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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CN RAIL BRIDGE REPLACEMENT  
QEW WIDENING BETWEEN GLENDALE AVENUE  
AND MOUNTAIN ROAD INTERCHANGES  
REGIONAL MUNICIPALITY OF NIAGARA FALLS  
G.W.P. 281-99-00, AGREEMENT NO. 2005-A-000197**

Submitted to:

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**PART A**

**FOUNDATION INVESTIGATION REPORT  
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## **1.0 INTRODUCTION**

Golder Associates Ltd. has been retained by the McCormick Rankin Corporation (McCormick Rankin) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the widening of a 4 km length of the Queen Elizabeth Way (QEW) between the Glendale Avenue and Mountain Road interchanges in Niagara Falls, Ontario. Foundation engineering services are required for the widening of the existing Canadian National Rail (CN Rail) bridge over the QEW, the extension and / or replacement of ten structural culverts, new retaining and noise barrier walls, and proposed high mast lighting.

This report addresses the replacement of the CN Rail bridge over the QEW, including both temporary detour and permanent structures. A foundation investigation was carried out to determine the subsurface conditions at the new foundation elements for the permanent and detour structures by drilling a limited number of boreholes, and carrying out in-situ testing and laboratory testing on selected samples.

The terms of reference for the scope of work are outlined in Golder Associates' Proposal No. P01-8048, dated April 2000. The work has been carried out in accordance with Golder Associates' Quality Control Plan for Foundation Design Services, dated April 2000.

The proposed alignment for the CN Rail bridge replacement was presented on profiles provided to us by McCormick Rankin. The General Arrangement plan showing the proposed abutment and pier layout for the CN Rail underpass structure was provided by McCormick Rankin in digital format on February 20, 2001.

## 2.0 SITE DESCRIPTION

The CN Rail bridge is located on the QEW between St. Catharines and Niagara Falls, about 1 km south of Highway 405 and 1.5 km north of Mountain Road. The site is located at Mile 5.6 of the CN Rail Grimsby Subdivision (London Division).

Between the north and south limits of the existing bridge structure, the QEW grade rises from about Elevation 153 m to 153.5 m, respectively. The rail is about Elevations 159.1 m to 159.3 m at the existing structure. The original ground surface in the site area was between Elevation 148 m and 156 m; the rail embankments are up to 10 m in height.

The existing CN Rail bridge, constructed in 1937, is a two-span structure with abutments and pier supported on spread footings. The founding elevations rise from west to east, and the individual footings step upward from west to east, as summarized in the following table:

| <i>Foundation Element<br/>(Existing Structure)</i> | <i>Approximate<br/>Founding Elevation</i> |
|--|---|
| West Abutment                                      | 150.3 m to 150.6 m                        |
| Centre Pier  | 150.7 m to 150.9 m                        |
| East Abutment                                      | 151.0 m to 151.3 m                        |

These founding conditions and elevations have been determined from copies of plans for the existing structure, which were provided by the MTO (General Plan – Drawing No. C-8591, Details of Abutments – Drawing No. C-8595 and Details of Pier – Drawing No. C-8592, dated February 1937).

### 3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out between September 2000 and February 2001. Six boreholes, numbered CN-00-1 to CN-00-6, were advanced to between 4.9 m and 17.8 m below the existing ground surface. Boreholes CN-00-1 and CN-00-3 were located in the vicinity of the proposed west abutment; Boreholes CN-00-2 and CN-00-4 were located in the area of the proposed central pier (near the existing west abutment); and Boreholes CN-00-5 and CN-00-6 were advanced in the vicinity of the west and east abutments for the proposed temporary detour structure. The general locations and depths of each of the boreholes are summarized in the following table:

| <i>Borehole Number</i> | <i>Location</i>   | <i>Depth</i> | <i>Comments</i>                        |
|------------------------|---|--------------|--|
| CN-00-1                | Proposed west abutment, drilled through CN Rail embankment  | 16.5 m       | Extended about 3 m into bedrock        |
| CN-00-2                | Proposed centre pier, drilled through CN Rail embankment  | 17.8 m       | Extended about 3 m into bedrock        |
| CN-00-3                | Proposed west abutment, drilled at north embankment toe   | 4.9 m        | Terminated at auger refusal on bedrock |
| CN-00-4                | Proposed centre pier, drilled on QEW at north end of existing north west wing wall                      | 7.3 m        | Terminated at auger refusal on bedrock |
| CN-00-5                | Proposed west abutment of detour structure  | 11.6 m       | Extended about 3 m into bedrock        |
| CN-00-6                | Proposed east abutment of detour structure, drilled on QEW at south end of existing southeast wing wall | 12.2 m       | Extended about 3 m into bedrock        |

The subsurface investigation was carried out using bombardier- and truck-mounted D-50 and B-57 drill rigs supplied and operated by Master Soil Investigation of North York. Overburden samples were obtained at 0.75 m to 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. Approximately 3 m of bedrock was cored in four of the boreholes (one borehole at each foundation element) using NQ-size coring equipment. The groundwater conditions in the open boreholes were observed throughout the drilling operations, and piezometers were installed in three of the boreholes to permit monitoring of the groundwater levels at the site.

The field work was supervised on a full-time basis by a member of Golder Associates' staff who located the boreholes in the field, directed the drilling, sampling, rock coring and in-situ testing operations, and logged the boreholes. The soil and rock samples were identified in the field, placed in labelled containers and transported to Golder Associates' laboratory in Mississauga for further examination and testing. Index and classification tests consisting of grain size analyses, Atterberg limits tests and water content determinations were carried out on selected soil samples, and point load tests were performed on selected rock cores.



The borehole locations and elevations were surveyed by members of Golder Associates' staff. The borehole locations were measured relative to the existing structure and highway, and the northing and easting coordinates (referenced to the NAD83 MTM system currently in use on this project) were determined from the digital files provided by McCormick Rankin. The borehole elevations, referenced to geodetic datum, were surveyed relative to Temporary Bench Mark 638 (Elevation 159.198 m) located on the northwest corner of the existing bridge abutment. The borehole elevations and northing and easting coordinates are given on the Record of Borehole sheets, and on the attached Drawing 1.

## **4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Site Geology**

The CN Rail bridge site is located along the Niagara Escarpment, which separates the lower Iroquois Plain to the north from the Haldimand Clay Plain physiographic region, located south of the escarpment. In the Niagara region, the escarpment base is located at about Elevation 105 m, and the top reaches about Elevation 190 m in this area. The escarpment itself consists of dolostone and shale bedrock, mantled by relatively thin deposits of sand, silt and till.

The original ground surface at the CN Rail bridge site is at about Elevation 150 m. The native overburden at the site consists of a clayey silt to sandy silt till, which is underlain by bedrock comprised of grey dolostone, with occasional argillaceous layers, and dark grey shale ascribed to the Clinton Group (probably the Decew and Rochester Formations). The depth to bedrock at this site is shallow, varying typically between 4 m and 5 m below the original ground surface.

### **4.2 Site Stratigraphy**

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets and Figures 1 to 3 following the text of this report. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoils at the site generally consist of road base and rail embankment fill material underlain by localized deposits of clayey silt overlying a clayey silt till to sandy silt till deposit. The overburden deposits are underlain by dolomite bedrock of the Clinton Group, which contains minor argillaceous lenses and occasional shale beds. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile and sections, are shown on the attached Drawing 1.

## **4.2.1 Fill**

### **4.2.1.1 Highway Fill**

In Boreholes CN-00-4 and CN-00-6, which were drilled on the QEW southbound and northbound lanes, respectively, the asphalt is underlain by about 100 mm of granular road base fill. The granular base is in turn underlain by a clayey silt fill which contains trace quantities of sand, gravel, shale fragments, rootlets and organics. The measured Standard Penetration Test (SPT) “N” values ranged from 7 to 46 blows, but were typically between 7 and 18 blows per 0.3 m of penetration, indicating that this fill has a stiff to very stiff consistency.

### **4.2.1.1 Rail Embankment Fill**

The upper 1.5 m of the rail embankment fill encountered in Boreholes CN-00-1 and CN-00-2 consisted of silty sand to sand and gravel. Below this cohesionless fill layer, about 7.5 m of predominantly clayey silt fill was encountered. About 4 m of this cohesive fill was also encountered in Borehole CN-00-5, drilled in the vicinity of the west detour bridge abutment, near the south toe of the existing rail embankment. In all three boreholes, the base of the fill layer was inferred to be between Elevation 149 m and 149.4 m.

The clayey silt fill contains minor quantities of sand, gravel, cinders and organics. A 0.8 m thick layer of silty sand was encountered within the cohesive fill in Borehole CN-00-2. A grain size distribution test result for a representative sample of the clayey silt fill material is shown on Figure 1.

The natural water contents measured on selected samples of the clayey silt fill ranged from about 13 to 24 per cent. An Atterberg limits test measured a plastic limit of 16 per cent, a liquid limit of 27 per cent, and a plasticity index of 11 per cent. These results, which are plotted on Figure 2, indicate that the cohesive fill is inorganic and of low plasticity.

The Standard Penetration Test (SPT) “N” values measured within the clayey silt embankment fill ranged from 9 to 21 blows per 0.3 m of penetration, indicating that this fill has a stiff to very stiff consistency. The measured SPT “N” values in the upper 1.5 m of cohesionless fill ranged from 14 to 67 blows, but were typically between 14 and 23 blows per 0.3 m of penetration, indicating that the rail ballast has a predominantly compact relative density.

#### **4.2.2 Clayey Silt**

A thin, localized deposit of clayey silt was encountered at the site in Boreholes CN-00-3 and CN-00-4, which were drilled on the north side of the existing embankment and structure. This clayey silt contains trace quantities of sand and organic matter, including a 100 mm thick black organic layer encountered in Borehole CN-00-4.

#### **4.2.3 Clayey Silt and Sandy Silt Till**

A till deposit was encountered in all boreholes below the rail embankment and road base fill, where present, and below the surficial layer of clayey silt elsewhere. The top of the till was encountered in the borings on the west side of the highway (Boreholes CN-00-1 to CN-00-5) between Elevation 148 m and 149.4 m; on the east side of the highway, in Borehole CN-00-6, the top of the till was encountered at Elevation 151.1 m. The till was between 3.5 m and 6.1 m thick, and extended to the bedrock surface which was encountered between Elevations 144 m and 145.1 m.

The till is comprised predominantly of grey-brown to red-brown clayey silt containing trace quantities of sand and gravel; lenses of silty sand were encountered within the till in one of the boreholes. Grain size distribution test results for representative samples of this clayey silt till are presented on Figure 3. At three of the borehole locations, the clayey silt till grades with depth into a sandy silt till layer, approximately 1 m to 1.5 m thick. The sandy silt till layer, where encountered, is approximately 1 m to 1.5 m thick and overlies the bedrock. A grain size distribution test result for a sample of the sandy silt till is shown on Figure 4.

Atterberg limits testing was carried out on selected samples of the clayey silt till, yielding plastic limits between 13 and 16 per cent, liquid limits between 20 and 30 per cent, and plasticity indices between 6 and 14 per cent, but typically between 6 and 10 per cent. These test results, which are plotted on Figure 5, indicate that the clayey silt is inorganic and of low plasticity. The measured water contents on selected samples of the clayey silt till ranged from about 13 to 22 per cent, but were typically between 13 and 19 per cent. The measured water contents on samples of the sandy silt till ranged from 13 to 16 per cent.

The measured SPT 'N' values within the clayey silt till typically ranged from 40 to greater than 100 blows per 0.3 m of penetration, indicating a hard consistency. In Borehole CN-00-2, one SPT 'N' value of 20 blows per 0.3 m of penetration was measured, indicating a "softened" zone with a very stiff consistency.

The measured SPT 'N' values within the sandy silt till were greater than 90 blows per 0.3 m of penetration, indicating a very dense relative density.

#### **4.2.4 Bedrock**

Bedrock was encountered in the boreholes between Elevations 144 m and 145.1 m. Approximately 3 m of bedrock was cored in Boreholes CN-00-1, CN-00-2, CN-00-5 and CN-00-6.

The bedrock consists of light grey to grey dolomite, containing minor argillaceous or shaley lenses. Typically, these lenses were less than 25 mm thick and accounted for about 1 to 3 per cent of the total rock core recovered. In Borehole CN-00-2, a 300 mm thick, fissile shale bed was encountered between Elevations 141.6 m and 141.3 m.

The upper 100 mm to 250 mm of the dolomite bedrock was moderately to slightly weathered; below this depth, the dolomite was slightly weathered. Rock Quality Designation (RQD) values measured within the dolomite were typically between about 50 and 100 per cent; these values reflect a rock mass of fair to excellent quality. Total core recovery was measured between 74 and 100 per cent. The measured RQD value within the shale layer was about 20 per cent reflecting very poor quality rock.

Point load index testing was carried out in the laboratory, in accordance with the standard test procedure recommended by the ISRM, on selected samples of the dolomitic bedrock core. The point load test gives an indirect measure of the tensile strength of the rock, which can be correlated with the uniaxial compressive strength. The measured diametral point load indices,  $Is_{50}$ , ranged from 4 to 10 MPa. These test results, plotted on the Record of Drillhole sheets, indicate that the dolomite bedrock is typically strong, with correlated uniaxial compressive strengths typically ranging from 50 to 150 MPa.

#### **4.3 Groundwater Conditions**

Water levels were noted in the open boreholes during and upon completion of the drilling operation; these levels are shown on the attached Record of Borehole Sheets. Piezometers were sealed in Boreholes CN-00-2, CN-00-3 and CN-00-5 to permit the monitoring of the groundwater levels at the site. Details of the piezometer installations and the groundwater level measurements are shown on the attached Record of Borehole Sheets.

The water levels in the piezometers were measured on February 9, 2001, and are summarized in the table below. These measurements indicate that the groundwater level slopes downward from the south to the north, similar to the topography at the site.

| <i>Borehole<br/>Number</i> | <i>Water Level in Piezometer</i> |                  |
|----------------------------|----------------------------------|------------------|
|                            | <i>Depth</i>                     | <i>Elevation</i> |
| CN-00-2                    | 9.75 m                           | 148.8 m          |
| CN-00-3                    | 1.8 m                            | 147.6 m          |
| CN-00-5                    | 3.7 m                            | 149.9 m          |

It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to be higher during wet periods of the year.

**GOLDER ASSOCIATES LTD.**

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**PART B**

**FOUNDATION DESIGN REPORT  
CN RAIL BRIDGE REPLACEMENT  
QEW WIDENING BETWEEN GLENDALE AVENUE  
AND MOUNTAIN ROAD INTERCHANGES  
REGIONAL MUNICIPALITY OF NIAGARA FALLS  
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## 5.0 ENGINEERING RECOMMENDATIONS

### 5.1 General

This section of the report provides recommendations on the foundation aspects of design of the proposed CN Rail bridge replacement based on interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. 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 method and scheduling.

At the site, the QEW grade rises southward from about Elevation 153 m to 153.5 m between the north and south limits of the existing bridge structure. The rail is at about Elevations 159.1 m to 159.3 m at the existing structure. The existing rail embankments are up to about 10 m in height.

The existing CN Rail bridge, constructed in 1937, is a two-span structure with abutments and pier supported on spread footings. The founding elevations rise eastward and southward, and the individual footings step upward toward the east and south, as summarized in the following table:

| <i>Foundation Element<br/>(Existing Structure)</i> | <i>Approximate<br/>Founding Elevation</i> |
|--|---|
| West Abutment                                      | 150.3 m to 150.6 m                        |
| Centre Pier  | 150.7 m to 150.9 m                        |
| East Abutment                                      | 151.0 m to 151.3 m                        |

These founding conditions and elevations have been determined from copies of plans for the existing structure, which were provided by the MTO (General Plan – Drawing No. C-8591, Details of Abutments – Drawing No. C-8595 and Details of Pier – Drawing No. C-8592, dated February 1937).

It is understood that the existing bridge will be replaced with a new longer and wider structure and that the new embankment will tie in with the existing embankments. The QEW and the rail lines will remain at the current grade. The rail lines will be diverted onto a detour bridge to be located to the south of the existing bridge.



## 5.2 Bridge Foundations

The soils encountered in the boreholes put down during the investigation typically consist of variable fill materials overlying a very stiff to hard clayey silt till deposit at about Elevation 148 m to 151 m. The clayey silt till is underlain by a thin layer of very dense sandy silt till which in turn overlies moderately to slightly weathered dolomitic bedrock. The fill and till deposits may contain cobbles or boulders. The water table was measured between about Elevation 147 m and 149.9 m in the immediate vicinity of the proposed structure.

Based on the above subsurface information, consideration may be given to supporting the structures on shallow spread footings placed on the very dense / hard till deposits. Alternatively, the structures may be supported on caissons / drilled piers founded on the surface of the dolomitic bedrock, or socketted into the bedrock.

### 5.2.1 Shallow Foundations

Spread footings may be used to support the abutments and the central pier location for the main bridge and detour bridge. The fill materials are not considered suitable for the support of the structure and spread footings must be placed on the underlying hard clayey silt till deposit.

#### 5.2.1.1 Allowable Soil Pressure

Spread footings placed on the hard clayey silt till at the site are considered suitable for the support of the bridge abutments and pier. The surface of the till is variable at the site, generally sloping downward toward the north and the west. The following founding levels may be assumed for design:

| <i>Foundation Element</i>   | <i>Design Founding Level</i>                                       |
|-----------------------------|--|
| Main bridge west abutment   | Elevation 148 m for north half<br>Elevation 149 m for south half   |
| Main bridge pier            | Elevation 148.5 m for north half<br>Elevation 149 m for south half |
| Main bridge east abutment   | Elevation 150 m  |
| Detour bridge west abutment | Elevation 149 m  |
| Detour east abutment        | Elevation 150.5 m  |

These founding levels are at depths of about 3 m to 5 m below the existing QEW grade.

For the site conditions, the allowable pressure for settlement (in accordance with AREMA 1999) governs due to the presence of a “softened” zone within the till which is evident in Borehole CN-00-2 located at the proposed center pier. For the pier of the main bridge and the west abutment of the detour, an allowable soil pressure of 400 kPa may be assumed for design. For the proposed abutments of the main bridge, an allowable soil pressure of 550 kPa may be assumed for design. These are net pressures and assume a total settlement of 25 mm. The settlement is, however, dependent on the size of the footing and these values should be reviewed once the footing size has been determined to confirm the magnitude of potential total and differential settlement.

The design should be checked against Ontario Highway Bridge Design Code (OHBDC) using a factored geotechnical resistance at Ultimate Limit States (ULS) of 600 kPa for the pier of the main bridge and the west abutment of the detour. For the east and west abutments of the main bridge, a factored geotechnical resistance at ULS of 700 kPa may be assumed. The geotechnical resistance at Serviceability Limit States (SLS) may be taken as 400 kPa for the pier of the main bridge and west abutment of the detour and 550 kPa for the abutments of the main bridge.

These founding levels for the footings on the till are close to or slightly below the groundwater level which varies from about Elevation 150 m on the east side of QEW to about Elevation 147.6 m at the west limit of the proposed structure. The above geotechnical resistances assume that appropriate construction procedures are adopted during footing construction to ensure that the founding soils are not softened / disturbed prior to concrete placement.

#### **5.2.1.2 Resistance to Lateral Forces**

Resistance to lateral forces / sliding resistance may be calculated assuming a coefficient of friction of 0.48 between the concrete and the founding soils.

#### **5.2.1.3 Frost Protection**

All footings should be provided with a minimum of 1.2 m of earth cover for frost protection purposes.

#### **5.2.1.4 Construction Considerations**

The founding level for spread footings placed on the hard till between Elevation 150 m and 148 m will be close to the groundwater table level. Perched water is likely within the fill below the QEW grade and some water inflow through the fill materials should be expected, particularly where sandy zones are intercepted in the excavation. It is expected that the quantity of flow will be nominal and pumping from properly filtered sumps placed at the base of the excavation should

provide sufficient groundwater control during foundation excavations. Sumps should be maintained outside of the footing area.

The founding soils will be sensitive to disturbance and softening due to water seepage or ponding. Placement of a mud coat will be required at the base of excavation for the footing area. Exposure without protection of the mud coat will allow water to soften the founding soils. The cleaned excavation base should be inspected by qualified geotechnical personnel prior to placing the mud coat. The mud coat should be placed within four hours after footing inspection.

It should be noted that the groundwater levels could be higher during wet periods of the year.

### 5.2.2 Deep Foundations

Consideration could be given to supporting the bridges on augered caissons or piers placed on or within the bedrock. Alternatively, driven steel piles founded on the bedrock could be used to support the bridges; however, pre-augering through the hard / very dense till may be required to ensure that the piles penetrate to the bedrock surface.

The surface of the bedrock is somewhat variable at the site and the following bedrock surface elevations may be assumed for design:

| <i>Foundation Element</i>   | <i>Design Bedrock Surface Elevation</i> |         |
|-----------------------------|---|---------|
| Main bridge west abutment   | Elevation                               | 144.5 m |
| Main bridge pier            | Elevation                               | 144 m   |
| Main bridge east abutment   | Elevation                               | 145 m   |
| Detour bridge west abutment | Elevation                               | 145 m   |
| Detour east abutment        | Elevation                               | 145 m   |

#### 5.2.2.1 Allowable Rock Pressure (Axial) – Caissons

For caissons founded on the surface of the bedrock, an allowable rock pressure of 7.5 MPa may be assumed for design (i.e. 3 and 5.4 MN for 0.9 and 1.2 m diameter caissons, respectively). For caissons socketted 2 m into the bedrock, an allowable rock pressure of 13 MPa may be assumed for design.

The above values may also be used for factored geotechnical resistance at ULS in accordance with the OHBDC. Serviceability Limit States (SLS) do not apply to caissons founded within the bedrock at this site.

### **5.2.2.2 Axial Capacity – Driven Piles**

Steel H-piles driven to refusal on the dolomite bedrock at this site may be utilized for support of the structure. For design, an allowable axial resistance of 1,800 kN may be assumed for HP 310 x 110 piles founded on the bedrock surface.

The above values may also be used for factored geotechnical resistance at ULS in accordance with the OHBDC. Serviceability Limit States (SLS) do not apply to piles founded within the bedrock at this site.

Due to the hard / very dense and potential bouldery nature of the till overlying the bedrock, pre-augering to the bedrock surface will be required to ensure that the piles can be advanced to the bedrock surface. This procedure will also ensure that vibration levels during driving are minimized where piling is carried out adjacent to the existing bridge.

### **5.2.2.3 Resistance to Lateral Loads**

The lateral loading could be resisted fully or partially by the use of battered caissons or piles. If the caissons are required to provide the resistance to the lateral loading, the coefficient of horizontal subgrade reaction to the pile or caisson,  $k_h$  (MPa/m), can be estimated using the following equation:

$$k_h = \frac{k_{s1}}{5B} \quad \text{where} \quad \begin{array}{l} B \text{ is the pile / caisson width or diameter (m) and} \\ k_{s1} \text{ is the coefficient of horizontal subgrade reaction} \\ \text{(MPa/m); the range of values to be used is shown below} \end{array}$$

| <i>Soil Type</i> | <i><math>k_{s1}</math> (MPa/m)</i> |
|------------------|------------------------------------|
| Clayey Silt Fill | 25 to 40                           |
| Clayey Silt Till | 40 to 60                           |

Group action for lateral loading should be considered when the pile / caisson spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of lateral subgrade reaction in the direction of loading by a reduction factor R as follows:

| <i>Pile Spacing in<br/>Direction of Loading</i> | <i>Subgrade Reaction<br/>Reduction<br/>Factor R</i> |
|---|---|
| 8B  | 1.00  |
| 6B  | 0.70  |
| 4B  | 0.40  |
| 3B  | 0.25  |

#### **5.2.2.4 Frost Protection**

The pile caps should be provided with minimum of 1.2 m soil cover for frost protection.

### **5.3 Retaining Walls**

It is understood that retaining walls are required in each quadrant to retain the existing embankment fill. The wall may be supported in shallow spread footings supported on the hard clayey silt till which was encountered at about Elevations 149 m to 149.5 m. On the east side of the QEW, in Borehole CN-00-6, the surface of the hard clayey silt till was encountered at about Elevation 151.1 m.

#### **5.3.1 Allowable Soil Pressure**

The following founding levels may be assumed for design of the walls:

|                 |                   |
|-----------------|-------------------|
| North-west Wall | Elevation 148 m   |
| South-west Wall | Elevation 149 m   |
| North-east Wall | Elevation 150 m   |
| South-east Wall | Elevation 150.5 m |

The above founding elevations are provided for design purposes. Variations in the surface of the till founding stratum must be expected and there should be provisions in the contract for subexcavation and replacement with mass concrete in the event that fill and/or incompetent till materials be encountered at the design founding level.

The allowable pressure for settlement (in accordance with AREMA 1999) of 500 kPa may be assumed for design of spread footings placed on undisturbed hard clayey silt till. This is a net pressure and assumes a total settlement of 25 mm for a 4 m wide footing. The settlement is,

however, dependent on the size of the footing and this value should be reviewed once the configuration is established.

The design should be checked against OHBDC using a factored geotechnical resistance at ULS of 700 kPa. The geotechnical resistance of SLS may be taken as 500 kPa.

The design parameters/comments for sliding resistance and frost protection as well as construction considerations as given in Sections 5.2.1.2, 5.2.1.3 and 5.2.1.4 apply to the retaining wall spread footings.

## **5.4 Lateral Earth Pressures**

The lateral pressures acting on the bridge abutments and retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill and on the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the abutments and the retaining walls in accordance with AREMA and OHBDC:

- Select free-draining granular fill meeting the specifications of OPSS Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the 200 sieve should be used as backfill behind the walls. All granular fill should be compacted in lifts of loose thickness not greater than 200 mm to 95 per cent of the material's Standard Proctor maximum dry density.
- Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.
- The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the stem (Case I) or within the wedge-shaped zone defined by a line drawn upwards at 1.5 horizontal to 1 vertical from the footing in accordance with OHBDC (Case II).
- If the wall support allows lateral yielding of the stem (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. If the abutment support does not allow lateral yielding (restrained structure), at-rest pressures should be assumed for geotechnical design.
- A compaction surcharge equal to 16 kPa should be included in the lateral earth pressures for the structural design of the abutment wall.

- For Case I, the pressures are based on the existing and proposed embankment fill materials and the following parameters (unfactored) may be assumed:

|   |                      |
|---|----------------------|
| Soil unit weight<br>(assuming clean earth fill) | 20 kN/m <sup>3</sup> |
| Coefficients of lateral earth pressure:         |                      |
| ‘active’  | 0.43                 |
| ‘at rest’                                       | 0.50                 |

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

|  | <b>Granular ‘A’</b>  | <b>Granular ‘B’<br/>Type II</b> |
|--|----------------------|---------------------------------|
| Soil Unit Weight                       | 22 kN/m <sup>3</sup> | 21 kN/m <sup>3</sup>            |
| Coefficients of Lateral Earth Pressure |                      |                                 |
| ‘active’                               | 0.27                 | 0.31                            |
| ‘at rest’                              | 0.43                 | 0.47                            |

It should be noted that the above design parameters assume level backfill and ground surface behind the wall.

## **5.5 Excavations and Temporary Cut Slopes**

Excavations for spread footing and / or pile cap construction will extend through clayey silt fill and till deposits consisting of clayey silt and sandy silt. At the proposed bridge locations the excavations for the spread footings at the abutments will be up to about 11 m in depth below existing rail grade and about 3 m to 5 m below the proposed grade for the QEW. Cobbles and boulders are inherent in the glacial deposits as encountered at this site and should be expected during excavation. The excavation bases will be at or close to the groundwater level as measured in the piezometers.

### **5.5.1 Open Cut Slopes**

Temporary open cut slopes should be maintained no steeper than 1 horizontal to 1 vertical (1H:1V). Where space restrictions dictate, the excavation could also be carried out within a fully braced excavation. The excavation for spread footing or pile cap construction adjacent to the QEW may have to be made with vertical supported sides to minimize disruption to road traffic.

Water seepage into the excavations through the fill and till deposits is expected to be minor, except during periods of sustained precipitation. Pumping from well-filtered sumps located at the

base of the excavation within the glacial till should provide adequate groundwater control during foundation excavations. The consideration with respect to protection of the founding soils as given in Section 5.2.1.4 must, however, be recognized. Sumps should be maintained outside the actual footing limits. Surface water run-off should be directed away from the excavations at all times. The appropriate NSSP should be included in the contract documents.

All excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Ontario Occupational Health & Safety Act. The native soils at this site would be classified as Type 1 soil. The fill deposits would be classified as Type 2 soil.

### **5.5.2 Temporary Excavation Support**

Where space is restricted and will not permit open cuts for footing / wall construction or where track protection for the CN Rail line is required during construction, a temporary support system should be installed to support the sides of the excavation and permit the use of vertical cuts. The temporary support system could consist of soldier piles and lagging where the piles would be socketted into pre-augered holes extended into the till deposits below the excavation base. Some cobbles and boulders should be expected during augering for the soldier pile installation. Support to the soldier pile and lagging wall system could be in the form of struts and walers in the case of footing excavations or rakers and anchors in the case of roadway protection excavations.

The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The 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 unfactored triangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; increasing with depth) can be calculated as follows:

$$p = K_a \gamma H$$

where

$H$  = the height of the excavation at any point in metres

$K_a$  = 0.25 for level ground behind excavation

$\gamma$  = soil unit weight =  $20 \text{ kN/m}^3$



The unfactored rectangular earth pressure distribution ( $p$  in  $\text{kN/m}^2$ ; constant with depth) can be calculated as follows:

$$p = K \gamma H$$

where

$H$  = the height of the excavation

$K$  = 0.25 for level ground behind excavation

$\gamma$  = soil unit weight =  $20 \text{ kN/m}^3$

Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter. The coefficient of passive lateral earth pressure,  $K_p$ , for the socket within the hard / very dense till may be taken as 8.7.

For the bridge footing excavations, the soldier piles will be socketted into the till deposits below the groundwater level. The soil unit weight should be taken as  $22 \text{ kN/m}^3$  and the unit weight of water should be taken as  $9.8 \text{ kN/m}^3$ . For design of the shoring, the groundwater level may be taken at Elevation 150 m, 149 m and 148 m at the east abutment, pier and west abutment footing locations, respectively.

Where roadway protection is required, grouted rock anchors are feasible and may be designed based on an ultimate bond stress between the grout and the rock of 1,500 kPa. For temporary anchors, a Factor of Safety of 2.0 should be applied to the ultimate rock anchor capacity calculated from the above adhesion values. The maximum permissible stress in the anchor tendon or bar under the design load should not exceed 60 per cent of the guaranteed ultimate tensile strength of the tendon or bar.

The Contractor should be held to an anchor performance specification enforced by proof tests and lift-off tests on all anchors and a performance test on at least one anchor in accordance with Special Provision 942S01 (April 2001). The performance test should be carried out to 2 times the design working load. In addition, each anchor should be proof tested to 1.5 times its working load. The tensile stress in the anchor bar during test loading should not exceed 0.8 of the guaranteed ultimate tensile strength of the bar. Anchor installation and testing should be carried out under the full-time inspection of geotechnical personnel. Anchor installation and preloading should be complete before the excavation proceeds below the anchor elevation.

## **5.6 Embankments**

Based on the drawings provided, there will not be any grade raise for the rail embankment and there will be only nominal widening of the embankments required within 20 m of the abutments. The existing embankment will in general be utilized for the detour bridge approaches.

If there is any widening required, side slopes should be maintained at 2 horizontal to 1 vertical. The new embankment fill should be keyed into the existing embankment by benching of the side slopes in accordance with OPSD 208.010. All topsoil and organics should be removed from the area of new fill placement.

Construction of the embankment above the prepared subgrade may be carried out using clean earth fill meeting specifications OPSS 212 or Selected Subgrade Material meeting specifications with OPSS 1010, depending on material availability. All embankment fill should be placed in regular lifts with loose thickness not exceeding 300 mm, and be compacted to at least 95 per cent of the material's Standard Proctor maximum dry density. Inspection and field density testing should be carried out by qualified geotechnical personnel during all fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved. Vegetation cover should be established on all soil slopes to protect embankment fill against surficial erosion, as per OPSS 572.

For embankments constructed in accordance with the above, embankment side slopes will have an adequate Factor of Safety (greater than 1.5) against failure. For the nominal widening anticipated, it is expected that settlement of the widened portion of the embankment will be negligible.

**GOLDER ASSOCIATES LTD.**

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## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

| Density Index<br>(Relative Density) | N<br>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                        |

### 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.)

#### Consistency

|            | $c_u, s_u$ | $c_u, s_u$     |
|------------|------------|----------------|
|            | 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     |

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> 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.

### 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 <sup>1</sup>                                       |
| CIU      | consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup> |
| $D_R$    | relative density (specific gravity, $G_s$ )   |
| DS       | direct shear test   |
| M        | sieve analysis for particle size  |
| MH       | combined sieve and hydrometer (H) analysis  |
| MPC      | Modified Proctor compaction test  |
| SPC      | Standard Proctor compaction test  |
| OC       | organic content test  |
| $SO_4$   | concentration of water-soluble sulphates  |
| UC       | unconfined compression test   |
| UU       | unconsolidated undrained triaxial test  |
| V        | field vane (LV-laboratory vane test)  |
| $\gamma$ | 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

|             |                                       |
|-------------|---------------------------------------|
| $\pi$       | 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

|                                |  |
|--------------------------------|--|
| $\gamma$                       | shear strain   |
| $\Delta$                       | change in, e.g. in stress: $\Delta \sigma$                                 |
| $\epsilon$                     | linear strain  |
| $\epsilon_v$                   | volumetric strain  |
| $\eta$                         | coefficient of viscosity   |
| $\nu$                          | poisson's ratio  |
| $\sigma$                       | total stress   |
| $\sigma'$                      | effective stress ( $\sigma' = \sigma - u$ )                                |
| $\sigma'_{vo}$                 | initial effective overburden stress  |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor)                              |
| $\sigma_{oct}$                 | mean stress or octahedral stress<br>$= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$                         | 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   |
| $\gamma'$          | unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )                                      |
| $D_R$              | relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ ) |
| e                  | void ratio   |
| n                  | porosity   |
| S                  | degree of saturation   |

#### (a) Index Properties (continued)

|           |  |
|-----------|--|
| w         | water content  |
| $w_l$     | liquid limit   |
| $w_p$     | plastic limit  |
| $I_p$     | plasticity index $= (w_l - w_p)$   |
| $w_s$     | shrinkage limit  |
| $I_L$     | liquidity index $= (w - w_p) / I_p$  |
| $I_C$     | consistency index $= (w_l - w) / I_p$  |
| $e_{max}$ | void ratio in loosest state  |
| $e_{min}$ | void ratio in densest state  |
| $I_D$     | density index $= (e_{max} - e) / (e_{max} - e_{min})$<br>(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                               |
| $\sigma'_p$ | pre-consolidation pressure                            |
| OCR         | over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$ |

#### (d) Shear Strength

|                  |  |
|------------------|--|
| $\tau_p, \tau_r$ | peak and residual shear strength                         |
| $\phi'$          | effective angle of internal friction                     |
| $\delta$         | angle of interface friction                              |
| $\mu$            | 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  $= (\text{compressive strength})/2$
  - \* density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density x acceleration due to gravity)

# LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

## WEATHERING STATE

**Fresh:** no visible sign of weathering.

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

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

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

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

## BEDDING THICKNESS

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

## JOINT OR FOLIATION SPACING

| Description      | Spacing     |
|------------------|-------------|
| Very wide        | > 3 m       |
| Wide             | 1 - 3 m     |
| Moderately close | 0.3 - 1 m   |
| Close            | 50 - 300 mm |
| Very close       | < 50 mm     |

## GRAIN SIZE

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

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

## CORE CONDITION

### Total Core Recovery

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

### Rock Quality Designation (RQD)

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

## DISCONTINUITY DATA

### Fracture Index

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

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

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

### Description and Notes

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

### Abbreviations

|                            |                  |
|----------------------------|------------------|
| B - Bedding                | 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       |                  |


| RECORD OF BOREHOLE No CN-00-1 |  |            |         |  |            |                            |                 |   |                   | 1 OF 3                             |                                     | METRIC                            |  |  |
|-------------------------------|--|------------|---------|--|------------|----------------------------|-----------------|---|-------------------|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| PROJECT 001-1127F             |  |            |         | LOCATION N 4,778,433; E 333,911            |            |                            |                 | ORIGINATED BY GM                            |                   |                                    |                                     |                                   |  |  |
| W.P. 281-99-00                |  |            |         | BOREHOLE TYPE 135mm dia. Solid Stem Augers |            |                            |                 | COMPILED BY LCC                             |                   |                                    |                                     |                                   |  |  |
| DIST Central HWY QEW          |  |            |         | DATE September 21, 2000                    |            |                            |                 | CHECKED BY ASP                              |                   |                                    |                                     |                                   |  |  |
| DATUM Geodetic                |  |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| SOIL PROFILE                  |  |            | SAMPLES |  |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                   | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
| ELEV<br>DEPTH                 | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE                                       | *N* VALUES |                            |                 | SHEAR STRENGTH kPa                          | WATER CONTENT (%) |                                    |                                     |                                   |  |  |
| 158.5                         | GROUND SURFACE   |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 0.0                           | Sand and gravel (Fill)<br>Compact to very dense<br>Black   |            | 1       | SS   | 14         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 2       | SS   | 67         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 156.9                         |  |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 1.5                           | Clayey silt, trace to some sand and<br>gravel, trace cinders (Fill)<br>Stiff to very stiff<br>Brown<br>Dry to Moist                  |            | 3       | SS   | 21         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 4       | SS   | 10         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 5       | SS   | 11         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 6       | SS   | 9          |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 7       | SS   | 14         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 8       | SS   | 14         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  |            | 9       | SS   | 19         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 149.3                         |  |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 9.1                           | Clayey Silt, trace to some sand,<br>trace gravel (Till)<br>Hard<br>Grey-brown<br>Moist   |            | 10      | SS   | 50         |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  | 11         | SS      | 100  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
|                               |  | 12         | SS      | 50   |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 144.8                         |  |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |
| 13.7                          | Dolostone (Bedrock); cored between<br>13.7m and 16.5m depth.<br>For bedrock coring details, refer to<br>Record of Drillhole CN-00-1. |            |         |  |            |                            |                 |   |                   |                                    |                                     |                                   |  |  |

ON\_MOT\_001-1127.GPJ ON\_MOT.GDT 19/12/01

Continued Next Page

+ 3, X 3; Numbers refer to  
Sensitivity

○ 3% STRAIN AT FAILURE

| RECORD OF BOREHOLE No CN-00-1        |  |   |        |  |                            |                 |   |  |  | 2 OF 3 |                                    | METRIC                              |                                   |   |  |
|--------------------------------------|--|---|--------|--|----------------------------|-----------------|---|--|--|--------|------------------------------------|-------------------------------------|-----------------------------------|---|--|
| PROJECT 001-1127F                    |  |   |        | LOCATION N 4,778,433; E 333,911            |                            |                 |   | ORIGINATED BY GM   |  |        |                                    |                                     |                                   |   |  |
| W.P. 281-99-00                       |  |   |        | BOREHOLE TYPE 135mm dia. Solid Stem Augers |                            |                 |   | COMPILED BY LCC  |  |        |                                    |                                     |                                   |   |  |
| DIST Central HWY QEW                 |  |   |        | DATE September 21, 2000                    |                            |                 |   | CHECKED BY ASP   |  |        |                                    |                                     |                                   |   |  |
| DATUM Geodetic                       |  |   |        |  |                            |                 |   |  |  |        |                                    |                                     |                                   |   |  |
| SOIL PROFILE                         |  | SAMPLES   |        |  | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  |  |        | PLASTIC<br>LIMIT<br>W <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W | LIQUID<br>LIMIT<br>W <sub>L</sub> | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br><br>GR SA SI CL |
| ELEV<br>DEPTH                        | DESCRIPTION  | STRAT PLOT  | NUMBER | TYPE                                       |                            |                 | "N" VALUES                                  | SHEAR STRENGTH kPa<br>20 40 60 80 100<br>○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL X REMOULDED |  |        |                                    |                                     |                                   |   |  |
| --- CONTINUED FROM PREVIOUS PAGE --- |  |   |        |  |                            |                 |   |  |  |        |                                    |                                     |                                   |   |  |
| 142.0                                | Dolostone (Bedrock); cored between 13.7m and 16.5m depth. For bedrock coring details, refer to Record of Drillhole CN-00-1.  |  |        |  |                            |                 | 143   |  |  |        |                                    |                                     |                                   |   |  |
| 16.5                                 | END OF BOREHOLE<br><br>Note:<br>1. Borehole dry on completion of overburden drilling operations.<br>2. Water was used during coring operations; water level in open hole on completion of rock drilling not representative of groundwater level. |   |        |  |                            |                 | 142   |  |  |        |                                    |                                     |                                   |   |  |

ON\_MOT 001-1127.GPJ ON\_MOT.GDT 19/12/01

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

PROJECT: 001-1127F

## RECORD OF DRILLHOLE: CN-00-1

SHEET 3 OF 3

LOCATION: N 4,778,433; E 333,911

DRILLING DATE: September 25/00

DATUM: Geodetic

INCLINATION: -90°

AZIMUTH: --

DRILL RIG: D-50 Bombardier

DRILLING CONTRACTOR: Master Soil Investigations

| DEPTH SCALE<br>METRES | DRILLING RECORD | DESCRIPTION   | SYMBOLIC LOG | ELEV.<br>DEPTH<br>(m) | RUN No. | PENETRATION RATE<br>(m/min) | FLUSH<br>% RETURN | COLOUR<br>% RETURN | FR-FRACTURE<br>CL-CLEAVAGE<br>SH-SHEAR<br>VN-VEIN | F-FAULT<br>J-JOINT<br>P-POLISHED<br>S-SLICKENSIDED | SM-SMOOTH<br>R-ROUGH<br>ST-STEPPED<br>PL-PLANAR | FL-FLEXURED<br>UE-UNEVEN<br>W-WAVY<br>C-CURVED | BC-BROKEN CORE<br>MB-MECH. BREAK<br>B-BEDDING | DIAMETRAL<br>POINT LOAD<br>INDEX (MPa) | NOTES<br>WATER LEVELS<br>INSTRUMENTATION |
|-----------------------|-----------------|---|--------------|-----------------------|---------|-----------------------------|-------------------|--------------------|---|--|---|--|---|--|--|
|                       |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
|                       |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 13                    |                 | Refer to Record of Borehole CN-00-1 for<br>Soil Conditions.   |              | 145.50<br>13.00       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 14                    |                 | Dolostone with thin argillaceous lenses<br>at 15.3m (Bedrock)<br>Light grey to grey<br>Moderately to slightly weathered<br>Medium to widely bedded<br>Medium to strong rock<br>Fine-grained |              | 144.78<br>13.72       | 1       |                             |                   |                    |   |  |   |  |   |  |  |
| 15                    | NQ              |   |              |                       | 2       |                             |                   |                    |   |  |   |  |   |  |  |
| 16                    |                 |   |              |                       | 3       |                             |                   |                    |   |  |   |  |   |  |  |
|                       |                 | END OF HOLE   |              | 142.04<br>16.46       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 17                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 18                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 19                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 20                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 21                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 22                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |
| 23                    |                 |   |              |                       |         |                             |                   |                    |   |  |   |  |   |  |  |

DEPTH SCALE

1 : 50



LOGGED: GM

CHECKED: ASP

DRILLHOLE 1127FROC.GPJ GLDR CAN.GDT 19/12/01 PS



| PROJECT 001-1127F    |   |            | RECORD OF BOREHOLE No CN-00-2              |      |            | 1 OF 3                                   |                 |                 | METRIC   |                   |   |             |
|----------------------|---|------------|--|------|------------|--|-----------------|-----------------|--|-------------------|---|-------------|
| W.P. 281-99-00       |   |            | LOCATION N 4,778,433; E 333,938            |      |            | ORIGINATED BY GM                         |                 |                 |  |                   |   |             |
| DIST Central HWY QEW |   |            | BOREHOLE TYPE 135mm dia. Solid Stem Augers |      |            | COMPILED BY LCC                          |                 |                 |  |                   |   |             |
| DATUM Geodetic       |   |            | DATE September 21, 2000                    |      |            | CHECKED BY ASP                           |                 |                 |  |                   |   |             |
| SOIL PROFILE         |   |            | SAMPLES                                    |      |            | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                 |                 | PLASTIC NATURAL LIQUID UNIT WEIGHT REMARKS & GRAIN SIZE DISTRIBUTION (%) |                   |   |             |
| ELEV<br>DEPTH        | DESCRIPTION   | STRAT PLOT | NUMBER                                     | TYPE | "N" VALUES | GROUND WATER CONDITIONS                  | ELEVATION SCALE | 20 40 60 80 100 | W <sub>p</sub> W W <sub>L</sub>  | WATER CONTENT (%) | γ | GR SA SI CL |
| 158.5                | GROUND SURFACE  |            |  |      |            |  |                 |                 |  |                   |   |             |
| 0.0                  | Silty Sand, trace gravel, clay and organics (Fill)<br>Compact<br>Brown<br>Dry                     |            | 1  | SS   | 17         |  | 158             |                 |  |                   |   |             |
|                      |   |            | 2  | SS   | 23         |  |                 |                 |  |                   |   |             |
| 157.0                |   |            |  |      |            |  | 157             |                 |  |                   |   |             |
| 1.5                  | Clayey Silt, trace sand and gravel (Fill)<br>Stiff<br>Brown<br>Moist                              |            | 3  | SS   | 9          |  |                 |                 |  |                   |   |             |
| 156.2                |   |            |  |      |            |  |                 |                 |  |                   |   |             |
| 2.3                  | Silty Sand, trace gravel (Fill)<br>Loose<br>Brown-black<br>Dry                                    |            | 4  | SS   | 7          |  | 156             |                 |  |                   |   |             |
| 155.5                |   |            |  |      |            |  |                 |                 |  |                   |   |             |
| 3.1                  | Clayey Silt, trace sand and gravel, trace cinders (Fill)<br>Stiff to very stiff<br>Brown<br>Moist |            | 5  | SS   | 15         |  | 155             |                 |  |                   |   |             |
|                      |   |            | 6  | SS   | 10         |  | 154             |                 |  |                   |   |             |
|                      |   |            | 7  | SS   | 10         |  | 153             |                 |  |                   |   |             |
|                      |   |            |  |      |            |  | 152             |                 |  |                   |   |             |
|                      | Organic odour in Samples 8 and 9  |            | 8  | SS   | 11         |  | 151             |                 |  |                   |   |             |
|                      |   |            | 9  | SS   | 18         |  | 150             |                 |  |                   |   |             |
| 149.4                |   |            |  |      |            |  |                 |                 |  |                   |   |             |
| 9.1                  | Clayey Silt, trace sand and gravel with silty sand seams (Till)<br>Hard<br>Brown<br>Moist         |            | 10   | SS   | 45         |  | 149             |                 |  |                   |   |             |
|                      |   |            | 11   | SS   | 41         |  | 148             |                 |  |                   |   |             |
|                      |   |            |  |      |            |  | 147             |                 |  |                   |   |             |
|                      |   |            | 12   | SS   | 20         |  | 146             |                 |  |                   |   |             |
|                      |   |            |  |      |            |  | 145             |                 |  |                   |   |             |
|                      |   |            | 13   | SS   | 100/00     |  | 144             |                 |  |                   |   |             |
| 144.0                |   |            |  |      |            |  |                 |                 |  |                   |   |             |
| 14.5                 |   |            |  |      |            |  |                 |                 |  |                   |   |             |

ON\_MOT\_001-1127.GPJ ON\_MOT.GDT 19/12/01

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+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

Continued Next Page

ON\_MOT 001-1127.GPJ ON\_MOT.GDT 19/12/01

PROJECT: 001-1127F

# RECORD OF DRILLHOLE: CN-00-2

SHEET 3 OF 3

LOCATION: N 4,778,433; E 333,938

DRILLING DATE: September 21/00

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: --

DRILL RIG: D-50 Bombardier

DRILLING CONTRACTOR: Master Soil Investigations

| DEPTH SCALE<br>METRES | DRILLING RECORD | DESCRIPTION  | SYMBOLIC LOG | ELEV.<br>DEPTH<br>(m) | RUN No. | PENETRATION RATE<br>(m/min) | FLUSH<br>% RETURN | FR-FRACTURE                    |  |  | F-FAULT                        |  |  | SM-SMOOTH                      |  |  | FL-FLEXURED                    |  |  | BC-BROKEN CORE                   |  |  | DIAMETER<br>INDEX (MPa) | NOTES<br>WATER LEVELS<br>INSTRUMENTATION |
|-----------------------|-----------------|--|--------------|-----------------------|---------|-----------------------------|-------------------|--------------------------------|--|--|--------------------------------|--|--|--------------------------------|--|--|--------------------------------|--|--|----------------------------------|--|--|-------------------------|--|
|                       |                 |  |              |                       |         |                             |                   | 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                       |  |  |                                  |  |  |                         |  |
|                       |                 |  |              |                       |         |                             |                   | RECOVERY                       |  |  | R.Q.D. %                       |  |  | FRACT. INDEX PER 0.3           |  |  | DISCONTINUITY DATA             |  |  | HYDRAULIC CONDUCTIVITY K, cm/sec |  |  |                         |  |
|                       |                 |  |              |                       |         |                             |                   | TOTAL CORE %                   |  |  | SOLID CORE %                   |  |  |                                |  |  | DIP w.r.t. CORE AXIS           |  |  | TYPE AND SURFACE DESCRIPTION     |  |  |                         |  |
|                       |                 |  |              |                       |         |                             |                   | 10 20 30 40 50 60 70 80 90 100 |  |  | 10 20 30 40 50 60 70 80 90 100 |  |  | 10 20 30 40 50 60 70 80 90 100 |  |  | 10 20 30 40 50 60 70 80 90 100 |  |  |                                  |  |  |                         |  |
| 10                    |                 | Refer to Record of Borehole CN-00-2 for Soil Conditions.   |              | 148.50<br>10.00       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 11                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 12                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 13                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 14                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 15                    |                 | DOLOSTONE<br>Light grey to grey<br>Moderately to slightly weathered<br>Medium to widely bedded<br>Medium to strong rock<br>Fine grained                |              | 144.00<br>14.50       | 1       |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 16                    |                 |  |              |                       | 2       |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 17                    |                 | SHALE<br>Grey to dark grey<br>Moderately to slightly weathered<br>Closely to very closely bedded (fissile)<br>Weak rock<br>Fine to very fine grained   |              | 141.58<br>16.92       | 3       |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 18                    |                 | DOLOSTONE<br>Light grey to grey<br>Moderately to slightly weathered<br>Medium to widely bedded<br>Medium to strong rock<br>Fine grained<br>END OF HOLE |              | 141.30<br>17.20       | 4       |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 19                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |
| 20                    |                 |  |              |                       |         |                             |                   |                                |  |  |                                |  |  |                                |  |  |                                |  |  |                                  |  |  |                         |  |

DEPTH SCALE

1 : 50



LOGGED: GM

CHECKED: ASP

DRILLHOLE 1127FROC.GPJ GLDR CAN.GDT 19/12/01 PS

| <div style="display: flex; justify-content: space-between;"> <span>PROJECT 001-1127F</span> <span><b>RECORD OF BOREHOLE No CN-00-3</b></span> <span>1 OF 1</span> <span><b>METRIC</b></span> </div> |  |  |        |                  |                            |                 |   |                 |                                 |  |  |  |   |  |
|---|--|--|--------|------------------|----------------------------|-----------------|---|-----------------|---------------------------------|--|--|--|---|--|
| W.P. 281-99-00  |  | LOCATION N 4,778,473; E 333,892            |        | ORIGINATED BY GM |                            |                 |   |                 |                                 |  |  |  |   |  |
| DIST Central HWY QEW  |  | BOREHOLE TYPE 135mm dia. Solid Stem Augers |        | COMPILED BY LCC  |                            |                 |   |                 |                                 |  |  |  |   |  |
| DATUM Geodetic  |  | DATE November 6, 2000                      |        | CHECKED BY ASP   |                            |                 |   |                 |                                 |  |  |  |   |  |
| SOIL PROFILE  |  | SAMPLES                                    |        |                  | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                 |                                 | PLASTIC NATURAL LIQUID<br>LIMIT MOISTURE CONTENT |  |  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |
| ELEV<br>DEPTH   | DESCRIPTION  | STRAT PLOT                                 | NUMBER | TYPE             |                            |                 | "N" VALUES                                  | 20 40 60 80 100 | W <sub>p</sub> W W <sub>L</sub> | WATER CONTENT (%)                                |  |  |   |  |
| 149.4   | GROUND SURFACE                                       |  |        |                  |                            |                 |   |                 |                                 |  |  |  |   |  |
| 0.0   | Silty Clay, some topsoil, trace sand                 |  | 1      | SS               | 12                         |                 |   |                 |                                 |  |  |  |   |  |
| 149.1   | Firm   |  | 2      | SS               | 40                         |                 |   |                 |                                 |  |  |  |   |  |
| 0.3   | Black-brown  |  | 3      | SS               | 41                         |                 |   |                 |                                 |  |  |  |   |  |
|   | Clayey Silt, trace to some sand,                     |  | 4      | SS               | 64                         |                 |   |                 |                                 |  |  |  |   |  |
|   | trace gravel (Till)                                  |  | 5      | SS               | 100                        |                 |   |                 |                                 |  |  |  |   |  |
|   | Hard   |  | 6      | SS               | 100/12                     |                 |   |                 |                                 |  |  |  |   |  |
|   | Grey-brown to red-brown                              |  | 7      | SS               | 40                         |                 |   |                 |                                 |  |  |  |   |  |
| 144.5   | Moist  |  |        |                  |                            |                 |   |                 |                                 |  |  |  |   |  |
| 4.9   | END OF BOREHOLE<br>Auger refusal on Probable bedrock |  |        |                  |                            |                 |   |                 |                                 |  |  |  |   |  |
| Note:<br>Water level in piezometer measured<br>at 1.8m depth (Elevation 147.6m) on<br>February 9, 2001.   |  |  |        |                  |                            |                 |   |                 |                                 |  |  |  |   |  |

ON\_MOT\_001-1127.GPJ ON\_MOT\_GDT\_20/12/01

| PROJECT 001-1127F    |   | RECORD OF BOREHOLE No CN-00-4              |         |      |            | 1 OF 1                     |                 | METRIC                                      |  |  |                                 |                                  |                                |                  |   |
|----------------------|---|--|---------|------|------------|----------------------------|-----------------|---|--|--|---------------------------------|----------------------------------|--------------------------------|------------------|---|
| W.P. 281-99-00       |   | LOCATION N 4,778,459; E 333,934            |         |      |            | ORIGINATED BY GM           |                 |   |  |  |                                 |                                  |                                |                  |   |
| DIST Central HWY QEW |   | BOREHOLE TYPE 135mm dia. Solid Stem Augers |         |      |            | COMPILED BY LCC            |                 |   |  |  |                                 |                                  |                                |                  |   |
| DATUM Geodetic       |   | DATE February 1, 2001                      |         |      |            | CHECKED BY ASP             |                 |   |  |  |                                 |                                  |                                |                  |   |
| SOIL PROFILE         |   |  | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  |  | PLASTIC LIMIT<br>W <sub>p</sub> | NATURAL MOISTURE<br>CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub> | UNIT WEIGHT<br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |
| ELEV<br>DEPTH        | DESCRIPTION   | STRAT PLOT                                 | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |  |  |                                 |                                  |                                |                  |   |
| 151.8                | GROUND SURFACE  |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 0.0                  | Asphalt and concrete pavement   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 151.4                |   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 0.5                  | Clayey Silt, trace to some sand, gravel, shale fragments and organics (Fill)<br>Very stiff to hard<br>Brown to grey-brown<br>Moist                                      |  | 1       | SS   | 18         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
|                      |   |  | 2       | SS   | 46         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 148.9                |   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 2.9                  | Silty Clay, trace to some sand and organics, including 100mm thick organic layer<br>Hard<br>Black-brown<br>Moist  |  | 3       | SS   | 36         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 148.0                |   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 3.8                  | Clayey Silt, trace sand, gravel and shale fragments (Till)<br>Hard<br>Brown to grey-brown<br>Moist  |  | 4       | SS   | 85         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
|                      |   |  | 5       | SS   | 84         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 145.7                |   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 6.1                  | Sandy Silt, trace to some clay, trace gravel (Till)<br>Very dense<br>Red brown<br>Moist   |  | 6       | SS   | 70         |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 144.5                |   |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |
| 7.3                  | END OF BOREHOLE<br>Auger refusal on Probable bedrock<br><br>Note:<br>The water level in the open borehole was at 1.8m depth (Elevation 150m) on completion of drilling. |  |         |      |            |                            |                 |   |  |  |                                 |                                  |                                |                  |   |

ON\_MOT 001-1127.GPJ ON MOT.GDT 19/12/01

|                                    |   |                                      |  |        |               |
|------------------------------------|---|--------------------------------------|--|--------|---------------|
| PROJECT <u>001-1127F</u>           |   | <b>RECORD OF BOREHOLE No CN-00-5</b> |  | 1 OF 2 | <b>METRIC</b> |
| W.P. <u>281-99-00</u>              | LOCATION <u>N 4,778,420; E 333,951</u>            | ORIGINATED BY <u>GM</u>              |  |        |               |
| DIST <u>Central</u> HWY <u>QEW</u> | BOREHOLE TYPE <u>135mm dia. Solid Stem Augers</u> | COMPILED BY <u>LCC</u>               |  |        |               |
| DATUM <u>Geodetic</u>              | DATE <u>November 7, 2000</u>                      | CHECKED BY <u>ASP</u>                |  |        |               |

| SOIL PROFILE  |   |            | SAMPLES |      |           | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT               |          | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)<br>GR SA SI CL |                   |  |
|---------------|---|------------|---------|------|-----------|----------------------------|-----------------|---|----------|------------------------------------|-------------------------------------|-----------------------------------|--|--|-------------------|--|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | *N VALUES |                            |                 | SHEAR STRENGTH kPa  |          |                                    |                                     |                                   |  |  | WATER CONTENT (%) |  |
|               |   |            |         |      |           |                            |                 | 20 40 60 80 100   | 20 40 60 |                                    |                                     |                                   |  |  |                   |  |
|               |   |            |         |      |           |                            |                 | ○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL × REMOULDED |          |                                    |                                     |                                   |  |  |                   |  |
| 153.6         | GROUND SURFACE  |            |         |      |           |                            |                 |   |          |                                    |                                     |                                   |  |  |                   |  |
| 0.0           | Topsoil   |            | 1       | SS   | 17        |                            |                 |   |          |                                    |                                     |                                   |  |  |                   |  |
| 153.3         | Clayey Silt, trace sand, gravel,<br>rootlets, shale fragments (Fill)<br>Stiff to very stiff<br>Grey-brown to black<br>Moist         |            | 2       | SS   | 12        |                            | 153             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 0.3           |   |            | 3       | SS   | 14        |                            | 152             |   |          |                                    |                                     |                                   |  |  |                   |  |
|               |   |            | 4       | SS   | 17        |                            | 151             |   |          |                                    |                                     |                                   |  |  |                   |  |
|               |   |            | 5       | SS   | 16        |                            | 150             |   |          |                                    |                                     |                                   |  |  |                   |  |
|               |   |            | 6       | SS   | 11        |                            | 149             |   |          |                                    |                                     |                                   |  |  |                   |  |
|               |   |            | 7       | SS   | 70/15     |                            | 148             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 149.0         | Clayey Silt, trace sand and gravel<br>(Till)<br>Hard<br>Brown to red-brown<br>Moist   |            | 8       | SS   | 41        |                            | 147             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 4.6           |   |            | 9       | SS   | 90/15     |                            | 146             |   |          |                                    |                                     |                                   | 3 25 60 12                               |  |                   |  |
| 146.0         | Sandy Silt, trace clay and gravel<br>Very dense<br>Red-brown  |            |         |      |           |                            | 145             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 145.1         | Dolostone (Bedrock); cored between<br>8.5m and 11.6m depth.<br>For bedrock coring details, refer to<br>Record of Drillhole CN-00-5. |            |         |      |           |                            | 144             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 8.5           |   |            |         |      |           |                            | 143             |   |          |                                    |                                     |                                   |  |  |                   |  |
|               |   |            |         |      |           |                            | 142             |   |          |                                    |                                     |                                   |  |  |                   |  |
| 142.0         | END OF BOREHOLE   |            |         |      |           |                            |                 |   |          |                                    |                                     |                                   |  |  |                   |  |
| 11.6          | Note:<br>Water level in piezometer measured<br>at 3.7m depth (Elevation 149.9m) on<br>February 9, 2001.                             |            |         |      |           |                            |                 |   |          |                                    |                                     |                                   |  |  |                   |  |

ON\_MOT\_001-1127.GPJ ON\_MOT\_GDT\_19/12/01

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT: 001-1127F

## RECORD OF DRILLHOLE: CN-00-5

SHEET 2 OF 2

LOCATION: N 4,778,420; E 333,951

DRILLING DATE: November 7/00

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: --

DRILL RIG: D-50 Bombardier

DRILLING CONTRACTOR: Master Soil Investigations

| DEPTH SCALE<br>METRES | DRILLING RECORD | DESCRIPTION   | SYMBOLIC LOG | ELEV.<br>DEPTH<br>(m) | PENETRATION RATE<br>(mm/min) | FLUSH<br>% RETURN | FR-FRACTURE     |                 | F-FAULT     |  | SM-SMOOTH                  |                                 | FL-FLEXURED        |     | BC-BROKEN CORE                         |     | DIAMETRAL<br>POINT LOAD<br>INDEX (MPa) | NOTES<br>WATER LEVELS<br>INSTRUMENTATION |  |
|-----------------------|-----------------|---|--------------|-----------------------|------------------------------|-------------------|-----------------|-----------------|-------------|--|----------------------------|---------------------------------|--------------------|-----|--|-----|--|--|--|
|                       |                 |   |              |                       |                              |                   | CL-CLEAVAGE     |                 | J-JOINT     |  | R-ROUGH                    |                                 | UE-UNEVEN          |     | MB-MECH. BREAK                         |     |  |  |  |
|                       |                 |   |              |                       |                              |                   | SH-SHEAR        |                 | P-POLISHED  |  | ST-STEPPED                 |                                 | W-WAVY             |     | B-BEDDING                              |     |  |  |  |
|                       |                 |   |              |                       |                              |                   | RECOVERY        |                 | R.Q.D.<br>% |  | FRACT.<br>INDEX<br>PER 0.3 |                                 | DISCONTINUITY DATA |     | HYDRAULIC<br>CONDUCTIVITY<br>K, cm/sec |     |  |  |  |
|                       |                 |   |              |                       |                              |                   | TOTAL<br>CORE % | SOLID<br>CORE % |             |  | DIP w.r.t.<br>CORE AXIS    | TYPE AND SURFACE<br>DESCRIPTION |                    | 10° | 10°                                    | 10° |  |  |  |
| 8                     |                 | Refer to Record of Borehole CN-00-5 for<br>Soil Conditions.   |              | 145.60<br>8.00        |                              |                   |                 |                 |             |  |                            |                                 |                    |     |  |     |  |  |  |
| 9                     |                 | Dolostone with occasional thin<br>argillaceous lenses at 10.18m-10.21m,<br>10.61m-10.64 and 10.92m-10.95m<br>Light grey<br>Moderately to slightly weathered<br>Medium to widely bedded<br>Medium to strong rock<br>Fine grained |              | 145.07<br>8.59        |                              |                   |                 |                 |             |  |                            |                                 |                    |     |  |     |  |  |  |
| 10                    |                 |   |              |                       |                              |                   |                 |                 |             |  |                            |                                 |                    |     |  |     |  |  |  |
| 11                    |                 |   |              |                       |                              |                   |                 |                 |             |  |                            |                                 |                    |     |  |     |  |  |  |
| 12                    |                 | END OF HOLE   |              | 142.00<br>11.60       |                              |                   |                 |                 |             |  |                            |                                 |                    |     |  |     |  |  |  |

DRILLHOLE 1127FROC.GPJ GLDR CAN GDT 19/12/01 PS

DEPTH SCALE

1 : 50



LOGGED: GM

CHECKED: ASP

| PROJECT   |       | 001-1127F  |            | RECORD OF BOREHOLE No CN-00-6 |      | 1 OF 2                                   |                         | METRIC          |                        |          |          |          |             |                             |         |  |  |
|---|-------|--|------------|-------------------------------|------|--|-------------------------|-----------------|------------------------|----------|----------|----------|-------------|-----------------------------|---------|--|--|
| W.P.  |       | 281-99-00  |            | LOCATION                      |      | N 4,778,425; E 333,976                   |                         | ORIGINATED BY   |                        |          |          |          |             |                             |         |  |  |
| DIST  |       | Central HWY QEW  |            | BOREHOLE TYPE                 |      | 135mm dia. Solid Stem Augers             |                         | COMPILED BY     |                        |          |          |          |             |                             |         |  |  |
| DATUM   |       | Geodetic   |            | DATE                          |      | January 31, 2001                         |                         | CHECKED BY      |                        |          |          |          |             |                             |         |  |  |
| ASP   |       |  |            |                               |      |  |                         |                 |                        |          |          |          |             |                             |         |  |  |
| SOIL PROFILE  |       |  | SAMPLES    |                               |      | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                         |                 | PLASTIC NATURAL LIQUID |          |          | UNIT     |             |                             | REMARKS |  |  |
| ELEV  | DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER                        | TYPE | *N VALUES                                | GROUND WATER CONDITIONS | ELEVATION SCALE | 20 40 60 80 100        | 20 40 60 | 20 40 60 | 20 40 60 | UNIT WEIGHT | GRAIN SIZE DISTRIBUTION (%) |         |  |  |
| 154.2   | 0.0   | Asphalt and concrete pavement  |            |                               |      |  |                         | 154             |                        |          |          |          |             |                             |         |  |  |
| 153.8   | 0.5   | Sand and Gravel (Fill)<br>Clayey Silt, trace sand, gravel, rootlets and organics (Fill)<br>Firm to stiff<br>Grey-brown to black-brown<br>Moist |            | 1                             | SS   | 7  |                         | 153             |                        |          |          |          |             |                             |         |  |  |
|   |       |  |            | 2                             | SS   | 15                                       |                         | 152             |                        |          |          |          |             |                             |         |  |  |
| 151.1   | 3.1   | Clayey Silt, trace sand, gravel and rock fragments (Till)<br>Hard<br>Brown to red-brown<br>Moist   |            | 3                             | SS   | 63                                       |                         | 151             |                        |          |          |          |             |                             |         |  |  |
|   |       |  |            | 4                             | SS   | 90/22                                    |                         | 150             |                        |          |          |          |             |                             |         |  |  |
|   |       |  |            | 5                             | SS   | 65                                       |                         | 149             |                        |          |          |          |             |                             |         |  |  |
|   |       |  |            | 6                             | SS   | 50                                       |                         | 148             |                        |          |          |          |             |                             |         |  |  |
| 146.6   | 7.6   | Sandy Silt, trace clay, trace gravel (Till)<br>Very dense<br>Red-brown<br>Dry to moist   |            | 7                             | SS   | 100/15                                   |                         | 146             |                        |          |          |          |             |                             |         |  |  |
| 145.0   | 9.2   | Dolostone (Bedrock); cored between 9.2m and 12.2m depth.<br>For bedrock coring details, refer to Record of Drillhole CN-00-6.                  |            | 8                             | SS   | 100/05                                   |                         | 145             |                        |          |          |          |             |                             |         |  |  |
| 142.0   | 12.2  | END OF BOREHOLE  |            |                               |      |  |                         | 142             |                        |          |          |          |             |                             |         |  |  |
| <p>Note:</p> <p>1. The water level in the open borehole was measured at 1.8m depth (Elevation 152.4m) on completion of the overburden drilling.</p> <p>2. Water used during coring operations; water level in open hole on completion of rock drilling not representative of groundwater level.</p> |       |  |            |                               |      |  |                         |                 |                        |          |          |          |             |                             |         |  |  |

ON\_MOT\_001-1127.GPJ ON\_MOT.GDT 19/12/01

Continued Next Page

+<sup>3</sup>.X<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



PROJECT: 001-1127F

## RECORD OF DRILLHOLE: CN-00-6

SHEET 2 OF 2

LOCATION: N 4,778,425; E 333,976

DRILLING DATE: January 31/01

DATUM: Geodetic

INCLINATION: -90°

AZIMUTH: --

DRILL RIG: D-50 Bombardier

DRILLING CONTRACTOR: Master Soil Investigations

| DEPTH SCALE<br>METRES | DRILLING RECORD | DESCRIPTION   | SYMBOLIC LOG | ELEV.<br>DEPTH<br>(m) | RUN No. | PENETRATION RATE<br>(mm/min) | FLUSH<br>% RETURN | FR-FRACTURE<br>CL-CLEAVAGE<br>SH-SHEAR<br>VN-VEIN | F-FAULT<br>J-JOINT<br>P-POLISHED<br>S-SLICKENSIDED | SM-SMOOTH<br>R-ROUGH<br>ST-STEPPED<br>PL-PLANAR | FL-FLEXURED<br>UE-UNEVEN<br>W-WAVY<br>C-CURVED | BC-BROKEN CORE<br>MB-MECH. BREAK<br>B-BEDDING | DIAMETRAL<br>POINT LOAD<br>INDEX (MPa) | NOTES<br>WATER LEVELS<br>INSTRUMENTATION |
|-----------------------|-----------------|---|--------------|-----------------------|---------|------------------------------|-------------------|---|--|---|--|---|--|--|
|                       |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
|                       |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
|                       |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 8                     |                 | Refer to Record of Borehole CN-00-6 for<br>Soil Conditions.   |              | 146.20<br>8.00        |         |                              |                   |   |  |   |  |   |  |  |
| 9                     |                 |   |              | 145.06<br>9.14        |         |                              |                   |   |  |   |  |   |  |  |
| 10                    |                 | Dolostone with occasional thin<br>argillaceous lenses at 9.60m-9.61m,<br>9.65m-9.70m and 9.83m-9.85m<br>Light grey to dark grey<br>Moderately to slightly weathered<br>Medium to widely bedded<br>Medium to strong rock<br>Fine grained |              |                       | 1       |                              |                   |   |  |   |  |   |  |  |
| 11                    |                 |   |              |                       | 2       |                              |                   |   |  |   |  |   |  |  |
| 12                    |                 |   |              | 142.00<br>12.20       |         |                              |                   |   |  |   |  |   |  |  |
| 13                    |                 | END OF HOLE   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 14                    |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 15                    |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 16                    |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 17                    |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |
| 18                    |                 |   |              |                       |         |                              |                   |   |  |   |  |   |  |  |

DRILL-HOLE 1127FROC.GPJ GLDR CAN.GDT 19/12/01 PS

DEPTH SCALE

1 : 50

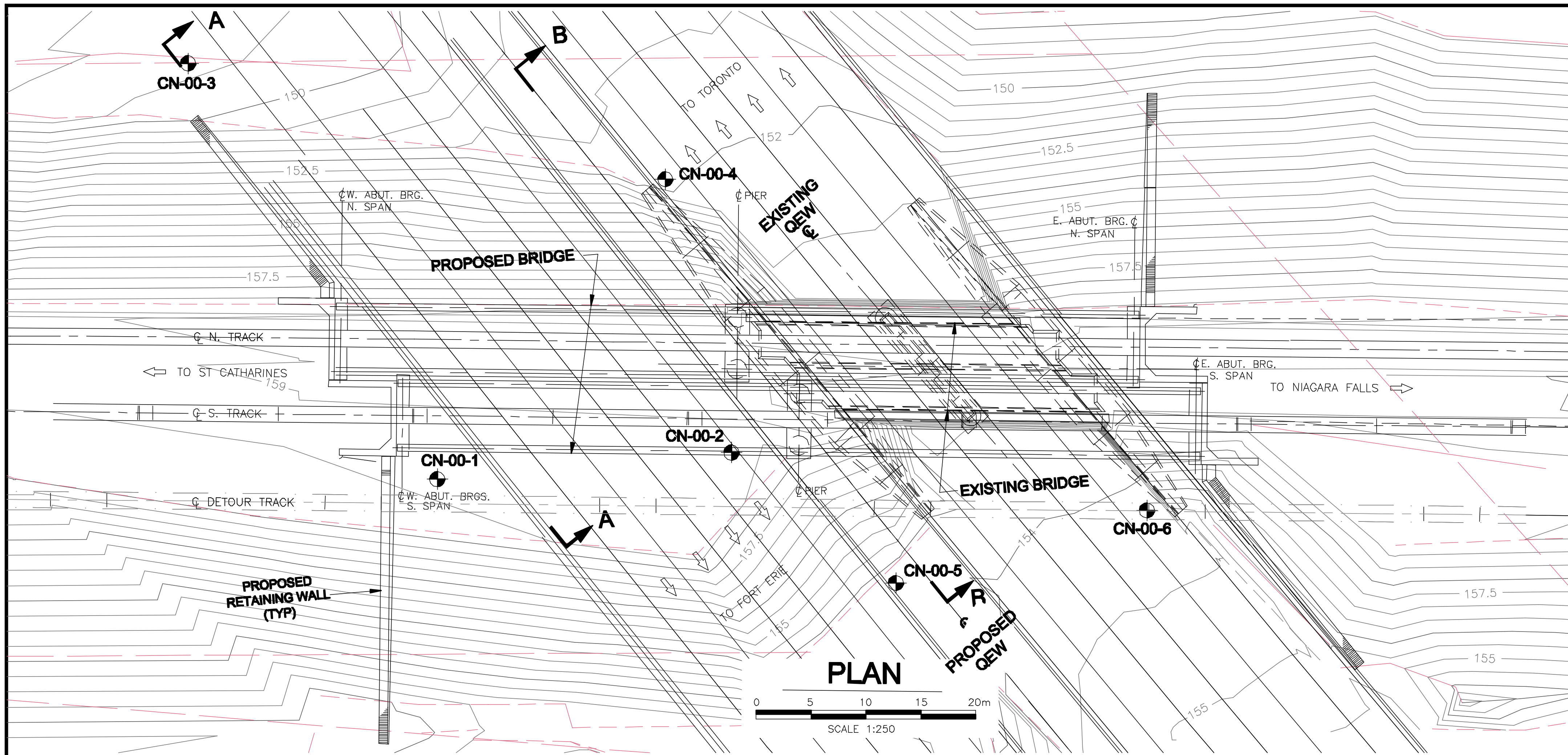


LOGGED: GM

CHECKED: ASP

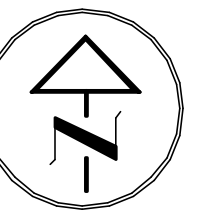


P1127F-1001.DWG



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

CONT No.  
WP No. 281 - 9 9- 00

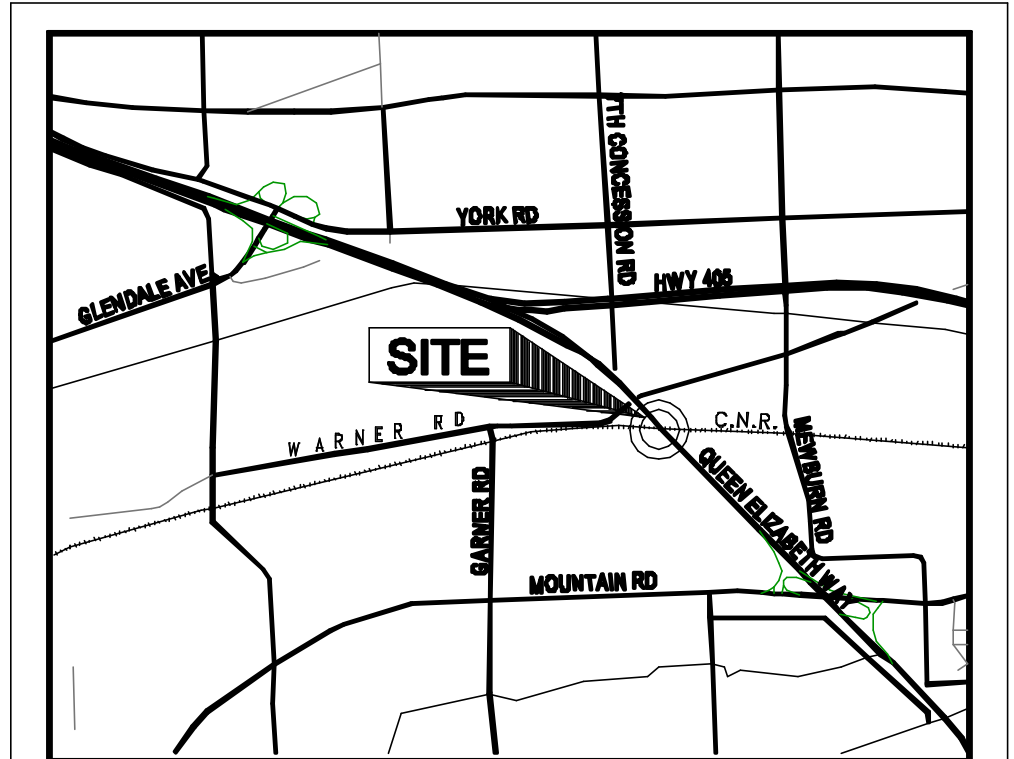


**Q.E.W. UNDERPASS AT  
C.N.R. BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA**

SHEET



**Golder Associates Ltd.**  
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

LEGEND

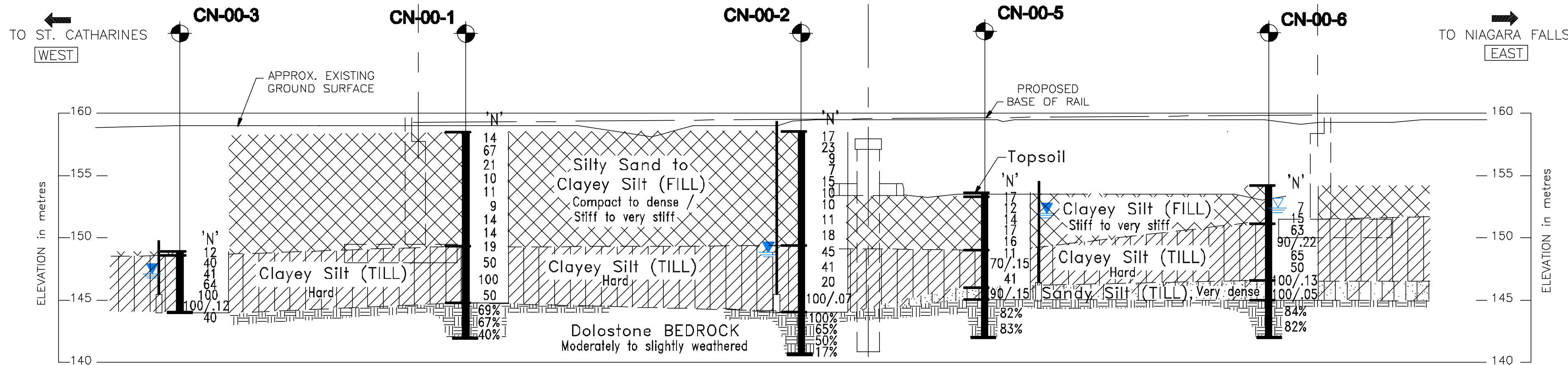
- Borehole
- Probehole
- Seal
- Piezometer
- N Standard Penetration Test value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL in piezometer, February 9, 2001
- WL upon completion of drilling

| No.     | ELEVATION | LOCATION  |         |
|---------|-----------|-----------|---------|
|         |           | NORTHING  | EASTING |
| CN-00-1 | 158.5     | 4,778,433 | 333,911 |
| CN-00-2 | 158.5     | 4,778,433 | 333,938 |
| CN-00-3 | 149.4     | 4,778,473 | 333,892 |
| CN-00-4 | 151.8     | 4,778,459 | 333,934 |
| CN-00-5 | 153.6     | 4,778,420 | 333,951 |
| CN-00-6 | 154.2     | 4,778,425 | 333,976 |

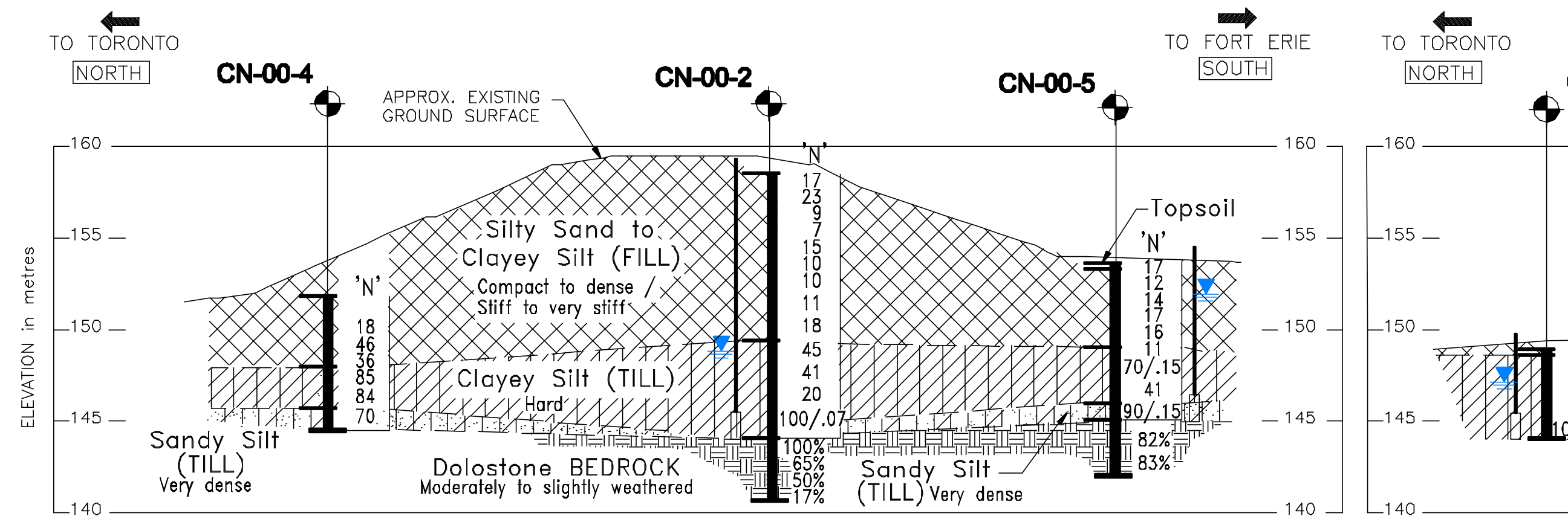
NOTES

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

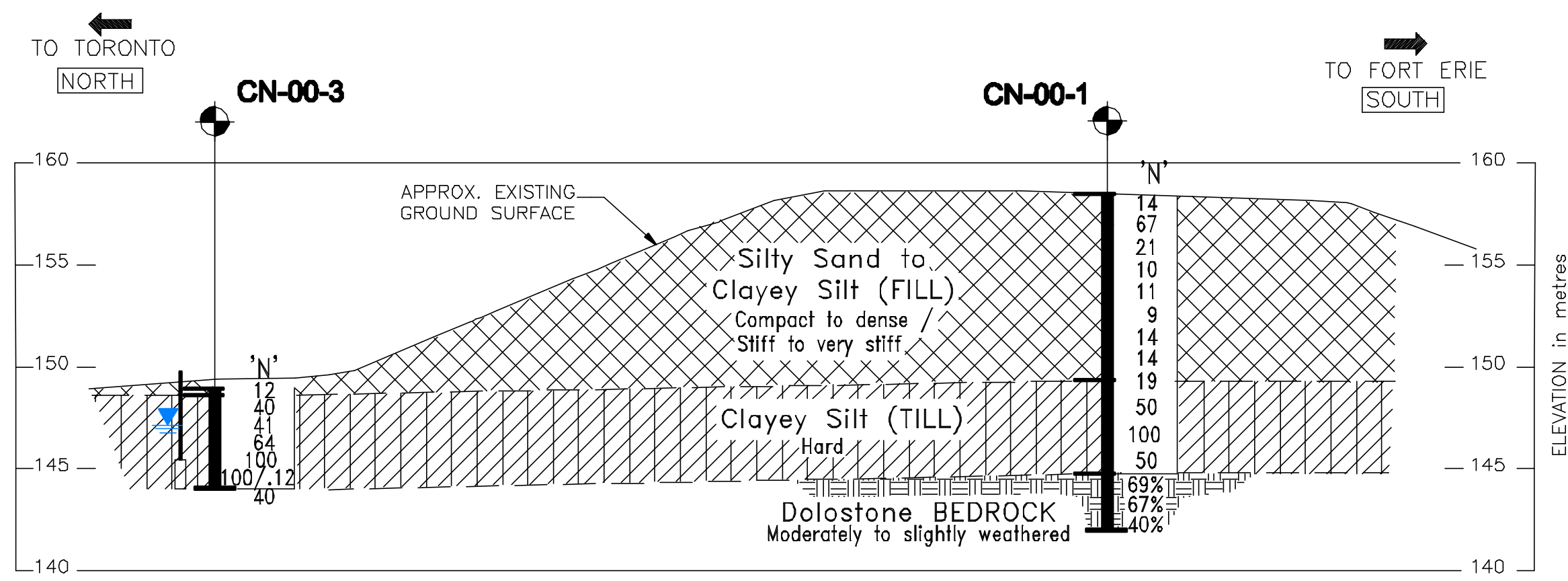
PROFILE ALONG CENTRELINE OF CNR STRUCTURE



SECTION B-B



SECTION A-A



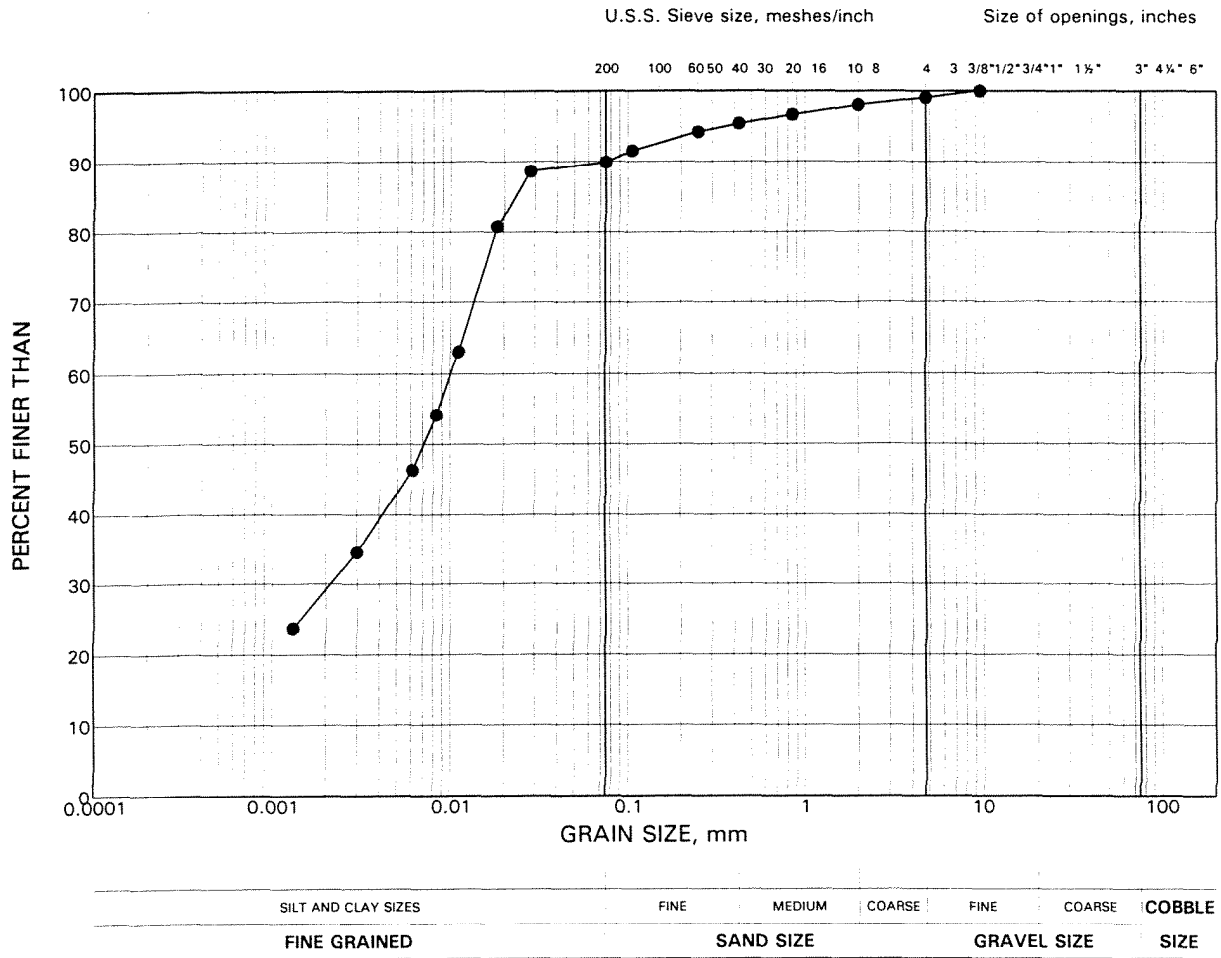
| NO.         | DATE   | BY                      | REVISION                  |
|-------------|--------|-------------------------|---------------------------|
|             |        |                         |                           |
| Geocres No. |        |                         |                           |
| HWY. Q.E.W. |        | PROJECT NO. 001-1127F-1 |                           |
| SUBM'D.     | P.D.G. | CHKD. LCC               | DATE: FEBRUARY 2001 SITE: |
| DRAWN:      | M.H.W. | CHKD. LCC               | APPD. ASP DWG. 1          |



# GRAIN SIZE DISTRIBUTION

Embankment Fill

FIGURE 1

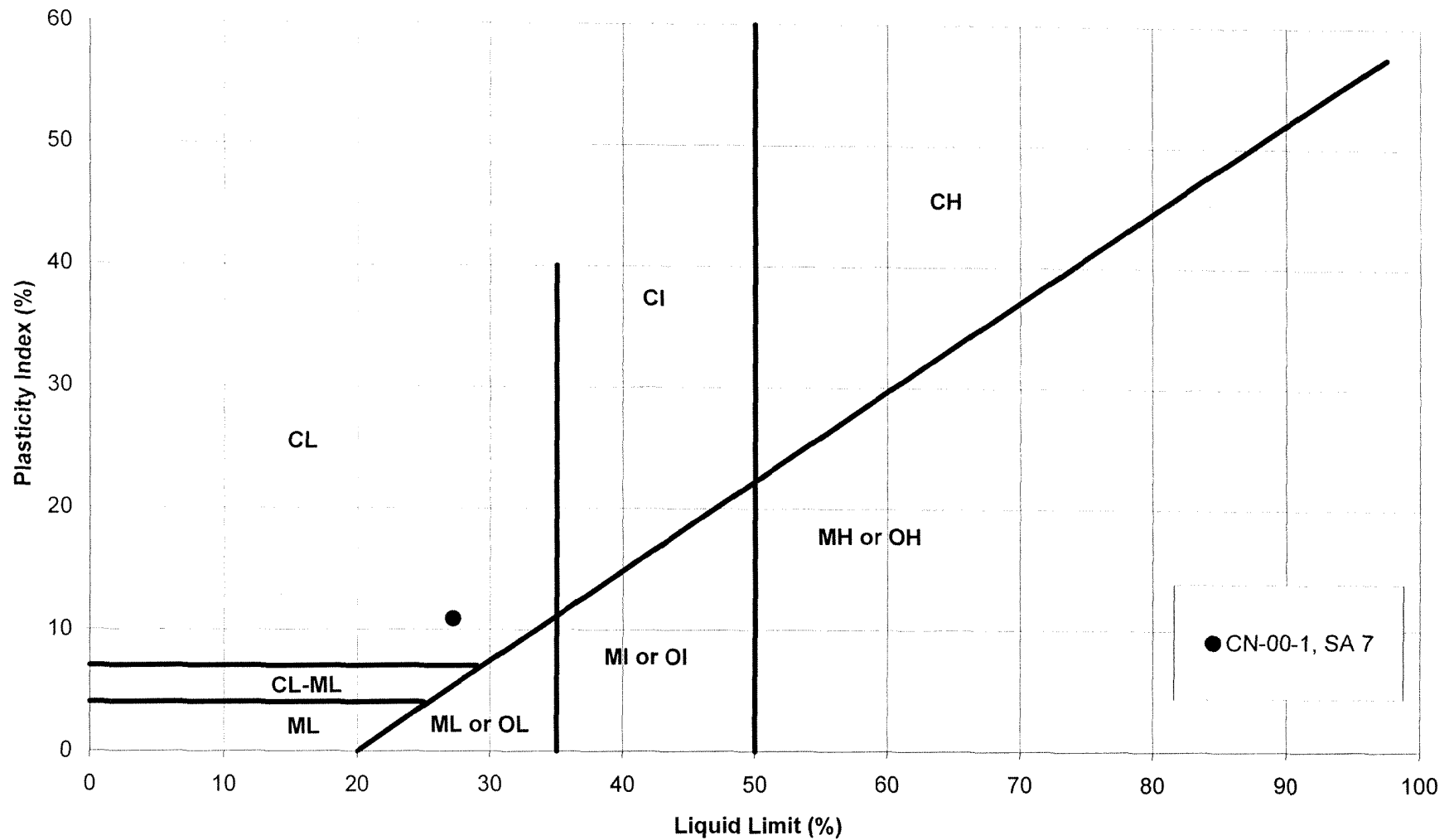


## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH (m) |
|--------|----------|--------|-----------|
| •      | CN-00-1  | 7      | 5.0       |

**PLASTICITY CHART  
Embankment Fill**

**FIGURE 2**



Date: September 2001

Project: 001-1127F-1

**Golder Associates**

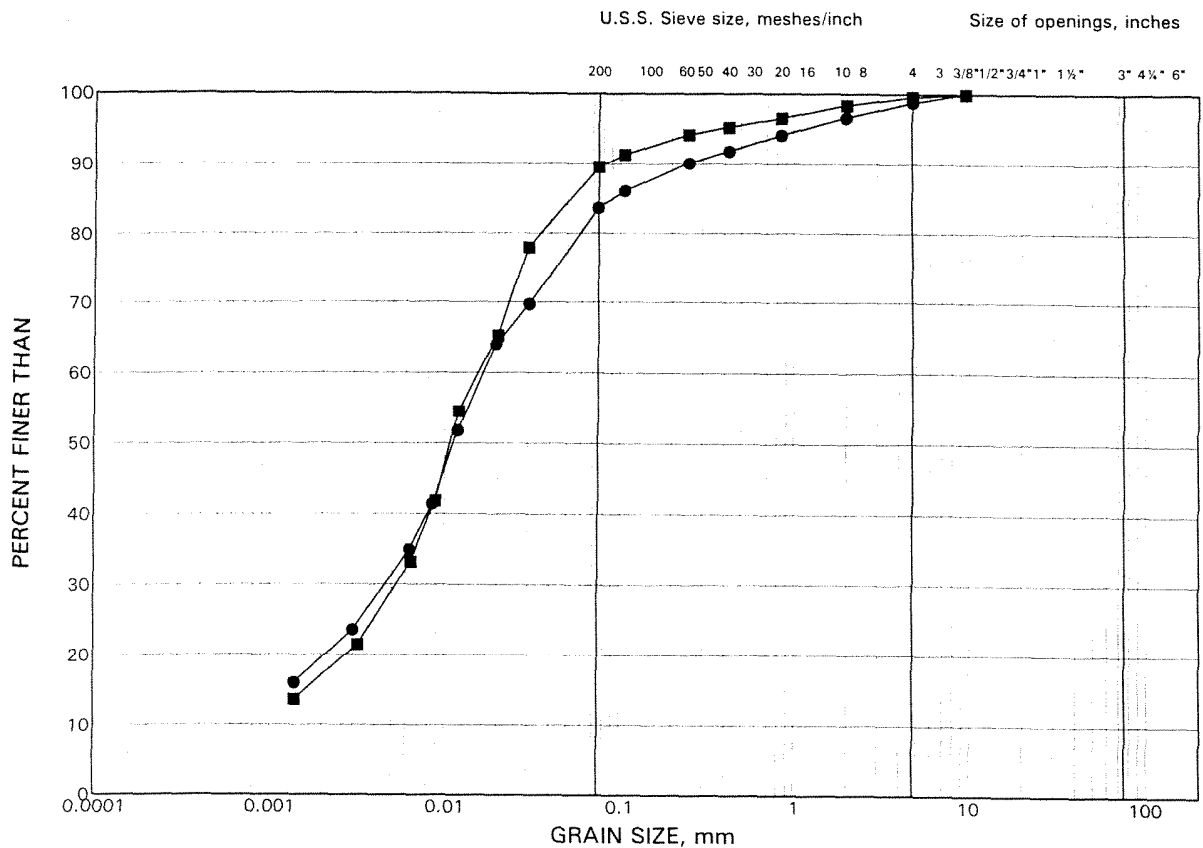
Drawn: LCC

Checked: LCC

# GRAIN SIZE DISTRIBUTION

Clayey Silt Till

FIGURE 3



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

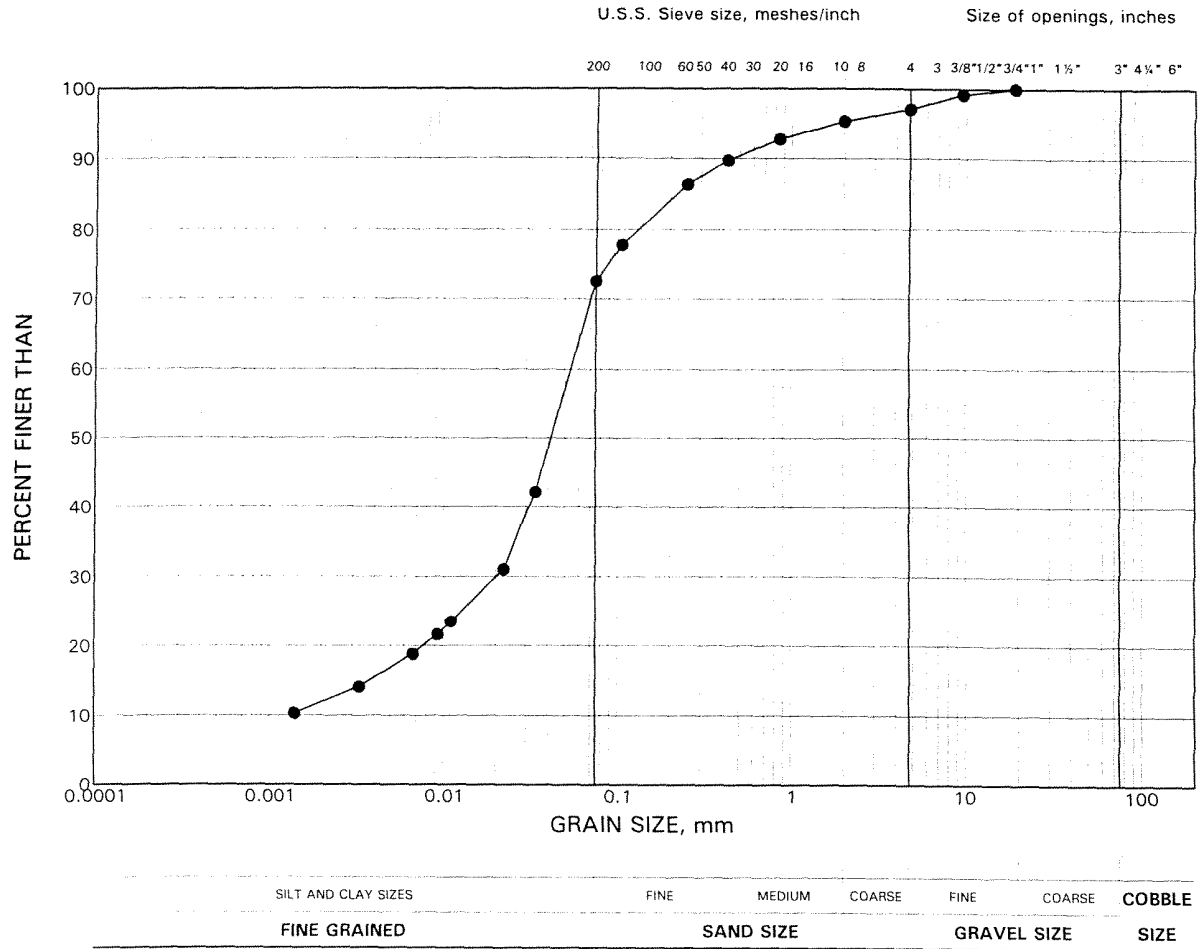
## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH (m) |
|--------|----------|--------|-----------|
| ●      | CN-00-1  | 11     | 11.1      |
| ■      | CN-00-3  | 4      | 2.7       |

# GRAIN SIZE DISTRIBUTION

Sandy Silt Till

FIGURE 4

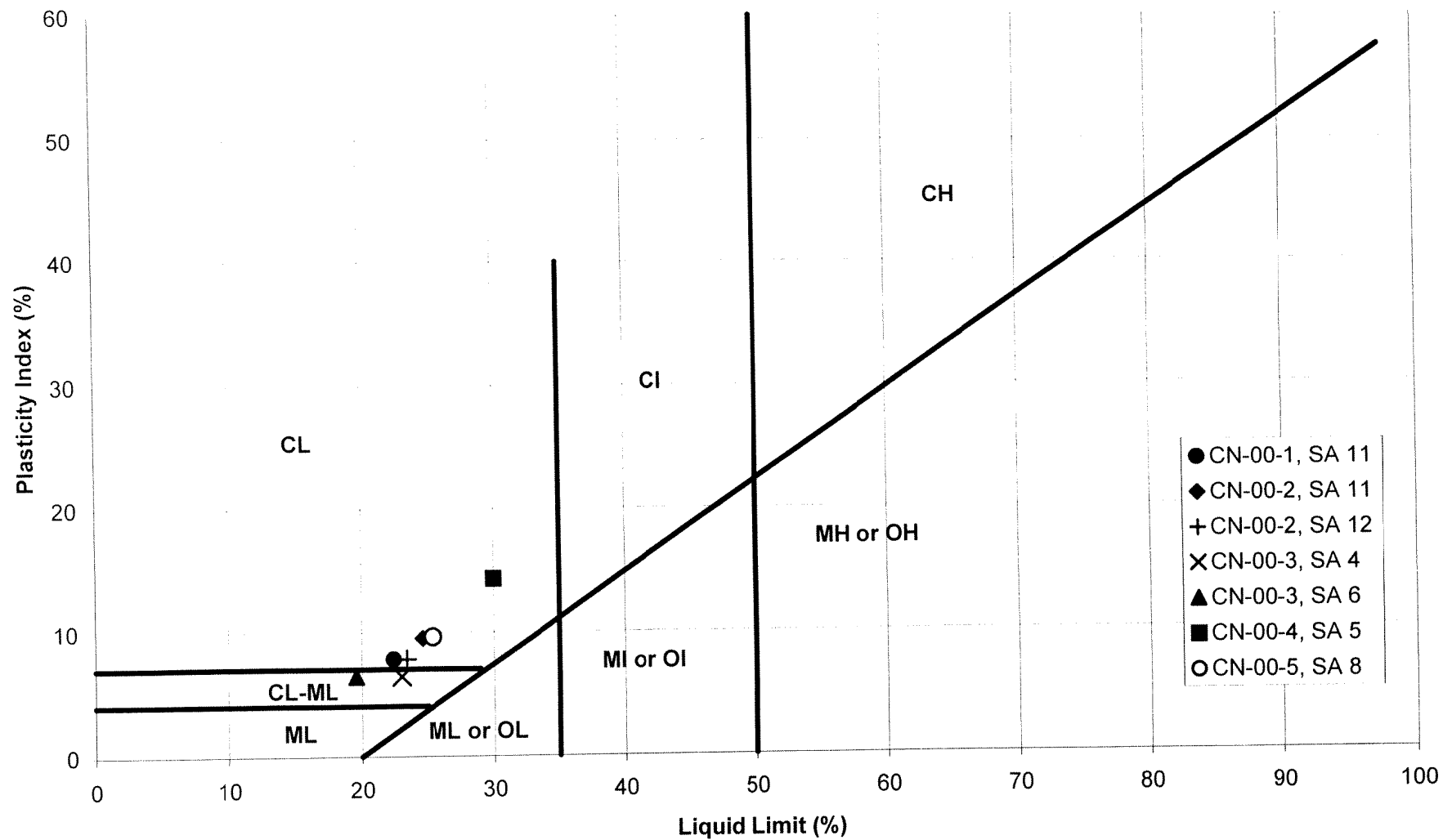


## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH (m) |
|--------|----------|--------|-----------|
| •      | CN-00-5  | 9      | 7.9       |

**PLASTICITY CHART**  
**Clayey Silt Till**

**FIGURE 5**



Date: September 2001

Project: 001-1127F-1

**Golder Associates**

Drawn: LCC

Checked: LCC