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PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT BARRIE / COLLINGWOOD RAILWAY OVERPASS STRUCTURE SITE 30-177 HIGHWAY 400 WIDENING FROM 1 KM SOUTH OF HIGHWAY 89 TO HIGHWAY 11 G.W.P. 30-95-00, AGREEMENT NO. 3005-A-000074

Submitted to:

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BARRIE / COLLINGWOOD RAILWAY OVERPASS
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PART A - PRELIMINARY FOUNDATION INVESTIGATION REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. has been retained by URS Cole, Sherman (Cole, Sherman) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the ultimate widening of Highway 400 from 1 km south of Highway 89, northerly 30 km to Highway 11, in Simcoe County, Ontario. Foundation engineering services are required for the widening and / or replacement of eighteen existing overpass and underpass structures, as well as five structural culverts.

This report addresses the widening and / or replacement of the Barrie / Collingwood Railway (former CN Rail) overpass structure in Barrie, Ontario. A subsurface investigation has been carried out, in which one borehole was advanced and in-situ and laboratory testing was conducted, to determine the subsurface conditions at the site for this preliminary design study.

The terms of reference for the scope of work are outlined in Golder Associates' Proposal No. P01-1192, dated June 2000. Under the original scope of work, two boreholes were to be advanced at this site for preliminary investigation purposes. However, during drilling of Borehole B10-1 at the Tiffin Street site, located less than 200 m north of the Barrie / Collingwood Railway site, the City of Barrie informed Golder Associates of the presence of trichloroethylene (TCE) contamination in the area encompassing the Barrie / Collingwood Railway, Tiffin Street and Dunlop Street sites. Based on review of the then-available subsurface information for the Essa Road and Anne Street sites to the south and north of this area, respectively, and following discussions with the MTO Foundations Section, the scope of work was revised as follows:

- Borehole B10-1, which had already been advanced at the Tiffin Street site, would be used to provide preliminary subsurface information for both the Tiffin Street site and the Barrie / Collingwood Railway (former CN Rail) site, less than 200 m to the south. No further drilling would be carried out at these two sites during the preliminary foundation investigation stage.

- One borehole would be drilled at the Dunlop Street (Simcoe Road 90, formerly Highway 90) site, located about 1 km north of the Tiffin Street site. This borehole would be advanced using environmental drilling procedures and telescoping of casing to minimize the potential for drilling-induced downward movement of any contaminants at the site.

The above revised scope of work was approved by the MTO Foundations Section.

2.0 SITE DESCRIPTION

The existing Barrie / Collingwood Railway (former CN Rail) overpass is located about 200 m south of the Tiffin Street overpass and 1.2 km south of the Dunlop Street (Simcoe Road 90, formerly Highway 90) interchange, in Barrie, Ontario. The MTO has designated this overpass as Structure Site 30-177.

At the site, the Barrie / Collingwood Railway grade is at about Elevation 235 m, near the original ground surface. Highway 400 has been constructed on embankment fill up to about 8 m high; the highway grade is at about Elevation 243 m, declining toward both the south and north.

The existing single-span overpass was constructed in the early 1950s under Contract 50-10. According to the general layout drawing for the existing structure, which was provided by Morrison Hershfield (the structural designers for this preliminary study), the abutments are supported on spread footings which step upward from about Elevation 233.5 m to 233.9 m between the east and west ends, respectively. The associated wing walls and retaining walls are also supported on spread footings founded to match the abutment footings.

3.0 INVESTIGATION PROCEDURES

A subsurface investigation was carried out at the Tiffin Street overpass site, located less than 200 m north of the Barrie / Collingwood Railway site, in October 2000. Due to the presence of trichloroethylene (TCE) contamination in the area encompassing the Barrie / Collingwood Railway and Tiffin Street sites, it was determined in conjunction with the MTO Foundations Section that the borehole that was advanced at the Tiffin Street site would be used to provide preliminary subsurface information for both the Tiffin Street site and the Barrie / Collingwood Railway site; no further drilling would be carried out at these two sites during the preliminary foundation investigation stage.

Borehole B10-1 was located on the west side of Highway 400, south of Tiffin Street. This borehole was advanced from slightly above Tiffin Street grade to about 23 m depth (approximately Elevation 212 m).

The investigation was carried out using a bombardier-mounted CME-55 drill rig supplied and operated by Master Soil Investigations Ltd. of Weston, Ontario. The borehole was advanced using hollow stem augers. Samples of the overburden were obtained at 0.75 m to 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. The water level in the open borehole was observed throughout the drilling operations, and a piezometer was installed to permit monitoring of the groundwater level at the site.

The field work was supervised on a full-time basis by a member of our staff who located the borehole in the field, directed the drilling, sampling, and in-situ testing operations, and logged the borehole. The soil samples were identified in the field, placed in labelled containers and transported to Golder Associates' laboratory in Mississauga for further examination. Index and classification tests consisting of water content determinations, Atterberg Limits testing and grain size distribution analyses were carried out on selected soil samples.

In addition, a sample of the stockpiled cuttings was obtained for chemical analysis, in order to determine the waste classification for disposal of this soil. This sample was submitted to Philip Analytical Services for leachate analysis in accordance with Ontario Regulation 347.

The borehole location and elevation were surveyed by Callon Dietz, Ontario Land Surveyors. The borehole elevation is referenced to geodetic datum, and the northing and easting co-ordinates are referenced to the MTM NAD83 survey system. The borehole location, ground surface elevation, and northing and easting co-ordinates are shown on the attached Drawing 1.

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

This 30 km section of Highway 400 traverses, from south to north, the following physiographic regions as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, Third Edition, 1984): the Simcoe Lowlands; the Peterborough Drumlin Field; a second lobe of the Simcoe Lowlands; and the Simcoe Uplands. Along Highway 400, the Simcoe Lowlands are present from the southern limit of the project to just south of Innisfil Creek, and again from Essa Road (Simcoe Road 30, formerly Highway 27) to about 1 km north of Dunlop Street (Simcoe Road 90, formerly Highway 90). The Peterborough Drumlin Field occupies the belt between these lobes of the Simcoe Lowlands, extending from just south of Innisfil Creek, which is located about 1 km north of Highway 89, to Essa Road. The Simcoe Uplands extend from about 1 km north of Dunlop Street to beyond the northern limit of the project at Highway 11.

The two sections where Highway 400 crosses the Simcoe Lowlands consist of two lobes of a sand plain which include the shores of Kempenfelt Bay, the Nottawasaga River and Innisfil Creek. The surficial soils of these sections of the Simcoe Lowlands consist primarily of sand, although silt, clay or peat may be found in low-lying areas. The Barrie / Collingwood Railway site within Barrie is located in this physiographic region.

The surficial soils in the Peterborough Drumlin Field consist primarily of gravelly sand till or sand and gravel deposits. Drumlins (glacially-shaped hills) are more frequent in the southern portion of the section of the Peterborough Drumlin Field traversed by Highway 400. Deposits of silt, clay or peat may be found in the low-lying areas between drumlins.

The surficial soils in the Simcoe Uplands physiographic region are primarily sandy silt till deposits, known to contain boulders. Low-lying areas may be infilled with shallow sand and gravel deposits, which are shoreline deposits of a former glacial lake that once flooded the area.

4.2 Site Stratigraphy

The subsurface soil and groundwater conditions encountered in the borehole and the results of in-situ and laboratory testing are given on the Record of Borehole sheets and Figures 1 and 2. The stratigraphic boundaries shown on the borehole records 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.

Borehole B10-1 was advanced in the southwest quadrant of the Tiffin Street structure site, from slightly above the Tiffin Street grade; the borehole is located between 170 m and 190 m from the Barrie / Collingwood Railway site. The location and elevation for this boring is shown on the attached Drawing 1. In summary, the soils encountered in Borehole B10-1 consist of topsoil and fill overlying deposits of silty sand and silt, underlain by a deposit of clayey silt to silty clay, in turn underlain by a lower silty sand deposit. A more detailed description of the subsurface conditions encountered in the borehole is provided in the following sections.

It is noted that no odour, staining or other evidence of contamination was observed in the recovered samples, or in the auger cuttings produced during drilling of Borehole B10-1. A sample of the stockpiled cuttings was submitted for Regulation 347 leachate testing in order to determine the disposal requirements for this soil. The analyzed material met the Schedule 4 concentrations set out in the regulation; the stockpiled soil was therefore classified as non-registerable, non-hazardous waste for disposal purposes.

4.2.1 Topsoil and Fill

Borehole B10-1 encountered about 100 mm of topsoil overlying 1.4 m of silty sand fill, extending to Elevation 233.5 m. The silty sand fill contains trace to some gravel, and trace organics. The measured Standard Penetration Test (SPT) 'N' values were 13 and 30 blows per 0.3 m of penetration, indicating that the fill has a compact relative density.

4.2.2 Silty Sand

A 3 m thick deposit of silty sand was encountered below the fill, with its surface at Elevation 233.5 m. A grain size distribution test result obtained for a representative sample of this material is shown on Figure 1. The recovered samples were moist, with measured natural water contents of 8 and 12 per cent. The measured SPT 'N' values ranged from 38 to 53 blows per 0.3 m of penetration, indicating that this silty sand has a dense to very dense relative density.

4.2.3 Silt

Underlying the silty sand deposit, Borehole B10-1 encountered a 7 m thick deposit of silt. The surface of the silt was at about Elevation 230.5 m.

The silt deposit contains trace to some sand and trace clay. Grain size distribution test results obtained for two samples of this material are shown on Figure 2. The recovered silt samples were wet and exhibited dilatant behaviour. The measured natural water contents ranged from 18 to 23 per cent.

The measured SPT 'N' values ranged from 48 to 20 blows per 0.3 m of penetration, decreasing with depth. It is noted that the lower samples may have been disturbed by groundwater inflow to the borehole during sampling. The silt deposit is therefore considered to have a predominantly dense relative density.

4.2.4 Clayey Silt to Silty Clay

The upper silty sand and silt deposits overlie a deposit ranging in composition from clayey silt to silty clay. The surface of the clayey silt to silty clay was encountered at about Elevation 223.5 in Borehole B10-1. The deposit is about 8 m thick at the borehole location, extending to about Elevation 215.5 m.

The clayey silt to silty clay contains trace quantities of sand. Silt interlayers were noted within the lower half of the deposit, below about 15 m depth (approximately Elevation 220 m). The recovered samples were moist, with measured natural water contents ranging from 20 to 29 per cent. Atterberg Limits testing on one representative sample of clayey silt measured plastic and liquid limits of 14 and 20 per cent, respectively, and a plasticity index of 6 per cent; the clayey silt is therefore inorganic and of low plasticity. It is noted that the measured natural water content on this particular sample was slightly above the liquid limit of the clayey silt, which is not consistent with an SPT 'N' value of 27 blows per 0.3 m of penetration; it is possible that the portion of the sample tested for moisture content contained more silty clay than the portion of the sample used for Atterberg Limits testing.

The clayey silt to silty clay has a very stiff to hard consistency, with measured SPT 'N' values ranging from 15 to 40 blows per 0.3 m of penetration.

4.2.5 Lower Silty Sand

A lower deposit of silty sand was encountered below the clayey silt to silty clay deposit in Borehole B10-1. The surface of this lower silty sand is at about Elevation 215.5 m. The deposit was not fully penetrated by the boring, which was terminated at Elevation 211.7 m; it is at least 4 m thick.

The recovered samples of the lower silty sand deposit were wet, with one measured natural water content of 17 per cent. The measured SPT 'N' values were greater than 100 blows per 0.3 m of penetration, indicating that this material has a very dense relative density.

4.3 Groundwater Conditions

The water level in Borehole B10-1 was at about 5 m depth (Elevation 230 m) during and on completion of the drilling operations. The groundwater level in the piezometer sealed within the upper silt layer was measured at 4.9 m depth in January 2001, and at 5 m depth in March 2001 (Elevations 230.1 m and 230 m, respectively). These measured water levels are near the surface of the silt layer. The groundwater level associated with the lower silty sand deposit was not determined during this preliminary investigation.

It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year. With a relatively impervious clay deposit underlying the upper silty sand and silt deposits, it is possible for an appreciable rise in the groundwater level to occur during periods of heavy precipitation.

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT
BARRIE / COLLINGWOOD RAILWAY OVERPASS
STRUCTURE SITE 30-177
HIGHWAY 400 WIDENING FROM 1 KM SOUTH
OF HIGHWAY 89 TO HIGHWAY 11
G.W.P. 30-95-00, AGREEMENT NO. 3005-A-000074

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides preliminary foundation design recommendations for the widening and / or replacement of the existing Barrie / Collingwood Railway (former CN Rail) overpass structure in Barrie, Ontario, associated with the widening of Highway 400. The recommendations are preliminary only and are based on interpretation of the factual data obtained from a single borehole advanced during subsurface investigation in the vicinity of this site. The interpretation and recommendations provided are intended for planning purposes only, to provide the information necessary at this stage of the study. As such, where comments are made on construction they are provided only in order to highlight those aspects which could affect the planning of the project. Further foundation investigation will be required at this structure site as part of the detailed design stage of the project.

It is understood that Highway 400 will be widened from its existing six-lane configuration to an interim configuration of eight-lanes, and an ultimate configuration of ten-lanes, and that an alternative for a twelve-lane express / collector system is under consideration between Molson Park Drive and Duckworth Street in Barrie. Throughout the project length, it is expected that the existing highway platform will be widened by between 13 m and 30 m. Widening and / or replacement of the existing Barrie / Collingwood Railway overpass structure will therefore be necessary.

Based on the available general layout drawing for the existing single-span structure, the abutments are supported on spread footings which step upward from about Elevation 233.5 m to 233.9 m between the west and east ends, respectively. The associated wing walls and retaining walls are also supported on spread footings founded to match the abutment footings. The Barrie / Collingwood Railway grade is at about Elevation 235 m, near the original ground surface. Highway 400 has been constructed on embankment fill up to about 8 m high; the highway grade is at about Elevation 243 m at the structure site.

5.2 Bridge Foundation Options

Based on the subsurface information obtained from Borehole B10-1, advanced at the Tiffin Street site less than 200 m to the north, the native soils consist of silty sand and silt overlying a clayey silt to silty clay deposit, in turn underlain by a lower deposit of silty sand. The groundwater level associated with the upper, unconfined aquifer at the site was at about Elevation 230 m in March 2001, approximately 5 m below the Barrie / Collingwood Railway grade. The presence of the relatively impervious clayey silty to silty clay deposit at depth creates a perched aquifer condition within the upper silty sand and silt deposits. It is understood from the City of Barrie that TCE contamination is present within the upper soils (i.e. above the clayey silt to silty clay deposit) in the vicinity of this structure site.

Based on these subsurface conditions and on the foundation conditions for the existing overpass structure, it is recommended that the widened portions of the structure be founded on spread footings to match the existing conditions. If a new or structurally separate overpass is to be constructed, consideration could also be given to the use of perched abutments, founded on spread footings placed on a well-compacted granular pad within the approach fill embankments. Preliminary recommendations for spread footings, including perched abutments, are provided in the following sections. However, it is noted that further borehole investigation will be required within the foundation footprints during detailed design in order to confirm the soil types and relative densities / consistencies. Future boreholes will have to be advanced using accepted environmental drilling, sampling and abandonment procedures.

Deep foundations, such as driven steel H-piles, are not recommended at this site due to the reported presence of TCE contamination in the upper aquifer. Trichloroethylene is a dense, non-aqueous phase liquid; it does not float atop the groundwater table, but instead migrates downward through an aquifer until it reaches a confining layer, such as the clayey silt to silty clay deposit. If driven steel H-piles were adopted at this site, they would have to be driven through the upper aquifer and the clayey silt to silty clay deposit, into the very dense lower silty sand deposit. The introduction of piles through the clayey silt to silty clay confining layer could create pathways for downward migration of the TCE, thereby introducing the contaminants to the lower aquifer at the site.

5.3 Spread Footings

For preliminary design of the abutment foundations, spread footings may be placed on the dense to very dense silty sand at or below Elevation 233.5 m; the footings should be maintained as high as possible to minimize the requirements for groundwater control during excavation and construction. For widening, the founding level of the existing overpass footings (about Elevation 233.5 m to 233.9 m) should be matched to prevent possible undermining of the existing foundations, provided that a minimum soil cover of 1.5 m is maintained at all footing locations.

Alternatively, consideration could be given to the use of abutment footings perched within the approach embankments.

5.3.1 Axial Geotechnical Resistance

Spread footings placed on the properly prepared, undisturbed silty sand deposit at or below the design elevation given above, but above the groundwater level, may be designed for a factored geotechnical resistance at Ultimate Limit States (ULS) of 700 kPa, assuming a 3 m wide footing. The settlement of footings founded on the dense to very dense silty sand soils will be dependent on the footing size and configuration, and on the applied loads. The majority of the settlement should occur during construction; however, the settlement will be differential with respect to the existing overpass structure. For preliminary design purposes, the geotechnical resistance at Serviceability Limit States (SLS) may be taken as 450 kPa. The geotechnical resistances at ULS and SLS will have to be reviewed during detailed design, once the footing size, configuration and loadings are known, and once further drilling has been carried out within the foundation footprints during the detailed design stage.

For spread footings placed within the approach embankments on a compacted Granular 'A' core, a factored geotechnical resistance at ULS of 900 kPa may be assumed for preliminary design. The geotechnical resistance at SLS will depend on the thickness of Granular 'A' and the consistency and thickness of the underlying soils; a value of 350 kPa may be assumed for preliminary design. These resistances will have to be confirmed during detailed design, once the composition and consistency of the upper soils at the site are confirmed.

The geotechnical resistances provided herein are given under the assumption that the loads will be applied perpendicular to the surface of the footings; where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with the Ontario Highway Bridge Design Code (OHBDC).

5.3.2 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the concrete footing and the subsoils should be calculated in accordance with Section 6-8.4.3 of the OHBDC. For preliminary design purposes, and subject to confirmation following the detailed design stage of drilling at this site, the angle of friction between the concrete and the undisturbed, dense to very dense silty sand founding soils should be taken as 24 degrees; the corresponding coefficient of friction, tan δ, would then be 0.45. Where "perched" abutment footings are adopted, the angle of friction between the concrete footings and the compacted Granular 'A' pad should be taken as 30 degrees; the corresponding coefficient of friction would be 0.58.

5.3.3 Frost Protection

All footings should be provided with a minimum of 1.5 m of soil cover for frost protection.

5.4 Lateral Earth Pressures

The lateral pressures acting on the bridge abutments and associated retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. The following recommendations are made concerning the design of the abutments, in accordance with the OHBDC:

- Select free-draining granular fill meeting the specifications of OPSS Granular 'A' or Granular 'B' but with less than 5 per cent passing the 200 sieve should be used as backfill behind the abutments and walls. This fill should be compacted in loose lifts not greater than 200 mm in thickness to 95 per cent of the material's Standard Proctor maximum dry density in accordance with OPSS 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the abutment granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3501.00 and 3504.00

- A compaction surcharge equal to 16 kPa should be included in the lateral earth pressures for the structural design of the abutment wall, in accordance with OHBDC Figure 6-7.4.3. Compaction equipment should be used in accordance with OPSS 501.06.

- The granular fill may be placed either in a zone with width equal to at least 1.5 m behind the back of the stem (Case I from OHBDC Figure 6-7.4.1) or within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II from OHBDC Figure 6-7.4.4).

- For Case I, the pressures are based on the existing and proposed embankment fill materials and the following parameters (unfactored) may be assumed:

Soil unit weight:	20 kN/m^3
Coefficients of lateral earth pressure:	
Active, K_a	0.35
At rest, K_o	0.50

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	Granular 'A'	Granular 'B' Type II
Soil unit weight:	22 kN/m^3	21 kN/m^3
Coefficients of lateral earth pressure:		
Active, K_a	0.27	0.31
At rest, K_o	0.43	0.47

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the abutment support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design.

The above design recommendations and parameters assume level backfill and ground surface behind the abutment and retaining walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

5.5 Embankment Design

Based on the topographic information on the Engineering and Title Records plates and on site reconnaissance, the existing Highway 400 embankment side slopes are formed at a gradient of about 2 horizontal to 1 vertical (2H:1V) at the Barrie / Collingwood Railway site. For widening of the Highway 400 embankments, the new side slopes should be formed at a maximum gradient of 2H:1V. The embankment widening should be carried out using conventional fill placement and compaction practices, and benching of the existing embankment side slopes should be carried out to key in the new fill.

5.6 Design and Construction Considerations

5.6.1 Groundwater Control

The groundwater level during the investigation period was found to be at about 5 m depth (Elevation 230 m), near the interface of the silty sand and silt deposits. The presence of the relatively impervious clayey silt to silty clay deposit could, during periods of heavy precipitation, create a marked rise in the groundwater level within the upper sand deposit, on which the spread footings are to be founded. It will, therefore, be important to have provision of appropriate groundwater and surface water control measures during construction to maintain the in-situ integrity of the silty sand and silt deposits.

5.6.2 Excavation

Excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act for Construction Activities. The footing excavations will extend a minimum of 1.5 m below lowest surrounding grade, through existing fill and into the dense to very dense silty sand. The fill and silty sand would be classified as Type 2 to 3 soils. Temporary open-cut slopes should therefore be maintained no steeper than 1 horizontal to 1 vertical (1H:1V). Where space restrictions dictate, adjacent to the new permanent cut slope, footing excavations could also be carried out within a braced excavation.

5.6.3 Settlement

Deformation of the ground due to foundation loading will result in settlement of the bridge abutments and superstructure. Settlement of the new, widened portions of the structure will be differential with respect to the existing overpass structure, and also could vary between the new foundation elements depending on the variability and consistency / relative density of the founding soils. The potential for differential settlement will have to be reassessed during the detailed design stage once the proposed bridge configuration is established.

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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
SS	Split-spoon
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 Cone 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)

A electronic cone penetrometer with a 60° conical tip and a project 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	c_u, s_u 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 (LV-laboratory vane test)
γ	unit weight

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

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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 $=\sigma'_p/\sigma'_{vo}$

(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 δ

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No B10-1

METRIC

PROJECT 001-1143F
W.P. 30-95-00
DIST SW HWY 400
DATUM Geodetic

LOCATION N 4914534.5; E 288241.1
BOREHOLE TYPE 108mm ID HOLLOW STEM AUGERS
DATE Oct.24-25/2000

ORIGINATED BY PKS
COMPILED BY LCC
CHECKED BY ASP

ELEV / DEPTH	DESCRIPTION
235.0	GROUND SURFACE
0.0	Topsoil
0.1	Silty Sand, trace to some gravel, trace organics (Fill); Compact; Brown; Moist
233.5 / 1.5	Silty Sand; Dense to very dense; Brown; Moist
230.4 / 4.6	Silt, trace to some sand, trace clay; Dense to compact; Dilatant; Brown to grey below 6m depth; Wet. SPT "N" values may be impacted by groundwater inflow to borehole during sampling.
223.4 / 11.6	Clayey Silt to Silty Clay, trace sand; Very stiff to hard; Grey; Moist

Sample No.	Type	"N" Values	Water content (%)	Remarks: GR	SA	SI	CL
1	SS	13					
2	SS	30					
3	SS	38	○				
4	SS	42					
5	SS	51	○	0	76	24	0
6	SS	53					
7	SS	48	○				
8	SS	37	○	0	1	95	4
9	SS	23					
10	SS	25	○	0	15	84	1
11	SS	20					
12	SS	27	W_P ⊢○				
13	SS	15					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (234, 233, 232, 231, 230, 229, 228, 227, 226, 225, 224, 223, 222, 221); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No B10-1

METRIC

PROJECT 001-1143F
W.P. 30-95-00
LOCATION N 4914534.5; E 288241.1
ORIGINATED BY PKS
DIST SW HWY 400
BOREHOLE TYPE 108mm ID HOLLOW STEM AUGERS
COMPILED BY LCC
DATUM Geodetic
DATE Oct.24-25/2000
CHECKED BY ASP

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES
	Clayey Silt to Silty Clay, trace sand Very stiff to hard Grey Moist Contains silt interlayers below 15.2m depth	14	SS	18
		15	SS	40
		16	SS	35
215.5 19.5	Silty Sand Very dense Grey Wet	17	SS	132
		18	SS	102
		19	SS	100
211.7 23.3	END OF BOREHOLE			

Elevation scale: 219, 218, 217, 216, 215, 214, 213, 212

Notes:
1. Water level in open borheole on compeltion of drilling at about 5m depth (Elev.230.0m).
2. Water level in piezometer at 4.9m depth (Elev.230.1m) on January 19, 2001, and at 5m depth (Elev.230.0m) on March 15, 2001.

$+^3, \times^3$: Numbers refer to Sensitivity
$\circ^{3\%}$ STRAIN AT FAILURE

DIST HWY 400 CONT. No. GWP No. 30-95-00	
BARRIE/COLLINGWOOD RAILWAY OVERPASS, HWY 400 BOREHOLE LOCATION PLAN	SHEET

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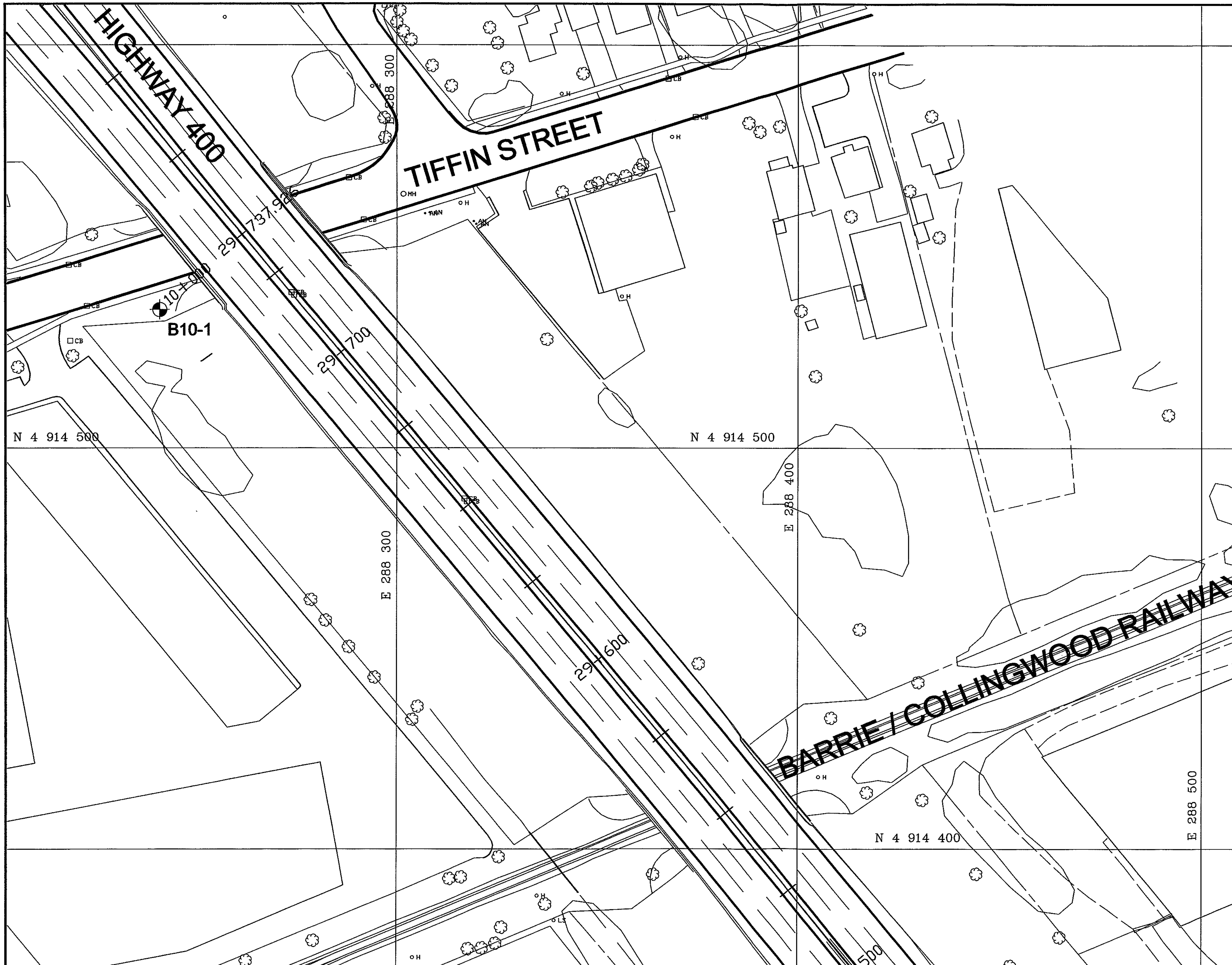
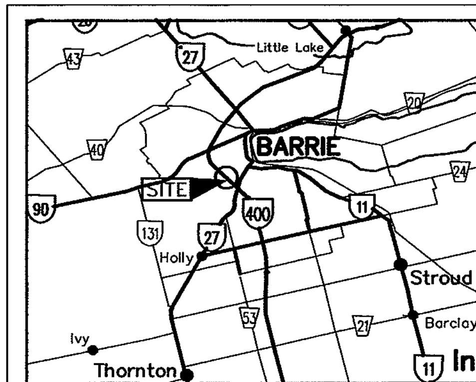
MISSISSAUGA, ONTARIO, CANADA





KEY PLAN

SCALE IN KILOMETRES

LEGEND

Borehole, previous investigation

Borehole, present investigation

No.	ELEVATION	LOCATION NORTHING	LOCATION EASTING
B10–1	235.0	4,914,534.5	288,241.1

REFERENCE

This drawing was created from digital file "50208.dwg" provided by URS Cole Sherman

0 10 20 30 40 50 100m

SCALE IN METRES

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

NO.	DATE	BY	REVISION

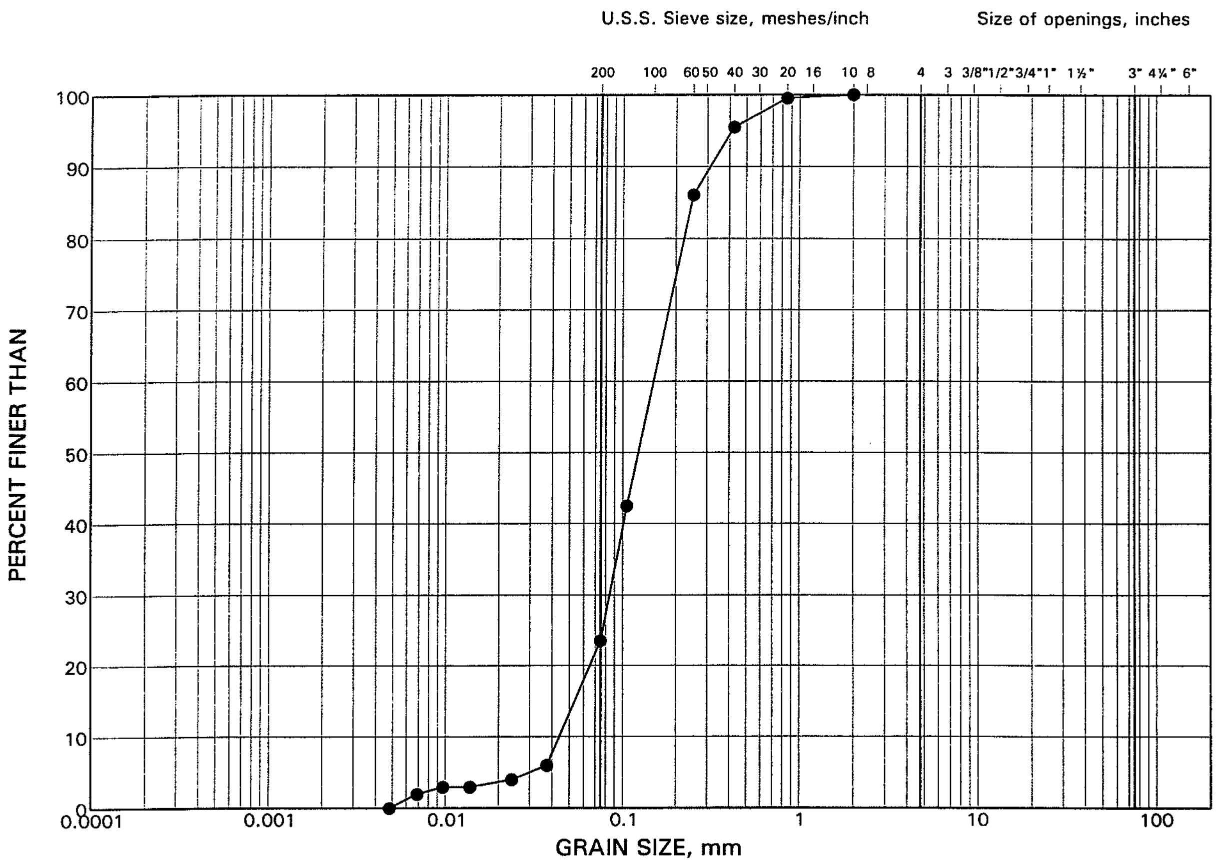
Geocres No.

HWY. No. 400		PROJECT NO.: 001-1143F	
SUBM'D. LCC	CHKD: ASP	DATE: JANUARY 2001	SITE 30-177
DRAWN: MHW	CHKD. LCC	APPD. ASP	DWG. 1

P1143F14.DWG

GRAIN SIZE DISTRIBUTION TEST RESULT
Silty Sand

FIGURE 1



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	B10-1	5	231.6

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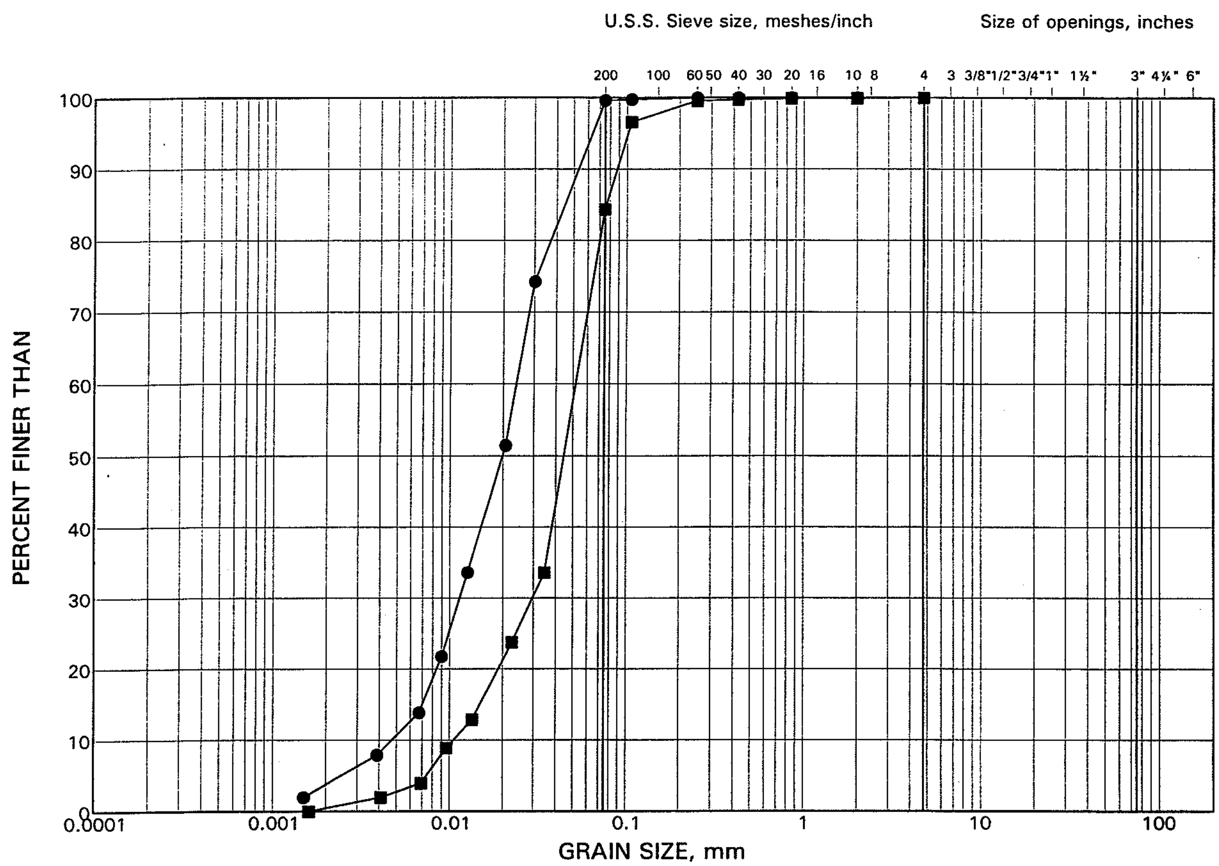
GRAIN SIZE DISTRIBUTION TEST RESULTS
Silt

FIGURE 2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	B10-1	8	228.6
■	B10-1	10	225.5

Project 001-1143F

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