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REPORT ON

**FOUNDATION INVESTIGATION AND DESIGN
PROPOSED CULVERT REPLACEMENTS
CULVERTS 13, 14, 35 AND 38
HIGHWAY 417
W.P. 258-98-00
LIMOGES TO CASSELMAN, ONTARIO**

Submitted to:

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September 2005

04-1120-013 (8000)



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PART A

**FOUNDATION INVESTIGATION
PROPOSED CULVERT REPLACEMENTS
CULVERTS 13, 14, 35 AND 38
HIGHWAY 417
W.P. 258-98-00
LIMOGES TO CASSELMAN, ONTARIO**

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation as part of the detailed design for the upgrading of Highway 417 between the Limoges Road and Casselman Road interchanges.

The terms of reference for the scope of work are outlined in Golder Associates Ltd. proposal numbered P31-2107, dated August 2003, that forms part of the Consultant's Agreement (Number P.O. 4005-A-000316) for this project, as amended by a subsequent proposal for this specific aspect of the project outlined in a proposal numbered P41-2114 and dated May 11, 2005. The work was carried out in accordance with the Quality Control Plan for this project dated February 2004.

This report addresses four proposed culvert replacements, at the following locations:

- Culvert 13 – Station 11+676 WBL
- Culvert 14 – Station 11+662 EBL
- Culvert 35 – Station 19+835 WBL
- Culvert 38 – Station 20+127 EBL

The work was carried out in accordance with the Quality Control Plan for this project dated February 2004.

2.0 SITE DESCRIPTION

All four culverts are located within the section of Highway 417 between the Limoges Road and Casselman Road interchanges. Culverts 13 and 14 are essentially coincident, and carry the same creek under the eastbound and westbound lanes respectively. The terrain in this area is generally flat lying.

The existing culverts consist of 3400 x 2010 SPPA sections, with lengths ranging from about 32 to 42 m and generally aligned along a slight skew to the highway centreline. All four culverts are to be replaced with precast concrete box culverts having a 3 m span. It is understood that the alignment, span, and invert elevations will be essentially maintained.

Although no GEOCRETS information is available for the specific locations of these culverts, published geologic information indicates that the subsurface conditions at these sites are similar and consist of a thick deposit of soft sensitive marine clay, locally underlain by surficial deposits of sand.

It is noted that the roadway surface over Culverts 13 and 14 has sagged by up to about 0.7 metres. The proposed roadway profile will correct that sag.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between May 17 and May 25, 2005. During this time, a total of eight (8) sampled boreholes (numbered 05-1 to 05-8, inclusive) were advanced approximately adjacent to the ends of the existing culverts, as follows:

- Boreholes 05-1 and 05-2: Culvert 14
- Boreholes 05-3 and 05-4: Culvert 13
- Boreholes 05-5 and 05-6: Culvert 35
- Boreholes 05-7 and 05-8: Culvert 38

The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers on a track-mounted drill rig, supplied and operated by Marathon Drilling Ltd. of Ottawa, Ontario. The boreholes were generally advanced to a depth of at least 10 metres below the proposed culvert invert elevations, which correspond to depths ranging from 13.4 to 16.5 metres below the existing ground surface at the borehole locations.

Soil samples were obtained at intervals ranging from 0.75 m to 1.5 m of depth, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. In-situ vane testing (N vanes) was carried out within the cohesive deposits. Relatively undisturbed, 75-millimetre diameter thin-walled Shelby tube (ASTM D1587) samples of the silty clay were retrieved using a fixed piston sampler.

Standpipe piezometers were installed in boreholes 05-2, 05-6, and 05-7 to monitor the groundwater levels at the site. The standpipes consist of 50 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed below minimum 0.3 m long sections of bentonite pellet backfill. The water levels in the standpipe piezometers were measured on June 15, 2005.

The boreholes were backfilled with bentonite pellets, mixed with native soils, and the site conditions restored following completion of work. The standpipe piezometers will be decommissioned following construction, unless instructed otherwise by the Ministry.

The field work was supervised throughout by members of our engineering and technical staff, who located the boreholes, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Ottawa geotechnical laboratory where the samples underwent further detailed visual examination and laboratory testing, including grain size distribution, water content, and Atterberg limit testing. Laboratory oedometer consolidation testing was carried out on two of the Shelby tube samples. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate.

The borehole locations were selected by Golder Associates personnel. The ground surface elevations at the borehole locations were provided by Morrison Hershfield and are understood to be referenced to Geodetic datum.

The borehole locations, including MTM NAD83 northing and easting coordinates, and ground surface elevations referenced to geodetic datum are summarized in the following table and are shown on Drawings 1 and 2.

Borehole No.	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)
05-1	Culvert 13	5019919.0	405104.4	68.5
05-2	Culvert 13	5019968.5	405089.9	68.2
05-3	Culvert 14	5019995.7	405091.7	68.6
05-4	Culvert 14	5020015.4	405079.3	68.0
05-5	Culvert 35	5019265.3	412677.2	63.7
05-6	Culvert 35	5019293.9	412658.6	63.5
05-7	Culvert 38	5019178.4	412969.9	63.7
05-8	Culvert 38	5019200.2	412967.8	62.6

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The study area for this assignment is within the minor physiographic region known as the Ottawa Valley Clay Plain that lies within the major physiographic region of the Ottawa-St. Lawrence Lowland (Chapman and Putnam, 1984). This physiographic region is underlain primarily by limestones of the Ottawa Formation that are, in turn, underlain by a series of sedimentary rocks, consisting of sandstone, dolostone, limestone and shale. These sedimentary formations are underlain by igneous and metamorphic bedrock of the Precambrian Shield. The Ottawa Valley Clay Plain region, present along Highway 417 in this area, is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock (Chapman and Putnam, 1984).

4.2 Site Stratigraphy

The detailed subsurface soil, bedrock and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at all four culvert locations are fairly similar, and consist of between 2.9 and 5.5 m of crushed stone and sand fill (roadway embankment fill) that is underlain by a thick deposit of sensitive silty clay. At Culvert 14 the fill materials are underlain by 0.3 m of topsoil and 1 m silty clay alluvium which in turn overlie the silty clay. The upper zone of the silty clay has locally been weathered to a stiff to very stiff grey brown crust; the weathered zone, where present, varies in thickness from about 0.7 to 1.8 m. The unweathered silty clay at depth is grey to red-grey in colour and has a generally soft to firm consistency. The unweathered silty clay extended to the full depth of all the boreholes (13.4 to 16.5 m depth).

A more detailed description of the subsurface conditions encountered in the boreholes put down for the present investigation at each culvert location is provided in the following sections, and stratigraphic profiles and sections of this site are shown on Drawing 4.

4.2.1 Culverts 13 and 14 (Stations 11+676 WBL and 11+662 EBL)

4.2.1.1 Topsoil and Fill Material (Sand Fill Over Crushed Stone)

Roadway embankment fill material exists at ground surface at all four borehole locations (Boreholes 05-1 to 05-4, inclusive). The fill material extends to depths of between about 3.4 and 4.6 m below existing ground surface.

At Borehole 05-4, the upper 0.1 metres of the fill material consists of topsoil. About 0.2 to 0.3 metres of crushed stone fill material exists at ground surface at the remaining locations, and beneath that topsoil layer.

The underlying fill materials consist of sand fill which extends to depths of between about 2.3 and 3.7 m below existing ground surface. Standard penetration test N values in the sand fill ranging from 1 to 32 blows per 0.3 m of penetration indicate it to be very loose to dense. The results of grain size distribution testing on five samples of the sand fill are provided on Figure 1 and indicate it to be a fine sand, with trace to some silt.

At Boreholes 05-1, 05-2 and 05-4, inclusive, the sand fill material is underlain by crushed stone fill that ranges in thickness from about 0.3 to 1.7 m. This crushed stone fill was not encountered in Borehole 05-3. Standard penetration test N values in this material ranging from 10 to 14 blows per 0.3 m of penetration indicate it to be compact.

4.2.2 Buried Topsoil and Alluvium

In Borehole 05-2, the fill material is underlain by a 0.3 m thick layer of topsoil followed by about 1 metre of alluvium, which extends to an overall depth of about 5.0 m below existing ground surface. The alluvium is composed of silty clay with organic matter.

The measured water content of the topsoil layer was about 39 percent, while the water content of two samples of the alluvium were about 28 and 49 percent.

The buried topsoil and alluvium were not encountered in the remaining three boreholes.

4.2.3 Silty Clay

The fill materials and the alluvium, where present, are underlain by a deposit of silty clay. The silty clay deposit was not fully penetrated but was proven for depths of between about 13.4 and 14.9 m below existing ground surface.

At Boreholes 05-1 and 05-3, the upper 1.8 m and 1.6 m, respectively, of the silty clay deposit have been weathered to a grey-brown crust. The measured SPT "N" values in this portion of the deposit ranged from 4 to 10 blows per 0.3 m of penetration, indicating it to be stiff to very stiff.

The results of Atterberg limit testing on one sample of the weathered crust indicate a plasticity index of 30 percent and a liquid limit of 48 percent. The measured natural water content of the weathered crust ranges from 30 to 36 percent.

The unweathered silty clay at depth is grey in colour. The results of grain size distribution testing carried out on two selected samples of this material are provided on Figure 2.

The measured SPT "N" values within the unweathered silty clay were less than 2 blows per 0.3 m of penetration, with the sampler often advanced by manual pressure only. In situ vane testing carried out in the boreholes measured undrained shear strengths generally ranging from about 21 to 26 kilopascals and then increasing to about 40 kilopascals by about 15 metres depths. These results indicate a generally soft to firm consistency for the deposit. In Boreholes 05-1 and 05-2, an approximately 1 m thick stiffer transitional zone was noted at the top of the unweathered clay, with undrained shear strengths of about 48 to 66 kilopascals.

The sensitivity of the deposit, as estimated from the field vane tests, ranges from about 3 to 6, indicating a highly sensitive soil.

The results of Atterberg limit testing on selected samples of the unweathered silty clay indicate plasticity index values ranging from 22 to 35 percent, and liquid limits ranging from 41 to 56 percent. These results, which are summarized on the plasticity chart on Figure 3, indicate this material to be a silty clay to clay, of intermediate to high plasticity. The measured natural water contents of the unweathered silty clay range from 34 to 72 percent.

Oedometer consolidation testing was carried out on one thin-walled Shelby tube sample of the unweathered silty clay. The results of that testing are provided on Figure 4 and are summarized in the table below.

Borehole/ Sample Number	Sample Depth/Elev. (m)	Unit Weight (kN/m ³)	σ_p' (kPa)	σ_{vo}' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	Cc	Cr	e_o	OCR	Cv cm ² /s
05-4 / 7	6.6 / 61.4	14.8	80	80	0	1.43	0.027	2.38	1	0.001

Notes:

- σ_p' - Apparent preconsolidation pressure
- σ_{vo}' - Computed existing vertical effective stress
- Cc - Compression index
- Cr - Recompression index
- e_o - Initial void ratio
- OCR - Overconsolidation ratio
- Cv - Coefficient of consolidation

As indicated above, the calculated effective stress level at the depth of the samples is essentially equal to the measured preconsolidation pressure, indicating that the sample is normally consolidated; the weight of the embankment fill has brought the deposit to a normally consolidated condition.

4.3 Culvert 35 (Stations 19+835 WBL)

4.3.1 Fill Material (Sand Fill Over Crushed Stone)

Fill material exists at ground surface at both Boreholes 05-5 and 05-6. The fill material extends to depths of 3.4 and 2.9 m below existing ground surface, respectively (elevations 60.3 m and 60.7 m).

The fill materials consist of about 0.1 m of topsoil fill overlying about 0.2 to 0.5 m of sand over 3.1 and 2.3 m, respectively, of crushed stone. The results of grain size distribution testing carried out on four samples of the crushed stone are summarized on Figure 5. Standard penetration test N values for the crushed stone ranging from 10 to 18 blows per 0.3 m of penetration indicate the material to be compact.

4.3.2 Silty Clay

The fill materials are underlain by a deposit of silty clay. The silty clay deposit was not fully penetrated but was proven for a depth of 13.4 m at both borehole locations.

At Boreholes 05-5, the upper 0.7 m of the silty clay deposit has been weathered to a grey-brown crust. In situ vane testing in that deposit in Borehole 05-5 indicate an undrained shear strength of 50 kilopascals and a stiff consistency for this material.

The unweathered silty clay below the depth of weathering is grey in colour. The results of grain size distribution testing carried out on one selected sample of this material are provided on Figure 6.

The measured SPT "N" values within the unweathered silty clay were 1 blow per 0.3 m of penetration, or less. In situ vane testing in this material measured undrained shear strengths ranging from about 25 to 35 kPa, then increasing somewhat to almost 40 kPa by about 12 m depth. These results indicate a generally firm consistency for the unweathered silty clay.

The sensitivity of the deposit, as estimated from the field vane tests, ranges from about 4 to 13, indicating a highly sensitive soil.

The results of Atterberg limit testing on selected samples of this portion of the deposit indicate plasticity indices ranging from 20 to 28 percent, and liquid limits ranging from 42 to 47 percent. These results, which are summarized on the plasticity chart on Figure 7, indicate this material to be a silty clay of intermediate plasticity. The measured natural water content of the unweathered grey silty clay ranges from 34 to 64 percent.

Oedometer consolidation testing was carried out on one thin-walled Shelby tube sample of the unweathered silty clay. The results of that testing are provided on Figure 8 and are summarized in the table below.

Borehole/ Sample Number	Sample Depth/Elev. (m)	Unit Weight (kN/m ³)	σ_p' (kPa)	σ_{vo}' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	Cc	Cr	e _o	OCR	Cv cm ² /s
05-6 / 4	6.6 / 59.1	17.9	100	60	40	0.40	0.016	1.06	1.7	0.005

Notes:

- σ_p' - Apparent preconsolidation pressure
- σ_{vo}' - Computed existing vertical effective stress
- Cc - Compression index
- Cr - Recompression index
- e_o - Initial void ratio
- OCR - Overconsolidation ratio
- Cv - Coefficient of consolidation

As indicated above, the calculated effective stress level at the depth of the sample is approximately 40 kilopascals in excess of the measured preconsolidation pressure.

4.4 Culvert 38 (Station 20+127 EBL)

4.4.1 Fill Material (Sand Fill Over Crushed Stone)

Fill materials associated with the existing lanes of Highway 417 exist at ground surface at Boreholes 05-7 and 05-8. In Borehole 05-8 the fill is covered by 0.1m of topsoil, whereas in Borehole 05-7 a 0.5 m layer of crushed stone fill exists at ground surface. The underlying fill material consists of approximately 1.4 to 2.7 m of fine sand fill, followed by 2.1 to 2.3 m of crushed stone. Standard penetration test 'N' values for the fine sand fill ranging from 4 to 6 blows per 0.3 m of penetration indicate the fine sand to be loose. Standard penetration test 'N' values for the crushed stone fill ranging from 6 to 26 blows per 0.3 m of penetration indicate the crushed stone to be loose to compact. The results of grain size distribution testing carried out on one sample of the fine sand fill are provided on Figure 9 and the results of grain size distribution testing carried out on two samples of the crushed stone fill are provided on Figure 10.

4.4.2 Silty Clay

A deposit of silty clay underlies the crushed stone fill at both borehole locations. The deposit extends to at least the depth investigated (13.4 to 16.5 m). The deposit contains occasional silty fine sand seams, trace amounts of organic matter (black staining), and is generally red grey in colour. The results of grain size distribution testing carried out on one selected sample of the silty clay are shown on Figure 11.

The results of Atterberg Limit testing on the silty clay indicate liquid limits ranging from about 51 to 72 percent and plasticity index values ranging from about 29 to 48 percent. These results are summarized on the plasticity chart on Figure 12 and indicate the deposit to consist of clay of high plasticity. The measured natural water content of the silty clay ranges from about 45 to 80 percent, which is generally at or greater than the measured liquid limit.

The measured undrained shear strength of the silty clay deposit generally varies from about 26 to 30 kPa, then generally increasing to about 60 to 70 kPa by about 12 to 14 m depth. Occasional anomalous higher undrained shear strength measurements of up to about 75 kPa may reflect the presence of sand seams within the deposit.

The sensitivity of the deposit, as estimated from the field vane tests, ranges from about 4 to 16, indicating a highly sensitive soil.

4.5 Groundwater Conditions

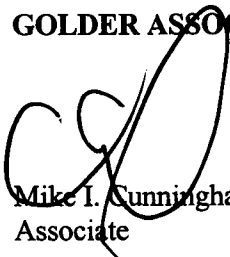
The water levels in the piezometers in Boreholes 05-2, 05-6 and 05-7, were measured on June 15, 2005. The piezometers were sealed into the silty clay deposit.

The water levels in the piezometers are summarized in the table below:

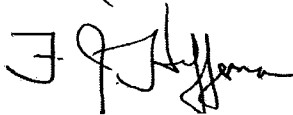
Borehole	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
05-2	68.2	1.90	66.3	June 15, 2005
05-6	63.5	1.16	62.3	June 15, 2005
05-7	63.7	3.72	60.0	June 15, 2005

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

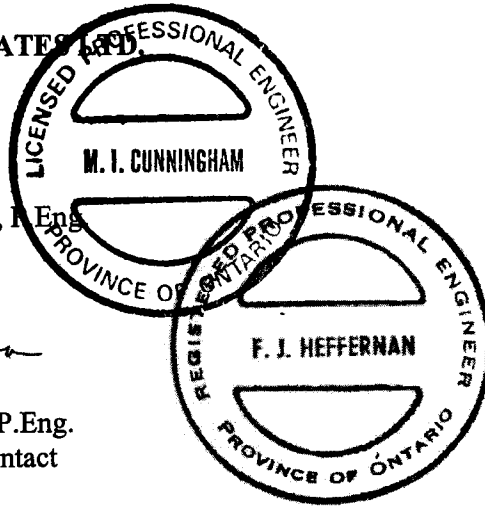
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PART B

FOUNDATION INVESTIGATION AND DESIGN

PROPOSED CULVERT REPLACEMENTS

CULVERTS 13, 14, 35 AND 38

HIGHWAY 417

W.P. 258-98-00

LIMOGES TO CASSELMAN, ONTARIO

5.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of four culverts along Highway 417 between the Limoges Road and Casselman Road interchanges. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site.

The interpretation and recommendations provided are intended only to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure foundations. 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.

5.1 General

Four existing culverts along Highway 417 between the Limoges Road and Casselman Road interchanges are to be replaced, as follows:

- Culvert 13 – Station 11+676 WBL
- Culvert 14 – Station 11+662 EBL
- Culvert 35 – Station 19+835 WBL
- Culvert 38 – Station 20+127 EBL

The existing culverts consist of 3400 x 2010 SPPA sections, with lengths ranging from about 32 to 42 m and generally aligned along a slight skew to the highway centreline. All four culverts are to be replaced with precast concrete box culverts having a 3 m span. It is understood that the alignment, span, and invert elevations will be essentially maintained. The invert elevations of the four culverts are as follows:

Culvert Number	Invert Elevation
13	64.61m – 64.69m
14	64.82m – 65.06m
35	61.50m – 62.10m
38	59.49m – 59.69m

In general, the subsurface conditions at all four culvert locations are fairly similar, and consist of between 2.9 and 5.5 m of crushed stone and sand fill (roadway embankment fill) that is underlain by a thick deposit of sensitive silty clay. At Culvert 14 the fill materials are underlain by 0.3 m of topsoil and 1 m silty clay alluvium which in turn overlie the silty clay. The upper zone of the

silty clay has locally been weathered to a stiff to very stiff grey brown crust; the weathered zone, where present, varies in thickness from about 0.7 to 1.8 m. The unweathered silty clay at depth is grey to red-grey in colour and has a generally soft to firm consistency. The unweathered silty clay extended to the full depth of all the boreholes (13.4 to 16.5 m depth).

Based on the subsurface information available at the culvert locations, and considering that the project involves the replacement of existing culverts with generally no or only limited change in the stress condition in the underlying silty clay, it is considered generally feasible to found the proposed culverts on the native soils. It is noted however that, for Culverts 13 and 14, the existing sag in the roadway will be removed. That sag appears to be the results of compression of the subgrade soils which at this site is normally consolidated and the correction of that sag will increase the stress level in the underlying soils and could result in additional roadway settlements.

It is understood that no headwalls or wingwalls are proposed for the ends of the culverts.

5.2 Culvert Foundations

It is presently proposed for all four culverts to be 3.0 x 1.8 m pre-cast concrete box culverts. It is understood that the existing invert levels will essentially be maintained.

As discussed below, it is considered generally feasible to support all four proposed culverts on the inorganic native subgrade soils. All four culvert sites are underlain by compressible silty clay deposits and are currently proposed to be founded directly on the subgrade soils. The structure settlements should therefore not be excessive provided the existing stress levels can be maintained. The correction of the sag at Culvert 13 and 14 will however result in some settlement, as discussed below.

This report provides guidelines only on the presently proposed design, as presented in the following sections.

5.2.1 Axial Geotechnical Resistance

Based on the borehole information, it is inferred that the subgrade soils will consist of limited thicknesses of crushed stone fill/bedding overlying the sensitive and compressible silty clay deposits. At Culvert 14, the results of Borehole 05-2 indicate that about 1 metre of organic alluvium exist below subgrade level. However that borehole is not located directly along the existing/proposed culvert axis and, considering that an existing culvert already exists at that location, the alluvium may not exist below the culvert itself. The presence/absence of alluvium should however be confirmed at the time of construction.

The organic alluvium is a potentially weak and compressible subgrade and, if present below founding level at Culvert 14, should be removed. Where that is the case, the alluvium should be replaced with compacted engineered fill; Granular A would generally be suitable for this purpose, though Granular B Type II may need to be substituted for the first lift where the subgrade is particularly wet, as should be expected for the wet subgrade conditions anticipated within the excavations. The replacement should be carried out wherever the alluvium lies within the zone of influence of the foundations, which is considered to extend out and down from the edge of the culvert foundations at an inclination of 1 horizontal to 1 vertical. Based on the borehole data, where subexcavation of alluvium is required, the subexcavation elevation would be Elevation 63.2 m.

Regardless of the need for subexcavation of alluvium, all four of the culverts should be supported on 300 mm of Granular A bedding.

The factored geotechnical resistance at Ultimate Limit States (ULS) for the culverts will be controlled by both the combined shear strength of the granular bedding, where present, and the silty clay, which is generally stiffer at subgrade level but soft to firm at a relatively shallow depth below that level; the failure mechanism would be one of potential 'punching' failure through the shallower materials into the soft clay. Based on the borehole data, and assuming a bearing width of 3 m, the ULS factored resistance may be taken as 135 kPa.

The geotechnical resistance at Serviceability Limits States (SLS) at all four culvert sites is controlled by the compressibility of the soft clay deposit present at shallow depth below founding level. In considering the height and weight of the existing fills at all four culvert sites, the available information indicates that the stress level within the silty clay deposit is at or near its preconsolidation pressure. That is, the deposit is essentially normally consolidated. Therefore any increase in stress above the existing value can be expected to result in settlements that would be significant. It is therefore proposed that the resistance at Serviceability Limits States (SLS) be taken as 95 kPa (gross), which is the calculated existing effective stress level at the expected founding level of the culverts.

It is understood that, for Culverts 35 and 38, the proposed design will respect the requirement to maintain the existing stress levels. However, at Culverts 13 and 14, the correction of the 0.7 m sag will increase the stress level in the subgrade soils above the existing levels. The resulting expected settlements are discussed in the following section.

5.2.2 Estimated Settlement for Culverts 13 and 14

Given the soft, sensitive, and compressible silty clay deposit that underlies the site of Culverts 13 and 14, the settlement of the culverts and roadway will be controlled by the stress increase on that deposit from the weight of the additional fill needed to correct the 0.7 m sag.

The 0.7 m raising of the roadway profile will increase the stress on the subgrade soils by about 15 kPa. Considering the width of the roadway and the length over which the sag will be corrected, it is considered that the clay deposit to a depth of about 30 metres below roadway level will experience an appreciable increase in its stress level; considering that the clay deposit is normally consolidated even a small increase in stress can result in significant strain. However the greatest stress increase (and strain) will be experienced within the upper 10 m of the deposit.

The results of the oedometer consolidation test data from this investigation indicate a preconsolidation pressure that is less than the calculated existing effective stress level beneath the roadway. The test sample was however retrieved from a borehole that is located on the embankment sideslope, where the ground surface is lower than the roadway level, and therefore the clay at that location is inferred to have been loaded to a lower stress level than beneath the roadway. Therefore, for the purposes of these settlement analyses, the preconsolidation pressure within the deposit has been inferred to be equal to the existing effective stress level in the deposit.

Based on the above, it is estimated that the resulting culvert settlements, resulting from the combined effects of primary consolidation and secondary compression, could be in the order of 250 mm.

Based on the coefficients of consolidation indicated from the laboratory testing and considering the significant thickness of the deposit, which results in a long drainage path for displaced pore water, it is estimated that this settlement would take in the order of 30 years to occur. The calculated settlements with time are summarized as follows:

Time (years)	Magnitude of Settlement (mm)
5	100
10	150
20	200
30	250

It should be noted that the settlements may be non-uniform along the length of the culverts, due to the variable fill height across the embankment width. The settlement at the centre of the embankment, and culvert, will be greater than that beneath the toe of the embankment (ends of the culverts). In addition to potentially impacting the culvert's hydraulic performance, these settlements would result in stresses within the culvert and irregular subsidence of the roadway surface. The distortion of the overlying roadway may be quite noticeable and require periodic maintenance. In essence, it is expected that the existing sag will return, though of lesser magnitude.

5.2.3 Resistance to Lateral Loads

The resistance to lateral forces/sliding should be calculated in accordance with Section 6.7.5 of the CHBDC, using the following parameters:

Interface and Loading Condition	Parameter
Concrete – Granular A pad: short or long term loading	Effective friction angle = 33 degrees
Granular A pad – clay subgrade: short term loading	Undrained cohesion = 12 kPa
Granular A pad - clay subgrade: long term loading	Effective friction angle of 25 degrees

These are unfactored values; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

5.2.4 Frost Protection

If the creeks which flow through these culverts are expected to neither freeze completely nor be dry during the winter months, then no frost protection needs to be provided for the culvert bearing surface.

5.3 Bedding and Backfill

The bedding, backfill and levelling pad requirements for the culverts should be in accordance with OPSD 803.010. The culverts should be designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 21 kN/m³.

The box culverts should be provided with a minimum 300 mm of OPSS Granular 'A' bedding. Additional Granular 'A' shall be placed if/where subexcavation is required. The bedding should be compacted in loose lifts not greater than 200 mm in thickness to 95 percent of the material's Standard Proctor maximum dry density in accordance with SSP105S10. Where the subgrade is particularly wet, Granular B Type II should be substituted for the first lift, since its compactability is generally less sensitive to the water content. Groundwater and surface water control will be required at the culvert locations to avoid "pumping" of water into the fill during compaction.

Backfill to the culvert walls and wing walls should consist of granular fill meeting the specifications for OPSS Granular 'A' or Granular 'B' Type II (but with less than 5 percent passing the 200 sieve). The backfill should be placed in lifts not exceeding 200 mm loose thickness and compacted to 95 percent Standard Proctor dry density. The fill depth during placement should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 400 mm.

5.4 Erosion Protection

The soils exposed at creek bank level consist of sandy soil (likely the embankment fill) and silty clay. The grain size distribution of the sand fill, which is the more erodable material, is shown on Figures 1 and 9, which indicate that essentially 100 percent of the particles are smaller than 0.3 mm and the mean particle size is about 0.1 to 0.2 mm. If the creek velocities warrant, provision should be made for scour and erosion protection. Consideration could be given to the use of suitable non-woven geotextiles and rip-rap to provide erosion protection based on hydraulic requirements. However no signs of active erosion were observed at the ends of the existing culverts.

In order to prevent creek water from flowing either beneath the culvert (potentially causing undermining and scouring), a cut-off (i.e., apron) wall or clay seal should be provided at the upstream end of the culvert (as is currently indicated on the design drawings). The cut-off wall or clay seal should be keyed into the native subsoil.

In addition, sediment control such as silt fences and / or erosion control blankets may be required during construction and diversion of the water course to mitigate migration of fine soil particles into the water courses.

5.5 Construction Considerations

5.5.1 Groundwater and Surface Water Control

It is assumed that coffer dams will need to be constructed to bypass the flows around the culvert areas during construction. The fill materials that will be excavated from the roadway are too permeable to be suitable for use in coffer dam construction. Interlocking steel sheet piling would be more suitable. Imported clayey soils might also be suitable, noting however that the coffer dams will need to penetrate any permeable soils present in the creek bed.

It is understood that, based on the proposed invert levels, culvert floor thicknesses, and bedding thicknesses, the excavations for all three culvert will extend about 5 to 6 m below roadway level, which is about 1 to 2.5 m below the water level. The excavations will be made predominantly in the sand and crushed stone embankment fills. Relatively significant groundwater flow could be expected from those permeable fills. The groundwater inflow from the underlying clay subgrade, which has a much lower hydraulic conductivity, should be fairly modest. It is not expected therefore that the overall volume of groundwater pumped by the contractor would exceed 50,000 Litres per day (which would require a Permit-to-Take-Water from the Ministry of the Environment), although the groundwater inflow could be initially quite high as water is removed from storage within the fills. It is expected that it should be feasible to handle the groundwater inflow by pumping from sumps in the excavations.

5.5.2 Excavations

The contractor should be aware that the silty clay subgrade, where exposed, will be sensitive to disturbance from construction traffic.

Temporary excavations 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. Where the fine sand fill is located below the water level, it would be classified as a Type 4 soil, according to the OHSA. The soft silty clay soils are also classified as Type 4 soils. Therefore, excavations that extend through the sand fills, without pre-drainage, or that will expose the soft silty clay, should be made with side slopes no steeper than 3 horizontal to 1 vertical. Above the groundwater level, the sand fill and crushed stone, as well as the stiff weathered silty clay crust, where present, would be classified by Type I soils and excavations may be made with side slopes no steeper than 1 horizontal to 1 vertical.

It is understood that the staging of the work will require that each culvert be constructed in two sections, with temporary excavation support for roadway protection provided at/near the roadway centreline. Where required, 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. However the design of that shoring must consider the soft silty clay deposit at depth and the potential for basal instability of the excavation. This possibility should be considered even where the soft clay deposit will not be exposed by the excavation but will exist within a depth below the excavation bottom that is less than 70 percent of the excavation width.

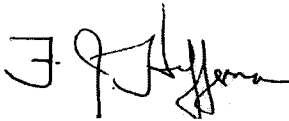
The design of the shoring will be entirely the responsibility of the contractor. At Culvert 35, it is considered that a conventional sheeted and braced excavation should have an adequate factor of safety (i.e., greater than 1.5) against basal instability. However preliminary calculations indicate that, for Culverts 13, 14, and 38, a vertical sheeted excavation may not have an adequate factor of safety unless the sheeting is driven to some depth below the excavation and the sheeting is both strong and stiff enough to resist the additional lateral forces exerted by the soil below excavation level. It is also noted however that none of the excavations are likely to have a factor of safety against basal instability of more than 2.0 and therefore, given the soft clay deposits, some distortion of the ground above/behind the sheeting should be expected. That distortion could be manifested as longitudinal and transverse differential settlement of the roadway surface above/behind the shoring, with the greatest settlement being immediately adjacent to the shoring. The contractor could need to temporarily pad the roadway.

For all three culvert sites, excavated soil should not be stockpiled adjacent to the crest of excavation side slopes (or above shoring) due to the potential to reduce the factor of safety against side slope or basal instability.

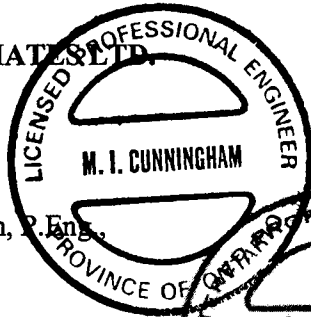
GOLDER ASSOCIATES LTD.



Mike I. Cunningham, P.Eng.
Associate



Fintan J. Heffernan, P.Eng.
Designated MTO Contact



MIC/FJH/rp/cr

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LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
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

Peizo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm² 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_{u2S_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 limited
w_l	liquid limit
C	consolidaiton (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 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 ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1 \sigma_2 \sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = p_s/p_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is p . Unit weight symbol is γ where $\gamma = pg$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (cont'd.)

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 (overconsolidated 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	Overconsolidation ratio = σ'_p/σ'_{vo}

(d) Shear Strength

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

Notes: 1. $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2

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MISS_MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05

Continued Next Page

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

PROJECT 04-1120-013-8000

RECORD OF BOREHOLE No 05-1

2 OF 2

METRIC

W.P. 258-98-00

LOCATION N 5019919.02, E 405104.43

ORIGINATED BY W.C.

DIST HWY 417

BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger

COMPILED BY J.M.

DATUM Geodetic

DATE May 17, 2005

CHECKED BY M.I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
— CONTINUED FROM PREVIOUS PAGE —																		
57.8	Silty CLAY Soft to firm Red grey Wet							X	+									
10.7	Silty CLAY with silty sand seams Firm Red grey Wet		11	SS	PM			X	+									
									X		+							
									X		+							
				12	SS	PM												
								X		+								
								X		+								
			13	SS	PM													
53.5								X		+								
14.9	End of Borehole							X		+								

MISS_MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05

PROJECT 04-1120-013-8000		RECORD OF BOREHOLE No 05-2		1 OF 2	METRIC
W.P. 258-88-00	LOCATION N 5019968.51; E 405089.89	ORIGINATED BY W.C.			
DIST HWY 417	BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger	COMPILED BY J.M.			
DATUM Geodetic	DATE May 18, 2005	CHECKED BY M.I.C.			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%) 25 50 75						
68.2	GROUND SURFACE																
0.0	Crushed stone (FILL)		1	GRAB													
67.9	Grey																
0.3	Fine sand, trace silt (FILL)																
	Loose to very loose		2	SS	8												
	Brown																
	Moist to wet																
			3	SS	11												
			4	SS	1												
64.9	Crushed stone (FILL)		5	SS	8												
3.4	Grey																
64.6	Wet																
3.7	TOPSOIL																
64.2	Wet																
4.0	Silty clay with organic matter (ALLUVIUM)		6	SS	9												
	Very stiff																
	Grey brown																
	Wet																
63.2	Silty CLAY		7	SS	PM												
5.0	Stiff																
	Red grey																
	Wet																
62.1	Silty CLAY		8	SS	PM												
6.1	Firm																
	Red grey																
	Wet																
			9	73 TP	PM												

MISS_MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05

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

PROJECT <u>04-1120-013-8000</u>		RECORD OF BOREHOLE No 05-2		2 OF 2	METRIC
W.P. <u>258-98-00</u>		LOCATION <u>N 5019968.51; E 405089.89</u>		ORIGINATED BY <u>W.C.</u>	
DIST <u> </u> HWY <u>417</u>		BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>		COMPILED BY <u>J.M.</u>	
DATUM <u>Geodetic</u>		DATE <u>May 18, 2005</u>		CHECKED BY <u>M.I.C.</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			W _p	W	W _L
SHEAR STRENGTH kPa								UNCONFINED		FIELD VANE		WATER CONTENT (%)					
	--- CONTINUED FROM PREVIOUS PAGE ---																
	Silty CLAY Firm Red grey Wet						58	X	+								
			11	SS	PM			X	+								
							57										
								X	+								
								X	+								
			12	SS	PM		56										
54.8							55	X	+								
13.4	End of Borehole							X	+								
	Note: Water level in standpipe at 1.90m depth below ground surface on June 15, 2005.																

MISS_MTO 04-1120-013-8000.GPJ ON_MOT.GDT 9/11/05

PROJECT 04-1120-013-8000		RECORD OF BOREHOLE No 05-3		1 OF 2	METRIC
W.P. 258-98-00	LOCATION N 5019995.68; E 405091.73	ORIGINATED BY W.C.			
DIST HWY 417	BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger	COMPILED BY J.M.			
DATUM Geodetic	DATE May 18, 2005	CHECKED BY M.I.C.			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
							20	40	60	80	100	25	50	75				
							○ UNCONFINED	+ FIELD VANE										
							● QUICK TRIAXIAL	x REMOULDED										
							20	40	60	80	100	25	50	75				
68.6	GROUND SURFACE																	
0.0	Crushed stone (FILL)																	
68.3	Grey																	
0.3	Fine sand, trace silt (FILL) Loose to compact Brown Moist						68											
			1	SS	14													
							67											
			2	SS	23													
			3	SS	32		66										2 70 27 1	
			4	SS	18												0 88 10 2	
64.9							65											
3.7	Silty CLAY (Weathered Crust) Stiff to very stiff Grey brown Wet		5	SS	10													
			6	SS	4		64											
63.2																		
5.3	Silty CLAY Firm Red grey Wet		7	SS	2		63											
			8	SS	WH		62											
			9	SS	PM		61											

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

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

PROJECT 04-1120-013-8000

RECORD OF BOREHOLE No 05-4

1 OF 2

METRIC

W.P. 258-98-00

LOCATION N 5020015.42; E 405079.33

ORIGINATED BY W.C.

DIST HWY 417

BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger

COMPILED BY J.M.

DATUM Geodetic

DATE May 19, 2005

CHECKED BY M.I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								20 40 60 80 100						
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			WATER CONTENT (%)				
							w _p w w _L			25 50 75				
							○ UNCONFINED + FIELD VANE							
							● QUICK TRIAXIAL x REMOULDED							
							20 40 60 80 100			25 50 75				
68.0	GROUND SURFACE													
0.0	TOPSOIL													
0.3	Crushed stone (FILL) Grey Fine sand, trace silt (FILL) Loose to very loose Brown Moist		1	SS	9		67							
			2	SS	2		66					1 84 15 0		
65.8														
2.3	Crushed stone (FILL) Compact Grey brown Wet		3	SS	10		65							
			4	SS	14		64							
64.1														
4.0	Crushed stone with silty clay pockets (FILL) Loose Grey Wet		5	SS	7		63							
63.5														
4.6	Silty CLAY Soft to firm Red grey Wet		6	SS	2									

Continued Next Page

+ 3, X 3. Numbers refer to
Sensitivity

O 3% STRAIN AT FAILURE

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

MISS_MTO 04-1120-013-8000.GPJ ON_MOT.GDT 9/11/05

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

PROJECT <u>04-1120-013-8000</u>			RECORD OF BOREHOLE No 05-5			2 OF 2			METRIC		
W.P. <u>258-98-00</u>			LOCATION <u>N 5019265.31; E 412677.16</u>			ORIGINATED BY <u>W.C.</u>					
DIST <u> </u> HWY <u>417</u>			BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>			COMPILED BY <u>J.M.</u>					
DATUM <u>Geodetic</u>			DATE <u>May 24, 2005</u>			CHECKED BY <u>M.I.C.</u>					

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
							<div style="display: flex; justify-content: space-between; font-size: small;"> 20 40 60 80 100 20 40 60 80 100 </div>					<div style="display: flex; justify-content: space-between; font-size: small;"> 25 50 75 </div>					
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED										
53.3							X	+									
10.4	Silty CLAY, trace organic matter, occasional silt seam Firm Red grey Wet					X	+										
			9	SS	PM	53											
							X	+									
							X	+									
			10	SS	PM	51											
50.3							X	+									
13.4	End of Borehole						X	+									

MISS_MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05



PROJECT <u>04-1120-013-8000</u>		RECORD OF BOREHOLE No 05-6		1 OF 2	METRIC
W.P. <u>258-98-00</u>	LOCATION <u>N 5019293.89; E 412658.55</u>	ORIGINATED BY <u>W.C.</u>			
DIST <u>HWY 417</u>	BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>	COMPILED BY <u>J.M.</u>			
DATUM <u>Geodetic</u>	DATE <u>May 26, 2005</u>	CHECKED BY <u>M.I.C.</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL x REMOULDED									
							WATER CONTENT (%)										
							20	40	60	80	100	25	50	75			
63.5	GROUND SURFACE																
0.0	Topsoil (FILL)																
0.1	Fine sand, trace to some silt (FILL) Brown																
62.9																	
0.6	Crushed stone (FILL) Compact Grey Moist to wet		1	SS	17												
			2	SS	11												
			3	SS	14												
60.7																	
2.9	Silty CLAY, trace organic matter Firm Red grey Wet																
			4	73 TP	PH								17.9				
			5	SS	WH												
			6	SS	1												
			7	SS	1												
			8	SS	PM												

Continued Next Page

+3, x3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>04-1120-013-8000</u>		RECORD OF BOREHOLE No 05-6		2 OF 2	METRIC
W.P. <u>258-98-00</u>	LOCATION <u>N 5019293.89; E 412658.55</u>	ORIGINATED BY <u>W.C.</u>			
DIST <u>HWY 417</u>	BOREHOLE TYPE <u>Power Auger 108mm I.D. Hollow Stem Auger</u>	COMPILED BY <u>J.M.</u>			
DATUM <u>Geodetic</u>	DATE <u>May 26, 2005</u>	CHECKED BY <u>M.I.C.</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED					w _p w w _L				
								20	40	60	80	100	25	50	75		
	— CONTINUED FROM PREVIOUS PAGE —																
	Silty CLAY, trace organic matter Firm Red grey Wet							X	+								
								53	X	+							
			9	SS	PM										○		
								52	X	+							
									X	+							
			10	SS	PM									○			
50.1								X	+								
13.4	End of Borehole							X	+								
	Note: Water level in well screen at 1.16m depth below ground surface on June 15, 2005.																

MISS MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05

PROJECT 04-1120-013-8000		RECORD OF BOREHOLE No 05-7		1 OF 2	METRIC
W.P. 258-98-00		LOCATION N 5019178.37; E 412969.96		ORIGINATED BY W.C.	
DIST HWY 417		BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger		COMPILED BY J.M.	
DATUM Geodetic		DATE May 25, 2005		CHECKED BY M.I.C.	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
63.7	GROUND SURFACE													
0.0	Crushed stone (FILL) Grey													
63.2														
0.5	Fine sand, trace to some silt (FILL) Loose Brown Moist to wet		1	SS	6		63							
			2	SS	6		62							0 65 (35)
			3	SS	4		61							
60.5														
3.2	Crushed stone (FILL) Loose to compact Grey Wet		4	SS	26		60							33 48 (19)
			5	SS	8		59							
			6	SS	6									
58.2														
5.5	Silty CLAY, trace organic matter Firm Red grey Wet		7	SS	1		58							
			8	73 TP	PH									
							57	X	+					
								X	+					
			9	SS	PM		56							
							55	X	+					
								X	+					
			10	SS	PM		54							

MISS_MTO 04-1120-013-8000.GPJ ON MOT GDT 9/11/05

Continued Next Page

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

PROJECT 04-1120-013-8000

RECORD OF BOREHOLE No 05-7

2 OF 2

METRIC

W.P. 258-98-00

LOCATION N 5019178.37; E 412969.96

ORIGINATED BY W.C.

DIST HWY 417

BOREHOLE TYPE Power Auger 108mm I.D. Hollow Stem Auger

COMPILED BY J.M.

DATUM Geodetic

DATE May 25, 2005

CHECKED BY M.I.C.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						
-- CONTINUED FROM PREVIOUS PAGE --								20 40 60 80 100					w _p w w _L						
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED												
53.3																			
10.4	Silty CLAY, trace organic matter Stiff Red grey Wet		11	SS	PM														
			12	SS	PM														
			13	SS	PM														
			14	SS	WR														
47.2																			
16.5	End of Borehole																		
	Note: Water level in well screen at 3.72m depth below ground surface on June 15, 2005.																		

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

MISS_MTO 04-1120-013-8000.GPJ ON MOT.GDT 9/11/05

MISS_MTO 04-1120-013-8000.GPJ ON_MOT.GDT 9/11/05

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

HWY. 417

WP No. WP 258-98-00

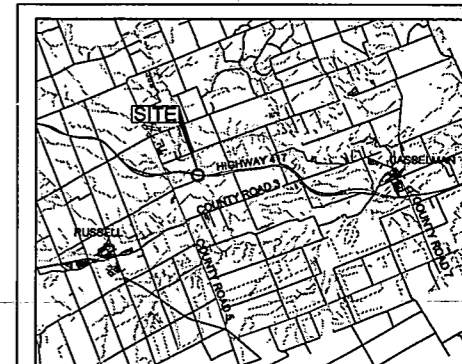
HIGHWAY 417
BOREHOLE LOCATIONS
CULVERTS 13 AND 14



SHEET





Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



KEY PLAN

LEGEND

-  Borehole - Current Golder Associates Ltd. Investigation
-  Location of cross-section

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
05-1	68.5	5019919.0	405104.4
05-2	68.2	5019968.5	405089.9
05-3	68.6	5019995.7	405091.7
05-4	68.0	5020015.4	405079.3

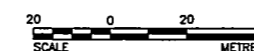
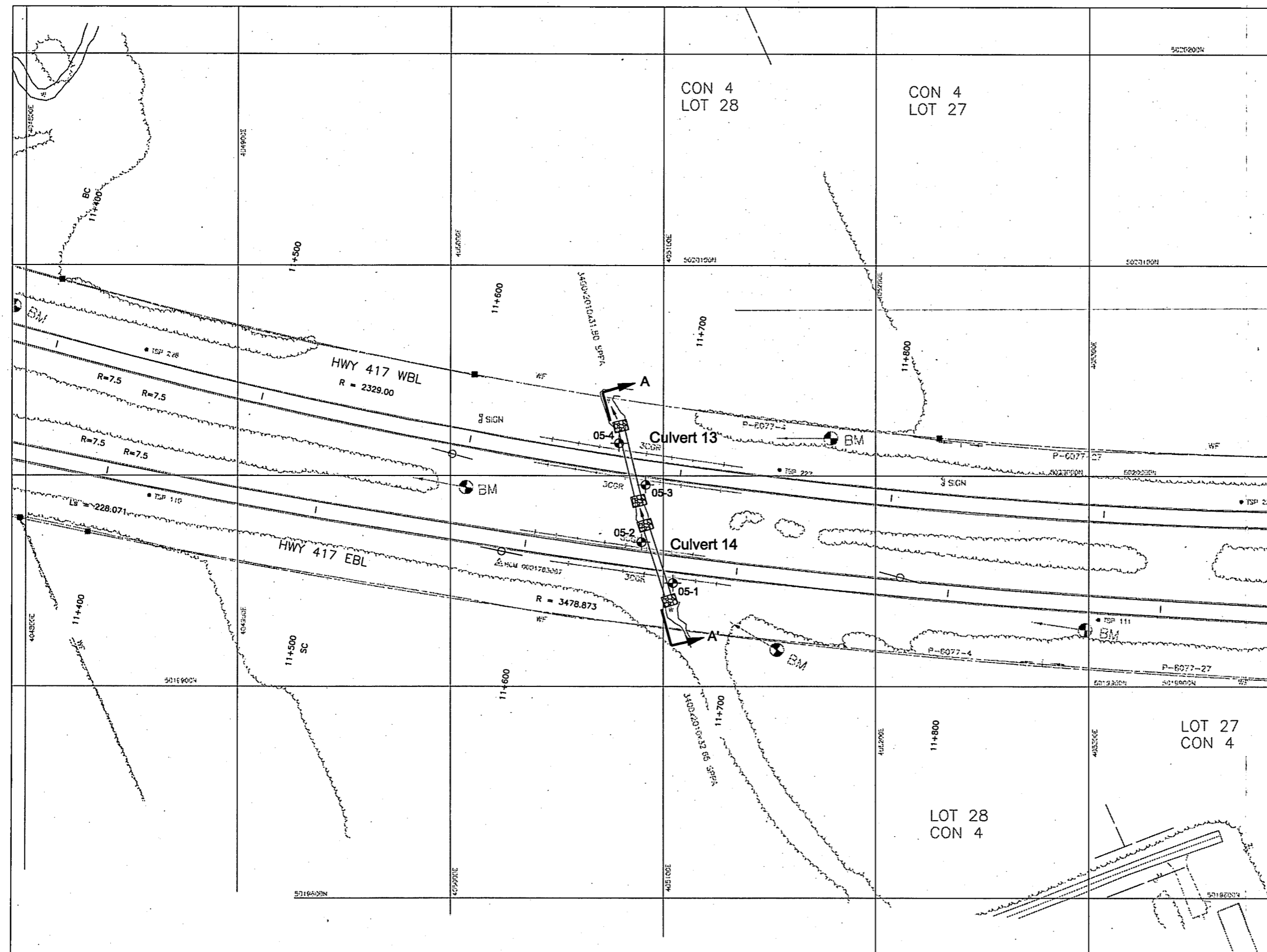
NOTES

The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
Base plan provided in electronic format by Morrison Hershfield

NO.	DATE	BY	REVISION

Geocres No.

HWY. 417		PROJECT NO. 04-1120-013-8000	DIST.
SUBM'D. W.C.	CHKD. M.I.C.	DATE: JULY 2005	SITE:
DRAWN: J.M.	CHKD. W.C.	APPD.	DWG. 1



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

HWY. 417

WP No. WP 258-98-00

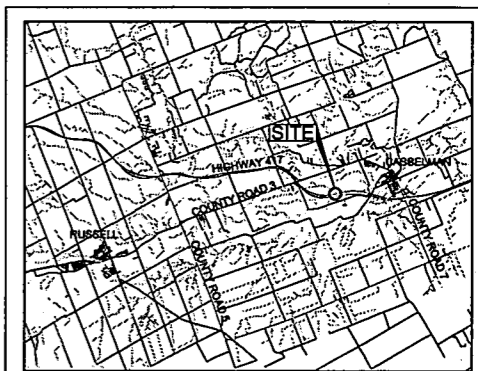
HIGHWAY 417
BOREHOLE LOCATIONS
CULVERT 35



SHEET



Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



KEY PLAN



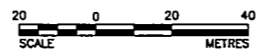
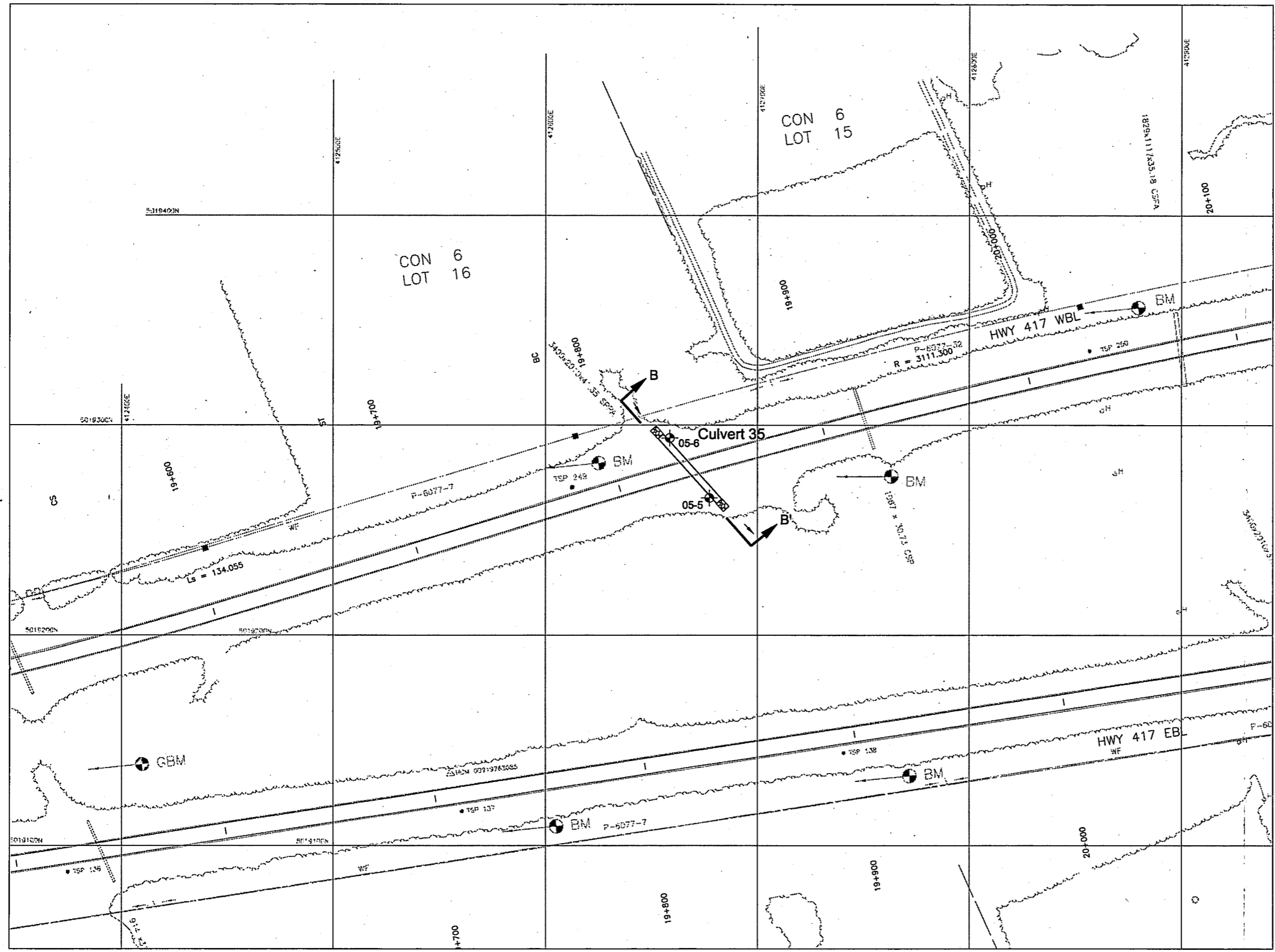
LEGEND

- Borehole - Current Golder Associates Ltd. Investigation
- Location of cross-section

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
05-5	63.7	5019265.3	412677.2
05-6	63.5	5019293.9	412658.6

NOTES

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.
Base plan provided in electronic format by Morrison Hershfield



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

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 417	PROJECT NO. 04-1120-013-8000		DIST.
SUBM'D. W.C.	CHKD. M.I.C.	DATE: JULY 2005	SITE:
DRAWN: J.M.	CHKD. W.C.	APPD.	DWG. 2

04-1120-013-8000-01.dwg

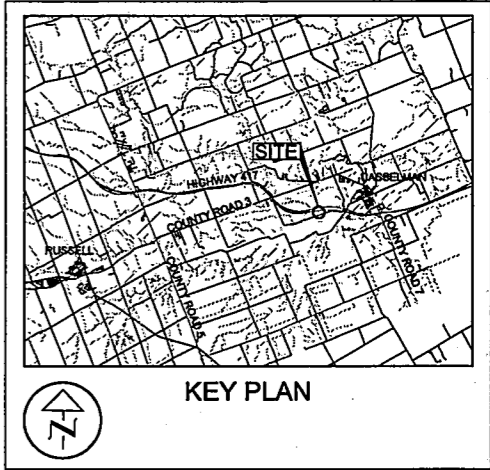
HWY. 417

WP No. WP 258-98-00

HIGHWAY 417
BOREHOLE LOCATIONS
CULVERT 38

SHEET

Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



LEGEND

Borehole - Current Golder Associates Ltd. Investigation

Location of cross-section

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
05-7	63.7	5019178.4	412969.9
05-8	62.6	5019200.2	412967.8

NOTES

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

Base plan provided in electronic format by Morrison Hershfield

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 417	PROJECT NO. 04-1120-013-8000		DIST.
SUBM'D. W.C.	CHKD. M.I.C.	DATE: JULY 2005	SITE:
DRAWN: J.M.	CHKD. W.C.	APPD.	DWG. 3

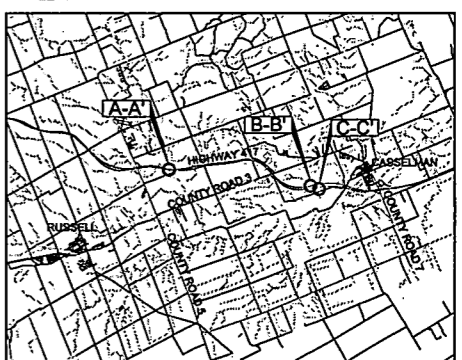


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

04-1120-013-8000-01.dwg



Golder Associates Ltd.
OTTAWA, ONTARIO, CANADA



KEY PLAN

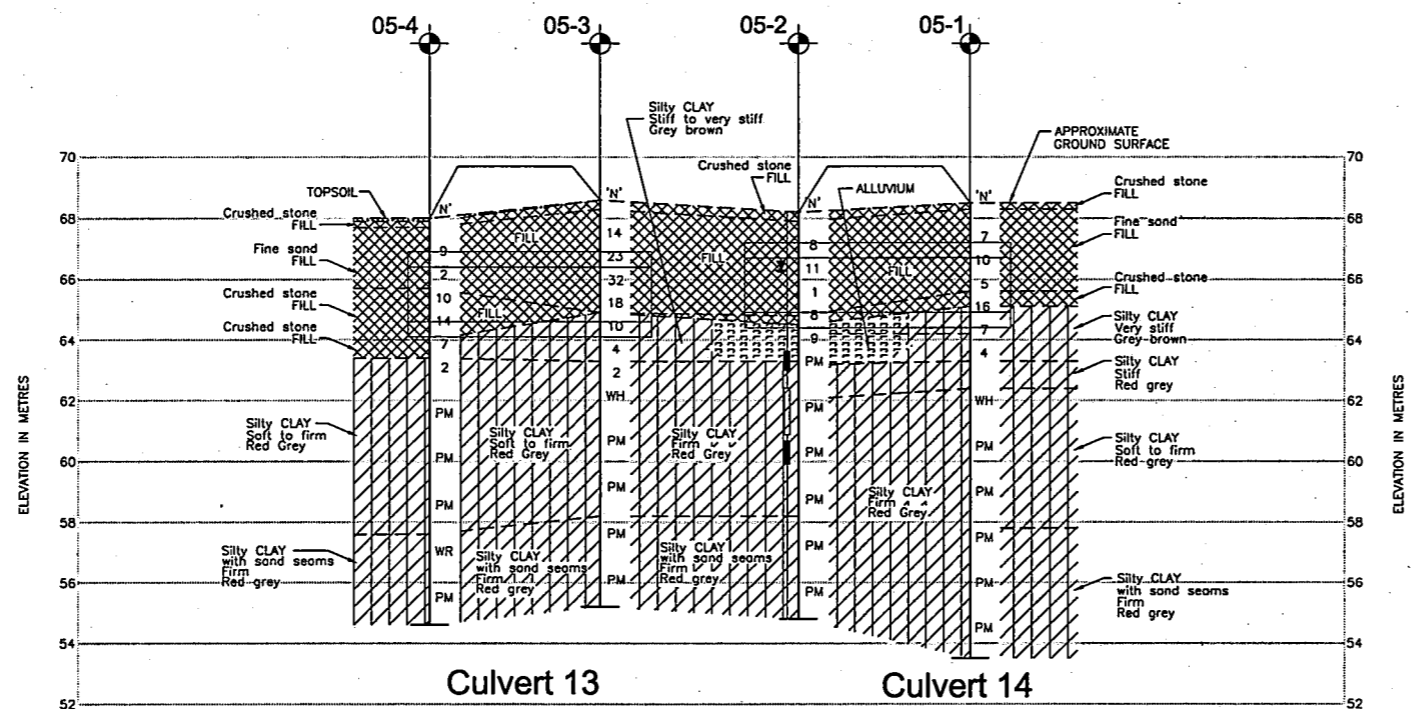
LEGEND

- Borehole - Current Golder Associates Ltd. Investigation
- Seal
- Piezometer
- Standard Penetration Test value
- Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 l/blow)
- Water Level

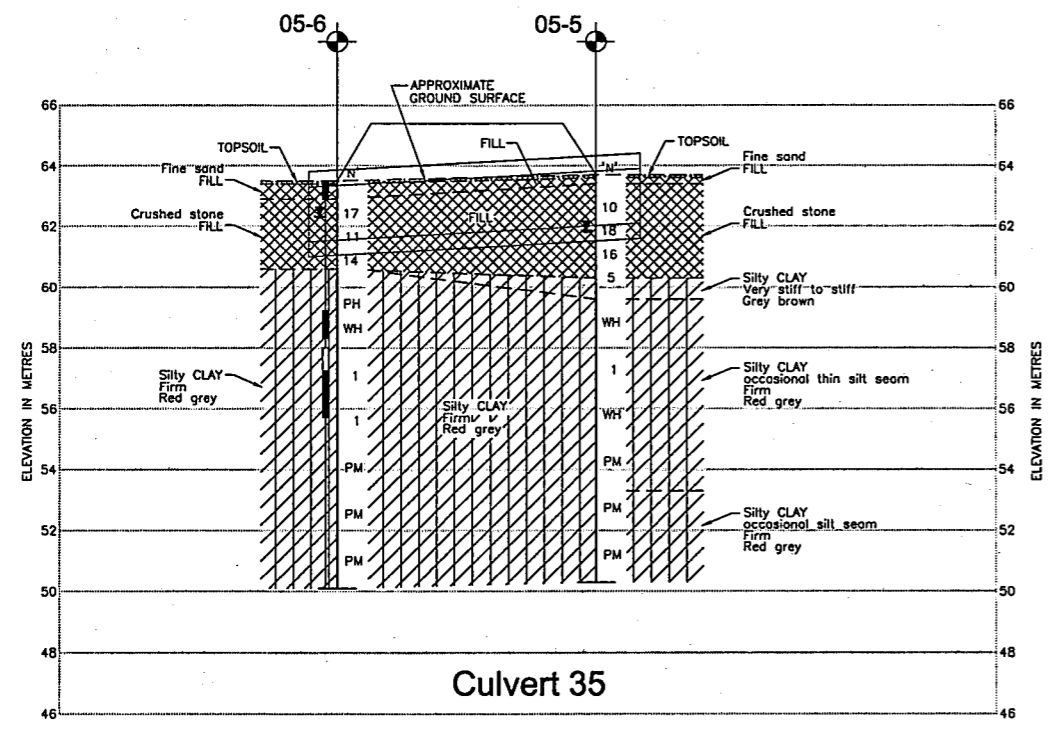
No.	ELEVATION	LOCATION	
		NORTHING	EASTING
05-1	68.5	5019919.0	405104.4
05-2	68.2	5019968.5	405089.9
05-3	68.6	5019995.7	405091.7
05-4	68.0	5020015.4	405079.3
05-5	63.7	5019265.3	412677.2
05-6	63.5	5019293.9	412658.6
05-7	63.7	5019178.4	412969.9
05-8	62.6	5019200.2	412967.8

NOTES

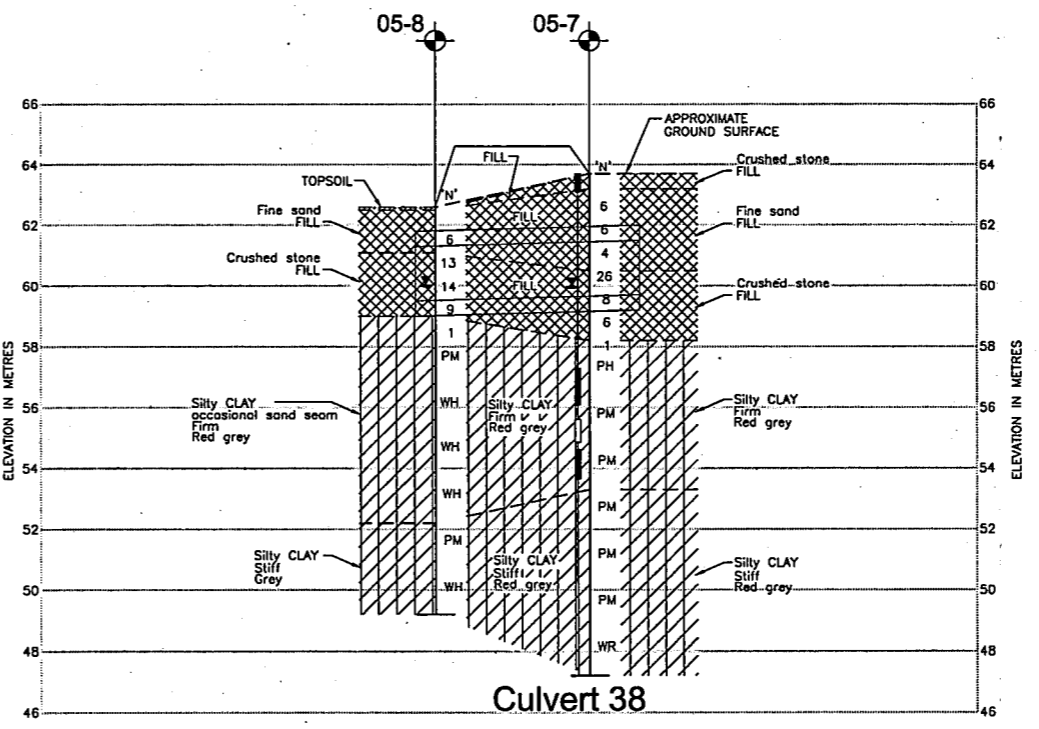
This drawing is for subsurface information only. Any surface details are for conceptual illustration.
The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
Base plan provided by Morrison Hershfield



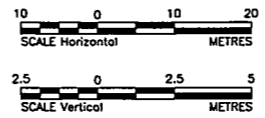
SECTION A-A'



SECTION B-B'



SECTION C-C'



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

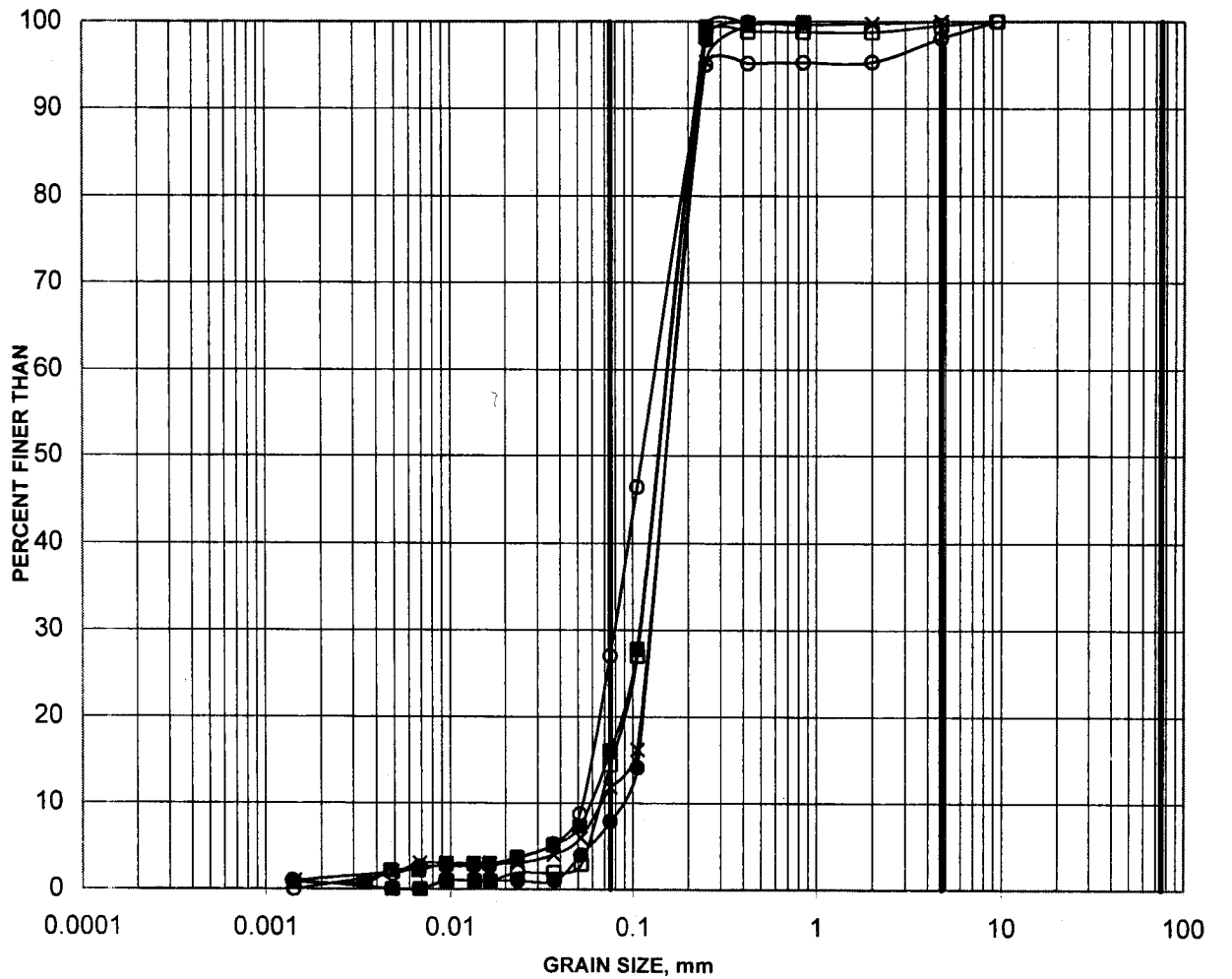
NO.	DATE	BY	REVISION

Geocres No.	PROJECT NO. 04-1120-013-8000	DIST.
HWY. 417		
SUBM'D. W.C.	CHKD. M.I.C.	DATE: JULY 2005
DRAWN: J.M.	CHKD. W.C.	APPD.
		DWG. 4

GRAIN SIZE DISTRIBUTION

FIGURE 1

Fine Sand Fill

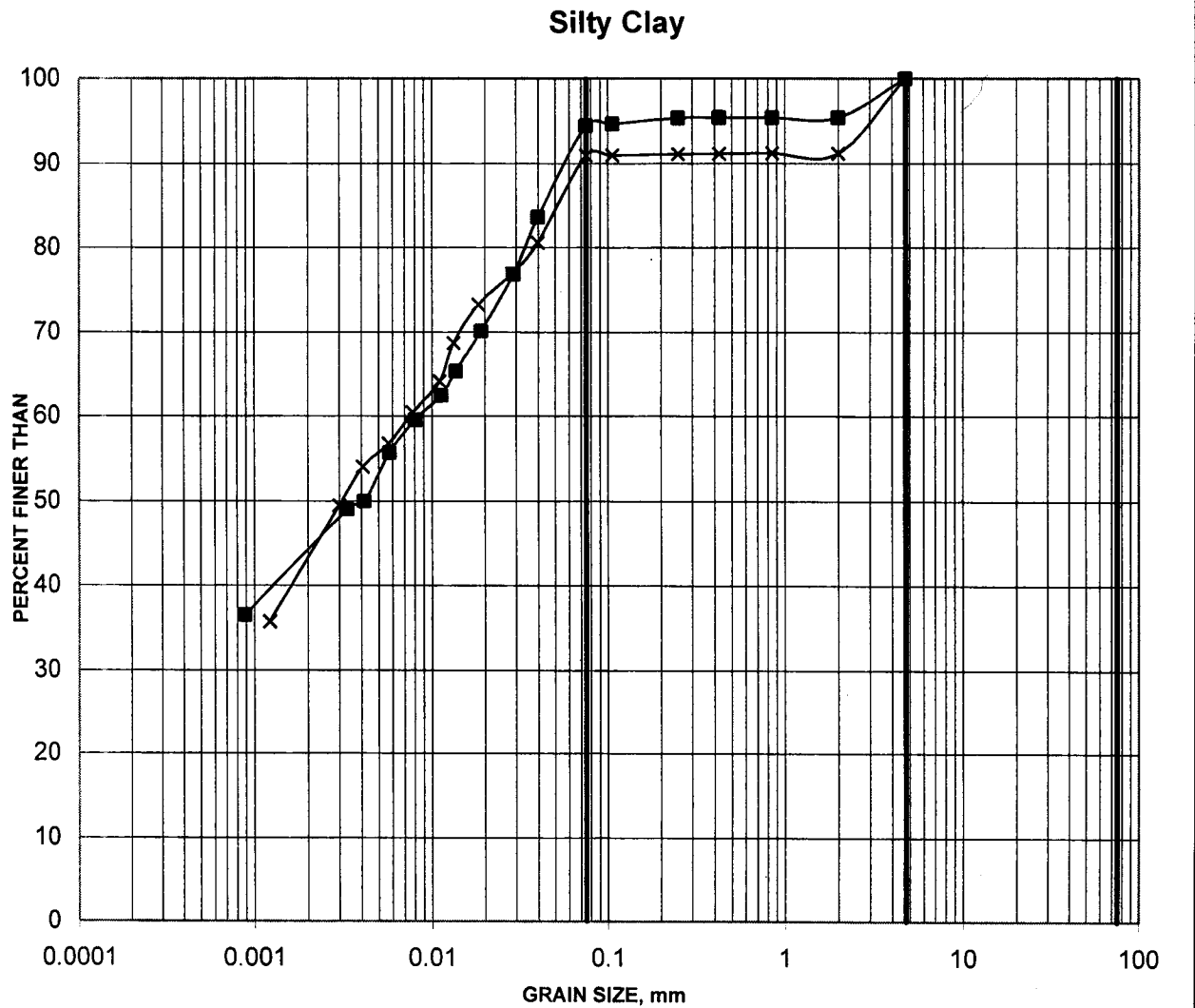


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
05-1	3	1.5-2.1
05-2	3	1.5-2.1
05-3	3	1.5-2.1
05-3	4	3.0-3.7
05-4	2	1.5-2.1

GRAIN SIZE DISTRIBUTION

FIGURE 2



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

Borehole	Sample	Depth (m)
—■— 05-1	6	3.8-4.4
—x— 05-2	8	6.1-6.7

Received:

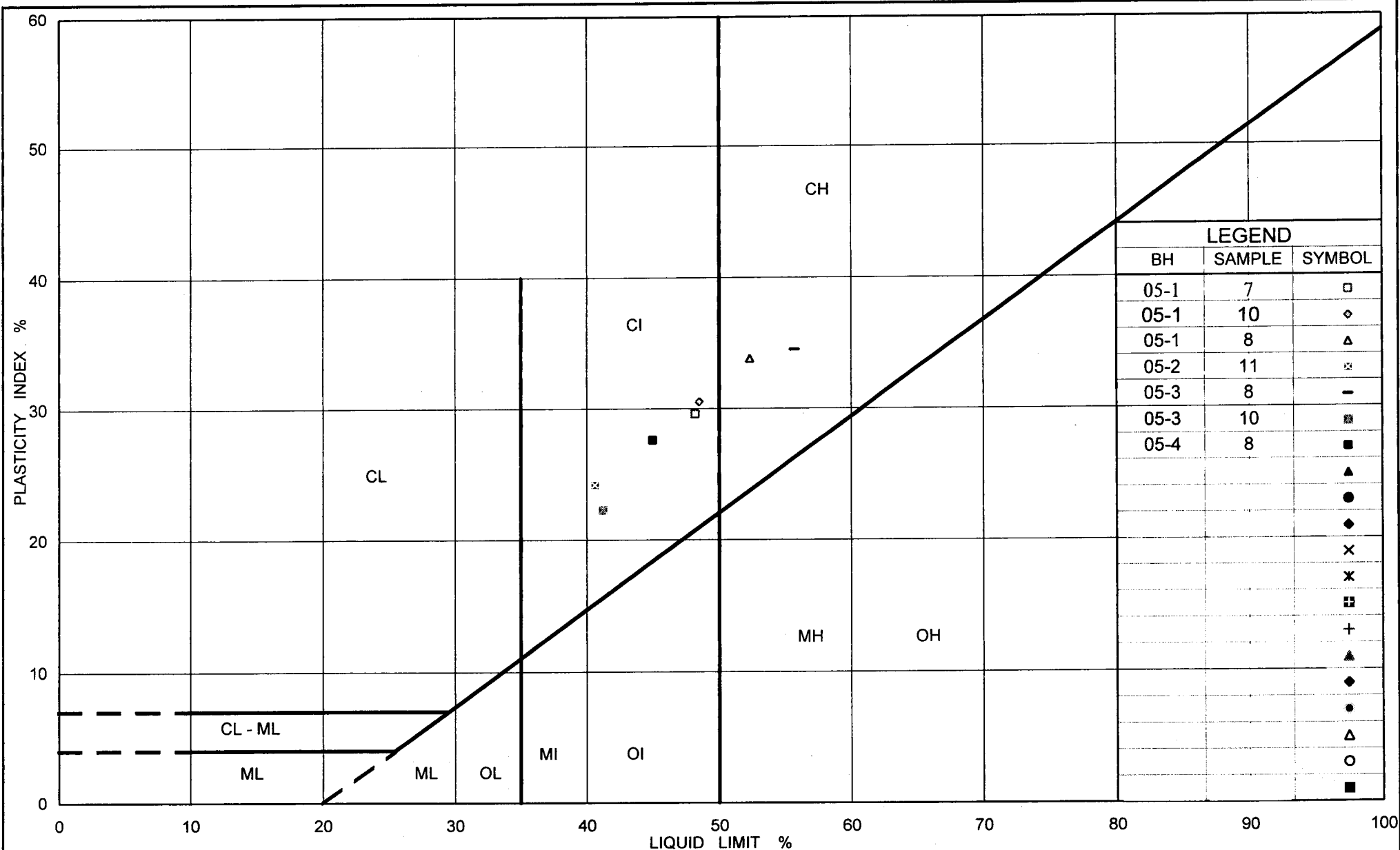
Project: 04-1120-013

Golder Associates

19-Jul-05

Created by:

Checked by:



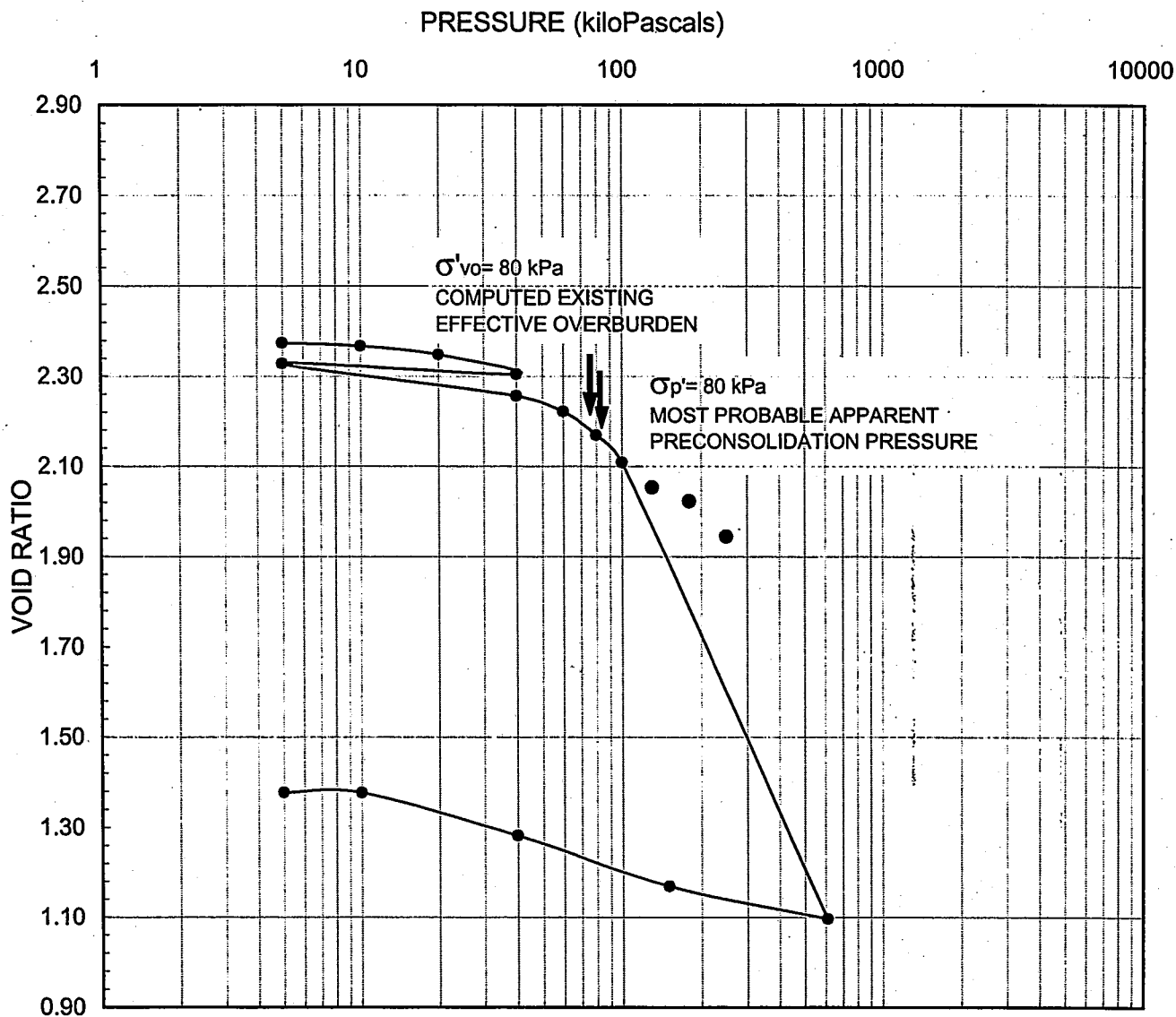
Ministry of Transportation

Ontario

PLASTICITY CHART Silty Clay to Clay

FIG No.3

Project No. 04-1120-013



LEGEND

Borehole: 05-4	$w_i = 87.5\%$	$S_o = 100\%$
Sample: 7	$w_f = 55.3\%$	$C_c = 1.43$
Depth (m): 6.60	$w_l = 70.6\%$	$C_r = 0.027$
	$w_p = 24.4\%$	



SCALE	AS SHOWN
DATE	07/20/05
DESIGN	NA
CADD	NA
CHECK	EWK
REVIEW	MIC

TITLE

CONSOLIDATION TEST RESULTS

FILE No.	Consolidation summary
PROJECT No.	04-1120-013
REV.	0

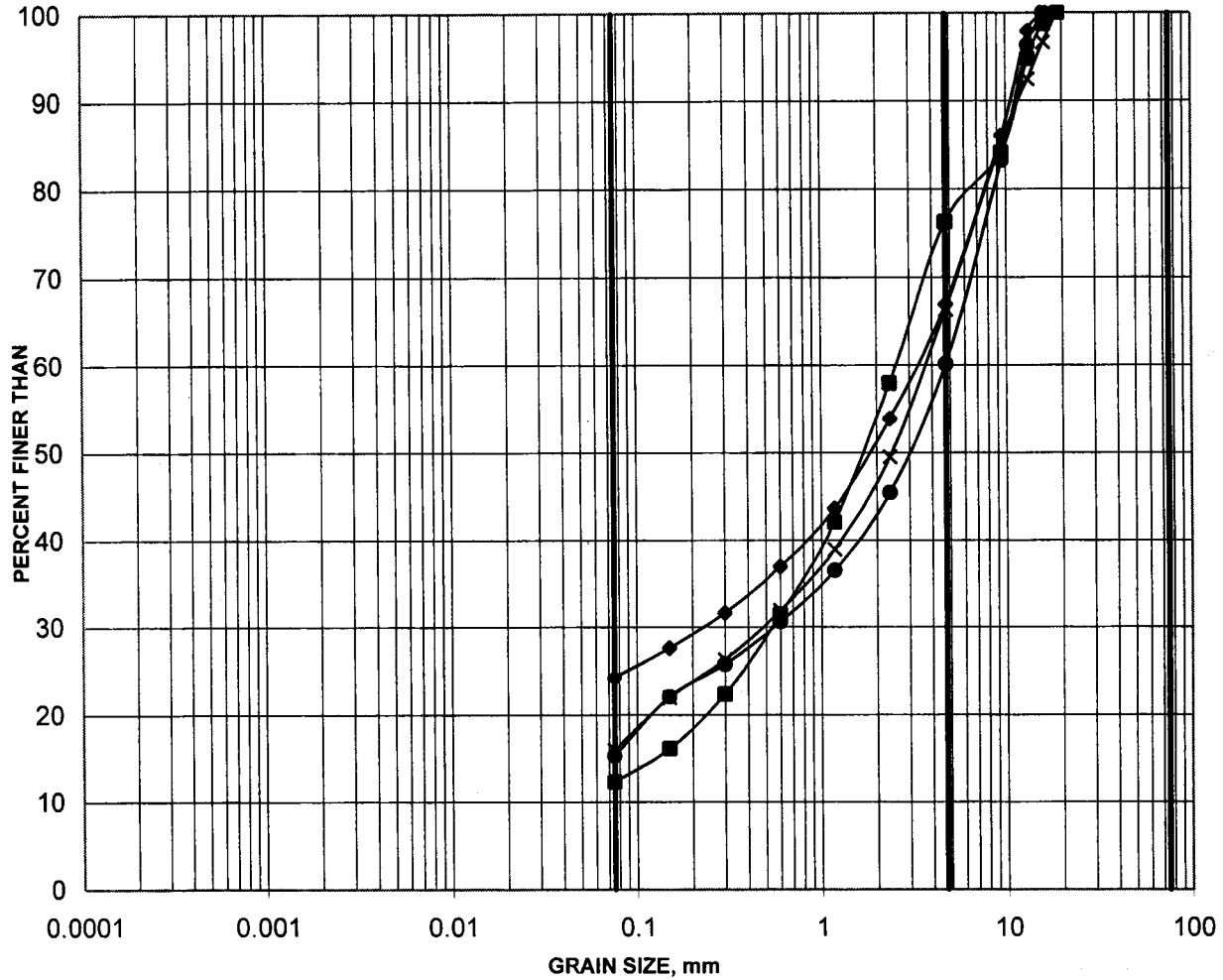
FIGURE

4

GRAIN SIZE DISTRIBUTION

FIGURE 5

Crushed Stone Fill

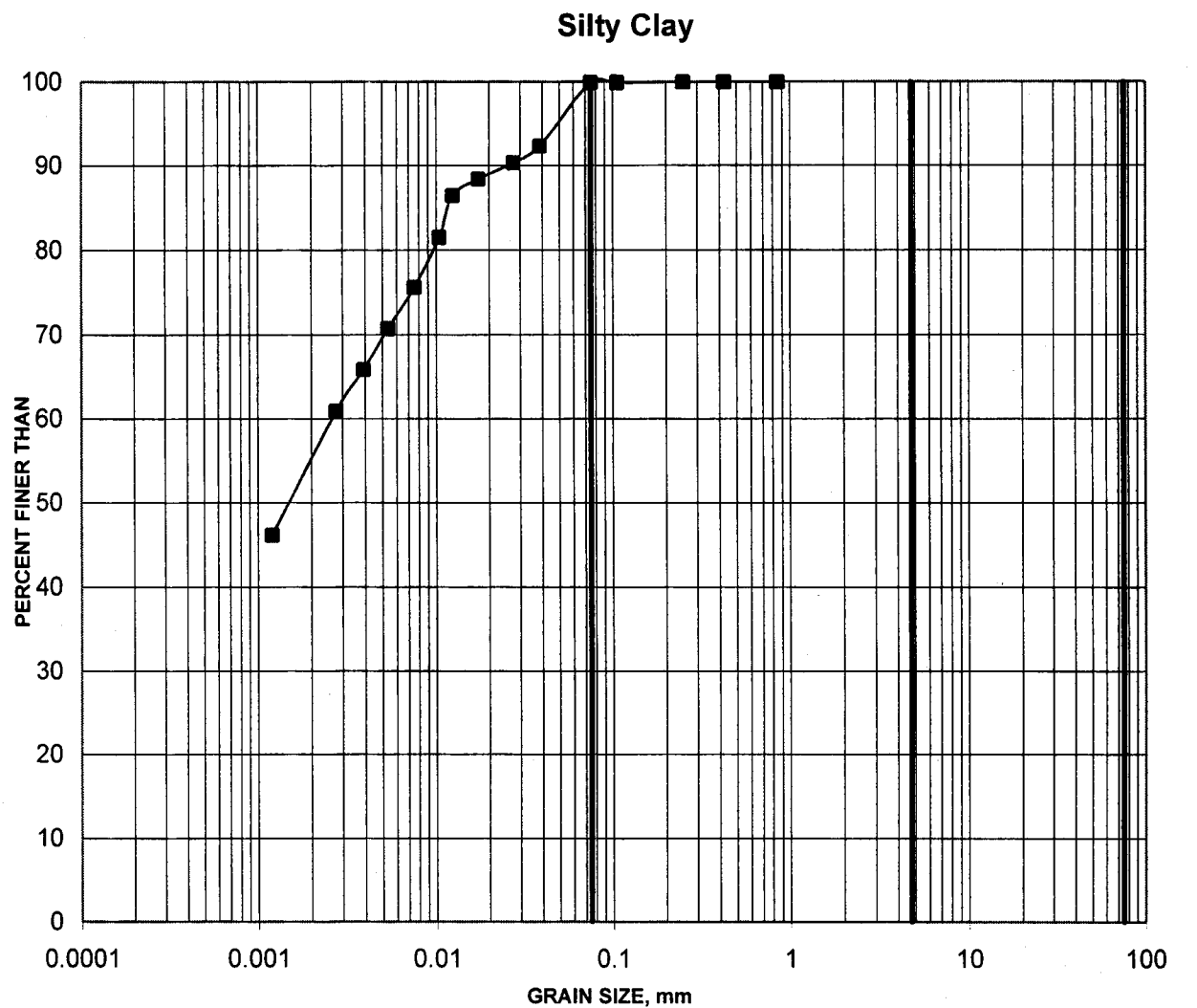


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
—■—	05-5	3
—×—	05-5	2
—●—	05-6	3
—◆—	05-6	2

GRAIN SIZE DISTRIBUTION

FIGURE 6



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

Borehole	Sample	Depth (m)
05-5	8	9.1-9.8

Received:

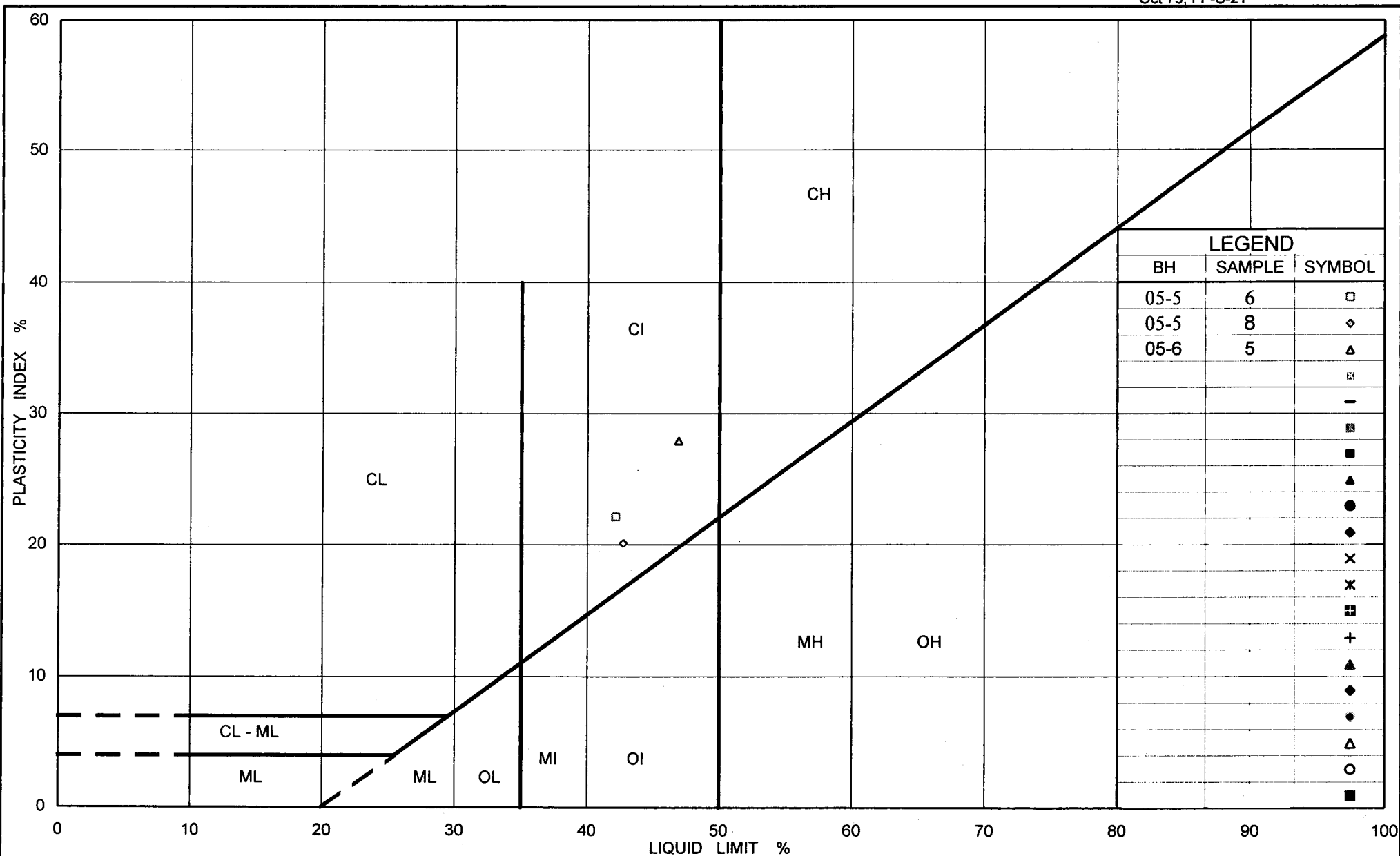
Project: 04-1120-013

Golder Associates

19-Jul-05

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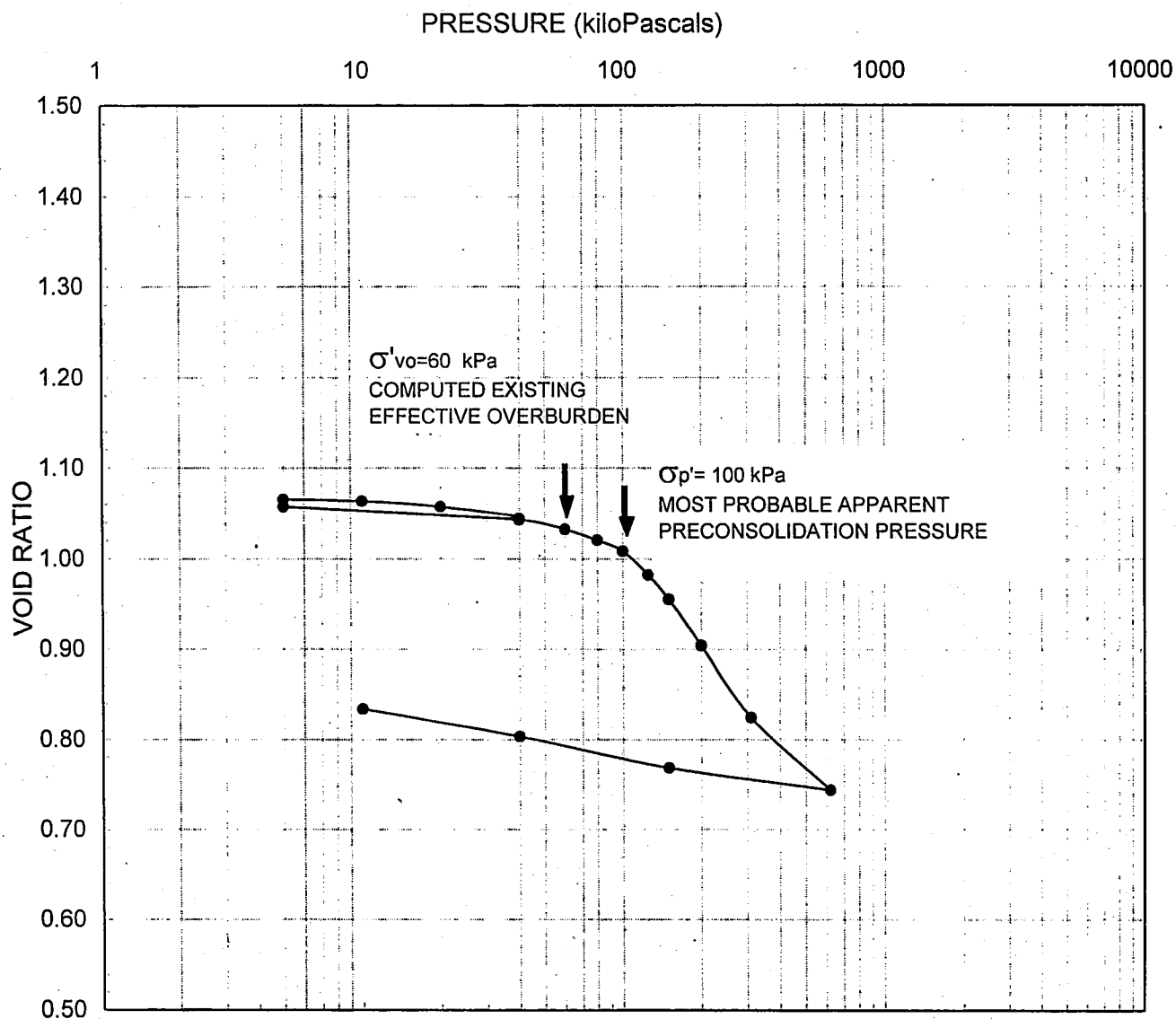
Ministry of Transportation

Ontario

PLASTICITY CHART **Silty Clay**

FIG No.7

Project No. 04-1120-013



LEGEND

Borehole: 05-6	$w_i = 40.2\%$	$S_o = 102\%$
Sample: 4	$w_r = 31.3\%$	$C_c = 0.40$
Depth (m): 4.40	$w_l = 47.4\%$	$C_r = 0.016$
	$w_p = 20.7\%$	



SCALE	AS SHOWN
DATE	07/19/05
DESIGN	NA
CADD	NA
CHECK	EWK
REVIEW	MIC

TITLE

CONSOLIDATION TEST RESULTS

FILE No.	Consolidation summary	
PROJECT No.	04-1120-013	REV. 0

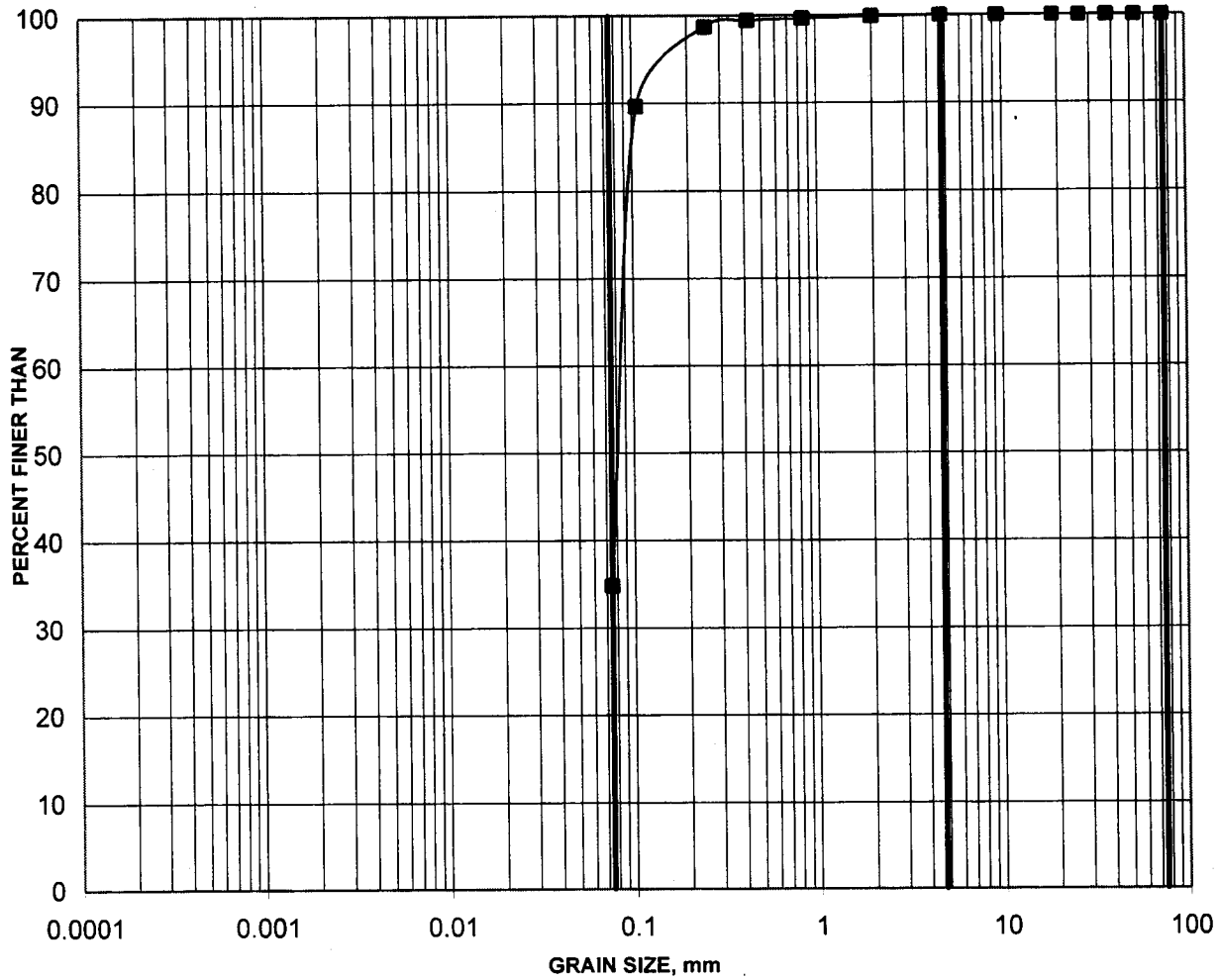
FIGURE

8

GRAIN SIZE DISTRIBUTION

FIGURE 9

Fine Sand Fill



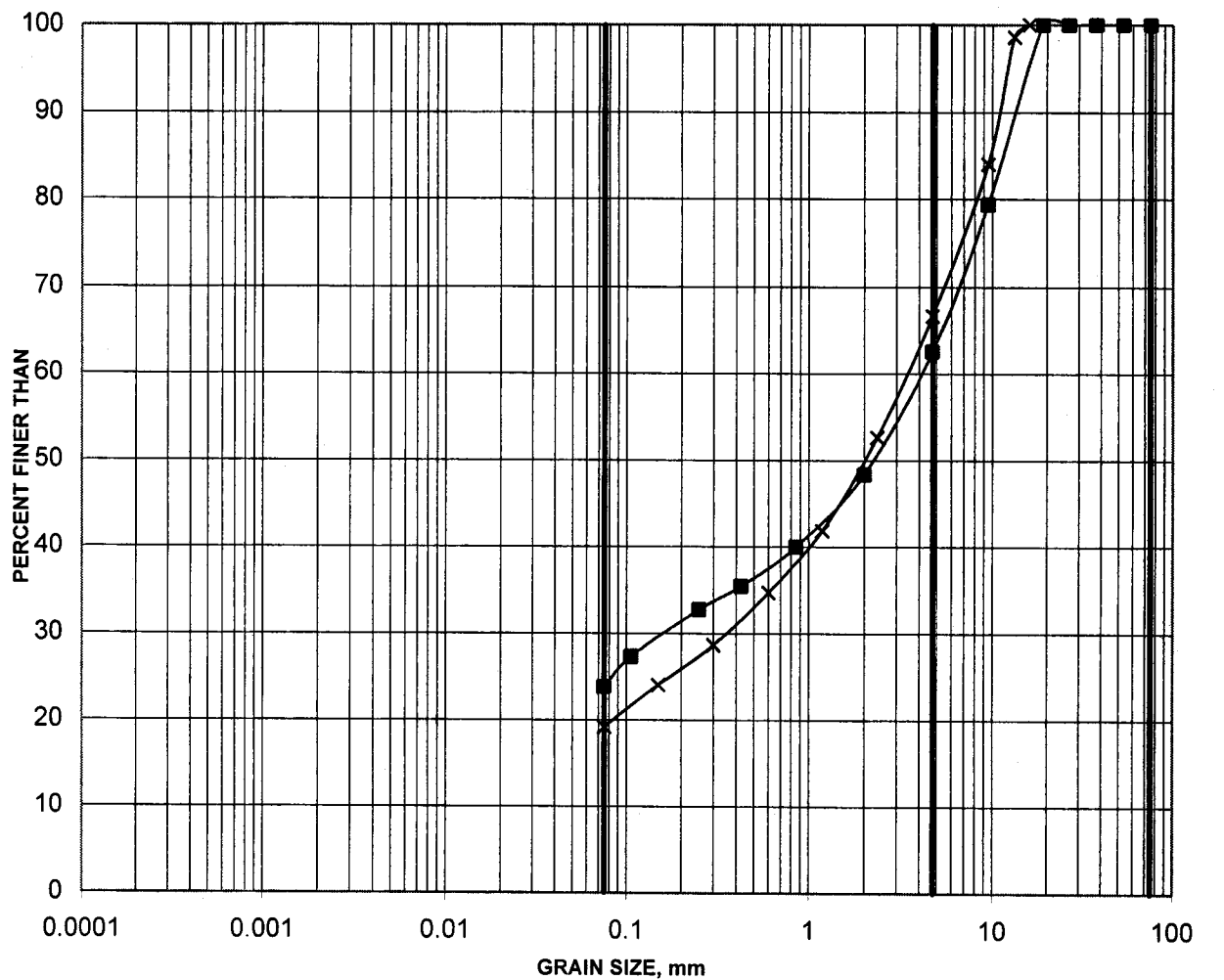
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
05-7	2	1.5-2.1

GRAIN SIZE DISTRIBUTION

FIGURE 10

Crushed Stone Fill

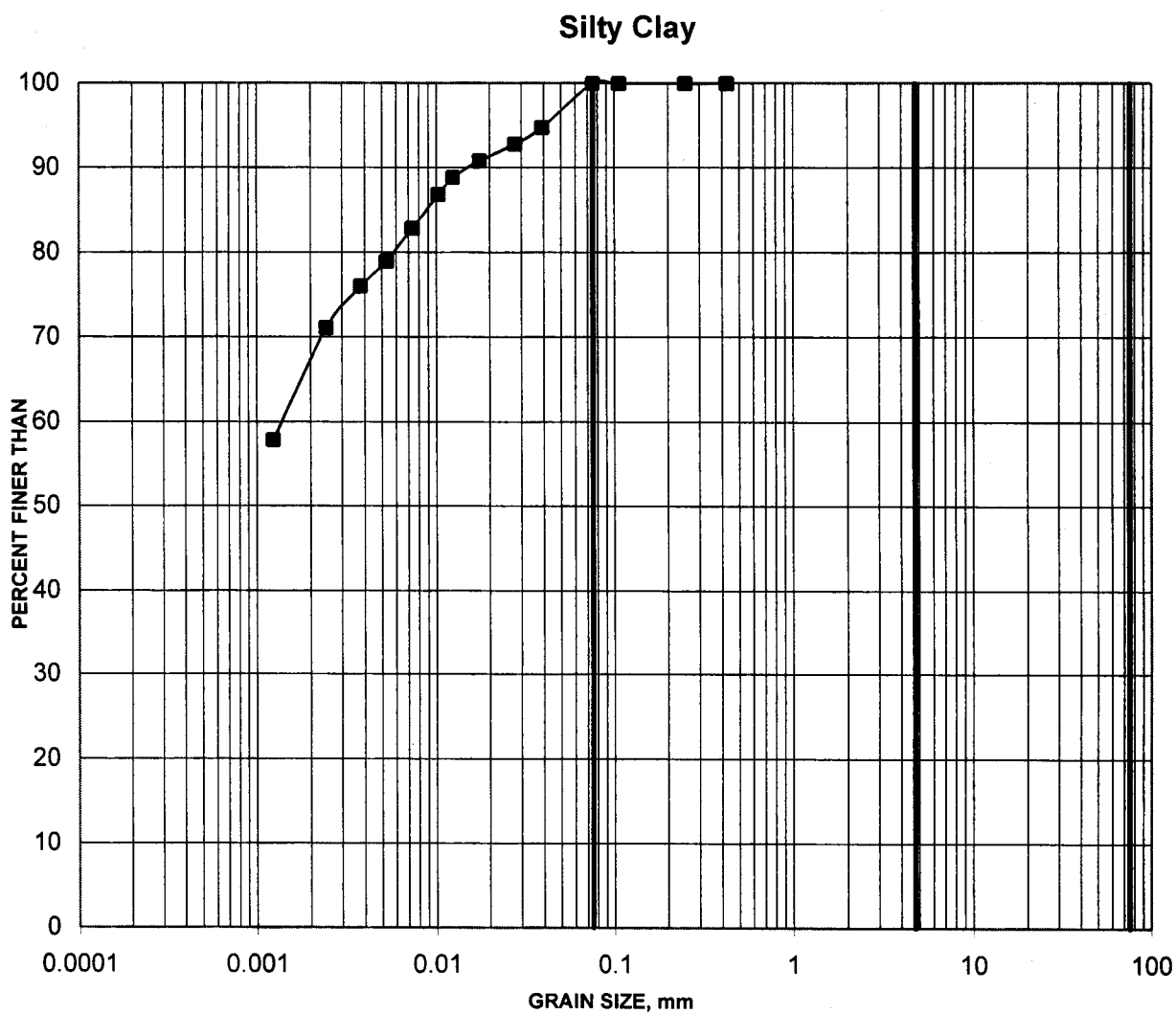


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
—■— 05-8	3	2.3-2.9
—×— 05-7	4	3.0-3.7

GRAIN SIZE DISTRIBUTION

FIGURE 11



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

Borehole	Sample	Depth (m)
—■— 05-8	6	4.6-5.2

Received:

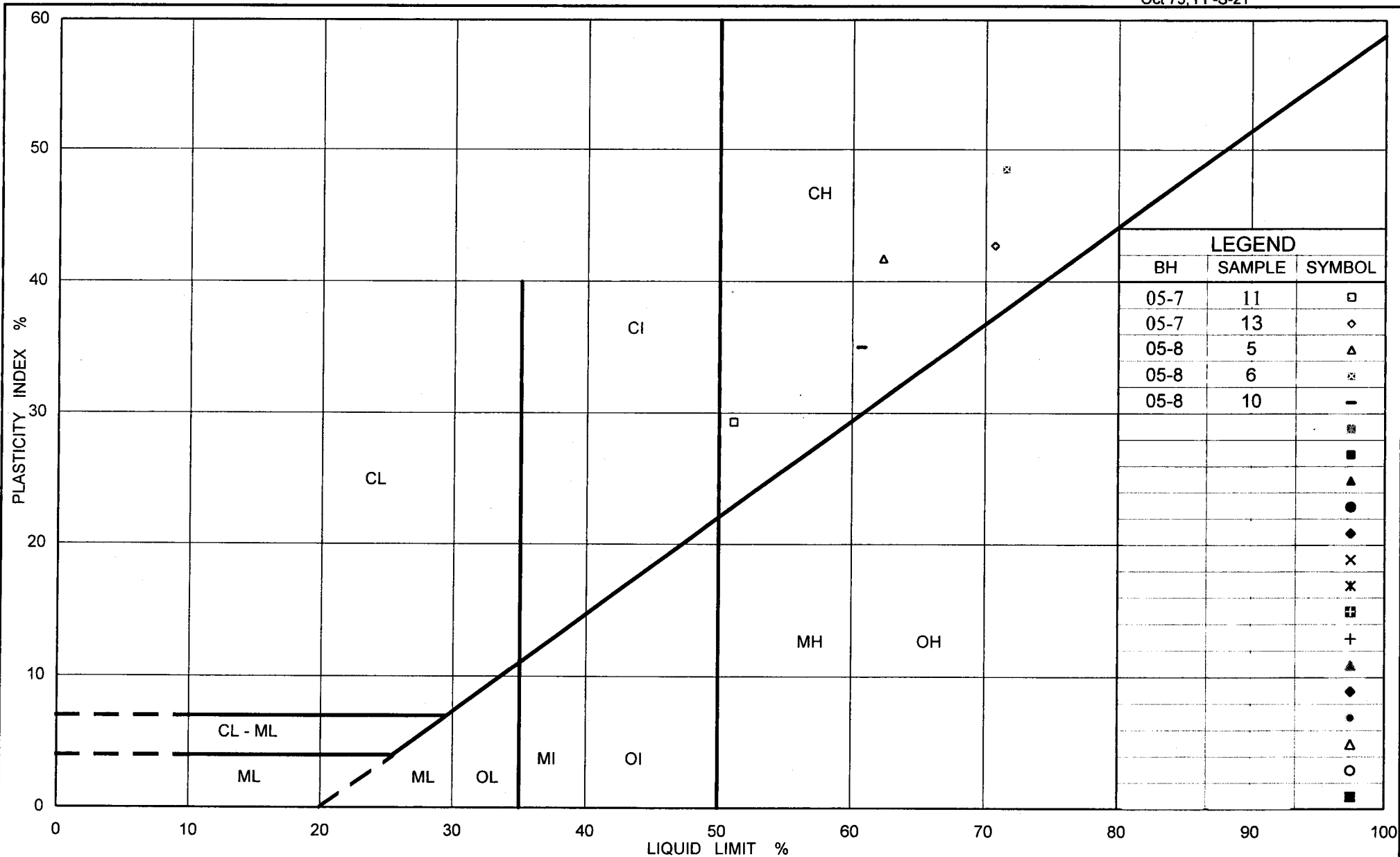
Project: 04-1120-013

Golder Associates

19-Jul-05

Created by:

Checked by:



Ministry of Transportation

Ontario

PLASTICITY CHART Clay

FIG No.12

Project No. 04-1120-013