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FOUNDATION INVESTIGATION REPORT

GO-ALRT Project No: EGG-000-003

Whitby Truck Inspection Station
Site 22-2-367 Highway 401

District 6 -Toronto- Central Region

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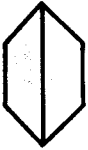
INTRODUCTION

C. Mirza Engineering Inc. have been retained by the Ministry of Transportation and Communications, on behalf of GO-ALRT, to carry out a subsurface investigation at the site of a proposed relocation of the Whitby Weigh Scale Station. The terms of reference of the study were to investigate the subsoil conditions at the location of a concrete box culvert and its associated earth fill retaining walls with a view to providing the necessary design information for bearing capacity, settlement and stability of approach fills.

SITE AND GEOLOGY

The site is located in Whitby, Ontario. Specifically, the proposed relocated structure will be situated in the southeast quadrant of the intersection formed by Thickson Road and Highway 401. In this area, the ground surface undulates gently, with a general slope towards Lake Ontario to the south. The area has been glaciated in the past. There is evidence geomorphologically of buried drumlins not too far from the site. Due to the proximity of the site to Lake Ontario, it is postulated that several advances and retreats of the ice occurred during the last glaciation, resulting in the deposition of glacio-fluvial/lacustrine deposits.

Physiographically, the site lies within the South Slope. The pleistocene deposits have been identified as a drumlinized till plain bordering with a clay plain. The underlying bedrock in the area consists of shales, limestone, sandstone and siltstones of Upper Ordovician age.



FIELD AND LABORATORY WORK

The field work consisted of the drilling and sampling of five boreholes and two probeholes. A bombardier mounted continuous flight augering machine was used to drill the boreholes using solid stem augers. Samples were obtained in the Standard Penetration Resistance Test (ASTM D-1586-67) at 1.5 metre depth intervals generally. In the cohesive portions of the subsurface, samples were obtained with a 50 mm diameter thin-walled tube. Where feasible after sampling, field vane tests were attempted in the cohesive portions of the soil using a standard MTC 'A' vane. Upon completion of the boreholes, the water levels were noted. Since no water was used in the drilling operation, the water levels measured are reflective of existing groundwater conditions. In one borehole, a standpipe was installed to monitor the water table over a period of time.

The boreholes were tied into existing ramp relocation survey stakes installed by others. Elevations were obtained by field surveying from an MTC Geodetic Benchmark at Station #322 MTC [Hydro Pole] at elevation 96.074.

Recovered soil samples were returned to our Richmond Hill Laboratories for further visual and classification tests. In addition, index property testing was carried out, including:

- Moisture Content
- Atterberg Limits
- Grain Size Distribution
- Quick Triaxial
- Unit Weight Determination

The test results are plotted on the various figures in the Appendix and are also shown on the individual borehole log sheets.

...../3



SUBSURFACE CONDITIONS

General:

The predominant soil stratum across the site is a sandy silt to silty sand glacial till. It is overlain by a silty clay deposit of low plasticity and underlain by a clay of hard consistency. Because of the glaciolacustrine nature of the till deposit, sand lenses are present at random within the till stratum. Details of the various strata encountered at this site are given below:

Topsoil and Fill Materials:

The site contains 150 to 200 mm of topsoil in areas not affected by previous construction activity. Elsewhere, up to 2.1 metres of fill was encountered, particularly in the area of an abandoned service road on the south side of Highway 401. The fill material consists of a heterogeneous mixture of silty clay and sand, with a trace of organics. In the upper zones, the fill material consists of sand sub-base material used in the construction of the service road in the past. The fill material is estimated to be loose to compact where non-cohesive and firm where cohesive, based only on tactile examination of auger cuttings.

Silty Clay of Low Plasticity:

Below the topsoil and/or fill material, the surficial deposit consists of a lacustrine stratum of silty clay. This deposit thickens in a west to east direction, being 1.0 metres at Borehole 4 and 3.6 metres at Borehole 1. It was sampled in Boreholes 1, 2, 3 and 4 by means of a split-spoon sampler. One thin-walled tube sample was obtained for detailed examination from Borehole 6. At Boreholes 5 and 7, the deposit was penetrated by augering only to establish its thickness and extent in the area of the investigation.

The silty clay has a laminated texture and contains nodules of light coloured silt. The presence of such silt nodules leads to a mottled brown to grey colour.



SUBSURFACE CONDITIONS - continued:

Silty Clay of Low Plasticity - continued:

The natural moisture content of this stratum was found to range between 17 and 28 per cent. The liquid limit of the soil was about 21 to 22 per cent, with corresponding plasticity indices of 9 and 8 per cent (see Figure 1). On the basis of these Atterberg Limits, the soil is classified as a silty clay of low plasticity (clayey silt).

The strength of the deposit was estimated from N values which ranged from 21 to 11 blows per 0.3 metres and decreased with depth. One field vane test attempted at Borehole 6 gave a value of the undrained shear strength in excess of 88 kPa. A quick triaxial test on the thin-walled sample from Borehole 6 gave a value of 76 kPa. At Borehole 1, one field vane test gave a value of 76 kPa, with a sensitivity of about 3. Based on these strength measurements, the consistency of the soil is estimated to be stiff to very stiff, generally decreasing with depth to stiff.

Compressibility characteristics of the silty clay soil were not determined by consolidation tests. From the low plasticity evidenced by the Atterberg Limits, it is expected that the compressibility of the soil is low, with a compression index, C_c , of about 0.1 [based on the Skempton w_L -- C_c correlation].

Sand:

Below the fill material in Borehole 2 and below the silty clay stratum at Borehole 3, a stratum of fine to medium, uniformly graded sand was encountered. The texture of the sand indicates a glacio-fluvial sedimentary environment. The sand is brown in colour. N values ranged between 26 and 34 blows per 0.3 metres, indicating it to be compact to dense.

It is suspected that the sand represents an isolated lens within the glacial till mass. Such lenses are potential sources of perched water.

**SUBSURFACE CONDITIONS- continued:**Silty Sand to Sandy Silt - Glacial Till:

The predominant deposit across the site is a glacial till consisting of a heterogeneous mixture of sand, silt and some gravel with occasional clayey zones. The material is essentially non-cohesive. However, the presence of silt and clay in small amounts gives the till a "cohesive" appearance. The till varies in colour from brown near the upper zones to grey below the water table.

Within the till matrix, small sand pockets are clearly identifiable. Their presence confirms the presumption that the till is of glacio-fluvial origin. The thickness of the till was proven only at Borehole 1 where it terminated in a hard clay stratum at about elevation 79. Its full depth at other locations was not identified in this investigation, since the other boreholes were terminated within this deposit.

The natural moisture content of the till ranged between 6 and 12 per cent, averaging about 8 per cent for the deposit. Typical grain size distribution curves of samples from this deposit are shown on Figure 2. The gravel content ranges between 1 and 12 per cent, sand between 40 and 46 per cent, and silt between 29 and 38 per cent. The clay size content averages about 19 per cent.

The result of one Atterberg Limits test is shown plotted on Figure 1. The liquid limit of the fine fraction of the soil was 13 per cent with a corresponding plasticity index of about 4. This suggests the finer portions of the till to consist of a silt of low plasticity.

The density of the glacial till, as measured by N values, was found to range between dense to very dense, being generally very dense (N values in excess of 100 blows per 0.3 metres). One exception to this was found at Borehole 1, where a blow count of 4 was recorded in the Standard Penetration Resistance Test. This low blow count represents a loose pocket within the glacial till. The occurrence of such loose pockets in glacial tills has been noted in the past in the Oshawa-Whitby-Pickering area bordering Lake Ontario by Mirza and others (see references appended).

**SUBSURFACE CONDITIONS - continued:**Glacial Till - continued:

The origins of loose or softer pockets of materials essentially the same as the surrounding soil within glacial till deposits have not been clearly explained. Such zones are generally associated with glacio-fluvial activity. They occur near or just below the water table. In this particular case, the soil had a moisture content slightly in excess of the average. In addition, the presence of clay precludes the possibility of boiling of the base of the borehole during sampling. Therefore, it is concluded that this loose zone within the till mass is an isolated occurrence. Hence, the till generally can be assumed to be competent throughout.

Clay:

A hard clay deposit, dark grey in colour, was encountered below the glacial till at the location of Borehole 1. Its plasticity characteristics are plotted on Figure 1. An N value of 54 blows per 0.3 metres indicates the clay to be of hard consistency.

GROUNDWATER CONDITIONS:

The groundwater conditions at the site were determined by measuring the water levels in the open boreholes upon completion of field work. At Borehole 1, a standpipe was installed to monitor the water levels over the duration of the field work. The prevailing groundwater levels are shown plotted on Drawing EGG0003-A. The gradient is generally downwards towards the east where a small gully is located. Therefore, it is presumed that the groundwater table is more or less parallel to the prevailing ground surface and is situated some 3 to 5 metres below grade.

In the sand lens at Boreholes 2 and 3, the water table was found to be higher than normal, indicating a perched condition. Excavations in the sand are likely to yield water on a temporary basis. Elsewhere, the tightly knit silty structure of the till is not likely to yield free water readily.



DISCUSSION AND RECOMMENDATIONS:

General:

The N/S-E Ramp from Thickson Road to eastbound Highway 401 will be constructed within a 44m by 13 m concrete culvert at its intersection with a proposed Truck Inspection Station (T.I.S.) Ramp. The eastbound T.I.S. Ramp will cross the culvert at a skew angle at elevations ranging from 94 metres at the west approach to 92 metres at the east approach. The culvert invert will be at elevation 86.5. Two 20 metre long retaining walls will extend from the culvert walls, one each on the north and south sides as shown on Drawing EGG0003-A. The approach fills will vary in height between 1 metre at the west to 5 metres at the east.

The soil investigation has revealed the presence of a surficial stratum of stiff silty clay of low plasticity, which ranges in thickness from less than one metre at the west end of the box culvert to over 4.5 metres at the east end. This cohesive deposit is underlain by a lens of fine to medium sand of compact to dense character in the immediate area of the base of the box culvert. Below this sand, and below the silty clay soil elsewhere, a glacial till deposit extends to below the invert level of the culvert. The till soil is essentially non-cohesive; however, it contains a significant proportion of fine sized silt and clay particles and binds together very well in a tightly knit matrix. The till is essentially competent, except for isolated loose pockets just east of the east end of the proposed box culvert.

The groundwater table is more or less parallel to the ground surface. It shows a downwards flow drainage gradient towards the east. A perched water table was encountered within the sand lens, at a depth of about one metre below prevailing grade.

Culvert Foundations:

The culvert footings may be located at elevation 85.0 within the glacial till deposit using the following factored bearing capacity values:



DISCUSSION AND RECOMMENDATIONS - continued:

Culvert Foundations-continued:

@ ULS	1500 kPa
@ SLS Type II	500 kPa

The above capacities take into account the fact that at or below elevation 85, portions of the footing may be located at the prevailing water table. Even though the foundation may be considered to be unyielding (Section 6.5.3 of the OHBD Code), allowances must be made in the serviceability capacity for the influence of a high water table on the settlement behaviour of the footings.

Retaining Wall Foundations:

The retaining walls will vary in height between 7 and 8 metres, portions of which will be located in the culvert approach cut. Therefore, both at-rest and active conditions will prevail, depending on construction details. At the east end, the presence of the silty clay stratum precludes the possibility of maintaining uniform footing bearing elevations across the wall length due to the danger of differential settlements. Therefore, it is recommended that the silty clay at the east end of the culvert be completely excavated from the base of the retaining wall footing down to the glacial till stratum. The subexcavation should be backfilled with mass concrete to the underside of the footing. At the contact between the till and the concrete a transition should be provided by sloping the subexcavation at a 4:1 gradient; i.e., the thickness of mass concrete below the footing should be increased gradually across the base of the footing. Hence some subexcavation of the till soil will also be required to accomplish this transition treatment. Alternatively, the silty clay subexcavation may be backfilled with compacted Granular A fill (100 per cent Standard Proctor density).

The footings of the retaining walls, located on foundations prepared in the manner prescribed at the east end, and on undisturbed glacial till elsewhere, may be designed at the factored capacities given for the culvert footings. The founding elevation should be 85 or below.



DISCUSSION AND RECOMMENDATIONS - continued:

Earth Pressures:

Culvert Walls: Depending on the sequence of construction, earth pressures against the culvert walls may be at-rest or active. The at-rest values will prevail if the top slab is cast prior to backfilling. The following equivalent fluid pressure values are recommended as per Section 6.6.1.2.2 of the OHBD Code:

Top Slab Restarint:	@ULS	10kPa/m
	@SLS	8.5kPa/m
No restraint	@ULS	8.0kPa/m
	@SLS	6.5kPa/m

If heavy vibratory equipment is used to compact the backfill, the following values should be used for design:

@ULS	25kPa/m
@SLS	40kPa/m

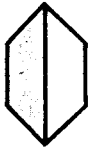
Retaining Walls: The earth pressures on the retaining walls will be of the active type due to movement at the top of the wall. The following design values are recommended:

@ULS	8.0kPa/m
@SLS	6.5kPa/m

These values do not include any allowances for surcharge loadings, particularly from the trucks going across the culvert. Surcharge loads from truck wheel loads should be calculated as per Provisions of Sections 6.6.1.2.4 to 6.6.2.5 of the OHBD Code.

The sliding resistance at the base of the retaining wall footings located within the glacial till may be calculated using $\phi=32^{\circ}$.

In order to minimize the build-up of excess hydrostatic pressures behind the walls, a heel drain should be provided below the backfill at footing level.



DISCUSSION AND RECOMMENDATIONS - continued:

Approach Fills:

The approach fills will vary in height from 1 metre at the west to 5 metres at the east. The fills will be underlain by glacial till or stiff silty clay. Therefore, fill stability is not a problem with a 2:1 side slope geometry. The factor of safety against a rotational type failure of the fill towards the north is marginal due to the absence of a resisting mass on the north side of the east retaining wall. Hence, the subexcavation of the silty clay from below the retaining wall footing will help improve this factor of safety by a significant margin.

To avoid differential settlements between the portions of the east approach fill located on the silty clay and those located on till, one of two methods may be used: the silty clay should be subexcavated at a 20 hor. to 1 vert. taper up going easterly from the limit of the retaining wall footing excavation. Alternatively, the fill should be constructed and left in place for a period of three months for all major differential settlements to be accommodated.

The natural ground surface slopes easterly from the culvert location, thus causing a slight increase in the height of fill proceeding easterly from the east tip of the east retaining wall. At the same time, the investigation shows the silty clay deposit to be increasing in thickness towards the east. Hence, the stability of the fill beyond the immediate approach limits should also be investigated, once the profile grade has been finalized.

Dewatering:

The sand lens located in the middle of the culvert is water bearing. It can be drained by advance ditching. Some sloughing of the ditch side slopes should be expected if the slopes are cut at 1:1 or steeper.

Alternatively, the N/S-E Ramp cut excavation could commence at the east or lower end and progress westerly. This will allow for drainage to occur concurrently with the construction activity.



DISCUSSION AND RECOMMENDATIONS - continued:

Dewatering - continued:

The glacial till soil is essentially non-cohesive. However, it has a tightly knit texture, which will not yield water readily. Therefore, natural drainage from cuts in the till will be quite slow. The quantities flowing in from the till soil should be small enough for handling with ordinary pumps.

Care should be taken to avoid bottom blow-out or boiling at the base of the culvert excavation due to excessive unbalanced hydrostatic heads. It is imperative that the water table be lowered to within half a metre of the base of the cut before the final grading occurs. Lowering of the water table may be accomplished by advanced ditching or pumping from sumps.

At the west portal of the culvert, a seepage cut-off is recommended to minimize seepage below the invert. The cut-off should be atleast 0.6 metres in depth to be effective.


Excavations:

All final cuts should be designed to a 2:1 geometry. Temporary cuts in the till and silty clay will stand up at 1:1 slopes for a short period of time. Cuts in the sand lens will slough, unless advance drainage has been carried out.

The glacial till is frost susceptible and should not be used within 1.2 metres of any paved surface. The silty clay exists at a moisture content well above the optimum. Its use in fills will require drying.

Respectfully submitted:

C. MIRZA ENGINEERING INC.


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1983 01 13





APPENDIX

Explanation of Terms Used in report

References

Record of Borehole Log Sheets 1-7

Figures 1 and 2

Drawing EGG0003-A



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:

R Q D (%)	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

f: failure

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



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The Discussion by Mirza refers to case histories of soft or loose
zones discovered in other tills by other reserachers such as Adams
and Eden.

loess deposit areas, innovative engineering techniques such as dynamic compaction or compaction by saturation and deep explosion may be required to insure safe construction.

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Soft zones in the glacial till in downtown Edmonton:¹ Discussion

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The note by Thomson *et al.* is a valuable contribution to the case history of Canadian glacial tills. It points out some important facts about foundation design in so-called competent glacial tills. Although their note refers to the Edmonton site, similar anomalous conditions have been reported by others (Adams 1960; Coates and McRostie 1960; Eden 1976) for other parts of Canada. Adams (1960) reported that, at a site 32 km west of Cornwall, the *N* values in the softer zones ranged between 5 and 20 blows per 300 mm in a till generally exhibiting blow counts of 50 or more. On removal from the sampling tubes, the material was reported to be "... quite soft and in many cases it slumped." The moisture content of the softer till was reported to be high. It would be extremely interesting to discover if the authors found a similar correlation between *N* values and moisture content for the 107 Street site.

In their paper, the authors predict settlements of the order of 110 mm for a bearing capacity of 240 kPa, based on the *in-situ* pressuremeter testing results of the softer till zones. However, earlier observations of actual building settlements in the Edmonton area reported by DeJong and Harris (1971) indicate the field modulus of deformation values to be significantly higher than those predicted by them from laboratory tests, or those reported later for *in-situ* pressuremeter tests by Eisenstein and Morrison (1973). Therefore, the uncorrected use of the *in-situ* pressuremeter modulus values to predict the 110-mm settlement may be on the conservative side. This is especially so if one postulates that ground disturbance around the pressuremeter probe is

likely to be much greater through the anomalous zones than elsewhere. A comment from the authors on this point would be appreciated.

On a recent project in Metropolitan Toronto, the writer has discovered anomalous till zones similar to those reported by the authors for the Edmonton tills. The anomaly occurs within the Leaside till (Karrow 1967) in the Borough of Scarborough at a site adjoining the Scarborough Civic Centre in the vicinity of Highway 401 and McCowan Road. The till is a silty sand with some gravel and is nonplastic.

During a preliminary site investigation in 1977, two low *N* values (5-10 blows per 300 mm) in two of six boreholes were passed off as being caused by "soil disruption" due to drilling and sampling. In a follow-up investigation in June 1981 for the building site, anomalously low *N* values were encountered in three of six boreholes. Subsequently, in October-November, 1981, a detailed investigation of the site was carried out (Mirza 1982) to find the extent of the anomalous zone. The additional work costing under \$15 000.00, resulted in savings of over \$250 000.00 in projected additional costs for piling, caisson, or raft foundations.

Because of the noncohesive nature of the till, extreme care was exercised during drilling and sampling to prevent unbalanced hydrostatic heads. Below the groundwater level, all borings were advanced by casing and washboring techniques, the casing being kept full of water during sampling. Upon recovery, the samples of the weaker silty sand till zone appeared limp, unlike the stiff samples from the competent zones which could be lifted out in one solid cylindrical mass from the split-barrel sampler body.

Samples from both the competent and incompetent

¹Note by S. Thomson, R. L. Martin, and Z. Eisenstein. 1982. Canadian Geotechnical Journal, 19, pp. 175-180.

TABLE 1. Comparison of *N* values and moisture contents

Borehole No.	Depth (m)	<i>N</i> value (blows/300 mm)	Moisture content (%)
Silty sand till—Scarborough site			
7	12.3	81	6.5
7	14.0	22	9.5
11	11.0	>100	8.2
11	12.4	20	10.0
11	13.8	8	9.5
11	15.5	11	10.5
G-1	11.0	60	10.0
G-1	12.4	20	10.0
Clayey silt till—Whitby site			
2	1.8	16	—
2	3.0	8	8.8
2	4.9	3	12.1
2	6.4	8	10.1
5	3.0	22	—
5	4.9	12	9.8
5	6.4	2	10.8
5	7.9	64	12.9

zones were immediately processed for moisture content. Little difference was found, the moisture content ranging between 8 and 12% and averaging 10%. In one case, the moisture content of the limp, weaker till was lower than that of the competent till located 1.4 m above it (Table 1). Both samples were recovered below the prevailing groundwater level.

Within this till complex, in the vicinity of the weaker till zone, thin zones of varved sediments were observed intermixed at relatively short spacings with open work sand and gravel pockets (as inferred by loss of wash water). Therefore, some form of depositional interruption is postulated for the occurrence of the anomaly.

At another site, in Whitby, Ontario, low *N* values (2–10 blows per 300 mm) were observed by the writer in an otherwise competent, clayey silt glacial till. However, at this site, the till was found to be subject to an upward hydrostatic pressure of about 1.5 m of water. Whether such seepage forces can soften a well-knitted, cohesive till exhibiting *N* values of 50–100 blows per 300 mm is debatable.

The Whitby till was explored by means of a conventional hollow-stem auger. The time lapse between pulling of the auger plug and insertion of the split-barrel sampler was generally less than 1 min due to the shallow

depths involved. Hence, the low *N* values encountered are considered to be representative of an *in-situ* condition and not one created by the exploration technique. Once again, moisture comparisons between the competent and incompetent till showed little difference (Table 1).

The anomaly in these two cases is the obvious lack of excessive moisture in the incompetent tills. Thus, the oft postulated theory that these weaker tills were once frozen and therefore not subject to consolidation by overriding ice masses is not applicable in these two cases. It is obvious that more research-oriented studies are required to unravel the mysteries of these anomalies. As the authors state, a good starting point would be the creation of a data bank designed specifically to record anomalous conditions in Canadian glacial tills. But first, there must be an awareness of the problem. The authors are to be complimented for creating that awareness.

The Scarborough data are published by permission of M. J. Kitchen, P.Eng., Senior Project Manager, Public Works Canada, Ontario Region. The Whitby data are published courtesy of First City Developments Ltd., Toronto, Ontario.

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- COATES, D. F., and MCROSTIE, G. C. 1960. Tests on glacial till: Discussion. National Research Council of Canada Technical Memorandum No. 69, Ottawa, Ont., pp. 49–51.
- DEJONG, J., and HARRIS, M. C. 1971. Settlements of two multistory buildings in Edmonton. Canadian Geotechnical Journal, 8, pp. 217–235.
- EDEN, W. J. 1976. Loose till in Labrador. In Glacial till—An inter-disciplinary study. Royal Society of Canada Special Publication No. 12, pp. 391–400.
- EISENSTEIN, Z., and MORRISON, N. A. 1973. Prediction of foundation deformations in Edmonton using an *in-situ* pressure probe. Canadian Geotechnical Journal, 10, pp. 193–210.
- KARROW, P. F. 1967. Pleistocene geology of the Scarborough area. Ontario Department of Mines Geological Report 46, Toronto, Ont., 108 p.
- MIRZA, C. 1982. Geotechnical report—Part A, subsoil and groundwater conditions, proposed Government of Canada building, Scarborough Town Centre. Unpublished report submitted to Public Works Canada, Ontario Region, by Warnock Hersey Professional Services Ltd., Mississauga, Ont.



Ministry of
Natural Resources and
Environment
Canada

RECORD OF BOREHOLE No 1

METRIC

W P EGG-000-3 LOCATION 4858872.2 N, 353134.5 E ORIGINATED BY MH
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger and Vane. COMPILED BY SQA
DATUM Geodetic DATE 1983-08-08 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20	40	60	80	100			W _p	W	W _L
88.1																	
0.0	20 cm Topsoil																
87.6	FILL MAT.- Het. mix.																
0.5			1	CS	-												
	SILTY CLAY																
	of Low Plasticity																
	with Silt pockets.		2	SS	21												
	Brown to Grey																
	V. Stiff - Stiff.																
	Tr. Sand.		3	SS	11												
84.0																	
4.1	GLACIAL TILL																
	Grey																
	(Reworked)		4	SS	4												
	Loose																
82.5																	
5.6	Het. Mixture																
	Sandy Silt		5	SS	109												
	with																
	Clay & Gravel																
	Grey to Dk. grey																
	V. Dense		6	SS	72/15 cm												
79.3																	
8.8	CLAY																
	Dk. Grey. - Hard																
78.5			7	SS	54												
9.6																	
	End of Borehole																

+3, x⁵: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

METRIC

W P EGG-000-3 LOCATION 4858878.2 N, 353112.2 E ORIGINATED BY MH/RB
 DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger. COMPILED BY SQA
 DATUM Geodetic DATE 1983-08-09 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
90.5																	
0.0	15cm Top Soil. --- FILL MATERIAL. Het. Mix. Silty Clay, Sand Tr. Organics.		1	CS	-												W.L. on 1983-08-09
88.9																	
1.6	Med. Sand Brown GLACIAL TILL Sandy Silt With Clay & Gravel Compact to V. Dense. occ. Sand Lenses.		2	SS	26												
86.2																	12-40-29-19
4.3																	
	Grey V. Dense becoming Silty Sand with Clay and gravel		3	SS	101												
82.7																	
			</														

+³, x⁵: Numbers refer to
Sensitivity

20
15 \diamond 5 (%) STRAIN AT FAILURE
10




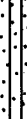
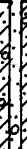


Ministry of
Transportation and
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Ontario

RECORD OF BOREHOLE No 3

METRIC

W P EGG-000-3 LOCATION 4858848.0 N, 353087.2 E ORIGINATED BY MH/RB
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SQA
DATUM Geodetic DATE 1983-08-08 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH									
								○ UNCONFINED	+ FIELD VANE				○				
						● QUICK TRIAXIAL	x LAB VANE										
91.8														10	20	30	
0.0	15cm. Topsoil - - - Brown SILTY CLAY of low Plasticity with Sand Tr. Org. - Firm		1	CS	-		91										
90.5																	
1.3	SAND Medium to Fine Grey Brown Compact to V. Dense.		2	SS	34		90										
88.5							89										
3.3	GLACIAL TILL Silty Sand V. Dense.		3	SS	99		88										
87.0							87										
4.8	Sandy Silt with Clay and Gravel V. Dense.		4	SS	88/15cm												
85.1							86										
6.7	End of Borehole																

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 4

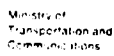
METRIC

W P EGG-000-3 LOCATION 4858847.2 N. 353061.0 E ORIGINATED BY MH/RB
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SQA
DATUM Geodetic DATE 1983-08-08 to 09 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
92.9	15cm Topsoil		1	CS	-												
91.8	SILTY CLAY of low plasticity with Sand. - Firm																
1.1	GLACIAL TILL		2	SS	46												
	Sandy Silt to Silty Sand with Clay and some Gravel		3	SS	127												
	V. Dense Grey		4	SS	124												
			5	SS	190/72cm												
			6	SS	153/25cm												
83.6			7	SS	108/15cm												
9.3	End of Borehole																

+³, x⁵ : Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAIL



METRIC

W P EGG-000-3 LOCATION 4858869.2 N, 353126.4 E ORIGINATED BY MH/RB
DIST 6 HWY 401 BOREHOLE TYPE Probe Hole - Solid Stem Auger COMPILED BY SQA
DATUM Geodetic DATE 1983-08-09 CHECKED BY CM

[illegible]

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 6

METRIC

W P EGG-000-3 LOCATION 4858870.6 N, 353130.8 E ORIGINATED BY MH/RB
DIST 6 HWY 401 BOREHOLE TYPE Solid Stem Auger COMPILED BY SQA
DATUM Geodetic DATE 1983-08-09 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa						
88.3								20 40 60 80 100		10 20 30				GR SA SI CL
0.0	20cm Topsoil						88						18.8	
	SILTY CLAY of low to medium plasticity						87							
	Brown to Lt. Grey		1	TW	PH		86							
	V. Stiff to Stiff						85							
84.7														
3.6	GLACIAL TILL Sandy Silt with Clay & Gravel													
83.7	V. Dense													
4.6	End of Borehole.													

+³, x⁵: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE



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RECORD OF BOREHOLE No 7

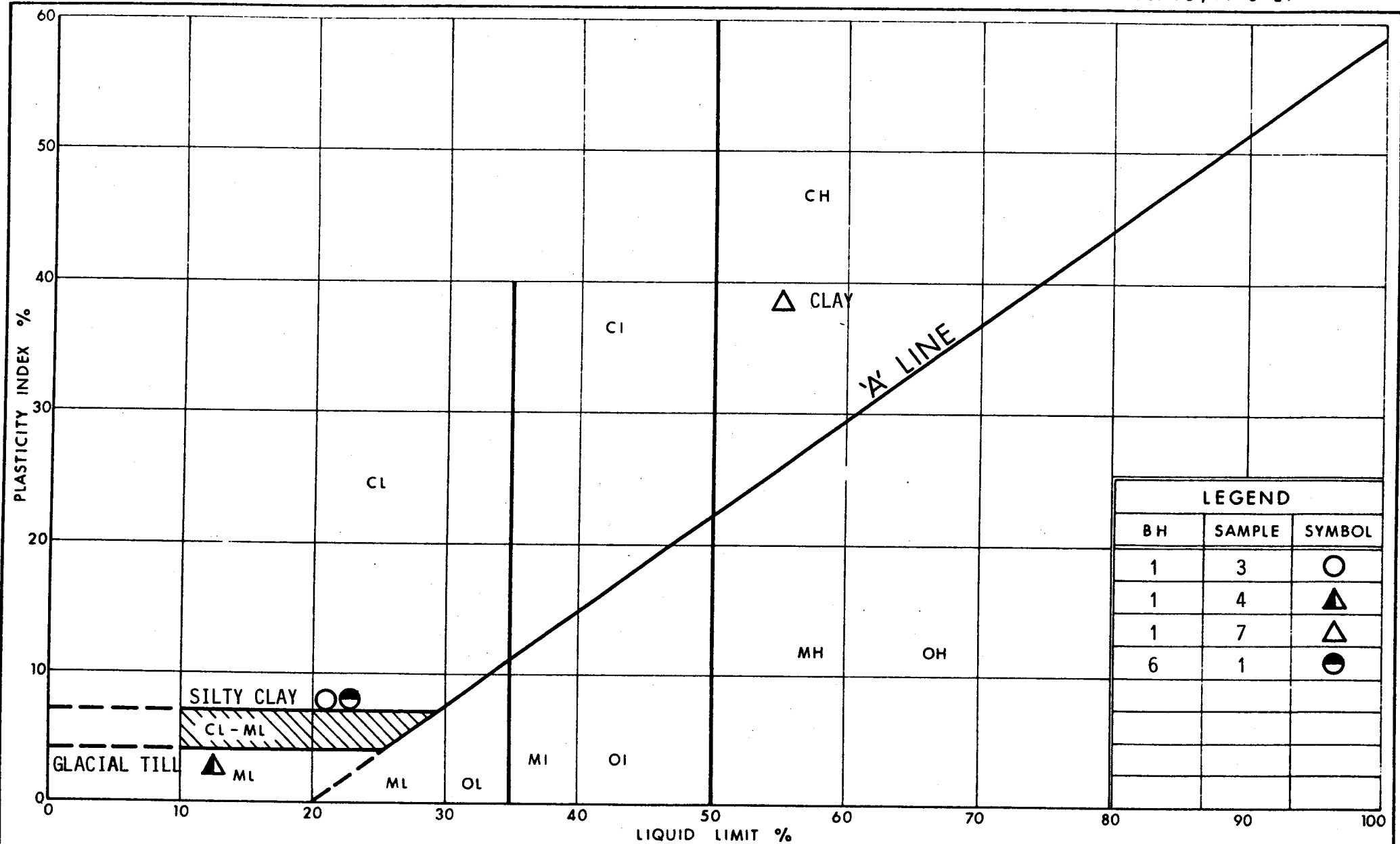
METRIC

W P EGG-000-3 LOCATION 4858882.4 N, 353125.6 E ORIGINATED BY MH/RB
DIST 6 HWY 401 BOREHOLE TYPE Probe Hole - Solid Stem Auger. COMPILED BY SQA
DATUM Geodetic DATE 1983-08-09 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
89.9																	
0.0	FILL MATERIAL Het. Mix. of Silty Clay, Sand and Gravel Tr. to some organics Dk. Brown Firm (Estimate)						89										
87.8							88										
2.1	SILTY CLAY Brown Stiff (Estimate)						87										
85.7							86										
85.3	GLACIAL TILL - V. Dense																
4.6	End of Probe Hole.																

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE



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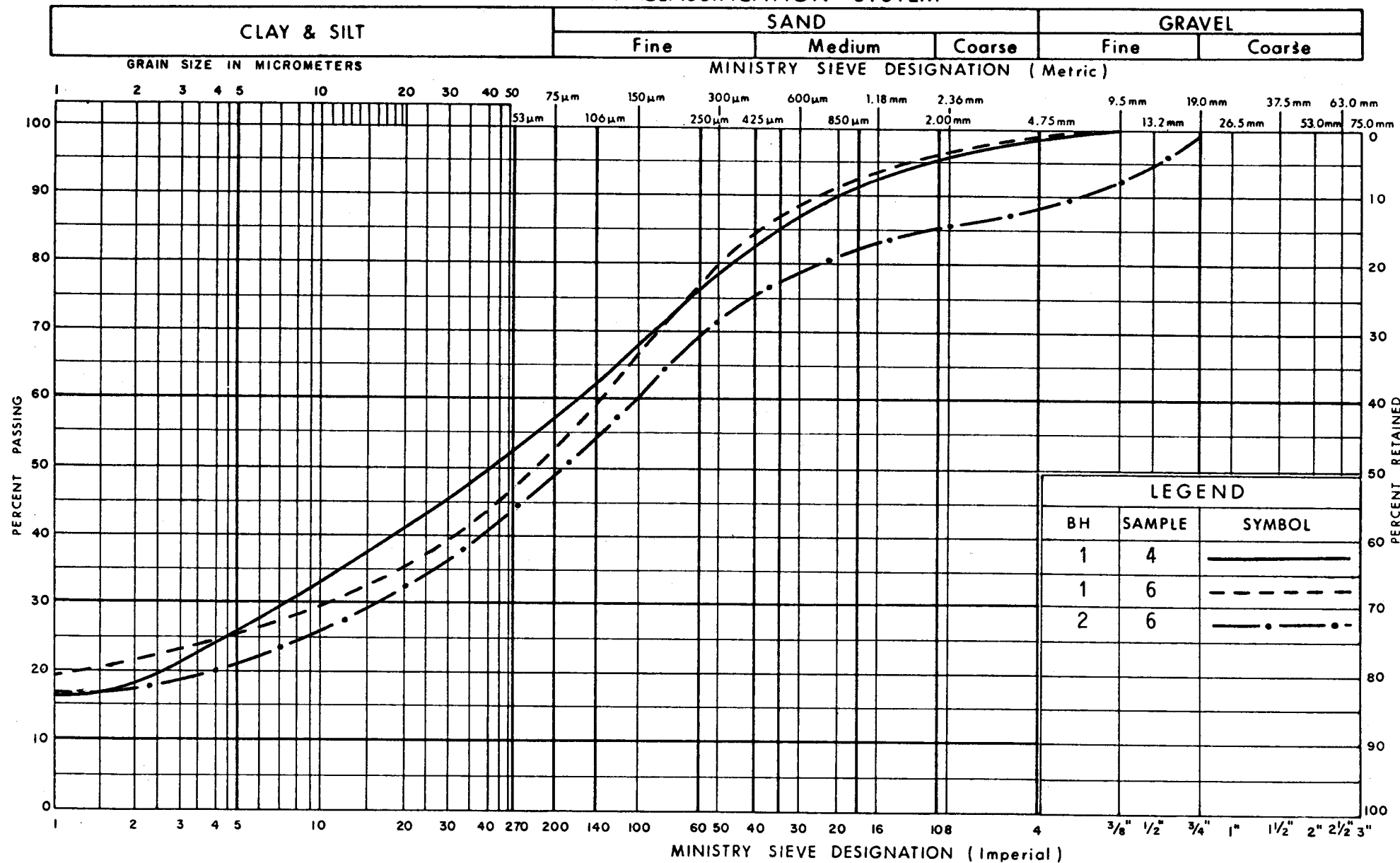
PLASTICITY CHART

FIG No 1

W P EGG-000-3

HWY 401

UNIFIED SOIL CLASSIFICATION SYSTEM



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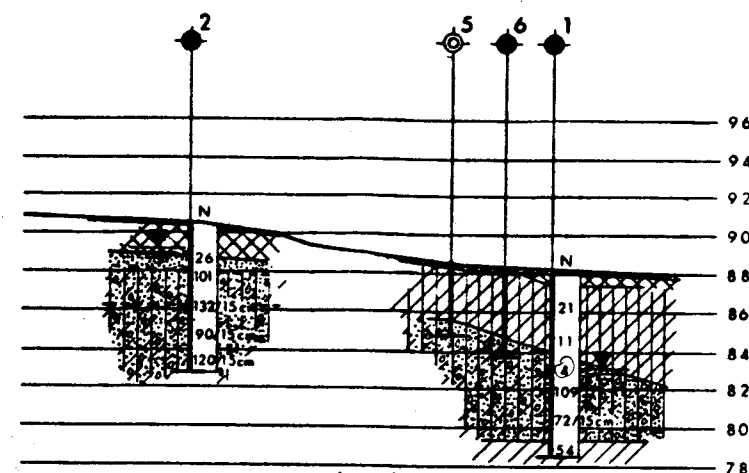
GRAIN SIZE DISTRIBUTION

GLACIAL TILL

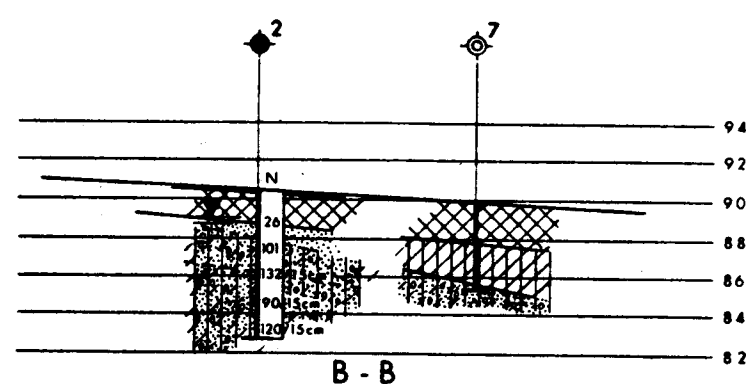
FIG No 2

W P EGG-000-3

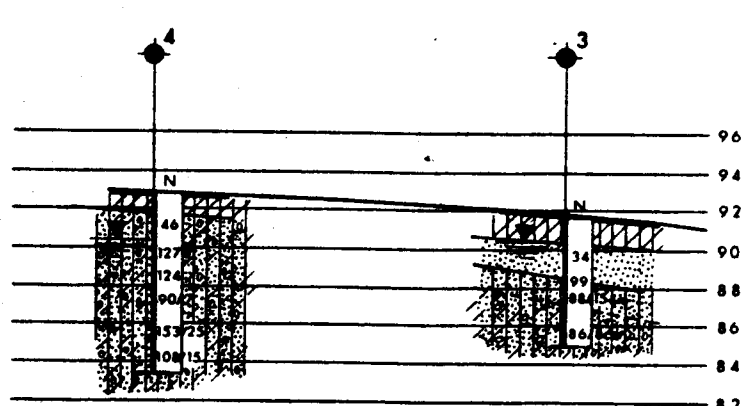
HWY 401



A - A



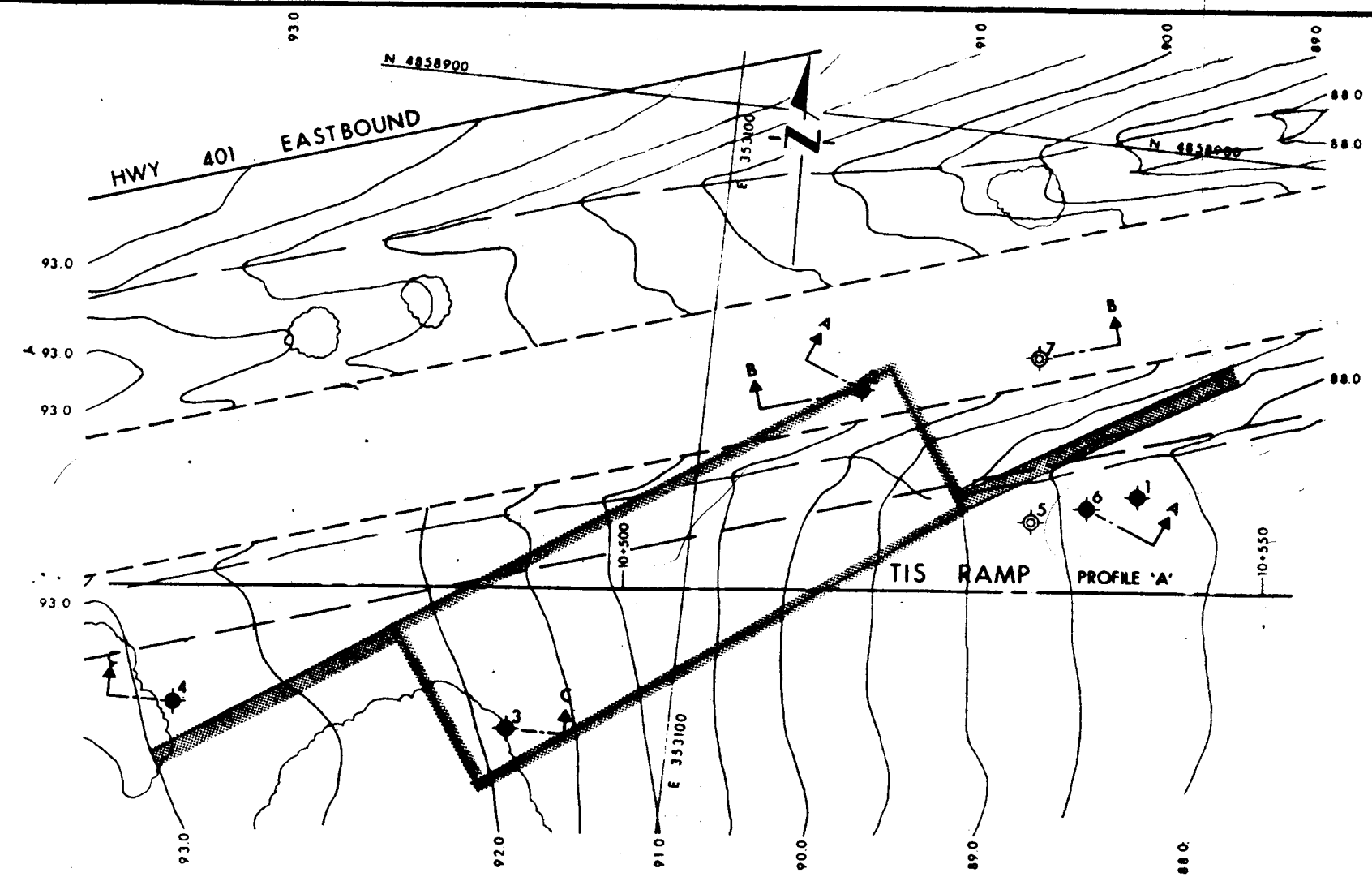
B - B



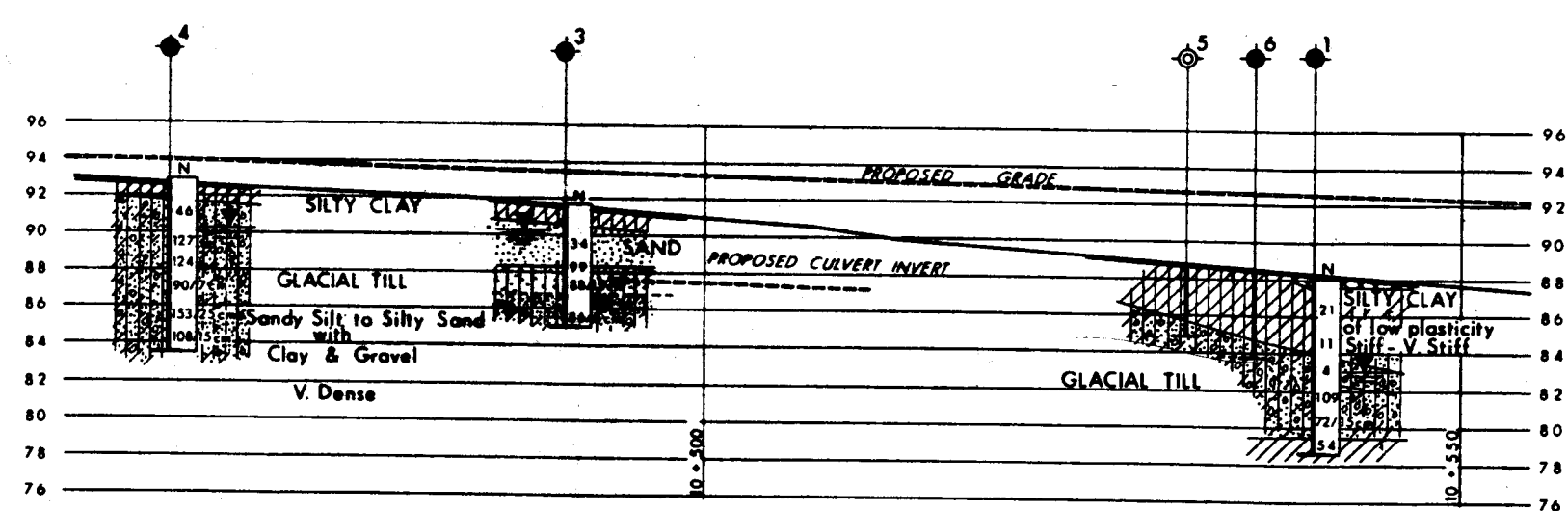
C - C
SECTIONS

SOIL STRATIGRAPHY LEGEND

- FILL MATERIAL**
Hot Mix Silty Clay & Sand
Tr Organics
- SILTY CLAY**
of low plasticity
Stiff - V Stiff
- GLACIAL TILL**
Sandy Silt to Silty Sand
with Clay & Gravel V Dense
- CLAY**
Hard
- SAND**
Compact-Dense



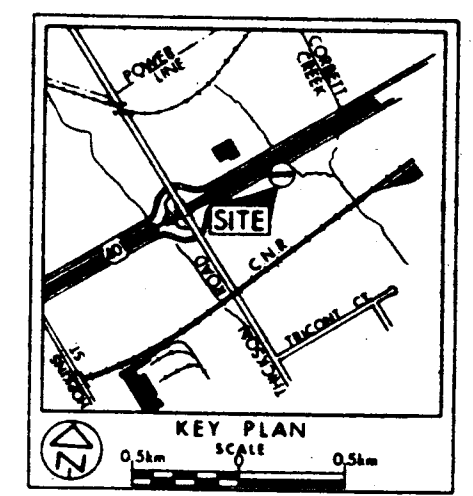
PLAN



T. I. S. RAMP PROFILE 'A'

METRIC
ALL DIMENSIONS SHOWN ARE
IN METRES AND/OR MILLI-
METRES UNLESS OTHERWISE
NOTED.

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GEOTECHNICAL SPECIALISTS



LEGEND

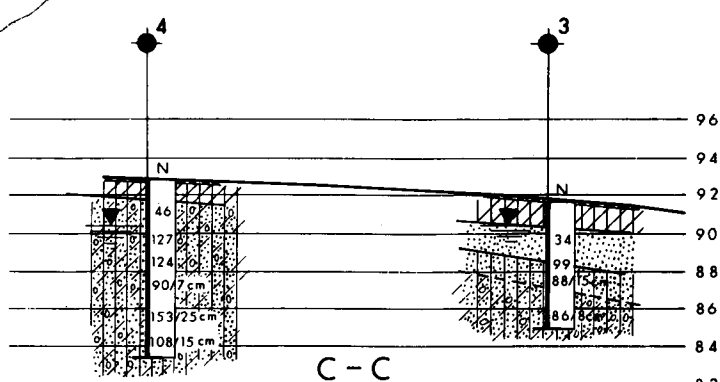
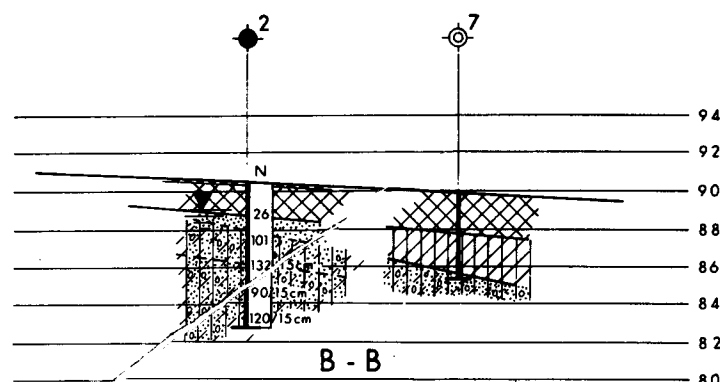
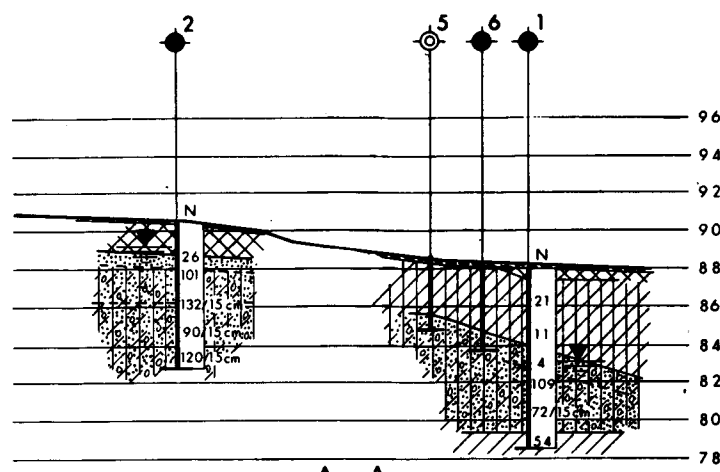
- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation 1983-08
- Probe Hole

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	88.1	4858872.2	353134.5
2	90.5	4858878.2	353112.2
3	91.8	4858848.0	353087.2
4	92.9	4858847.2	353061.0
5	88.6	4858869.2	353126.4
6	88.3	4858870.6	353130.8
7	89.9	4858882.4	353125.6

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.

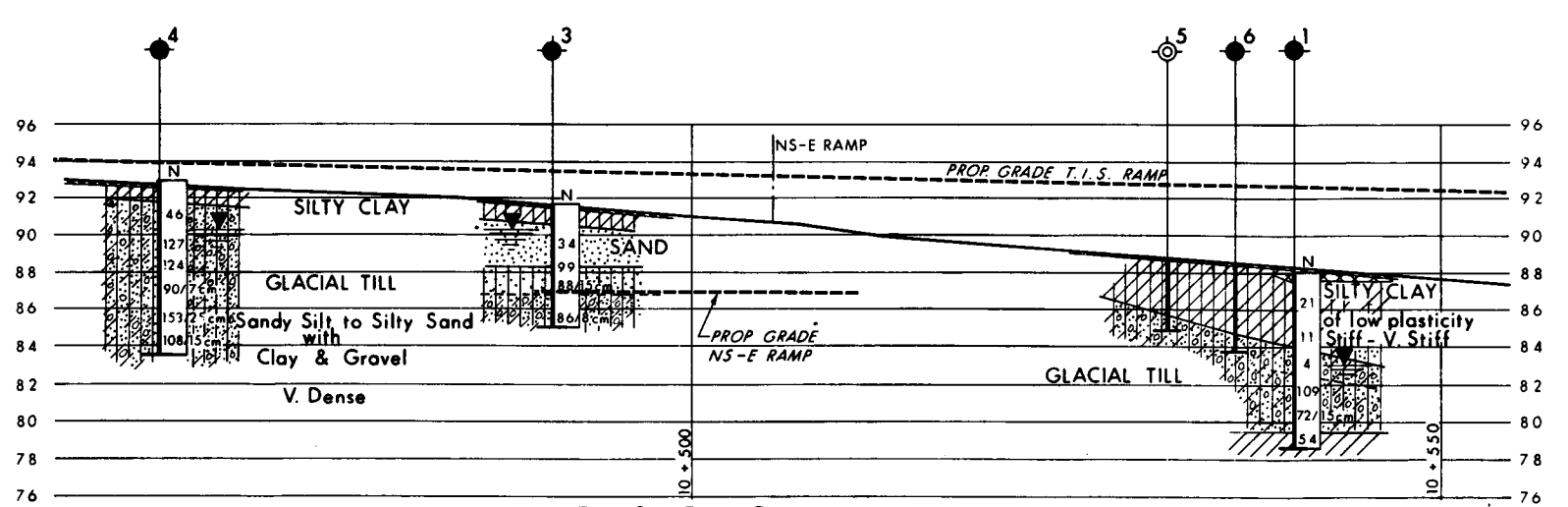
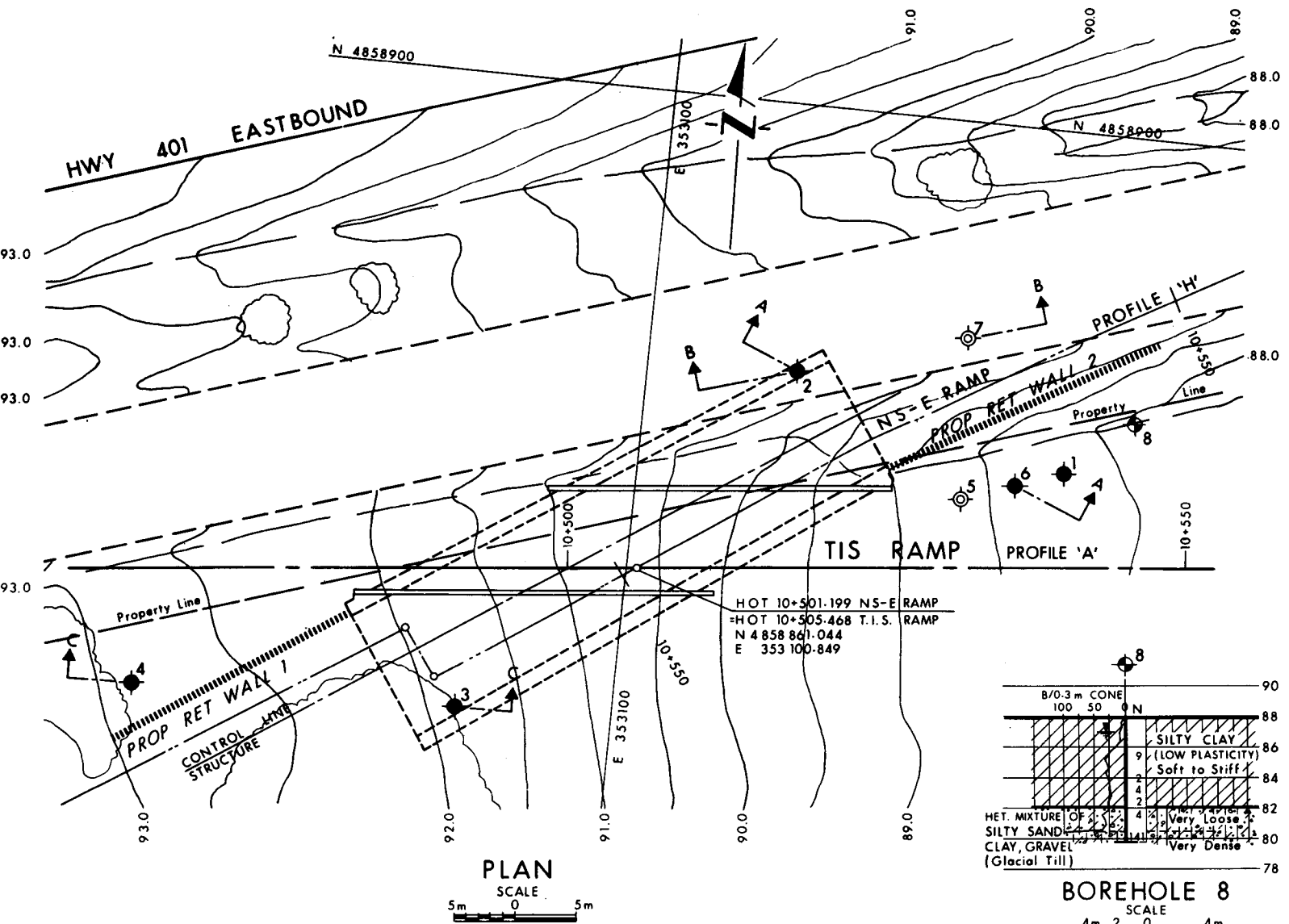
REFERENCE DRAWINGS		REVISIONS		DRAWN BY: SQA	DESIGNED BY: RB	GO-ALRT Ministry of Transportation and Communications	
				CHK'D BY:	APPROVED BY:		
				SCALE: FULL SIZE ONLY			
				<div style="display: flex; align-items: center;"> <div style="flex: 1;"> <div style="border-bottom: 1px solid black; width: 100%;"></div> <div style="display: flex; justify-content: space-between; font-size: 8px;"> HOR 1" = 10' VER 1" = 10' </div> </div> </div>			
				PROJECT MANAGER			CONTRACT NO EGG0003 - A ; 1983 11 22



SECTIONS
SCALE
HOR 5m 0 5m
VERT 4m 2 0 4m

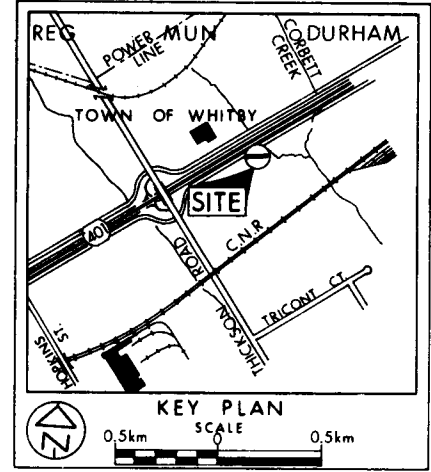
SOIL STRATIGRAPHY LEGEND

- | | | | |
|--|--|--|-------------------------|
| | FILL MATERIAL
Het Mix Silty Clay & Sand
Tr Organics | | CLAY
Hard |
| | SILTY CLAY
of low plasticity
Stiff - V Stiff | | SAND
Compact - Dense |
| | GLACIAL TILL
Sandy Silt to Silty Sand
with Clay & Gravel V Dense | | |



METRIC
ALL DIMENSIONS SHOWN ARE
IN METRES AND/OR MILLI-
METRES UNLESS OTHERWISE
NOTED.

C. MIRZA ENGINEERING INC.
GEOTECHNICAL SPECIALISTS



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 1983-08 and 1984 04 10
- ⊙ Probe Hole

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	88.1	4858872.2	353134.5
2	90.5	4858878.2	353112.2
3	91.8	4858848.0	353087.2
4	92.9	4858847.2	353061.0
5	88.6	4858869.2	353126.4
6	88.3	4858870.6	353130.8
7	89.9	4858882.4	353125.6
8	87.9	4858876.7	353139.8




Borehole 8 was done by the
Foundation Design Section M.T.C

Geocres No 30M15-69

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.

REFERENCE DRAWINGS		REVISIONS		DRAWN BY:	DESIGNED BY:		 Ministry of Transportation and Communications  PROJECT MANAGER	T.I.S. RAMP BASKET WEAVE STRUCTURE BOREHOLE LOCATIONS & SOIL STRATA			
1983 10	B-3-G-A-7	84 05	Borehole No 8 Added	SQA	RB			CONTRACT NO	DWG NO	REV	SHEET
				CHK'D BY:	APPROVED BY:			GGE 331	S-002	0	105
				SCALE: FULL SIZE ONLY							
				AS NOTED							