GEOCRES No:

31B-72

GIFFELS ASSOCIATES LIMITED
FOUNDATION INVESTIGATION
CULVERT AT NORTH BRANCH OF
THE SOUTH NATION RIVER
HWY 416 NORTHBOUND AND SOUTHBOUND LANES

WP 369-89-00

~~W.P. 101-91-01~~

HWY. 416, DISTRICT 9, EASTERN REGION

GEOCRES # 31B-72

Project No. 10917

Report To

Giffels Associates Limited

On

Foundation Investigation

Culvert at North Branch of
The South Nation River
Hwy 416 Northbound and Southbound Lanes

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June 2, 1997

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1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out at the above noted site for the construction of a proposed culvert beneath Highway 416 in the Township of Oxford, Ontario. A draft foundation investigation report (Project No. 10187 dated May 29, 1991) had been previously carried out for the proposed culvert beneath the Highway southbound lane (SBL). The information from that report has been reviewed in order to present a final foundation investigation report for both the NBL and SBL of Highway 416.

A total of four (4) boreholes were drilled for this investigation. The field work for the investigation of the proposed culvert section beneath Highway 416 SBL was carried out on December 18, 1990. Two boreholes, (numbered 90-1 and 90-2) were put down at the site. Both boreholes were put down at the bank of the river near the proposed culvert location. The recent field work for the investigation of the proposed culvert section beneath the Highway 416 NBL was carried out on May 26, 1997. Two additional boreholes (numbered 97-1 and 97-2) were put down at the site. These were put down on the existing west shoulder of the road (Highway 16) and at the bank of the river near the existing CSP culvert east end outlet. The borehole locations and the proposed structure locations are indicated on Drawing No. 1019101-B provided in Appendix 2.

All four boreholes were put down using a track-mounted CME 55 power auger drill rig. Borehole 90-1 was put down to a depth of 3.7 m upon hollow stem auger refusal. Borehole 90-2 was put down to a depth of 4.6 m, after coring in BWL size 1.6 m into bedrock. A Dynamic Cone Penetration Test was conducted at Borehole 90-2 until refusal to further penetration was met. Boreholes 97-1 and 97-2 beneath the proposed culvert on the side of the NBL were put down to 7.7 m and 4.6 m, respectively where they were ended by hollow stem auger refusal on probable bedrock.

2.0 SITE DESCRIPTION AND GEOLOGY

The site is located at the North Branch of the South Nation River about 750 metres south of County Road 20. The proposed Highway 416 SBL is located approximately 40 metres west of the existing Highway 16. The proposed Highway 416 NBL is to coincide with the roadway of existing Highway 16. The site is currently grassed and is flat with a difference of about 0.6 m between the two boreholes drilled in the area of the proposed culvert under Hwy 416 SBL. However, there is a greater change in grade between the existing riding surface of Highway 16 and the adjacent ground surface as the roadway is in a fill area. A difference of about 2.7 m exists between the two boreholes drilled in the area of the proposed culvert under Hwy 416 NBL. The river in the area of proposed Hwy 416 SBL is about 4 m wide. Under the existing Highway 16, drainage of the river is provided by one (1) 1220 mm diameter and three (3) 1829 mm diameter corrugated steel pipes (CSP).

The existing geotechnical/geological information suggests that the proposed site is within a glacial till plain with sand and silt deposits in the low-lying areas. Bedrock underlying the overburden consists of Ordovician limestone bedrock of the Oxford Formation. Overburden thickness at the site is expected to be less than 5 metres.

3.0 RESULTS OF THE INVESTIGATION

3.1 General

The subsurface conditions observed in the boreholes are presented in detail on the Record of Boreholes provided in Appendix 1. An explanation of Terms Used in Report is also provided in Appendix 1. The laboratory test results are summarized on the Record of Boreholes and also on Figures 1 to 3 in Appendix 1.

The ground surface elevations at the borehole locations 90-1, 90-2, 97-1 and 97-2 were El. 95.5 m, El. 94.9 m, El. 98.4 m and 95.7 m, respectively, at the time of the investigation. The subsurface soils consists of organic silt and sand as well as heterogeneous fill overlying clayey silt, underlain by glacial till which in turn is underlain by limestone bedrock at elevation ranging from about El. 90.8 m to El. 91.9 m. The groundwater table was observed between El. 93.4 m and El. 94.0 m in December 1990, and at El. 94.6 m in May 1991 in the area of the proposed SBL. The groundwater table was observed between El. 93.6 m and 94.4 m at the time of drilling in May 1997 in the area of the proposed NBL (existing Highway 16).

A brief discussion of the observed subsurface conditions is provided below. Specific details of the subsurface materials should be obtained from the Record of Boreholes.

3.1.1 Organic Silt and Organic Sand

Organic silt and sand was encountered from ground surface in boreholes 90-1 and 90-2 and under a 750 mm layer of rootmat in Borehole 97-2. The organic silt and sand extended to depths of 1.8 m, 0.2 m, 1.3 m in Boreholes 90-1, 90-2, and 97-2, respectively.

The SPT conducted in the organic silt and sand layer yielded a typical N value of 3, indicating that this material is very loose. The grain size distribution obtained from laboratory sieve analysis of a representative sample is 58% sand, and 42% silt and clay (Figure 1 in Appendix 1). Moisture content tests of four (4) representative samples yielded 34% to 61%. Based on visual identification and Atterberg Limits analysis, the organic silt and sand is classified as a cohesionless material.

3.1.2 Fill

Numerous layers of fill were encountered from ground surface on the west shoulder of the existing Highway 16 at borehole location 97-1. The fill varied in consistency from gravelly sand or sand, some silt and gravel to clayey silt, trace gravel or silty sand and sandy silt, some gravel. The fill materials extended to a depth of 4.9 m below the shoulder of the road at Borehole 97-1. The relative density of the fill layers, based on the standard penetration testing, is generally compact to dense.

The moisture content of the fill materials ranges from 7% to 19% with an average of 12% for the four samples tested.

3.1.3 Clayey Silt

Clayey silt was encountered underlying the organic silt and sand in both boreholes. The thickness of the clayey silt was 1.9 m and 2.8 m in Boreholes 90-1 and 90-2, respectively in the area of the proposed SBL. The thickness of the clayey silt was 1.7 m and 2.7 m in Boreholes 97-1 and 97-2, respectively in the area of the proposed NBL. Field vane tests conducted in the clayey silt layer yielded undrained shear strengths from 100 kPa to over 200 kPa in Boreholes 90-1 and 90-2, indicating a consistency ranging from stiff to hard and about 84 kPa in Borehole 97-2 indicating a stiff consistency. Based on visual identification, the clayey silt layer in Borehole 97-1 had a firm consistency.

The moisture content of the clayey silt ranges from 20% to 39% with an average of 26%. Atterberg Limited determinations indicate an average liquid limit of 27% and an average Plasticity Index of 12% (figure 2 in Appendix 1). The grain size distribution of two representative clayey silt samples is 2 to 9% sand, 65 to 54% silt, and 26 to 44% clay (figure 3 in Appendix 1). Based on visual identification and laboratory tests, the clayey silt is classified as a cohesive material of low plasticity.

3.1.4 Glacial Till

A deposit of grey glacial till material was observed below the clayey silt material Boreholes 97-1 and 97-2. The till was encountered below the clayey silt layer in Boreholes 97-1 and 97-2 at depths of about 4.9 m and 1.3 m, respectively. Although it was not sampled, some till may have been encountered at a depth of about 2.8 m in Borehole 90-2 by the monitored resistance to the dynamic penetration of a cone.

The till generally consisted of a sandy silty gravel, trace clay with the occasional presence of organics specifically in Borehole 97-2. The thickness of the till layer was approximately 1.1 m and 0.6 m in Boreholes 97-1 and 97-2, respectively and appeared to be about 0.2 to 0.3 m at Borehole 90-2 based on the monitored resistance to the dynamic penetration of a cone. The till material was observed to range from a compact to dense state of relative density based on an SPT blow counts of N=25 and 37.

Laboratory testing indicated the moisture content of the glacial till to range from 9% to 15% for the two representative samples tested.

3.1.5 Bedrock

Underlying the clayey silt, bedrock was encountered and proven by coring in BWL size in Borehole 90-2. The bedrock surface was encountered at El. 91.9m (a depth of 3.0 m) at this location. The bedrock is a grey limestone with close to moderately spaced horizontal fractures. Based on the core recovered, the bedrock is of good quality (RQD of 75%). Core recovery was 93%.

Coring of the bedrock was not carried out in Boreholes 90-1, 97-1 and 97-2. Hollow stem auger refusal was encountered at El. 91.8 m (a depth of 3.7 m), El. 90.8 m (a depth of 7.7 m) and El. 91.1 m (a depth of 4.6 m), respectively, at these locations. Comparing with the proven (cored) bedrock elevation, it is likely that auger refusal was encountered on probable bedrock in Boreholes 90-1, 97-1 and 97-2.

3.2 Groundwater Conditions

Standpipe piezometers 19 mm in diameter were installed to depths of 3.7 m and 3.0 m in Boreholes 90-1 and 90-2 respectively, as shown on the Record of Boreholes in Appendix 1. The boreholes were backfilled to ground surface with soil cuttings and mounded at the ground surface to prevent water infiltration.

Groundwater levels were recorded during the drilling and in the standpipe piezometers after drilling. Groundwater levels in December 1990 were recorded between El. 93.4 m and 94.0 m (a depth of 1.5 m). In May 1991, groundwater levels were recorded at El. 94.6 m (depths of 0.3 m and 0.9m). The groundwater table was observed between El. 93.6 m and 94.4 m at the time of drilling in May 1997 in the area of the proposed NBL (existing Highway 16).

As shown above, groundwater levels are subjected to seasonal fluctuations and can vary from the values given in this report.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Proposed Development

The North Branch of the South Nation River crosses the existing Highway 16 approximately 750 m south of County Road 20 in the Township of Oxford, Ontario (refer to the Key Plan provided on Drawing No. 1019101-B in Appendix 2).

The proposed culvert structure is part of the Highway 416 development from Highway 401 to Highway 43, and will extend from east of the existing Highway 16 embankment fill to west of the future Highway 416 SBL for a total length of about 61 m. Details of the culvert are as follows:

- The culvert at this location is proposed to be a continuous concrete closed box culvert placed beneath both the Highway 416 NBL and SBL. This report addresses the culvert section beneath the NBL and SBL or proposed Highway 416.

- The dimensions of the culvert will be about 5 m wide by 3.5 m high. The invert elevation will be at El. 92.9 m at the SBL end and 92.8 m at the NBL end. The top of pavement elevation of the proposed SBL at the culvert location will be at about El. 98.6 m and will remain the same at the proposed NBL (existing Highway 16).

- Wing walls are proposed at both ends of the culvert to reduce the culvert length and to support the proposed embankment fill.

4.2 Geotechnical Assessment

The proposed elevation of the underside of the culvert is expected to be within 500 mm of the top of bedrock under the proposed SBL and within less than 0.4 m of the top of glacial till under the proposed NBL. It is therefore recommended that all underlying clayey silt be removed and replaced with Granular "A" fill or lean concrete to act as a levelling and/or grading pad. Alternatively, consideration could be given to supporting the culvert directly on bedrock or glacial till.

The associated wing walls may be founded on spread footings placed within the clayey silt, glacial till or bedrock. As well, the footings could be placed on Granular "A" or lean concrete placed on these materials. As an alternative to a closed box culvert, consideration could also be given to utilizing an open culvert with footings placed on bedrock.

The embankment fill overlying the culvert may be constructed using side slopes of 2 horizontal to 1 vertical for granular or fine-grained borrow. Embankment fill stability and settlement problems are not anticipated provided that the overburden soil is subexcavated as discussed below.

This report contains our detailed recommendations in the following areas:

1) Structure Foundations
2) Stability and Settlement of Approach Fills
3) Lateral Earth Pressures
4) Construction Considerations.

4.3 Structure Foundations

4.3.1 Culvert Foundation

It is understood that the underside of the culvert will be placed at El. 92.4 m under the proposed SBL and at El. 92.3 m under the proposed NBL, which are 0.5 m to 0.7 m to the anticipated underside of the clayey silt deposit. It is recommended that all in situ clayey silt material be excavated and replaced with compacted Granular "A" fill, lean concrete, or non-shrink fill to support the culvert. Compaction of the granular fill should be in accordance with OPSS 501. The following design values are recommended:

	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
Granular "A" on Bedrock	900 kPa	350 kPa
Till or Engineered Fills on Till	300 kPa	200 kPa

Engineered Fills include Granular "A", lean concrete or non-shrink fill.

A footing width (B) of 5 m was used in the calculation of the capacities. The S.L.S. Type II bearing pressure has been calculated assuming that a total settlement of 25 mm is satisfactory.

4.3.2 Wing Wall Foundations

The associated wing wall structures may be founded on spread footings placed on the native till or bedrock, or on Engineered fills on these materials. The above recommendations would be applicable in this case. The wing walls could also be founded on undisturbed native clayey silt using reduced bearing capacities.

	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
Undisturbed Clayey Silt	210 kPa	140 kPa

The underside of the footings should be provided with a minimum of 1.8 m of earth cover or equivalent insulation for frost protection.

The frost cover criteria at this site may place the spread footings for the wing walls at or near the bedrock elevation varying from El. 90.8 m to about El. 91.9 m. In this case, consideration should be given to placing spread footings of wing wall structures on the limestone bedrock. Spread footings founded on the bedrock may be designed using the following value:

Factored Bearing Capacity at U.L.S.	3000 kPa

The limestone bedrock is considered to be an unyielding foundation base and hence a S.L.S. Type II bearing capacity would not be applicable.

Sliding resistance may be calculated using the following unfactored friction factors.

	tanδ
Mass concrete on Granular "A"	0.6
Mass concrete on bedrock	0.7
Mass concrete on till/lean concrete/ non-shrink fill	0.45

4.4 Stability and Settlement of Approach fills

Fill placement of about 2 m is proposed on top of the culvert. The fill thickness will be in the order of 5 m from the top of pavement to the culvert invert. Side slopes of 2 horizontal to 1 vertical would be appropriate for fills constructed of granular and fine-grained borrow.

All very loose organic soil and any softened clayey silt material should be removed within the plan limits of the fill prior to its placement. Borehole 90-1 suggests that as much as 1.8 m of organic silt and sand would require excavation. Borehole 97-2 suggests that as much as 0.8 m of organic materials would require excavation. The limits of the excavation are not expected to extend significantly on either side of the centreline of the proposed Highway 416 SBL or NBL. The excavation backfill should be placed and compacted in accordance with OPSS 212 and 501.

With the organic soil removed as recommended above, total settlement of the embankment fill and the underlying soil are not expected to exceed 25 mm. It is recommended that the fill be placed early in the highway construction stage of the SBL, and to delay paving, to allow any time dependent portions of the settlements to take place and therefore to minimize differential settlements.

To protect against surficial instability, normal slope vegetation should be established in accordance with MTO standards as soon as possible after construction.

4.5 Lateral Earth Pressures

Culver backfill requirement should be in accordance with OPSD 803 series. To prevent hydrostatic pressure buildup, backfill to culvert walls and wing walls should consist of Granular "A" or Granular "B" Type I or Type II.

Computation of earth pressures should be in accordance with Section 6-6.1.2.1 of the O.H.B.D.C.. The active pressure should be used if the structure is yielding. For rigidly tied structures, the at-rest earth pressure should be used for design, unless the stem can deflect enough (approximately 0.05 percent of the wall height) to establish the active pressure.

For a horizontal backfill, the following soil parameters are recommended for design:

	Granular "A"	Granular "B"
Bulk unit weight, γ (kN/m^3)	22.8	21.2
Effective friction angle, ϕ'	35°	30°
Coefficient of active earth pressure (K_a)	0.27	0.33
Coefficient of earth pressure at rest (K_o)	0.43	0.50

Compaction of the granular backfill near the culvert walls and wing walls should be carried out using hand-operated equipment to prevent overstressing the structure walls. Backfill placement adjacent to culvert walls should be carried out simultaneously on both sides.

4.6 Construction Considerations

4.6.1 Dewatering

Temporary diversion of the North Branch of the South Nation River waters will be required during construction. Footing excavations will extend some 2 to 3 metres below the groundwater level depending on seasonal fluctuations. Therefore, in addition to the temporary diversion, a temporary dewatering scheme will likely be required. Dewatering may be achieved by utilizing perimeter ditches within a gravity system in conjunction with a sump pump discharge system to drain accumulated water.

Other dewatering alternatives may also be considered. The most economical and practically feasible dewatering alternative should be selected. It is the responsibility of the contractor to lower the groundwater below the excavation base, and to construct the footings in the dry without disturbing the underlying foundation soils.

4.6.2 Temporary Excavations

All softened and organic soil should be removed as recommended in Section 4.3. Any temporary excavations should be no steeper than 1 horizontal to 1 vertical in the materials underlying the organic silt and sand. Under heavy seepage conditions, flatter side slopes may be required or alternatively a shoring may be utilized.

4.7 Groundwater Chemistry

Two (2) groundwater samples were submitted for pH, sulphate and chloride testing. The test results are summarized below:

Borehole	pH	Sulphate (ppm)	Chloride (ppm)
90-1	7.5	210	93
90-2	7.8	72	23

The test results indicate positive degree of sulphate attack. Based on the above, we recommend that positive epoxy-coated reinforcing steel be used.

5.0 MISCELLANEOUS

The field work for this investigation was carried out under the supervision of Allen MacGarvie, CET, and Dean Pidgeon, tech. utilizing equipment owned and operated by George Downing Estate Drilling Limited.

The project was carried out under the general supervision of G. Kack, 1990 project manager and Raymond Haché, 1997 project manager. The report was written by both undersigned.

Yours truly,

JACQUES, WHITFORD LIMITED

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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 90-1 METRIC

W P 101-91-01 LOCATION Co-ords: N 4 978 289.1; E 377 306.1 ORIGINATED BY A.M.

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

DATUM Geodetic DATE December 18, 1990 CHECKED BY G.J.K.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
95.5	Ground Surface					
0.0	Organic Silt and Sand, Very Loose, Dark brown	1	SS	3	Native Backfill	
		2	SS	3	May 8, 1991 94.6	0 58 (42)
					Dec. 19, 1990 93.9	
93.7		3	SS	0		
1.8	Clayey Silt, Hard, Grey					0 2 71 27
		4	TW	PH	Piezometer	
		5	SS	20/10cm		
91.8						
3.7	End of Borehole, Auger Refusal on Probable Bedrock					

Elevation scale: 95, 94, 93, 92

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 40 80 120 160 200 240

Field vane results: >>+ (four tests in Clayey Silt); +4 near elevation 92

PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL — 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 90-2 METRIC

W P 101-91-01 LOCATION Co-ords: 4 978 290.3; E 377 334.5 ORIGINATED BY A.M.

DIST 9 HWY 416 BOREHOLE TYPE HS Auger, BW Casing, Rock Coring, Cone Penetration COMPILED BY C.K.K.

DATUM Geodetic DATE December 18, 1990 CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.9	Ground Surface				
0.0 / 94.7	Organic Silt and Sand Loose				
0.2	Clayey Silt Stiff to Hard Grey	1	SS	5	
		2	SS	4	
		3	TW	PH	
		4	SS	5	
91.9 / 3.0	Bedrock Limestone Good Grey	5	BWL RC	REC 93%	RQD = 75%
90.3 / 4.6	End of Borehole				

Ground water conditions: May 8, 1991 94.6; Dec. 19, 1990 93.4; Native Backfill; Piezometer

Elevation scale: 94, 93, 92, 91

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE — 40 80 120 160 200

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 / 10)

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 97-1

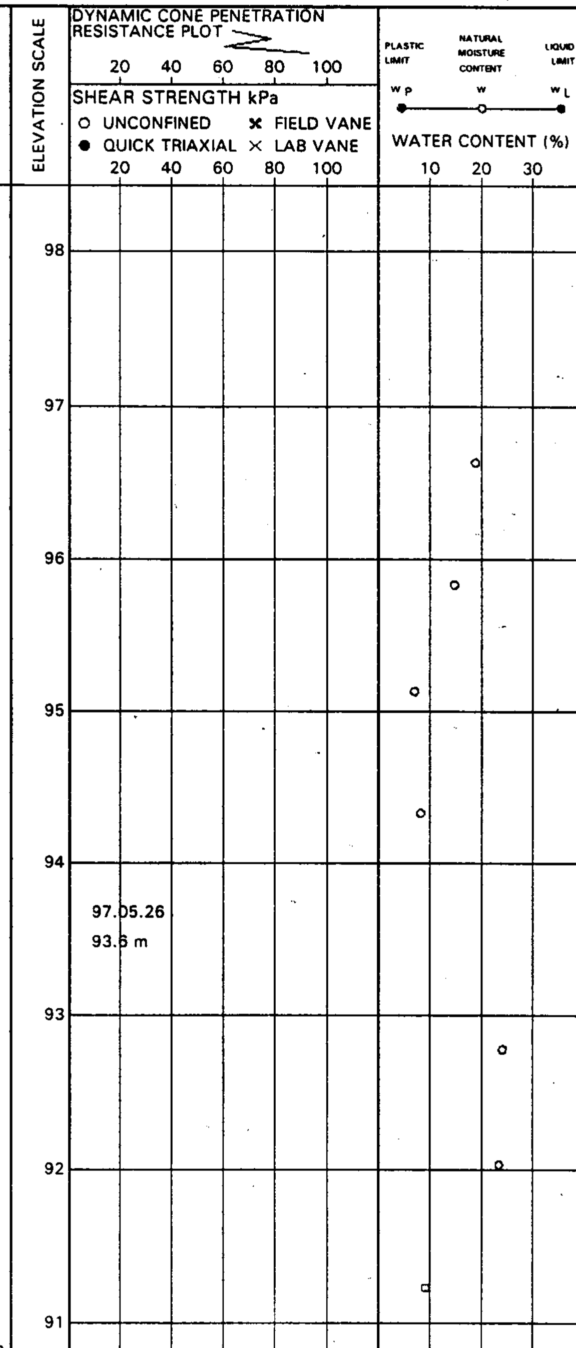
METRIC

W.P. 101-91-01 LOCATION Co-ords: N 4 978 312.0; E 377 343.5 ORIGINATED BY D.P.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY J.L.L.

DATUM Geodetic DATE 97.05.26 CHECKED BY R. Haché

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
98.4 / 0.0	Compact, brown gravelly sand, trace silt: FILL					
98.2 / 0.3	Compact, brown sand, some silt and gravel: FILL					
97.6 / 0.8	Grey, clayey silt, trace gravel: FILL	1	SS	26		
		2	SS	26		
96.4 / 2.0	Compact, brown silty sand: FILL					
96.2 / 2.2	Compact, grey sandy silt, some gravel, trace clay: FILL	3	SS	29		
		4	SS	24		
		5	SS	55		
93.6 / 4.9	Firm, grey CLAYEY SILT	6	SS	20	Water level 97.05.26, 93.6 m	
		7	SS	4		
		8	SS	3		0 9 65 26
91.9 / 6.6	Compact, grey sandy silty gravel, trace clay: TILL	9	SS	25		
		10	SS	>100		
90.8 / 7.7	End of Borehole Auger Refusal on Probable Bedrock					



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

RECORD OF BOREHOLE No 97-2

METRIC

W.P. 101-91-01 LOCATION Co-ords: N 4 978 326.6; E 377 367.0 ORIGINATED BY D.P.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY J.L.L.

DATUM Geodetic DATE 97.05.26 CHECKED BY R. Haché

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
95.7 / 0.0	Brown, silty ROOTMAT			
94.9 / 0.8	Very loose, dark brown, sandy organic SILT	1	SS	3
94.4 / 1.3	- trace gravel Firm to stiff, grey CLAYEY SILT, trace organics	2	SS	3
		4	SS	5
91.7 / 4.0	Dense, grey, sandy, silty gravel, some organics: TILL	5	SS	37
91.1 / 4.6	End of Borehole Auger Refusal on Probable Bedrock			

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

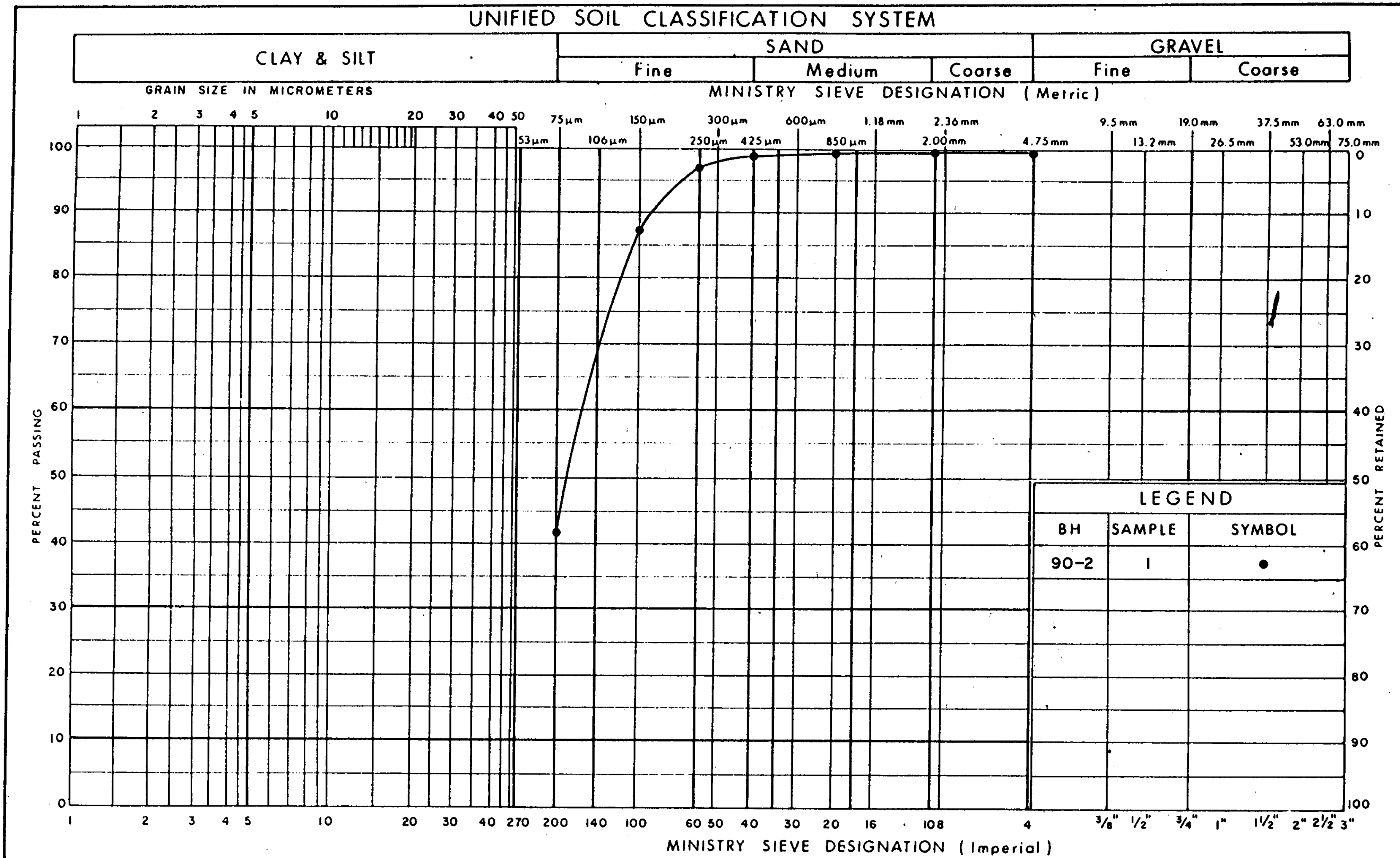
Elevation scale: 95, 94, 93, 92

Groundwater: 97.05.26 94.4 m

Plotted: 51.6 (water content, sample 1); ✖⁴ (field vane)

✖³, ×³: Numbers refer to Sensitivity — 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

78 12 M



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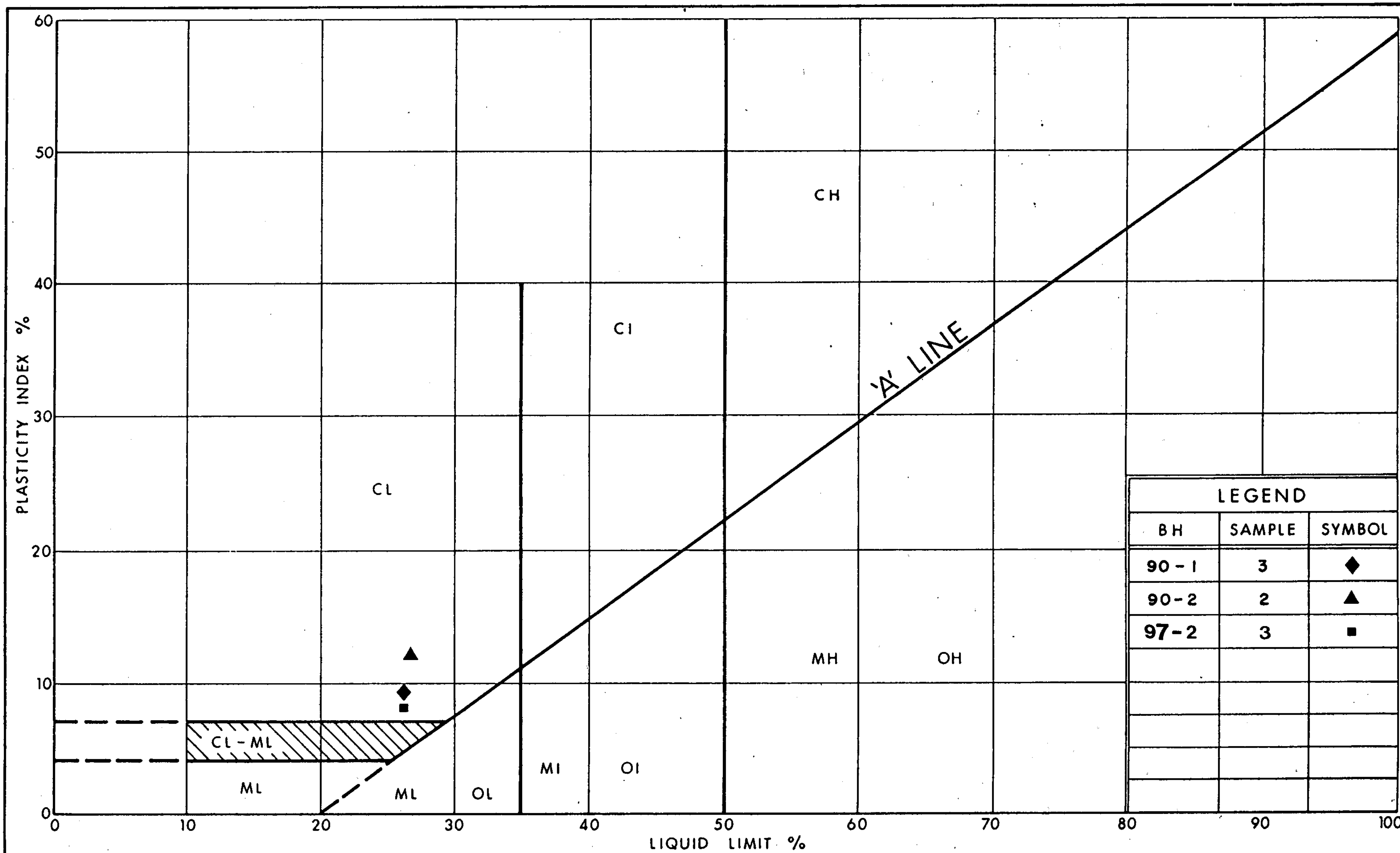
Ontario

GRAIN SIZE DISTRIBUTION
ORGANIC SILT & SAND

FIG No 1

W P 101 - 91 - 01

Oct 75, FF-S-21

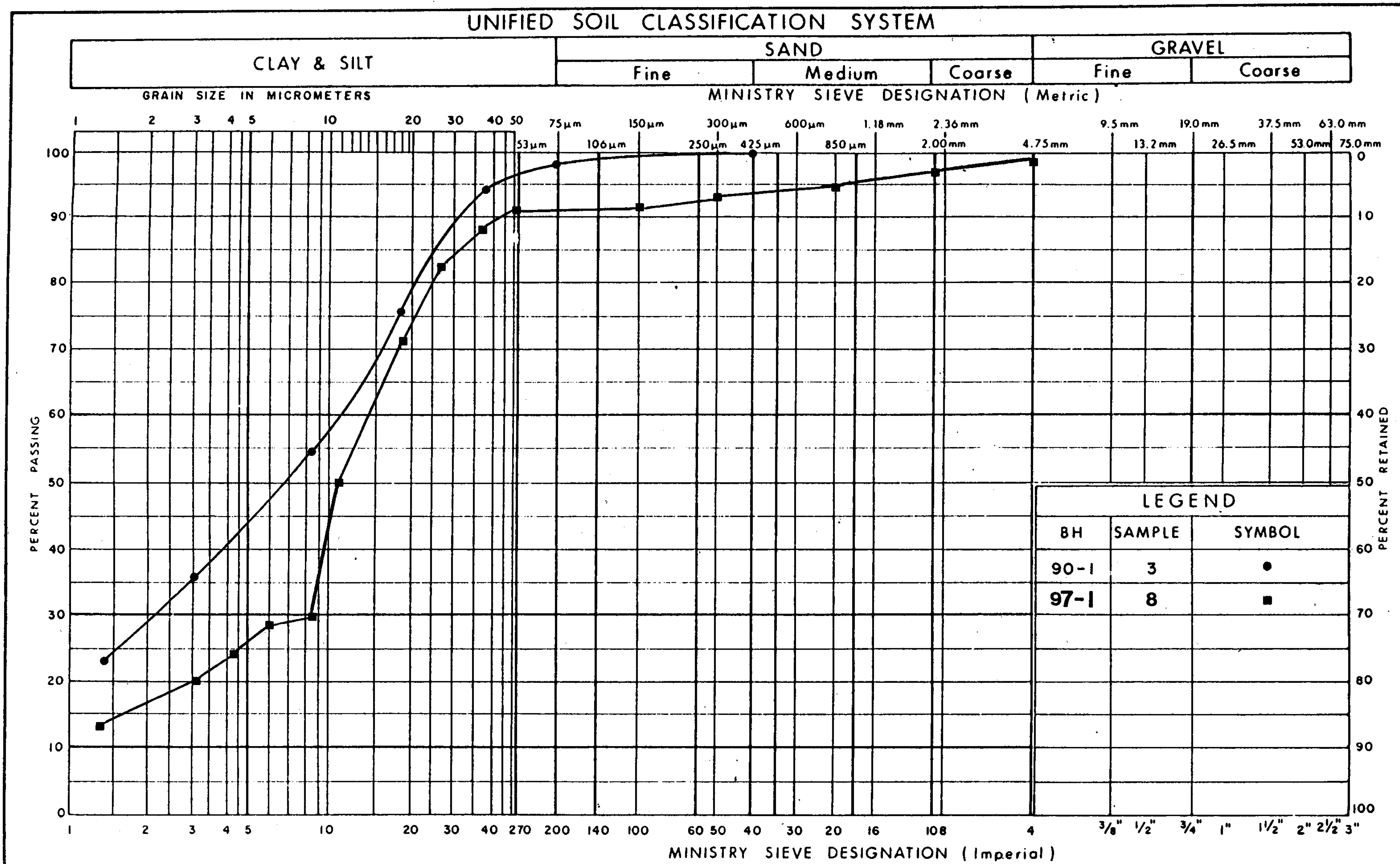


Ministry of Transportation
Ontario

PLASTICITY CHART
CLAYEY SILT

FIG No 2
W P 101 - 91 - 01

78 12 M



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT

FIG No 3

W P 101 - 91 - 01

METRIC

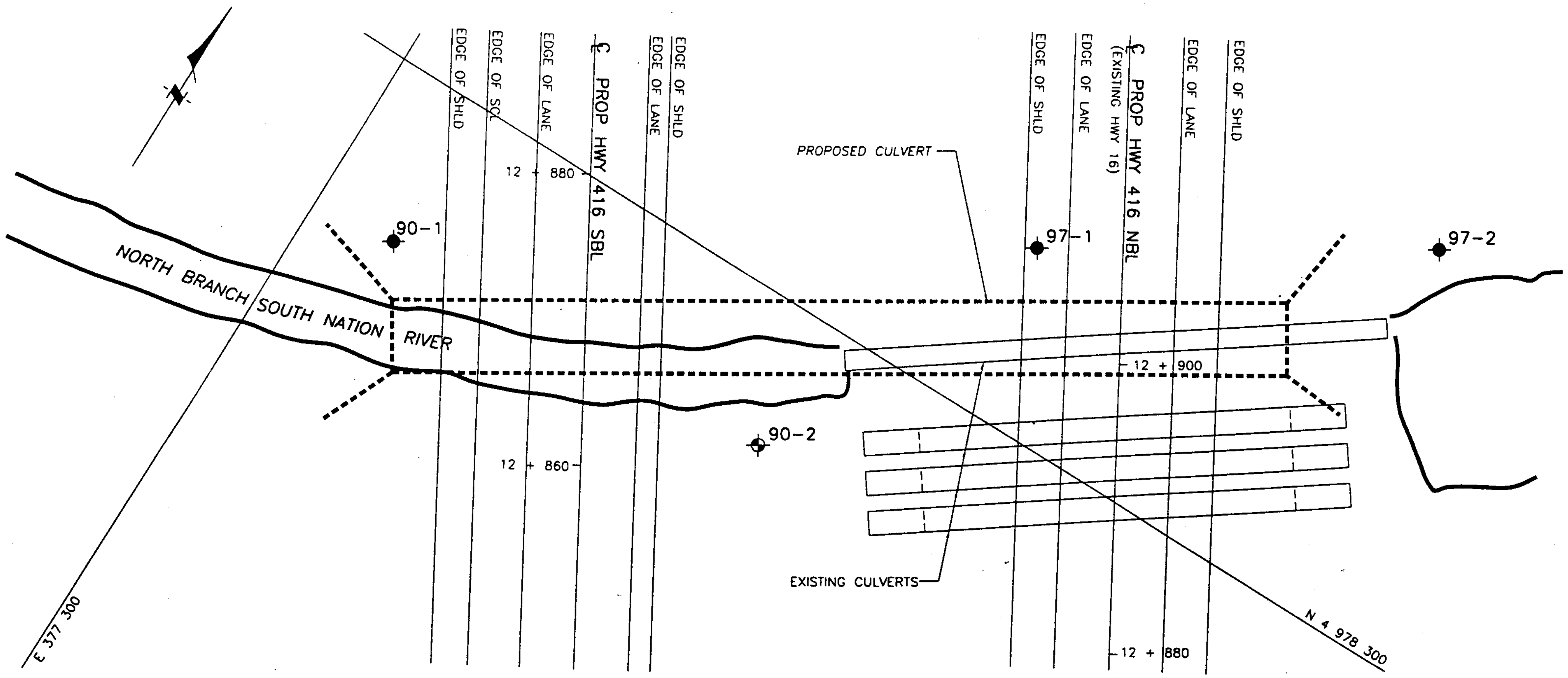
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 101-91-01

HWY 416 & NORTH BRANCH SOUTH NATION RIVER
(CULVERT STRUCTURE)
BORE HOLE LOCATIONS & SOIL STRATA

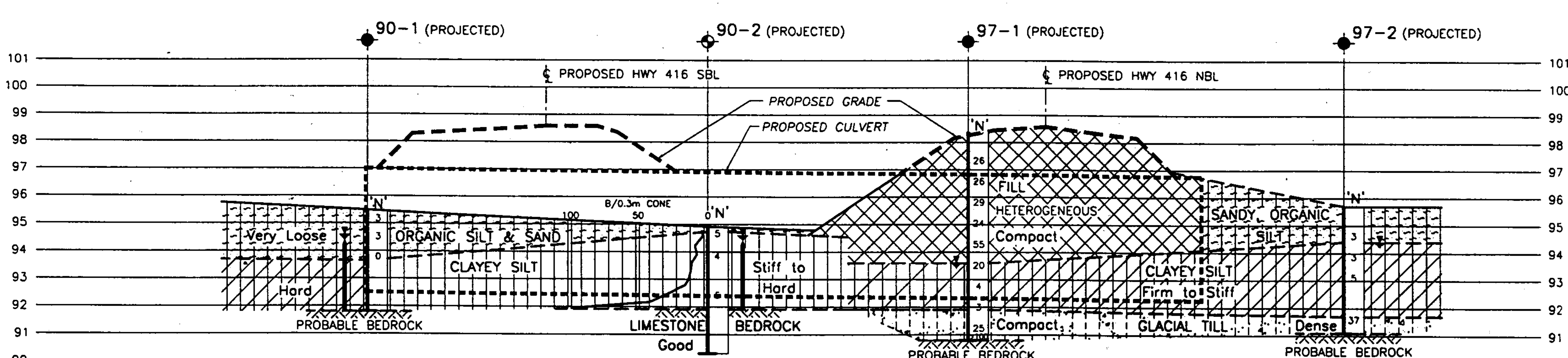
SHEET

JACQUES, WHITFORD LIMITED



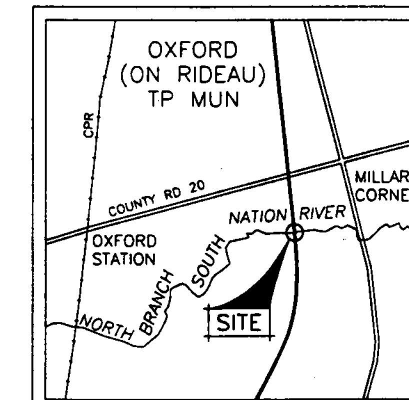
PLAN

SCALE 5m 0 5m



PROFILE ALONG CULVERT

SCALE 5m 0 5m HOR; 2.5m 0 2.5m VERT



KEY PLAN

SCALE 1km 0 1 2km

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 tine of investigation 97 05
- WL in Piezometer 91 05
- Piezometer

No	ELEVATION	COORDINATES NORTH	EAST
90-1	95.5	4 978 289.1	377 306.1
90-2	94.9	4 978 290.3	377 334.5
97-1	98.4	4 978 312.0	377 343.5
97-2	95.7	4 978 326.6	377 367.0

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

HWY No 416			DIST 9
SUBM'D JLL	CHECKED	DATE 1997-06-02	SITE
DRAWN GBB	CHECKED	APPROVED	DWG 1019101-B