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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. _____

REMARKS: _____

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FINAL REPORT

**FOUNDATION INVESTIGATION AND DESIGN REPORT
FOR HIGHWAY 11 NORTHBOUND
CROSSING BIG EAST RIVER
W.P. 454-93-00, SITE 42-09N
HIGHWAY 11, DISTRICT 52
HUNTSVILLE, ONTARIO**

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Ministry of Transportation

W.P. 207-93-01

1.0 INTRODUCTION

Golder Associates Ltd. has been retained by Cole, Sherman & Associates (Cole, Sherman) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a geotechnical investigation at the site of the proposed bridge to carry northbound lanes of the proposed Highway 11 over Big East River. The northbound bridge over Big East River is part of the four laning of Highway 11 project, which extends from 2.2 km north of Highway 60 in Huntsville and 4.5 km northerly. This report addresses the proposed bridge and its approaches within 20 m of the structure. The site of the project is designated as Site 42-09N.

The purpose of this investigation is to determine the subsurface conditions at the site of the proposed bridge structure by means of a limited number of boreholes, in-situ tests and laboratory tests on selected samples. Based on our interpretation of the data obtained, recommendations on the geotechnical aspects of design of the proposed works are provided. Comments are also provided on anticipated construction problems where they may affect design of the proposed bridge and approach embankments.

The subsurface information obtained during a previous investigation carried out by the MTO Foundation Design Section, for the then proposed detour structure over Big East River, contained in a report prepared by MTO, dated March 26, 1997, has been utilized in the preparation of this report.

The terms of reference for the scope of work are outlined in our proposal letter P71-8053, dated June 18, 1997 and the work was carried out in accordance with our Quality Control Plan for Foundation Design Services, dated August 1, 1997. During the course of the field work, the number of boreholes and extent of testing was revised slightly to accommodate the subsoil and site conditions as encountered.

2.0 SITE DESCRIPTION

The site is located approximately 6.7 km north of Highway 60 within the MTO District 52 in Huntsville, Ontario and is designated as Site 42-09N. It is understood that the existing bridge will be replaced by a new Highway 11 Northbound bridge and that the centreline of the proposed bridge alignment will be coincident with the existing Highway 11 centreline. The existing bridge carrying Highway 11 over Big East River is a 36.6 m span steel plate girder bridge. The existing approach embankments are about 4 m in height. The topography of the area adjacent to the road embankment is undulating with ground surface between approximately Elevation 288.0 m and Elevation 292.5 m. The banks of the Big East River at the crossing are approximately 2.5 m in height. Vegetation cover on the tableland consists of trees, shrubs and grass. Based on the information provided to us the water level in the river was at Elevation 286.4 m in November 1996 and in August 1997.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between August 26, 1997 and September 5, 1997. At this time, one borehole (97-5) was put down at the proposed north bridge abutment and one dynamic cone penetration test (CT 97-1) was carried out at the proposed south abutment. In addition, two boreholes (97-6 and 97-7) were drilled to the west of the existing highway embankment, in the vicinity of the south abutment. The investigation was carried out using bombardier mounted CME 55 drill rigs supplied and operated by Marathon Drilling Inc. of Ottawa.

In the borings, samples were obtained at regular intervals of depth using 50 mm outside diameter split spoon samplers, in accordance with Standard Penetration Test (SPT) procedures. Groundwater conditions in the open boreholes were observed throughout the drilling operations.

The field work was supervised on a full time basis by a member of our technical staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in containers and transported back to our laboratory in Sudbury for further examination. Index and classification tests were carried out on selected samples.

The as-drilled borehole and dynamic cone locations were determined by our field personnel based on the highway chainages as staked in the field. Surveyed borehole locations and elevations were provided by Cole, Sherman and we understand that the elevations are referenced to Geodetic Datum. The northing and easting co-ordinates of the boreholes and dynamic cone test, are shown on the Record of Borehole and cone sheets and Drawing M8033002.

4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY

4.1 Site Geology

From published geologic information, the site is located in the physiographic region known as the Canadian Precambrian Shield. The shield terrain comprises large expanses of intrusive rocks such as gneisses and gneissic or massive granitic rocks. The rocks are geologically complex with considerable folding, intrusive activity, regional metamorphism and faulting. Pleistocene lacustrine/fluvial deposits and recent swamp sediments have been laid down in depressions and are associated with the Glacial Lake Algonquin. The local physiography is characterized by the overburden consisting mainly of discontinuous glaciolacustrine deposits and irregular, variable bedrock surface with frequent rock outcrops and shallow bedrock. Since irregular bedrock surface is typical in the area, organic terrain is widespread.

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, following the text of this report. The stratigraphic boundaries shown on the boreholes logs 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.

Relevant information on subsurface conditions was obtained from Borehole 97-5 put down on the north side of the river, dynamic cone test CT 97-1 carried on the south side of the river and Borehole 97-7 which was located some 18 m to the west of the centreline of the existing highway. Boreholes 97-5 and 97-7 were advanced to about 32 m and 25.3 m depths (Elevation 260.5 m and 263.2 m), respectively; the dynamic cone was advanced to 25.5 m depth (Elevation 266.7 m).

In addition, information on subsurface conditions was obtained from Boreholes 1 and 2 drilled during a previous investigation carried out by MTO in 1996 for the detour structure over Big East River, documented in a report titled "Foundation Investigation Report for Detour Structure, Big East River, W.P. 207-93-01, Site 42-09, Highway 11, District 52, Huntsville", dated March 26, 1997. These boreholes, indicated on our drawing as 96-1 and 96-2, were located some 19 m east of the centreline of the existing Highway 11. The boreholes were advanced to depths of 21.5 m (Elevation 267.0 m) and 20.9 m (Elevation 267.3 m).

In summary, the soils encountered in the boreholes consist of extensive glaciofluvial and/or lacustrine deposits of sand, silt and clayey silt. About 2.7 m of a deposit consisting of boulders, cobbles and sand was encountered overlying the bedrock in the borehole located to the west of the existing embankment. The overburden is underlain by a gneiss bedrock. The surface of the bedrock was encountered at 28.9 m depth (Elevation 263.5 m) on the north side of the river and was inferred by dynamic cone refusal at 25.5 m (Elevation 266.7 m) on the south side of the river. Based on the borehole results in the general area, this refusal depth could be either on the bouldery layer or on bedrock.

The locations of the boreholes and stratigraphic section showing the inferred subsurface conditions at the proposed bridge site are shown on Drawing M8033002. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill Materials

Borehole 97-5 was put down through the existing road embankment on the north side of the river. Some 2.2 m of embankment fill material consisting of sand and gravel was encountered in the borehole. The fill is generally compact to dense with two measured SPT "N" values of 21 and 35 blows per 0.3 m of penetration. The measured water content of one sample of the fill was 3 per cent.

4.2.2 Upper Sand and Silty Sand

Extending from the ground surface and/or underlying the fill is a sand deposit. The sand extends to depths of 8.5 m and 7.6 m in Boreholes 97-5 and 97-7, respectively. Some 2.3 m of silty sand extends beneath sand deposit in Borehole 97-7. The sand and silty sand was encountered to Elevation 283.9 m in Borehole 97-5 and to Elevation 278.6 m in Borehole 97-7.

The sand is typically in a very loose to compact state of packing; the measured Standard Penetration Test (SPT) 'N' values range from 1 blow to 13 blows for 0.3 m of penetration. The measured natural water contents of selected samples of this deposit range from 4 per cent to 30 per cent.

4.2.3 Silt

Underlying the sand in both boreholes is a silt deposit. The silt is greenish grey to grey in colour; trace organic matter, thin sand seams and trace clay were noted throughout this silt deposit. The silt deposit is 3.5 m thick in Borehole 97-5 and 3.5 m thick in Borehole 97-7. The silt is in a very loose to loose state of packing. The measured SPT 'N' values range from 2 to 4 blows for 0.3 m of penetration. The base of the silt was encountered at 12.0 m depth (Elevation 280.5 m) in Borehole 97-5 and at 13.1 m depth (Elevation 275.4 m) in Borehole 97-7.

The measured natural water contents of selected samples of this deposit range from 28 per cent to 32 per cent.

4.2.4 Clayey Silt and Silty Clay

A deposit of silty clay and clayey silt was encountered in Boreholes 97-5 and 97-7 extending below about 12 m and 13.1 m depth, respectively, underlying the silt. The upper 1.7 m to 2 m of the deposit is comprised of clayey silt with a liquid limit of 28 per cent and plasticity index of 5 per cent. Five Atterberg Limit tests carried out on the underlying silty clay deposit indicated liquid limits between 29 per cent and 35 per cent and plasticity indices between 8 per cent and 14 per cent.

The measured SPT 'N' values in the clayey silt / silty clay generally range from 7 to 53 blows per 0.3 m of penetration indicating a firm to hard consistency. The upper 1.7 m of the deposit in Borehole 97-5 has a very soft consistency. The measured natural water content of the samples of this deposit varied from 25 per cent to 34 per cent. Grain size distribution for one sample of the clayey silt and one sample of the silty clay are shown on Figures 1 and 2.

The base of clayey silt / silty clay was encountered at about 26 m depth (Elevation 266.5 m) in Borehole 97-5 and at about 21 m depth (Elevation 267.5 m) in Borehole 97-7.

4.2.5 Lower Sand and Silty Sand

The clayey silt / silty clay deposit in both boreholes is underlain by about 1.7 m to 3 m of silty sand and sand. The sand deposit in Borehole 97-5 is in a compact state of packing. The silty sand in Borehole 97-7 is in a very loose state of packing.

4.2.6 Layer of Cobbles and Boulders

Approximately 2.7 m of cobbles and boulders with sand, gravel and silty clay underlies the silty sand deposit at about 22.5 m depth in Borehole 97-7. The cobbles and boulders were inferred based on auger resistance during drilling with persistent grinding and bouncing of the augers observed during drilling. No samples were recovered of this deposit. The lower about 0.6 m of the deposit was relatively fine and was classified as silty sand with some gravel.

4.2.7 Bedrock

Refusal to auger penetration in Borehole 97-5 put down on the north side of the river was met at 28.9 m depth (about Elevation 263.5 m). The dynamic cone penetration test carried out at the south abutment met abrupt refusal on bedrock/boulders at 25.5 m depth (about Elevation 266.7 m). Refusal to further auger penetration in Borehole 97-7, located some 18 m west of the existing highway centreline, was encountered at 25.3 m depth (about Elevation 263.2 m).

Rock coring was carried out in Borehole 97-5 for a length of 3 m. The Rock Quality Designation (RQD) measured on the core samples range from 80 per cent to 85 per cent. Based on the rock core obtained, the bedrock consists of a Biotite-Hornblende Gneiss.

The MTO Boreholes 1 and 2 (96-1 and 96-2 on the drawing) encountered bedrock at 19.1 m and 19.3 m depth (Elevations 269.4 m and 268.9 m), respectively. Bedrock coring was carried out in these boreholes for lengths of 1.6 m and 2.4 m. The RQD measured on the core samples ranged from 21 per cent to 93 per cent.

Based on the results of the boreholes located to the west and east, the bedrock surface slopes steeply downwards to the west (perpendicular to the road alignment).

4.2.8 Groundwater Conditions

No piezometers were installed in the borehole put down along the Highway 11 northbound bridge. The water levels in the open boreholes varied from 7.6 m to 3.4 m depth (between Elevations 284.9 m to 285.0 m) during drilling operations. It should be noted that the water levels are subject to seasonal and river water level fluctuations.

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides our recommendations on the geotechnical aspects of design of the Highway 11 northbound bridge based on our 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.

The works described in this report are associated with the proposed bridge and its approaches within 20 m of the structure. It is understood that the Highway 11 northbound lanes will be carried over Big East River by a new three span structure about 50 m in length; the existing bridge will be demolished. As shown on the profile drawings (revised), the final road grade will be at about Elevation 293 m on the south side of the crossing and at about Elevation 293.5 m on the north side of the crossing. The proposed horizontal alignment of the new Highway 11 northbound will coincide with the alignment of the existing Highway 11 and the vertical alignment of the new road will be about 1.2 m higher than the existing road.

The proposed horizontal and vertical alignment for Highway 11 and the locations of the bridges were provided to us on 1: 2000 plan drawings and section prepared by Cole, Sherman. Revisions to the vertical alignment have been made and the revised data were received on August 21, 1997.

5.2 Bridge Foundations

The subsoils encountered in the boreholes put down at this site are not suitable for support of shallow spread footings; therefore, deep foundations are recommended for the support of the abutments and the piers. Consideration could be given to the use of closed-end or open-end pipe piles and steel H-piles driven to the bedrock surface which was encountered at about Elevation 263.5 m (Borehole 97-5) on the north side of the river and is probably at the same elevation on the south side of the river. It is considered that the practical refusal encountered in the cone test CT 97 -1 (Elevation 266.7 m) was possibly on bedrock or on the bouldery layer; for design, the bedrock surface on the south side of the river should be taken as Elevation 263.5 m.

Based on the general arrangement plan provided, the base of the pile cap at the abutments will be at about Elevation 289 m, which is at approximately the original ground surface; the base of pile cap at the piers will be at approximately Elevation 283 m. All pile caps should be provided with at least 1.8 m of soil cover for frost protection.

Some 2.7 m thickness of cobbles and boulders directly overlies the bedrock in Borehole 97-7 put down on the south side of the river, approximately 18 m to the west. It is probable that this bouldery layer extends east to the proposed abutment area and therefore, there is a possibility of encountering refusal to pile penetration on this bouldery layer. Steel H-piles would have a better chance of penetrating a cobble/boulder layer. Closed-end pipe piles would be most prone to "hanging up" on the boulders and a reduced pile capacity may have to be used and additional piles installed.

5.2.1 Factored Geotechnical Resistance

The geotechnical resistance at Ultimate Limit States (ULS) for piles driven to practical refusal on the Biotite-Hornblende Gneiss bedrock at this site will be greater than the structural capacity of the piles. In addition, the geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement is not applicable to piles driven to refusal on the bedrock since the stresses required to induce 25 mm of settlement exceed those at ULS.

For this site, therefore, the structural resistance of the piles will govern and the following values may be assumed:

<u>HP 310x110</u>	<u>HP 310x79</u>	<u>324 mm dia. pipe</u>
2800 kN/pile	2000 kN/pile	1900 kN/pile

Where piles "hang up" in the bouldery layer, (anticipated on the south side) an axial capacity at ULS of 1,100 kN and at SLS of 950 kN may be assumed.

The piles should be equipped with suitable rock points to ensure penetration to and seating into the bedrock and other stiffening as appropriate in anticipation of heavy driving through the bouldery layer. Based on the results of the boreholes located to the west and east, the bedrock surface slopes downward to the west and rock points / driving shoes as well as appropriate driving procedures are essential to bite into the bedrock and prevent sliding along the surface.

The H-piles should be driven to an initial set equal to or greater than 10 blows per 12 mm of penetration (unless abrupt peaking occurs) using a hammer with rated energy of about 50 kilojoules but not exceeding 60 kilojoules. On reaching the required set, the hammer energy should be reduced by about 75 per cent and the pile should then be re-driven by increasing the hammer energy slowly up to the maximum rated energy over about 40 blows. This procedure is intended to improve the process of seating of the pile on the sloping bedrock surface.

A final set of no less than 10 blows per 12 mm of penetration should be obtained at the maximum hammer energy. Provision should be made to re-tap all piles to confirm the set after adjacent piles have been driven. The above set criteria should be reviewed at the time of construction in light of the contractor's proposed equipment, so that over-driving and possible damage to the piles is avoided.

The pipe piles should be driven to the same set criteria, with the exception that the hammer should have a rated energy of about 65 kilojoules and not exceed 80 kilojoules.

5.2.2 Resistance to Lateral Loads

The lateral loading could be resisted fully or partially by the use of battered piles. If vertical piles are to resist the lateral loading, the horizontal reaction to the pile can be calculated from the expression:

$$k_s = z \times n_h / d,$$

where

k_s = coefficient of horizontal subgrade reaction (MPa/m)

d = pile diameter (m)

n_h = constant of horizontal subgrade reaction (MPa/m)

z = depth (m)

The constant of horizontal subgrade reaction depends on the soil type and soil density/consistency around the pile shaft. For design of resistance to lateral loads, the values (or range of values) indicated in the tables below may be assumed:

<i>Elevation (m) (approx.)</i>	<i>Soil Type</i>	<i>$z \times n_h$ (MPa)</i>
290.0 to 277.0	Sand and Silt, very loose to loose	$z \times 1.0$
277.0 to 275.0	Clayey Silt / Silty Clay, very soft	0.5 (constant with depth)
275.0 to 267.0	Clayey Silt / Silty Clay, stiff to hard	2.0 to 5.0 (constant with depth)
267.0 to 263.5	Sand, Silty Sand and Cobbles and Boulders, compact	$z \times 4.0$
263.5	Bedrock	-

Group action for lateral loading should be considered when the pile spacing in the direction of loading is less than 6 to 8 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 Direction of Loading d = Pile Diameter</i>	<i>Subgrade Reaction Reduction Factor R</i>
8d	1.00
6d	0.70
4d	0.40
3d	0.25

5.3 Lateral Earth Pressures

The lateral pressures acting on the bridge abutments 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 OHBDC:

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B 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 1.8 m behind the back of the stem (Case I) or within the wedge-shaped zone defined by a 60 degree line extending up and back from the bottom of the rear face of the footing (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 in accordance with OHBDC Figure 6-7.4.3.
- For Case I, the pressures are based on the in-situ soils/embankment fill materials and the following parameters (unfactored) may be assumed:

Soil unit weight (assuming the in-situ soils and/or clean earth fill)	20 kN/m ³
--	----------------------

Coefficients of lateral earth pressure:

'active'	0.33
'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:

	Granular A	Granular B
Soil Unit Weight	22 kN/m ³	21 kN/m ³
Coefficient 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. Other aspects of the abutment granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD-3501.00.

5.4 Excavations

Based on the general arrangement plan provided, the bases of the pile caps at the abutments will be at about Elevation 289 m and at about Elevation 283 m at the piers.

At the abutments, the excavations for the pile cap construction will extend through the embankment fill into the native sand deposit and the base of the excavations for the pile cap construction will be above the groundwater level. Excavations which will be open for relatively short period of time can be made in temporary unsupported cut with side slopes maintained not steeper than 1.5 horizontal to 1 vertical.

At the piers, excavations may extend up to about 2.5 m below the existing river channel base and possibly to about 3.4 m below the river water level as shown to be at Elevation 286.4 m in November 1996. Some form of groundwater control will be required to permit pile installation and pile cap construction in the dry. In general, the sands are sensitive to disturbance and where they form the excavation base or side walls below the groundwater level, the soils undergo rapid loosening due to upward water seepage. Closed steel sheetpiling could be used as a cut-off to groundwater flow and to form temporary support to the excavation. The cut-off wall must extend to sufficient depth below the base of the excavation to minimize piping of the sands forming the base. To provide groundwater cut-off, sheetpiling should be extended into the clayey silt / silty clay stratum below Elevation 276 m on the south side and below Elevation 279 m on the north side. The actual pile depth requirements must be established by the contractor to ensure adequate base stability and overall stability of the sheetpile cofferdam. An undrained shear strength of 50 kPa may be assumed for the clayey silt / silty clay deposit.

Provision for pumping through properly filtered sumps at the base of excavation must be made. Alternatively, the excavation may be made in the wet within closed steel sheetpiling with a tremie plug placed at the base of excavation.

All excavations should be carried out in accordance with the current Occupational Health and Safety Act.

5.5 Approach Embankments

The proposed road grade at the crossing will be about 1.2 m above the existing Highway 11 grade. It was assumed, that the paved width will not change significantly. Based on the subsurface information, the subsoils underlying the approach embankment consist of compact to dense embankment fill underlain by generally a very loose to loose sands and silts overlying firm to hard clayey silt / silty clay.

Given the above, stability of the proposed embankments is not a concern with respect to deep seated failure through the founding soils. There will be only minimal settlement of the embankment due to consolidation of the upper sand and silt deposits and this settlement will occur during embankment construction. As a consequence of the nominal grade raise, long term settlement of the embankments due to consolidation of the 12 m thick clayey silt / silty clay deposit will be minimal.

5.6 Subgrade Preparation and Embankment Construction

Topsoil and organic deposits should be stripped from below the widened areas of the fill embankment and all subgrade soils should be proof-rolled prior to fill placement. The subgrade consists of sand and silty sand.

The proposed Highway 11 Northbound will be wider than the existing Highway 11. The existing approach embankment should be benched in accordance with OPSD 208.01 to ensure that the new fill is keyed into the existing fill and to minimize differential settlement between the new and the existing embankments.

Construction of the embankment above the prepared subgrade may be carried out using clean earth fill (in accordance with OPSS 212) or Select Subgrade Material (in accordance with OPSS 1010), depending on material available. 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. The final lift prior to placement of the granular subbase or base course should be compacted to 100 per cent of the 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. The permanent slopes of the embankment should be maintained not steeper than 2 horizontal to 1 vertical. Vegetation cover should be established on all slopes to protect embankment fill against surficial erosion. Depending on the final layout and configuration of the abutments, some rip-rap placement at the slope toe may be required.

Alternatively, the approach embankments could be constructed using rockfill if available to the project. The permanent side slopes of the rockfill embankments should be maintained not steeper than 1.25 horizontal to 1 vertical.

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LIST OF ABBREVIATIONS

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

I SAMPLE TYPE

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

II PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Penetration Resistance; N_d :

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

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

Piezo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

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

Note:

- Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

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

I GENERAL

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

II STRESS AND STRAIN

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

III SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (con't.)

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

(c) 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

(d) Consolidation (one-dimensional)

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

(e) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_1	sensitivity

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

2. Shear strength = (Compressive strength)/2

PROJECT: 971-8033

RECORD OF BOREHOLE 97-5

SHEET 1 OF 4

LOCATION: N 5026672.113; E 326520.608



BORING DATE: SEPT.5/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	nat V - + rem V - ⊕			Q - ● U - ○	WATER CONTENT, PERCENT Wp — W — Wt
				DEPTH (m)									
0		GROUND SURFACE		292.45 0.00									
1	BOMBARDIER CME-55 HOLLOW STEM AUGERS	Sand and gravel Compact to dense Brown Moist (FILL)		1	50 DO	35			○				
2				50 DO	21								
2			290.25 2.20										
3		3	50 DO	2									
4		4	50 DO	13			○						
5		Sand, fine to medium Very loose to compact Brown Moist	5	50 DO	7								
6			6	50 DO	3		○						
7													
8		-coarse below 7.6m depth			7	50 DO	7						
9			Silt with some sand and little clay Very loose Grey Wet		8	50 DO	2			○			
10													
CONTINUED ON NEXT PAGE													

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-5

SHEET 2 OF 4

LOCATION: N 5026672.113; E 326520.608

BORING DATE: SEPT.5/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	nat V - + rem V - ⊗	q - ● u - ○			WATER CONTENT, PERCENT Wp ——— W ——— Wi 10 20 30 40
				DEPTH (m)									
10	BOMBARDIER CME-55 HOLLOW STEM AUGERS	CONTINUED FROM PREVIOUS PAGE											
11		Silt with some sand and little clay Very loose Grey Wet		9	50 DO	2							
12			280.45 12.00										
13		Clayey Silt, trace sand Soft Grey Wet		10	50 DO	4				○	MH		
14			278.43 14.02										
15		Silty Clay, trace sand Very soft to soft Grey Wet		11	50 DO	WH				○			
16			275.99 16.46										
17													
18		Silty Clay with trace sand Stiff to hard Grey Wet		12	50 DO	10				○			
19													
20		CONTINUED ON NEXT PAGE											

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-5

SHEET 3 OF 4

LOCATION: N 5026672.113; E 326520.608

BORING DATE: SEPT.5/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT, PERCENT Wp — W — Wt			
												nat V - + Q - ● rem V - ⊕ U - ○
20	BOMBARDIER CME-55 HOLLOW STEM AUGERS	CONTINUED FROM PREVIOUS PAGE										
21												
22		Silty Clay with trace sand Stiff to hard Grey Wet		13	50 DO	17					MH	
23												
24												
25												
26			266.55 25.90	14	50 DO	53						
27		Sand, coarse with trace of gravel Compact Grey Wet										
28												
29		AUGER REFUSAL ON BEDROCK BOREHOLE CONTINUED For bedrock coring description refer to sheet 4.	263.60 28.85	15	50 DO	18						
30	CONTINUED ON NEXT PAGE											

NOTE:
Water level in
open borehole at
7.6m depth on
completion of
drilling.

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF DRILLHOLE: 97-5

SHEET 4 OF 4

LOCATION: N 5026672.113; E 326520.608

DRILLING DATE: SEPT.5/97

DATUM: GEODETIC

INCLINATION: AZIMUTH:

DRILL RIG: BOMBARDIER CME-55

DRILLING CONTRACTOR: MARATHON DRILLING



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH % RETURN	FR-FRACTURE CL-CLEAVAGE SH-SHEAR VN-VEIN	F-FAULT J-JOINT P-POLISHED S-SUCKENSIDED	SM-SMOOTH R-ROUGH ST-STEPPED PL-PLANAR	FL-FLEXURED UE-UNEVEN W-WAVY C-CURVED	BC-BROKEN CORE MB-MECH. BREAK B-BEDDING	DIAMETRAL CORRECT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
28		CONTINUED FROM PREVIOUS PAGE												
29	NQ CORING SEPT.5/97	BIOTITE-HORNBLLENDE GNEISS, cystalline, light grey, medium grained. (Bedrock)		263.59 28.86	1									
30														
31														
32		END OF DRILLHOLE		260.50 31.95										
33														
34														
35														
36														
37														
38														

DEPTH SCALE:

1 to 50

Golder Associates

LOGGED: MSB

DATE:

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-6

SHEET 1 OF 1

LOCATION: N 5026589.788; E 326538.239

BORING DATE: AUG.26/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, K, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT	
								Cu, kPa	nat V - + Q - ● rem V - ⊕ U - ○			Wp	W
0		GROUND SURFACE		288.41 0.00									
1	BOMBARDIER CME-55 HOLLOW STEM AUGERS	Sand, fine with some silt Very loose to loose Brown to grey Moist, becoming wet at 3.0m depth -trace organics noted to approx. 0.6m depth -becoming coarse at 4.6m depth		1	50 DO	2							
2				50 DO	4								
3				50 DO	4								
4				50 DO	2								
5				50 DO	1								
6				50 DO	4								
5		END OF BOREHOLE		283.23 5.18									
6													
7													
8													
9													
10													

NOTE:
Water level in
open borehole at
3.1m depth on
completion of
drilling.

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-7

SHEET 1 OF 3

LOCATION: N 5026615.518; E 326524.276

BORING DATE: AUG.27/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLAT ELEV. DEPTH (m)	NUMBER TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT, PERCENT Wp W Wl				
0		GROUND SURFACE	286.45 0.00	1 50 DO	1						
1		Sand, fine to medium with trace to some silt Very loose to loose Brown Moist to wet		2 50 DO	2						
2			3 50 DO	1							
3			4 50 DO	2							
4			5 50 DO	4							
5			6 50 DO	1							
6		-becoming coarse with trace gravel below 6m depth		7 50 DO	4						
7											
8		Silty Sand with trace clay and thin sand seams Very loose Dark greenish grey to grey Wet -trace organics noted to 8.5m depth	280.83 7.62	8 50 DO	2						
9			9 50 DO	2							
10			278.55 8.90								
CONTINUED ON NEXT PAGE											

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-7

SHEET 2 OF 3

LOCATION: N 5026615.518; E 326524.276

BORING DATE: AUG.27/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	nat V - + Q - ● rem V - ⊕ U - ○	WATER CONTENT, PERCENT Wp ----- W ----- Wt 10 20 30 40		
				DEPTH (m)								
10	BOMBARDIER CME-35 HOLLOW STEM AUGERS	CONTINUED FROM PREVIOUS PAGE										
11		Silt with trace clay and thin sand seams Very loose Dark greenish grey to grey Wet		10	50 DO	3						
12												
13												
14		Clayey Silt, trace sand Stiff Grey Wet		11	50 DO	WH						
15												
16			275.35 13.10									
17		Silty Clay with trace sand Firm to stiff Brown to grey Wet		12	50 DO	9						
18												
19				273.65 14.80								
20					13	50 DO	7					
									</			

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF BOREHOLE 97-7

SHEET 3 OF 3

LOCATION: N 5026615.518; E 326524.276

BORING DATE: AUG.27/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	nat V - + Q - ● rem V - ⊕ U - ○	WATER CONTENT, PERCENT Wp — W — Wi		
				DEPTH (m)								
20	BOMBARDIER CME-55 HOLLOW STEM AUGERS	CONTINUED FROM PREVIOUS PAGE										
				267.55	16	50 DO	9					
21				20.90								
		Silty Sand Very loose Grey Wet			17	50 DO	2					
22				265.89								
				22.58								
23		Cobbles and Boulders with some sand, gravel and silty clay (inferred from resistance to augering and observations of auger cuttings during drilling operations).			18	50 DO	28/ 12					
24												
25		-predominantly silty sand with some gravel below 24.7 depth			19	AS						
				263.15								
				25.30								
26		END OF BOREHOLE Refusal to augering Probably on bedrock										
27												
28												
29												
30												

NOTE:
Water level in
open borehole at
3.4m depth on
completion of
drilling.

NOTE:
Water level in
open borehole at
3.4m depth on
completion of
drilling.

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MSB

CHECKED: DC

PROJECT: 971-8033

RECORD OF CONE TEST CT97-1

SHEET 1 OF 3

LOCATION: N 5026615.981; E 326539.921

BORING DATE: SEPT.4/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER TYPE	BLOWS/0.3m	30 60 90 120	SHEAR STRENGTH Cu, kPa	WATER CONTENT, PERCENT Wp W Wi			
0		GROUND SURFACE	292.14 0.00								
1		For soil stratigraphy refer to Borehole 97-7.									
2											
3											
4											
5											
6											
7											
8											
9											
10											

CONTINUED ON NEXT PAGE

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MB

CHECKED: AMP

PROJECT: 971-8033

RECORD OF CONE TEST CT97-1

SHEET 2 OF 3

LOCATION: N 5026615.981; E 326539.921

BORING DATE: SEPT.4/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, K, cm/s		ADDITIONAL LAB TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH				WATER CONTENT, PERCENT	
								Cu, kPa	nat V - + Q - ● rem V - ⊗ U - ○			Wp	W
10	BOMBARDIER CMES55	CONTINUED FROM PREVIOUS PAGE											
11													
12													
13													
14													
15													
16													
17													
18													
19													
20			CONTINUED ON NEXT PAGE										

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MB

CHECKED: AMP

PROJECT: 971-8033

RECORD OF CONE TEST CT97-1

SHEET 3 OF 3

LOCATION: N 5026615.981; E 326539.921

BORING DATE: SEPT. 4/97

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE		SAMPLES		DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m		HYDRAULIC CONDUCTIVITY, k, cm/s		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLLOT ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH		WATER CONTENT, PERCENT			
							nat V - + Q - ● Cu, kPa rem V - ⊕ U - ○	Wp — W — Wi 10 20 30 40				
20	BOMBARDIER CME-55	CONTINUED FROM PREVIOUS PAGE										
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

DEPTH SCALE

1 to 50

Golder Associates

LOGGED: MB

CHECKED: AMP

FIGURE . 1

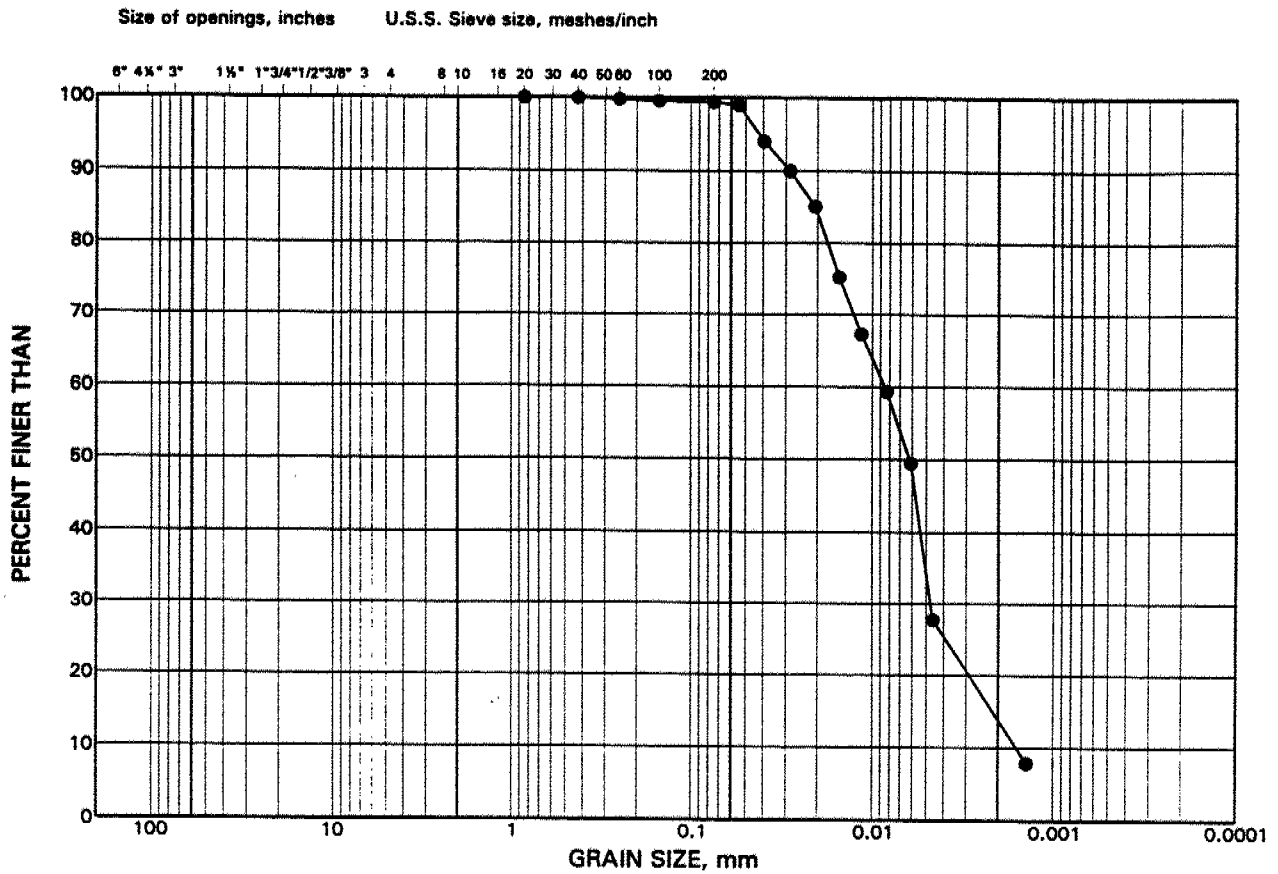


SYMBOL	BOREHOLE	SAMPLE ELEVATION(m)
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
13	13	13
14	14	14
15	15	15
16	16	16
17	17	17
18	18	18
19	19	19
20	20	20
21	21	21
22	22	22
23	23	23
24	24	24
25	25	25
26	26	26
27	27	27
28	28	28
29	29	29
30	30	30
31	31	31
32	32	32
33	33	33
34	34	34
35	35	35
36	36	36
37	37	37
38	38	38
39	39	39
40	40	40
41	41	41
42	42	42
43	43	43
44	44	44
45	45	45
46	46	46
47	47	47
48	48	48
49	49	49
50	50	50
51	51	51
52	52	52
53	53	53
54	54	54
55	55	55
56	56	56
57	57	57
58	58	58
59	59	59
60	60	60
61	61	61
62	62	62
63	63	63
64	64	64
65	65	65
66	66	66
67	67	67
68	68	68
69	69	69
70	70	70
71	71	71
72	72	72
73	73	73
74	74	74
75	75	75
76	76	76
77	77	77
78	78	78
79	79	79
80	80	80
81	81	81
82	82	82
83	83	83
84	84	84
85	85	85
86	86	86
87	87	87
88	88	88
89	89	89
90	90	90
91	91	91
92	92	92
93	93	93
94	94	94
95	95	95
96	96	96
97	97	97
98	98	98
99	99	99
100	100	100

●	97-5	10	280.2
---	------	----	-------

GRAIN SIZE DISTRIBUTION SILTY CLAY

FIGURE 2



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

LEGEND

SYMBOL BOREHOLE SAMPLE ELEVATION(m)

• 97-5 13 270.9

December 22, 1997

971-8033-4

APPENDIX A

**RECORD OF BOREHOLE SHEETS
MINISTRY OF TRANSPORTATION
W.P. 207-93-01**

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 207-93-01 LOCATION Co-ords.: N 5 026 632.4; E 326 556.4 ORIGINATED BY LV
 DIST 32 HWY 11 BOREHOLE TYPE Hollow Stem Auger, BX Core, Cone Test COMPILED BY KA
 DATUM Geodetic DATE 1996 08 08.09 CHECKED BY TC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
288.5	Ground Surface													
0.0	Silty Sand to Sand Very Loose to Loose Brown, Moist to Wet		1	SS	2		288							0 84 14 2
			2	SS	4		286							0 90 (10)
			3	SS	6		284							0 98 (2)
			4	SS	7		282							
			5	SS	5		280							
			6	SS	2		278							
			7	SS	3		276							
			8	SS	2		274							
281.3	Silt, with a trace of Clay Soft to Stiff Grey, Wet		9	SS	2		272							
7.2			10	SS	10		270							
			11	SS	11		268							
			12	SS	11									
275.3	Silt to Coarse Sand trace Gravel Loose to Very Dense Grey, Wet		13	SS	6									0 11 85 4
13.2			14	SS	54									
			15	SS	88									
			16	RC	REC									ROD %
269.4	Biotite-Hornblende Gneiss Bedrock		17	RC	REC									ROD 21%
19.1			18	RC	REC									ROD 24%
			19	RC	REC									ROD 76%
			20	RC	REC									ROD 48%
267.0	End of Borehole													
21.5														

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 207-93-01 LOCATION Co-ords.: N 5 026 673.8; E 326 535.0 ORIGINATED BY LV
 DIST 52 HWY 11 BOREHOLE TYPE Hollow Stem Auger, BX Core, Cone Test COMPILED BY KA
 DATUM Geodetic DATE 1996 08 07 CHECKED BY TC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT 7 KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N* VALUES			20 40 60 80 100	20 40 60 80 100					
288.2	Ground Surface						288							
0.0	Silty Sand to Sand Very Loose to Compact Brown, Moist to Wet		1	SS	5		288							
			2	SS	10		286							0 82 16 2
			3	SS	9		284							0 95 (5)
			4	SS	3		282							
283.8			5	SS	2		280							
4.4	Silt with a trace of Clay Soft to Very Stiff Grey, Wet		6	SS	2		278							
			7	SS	2		276							
			8	SS	5		274							
			9	SS	2		272							
			10	SS	3		270							
			11	SS	12		268							
			12	SS	11									
			13	SS	12									
			14	SS	19									
272.0			15	SS	0									
16.2	Silt, some sand, Tr. Clay Trace Gravel Compact, Grey, Wet		16	SS	16									0 8 86 6
268.9			17	RC	REC	96%								ROD 93%
19.3	Biotite-Hornblende Gneiss Bedrock													
267.3														
20.9	End of Borehole													

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4

Sand

A deposit of sand was encountered beneath the sand and gravel/cobbles at boreholes 1 and 2 at depths of 2.3 to 3.6 m (elevation 282.9 to 283.5). The layer was 400 to 900 mm thick and was fully penetrated at depths of 3.3 to 4.0 m (elevation 282.5 to 282.6).

The material comprised brown fine to medium or fine to coarse sand, trace gravel, trace silt. The sand was loose to compact based on standard penetration resistance "N" values of 5 to 12 blows/0.3 m. The material was wet with a moisture contents of 22 to 30%.

At borehole 3, located at the top of bank, a major sand stratum was contacted at ground surface (elevation 288.4). The unit was fully penetrated at 6.3 m depth (elevation 282.1). The material comprised brown fine sand, trace to some silt and contained occasional layers of sandy silt and pieces of wood. The sand was loose, based on "N" values of 4 to 6 blows/0.3 m. The material was moist becoming wet below 3.6 m depth. Moisture contents were variable ranging from 5 to 38%.

Silt/Sand and Silt

A deposit of silt/sand and silt was contacted beneath the sand stratum in each borehole at elevation 282.2 to 282.5 about 3.3 to 6.3 m depth. The unit was 1.1 to 1.9 m thick and was fully penetrated at depths of 5.1 to 7.8 m (elevation 280.6 to 281.4).

The material comprised grey silt, trace to some fine sand ranging to fine sand and silt and locally contained layers of fine sand and thin black organic seams. The material was wet and dilatant with water contents of 24 to 34%.

The relative density was variable ranging from loose ("N" values of 4 at borehole 3), to compact ("N" values of 11 at borehole 1) to compact to dense ("N" values of 27 and 34 at borehole 2).

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5

Silt/Organic Silt

A deposit of silt/organic silt was contacted beneath the silt/sand and silt stratum in each borehole at depths of 5.2 to 7.8 m (elevation 280.6 to 281.4). The layer was 2.3 to 3.4 m thick and was fully penetrated at depths of 7.5 to 10.1 m (elevation 277.3 to 279.0).

The material was typically dark grey to black with olive green layers and comprised organic silt or silt with organic seams and shell fragments. Locally, the unit included layers of dark grey silt, trace fine sand, stratified with thin black organic seams.

The silt/organic silt was ~~very loose to loose~~ based on standard penetration resistance values of 2 to 6 blows/0.3 m. Moisture contents ranged from 38 to 67%.

Silt

A deposit of silt was encountered beneath the silt/organic silt stratum in each borehole at depths of 7.5 to 10.1 m (elevation 277.3 to 279.0). Each of the boreholes terminated within this deposit at depths of 9.6 to 12.7 m (elevation 273.3 to 276.9).

This deposit comprised grey silt with trace to some clay and contained seams of sandy silt or sand. The silt was ~~very loose to loose~~ based on standard penetration resistance "N" values of 2 blows/450 mm to 8 blows/0.3 m. The material was wet with water contents of 27 to 31%.

Groundwater

Upon completion of augering, free water was observed in borehole 3 at 2.7 m depth (elevation 285.7). Boreholes 1 and 2 were drilled within the river, which was at elevation 285.43 at the time of the fieldwork. Seasonal fluctuations in both groundwater and river levels should be anticipated.

LIST OF ABBREVIATIONS

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N'. - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 0.3m INTO THE SUBSOIL. DRIVEN BY MEANS OF A 63.5kg HAMMER FALLING FREELY A DISTANCE OF 0.76m.

DYNAMIC PENETRATION RESISTANCE: - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 51mm, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS. 0.3m INTO THE SUBSOIL. THE DRIVING ENERGY BEING 475J PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS:-

<u>CONSISTENCY</u>	<u>'N' BLOWS/0.3m</u>	<u>ckPa</u>	<u>DENSENESS</u>	<u>'N' BLOWS/0.3m</u>
VERY SOFT	0 - 2	0 - 12	VERY LOOSE	0 - 4
SOFT	2 - 4	12 - 25	LOOSE	4 - 10
FIRM	4 - 8	25 - 50	COMPACT	10 - 30
STIFF	8 - 15	50 - 100	DENSE	30 - 50
VERY STIFF	15 - 30	100 - 200	VERY DENSE	> 50
HARD	> 30	> 200		

W.T.P.L. WETTER THAN PLASTIC LIMIT

D.T.P.L. DRIER THAN PLASTIC LIMIT

A.P.L. ABOUT PLASTIC LIMIT

TYPE OF SAMPLE

S.S. SPLIT SPOON	T.W. THINWALL OPEN
W.S. WASHED SAMPLE	T.P. THINWALL PISTON
S.B. SCRAPER BUCKET SAMPLE	O.S. OESTERBERG SAMPLE
A.S. AUGER SAMPLE	F.S. FOIL SAMPLE
C.S. CHUNK SAMPLE	R.C. ROCK CORE
S.T. SLOTTED TUBE SAMPLE	
P.H. SAMPLE ADVANCED HYDRAULICALLY .	
P.M. SAMPLE ADVANCED MANUALLY	

SOIL TESTS

Qu UNCONFINED COMPRESSION	L.V. LABORATORY VANE
Q UNDRAINED TRIAXIAL	F.V. FIELD VANE
Qcu CONSOLIDATED UNDRAINED TRIAXIAL	C CONSOLIDATION
Qd DRAINED TRIAXIAL	

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LOG OF BOREHOLE NO. 1

PROJECT Highway 11 South Bound Crossing Big East River

OUR PROJECT NO. 99 BF 016

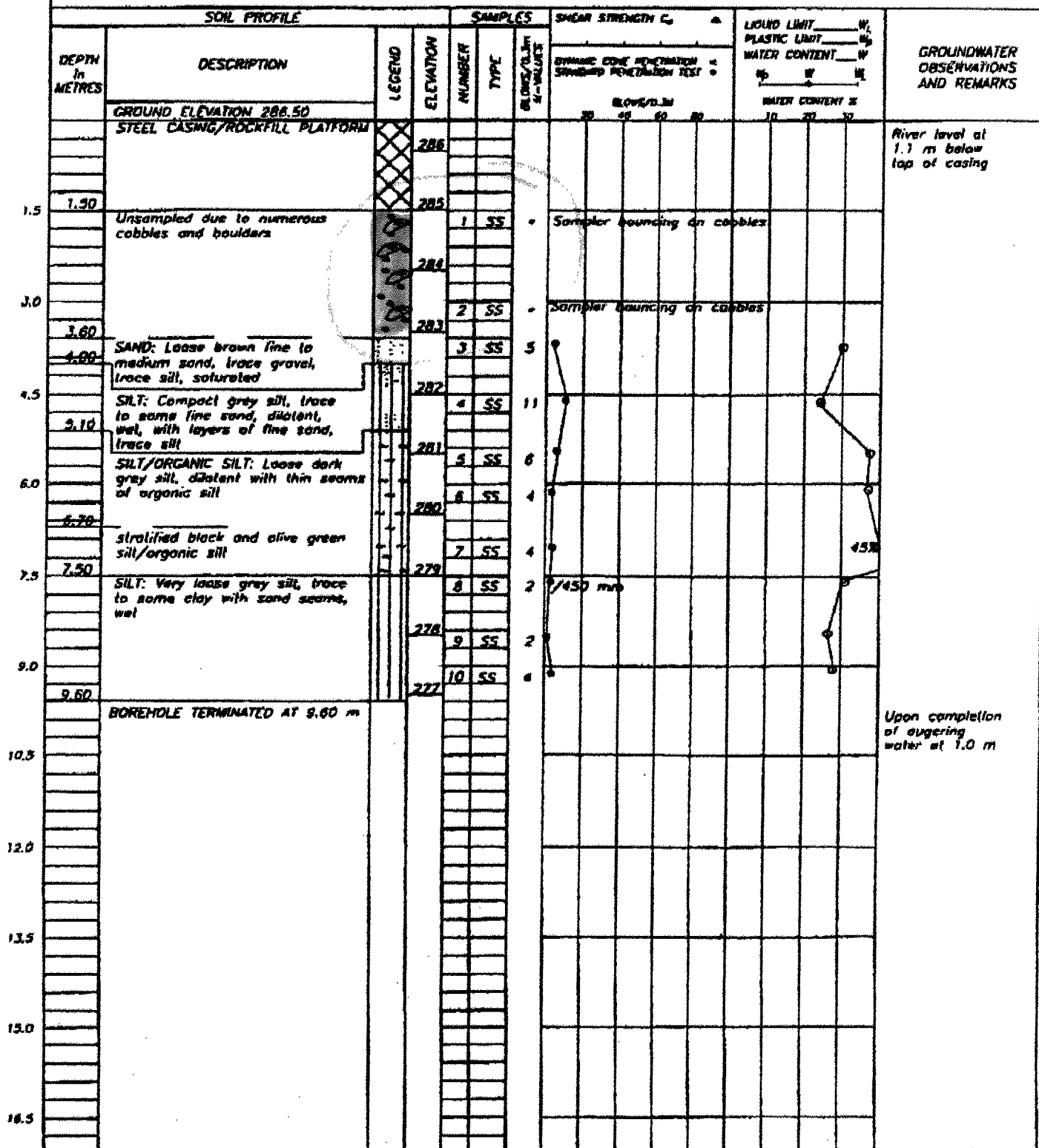
LOCATION Huntsville, Ontario

ENGINEER TLB

BORING METHOD Wash Boring NW Casing

BORING DATE April 22, 1999

TECHNICIAN JFW



NOTES

- 1) Excavated existing rip rap to native subgrade.
- 2) Set 300 mm diameter steel casing and backfill with rip rap.
- 3) Located in line with south wall, 2.4 m east of east wall.

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LOG OF CONE TEST NO. 1A

PROJECT Highway 11 South Bound Crossing Big East River

OUR PROJECT NO. 99 BF 018

LOCATION Huntsville, Ontario

ENGINEER TLB

BORING METHOD Dynamic Cone Penetration Test

BORING DATE April 22, 1999

TECHNICIAN

JFW

[illegible]

NOTES

- 1) Cone driven within previously excavated cell.
- 2) Located 1.2 m south of north wall, 0.4 m west of east wall.

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CONSULTING ENGINEERS

LOG OF CONE TEST NO. 1B

PROJECT Highway 11 South Bound Crossing Big East River

OUR PROJECT NO. 99 BF 016

LOCATION Huntsville, Ontario

ENGINEER TLB

BORING METHOD Dynamic cone Penetration Test

BORING DATE April 22, 1999

TECHNICIAN JFW

SOIL PROFILE			SAMPLES				SHEAR STRENGTH C_u				LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			GROUNDWATER OBSERVATIONS AND REMARKS
DEPTH in METRES	DESCRIPTION	LEGEND	ELEVATION	NUMBER	TYPE	BLOW/CLM N-VALUES	DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST				WATER CONTENT W			
							BLOW/CLM				WATER CONTENT W			
	GROUND ELEVATION 286.50						20	40	60	80	10	20	30	Water level at 1.05 m below top of sheet pile
	AIR		288											
1.05	WATER		285											
			284											
1.5														
			283											
3.0			282											
4.5														
5.28	START OF CONE TEST		281											
6.0			280											
			279											
7.5			278											
			277											
9.0			276											
10.5			275											
11.90		END OF CONE TEST												
12.0														
13.5														
15.0														
16.5														

NOTES

- 1) Cone driven within previously excavated cell.
- 2) Located 0.3 m south of north wall, 0.5 m west of east wall.

Peto MacCallum Ltd.

CONSULTING ENGINEERS

LOG OF BOREHOLE NO. 2

PROJECT Highway 11 South Bound Crossing Big East River

OUR PROJECT NO. 99 BF 016

LOCATION Huntsville, Ontario

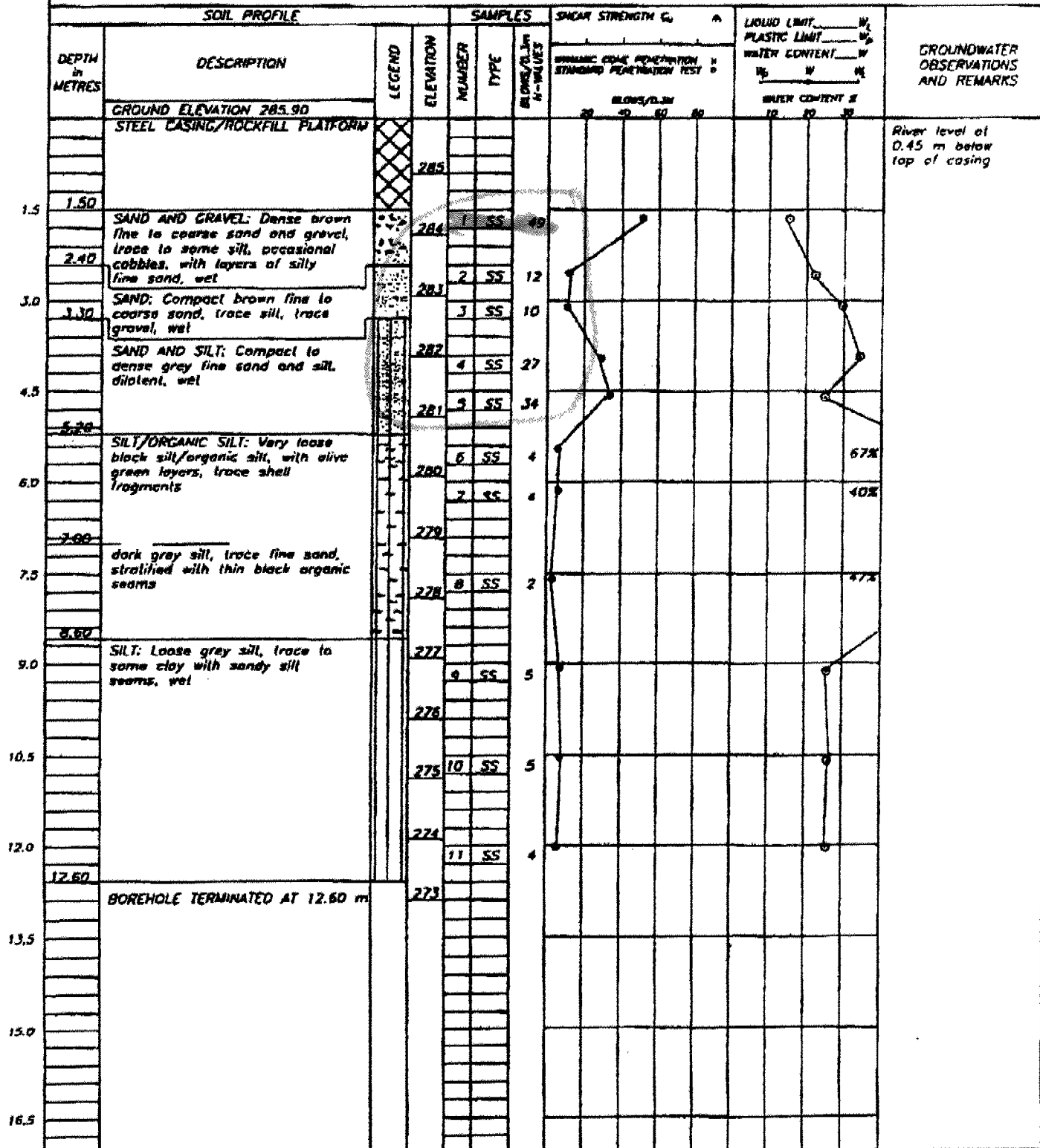
ENGINEER TLB

BORING METHOD Continuous Flight Hollow Stem Augers

BORING DATE April 23, 1999

TECHNICIAN

JFW



NOTES

- 1) Excavated existing rip rap to native subgrade.
- 2) Set 300 mm diameter steel casing and backfill with rip rap.
- 3) Located 1.0 m south of north wall, 1.0 m west of west wall.

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CONSULTING ENGINEERS

LOG OF CONE TEST NO. 2A

PROJECT Highway 11 South Bound Crossing Big East River

OUR PROJECT NO. 99 BF 016

LOCATION Huntville, Ontario

ENGINEER TLB

BORING METHOD Dynamic Cone Penetration Test

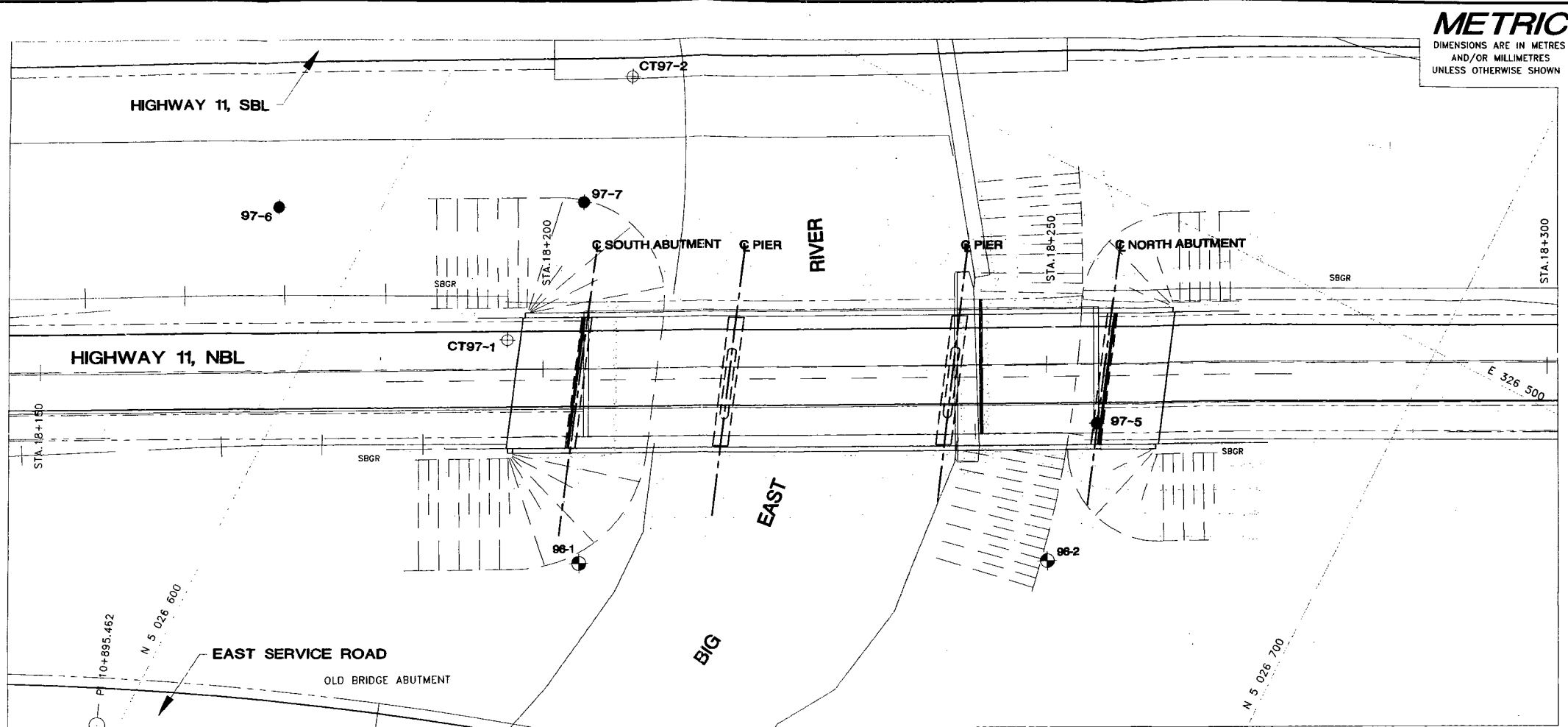
BORING DATE April 22, 1999

TECHNICIAN JFW

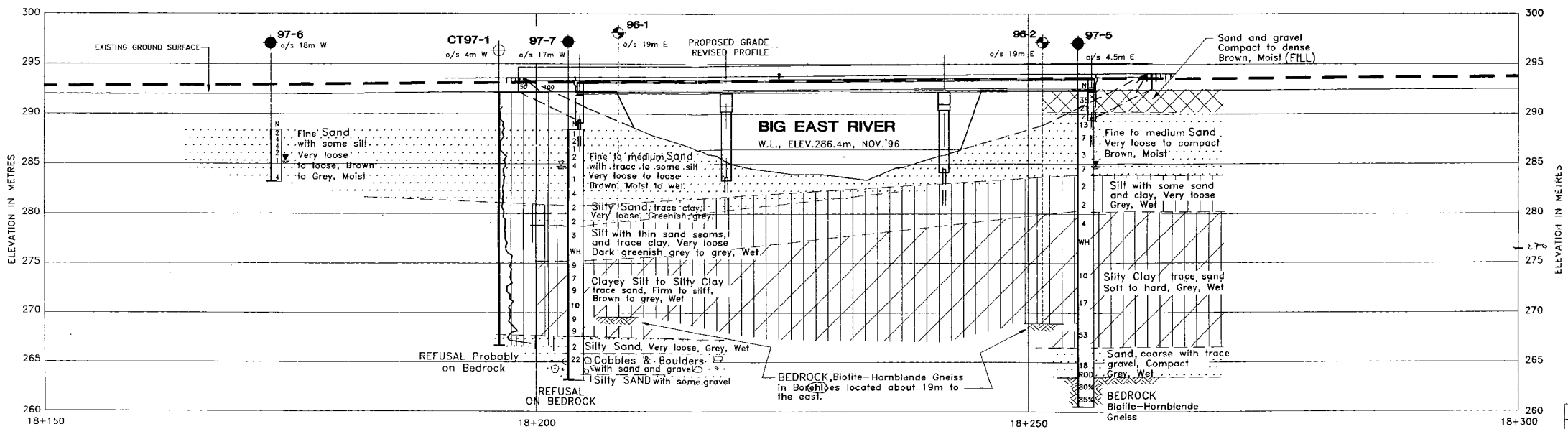
SOIL PROFILE			SAMPLES			SHEAR STRENGTH C_u		LIQUID LIMIT W_L		PLASTIC LIMIT W_P		WATER CONTENT W		GROUNDWATER OBSERVATIONS AND REMARKS
DEPTH in METRES	DESCRIPTION	LEGEND	ELEVATION	NUMBER	TYPE	BLOWES/30 mm N-VALUES	DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST		BLOWES/30 mm		WATER CONTENT W			
	GROUND ELEVATION 285.43													
	WATER		285											
			284											
1.5	1.05		283											
	START OF CONE TEST													
			282											
3.0			281											
			280											
4.5			279											
			278											
6.0			277											
			276											
7.5			275											
9.0														
10.5														
11.10	END OF CONE TEST													
12.0														
13.5														
15.0														
16.5														

NOTES

- 1) Excavated rip rap to native subgrade.
- 2) Set 300 mm diameter steel casing and backfilled with rip rap.
- 3) Located 1.6 m south of north wall, 0.3 m west of west wall.



PLAN
SCALE IN METRES



PROFILE ALONG HIGHWAY 11, NORTH BOUND LANES

SCALE IN METRES

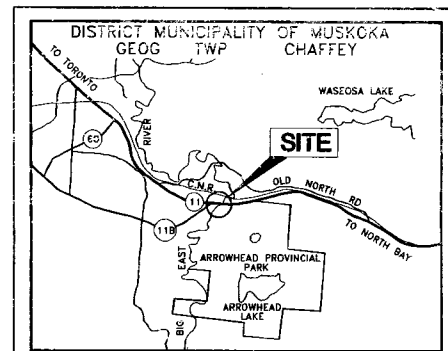
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT. No.
WP No. 454-93-00

HIGHWAY 11 NORTHBOUND LANES
OVER BIG EAST RIVER
BORE HOLE LOCATIONS & SOIL STRATA

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE, km

LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std. Pen. Test, 475 j/blow)
- Cone Blows/0.3m (60' Cone, 475 j/blow)
- WL at time of investigation 1997 08

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
CT97-1	292.14	5026615.98	326539.92
97-5	292.45	5026672.11	326520.61
97-6	288.41	5026589.79	326538.24
97-7	288.45	5026615.52	326524.28
96-1	288.5	5026632.4	326556.4
96-2	288.2	5026673.8	326535.0

NOTES

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

A	97/09/12	AMP	ISSUED FOR REVIEW
NO.	DATE	BY	REVISION

Geocres No.			
HWY. No. 11	PROJECT NO.: 971-8033	DIST. S2	
SUBM'D. AMP	CHKD. ASP	DATE: 1997 08 15	SITE 42-09 N
DRAWN: MHW	CHKD. AMP	APPD.	DWG. M8033002