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STR. SITE No.

HWY. No. 410

LOCATION Prop. Brampton Es Ler Outlet Extension North of Williams Parkway

No of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

G.I.-30 SEPT. 1976

Cont 88-67

Ministry of
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Ontario

FOUNDATION DESIGN SECTION

foundation investigation and design report

F

ENGINEERING MATERIALS OFFICE
FOUNDATION DESIGN SECTION

WP 21-79-13 DIST 6

HWY 410 STR SITE -

BRAMPTON ESKER OUTLET EXTENSION
(in vicinity of Williams Parkway)

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DATE MAR 16 1987

FOUNDATION INVESTIGATION REPORT

For

Brampton Esker Outlet Extension

Hwy. 410 and Williams Parkway

W.P. 21-79-13

District 6, Toronto

INTRODUCTION

This report summarizes the information obtained from a foundation investigation carried out at the above-noted site between 86 09 23 and 86 09 24 and between 86 12 17 and 86 12 22. The fieldwork consisted of 6 sampled boreholes (BH 1, 2 and 12 to 15) advanced by means of hollow stem augers. A dynamic cone penetration test accompanied two of the boreholes. The six boreholes were advanced to depths ranging between 7.8 and 15.5 m below the ground surface.

In Sept. 1986, a subsurface investigation was carried out immediately adjacent to this site for a proposed Esker Outlet alignment which has since been revised to the alignment described in this report. The investigation consisted of 5 boreholes identified as BH 1 to BH 5. BH 1 and BH 2 have been incorporated in this report.

SITE DESCRIPTION AND GEOLOGY

The site is located in the vicinity of the intersection of Hwy. 410 (Heart Lake Road) and Williams Parkway, in the City of Brampton, Municipality of Peel.

Land in the general area is predominantly used for residential subdivisions. However, an extensive gravel pit immediately to the north of the site is still operational. A large park with a pond is situated in the north-west quadrant of the intersection of Heart Lake Road and Williams Parkway. Topography across the immediate site is gently rolling with a large knob in the north-west quadrant of the intersection. The general topography across the site slopes gently towards the southeast.

The site is located in the physiographic region known as the "Peel Plain". This region is generally characterized by a level to undulating "till or boulder clay plain" underlain by shale or limestone bedrock. Locally, there is a partly buried esker which runs to the east of the site. The esker serves as a source of aggregate material and as an aquifer for local wells.

SUBSURFACE CONDITIONS

The predominant deposits across the site are non-cohesive in nature and consist primarily of fine to medium sands, and of a heterogeneous mixture of sand and gravel (glacial till). Silty clay fill is also encountered.

The boundaries between the various soil types, in-situ and laboratory test results, as well as groundwater levels are shown on the Record of Borehole sheets in the Appendix. The location of each borehole is shown in plan on Dwg. No.217913-A together with a longitudinal stratigraphical section along the Esker Outlet Extension centreline.

For information only, the Record of Borehole Sheets for BH 3, 4 and 5, previously mentioned, have been included in the Appendix. The location of these boreholes are also shown in plan on Dwg. No. 217913-A.

The various soils encountered at this site are described as follows:

Topsoil

The area through which the Esker Outlet Extension will be constructed is generally covered by a veneer of topsoil with the obvious exception of where the ground is covered by pavement or shoulder material. The thickness of the topsoil varies between 120 and 250 mm and consists primarily of silt with organics or silty clay with organics.

In BH 3, the original topsoil was encountered under approximately 5.2 m of fill material. At this location, the lower topsoil stratum was found to have a thickness of about 300 mm.

Silty Clay (Fill)

Silty clay fill was encountered in BH 1, 2, 12, 13 extending from under the topsoil to depths ranging between 1.5 and 7.9 m below the ground surface.

The results of Atterberg Limits testing carried out on 7 samples of this cohesive material are shown on Figure 1 in the Appendix and can be summarized as follows:

		Range (%)
Moisture Content	(W_o)	10 - 24
Liquid Limit	(W_L)	21.5 - 34.5
Plastic Limit	(W_p)	15 - 22
Plasticity Index	(I_p)	4.5 - 15

The results indicate that this cohesive material consists of a silty clay of low plasticity (CL group).

No field or laboratory shear tests were carried out on samples of this material. However, based on the interpretation of standard Penetration Test 'N' values obtained within the material, it could be assumed that the fill has been well compacted.

The results of grain size distribution tests carried out on 7 samples of this material are shown in envelope form on Figure 2 in the Appendix, and are summarized as follows:

	Range (%)	Average (%)
Gravel	3 - 13	6
Sand	17 - 58	37
Silt	29 - 62	42
Clay	5 - 30	15

It should be noted that within the fill material it may be possible to encounter occasional cobbles and boulders. Similarly, it is possible to encounter large buried tree stumps. Occasional large tree stumps were encountered in the immediate vicinity of this site in a recent excavation carried out for the construction of the Hwy. 410 ramps immediately north of Williams Parkway. In addition, tree stumps were encountered in this investigation in BH 13, as shown on the Record of Borehole Sheet #3.

Seams of fine to medium sand were randomly found within the fill material. The seams vary in thickness, but are generally less than 1 m.

Sand with gravel, trace silt (Fill)

Well graded sand with gravel fill was found in BH 14 and 15 extending from the ground surface down to a depth of 3.0 and 3.7 m respectively.

A grain size distribution test was carried out on a sample of this material and the results indicate 26% gravel, 62% sand, 10% silt and 2% clay. The results are plotted on Figure 3. However, based on visual examination of the recovered samples, it appears that the gravel content varies up to 40%±.

Occasional thin seams of silt or fine sand may be randomly encountered within this non-cohesive fill, as well as occasional cobbles.

Based on the interpretation of Standard Penetration Test 'N' values, this fill is considered to be well compacted.

Fine to Medium Sand

A deposit of fine to medium sand was encountered below the silty clay fill in BH 1, 2 and 12. In BH 1, this non-cohesive deposit was found to extend from 1.5 to 2.9 m below the ground surface. In BH 2, the deposit was found to be the thickest, and encountered between depths of 2.4 and 10.5 m, while in BH 12, this sand stratum was found between depths of 7.9 and 9.4 m below the ground surface.

Based on the interpretation of Standard Penetration Test 'N' values ranging generally between 17 and 25 blows/0.3 m, the deposit is considered to be in a compact state. However, loose and dense zones may also be encountered.

Grain size distribution tests were carried out on 4 samples of this non-cohesive material and the results are shown in Figure 4 in the Appendix. The results can also be summarized as follows:

	Range (%)
Gravel	0 - 3
Sand	87 - 91
Silt and Clay	4 - 13

Based on the results, this material can be described as a fine to medium sand, trace gravel, silt, clay.

In BH 2, it was determined that below Elev. 229±, the sand particles become coarser with depth.

The natural moisture content of this deposit was found to vary between 2.5% and 4.5% in the 4 samples tested.

It should be noted that when this cohesionless deposit is excavated or directly tunnelled into, below the prevailing groundwater level, seepage, caving or 'boiling' could result.

Silty Clay

A seam of silty clay was encountered in BH 2 at a depth of 10.5 m below the ground surface. The thickness was determined to be approximately 1.5 m.

Based on visual identification, it appears that the deposit consists of a silty clay of low plasticity (CL group), with sand, trace gravel.

Based on a Standard Penetration Test 'N' value of 10 blows/0.3 m, this cohesive deposit is considered to have a stiff consistency.

Heterogeneous Mixture of Sand and Gravel, trace silt, clay (Glacial Till)

The predominant material across this site consists of a glacial mixture of sand and gravel and was encountered in all boreholes at depths ranging between 2.4 and 7.9 m below the ground surface. The surface of this generally non-cohesive till was found to undulate as it was encountered between Elev. 225.6 and 234.3.

Based on the interpretation of Standard Penetration Test 'N' values generally over 50 blows/0.3 m, this deposit is considered to be in a dense to very dense state.

Figure 5 in the Appendix illustrates in envelope form the results of grain size distribution tests carried out on 15 samples of this material. The results can be summarized as follows:

	Range (%)	Average (%)
Gravel	29 - 65 (but generally >40)	47
Sand	30 - 55	42
Silt	3 - 13	9
Clay	1 - 4	2

As evidenced by the results, only traces of silt and clay are included. In addition, occasional to frequent cobbles, and possibly boulders may be encountered randomly throughout this deposit.

The natural moisture content as measured in 15 samples of this material was found to range between 3% and 8.5%, with an average moisture content of 6%.

Generally this glacial deposit is cohesionless in nature. However, occasional isolated slightly plastic zones may be randomly encountered. Seams of varying thickness of sand or silt may also be found within the deposit.

It should be noted that if this material is directly tunnelled or excavated into, below the prevailing groundwater level, seepage and caving can be anticipated unless appropriate control measures are adopted.

Sand with Silt

A 1.2 m thick seam of well graded sand with silt was encountered in BH 13 at a depth of 5.2 m below the ground surface.

A grain size distribution test was carried out on a sample of this non-cohesive material, and the results are indicated on Figure 3 in the Appendix. The results can be summarized as follows: 9% gravel, 58% sand, 23% silt and 10% clay. As evidenced, the deposit also contains traces of gravel and clay.

Sand with Gravel

A 3.6 m thick deposit of sand with gravel was encountered in BH 15 at a depth of 3.7 m below the ground surface.

A grain size distribution test was carried out on a sample of this non-cohesive material, and the results are shown on Figure 3 in the Appendix. The results indicate that the tested sample consisted of 30% gravel, 58% sand, 10% silt, and 2% clay.

Based on the interpretation of Standard Penetration Test 'N' values of 29 and 41 blows/0.3 m, this deposit is considered to be in a dense state.

GROUNDWATER CONDITIONS

Standpipes were installed in each borehole with the exception of BH 14 so that stabilized groundwater levels could be determined after the boreholes were back-filled. The standpipes were installed such that they would effectively function as piezometers.

The standpipes consisted of 13 mm O.D. CPVC pipe and were saw-slotted at the tip for sections varying between 200 and 450 mm. The slotted sections were enveloped in free-draining 'P-Gravel' and the boreholes were sealed with bentonite pellets above and below the slotted standpipe section. The impermeable seals were a minimum of 350 mm thick. This type of installation ensured that the standpipes would function as piezometers.

The Record of Borehole Sheets in the Appendix illustrate the standpipe installation details.

Table 1 below summarizes the groundwater conditions across the site as determined by the field measurements within the standpipes or open boreholes.

The groundwater levels shown on the Record of Borehole Sheets most probably represent the seasonal stabilized conditions on the date indicated. It should, however, be noted that the levels may fluctuate somewhat in accordance with the time of year.

No artesian conditions were encountered with the area investigated.

As previously noted, a small pond is situated in the north-west quadrant of the intersection of Heart Lake Road and Williams Parkway. The pond is located about 350 m west of Heart Lake Road. On 86 12 23, the level of the water/ice in the pond was at Elev. 229.6±.

TABLE 1
GROUNDWATER LEVELS

Borehole (BH)	1	2	12	13	14	15
Ground Elev. @ Borehole	231.1	237.5	240.8	237.4	237.3	238.2
Date Standpipe Installed	86 09 23	86 09 24	86 12 17	86 12 18	86 12 22	86 12 19
Standpipe Tip Elev.	225.2	227.7	225.5	224.9	N/A*	224.2
Groundwater Level in open Borehole **	226.8	227.0	226.1	225.7	226.1	
Standpipe Groundwater Levels						
86 09 25	227.4	-	-	-	-	-
86 09 26	227.6	STDPIPE. DRY	-	-	-	-
86 10 08	227.7	***	-	-	-	-
86 12 05	227.5	"	-	-	-	-
86 12 22	227.4	"	227.6	227.3	-	226.8
87 01 09	227.6	"	227.6	227.3	-	226.8

NOTES:

* No standpipes installed

** Levels were measured in open boreholes at completion of borehole sampling. Levels may not therefore be stabilized.

*** Groundwater level in BH 2 below Elev. 227.7 as of 87 01 09.

DISCUSSION AND RECOMMENDATIONS

It is proposed to install a 450 mm diameter pipe extending from the southeast corner of the football field in the park in the northwest quadrant of the interchange to the terminal of the existing Esker Outlet pipe on the east side of Hwy. 410. Dwg. 217913-A in the Appendix indicates the location of the proposed pipe both in plan and profile. For the purpose of this report, an arbitrary station of 1+000 was assigned to Point A1. Stations increase towards the plug, which is located at Sta. 1+130±.

The proposed Esker Outlet Extension will be approximately 130 m long, with a 0.3% downward slope towards the south east. Point A2, as shown on Dwg. 217913-A, indicates a change in the horizontal alignment of the pipe.

The subsurface investigation consisted of advancing 6 boreholes to depths ranging between 7.8 and 15.5 m below the ground surface. Each borehole was advanced a minimum of 3 m below the proposed invert elevation. A standpipe was installed in each borehole, except BH 14, for groundwater level monitoring.

Within the section being considered in this report, the proposed invert of the Esker Outlet pipe varies between approximately Elev. 227.3 to 226.8.

For the installation of the pipe the following two options can be considered:

I) tunnel entire length;

II) tunnel beneath travelled portion of Hwy. 410, and open-cut the remainder.

It is not desirable to install the pipe by open-cut methods within the section under the travelled portion of Hwy. 410. Within the plan limits of the pavement the pipe invert will be some 9 to 10 m below the pavement surface. Past experience indicates that when a trench is excavated to such depths under an existing pavement, continual future maintenance will be required.

Even though such a deep trench is backfilled with select granular material and strict compaction controls are employed, some additional settlement of the fill material itself will occur over time. Consequently, the portion of pavement which involved the trench will experience numerous cracks and, possibly, dishing. Generally, the deeper the excavation, the more severe the cracking and dishing will be. Trenches with depths in the order of 4 or 5 m or less should not result in major cracking or differential settlement of the overlying pavement.

The following are our recommendations for the construction/installation of the Brampton Esker Outlet Extension.

Alternative I - Tunnel Option

This alternative involves tunnelling the full length of the pipe. However, for this option, the subsurface investigation revealed two areas of concern: 1) the location of the groundwater table, and 2) the glacial till which was encountered at some depth in each borehole. As previously described elsewhere in this report, the glacial till deposit across this site can generally be described as a cohesionless dense to very dense mixture of sand and gravel with occasional to frequent cobbles and boulders. Furthermore, the groundwater level at this site is generally found at the proposed invert elevation or immediately below it. In one area, however, the groundwater level was found above the invert elevation.

The proposed pipe will extend through the cohesionless glacial till stratum. Consequently, tunnelling of a 0.450 m dia. pipe through the till is not practical in view of the denseness of the till material and the likely presence of the cobbles and boulders.

Based on the Foundation Design Section's experience with this type of installation and numerous recent discussions with prominent contractors specializing in this type of work, we feel that consideration should be given to tunnelling a minimum 1.2 m dia. pipe. Such a diameter pipe would allow, if necessary, the manual mining of any obstruction which may be encountered and could not be penetrated by the boring machine.

If a 1.2 m diameter pipe is impractically large for the design flows, a 0.450 m diameter pipe can be placed with the larger casing, and the void could be filled with sand or concrete.

Groundwater measurements taken in early January 1987, indicate that the groundwater level across the site varied between Elev. 226.8 and 227.6. Generally, the groundwater table slopes very gradually down in a south-easterly direction. Since the invert of the proposed pipe ranges between Elev. 227.3 and 226.8, the invert will be located at or just below the prevailing groundwater table. However, it should be noted that it is expected that the groundwater level will fluctuate somewhat depending on the time of year.

Based on the subsurface information obtained from the 6 borings, the pipe will be constructed through cohesionless soils. In areas where the groundwater table is above or slightly below the pipe invert, it will be necessary to control the seepage at the advancing end of the liner. The contractor should be informed of the potential of encountering groundwater and the contractor should be prepared to provide control measures as required.

Dewatering concerns could be appreciably reduced if the pipe invert were raised about 1 m. If the invert elevations at the inlet and outlet have already been established, the invert within the Outlet Extension could still be raised by providing specially designed manholes for the inlet and outlet.

At the inlet, water could come into the manhole at the established elevation, and could leave the manhole from an outlet located 1 m above. Similarly, a 1 m drop structure could be provided at the Extension outlet.

<u>Alternative II</u> - Tunnel & Open Cut Combination

This alternative involves the tunnelling of the pipe under the travelled portion of Hwy. 410 and open-cutting the remaining section.

The recommendations pertaining to the tunnelling of this specific section as given under Alternative I also apply here.

The remaining section of pipe could be constructed by using cut and cover methods. Cuts varying between 4 and 14 m will be required.

All temporary cuts could be constructed using 1.25H:1V side slopes provided that sloughing of the sides does not occur. It is possible that some of the excavations in the cohesionless deposits may not naturally stand at such an inclination and shallower slopes such as 1.5H:1V may have to be constructed.

It should also be noted that if it rains during the construction period, exposed non-cohesive side slopes may severely deteriorate and large amounts of sand and silt may wash to the bottom of the excavation. It is therefore recommended that in order to minimize the effects of such an occurrence, the open-cut be excavated in sections. Each section should be fully constructed and backfilled prior to opening the adjacent section. Sections of 15 to 20 m could be considered.

The contractor may elect to construct the excavation with 1.25H:1V side slopes to a certain depth, and provide either sheeting (steel or timber) or some type of 'trench box' for the bottom 2 to 3 m in order to minimize the quantity of material which has to first be excavated and then used as backfill.

It should again be stressed that the proposed pipe invert will be either below or just above the groundwater level for the most part. Zones composed of medium sand-sized particles or finer which are exposed to an unbalanced hydrostatic pressure will boil. Zones of coarser material will experience substantial seepage. The contractor should be prepared to control either the boiling or seepage, or both, which may be experienced during construction. The contractor should also be prepared to control surface run off. A dewatering scheme should be submitted by the contractor for MTC review (<u>not</u> approval). However it should be noted that the ultimate responsibility of the dewatering scheme performance lies with the contractor.

Alternatively, dewatering requirements could be appreciably reduced if the invert elevation was raised about 1 m. The treatment described under Alt. I could be adopted.

The excavation should be backfilled and compacted as per current OPSS (MTC) specifications. Similarly, bedding and backfilling for the pipe should conform to current OPSS standards.

MISCELLANEOUS

The fieldwork for this investigation was carried out during the period from 86 09 23 to 86 09 24 and 86 12 17 to 86 12 22 under the supervision of L. Politano (Project Foundations Engineer), R. Kohlberger (Trainee Engineer) and V. Bonnici (Student Engineer). The equipment used was owned and operated by Master Soil Investigations Ltd. of Toronto.

This report was written by L. Politano and reviewed by M. Devata, Chief Foundations Engineer (East).

REGISTERED PROFESSIONAL ENGINEER 87-03-10 L. R. POLITANO PROVINCE OF ONTARIO

L. Politano, P.Eng.
Project Foundations Engineer

M. Devata, P.Eng.
Chief Foundations Engineer (East)

March, 1987.

APPENDIX

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/0.3 m)	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

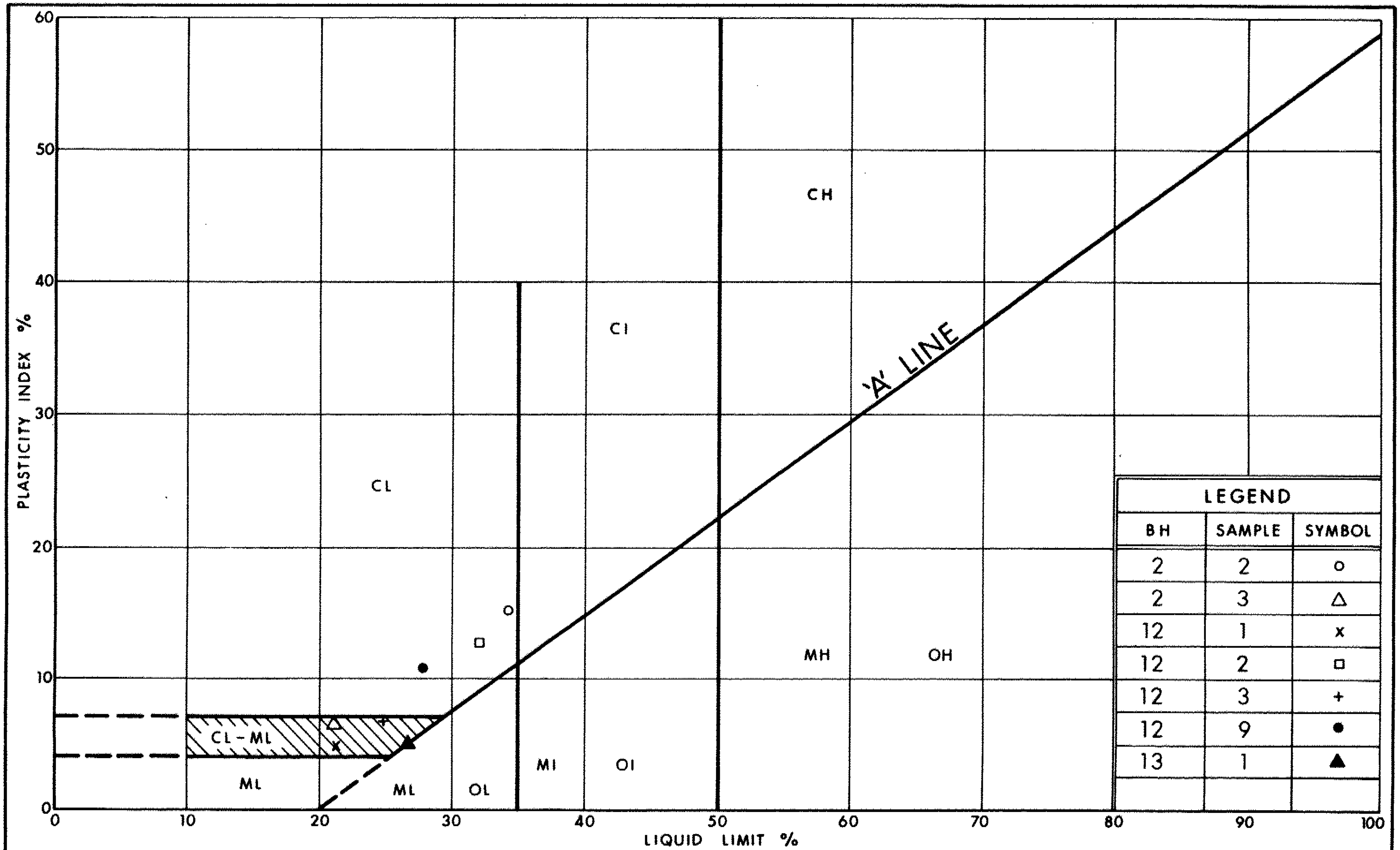
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
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



LEGEND

BH	SAMPLE	SYMBOL
2	2	o
2	3	△
12	1	x
12	2	□
12	3	+
12	9	●
13	1	▲

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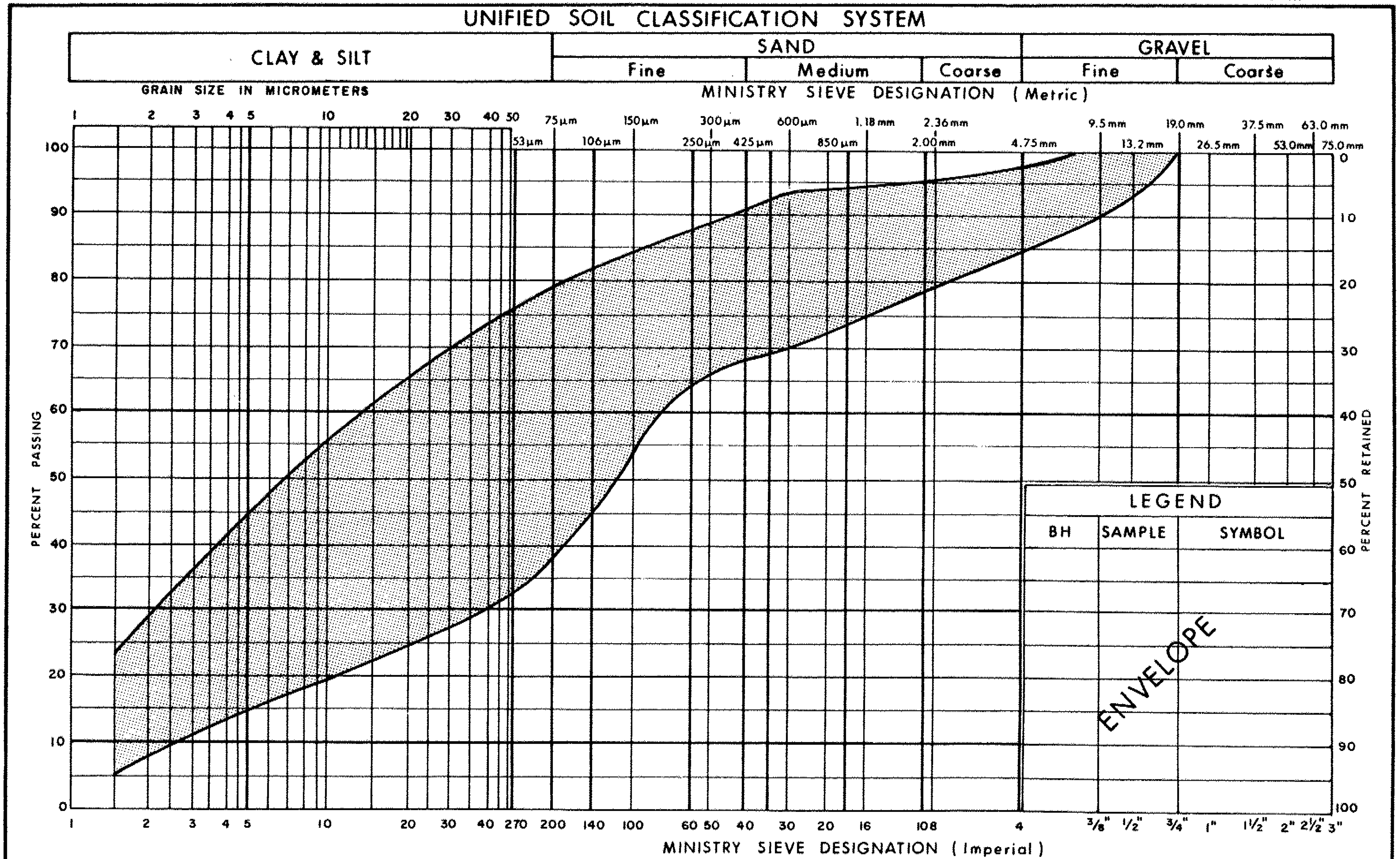
PLASTICITY CHART
SILTY CLAY, SOME/AND SAND, TRACE GRAVEL (FILL)

FIG No 1
W P 21-79-13

78 12 M



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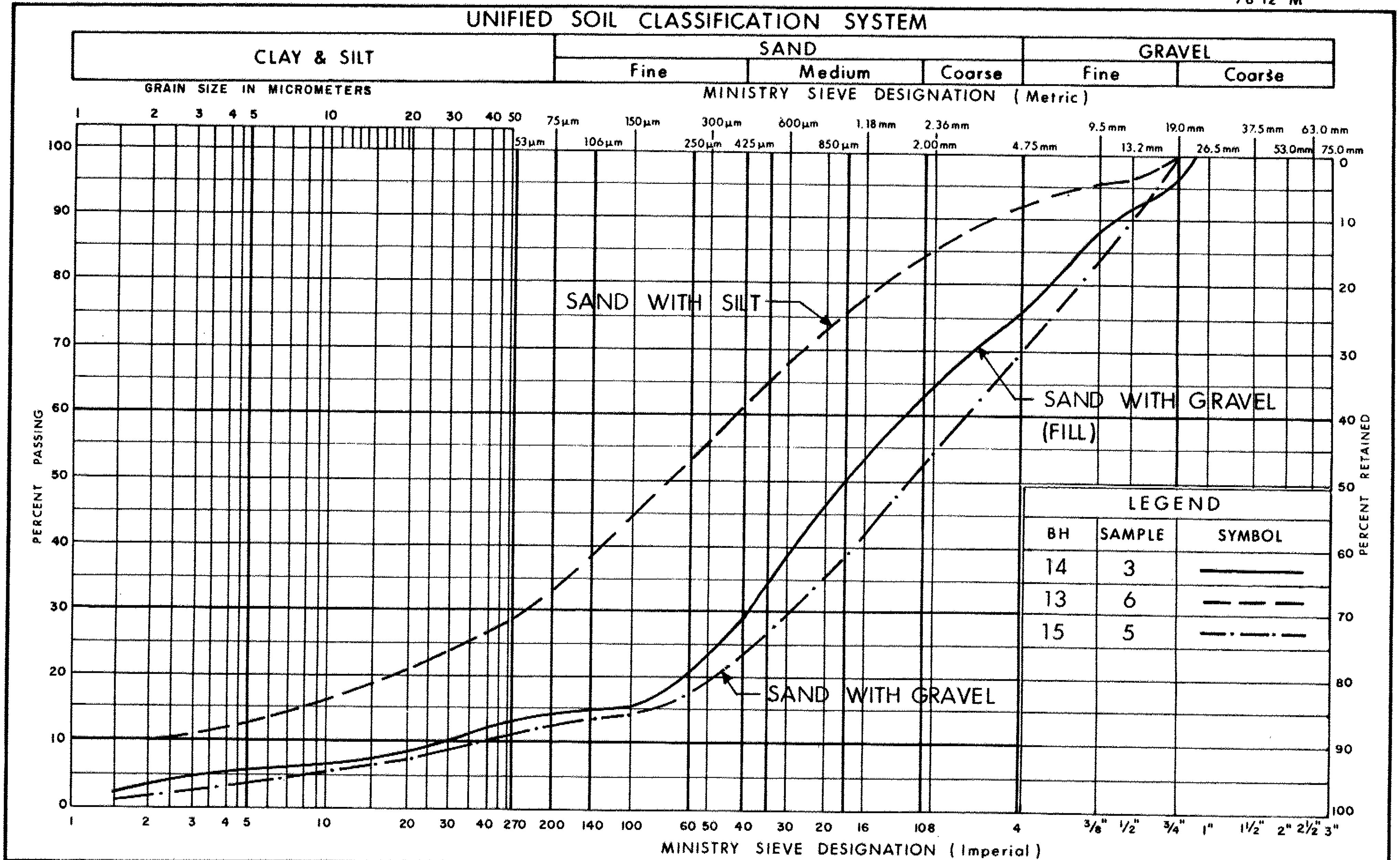
GRAIN SIZE DISTRIBUTION

SILTY CLAY, SOME / AND SAND, TRACE GRAVEL (FILL)

FIG No 2

W P 21-79-13

78 12 M



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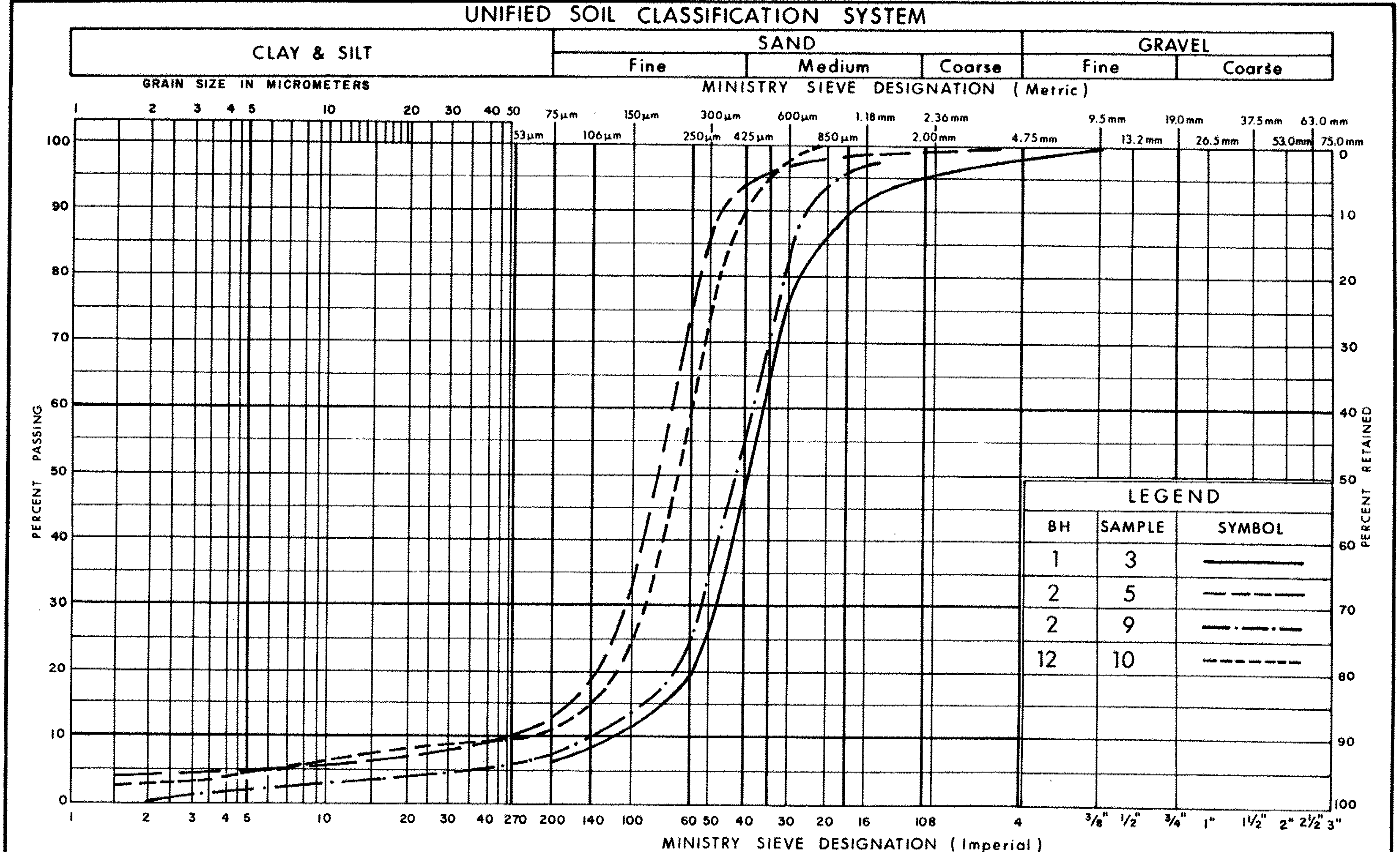
GRAIN SIZE DISTRIBUTION

FIG No 3

W P 21 - 79 -13

78 12 M



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Ontario

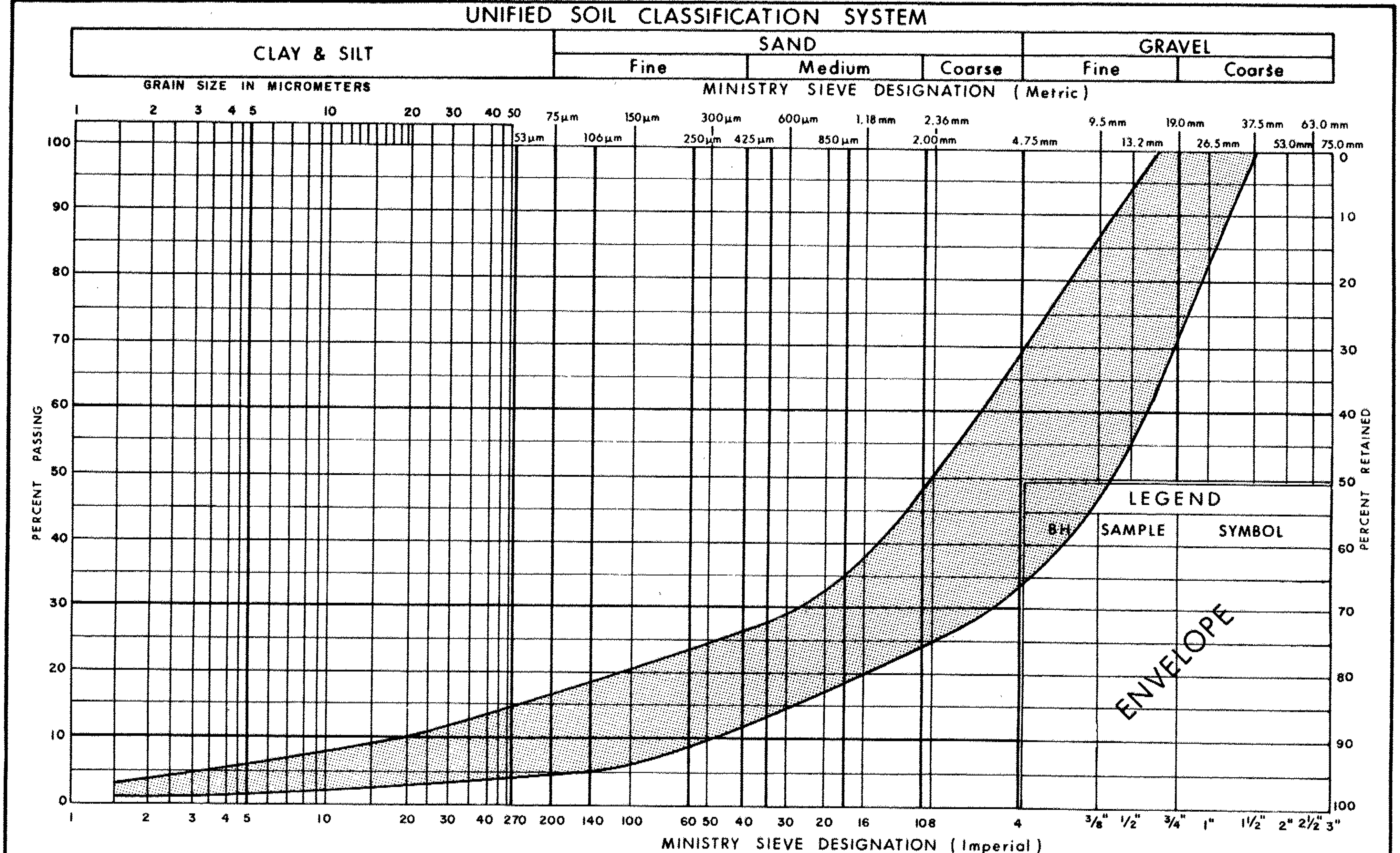
GRAIN SIZE DISTRIBUTION

FINE TO MED SAND TRACE GRAVEL, SILT, CLAY

FIG No 4

W P 21-79-13

78 12 M



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Ontario

GRAIN SIZE DISTRIBUTION

HET MIXTURE OF SAND & GRAVEL, TRACE SILT, CLAY
OCC TO NUMEROUS COBBLES & BOULDERS (GLACIAL TILL)

FIG No 5

W P 21 - 79 - 13

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 1 METRIC

W P 21-79-13 LOCATION Co-ords. N 4 841 575.5; E 284 276.0 Sta. 1 + 000 1m Rt. of Outlet ℄ ORIGINATED BY VB

DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY LP

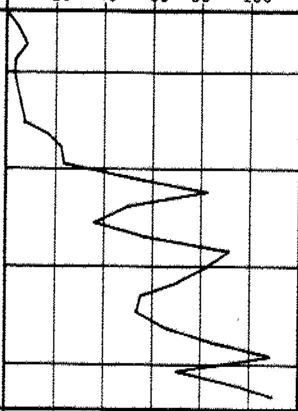
DATUM Geodetic DATE 86 09 23 CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
231.1	Ground Surface							
0.0	Topsoil							
	Silty Clay, some sand trace gravel (CL)	1	SS	4				
229.6	(Probable Fill)					230		
1.5	Fine to Medium Sand	2	SS	7				
228.2	Loose - Compact	3	SS	20			o	3 90 (7)
2.9	Heterogeneous Mixture sand and gravel	4	SS	33	▼*	228		
	trace silt, clay (Glacial Till)	5	SS	40				
		6	SS	61	SEAL		o	59 34 6 1
	Occasional-numerous cobbles and boulders	7	SS	48		226		
	Medium to Coarse Sand	8	SS	61	SEAL		o	27 65 7 1
	Dense to Very Dense					224		
223.3		9	SS	105			o	54 35 9 2
7.8	End of Borehole							
	* on 87 01 10				STANDPIPE INSTALLED BOTTOM 450 mm SLOTTED			

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 Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ



OFFICE REPORT ON SOIL EXPLORATION

+3, x5 : Numbers refer to Sensitivity

15 -◇- 5 (%) STRAIN AT FAILURE (20 / 10)

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Ontario

RECORD OF BOREHOLE No 2

METRIC

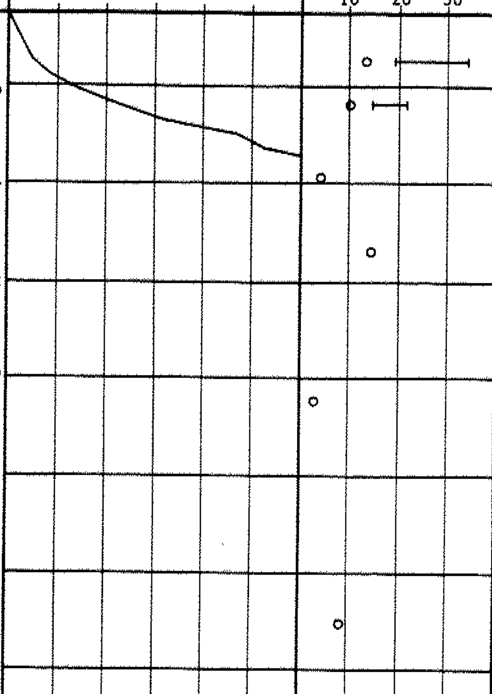
W P 21-79-13
LOCATION Co-ords. N 4 841 576.5; E 284 302.0 Sta. 1 + 025.3 m 2.5 m left of Outlet ℄
ORIGINATED BY VB

DIST 6 HWY 410
BOREHOLE TYPE Hollow Stem Auger, Cone Test
COMPILED BY LP

DATUM Geodetic
DATE 86 09 24
CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.5	Ground Surface						
0.0	Topsoil	1	SS	7			
	Silty Clay with sand trace gravel (CL) Occasional cobbles	2	SS	15			7 30 43 20
	(Fill)	3	SS	36		236	13 37 37 13
235.1 / 2.4	Fine to Medium Sand	4	SS	49			
	trace silt, clay	5	SS	25		234	0 87 8 5
		6	SS	18			
	fine sand and silt	7	SS	19			3 40 54 3
						232	
	Sand becoming	8	SS	25			
	coarser with depth	9	SS	20		230	0 91 8 1
	Compact	10	SS	17			
		11	SS	19	SEAL	228	
		12	SS	19	SEAL		
227.0 / 10.5	Silty Clay with sand trace gravel (CL) Stiff	13	SS	10	**	226	
225.6 / 11.9	Heterogeneous mixture sand and gravel, trace silt, clay (Glacial Till) numerous cobbles and boulders	14	SS	42			66 30 3 1
						224	
223.3 / 14.2	Very Dense / End of Borehole	15	SS	100/ 15 cm*			

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE
PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ



* Spoon bouncing probable cobble

** Standpipe dry water level measured in open borehole on 86 09 24. Water level indicated here may not represent stabilized condition.

STANDPIPE INSTALLED BOTTOM 450mm SLOTTED

OFFICE REPORT ON SOIL EXPLORATION

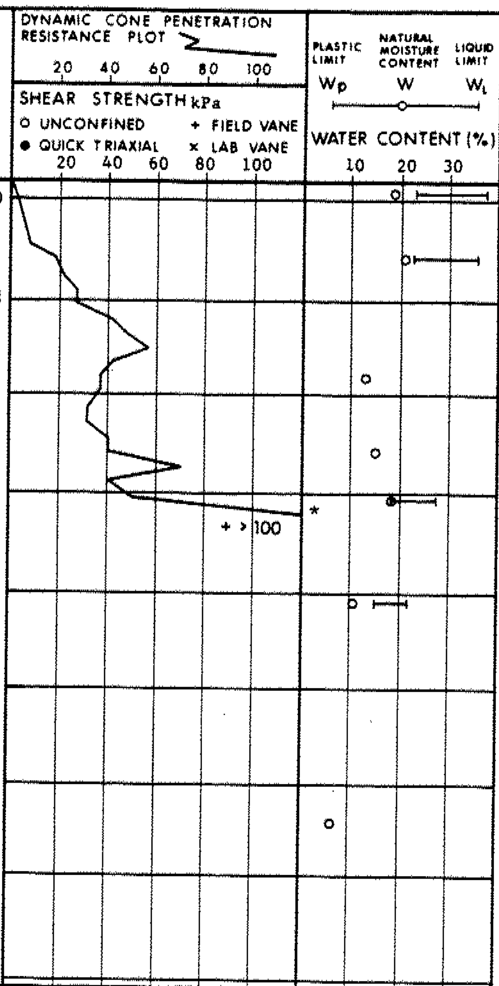
+3, ×5 : Numbers refer to Sensitivity   15 ⊕ 5 (20 / 10) (%) STRAIN AT FAILURE

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 3 METRIC

W P 21-79-13 LOCATION Co-ords. N 4 841 569.0; E 284 338.5 ORIGINATED BY VB
DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY LP
DATUM Geodetic DATE 86 09 25/26 CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.3	Ground Surface				
0.0	Topsoil	1	SS	9	5 22 52 21
	Silty Clay some sand trace gravel (Fill) gravel content increases with depth	2	SS	14	
237.9		3	SS	11	7 18 46 29
2.4	Fine to Medium Sand with silt, trace clay, gravel (Fill)	4	SS	25	
	Occasional boulders	5	SS	14	
		6	SS	2	5 67 21 7
	decayed wood	7	SS	23	
234.5	Topsoil (organics)	8	SS	3	1 62 27 10
5.8	Silty clay with sand trace gravel (CL)	9	SS	4	3 41 41 15
	Firm to Very Stiff	10	SS	16	
230.8		11	SS	26	7 37 38 18
9.5	Heterogeneous mixture sand and gravel, some silt, clay (Glacial Till)	12	SS	76	
	Occasional to numerous cobbles and boulders	13	SS	30	
	Dense to Very Dense	14	SS	129	21 47 22 10
		15	SS	33	
	Fine to Medium Sand Compact	16	SS	19	
223.8		17	SS	38	
16.5	End of Borehole				



GROUND WATER CONDITIONS: ** SEAL SEAL
STANDPIPE INSTALLED BOTTOM 400mm SLOTTED

* cone bouncing probable cobble

** On 86 11 05

+3, x5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 4 METRIC

W P 21-79-13 LOCATION Co-ords. N 4 841 579.5; E 284 411.5 ORIGINATED BY VB

DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger COMPILED BY LP

DATUM Geodetic DATE 86 09 29 CHECKED BY

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.4	Ground Surface							
0.0	Topsoil	1	SS	-				
	Silty Clay some sand trace gravel (CL)	2	SS	16				6 24 50 20
		3	SS	13		236		
		4	SS	7				3 26 46 25
	Occasional cobbles and boulders	5	SS	7		234	+ >120	
							+ >120	
	Firm to Very Stiff	6	SS	11				0 14 61 25
						232		
		7	SS	13				
	Med. to Coarse Sand with gravel trace silt, clay Compact	8	SS	13		230		25 59 11 5
	Sand and gravel content increasing	9	SS	30				
227.6		10	SS	30		228		
9.8	Medium to Coarse Sand with gravel trace silt, clay Dense	11	SS	11				
		12	SS	32	▼ *			28 59 10 3
225.7					SEAL	226		
11.7	Heterogenous Mixture sand and gravel, trace silt, clay (Glacial Till) Occasional cobbles and boulders Dense	13	SS	34	SEAL			
						224		
223.2		14	SS	34				42 51 6 1
14.2	End of Borehole							
	* On 86 10 20							

STANDPIPE INSTALLED BOTTOM 450 mm SLOTTED

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

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

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 5 — METRIC

W P 21-79-13 LOCATION Co-ords. N 4 841 564.5; 284 380.5 ORIGINATED BY VB

DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger COMPILED BY LP

DATUM Geodetic DATE 86 09 29/30 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
236.6	Ground Surface							
0.0	Silty Clay with sand trace of gravel (CL) Firm		1	SS	3		236	1 28 49 22
			2	SS	88	*		
235.2 / 1.4	Silt		3	SS	26			0 73 22 5
			4	SS	31		234	
			5	SS	42			
	Fine Sand and Silt Dense		6	SS	33			0 40 55 5
			7	SS	60		232	
	Fine to Medium Sand trace silt clay, gravel Dense		8	SS	58			
			9	SS	42		230	
			10	SS	28			1 83 8 4
			11	SS	29			1 90 7 2
			12	SS	39		228	
			13	SS	29			0 91 6 3
226.2			14	SS	25			
10.4	Heterogenous mixture of sand and gravel trace silt, clay (Glacial Till) Occ. to numerous cobbles and boulders Dense		15	SS	51	** ▼	226	
						SEAL		
224.0			16	SS	39	SEAL		28 62 8 2
12.6	End of Borehole							

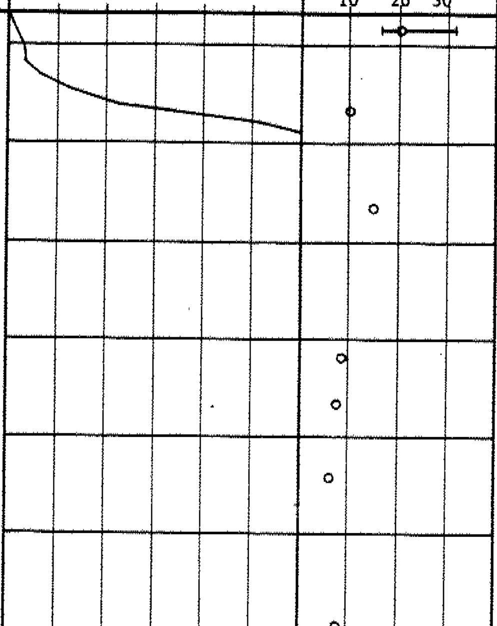
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT Wp — NATURAL MOISTURE CONTENT W — LIQUID LIMIT WL

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ



* Cobble encountered spoon jammed

**On 86 10 08

STANDPIPE INSTALLED BOTTOM 300mm SLOTTED

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 12

METRIC

W P 21-79-13
LOCATION Co-ords. N 4 841 581.5; E 284 327.0
Sta. 1 + 050 @ ℄ of Outlet
ORIGINATED BY RK
DIST 6 HWY 410
BOREHOLE TYPE Hollow Stem Auger
COMPILED BY LP
DATUM Geodetic
DATE 86 12 17
CHECKED BY

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ / REMARKS	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.8	Ground Surface					
0.0	Topsoil					
	Silty Clay, some to and sand, trace clay (CL) (Fill)	1	SS	15	Org. Content 2%	3 49 37 11
		2	SS	5		5 17 48 30
		3	SS	21		5 41 40 14
	Fine to Medium Sand	4	SS	24		
		5	SS	14		
		6	SS	8		
		7	SS	8		
		8	SS	7		
		9	SS	7		3 30 62 5
232.9 / 7.9	Fine Sand trace silt, clay Dense	10	SS	43		0 89 7 4
231.4 / 9.4	Heterogeneous mixture of sand and gravel trace silt, clay (Glacial Till)	11	SS	90		43 43 10 4
		12	SS	34/15 cm*		
	Occasional cobbles and boulders	13	SS	103		43 44 10 3
		14	SS	97		
	Fine Sand	15	SS	64		
	Very Dense					
225.3 / 15.5		16	SS	82/15 cm*		44 47 7 2
	End of Borehole					

* Spoon bouncing
** Groundwater level measured on 87 01 09

GROUND WATER CONDITIONS: SEAL; ** groundwater level at approx. elev. 227.9

STANDPIPE INSTALLED BOTTOM 200mm SLOTTED

ELEVATION SCALE: 240, 238, 236, 234, 232, 230, 228, 226

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

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

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 13

METRIC

Co-ord N 4 841 583.0; E 284 353.5

W P 21-79-13 LOCATION Sta. 1 + 077 @ 1 m Rt. ℄ of Outlet ORIGINATED BY RK

DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger COMPILED BY LP

DATUM Geodetic DATE 86 12 18 CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	REMARKS / Unit Weight	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.4	Ground Surface					
0.0	Topsoil					
	Silty Clay and Sand (Fill)	1	SS	7	Org. Content 4%	4 58 29 9
	Fine to Medium Sand Fill	2	SS	17		
		3	SS	28		
	Decayed Wood	4	SS	25/8cm*		
	Decayed Wood	5	SS	16		
232.2 / 5.2	Silty Clay with Org. Top Soil					
	Sand with silt trace gravel, clay	6	SS	15		9 58 23 10
231.0 / 6.4	Heterogeneous mixture of sand and gravel, trace silt, clay (Glacial Till)	7	SS	48		
		8	SS	47		
		9	SS	60		40 46 12 2
		10	SS	59		
		11	SS	59		
	Occasional cobbles and boulders	12	SS	64		40 46 11 3
		13	SS	66		
		14	SS	73		
	Very Dense	15	SS	89		
224.8 / 12.6	End of Borehole	16	SS	136		48 42 9 1

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, 'N' VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (236, 234, 232, 230, 228, 226); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE); PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Ground water conditions: SEAL; groundwater level symbol shown at approx. elev. 227.4.

STANDPIPE INSTALLED
BOTTOM 450mm SLOTTED

* Spoon bouncing
** Groundwater level measured on 87 01 09

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 14

METRIC

Co-ords. N 4 841 586.5, E 284 371.5

W P 21-79-13 LOCATION Sta. 1 + 095 @ ℄ of Outlet ORIGINATED BY RK

DIST 6 HWY 410 BOREHOLE TYPE Hollow Stem Auger COMPILED BY LP

DATUM Geodetic DATE 86 12 22 CHECKED BY

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
237.3	Ground Surface										
0.0	Topsoil				*						
	Sand, with to and gravel, trace silt, clay (Fill)	1	SS	38		236					
		2	SS	59							
		3	SS	42			o	26	62	10	2
234.3 / 3.0	Heterogeneous mixture of sand and gravel, some silt, trace clay (Glacial Till)	4	SS	81		234	o	45	41	11	3
		5	SS	32		232	o H	36	48	13	3
		6	SS	66		230					
	Occasional cobbles and boulders	7	SS	78			o	36	49	11	4
		8	SS	51							
		9	SS	58							
	Very Dense	10	SS	71		228					
		11	SS	80			o	29	55	13	3
		12	SS	56		226					
		13	SS	78							
224.7		14	SS	58			o	62	31	5	2
12.6	End of Borehole										

* Groundwater Level not established

Other columns: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE); PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ; REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3$, $\times^5$: Numbers refer to Sensitivity   15 ✧ 5 (20 / 10) (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 15

METRIC

W P 21-79-13
DIST 6 HWY 410
DATUM Geodetic

LOCATION Co-ords. N 4 841 589.0; E 284 386.5 Sta. 1 + 110 @ ℄ of Outlet
BOREHOLE TYPE Hollow Stem Auger
DATE 86 12 19

ORIGINATED BY RK
COMPILED BY LP
CHECKED BY

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
238.2 / 0.0	Silt, trace sand, clay; Sand with gravel, trace silt, clay (Probable Fill)
234.5 / 3.7	Sand with gravel, trace silt, clay. Dense
230.9 / 7.3	Heterogeneous mixture of sand and gravel, trace silt, clay. Occasional cobbles and boulders. Sand, some gravel. Very Dense
224.1 / 14.1	End of Borehole

SAMPLES

NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	36	0 7 88 5
2	SS	66	
3	SS	61	
4	SS	50/ 8cm	
5	SS	41	30 58 10 2
6	SS	29	
7	SS	48	
8	SS	77	53 36 9 2
9	SS	54	
10	SS	66	
11	SS	81	17 70 10 3
12	SS	89	
13	SS	80	
14	SS	50/10cm	50 41 7 2

GROUND WATER CONDITIONS: STANDPIPE INSTALLED BOTTOM 450mm SLOTTED; SEAL; **

ELEVATION SCALE: 238, 236, 234, 232, 230, 228, 226

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ

* Spoon bouncing

** Groundwater level measured on 87 01 09

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, ONTARIO PH-0-207 82 04

METRIC

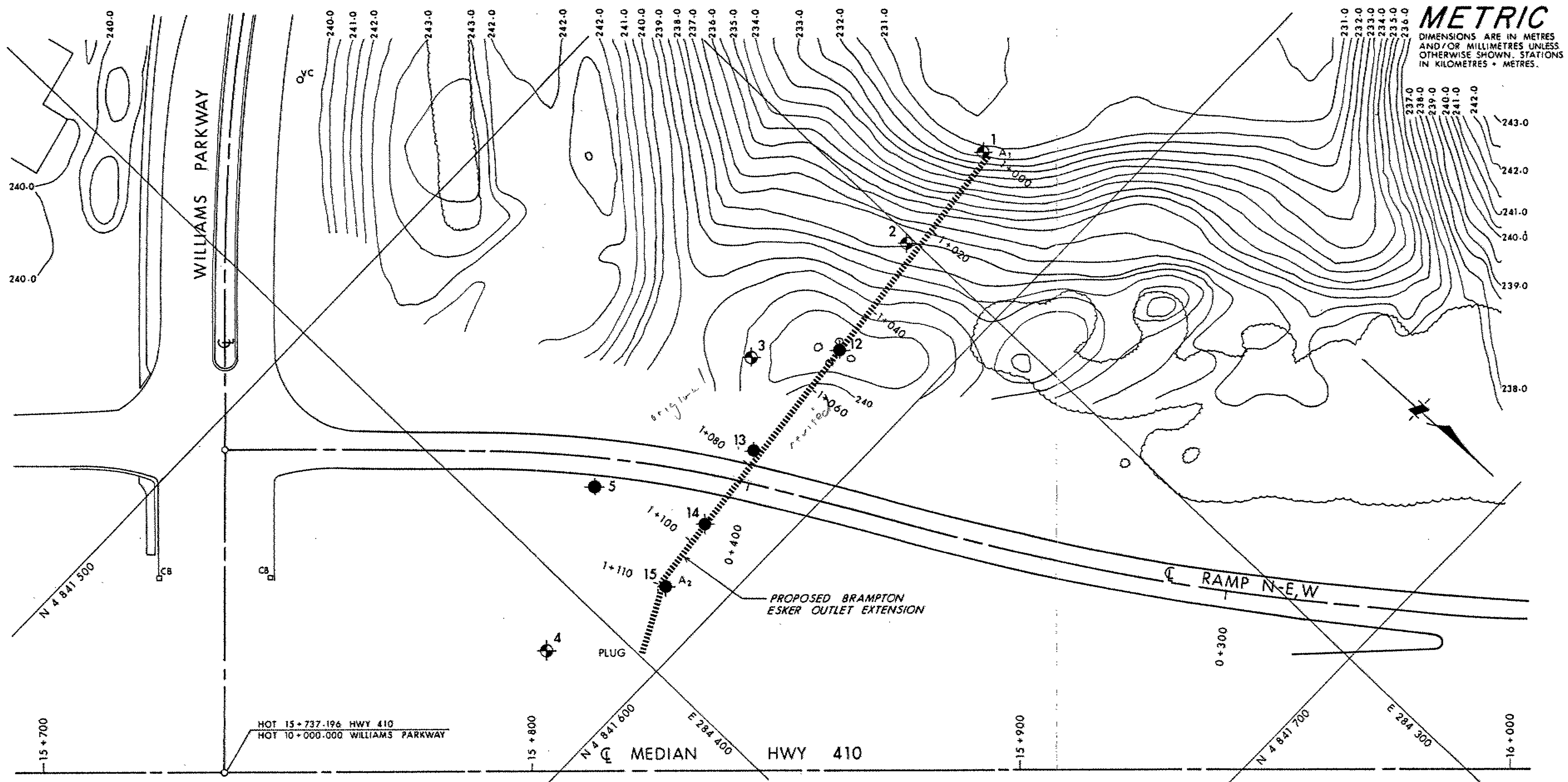
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 21-79-13

ESKER OUTLET EXTENSION

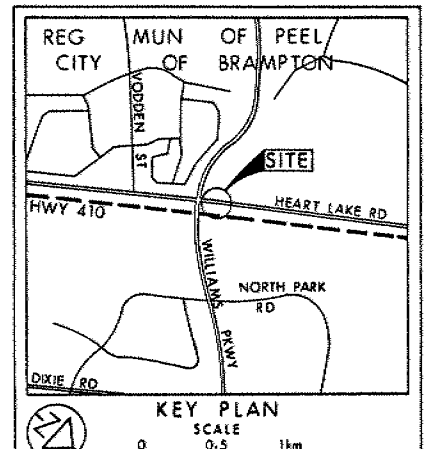
BORE HOLE LOCATIONS & SOIL STRATA

SHEET



PLAN

SCALE



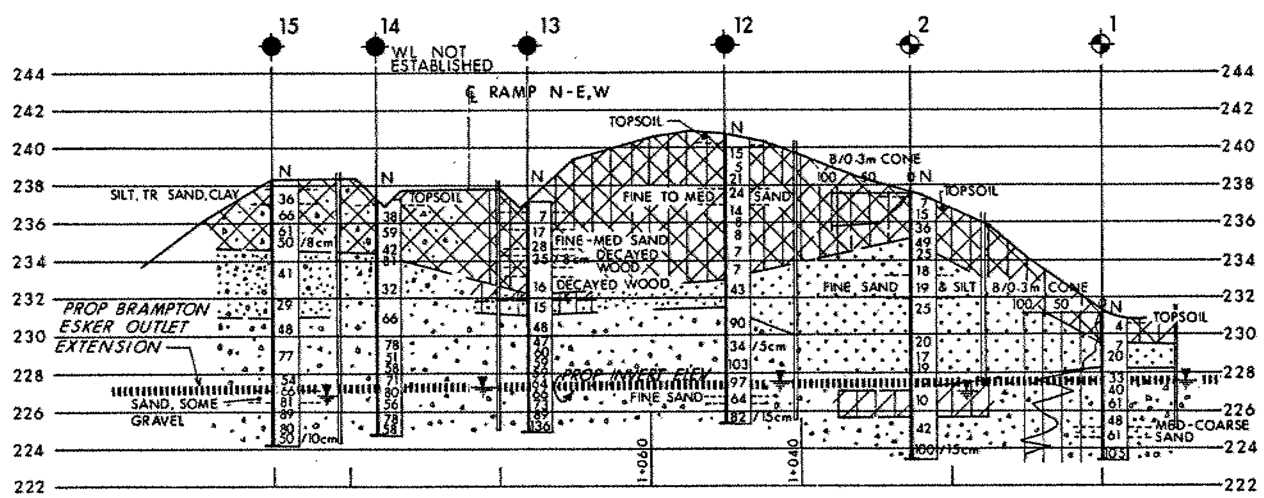
KEY PLAN

SCALE

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 86 09
- Standpipe

No	ELEVATION	CO-ORDINATES NORTH	CO-ORDINATES EAST
1	231.1	4 841 575.5	284 276.0
2	237.5	4 841 576.5	284 302.0
12	240.8	4 841 581.5	284 327.0
13	237.4	4 841 583.0	284 353.5
14	237.3	4 841 586.5	284 371.5
15	238.2	4 841 589.0	284 386.5
3	240.3	4 841 569.0	284 338.0
4	237.4	4 841 579.5	284 411.5
5	236.6	4 841 564.5	284 380.5



PROFILE ESKER OUTLET ALIGNMENT

SCALE

SOIL STRATIGRAPHY LEGEND

- SILTY CLAY (FILL) SOME TO AND SAND TRACE OF GRAVEL
- SAND WITH GRAVEL (FILL) TRACE SILT, CLAY
- FINE TO MEDIUM SAND
- SAND WITH GRAVEL TRACE SILT, CLAY Dense
- SILTY CLAY WITH SAND, TRACE GRAVEL Stiff
- HET MIXTURE OF SAND & GRAVEL TRACE SILT, CLAY OCC TO NUMEROUS COBBLES & BOULDERS V Dense GLACIAL TILL

=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 30M12-197

HWY No 410			DIST 6
SUBM'D LP	CHECKED	DATE 87 03 03	SITE
DRAWN DT	CHECKED	APPROVED	DWG 217913-A

memorandum

Ontario

To: H. Chyc
Head, Quality Assurance Section
5000 Yonge Street

Date: 1989 02 02

Atten: S. Gwartz

From: Foundation Design Section
Room 315, Central Building

Re: Brampton Esker Outlet Extension
Tunnel Construction Proposal
Contract 88-67, W.P. 21-79-13
Hwy. 410/Williams Parkway

As requested in your memo dated January 24, 1989, this Section has reviewed, albeit in the absence of appropriate drawings, the proposed tunnel construction procedure as outlined in a letter supplied by John Emery Geotechnical Engineering Limited (JEGEL) dated January 18, 1989, and based on this review and examination of subsoil conditions as provided in our original foundation investigation, the following comments are provided:

1) The success of the project is undoubtedly contingent on the groundwater conditions at the site and although it appears the contractor is aware of the potential soil behaviour in the tunnelling process, there is no convincing evidence of a planned scheme to mitigate damages that can result when fast ravelling and/or flowing ground conditions are confronted. These types of conditions, as stated in our original foundation report, occur when cohesionless soils such as the heterogeneous sand and gravel mixture (glacial till) and compact sand present at the proposed tunnel elevation are submerged within the prevailing groundwater table. The groundwater table at the time of the site investigation (87 01 09) ranged between about Elevation 227 m to 228 m, whilst the proposed tunnel invert elevation varies from approximately 227 to 227.5 m. However, groundwater tables tend to fluctuate with time and consequently, an established procedure should be planned that considers these unfavourable conditions and the potential ravelling that can result at the crown and excavated face of the tunnel. Loss of ground that may result from these sources and any unbalanced hydrostatic head that may develop can lead to settlements of the ramp and subsequent expensive maintenance. The methods described in JECEL, namely advance jacking and/or forepoling may encounter uncontrollable resistance due to the denseness of the till deposit and the presence of cobbles and possible boulders within the deposit.

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2) Due to the absence of drawings illustrating the proposed plan, the method of shaft construction is hereby unknown. The proposed scheme should comply with the recommendations provided in our original foundation report.

If you have any queries regarding the above comments or require further assistance, please do not hesitate to contact this office.

T. Sangiuliano, P. Eng.
Foundation Engineer

TS/mmj

c.c. - T. Zander
K. Saaritis

JOHN EMERY GEOTECHNICAL ENGINEERING LIMITED

52 Ashwarren Road
Downsview, Ontario M3J 1Z5
(416) 630-1060
Fax: (416) 630-7045

January 18, 1989
JEGEL: 89006

Graham Bros. Construction Limited
290 Clarence Street
Brampton, Ontario L6W 1T4

Attention: Mr. T. Walsh

Dear Sirs:

MTO Contract 88-67
Brampton Esker Outlet Extension

Further to your request, we have reviewed the geotechnical aspects of the proposed 1.2 m diameter drainage outlet (jacked concrete pipe sections), as shown on Drawing 1 provided by Armagh Contractors Ltd., and have made the following comments concerning the proposed method of construction, potential stability of the outlet crown and advancing face, and loads which the concrete pipe and any bulkhead must be designed to resist.

It is our understanding that the proposed outlet is to be installed using conventional pipe jacking methods with hand mining at the face limited to 300 mm ahead of the concrete pipe sections. The proposed tunnel invert elevation varies across the site from approximately Elevation 227 m to 227.5 m. The tunnel depth ranges from about 3 to 13 m. From approximately Sta. 1+080 m to 1+090 m, the tunnel crosses underneath the existing Hwy. 410, Williams Parkway N-E, W Ramp.

Our review of the project foundation investigation report (prepared by MTO and given as part of Contract 88-67, W.P. 21-79-13) indicates that the subsoil and groundwater conditions along the proposed tunnel elevation generally consist of either cohesionless sand in a loose to compact state or a heterogeneous sand and gravel mixture (glacial till) in a dense to very dense state. The sand and gravel till has occasional to numerous cobbles and boulders. Standpipe monitoring at the borehole locations indicated that the groundwater table is located between about Elevation 227 m to 228 m in either of the cohesionless stratum.

The type of ground behaviour and stability of the outlet crown and face in cohesionless subsoils are dependent upon the method of construction and following groundwater table location:

a) If the groundwater table is located below the outlet invert, ground behaviour should generally be characterized by slow ravelling. Running ground conditions may be anticipated in medium or coarse sand subsoils;

b) If the groundwater table is located above the outlet invert, ground behaviour should generally be characterized by fast ravelling and/or flowing ground.

Regardless of the groundwater table location, it is likely that pockets of sand and gravel with perched water conditions will be encountered and result in localized running or flowing ground conditions.

The proposed method of excavation, indicated by the contractor in Drawing 1, is considered to be acceptable given the relatively small outlet diameter and that the contractor appears to have recognized the potential ground behaviour. However, where running or flowing ground conditions occur, full or partial support of the tunnel crown and face will be required with possible dewatering to ensure safe and stable conditions. Support of the crown in difficult soils may be achieved by jacking the concrete pipe sections ahead of the excavated face and/or advance crown protection ("forepoling"). All pipe jacking and associated work must be performed in accordance with the Occupational Health and Safety Act and sound construction practice.

Is this practically feasible in view of presence of boulders/cobbles & denseness of material

The pipe sections must be able to safely resist the following ring load, P_r, and bending moments, M_{max}:

$$P_r = \gamma z R$$

where P_r = ring load (kN/m)

γ = unit weight of overburden, (assume 20 kN/m^3 for groundwater below invert)

z = maximum depth of tunnel (m)

R = outside radius of tunnel (m)

In addition, the contribution of any surcharge loadings or additional fill materials should be considered;

and $$M_{max} = (3EI/R_m)\ (\Delta R/R)$$

where M_{max} = maximum bending moment (N·mm)

E = modulus of elasticity of liner (MPa)

I = moment of inertia of liner (mm^4)

R_m = average radius of liner (mm)

$\Delta R/R$ = relative distortion of liner (assume $\Delta R/R$ = 0.3%)

The concrete pipe sections must also be designed to safely withstand the large compression jacking forces as the pipe sections are advanced. Any bulkhead structures installed at the face of the tunnel must be designed to safely resist full overburden pressure across the face of the tunnel, given by:

$$P = \gamma_b z_w + \gamma_{sat} (z - z_w)$$

where P = overburden pressure (kPa)

γ_b = bulk unit weight of overburden above the water table (kN/m^3)

γ_{sat} = saturated unit weight of overburden below the water table (kN/m^3)

z = depth (m)

z_w = depth to groundwater (m)

GENERAL COMMENTS

The recommendations provided in this report are based on subsoil and groundwater conditions determined from the MTO Contract 88-67, Foundation Investigation Report. Subsoil and groundwater conditions were determined at the borehole locations only and have not been confirmed by JEGEL. Therefore the recommendations are contingent upon site inspection and confirmation as the tunnel is advanced, particularly since groundwater levels are subject to seasonal fluctuation in the granular subsoils and will impact on the stability and effectiveness of the tunnelling method. All work must be additionally in accordance with the Occupational Health and Safety Act.

We trust this meets your present requirements. Please do not hesitate to contact this office if you have any questions.

JOHN EMERY GEOTECHNICAL ENGINEERING LIMITED

Steve R. Nesbitt, P. Eng.
Geotechnical Engineer

Michael H. MacKay, P. Eng.
Manager

SRN/cc

JEGEL
89006
Drawing 1

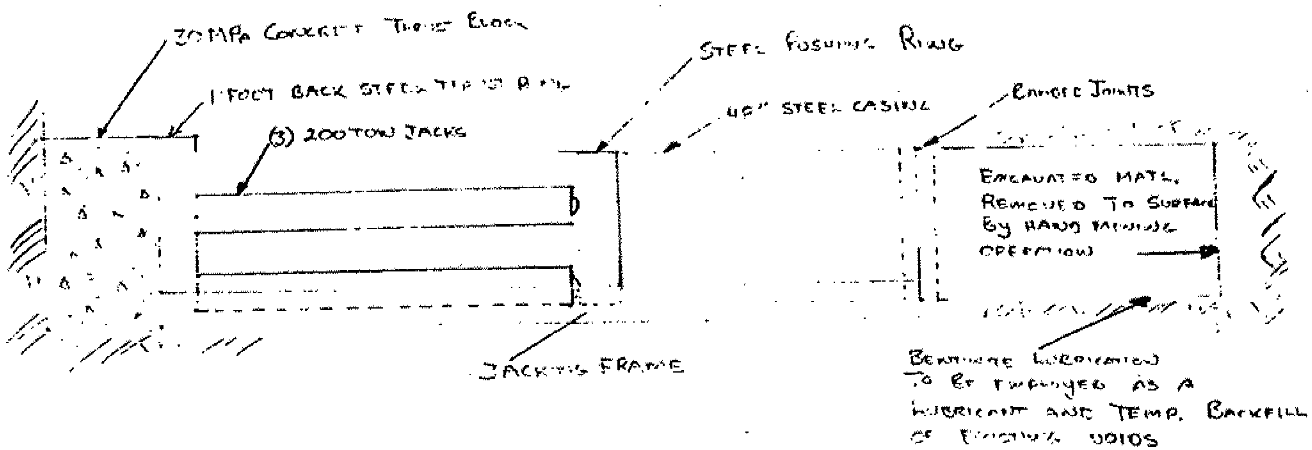
01/10/89 10:16 ☎ 416 453 2217 GRAHAM CONST 02

Armagh CONTRACTORS LTD.
BORING, TUNNELING AND PIPE JACKING
107 WINCHESTER ST. TORONTO M4X 1B3 Tel. 924-4275

TYPICAL TUNNEL DETAIL FOR 48" O.D. STEEL LINER.

NOTES

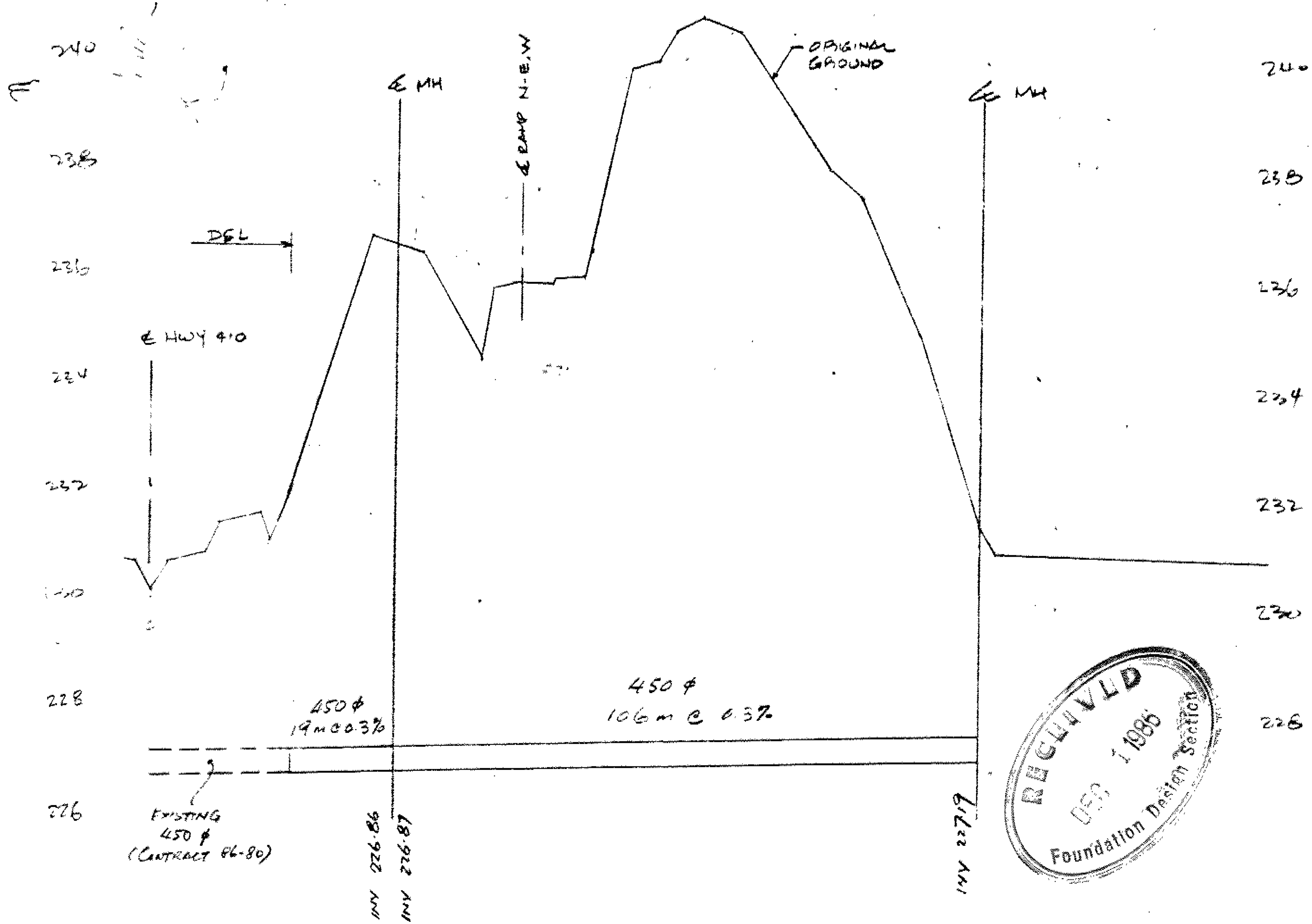
1. BANDED JOINTS TO BE EMPLOYED @ EACH SUCCESSIVE PIPE LENGTH IN THE EVENT OF UNSTABLE SOIL AND SPEED OF OPERATION
2. 2" ROUGH CUT TIMBER BULKHEAD TO BE INSTALLED @ END OF EACH SHIFT
3. NO MORE THAN 300 mm OF EXCAVATED MAT'L IS TO BE TAKEN @ ANY TIME WITH STEEL COVER PUSHED INTO PLACE
4. GROUT BACKFILL TO BE INSTALLED INTO EXTERIOR VOID UPON COMPLETION OF TUNNEL CROSSING



JEGEL NOTE:

THIS DRAWING MUST BE READ IN ACCORDANCE WITH JEGEL LETTER DATED JANUARY 18, 1989.

O/G - PROFILE - BRAMPTON ESKER



REVISED VERSION

memorandum

Ontario

To: D. Gunter
Head, Geotechnical Section
Central Region

Date: 1986 10 31

Atten: D. Mullett

From: Foundation Design Section
Room 315, Central Building

RE: Foundation Investigation
Brampton Esker Outlet
W.P. 21-79-13
Hwy. 410, District 6, Toronto

Further to the meeting of 86 10 29 attended by D. Mullett, B. Dickey, W. Lachmaniuk, M. Devata and L. Politano, this memorandum summarizes our preliminary findings and associated comments with regards to the above-noted project.

This section was requested by the Central Region Geotechnical Section on 86 08 20 to provide recommendations for the construction of the proposed 0.450 m dia. Brampton Esker Outlet. A subsurface investigation was carried out by this section between 86 09 23 and 30. A simplified preliminary stratigraphy (Fig. 1) is attached for your information.

In addition to the subsurface conditions, Figure 1 illustrates the existing ground profile along the 0.450 m sewer and the proposed vertical alignment of the pipe.

The proposed Esker Outlet will be approximately 140 m long, with a 0.3% downward slope towards the south-east direction. A2 as shown on Fig. 1, indicates a change in the horizontal alignment of the sewer.

The investigation consisted of advancing 5 boreholes to depths ranging between 8.1 and 16.4 m below the existing ground surface. Each borehole was advanced a minimum of 3.0 m below the proposed invert elevation. A standpipe was installed in each borehole so that groundwater levels could be periodically monitored in the future.

The investigation revealed 2 areas of concern: (1) the location of the groundwater table, and (2) the composition of the glacial till which was encountered in most boreholes at lower depths. The glacial till at this site can generally be described as a very dense heterogeneous mixture of gravel, sand, silt and clay. Occasional, and perhaps, numerous cobbles and boulders may be encountered randomly within this non-cohesive deposit.

Our comments with regards to the construction of this sewer are as follows:

- In view of the depth of the proposed sewer invert, consideration should be given to alternatives other than installation by cut and cover methods.

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- Cut and cover construction should not be used, if possible, under the highway and ramps since our experience indicates that under these circumstances, continual maintenance problems will most likely arise. However, if strict controls are placed on the type of material which is used to backfill the excavation and the compaction, and if the depth of excavation is "nominal", this Section can give consideration to open cutting a trench under the travelled portion of the highway.

- In view of the nature of the subsoils and the length of the sewer pipe, jacking the pipe in place is not feasible.

- Some form of tunnelling technique could be used for the installation. However, modifications to the sewer dimensions and vertical alignment are required.

- Tunnelling of a 0.450 m dia. pipe through the soils encountered at the proposed invert elevation is not feasible in view of the denseness of the non-cohesive glacial till and the presence of cobbles and boulders.

  Based on our past experience with this type of installation, and numerous discussions with prominent contractors specializing in this type of work, consideration should be given to tunnelling a 1.2 m dia. pipe. Such a large diameter pipe will allow, if necessary, manual mining of any large boulder which may be encountered.

- In order to tunnel this pipe, 3 or 4 access shafts will be required. The cost of each shaft varies with the depth and size, but generally ranges between $20,000 and $50,000. The cost of tunnelling a 1.2 m dia. pipe through this type of material ranges between $900 and $1300 per metre. These costs are only crude estimates based on past tunnelling projects. More accurate costing should be developed for the purpose of comparison to open-cutting.

- At the time of the investigation, the groundwater table was found to vary between Elev. 227.5± and 226.0± Generally, the groundwater table slopes down gradually in a south-easterly direction. As previously noted, standpipes were installed at each borehole location. We intend to periodically monitor the groundwater levels as it is believed that the groundwater level may seasonally fluctuate to some extent.

  The proposed invert of the 0.450 m dia. pipe is at or below the groundwater table in the vicinity of Sta. 0+000 to 0+050±. In view of the non-cohesive nature of the subsoils, it is recommended that the invert of the pipe be raised a minimum of 1 m, particularly between the stations previously mentioned. The intent is to eliminate the need for costly dewatering.

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The final report for this project will be issued by this Section within 6 weeks. If, in the meantime, you require clarification or additional information, please do not hesitate to contact us.

L. Politano
Project Foundations Engineer

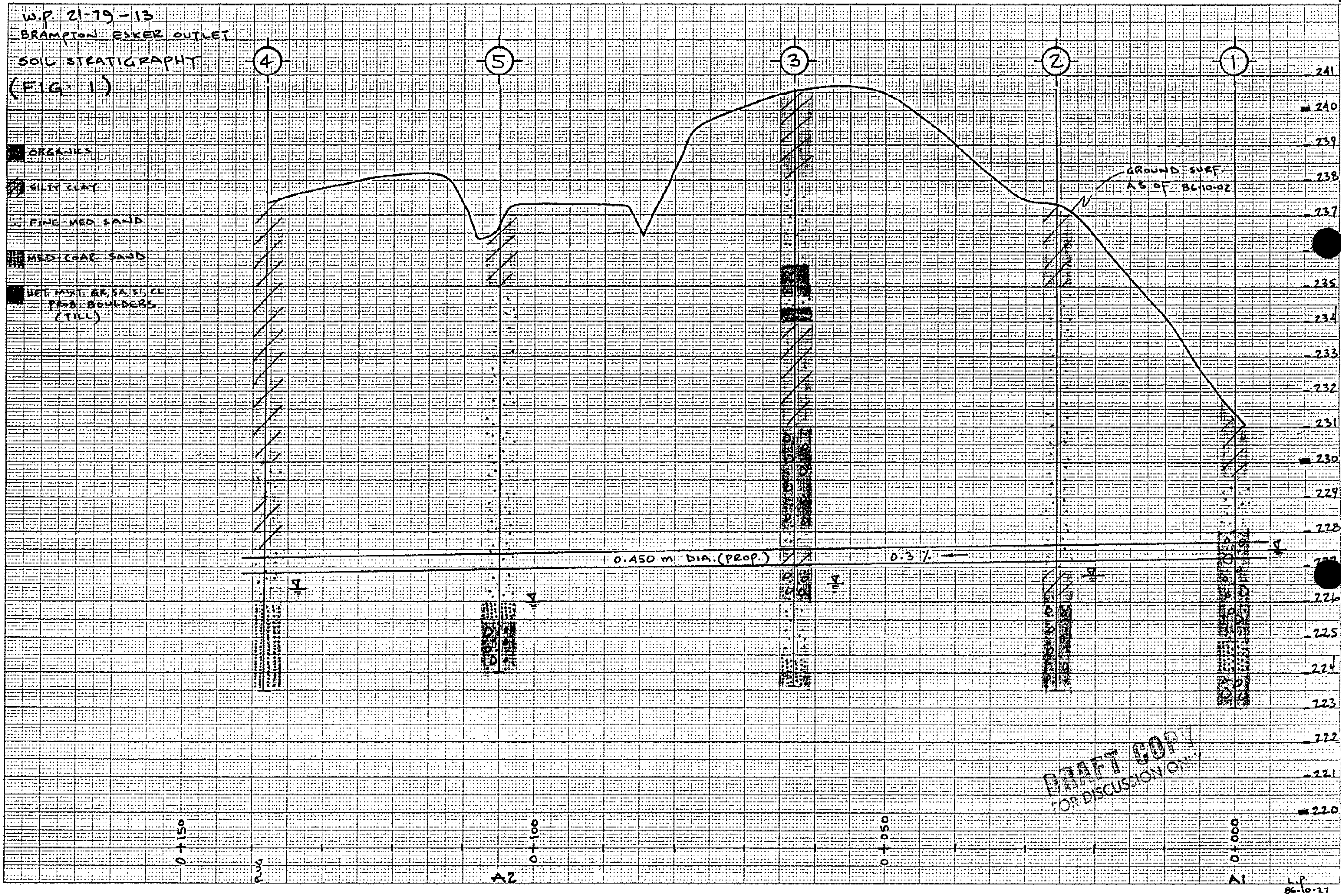
for

M. Devata
Chief Foundations Engineer
(East)

MD/mmj

Attach.

c.c. - B. Dickey
W. Lachmaniuk (Giffels)



W.P. 21-79-13
BRAMPTON ESKER OUTLET
SOIL STRATIGRAPHY
(FIG. 1)
ORGANICS
SILTY CLAY
FINE-MED SAND
MED-COAR SAND
HET. MIXT. GR, SA, SI, CL
PROB. BOULDERS
(TILL)
4
5
3
2
1
GROUND SURF.
AS OF 86-10-02
0.450 m DIA. (PROP.)
0.3 %
241
240
239
238
237
235
234
233
232
231
230
229
228
226
225
224
223
222
221
220
ELEVATION (m)
0+150
0+100
0+050
0+000
RW4
A2
A1
DRAFT COPY
FOR DISCUSSION ONLY
L.P.
86-10-27