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REMARKS: _____

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REPORT ON

**FOUNDATION INVESTIGATION AND DESIGN
QUEEN ELIZABETH WAY
TRAFALGAR ROAD TO HIGHWAY 403
W.O. 98-23024
AGREEMENT NO. 9820-7411-2920**

G.W.P 284-99-01

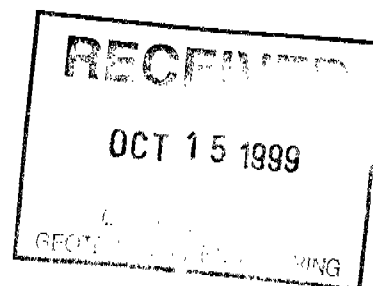
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October 1999



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PART A - FOUNDATION INVESTIGATION

**QUEEN ELIZABETH WAY
TRAFALGAR ROAD TO HIGHWAY 403
W.O. 98-23024
AGREEMENT NO. 9820-7411-2920**

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List of Abbreviations and Symbols

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1.0 INTRODUCTION

Golder Associates Ltd. has been retained by McCormick Rankin Corporation (McCormick Rankin) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation for the detail design work, as part of W.O. 98-23024. The project involves design work for the construction of an additional eastbound lane and a median on Queen Elizabeth Way (QEW) from Trafalgar Road to Highway 403 (Oakville Link), including highway widening, median reconstruction and upgrade and illumination. The foundation component of the project includes the construction of five (5) overhead signs, fourteen (14) High Mast Lights (HML) located in the median, and three (3) culvert extensions on the south side of the QEW.

The purpose of the foundation investigation is to determine the subsurface conditions at the site by means of a limited number of boreholes, in-situ tests and laboratory tests on selected samples. Based on our interpretation of the data obtained, recommendations on the foundation aspects of design of the proposed works are provided. Comments are also provided on anticipated construction problems where they may affect design of the high mast lighting, culvert extensions and overhead signs.

The terms of reference for the scope of work are outlined in our proposal letter P91-8018, dated March 25, 1999. The work was carried out in accordance with our Quality Control Plan for Foundation Design Services, dated May 10, 1999.

2.0 SITE DESCRIPTION

The site extends along the QEW from about 300 m to the east of Trafalgar Road to east of the existing Royal Windsor Drive underpass in the Town of Oakville, Ontario, within MTO District 4/6.

The topography of the site is relatively flat. The ground surface generally slopes down to the south-east towards Lake Ontario. The grade of the existing highway within the project area varies from Elevation 105.1 m to Elevation 108.4 m. The ground surface to the south and north of QEW varies between Elevation 103.5 m to Elevation 109 m. There is a drainage ditch approximately 2 m in depth along the north and south sides of QEW. Vegetation cover on both sides of the existing highway consists of grass and shrubs.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between August 25 and September 10, 1999. At this time fifteen (15) boreholes were put down at the site. Four (4) boreholes (Boreholes 1 to 4) were put down for the proposed overhead signs, seven (7) boreholes (Boreholes 5 to 12) were drilled along the median for the HML's, and three (3) boreholes (Boreholes 13 to 15) were drilled at the locations of the proposed culvert extensions. The table below summarizes the locations and depths of the boreholes drilled as part of this investigation.

<i>Borehole Number</i>	<i>Chainage (m)</i>	<i>Borehole Depth (m)</i>
1	19+750, 30m LT	4.6
2	20+050, 2m RT	4.6
3	20+404, 2m RT	4.6
4	21+480, 2m RT	4.6
5	20+790, 105m LT	3.8
6	20+160, 2m RT	4.6
7	20+320, 2m RT	4.4
8	20+570, 2m LT	6.1
9	20+720, 2m RT	4.4
10	20+970, 2m LT	4.6
11	21+240, 2m LT	4.6
12	21+380, 2m LT	4.6
13	20+680, 25m RT	4.6
14	20+920, 25m RT	4.7
15	21+460, 25m RT	3.8

NOTE: RT right of the centerline of the QEW median
LT left of the centreline of the QEW median

The investigation was carried out using truck mounted CME 55 and Diedrich D-50 drill rigs supplied and operated by Master Soil Investigations and Superior Soil Drilling of North York. In the boreholes, samples of the overburden and bedrock were obtained at regular intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedures. The boreholes were terminated between 3.8 m and 6.1 m depth below existing ground surface within weathered shale bedrock. Groundwater conditions in the open boreholes were observed throughout the drilling operations. Piezometers were installed in Boreholes 13, 14 and 15 to permit monitoring of the groundwater levels at the site.

The field work was supervised on a full-time basis by a member of our engineering staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The samples were identified in the field, placed in labeled containers and transported back to our laboratory in Mississauga for further examination. Index and classification tests were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and on Figures 5 and 6.

The as-drilled borehole locations were determined by our personnel relative to the chainage, as marked along the median of the QEW prior to our mobilization to the site. Elevations at the borehole locations were determined based on the QEW longitudinal section included in the Preliminary Design Report Queen Elizabeth Way, Dorval Drive to Erin Mills Parkway. W.P. 223-87-00. The locations of the boreholes are shown on the Record of Borehole sheets and on Drawings 1 to 4, attached.

4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY

4.1 Site Geology

From published geologic information, the site is located in the physiographic region known as the Peel Plain. The Peel Plain is generally composed of clayey soils covering the central portions of York, Peel and Halton Regions (Chapman and Putnam, "The Physiography of Southern Ontario", 3rd Edition, 1984). The surface topography of the Peel Plain slopes gradually and fairly uniformly towards Lake Ontario. The local physiography is characterized by shallow overburden consisting mainly of silty clay till with frequent shale fragments. The overburden is underlain by shale bedrock of the Georgian Bay Formation. The depth to bedrock at this site is shallow, varying typically between 1.5 m and 2 m below existing ground surface.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets and on Figures 5 and 6, following the text of this report. The stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

Relevant information on subsurface conditions was obtained from Boreholes 1 to 15. The subsurface information obtained from the current investigation was supplemented by the borehole information obtained for the foundation investigation for the proposed Royal Windsor Drive Underpass carried out by Golder Associates and included into report titled "Foundation Investigation and Design, Royal Windsor Drive Underpass, Queen Elizabeth Way / Highway 403, W.P. 67-98-00, District 4/6, Toronto", dated November 1998.

In summary, the pavement structure and / or fill materials overlay a silty clay till. The fill and / or till are underlain by grey shale bedrock that contains limestone interlayers. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Pavement Structure and Topsoil

The pavement structure encountered in the Boreholes 2 to 4 and 6 to 12, put down along the QEW roadway, consisted of asphalt / concrete underlain by granular road base fill. The thickness of the asphalt / concrete layer is approximately 0.3 m. No concrete was encountered below the asphalt in Boreholes 4 and 12. The granular road base fill generally consists of sand with some gravel and trace silt. The thickness of this layer is typically about 0.3 m; however, in Boreholes 4 and 11, the granular fill was about 2.3 m and 0.5 m thick, respectively. SPT 'N' values ranging from 12 blows to 44 blows per 0.3 m of penetration were measured within this fill, indicating a compact to dense state of packing. Measured water contents of samples from this fill range from about 4 percent to 6 percent.

A thin layer of topsoil was encountered in Boreholes 1, 5 and 13 to 15.

4.2.2 Fill Materials

Brown silty sand to sandy silt fill containing some gravel, trace to some clay and trace rootlets was encountered in Boreholes 5 and 13 to 15. The silty sand / sandy silt fill extends to between 0.8 m and 1.5 m depth. SPT 'N' values ranging from 19 blows to 32 blows per 0.3 m of penetration were measured within the silty sand / sandy silt fill, indicating a compact to dense state of packing. Measured water contents of samples from this fill ranged from about 6 percent to 14 percent.

Underlying the pavement structure in Boreholes 2, 3 and 6 to 12 and the silty sand fill in Boreholes 14 and 15, a fill material consisting of grey / brown / red silty clay with some sand and gravel was encountered. Trace shale fragments were encountered within the silty clay fill in Boreholes 6 and 12. The silty clay fill in these boreholes extends to depths between about 0.9 m and 2.1 m below the existing ground surface; this fill is likely native silty clay till reworked during QEW construction.

The silty clay fill is firm to very stiff; SPT 'N' values typically ranging from 6 blows to 18 blows per 0.3 m penetration were obtained in this deposit. Measured water contents of samples ranged from about 15 percent to 24 percent. Atterberg limits tests for four samples of the fill indicate liquid limits ranging from 21 percent to 51 percent and plasticity indices ranging from 8 percent to 28 percent. A grain size distribution curve of one sample of the silty clay fill is shown on Figure 5.

4.2.2 Silty Clay Till

A till deposit consisting of brown and grey silty clay with trace to some sand, trace gravel and shale fragments underlies the fill in the majority of the boreholes. The silty clay till was not present in Boreholes 1 to 3, 5 and 13. The top of the silty clay till varies between Elevation 103.6 m and 107.1 m.

SPT 'N' values measured within the till deposit range from 16 blows to in excess of 100 blows per 0.3 m of penetration, indicating a very stiff to hard consistency. Atterberg limits test for two samples of silty clay till indicates liquid limits of 44 percent and 38 percent and plasticity indices of 22 percent and 18 percent. A grain size distribution curve of one sample of the silty clay till is shown on Figure 6.

4.2.3 Bedrock

Bedrock of the Georgian Bay Formation consisting of grey shale with interbeds of limestone was encountered in all of the boreholes. No bedrock coring was carried out during this investigation. The bedrock surface was inferred from observations during drilling, penetration resistance and visual examination of samples retrieved. The bedrock samples retrieved consist of grey weathered shale. Limestone layers were inferred from resistance to further auger penetration or from grinding during augering. Resistance to further auger penetration was encountered in Boreholes 4, 5 and 9 at about Elevation 104.6 m, 103.2 m and 101.0 m, respectively, about 2 m below the bedrock surface at the borehole locations.

The surface of the bedrock varies from about Elevation 102.8 m to about Elevation 107.9 m. The bedrock surface is generally lowest in the vicinity of Station 20+600 and slopes up towards both the east and west. The bedrock surface depths and elevations at the borehole locations put down during the investigation are summarized in the table below:

<i>Borehole Number</i>	<i>Ground Surface Elevation (m)</i>	<i>Bedrock Surface Elevation (m)</i>
1	108.0	107.9
2	106.8	104.6
3	105.3	103.7
4	109.1	106.4
5	107.0	105.5
6	106.3	104.2
7	105.6	103.8
8	105.1	102.9
9	105.4	103.1
10	106.0	104.2
11	107.3	105.8
12	108.4	106.5
13	103.9	103.1
14	105.0	103.2
15	107.8	106.2

4.3 Groundwater Conditions

Groundwater conditions were observed during drilling operations and on completion of drilling. Piezometers were installed in Boreholes 13, 14 and 15 to monitor for the groundwater conditions at the site. Details of the piezometer installations are provided on the attached Record of Borehole sheets. The table below summarizes the groundwater conditions in the boreholes. Groundwater levels are expected to fluctuate seasonally and are expected to be higher during wet periods of the year.

<i>Borehole Number</i>	<i>Ground Surface Elevation (m)</i>	<i>Groundwater Level in Open Borehole on Completion of Drilling</i>		<i>Groundwater Level in Piezometer on September 29, 1999</i>	
		<i>Depth below existing ground surface (m)</i>	<i>Elevation (m)</i>	<i>Depth Below Existing Ground Surface (m)</i>	<i>Elevation (m)</i>
1	108.0	-	dry	-	-
2	106.8	4.0	102.8	-	-
3	105.3	3.1	102.2	-	-
4	109.1	2.3	106.8	-	-
5	107.0	-	dry	-	-
6	106.3	-	dry	-	-
7	105.6	4.4	101.2	-	-
8	105.1	3.1	102.0	-	-
9	105.4	-	dry	-	-
10	106.0	4.5	101.5	-	-
11	107.3	3.7	103.6	-	-
12	108.4	4.2	104.2	-	-
13	103.9	-	-	2.7	101.2
14	105.0	-	-	3.0	102.0
15	107.8	-	-	2.0	105.8

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PART B - FOUNDATION DESIGN

**QUEEN ELIZABETH WAY
TRAFALGAR ROAD TO HIGHWAY 403
W.O. 98-23024
AGREEMENT NO. 9820-7411-2920**

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides our recommendations on the foundation aspects of design for the construction of the QEW widening project from Trafalgar Road to Highway 403 (Oakville Link). Our recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction method and scheduling.

The works described in this report are associated with the foundation component of the project, which includes the construction of five (5) overhead signs, fourteen (14) High Mast Lights (HML) in the median, and the extension of three culverts on the south side of the QEW.

The locations of the proposed overhead signs and culvert extensions, as well as, the preliminary locations of the HML were provided to us on the preliminary site location plan prepared by McCormick Rankin. It is understood that the HML will be spaced at approximately 130 m commencing at about Station 20+000. It is also understood that the locations of the proposed overhead signs and culvert extensions are as follows:

Overhead Signs

Station 19+750 - WBL
Station 20+005 - WBL
Station 20+085 - EBL
Station 20+410 - EBL
Station 21+480 - EBL

Culvert Extensions

Station 20+692
Station 20+944
Station 21+460

5.2 Overhead Signs and High Mast Lighting

Boreholes 1 to 12 are relevant to the proposed HML and overhead signs.

In summary, the soils underlying the pavement structure along the QEW median at the borehole locations generally consist of fill materials underlain by native silty clay till and / or weathered shale bedrock. The following simplified stratigraphies may be assumed for design.

Area Station to Station	Representative Borehole(s)	Depth* to Base of Strata (m)		Bedrock Surface		Water Level	
		Fill	Silty Clay Till	Depth* (m)	Elev. (m)	Depth* (m)	Elevation (m)
19+740 to 19+780	1	0.1	-	0.1	107.9	dry	dry
20+000 to 20+100	2	2.1	-	2.1	104.6	4.0	102.8
20+100 to 20+450	6, 7**, 3	1.5	1.8	1.8	103.8	3.6	102.0
20+450 to 20+850	8**, 9	1.5	2.2	2.2	103.0	3.2	102.0
20+850 to 20+150	10	1.4	1.8	1.8	104.2	4.5	101.5
20+150 to 21+300	11	0.8	1.5	1.5	105.8	3.7	103.6
21+300 to 21+450	12	1.2	1.8	1.8	106.5	4.2	104.2
21+450 to 21+500	4	2.4	2.7	2.7	106.4	2.3	106.8
20+790, offset 105 LT (ramp)	5	1.5	1.5	1.5	105.5	dry	Dry

* Depth below ground surface at the representative borehole location (designated with **, where more than one borehole)

The anticipated conditions at the overhead signs and HML locations can be inferred from the results of the closest boreholes.

It is expected that foundation design for the overhead signs and HML will be governed by horizontal loading and overturning load cases. Therefore, we have assumed that the foundations will consist of drilled, cast-in-place, concrete piers. Based on the results of the boreholes, it is expected that the piers will be socketted into the weathered shale bedrock.

Application of horizontal loads such as wind and earthquake are intermittent and generally of short duration. For 'undrained' or 'short-term' conditions applicable to the fill and the native silty clay till, the ultimate or nominal geotechnical resistance along the shaft is represented by a constant distribution with depth and given by $4.5 c_u B$, where c_u = undrained shear strength (kPa) and B is the diameter of the shaft (m). The factored lateral force resisted by a shaft L m long at ULS (P_{ULS}) is given by:

$$P_{ULS} = \Phi 4.5 c_u B (L - 1.5 B)$$

The above equation is based on the assumption that the lateral geotechnical resistance acts over a width equal to three times the shaft diameter. Further, large deformation (lateral movement) would be required to fully mobilize lateral shaft resistance.

The upper portion of the shaft for a distance equal to 1.5 diameter of the pile (1.5 B in the above formula) or the frost depth, whichever is larger, should be neglected. A resistance factor, Φ , equal to 0.5 should be applied to the above formula.

The fill materials below a depth of about 1.2 m, where encountered, are generally comprised of silty clay. The maximum design thickness of the fill based on the above table would be about 1 m. The underlying till would have a maximum design thickness of about 0.7 m. The lateral resistance would therefore be mainly taken up by the length of the socket within the bedrock. The upper 2 m of the bedrock should be assumed for design to be highly weathered.

The following design parameters may be assumed for the overburden and weathered shale bedrock:

Fill Materials:

q_u = unconfined compressive strength = 100 kPa

γ = unit weight = 19 kN/m³

Silty Clay Till:

q_u = unconfined compressive strength = 500 kPa

γ = unit weight = 21 kN/m³

Weathered Shale Bedrock:

q_u = unconfined compressive strength = 750 kPa

γ = unit weight = 22 kN/m³

If insufficient lateral capacity is derived from the overburden and weathered shale bedrock, the additional capacity will be derived by extending the caisson into the unweathered shale. For design, the unconfined compressive strength may be taken as 1,500 kPa.

The water level for design should be taken as indicated in the table above.

The axial capacity of the concrete piers is achieved by a combination of end-bearing and shaft resistance. For the design of drilled shafts socketted only nominally (less than 3 diameters) into

shale bedrock, it may be assumed that the axial capacity is derived solely from end bearing resistance. For this case a factored end bearing resistance at ULS of 500 kPa be used for design.

Sockets for the HML foundations will primarily be in bedrock. It is noted that refusal to further auger advance and / or spoon penetration during drilling through the bedrock was met in three (3) of the twelve (12) boreholes drilled. Augering through the bedrock for caisson construction will be relatively difficult given the anticipated limestone layering within the shale bedrock and the caisson may have to be advanced using tricone / churn drilling techniques to break through the hard layers. In addition, although boulders were not encountered in the boreholes, boulders are inherent within the glacial till deposits in the general area and should be anticipated. The contractors' method of caisson construction should allow for break-up and removal of boulders.

5.2 Culvert Extensions

We understand that three existing concrete box culverts will have to be extended to the south as part of this project. The table below summarizes the subsurface conditions at the culvert locations. The culvert size and invert elevations were obtained from the Preliminary Design Report for the QEW, Dorval Drive to Erin Mills Parkway (W.P. 223-87-00).

<i>Culvert Location</i>	<i>Size (m)</i>	<i>Invert Elevations (m)</i>	<i>Borehole No.</i>	<i>Subsurface Conditions</i>
Station 20+692	3 x 1.2	102.80 RT	13	compact sandy silt fill to Elevation 103.1 m weathered shale bedrock
Station 20+944	2.4 x 1.2	103.80 RT	14	dense sandy silt fill to Elevation 104.2 m very stiff silty clay fill to Elevation 103.6 m hard silty clay till to Elevation 103.2 m weathered shale bedrock
Station 21+460	1.8 x 1.2	106.68 RT	15	dense silty sand fill to Elevation 107.0 m stiff silty clay fill to Elevation 106.4 m hard silty clay till to Elevation 106.2 m weathered shale bedrock

Based on the results of the boreholes, it appears that the existing culverts are founded within the hard silty clay till or weathered bedrock depending on the base slab thickness in the case of Station 21+460. The proposed extensions will therefore be founded on these competent subsoils. Depending on the variability of the fill thickness as encountered at Borehole 15, some subexcavation to found the culvert on the hard till may be required

For the culvert extensions founded on the hard silty clay till or weathered bedrock surface, a factored bearing resistance at ULS of 500 kPa may be assumed for design. The culvert should be designed to withstand the appropriate weight of fill and traffic loading. The culvert extensions should be placed at a grade at least equal to the existing culverts to ensure the direction of drainage is maintained. Provided that the culvert is founded on an appropriately prepared subgrade, settlement should be negligible.

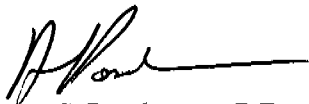
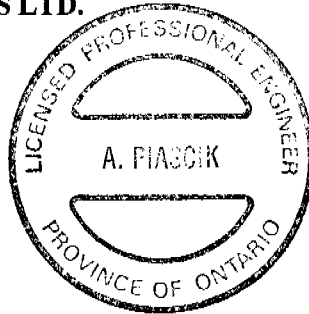
Backfill around the culvert should be carried out as per OPSD 802.02. Culvert backfill material should consist of free-draining, non-frost susceptible granular materials such as OPSS Granular 'A' or Granular 'B', Type II. All granular fill should be placed in loose lifts not exceeding 200 mm thickness and compacted to at least 95 percent of the material's Standard Proctor maximum dry density.

Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. The height of backfill to the culvert walls should be maintained equal on both sides of the structure during all stages of backfill placement. Temporary diversion of surface water flow may be required during culvert installation. Adequate erosion protection, as determined by hydraulic assessment, should be provided to the outlet slope.

GOLDER ASSOCIATES LTD.



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BVB/AMP/ASP/FJH/clg

WORD S/FINALDAT/1100/991-1140/81140JR1

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.).

Dynamic Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	C_u, S_u kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane test (LV-laboratory vane test)
γ	unit weight

Note:

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I GENERAL

π	= 3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (con't.)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity Index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_c	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(c) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(d) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	Overconsolidation ratio = σ'_p / σ'_{vo}

(e) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1. $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2

ON_MOT 991-1140.GPJ ON_MOT.GDT 12/10/99

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

PROJECT 991-1140			RECORD OF BOREHOLE No 2				1 OF 1		METRIC								
W.P. 98-23024			LOCATION Sta. 20+050, 2m Right of centerline of the median				ORIGINATED BY BVB										
DIST _____ HWY QEW			BOREHOLE TYPE _____				COMPILED BY BVB										
DATUM Geodetic			DATE 26.8.99				CHECKED BY AMP										
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									
106.75	Pavement							20	40	60	80	100					
106.45	Granular Fill																
106.14	Silty Clay, some sand and gravel Firm Reddish grey (Fill)		1	50 DO	6		106										
			2	50 DO	>50		105										
104.62	Shale Bedrock Weathered Grey		3	50 DO	50/.08		104										
	(Georgian Bay Formation)		4	50 DO	50/.05		103										
102.18	END OF BOREHOLE		5	50 DO	50/.01												
4.57	Note: Water level in open borehole at 4.0m depth on completion of drilling.																

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON_MOT 991-1140.GPJ ON_MOT.GDT 12/10/99

PROJECT 991-1140				RECORD OF BOREHOLE No 4				1 OF 1				METRIC				
W.P. 98-23024				LOCATION Sta. 21+480, 2m Left of centerline of the median				ORIGINATED BY BVB								
DIST HWY QEW				BOREHOLE TYPE				COMPILED BY BVB								
DATUM Geodetic				DATE 25.8.99				CHECKED BY AMP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
109.12							20	40	60	80	100	20	40	60		
108.99	Pavement															
0.15	Sand, some gravel Dense to compact Brown (Fill)		1	50 DO	36											
			2	50 DO	44											
			3	50 DO	12											
106.69			4	50 DO	50/20											
2.43	Silty Clay, trace to some sand and gravel Hard Brown (Till)															
106.38																
2.74	Shale Bedrock Weathered Grey (Georgian Bay Formation)															
104.55	END OF BOREHOLE (AUGER REFUSAL)															
4.57	Note: Water level in open borehole at 2.3m depth on completion of drilling.															

ON MOT 991-1140.GPJ ON MOT.GDT 12/10/99

PROJECT 991-1140			RECORD OF BOREHOLE No 5				1 OF 1		METRIC								
W.P. 98-23024		LOCATION Sta. 20+790, 105m Left of centerline of the median				ORIGINATED BY BVB											
DIST _____ HWY QEW		BOREHOLE TYPE _____				COMPILED BY SB											
DATUM Geodetic		DATE 10.9.99				CHECKED BY AMP											
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED									
107.00	Topsoil Sandy Silt, some clay, trace gravel Very stiff Black to brown/grey (Fill)		1	50 DO	21												
106.88			2	50 DO	22												
105.48	Shale Bedrock Weathered Grey (Georgian Bay Formation)		3	50 DO	>100												
1.52			4	50 DO	>100												
103.19	END OF BOREHOLE (AUGER REFUSAL) Note: Open hole dry on completion of drilling.																
3.81																	

PROJECT 991-1140			RECORD OF BOREHOLE No 6			1 OF 1			METRIC						
W.P. 98-23024			LOCATION Sta. 20+160, 2m Right of centerline of the median			ORIGINATED BY BVB									
DIST HWY QEW			BOREHOLE TYPE			COMPILED BY BVB									
DATUM Geodetic			DATE 26.8.99			CHECKED BY AMP									
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60					
106.29 0.00	Pavement														
105.99 0.30	Granular Fill														
105.68 0.61	Silty Clay, some sand and gravel, shale fragments Stiff Red (Fill)		1	50 DO	9										
104.77 1.52	Silty Clay, trace to some sand and gravel Hard Reddish grey (Till)		2	50 DO	37										
104.16 2.13	Shale Bedrock Weathered Grey		3	50 DO	50.04										
	(Georgian Bay Formation)		4	50 DO	50.04										
101.72 4.57	END OF BOREHOLE		5	50 DO	50.04										
	Note: Open hole dry on completion of drilling.														

PROJECT 991-1140			RECORD OF BOREHOLE No 7				1 OF 1		METRIC								
W.P. 98-23024			LOCATION Sta. 20+320, 2m Right of centerline of the median				ORIGINATED BY BVB										
DIST HWY QEW			BOREHOLE TYPE				COMPILED BY BVB										
DATUM Geodetic			DATE 27.8.99				CHECKED BY AMP										
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									
105.62 0.00	Pavement							20	40	60	80	100					
105.32 0.30	Granular Fill																
105.02 0.60	Silty Clay, some sand and gravel Very stiff Reddish grey (Fill)		1	50 DO	16												
104.10 1.52	Silty Clay, trace to some sand and gravel Hard Reddish grey (Till)		2	50 DO	50/1												
103.79 1.83	Shale Bedrock Weathered Grey (Georgian Bay Formation)		3	50 DO	50/13												
			4	50 DO	50/15												
101.21 4.41	END OF BOREHOLE Note: Water level in open borehole at 4.4m depth on completion of drilling.		5	50 DO	50/04												

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

PROJECT 991-1140			RECORD OF BOREHOLE No 9			1 OF 1			METRIC								
W.P. 98-23024			LOCATION Sta. 20+720, 2m Right of centerline of the median			ORIGINATED BY BVB											
DIST HWY QEW			BOREHOLE TYPE			COMPILED BY BVB											
DATUM Geodetic			DATE 27.8.99			CHECKED BY AMP											
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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
105.42 0.00	Pavement																
105.12 0.30	Granular Fill																
104.81 0.61	Silty clay, some sand and gravel Stiff to hard Brown/grey (Fill)		1	50 DO	9												4 22 50 24
103.90 1.52	Silty Clay, trace to some sand and gravel Hard Brown/Grey (Till)		2	50 DO	35												
103.13 2.29	Shale Bedrock Weathered Grey		3	50 DO	50/08												
	(Georgian Bay Formation)		4	50 DO	50/01												
101.01 4.41	END OF BOREHOLE (AUGER REFUSAL)		5	50 DO	50/01												
Note: Open hole dry on completion of drilling.																	

ON MOT 991-1140.GPJ ON MOT.GDT 12/10/99

+3, X3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 991-1140			RECORD OF BOREHOLE No 12				1 OF 1		METRIC							
W.P. 98-23024			LOCATION Sta. 21+380, 2m Left of centerline of the median				ORIGINATED BY BVB									
DIST HWY QEW			BOREHOLE TYPE				COMPILED BY BVB									
DATUM Geodetic			DATE 25.8.99				CHECKED BY AMP									
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								WATER CONTENT (%)
108.35								20	40	60	80	100				
108.98	Pavement															
0.15	Granular Fill															
107.74			1	50 DO	15		108									
0.61	Silty Clay, some sand and gravel, shale fragments Firm Grey (Fill)		2	50 DO	7											
107.13							107									
1.22	Silty Clay, trace to some sand and gravel Hard Grey (Till)		3	50 DO	50/05											
106.52																
1.83	Shale Bedrock Weathered Grey		4	50 DO	50/08		106									
	(Georgian Bay Formation)															
			5	50 DO	50/02		105									
							104									
103.78			6	50 DO	50/01											
4.57	END OF BOREHOLE															
	Note: Water level in open borehole at 4.2m depth on completion of drilling.															

PROJECT 991-1140			RECORD OF BOREHOLE No 13			1 OF 1			METRIC								
W.P. 98-23024			LOCATION Sta. 20+680, 25m Right of centerline of the median			ORIGINATED BY SB											
DIST HWY QEW			BOREHOLE TYPE			COMPILED BY BVB											
DATUM Geodetic			DATE 10.9.99			CHECKED BY AMP											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED					WATER CONTENT (%) w _p w w _L				
103.87 0.00	Sandy Silt, some clay, trace gravel Very stiff Brown (Fill)		1	50 DO	19												
103.11 0.76	Shale Bedrock Weathered Grey (Georgian Bay Formation)		2	50 DO	>250												
			3	50 DO	>100												
			4	50 DO	>100												
99.23 4.64	END OF BOREHOLE Note: Open hole dry on completion of drilling. Water level in Piezometer at Elev.101.2m on Sept.29/99.		5	50 DO	>100												

ON MOT 991-1140.GPJ ON MOT.GDT 12/10/99

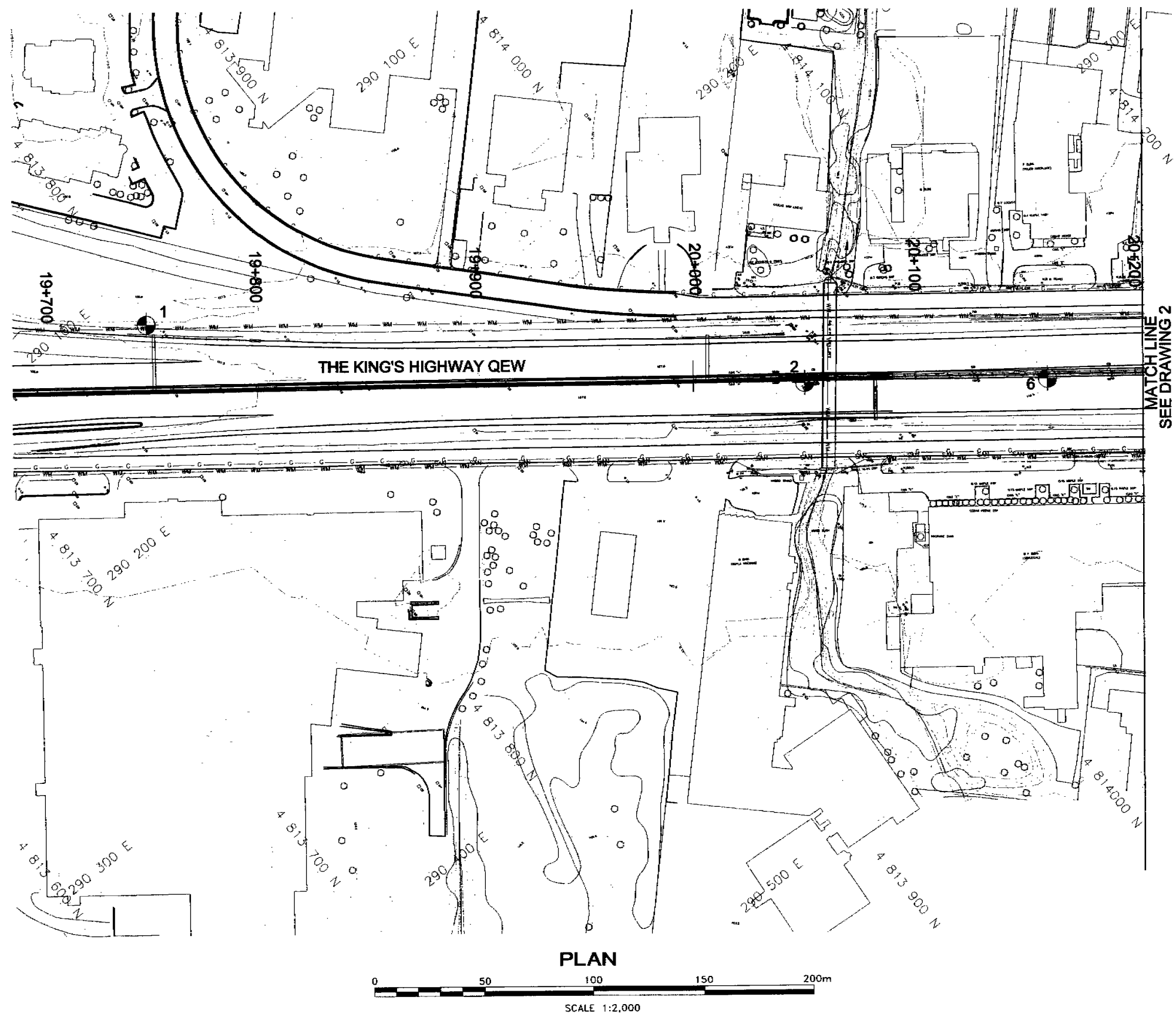
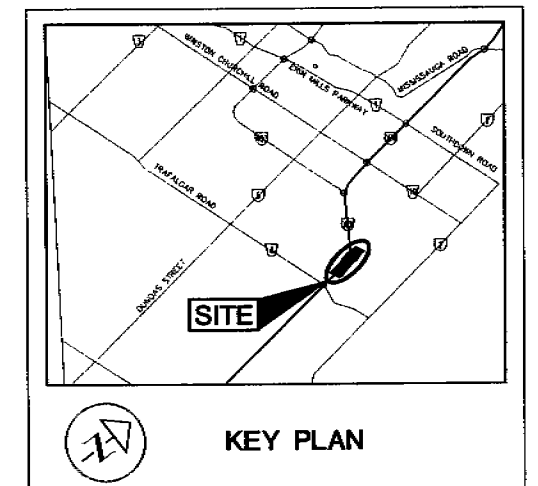
ON MOT 991-1140.GPJ ON MOT.GDT 12/10/99

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

PROJECT 991-1140		RECORD OF BOREHOLE No 15				1 OF 1		METRIC									
W.P. 98-23024		LOCATION Sta. 21+460, 25m Right of centerline of the median				ORIGINATED BY SB											
DIST HWY QEW		BOREHOLE TYPE				COMPILED BY BVB											
DATUM Geodetic		DATE 10.9.99				CHECKED BY AMP											
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
107.75	Silty Sand, some gravel, trace clay, trace rootlets Dense Brown (Fill)		1	50 DO	31												
108.99	Silty Clay, some sand and gravel Stiff Brown/gray (Fill)		2	50 DO	9												
106.38	Silty Clay, trace to some sand and gravel Hard Brown/gray (Fill)		3	50 DO	>100												
1.37 106.15 1.60	Shale Bedrock Weathered Gray (Georgian Bay Formation)		4	50 DO	>100												
103.94	END OF BOREHOLE (AUGER REFUSAL)																
3.81	Note: Open hole dry on completion of drilling. Water level in Piezometer at Elev. 105.8m on Sept. 29/99.																



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND				
Borehole Location in Plan				
No.	ELEVATION	COORDINATES		
		STATION	OFFSET	
1	108.01	19+750	30m LT.	
2	106.75	20+050	2m RT.	
6	106.29	20+160	2m RT.	

NOTES
Base Mapping obtained from digital files, (File No.'s B-82-QEW-35, B-82-QEW-36n83, B-QEW-37n83), provided by McCormick Rankin Corporation.

NO.	DATE	BY	REVISION
Geocres No.			
QEW	PROJECT NO.: 991-1140		DIST.
SUBM'D.	CHKD:	DATE: 1999 09 23	SITE
DRAWN: JFC	CHKD.	APPD.	DRAWING 1

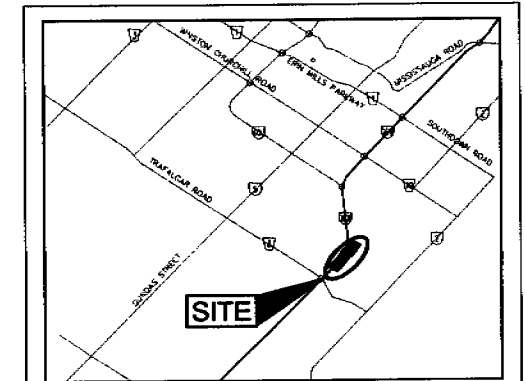


QUEEN ELIZABETH WAY
Sta. 20+200 to Sta. 20+700
BOREHOLE LOCATIONS

SHEET



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

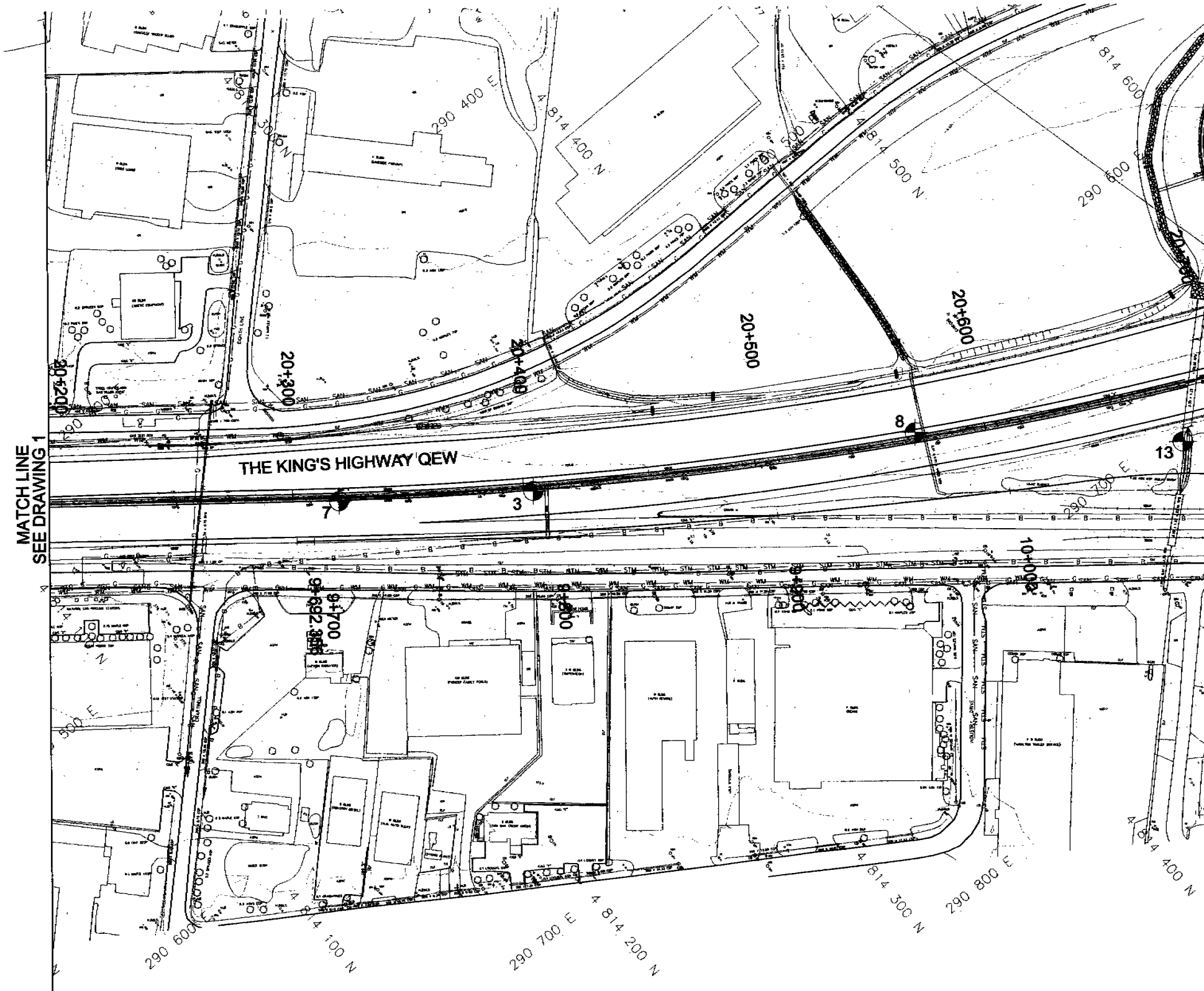
LEGEND

Borehole Location in Plan

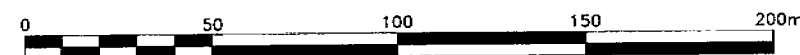
No.	ELEVATION	COORDINATES	
		STATION	OFFSET
3	105.26	20+404	2m RT.
7	105.62	20+320	2m RT.
8	105.06	20+570	2m LT.
13	103.87	20+680	25m RT.

NOTES

Base Mapping obtained from digital files. (File No.'s
B-82-QEW-35, B-82-QEW-36n83, B-QEW-37n83).
provided by McCormick Rankin Corporation.



PLAN

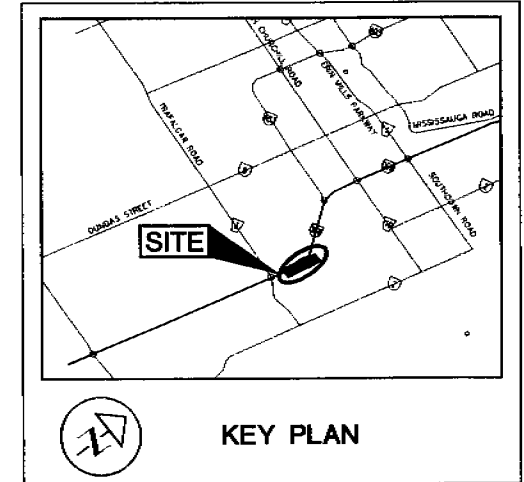


SCALE 1:2,000

NO.	DATE	BY	REVISION

Geocres No.

QEW	PROJECT NO.:	991-1140	DIST.
SUBM'D.	CHKD:	DATE: 1999 09 23	SITE
DRAWN: JFC	CHKD.	APPD.	DRAWING 2



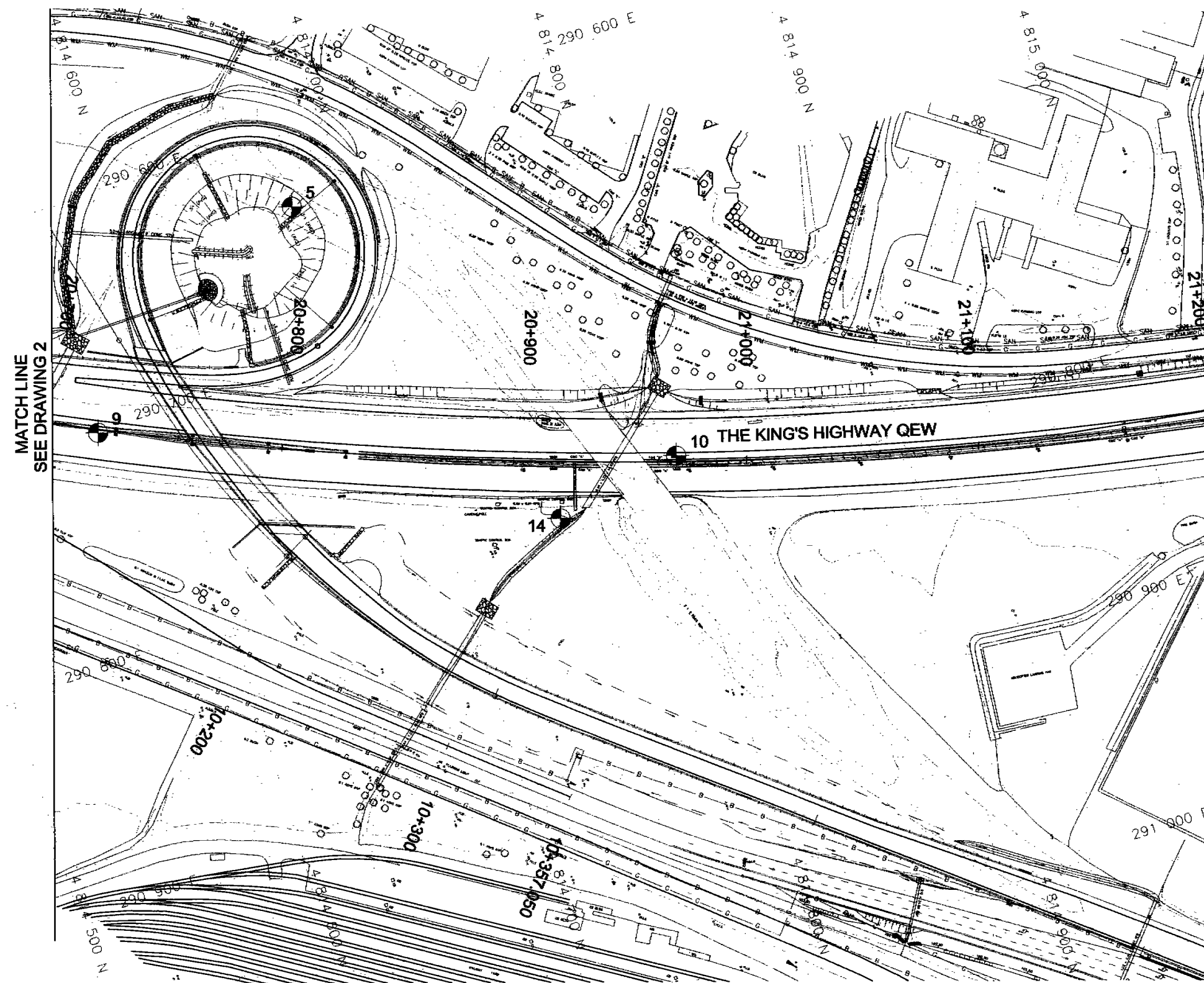
LEGEND

Borehole Location in Plan

No.	ELEVATION	COORDINATES	
		STATION	OFFSET
5	107.00	20+790	105m LT.
9	105.42	20+720	2m RT.
10	106.02	20+970	2m LT.
14	105.00	20+920	25m RT.

NOTES

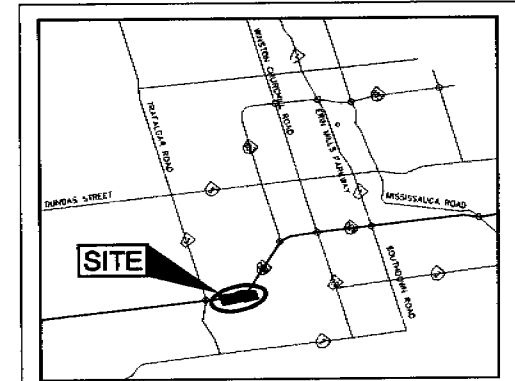
Base Mapping obtained from digital files. (File No.'s B-82-QEW-35, B-82-QEW-36n83, B-QEW-37n83), provided by McCormick Rankin Corporation.



NO.	DATE	BY	REVISION

Geocres No.

QEW	PROJECT NO.: 991-1140	DIST.
SUBM'D.	CHKD: DATE: 1999 09 23	SITE
DRAWN: JFC	CHKD: APPD.	DRAWING 3



KEY PLAN

LEGEND

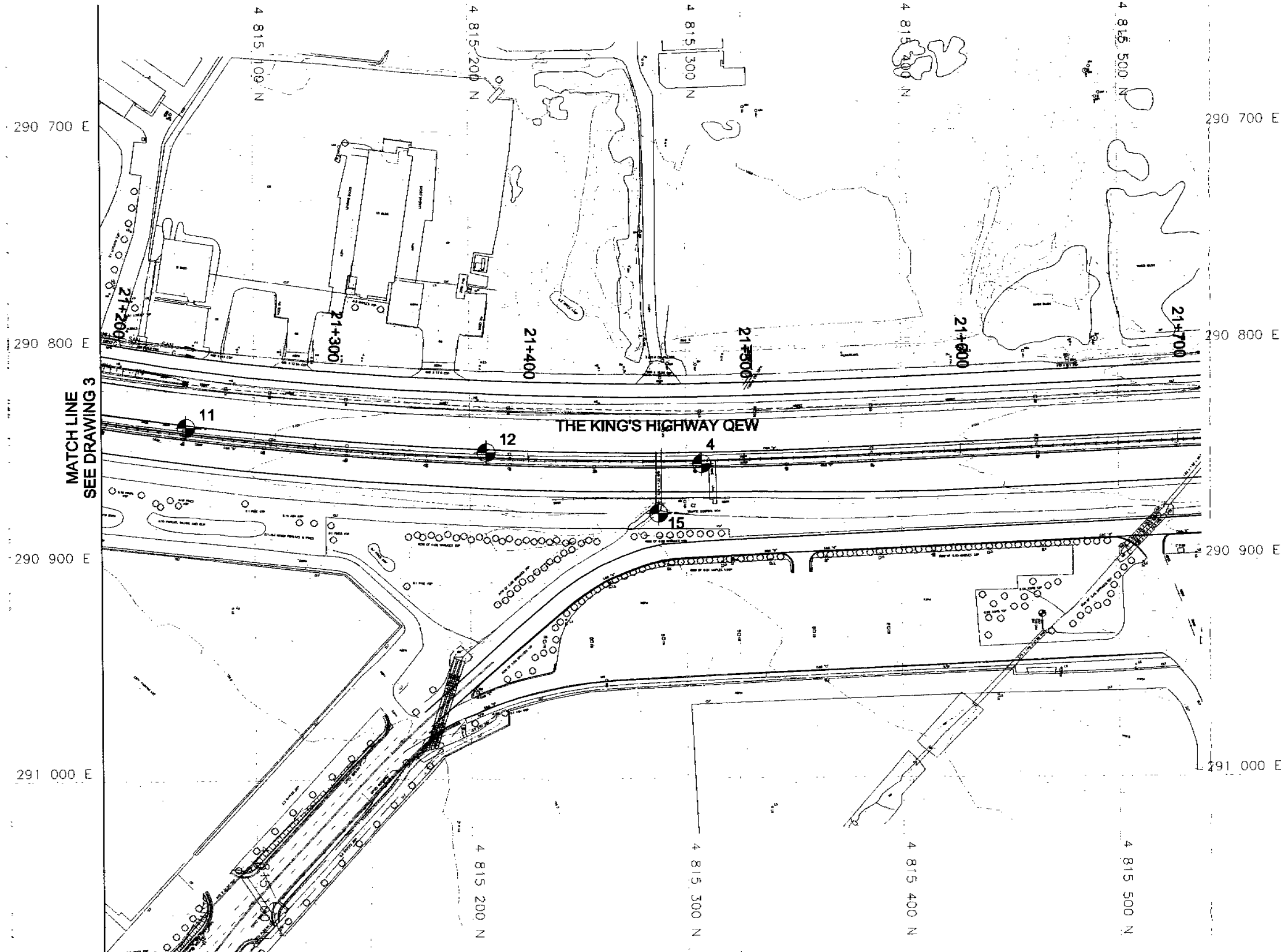


Borehole Location in Plan

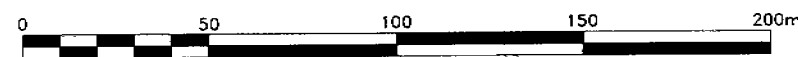
No.	ELEVATION	COORDINATES	
		STATION	OFFSET
4	109.12	21+480	2m LT.
11	107.27	21+240	2m LT.
12	108.35	21+380	2m LT.
15	107.75	21+460	25m RT.

NOTES

Base Mapping obtained from digital files, (File No.'s B-82-QEW-35, B-82-QEW-35n83, B-QEW-37n83), provided by McCormick Rankin Corporation.



PLAN



SCALE 1:2,000

NO.	DATE	BY	REVISION

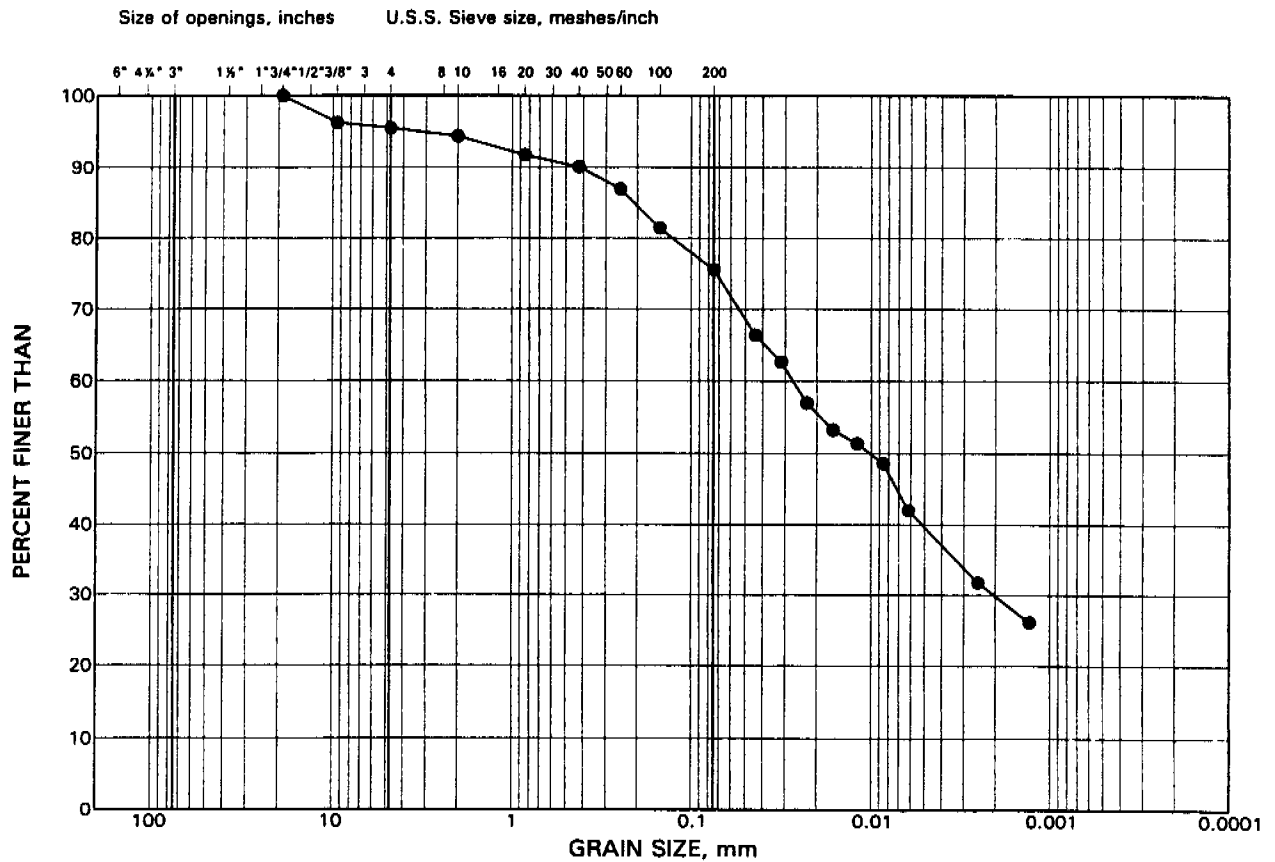
Geocres No.

QEW	PROJECT NO.: 991-1140	DIST.
SUBM'D.	DATE: 1999 09 23	SITE
DRAWN: JFC	CHKD.	APPD.
		DRAWING 4

GRAIN SIZE DISTRIBUTION

Silty Clay, some sand, trace gravel (Fill)

FIGURE 5



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

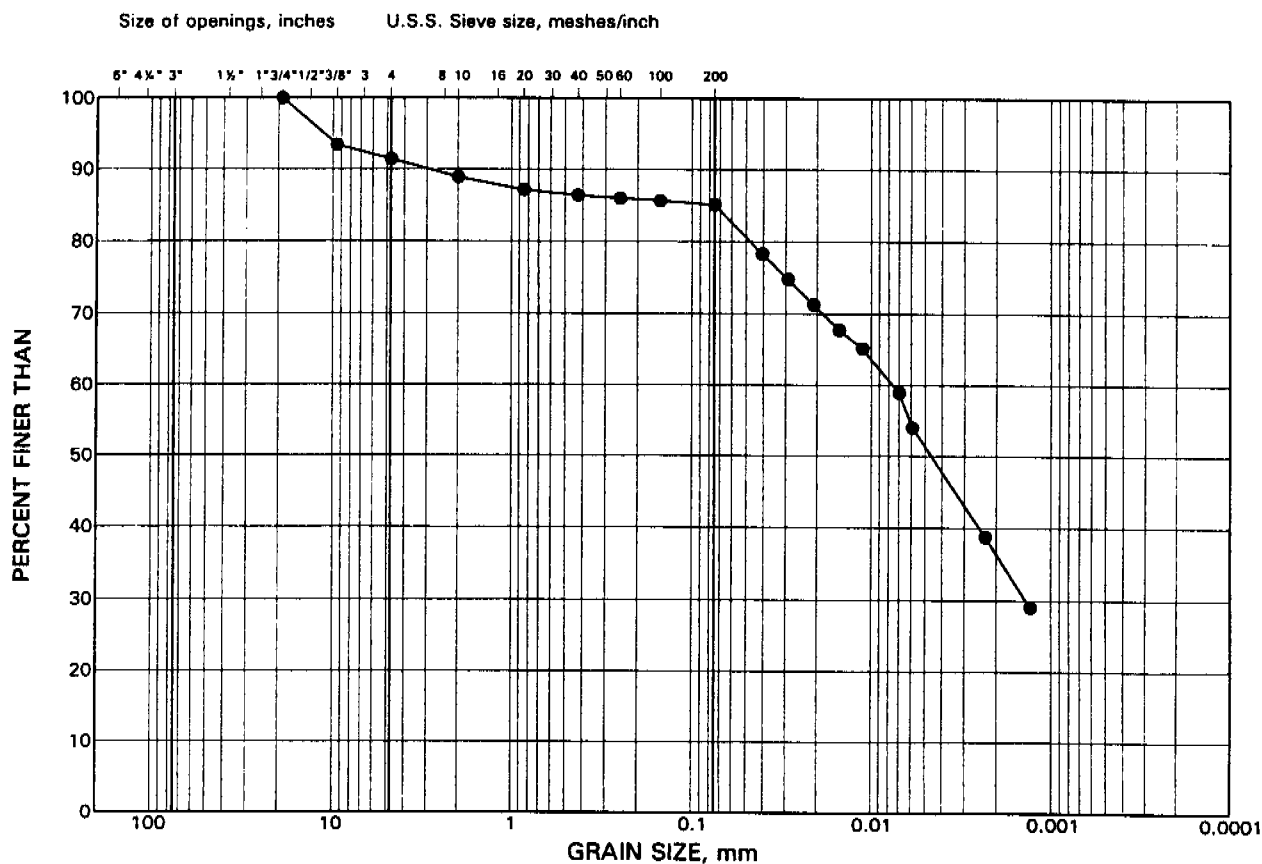
LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	9	1	0.8-1.2

GRAIN SIZE DISTRIBUTION

Silty Clay, trace to some sand, trace gravel (Till)

FIGURE 6



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
•	8	2	1.5-2.0