

**Golder Associates Ltd.**

309 Exeter Road, Unit #1  
London, Ontario, Canada N6L 1C1  
Telephone: (519) 652-0099  
Fax: (519) 652-6299



**FOUNDATION INVESTIGATION  
AND DESIGN REPORT**

**MTO FERRY DOCK AT KINGSVILLE  
DISTRICT #31 CHATHAM, SOUTHWESTERN REGION  
WORK ORDER NUMBER 01-33-001  
PURCHASE ORDER NUMBER 3005-A-000218**

Submitted to:

Morrison Hershfield Limited  
235 Yorkland Boulevard  
Toronto, Ontario  
M2J 1T1

**DISTRIBUTION:**

12 Copies - Morrison Hershfield Limited  
2 Copies - Golder Associates Ltd.

October 20, 2005

021-4216-1-2  
Geocres No. 40J2-67



---

**TABLE OF CONTENTS**

<u>SECTION</u>	<u>PAGE</u>
1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	2
3.0 INVESTIGATION PROCEDURES.....	3
4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY.....	4
4.1 Geology .....	4
4.2 Site Stratigraphy .....	4
4.2.1 Surficial Silt, Sandy Silt, Silty Fine Sand and Sand .....	5
4.2.2 Sandy Silt Till .....	5
4.2.3 Clayey Silt Till .....	6
4.2.4 Bedrock.....	6
4.3 Water Conditions and Lake Bed Elevations .....	6
5.0 ENGINEERING RECOMMENDATIONS .....	8
5.1 General.....	8
5.2 Existing Sheet Pile Walls.....	8
5.2.1 Geotechnical Parameters .....	9
5.2.2 Geotechnical Considerations.....	10

## **TABLE OF CONTENTS**

In Order  
Following  
Page 11

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

RECORDS OF BOREHOLES

FIGURE 1 - Site Location Map

DRAWING 1 - MTO Ferry Dock at Kingsville, Borehole Locations

DRAWING 2 - MTO Ferry Dock at Kingsville, Stratigraphic Profile and Sections

APPENDIX A – Records of Previous Boreholes

APPENDIX B - Site Photographs

APPENDIX C - Laboratory Test Data (Figures C-1 to C-6)

## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (Morrison Hershfield) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out additional preliminary foundation investigations for the MTO ferry docks at Leamington, Kingsville and Pelee Island in conjunction with Work Order Number 01-33-001. This report addresses the additional investigation at the Kingsville dock site.

The purpose of this foundation investigation is to determine the subsurface conditions in front of the sheet pile walls and to obtain the soil parameters and lake information necessary to revise and complete stability calculations for the sheet pile walls. The work includes drilling three new boreholes at each site as well as utilizing existing borehole, lake level and scour/dredging data. The terms of reference for the scope of work are outlined in Golder's proposal for additional preliminary foundations engineering services dated August 18, 2004. The work was carried out in accordance with our Quality Control Plan dated October 30, 2002.

The report is provided as part of the planning phase of the project. Morrison Hershfield provided Golder with drawings for the existing dock and scour profiles.

The results of previous foundation investigations carried out at the site were reviewed during preparation of this report and the relevant borehole records from these reports are provided in Appendix A in their original format. The previous reports are:

- Golder Associates Preliminary Foundation Investigation Report, Geocres No. 40J2-57 entitled "MTO Ferry Docks at Leamington, Kingsville and Pelee Island, Townships of Mersea, Gosfield South and Pelee Island, District 31, Chatham, Work Order Number: 01-33-001, Purchase Order Number: 3005-A-000218", dated February 26, 2003.
- Trow Consulting Engineers Ltd. report prepared for Public Works Canada entitled "Geotechnical Investigation, Proposed Ferry Terminal, Kingsville, Ontario", dated January 1993.

## **2.0 SITE DESCRIPTION**

The Kingsville ferry dock site is located at the southerly extension of Lakeview Avenue in the Town of Kingsville, Ontario. The present ferry dock is situated east of and replaced the former docking facility at the south end of the original east pier which contains the Kingsville fishing operations building. The current ferry dock complex extends approximately 300 metres out from shore. The dock has an asphalt paved surface and is enclosed at the south and west sides by steel sheet piling with a concrete cap. An armour stone breakwall protects the east side the dock. Pelee Island Transportation Services currently operates the dock facilities.

The site location is shown on Figure 1 and select site photographs taken during the investigation are provided in Appendix B.

Based on information provided by Morrison Hershfield, the existing dock is at elevation 176 metres (all elevations are referenced to International Great Lakes Datum, IGLD), the lake water level is at about elevation 174 metres, the design dredge line is at elevation 169.1 metres and the design sheet pile tip is at elevation 165.1 metres.

### **3.0 INVESTIGATION PROCEDURES**

The field work for this investigation was carried out between September 7 and 27, 2004. During that time, three boreholes were put down in front of the steel sheet pile walls about 0.4 to 3.4 metres from the dock using a timber platform with safety rails cantilevered over the walls (boreholes 101 and 102). No access was available from the dock for the middle borehole (103) and a barge was brought to the site, the drill rig loaded on it and the boring was put down some 3.4 metres from the dock. The boreholes were drilled and sampled to depths of 14.8 to 18.3 metres below the dock surface. The borehole locations are shown in plan on Drawing 1 together with the location of the boreholes put down in previous investigations (1993 and 2003).

The investigation was carried out using an all terrain vehicle mounted CME-750 drill rig supplied and operated by Lantech Drilling Services Inc. The boreholes were advanced using a combination of rotary drilling techniques in NW size casing and coring the bedrock in NQ size. In the boreholes, samples of the overburden and rock were obtained at regular intervals of depth using 50 millimetre outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedures. Dynamic cone penetration testing was also carried out in the surficial materials. The boreholes were backfilled using Ministry of Transportation, Ontario (MTO) recommended procedures and as required by Ontario Regulation 903 (amended by Ontario Regulation 128/03).

The field work was supervised on a full-time basis by members 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 soil samples were identified in the field, placed in labeled containers and transported to our laboratory in London, Ontario for further examination. Index and classification tests consisting of grain size analyses, Atterberg limits tests and water content determinations were carried out on selected samples. The rock samples were transported to our laboratory in Mississauga, Ontario for detailed description. The soil and rock stratigraphy is shown on the attached Record of Boreholes and on the section, Drawing 2. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix C.

The as-drilled borehole locations and elevations were referenced to a temporary benchmark and stations provided by Callon Dietz Inc. The benchmark elevation is understood to be referenced International Great Lakes Datum (IGLD).

## **4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Geology**

The Town of Kingsville is located in the physiographic region of southwestern Ontario known as the St. Clair Clay Plain. The base soils in the Kingsville area are characteristically described as comprising of extensive deposits of glacio lacustrine clays. The massive clay stratum is generally considered to have a till-like structure exemplified by a random distribution of coarser particles throughout the stratum and a general lack of stratification. The plain is overlain by small discontinuous morainic deposits consisting of sands and gravels.

The Kingsville dock has been constructed into Lake Erie about 300 metres south of the current shoreline. This has been accomplished by mass filling to raise the grade in the Lake Erie bed.

The bedrock is Devonian age dolomitic limestone of the Dundee Formation belonging to the Hamilton Group over Lucas Formation limestone of the Detroit River Group. The limestone is light brown to grey and fine to medium grained.

### **4.2 Site Stratigraphy**

The detailed subsurface water, soil and rock conditions encountered in the boreholes together with the results of the field and laboratory testing are shown on the Record of Borehole sheets following the text of this report and in Appendix C. The records of relevant boreholes previously drilled at the site are provided in Appendix A. The stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, may represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoils in front of the sheet pile wall at the site generally consist of variable thicknesses of silts and sands extending to about elevation 164 to 167 metres which are underlain by sandy silt till and clayey silt till deposits extending about 3 to 6 metres in total thickness. The till deposits contained cobbles and boulders and extended to a depth of about 14.5 metres where the limestone bedrock was encountered at about elevation 161.5 metres.

Locations and elevations of the borings, together with the interpreted stratigraphical profiles, are shown on the attached Drawings 1 and 2. A detailed description of the subsurface conditions encountered in the boreholes for this investigation is provided on the Record of Borehole sheets and is summarized in the following sections.

#### **4.2.1 Surficial Silt, Sandy Silt, Silty Fine Sand and Sand**

Boreholes 101, 102 and 103 encountered very loose to compact surficial lake bed deposits consisting of silt, silty fine sand and sand beneath some 5.3 to 6.8 metres of water. Shells and organics were noted in the upper layers of the deposits. The surficial deposits had a total thickness of about 2.2 to 3.1 metres and extended to between elevations 164.3 and 166.8 metres. The results of dynamic cone penetration testing carried out in the surficial deposits are shown on the Record of Borehole sheets and a summary of the soil stratigraphy is provided in the following paragraphs.

Beneath the water, boreholes 101 and 102 encountered a 0.2 to 1.4 metre thick layer of silt sediments with organic materials while borehole 103 encountered about 0.3 metres of silty fine sand with shells. The silt in borehole 102 had water contents of 76 to 111 per cent consistent with an elevated organic content. Little resistance to penetration was obtained in the dynamic cone penetration testing in borehole 102 reflecting the very loose relative density of the deposit. The results of grain size analyses carried out on the sample of silt sediments from borehole 102 are shown on Figure C-1 in Appendix C following the text of this report.

Beneath the silt sediments in borehole 101, additional layers of silt 0.3 to 1.0 metre thick were encountered together with a 0.3 metre thick pocket of stiff silty clay. The silts in borehole 101 had standard penetration test N values of 10 to 22 blows per 0.3 metres penetration and water contents of about 24 to 28 per cent. The results of dynamic cone penetration testing were consistent with the N values indicating a loose to compact relative density. The results of the grain size analysis carried out on a sample of the silt from borehole 101 are shown on Figure C-2.

Beneath the silt sediments in borehole 102 and the surficial layer of silty fine sand in borehole 103, 0.9 to 2.8 metre thick deposits of sandy silt, silty fine sand and fine sand were encountered. These deposits had standard penetration test N values of 10 to 38 blows per 0.3 metres of penetration, indicating a compact to dense relative density, and water contents of about 10 to 27 per cent. The results of the grain size analysis carried out on a sample of the sandy silt from borehole 103 are shown on Figure C-3.

#### **4.2.2 Sandy Silt Till**

Beneath the silts in borehole 101 and silty fine sand in borehole 102, 1.4 to 2.1 metre thick layers of sandy silt till with some gravel and cobbles were encountered. A one metre boulder was encountered at the base of the sandy silt till in borehole 101. Also, a 0.8 to 1.2 metre thick layer of sandy silt till was encountered over the bedrock in boreholes 102 and 103. The upper sandy silt till deposits were encountered between elevation 164.0 and 166.8 metres and the lower sandy silt till deposit extended to between elevation 161.3 and 162.4 metres. The sandy silt till deposits had standard penetration test N values of 44 blows per 0.3 metres penetration to 150 blows per 150



millimetres penetration. The results of dynamic cone penetration testing in the upper till deposit in boreholes 101 and 102 are shown on the Record of Borehole sheets. The testing indicated that the sandy silt till materials are of dense to very dense relative density.

The water contents of the sandy silt till samples ranged from about 9 to 13 per cent. The results of a grain size analysis carried out on a sample of the sandy silt till obtained from borehole 102 are shown on Figure C-4.

#### **4.2.3 Clayey Silt Till**

Located between the sandy silt till deposits and over the bedrock surface, the boreholes encountered layers of clayey silt till. The clayey silt till layers are 0.8 to 2.4 metres thick and were encountered at elevations of about 162.9 to 164.7 metres, and extended to the bedrock surface at about elevation 161.5 metres in borehole 101. A boulder was encountered between the sandy silt till and the clayey silt till deposits in borehole 101 and a silt pocket was encountered between the clayey silt till layers in borehole 103. The results of a grain size analysis carried out on a sample of the clayey silt till from borehole 103 are shown on Figure C-5.

The clayey silt till layers had standard penetration test N values of 34 to 107 blows per 0.3 metres penetration, with an average of about 52 blows per 0.3 metres penetration, indicating a hard consistency. The clayey silt till samples had measured water contents between about 8 to 11 per cent. Based on two Atterberg limits determinations, the clayey silt till deposits had average plastic and liquid limits of about 12 and 24 per cent, respectively, with an average plasticity index of 12. The results are shown on the Plasticity Chart, Figure C-6, which indicates a clayey silt material of low plasticity.

#### **4.2.4 Bedrock**

The bedrock surface was encountered in the boreholes some 14.5 to 14.7 metres below the dock surface, or at elevation 161.3 to 161.6 metres. The top 3.6 to 3.8 metres of the bedrock was cored in NQ size in boreholes 101 and 102. The bedrock was identified to be light brown to grey, medium strong to strong, argillaceous dolomitic limestone of the Dundee formation. The total rock core recoveries (TCR) recorded were 48 to 100 per cent, with measured solid core recoveries (SCR) of 43 to 100 per cent and rock quality designations (RQD) of zero to 100 per cent.

### **4.3 Water Conditions and Lake Bed Elevations**

Lake Erie water levels were noted at the three borehole locations during drilling and are reported to about 1.6 to 1.8 metres below the dock, or at about elevation 174.3 metres. No artesian water levels were noted in the borehole casings. These measured water levels and lake bed elevations are shown on the attached Record of Borehole sheets and are summarized below:

---

<b>BOREHOLE</b>	<b>LAKE WATER ELEVATION (m)</b>	<b>LAKE BED ELEVATION (m)</b>
101	174.28	167.58
102	174.41	169.10
103	174.26	167.44

Based on the scour profile drawings provided, it is understood that the design dredge elevation at the ferry dock is at elevation 169.1 metres, with about 0.7 to 1.4 metres of scour measured along the ferry dock in 2003. Also, some 2.4 metres of deposition is indicated at the north end of the harbour. The measured scour/deposition level and lake levels are shown in profile and section on Drawing 2 together with the subsurface stratigraphy encountered in the boreholes.

Lake level data collected since 1918 by the Canadian Hydrographic Service indicate that the minimum and maximum recorded water levels for Lake Erie are 173.18 and 175.04 metres, respectively. It should be noted that the lake level is subject to seasonal fluctuations and the mean level for the month of August is reported to be 174.94 metres.

## **5.0 ENGINEERING RECOMMENDATIONS**

### **5.1 General**

This section of the report provides our recommendations on the foundation aspects of the sheet pile walls for the MTO ferry dock at Kingsville. Similar foundation investigations were undertaken for this project at the ferry docks in Leamington and Pelee Island.

Our recommendations are based on our interpretation of the factual information obtained during the investigation and the results of field and laboratory testing. 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.

### **5.2 Existing Sheet Pile Walls**

Based on information provided by Morrison Hershfield, the existing dock is at elevation 176.0 metres (all elevations are referenced to International Great Lakes Datum, IGLD) and the lake water level is at elevation 174.3 metres. Lake level data collected since 1918 by the Canadian Hydrographic Service indicate that the minimum and maximum recorded water levels for Lake Erie are 173.18 and 175.04 metres, respectively. Based on the information provided, it is understood that the design dredge elevation at the ferry dock is at elevation 169.1 metres. The current lake bed survey data provided indicate that about 0.7 to 1.4 metres of scour and up to 2.4 metres of sediment deposition were measured below and above the design dredge level in 2003. The design sheet pile tips are at elevation 165.1 metres. Based on the pile lengths noted on Public Works Canada drawing number MA005, dated January 15, 1993, most of the piles extend to elevation 164.95 metres and a few piles at the south end of the dock extend somewhat below that elevation.

The dynamic cone penetration tests at borehole 101 at the south end of the dock and borehole 103 at the middle of the dock met refusal at about elevation 164.3 and 164.1 metres, respectively. The dynamic cone penetration test at borehole 102 at the north end of the dock met refusal at about elevation 166.5 metres.

It is understood that soil parameters are required to analyze the stability of the existing sheet pile walls at the dock. The subsurface conditions encountered in the three boreholes drilled in Lake Erie adjacent to the retaining wall during this investigation typically consisted of surficial very loose to compact fine grained granular deposits below some 5.3 to 6.8 metres of water. These deposits extended to about elevation 164 to 166 metres and were underlain by 3 to 6 metres of dense to very dense sandy silt till and hard clayey silt till with cobbles and boulders. Below the till layers at a depth of about 14.5 metres, limestone bedrock was encountered at elevation 161.5

metres. The stratigraphy encountered in the boreholes is detailed on the Record of Borehole sheets and Drawing 2.

### 5.2.1 Geotechnical Parameters

Based on the subsurface conditions encountered in the boreholes, the following parameters are recommended for the analyses and design of the sheet pile walls in accordance with the Canadian Highway Bridge Design Code (CHBDC):

Total unit weight of granular backfill: 22 kN/m<sup>3</sup>

Total unit weight of native soils:

Surficial granular soils 17 kN/m<sup>3</sup>

Silty clay 17 kN/m<sup>3</sup>

Till deposits 22 kN/m<sup>3</sup>

Undrained shear strength of cohesive soils:

Silty clay 80 kPa

Clayey silt till 200 kPa

MATERIAL	ANGLE OF FRICTION		COEFFICIENTS OF LATERAL EARTH PRESSURE			
			No Wall Friction		With 10° Wall Friction	
	Internal	Soil/Steel	'active', K <sub>a</sub>	'passive', K <sub>p</sub>	K <sub>a</sub>	K <sub>p</sub>
Compact to dense rock fill	40°	25°	0.22	4.60	0.21	7.0
Very loose to loose surficial granular soils	28°	17°	0.36	2.77	0.34	3.7
Stiff to very stiff silty clay	32°	21°	0.31	3.20	0.29	4.6
Compact to dense sandy silt	35°	22°	0.27	3.77	0.25	5.3
Hard clayey silt till deposit	34°	22°	0.25	4.00	0.23	6.0
Dense to very dense lower granular soils and sandy silt till	35°	22°	0.25	4.00	0.23	6.0

The inclusion of soil/wall friction in the analyses will depend upon the amount of relative movement which has or can occur or would be required to develop these forces. Further, the wall friction coefficient has been limited to 10° since larger values would necessitate substantial wall deformation, particularly to develop passive resistance.

An unbalanced water head behind the sheeting of at least 0.3 metres should be included in the structural analyses. In addition, the analyses should address the potential for future dredging if required for dock and ferry operations and/or the potential for additional scour.

Section B-B<sup>1</sup>, as shown on Drawing 2 should be used for the analytical model.

### 5.2.2 Geotechnical Considerations

A conventional factor of safety of 1.3 should be applied to the calculated depth of embedment or, alternatively, a factor of safety of 1.5 should be applied to  $K_p$ . The degree to which forces between the soil and steel sheeting can be mobilized will be dependant upon the amount of relative movement which has or can occur.

We understand that if the stability of the sheet pile walls is found to be marginally acceptable, consideration would be given to replacing the loose surficial sands and silts in the lake bed adjacent to the dock with less erodable and heavier fill. In addition, we recommend that consideration be given to replacing the rock fill below the deck of the dock with lighter weight fill. It should be noted that expanded polystyrene fill is not considered suitable at this site due to the high water level.

In addition to these geotechnical considerations, a number of structural options could be considered such as a pile supported relieving platform constructed behind the wall or steel pipes inserted into the hard clayey silt till to effectively increase the toe resistance. The table below provides a summary of the various stabilization alternatives, their advantages, disadvantages, relative costs and risks.

ALTERNATIVE	ADVANTAGES	DISADVANTAGES	COSTS	RISKS
Relieving Platform (piles driven to bedrock for support of backfill)	Decreases active pressures	Disturbance of dock area	Expensive construction	Interference with existing services below dock
Light Weight Fill Above the water level	Decreases active pressures	Disturbance of dock area, installation below water level less effective	Expensive construction	Interference with existing services below dock
Drilled Pile/Grouted Toe Restraint	Increases passive pressures	Installation below water	Less expensive	Buckling of existing sheeting
Rock Anchors Connected to Walers	Increases stability	Installation from marine equipment	Moderately expensive	Some below water operations
Addition of Lake Bed Fill	Reduces scour and increases passive pressures	Requires careful placement	Less expensive	Below water operations

If the analyses indicate that the stability of the wall is not acceptable, a monitoring program should be implemented to assess the magnitude and rate of wall deformations and related effects.

**GOLDER ASSOCIATES LTD.**

Azmi M. Hammoud, P. Eng.

Philip R. Bedell, P. Eng.  
Principal

Fintan J. Heffernan, P. Eng.  
Designated MTO Contact

AMH/PRB/FJH/jk  
n:\active\projects - other offices\windsor\2002\021-4200\021-4216-1 mh - ferry docks - pelee island\reports\kingsville (021-4216-1-2)\oct 20 05-fdn inv report- kingsville.doc

## LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole", on the figures and in the text of the report, are as follows:

### I. SAMPLE TYPES

<i>AS</i>	auger sample
<i>CS</i>	chunk sample
<i>DO</i>	drive open
<i>DS</i>	Denison type sample
<i>FS</i>	foil sample
<i>RC</i>	rock core
<i>SC</i>	soil core
<i>ST</i>	slotted tube
<i>TO</i>	thin-walled, open
<i>TP</i>	thin-walled, piston
<i>WS</i>	wash sample
<i>SS</i>	split spoon

### II. PENETRATION RESISTANCES

#### Dynamic Penetration Resistance:

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 0.3 m (12 in.).

#### Standard Penetration Resistance, 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 0.3 m (12 in.).

<i>WH</i>	sampler advanced by static weight-weight, hammer
<i>PH</i>	sampler advanced by hydraulic force
<i>PM</i>	sampler advanced by manual force

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

	"N" Blows/0.3 m or Blow/ft.
Relative Density	
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils

	"Cu" = "Su"	
Consistency	kPa	psf.
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000

### IV. SOIL TESTS

<i>C</i>	consolidation test
<i>H</i>	hydrometer analysis
<i>M</i>	sieve analysis
<i>MH</i>	combined analysis, sieve and hydrometer <sup>1</sup>
<i>Q</i>	undrained triaxial <sup>2</sup>
<i>R</i>	consolidated undrained triaxial <sup>2</sup>
<i>S</i>	drained triaxial
<i>U</i>	unconfined compression
<i>V</i>	field vane test
<i>Chem</i>	chemical analysis

#### NOTES:

1. Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.
2. Undrained triaxial tests in which pore pressures are measured are shown as Q or R.

## LIST OF SYMBOLS

### I. GENERAL

$\pi$	= 3.1416
e	= base of natural logarithms 2.7183
$\log_e$	a or $\ln$ a, natural logarithm of a
$\log_{10}$	a or $\log$ a, logarithm of a to base 10
$t$	time
$g$	acceleration due to gravity
$V$	volume
$W$	weight
$m$	mass
$M$	moment
$F$	factor of safety

### II. STRESS AND STRAIN

$u$	pore pressure
$\sigma$	normal stress
$\sigma'$	normal effective stress ( $\sigma$ is also used)
$\tau$	shear stress
$\varepsilon$	linear strain
$\varepsilon_{sy}$	shear strain
$\nu$	Poisson's ration ( $\mu$ is also used)
$E$	modulus of linear deformation (Young's modulus)
$G$	modulus of shear deformation
$K$	modulus of compressibility
$\eta$	coefficient of viscosity

### III. SOIL PROPERTIES

#### (a) Unit weight

$\gamma$	unit weight of soil (bulk density)
$\gamma_s$	unit weight of solid particles
$\gamma_w$	unit weight of water
$\gamma_d$	unit dry weight of soil (dry density)
$\gamma'$	unit weight of submerged soil
$G_s$	specific gravity of solid particles $G_s = \gamma_s/\gamma_w$
$e$	void ratio
$n$	porosity
$w$	water content
$S_r$	degree of saturation

#### (b) Consistency

$w_L$	liquid limit
$w_P$	plastic limit
$I_P$	plasticity index
$w_S$	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
$D_r$	relative density = $(e_{max} - e)/(e_{max} - e_{min})$

#### (c) Permeability

$h$	hydraulic head or potential
$q$	rate of discharge
$v$	velocity of flow
$i$	hydraulic gradient
$\kappa$	coefficient of permeability
$j$	seepage force per unit volume

#### (d) Consolidation (one-dimensional)

$m_v$	coefficient of volume change = $-\Delta e/(1+e)\Delta\sigma'$
$C_c$	compression index = $-\Delta e/\Delta\log_{10}\sigma'$
$c_v$	coefficient of consolidation
$T_F$	time factor = $c_v t/d^2$ ( $d$ , drainage path)
$U$	degree of consolidation

#### (e) Shear strength

$\tau_f$	shear strength	$\left. \begin{array}{l} \text{in terms} \\ \text{of effective} \\ \text{stress} \end{array} \right\} \tau_f = c' + \sigma' \tan \phi$
$c'$	effective cohesion intercept	
$\phi'$	effective angle of shearing resistance, or friction	
$S_u$	apparent cohesion*	
$\phi_u$	apparent angle of shearing resistance, or friction	$\left. \begin{array}{l} \text{in terms of} \\ \text{total stress} \end{array} \right\} \tau_f = cu + \sigma \tan \phi_u$
$\mu$	coefficient of friction	
$S_t$	sensitivity	

\*For the case of a saturated cohesive soil,  $\phi_u = 0$  and the undrained shear strength  $\tau_f = S_u$  is taken as half the undrained compressive strength.



## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERING STATE

Fresh: no visible sign of weathering.

**Faintly weathered:** weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.  
Completely weathered: rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

### BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing-</u>
Very thickly bedded	>2 m
Thickly bedded	0.6 m to 2m
Medium bedded	0.2 m to 0.6m
Thinly bedded	60 m to 0.2 m
Very thinly- bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	< 6 mm

### JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	> 3 m
Wide	1 – 3 m
Moderately close	0.3 – 1 m
Close	50 – 300 mm
Very close	< 50 mm

### GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	> 60 mm
Coarse Grained	2 – 60 mm
Medium Grained	60 microns – 2 mm
Fine Grained	2 – 60 microns
Very Fine Grained	< 2 microns

Note: \*Grains >60 microns diameter are visible to the naked eye.

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid sticks.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to (W.R.T.) Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

#### Description and Notes

An abbreviated description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces

#### Abbreviations

B – Bedding	P - Polished
FO - Foliation Schistosity	S - Slickensided
CL - Cleavage	SM - Smooth
SH - Shear Plane Zone	R - Ridged / Rough
VN - Vein	ST - Stepped
F - Fault	PL - Planar
CO - Contact	FL - Flexured
J - Joint	UE - Uneven
FR - Fracture	W - Wavy
M F - Mechanical Fracture	C - Curved
- Parallel To	
⊥ - Perpendicular To	

PROJECT 021-4216-1-2

# RECORD OF BOREHOLE No 101

1 OF 2

METRIC

G.W.P. (WO No. 01-33-001)

LOCATION N 4653843.4 :E 356665.9

ORIGINATED BY MA

DIST 31 HWY N/A

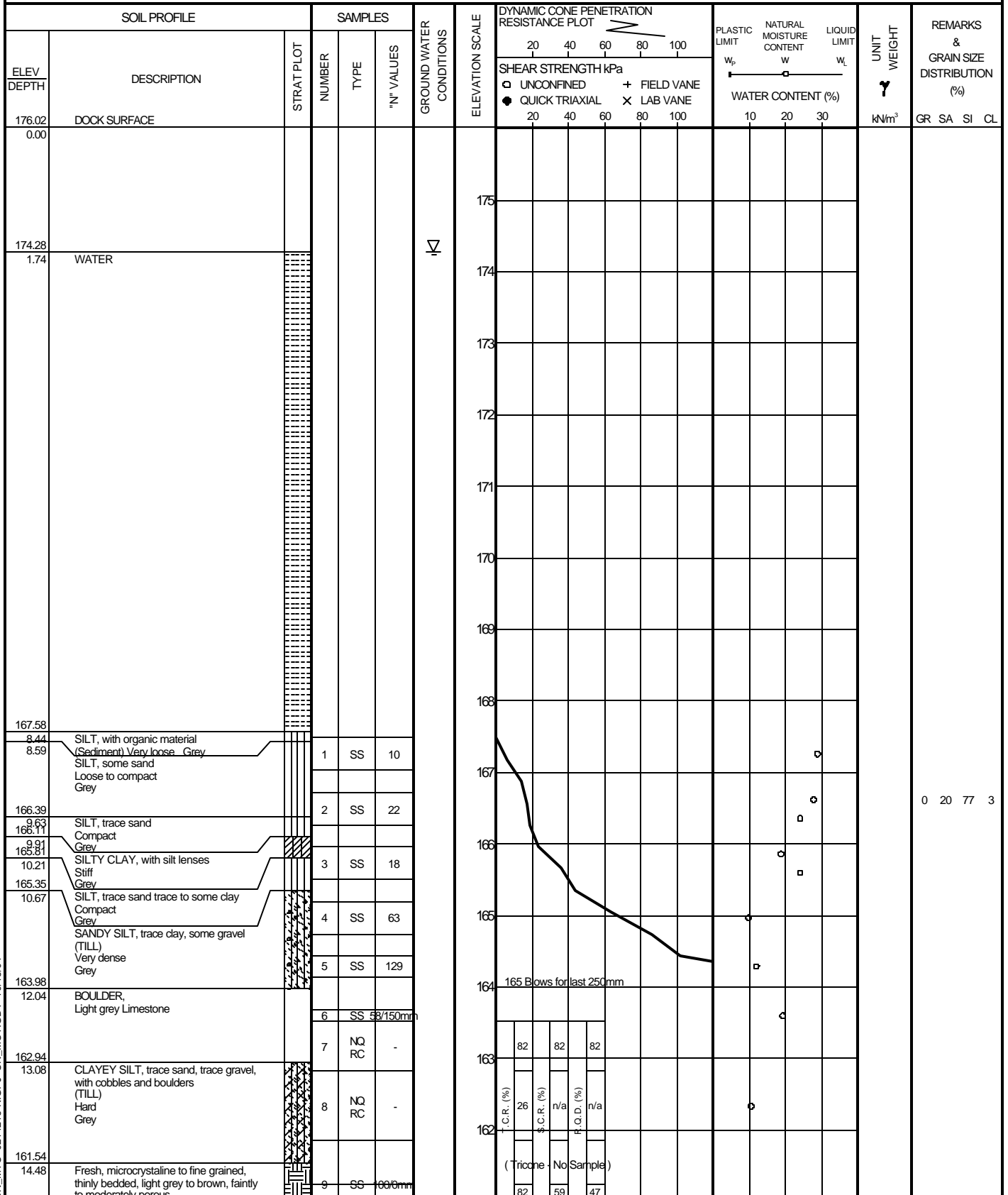
BOREHOLE TYPE ROTARY DRILLING / TRICONE

COMPILED BY WF

DATUM I.G.L.D.

DATE September 7, 2004 - September 8, 2004

CHECKED BY AMH



ON\_MTO 0214216-K.GPJ ON\_MOT.GDT 10/15/04

Continued Next Page

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

PROJECT 021-4216-1-2

# RECORD OF BOREHOLE No 101

2 OF 2

METRIC

G.W.P. (WO No. 01-33-001)

LOCATION N 4653843.4 ; E 356665.9

ORIGINATED BY MA

DIST 31 HWY N/A

BOREHOLE TYPE ROTARY DRILLING / TRICONE

COMPILED BY WF

DATUM I.G.L.D.

DATE September 7, 2004 - September 8, 2004

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W <sub>p</sub> W W <sub>L</sub>				
								20 40 60 80 100								
								20 40 60 80 100								

PROJECT 021-4216-1-2

# RECORD OF BOREHOLE No 102

1 OF 2

METRIC

G.W.P. (WO No. 01-33-001)

LOCATION N 4653905.9; E 356673.5

ORIGINATED BY MA

DIST 31 HWY N/A

BOREHOLE TYPE ROTARY DRILLING / TRICONE

COMPILED BY WF

DATUM I.G.L.D.

DATE September 8, 2004 - September 10, 2004

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT			LIQUID LIMIT	UNIT WEIGHT  Y  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W W <sub>L</sub>					
								□ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      X LAB VANE	WATER CONTENT (%)						
175.96	DOCK SURFACE						20 40 60 80 100							GR SA SI CL	
0.00															
174.41															
1.55	WATER														
169.10															
6.86	SILT, with organic material (Sediment) Very loose Grey														
167.73															
8.23	SILTY FINE SAND, Compact Grey		1	SS	22									0 8 47 45	
166.82															
9.14	SANDY SILT, trace clay, some gravel, with cobbles (TILL) Dense to Very dense Grey		2	SS	43									6 35 45 14	
			3	SS	59										
			4	SS	130										
164.68															
11.28	CLAYEY SILT, some sand, some gravel, with cobbles (TILL) Hard Grey		5	SS	47										
			6	SS	35										
			7	SS	55										
162.40															
13.56	SANDY SILT, trace clay, some gravel, with cobbles (TILL) Very dense Grey		8	SS	111										
161.25			9	SS 100/100mm											
14.71	Fresh, microcrystalline to fine		10												
							91 87 70								

ONL\_MTO 0214216-K.GPJ ON\_MOT.GDT 10/15/04

Continued Next Page

+3, X 3: Numbers refer to  
Sensitivity

3% STRAIN AT FAILURE

PROJECT 021-4216-1-2

# RECORD OF BOREHOLE No 102

2 OF 2

METRIC

G.W.P. (WO No. 01-33-001)

LOCATION N 4653905.9; E 356673.5

ORIGINATED BY MA

DIST 31 HWY N/A

BOREHOLE TYPE ROTARY DRILLING / TRICONE

COMPILED BY WF

DATUM I.G.L.D.

DATE September 8, 2004 - September 10, 2004

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W <sub>p</sub> W W <sub>L</sub>				GR	SA	SI	CL
								□ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE	WATER CONTENT (%)										
	grained, thinly bedded, light grey to brown, faintly to moderately porous, medium strong to strong, argillaceous DOLOMITIC LIMESTONE, occasionally fossiliferous and interclustic with vuggy zones and calcite nodules (DUNDEE FORMATION)		10	NQ RC	-		91	87	70										
			11	NQ RC	-		97	97	88										
			12	NQ RC	-		100	100	100										
157.70																			
18.26	END OF BOREHOLE																		

PROJECT 021-4216-1-2

# RECORD OF BOREHOLE No 103

1 OF 1

METRIC

G.W.P. (WO No. 01-33-001)

LOCATION N 4653877.0; E 356667.0

ORIGINATED BY DJM

DIST 31 HWY N/A

BOREHOLE TYPE ROTARY DRILLING / TRICONE

COMPILED BY WF

DATUM I.G.L.D.

DATE September 26, 2004 - September 27, 2004

CHECKED BY AMH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
176.03 0.00	DOCK SURFACE							20 40 60 80 100		10 20 30				GR SA SI CL	
174.26 1.77	WATER														
167.44 8.59 167.13	SILTY FINE SAND, with shells Very loose Grey		1	SS	4										
8.90	SANDY SILT, with clayey silt layers, trace gravel Compact to dense Grey		2	SS	23										
			3	SS	38									1 18 70 1	
			4	SS	20										
164.30 11.73	CLAYEY SILT, trace sand, trace gravel, (TILL) Hard Grey		5	SS	34										
163.23 12.80 12.95	SILT, some sand Dense Grey		6	SS	35										
	CLAYEY SILT, trace sand, trace gravel, (TILL) Hard Grey		7	SS	107									0 38 51 11	
162.31 13.72	SANDY SILT, some clay, trace gravel, (TILL) Very dense Grey		8	SS	150/100mm										
161.55 14.48 161.25	DOLOMITIC LIMESTONE, (DUNDEE FORMATION)		9	WS	-										
14.78	END OF BOREHOLE														

ON MTO 0214216-K.GPJ ON MOT.GDT 10/15/04

+3, X 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

**RECORD OF BOREHOLE No K1**

1 OF 1

**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653836N, 356683E ORIGINATED BY C.C.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 18, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)				
								○ UNCONFINED		+ FIELD VANE												
								● QUICK TRIAXIAL		× LAB VANE												
175.96	GROUND SURFACE						20	40	60	80	100						GR SA SI CL					
0.00	FILL, granular base, with layers of brown silty fine sand, geotextile at about 0.9 m depth Very dense Grey Brown		1	AS	-	▽																
174.80			2	SS	>50		175															
1.16	FILL, rock (cobble size), some sand layers/ inclusions Compact to very dense Grey Brown		3	SS	118		174															
			4	SS	11		173															
			5	SS	12		172															
			6	SS	23		171															
			7	SS	8		170															
170.47																						
5.49	SILTY FINE SAND to SANDY SILT Dense to very dense Grey Brown		8	SS	39		169															
			9	SS	30		168															
							167															
			10	SS	59	166																
165.90						165																
10.06	SANDY SILT TILL, trace to some clay and gravel, occ. cobbles Very dense Grey																					
164.84			11	SS	73																	
11.13	End of Borehole																					
	NOTE: Water level in Borehole at about elev. 174.13m during drilling Sept. 18, 2002  Borehole drilled in repaired area.																					

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

**RECORD OF BOREHOLE No K2**

1 OF 1

**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653829N, 356673E ORIGINATED BY R.W.W.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 19, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	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    × LAB VANE									
								20 40 60 80 100									
								WATER CONTENT (%)									
175.95	GROUND SURFACE																
0.00	FILL, granular base, with geotextile @ 0.3m Grey Brown		1	AS	-												
175.34																	
0.61	FILL, fine sand to silty fine sand mixed rock fragments Brown		2	SS	20												
0.76																	
174.73	FILL, crushed rock (clear stone), with layers of silty fine sand, with geotextile Compact Brown to Grey		3	SS	23												
1.22	FILL, rock (cobble size), with layers/pockets of silty fine sand Compact Grey Brown																
			4	SS	13												
			5	SS	11												
			6	SS	12												
			7	SS	18												
170.16																	
5.79	SILTY FINE SAND Very loose Grey Brown		8	SS	3												
169.64																	
6.31	CLAYEY SILT, some sand, occ. grey black organic inclusions Soft to very stiff Grey																
168.09			9	SS	23												
7.86	SILTY FINE SAND to FINE SAND, occ. grey black organic pockets Compact Grey																
			10	SS	25												
166.20																	
9.75	End of Borehole																
NOTES: Water level in Borehole at about elev. 173.92m during drilling on Sept. 19, 2002  Borehole drilled in a repaired area.																	



**RECORD OF BOREHOLE No K3**

1 OF 1

**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653845N, 356668E ORIGINATED BY R.W.W.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 19, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	20	40	60						80	100	10
175.97	GROUND SURFACE																			
0.00	FILL, granular base, with geotextile @ depth		1	AS	-								○							
175.63			2	AS	-								○							
0.34	FILL, silty fine sand, some rock fragments																			
175.30	Brown																			
0.67	FILL, rock (cobble size), with some sand inclusions/ layers Loose to dense Grey Brown		3	SS	26		175						○							
			4	SS	8								○							
							174													
			5	SS	36									○						
			6	SS	12		173							○						
			7	SS	8		172							○						
			8	SS	8		171							○						
170.48																				
5.49	CLAYEY SILT, some sand partings/ seams, with occ. grey black organic inclusions Soft Grey Brown						170													
169.57			9	SS	3										○					
6.40	SANDY SILT to SILTY FINE SAND Very loose to dense Grey Brown						169													
			10	SS	32		168								○					
							167													
			11	SS	36									○						
							166													
165.61																				
10.36	SANDY SILT TILL Very dense Grey Brown						165								○					
164.69			12	SS	96															
11.28	End of Borehole																			
	NOTES: Water seepage into borehole encountered at about elev. 173.94m during drilling Sept. 19, 2002  Borehole drilled in a repaired area.																			

**RECORD OF BOREHOLE No K4**

1 OF 1

**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653866N, 356672E ORIGINATED BY C.C.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 20, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	20						40	60	80
176.00	PAVEMENT SURFACE																			
0.00	ASPHALT																			
0.16	FILL, granular base		1	AS	-								○							
175.49																				
0.51	FILL, fine sand, some rock fragments												○							
0.76	Compact Brown		2	SS	24		175						○							
	FILL, rock (cobble size), some sand inclusions/ layers																			
	Compact to very dense Grey Brown		3	SS	24		174						○							
							173							○						
			4	SS	21															
			5	SS	28		172						○							
			6	SS	58		171						○							
170.21																				
5.79	SANDY SILT TILL, some sand and gravel, occ. silt seams						170							○						
	Compact Grey		7	SS	27															
168.99																				
7.01	FINE SAND, trace silt						169													
	Dense Grey																			
			8	SS	32		168							○						
167.47																				
8.53	CLAYEY SILT TILL, some sand and gravel						167													
	Hard Grey																			
			9	SS	63								○							
166.25																				
9.75	End of Borehole																			
NOTE: Water level in Borehole at about elev. 174.07m during drilling Sept. 20, 2002  Borehole drilled in a settled pavement area.																				

**RECORD OF BOREHOLE No K5**

1 OF 1

**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653900N, 356678E ORIGINATED BY C.C.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (SOLID STEM, HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 18, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
175.98	PAVEMENT SURFACE																			
0.00	ASPHALT																			
0.13	FILL, granular base																			
0.30	FILL, crushed rock, mixed with brown silty fine sand, aluminum can and pieces of clay brick		1	AS	-															
175.22	Compact Brown						175													
0.76	FILL, rock (cobble size), occ. brick fragments, some sand		2	SS	21															
	Compact to Loose Grey Brown		3	SS	8		174													
			4	SS	19															
							173													
			5	SS	24															
172.32																				
3.66	SILTY FINE SAND to FINE SAND, some rock fragments near surface, occ. grey black organic inclusions		6	SS	14		172													
	Compact Grey Brown																			
			7	SS	21		171													
170.49							170													
5.49	SILTY FINE SAND to SANDY SILT																			
	Dense Grey		8	SS	37		169													
			9	SS	42		168													
167.44																				
8.53	CLAYEY SILT TILL, some sand and gravel						167													
	Hard Grey		10	SS	63															
166.23																				
9.75	End of Borehole																			
	NOTES: Water level in Borehole at about elev. 173.97m during drilling on Sept. 18, 2002  Borehole drilled in a settled pavement area.																			

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

**RECORD OF BOREHOLE No K6**

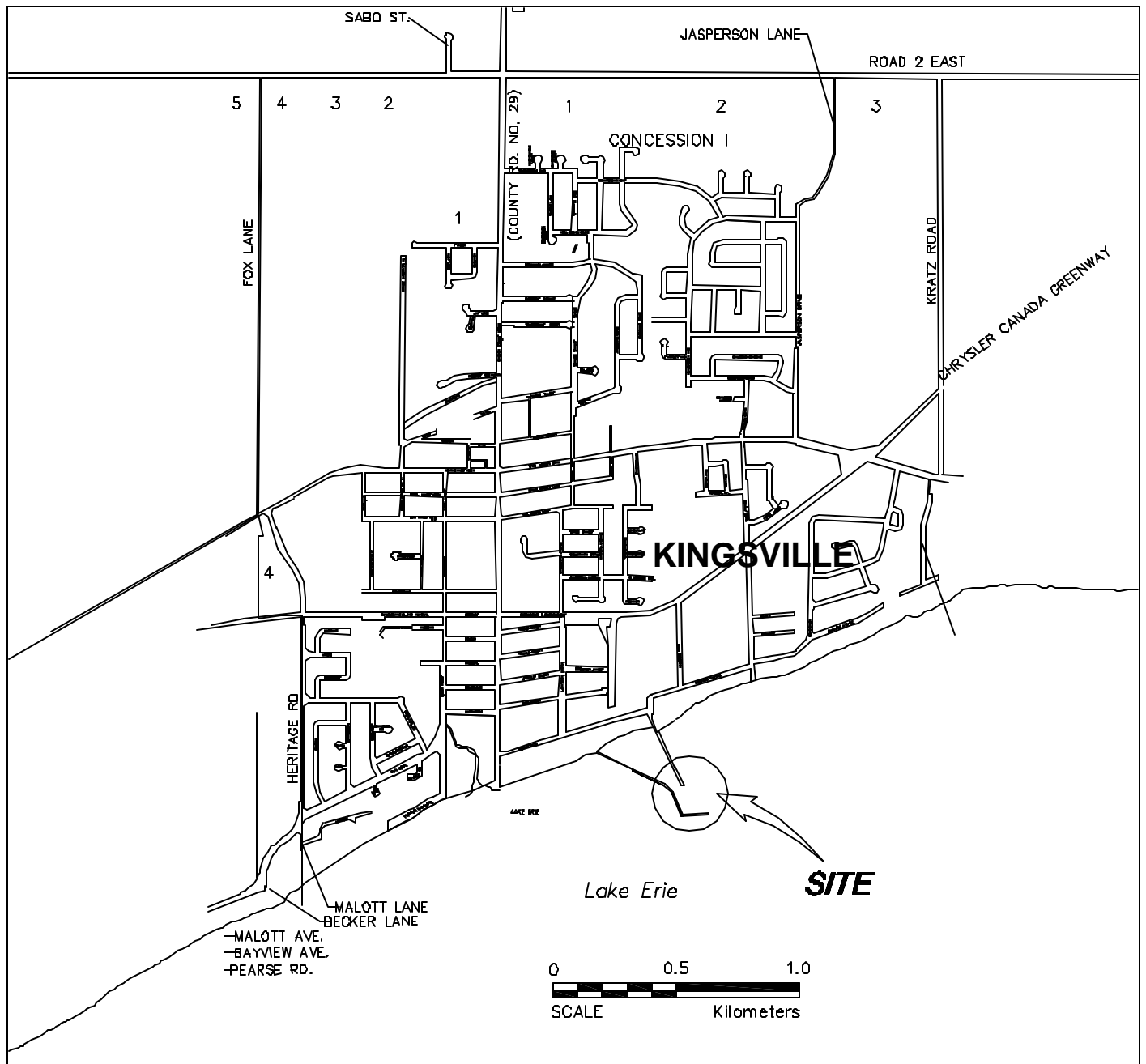
1 OF 1


**METRIC**

PROJECT 021-4216  
G.W.P. 01-33-001 LOCATION 4653922N, 356676E ORIGINATED BY C.C.  
DIST #31 HWY N/A BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY T.M.  
DATUM Geodetic DATE September 20, 2002 CHECKED BY H.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
176.01	GROUND SURFACE						20	40	60	80	100	10	20	30						
0.00	FILL, granular base, with silty fine sand layers and asphalt fragments, filter fabric at 0.3m Compact grey		1	AS	-	▽														
			2	SS	16		175													
174.64							174													
1.37	FILL, rock (cobble size), with sand layers/ inclusions Compact to dense Grey Brown		3	SS	30		173													
			4	SS	11		172													
		5	SS	14	171															
					170															
		6	SS	16	169															
					168															
170.52					167															
5.49	SILTY FINE SAND to SANDY SILT Compact Grey		7	SS	25	166														
			8	SS	22	165														
167.48																				
8.53	SILT to SANDY SILT Dense Grey		9	SS	33															
166.56																				
9.45	CLAYEY SILT TILL, some sand and gravel Hard grey																			
164.88			10	SS	81															
11.13	End of Borehole																			
	NOTES: Water level in Borehole at about elev. 174.09m during drilling on Sept. 20, 2002  Borehole drilled in a repaired area.																			

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



PROJECT		MTO FERRY DOCKS KINGSVILLE, ONTARIO	
TITLE		SITE LOCATION PLAN	
 Golder Associates LONDON, ONTARIO		PROJECT No. 021-4216-1-2	FILE No. 021-4216-1-K-DDO
		CADD WDF Sept 2004	SCALE AS SHOWN REV. 0
		CHECK ANH Oct 2004	<b>FIGURE 1</b>

**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

**DIST** 31  
**W.O. No.** 01-33-001  
**P.O. No.** 3005-A-000218



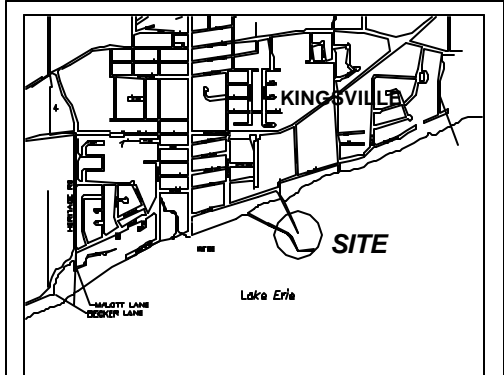
**MTO FERRY DOCK  
KINGSVILLE, ONTARIO**  
**BOREHOLE LOCATIONS**

**SHEET**



Golder Associates Ltd.  
LONDON, ONTARIO, CANADA

**REFERENCE**  
DRAWING SUPPLIED BY PUBLIC WORKS CANADA  
ARCHITECTURAL AND ENGINEERING SERVICES, ONTARIO REGION  
KINGSVILLE, ONTARIO, FERRY WHARF  
GENERAL ARRANGEMENT PLAN  
PROJECT No. 670762, DRAWING No. MA002  
DATED 1993 01 15



**KEY PLAN**

**LEGEND**

- Borehole Current Investigation
- Borehole Previous Investigations  
(Boreholes by others indicated by 1988)

No.	ELEVATION (metres)	CO-ORDINATES	
		NORTH	EAST
101	178.02	4 853 843.4	356 885.9
102	175.98	4 853 905.9	356 873.5
103	178.03	4 853 877.0	356 887.0
K1	175.98	4 853 838	356 883
K2	175.95	4 853 829	356 873
K3	175.97	4 853 845	356 868
K4	175.00	4 853 886	356 872
K5	175.98	4 853 900	356 878
K6	178.01	4 853 922	356 876
( 1988 )			
BH2	174.0 (WL)	4 853 932	356 826
BH10	174.1 (WL)	4 853 946	356 849

**NOTES**

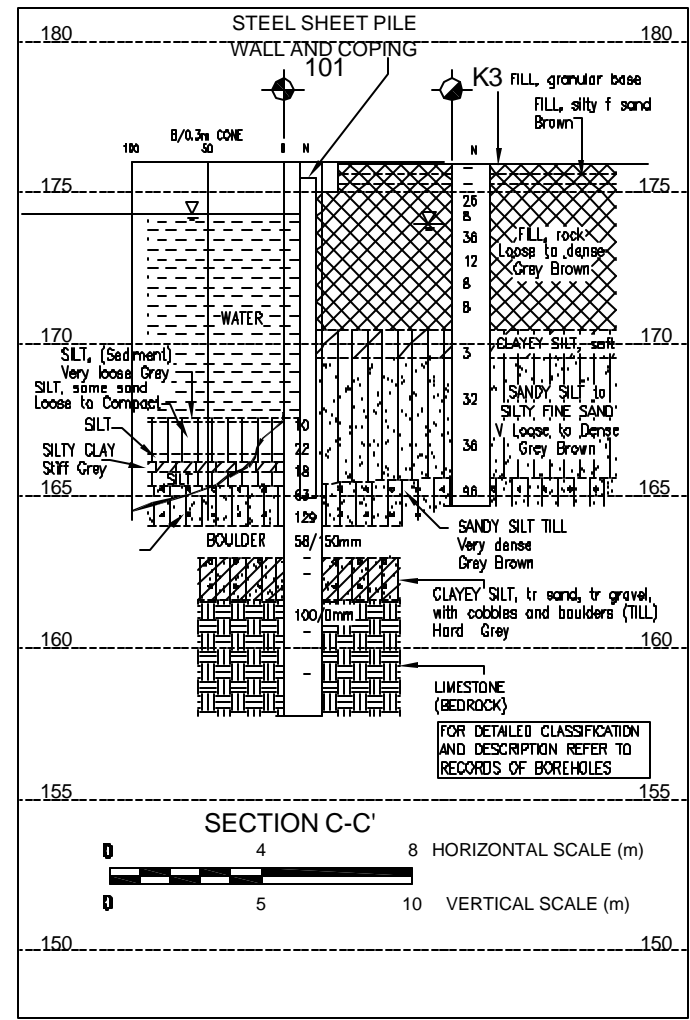
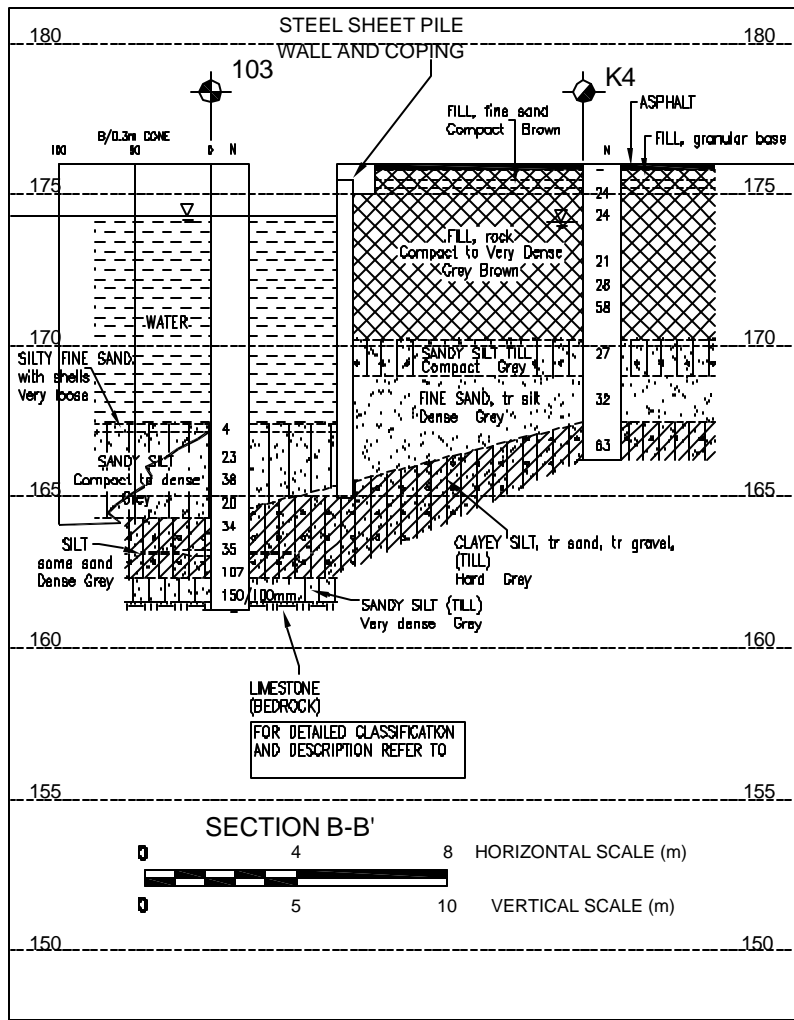
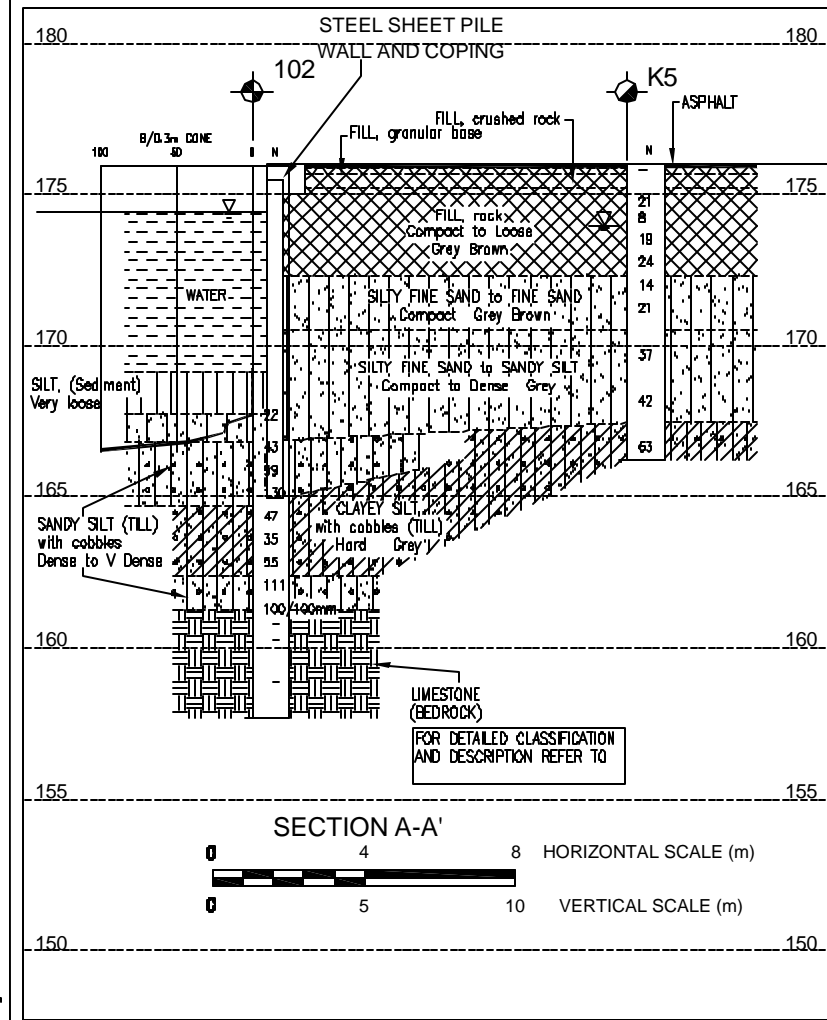
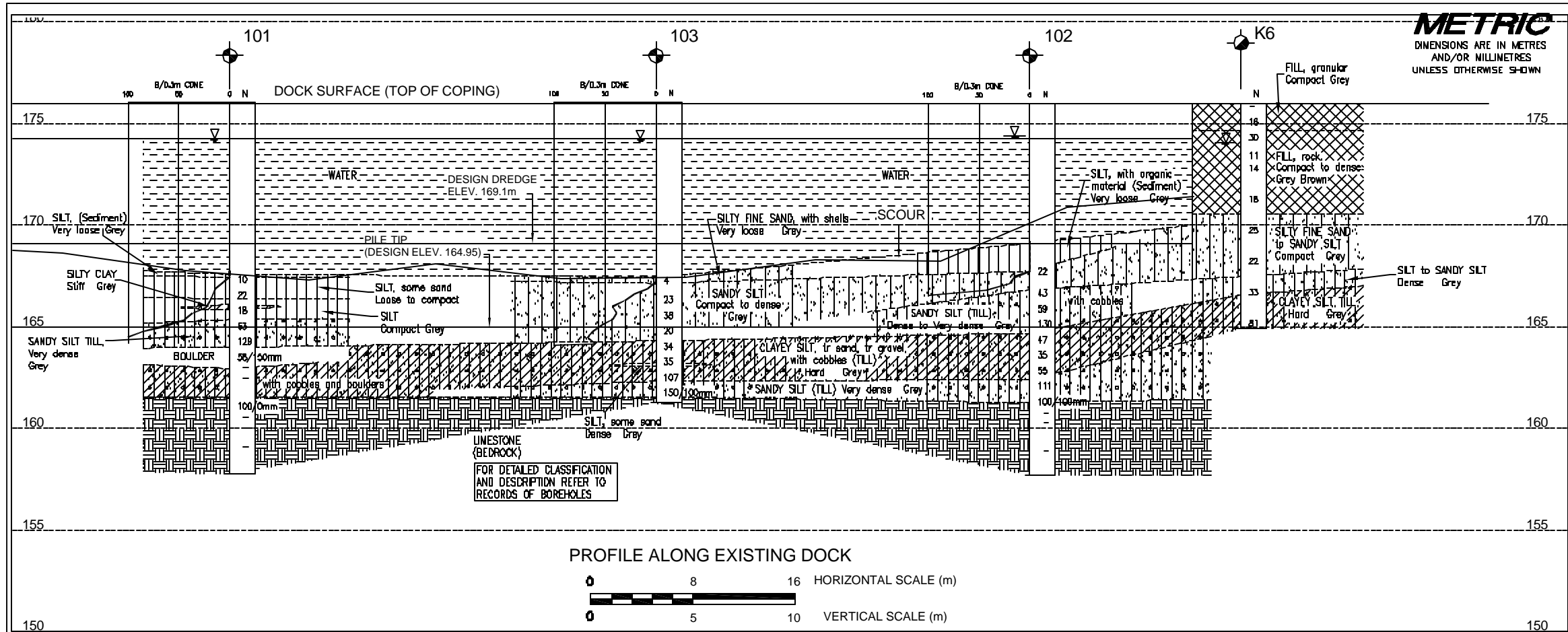
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

NO.	DATE	BY	REVISION

Geocres No.

HWY. No.	N/A	PROJECT NO.:	021-4218-1-2
SUBM'D.	-	CHK'D.	-
DRAWN:	WDF	Q-CKD.	ANH
DATE:	SEPT 2004	APPD.	
DWG.	1		

Drawing File: 0214218-1-K-001.DWG



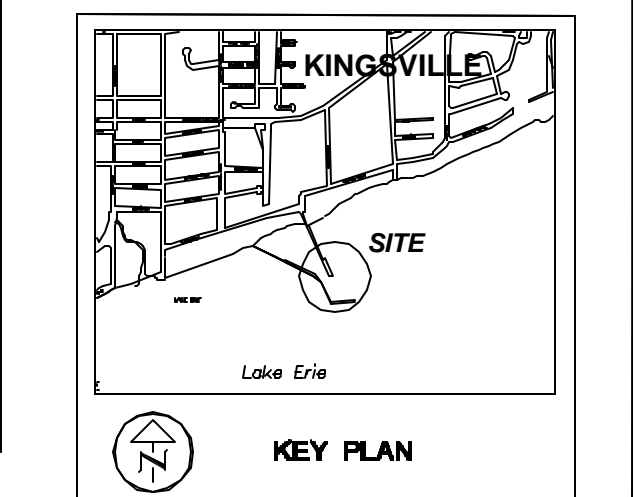
**DIST** 31  
**W.O. No.** 01-33-001  
**P.O. No.** 3005-A-000218

**MTO FERRY DOCK**  
**KINGSVILLE, ONTARIO**

**SOIL STRATA**

**Golder Associates Ltd.**  
 LONDON, ONTARIO, CANADA

**REFERENCE**  
 DRAWING SUPPLIED BY PUBLIC WORKS CANADA  
 ARCHITECTURAL AND ENGINEERING SERVICES, ONTARIO REGION  
 KINGSVILLE, ONTARIO, FERRY WHARF  
 GENERAL ARRANGEMENT PLAN  
 PROJECT No. 670762, DRAWING No. MA002  
 DATED 1993 01 15



**LEGEND**

- Borehole Current Investigation
- Borehole Previous Investigations (Boreholes by others indicated by 1988 and 1993)
- Seal
- Piezometer
- N Blows/0.3m (Std. Pen. Test, 475 j/blow)
- WL in piezometer
- WL during drilling

No.	ELEVATION (metres)	CO-ORDINATES	
		NORTH	EAST
101	178.02	4 653 843.4	356 885.9
102	175.96	4 653 905.9	356 873.5
103	178.03	4 653 877.0	356 887.0
K3	175.97	4 653 845	356 868
K4	175.00	4 653 866	356 672
K5	175.98	4 653 900	356 678
K6	176.01	4 653 922	356 676

**NOTES**  
 The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

NO.	DATE	BY	REVISION

**Geocres No.**

HWY. No.	N/A	PROJECT NO.:	021-4218-1-2
SUBW'd.	-	CHK'd.	DATE: SEPT 2004
DRAWN:	WDF	CHK'D.	APP'D.

DWG. 2

Drawing File: 0214218-1-K-002.DWG

**APPENDIX A**  
**RECORDS OF PREVIOUS BOREHOLES**

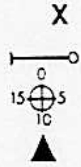


# Log of Borehole 2



Auger Sample   
 SPT (N) Value   
 Dynamic Cone Test   
 Shelby Tube   
 Field Vane Test

Natural Moisture   
 Plastic and Liquid Limit   
 Undrained Triaxial at Overburden Pressure   
 % Strain at Failure   
 Penetrometer



Project Kingsville Harbour Improvements Dwg. No. 7

Kingsville, Ontario

Project No. L02535AGI

Hole location and datum see drawing No. 1

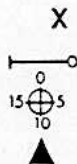
G W L	S Y M B O L	Soil Description	IGLD ELEV. m	D E P T H m	N Value				Natural Moisture Content and Atterberg Limits % Dry Weight			Natural Unit Weight kN/m <sup>3</sup>
					20	40	60	80	10	20	30	
					Shear Strength MPa							
		Water Level (September 15, 1988) (Gauge +0.73 m)	174	0								
		SAND-fine to medium grained, grey, compact to dense below 3 m,  silty, fine grained below about 4 m depth, grey-brown	172.5	2								
				4								
				6								
			166.9	8								
		SILT to SANDY SILT TILL- cohesive, trace to some gravel, occasional cobbles and boulders, gravelly pockets, grey, very dense,  dense fine sand pockets or layer near 11 m depth, clayey silt zones  very dense SILTY SAND TILL near 12 m depth		10								
				12								
				14								
			160.6	16								
		LIMESTONE BEDROCK-grey to light brown, very thin shaley seams, poor to excellent		18								
				20								
		End of Borehole	157.6	22								

NOTE: BOREHOLE REQUIRES INTERPRETATION ASSISTANCE FROM TROW BEFORE USE BY OTHERS.

# Log of Borehole 10



Auger Sample Natural Moisture  
 SPT (N) Value Plastic and Liquid Limit  
 Dynamic Cone Test Undrained Triaxial at Overburden Pressure  
 Shelby Tube % Strain at Failure  
 Field Vane Test Penetrometer

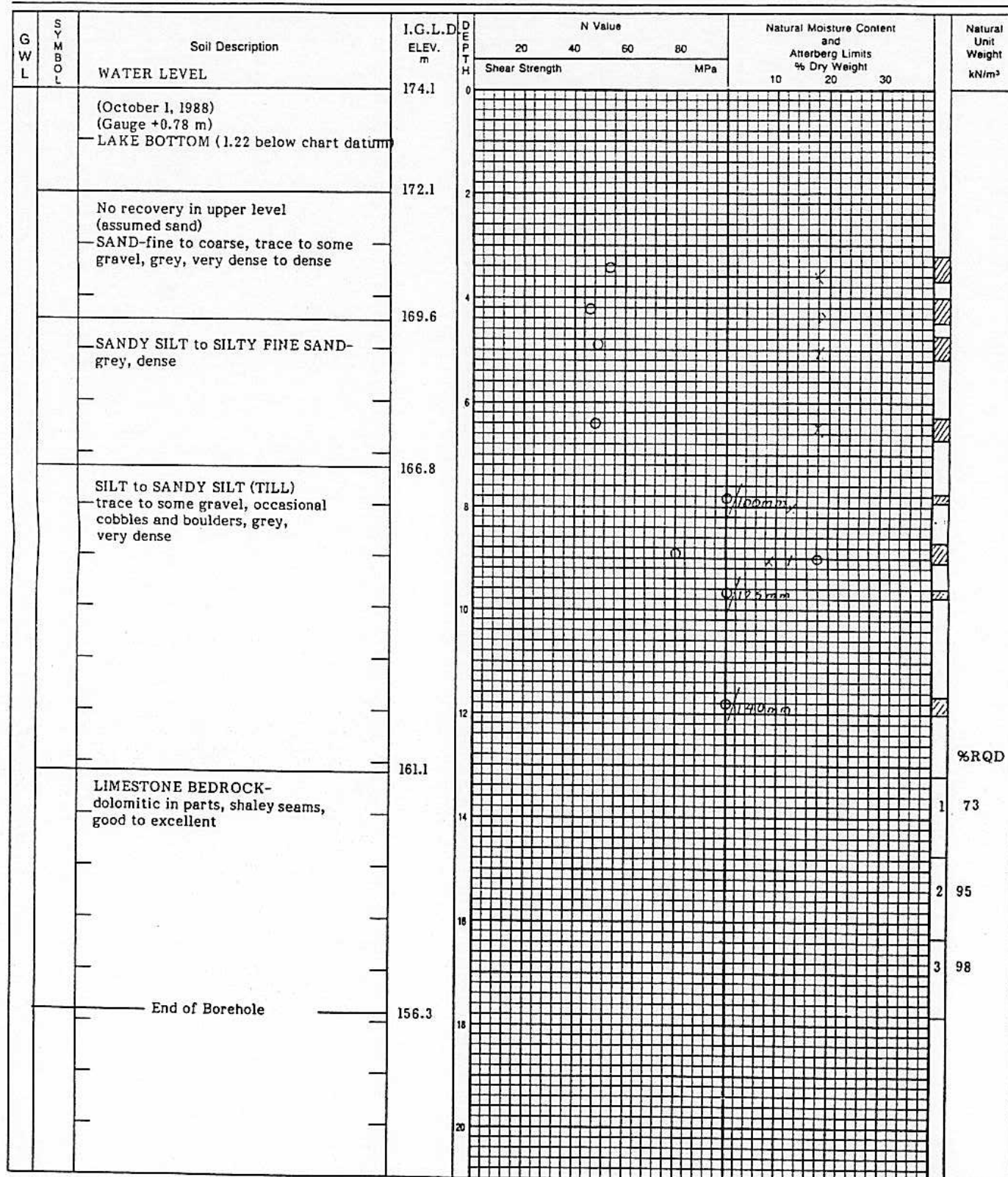


Project Kingsville Harbour Improvements Dwg. No. 9

Kingsville, Ontario

Project No. L02535AGI

Hole location and datum see drawing No. 1



NOTE: BOREHOLE REQUIRES INTERPRETATION ASSISTANCE FROM TROW BEFORE USE BY OTHERS.

**APPENDIX B**  
**SITE PHOTOGRAPHS**



## SITE PHOTOGRAPHS

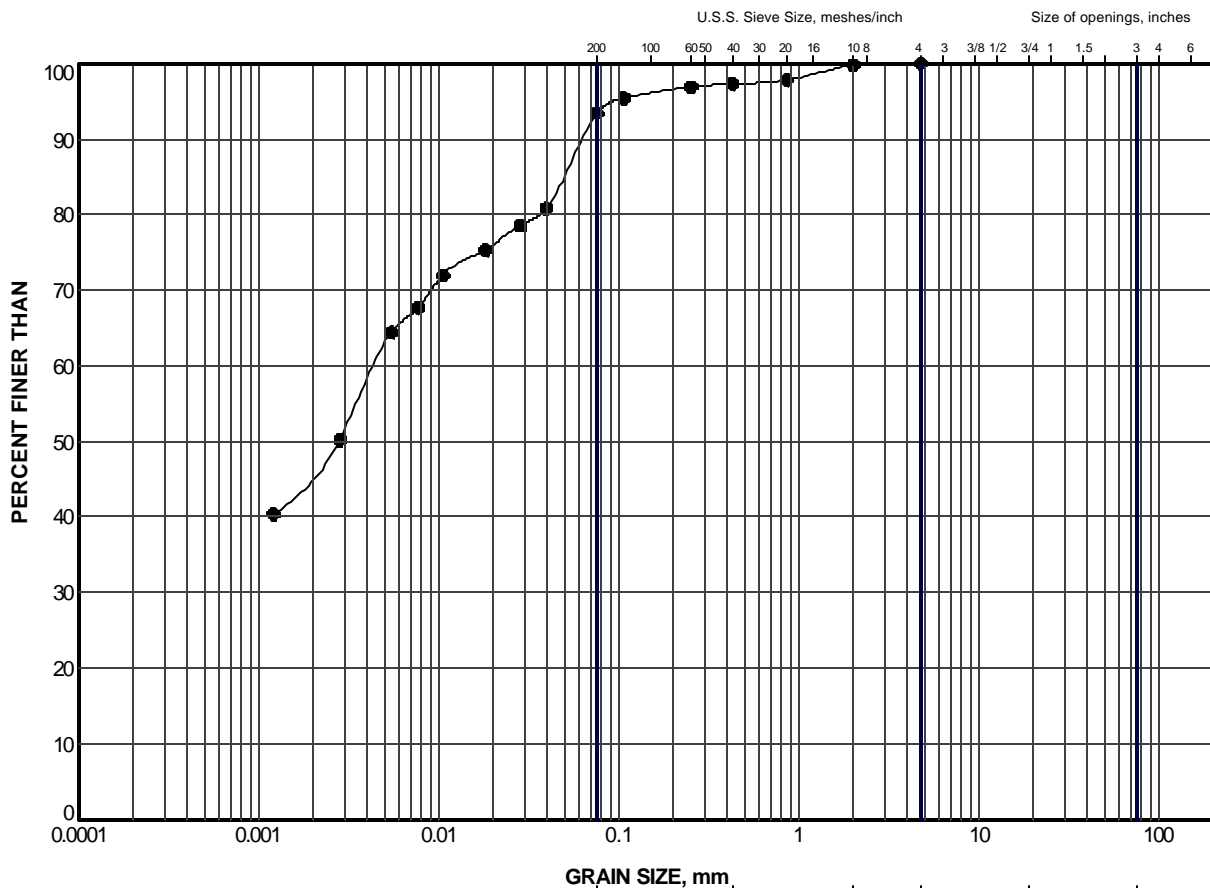


Photo 1: General view of drilling platform at Kingsville dock.




Photo 2: Washboring through drill casing.

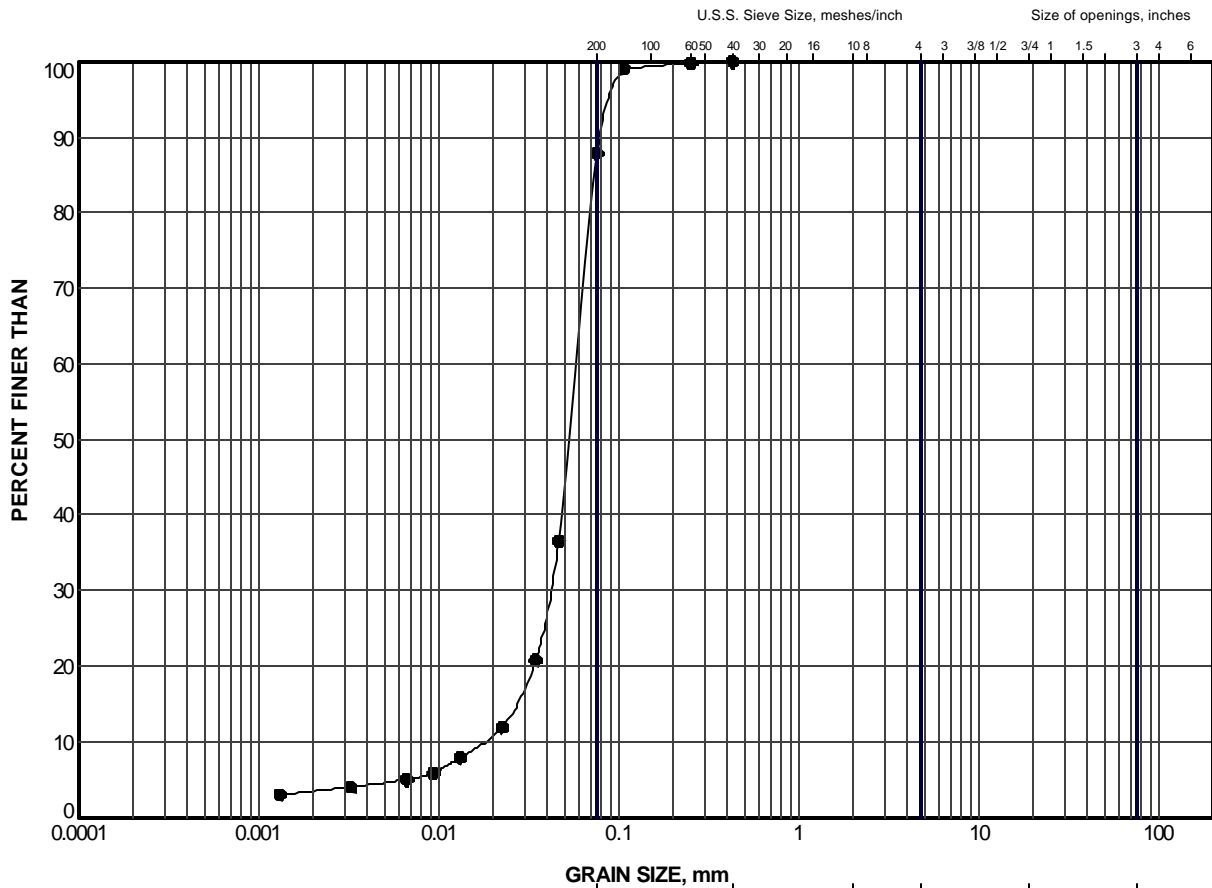
**APPENDIX C**  
**LABORATORY TEST DATA**



GRAIN SIZE, mm		U.S.S. Sieve Size, meshes/inch		Size of openings, inches	
0.075	0.15	20	10	0.075	0.15
0.3	0.6	60	30	0.075	0.15
1.18	2.5	16	8	0.075	0.15
5.0	10.0	4	2	0.075	0.15
20.0	40.0	1	0.5	0.075	0.15


LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
◆	102	1A	167.8

PROJECT		MTO FERRY DOCK KINGSVILLE, ONTARIO	
TITLE		GRAIN SIZE DISTRIBUTION SILT (SEDIMENT)	
PROJECT No.	021-4216-1-2	FILE No.	0214216-K.GPJ
DRAWN	WDF	Oct 13/04	SCALE N/A
CHECK	AMH	Oct 13/04	REV.
		FIGURE C-1	

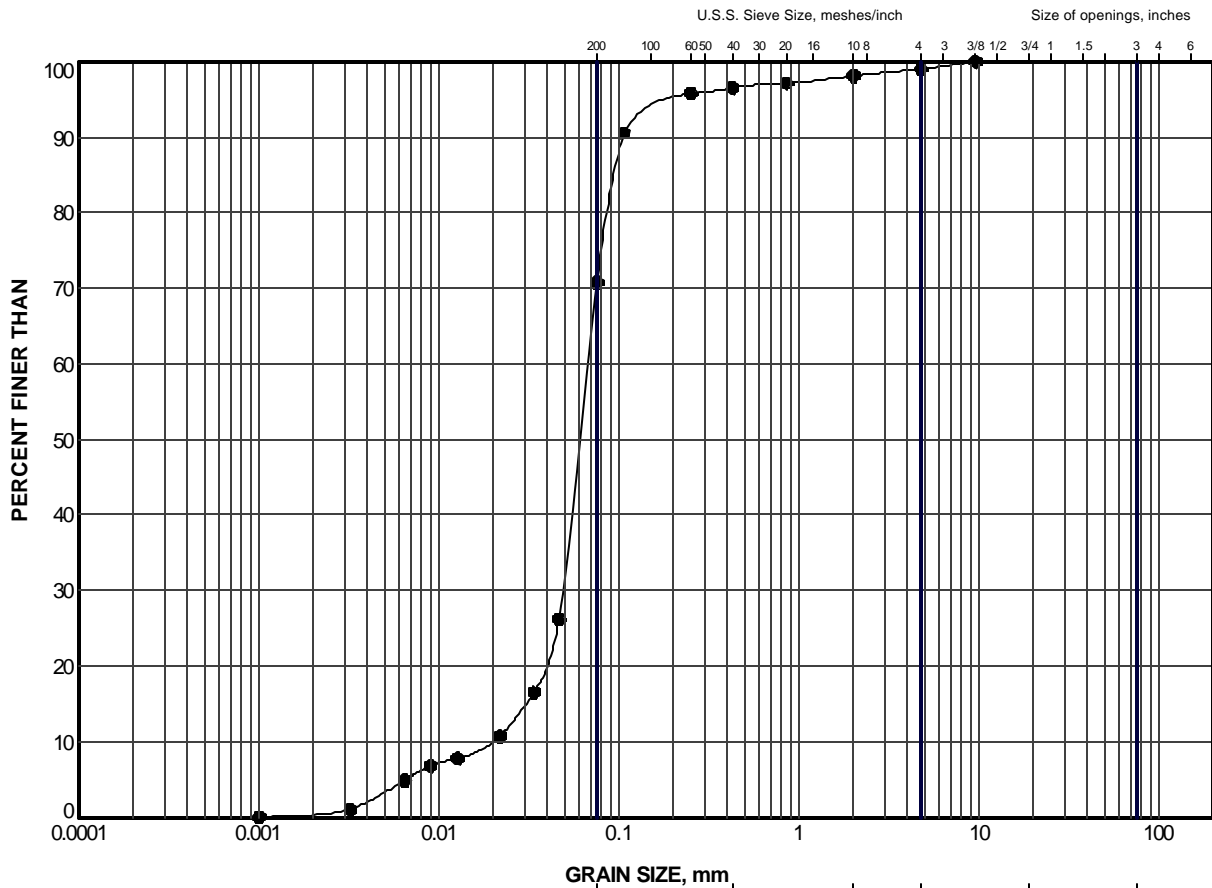


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
◆	101	2A	166.6


PROJECT				MTO FERRY DOCK KINGSVILLE, ONTARIO			
TITLE				GRAIN SIZE DISTRIBUTION SILT, some sand			
PROJECT No.		021-4216-1-2		FILE No.		0214216-K.GPJ	
DRAWN		WDF		SCALE		N/A	
CHECK		AMH		REV.			
		Oct 13/04					
		Oct 13/04					
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE C-2</b>			

LDN\_MTO\_NEW GLDR\_LDN.GDT



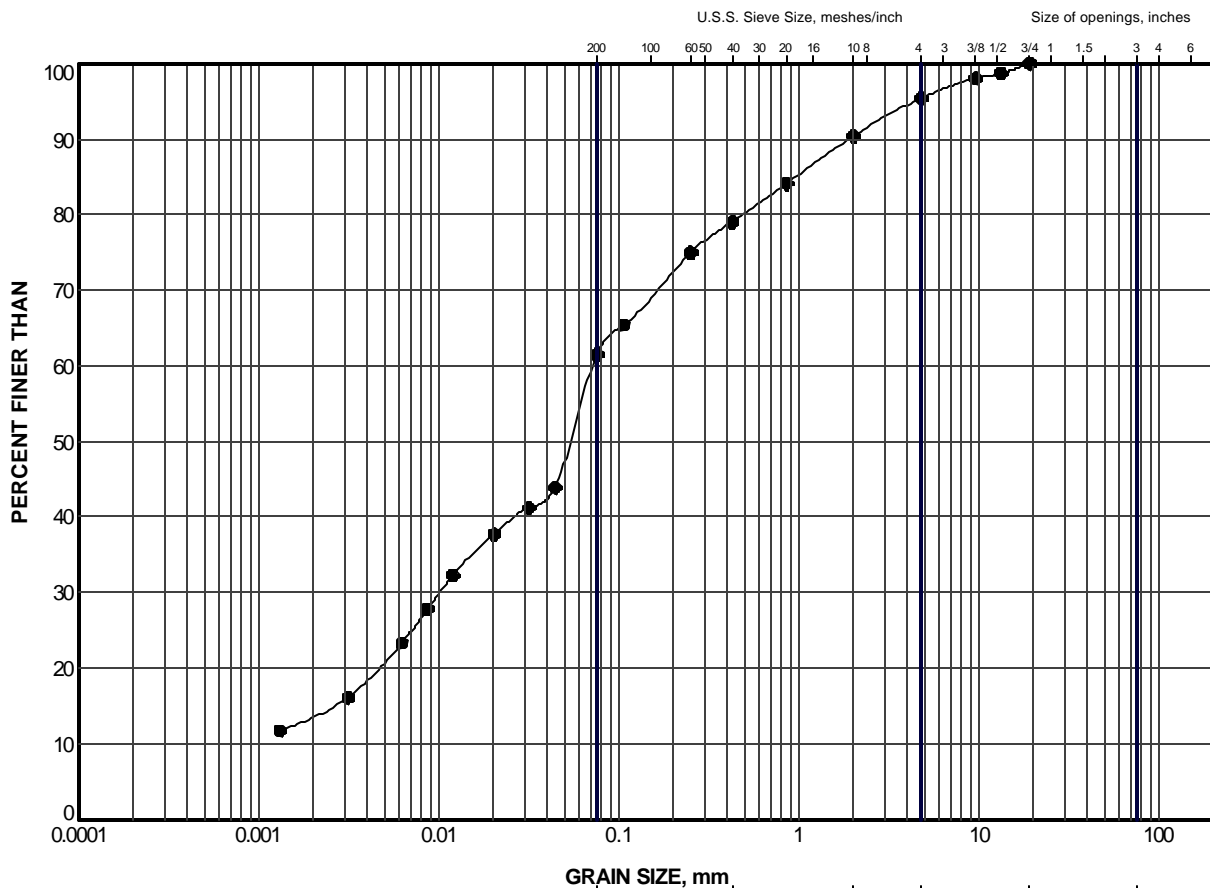
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
◆	103	3	165.5

PROJECT				MTO FERRY DOCK KINGSVILLE, ONTARIO			
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT			
PROJECT No.		021-4216-1-2		FILE No.		0214216-K.GPJ	
DRAWN		WDF		SCALE		N/A	
CHECK		AMH		REV.			
		Oct 13/04					
		Oct 13/04					
				<b>FIGURE C-3</b>			


LDN\_MTO\_NEW GLDR\_LDN.GDT

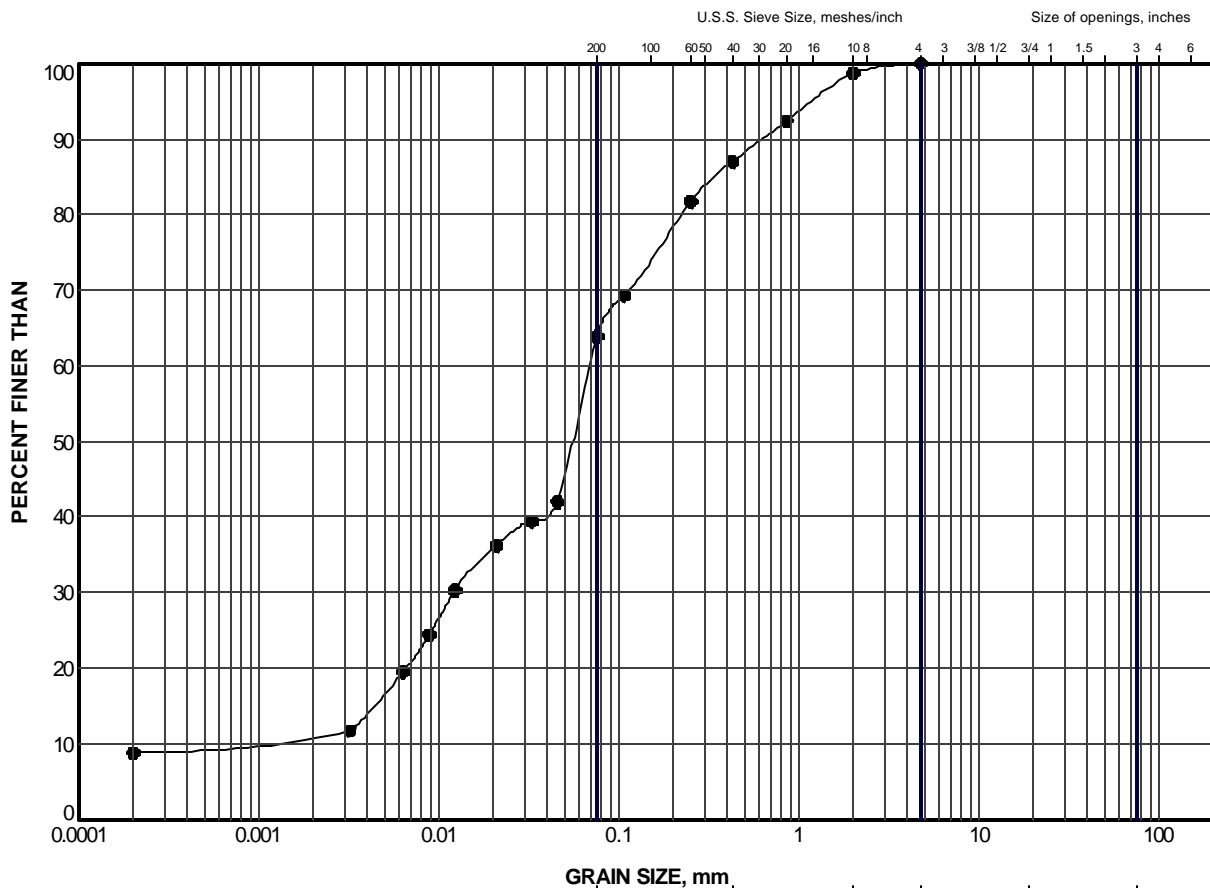





CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
◆	102	3	165.8

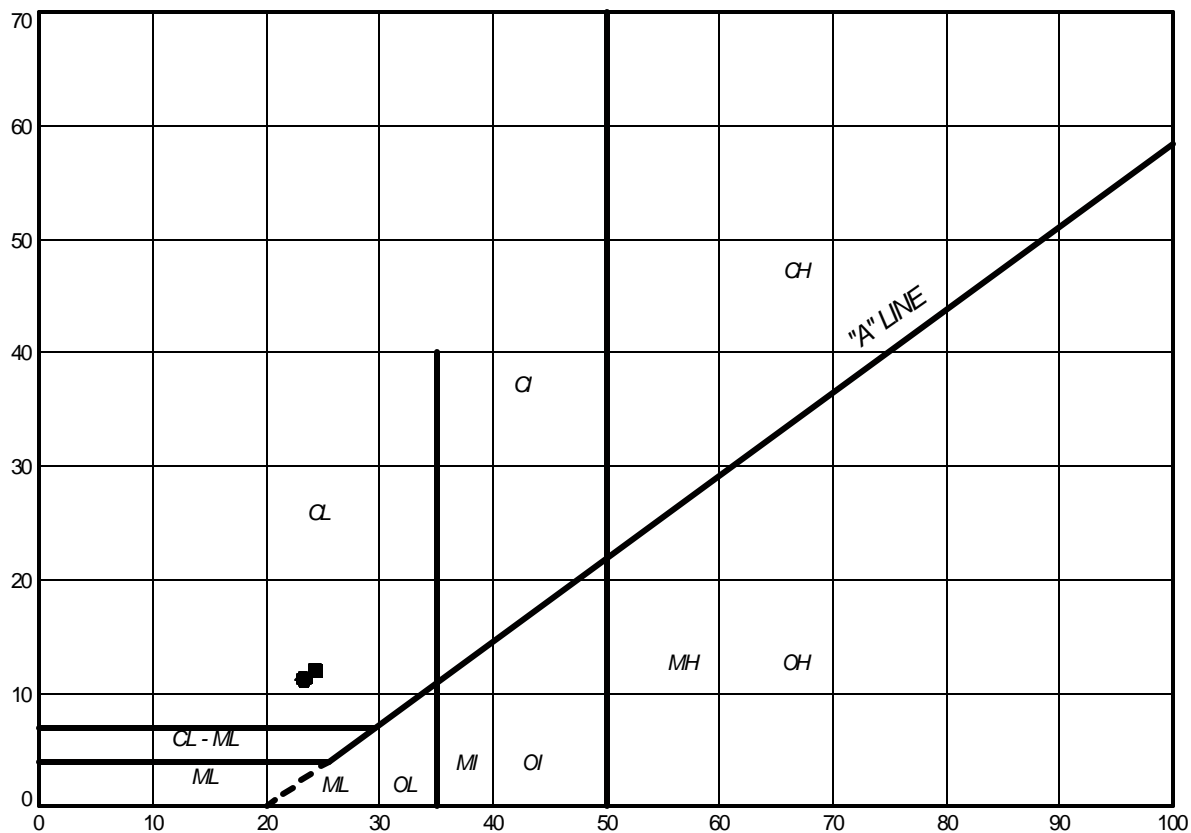
PROJECT				MTO FERRY DOCK KINGSVILLE, ONTARIO									
TITLE				GRAIN SIZE DISTRIBUTION SANDY SILT TILL									
 <b>Golder Associates</b> LONDON, ONTARIO				PROJECT No.		021-4216-1-2		FILE No.		0214216-K.GPJ			
								SCALE		N/A		REV.	
				DRAWN		WDF		Oct 13/04		<b>FIGURE C-4</b>			
				CHECK		AMH		Oct 13/04					



LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
◆	103	7	1625

PROJECT				MTO FERRY DOCK KINGSVILLE, ONTARIO			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL			
PROJECT No.		021-4216-1-2		FILE No.		0214216-K.GPJ	
DRAWN		WDF		SCALE		N/A	
CHECK		AMH		REV.			
		Oct 13/04					
		Oct 13/04					
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE C-5</b>			

PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

**SOIL TYPE**

C = Clay

M = Silt

O = Organic

**PLASTICITY**


L = Low

I = Intermediate

H = High

**LEGEND**

SYMBOL	BORE-HOLE	SAMPLE	ELEV (m)	LL(%)	PL(%)	PI
◆	102	5	164.5	23.3	12.1	11.2
■	103	5	164.2	24.3	12.3	12.0

PROJECT				MTO FERRY DOCK KINGVILLE, ONTARIO			
TITLE				PLASTICITY CHART			
PROJECT No.		021-4216-1-2		FILE No.		0214216-K.GPJ	
DRAWN		WDF		SCALE		N/A	
CHECK		AMH		REV.			
 <b>Golder Associates</b> LONDON, ONTARIO				<b>FIGURE C-6</b>			