FOUNDATION INVESTIGATION REPORT

Culvert Locations, Various Sites
Whitby, Ontario

GO TRANSIT GGE - 330

1986 04 07

Our File:S-86-111

Distribution:
See page 10 of Report

GEO No. 30M15-78

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GO TRANSIT GGE - 330

1.0 INTRODUCTION

The Foundations Design Section of the Ministry of Transportation and Communications has retained the services of Strata Engineering Corp., on behalf of GO TRANSIT, to conduct soils investigations at the sites of four culverts below the prebuild GO ALRT track embankment in Whitby, Ontario. The terms of reference for the investigation were to put down two boreholes at each culvert location to bedrock, and to provide geotechnical recommendations for the design of load relieving slabs supported on piled foundations into bedrock at these locations. The changeover from light to heavy rail on the prebuild section requires protective measures such as load relieving slabs over the culvert crowns to protect the structures from the heavier locomotive loadings.

2.0 SITE AND GEOLOGY

A key plan of the site is shown in the Appendix. The prebuild embankment lies just south of Highway 401 and abuts the existing CN railway tracks. The four culverts have been numbered by GO TRANSIT as follows:

Culvert No.	Station
19	17+551
20	17+836
21	19+062
23	20+522

The Stations refer to chainages established under Contract EGG-320. Culvert numbers were provided by GO TRANSIT in their Purchase Order No.53435. Site plans were provided by the Foundations Section of the MTC.

The topography along the site is gently undulating, representing a drumlinized till plain. The bedrock in this area has been mapped as a shale of Upper Ordovician age (the Whitby Formation), and may be found immediately below a glacial till deposit which covers the site.

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3.0 FIELD AND LABORATORY WORK

The field work was carried out between 1986 03 20 and 27 using a bombardier mounted auger drilling machine. The borehole locations are shown on the individual culvert site plans, included as Drawings S86111-1 to -4 in the Appendix.

The boreholes were advanced by hollow stem auger drilling techniques. Standard Penetration Tests were carried out at 1.5 m intervals, the N values being noted at each sampling location. Recovered samples were transported to our Toronto Laboratories for further examinations. Sampling was continued through the fill and natural overburden materials until bedrock was encountered. The bedrock was cored in BQ size using diamond drilling techniques. The recovered cores were immediately examined for per cent recovery and RQD before being placed in storage trays for transportation to our Toronto Laboratories.

The borehole locations were tied into the existing culvert features, and ground elevations were obtained from the site plans and profiles provided by the MTC. Water levels were measured in every borehole when first encountered, and later after completion of diamond drilling, in which water is used to facilitate coring operations. These are shown on the Record of Borehole Logs in the Appendix, along with sampling details and laboratory test results. Testing was limited to index properties only for classification purposes under the investigation terms of reference of the study.

For ease of reference, the boreholes are numbered using the culvert numbers cited earlier and a postscript number denoting the borehole number at that culvert location.

All the drilled boreholes were backfilled upon completion of the investigation. Those that remained open were observed for water levels prior to backfilling. No pipes or piezometers were installed in these holes.

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4.0 SUBSURFACE CONDITIONS

4.1 General:

All culverts are overlain by fill materials which constitute the rail embankment. The fill is underlain by the natural overburden soils which comprise a cohesive competent glacial till overlying bedrock. The till is overlain by cohesive lacustrine deposits, and at the western extremity of the site (Culvert 19) is overlain by glacio-fluvial non-cohesive sediments. Since the culvert sites are separated by large distances between them, the subsurface conditions are described for each culvert location in the subsections below:

4.2 Culvert 19

The soil stratigraphy at this site consists of a fill material some 11 m in thickness overlying a 1.0 to 1.5 m thickness of sand and gravel over a thin stratum (2m±) of glacial till over shale bedrock. A summary of these strata is given as follows:

4.2.1 Fill Material: The fill material is locally derived from earth cuts in the area, and is essentially non-coehesive except in random pockets or layers. N values ranged between 5 and 55 blows per 0.3 m, indicating it to be of variable consistency or density, being generally compact where cohesionless and firm where cohesive.

4.2.2 Sand and Gravel: The fill material is underlain by a thin (1.0 - 1.5m) stratum of silty sand and gravel which is in a loose to dense state.

4.2.3 Glacial Till: The glacial till below the sand and gravel is a brown-grey silty clay of low plasticity with some sand and a trace of gravel, of generally hard consistency. This essentially cohesive till contains pockets of cohesionless materials, one of which was penetrated in Borehole 19-2 and consisted of a grey silty sand to sand. The till was encountered at elevation 80.2, and overlies shale bedrock at elevation 78±.

4.2.4 Shale Bedrock: Shale bedrock was encountered at elevations 78.1 to 78.5 and was proven by coring to elevation 74.1 in Borehole 19-1. It is highly weathered as evidenced by an RQD of 6 to 15 per cent. Sounder shale is estimated to be located at or just below elevation 75.

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4.2.5 Groundwater Conditions: The groundwater level was observed in Borehole 19-1 just before diamond coring, and was found to be at elevation 83±. After coring, the water level was measured at about elevation 90±, but is not reported as such since the water used in diamond drilling had remained undrained within the borehole at the time of measurement. In Borehole 19-2, the water table was measured at elevation 79.4, immediately after completion of sampling. This is a low level, and may represent an unstabilized condition within the borehole (not sufficient time for water to rise within borehole prior to backfilling). Borehole 19-2 was the last borehole drilled at the site.

Since the culvert invert elevation is 81.3, the water table elevation of 83± appears to be the more representative of general site conditions at this culvert location.

4.3 Culvert 20

The soil stratigraphy at this site consists of about 6 m of fill material overlying a thick (4 to 4.5 m) deposit of silty clay which in turn overlies a glacial till stratum of some 4 to 6 m thickness. The bedrock is located at a depth of about 16 m below top of rail.

4.3.1 Fill Materials: Except for a surficial layer of cohesionless fine to medium sand of just over 1 m thickness, the fill material consists essentially of a cohesive mixture of silty clay, sand and gravel, representing local cut material from the glacial till overburden around the site. N values ranged from a low of 4 blows per 0.3 m in Borehole 20-1 at the contact of fill and silty clay, to a high of 38 near the surface in Borehole 20-2. The fill is considered to be generally in a stiff state of consistency.

4.3.2 Silty Clay: The fill is underlain by a silty clay of low to medium plasticity, whose consistency reduces from stiff to soft with depth at its contact with the underlying glacial till stratum. The silty clay stratum is 4 to 4.5 m thick.

4.3.3 Glacial Till: At a depth of just over 10 m, a glacial till underlies the silty clay stratum. It consists of a dark grey sandy silt, with some gravel. The till is essentially non-cohesive, although it does contain clay fines, which give it an apparent cohesion. The till is generally very dense.

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4.3.3 Glacial Till - continued

being very stiff to hard in the more cohesive portions. A large boulder was cored in this stratum.

4.3.4 Shale Bedrock: Shale bedrock was encountered at elevation 75±, nearly 16 m below top of rail. It is very thinly bedded and the upper 1 m or so is highly weathered. RQD values were zero due to thin bedding of the shale. Sound shale is estimated to occur at elevation 74±.

4.3.5 Groundwater Conditions: The groundwater table was measured at elevation 86.5 in both boreholes at this culvert location. This elevation represents the original ground level at the site. The culvert invert elevation is 85.6 m.

4.4 Culvert 21

The soil stratigraphy at this site consists of about 4 m of fill followed by a thin (1.5 - 2 m) stratum of sand and gravel over a 5 m thick silty clay deposit which is underlain by a glacial till deposit of 2 to 3 m thickness. Shale bedrock underlies the till at a depth of some 13 m below top of rail.

4.4.1 Fill Material: The upper 2 m or so of the fill consists of dense to very dense silty sand followed by a silty clay derived from local cuts. N values ranged from 15 to 48 blows per 0.3 m. The fill is 3.5 to 4.0 m in thickness.

4.4.2 Sand and Gravel: The fill is underlain by a 1.5 to just over 2 m thick stratum of sand and gravel, which is fairly clean in terms of fines. Low N values indicate this stratum to be loose.

4.4.3 Silt to Silty Clay: The sand and gravel stratum is underlain by a 4.5 to 5.5 thick deposit of cohesive silt to silty clay of low plasticity, containing some sand and a trace of gravel. Based on N values of zero to 6, this deposit is considered to be very soft to firm in consistency.

4.4.4 Glacial Till: Glacial till was encountered at depths of 10 to 11 m below top of rail, and was found to be some 2 to 3 m in thickness. It consists of a dark grey silty sand which is very dense.

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4.4.5 Shale Bedrock: Shale bedrock was encountered at elevation 73±. It is generally sound below elevation 72±. RQD values ranged from zero to 62 per cent.

4.4.6 Groundwater Conditions: Groundwater was measured only in Borehole 21-1 where it was found to be at elevation 80.8 m.From field drilling observations, the water table is suspected to be located as a perched condition at the base of the sand and gravel stratum in Borehole 21-2 just above its contact with the silty clay deposit. The invert elevation of the culvert is 82.2 m.

4.5 Culvert 23

The soil stratigraphy at this site consists of 4 m of fill overlying a 2.6 m thick stratum of sand and gravel above a silty clay deposit overlying glacial till. The bedrock occurs at a depth of about 13 m below top of rail.

4.5.1 Fill Material: The upper 1.5 m of the fill consists of sand with some clay and a trace of gravel, while the remainder is a slightly cohesive clayey sand with cobbles and boulders. The fill thickness is 4 m, although the profile sheets for the contract at this location show a fill thickness of over 6 m. The reason for the difference is that select subgrade material was used at this location, and is represented by the sand and gravel stratum described below. N values in the fill ranged between 24 and 50 blows per 0.3 m, indicating its relative density (or consistency where cohesive) to be generally dense (or very stiff to hard, where cohesive).

4.5.2 Sand and Gravel: The fill material is underlain by about 2.6 m of sand and gravel, representing a select subgrade material used at this location. N values of 10 to 28 blows per 0.3 m indicate this material to be of loose to compact relative density.

4.5.3 Silty Clay: The sand and gravel stratum is underlain by a 4 m± thickness of silty clay of low plasticity. The consistency of this material is estimated to range from very soft to stiff.

4.5.4 Glacial Till: Glacial till is encountered at elevation 72 to 73 below the silty clay deposit, and was found to be about 3 m in thickness. The

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4.5.4 Glacial Till - continued:

upper parts of the till are non-cohesive, whereas the lower portions are cohesive. N values in excess of 45 to 50 blows per 0.3 m indicate the till to be very dense or hard.

4.5.5 Shale Bedrock: Shale bedrock was encountered at elevation 70±, at a depth of about 13 m below top of rail. From the recovered cores, it is estimated sound shale is located at elevation 69±. RQD values ranged from zero to 22 per cent due to the thinly bedded formation.

4.5.6 Groundwater Conditions: The water table measurements at the two borehole locations at this site show a wide divergence. In borehole 23-2, just prior to coring of the bedrock, the water table was measured to be at elevation 70.5±. After coring, in Borehole 23-1, the water table was measured at about elevation 78.5±. Since an 8 m differential is impossible in such a short distance between the two boreholes, the true water table is estimated to be located at about elevation 76±, based on the observations made during the field investigation that the split-spoon sampler was wet at about this elevation, and also the fact that the original ground level at this location was at elevation 77.7±. The present invert of the culvert is at elevation 77.1 m.

4.6 Subsurface Conditions - Summary

Culvert No.	Average Fill Thickness (m)	Average Depth to Bedrock (m)	Average Sound Rock Elev. m
19			
19	11.2 *	14.4	74.5
20	6.2	15.7	74.0
21	3.7 *	13.2	72.0
23	4.0 *	13.1	69.5

* Not including select subgrade materials.

The long term groundwater table will stabilize at or near the culvert invert elevations, with a seepage front down from the fill towards the invert.

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5.0 DISCUSSION AND RECOMMENDATIONS

5.1 General

The site investigation consisted of a pair of boreholes on a diagonal across each culvert location. A summary of the subsoil conditions has been given in the earlier text. Briefly, the subsurface conditions include fill materials, derived mostly from local cuts, with a basal select subgrade material of sands and gravel, followed by a silty clay of low plasticity and soft to firm consistency. This cohesive deposit is further underlain by a thin stratum of competent glacial till overlying bedrock at depths of 13 to 15 m below top of rail.

It is understood there is a concern for the ability of the four culverts investigated to withstand the higher engine loadings from the conversion of the present prebuild portion of the former GO-ALRT tracks to heavy rail. All of the investigated culverts are of concrete and some are box culverts. The fill thickness above the culvert crown ranges from 4 to 7 metres. With the exception of Culvert 19, all other locations show the presence of a soft to firm silty clay deposit below the culvert inverts. Engine loadings are dynamic in nature and have no influence on the compressibile behaviour of such cohesive deposits. The chief concern is with the structural integrity of the culverts themselves, which were originally designed for the much lighter GO-ALRT system (light rail). To preserve the structural integrity of these culverts, it has been proposed that load relieving slabs be constructed above the culvert crowns. Such slabs will need to be supported either within the fill surrounding the culverts or on piles. Since the fill material is of questionable quality and is likely to settle in the long term, it has been decided to support the slabs on a piled foundation.

5.2 Piled Foundation

In view of the prevailing subsoil conditions, it is recommended that the piled foundation at each culvert site consist of driven H piles supported essentially in end bearing within the competent (or sound) shale bedrock. Since the present embankments have already been in place for some time, loading on installed piles from negative skin friction arising out of further fill settlements is unlikely. Therefore the pile section chosen need only satisfy the slab and engine loading load criteria, inclusive of any fill dead loads above the slab.

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5.2 Piled Foundation - continued

As an alternative, pipe piles may be considered founded in end bearing within the glacial till stratum. However, the presence of boulders in the till, and in some cases the fill may interfere with the full penetration of the pipe piles into the glacial till stratum. Also, in view of the fact that the till stratum is generally only a few metres thick, the length difference between H and pipe piles will be minimal. When this is taken into consideration along with the fact that an H pile can be driven down to bedrock through the till with a higher factored capacity than a pipe pile, it may prove economically comparable to select H piles.

Steel H piles driven to or just below the sound shale bedrock elevations given in Section 4.6 of this report may be designed for the following factored capacities:

@ ULS	3500 kN
@ SLS Type II	1000 kN

for an HP 310x110 pile.

5.3 Construction Considerations

5.3.1 Piles: The piles should be designed with a reinforced tip as per Driving Shoe Details given in Standard DD-3301 (MTC Highway Engineering Standard - Structural).

Driven piles in the area of Culvert 23 may encounter boulders within the fill material. Driven piles in the vicinity of Culvert 20 are likely to encounter boulders within the glacial till deposit. It may therefore be necessary to either repull and redrive such piles or to cut them off and to install new piles next to them. This will necessitate field adjustments during construction. A Special Provision should be issued with the contract documents that boulders may be encountered at Culverts 20 and 23.

5.3.2 Pile Caps: All pile caps should be provided with a minimum earth cover of 1.2 m to protect against frost action effects.

5.3.3 Relieving Slab: In order for the relieving slab to be effective, provisions should be made for a gap between the crown of the culvert and the base of the slab.

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5.3 Construction Considerations - continued:

5.3.4 Dewatering: The groundwater table at all culvert locations is situated well below the crown elevation of the culverts. Therefore no dewatering will be required for the construction of the relieving slabs.

6.0 ACKNOWLEDGEMENTS

The field investigation was carried out with equipment rented from Master Soil Investigation Limited of Weston. It was supervized by John A. Blair, P.Eng. The assistance provided by Mr. Carl Watson of GO TRANSIT construction office is gratefully acknowledged. This report was written by J.Blair, P.Eng.under the direct supervision of C. Mirza, P.Eng.

Respectfully submitted:
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REGISTERED PROFESSIONAL ENGINEER
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PROVINCE OF ONTARIO

Encl: Appendix

APPENDIX

Explanation of Terms Used in Report

Office Record of Boreholes 19-1, 19-2, 20-1, 20-2
21-1, 21-2, 23-1, 23-2

Key Plan of Site

Site Location Drawings:

S86111-1	Culvert 19
-2	Culvert 20
-3	Culvert 21
-4	Culvert 23

STRATA ENGINEERING CORP.

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 **f: failure**
$\epsilon_1, \epsilon_2, \epsilon_3$	%	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	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				k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE			

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 19-1 METRIC

W P GGE 330 LOCATION Station 17+558 Offset 4.0m Rt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Core COMPILED BY SQA
DATUM Geodetic DATE 1986 03 26 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.7	Ground Surface										
0.0	Sand & Gravel FILL Brown silty fine sand with a trace of gravel Moist, Dense		1	SS	35		92		○		
			2	SS	55		91				
			3	SS	41		90				
			4	SS	44		89		○		
	Brownish grey silt with some clay to silty sand. Firm to v. stiff where cohesive. Compact to v. Dense where non-cohesive.		5	SS	19		88				
			6	SS	5		87				
			7	SS	17	▼	86		○		W.L. on 1986 03 26 measured prior to coring
			8	SS	10		85				
81.2	Dark grey silty fine sand with a tr. of gravel & clay. Contains wood, brick, paper etc.						84				
11.5	Dark brown silty SAND & GRAVEL		9	SS	37		83		○		
80.2	Moist to wet, Dense						82				
12.5	GLACIAL TILL Dark grey clayey silt with fine sand and a trace of gravel.		10	SS	78		81		○		
78.1	Moist, Hard						80				
14.6			11	SS	109/ 27cm		79				
	Shale BEDROCK		12	BQ	Rec. 73%		78				RQD 6%
	weathered		13	BQ	Rec. 85%		77				RQD 15%
74.1	Very thinly bedded dark grey Shale						76				
18.6	End of Borehole						75				

+³, ×⁵ : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 19-2 METRIC

W P GGE 330 LOCATION Station 17+544 Offset 4.1m Lt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, COMPILED BY SQA
DATUM Geodetic DATE 1986 03 27 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
92.7	Ground Surface										
0.0	Sand & Gravel Brown silty fine sand with a trace of gravel		1	SS	33		92				
							91				
			2	SS	30		90		○		
	FILL										
	Brownish grey to greyish brown sandy silt fo silty sand with a tr. of gravel and clay.		3	SS	29		89				
	Moist						88				
	Very stiff to hard where cohesive.		4	SS	49		87				
	Compact to very dense where non-cohesive.		5	SS	44		86		○		
							85				
							84				
	Brownish grey gravelly sand and silt. Contains organics.		6	SS	32		83				
81.7	Moist, Dense						82				
11.0	Brownish grey well-graded SAND & GRAVEL		7	SS	10		81		○		
	Moist to Wet										
80.2	Loose to compact						80				W.L. on 1986 03 27
12.5	GLACIAL TILL Brownish grey silty sand to sand & gravel		8	SS	140	▼					
78.5	Weathered Shale BEDROCK		9	SS	180		79		○		
14.2	End of Borehole Augered to refusal probably shale Bedrock										

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 20-1 METRIC

W P GGE 330 LOCATION Station 17+840 Offset 3.8m Rt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Core COMPILED BY SQA
DATUM Geodetic DATE 1986 03 24/25 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
91.3	Ground Surface										
0.0	Sand & gravel						91				
	Brown fine to medium sand with a trace of gravel. Comp. - Dense		1	SS	30						
	FILL		2	SS	35		90				
	Brown grey to greyish silty clay with some fine sand to sand and silt with a trace of gravel.		3	SS	29		89				
	Contains some root hairs.		4	SS	16		88				
	Moist		5	SS	11	▼	87				W.L. on 1986 03 25
	Firm to Hard										
85.4			6	SS	4		86				
5.9	Grey to light brown silty CLAY with some fine sand to Sandy SILT containing a trace of gravel.		7	SS	5		85				
	V. Soft to Firm		8	SS	8		84				
			9	SS	0		83				
81.1							82				
10.2	GLACIAL TILL						81				
	Dark grey sandy silt with some gravel and clay.		10	SS	25		80				
	Moist										
	V. Stiff to Hard		11	SS	91		79				24.7
	Dark grey well-graded silty sand and gravel		12	SS	122		78				
	Moist to Wet						77				
	V. Dense		13	SS	112/ 23cm		76				
75.3			14	SS	132/ 12cm						
16.0	Shale BEDROCK						75				
	weathered										
	Very thinly bedded dark grey shale		15	BQ	Rec. 83%		74				RQD 0%
73.0											
18.3	End of Borehole										

+³, ×⁵ : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 20-2 METRIC

W P GGE 330 LOCATION Station 17+832 Offset 4.3m Lt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Coring COMPILED BY SQA
DATUM Geodetic DATE 1986 03 25/26 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (o UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
91.3	Ground Surface										
0.0	Sand & Gravel						91				
	Brownish grey silty sand with some fine gravel. Moist		1	SS	38		90				
	FILL										
	Brownish grey silty clay with some fine sand and a trace of gravel.		2	SS	27		89		o	21.5	
	Moist						88				
	Stiff to v. Stiff					▼	87				W.L. on 1986 03 27
84.9			3	SS	9		86				
6.4	Grey to light brown silty CLAY with some fine sand and a trace of gravel.		4	SS	24		85		o		
	Moist to Wet		5	SS	6		84				
	V. Stiff becoming very soft with depth.						83				
80.4			6	SS	1		82				
10.9	GLACIAL TILL						81				
	Dark grey sandy silt with some gravel and clay.		7	SS	44		80		o	25.2	
	Boulder		8	BQ	Rec. 100%		79				RQD 56%
	Moist		9	BQ	Rec. 28%		78				RQD 0%
	Dense to very Dense						77				
75.8			10	SS	30/13cm		76				
15.5	BEDROCK - weathered		11	BQ	Rec. 40%		75				RQD 0%
74.9	dark grey Shale										
16.4	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

20
15 ⊹ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 21-1 METRIC

W P GGE 330 LOCATION Station 19+065 ℄ ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Coring COMPILED BY SQA
DATUM Geodetic DATE 1986 03 21/24 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Ground Surface										
0.0	Sand & Gravel						86				
	Greyish brown sandy silt to silty sand with a tr. of gravel and clay. Moist, Dense - V. Dense		1	SS	40/ 23cm		85				
			2	SS	48				○		
	FILL						84				
	Greyish brown silty clay with some fine sand and a tr. of gravel. V. Stiff.		3	SS	19						
82.3			4	SS	15		83				
4.0	Greyish brown well graded silty fine SAND & GRAVEL						82				
			5	SS	8				○		
80.8	Wet, Loose					▼	81				W.L. on 1986 03 24
5.5	Light grey SILT with some clay and a trace of gravel. Moist to Wet. V. Soft to Firm		6	SS	5		80				
							79				
			7	SS	1				○		
							78				
			8	SS	0		77				
76.3											
10.0	GLACIAL TILL Dark grey silty sand with a tr. of gravel to silty sand & gravel with a tr. of clay. Moist						76				
			9	SS	118				○		
			10	SS	55		75				
			11	SS	119		74				
73.0	V. Dense										
13.3	Shale BEDROCK weathered		12	SS	163		73				
	Very thinly bedded dark grey		13	BQ	Rec. 75%		72				RQD 0%
71.3											
15.0	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 21-2 METRIC

W P GGE 330 LOCATION Station 19+057 Offset 4.5m Rt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Core COMPILED BY SQA
DATUM Geodetic DATE 1986 03 24 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.4	Ground Surface										
0.0	Sand & gravel						86				
	FILL		1	SS	46						
	Brown fine to medium sand with a trace of gravel. Moist, Dense.						85				
			2	SS	38						
	Greyish brown silty clay with some fine sand and a trace of gravel. Moist, v. stiff.		3	SS	21		84		○	20.5	
82.9							83				
3.5	Greyish brown well graded SAND & GRAVEL		4	SS	24				○		
	Moist						82				
	Loose to Compact										
80.6			5	SS	8		81				
5.8	Mottled light grey and brown silty Clay with some fine sand and a trace of gravel						80				
			6	SS	0		79				
	Moist to wet						78				
	V. Soft to Firm						77		○		
			7	SS	6		76				
75.3											
11.1	GLACIAL TILL		8	SS	58		75				
	Dark grey silty sand with a trace of gravel and clay to silty sand and gravel. V. Dense.						74				
73.3											
13.1	Shale BEDROCK		9	SS	115/ 20cm		73		○	25.3	
	weathered		10	BQ	Rec. 31%		72				RQD 31%
	Very thinly bedded dark grey										
70.5			11	BQ	Rec. 100%		71				RQD 62%
15.9	End of Borehole										

+³, ×⁵ : Numbers refer to Sensitivity

15 ⟨ 20 / 10 ⟩ 5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 23-1 METRIC

W P GGE 330 LOCATION Station 20+527 Offset 4.6m Rt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Core COMPILED BY SQA
DATUM Geodetic DATE 1986 03 20 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
83.4	Ground Surface								
0.0	Sand & gravel Brown fine to medium sand with some clay and a tr. of gravel		1	SS	50		83		
	FILL Clayey sand and silt to silty fine sand Cobbles Moist, Comp. to Dense		2	SS	47		82		
			3	SS	28		81		
79.4			4	SS	27		80		
4.0	Dark brown SAND & GRAVEL with nodules of brown silty clay Boulders Moist to Wet		5	SS	28	▼	79		W.L. on 1986 03 24
76.8	Compact		6	SS	14		78		
6.6	Grey Silty CLAY with some fine sand and a trace of gravel Moist to Wet		7	SS	17		77		
	V. Soft to Stiff		8	SS	0		76	20.0	
72.4			9	SS	3		75		
11.0	GLACIAL TILL Dark grey well graded silty sand to gravelly sand with some silt and clay. Moist, Dense		10	SS	45		74		
70.4							73		
13.0	weathered		11	SS	100/ 8cm		72		
	Shale BEDROCK Very thinly bedded dark grey Shale.		12	BQ	Rec. 83%		71		RQD 0%
67.7			13	BQ	60%		70		RQD 22%
15.7	End of Borehole						69		
							68		

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

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

$\frac{20}{15}\diamond\frac{}{10}5$ (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 23-2 METRIC

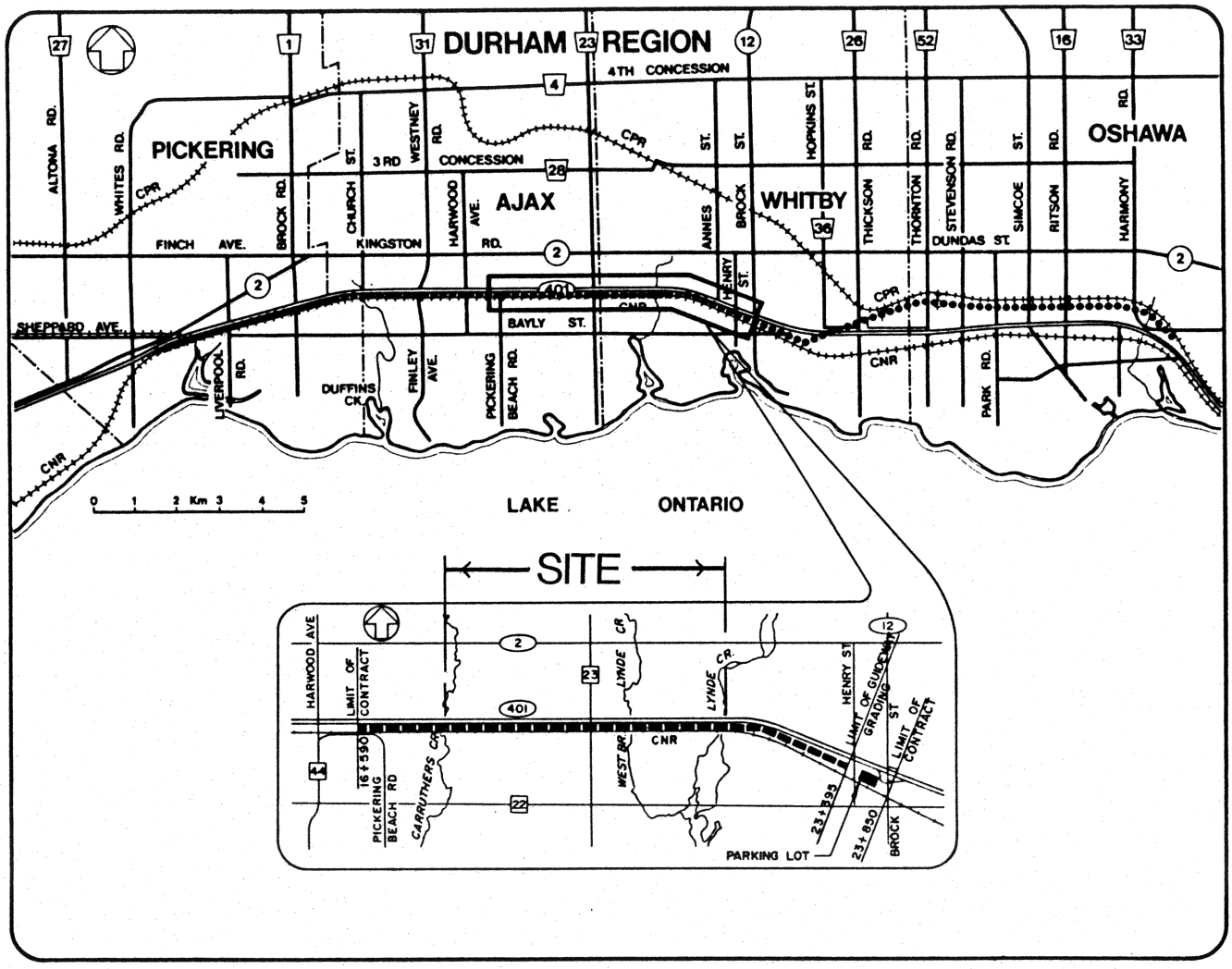
W P GGE 330 LOCATION Station 20+515 Offset 4.4m Lt. ORIGINATED BY JAB
DIST 6 HWY BOREHOLE TYPE Hollow Stem Auger, BQ Core COMPILED BY SQA
DATUM Geodetic DATE 1986 03 21 CHECKED BY CM

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT W_p / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_l — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
83.5	Ground Surface										
0.0	Sand & gravel Brown fine to medium sand with some clay tr. of gravel						83				
	FILL Greyish brown sandy silt with some clay and gravel.		1	SS	27		82		○	24.3	
	Moist to Wet						81				
	Compact		2	SS	24		80				
79.5											
4.0	Dark brown well graded SAND & GRAVEL		3	SS	10		79		○		
	Moist to Wet						78				
	V. Soft to Stiff		4	SS	17		77				
76.8											
6.7	Light grey silty Clay with sand and traces of gravel.		5	SS	0		76				
	Moist to Wet		6	SS	10		75		○		
	Very Soft to Stiff		7	SS	7		74		○		
73.0											
10.5	GLACIAL TILL Dark grey well graded sand and gravel with some silt & clay		8	SS	50		73		○		W.L. measured prior to coring
	Dark grey silty clay with some sand and a trace of gravel.					▼	72				
70.2	Moist, Hard		9	SS	123		71				W.L. on 1986 03 21
13.3	Shale BEDROCK weathered						70				
	Very thinly bedded dark grey Shale		10	BQ	Rec. 82%		69				RQD 7%
68.4											
15.1	End of Borehole										

+3, ×5 : Numbers refer to Sensitivity

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

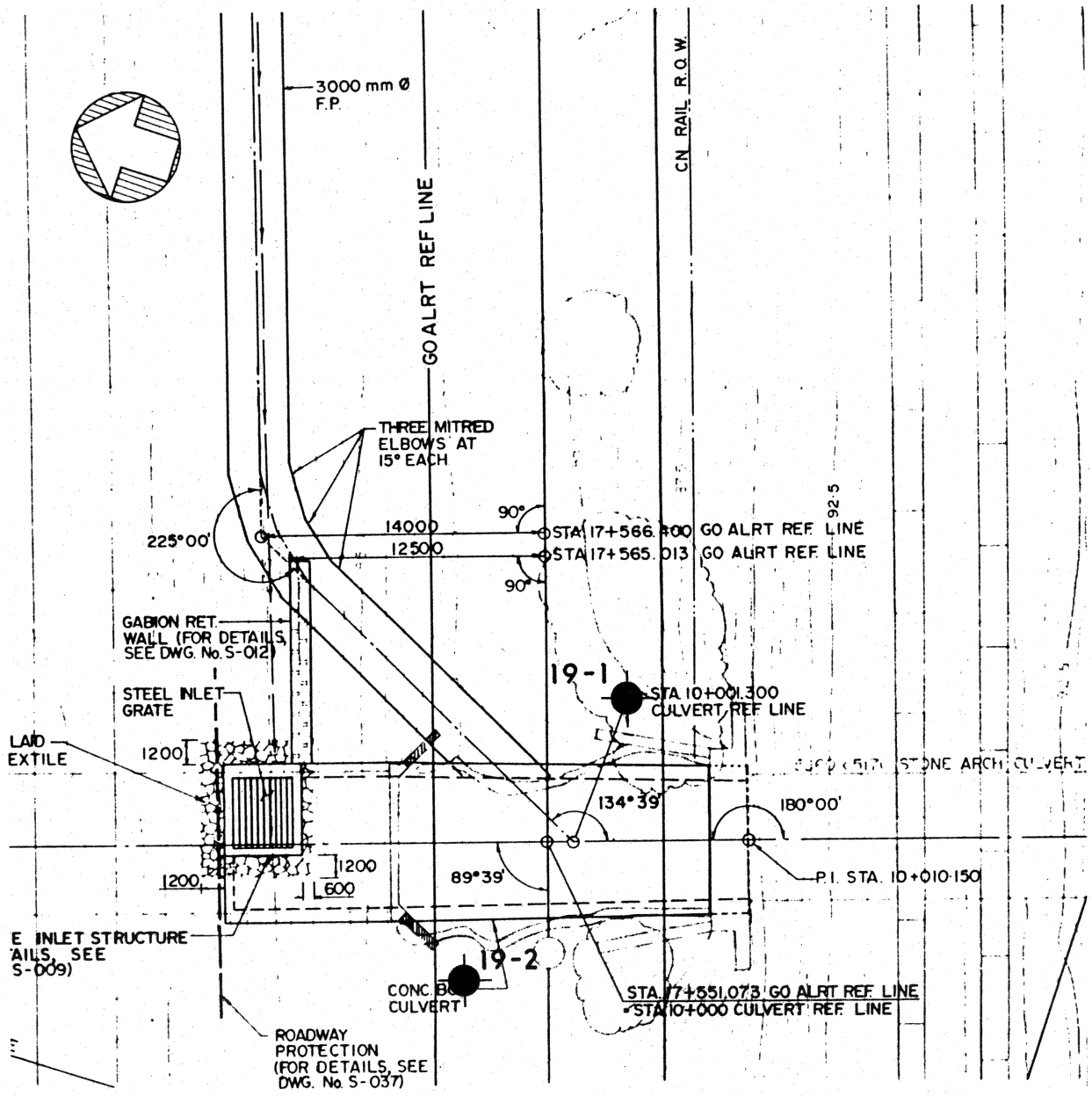
OFFICE REPORT ON SOIL EXPLORATION


DURHAM REGION
PICKERING
AJAX
WHITBY
OSHAWA
4TH CONCESSION
3RD CONCESSION
FINCH AVE.
KINGSTON RD.
BAYLY ST.
401
CNR
CPR
SHEPPARD AVE.
LIVERPOOL RD.
DUFFINS CK.
FINLEY AVE.
PICKERING BEACH RD.
PARK RD.
DUNDAS ST.
ALTONA RD.
WHITES RD.
BROCK RD.
CHURCH ST.
WESTNEY RD.
HARWOOD AVE.
ANNES ST.
BROCK ST.
HENRY ST.
HOPKINS ST.
THICKSON RD.
THORNTON RD.
STEVENSON RD.
SIMCOE ST.
RITSON RD.
HARMONY RD.
0 1 2 Km 3 4 5
LAKE ONTARIO
SITE
HARWOOD AVE
LIMIT OF CONTRACT
LYNDE CR.
HENRY ST
LIMIT OF GRADING
PICKERING BEACH RD
CARRUTHERS CR.
WEST BR
16+550
23+333
23+850
PARKING LOT

KEY PLAN

STRATA ENGINEERING CORP.
CONSULTING ENGINEERS & GEOTECHNICAL SPECIALISTS

Ref: Contract No. EGG-320,
Drawing No.S-007, Sheet 81



SCALE

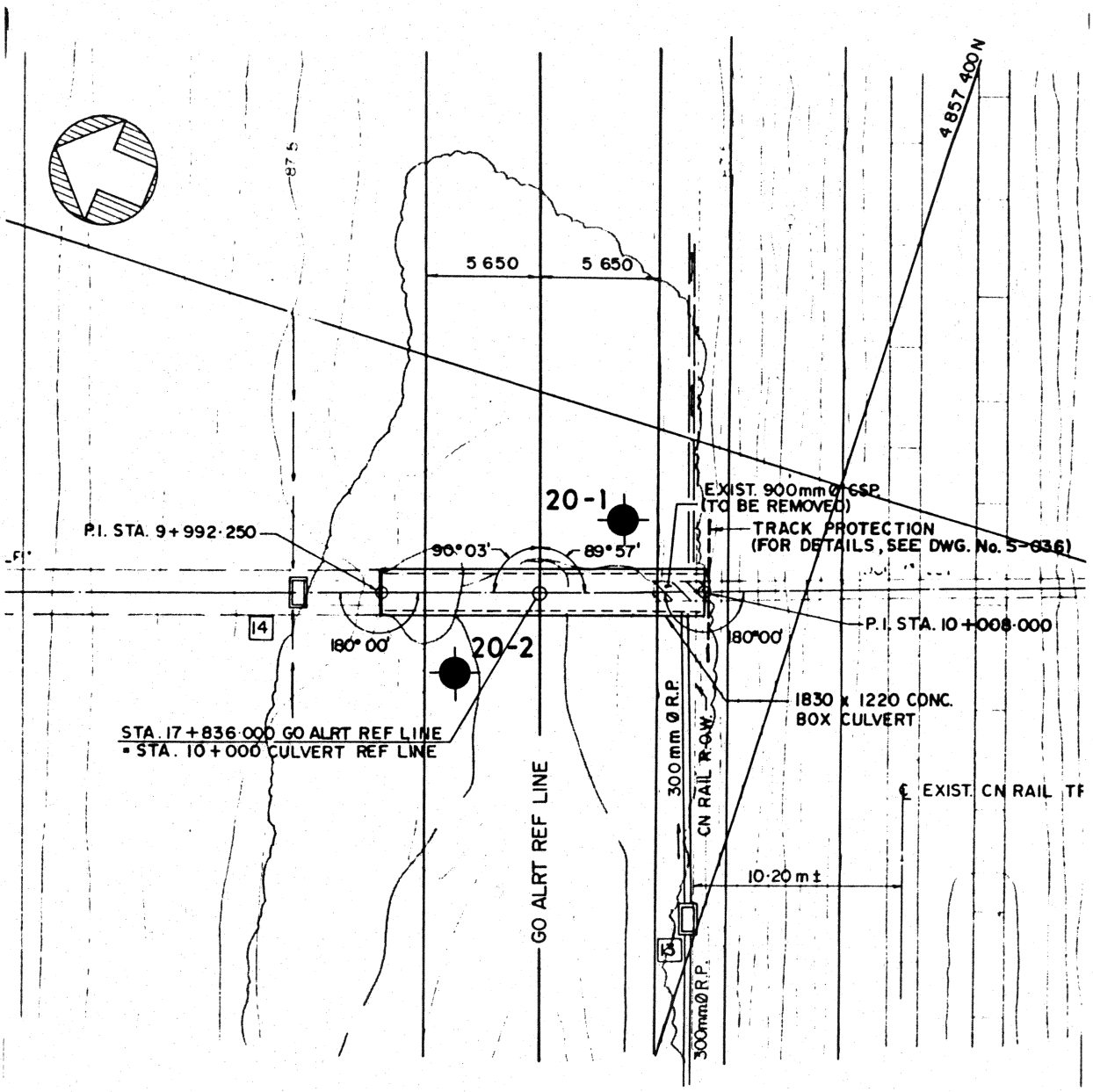
10m 0 10m

BOREHOLE LOCATION PLAN
CULVERT No. 19, STA. 17 + 551
GO TRANSIT

Drawn SQA	Date 1986 03 31	Scale As Shown	Sketch No. S86111 - 1

STRATA ENGINEERING CORP.
CONSULTING ENGINEERS & GEOTECHNICAL SPECIALISTS

Ref: Contract No. EGG-320
Drawing No. S-014, Sheet 88



SCALE

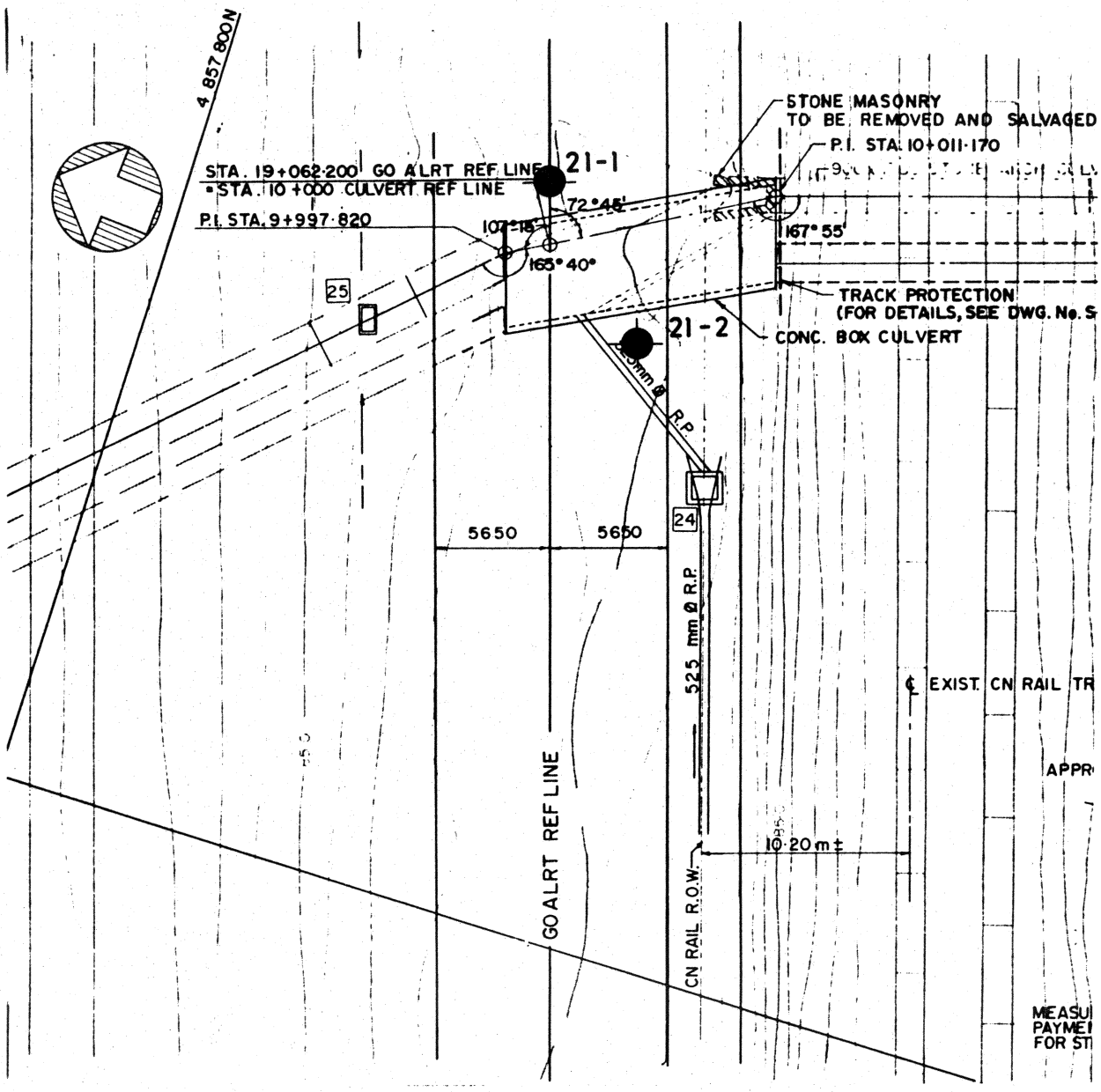
10m 0 10m

BOREHOLE LOCATION PLAN
CULVERT No. 20, STA. 17 + 836
GO TRANSIT

Drawn SQA	Date 1986 03 31	Scale As Shown	Sketch No. S86111 - 2

STRATA ENGINEERING CORP.
CONSULTING ENGINEERS & GEOTECHNICAL SPECIALISTS

Ref: Contract No. EGG-320
Drawing No. S-016, Sheet 90



SCALE

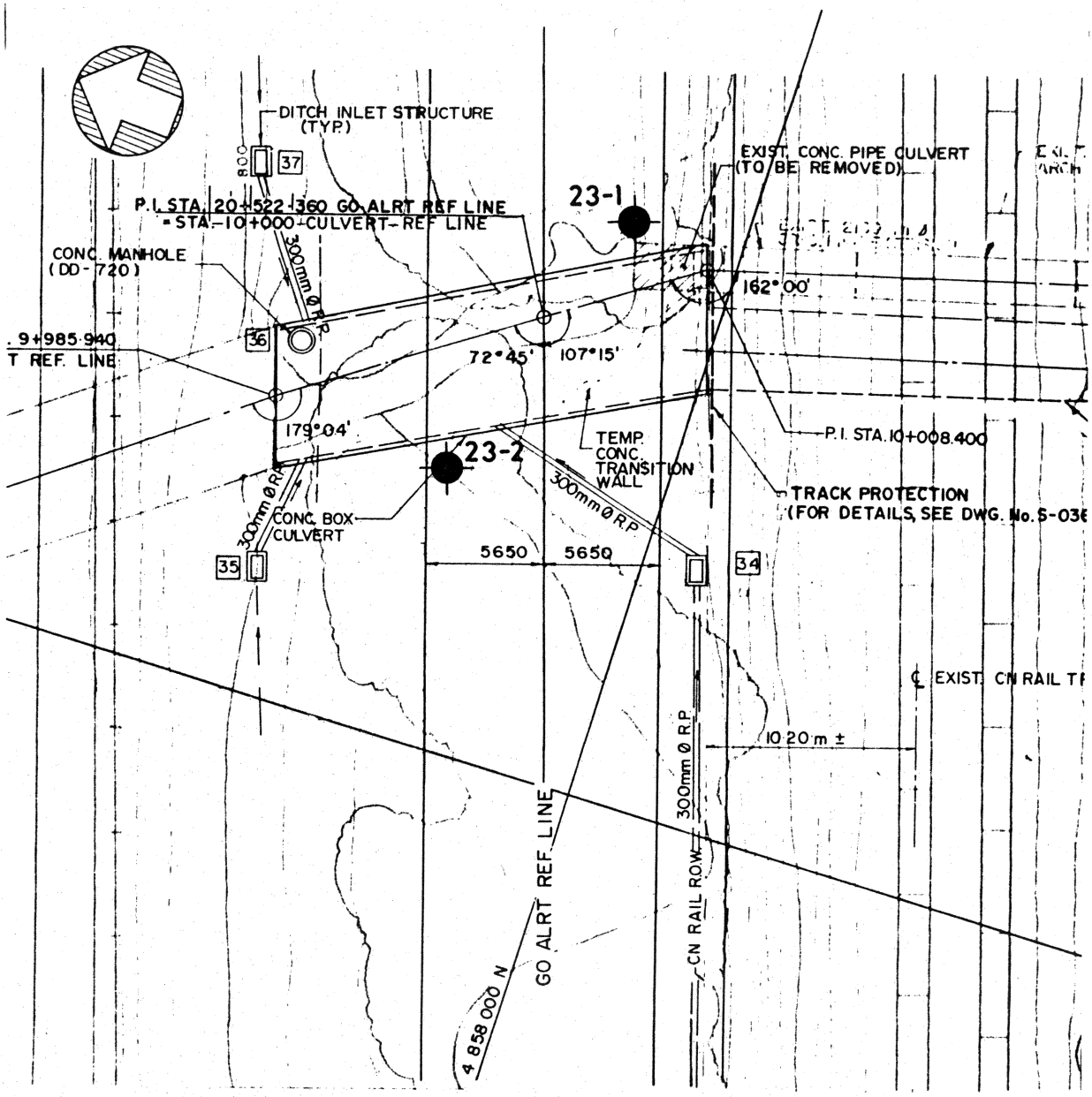
10m 0 10m

BOREHOLE LOCATION PLAN
CULVERT No. 21, STA. 19 + 062
GO TRANSIT

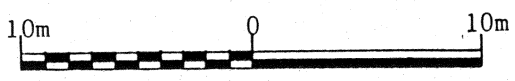
Drawn SQA	Date 1986 03 31	Scale As Shown	Sketch No. S86111 - 3

STRATA ENGINEERING CORP.
CONSULTING ENGINEERS & GEOTECHNICAL SPECIALISTS

Ref: Contract No. EGG-320
Drawing No. S-020, Sheet 94



SCALE



BOREHOLE LOCATION PLAN
CULVERT No. 23, STA. 20 + 522
GO TRANSIT

Drawn SQA	Date 1986 03 31	Scale As Shown	Sketch No. S86111 - 4

memorandum

Ontario

To: Mr. J. G. Ashbee,
Civil & Signals Design Co-Ord.,
Go Transit,
555 Wilson Avenue,
DOWNSVIEW, Ontario

Date: 86 04 10

From: Engineering Materials Office,
Foundation Design Section,
Central Building, Room 315

Re: Foundation Investigation and Design Report
Go Transit Contract GGE-330
Remedial Measures for Culverts
- No. 19 (STA. 17 + 551)
- No. 20 (STA. 17 + 836)
- No. 21 (STA. 19 + 062)
- No. 23 (STA. 20 + 522)

As requested by Go Transit, we have arranged for foundation investigations to be carried out for the above-noted projects. These investigations were required in order to verify bedrock elevations for pile driving design purposes.

The foundation investigations were assigned to the geotechnical engineering consulting firm, Strata Engineering Corp., and carried out under the technical supervision of this office.

We have reviewed the consultant's progress at each stage of the assignment. This involved defining terms of reference and reviewing the design recommendations. Only the format of the subsurface information and drafting has been reviewed. The accuracy of this portion of the report is considered to be the responsibility of the consultant.

Enclosed in the final Foundation Investigation and Design Report. We consider that the report provides sufficient details for design and construction to proceed, subject to the following comments:

1) The pile capacities, recommended by the consultant on page 9 of his report should be disregarded. Refer to our letter to Totten, Sims, Hubicki Associates Limited (Attention: Mr. G. Aleong) dated April 1, 1986 for our recommended pile design capacities.

2) Based on the Foundation Report following are our recommendation's for estimated refusal elevations for piles, which supersede the consultant's recommendations.

.....2

Re: Foundation Investigation and Design Report
Go Transit Contract GGE-330
Remedial Measures for Culverts
- No. 19 (STA. 17 + 551)
- No. 20 (STA. 17 + 836)
- No. 21 (STA. 19 + 062)
- No. 23 (STA. 20 + 522)

Culvert	Location	Refusal Elevation (m)
#19	STA. 17 + 551	77.5
#20	STA. 17 + 836	75.0
#21	STA. 19 + 062	73.0
#23	STA. 20 + 527	70.0

Note that boulders were encountered in the glacial till stratum, immediately above the bedrock.

If there are any questions, please contact this office.

D. H. Dundas

D. H. Dundas, P. Eng.,
Sr. Foundations Engineer

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

DHD:ma

encl.

cc: Distribution