Geocres No
31B-70

GIFFELS ASSOCIATES LIMITED

FOUNDATION INVESTIGATION
HWY 416 UNDERPASS AT JOCHEMS ROAD
(STRUCTURES 6A AND 6B)

W.P. 369-89-04, SITE #16-313/1 (NBL)
W.P. 369-89-07, SITE #16-313/2 (SBL)
HWY. 416, DISTRICT 9, EASTERN REGION
GEOCRES # 31B-70

APRIL 26, 1991
PROJECT NO. 10187

JACQUES, WHITFORD LIMITED

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to

Giffels Associates Limited

on

Foundation Investigation

Highway 416 Underpass at Jochems Road
(Structures 6A and 6B)

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Hwy. 416
District 9
Eastern Region

Jacques, Whitford Limited

April 26, 1991

Project No. 10187

FOUNDATION INVESTIGATION REPORT

for

Highway 416 Underpass at Jochems Road
(Structures 6A and 6B)

W.P. 369-89-04, Site #16-313/1 (NBL)
W.P. 369-89-07, Site #16-313/2 (SBL)
DISTRICT 9, EASTERN REGION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out at the above noted site in the Township of Edwardsburgh, Ontario. The investigation was carried out in accordance with our proposals dated August 1 and October 15, 1990. Authorization to carry out the work was provided by Mr. R.W. Bratty, P.Eng., of Giffels Associates Limited on November 1, 1990.

This report contains factual information obtained from this investigation pertaining to the subsurface conditions.

2.0 SITE DESCRIPTION AND GEOLOGY

The site is located along existing Highway 16 some 7.5 kilometres north of Spencerville, Ontario. The proposed Jochems Road overpass is to be located approximately 50 m south of the existing Jochems Road intersection. The topography in the vicinity of the proposed intersection is generally undulating. The proposed intersection is low lying relative to the surrounding area. The existing ground slopes upward from the intersection at about 1% to 2% in the east and west directions. The existing Jochems Road is a two-lane gravel road. Outside of the right-of-ways of existing Highway 16 and Jochems Road, the site is generally treed. Deterioration of vegetation and surface water ponding were observed at the southwest quadrant of the existing intersection.

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 of the Oxford Formation bedded with sandstone. Overburden thickness is in the order of 10 m to 15 m.

3.0 PROCEDURE

3.1 Field Investigation

Prior to the onset of the drilling investigation, the necessary utility clearances were obtained by our site personnel.

The field work for this investigation was carried out between November 15 and 20, 1990. A total of eight (8) boreholes, (numbered 90-1 to 90-8) were put down at the site. Boreholes 90-1, 90-2, 90-7 and 90-8 were put down at the approach fill locations. Boreholes 90-3 to 90-6 inclusive were put down at the proposed abutment locations. The test locations and the proposed structure locations are indicated on Drawing No. 3698904-A provided in Appendix 2.

All boreholes were put down using a track-mounted power auger drill suitably equipped for soil and bedrock sampling. Due to the high cobble and boulder content of the overburden, hollow stem augers, solid stem augers, B-sized casing and rock coring techniques were employed during the course of the investigation to advance the boreholes.

The boreholes were put down to depths ranging from 2.9 m to 17.6 m. Boreholes 90-3 and 90-6 were terminated after coring in BWL-size 2.6 m and 2.9 m into bedrock. The remaining boreholes (Boreholes 90-1, 90-2, 90-4, 90-5, 90-7 and 90-8) were terminated at depths ranging from 2.9 m to 11.4 m upon solid stem auger refusal.

The overburden soils encountered were sampled by means of a split tube sampler during the performance of Standard Penetration Tests (SPT) (ASTM D1586). Sampling was intended to be conducted on a near continuous basis (intervals of 0.76 m). Due to the high cobble and boulder content in the overburden below depths ranging from 2 m to 8 m, the SPT conducted yielded limited penetration of typically less than 75 mm. Sampling below these depths was therefore restricted.

All soil samples recovered were stored in moisture-proof bags and were returned to our Ottawa laboratory for detailed classification and testing.

Standpipe piezometers 19 mm in diameter were installed in all boreholes between depths of 2.9 m and 17.4 m, as shown on the Record of Boreholes in Appendix 1. The standpipes in Boreholes 90-3 and 90-6 were backfilled with sand and sealed within the bedrock. Soil cuttings were then used to backfill these two boreholes from the seal to the ground surface. All remaining boreholes were backfilled to ground surface with soil cuttings and mounded at the ground surface to prevent water infiltration.

3.2 Survey

The borehole locations and ground surface elevations were surveyed by Giffels Associates Limited personnel after completion of the field work. The elevations are referenced to Geodetic datum. The borehole coordinates and elevation data is summarized on Drawing 3698904-A in Appendix 2.

3.3 Laboratory Testing

To identify the behaviour and properties of the soil samples collected during the field investigation, the following laboratory tests were carried out:

- Detailed visual classification,
- Natural moisture content,
- Sieve and hydrometer analyses,
- Atterberg Limits determination.

Samples remaining after testing will be stored in our laboratory for a period of six months after issuance of the final report. They will then be discarded unless we are directed otherwise.

4.0 RESULTS OF THE INVESTIGATION

4.1 Surface Conditions

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 in the Record of the Boreholes and also on Figures 1 to 4 in Appendix 1.

The ground surface elevations at the borehole locations varied from El. 100.0 m to 101.5 m Geodetic at the time of the investigation. The soil profile consists of a surficial topsoil/rootmat, overlying silty sand fill, or sand / silty sand and gravel, overlying a heterogeneous mixture clay, silt, sand, gravel and boulders (glacial till), underlain by limestone bedrock. The bedrock surface was encountered between about El. 86.6 m to 88.4 m. The groundwater table was observed between El. 99.9 m to 101.3 m.

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.

4.1.1 Topsoil/Rootmat

A surficial layer of topsoil was encountered from the ground surface in all boreholes. The thickness of the topsoil/rootmat layer ranges from 100 mm to 250 mm.

4.1.2 Silt Sand (Fill)

Silty sand, trace gravel (fill) was encountered underlying the topsoil in Boreholes 90-5 and 90-6. This thickness of the fill is 0.5 m. The fill has a denseness of loose. The fill is believed to have been placed during the construction of the existing Highway 16.

4.1.3 Sand

Sand, trace silt was encountered underlying the topsoil in Boreholes 90-1 to 90-4 inclusive. The thickness of the sand layer ranges from 0.5 m to 2.0 m.

The SPT conducted in the sand layer yielded N values ranging from 4 to 13, indicating a denseness of loose to compact. The grain size distribution obtained from laboratory sieve analysis of a representative sand sample indicated 95% sand and 5% silt and clay sizes (Figure 1 in Appendix 1).

Based on visual identification and laboratory test, the sand is classified as a cohesionless material.

4.1.4 Silty Sand and Gravel

Silty sand and gravel was encountered underlying the topsoil in Boreholes 90-7 and 90-8. The thickness of the silty sand and gravel ranges from 0.6 m to 1.2 m.

The silty sand and gravel has a denseness of loose to compact (N values of 2 and 32). A grain size distribution analysis carried out on a representative sample of the silty sand and gravel indicated 28% gravel, 39% sand and 33 % silt and clay sizes (Figure 2 in Appendix 1).

4.1.5 Heterogeneous Mixture of Clay, Silt, Sand, Gravel and Boulders (Glacial Till)

A heterogeneous mixture of clay, silt, sand, gravel and boulders (glacial till) was encountered underlying the above noted materials. The glacial till can be generally described as silt with some clay, sand, gravel and boulders. The top of the till stratum was encountered between El. 98.0 m and 100.8 m (depths of 0.7 m to 2.2 m). The till generally consists of a finer upper layer underlain by a coarser layer which contains more cobbles and /or boulders. The transition was encountered between about El. 92 m and El. 98 m, or depths of about 2 m to 8 m.

The SPT conducted within the upper till stratum yielded N values ranging from 7 to over 80, indicating a denseness of loose to very dense, and typically in the compact to dense range. The majority of the SPT conducted in the lower coarser till layer met refusal on cobbles and/or boulders before the required penetration of 450 mm was achieved. The N values obtained are typically over 50 (though most are influenced by the presence of cobbles and boulders), indicating a denseness of very dense.

The results of the laboratory tests on the glacial till are provided on the Record of Boreholes and on Figures 3 and 4 in Appendix 1, and are summarized below:

Property	Range	# Tests	Average
Unit Weight (kN/m^3)	21 - 24	9	23
Moisture Content (%)	5 - 22	32	11
% Gravel	0 - 7	6	3
% Sand	3 - 41	6	18
% Silt	28 - 69	5	55
% Clay	18 - 28	5	24
Plastic Limit (%)	14 - 28	5	20
Liquid Limit (%)	12 - 22	5	16
Plasticity Index (%)	1 - 6	5	3

The above grain-size distributions represent the minus 38 mm fraction of the glacial till. Cobbles and boulders are also present in this material. Based on the above tests and visual identification, this till can be classified as a cohesionless material.

4.1.5 Bedrock

Underlying the glacial till, bedrock was encountered and proven by coring in BWL size in Boreholes 90-3 and 90-6. The bedrock surface was encountered at El. 88.4 m and El. 86.6 m (depths of 11.7 m and 14.7 m) in Boreholes 90-3 and 90-6, respectively. The bedrock is a grey, unweathered limestone with close to moderately spaced horizontal fractures. The bedrock is of poor to good quality (RQD ranging from 36% to 93%). Core recoveries ranged between 93% to 100%.

In boreholes where coring was not conducted (Boreholes 90-1, 90-2, 90-4, 90-5, 90-7 and 90-8), solid stem auger refusal was encountered between El. 88.8 m and El. 97.7 m (depths of 2.9 m to 11.4 m). At borehole locations where bedrock coring was not carried out, it could not be determined whether auger refusal was encountered in glacial till or on bedrock.

4.2 Groundwater

Groundwater levels were recorded during drilling and in the standpipe piezometers after drilling. Groundwater levels were recorded between El. 99.9 m and 101.3 m (depths of 0.0 m to 1.0 m). Groundwater levels are subjected to seasonal fluctuations and can vary from the values given in this report.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 Proposed Development

The site is located at approximately 50 m south of the existing intersection of Highway 16 and Jochems Road in the Township of Edwardsburgh, Ontario (refer to the Key Plan provided on Drawing No. 3698904-A in Appendix 2).

The proposed bridge structures are part of the Highway 416 development from Highway 401 to Highway 43. The Jochems Road structures are to consist of the following components:

- Two (2) 37-metre single span fly-over structures spanning over Highway 416 southbound lane (SBL) and northbound lane (NBL).
- The structures will be supported by four (4) abutments with associated approach fills and median fills.
- Fill heights at abutment locations are to range from approximately 9 m to 11 m.

5.2 Geotechnical Assessment

Abutments may be founded on spread footings perched within compacted Granular 'A' fill. Structure foundations may also consist of conventional spread footings placed below frost depth on undisturbed glacial till.

The use of perched abutments appears to be the more viable alternative at this site due to the relatively high groundwater level, and the added excavation and concrete placement required for spread footings placed on glacial till.

The approach and median fills of up to about 11 m in height may be constructed using side slopes of 2 horizontal to 1 vertical for granular borrow, or side slopes of 2.5 horizontal to 1 vertical for fine-grained borrow. No embankment stability and settlement problems are anticipated.

This report contains our detailed recommendations in the following areas:

1) Structure Foundations
2) Abutment Backfill
3) Approach / Median Fills
4) Construction Considerations

5.3 <u>Structure Foundations</u>

5.3.1 Perched Abutments

The abutments may be founded on spread footings perched within compacted Granular 'A' fills. Silty sand fill was encountered underlying the topsoil in Boreholes 90-5 and 90-6. To ensure uniform density under the perched abutment, and that the required degree of compaction is achieved, the existing fill should be removed and replaced with compacted Granular 'A' fill. Prior to the placement of the granular fill, the following is recommended:

- Remove all surficial organic/loosened materials and existing fill within the plan limits of the granular core.

- Proof roll the exposed surface. Soft areas revealed under proof rolling should be excavated.

- Construct granular pads using OPSS Granular 'A' material, and in accordance with details shown on Figure 5 in Appendix 1. The Granular 'A' should be compacted in accordance with OPSS 501.

Spread footings placed on granular pads constructed as recommended above may be designed based on the following bearing pressures:

SBL Structure

Footing Location	Underside Abutment Footing Elev. (m) *	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
West Abut.	103.5	850 kPa	325 kPa
East Abut.	104.0	850 kPa	325 kPa

* Elevations supplied by Giffels Associates Limited

NBL Structure

Footing Location	Underside Abutment Footing Elev. (m)*	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
West Abut.	104.0	850 kPa	325 kPa
East Abut.	104.0	850 kPa	325 kPa

* Elevations supplied by Giffels Associates Limited

The above bearing pressures have been calculated based on a footing width (B) of 4 m. The S.L.S. Type II bearing pressure has been calculated assuming that a total settlement of 25 mm is satisfactory. If a total settlement of up to 30 mm is considered satisfactory, the Bearing Capacity at S.L.S. Type II can be increased to 350 kPa.

A minimum earth cover of 1.8 m over the footings should be provided for frost protection purposes and has been assumed in the calculations.

Sliding resistance between the concrete footing and the Granular 'A' should be calculated in accordance with Section 6-7.3.3.2 of the O.H.B.D.C. using a factored friction coefficient of 0.56. This coefficient is obtained assuming an unfactored angle of friction of 35 degrees. Sliding resistance can be supplemented if necessary by constructing shear keys at the base of the footing.

5.3.2 Spread Footings

As an alternative to the perched abutments, the structures can be supported on conventional spread footings founded on the undisturbed glacial till. All footings must have a minimum earth cover of 1.8 m for frost protection. Spread footings placed on the glacial till may be designed based on the following bearing pressures:

SBL Structure

Footing Location	Foundation Elev. (m)	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
West Abut.	97.5 and below	900 kPa	450 kPa
East Abut.	97.5 and below	900 kPa	450 kPa

NBL Structure

Footing Location	Foundation Elev. (m)	Factored Bearing Capacity at U.L.S.	Bearing Capacity at S.L.S. Type II
West Abut.	98.5 to 97.5	725 kPa	350 kPa
East Abut.	99.5 to 98.5	725 kPa	350 kPa

The above bearing pressures have been calculated based on a footing width of 4 m. The S.L.S. Type II bearing pressure has been calculated based on 25 mm of allowable settlement.

Sliding resistance between the concrete and the foundation soil can be calculated using a factored friction coefficient of 0.41, assuming an unfactored angle of friction of 27 degrees.

To protect the cohesionless glacial till from being disturbed due to weather and construction activities, it is recommended that a working slab of lean concrete be placed on the bearing surfaces within six (6) hours after footing excavation.

To facilitate construction of the footings, a dewatering scheme will be required to lower the water level below the excavation (bearing) level. Refer to Section 5.6 for details.

5.4 Abutment Backfill

The abutments should be backfilled with free draining material such as OPSS Granular 'A' or Granular 'B' Type I or Type II, to prevent hydrostatic pressure build-up.

Computation of earth pressures should be in accordance with Section 6-6.1.2.1 of the O.H.B.D.C. For abutments that are designed to allow rotation, active earth pressure may be used for design. 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' Type I
Bulk unit weight, γ (kN/m^3)	22.0	21.2
Effective friction angle, ϕ'	35°	30°
At Ultimate Limit States		
Coefficient of active earth pressure (K_a)	0.34	0.41
Coefficient of earth pressure at rest (K_o)	0.51	0.58
At Serviceability Limit States		
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 walls should be carried out using hand-operated equipment to prevent overstressing the abutment walls.

5.5 Approach / Median Fills

Fill placement of up to 11 metres is proposed for the approach and median fills within the investigated area. Side slopes of 2 horizontal to 1 vertical would be appropriate for fills constructed of granular borrow or select subgrade materials. If fine-grained borrow materials are to be used, side slopes of 2.5 horizontal to 1 vertical would be appropriate.

All organic, fill and deleterious materials should be stripped and removed prior to fill placement within the entire fill area. Based on the boreholes (Boreholes 90-1, 90-2, 90-7 and 90-8), the anticipated depth of stripping varies from 100 mm to 500 mm.

The exposed surface should be proof rolled and soft areas removed prior to fill placement. The fills should be placed and compacted in accordance with OPSS 212 and 501.

Settlement of the embankment and the underlying soil are not expected to exceed 25 mm and will be largely complete after construction. It is recommended to place the fill early in the construction stage, and to delay the paving, to allow any time dependent portions of these settlements to take place.

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

5.6 Construction Considerations

5.6.1 Dewatering

For the perched abutment system, only minor dewatering will be required during existing fill removal. However, excavations for spread footings at this site are expected to be below the groundwater table. Due to their cohesionless nature, both the fill, sand and the glacial till will likely become unstable under saturated or seepage conditions. A dewatering scheme is therefore required if spread footings placed on glacial till are used.

Dewatering may be achieved by utilizing perimeter ditches within a gravity system in conjunction with a sump pump discharge system to drain accumulated water. Alternatively, a well point system installed outside of the excavation may be used to drawdown the water table. It is recommended that well points be installed concentrically in cased holes, and surrounded by a well screen and a properly graded free draining soil filter.

Other dewatering alternatives can also be considered. The more 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.

5.6.2 Temporary Excavations

In view of the high groundwater table present at the time of the investigation, and the cohesionless nature of the surficial native soil, temporary excavations up to 3 m high should be undertaken using slopes no steeper than 1 horizontal to 1 vertical. Under heavy seepage conditions, flatter side slopes may be required or alternatively a shoring system may be utilized.

5.7 Groundwater Chemistry

Three (3) groundwater samples were submitted to Areco Canada Inc. in Ottawa for pH, sulphate and chloride testing. The test results are summarized below:

Borehole	pH	Sulphate (ppm)	Chloride (ppm)
90-2	9.7	74	34
90-4	7.0	2	68
90-7	7.7	19	372

The above test results indicate that the potential degree of sulphate attack is negligible. However the high chloride ion concentrations and high pH values of above 9.0 indicate positive degree of potential attack on exposed steel.

Based on the above, we recommend that epoxy coated reinforcing steel be used.

6.0 MISCELLANEOUS

The field work for this investigation was carried out under the supervision of M. Corbett, Engineer In Training, utilizing equipment owned and operated by Marathon Drilling Co. Ltd.

The project was carried out under the general supervision of G. Kack, Project Manager. The report was written by both undersigned.

Respectfully submitted,

JACQUES, WHITFORD LIMITED

LICENSED PROFESSIONAL ENGINEER
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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 369-89-04 & 07 | LOCATION Co-ords: N 4 974 164; E 377 735 | ORIGINATED BY M.C.

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

DATUM Geodetic | DATE November 20, 1990 | CHECKED BY G.J.K.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.2	Ground Surface							
99.9	Topsoil (250 mm)	1	SS	4	Nov.22, 1990			
	Sand, trace silt Loose Brown Grey	2	SS	6		99		
98.0	Compact	3	SS	12		98		
2.2	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders	4	SS	19	Native Backfill		22.0	
	(Glacial Till)	5	SS	18		97		
	Compact to Very Dense	6	SS	20		96		
	Grey	7	SS	31		95		
	- Hollow stem auger refusal at El. 94.9m	8	SS	50/8cm		94		
		9	SS	50/3cm		93, 92		
					Piezometer	91		
90.0 10.4	End of Borehole (Solid stem auger refusal)							

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 (%)

SOIL PROFILE | SAMPLES | STRAT PLOT

OFFICE REPORT ON SOIL EXPLORATION

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

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

Ministry of Transportation
Ontario

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 90-2

METRIC

W P 369-89-04 & 07 — LOCATION Co-ords: N 4 974 140; E 377 752 — ORIGINATED BY M.C.

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

DATUM Geodetic — DATE November 20, 1990 — CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.2	Ground Surface							
100.0	Topsoil (200 mm)				Nov.22, 1990 (water level)			
0.2	Sand, trace silt Loose Brown / Grey	1	SS	2				
		2	SS	5		99		
		3	SS	4				0 95 (5)
98.0 2.2	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders (Glacial Till) Loose to Very Dense Grey					98		
		4	SS	7				0 3 69 28
		5	SS	19	Native Backfill	97		
		6	SS	31		96		
		7	SS	52		95		
		8	SS	61			23.0	
	- Hollow stem auger refusal at El. 94.1m					94		
						93		
		9	SS	50/8cm		92		
						91		
		10	SS	50/5cm	Piezometer	90		
88.8 11.4	End of Borehole (Solid stem auger refusal)					89		

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 (%)

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

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

Ministry of Transportation Ontario

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 90-3 METRIC

W P 369-89-04 & 07 LOCATION Co-ords: N 4 974 169; E 377 767 ORIGINATED BY M.C.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BW Casing, Rock Coring COMPILED BY C.K.K.

DATUM Geodetic DATE November 16, 1990 CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.1	Ground Surface								
100.0	Topsoil (125 mm)				▽ Nov.22, 1990				
0.1	Sand, trace silt Loose to Compact Brown	1	SS	1					
		2	SS	13		99			
98.4 / 1.7	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders (Glacial Till) Compact to Very Dense Grey	3	SS	15		98			5 25 52 18
		4	SS	88		97		23.7	
		5	SS	61	Native Backfill				
		6	SS	89		96			
		7	SS	66		95			3 19 (78)
		8	SS	50/8cm		94			
		9	SS	50/8cm		93			
		10	SS	50/8cm		92			
		11	SS	50/8cm		91, 90, 89			
88.4 / 11.7	Bedrock Limestone, bedded with sandstone Poor to Excellent Grey				Seal	88			
		12	BWL RC	REC 100%	Sand Backfill	87			RQD = 92%
		13	BWL RC	REC 93%	Piezometer				RQD = 36%
85.8		14	BWL RC	REC 93%		86			RQD = 50%
14.3	End of Borehole								

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

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

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 90-4

METRIC

W P 369-89-04 & 07 | LOCATION Co-ords: N 4 974 191; E 377 797 | ORIGINATED BY M.C.

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

DATUM Geodetic | DATE November 15, 16, 1990 | CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.0	Ground Surface				Nov.22, 1990				
99.8	Topsoil (150 mm)								
0.2 / 99.3	Sand, trace silt, Loose, Brown	1	SS	5					
0.7	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders (Glacial Till) Compact to Very Dense Grey	2	SS	12	Native Backfill	99	o	20.8	
		3	SS	20		98	o		
		4	SS	42		97	o		
		5	SS	51			o	23.9	
		6	SS	53	Piezometer	96	o		
	Hollow stem auger refusal at El. 95.6m					95			
94.2 / 5.8	End of Borehole (Solid stem auger refusal)								

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

+3, x5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 90-5

METRIC

W P 369-89-04 & 07 LOCATION Co-ords: 4 974 214; E 377 828 ORIGINATED BY M.C.

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

DATUM Geodetic DATE November 15, 1990 CHECKED BY G.J.K.

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 (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.3	Ground Surface										
100.1	Topsoil (200 mm)										
0.2 / 99.6	Silty Sand, trace gravel (Fill) Loose Brown		1	SS	3	▼ Nov.22, 1990; Native Backfill					
0.7	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders (Glacial Till) Compact Grey		2	SS	12		99		○		
	- Hollow stem auger refusal at El. 98.0m		3	SS	32	Piezometer	98		○⊢⊣		7 41 28 24
97.4 / 2.9	End of Borehole (Solid stem auger refusal)										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 90-6 METRIC

W P 369-89-04 & 07 | LOCATION Co-ords: N 4 974 236; E 377 858 | ORIGINATED BY M.C.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger, BW Casing, Rock Coring | COMPILED BY C.K.K.

DATUM Geodetic | DATE November 17, 19, 1990 | CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.3	Ground Surface								
101.1 / 0.2	Topsoil (225 mm); Silty Sand, trace gravel (Fill) Loose Brown	1	SS	2	Nov.22, 1990				
100.6 / 0.7	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders (Glacial Till) Compact to Very Dense	2	SS	11		100			0 9 69 22
		3	SS	70		99			
		4	SS	44		98		23.0	
		5	SS	43					
	Brown / Grey	6	SS	30		97		23.7	
		7	SS	28	Native Backfill	96			
		8	SS	16		95			
		9	SS	29					
		10	SS	33		94			
	Hollow stem auger refusal at El. 92.9m	11	SS	56		93			
		12	SS	50/3cm		92			
		13	SS	114		91, 90			
		14	SS	65		89			
		15	BWL RC	REC 5cm		88			
86.6		16	SS	50/3cm	Seal	87			
14.7	Bedrock Limestone, bedded with sandstone Good to Excellent Grey	17	BWL RC	REC 94%	Sand Backfill	86			RQD = 85%
		18	BWL RC	REC 93%	Piezometer	85, 84			RQD = 93%
83.7 / 17.6	End of Borehole								

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.

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 90-7

METRIC

W P 369-89-04 & 07 — LOCATION Co-ords: N 4 974 272; E 377 881 — ORIGINATED BY M.C.

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

DATUM Geodetic — DATE November 19, 1990 — CHECKED BY G.J.K.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ (kN/m3)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.3	Ground Surface							
101.1	Topsoil (200 mm)							
0.2	Silty Sand and Gravel	1	SS	1	Nov.21, 1990 (water level)			
	Compact Brown	2	SS	32		100		28 38 (33)
99.9 / 1.4	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders	3	SS	15	Native Backfill			1 14 57 28
	(Glacial Till)	4	SS	43		99		
	Compact to Very Dense	5	SS	82		98		
	Grey	6	SS	31		97	23.8	
		7	SS	85	Piezometer	96		
	- Hollow stem auger refusal at El. 95.7m					95		
94.7 / 6.6	End of Borehole (Solid stem auger refusal)							

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 (%)

$+^3$, x^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 90-8

METRIC

W P 369-89-04 & 07 LOCATION Co-ords: N 4 974 248; E 377 899 ORIGINATED BY M.C.

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

DATUM Geodetic DATE November 19, 1990 CHECKED BY G.J.K.

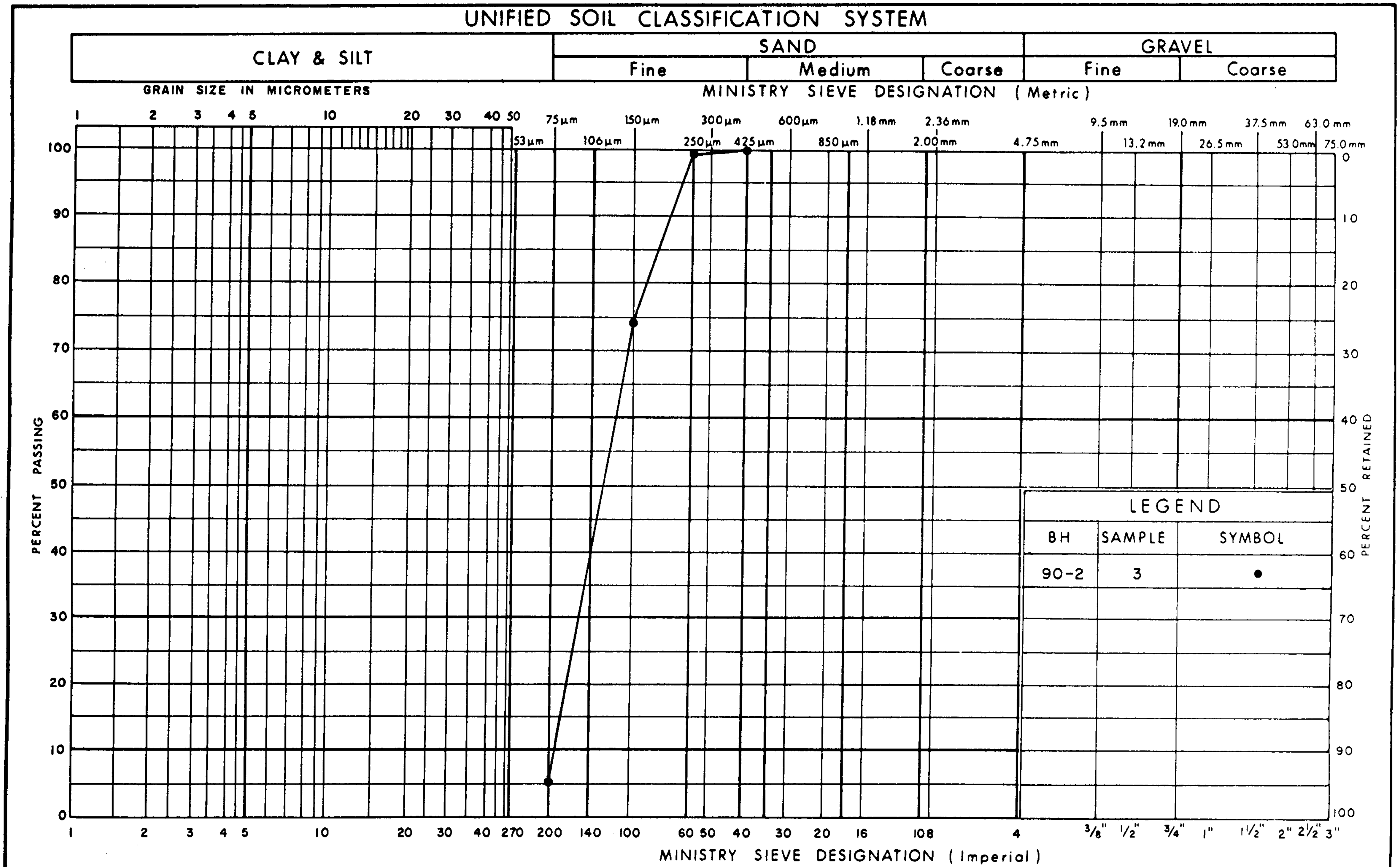
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
101.5	Ground Surface										
101.4	Topsoil (100 mm)										
0.1	Silty Sand and Gravel		1	SS	2		101				
100.8	Loose Brown										
0.7	Het. Mixture of Silt, Clay, Sand, Gravel and Boulders		2	SS	27	Nov.22, 1990					
							100				
	(Glacial Till)		3	SS	34	Native Backfill					
	Compact to Very Dense Brown / Grey						99			23.2	
			4	SS	76	Piezometer					
	-Hollow stem auger refusal at El. 97.8m		5	SS	129/22cm		98				
97.7 / 3.8	End of Borehole (Solid stem auger refusal)										

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

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

OFFICE REPORT ON SOIL EXPLORATION

78 12 M



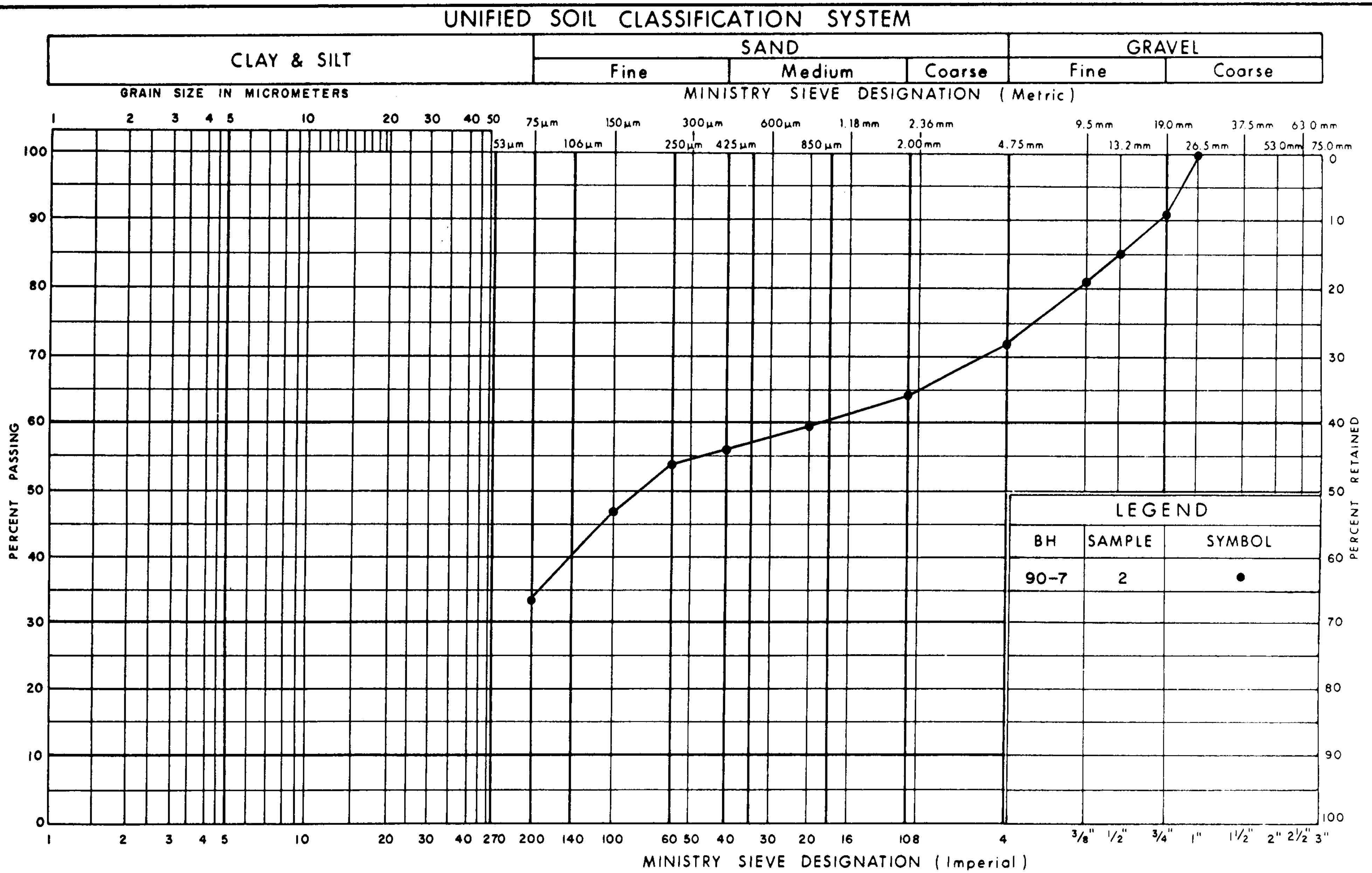
Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SAND

FIG No 1

W P 369-89-04 & 07

78 12 M



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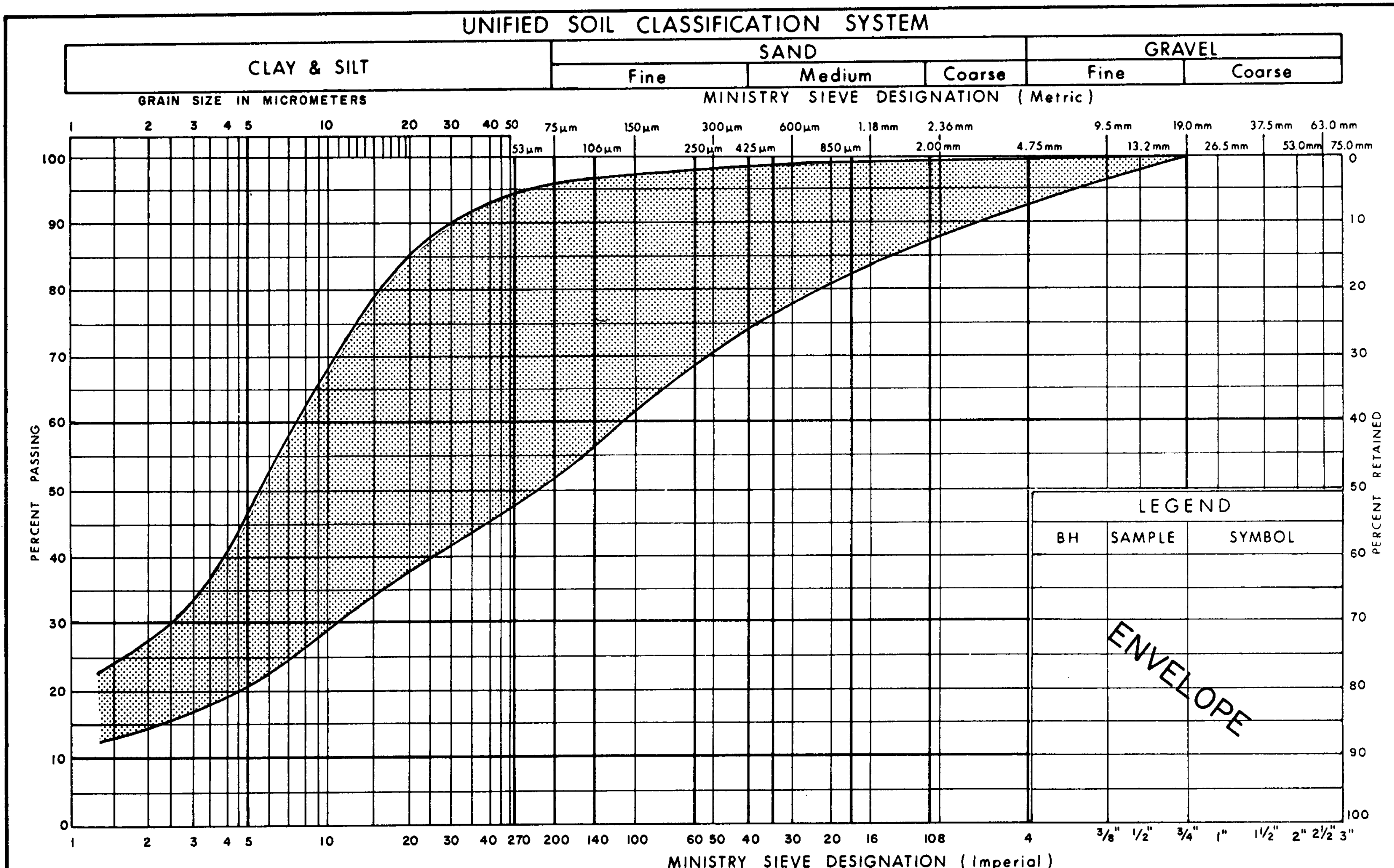
Ontario

GRAIN SIZE DISTRIBUTION
SILTY SAND & GRAVEL

FIG No 2

W P 369-89-04 & 07

78 12 M



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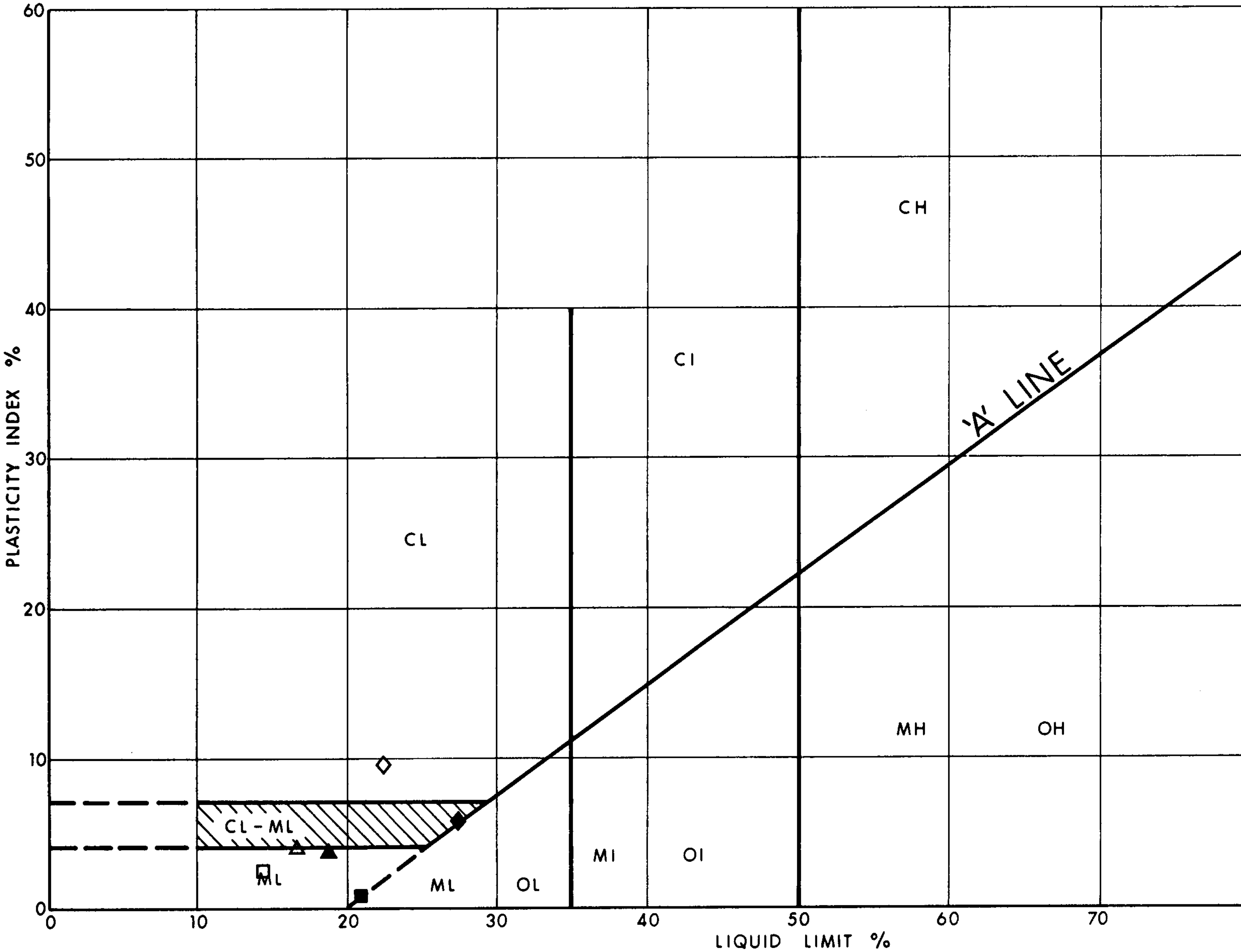
GRAIN SIZE DISTRIBUTION

HET MIXTURE OF CLAY, SILT, SAND, GRAVEL & BOULDERS (Glacial Till)

FIG No 3

W P 369-89-04 & 07

Oct 75, FF-S-21

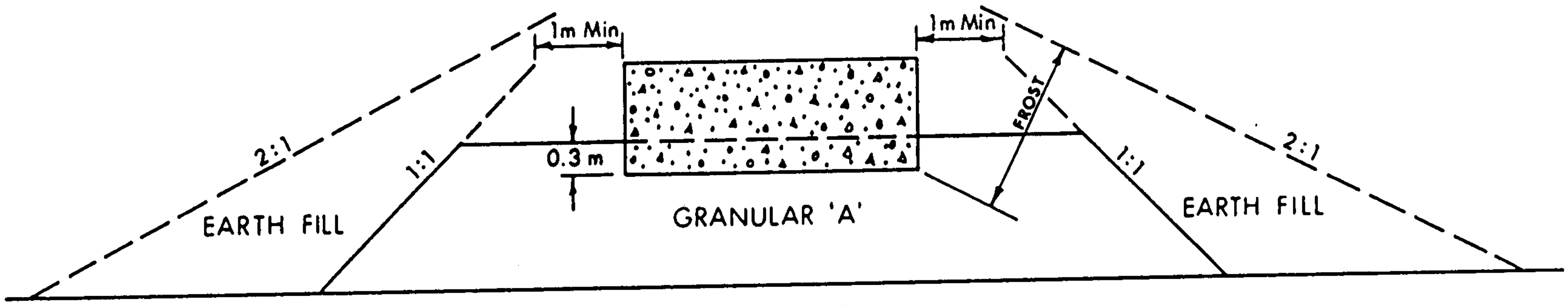


LEGEND		
BH	SAMPLE	SYMBOL
90-2	4	■
90-3	3	□
90-3	7	▲
90-5	3	△
90-6	2	◆
90-7	3	◇

Ministry of Transportation
Ontario

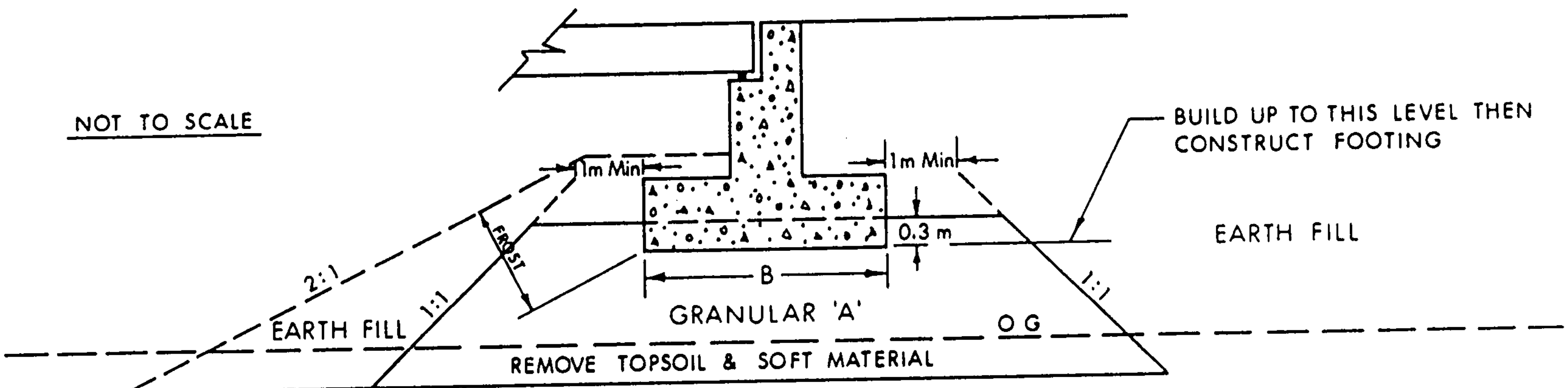
PLASTICITY CHART
HET MIXTURE OF CLAY, SILT, SAND, GRAVEL & BOULDERS (Glacial Till)

FIG No 4
W P 369-89-04 & 07



X SECTION

NOT TO SCALE



LONGITUDINAL SECTION

NOTES:

1 - REMOVE TOPSOIL &/OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' & EARTH FILL.

2 - PLACE GRANULAR 'A' & EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO CURRENT M T O STANDARDS.

3 - CONSTRUCT CONCRETE FOOTING.

4 - PLACE REMAINDER OF GRANULAR 'A' & EARTH FILL AS REQUIRED.

Ministry of Transportation Ontario	ABUTMENT ON COMPACTED FILL SHOWING GRANULAR 'A' CORE	FIG No 5 W P 369-89-04 & 07

METRIC

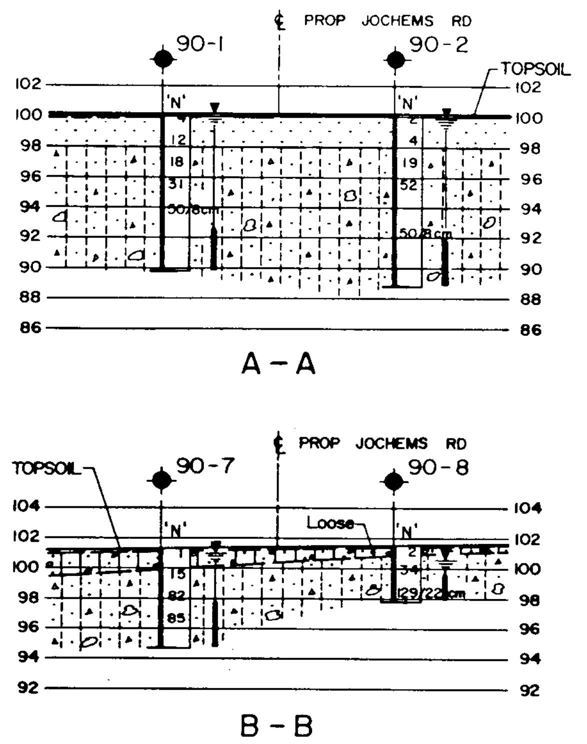
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 369-89-04 & 07

HWY 416 UNDERPASS AT JOCHEMS RD
BORE HOLE LOCATIONS & SOIL STRATA

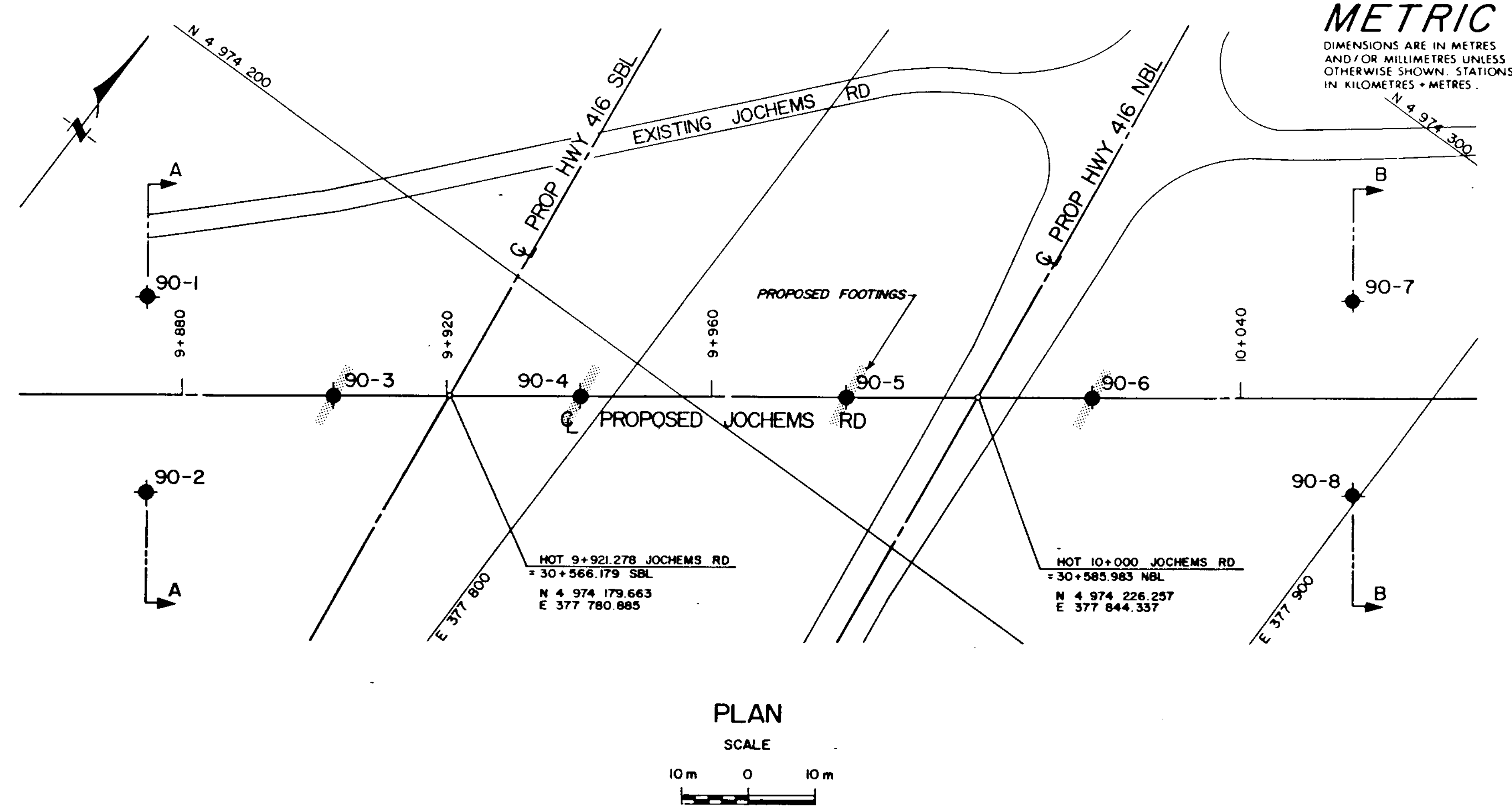
SHEET

JACQUES, WHITFORD LIMITED



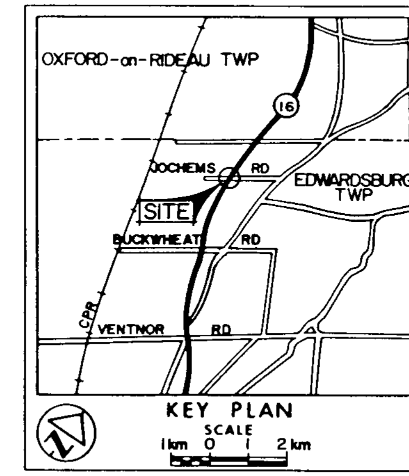
SECTIONS

SCALE
10m 0 10m HOR
5m 0 5m VERT



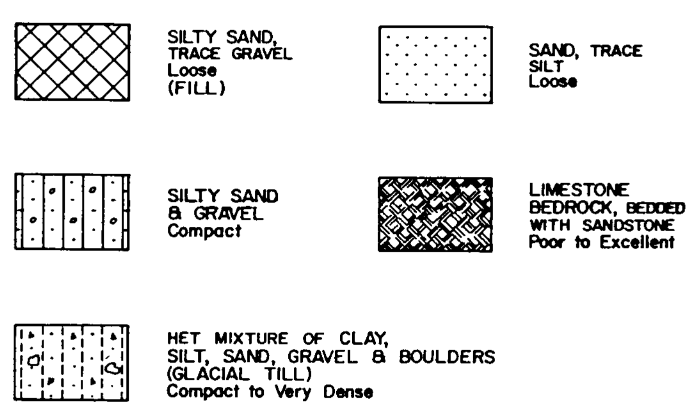
PLAN

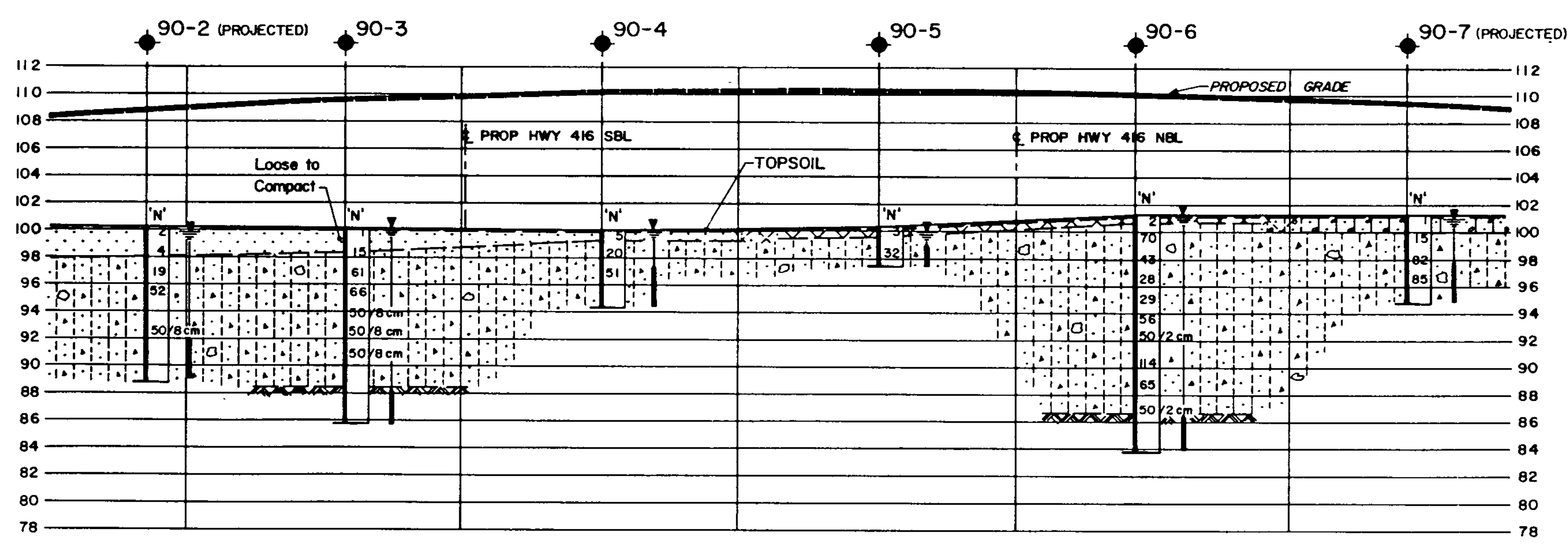
SCALE
10m 0 10m



KEY PLAN
SCALE
1km 0 1 2km

SOIL STRATIGRAPHY LEGEND





PROFILE PROPOSED JOCHEMS RD

SCALE
10m 0 10m HOR
5m 0 5m VERT

LEGEND

Symbol	Description
●	Bore Hole
⊕	Dynamic Cone Penetration Test (Cone)
◆	Bore Hole & Cone
N	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
▽	WL at time of investigation 90 11
▼	WL in Piezomer
	Piezometer

No	ELEVATION	CO-ORDINATES NORTH	EAST
90-1	100.2	4 974 164	377 735
90-2	100.2	4 974 140	377 752
90-3	100.1	4 974 169	377 767
90-4	100.0	4 974 191	377 797
90-5	100.3	4 974 214	377 828
90-6	101.3	4 974 236	377 858
90-7	101.3	4 974 272	377 881
90-8	101.5	4 974 248	377 899

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-70

HWY No 416			DIST 9
SUBM'D CKK	CHECKED	DATE 1991 03 27	SITE 16-313/182
DRAWN GBB	CHECKED	APPROVED	DWG 3698904-A