GEOCRES No:
31B-63

Golder Associates Ltd.
CONSULTING ENGINEERS

REPORT TO

TOTTEN SIMS HUBICKI ASSOCIATES

FOUNDATION INVESTIGATION

PROPOSED SOUTH NATION RIVER OVERPASS

HIGHWAY 416 SOUTH BOUND LANES

W.P. 177-89-~~01~~ 08, SITE 16-189A

DISTRICT 9 (OTTAWA) EASTERN REGION

GEOCRES # 31B-63

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1. INTRODUCTION

Golder Associates Ltd. has been retained by Totten Sims Hubicki Associates, consultants to the Ministry of Transportation Ontario (MTO), to carry out a subsurface investigation at the site of a proposed overpass for the south bound lanes of Highway 416 at the South Nation River (see Key Plan, Figure 1). The purpose of the investigation was to determine the subsurface conditions at the site and, based on the factual information obtained, to provide recommendations on the geotechnical design aspects of this project, including construction considerations which could influence design decisions.

The proposed overpass for the south bound lanes is to be located about 35 to 40 metres south west of the present Highway 16 bridge over the South Nation River. The overpass structure will consist of a three span concrete bridge having a total length of about 52 metres and a width of about 17 metres. The approach embankments will have a maximum height of about 4 metres above existing ground surface.

2. SITE DESCRIPTION AND GEOLOGY

The site is located along the existing Highway 16, east of Spencerville, Ontario.

The proposed bridge site area is low lying, relatively flat and for the most part tree covered. On the north side of the river, an intermittent stream and poorly drained low lying area exist, being part of the flood plain of the South Nation River.

As part of the construction of the existing Highway 16 overpass, the South Nation River channel was realigned to the south. Based on available drawings, the centreline of the former river channel was about 45 metres north of its present position.

Geology maps suggest that this area is underlain by deposits of silty clay of marine origin. Bedrock is expected to consist of Oxford formation dolostone. Drift thickness maps suggest that the overburden thickness may be about 11 metres.

A previous subsurface investigation was carried out for the existing bridge over the South Nation River by MTO in 1967. The results of that work show that this site is underlain by deposits of loose sand extending to about 3 metres below ground surface, followed by successive deposits of very stiff clayey silt and glacial till. Bedrock was encountered in the borings at the existing bridge site at depths of about 10.4 to 11.4 metres below existing ground surface (elevation 76.0 to 76.5 metres)

3. PROCEDURE

The field work for this investigation was carried out between May 18 to 24, and September 10 to 12, 1990. During this time, five (5) boreholes were advanced on land using a track mounted hollow stem auger drill rig and two (2) boreholes were put down over water using a portable electric drill rig operating from a small floating raft. Four of the land boreholes were advanced to practical auger refusal for foundation design purposes, while one shallow borehole was put down about 30 metres north of the north bridge abutment to evaluate the subgrade conditions for the north approach embankment. The overwater borings were taken to a depth of about 3 metres below river level at the approximate locations of the proposed bridge piers. Standard penetration tests were carried out in the boreholes and samples of the soils encountered were recovered using drive open sampling equipment. The groundwater levels at the site were determined by measuring the position of the water level in the open boreholes following the completion of drilling and from standpipes sealed into the completed borings. One sample of groundwater was recovered from borehole 4-3 and was sent to a laboratory for basic chemical testing to evaluate the corrositivity of the groundwater on exposed concrete and unprotected steel. The field work was supervised throughout by members of our engineering staff.

Logs of the soil, and groundwater conditions encountered in the borings put down during this investigation are shown on the Record of Borehole sheets following the text of this report. The locations of the boreholes are given on the Borehole Locations and Soil Strata, Drawing 1778902-A.*

As well, attached in Appendix 1 of this report are copies of the pertinent logs of borings put down in 1967 by MTO. The approximate locations of these borings relative to the existing site conditions are shown on Drawing 1778902-A.*

Samples of the soils encountered were taken to our laboratory for examination and classification testing. Samples of the soil were tested for moisture content, organic content, liquid and plastic limit, and grain size distribution. The results of the laboratory testing are given on the Record of Borehole sheets and on Figures 2 to 5.

The borehole locations and elevations were determined by Totten Sims Hubicki Associates personnel. The elevations are referenced to Geodetic datum.

* Dwg No 2 (Sheet No 228) of the Contract Drawings

4. SUBSURFACE CONDITIONS

4.1 General

The borehole logs indicate the approximate subsurface conditions only at the specific test locations. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of boring, the frequency of sampling, the method of sampling and the uniformity of the subsurface conditions.

Subsurface conditions between the boreholes may vary significantly from conditions encountered at the boreholes.

Groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil involves judgement and Golder Associates Ltd. does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The soil conditions described in this report are those observed at the time of the study. Unless otherwise noted, those conditions form the basis of the recommendations in this report.

The condition of the soil may be significantly altered by construction activities such as construction traffic, excavation, pile driving, etc. Excavation may expose the soils to changes due to wetting, drying, or frost.

As previously indicated, the detailed soil and groundwater conditions determined from the boreholes are given on the Record of Borehole sheets following the text of this report. The following sections present descriptions of the soil and groundwater conditions encountered in the boreholes.

4.2 Topsoil, Alluvium, Fill

Surficial deposits of topsoil having a thickness of 0.2 to 0.3 metres were encountered in boreholes 4-1 and 4-2 advanced on the south side of the river.

On the north side of the river, boreholes 4-3, 4-4 and 4-5 encountered surficial fill deposits composed of silty clay and clayey silt with some gravel and trace amounts of organic matter. The thickness of these fills ranges from about 0.6 to 0.9 metres.

The surficial fills on the north side of the river and the river bottom are underlain by alluvial deposits composed of silty clay, clayey silt, sandy silt, silty sand and sand. Some inorganic fine to coarse sand layers were also encountered within or beneath the alluvium. The thickness of the alluvium deposits was found to be about 3.1 to 3.4 metres north of the river, and about 0.6 to 0.8 metres on the river bottom. Standard penetration tests carried out within the alluvium gave N values ranging from 1 to 17 blows per 0.3 metres (average of 3 blows per 0.3 metres), which reflect, for the most part, a very loose relative density.

The measured organic content of the alluvium ranges from 3.6 to 6.0 percent. The moisture content of these deposits is about 25 to 57 percent.

4.3 Silty Clay, Clayey Silt, Silt

Deposits of silty clay, clayey silt and silt were encountered beneath the surficial topsoil at boreholes 4-1 and 4-2, and beneath the alluvium and sand at boreholes 4-3, 4-4, 4-5, 4-10 and 4-11.

These deposits have a thickness of about 0.3 to 6.2 metres and extend to depths ranging from 4.3 to 9.0 metres below ground surface (elevation 78.1 to 82.9 metres). The results of a grain size distribution analysis carried out on a sample of the clayey silt are given on Figure 3.

Standard penetration testing carried out within these deposits gave N values of 5 to 36 blows per 0.3 metres which indicate that these deposit have either a very stift consistency (silty clay, clayey silt) or are in a loose to compact state of packing (silt).

Atterberg limit tests carried out on samples of the clayey silt gave a liquid limit value of 29 and a plastic limit value of 19, which reflect a low plasticity. A summary of the Atterberg limit results is given on the Plasticity Chart, Figure 2. The moisture content of the silty clay is about 32 percent. For the clayey silt, the moisture content is generally near the plastic limit, ranging from about 18 to 20 percent.

4.4 Sand

Deposits of sand were encountered beneath the upper deposits of brown to grey brown silty clay and clayey silt at boreholes 4-1 and 4-2 and within and/or beneath the alluvial deposits encountered in boreholes 4-3 and 4-5. The thickness of the sand deposit ranges from 0.3 to 1.3 metres. One grain size distribution curve for a sample of the sand obtained from borehole 4-1 is given on Figure 4.

Standard penetration testing carried out within the sand gave N values ranging from 1 to 7 blows per 0.3 metres, which reflect a very loose to loose relative density.

The moisture content of the sand ranges from 22 to 25 percent.

4.5 Glacial Till

Deposits of glacial till were encountered beneath the clayey silt and silt deposits. The glacial till deposits have a thickness of at least 2.3 to 4.9 metres.

The glacial till consists of a heterogeneous mixture of all grain sizes but may be generally described as a sandy silt with gravel, clay, cobbles and boulders. The results of grain size distribution tests carried out on samples of the glacial till are given on Figure 5. It should be noted that the gradation tests were carried out on 38 millimetre I.D. split barrel samples and so do not reflect the presence of cobbles or boulders within the glacial till.

Standard penetration tests carried out within the glacial till gave N values of 5 to greater than 100 blows per 0.3 metres, which reflect a somewhat variable, loose to very dense relative density.

The moisture content of the glacial till ranges from about 9 to 10 percent.

4.6 Auger Refusal

Practical auger refusal was encountered at depths ranging from 10.6 to 12.2 metres below ground surface (elevation 75.1 to 76.7 metres). These results are in general agreement with the bedrock elevation results obtained in previous cored boreholes put down by MTO for the existing Highway 16 bridge. It should be noted however that auger refusal can sometimes be obtained within dense or bouldery material and that it may not necessarily be representative of the upper surface of the bedrock at the refusal locations.

4.7 Groundwater

Groundwater levels were obtained from standpipes sealed in the completed borings and by observing the water level in the open boreholes at the completion of drilling. Details on the standpipe installations and the groundwater information (elevation and time of measurement) are given on the Record of Borehole sheets. The groundwater level in the open boreholes was found to range from 0.2 to 0.5 metres below ground surface (elevation 86.8 to 87.0 metres). The groundwater level measured in standpipes sealed into the lower part of the glacial till was found to range from 0.3 to 0.4 metres above ground surface (elevation 87.4 to 87.5 metres). These results reflect an upward hydraulic gradient (flow) through the overburden.

The results of the chemical analysis on one groundwater sample recovered from the site are as follows:

pH	-	6.98	
Conductivity	-	987	umhos/cm
Sulphate (SO_4)	-	4	mg/L
Chloride (Cl)	-	40	mg/L

These results are also shown on Accutest Laboratories Ltd. report A0-0941 following the text of this report.

5. PROPOSED SOUTH NATION RIVER OVERPASS
(HIGHWAY 416 SOUTH BOUND LANES)

5.1 Bridge Foundations

The proposed three span structure is to be supported on two end abutments and on two piers located in the river channel. It is understood that this structure will be relatively sensitive to post construction differential movement of the foundation; the allowable differential movement is understood to be about 15 millimetres.

Since the existing alluvial deposits encountered on the north side of the river would not be suitable for the support of the structure on conventional spread footings, it is recommended that the structure be founded on driven end bearing piles. Based on the auger refusal information and previous bedrock core information, the piles may be expected to terminate at between about elevation 75.1 to 76.7 (average of 76.0 metres at four borehole locations), provided that large boulders are not encountered by the piles during driving within the glacial till.

As a design example, the Serviceability Limit State (SLS) load for a 245 millimetre diameter closed ended steel pipe pile having a wall thickness of 12 millimetres may be taken as 1150 kilonewtons; the factored capacity at Ultimate Limit State (ULS) can be taken as 1350 kilonewtons. These values assume that 350 megapascal strength steel and 30 megapascal concrete are used. The pipe piles should be set to a final termination of 10 blows for the last 12 millimetres of penetration using a hammer transferring about 40 kilojoules of energy per blow.

Alternatively, for an HP 310x110 steel H pile, the SLS and ULS loads could be taken as 1150 and 1600 kilonewtons, respectively. In this case, the H-piles should be set to a termination of 10 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Based on piling experience in this area, it is possible that several rounds of restriking could be required to achieve permanence of the final set. Therefore, provision should be made for restriking all of the piles at least once to confirm the set. Piles that do not meet the design set criteria on the first or subsequent restrike would require additional restriking. A minimum of two days should be allowed before restriking a pile.

Since the glacial till contains boulders, some pile alignment and driving difficulties should be expected; some of the piles may be driven off plumb, or bend, or may terminate erratically in the glacial till. In this regard, pipe piles offer some advantage over H-piles since they can be inspected for damage following installation and can be checked for plumbness and curvature. Steel H-piles should be equipped with cast steel driving shoes to reduce pile damage during driving; for closed ended steel pipe piles, the need for a driving shoe could be assessed following the driving and inspection of the first few piles.

Allowance should be made for pile load testing at the time of construction.

For snow cleared or covered areas such as the abutments, the pile caps should be provided with at least 1.8 metres of earth cover for frost protection purposes. The river channel piers could be provided with at least 1.2 metres of earth cover (including rip rap) or should be positioned to provide at least 0.3 metres of rip rap over the pile caps. However if the river is expected to freeze throughout its depth at the pier locations, the earth cover for the river channel piers should be increased to at least 1.5 metres.

5.2 Abutment Wall Backfill and Earth Pressures

The abutments should be backfilled with compacted non frost susceptible, free draining backfill such as that meeting Ontario Provincial Standard Specifications (OPSS) for Granular B Type I or II. The granular fill should extend at least 1.5 metres beyond the inside face of the abutments and should be compacted in thin lifts to at least 95 percent of standard Proctor density. If lateral movement at the top of the abutment of about 0.05 percent of the retained height is expected to occur, "active" earth pressure coefficients (Ka) should be used in determining the horizontal load on the abutments. If the wall movement is expected to be less, then "at rest" pressure coefficients (Ko) should be used.

Assuming that a well graded sand and gravel backfill material meeting OPSS Granular B Type I material is used behind the abutments, a material unit weight of 21.2 kilonewtons per cubic metre could be used together with the following earth pressure coefficients in determining the lateral load on the abutments.

	Earth Pressure Coefficient
At Ultimate Limit State (ULS)	
"at rest" condition	0.55
"active" condition	0.38
At Serviceability Limit State (SLS)	
"at rest" condition	0.47
"active" condition	0.31

Earth pressure parameters for other materials could be provided if necessary.

To reduce compaction induced stress on the abutment walls, the granular fill near the abutments should be compacted with walk behind compaction equipment.

Highway live loads should be considered on the abutments unless approach slabs are used.

5.3 Embankment Stability and Settlement

The approach embankments within 30 metres of the bridge will have a maximum height of about 4 metres above existing ground surface.

Initial calculations indicate that no short term or long term stability problems are expected for the embankments within 30 metres of the abutments. Embankment fill should meet the requirements of OPSS 212 for borrow material, and should be placed and compacted in accordance with OPSS 206. If sandy earth borrow, rock borrow, or select subgrade material is used, embankment side slopes may be constructed at 2 horizontal to 1 vertical. If silty or clayey earth borrow is used, embankment side slopes should be 2.5 horizontal to 1 vertical or flatter. Erosion protection of the side slopes using seeding or mulching should be carried out to reduce surficial erosion and gullying.

At boreholes 4-1 and 4-2 on the south side of the river, thin surficial deposits of topsoil followed by deposits of sand and very stiff silty clay or clayey silt were encountered. Provided that all surficial topsoil or disturbed soil are removed from the proposed south approach fill area, the long term settlement of the south approach embankment should be minimal.

The north approach embankment area near the proposed bridge however was found to be underlain by silty clay fill followed by very loose to loose alluvium. The alluvium has a thickness of about 3.1 to 3.4 metres and has an organic content of about 3.6 to 6.0 percent. If the alluvial deposits are left in place, it is expected that the north approach embankment will settle for some time after construction. To reduce the effects of post construction settlement of the north approach embankment near the rigidly supported bridge, the north embankment could be constructed a few months in advance of the bridge construction and an appproach slab could be used for the bridge. Prior to placing the embankment and fill materials, the subgrade area should be inspected and any surface peat, highly organic, or disturbed materials should be removed. Settlement monitoring should be carried out during and after construction of the embankment to ensure that most of the settlement has occurred prior to the bridge construction.

The banks and bottom of the river near the pile supported abutment and piers should be protected from erosion by means of rip rap underlain by a suitable non woven geotextile.

5.4 Corrosion of Buried Structures

As previously indicated, the sulphate content of the groundwater at this site was found to be 4 milligrams per litre. According to CSA CAN 3 A23.1-M90, this measured level of sulphate should not be corrosive to concrete where normal Portland Type 10 cement is used.

Based on the elevated conductivity and low pH value of the groundwater, this site can be classified as slightly aggressive toward unprotected steel. Corrosion of driven piles in the native homogenous and undisturbed soil below the groundwater level is not expected to be a problem. However, the potential exists at this site for corrosion of the driven piles along that portion of the pile within the perched abutment fill, at the interface of the abutment fill and the native subsoil, and within the groundwater fluctuation zone. To reduce this corrosion potential, it is suggested that all piles at this site be provided with a bituminous coating (such as Bakelite 700-1) and that the pile cap be designed such that the steel pile is electrically isolated from the remainder of the bridge structure i.e. no steel to steel contact with the piles in the pile cap.

5.5 Construction Considerations

Pile driving and excavation for the proposed bridge piers will be carried out within the existing river channel. Sandy silt alluvial deposits were encountered below river bottom level in the boreholes at the pier locations. As such, excavation and construction of the river channel piers should be carried out within driven interlocking sheet piling advanced to within the underlaying clayey silt. Alternatively and provided space permits, the existing alluvial deposits could be dredged and/or excavated to expose the underlying clayey silt and an earth cofferdam cell could be constructed over the exposed clayey silt subgrade using suitable compacted earth materials. A working mat of concrete or crushed stone would likely be required in the pile driving area. Water inflow should be controlled by pumping from within the excavation.

It is recommended that the pile driving equipment proposed by the contractor be reviewed in light of the contract pile type and set criteria and be accepted by the geotechnical engineer well in advance of any pile driving operations. Also, all piling operations should be inspected throughout by qualified geotechnical personnel.

Groundwater and surface water control may be required while placing and compacting the lower lifts of fill for the embankments. The intermittent stream on the north side of the river should be diverted and any loose or soft areas in the embankment area may have to be firmed up with coarse crushed rock material. To facilitate pile driving and to limit disturbance of the bituminous coating on the piles, the embankment fill material beneath the abutments should consist of pit run sand, free of gravel, cobble or boulder size material.

The soils at this site are highly susceptible to frost heaving. Therefore, the native soils around the piles should be protected from freezing during construction to prevent pile jacking due to freeze effects.

If welded pile splices are to be used, a licensed welding inspector should be retained during the pile driving to periodically inspect the welding procedures used by the contractor.

We trust that this report contains sufficient information for your purposes. Should you have any questions, please call us.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
A. F. CHEVRIER
PROVINCE OF ONTARIO

A.F. Chevrier, P. Eng.

REGISTERED PROFESSIONAL ENGINEER
R. A. J. MONTGOMERY
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Disk 17

Att.

ACCUTEST LABORATORIES LTD.
146 Colonnade Rd., Suite 202, Nepean, Ontario K2E 7Y3 (613) 727-5692

LAB REPORT NO.: A0-0941

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REPORT OF ANALYSES

Client: Golder Associates

Attn; Mr. Andrew Chevrier

Date: June 12 1990

GOLDER ASSOCIATES
JUN 15 1990
RECEIVED — OTTAWA

Project: 891-2582

P. O. No: 01584

Parameter	Units	Sample BH 4-3	Sample	Sample	Sample	Sample
Fe	mg/L					
Mn	mg/L					
Hardness	mg/L $CaCO_3$					
Alkalinity	mg/L $CaCO_3$					
pH		6.98				
Conductivity	umhos /cm	987				
F	mg/L					
Na	mg/L					
$N-NO_3$	mg/L					
$N-NO_2$	mg/L					
$N-NH_3$	mg/L					
SO_4	mg/L	4				
CL	mg/L	40				
Phenols	mg/L					
Turbidity	NTU					
Colour	Pt/Co Units					
Ca	mg/L					
Mg	mg/L					
Tannin & Lignin	mg/L					
Total Nitrogen	mg/L					

ANALYST: [signature]

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY $= \frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX $= w_L - w_P$
I_L	1	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE
e_{min}	1, %	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4-1

METRIC

W P 177-89-02 LOCATION Sta. 23 + 631.2 5.7 Rt. ORIGINATED BY D.J.S.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY A.C.

DATUM Geodetic DATE May 18, 1990 CHECKED BY A.C.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
87.3	Ground Surface						
87.0 / 0.0	Topsoil				Water level in open hole at elev. 86.8 metres on May 18, 1990	87	
86.4 / 0.3	Clayey silt, Brown						
85.8 / 0.9	Silty clay (weathered crust) Very stiff Grey brown	1	SS	5		86	
84.5 / 1.5	Sand, fine to medium, trace gravel, some silt. Loose, Grey brown to grey	2	SS	7		85	7 74 (19)
		3	SS	6			
79.5 / 2.8	Clayey silt. Very stiff, Grey	4	SS	15		84	0 3 69 28
		5	SS	20		83	
		6	SS	12		82	
		7	SS	12		81	
		8	SS	9		80	
		9	SS	9			
78.3 / 7.8	Silt. Compact, Grey	10	SS	20		79	
		11	SS	23			
75.1 / 9.0	Sandy silt, some gravel and clay, numerous cobbles and boulders (glacial till). Very dense, Grey	12	SS	69		78, 77	
		13	SS	>100		76	13 25 52 10
12.2	End of Borehole. Auger Refusal					75, 74	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ

$+^3, \times^5$: Numbers refer to Sensitivity

15 ◇ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4-2

METRIC

W P 177-89-02 | LOCATION Sta. 23 + 610.1 12.4 Lt. | ORIGINATED BY D.J.S.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY A.C.

DATUM Geodetic | DATE May 22, 1990 | CHECKED BY A.C.

OFFICE REPORT ON SOIL EXPLORATION

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS / ELEVATION SCALE
87.1	Ground Surface				
0.0	Topsoil				87 Bentonite
0.2 / 86.5	Clayey silt, Brown				
0.6 / 85.2	Silty clay, occasional sand seam (weathered crust) Very stiff, Grey brown	1	SS	6	86
		2	SS	4	
1.9 / 84.4	Sand, fine to coarse trace gravel and silt Loose, Grey	3	SS	5	85
2.7 / 78.6	Clayey silt Very stiff, Grey	4	SS	12	Native 84 Backfill
		5	SS	21	83
		6	SS	11	82
		7	SS	11	81
		8	SS	16	80
		9	SS	9	
		10	SS	12	79
8.5 / 78.1	Possibly silt				78
9.0 / 75.8	Sandy silt, some gravel and clay, occasional cobble (glacial till) Loose, Grey	11	SS	6	77 Bentonite
		12	SS	5	Standpipe 76
11.3	End of Borehole Auger Refusal				75

Water level in standpipe at elev. 87.5 metres on July 19, 1990

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, x LAB VANE: 20 40 60 80 100

PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ

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

$+^3$, $\times^5$: Numbers refer to Sensitivity

15 ◇ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 4-3

METRIC

W P 177-89-02 LOCATION Sta. 23 + 680.8 5.1 Rt. ORIGINATED BY D.J.S.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY A.C.

DATUM Geodetic DATE May 22 and 23, 1990 CHECKED BY A.C.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
87.3	Ground Surface						
86.5 / 0.0	Fill, silty clay, some sand and gravel, trace organic matter				Water level in open hole at elev. 86.8 metres on May 23, 1990	87	Org. Content =3.6%
85.7 / 0.8	Alluvium, sandy silt some clay and gravel, trace organic matter. Very loose Grey brown	1	SS	2		86	
85.1 / 1.6	Alluvium, silty sand trace wood and organic matter. Very loose Brown	2	SS	3			
84.4 / 2.2	Sand, fine to coarse, trace wood. Very loose Brown	3	SS	1		85	
83.2 / 2.9	Alluvium, sandy silt to sand, trace wood and shells. Very loose Brown to grey brown	4	SS	1		84	Org. Content=6.0%
80.0 / 4.1	Clayey silt. Very stiff Grey	5	SS	3		83	
		6	SS	12		82	
		7	SS	16		81	
		8	SS	16		80	
76.7 / 7.3	Sandy silt, some gravel and clay, numerous cobbles and boulders (glacial till). Compact to dense Grey	9	SS	40		79	25 29 38 8
		10	SS	10		78	
						77	
10.6	End of Borehole. Auger Refusal					76	

Dynamic Cone Penetration Resistance Plot: 20 40 60 80 100

Shear Strength kPa: o Unconfined + Field Vane • Quick Triaxial × Lab Vane — 20 40 60 80 100

Plastic Limit W_p — Natural Moisture Content W — Liquid Limit W_L; Water Content (%) 20 40 60

Unit Weight γ

$+^3$, $\times^5$: Numbers refer to Sensitivity

15 ◇ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4-4

METRIC

W P 177-89-02 LOCATION Sta. 23 + 663.7 12.0 Lt. ORIGINATED BY D.J.S.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY A.C.

DATUM Geodetic DATE May 23, 1990 CHECKED BY A.C.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	ELEVATION SCALE	REMARKS
87.1	Ground Surface				87	
0.0	Fill, silty clay and clayey silt, some gravel and boulders Brown					Bentonite
86.2 / 0.9	Alluvium, silty sand some clay, trace organic matter Compact Grey	1	SS	17	86	Water level in standpipe at elev. 87.4 metres on July 19, 1990
1.5	Alluvium, silty sand and sandy silt, trace wood and organic matter Very loose Grey	2	SS	1	85	
		3	SS	1	84	
		4	SS	1		Native Backfill
83.1 / 4.0	Sand, fine to coarse, trace gravel Loose Grey	5	SS	4	83	
82.8 / 4.3	Clayey silt Very stiff Grey	6	SS	14	82	
81.3 / 5.8	Sandy silt, some gravel, clay, cobbles and boulders (glacial till) Loose to dense Grey	7	SS	38	81, 80	
		8	SS	7	79, 78	
		9	SS	15	77	Bentonite
76.4 / 10.7	End of Borehole Auger Refusal				76	Standpipe

OFFICE REPORT ON SOIL EXPLORATION

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+3, ×5: Numbers refer to Sensitivity

15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 4-5

METRIC

W P 177-89-02 | LOCATION Sta. 23 + 703.6 0.3 Rt. | ORIGINATED BY D.J.S.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger | COMPILED BY A.C.

DATUM Geodetic | DATE May 23, 1990 | CHECKED BY A.C.

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	SAMPLES: TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
87.2	Ground Surface									
0.0	Fill, silty clay and clayey silt, some gravel Brown				▽	87	Water level in open hole at elev. 87.0 metres on May 24, 1990			
86.6 / 0.6	Alluvium, sandy silt and silty sand, trace organic matter Very loose Brown	1	SS	1				o	Org. Content = 3.6%	
86.1 / 1.1	Alluvium, silty clay and clayey silt, trace organic matter Very stiff Grey					86				
85.7 / 1.5	Alluvium, sand, some sandy silt, trace organic matter	2	SS	5		85				
		3	SS	2						
	Very loose Grey brown to grey	4	SS	WR*		84				
83.2 / 4.0	Clayey silt Very stiff Grey	5	SS	6		83				
82.9 / 4.3	Sandy silt, some gravel and clay (glacial till)									
4.4	End of Borehole					82				

* Split spoon sank under weight of rods.

Header legend: Dynamic cone penetration resistance plot 20 40 60 80 100; Shear strength kPa: o Unconfined, + Field vane, ● Quick triaxial, × Lab vane, 20 40 60 80 100; Plastic limit W_p, Natural moisture content W, Liquid limit W_L; Water content (%) 20 40 60.

+3, ×5 : Numbers refer to Sensitivity   15 ◇ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4-10

METRIC

W P 177-89-02 LOCATION Sta. 23+656 - 3.5 m Lt. SBL ORIGINATED BY R.B.

DIST 9 HWY 416 BOREHOLE TYPE Wash Boring COMPILED BY R.A.M.

DATUM Geodetic DATE September 12, 1990 CHECKED BY R.A.M.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L – WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Water Surface										
	Water (South Nation River)						86				
85.1	River Bottom										
1.2	Alluvium, sandy silt, trace gravel, some organic material		1	SS	1		85				
84.3	Very loose Dark grey										
2.0	Clayey silt, some sand		2	SS	20		84				
			3	SS	18						
			4	SS	26		83				
82.4	Very Stiff Grey		5	SS	17						
3.9	End of Borehole						82				

$+^3$, $\times^5$: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 4-11 METRIC

W P 177-89-02 LOCATION Sta. 23+638 - 4.0 m Lt SBL ORIGINATED BY R.B.

DIST 9 HWY 416 BOREHOLE TYPE Wash Boring COMPILED BY R.A.M.

DATUM Geodetic DATE Sepptember 12, 1990 CHECKED BY R.A. M.

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Water Surface										
	Water (South Nation River)						86				
85.2 / 1.1	Alluvium, sandy silt, some organic material		1	SS	1		85				
84.6 / 1.7	Clayey silt, trace gravel		2	SS	9						
			3	SS	22		84				
			4	SS	29						
			5	SS	36		83				
82.3	Very Stiff Dark grey to grey		6	SS	31						
4.0	End of Borehole						82				

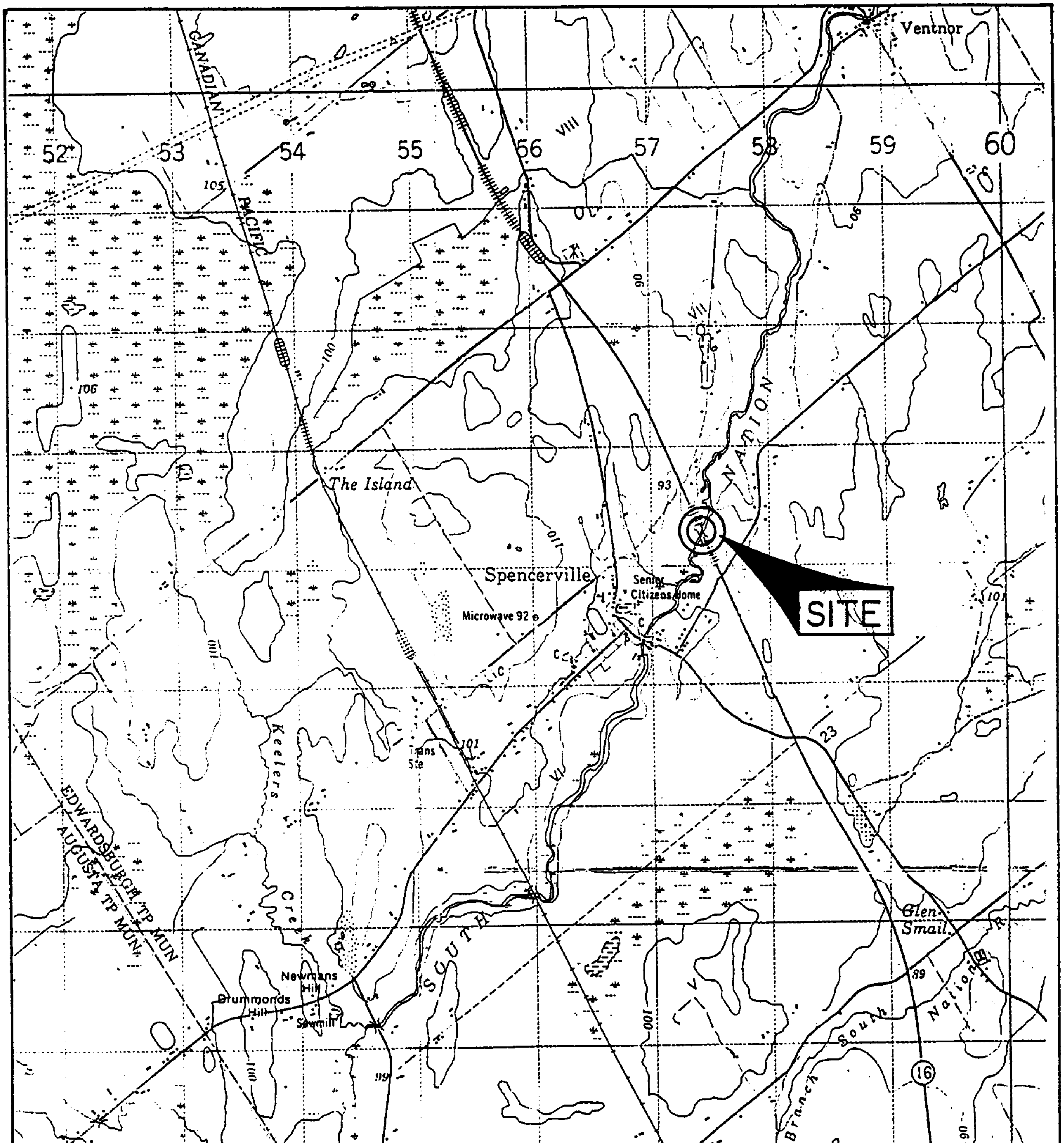
+3, ×5 : Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

KEY PLAN

FIGURE 1
WP 177-89-02



SCALE
1 : 50,000

N

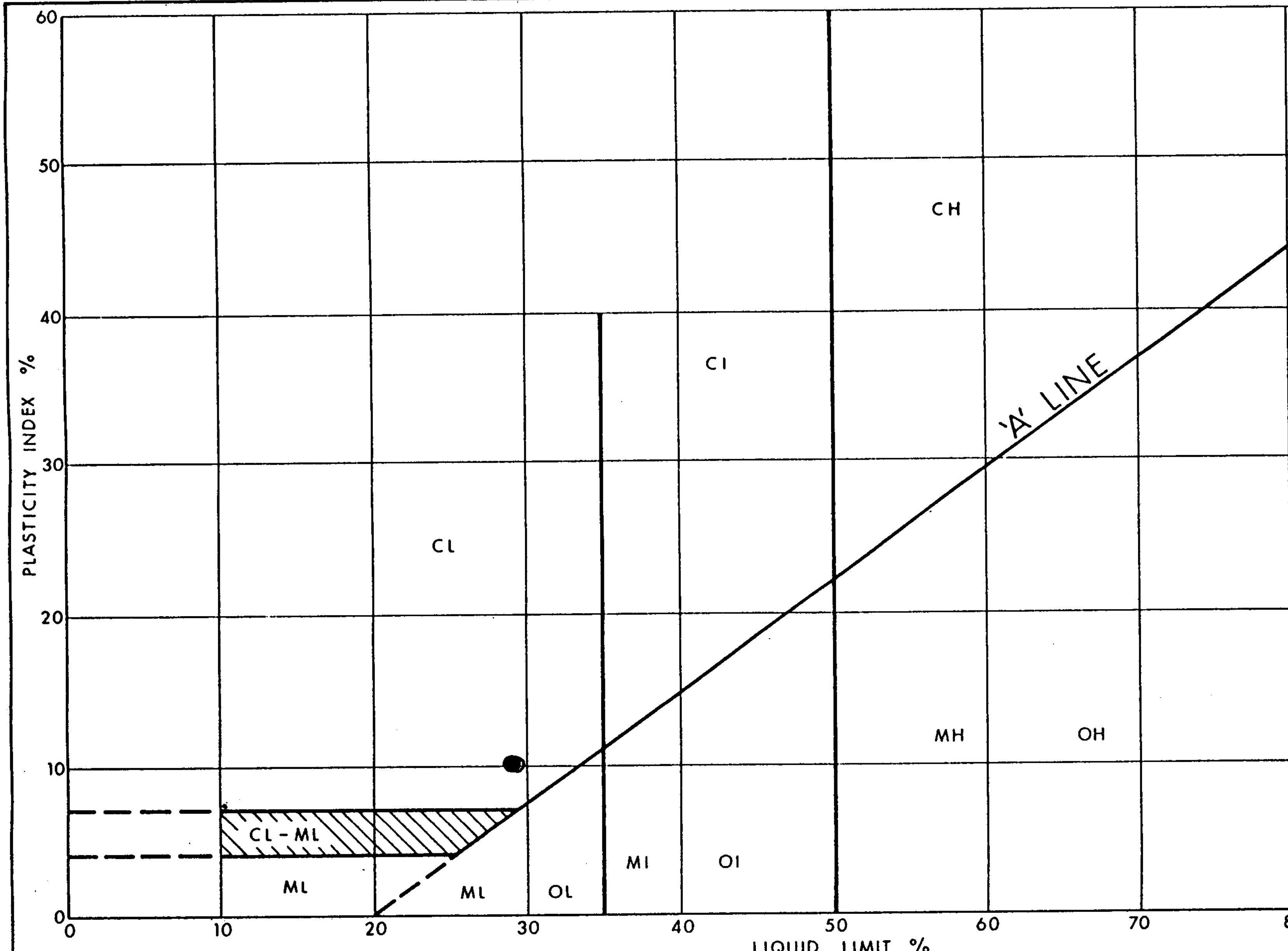
SPECIAL NOTE
THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT

Date AUG. 22, 1990
Project 891-2582-4

Golder Associates

Drawn JC
Chkd.

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
4-1	5	●
4-3	6	○

Ministry of Transportation
Ontario

PLASTICITY CHART
CLAYEY SILT

FIG No 2
W P 177-89-02

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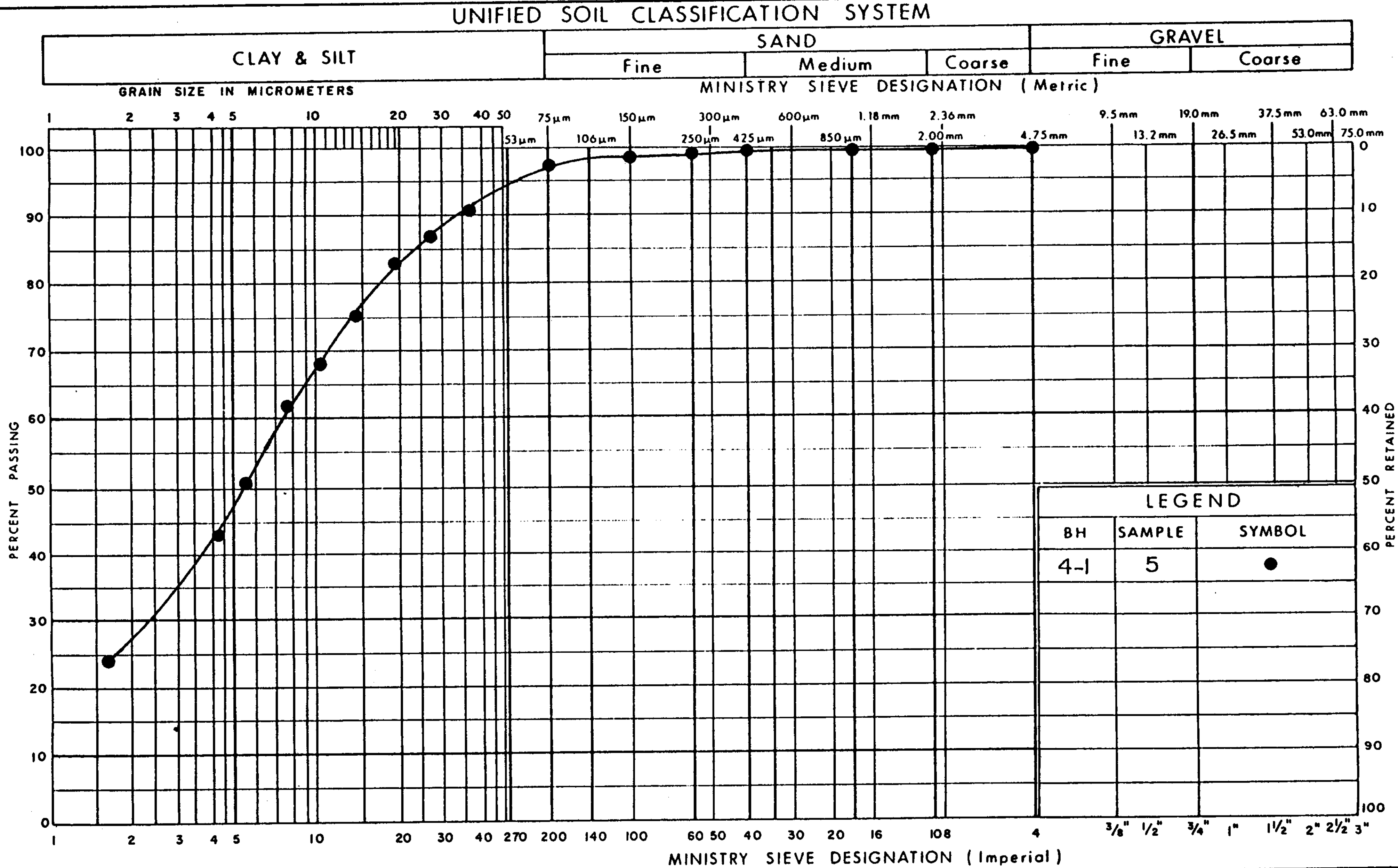


Ministry of Transportation

Ontario

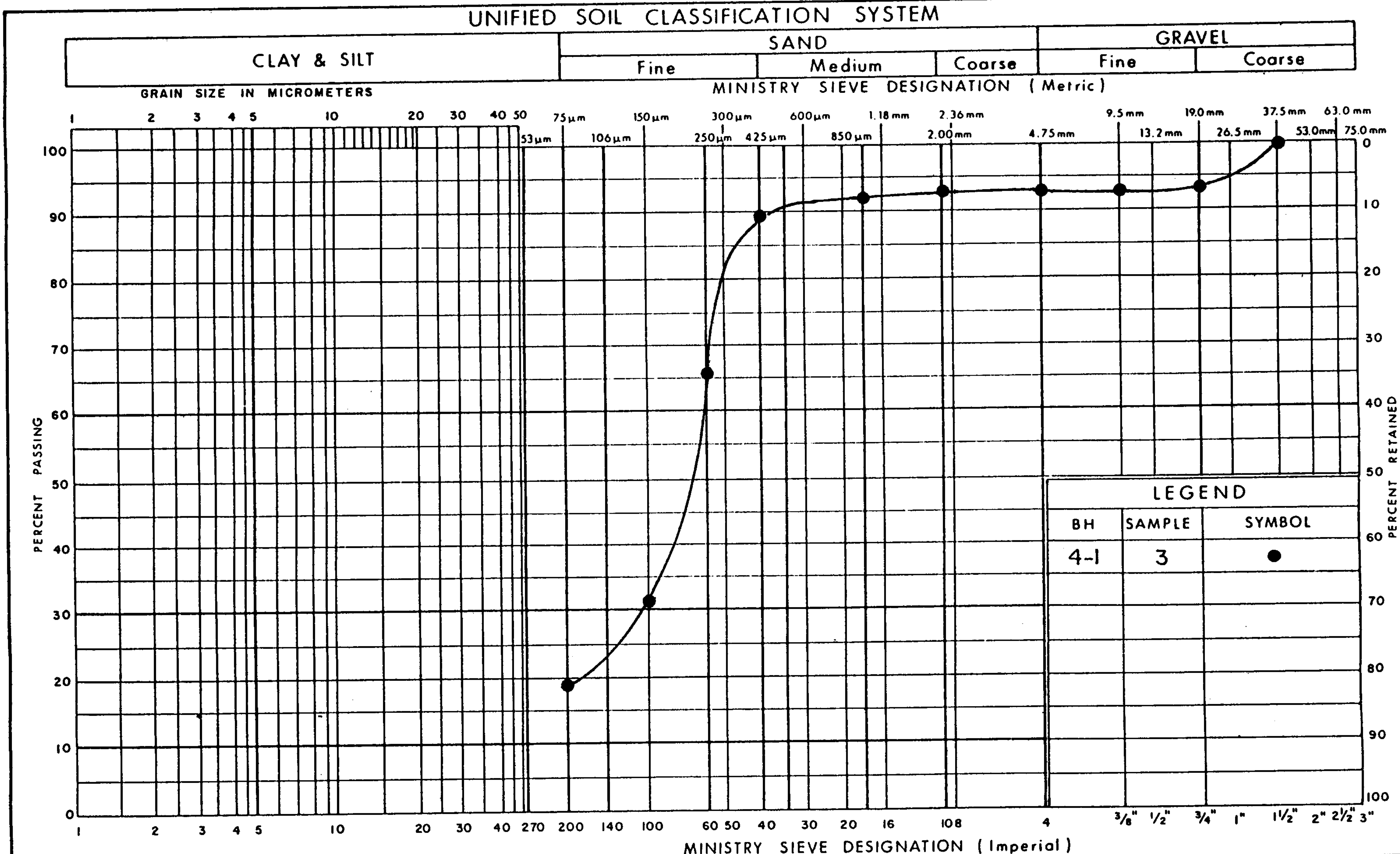
GRAIN SIZE DISTRIBUTION

CLAYEY SILT

FIG No 3

W P 177-89-02

78 12 M



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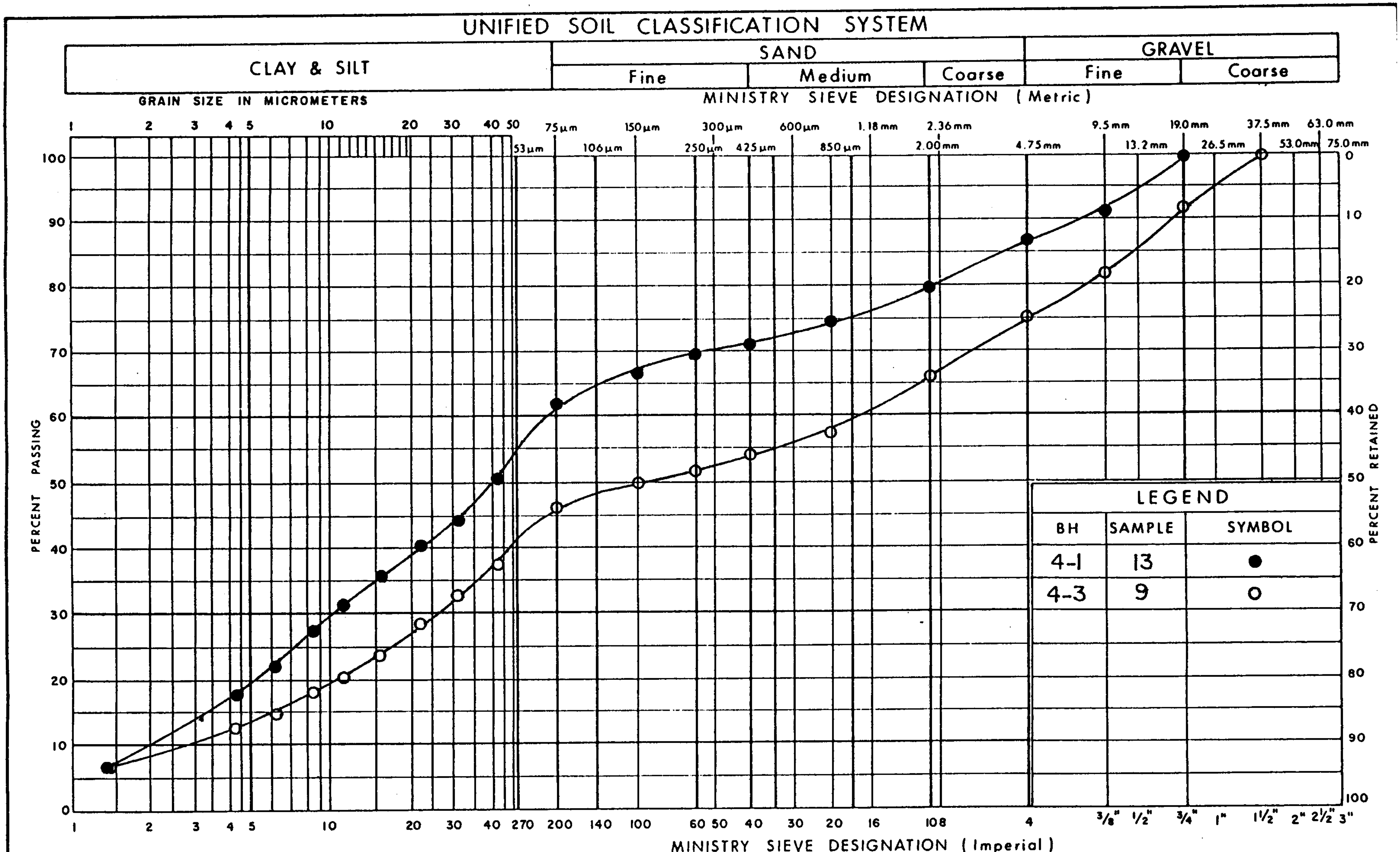
Ontario

GRAIN SIZE DISTRIBUTION
SAND, some silt

FIG No 4

W P 177-89-02

78 12 M



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GRAIN SIZE DISTRIBUTION

GLACIAL TILL

FIG No 5

W P 177-89-02

APPENDIX 1

RECORD OF BOREHOLE SHEETS

PREVIOUS BORINGS BY MINISTRY OF
TRANSPORTATION ONTARIO

FORM CO-MT-24
66-4946

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 67-F-55
W.P. 153-64-93
DATUM Geodetic

LOCATION Sta. 118 + 29; 23' Lt. of ℄
BORING DATE July 10, 1967
BOREHOLE TYPE Washboring, BX Casing

ORIGINATED BY AKB
COMPILED BY AKB
CHECKED BY [signature]

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLE NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	REMARKS
286.7	GROUND LEVEL						
0.0	Silty sand Compact						Sa. 88 Si.& Cl.12
280.5			1	SS	23	280	
6.2	Silty clay becoming clayey silt to silt. Very stiff to stiff.		2	SS	18		
			3	SS	13	270	
267.7							
19.0	Clayey silt to silt with gravel and boulders. (Glacial till) Hard		4	SS	100/4.5"		
			5	SS	112	260	
				Drill			
249.2						250	
37.5	Dolomite Bedrock		6	RC	100%		
245.7							
41.0	End of Borehole						

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
SHEAR STRENGTH P.S.F.
LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w
WATER CONTENT % 10 20 30
BULK DENSITY γ P.C.F.

184

FORM 06-MT-124
58-4846

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

JOB 67-F-55
W.P. 253-66-03
DATUM Geodetic
LOCATION Sta. 448 + 97± 23' Lt. of ℄
BORING DATE July 7, 1967
BOREHOLE TYPE Washboring, BX Casing
ORIGINATED BY AKB
COMPILED BY AKB
CHECKED BY [signature]

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F. (Unconfined / Quick Triaxial)	WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
286.7	GROUND LEVEL									
0.0	Silty sand. Compact		1	SS	24	280				▽ 283.5'
278.7 / 8.0	Clayey silt. Stiff to very stiff		2	SS	10					
			3	TW	PH				127	
			4	TW	PH	270			130	
			5	TW	PH				132	
264.7 / 22.0	Clayey silt with gravel.		6	SS	100/3.5"	260				
	Boulders Hard			AXT R.C						
256.8 / 29.9	End of Borehole									

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OFFICE REPORT ON SOIL EXPLORATION

FORM 08-MT-124
14-4544

DEPARTMENT OF HIGHWAYS – ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

JOB 67-F-55
W.P. 253-66-03
DATUM Geodetic

LOCATION Sta. 449 + 95; 23/ Lt. of ℄
BORING DATE July 6, 1967
BOREHOLE TYPE Washboring, BX Casing

ORIGINATED BY AKB
COMPILED BY AKB
CHECKED BY [signature]

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	REMARKS
286.2	GROUND LEVEL						
0.0	Silty sand. Very loose		1	SS	1	280	Sa.83 Si.&Cl.17
278.0 / 8.2	Clayey silt Sitff to very stiff		2	SS	12		
			3	SS	24		
			4	SS	19	270	
			5	SS	16		
			6	SS	16	260	
256.2 / 30.0	Clayey silt with gravel. Hard Boulders		7	SS	24		
251.2 / 35.0	End of Borehole					250	

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.

LIQUID LIMIT — w_L
PLASTIC LIMIT — w_p
WATER CONTENT — w

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

FORM OS-MT-126
6-4846

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS – ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

JOB 67-F-55
W.P. 253-66-03
DATUM Geodetic
LOCATION Sta. 150 + 58; 23' Lt. of ℄
BORING DATE July 5, 1967
BOREHOLE TYPE Washboring, BX Casing
ORIGINATED BY AKB
COMPILED BY AKB
CHECKED BY [signature]

ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT
285.0	Ground Level			
0.0	Silty sand. Very loose to loose	1	SS	3
		2	SS	5
277.0 / 8.0	Clayey silt. Firm to stiff	3	SS	5
		4	SS	16
		5	SS	11
		6	SS	13
261.0 / 24.0	Clayey silt with gravel (Glacial Till) Stiff to very stiff	7	SS	25
		8	SS	11
251.0 / 34.0	Dolomite – Bedrock	9	RC	100% Rec
245.7 / 39.3	End of Borehole			

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
SHEAR STRENGTH P.S.F.
LIQUID LIMIT — W_L; PLASTIC LIMIT — W_P; WATER CONTENT — W
WATER CONTENT % 10 20 30
ELEV. SCALE 280, 270, 260, 250
BULK DENSITY γ P.C.F.
REMARKS
▽ 284

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METRIC

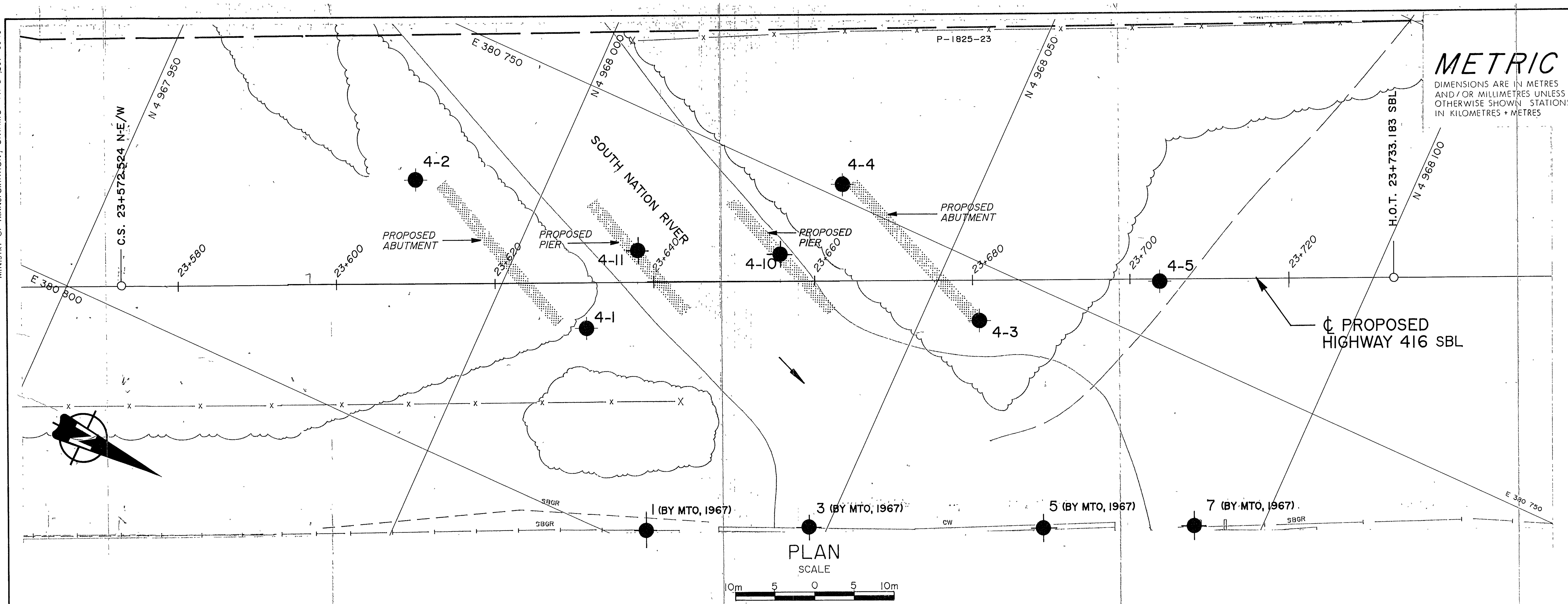
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES

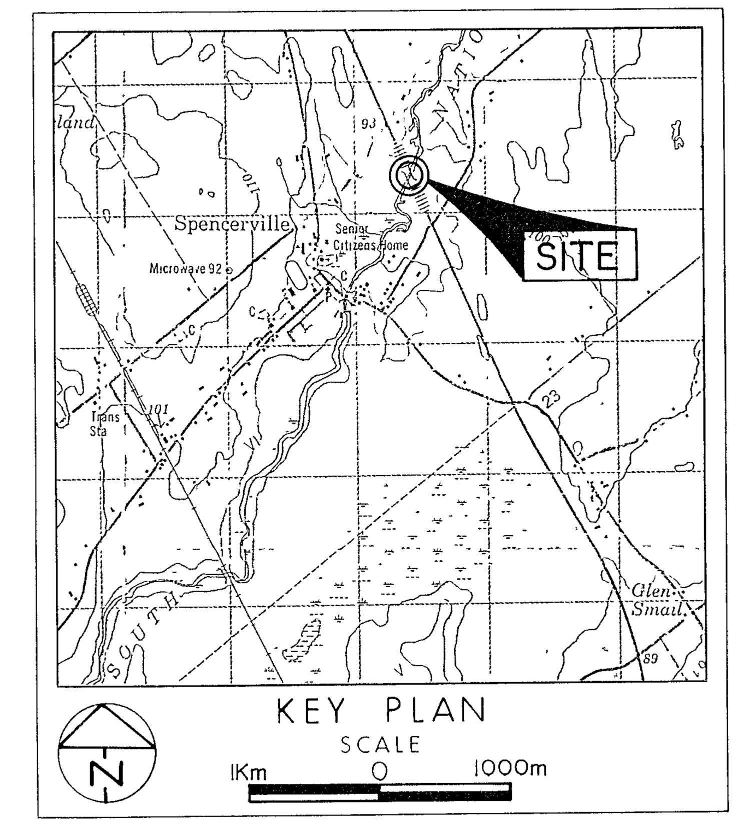
CONT No
WP No 177-89-08

SOUTH NATION RIVER OVERPASS
HWY 416 SOUTH BOUND LANES
BORE HOLE LOCATIONS & SOIL STRATA

SHEET

Golder Associates Ltd.

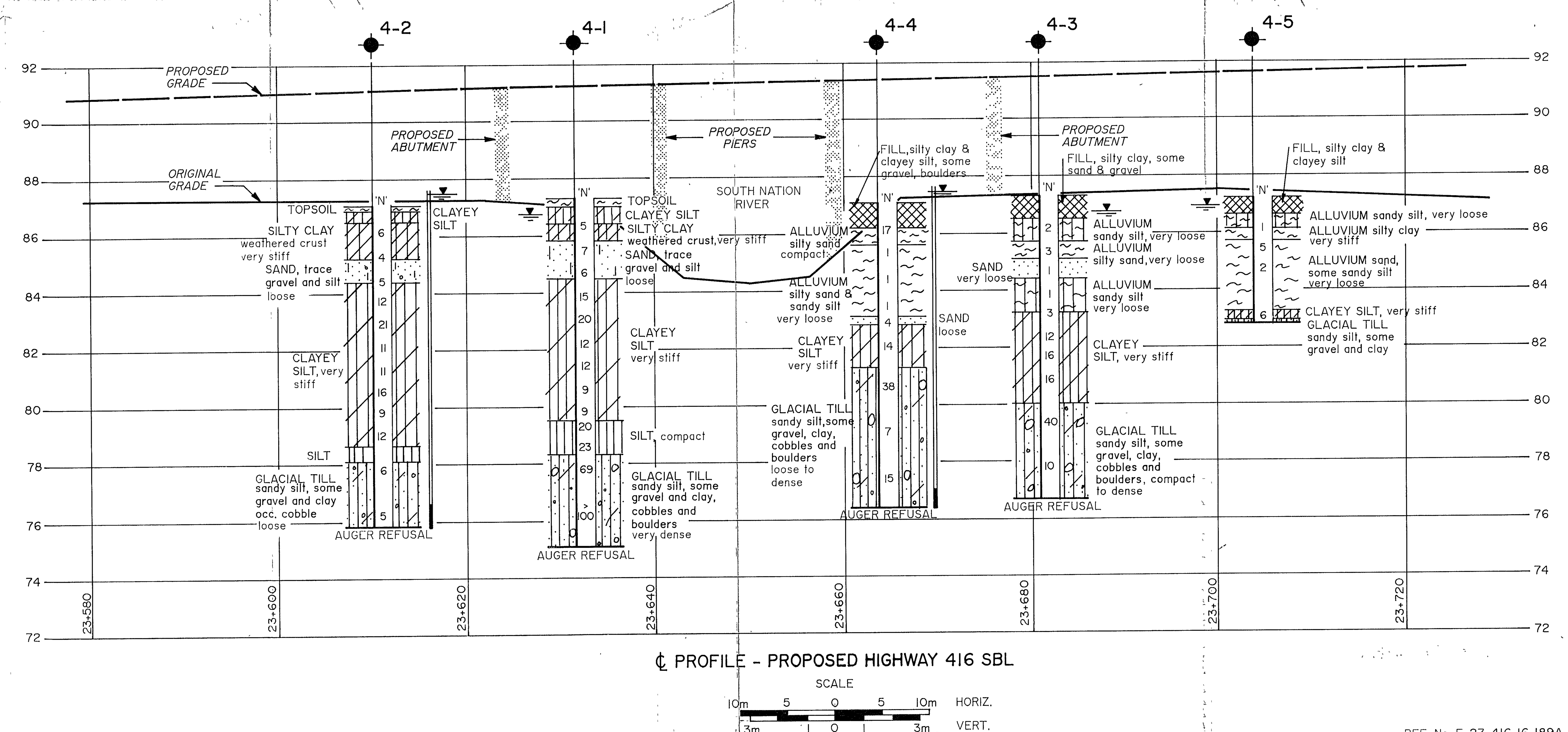




LEGEND

- 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)
- W.L. at time of investigation (MAY & JULY 1990)
- Standpipe

No	ELEVATION	STATION	OFFSET
4-1	87.3	23+631.2	5.7m Rt
4-2	87.1	23+610.1	12.4m Lt
4-3	87.3	23+680.8	5.1m Rt
4-4	87.1	23+663.7	12.0m Lt
4-5	87.2	23+703.6	0.3m Rt
4-10	86.3	23+656	3.5m Lt
4-11	86.3	23+638	4.0m Lt



REF. No. E-27-416-16-189A

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

NOTE- The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV	DATE	BY	DESCRIPTION

Geocres No 31B-63

HWY No 416 SBL			DIST 9
SUBM'D AC	CHECKED AC	DATE 90/08/21	SITE 16-189A
DRAWN JC	CHECKED	APPROVED	DWG 1778902-A

Golder Associates Ltd.

1796 Courtwood Crescent
Ottawa, Ontario, Canada K2C 2B5
Telephone (613) 224-5864
Fax (613) 224-9928

Golder Associates

GEOCRES No: 31B-63

REPORT ON

ADDITIONAL SUBSURFACE INVESTIGATION

PROPOSED SOUTH NATION RIVER OVERPASS
HIGHWAY 416 SOUTHBOUND LANES
W.P. 177-89-08, SITE 16-189A
DISTRICT 9 (OTTAWA)
EASTERN REGION

Submitted to:

Totten Sims Hubicki Associates
300 Water Street
Whitby, Ontario
L1N 9J2

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September 1997

971-2161

Golder Associates Ltd.

1796 Courtwood Crescent
Ottawa, Ontario, Canada K2C 2B5
Telephone (613) 224-5864
Fax (613) 224-9928

September 29, 1997

971-2161

Totten Sims Hubicki Associates
300 Water Street
Whitby, Ontario
L1N 9J2

Attention: Mr. J. Aleong

RE: ADDITIONAL SUBSURFACE INVESTIGATION
PROPOSED SOUTH NATION RIVER OVERPASS
HIGHWAY 416 SOUTHBOUND LANES
W.P. 177-89-02, SITE 16-189A
DISTRICT 9 (OTTAWA), EASTERN REGION

Dear Sirs:

This report presents the results of additional subsurface investigation carried out at the above site (see Key Plan, Figure 1). The purpose of the investigation was to determine the bedrock conditions at the site by means of two boreholes and, based on an interpretation of the information obtained together with that previously obtained at the site, to provide engineering guidelines on the foundation design of the proposed bridge, including construction consideration which could influence design decisions.

DESCRIPTION OF PROJECT

The above bridge is being redesigned and consideration is being given to foundations consisting of caissons (socketed piles). The original foundation investigation carried out for this project is described in Golder Associates report 891-2582-4 dated October 1990. That investigation provided no information on the bedrock at the site.

Reference should be made to the earlier report and that report should be read in conjunction with this document.

PROCEDURE

Between September 11 and 15, 1997, two boreholes, numbered 97-1 and 97-2 were put down near the northeast and southwest corners of the proposed bridge. The boreholes were advanced to auger refusal without sampling or testing and then extended by diamond coring in NQ size for at least 4 metres. In situ permeability testing was carried out after each run of core using either falling head or pumping tests. On completion, both boreholes were completely sealed full depth. The field work was supervised by a member of our engineering staff.

A detailed log of each boreholes is given on the Record of Borehole Sheets which follow this text. On these logs, the soil stratigraphy above the bedrock was taken from the previous boreholes put down at the site, which were adjacent to the present boreholes.

The approximate locations of the boreholes is given on the Site Plan, Figure 2. The elevations given in this report are referenced to Geodetic bench mark 77-U006 located on the existing Highway 16 bridge.

SUBSURFACE CONDITIONS

Refer to report 891-2582-4 for information on the soil overburden.

Bedrock

Examination of the core recovered from the boreholes indicates that the rock consists of fresh grey dolomitic bedrock. The total core recovered was consistently 100 percent; solid core recovered is 97 to 99 percent in borehole 97-1 and 94 to 97 percent in borehole 97-2 below the upper metre. The upper metre of rock in borehole 97-2 contains some thin mud seams between closely spaced bedding planes. The rock quality designation values range from 78 to 98 percent at borehole 97-1 and below the upper metre at borehole 97-2.

One unconfined compression test was carried out on an intact piece of core from borehole 97-1; the measured compressive strength is 91 megapascals.

Groundwater

The groundwater level from above the upper metre of the bedrock is at about 0.8 metres below existing ground surface. Below this depth the groundwater level reflects an artesian condition with the groundwater level 0.15 and 0.22 metres above ground surface in boreholes 97-1 and 97-2, respectively.

DISCUSSION

Cast-in-place concrete caissons or piles socketed for several feet into the sound bedrock would be a suitable means of providing the required bridge support. The caisson sockets should be designed for an adhesion (bond) stress of 1400 kilopascals at SLS and 2000 kilopascals at ULS between the concrete and the sound bedrock. This will require that the upper 1 metre of bedrock not be considered in the design socket length.

During installation of caissons, some 4 metres of bouldery till will be penetrated. The permanent casing or liner should be advanced slightly behind a socket in the till, formed by churn drilling. The casing should be driven to an adequate set to achieve some penetration of the bedrock surface and to aid in providing an effective water seal for the socket. Effective water control in the socket is required if inspection of the churn drilled sockets is to be carried out.

The sockets should be inspected to verify that the required length within sound bedrock has been obtained. At some locations as much as 1 metre of bedrock containing thin mud seams exists above the sound rock required for acceptable sockets. At these locations it may not be possible to carry out dewatering of the caisson which must precede inspection.

It should be pointed out that after the first run of core was recovered from the boreholes, artesian groundwater conditions were encountered in each borehole. Also, the measured permeability of the bedrock ranged from about 10^{-2} to 10^{-3} centimetres per second, values which will result in significant water inflow to the caisson liner. Heavy pumping will be required to keep the sockets dry for inspections; alternatively the inspections could be carried out underwater by a diver with a geotechnical background if the caisson is 1 metre diameter or larger.

Provision should be made for tremie concreting of caissons after the sockets have been cleaned, inspected and the reinforcing cages have been installed; this concreting work should only be carried out under the full stablized water level in the caisson i.e. no groundwater inflow should be occurring. The tremie discharge pipe should extend to the base of the socket for such concreting.

We trust that this report contains sufficient information for your present requirements. Please call us if you have any questions.

Yours truly,

GOLDER ASSOCIATES LTD.

G.S. Webb, P.Eng.
Principal

GSW:dc
Rpt-001.doc

Attachments:

Abbreviations and Symbols
Record of Boreholes
Figures 1 and 2

The abbreviation commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

- *AS* auger sample
- *CS* chunk sample
- *DO* drive open
- *DS* Denison type sample
- *FS* foil sample
- *RC* rock core
- *ST* slotted tube
- *TO* thin-walled, open
- *TP* thin-walled, piston
- *WS* wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance:

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 0.3 m (12 in.).

Standard Penetration Resistance, *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 0.3 m (12 in.).

WH sampler advanced by static weight—weight, hammer

PH sampler advanced by pressure—pressure, hydraulic

PM sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) *Cohesionless Soils*

Relative Density	*'N'* Blows/0.30m 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	*'Cu'* kPa	psf.
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000

IV. SOIL TESTS

- *C* consolidation test
- *H* hydrometer analysis
- *M* sieve analysis
- *MH* combined analysis, sieve and hydrometer[1]
- *Q* undrained triaxial[2]
- *R* consolidated undrained triaxial[2]
- *S* drained triaxial
- *U* unconfined compression
- *V* field vane test

NOTES:

[1]Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

[2]Undrained triaxial tests in which pore pressures are measured are shown as $\bar{Q}$ or $\bar{R}$.

LIST OF SYMBOLS

I. GENERAL

$\pi = 3.1416$

e = base of natural logarithms 2.7183

$\log_e a$ or $\ln a$, natural logarithm of a

$\log_{10} a$ or $\log a$, logarithm of a to base 10

- t time
- g acceleration due to gravity
- V volume
- W weight
- M moment
- F factor of safety

II. STRESS AND STRAIN

- u pore pressure
- σ normal stress
- σ' normal effective stress ($\bar{\sigma}$ is also used)
- τ shear stress
- ϵ linear strain
- ϵ_{xy} shear strain
- ν Poisson's ratio (μ is also used)
- E modulus of linear deformation (Young's modulus)
- G modulus of shear deformation
- K modulus of compressibility
- η coefficient of viscosity

III. SOIL PROPERTIES

(a) *Unit weight*

- γ unit weight of soil (bulk density)
- γ_s unit weight of solid particles
- γ_w unit weight of water
- γ_d unit dry weight of soil (dry density)
- γ' unit weight of submerged soil
- G_s specific gravity of solid particles $G_s = \gamma_s/\gamma_w$
- e void ratio
- n porosity
- w water content
- S_r degree of saturation

(b) *Consistency*

- w_L liquid limit
- w_P plastic limit
- I_P plasticity index
- 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
- D_r relative density $= (e_{max} - e)/(e_{max} - e_{min})$

(c) *Permeability*

- h hydraulic head or potential
- q rate of discharge
- v velocity of flow
- i hydraulic gradient
- k coefficient of permeability
- j seepage force per unit volume

(d) *Consolidation (one-dimensional)*

- m_v coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$
- C_c compression index $= -\Delta e/\Delta \log_{10} \sigma'$
- c_v coefficient of consolidation
- T_v time factor $= c_v t/d^2$ (d, drainage path)
- U degree of consolidation

(e) *Shear strength*

- τ_f shear strength
- c' effective cohesion intercept
- ϕ' effective angle of shearing resistance, or friction

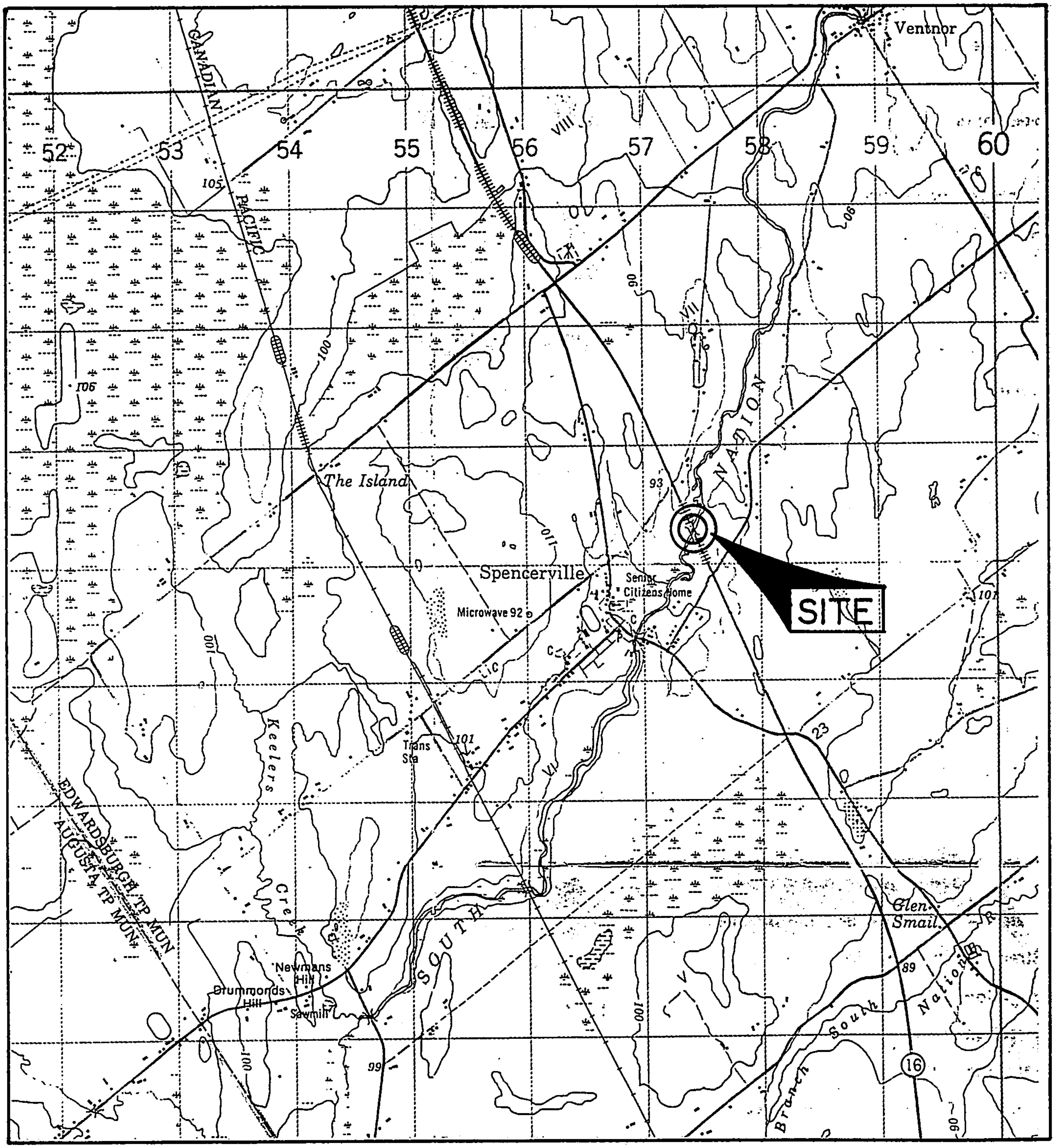
  (c' and ϕ':) in terms of effective stress $\tau_f = c' + \sigma' \tan \phi'$
- c_u apparent cohesion*
- ϕ_u apparent angle of shearing resistance, or friction

  (c_u and ϕ_u:) in terms of total stress $\tau_f = c_u + \sigma \tan \phi_u$
- μ coefficient of friction
- S_t sensitivity

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = c_u$ is taken as half the undrained compressive strength.

KEY PLAN

FIGURE I
WP 177-89-02



SCALE
1 : 50,000

N

SPECIAL NOTE
THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING REPORT

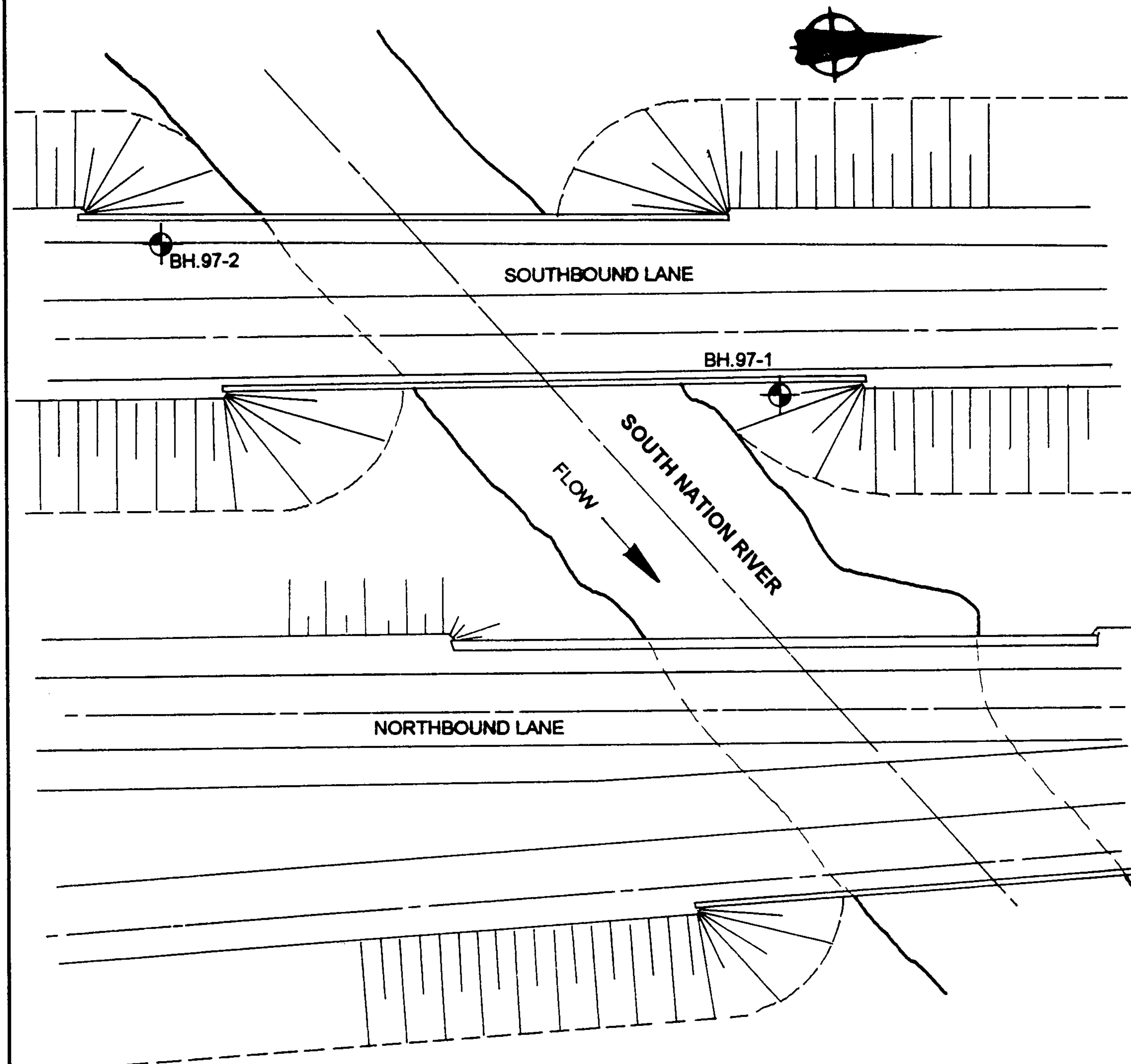
Date Sept. 25, 1997
Project 971-2161

Golder Associates

Drawn S.L
Chkd.

SITE PLAN

FIGURE 2



LEGEND

BOREHOLE LOCATION IN PLAN

REFERENCE: BASE PLAN BY MINISTRY OF TRANSPORTATION, ONTARIO

SCALE 1 : 600

SPECIAL NOTE
THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT

Date: Sept. 25, 1997

Project: 971-2161

Golder Associates

Drawn: S.L.

Chkd: ....

RECORD OF BOREHOLE 97-1

PROJECT: 971-2161
LOCATION: See Plan
SAMPLER HAMMER, 63.6kg; DROP, 760m
BORING DATE: Sept.11&12,1997
SHEET 1 OF 1
DATUM: Geodetic
PENETRATION TEST HAMMER, 63.6kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT, PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		Ground Surface	87.46							
0	Power Auger 200mm Diam (Hollow Stem)	Silty clay, some sand and gravel, trace organic matter (FILL)	0.00 / 86.66							
1		Very loose grey brown sandy silt, some clay and gravel, trace organic matter (ALLUVIUM)	0.80 / 85.86							
2		Very loose brown silty sand, trace wood and organic matter (ALLUVIUM)	1.60 / 85.26							
		Very loose brown fine to coarse SAND, trace wood	2.20 / 84.56							
3–4		Very loose brown to grey brown sandy silt to sand, trace wood (ALLUVIUM)	2.90 / 83.36							
4–7		Very stiff grey CLAYEY SILT	4.10 / 80.16							
7–10		Compact to dense grey sandy silt, some gravel and clay, numerous cobbles and boulders (GLACIAL TILL)	7.30 / 76.70							
11–15	Rotary Drill NQ Core	Fresh grey DOLOMITIC BEDROCK	10.76 / 72.04	1	NQ RC	–	T.C.R. 100% S.C.R. 97% R.Q.D. 92%			
				2	NQ RC	–	T.C.R. 100% S.C.R. 99% R.Q.D. 98%		Q=91 MPa	
				3	NQ RC	–	T.C.R. 100% S.C.R. 98% R.Q.D. 85%			
15.42		End of Hole	15.42							W.L in Open Hole at Elev.87.61m (0.15m above ground surface) Sept. 12, 1997

Legend: nat.V - + ; rem.V - ⊕ ; Q - ● ; U - O ; Wp —O W— Wl ; k: 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}

DATA INPUT: O:97-1-161.drf/8.L

DEPTH SCALE 1 to 100

Golder Associates

LOGGED: D.J.S
CHECKED:

RECORD OF BOREHOLE 97-2

PROJECT: 971-2161
LOCATION: See Plan
SAMPLER HAMMER, 63.6kg; DROP, 760m

BORING DATE: Sept.12-15,1997

SHEET 1 OF 1
DATUM: Geodetic
PENETRATION TEST HAMMER, 63.6kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	ELEV. / DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s / WATER CONTENT, PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		Ground Surface	87.18							
0	Power Auger 200mm Diam (Hollow Stem)	TOPSOIL	0.00							
		Brown CLAYEY SILT	0.20							
		Stiff grey brown silty clay, occasional sand seam (Weathered Crust)	0.60							
		Loose grey fine to coarse SAND, trace gravel and silt	85.28 / 1.90							
		Very stiff grey CLAYEY SILT	84.48 / 2.70							
		Possibly Silt	78.68 / 8.50							
		Loose grey sandy silt, some gravel and clay, occasional cobble (GLACIAL TILL)	78.18 / 9.00							
	Rotary Drill NQ Core	Fresh grey DOLOMITIC BEDROCK, occasional very thin mud seams in top 1m of bedrock	75.84 / 11.34	1	NQ RC	–	T.C.R. 100% S.C.R. 66% R.Q.D. 40%			
				2	NQ RC	–	T.C.R. 100% S.C.R. 97% R.Q.D. 85%			
				3	NQ RC	–	T.C.R. 100% S.C.R. 94% R.Q.D. 78%			
		End of Hole	71.85 / 15.33							W.L in Open Hole at Elev.87.40m (0.22m above ground surface) Sept. 15, 1997

DATA INPUT: O:97-2-161.drf/S.L

DEPTH SCALE 1 to 100

Golder Associates

LOGGED: D.J.S
CHECKED: