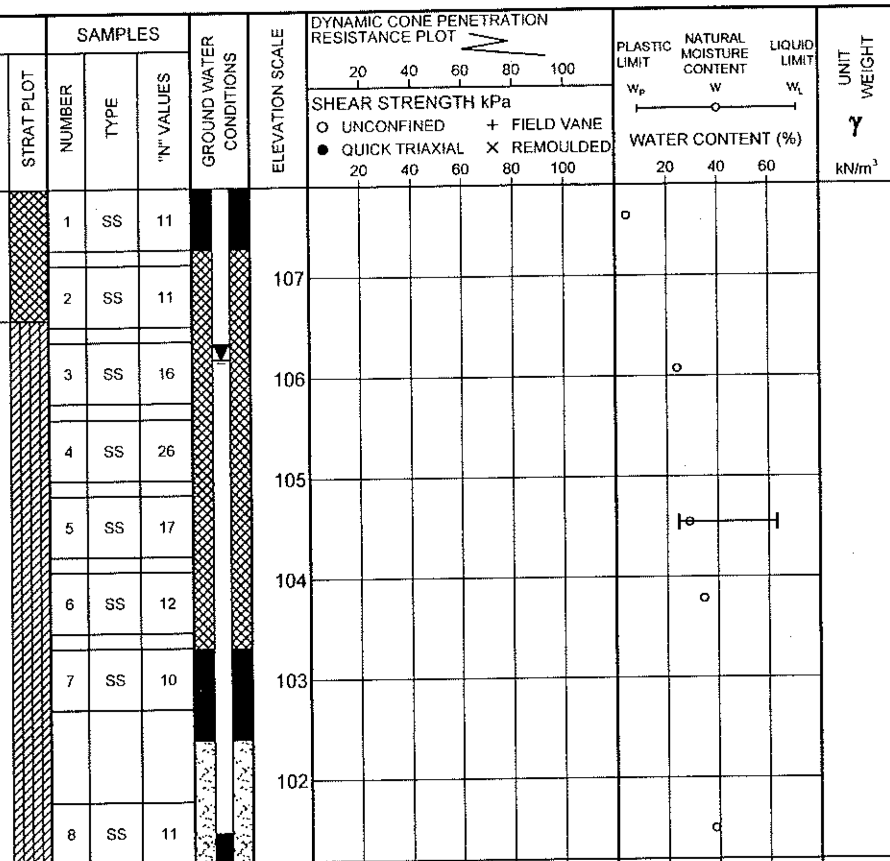
Golder Associates

RECORD OF BOREHOLE No CU9-1

METRIC

PROJECT 03-1111-016
W.P. 76-99-01
DIST 42 HWY 401
DATUM Geodetic
LOCATION N 4905151.8 ;E 299131.2
BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger
DATE Nov. 17, 2003
ORIGINATED BY PKS
COMPILED BY KG
CHECKED BY KN

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
107.9	GROUND SURFACE					
0.0	Sand, trace gravel to Sand and Gravel, including crushed asphalt pieces, trace silt (FILL) Compact Brown Moist	1	SS	11		
		2	SS	11	107	
106.6 / 1.3	Silty Clay, trace sand, occasional gravel and sandy silt seams Stiff to very stiff Brown to grey Moist	3	SS	16	106	
		4	SS	26	105	
	Becomes grey below 3.0 m depth	5	SS	17		0 3 44 53
		6	SS	12	104	
		7	SS	10	103	
					102	
		8	SS	11		
101.2 / 6.7	End of Borehole					



Notes:

1. Open borehole dry upon completion of drilling operations
2. Water level in piezometer at Elevation 106.2 m on December 13, 2003

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

Golder Associates

RECORD OF BOREHOLE No CU9-2

METRIC

PROJECT 03-1111-016

W.P. 76-99-01

LOCATION N 4905148.0 ;E 299119.1

ORIGINATED BY PKS

DIST 42 HWY 401

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger

COMPILED BY KG

DATUM Geodetic

DATE Nov. 18, 2003

CHECKED BY KN

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
106.4	GROUND SURFACE				
0.0	Silty Clay, some sand, trace gravel Very stiff Grey and brown Moist	1	SS	16	
105.6 0.8	Silty Clay, trace sand, occasional sand seams Very stiff to stiff Brown to grey Moist	2	SS	21	
		3	SS	20	0 4 43 53
	Becomes grey below 2.3 m depth	4	SS	17	
	Becomes stiff below 3.0 m depth	5	SS	11	
		6	SS	11	
		7	SS	10	
100.6 5.8	Silty Clay with sand, some gravel (TILL) Firm Grey Moist	8	SS	7	
100.0 6.4	End of Borehole				

Elevation scale: 106, 105, 104, 103, 102, 101, 100

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³

Notes:

1. Auger and spoon refusal at 6.4 m depth (Elev. 100 m)
2. Open borehole dry upon completion of drilling operations

$+^3, X^3$: Numbers refer to Sensitivity

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

DRAWINGS

DIST. 42 HWY. 401
CONT No.2003–4010
WP No.76–99–01

SHEET 95

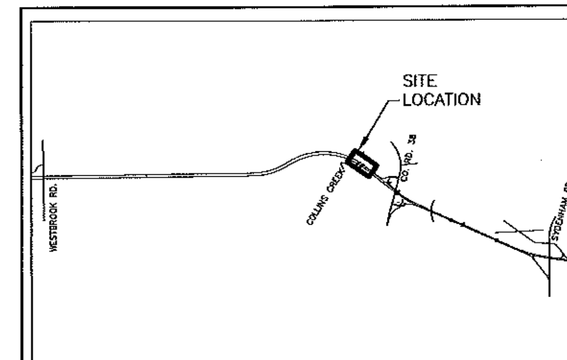
SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS

Golder Associates

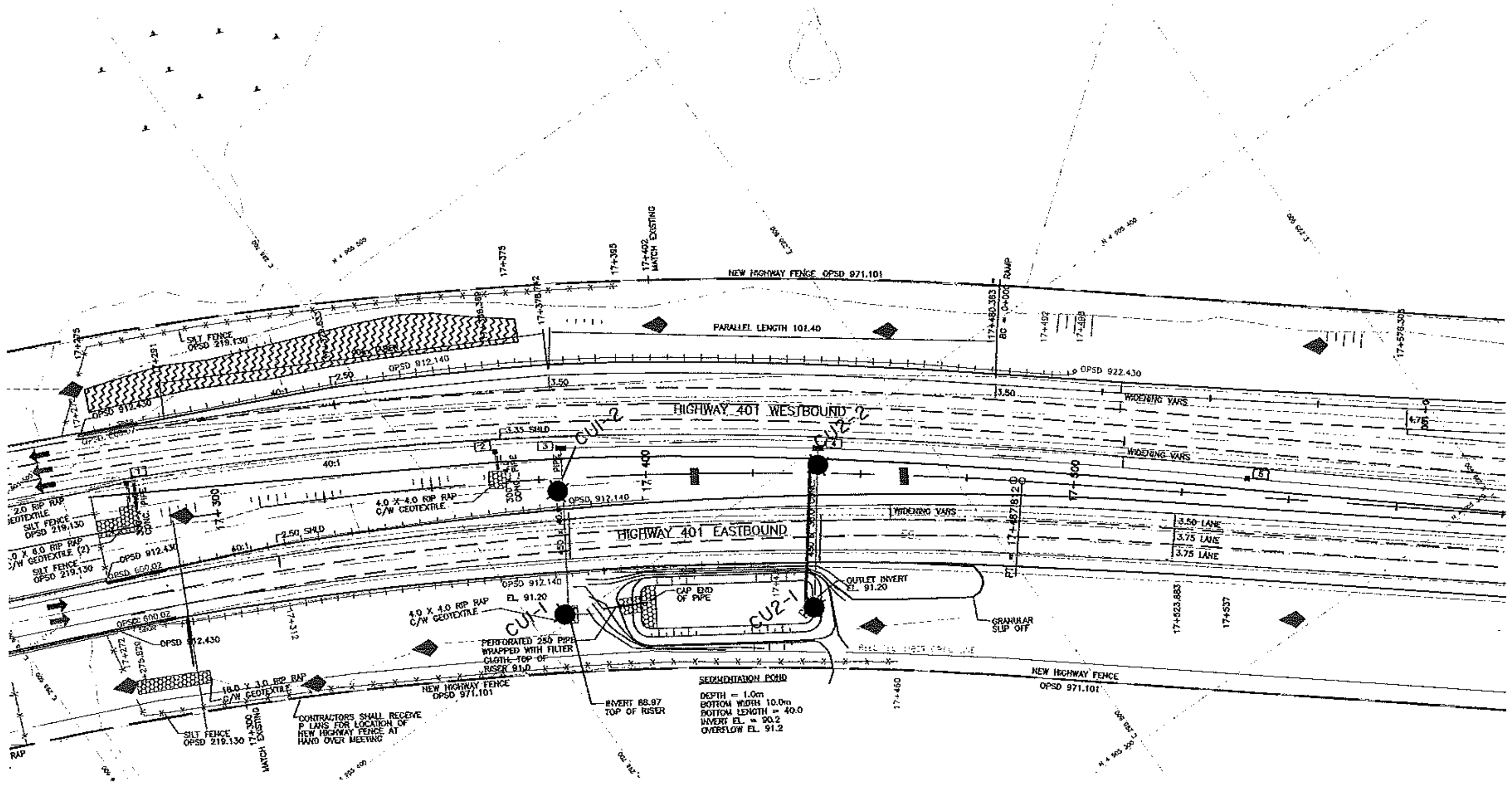
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



KEY PLAN



PLAN

15 0 15 30
SCALE METRES

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
CU1–1	89.0	4905401.9	298707.4
CU1–2	92.8	4905426.5	298722.8
CU2–1	92.0	4905369.7	298755.8
CU2–2	94.4	4905396.5	298775.8

NOTES

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

REFERENCE

Base plans provided in digitial format by MTO, drawing file nos. n–17250.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03–1111–016	DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

PLOT DATE: May 07, 2004

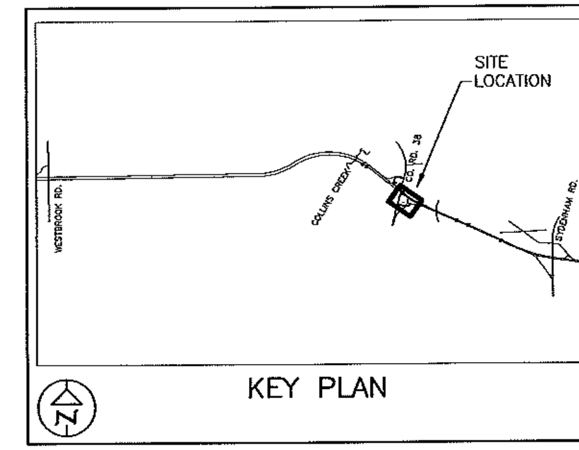
MINISTRY OF TRANSPORTATION, ONTARIO

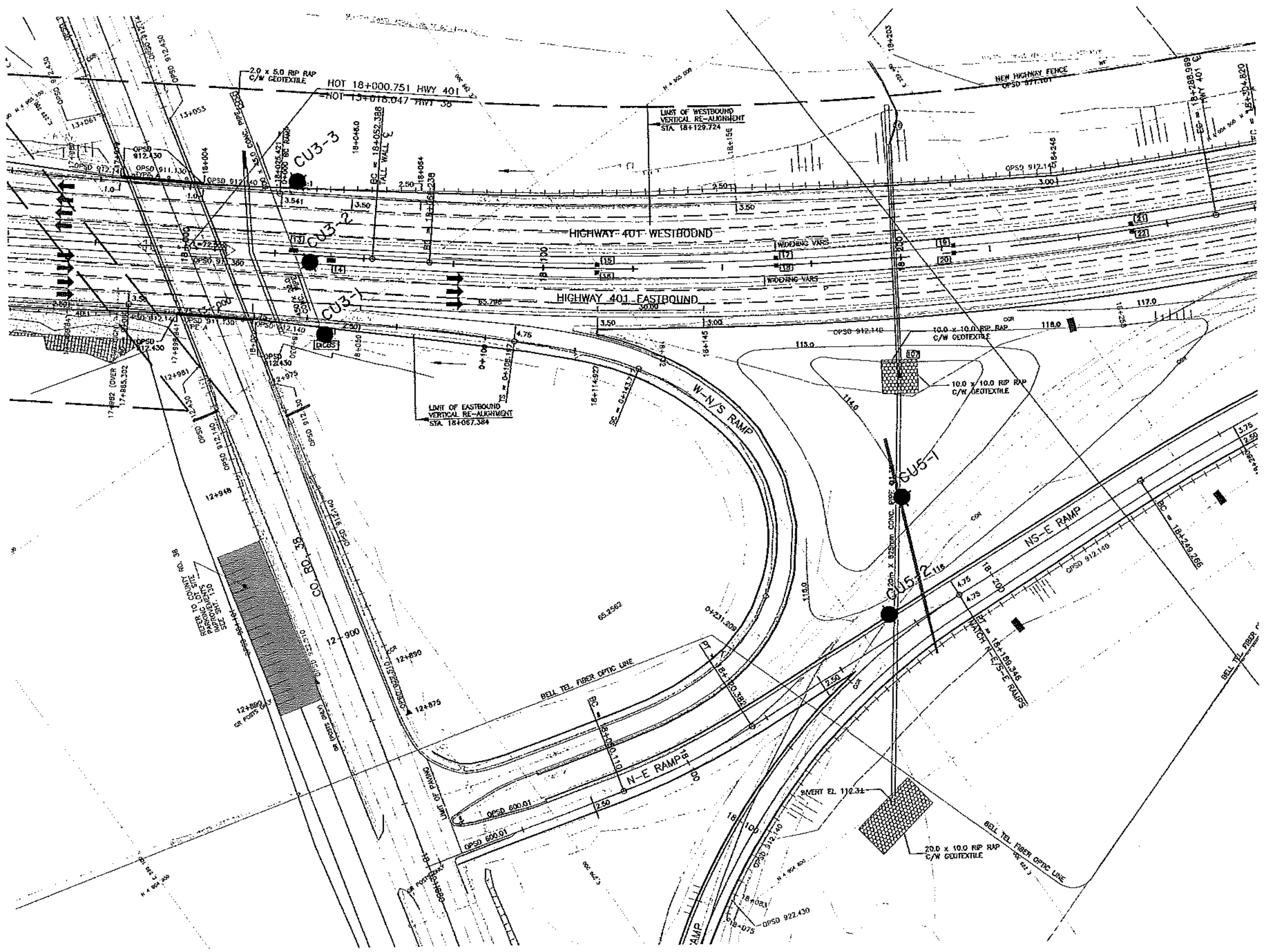
DIST. 42 HWY. 401 CONT No. 2003–4010 WP No. 76–99–01	
SEWER/CULVERT CROSSINGS HIGHWAY 401 WIDENING BOREHOLE LOCATIONS	SHEET 99

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN





PLAN

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES NORTHING	EASTING
CU3–1	111.9	4904999.5	299226.9
CU3–2	111.6	4905018.4	299235.3
CU3–3	111.3	4905039.0	299245.7
CU5–1	115.8	4904868.3	299331.4
CU5–2	113.2	4904843.4	299309.2

NOTES

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

REFERENCE

Base plans provided in digital format by MTO, drawing file nos. n–17950.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03–1111–016	DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 2

PLOT DATE: May 07, 2004

DIST. 42 HWY. 401
CONT No. 2003–4010
WP No. 76–99–01

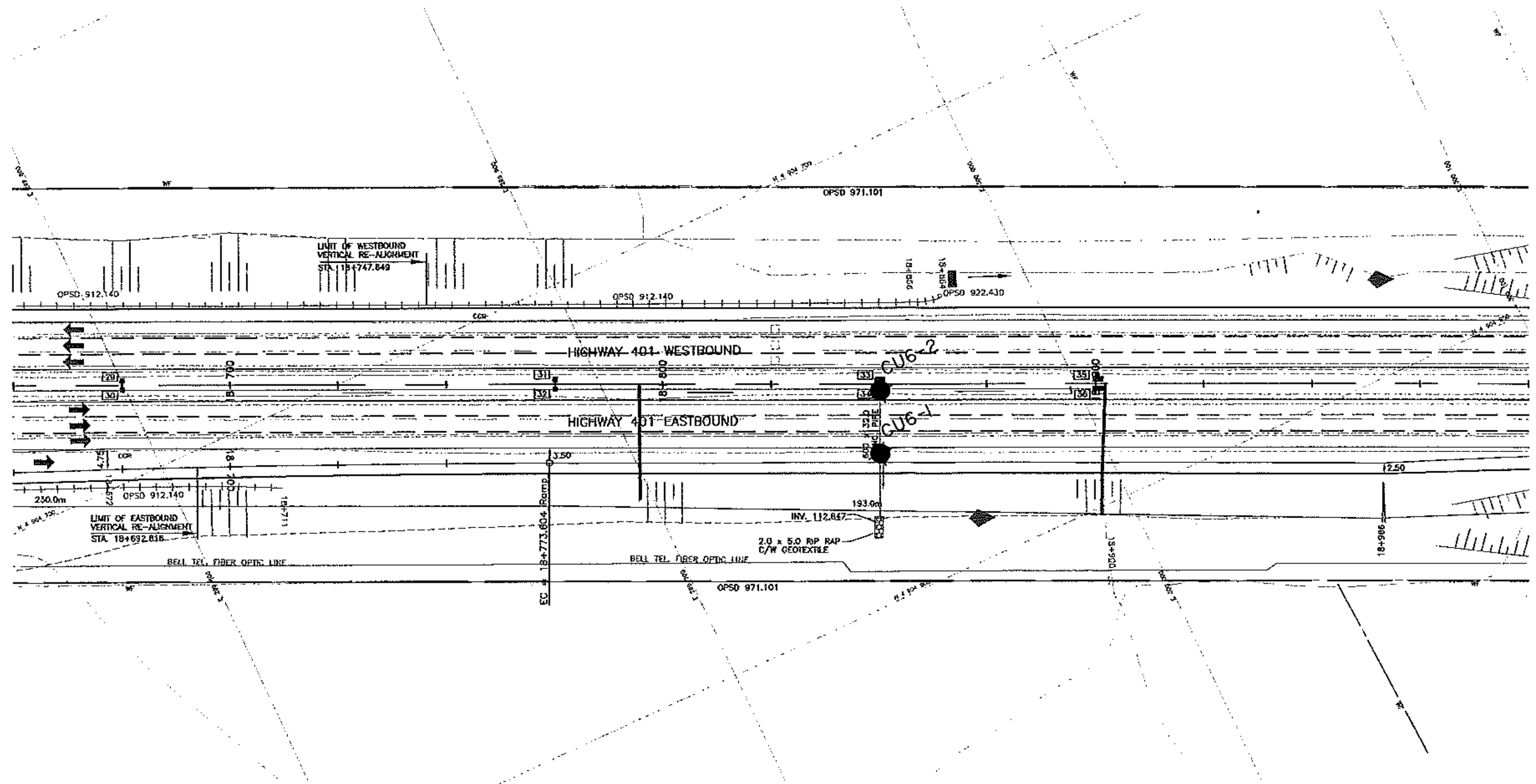
SHEET 103

SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

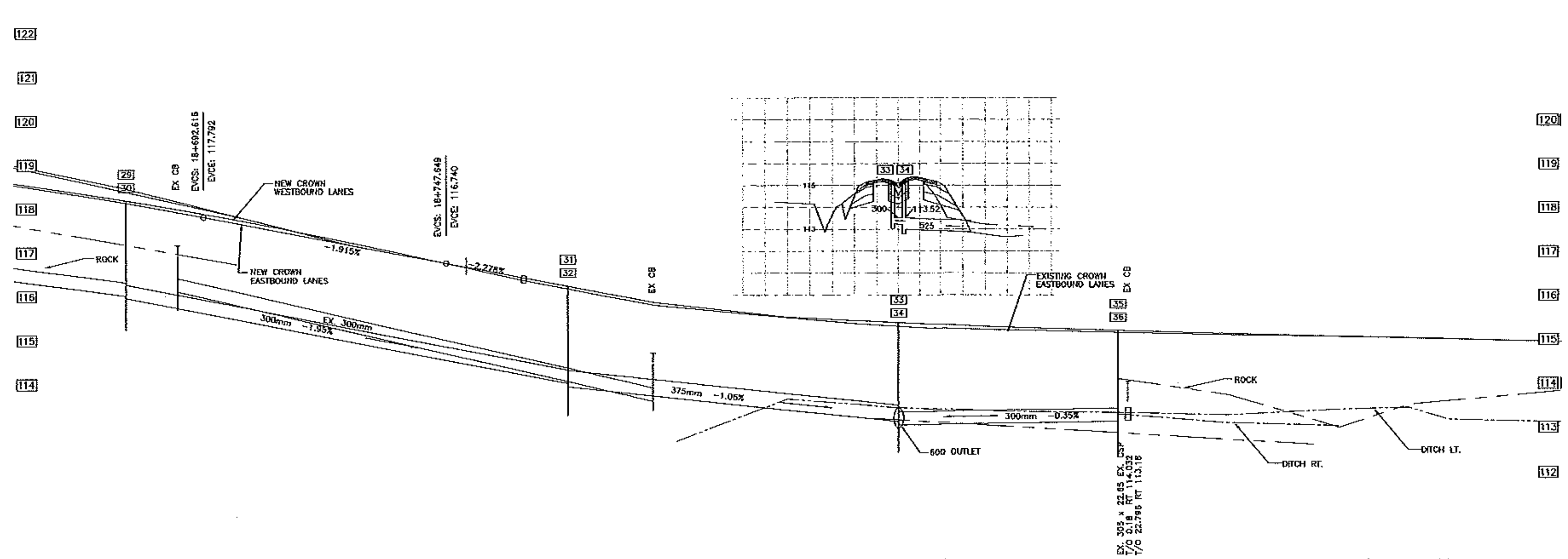
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



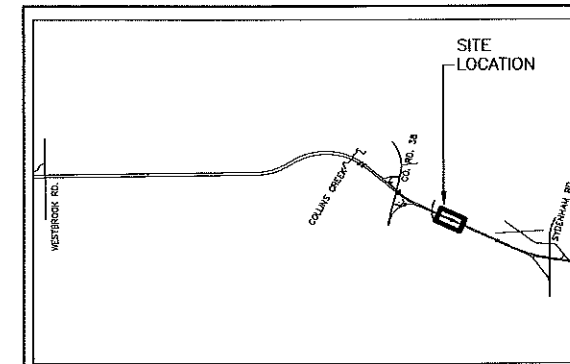
PLAN

15 0 15 30
SCALE METRES



SECTION/PROFILE

15 0 15 30
SCALE METRES



KEY PLAN

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
CU6–1	114.9	4904632.9	299951.9
CU6–2	114.9	4904646.2	299958.0

NOTES

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

REFERENCE

Base plans provided in digitial format by MTO, drawing file nos. n–18650.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03–1111–016	DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 3

MINISTRY OF TRANSPORTATION, ONTARIO

PLOT DATE: May 07, 2004

DIST. 42 HWY. 401
CONT No. 2003–4010
WP No. 76–99–01

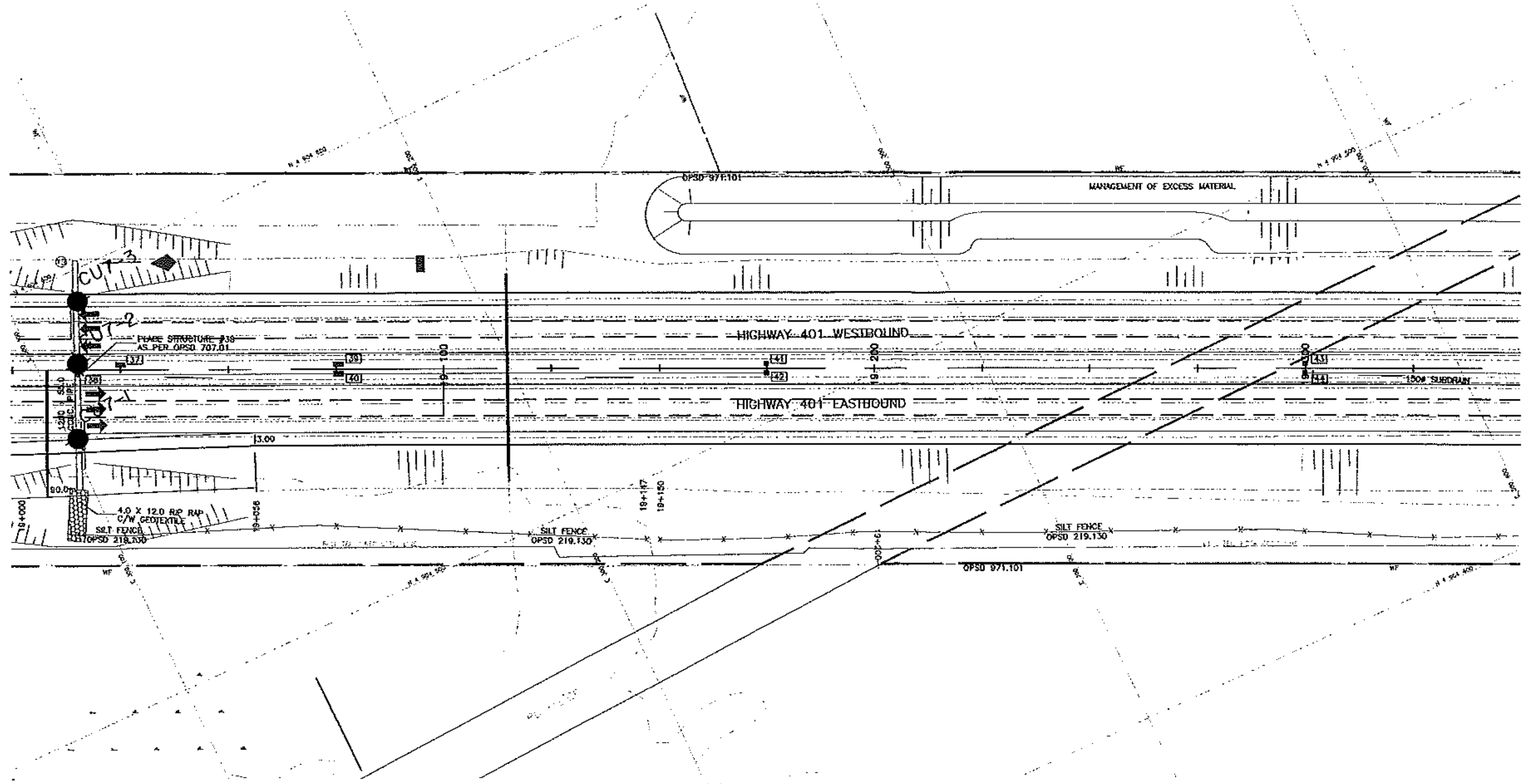
SHEET 104

SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

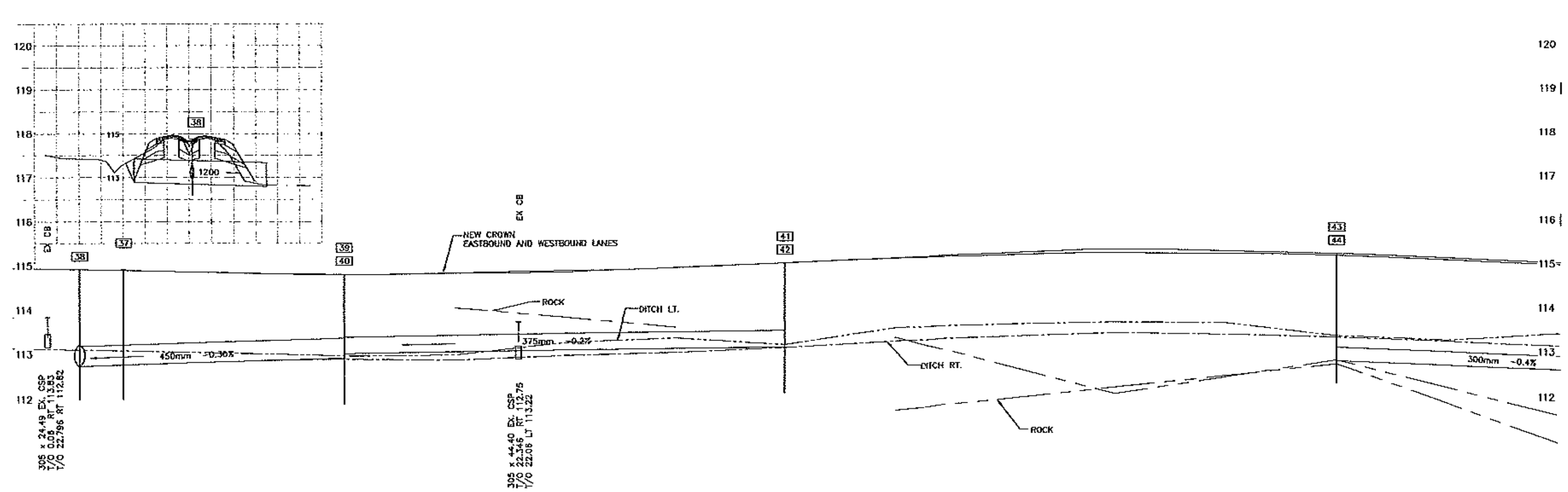
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



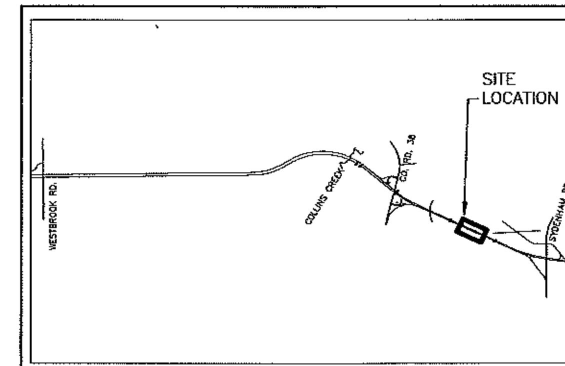
PLAN

15 0 15 30
SCALE METRES



SECTION/PROFILE

15 0 15 30
SCALE METRES



KEY PLAN

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
CU7–1	114.5	4904564.0	300101.8
CU7–2	114.9	4904579.8	300109.1
CU7–3	113.4	4904593.0	300115.2

NOTES

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

REFERENCE

Base plans provided in digital format by MTO, drawing file nos. n–19000.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03–1111–016	DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 4

DIST. 42 HWY. 401
CONT No. 2003-4010
WP No. 76-99-01

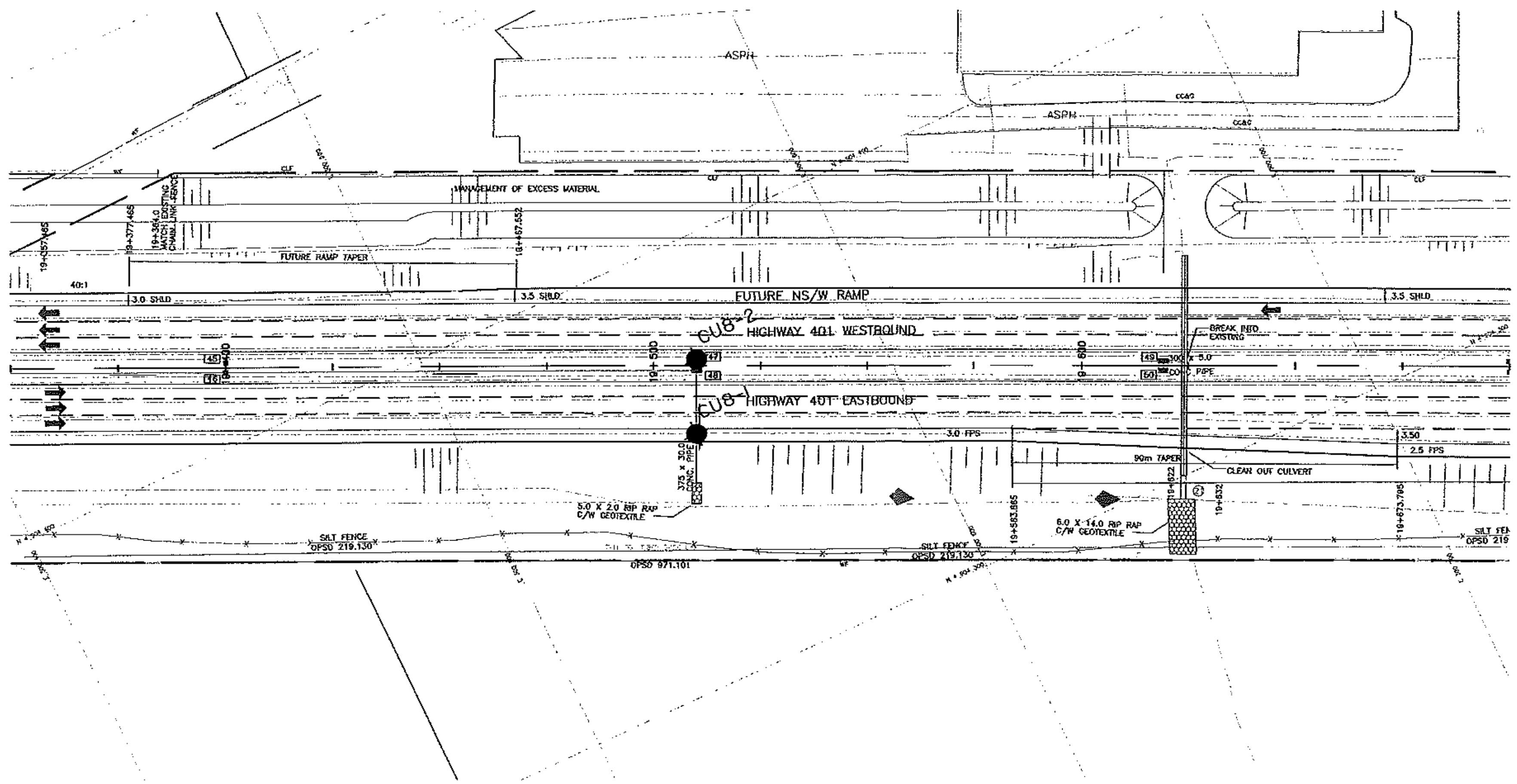
SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS

SHEET 105

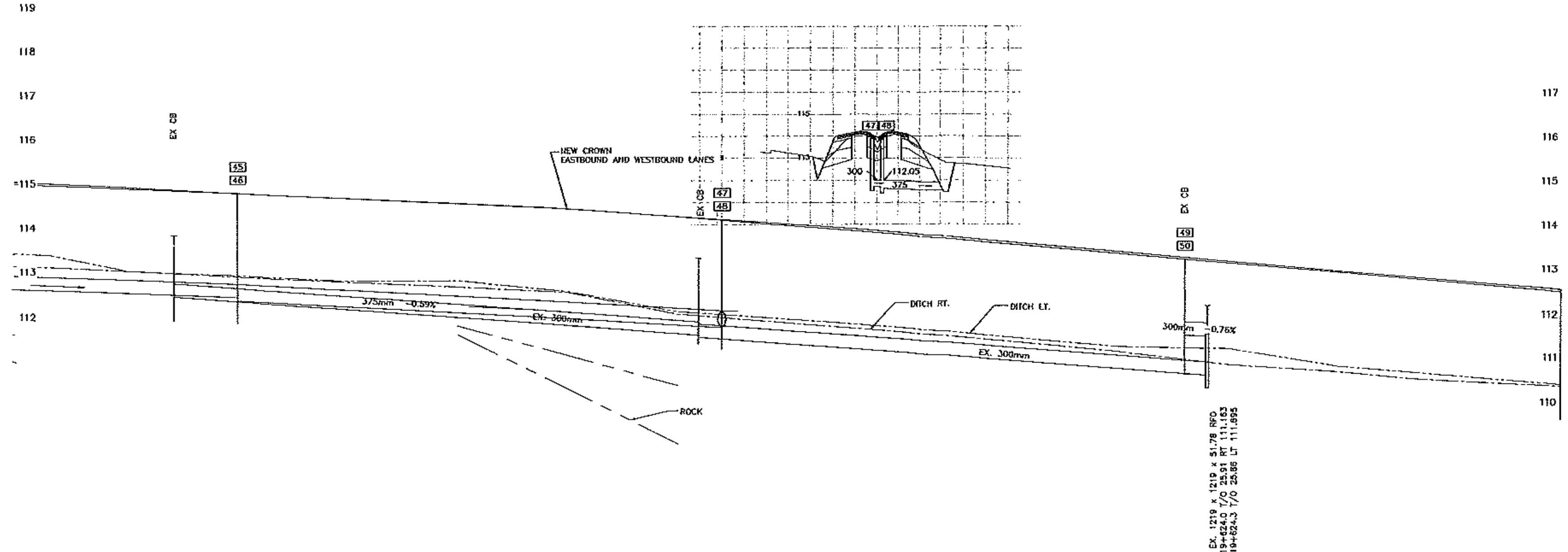
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC

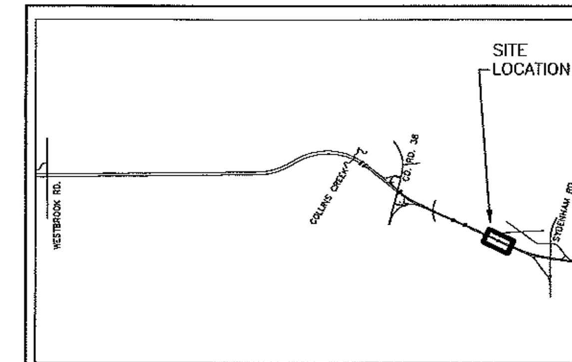
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN
15 0 15 30
SCALE METRES



SECTION/PROFILE
15 0 15 30
SCALE METRES



KEY PLAN

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES NORTHING	CO-ORDINATES EASTING
CU8-1	113.7	4904356.8	300551.3
CU8-2	113.8	4904372.6	300558.7

NOTES

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

REFERENCE

Base plans provided in digital format by MTO, drawing file nos. n-19350.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401	PROJECT NO. 03-1111-016		DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 5

MINISTRY OF TRANSPORTATION, ONTARIO

DIST. 42 HWY. 401
CONT No. 2003–4010
WP No. 76–99–01

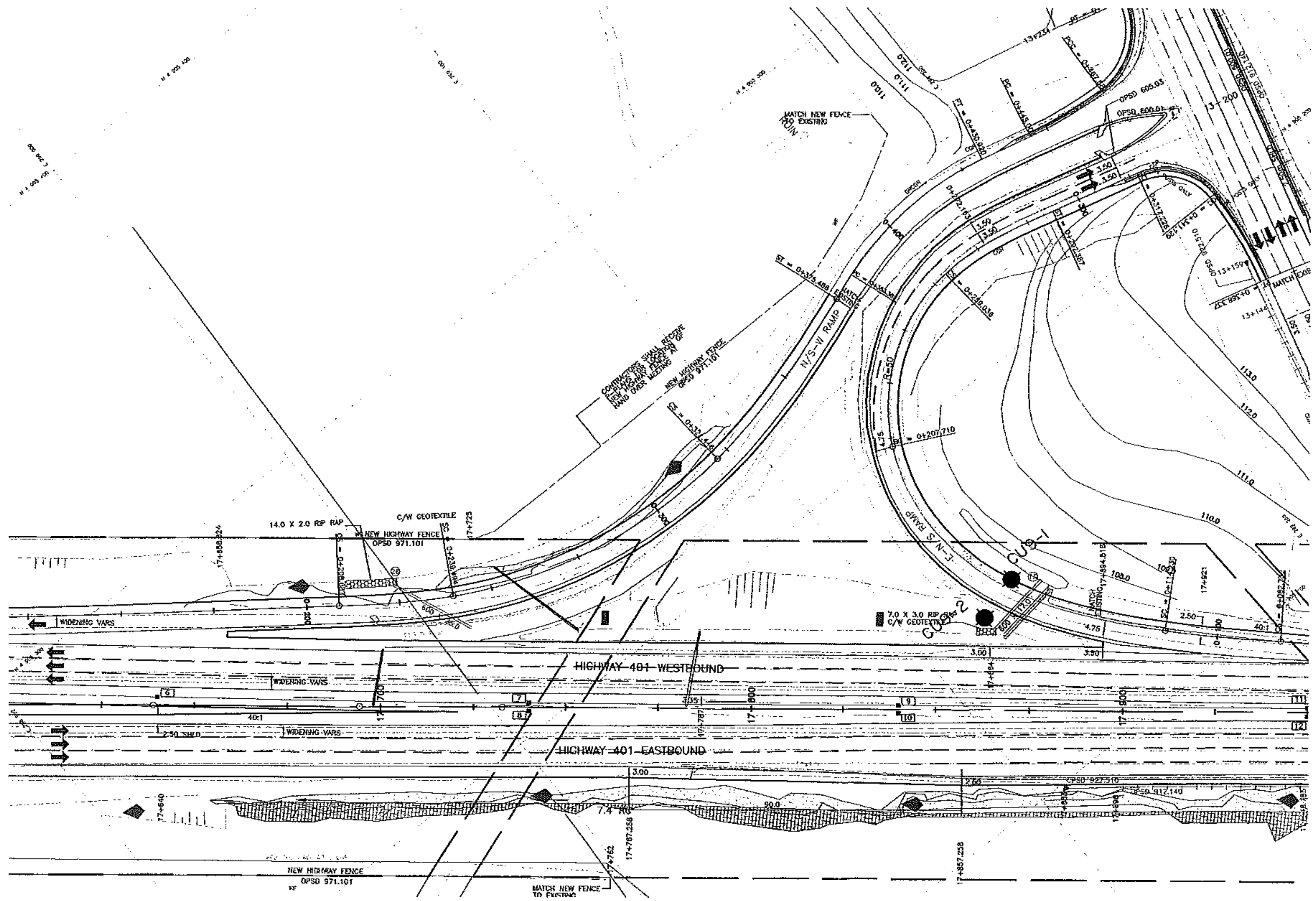
SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
BOREHOLE LOCATIONS

SHEET 97

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

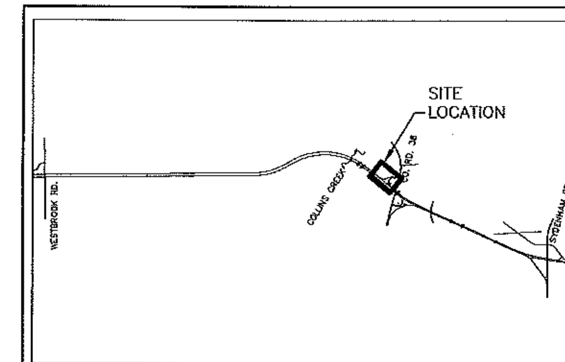
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN

15 0 15 30
SCALE METRES



KEY PLAN

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
CU9–2	106.4	4905148.0	299119.1
CU9–1	107.9	4905151.8	299131.2

NOTES

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

REFERENCE

Base plans provided in digitial format by MTO, drawing file nos. n–1760.dwg, received DECEMBER 1, 2003.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03–1111–016	DIST. 42
SUBM'D.	CHKD. KN	DATE: DEC., 2003	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 6

PLOT DATE: May 07, 2004

MINISTRY OF TRANSPORTATION, ONTARIO

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

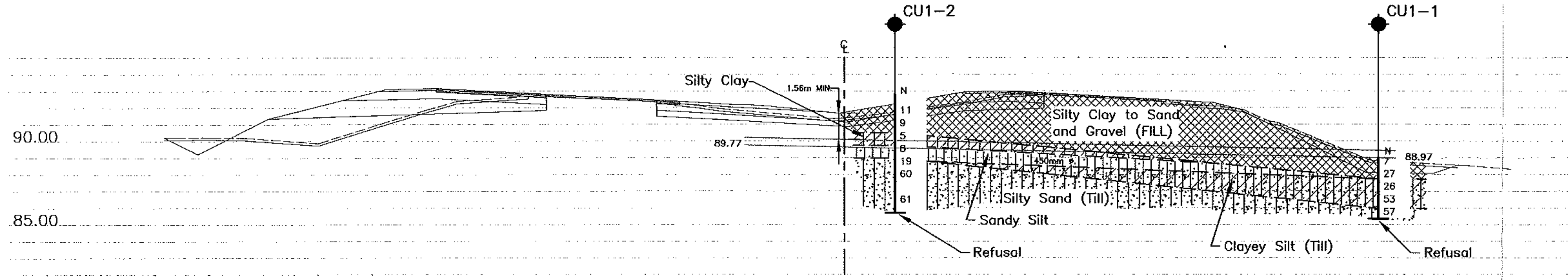
CONT No. 2003-4010
WP No. 76-99-01

SHEET

SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
SECTIONS

Golder Associates

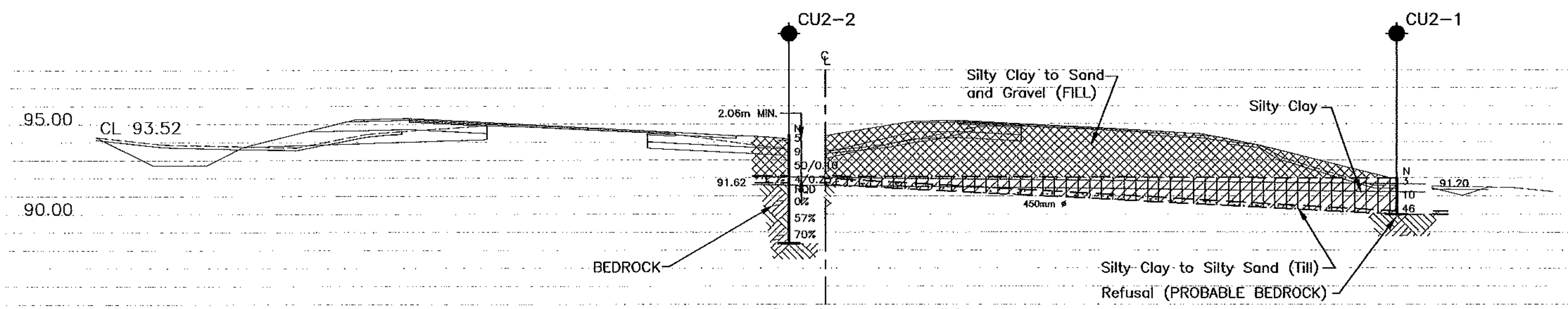
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



450mm DIA. SEWER
ACT. STA. = 17+380
6m LT. - 33m RT.
(STR #3 - OUTLET)
MIN. COVER = 1.56m

SECTION AT STN 17+379
CROSSING LOCATION 1

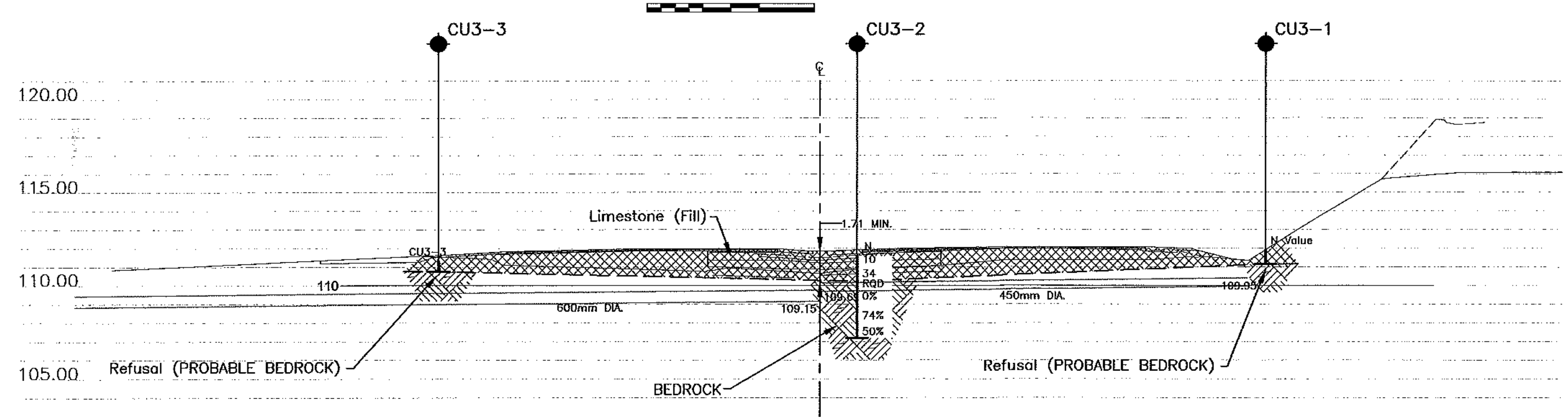
SCALE 3 0 3 6 m



450mm DIA. SEWER
ACT. STA. = 17+440
4m LT. - 33m RT.
(STR #4 - OUTLET)
MIN. COVER = 2.06m

SECTION AT STN 17+450
CROSSING LOCATION 2

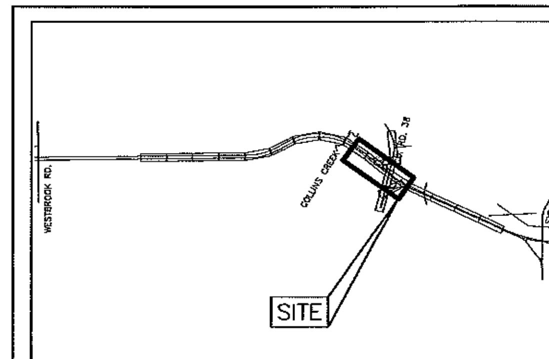
SCALE 3 0 3 6 m



450mm / 600mm DIA. SEWER
ACT. STA. = 18+010 - 18+040
40m LT. - 23m RT.
(DICB'S" - STR #13 - OUTLET)
MIN. COVER = 1.71m

SECTION AT STN 18+025
CROSSING LOCATION 3 & 4

SCALE 3 0 3 6 m



KEY PLAN
SCALE 1 0 1 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation 1
- Borehole - Previous Investigation 2
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling
- Proposed Sewer Crossing

No.	ELEVATION	CO-ORDINATES NORTHING	CO-ORDINATES EASTING
CU1-1	89.0	4905401.9	298707.4
CU1-2	92.8	4905426.5	298722.8
CU2-1	92.0	4905369.7	298755.8
CU2-2	94.4	4905396.5	298775.8
CU3-1	111.9	4904999.5	299226.9
CU3-2	111.6	4905018.4	299235.3
CU3-3	111.3	4905039.0	299245.7

NOTES

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.

For subsurface information only.

REFERENCE

Base plans provided in digital format by Greer Galloway Group, drawing file nos. JACK_BORE_XS (2).dwg, received March 22, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 401		PROJECT NO. 03-1111-016	DIST. 42
SUBM'D.	CHKD.	DATE: APRIL 2004	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 7

PLOT DATE: May 07, 2004

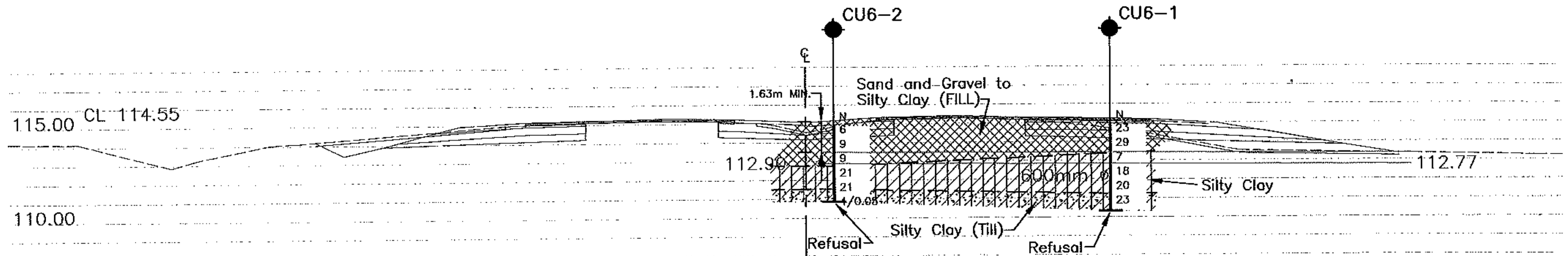
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2003-4010
WP No. 76-99-01

SEWER/CULVERT CROSSINGS
HIGHWAY 401 WIDENING
SECTIONS

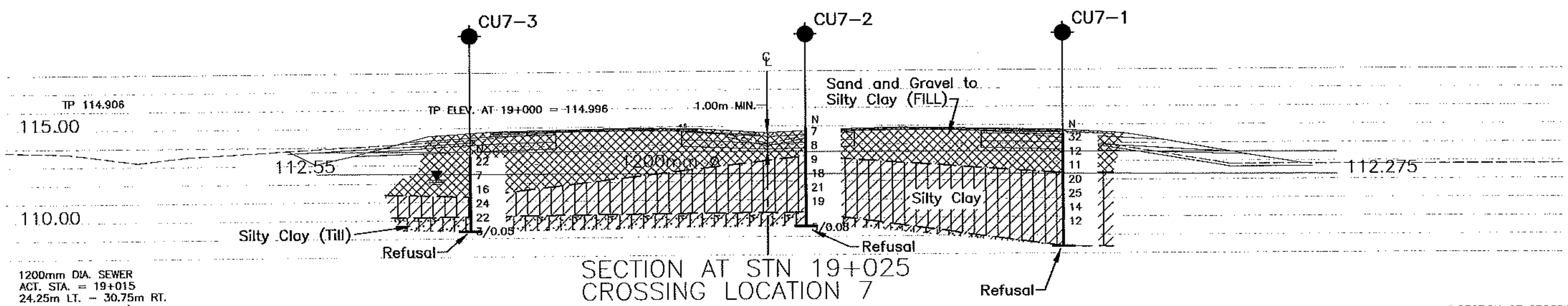
SHEET

Golder Associates
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



600mm DIA. SEWER
ACT. STA. = 18+850
0.85m RT. – 32m RT.
(STR #34 – OUTLET)
MIN. COVER = 1.63m

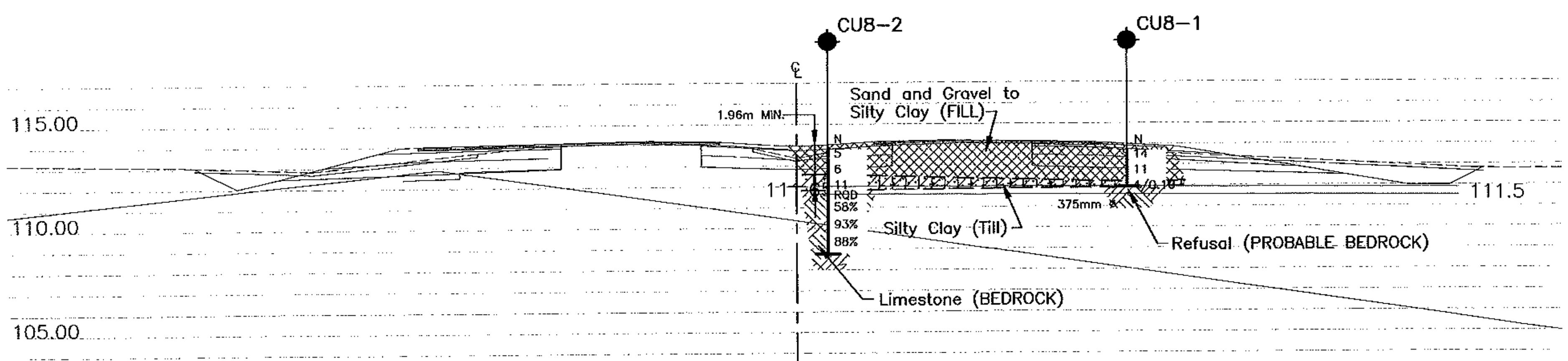
SECTION AT STN 18+850
CROSSING LOCATION 6



1200mm DIA. SEWER
ACT. STA. = 19+015
24.25m LT. – 30.75m RT.
(CROSSING CULVERT)
MIN. COVER = 1.00m

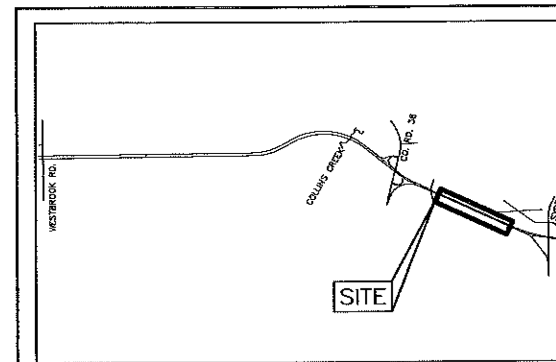
SECTION AT STN 19+025
CROSSING LOCATION 7

* – NOTE: ACTUAL CULVERT CROSSING IS LOCATED AT 19+015. GRADE IS INCREASING IN DIRECTION OF CROSSING. THEREFORE, THE ACTUAL DEPTH OF COVER OVER THE CULVERT CROSSING WILL BE IN EXCESS OF THAT INDICATED ABOVE. THIS CROSS SECTION SHALL BE CONSIDERED A "WORSTE-CASE" SCENARIO.



375mm DIA. SEWER
ACT. STA. = 19+510
0.85m RT. – 32m RT.
(STR #48 – OUTLET)
MIN. COVER = 1.96m

SECTION AT STN 19+500
CROSSING LOCATION 8



KEY PLAN
SCALE 1 0 1 km

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation 1
- Borehole – Previous Investigation 2
- Dynamic Cone Penetration Test
- Borehole and Cone
- Probehole
- Test Pit
- 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 MMM DD, YYYY
- WL upon completion of drilling
- Proposed Sewer Crossing

No.	ELEVATION	CO-ORDINATES NORTHING	CO-ORDINATES EASTING
CU6-1	114.9	4904632.9	299951.9
CU6-2	114.9	4904646.2	299958.0
CU7-1	114.5	4904564.0	300101.8
CU7-2	114.9	4904579.8	300109.1
CU7-3	113.4	4904593.0	300115.2
CU8-1	113.7	4904356.8	300551.3
CU8-2	113.8	4904372.6	300558.7

NOTES

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.

For subsurface information only.

REFERENCE

Base plans provided in digital format by Greer Galloway Group, drawing file nos. JACK_BORE_XS (2).dwg, received March 22, 2004.

NO.	DATE	BY	REVISION

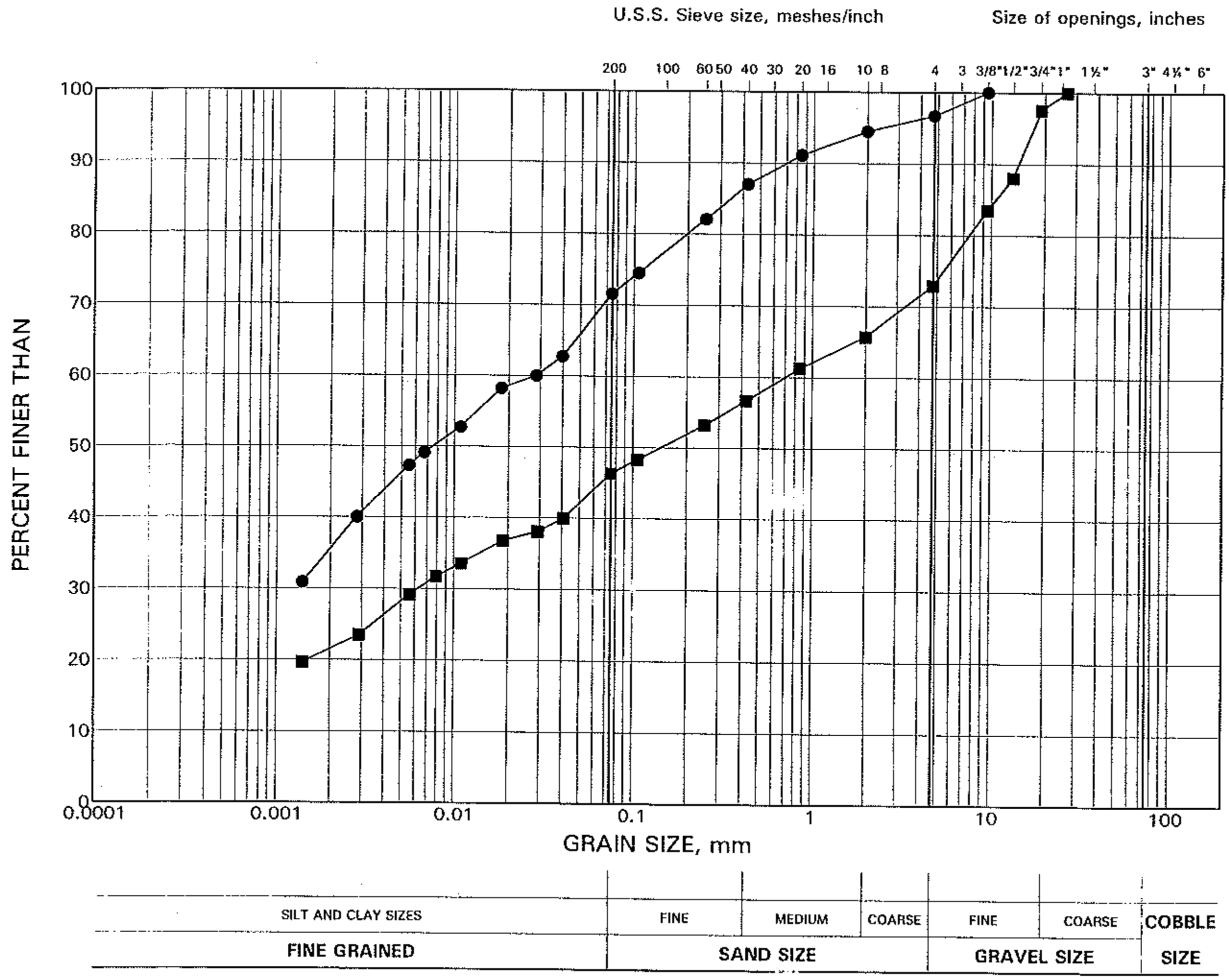
Geocres No.			
HWY. 401		PROJECT NO. 03-1111-016	DIST. 42
SUBM'D.	CHKD.	DATE: APRIL 2004	SITE:
DRAWN: JDR	CHKD.	APPD.	DWG. 8

APPENDIX A

LABORATORY TESTING DATA

GRAIN SIZE DISTRIBUTION
Silty Clay (Fill)

FIGURE A1

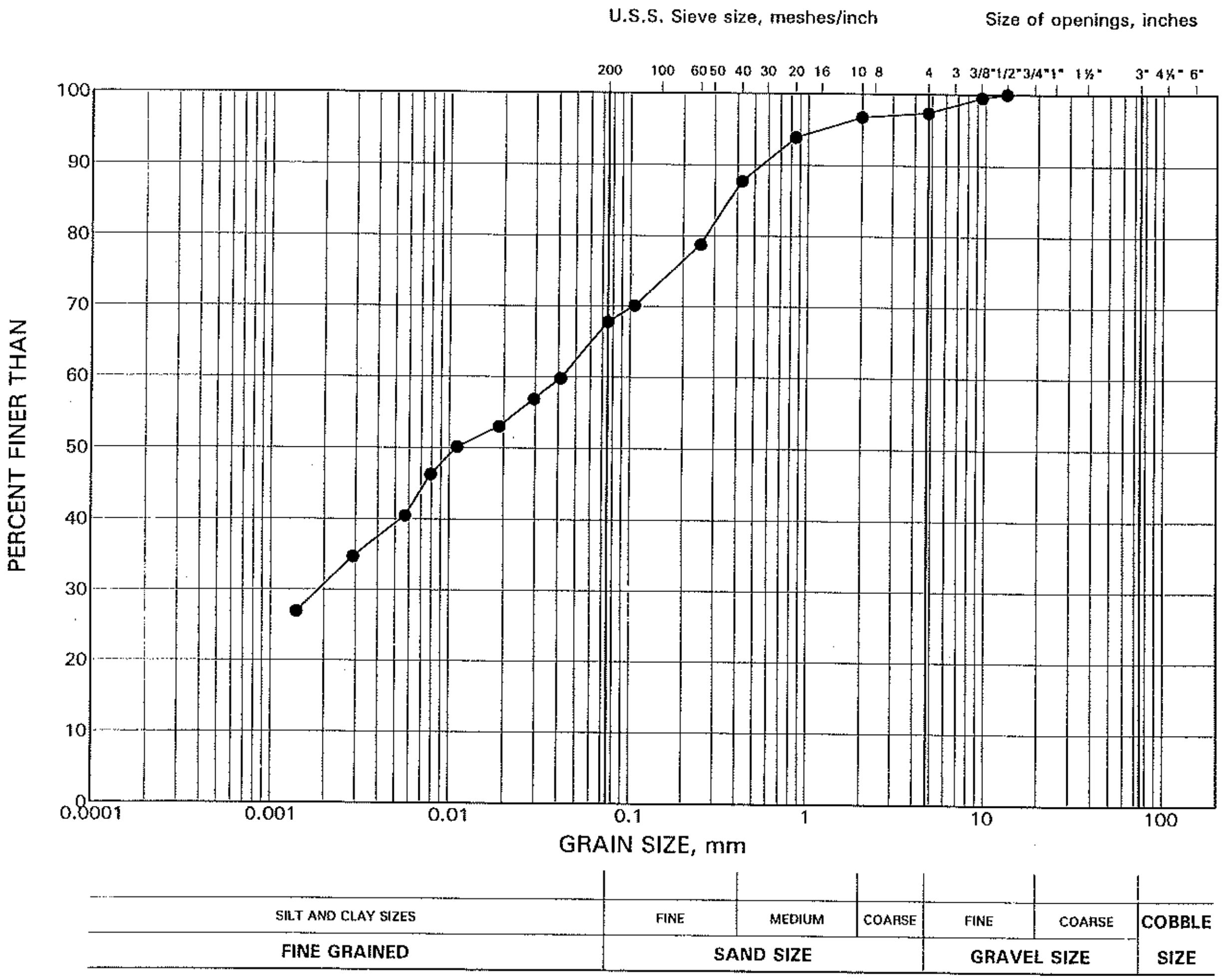


LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU1-1	1	0-0.6
■	CU1-2	2	1.5-1.9

GRAIN SIZE DISTRIBUTION
Silty Clay

FIGURE A2

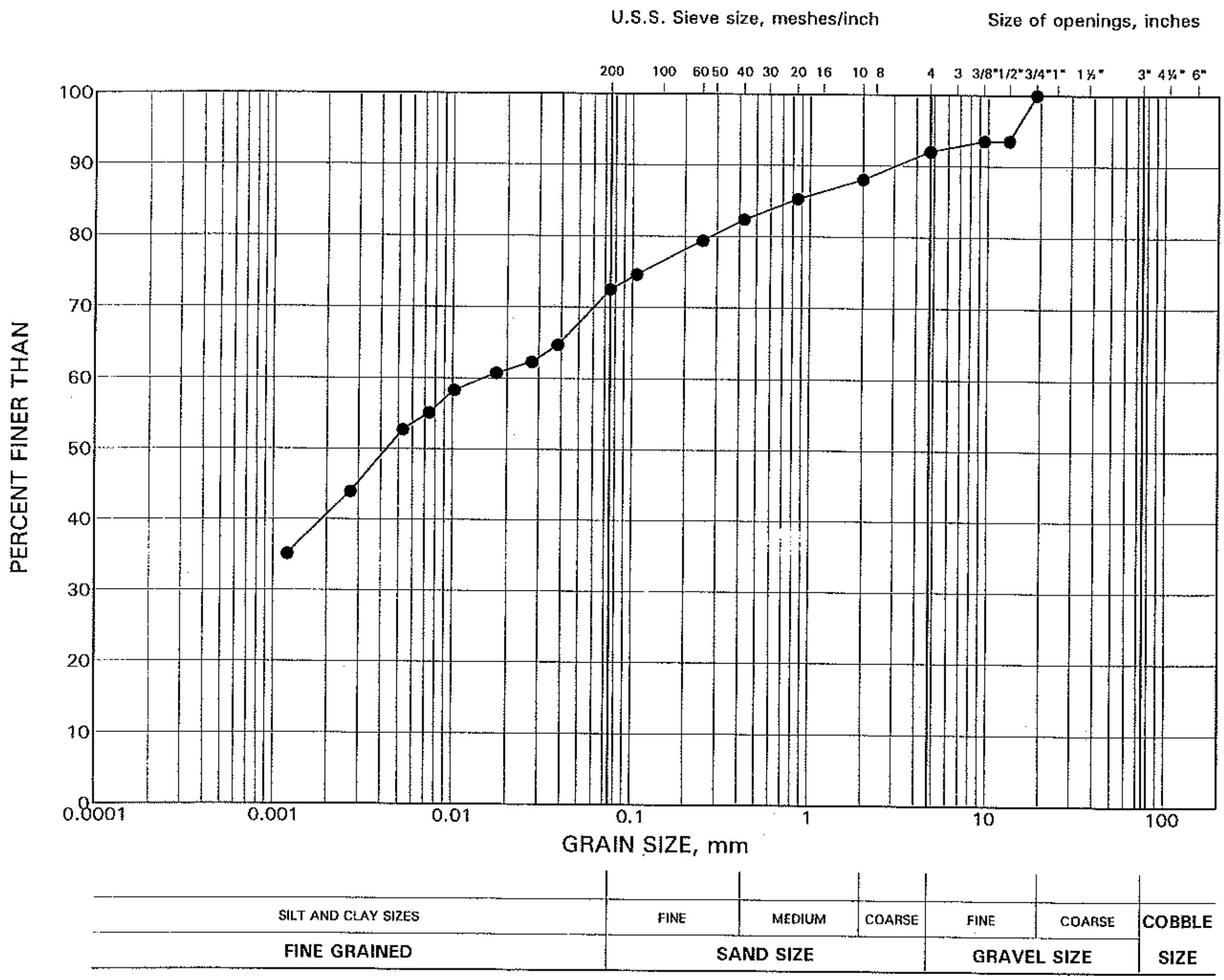


LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU2-1	1	0.0-0.6

GRAIN SIZE DISTRIBUTION
Silty Clay (Fill)

FIGURE A3

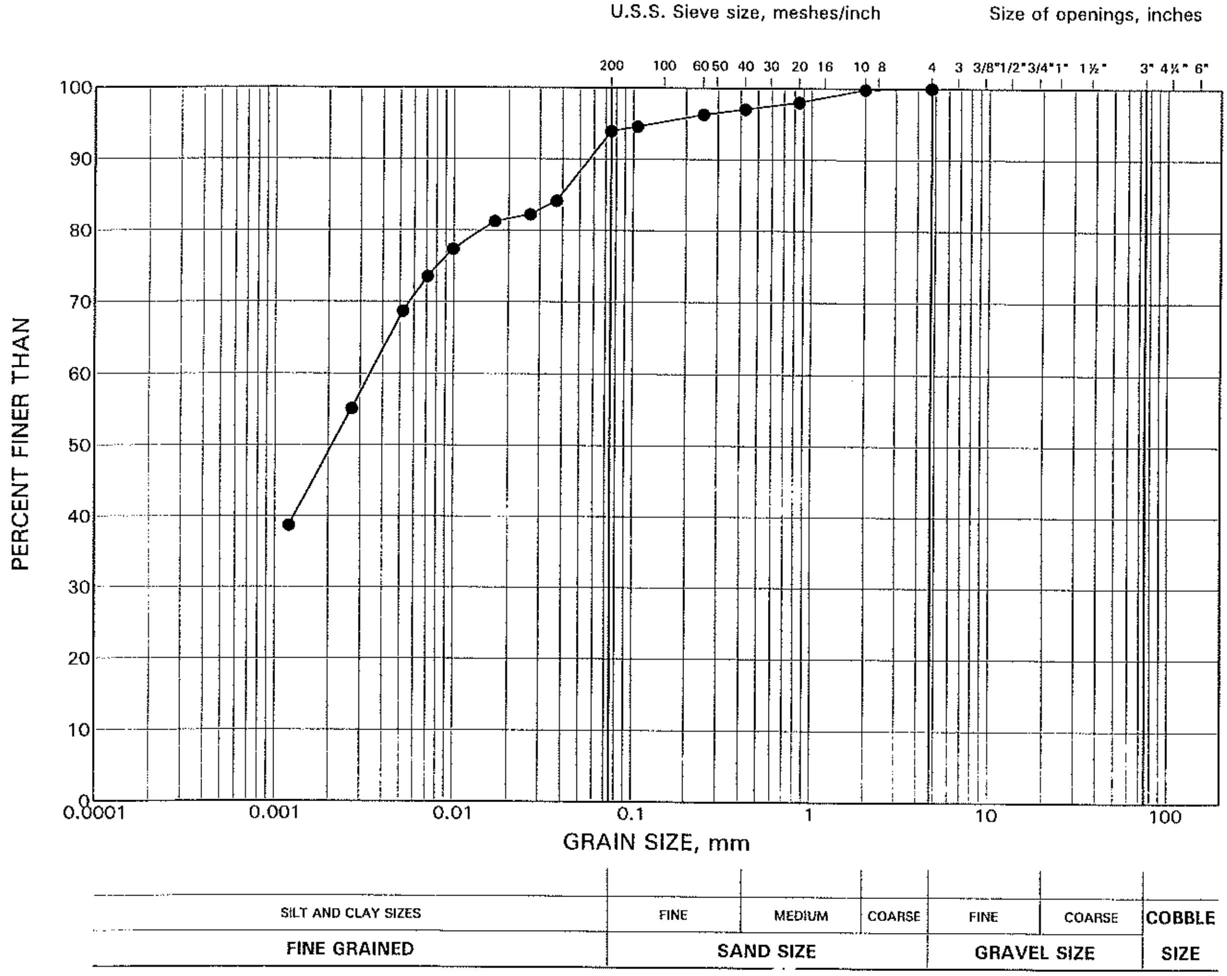


LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU2-2	3	1.5-1.6

GRAIN SIZE DISTRIBUTION
Silty Clay

FIGURE A4



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU-5-2	1	0.8-1.4

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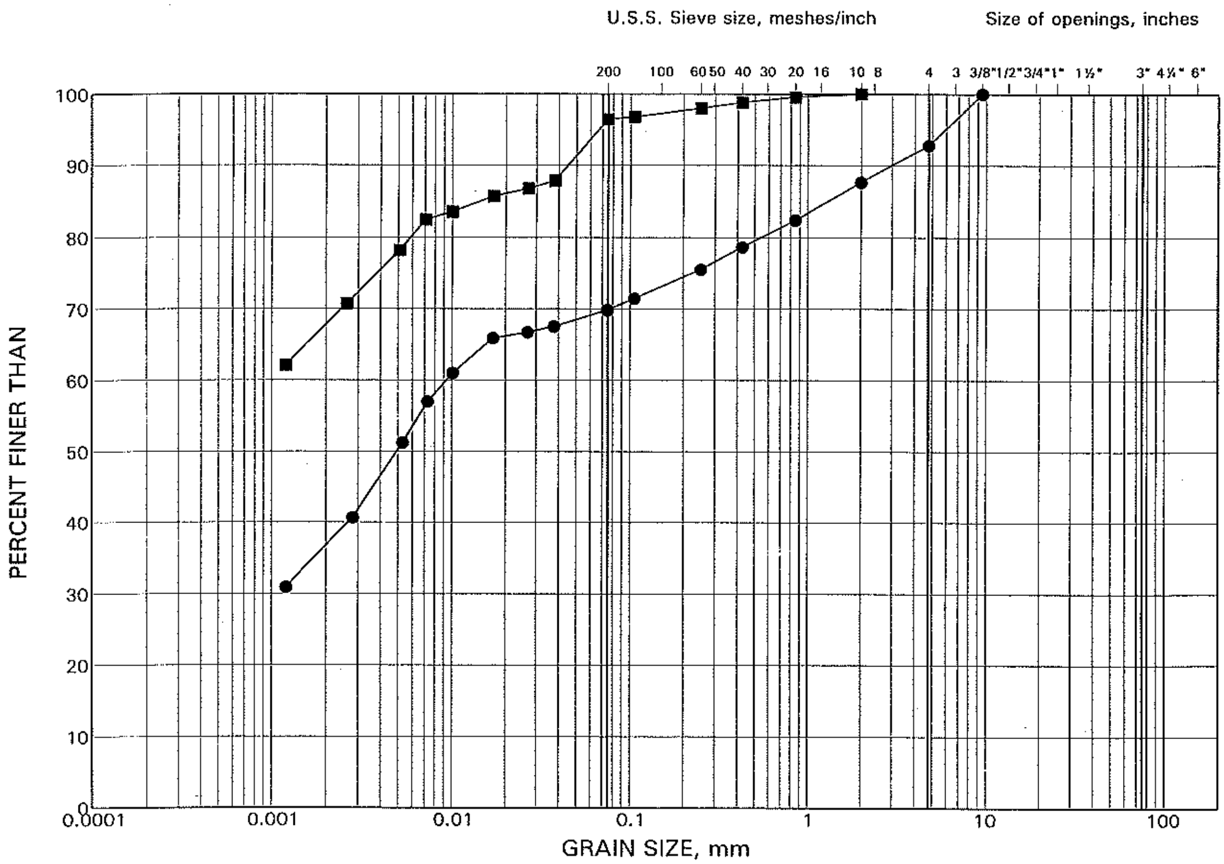
GRAIN SIZE DISTRIBUTION
Clay to Silty Clay (Fill)

FIGURE A5



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU6-1	2	0.8
■	CU6-2	3	1.5-2.1

Project 031-111016

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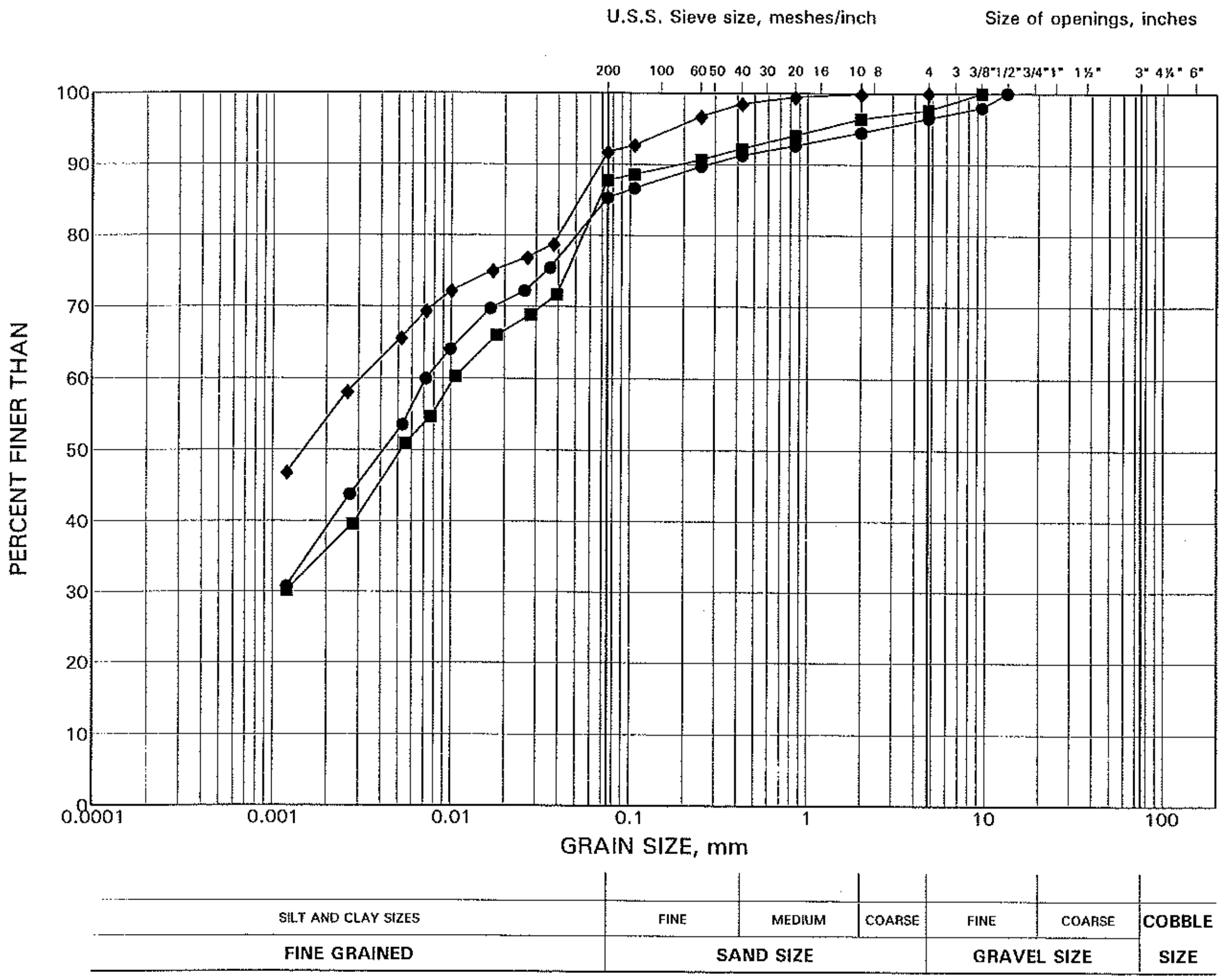
GRAIN SIZE DISTRIBUTION
Silty Clay (Fill)

FIGURE A6



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU7-1	2	0.8-1.4
■	CU7-2	2	0.8-1.4
♦	CU7-3	3	1.5-2.1

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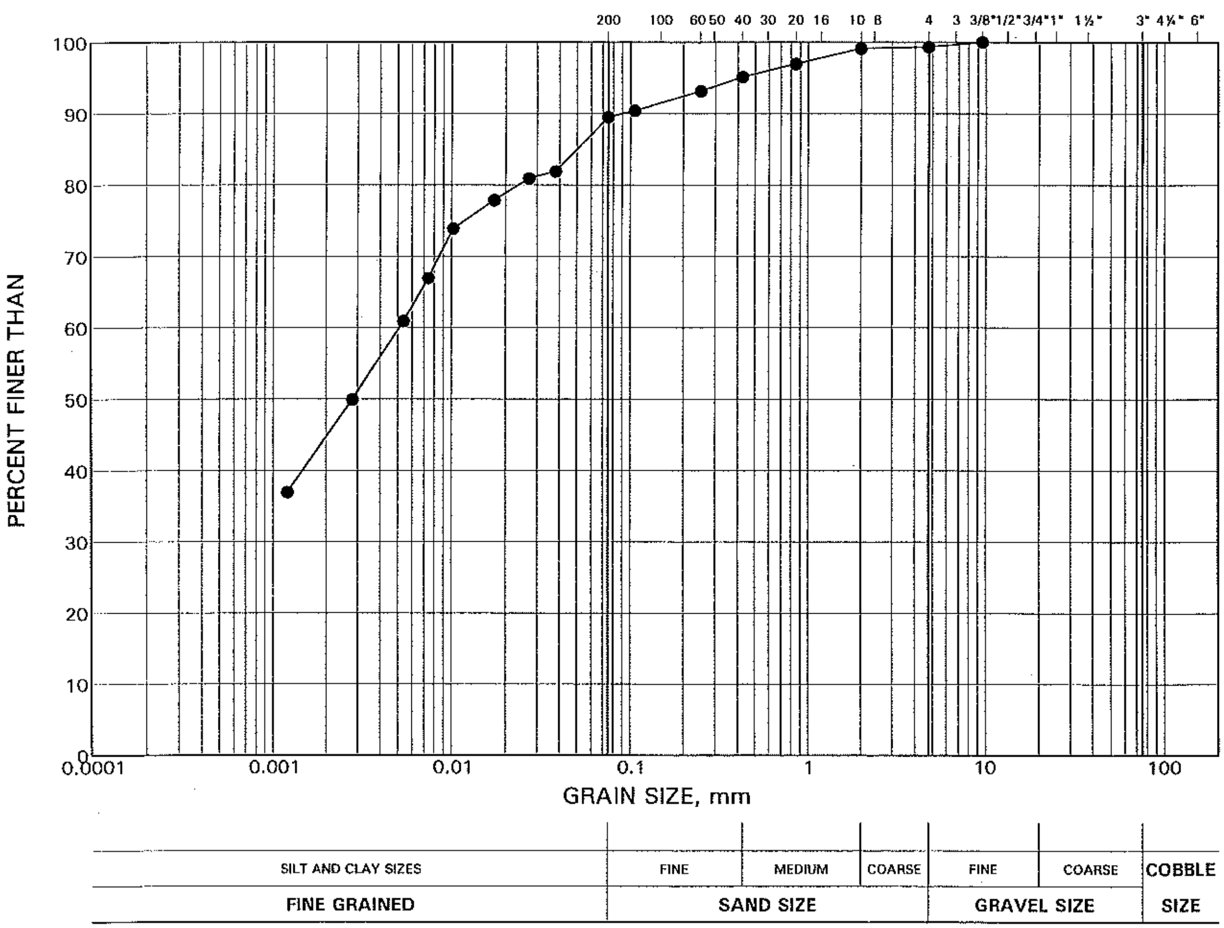
GRAIN SIZE DISTRIBUTION
Silty Clay (Fill)

FIGURE A7



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU8-2	2	0.8-1.4

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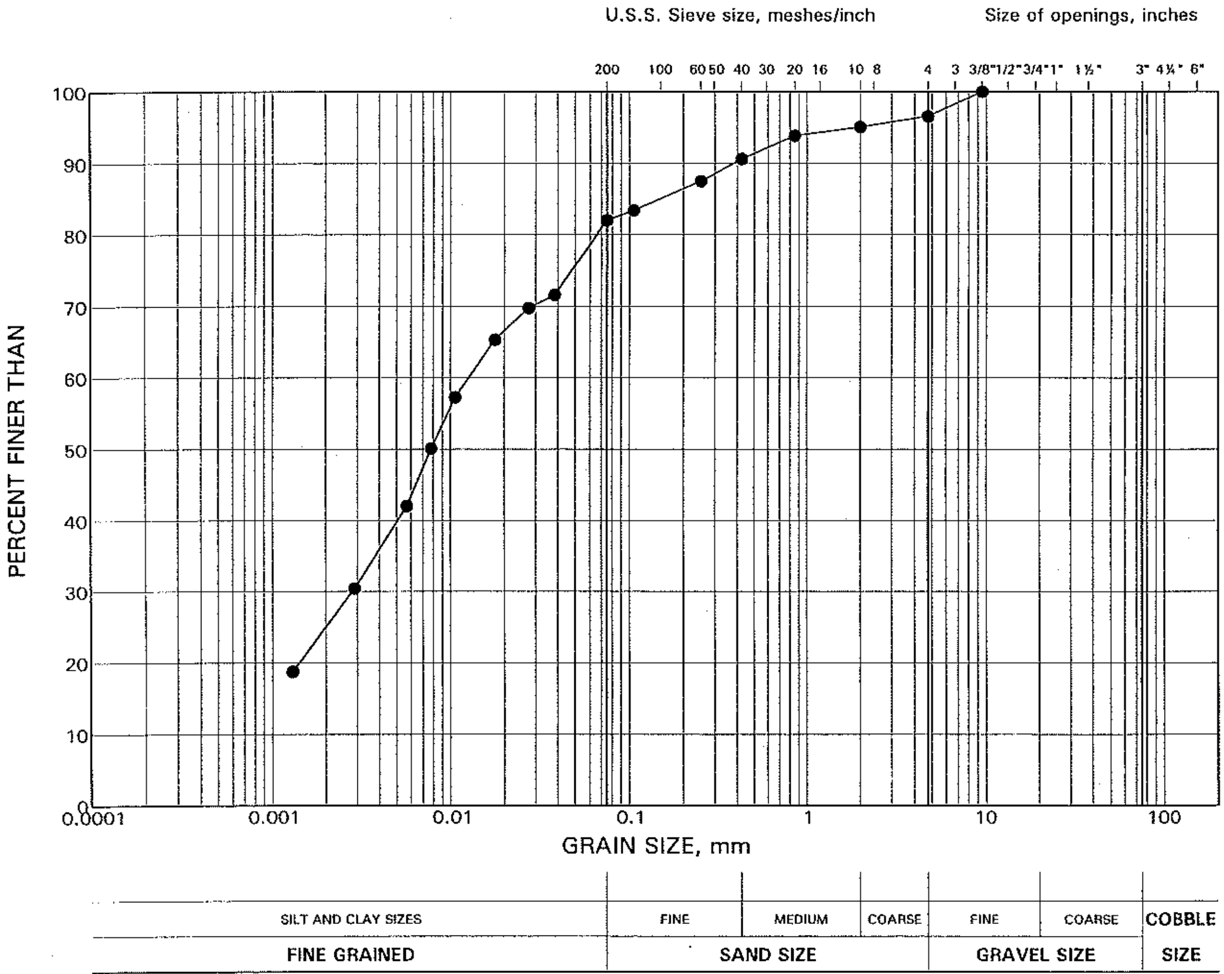
GRAIN SIZE DISTRIBUTION
Silty Clay (Till)

FIGURE A8

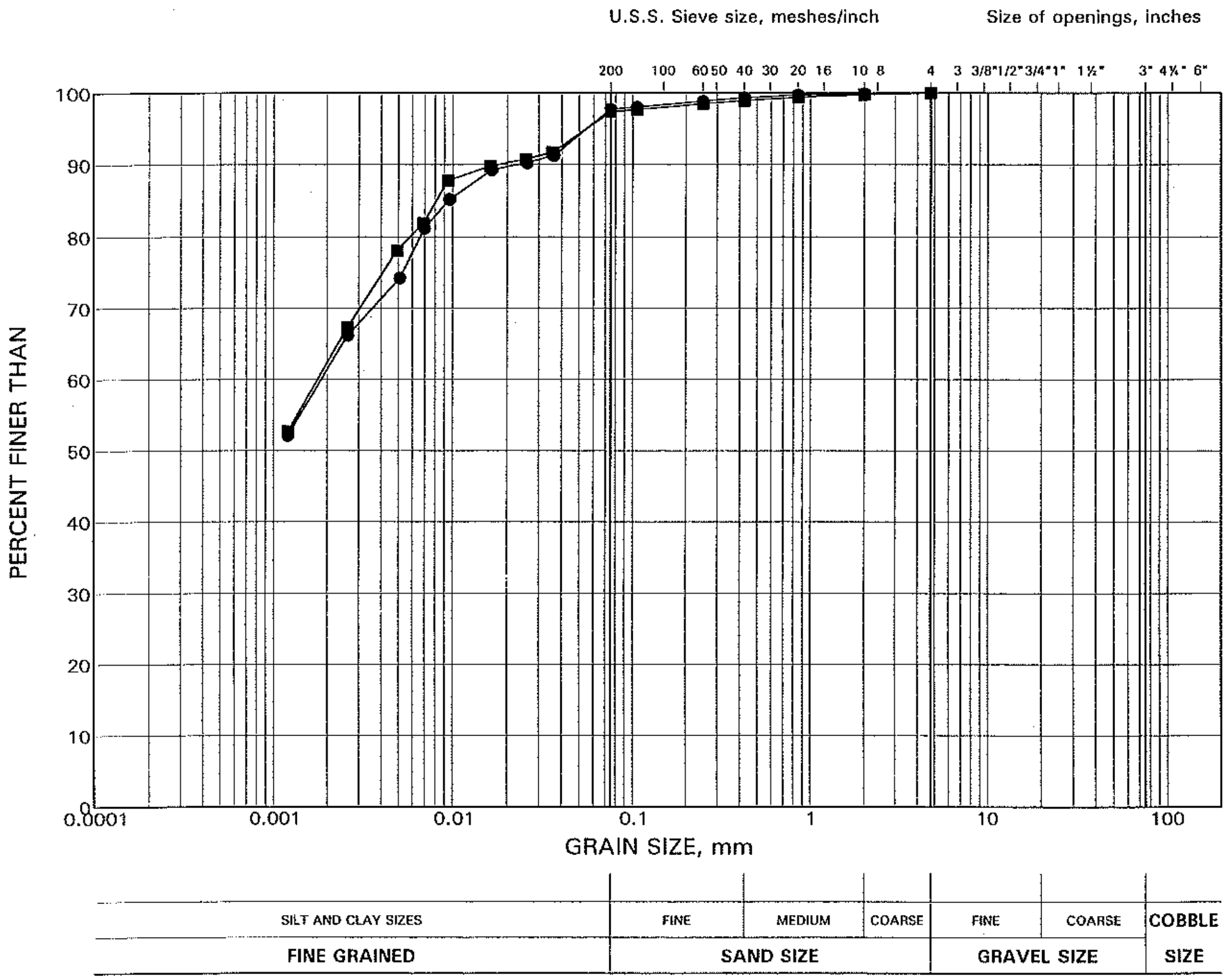


LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU8-1	3	1.5-1.6

GRAIN SIZE DISTRIBUTION
Clay

FIGURE A9



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
●	CU9-1	4	2.3-2.9
■	CU9-2	3	1.5-2.1

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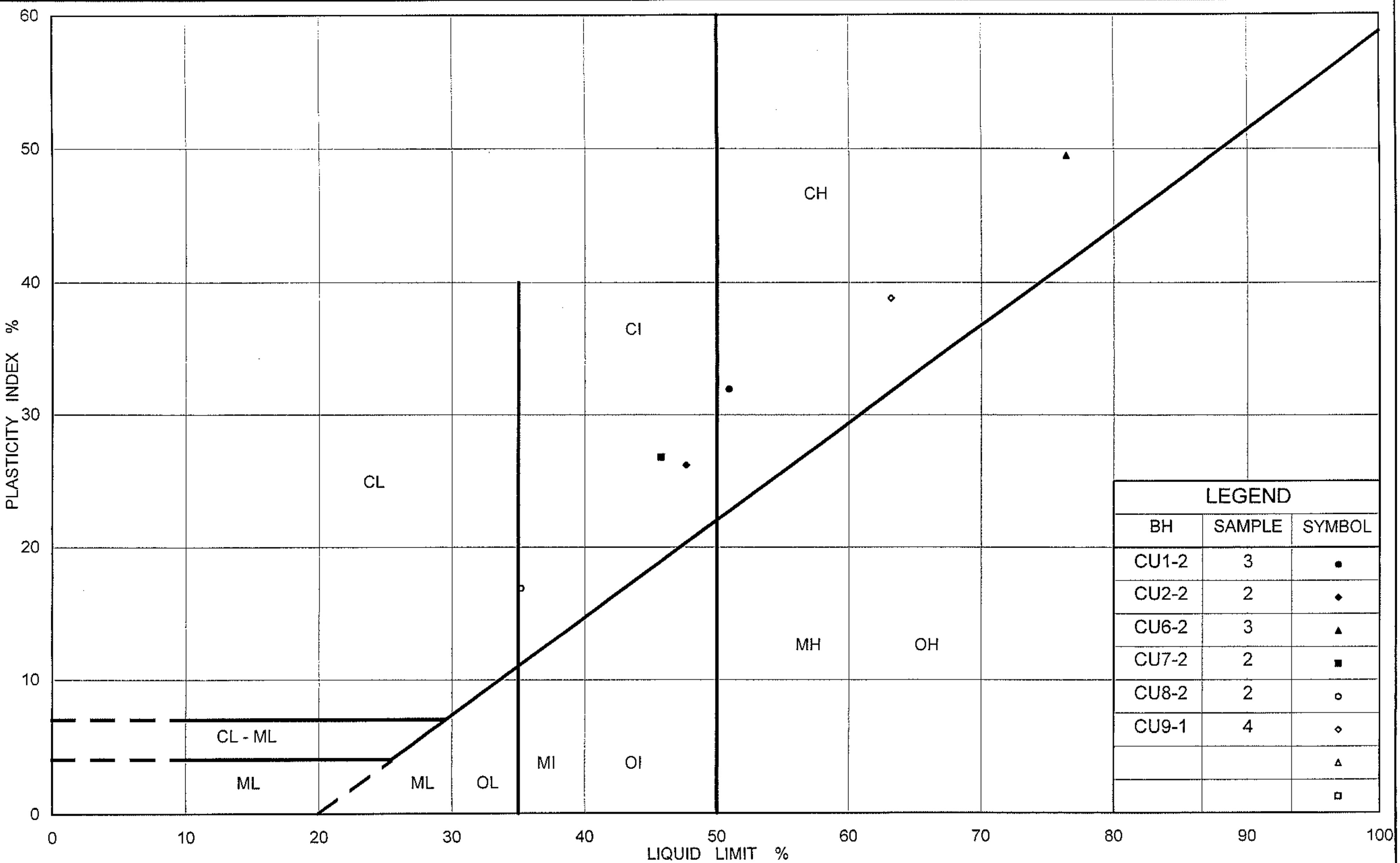
Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART

FIG No. A10

Project No. 031-111016

TABLE A1 - POINT LOAD TEST ON ROCK SAMPLES

PROJECT NO. 03-1111-016

TITLE MTO / Jack and Bore / Kingston

DATE 5-Dec-03

Borehole Number	Sample Number	Sample Depth (ft)	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)
CU2-2	1	16.0	D		47.00		9,000	12.20		5.5	5.4	123.5
	2	16.0	A	60.00	47.00	59.92	13,000	17.62	4.9		5.3	122.4
CU3-2	1	8.0	A	55.00	47.00	57.37	10,000	13.55	4.1		4.4	100.7
	2	8.0	D	72.00	47.00		10,000	13.55		6.1	6.0	137.2
CU5-1	5	26.0	A	68.00	47.00	63.79	20,000	27.10	6.7		7.4	170.9
	6	26.0	D		47.00		5,000	6.78		3.1	3.0	68.6
CU8-2	1	15.0	A	50.00	47.00	54.70	13,000	17.62	5.9		6.1	141.0
	2	15.0	D		47.00		5,000	6.78		3.1	3.0	68.6
									Mean Axial		5.8	133.8
									Mean Diametral		4.3	99.5

Axial Test are perpendicular to Bedding.
Diametral Tests are parallel to Bedding.

A 10cm-12cm thick SHALE bed was intercepted in CU3-2, CU5-1 and CU8-2. This interval was too weak to Point Load Test. Estimated UCS is 25 Mpa

Testing data indicates the rock is slightly weaker parallel to bedding.

(1) Is_{50} x 23 (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. 51-60.

(2) Actual distance between point load cones at time of failure on specimens tested diametraly.