Golder Associates Ltd.

2390 Argentia Road
Mississauga, Ontario, Canada L5N 5Z7
Telephone: (905) 567-4444
Fax: (905) 567-6561

REPORT ON

DETAILED DESIGN
FOUNDATION INVESTIGATION AND DESIGN
CULVERTS
HIGHWAY 69 FOUR-LANING FROM 0.3 KM NORTH OF HIGHWAY 537 NORTHERLY 8.8 KM
G.W.P 327-91-00
MINISTRY OF TRANSPORTATION, ONTARIO
SUDBURY, ONTARIO

Submitted to:

URS Canada Inc.
75 Commerce Valley Drive East
Markham, Ontario
L3T 7N9

GEOCRES NO. 41I-189

DISTRIBUTION

5	Copies -	Ministry of Transportation, Ontario, North Bay, Ontario (Northeastern Region)
1	Copy -	Ministry of Transportation, Ontario, Downsview, Ontario (Foundation Section)
2	Copies -	URS Canada Inc. Markham, Ontario
2	Copies -	Golder Associates Ltd., Mississauga, Ontario

June 2005

03-1111-011-4

TABLE OF CONTENTS

SECTION **PAGE**

PART A - FOUNDATION INVESTIGATION REPORT

TABLE OF CONTENTS (CONT'D)

PART B - FOUNDATION DESIGN REPORT

TABLE OF CONTENTS (CONT'D)

In Order
Following page 68

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

TABLE OF CONTENTS (CONT'D)

LIST OF APPENDICES

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

PART A

FOUNDATION INVESTIGATION REPORT
CULVERTS
HIGHWAY 69 FOUR-LANING FROM 0.3 KM NORTH OF HIGHWAY 537 NORTHERLY 8.8 KM
G.W.P 327-91-00
MINISTRY OF TRANSPORTATION, ONTARIO
SUDBURY, ONTARIO

TABLE OF CONTENTS

SECTION **PAGE**

PART A - FOUNDATION INVESTIGATION REPORT

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF DRAWINGS

LIST OF APPENDICES

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) to carry out a detailed foundation investigation as part of the detailed design for the new four-lane Highway 69 alignment and associated Highway 537 re-alignment being carried out for the Ministry of Transportation, Ontario (MTO). The proposed works consist of re-aligning the existing highways including associated north and south tie-ins to the existing Highway 69, construction of the Highway 537 Bridge, culverts and overhead truss sign structures. The general location of the Highway 69 and Highway 537 alignments are shown on the Key Plan on Drawing 1.

The terms of reference for the scope of work were outlined in Golder's proposal P31-1084, dated February 2003, that formed part of the Consultant's Agreement (Number P.O.5005 – A 000287) for this project. The work was carried out in accordance with the Quality Control Plan for this project dated August 2003. The plans and profiles detailing the proposed new alignments were provided to Golder by URS in January 2004.

This report addresses the 8 culverts that are located beneath the high fill embankments and/or over swamp areas. A detailed listing of the culvert locations is presented in a subsequent section of this report. The foundation investigation and design recommendations for the bridge, swamp crossings/high embankments, and overhead truss sign structures are reported separately.

The purpose of the investigation is to document the encountered subsurface conditions at the areas of the proposed culverts associated with the new Highway 69 and Highway 537 alignments. The locations of these sites within the project limits are shown in plan on Drawing 1. The culverts are typically located within the high fill/swamp crossings which were investigated by Golder Associates Ltd. in the following report:

- Foundation Investigation and Design Report, High Embankment Fills and Swamp Crossings, Highway 69, G.W.P. 327-91-00, Ministry of Transportation, Ontario, District 54, Sudbury, dated July 2005.

Two culverts, located within the high fill/swamp crossings, were investigated by others and are referenced in the following report:

- Foundation Investigation Report, Swamp/High Fill Crossings, Highway 69 Four-Laning from 0.3 km North of Highway 537 Northerly 8.8 km, District 54, Township of Dill, Sudbury, Ontario, G.W.P. 327-91-00, by Peto MacCallum Ltd. – Report 01TF003, dated May 2003.

During the course of design, the proposed alignment of the highway was changed. The Peto MacCallum Ltd. (PML) foundation investigation report (PML, May 2003) listed above was completed for swamp crossings that are concurrent with the new alignment; however, the station references may differ due to the shifts in overall alignment.

It should be noted that the location of the culvert at the Dill Creek crossing (Hwy 69 Station 17+050) will be not be included in this report, rather, a separate Dill Creek report will be issued in the future.

2.0 SITE DESCRIPTION

The site is located east of the existing two-lane Highway 69 alignment, north of Estaire, Ontario between Highway 537 and approximately one kilometre north of the intersection of Highway 69 and Gladu Road in the Township of Dill, District 54, Sudbury, Ontario.

The overall site of the project has been divided into sections of swamp crossings and high fill areas for the purposes of design and description and generally, the culverts are located within these areas. The culverts were outlined within the Terms of Reference for this project as defined by MTO (Request for Proposals, February 4, 2003). In general, the overall site consists of rolling terrain including open fields, bush areas, swamp areas, and numerous rock outcrops at ground surface. The ground surface within the limits of the project area varies between Elevations 220 m and 285 m. The topography in each of the culvert areas will be discussed in detail in Section 4.0. The location of the sites is shown on Drawing 1.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The table below summarizes the culvert locations and the investigations carried out, including the reports where the subsurface investigation can be referenced.

Field investigation work for a portion of the new Highway 69 alignment including some culvert locations was performed by Peto MacCallum Ltd. (PML) in 2001. The methods of investigation and results of this field work are included in the report referenced in Section 1.0 (PML, May 2003).

Field investigation work for the other culverts was carried out by Golder in July 2004, during which time a total of 17 sampled boreholes (BHs), 3 shallow boreholes (SBH) and 8 Dynamic Cones Penetration Tests (DCPTs) were advanced at or near the culvert locations. Additional drilling in one area was carried out in January/February 2005 at which time a total of 13 BHs and 3 DCPTs were advanced at or near the culvert locations. Seven CPTs were advanced as part of the swamp investigations carried out by Golder Associates in 2003 (Golder, July 2005).

CULVERT LOCATIONS

Station	*Referenced Report*	*Crossing*	*Proposed Embankment Height*	*This Investigation*
Hwy 69 12+200	This Report	Swamp	6.5 m	BH-20, 21, 23, 120, 121 DCPT-13, 14 CPT-8, 9
Hwy 69 14+100	This Report	Swamp	7.0 m	BH-49, 50, 122, 123 SBH-12, 17, 18 DCPT-40 to 43 CPT-21, 22
Hwy 69 14+940	PML, May 2003	Swamp	5.5 m	CPT04-57-1
Hwy 69 16+016 Hwy 69 16+137	This Report	Swamp	6.0 m 6.0 m	BH-61 to 64, 76A, 76B, 77B, 126, to 129 DCPT-54, 55, 61
Hwy 69 19+845	PML, May 2003 and This Report	Swamp	3.0 m	BH-186, 187
Hwy 537 11+015	This Report	High Fill	13 m	BH-156,157
Hwy 537 11+940 or Hwy 537 12+130	This Report	Swamp	10 m 3.5 m	BH-83 to 85, 158, 159, 159A CPT-39, 42 DCPT-69, 70

The Golder foundations borehole investigation was carried out using two, track-mounted CME 55 drill rigs supplied and operated by Marathon Drilling Co. Ltd. of Ottawa, Ontario. The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers. Where it was not possible to access the culvert locations with a drill rig, portable (tripod) equipment was used. The portable equipment used standard N size casing to advance the borehole using wash boring techniques. Soil samples were obtained, where possible, continuously or at intervals ranging from 0.75 m to 1.5 m in depth, using a 50 mm O.D. split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-99). Where portable equipment was used, a half weight hammer was used and the results converted to the standard weight. All boreholes were advanced to depths ranging from 4.7 m to 37 m, generally penetrating into competent material or to refusal.

In situ vane shear strength testing and Shelby tube samples were obtained at regular intervals, where appropriate, in the clayey strata. One borehole, advanced using portable equipment, obtained samples of the bedrock using an ‘NQ’ size rock core barrel.

The groundwater conditions in the open boreholes were observed during the drilling operations and piezometers were installed in four boreholes to permit monitoring of the groundwater levels. The piezometers consisted of a 50 mm diameter pipe with a 1.5 m slotted screen at the base. Where artesian groundwater conditions were observed during drilling, the boreholes were grouted with a cement bentonite grout by tremie down to the artesian source using a pump. These techniques are in accordance with O. Reg. 128 (amendment to O. Reg. 903). The piezometers, where they encountered artesian groundwater, were also sealed by pumping cement bentonite grout down the pipe using tremie methods. The results of the water level measurements are shown on the Record of Borehole Sheets following the text of this report. In general, the boreholes were abandoned by using holeplug to seal the boreholes.

The field work was supervised throughout by members of our engineering and technical staff, who located the boreholes and test holes, arranged for the clearance of underground service locations, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as relevant. Classification testing such as water content, grain size distribution, specific gravity, unit weight, and Atterberg Limits were carried out. In addition, one dimensional consolidation (oedometer) tests were carried out on select samples of the clayey deposits. The results of the laboratory testing are included in Appendix A.

On completion of the fieldwork, all investigated boreholes, were located and surveyed by members of our engineering staff. Locations were measured in reference to stationing and offsets from the proposed median centre-line as staked by URS and surveyed relative to the geodetic datum for elevation. The northing and easting coordinates depicted on the Record of Borehole and Record of Penetration Test sheets were derived from these station and off-set measurements and using the DTM (digital terrain map) for the project provided by URS.

4.0 GENERAL SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

From published geologic information, the site is located in the physiographic region known as the Laurentian Highlands that form the southernmost part of the Canadian Shield (Geology of Ontario; OGS Special Volume 4). The Laurentian Highlands comprise a southeast-trending and slightly elevated region that is underlain by Precambrian bedrock. These Precambrian rocks, of the Central Gneiss Belt, forming part of the Grenville Structural Province, were eroded to a gently undulating land surface. Subsequent deposition of Palaeozoic strata and later erosion during glaciation left behind only scarred Precambrian rocks covered in a few places by flat-lying Palaeozoic strata. Pleistocene deposits of lacustrine and fluvial origin, most likely associated with the Nipissing post-glacial stage of the Great Lakes, together with more recent swamp sediments have been accumulated between undulating rock ridges. Consequently, the local physiography is generally characterized by variable overburden materials and an irregular, variable bedrock surface with rock outcrops.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes and Cone Penetration Tests (CPTs) advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Record of Cone Penetration Test sheets following the text of this report. More detailed results from the laboratory testing are provided in Appendix A. The thickness of the overburden in the swamp areas as inferred from the resistance to Dynamic Cone Penetration Test (DCPT) results are shown on the Record of Penetration Test sheets following the text of this report. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs) and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The soil stratigraphy as encountered in the boreholes in the proposed culvert locations are shown on Drawings 2 to 8 inclusive and in the reports referenced in Section 1.0.

In general, the stratigraphy encountered at the areas investigated is similar; however, the overburden (soil materials) thickness is variable ranging from no cover (i.e. bedrock outcrops present at ground surface) to about 37 m deep. The stratigraphy generally consists of:

- surficial layers of topsoil or fibrous peat ranging in thickness from about 0.1 m to 2.9 m, typically less than 1.0 m;
- relatively thin (on the order of 2 to 3 m) glacio-lacustrine deposits of silty sand in some areas, particularly at Station 14+100;
- deposits of glacio-lacustrine mixtures of cohesive silt and clay ranging from about 0.1 to about 21 m thick interbedded with silt and sand layers in some areas; and
- granular silt and sand were encountered between the cohesive deposits and bedrock, with thicknesses up to or exceeding 23m.

Detailed descriptions of the subsurface conditions at each investigated high embankment fill and swamp crossing are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or layer.

4.3 Culvert Highway 69 Station 12+200 (Drawing No. 2)

Boreholes BH-120 and BH-121 were advanced along the length of the culvert crossing Highway 69 at station 12+200. Boreholes BH-20, BH-21 and BH-23, Dynamic Cone Penetration Tests DCPT-13 and DCPT-14 and Cone Penetration Tests CPT-8 and CPT-9 were advanced in the vicinity of the proposed culvert. The records are given in Appendix B. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert centreline are shown on Drawing 2. The sections below describe the detailed subsurface conditions in this area. The ground surface at the borehole locations is between Elevation 238.0 m and 238.5 m. The topography of this site is generally flat and grassy, with occasional standing water.

4.3.1 Topsoil and Peat

Topsoil was encountered at the existing ground surface in Boreholes BH-21, BH-23 and BH-121 and was about 0.1 m in thickness. Black peat was encountered below the topsoil in Boreholes BH-20 and BH-120 and ranged in thickness from 0.3 m to 0.6 m. The peat was generally fibrous and contained occasional topsoil and gravel.

Standard Penetration Testing (SPT) measured ‘N’ values ranging from 0 blows (weight of the hammer) to 4 blows per 0.3 m of penetration, indicating a very soft to soft consistency.

4.3.2 Silty Clay to Clay

A deposit of mottled brown and grey silty clay with trace organics, roots, sand and gravel was encountered in all boreholes immediately below the topsoil and peat. The surface of this deposit ranged from Elevation 237.7 m and 238.4 m and the layer ranged in thickness from 2.8 m to 3.4 m.

Standard Penetration Testing (SPT) measured 'N' values ranging from 1 to 6 blows per 0.3 m of penetration.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 64 kPa to greater than 100 kPa. The sensitivity, defined as the ratio of undisturbed field vane shear strength to remoulded field vane shear strength, ranged from about 2.0 to 5.3. Measured tip resistances from the CPT work ranged from 0.1 to 6.7 MPa. In general, the field vane and cone penetration test results suggest the silty clay to clay stratum has a firm to stiff consistency.

Two Atterberg limit tests were performed on samples of the silty clay to clay deposit. The liquid limits were 40 and 54 percent, the plastic limits were 20 and 26 percent, yielding plasticity indices of 20 and 28 percent, indicating that this sample ranges from a silty clay of intermediate plasticity to a clay of high plasticity. The results of the Atterberg limits testing are shown on the plasticity chart on Figure A-1 in Appendix A

The natural water content measured on selected samples of this deposit ranged between 30 and 50 percent, typically less than 40 percent.

4.3.3 Clayey Silt to Clay

A grey clayey silt to clay deposit was encountered below the brown and grey silty clay to clay crust in all boreholes. This clayey silt to clay contained trace to some sand, trace gravel and trace organics in certain boreholes. The deposit also contained occasional faint reddish grey varves/irregularly structured laminae below about Elevation 234 m. Thin silty sand to sandy silt seams were observed in select boreholes across the culvert location below about Elevation 232.0 m. The surface of this deposit varied between Elevations 234.3 m and 235.4 m. The thickness ranged from 2.2 m to 7.6 m.

Standard Penetration Testing (SPT) carried out within this stratum measured 'N' values ranging from 0 blows (weight of hammer) to 2 blows per 0.3 m of penetration, suggesting that the deposit has a very soft consistency. Measured SPT 'N' values greater than 0 blows per 0.3 m of penetration were observed to be associated with sand seams or elevated silt content within the stratum.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 10 kPa to 43 kPa. Sensitivity was found to range from 1.5 to 6.0. Measured tip resistances from the CPT testing ranged from 0.3 to 2.0 MPa. In general, the field vane and cone penetration test results together with the SPT ‘N’ values suggest the silty clay to clay stratum has a very soft to firm consistency.

Atterberg limits testing was carried out on two samples of the clayey silt to clay deposit. The liquid limit ranged from about 21 to 54 percent and the plastic limit ranged from about 13 to 23 percent yielding a plasticity index ranging from about 8 to 31 percent. The results of the Atterberg limits testing are shown on the plasticity chart on Figure A-2 in Appendix A and indicate that the material ranges from a clayey silt of low plasticity to a clay of high plasticity. A grain size distribution for one sample from the lower portion of the deposit (transition to the underlying sandy silt to silt deposit) is shown on Figure A-3 in Appendix A.

Although no oedometer (consolidation) tests were carried out on samples from the boreholes in the culvert area, two oedometer tests were carried out on specimens of the clayey silt to clay obtained from Boreholes 11 and 17 and have been incorporated to assist in interpreting the geologic stress-history and geotechnical engineering properties of the overall deposit. Preconsolidation pressures of approximately 73 kPa and 82 kPa for this stratum were estimated from the voids ratio versus logarithmic pressure plots and from the total work versus pressure plots. Details of the test results are shown on Figures A-4 and A-5 in Appendix A. The following table summarizes the relevant oedometer test results:

Borehole and Sample No.	Elevation (m)	σ_{vo}' (kPa)	σ_p' (kPa)	σ_{vo}' - σ_p' (kPa)	OCR	e_o	C_r	C_c	c_v^* (cm^2/s)
BH 11 Sa#5	233.0	45	82	37	1.82	0.83	0.033	0.255	3.08×10^{-3}
BH 17 Sa#6	231.6	59	73	14	1.24	0.77	0.022	0.154	1.49×10^{-2}

Note: *For stress range of $150 \leq \sigma_v' \leq 2000$ kPa

where:	
σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm^2/s in the normally consolidated range

Laboratory consolidated undrained (CIU) triaxial compression test were carried out on one carefully trimmed specimen of the clayey silt to clay obtained from Borehole BH-120. The test results indicate effective angle of shearing resistance of 26.5 degrees and effective shear resistance of 0 kPa. Details of the test results are shown on Figure A-6 in Appendix A.

The natural water content measured on select samples of this deposit ranged between 21 percent and 64 percent, typically higher near the surface of the deposit. Generally, water content was found to decrease with depth within the deposit, particularly below Elevation 231.0 m, where the deposit becomes siltier.

4.3.4 Silty Sand to Sandy Silt

A deposit of grey silty sand to sandy silt was encountered immediately below the clayey silt to silty clay deposit in all boreholes. The deposit contained trace to some clay within the soil matrix. The thickness of this deposit varied from 1.3 m to 2.7 m with the surface encountered between Elevations 227.8 m and 233.1 m.

Standard Penetration Testing (SPT) measured ‘N’ values ranging from 5 to 21 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The natural water content measured on select samples of this deposit ranged between 22 percent and 30 percent.

4.3.5 Clayey Silt to Silty Clay

Below the silty sand to sandy silt deposit, a deposit of grey clayey silt to silty clay containing trace to some sand was encountered in all boreholes except Borehole BH-23. The surface of this deposit varied between Elevation 227.5 m to 230.8 m and the thickness of the deposit ranged from 1.5 m to 3.1 m.

Standard Penetration Testing (SPT) measured 'N' values ranging from 0 blows (weight of hammer) to 3 blows per 0.3 m of penetration.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 22 kPa to 65 kPa. Sensitivity was found to range from 2.0 to 3.8. Tip resistance, as measured during the cone penetration testing, ranged from about 0.4 to 1.8 MPa. In general, the field vane and cone penetration test results suggest the clayey silt to silty clay stratum has a soft to stiff consistency.

Atterberg limits testing was carried out on one sample of the clayey silt deposit. The liquid limit was 36 percent and the plastic limit was 20 percent yielding a plasticity index of 16 percent, indicating that the deposit is a silty clay of intermediate plasticity. However, based on visual classification, as well as testing elsewhere within the swamp, the deposit can be classified as a clayey silt of low plasticity to a silty clay of intermediate plasticity.

One laboratory oedometer (consolidation) test was carried out on a specimen of the clayey silt to silty clay obtained from Borehole BH-121. A preconsolidation pressure of approximately 130 kPa for this stratum were estimated from the voids ratio versus logarithmic pressure plots and from the total work versus pressure plots. Details of the test results are shown on Figure A-7 in Appendix A. The following table summarizes the relevant oedometer test results:

Borehole and Sample No.	***Elevation (m)***	σ_{vo}' ***(kPa)***	σ_p' ***(kPa)***	$\sigma_{vo}' - \sigma_p'$ ***(kPa)***	***OCR***	e_o	C_r	C_c	c_v^* ***(cm²/s)***
BH 121 Sa#9	229.0	86	142	56	1.70	1.09	0.041	0.329	1.08×10^{-2}

Note: *For stress range of $20 \leq \sigma_v' \leq 300$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm²/s in the normally consolidated range

The natural water content measured on select samples of this deposit ranged between 25 percent and 40 percent.

4.3.6 Silty Sand to Sandy Silt

A deposit of silty fine sand to sandy silt was encountered below the clayey silt to silty clay deposit in all boreholes except Borehole BH-23. The silty fine sand to sandy silt deposit contained trace clay. The surface of this deposit ranged from Elevation 225.8 m to 227.7 m and the thickness ranged from 0.6 m to 4.2 m, except in Borehole BH-120, where the deposit was 11.3 m thick. Boreholes BH-20 and BH-21 were terminated within this deposit.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 2 to 12 blows per 0.3 m of penetration indicating a very loose to compact relative density. These SPT ‘N’ values were likely influenced by groundwater conditions and are not considered fully representative of the deposits relative density.

Grain size distributions for one sample from this deposit is shown on Figure A-8 of Appendix A. The natural water content measured on selected samples of this deposit ranged between 18 percent and 26 percent.

4.3.7 Sand to Silty Sand and Gravel

In Boreholes BH-23 and BH-121, the silty fine sand to sandy silt layer was found to gradually transition into a deposit more characteristically described as a fine to coarse sand deposit containing trace silt and trace gravel. This deposit becomes coarser with depth, gradually becoming a silty sand and gravel. The surface of this deposit ranged from Elevation 223.5 m to

225.1 m. Due to the limited depth of the investigation in some areas, the full extent of this deposit could not be defined, however it ranges from 5.4 to 12.7 m in thickness.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 0 blows (weight of rods) to 7 blows per 0.3 m of penetration indicating a very loose to loose relative density within the sand deposit. These SPT ‘N’ values were likely influenced by groundwater conditions and are not considered fully representative of the deposits relative density.

The bottom 0.8 m of this deposit in BH-23 is described as a silty sand and gravel with occasional cobbles. Here, the measured SPT ‘N’ value was greater than 100 blows per 0.3 m of penetration, indicating a very dense relative density. In addition, at the base of the deposit in Borehole BH-121, the measured SPT ‘N’ value from the dynamic cone test was 23 blows per 0.3 m of penetration indicating a compact relative density.

The natural water content measured on select samples of this deposit ranged between 21 percent and 25 percent.

4.3.8 Silty Sand Till

A deposit of silty sand till was encountered in Borehole BH-120 underlying the sand to silty sand and gravel deposit. The silty sand till contained trace to some gravel, with the surface of the deposit at Elevation at 215.4 m. Due to the limited depth of the investigation, the full extent of this deposit could not be defined, however it was found to have a thickness of at least 2.1 m.

The SPT ‘N’ value measured for this deposit was 27 blows per 0.3 m of penetration, indicating that the deposit has a compact relative density.

4.3.9 Bedrock/Refusal

Refusal, typically defined by greater than 100 blows per 0.3 m penetration in the boreholes and DCPTs, was defined at several locations across the swamp. In addition, auger or spoon refusal was encountered at the base of some of the boreholes. These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. The depth, elevation, and type of refusal is given in the table below.

Borehole	*Refusal Type*	*Refusal Depth (m)*	*Refusal Elevation (m)*
BH-23	Auger and Spoon Refusal	18.8	219.7
BH-120	Auger Refusal	25.0	213.3
BH-121	Dynamic Cone Refusal	27.6	210.8
DCPT-13	Dynamic Cone Refusal	29.0	209.2
DCPT-14	Dynamic Cone Refusal	26.0	212.0

4.3.10 Groundwater Conditions

In general, the samples taken in boreholes BH-20, BH-21, and BH-23, drilled in September 2003, were noted to be moist to wet. Water levels observed in these open boreholes at the time of drilling ranged from Elevation 240.1 m to 231.3 m, typically between 1.5 m and 5.5 m below the ground surface. Details of the groundwater conditions at the time of drilling are summarized on the Record of Borehole sheets following the text of this report.

Several boreholes had sand flow into the hollow-stem augers due to water pressure confined below the cohesive deposits. This required either drilling mud or an external source of water to be pumped into the borehole to maintain a constant head of water in order to obtain SPT samples.

Water levels observed in boreholes BH-120 and BH-121 at the time of drilling in July 2004, were typically observed at or above ground surface. The water levels observed in these boreholes upon completion of drilling was between 0.3 m above ground surface to 0.9 below the ground surface. A piezometer was installed in Borehole-121 and sealed within the sand deposit. The water level inside the 50 mm piezometer are given in the table below. The measured water levels indicate the presence of artesian pressures in the area.

Date and Time	*Water Level Depth (m)*	*Water Level Elevation (m)*
July 8, 2004; 8:00 am	0.6 m above ground surface and flowing out of casing (additional pipe added)	239.0
July 8, 2004; 3:00 pm	2.0 m above the ground surface	240.4
July 14, 2004	1.9 m above the ground surface	240.3
October 5, 2004	1.1 m above ground surface	239.5

It should be noted that groundwater levels in the area are subject to seasonal fluctuations, and the groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized prior to completion of drilling. Furthermore, groundwater elevations will vary depending on precipitation and local soil permeability.

4.4 Culvert Highway 69 Station 14+100 (Drawing No. 3)

Boreholes BH-122 and BH-123 were advanced along the length of the culvert crossing Highway 69 at station 14+100. Boreholes BH-49 and BH-50 were advanced in the vicinity of the proposed culvert. In addition to the boreholes above, shallow boreholes SBH-12, SBH-17 and SBH-18, Dynamic Cone Penetration Tests DCPT-40 to DCPT-43 and Cone Penetration Tests CPT-21 and CPT-22 were also conducted in the vicinity of the proposed culvert. The records are given in Appendix C. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert centreline are shown on Drawing 3. The sections below describe the detailed subsurface conditions in this area. The ground surface at the borehole locations is between Elevation 237.2 m and 237.9 m. The topography in this area is generally flat and low-lying with partial tree cover towards the south end of the swamp.

4.4.1 Topsoil

A layer of dark brown topsoil was encountered at ground surface in all boreholes. The thickness of the topsoil ranged between 0.1 m and 0.3 m.

4.4.2 Silty Sand to Sandy Silt

A deposit of brown and grey silty fine sand to sandy silt was encountered immediately below the topsoil layer in all boreholes. The deposit contains trace amounts of clay and trace rootlets near the surface. The surface of this deposit varied from Elevation 237.4 m to 237.7 m and the deposit ranged in thickness from 1.1 m to 1.7 m.

Standard Penetration Testing (SPT) measured ‘N’ values ranging from 3 blows to 17 blows per 0.3 m of penetration, typically less than 10 blows per 0.3 m of penetration. This indicates that he deposit has a very loose to compact relative density.

The natural water content measured on selected samples of this deposit ranged between 16 percent and 56 percent.

4.4.3 Silty Clay to Clayey Silt

A deposit of brown and grey silty clay to clayey silt containing trace sand was encountered underlying the silty fine sand to sandy silt. Trace amounts of rootlets were observed in boreholes BH-49 and BH-122. Occasional silt layers and clay seams were also encountered in borehole BH-123. The top of this deposit varied between Elevation 235.7 m and 236.4 m and the thickness ranged from 1.0 m to 1.6 m.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 3 blows to 4 blows per 0.3 m of penetration.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 82 kPa to greater than 100 kPa. The sensitivity was found to range from 4.0 to 8.5. Tip resistance, as measured by the cone penetration testing, ranged from about 0.3 to 10 MPa. In general, the field vane and cone penetration test results together with the SPT ‘N’ values suggest the silty clay to clayey silt stratum has a firm to very stiff consistency.

The natural water content measured on two selected samples of this deposit were 32 percent.

4.4.4 Clayey Silt to Clay

A grey clayey silt to clay deposit was encountered below the silty clay to clayey silt crust. The deposit contains trace amounts of sand throughout with occasional silt and sand seams observed in borehole BH-123. Faint reddish grey varves and irregularly structured laminae were observed in the samples taken from this deposit, possibly associated with zones of higher silt content. The elevation of the surface of this deposit varied between Elevation 234.2 m and 235.3 m. The thickness ranged from 10.6 m to 18.7 m.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 0 blows (weight of hammer) to 1 blow per 0.3 m of penetration suggesting a soft consistency.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 19 kPa to 62 kPa, but typically less than 30 kPa. Sensitivity was found to range from 2.0 to 13.5. Tip resistance, as measured by the cone penetration test, ranged from about 0.2 to 2.0 MPa. In general, the field vane test results together with the SPT ‘N’ values suggest the clayey silt to clay stratum has a soft to stiff consistency. Generally, higher measured undrained shear strengths are attributed to sand seams and zones of elevated sand and silt content within the deposit.

Atterberg limit testing was carried out on several samples of the clayey silt to clay deposit. The liquid limit ranged from about 25 to 68 percent and the plastic limit ranged from about 15 to 23 percent yielding a plasticity index ranging from about 10 to 46 percent. The results of the Atterberg limits are shown on the plasticity chart on Figure A-9 in Appendix A and indicate that the deposit ranges from a clayey silt of low plasticity to a clay of high plasticity. A grain size distribution of one sample of the clayey silt to clay is shown on Figure A-10 in Appendix A.

Laboratory oedometer (consolidation) tests were carried out on specimens of the silty clay to clay deposit. In addition to the sample obtained from Boreholes BH-122 and BH-123, testing from other boreholes in this swamp (i.e. from Borehole BH-51) have also been included. Details of the test results are shown on Figure A-11 to A-14 in Appendix A. It should be noted that applicable oedometer testing from the original draft report by PML (PML, August 2001) has also been incorporated to assist in interpreting the geologic stress-history and geotechnical engineering properties of the overall deposit. The following table summarizes the relevant oedometer test results.

Borehole and Sample No.	***Elevation (m)***	σ_{vo}' ***(kPa)***	σ_p' ***(kPa)***	$\sigma_{vo}' - \sigma_p'$ ***(kPa)***	***OCR***	e_o	C_r	C_c	c_v^* ***(cm²/s)***
BH 51 Sa#10	226.9	100	134	34	1.34	1.45	0.075	0.680	1.03×10^{-3}
BH 122 SA#10	225.4	116	163	47	1.40	1.01	0.036	0.328	1.01×10^{-2}
BH 123 SA#8	229.9	70	100	30	1.43	1.35	0.065	0.582	1.59×10^{-3}
BH 123 SA#12	223.8	120	146	26	1.20	1.68	0.107	0.812	9.92×10^{-4}

Note: *For stress range of $150 \leq \sigma_v' \leq 2000$ kPa
For PML test results, average is for stress range of $50 \leq \sigma_v' \leq 400$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm²/s in the normally consolidated range

Laboratory consolidated undrained (CIU) triaxial compression test were carried out on two carefully trimmed specimen of the silty clay to clay obtained from Boreholes BH-122 and 123. The test results indicate effective angle of shearing resistance between 25 degrees and 31.5

degrees and effective shear resistance of 0 kPa. Details of the test results are shown on Figures A-15 and A-16 in Appendix A.

The natural water content measured on selected samples of this deposit ranged between 19 percent and 65 percent, typically greater than 30 percent.

4.4.5 Silt to Sandy Silt

A deposit of grey silt to sandy silt containing trace clay and trace gravel was encountered below the clayey silt to clay deposit. Boreholes BH-122 and BH-123 contained occasional sand seams, while borehole BH-122 also contains occasional clay and gravel seams. The surface of this deposit ranged between Elevation 216.1 m and 223.5 m and the thickness ranged from 3.7 m to 8.2 m. Borehole BH-50 was terminated within this deposit.

Standard Penetration Testing (SPT) measured ‘N’ values ranging from 0 blows (weight of rods) to 16 blows per 0.3 m of penetration. This indicates a very loose to compact relative density within the deposit. These SPT ‘N’ values were likely influenced by groundwater conditions and are not considered fully representative of the deposits relative density. Grain size distributions for two samples of this deposit are shown on Figure A-17 of Appendix A.

The natural water content measured on select samples of this deposit ranged between 12 percent and 27 percent.

4.4.6 Sand and Gravel to Sand

A sand and gravel to sand deposit was encountered below the silt to sandy silt deposit in boreholes BH-49, BH-122, and BH-123. This deposit ranged in thickness from 0.7 m to 9.1 m, with the top between Elevation 209.6 m to 212.2 m. Increased resistance to penetration with depth in several Dynamic Cone Penetration tests suggests that this deposit may be laterally extensive beneath the site.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 8 blows to 16 blows per 0.3 m of penetration, typically increasing with depth. This is consistent with the DCPT results indicating a very loose to compact relative density within the deposit.

The natural water content for the deposit ranged from 17 to 21 percent.

4.4.7 Bedrock/Refusal

Refusal, typically defined by greater than 100 blows per 0.3 m penetration in the boreholes and DCPTs, was defined at several locations across the swamp. In addition, auger or spoon refusal was encountered at the base of some of the boreholes. These refusal depths, while they do not confirm bedrock elevations, maybe inferred to indicate potential proximity to the bedrock interface. The depth, elevation, and type of refusal is given in the table below.

Borehole	*Refusal Type*	*Refusal Depth (m)*	*Refusal Elevation (m)*
BH-122	Auger Refusal	31.2	206.6
BH-123	Auger Refusal	35.0	202.7
DCPT-40	Dynamic Cone Refusal	29.3	208.2
DCPT-41	Dynamic Cone Refusal	33.2	204.4
DCPT-42	Dynamic Cone Refusal	35.4	202.2
DCPT-43	Dynamic Cone Refusal	27.4	210.3

4.4.8 Groundwater Conditions

In general, the samples taken in boreholes BH-49 and BH-50, drilled in August 2003, were noted to be moist to wet. In Boreholes BH-49 and BH-50, the water levels observed in the open boreholes at the time of drilling ranged from Elevation 230.8 m to 232.6 m (between 5.3 m and 6.4 m depth). Details of the groundwater conditions at the time of drilling are summarized on the Record of Borehole sheets following the text of this report.

Several boreholes had sand flow into the hollow-stem augers due to water pressure confined below the cohesive deposits. This required drilling mud or an external source of water to be pumped into the borehole to maintain a constant head of water in order to obtain SPT samples.

Water levels observed in boreholes BH-122 and BH-123 at the time of drilling in July 2004 were typically observed at or near the ground surface. A piezometer was installed in Borehole BH-122 and sealed within the silt to sandy silt deposit. The water level in the 50 mm piezometer are given in the table below. The measured water levels indicate the presence of artesian pressures in the area.

Date and Time	*Water Level Depth (m)*	*Water Level Elevation (m)*
July 12, 2004	0.6 m above ground surface in piezometer	238.4
July 13, 2004	0.8 m above ground surface in piezometer	238.6
October 8, 2004	0.5 m above ground surface in piezometer	238.3

In Borehole BH-123, on July 13, 2004, the water level was 0.2 m below the ground surface, and on July 14, 2004 water was flowing out of the augers, at which time extra augers were added, and a rising head test was conducted. The rising head test involved pumping water out of the augers and measuring the water level over a period of time. The results of the rising head test are given in Table A-1 in Appendix A.

It should be noted that groundwater levels in the area are subject to seasonal fluctuations, and the groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized prior to completion of drilling. Furthermore, groundwater elevations will vary depending on precipitation and local soil permeability.

4.5 Culvert Highway 69 Station 14+940 (Drawing No. 4)

The scope of investigation carried out by Peto MacCallum in the area of the proposed culvert, cited as Swamp 110, is included in their report referenced in Section 1.0 (PML, May 2003). It is important to note that the stationing found in the PML reports differ from that of the newly proposed alignments. For this report, the PML stations were converted to the current project stations by adding 30 m. In addition to the boreholes drilled by PML, one cone penetration test, CPT04-57-1 was advanced in the culvert area during the current investigation. The records are given in Appendix D. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert centreline are shown on Drawing 4. The ground surface at the borehole locations is between Elevation 242.0 m and 245.4 m. This elevation difference is mainly due to the presence of beaver dams. The topography of the area is flat and low-lying with swampy areas and a shallow pond in the area of the culvert. A brief summary of the soil conditions for the area of the proposed culvert is provided below.

In general, the sampled subsurface soils were observed to be comprised of peat underlain by loose to compact silt, sandy silt, or silty fine sand or soft to stiff silty clay to clayey silt deposits. The peat was encountered at the ground surface or at the bottom of the pond and were generally between 0.2 m and 1.1 m thick, being thicker at the bottom of the pond. A deposit of soft to stiff silty clay was encountered below the peat and was between 2.0 m and 6.0 m thick. The surface of this deposit was between Elevation 241.1 m and 243.8 m. A 2.6 m to 6.1 m thick deposit of loose to compact silty fine sand to sandy silt was encountered below the upper clay deposit, the surface of which is between Elevation 237.1 m and 239.1m. A lower deposit of soft to stiff silty clay to clayey silt was encountered below the upper granular deposit. The surface of this deposit ranged from Elevation 232.7 m to 235.0 m and was between 1.5 m and 4.6 m thick. A 2.0 m to 4.7 m thick deposit of compact to loose sandy silt to silty fine sand was encountered below the silty clay to clayey silt deposit Between Elevation 229.8 m and 232.5m. Refusal was encountered at the base of this deposit between Elevations 226.2 m to 229.5 m (between 15 and 18 m depth), where the bedrock surface is inferred.

Water content determinations for the silty sand to sandy silt deposits ranged from 10 percent to 42 percent, but were typically between 18 percent to 25 percent. The clayey silt to silty clay (cohesive) deposits measured undrained shear strengths ranging from 40 kPa to 80 kPa, locally 10 kPa to greater than 100 kPa based on the field vane shear test results. Tip resistance, as measured by the cone penetration test, ranged from about 1 to 2.5 MPa within the clayey silt to silty clay deposit. Water content determinations for the cohesive deposits were found to range from 18 percent to 58 percent.

Since the boreholes were drilled within the area of the pond, the ice/water surface was encountered between Elevation 244.0 m and 245.3 m. Elsewhere, the groundwater was observed in the boreholes to be at the ground surface.

The detailed laboratory testing by PML for this swamp crossing have been summarized below. The detailed lab results are contained in their report referenced in Section 1.0 (PML, May 2003).

Borehole and Sample No.	***Elevation (m)***	***σ_{vo}' (kPa)***	***σ_p' (kPa)***	***σ_{vo}' - σ_p' (kPa)***	***OCR***	***e_o***	***C_r***	***C_c***	***c_v^* (cm^2/s)***
110-2S Sa#3	239.3	32	640	608	20.00	0.90	0.055	0.490	7.00 x 10^{-3}
110-3S Sa#9	230.0	108	250	142	2.69	0.88	0.020	0.250	5.17 x 10^{-3}

Note: *For stress range of $50 \leq \sigma_v' \leq 400$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm^2/s in the normally consolidated range

4.6 Culverts Highway 69 Stations 16+016 and 16+137 (Drawing No.'s 5A, 5B)

Boreholes BH-61 to 64, 76A, 76B, 77B, and 126 to 129 and Dynamic Cone Penetration Tests DCPT-54, 55 and 61 were advanced in the vicinity of the proposed culvert alignments. The records are given in Appendix E. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert alignment centrelines are shown on Drawings 5A and 5B. The topography is characterized by shallow deposits of sand and clay and exposed bedrock outcrops. The rock outcrops typically cross the Highway 69 alignment in a roughly northeast to southwest direction. The ground surface elevations vary between the rock outcrops due to the presence of numerous beaver dams in the area, which have resulted in poor drainage and open water areas.

The ice surface at the borehole locations for the culvert at Station 16+016 is between Elevation 254.6 m and 255.3 m and between 0 m and 0.4 m of ice was encountered in the boreholes. Therefore, the swamp bed is between Elevation 254.2 m and 255.0 m. The ice surface at the borehole locations for the culvert at Station 16+137 is between Elevation 256.0 m and 256.5 m and between 1.2 m and 1.8 m of ice and water were encountered in the boreholes. Therefore, the swamp bed is between Elevation 254.2 m and 255.3 m. The sections below describe the detailed subsurface conditions in this area.

4.6.1 Peat/Organics

A deposit of brown to black peat and organics was encountered in all of the boreholes except Borehole BH-63, 127 and 128 below the ice and/or water. The surface of the peat was encountered between Elevation 254.2 m and 255.3 m and the thickness ranged between 0.2 m and 0.8 m across the site.

The measured SPT ‘N’ values within the peat ranged from 1 blow to 3 blows per 0.3 m of penetration, indicating that the peat has a very loose relative density. The natural water content of the peat ranged from 92 percent to 292 percent.

4.6.2 Clayey Silt to Clay

A deposit of grey clayey silt to clay was encountered below the peat or ice/water in all the boreholes for the culvert at Station 16+016 (BH-61 to 64, 126 and 127) and only in Boreholes BH-76A and 129 for the culvert at Station 16+137. The clayey silt to clay contained trace sand with occasional reddish-brown varves/laminae. Occasional rootlets and organics were encountered near the surface of the deposit. The top of this deposit varied between Elevations 253.7 m and 255.0 m. The thickness of the deposit ranged from 0.4 m to 4.4 m, being thickest in the area of the culvert at Station 16+000.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging between 3 blows and 16 blows per 0.3 m of penetration.

In situ field vane testing carried out within this stratum, typically near the base of the deposit, measured undrained shear strengths ranging from 34 kPa to 60 kPa. In general, the field vane results suggest the clayey silt to clay stratum has a firm to stiff consistency.

Atterberg limits testing was carried out on samples of the clayey silt to clay deposit. The liquid limit ranged between 28 and 51 percent and the plastic limit ranged between 18 and 26 percent, yielding plasticity indices ranging between 10 and 26 percent. The results of the Atterberg limits are shown on the plasticity chart on Figure A-18 in Appendix A and indicate that the deposit ranges from a clayey silt of low plasticity to a clay of high plasticity. A grain size distribution on two samples of the clayey silt to clay are shown on Figure A-19 in Appendix A.

One sample of the clayey silt to clay was tested for organic content. The results of the test indicated that the sample, near the surface of the deposit, had an organic content of 1.7 percent.

The natural water content measured on select samples of this deposit ranged between 23 percent and 40 percent.

4.6.3 Silt to Sandy Silt

A deposit of silt and sandy silt was encountered below the clayey silt to clay deposit in all the boreholes except Boreholes BH-61 and BH-76A. The deposit is generally described as a silt, containing trace to some sand and clay, and occasional peat/organics; however, in Borehole BH-76B, the deposit is described as a sandy silt containing trace of clay. The surface of this deposit was encountered between Elevation 250.3 m to 252.3 m in the area of the culvert at Station 16+016 and between Elevation 253.6 m and 255.0 m in the area of the culvert at Station 16+137. The deposit ranged from 0.4 m to 5.1 m in thickness.

Standard Penetration Testing (SPT) carried out within this stratum measured 'N' values between 2 blows and 18 blows per 0.3 m of penetration indicating that this deposit has a very loose to compact relative density. At the base of the deposit in Borehole BH-64 and BH-127, the SPT 'N' value measured was greater than 100 blows per 0.3 m of penetration, and may be inferred to indicate potential proximity to the bedrock surface at this location. A grain size distribution on one sample of the silt to sandy silt is shown on Figure A-20 in Appendix A.

One sample of the silt deposit was tested for organic content. The results of the test indicated that the sample had an organic content of 2.0 percent.

The natural water content measured on samples of this deposit were between 17 and 32 percent.

4.6.4 Sand to Sand and Gravel

A deposit of grey sand to sand and gravel was encountered below the clayey silt to clay deposit in Borehole BH-61 and below the silt to sandy silt deposit in Borehole BH-126 and in all the boreholes in the culvert area at Station 16+140 (BH-76A, 76B, 77B, 128 and 129). The composition of the deposit ranges from a sand containing trace to some silt to a sand and gravel containing occasional cobbles. The surface of this deposit was encountered at Elevation 245.3 m and 250.4 m in Borehole BH-126 and BH-61, respectively. In the culvert area at Station 16+137, the surface of the deposit ranged from Elevation 252.6 m to 253.6 m. The thickness of this deposit ranges from 0.2 m to 1.0 m.

Standard Penetration Testing (SPT) carried out within this stratum measured 'N' values typically between 10 blows and 19 blows per 0.3 m of penetration indicating that this deposit has a very compact relative density. However, at the base of the deposit, the 'N' values are greater than 100 blows per 0.3 m of penetration, and may be inferred to indicate potential proximity to the bedrock surface.

The natural water content measured on samples of this deposit were between 9 and 21 percent.

4.6.5 Bedrock/Refusal

Refusal is typically defined by greater than 100 blows per 0.3 m penetration in the boreholes. In addition, auger or spoon refusal was encountered at the base of some of the boreholes. These refusal depths, while they do not confirm bedrock elevations, maybe inferred to indicate potential proximity to the bedrock interface. In addition, the bedrock was cored in Borehole BH-129. The depth, elevation, and type of refusal is given in the table below.

Borehole	*Refusal Type*	*Refusal Depth* (m)*	*Refusal Elevation (m)*
Culvert Station 16+016			
BH-61	Auger and Spoon Refusal	4.9	249.7
BH-62	Auger Refusal	5.3	249.7
BH-63	Auger Refusal	9.1	245.9
BH-64	Auger Refusal	4.2	250.8
BH-126	Auger Refusal	10.1	244.9
BH-127	Auger Refusal	3.7	251.6
DCPT-54	Refusal to further dynamic cone penetration	4.9	250.0
DCPT-55	Refusal to further dynamic cone penetration	9.0	246.2
Culvert Station 16+137			
BH-76A	Spoon Refusal	3.5	252.5
BH-76B	Auger and Spoon Refusal	4.7	251.3
BH-77B	Spoon Refusal	3.2	252.8
BH-128	Spoon Refusal	3.2	253.3
BH-129	Bedrock	5.1	251.4
DCPT-61	Refusal to further dynamic cone penetration	5.6	250.4

* Depth below the ice surface

The upper 3 m of the bedrock was cored in Borehole BH-129 using a NQ size core barrel. The bedrock samples consisted of consisted of fresh, foliated, dark grey to black, crystalline biotite schist. The total core recovery was 100 percent and the Rock Quality Designation (RQD) measured on the core sample was 85 percent indicating a rock mass of good quality.

4.6.6 Groundwater Conditions

Details of the groundwater conditions and water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets following the text of this report. In general, the samples taken in the boreholes were noted to be moist to wet. The water levels observed in the boreholes were typically measured between 0.3 m and 0.8 m below the ice surface, corresponding to between Elevations 254.3 m and 255.8 m. In Borehole BH-62, the water level was measured at 3.7 m (Elevation 251.3 m) below the ice surface upon completion of drilling.

It should be noted that groundwater levels in the area are subject to seasonal fluctuations and will vary depending on precipitation and local soil permeability.

4.7 Culvert Highway 69 Station 19+845 - North Tie-In (Drawing No. 6)

The scope of investigation carried out by Peto MacCallum in this culvert area, cited as Swamp 305, is included in their report referenced in Section 1.0 (PML, May 2003). It is important to note that the stationing found in the PML reports differ from that of the newly proposed alignments. For this report, the PML stations for the culvert were converted to the current project stations by adding 7+665 m. In addition, Boreholes BH-186 and BH-187 were drilled close to the new culvert alignment, through the existing embankment. The records are given in Appendix F. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert centreline are shown on Drawing 6 and includes both Golder and PML boreholes. The ground surface at the borehole locations is between Elevation 235.8 m at the toes of the existing embankment and 238.0 m (current Highway 69 grade). The topography of this site is generally low-lying and swampy, with open water present on either side of the highway for a portion of area of the proposed culvert. Occasional rock outcrops are present around the site. The sections below describe the detailed subsurface conditions in this area.

4.7.1 Embankment Fill

Embankment fill was encountered at this site in Boreholes BH-186 and BH-187, which were drilled through the shoulder of the embankment. The fill consists of between 0.8 m and 1.7 m of sand and gravel underlain by 0.7 m to 1.0 m of rock fill, for a total embankment thickness at the borehole locations ranging from 1.8 m to 2.4 m below the ground surface. One measured SPT 'N' value for the sand and gravel portion of the fill was 4 blows per 0.3 m of penetration, indicating that the deposit has a loose relative density.

4.7.2 Peat

A deposit of peat was encountered in all of the boreholes drilled near the culvert alignment. The peat is described as dark brown, fibrous to amorphous. In Boreholes BH-186 and BH-187, the peat was encountered below the embankment fill between Elevation 235.6 m and 235.9 m. In Boreholes C1 and 4N (PML, May 2003), drilled at the embankment toe, the peat was encountered at the ground surface between Elevation 235.8 m and 235.9 m. The thickness of the peat was between 0.8 m and 1.7 m at the embankment toes and between 1.0 m and 1.6 m thick below the embankment.

The measured SPT 'N' values within the peat ranged from 1 blow to 5 blows per 0.3 m of penetration, indicating that the peat has a very loose to loose relative density. The natural water content of the peat ranged from 148 percent to 390 percent.

4.7.3 Silt to Silty Clay

A deposit of silt to silty clay was encountered below the peat in all of the boreholes. The deposit is described as a silt containing trace to some clay, trace to some sand, trace organics and frequent fine sand seams to a silty clay with sand containing interbedded sand and silt seams. The surface of this deposit was encountered between Elevations 234.2 m and 235.0 m. The thickness of the silt deposit was between 1.0 m and 2.2 m thick, being thickest towards the east. Borehole 4N (PML, May 2003) encountered refusal at the base of this deposit.

The measured SPT 'N' values ranged from 3 blows to 5 blows per 0.3 m of penetration, indicating that the silt has a very loose to loose relative density.

Atterberg limit testing was carried out on one sample of the silt to silty clay deposit. The liquid limit and plastic limit were 37 percent and 18 percent, respectively, yielding a plasticity index of 18 percent. The test result indicates that the sample is a silty clay of intermediate plasticity.

The natural water content of the silt deposit ranged from 28 percent to 56 percent.

4.7.4 Silty Clay to Clay

A silty clay to clay deposit was encountered below the silt to silty clay deposit in the boreholes. The deposit contained trace sand, interbedded layers of silt with clay as well as occasional vertical sand seams. The surface of this deposit was encountered between Elevation 232.7 m and 233.6 m. The deposit was between 6.0 m and 9.2 m in thickness.

The measured SPT 'N' values within the silty clay to clay deposit ranged from 0 blows (weight of rods) to 2 blows per 0.3 m of penetration, indicating that the silty clay to clay has a very soft to soft consistency.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 19 kPa to 67 kPa. The higher shear strengths were measured near the surface of the deposit and typically, the undrained shear strength ranged from 19 kPa to 38 kPa. In general, the field vane test results together with the SPT 'N' values suggest the clayey silt to clay stratum has a soft to firm consistency, and a stiff consistency near the surface of the deposit.

Atterberg limit testing was carried out on one sample of the silty clay to clay deposit. The liquid limit and plastic limit were 52 percent and 20 percent, respectively, yielding a plasticity index of 32 percent. The test result indicates that the sample is a clay of high plasticity.

Although no oedometer (consolidation) tests were carried out on samples from the boreholes in the culvert area, one oedometer tests were carried out on specimens of the silty clay to clay obtained from Boreholes 305-3N (PML, May 2003) and has been incorporated to assist in interpreting the geologic stress-history and geotechnical engineering properties of the overall deposit. The detailed laboratory testing by PML for this swamp crossing has been summarized below. The detailed lab results are contained in their report referenced in Section 1.0 (PML, May 2003).

Borehole and Sample No.	***Elevation (m)***	***σ_{vo}' (kPa)***	***σ_p' (kPa)***	***$\sigma_{vo}' - \sigma_p'$ (kPa)***	***OCR***	***e_o***	***C_r***	***C_c***	***c_v^* (cm^2/s)***
305-3N Sa#4	231.3	43	290	247	6.74	0.93	0.055	0.260	9.50×10^{-3}

Note: *For stress range of $50 \leq \sigma_v' \leq 400$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm^2/s in the normally consolidated range

The natural water content of the silt deposit ranged from 33 percent to 63 percent.

4.7.5 Silty Sand to Silt

A deposit of silty sand to silt was encountered below the silty clay to clay deposit in the boreholes. The deposit ranges from a silt containing trace sand, trace clay and occasional clay seams to a silty sand with trace to some gravel. The surface of this deposit was encountered between Elevations 223.6 m and 227.6 m. Boreholes BH-186 and BH-187 were terminated in this deposit before reaching refusal at depths of 12.8 m and 11.3 m below the ground surface, respectively. Borehole C1 (PML, May 2003) encountered refusal at the base of this deposit after penetrating 1.7 m.

The measured SPT 'N' values ranged from 0 blows (weight of hammer, weight of rods) to greater than 100 blows per 0.3 m of penetration, however, the high 'N' value is likely the result of reaching refusal in one of the boreholes. Typically, the deposit has a very loose to compact relative density. The natural water content of the silty sand to silt deposit ranged from 9 percent to 32 percent.

4.7.6 Refusal/Bedrock

Refusal to further auger penetration and dynamic cone penetration was encountered in Boreholes C1 and 4N (PML, May 2003) at 14.1 m and 3.0 m, respectively. These refusal depths, while they do not confirm bedrock elevations, maybe inferred to indicate potential proximity to the bedrock interface. These refusal depths indicate that the bedrock surface likely slopes downwards towards the west. Refusal was not reached in Boreholes BH-186 and BH-187.

4.7.7 Groundwater Conditions

Details of the groundwater conditions and water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets following the text of this report. In general, the samples taken in the boreholes were noted to be moist to wet. Water levels observed in the open Boreholes BH-186 and BH-187 ranged from 1.0 m to 4.9 m depth below the existing road grade upon completion of drilling corresponding to Elevations 236.7 m and 233.1 m, respectively.

The groundwater level was not established in any of the boreholes at the toe of the slope, however, open water is present in this area, indicating that the groundwater level is likely at the ground surface (about Elevation 235.9). It should be noted that, groundwater elevations will vary depending on precipitation and local soil permeability.

4.8 Culvert Highway 537 Station 11+015 (Drawing No. 7)

Boreholes BH-156 and BH-157 were advanced along the length of the culvert crossing Highway 537 at Station 11+015 and are given in Appendix G. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert centreline are shown on Drawing 7. The sections below describe the detailed subsurface conditions in this area. The ground surface at the borehole locations is between Elevation 238.0 m and 238.5 m. The topography is of rolling terrain and consists of rock outcrops typically interspersed by shallow deposits of sand and gravel and occasional open water. The sections below describe the detailed subsurface conditions in this area.

4.8.1 Sand and Gravel to Gravel

A 5.2 m thick layer of sand and gravel to gravel containing trace silt and occasional cobbles was encountered at the surface of Borehole BH-157. The measured SPT 'N' values for this layer ranged from 6 to 32 blows per 0.3 m of penetration, but generally the values were less than 10 blows per 0.3 m of penetration, indicating that the deposit has a loose to compact relative density. The water content for the deposit ranged from 2 to 10 percent.

4.8.2 Sand

A deposit of sand underlies the gravel in Borehole BH-157, and was encountered at the surface of Borehole BH-156. The deposit ranges in thickness from 4.7 m to 9.2 m, with the top between Elevation 243.4 m and 248.0 m.

The measured SPT 'N' values ranging from 9 blows to greater than 100 blows per 0.3 m of penetration, and were generally less than 40 blows per 0.3 m of penetration, indicating that the deposit has a loose to dense relative density. Typically, the higher 'N' values were encountered near the base of the deposit.

Grain size distributions for two samples of this deposit are shown on Figure A-22 of Appendix A. The natural water content of the sand ranged from 8 to 18 percent.

4.8.3 Cobbles and Boulders

A 0.5 m thick layer of cobbles and boulders was encountered beneath the sand deposit and above the bedrock surface in Borehole BH-157 at Elevation 238.7 m. The presence of cobbles and boulders was inferred by the grinding of augers at this elevation.

4.8.4 Bedrock

The surface of the bedrock was encountered in the boreholes between Elevations 238.2 m and 238.8 m. The upper 3 m of the bedrock was cored in each borehole.

The bedrock samples consisted of consisted of fresh, foliated, light grey to dark grey and pink, crystalline biotite gneiss. The total core recovery was between 95 percent and 100 percent. The Rock Quality Designation (RQD) measured on the core samples from the boreholes ranged from about 65 percent to 98 percent indicating a rock mass of fair to excellent quality. The bedrock surface dips slightly towards the south.

4.8.5 Groundwater Conditions

Details of the groundwater conditions and water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets following the text of this report. In general, the samples taken in the boreholes were noted to be moist to wet. Water levels observed in the open boreholes ranged from 1.7 m to 2.7 m depth upon completion of drilling. A piezometer was installed at the base of the sand deposit in Borehole BH-156 and the readings are given in the table below.

Date	*Depth to Groundwater (m)*	*Groundwater Elevation (m)*
April 20, 2004	0.6	247.4
April 22, 2004	1.3	246.7
June 12, 2004	0.5	247.5
October 6, 2004	1.8	246.2

It should be noted that, groundwater elevations will vary depending on precipitation and local soil permeability.

4.9 Culvert Highway 537 Station 11+940/12+130 (Drawing No.'s 8A, 8B)

Boreholes BH-83, to 85, 158, 159A and BH-159, Dynamic Cone Penetration Tests DCPT-69 and 70, and Cone Penetration Tests CPT-39 and 42 were advanced in the vicinity of the proposed culvert alignments. The records are given in Appendix H. The plan and profile showing the borehole locations and interpreted stratigraphy along the culvert/Hwy 537 alignment centreline are shown on Drawings 8A and 8B. The ground surface at the borehole locations is between Elevation 227.2 m and 229.0 m. The topography at this site is generally low-lying with grassy areas and occasional open water. A large rock outcrop is present immediately to the west of the site at about Station 11+920. The sections below describe the detailed subsurface conditions in this area.

4.9.1 Topsoil

A layer of dark brown topsoil containing organics was encountered at ground surface of both boreholes. The thickness of this layer was between 0.2 m and 0.4 m.

4.9.2 Silty Sand

A 0.8 m thick silty sand deposit was encountered below the topsoil in borehole BH-159. The measured SPT ‘N’ values ranged from 0 blows (weight of hammer) to 7 blows per 0.3 m of penetration, indicating that the deposit has a very loose to loose relative density.

4.9.3 Silty Clay to Clay

A deposit of brown and grey silty clay to clay containing trace to some sand and trace amounts of rootlets was encountered below the topsoil layer in Boreholes BH-83 to 85 and BH-158 and below the silty sand layer in Borehole BH-159. The deposit contained sand and silt seams throughout. The surface of this deposit varied between Elevation 226.8 m and 228.8 m, and the thickness ranged from 1.1 m to 2.9 m.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging from 3 blows to 8 blows per 0.3 m of penetration, indicating that the deposit has a soft to stiff consistency.

In situ field vane testing carried out within this stratum measured an undrained shear strength of about 70 kPa. Tip resistance, as measured by the cone penetration tests, was up to about 11 MPa. In general, the field vane and cone penetration test results together with the SPT ‘N’ values suggest the silty clay to clay stratum has a soft to stiff consistency.

Atterberg limits testing was carried out on one sample of the silty clay to clay. The liquid limit was 51 percent and the plastic limit was 22 percent yielding a plasticity index of 28 percent indicating that this sample is a clay of high plasticity. However, based on visual classification, as well as testing elsewhere within the swamp, the deposit ranges from a silty clay of intermediate plasticity to a clay of high plasticity.

The natural water content measured on samples of this deposit range from 27 to 37 percent.

4.9.4 Sand

A deposit of grey sand, containing trace silt and trace clay was encountered below the silty clay to clay deposit in Borehole BH-85. The surface of this deposit was encountered at Elevation 224.7 m and has a thickness of 0.8 m.

Standard Penetration Testing (SPT) carried out within this stratum measured one ‘N’ value of 10 blows per 0.3 m of penetration indicating that this deposit has a compact relative density. The natural water content measured on one sample of this deposit was 19 percent.

4.9.5 Clayey Silt to Clay

A deposit of grey clayey silt to clay was encountered below the upper silty clay to clay crust. The clayey silt to clay contained trace amounts of sand throughout with occasional sand seams and grey varves/laminae. The clayey silt to clay was observed to become siltier with increasing depth, transitioning to the underlying granular deposits. The top of this deposit varied between Elevations 224.0 m and 227.2 m. The thickness of the deposit ranged from 2.7 m to 9.2 m, being thickest in the area of Boreholes BH-83 and 84.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values ranging between 0 blows (weight of hammer of weight of rods) and 4 blows per 0.3 m of penetration.

In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from 15 kPa to 64 kPa. In general, the higher shear strengths were measured near the surface and base of the deposit, with the majority of the deposit having undrained shear strengths between 15 kPa and 35 kPa. Sensitivity was found to range from 5.2 to 10.8. Tip resistance, as measured by the cone penetration tests, ranged from 0.2 to 1.5 MPa. In general, the field vane and cone penetration test results suggest the clayey silt to clay stratum has a soft to stiff consistency.

Atterberg limits testing was carried out on samples of the clayey silt to clay deposit. The liquid limit ranged between 24 and 58 percent and the plastic limit ranged between 16 and 20 percent, yielding plasticity indices ranging between 12 and 40 percent. The results of the Atterberg limits are shown on the plasticity chart on Figure A-23 in Appendix A and indicate that the deposit ranges from a clayey silt of low plasticity to a clay of high plasticity. Typically, the samples with the higher plasticity were measured close to the surface of the deposit, and decreasing with depth. A grain size distribution on two samples of the clayey silt to clay are shown on Figure A-24 in Appendix A.

Although no oedometer (consolidation) tests were carried out on samples from the boreholes in the culvert area, two oedometer tests were carried out on specimens of the clayey silt to clay obtained from Boreholes 85 and 92 and have been incorporated to assist in interpreting the geologic stress-history and geotechnical engineering properties of the overall deposit. Preconsolidation pressures of approximately 104 kPa and 242 kPa for this stratum were estimated from the void ratio versus logarithmic pressure plots and from the total work versus pressure plots. Details of the test results are shown on Figures A-25 and A-26 in Appendix A. The following table summarizes the relevant oedometer test results.

Borehole and Sample No.	***Elevation (m)***	σ_{vo}' ***(kPa)***	σ_p' ***(kPa)***	$\sigma_{vo}' - \sigma_p'$ ***(kPa)***	***OCR***	e_o	C_r	C_c	c_v^* ***(cm^2/s)***
BH 85 Sa#6	222.8	45	104	59	2.31	1.25	0.051	0.475	1.91×10^{-3}
BH 92 Sa#5	224.7	31	242	211	7.81	0.94	0.035	0.287	9.36×10^{-3}

Note: *For stress range of $150 \leq \sigma_v' \leq 2000$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm^2/s in the normally consolidated range

The natural water content measured on select samples of this deposit ranged between 28 percent and 69 percent; typically, the higher water contents were measured near the surface of the deposit and decreased with depth.

4.9.6 Silt to Sandy Silt

A deposit of grey sand to silt and sand containing trace to some clay was encountered below the clayey silt to clay deposit in all the boreholes except Borehole BH-159. In Boreholes BH-83 to BH-85, the surface of this deposit was encountered between Elevation 216.5 m and 217.3 m with a thickness ranging from 1.8 m to 3.9 m. In Borehole BH-158, the deposit contained some gravel and occasional cobbles. In this borehole, the surface of the deposit was encountered at Elevation 224.4 m and was 0.2 m in thickness.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values between 0 blows (weight of hammer of weight of rods) and 8 blows per 0.3 m of penetration indicating that this deposit has a very loose to loose relative density. At the base of the deposit in Borehole BH-158, the SPT ‘N’ value measured was greater than 100 blows per 0.3 m of penetration, and may be inferred to indicate potential proximity to the bedrock surface at this location.

A grain size distribution on one sample of the silt to sandy silt is shown on Figure A-27 in Appendix A. The natural water content measured on samples of this deposit were between 24 and 27 percent.

4.9.7 Sand to Silt and Sand

A deposit of grey sand to silt and sand was encountered below the clayey silt to clay deposit in Borehole BH-159 and below the silt to sandy silt deposit in Borehole BH-83. The composition of the deposit ranges from a sand containing trace to some silt to a silt and sand. The surface of this deposit was encountered at Elevation 213.7 m and 222.2 m in Boreholes BH-83 and BH-159, respectively. The thickness of this deposit ranges from 0.9 m in Borehole BH-159 to 8.4 m in Borehole BH-83.

Standard Penetration Testing (SPT) carried out within this stratum measured ‘N’ values typically between 0 blows (weight of hammer of weight of rods) and 22 blows per 0.3 m of penetration indicating that this deposit has a very loose to compact relative density. However, at the base of the deposit, the ‘N’ values are greater than 100 blows per 0.3 m of penetration, and may be inferred to indicate potential proximity to the bedrock surface.

A grain size distribution on two samples of the sand to silt and sand are shown on Figure A-28 in Appendix A. The natural water content measured on samples of this deposit were between 23 and 24 percent.

4.9.8 Bedrock/Refusal

Refusal is typically defined by greater than 100 blows per 0.3 m penetration in the boreholes. In addition, auger or spoon refusal was encountered at the base of some of the boreholes. These refusal depths, while they do not confirm bedrock elevations, maybe inferred to indicate potential proximity to the bedrock interface. In addition, grinding of the augers was noted below 6.9 m depth in Borehole BH-159. The depth, elevation, and type of refusal is given in the table below.

Borehole	*Refusal Type*	*Refusal Depth (m)*	*Refusal Elevation (m)*
BH-83	Refusal to further dynamic cone penetration	26.4	200.8
DCPT-69	Refusal to further dynamic cone penetration	24.6	202.6
DCPT-70	Refusal to further dynamic cone penetration	22.6	204.8
BH-158	Auger and Spoon Refusal	4.7	221.1
BH-159A	Auger Refusal	8.1	220.7
BH-159	Auger Refusal	7.5	224.2

In general, the borehole logs for BH-158, 159 and 159A noted that the augers were dipping towards the east (i.e. away from the rock outcrop) indicating that the bedrock surface is sloping eastwards at this location.

4.9.9 Groundwater Conditions

Details of the groundwater conditions and water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets following the text of this report. In general, the samples taken in the boreholes were noted to be moist to wet. Borehole BH-159A had sand flow into the hollow-stem augers due to water pressure confined below the cohesive deposits.

Water levels observed in boreholes BH-158 and BH-159 were measured at about 2 m below the ground surface upon completion of drilling. The water level in Boreholes BH-83 to BH-85 were measured between 0 m (i.e. at the ground surface) to 0.3 m below the ground surface upon completion of drilling. A piezometer was installed in Borehole-159 and sealed within the sand to silt and sand deposit below the clayey silt to clay deposit. The water level was measured at the ground surface inside the piezometer on October 13, 2004.

It should be noted that groundwater levels in the area are subject to seasonal fluctuations and will vary depending on precipitation and local soil permeability.

4.10 Closure

This report was prepared by Miss Sarah Poot, P.Eng., a senior geotechnical engineer and the technical aspects were reviewed by Mr. Storer J. Boone, P. Eng., an Associate with Golder

Associates Ltd. Mr. Fintan J. Heffernan, P. Eng., a Designated MTO Contact for Golder, conducted a quality control review of the report.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
S. E. M. POOT
PROVINCE OF ONTARIO

Sarah Poot, P. Eng.,
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
F. J. HEFFERNAN
PROVINCE OF ONTARIO

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

for Storer J. Boone, P.Eng.,
Associate

SEP/SJB/FJH/sep
n:\active\2003\1111\03-1111-011 urs hwy 69\5000 reporting\4-culverts\final report\03-1111-011-4 rpt 05jun final culvert report.doc

PART B

FOUNDATION DESIGN REPORT
CULVERTS
HIGHWAY 69 FOUR-LANING FROM 0.3 KM NORTH OF
HIGHWAY 537 NORTHERLY 8.8 KM
G.W.P 327-91-00
MINISTRY OF TRANSPORTATION, ONTARIO
SUDBURY, ONTARIO

5.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides our interpretation of the factual geotechnical data obtained during the investigation and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as it affects their proposed construction methods, costs, equipment selection, scheduling and the like.

5.1 General Discussion

The overall project involves the design of the new Highway 69 and Highway 537 alignments, including the Highway 537 Interchange north of Estaire, Ontario. The overall project involves construction of high fill embankments and swamp crossings, two bridges and culverts. The culvert crossings are the subject of this report as the design recommendations for the swamp crossings/high fill embankments have been addressed under separate cover.

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) to provide recommendations on geotechnical aspects related to the final design and construction of the culverts at the locations noted in the table below. The scope of work includes an assessment of the anticipated culvert settlements, proposed construction methodology, recommendations on the bedding requirements and a review of the stability of temporary cut slopes associated with the excavation for the construction of the culverts. Each of these requirements is addressed in the following sections.

Generally, the culvert crossings are located within high fill embankment sections of the proposed highway and/or within swamp crossing areas. Swamp crossings generally refer to areas where the topography is low-lying and has poor drainage, regardless of the embankment height. The subsurface conditions in the swamp areas usually consist of organic deposits of variable thickness underlain by deep, soft compressible clays. The embankment height and culvert details are also given in the table below.

CULVERT LOCATIONS

Culvert Location	*Proposed Structure Size*	*Culvert Length (m)*	*U/S Invert Elevation (m)*	*D/S Invert Elevation (m)*	*Proposed Embankment Height*	*Preferred Foundation Treatment*
Hwy 69 12+200	1.8 m x 1.2 m	78	237.8	237.8	6.5 m	Wick Drains
Hwy 69 14+100	1.2 m x 1.2 m	114	237.0	236.8	7.0 m	Wick Drains
Hwy 69 14+940	1.8.m x 1.2 m	114	242.7	242.4	5.5 m	Wick Drains
Hwy 69 16+016	1.2 m x 1.2 m	74	254.4	254.1	6.0 m	Preloading
Hwy 69 16+137	1.2 m x 1.2 m	81	255.2	254.9	6.0 m	
Hwy 69 19+845 (1)	2.4 m x 1.5 m	41	235.2	235.2	3 m	Preloading (2)
Hwy 537 11+015	1.2 m x 1.2 m	71	247.7	247.7	13 m	Preloading
Hwy 537 11+940/ 12+130	1.8 m x 1.2 m	29	227.0	226.9	10 m	Wick Drains

1. North tie-in area. Widening of existing embankment only.
2. In addition to the preloading, removal of the peat/organics is also required.

As part of the scope of work for the swamps/high fill embankments, recommendations for foundation treatments in order to reduce the long-term settlements of the proposed embankments were given in the High Embankment Fills/Swamp Crossings Report (Golder, July 2004). In several swamps, the treatment will consists of a wick drains with the embankment constructed in several stages and preloaded for a period of time (typically about one year), including the addition of a surcharge loading. Elsewhere, preloading (with no foundation treatment) has been recommended as the preferred settlement/stability mitigation alternative. The preferred swamp foundation treatment at each culvert location has also been noted in the table above.

5.2 Construction Considerations

In general, the underlying subsoils at the culvert sites will undergo settlement as a result of embankment loading as discussed in Section 5.4.1, regardless of the foundation treatment used. Therefore, the timing of culvert construction, with respect to the anticipated settlement, is considered to be a critical design issue. Several alternatives for culvert construction can be considered:

- Construction of culvert prior to embankment construction;
- Construction of culvert following the preload period;
- Partial sub-excavation;
- A pile supported culvert;
- Lightweight Fill;

- Ground Improvement;
- Tunnelling; and
- Culvert Relocation

A summary of the advantages, disadvantages, cost and risks/consequences for each of the alternatives is given in Table 1 following the text of this report. Due to the anticipated settlements at most of the culvert sites, it is recommended that the culverts be constructed following the preload period to give better long-term performance of the culvert and roadway (overall drainage, differential settlement etc.). However, at some locations, culvert relocation and/or partial sub-excavation may be the preferred option so that culvert construction can take place prior to embankment construction. The following sections discuss each of the alternatives in more detail.

5.2.1 Culvert Construction Prior to Embankment Construction

If culverts are to be constructed prior to the new embankments, the culverts will experience both vertical settlement (both short-term and long-term) as well as horizontal spreading (or strain) as a result of the embankment loading. The magnitudes of settlement and horizontal strain are discussed in Sections 5.4.1 and 5.4.2, respectively. If the culvert can tolerate the anticipated settlements and horizontal strains, the culvert could be constructed with a camber, such that after the settlement has occurred, the drainage may be positive. Choosing an appropriate camber, however, is considered both problematic and risky for some of the culverts on this project. It is inherently difficult to predict settlement for the variable soil conditions that exist with the degree of precision that may be required to choose a successful camber for the culverts. If actual settlements are less than predicted, the culvert may not permit adequate flow of water. If actual settlements are greater than expected, any sag in the culvert would become filled with sediment and impede the flow of water. In addition, expansion joints should be present along the culvert length to accommodate horizontal strain. If the culvert cannot tolerate the settlement and horizontal strain, consideration could be given to constructing the culvert following the preload period or to one of the other alternatives presented below.

Depending on the type and material of culvert selected, some settlement could be accommodated by a camber (see Section 5.3). In addition to the use of a camber, consideration could be given to the use of an oversized culvert such that positive flow is still achieved even after some settlement has occurred.

5.2.2 Culvert Construction Following Preload Period

If the magnitudes of settlement and horizontal strain cannot be tolerated, then consideration could be given to constructing the culverts following the preload period. Preloading of the embankments over the swamps and in high fill areas is being recommended to reduce the long-term settlement of the roadway. In all areas, preloading (with or without wick drains) is to be used to limit the post-construction compression of the foundation soils and consequent settlement of the embankment. If the foundation treatment and preloading period is completed prior to culvert construction, the settlement beneath the culvert may be reduced to tolerable levels; however, this would require excavation through the new embankment fill (rock fill) to the culvert founding elevation in order to construct the culvert. Provided that the rock fill above the culvert is properly placed and compacted, differential settlement between the rock fill embankment (that has been consolidating under its self weight for the entire preload period) and the rock fill backfill above the culvert should be acceptable as discussed in Section 5.4.1. This construction following the preload period option is considered to be the most practical and most cost effective of the three possible alternatives.

It should be noted that with this alternative, it may be prudent to use a temporary earth fill or granular core of material in the area of the culvert to allow for ease of sub-excavation through the embankment after preloading. Details of such a core are given in Section 5.8.4.

5.2.3 Partial Sub-excavation

In some swamp areas, the magnitude of settlement could be reduced by partial sub-excavation of the soft, compressible silty clay to clay stratum in the area of the culvert. Excavation depths of up to about 8 m are considered to be commonplace in Northern Ontario and are within the practical limit of sub-excavation below the water table. Depending on the depth and thickness of the soft clay layer, the magnitude of settlement could be reduced to allow construction of the culvert prior to embankment loading. In some of the culvert locations, the thickness of clay and resulting magnitude of settlement and horizontal strain, with or without partial, localized, sub-excavation would still be too large to be accommodated by standard culvert construction. However, at some culvert locations, where the soft clay stratum is thinner and near the surface, the post-construction settlements may be reduced to a level that could be accommodated by culvert construction with a suitable camber. In addition, the costs of sub-excavation and backfill would have to be considered in the cost/benefit analysis.

Although partial sub-excavation will improve the settlement performance of the culvert and embankments in the immediate area of the sub-excavation, adjacent areas will not experience the same improvements in settlement performance. As a result, the overlying embankments will experience differential settlement that may produce a differential “rise” or “hump” in the road surface depending on the timing of embankment construction, culvert construction, and final earthwork and paving.

It should also be noted that settlement of the rock fill beneath the culvert will occur and could be significant depending on the depth of sub-excavation. There may also be difficulty obtaining a neat excavation within the clay below the water table in order to place rock fill; the remaining clay will migrate to fill the void spaces between the rock fill at both the sides and base of the excavation which could lead to increased post-construction settlement beneath the culvert and the embankment adjacent to the culvert.

If partial sub-excavation is being considered, the limits of the sub-excavation should extend downwards and outwards at 1 horizontal to 1 vertical (1H:1V) from the underside of the culvert base. Side slopes within the native soils below the water table should be formed at no steeper than 3H:1V. Recommendations with respect to temporary excavation side slopes and dewatering are given in Section 5.10. The sub-excavated materials (i.e. soft clay) should be considered as unsuitable for use as fill in any other areas. The excavation should be backfilled with rock fill which will have to be placed below the water table.

5.2.4 Pile Supported Culvert

If the magnitudes of settlement and horizontal strain cannot be tolerated, and if it is not practical to excavate through the newly constructed embankment to construct the culverts, then consideration could be given to supporting culverts on piles driven to competent stratum, which is typically between 10 m and 35 m depth below ground surface at the culvert locations. Since the piling and culvert construction would take place prior to the embankment construction, downdrag loads on the piles, as a result of compression of the underlying soils, would have to be taken into account for the design (potentially requiring more piles or larger piles than might ordinarily be necessary). In this case, the settlement of the culvert will be nominal; however, the settlement of the embankment around the culvert will be significant and will cause the road surface to have a “hard point”. For this reason and for the potentially high costs of materials and installation, a pile-supported culvert is not recommended.

It may be possible to reduce the effect of downdrag loads on the piles by the use of a bitumen coating, a sleeve, or by the use of a heavier pile section. Bitumen is not widely used on small piling projects because of set-up costs. Another method to reduce downdrag loads on the piles would be to use a steel tube pile around the HP 310x110 load bearing pile, through the soft clay zone. The material inside the sleeve would have to be cleaned out in order prevent the compressible soil from being in direct contact with the H-pile and thus, preventing downdrag loads from being applied to the pile. The tubes would add extra cost to the piling operation, and could ultimately double the cost of this already expensive option. In addition, it may be difficult to drive H-piles within the tubes, especially if piles are to be battered. A heavier pile section (i.e. HP 360x110) would reduce the effect of downdrag loads on the piles by increasing the geotechnical resistance available to accommodate downdrag forces. In this case, it would be recommended that the piles be driven to the bedrock surface.

5.2.5 Lightweight Fill

Another alternative to reduce post-construction settlement beneath the culvert would be to construction the embankment above the culvert out of lightweight fill. The lightweight fill could consist of either expanded polystyrene (EPS) blocks or slag. In the case of EPS, which has a nominal unit weight (less than 1 kN/m^3), the loading on the subsoils would be substantially reduced and consequently, the post-construction settlement beneath the culvert would be reduced significantly (where the culvert is constructed prior to embankment construction). However, for the proposed embankment heights on this project, a considerable amount of EPS would be required and could prove cost prohibitive. Typically, EPS is recommended in areas where staging precludes the use of other alternatives, and where only small amounts of EPS are required to achieve the desired post-construction settlement results. The use of lightweight slag fill (typically available from Sault Ste. Marie or Hamilton) could also reduce the magnitude of post-construction settlement beneath the culvert. Typically, lightweight slag fill has a unit weight of about 14 kN/m^3, which is only slightly lower than that of rock fill (19 kN/m^3) and therefore, the magnitude of reduction may not be significant enough to justify the cost and the transport cost. Because the embankments surrounding the culverts will also induce settlement within the ground beneath the culverts, it would be necessary to extend the limits of lightweight fill well beyond the limits of the culvert such that it forms a significant proportion of the embankment in the general culvert area. Typically, the extent might be defined based on a base width (perpendicular to the road alignment, within which the culvert would be constructed) similar to the embankment height with a 2:1 (horizontal:vertical) slope between the rock fill and lightweight fill materials extending from the subgrade to the top of the embankment on both sides of the culvert.

5.2.6 Ground Improvement

Ground improvement techniques, such as wick drains or stone columns, could be considered to reduce the magnitude of post-construction settlement beneath the culvert. In some swamp areas, wick drains are currently recommended to reduce the amount of time required for embankment construction. After the preload period, the subsoils will have gained sufficient strength and undergone substantial proportions of their anticipated total settlements such that the post-construction settlement will be comparably small. In this case, the culvert would have to be constructed after the preload period (as discussed above) to benefit from the increase in soil strength.

Stone columns or other soil reinforcement techniques could be considered to locally strengthen the soil beneath the culvert prior to embankment construction. With the limited depth of such systems and the large thicknesses of clay soils at many of the culvert locations, these systems may only reduce the magnitude of post-construction settlement, which would vary depending on the soft clay depth and thickness. In addition, the interaction of any such system may affect the effectiveness of the wick drain system which is required to mitigate settlement and stability issues for embankment construction. The feasibility of a ground improvement system, such as stone columns, should be considered only in areas where the soft clay is shallow.

5.2.7 Tunnelling

Consideration could be given to constructing the culverts in tunnel, after settlement has occurred (i.e. after the preload period). In this case, a temporary earth fill or granular core would be recommended to facilitate tunnelling since tunnelling through rock fill would be difficult and impracticable. Given that tunnelling is not a common construction technique for culverts in Northern Ontario, the costs associated with such an option may also be prohibitively expensive, depending on the tunnelling method used, and the number of culverts requiring tunnelling. Two main tunnelling methods could be considered including the use of a shielded, tunnel boring machine (TBM) or jack-and-bore techniques if this option were to be considered further. If tunnelling is to be considered, recommendations for such work should be prepared for each specific location based on anticipated construction techniques and the site specific conditions. Detailed recommendations for tunnelling of culverts are not provided within this report.

5.2.8 Culvert Relocation

A simple way to reduce the post-construction settlements below the culverts would be to re-locate the culvert to an area where soft compressible soils are not present. This may require moving the culvert to the nearest bedrock outcrop or moving the culvert to a location of reduced embankment height. In some cases, it may not be possible to relocate the culvert from a drainage perspective or from a fisheries perspective. However, in areas where drainage patterns permit relocation, this may be the most recommended alternative. The designer should consider the costs associated with bedrock blasting when considering culvert relocation.

5.3 Culvert Options

The selection of culvert type, shape and material is based on several factors, including foundations (i.e. settlement expected, subgrade material), hydrogeology, environmental, structural and economical. A brief discussion on the advantages and disadvantages from a geotechnical engineering perspective is given below for culvert type, shape and material. After considering all the information below, we recommend that pre-cast box culverts be used for most applications at this site.

5.3.1 Cast-in-Place versus Pre-cast Culverts

Cast-in-place concrete culverts are generally used when the post-construction (long-term) settlements are expected to be nominal. Cast-in-place culverts are prone to cracking if large settlements or large horizontal strains occur (see Section 5.4).

Pre-cast culverts may come in small segments and can be positioned to accommodate some settlement. It is our understanding that, depending on the segment length and the construction technique, pre-cast culverts could accommodate up to 150 mm of settlement (in a camber or articulated arrangement). This settlement will be taken up in the joints between the segments, provided that the joint opening of the segments does not exceed the acceptable joint opening.

At this site, relatively large settlements are expected at most culvert locations and in some areas, these settlements may still be to large to accommodate pre-cast culverts. The magnitude of expected settlement may determine the construction sequence and the type of culvert required. In the case where the culverts are constructed after preloading, the post-culvert construction settlements may be reduced to levels that could be accommodated by pre-cast culverts. However, due to the risk associated with determining the exact amount of post-construction settlement (due to creep, construction techniques, etc.), it is recommended that pre-cast culverts be used at all permanent culvert locations on this project. In addition, pre-cast culverts are often less expensive and are widely used throughout Northern Ontario.

5.3.2 Box Culvert versus Open Footing Culvert

Open footing culverts are generally chosen for large culverts with suitable bearing soils. At this site, the culverts are generally small (i.e. less than 2 m wide) and long (over 150 m total length) and the subgrade soils are generally poor (swamp crossings) with large settlements anticipated. For these conditions, it may be difficult to construct the size of footing that would be required for the low geotechnical foundation bearing resistances available. If, however, the culvert construction took place after preloading, the subsoils may have gained sufficient strength to provide adequate geotechnical resistance with realistic footing sizes. In general, open-bottom culverts supported by footings should not be used for this project.

Culverts that consists of rigid boxes (whether pre-cast or cast-in place) are generally easier to construct for the small size culverts at this site. Higher geotechnical resistances for the same size culvert, compared to open footings, will increase the desirability of using box culverts at this site.

5.3.3 Culvert Shape and Materials

Typically, three culvert shapes are considered in culvert design – arch, pipe (i.e. round), or rectangular. For arch or round culverts, special attention must be paid to compaction quality control for the bedding under or around the haunches (sides) of the culvert, or the culvert could collapse under the embankment loading. If this happens, replacement of the culvert would be required at great expense. This is primarily a concern for steel culverts as opposed to concrete culverts since concrete culverts are typically more rigid than steel arch or pipe culverts. In addition, steel culverts may be more susceptible to damage during placement of rock fill or backfill. Selection of culvert shape and materials should be made by the designers of the drainage systems and, should steel arch or circular culverts be selected additional geotechnical engineering recommendations for control of backfill may be necessary. For this project it understood that all culverts will be pre-cast concrete box structures with a rectangular cross section.

5.4 Settlement, Horizontal Strain and Stability

Settlement of the culvert is a key issue in the design and construction of the culverts. In addition to vertical settlement beneath the culverts, lateral spreading of the new embankment should also be considered in the design of the culverts. Section 5.4.1 and 5.4.2 of this report summarize the methods used for the analysis of settlement of the culverts and the methods used for evaluating horizontal strain under the proposed embankment loading. A summary of the methodology used for stability analysis of the high fill embankments is given in Section 5.4.3.

5.4.1 Settlement

The following sections outline the methods used to conduct the settlement analyses at the various sites. In addition, the parameters used in the analyses for each of the critical areas are also presented. The results of the analyses are presented in Section 5.5.

At most of the culvert locations, thick deposits of cohesive, compressible strata were typically encountered, underlain by granular soils at depth. At other culvert locations, the subsoils are composed primarily of granular soils over relatively shallow bedrock. At all culvert locations, thin, surficial deposits of soft organic soils (i.e. topsoil and/or fibrous peat) were encountered.

5.4.1.1 Summary of Geotechnical Engineering Parameters

Cohesive foundation soils were encountered in a number of swamp areas (i.e. culvert locations) as summarized in Section 5.1. The design parameters, including deformation and time-rate-of-consolidation properties for each of the critical areas are given in Figure 1 and Table 2, following the text of this report. The rock fill used in the analysis was assigned a unit weight of 19 kN/m^3 and an effective friction angle of 38 degrees and 1.25H:1V side slopes.

The immediate compression of the very loose to very dense silt, sandy silt to silty sand, sand, and gravel layers was modeled by estimating an elastic modulus of deformation based on the SPT 'N' values and correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990).

Settlement analyses were carried out using the results of borehole information, in situ field test data (field vane, CPT, and SPT), and/or laboratory oedometer (consolidation) tests from all of the swamp crossing sites to estimate the average deformation parameters of the subsoils. The consolidation parameters for the cohesive layers obtained from the results of the oedometer tests are given in Table 3. It should be noted that results from the oedometer testing for relevant swamps from the original draft report by PML (PML, August 2001) were utilized where it was considered appropriate. The oedometer testing completed by PML and reported in their draft report was only used with due consideration of its spatial and depositional distance from the culvert alignment and testing. The data was considered in conjunction with the results of the in situ field vane shear and cone penetrometer tests and the laboratory results of water content and Atterberg limits determinations.

The over-consolidation ratio (OCR) profile required in the settlement analyses was established using the results of the oedometer tests as well as correlations with the results of the in situ vane shear and cone penetrometer tests. The following correlation relating in situ undrained shear strength to preconsolidation pressure (Mesri, 1975) was employed:

$$s_u = 0.22\sigma_p'$$

where :
s_u = average mobilized undrained shear strength (kPa)
σ_p' = preconsolidation pressure

The compression and recompression index profiles required in the analysis were established using the results of the oedometer tests as well as correlation with laboratory test data. The following published correlation (Kulhawy and Mayne, 1990) relating the plasticity index to the compression and recompression indices was employed as it was also consistent with the available data.

$$C_c = I_p/74$$
$$C_r = C_c/10$$

where :
C_c = compression index
C_r = recompression index
I_p = plasticity index

The coefficient of consolidation, c_v, required in the analysis was established using the results of the oedometer tests and a site-specific correlation with water content. The following equation was used to relate natural water content to the coefficient of consolidation:

$$c_v = -0.0002w_n + 0.0136$$

where :
c_v = coefficient of consolidation (cm^2/s)
w_n = natural water content (%)

When developing the site-specific correlations of engineering parameters and laboratory or field test data, the results from all swamp areas were combined to provide a larger set of parameters to evaluate. It was considered that all the swamp areas exhibited sufficiently similar soil mineralogy and geology that correlations based on all of the data would be justified. Having determined the site specific correlations, the test results for each individual swamp area were examined and the design lines developed accordingly.

5.4.1.2 Methods of Analysis

Settlement analyses of the culverts were performed based on the proposed embankment height at the culvert locations.. The sources of settlement below the founding level of the culverts were considered to include:

- primary time-dependent consolidation of the cohesive deposits;
- secondary time-dependent consolidation of the cohesive deposits (long term); and
- immediate settlement of the native granular soils.

In addition to the settlement below the culvert, self-weight compression of the embankment fill materials above the culvert were also considered to evaluate future roadway performance.

In areas where thick deposits of cohesive strata were encountered in the subsoils, the settlement analysis was carried out using the commercially available program UNISETTLE (Version 3.2) produced by Unisoft Limited. In areas where the subsoils consisted of thin deposits of cohesive strata and/or granular soils only, the settlement analysis was performed using hand calculations. In most cases, hand calculations were performed to check the UNISETTLE results.

The thickness of the compressible stratum along the length of each culvert is variable which implies that the consolidation settlement along the length of the culvert will also be variable. The embankment height is constant along the length of the culvert (assuming extra rock fill is used to infill the median between the embankments) except at the side slopes, where the effective height transitions to zero by the ends of the culverts.

A parametric study was carried out to determine the primary consolidation settlement of the native cohesive and granular soils under various embankment load and cohesive deposit thickness conditions. From these analyses, the relationship between settlement and embankment height for different thicknesses of compressible stratum was derived as illustrated in Figure 2. Estimates of the magnitude of settlement at each swamp location were then determined by interpolation from this graph with consideration given to any assessed differences in geotechnical conditions in order to obtain a settlement profile along the length of each swamp. Similarly, the time rate of settlement was obtained for each of the swamp areas based on the coefficient of consolidation and the given embankment heights and clay thickness.

At all areas, the settlement analyses assume that organic soils have been removed prior to construction of the proposed embankments. For design purposes, the groundwater level was based on piezometric conditions observed during drilling and accounting for seasonal variations. Typically, the groundwater level used was within 1.5 m of ground surface.

It is known that some consolidation settlement occurs following the completion of primary settlement. This secondary settlement, or creep settlement occurs over the long term (i.e. decades) for the normally consolidated clays at this site and has been included in the analyses. The following equations for secondary (creep) settlement from Holtz and Kovacs (1981) were employed in the analyses.

$$S_c = C_{\alpha\varepsilon} \text{ x } L_o$$

$$C_{\alpha\varepsilon} = w_n/100$$

where : S_c = secondary (creep) settlement (mm)
$C_{\alpha\varepsilon}$ = modified secondary compression index (%)
L_o = initial thickness of compressible clay deposit (mm)

Where rock fill is used for the construction of the embankments, in addition to the embankment settlement due to compression of the granular foundation soils and the consolidation of underlying cohesive layers, there will be settlement due to compression of the rock fill itself. Settlement of the rock fill depends on the method and sequence of placement and compaction of the rock fill.

The data contained in the document entitled “Rockfill in the Foundation Design of Highway Structures” by the Ministry of Transportation and Communications, Research and Development Branch, dated 1982, was used to establish the relative percentages for varying of rock fill embankment heights. The post-construction settlement depends on the method of placement; the two methods are discussed as follows:

1. **Compacted Rock Fill:** Compacted rock fill is placed in regular lifts and in accordance with the Special Provision SP206S03 (dated January 2004). This would be the type of method used to construct rock fill embankments above the existing ground surface.

2. **Dumped Rock Fill:** This is rock fill that is end-dumped into place with little or no control over the compaction. This method would be used in backfilling the sub-excavated area below the water table.

Long term post-construction settlement may occur as a result of time-dependent creep due to rearrangement of rock particles under load and breakage of rock particles (i.e. local crushing and degradation). The majority of this settlement (approximately 60% - MTO, 1982) will occur in the first year following construction.

The following table gives estimated long term post-construction settlements as a percentage of total embankment height for a range of embankment heights/rock fill thickness and the two methods of placement. For intermediate embankment heights, the percentage can be determined by interpolation.

Embankment Height/ Sub-excavation Depth (m)	***Rock Fill Consolidation Settlement (%)***	
	Compacted (embankment construction)	***Dumped (sub-excavation backfill)***
5	0.4	0.9
10	0.8	1.8
15	1.2	2.7
20	1.6	3.6
25	2.0	4.5
30	2.4	5.4
35	2.8	6.3

This settlement is graphically displayed in Figure 3.

5.4.2 Horizontal Strain

As a result of the two-dimensional nature of the proposed embankment geometry, shear stresses will be mobilized in the foundation soils (after embankment construction and during the staged construction/preload period) causing lateral spreading of the new embankment. This, in conjunction with the non-uniform vertical settlement of the culvert will generate horizontal straining within the newly constructed culvert if constructed prior to embankment construction. In this case, the culvert design must incorporate a suitable allowance for extension at the joints / couplings of a number of culvert segments in order to prevent the culverts from failing in tension. The results of the analyses are presented in Section 5.5.

The research work by Rutledge and Gould (1973) on the movements of articulated conduits under earth dams on compressible foundations can be used to estimate the magnitude of the horizontal strain likely to occur as a result of the proposed high embankment construction at the culvert sites. The following equations were used to relate horizontal strain to vertical strain and maximum joint opening as a result of settlement of the underlying subsoils:

$$\Delta L = \varepsilon_h \times L$$
$$\varepsilon_v = \delta / d$$

where:

ΔL	is the maximum joint opening (m)
ε_h	is the horizontal strain
ε_v	is the vertical strain
δ	is the maximum anticipated settlement under the culvert as a result of immediate and long-term compression of the subsoils (m)
d	is the thickness of compressible stratum (m)
L	is the culvert segment length (m)

The vertical strain can be estimated from the anticipated settlement beneath the culvert and the thickness of the compressible stratum. The horizontal strain is a function of the vertical strain and the ratio of the horizontal to vertical strain. This ratio can be obtained from the literature based on the embankment height and width and the thickness of the compressible stratum. Once this ratio has been established and the horizontal strain estimated, the maximum joint opening, as a function of the culvert segment length can be calculated. The values of strain and the resulting joint opening are given in Table 4. Similar to the case of vertical settlement, horizontal spreading will occur immediately as a result of the immediate settlement of the granular soils and will occur over a longer period of time as a result of the consolidation of the soft clay stratum.

Where horizontal strains are low, the potential joint openings will be small, and culvert segment lengths can be increased. Where horizontal strains are high (i.e. when anticipated settlements are large), then the potential joint openings will be longer and the design should account for much shorter culvert segments. The provision for multiple short segment lengths and joints may affect material selection and pipe construction (i.e. pre-cast concrete vs. cast-in-place concrete).

5.4.3 Stability

As discussed in the High Fill Embankments/Swamp Crossings Report (Golder, July 2004), stability analysis was carried out for each of the swamp crossings/high fill embankment areas. The methodology used in the analysis is also detailed in the previous report. A target factor of safety of 1.3 is considered adequate for the design of the embankment slopes at these sites under static conditions. The parameters used in the analysis at each of the culvert sites are given in Table 2. The analysis assumed that rock fill will be used for embankment construction and will employ a unit weight of 19 kN/m^3 and an effective friction angle of 38 degrees and 1.25H:1V side slopes. The results of the analyses are presented in Section 5.5.

It should be noted that in all areas, the analyses assume that the organic soils (encountered at or below the ground surface during drilling operations) were removed prior to construction of the new embankments.

5.5 Analysis of Results

5.5.1 General

The following data is summarized on Table 4 following the text of this report for each culvert:

- Culvert location, summarized soils conditions, proposed embankment height, the preferred embankment construction methodology (i.e. settlement/stability mitigation alternative) and the estimated preload period;

- the factor of safety obtained for the proposed embankment heights and requirements for mid-height berms;

- the settlement beneath the culvert due to settlement of the foundation soils (for culvert construction before and after preload period); and

- the expected vertical and horizontal strain due to the embankment construction and subsequent settlement of the foundation soils and estimates of the maximum joint openings.

Plots showing settlement along the length of each culvert, where appropriate, are contained in Figures 4 to 9. It should be noted that for all of the analyses performed, it is assumed that all organic soils (peat and/or topsoil) have been removed within the footprint of the embankments prior to construction of the embankments and culverts. The thickness of the organic deposits at each culvert location are given in Section 4 of this report.

Provided that the proper embankment construction techniques are employed (i.e. wick drains, staged construction, preloading, berms etc.), then the stability of the rock fill embankments above and adjacent to the culvert should be stable, with a factor of safety of greater than 1.3.

If the culvert is constructed prior to embankment construction, the culvert must be able to tolerate the maximum anticipated settlement and horizontal strain (i.e. joint opening). Due to the variability in soil conditions along the length of the culverts, the settlement/horizontal strain will also be variable along the length of the culvert (see Figures 4 to 9) and this should be considered in deciding which construction methodology is to be employed (as discussed in Section 5.2). In addition, since the embankment side slopes are constructed at 1.25 horizontal to 1 vertical (1.25H:1V), the settlement at the ends of the culvert (i.e. zero embankment loading) will approach zero, creating a potentially abrupt transition between zero settlement and the maximum settlement.

If the culvert is constructed following the preload period, construction cannot take place until the full preload period is complete. Where staged construction/preloading is required for embankment construction, the preload period is anticipated to be between about 6 months and 1 year, as reported in the High Fill Embankments/Swamp Crossings Report (Golder, July 2004). The ultimate preload period will be dependant on the results of the monitoring program, which will indicate when sufficient consolidation of the subsoils has occurred. If sufficient settlement has not occurred prior to culvert construction, then significant settlement beneath the culvert could still occur.

5.5.2 Site Specific Results

The recommended culvert construction alternative for each culvert location is discussed below. In each case, the most feasible alternatives from Table 1 have been considered and are included in the discussion. This recommended alternative for each culvert location is summarized in Table 5.

5.5.2.1 Culvert Highway 69 Station 12+200 and 14+100

Settlements of approximately 400 mm and 725 mm (including immediate and long-term settlement) are anticipated under the proposed embankment loading of about 6.5 m and 7 m for the culverts at Station 12+200 and 14+100, respectively. A profile of settlement along the length of these culverts is shown on Figures 4 and 5. Standard culvert design cannot accommodate this magnitude of settlement and associated horizontal strain. The most feasible culvert design alternatives at this location from a geotechnical engineering perspective are to construct the culverts after the preload period. It should be noted that currently wick drains are the recommended foundation treatment for the swamp crossing in the area of these culverts.

If the culverts are constructed following the preload period and removal of surcharge, then the magnitude of settlement expected beneath the culvert is estimated to be less than 25 mm, which may be accommodated by the standard culvert design. In this case, excavation through the embankment will be required and the designer should also consider the affect of such a construction sequence on the overall construction schedule.

Even if partial sub-excavation of the compressible silty clay is carried out to a depth of about 6 m, the magnitude of total settlement during and following the preload period (including immediate and long-term settlement) would be approximately 325 mm and 650 mm at Station 12+200 and 14+100, respectively. This magnitude is still considered to be too large to accommodate a standard culvert design. There is little difference in the overall magnitude of settlement beneath the culvert with the sub-excavation alternative. Although the magnitude of primary consolidation settlement is reduced, the magnitude of settlement of the rock fill backfill (which is end-dumped below the water table) must also be considered.

For the embankment heights at this location, the use of EPS fill is not considered to be economically feasible, although the magnitude of settlement would be reduced such that the culvert could likely be constructed prior to embankment construction. Drainage and environmental considerations preclude the relocation of the culvert in these swamp areas.

Based on the above discussion, we recommend that a pre-cast box culvert be constructed after the preload design by excavating through the embankment. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.2.2 Culvert Highway 69 Station 14+940

Settlement of approximately 225 mm (including immediate and long-term settlement) are anticipated under the proposed embankment loading of about 5.5 m for this culvert. A profile of settlement along the length of this culvert is shown on Figure 6. Standard culvert design cannot accommodate this magnitude of settlement and associated horizontal strain. The most feasible culvert design alternatives at this location from a geotechnical engineering perspective are to construct the culvert after the preload period or to carry out partial sub-excavation of the clay to reduce the magnitude of settlement beneath the culvert. It should be noted that currently, wick drains are the recommended foundation treatment for the swamp crossing, including underneath the culvert.

If the culverts are constructed following the preload period and removal of surcharge, then the magnitude of settlement expected beneath the culvert is estimated to be less than 25 mm, which may be accommodated by the standard culvert design. In this case, excavation through the embankment will be required and the designer should also bear in mind the impact to the overall construction schedule.

If partial sub-excavation of the compressible silty clay is carried out to a depth of about 7 m, the magnitude of total settlement during and following the preload period (including immediate and long-term settlement) would be approximately 185 mm, which is considered to be a borderline case for a standard culvert design. Again, there is not much change in the overall magnitude of settlement beneath the culvert with the sub-excavation alternative. Although the magnitude of primary consolidation settlement is reduced, the magnitude of settlement of the rock fill backfill (which is end-dumped below the water table) must be considered.

For the embankment heights at this location, the use of EPS fill is not considered to be economically feasible, although the magnitude of settlement would be reduced such that the culvert could likely be constructed prior to embankment construction. Drainage and environmental considerations preclude the relocation of the culvert in this swamp area.

Based on the above discussion, we recommend that a pre-cast box culvert be constructed after the preload design by excavating through the embankment. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.2.3 Culvert Highway 69 Stations 16+016 and 16+137

Settlements of approximately 100 mm and 25 mm (mainly immediate settlement) are anticipated under the proposed embankment loading of about 6 m for the culverts at Station 16+016 and 16+137, respectively. A profile of settlement along the length of these culverts is shown on Figures 7A and 7B. Since this magnitude of settlement can be accommodated with a standard culvert design involving a camber, it is recommended that these culverts be pre-cast boxes and be constructed prior to embankment construction. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.2.4 Culvert Highway 69 Station 19+845 (North Tie-in)

At the north tie-in culvert (Highway 69 Station 19+845), due to construction staging, it is anticipated that the culvert will be constructed prior to embankment widening and preloading. The new culvert will replace the existing culvert in about the same location and since the existing embankment will not be raised, no additional loads will be added to the subsoils and, consequently, nominal settlement will occur under the culvert under the existing embankment. However, after culvert construction, when the embankment is widened to accommodate extra lanes, settlement of the subsoils under the existing and widened embankments will take place as described in the High Fill Embankments/Swamp Crossings Report (Golder, July 2004). Settlement would then occur beneath the ends of the culvert underneath the widened portion of the embankment (which is up to 3 m in height). This settlement is estimated to be up to about 75 mm and would be differential with respect to the culvert ends and with respect to the existing roadway embankment as shown on Figure 8. It should be noted that this settlement is as a result of the underlying clay deposits and assumes that the peat, up to 1.7 m thick below the culvert, has been removed from below the widened portion of the embankments.

Although there is limited backfill (or cover) above the culvert itself, settlement of the subsoils under the culvert will occur as a result of the embankment loading immediately adjacent to the culvert, which is 2.4 m wide at this location, and also due to the weight of the cover material and the culvert itself.

Feasible culvert design alternatives at this location to mitigate the settlement beneath the culvert would be to construct a pre-cast box culvert with joints designed to accommodate the horizontal strain as well as be constructed with a camber to accommodate the settlement, or to construct temporary culverts under the widened portion of the embankment until preloading is complete before constructing the permanent culvert.

For the embankment heights at this location, the use of EPS fill in the area could be feasible due to the limited embankment height. However, due to the minimum cover required over EPS blocks, and the low embankment height, the settlement may only be reduced to about half of the 75 mm, and the above alternatives should still be considered.

From a geotechnical engineering perspective, given the relatively low anticipated settlements, it is recommended that this culvert be constructed out of pre-cast boxes and be constructed prior to embankment construction. The appropriate camber should be included in the design. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.2.5 Culvert Highway 537 Station 11+015

Settlements of approximately 100 mm (mainly immediate settlement) is anticipated under the proposed embankment loading of about 13 m for this culvert. Since this magnitude of settlement may be accommodated with a standard culvert design involving a camber, it is recommended that this culvert be a pre-cast box and be constructed prior to embankment construction. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.2.6 Culvert Highway 537 Station 11+940/12+130

At the originally proposed culvert location, a settlement of approximately 225 mm (including immediate and long-term settlement) is anticipated under the proposed embankment loading of about 10 m. A profile of settlement along the length of this culvert is shown on Figures 9A. Standard culvert design cannot accommodate this magnitude of settlement and associated horizontal strain. The most feasible culvert design alternatives at this location from a foundations perspective are to construct the culvert after the preload period or to relocate the culvert. It should be noted that currently, wick drains are the recommended foundation treatment for the swamp crossing in the area of this culvert.

Due to drainage considerations in this swamp area, URS have identified an alternate culvert location at Station 12+130. At this location, although the compressible silty clay stratum is still present, the embankment height over the culvert is greatly reduced, from 10 m to 3.5 m. The approximate settlement under the embankment loading at Station 12+130 is about 75 mm (including immediate and long-term settlement), which may be accommodated by a standard culvert design involving a camber. In this case, the culvert could be constructed prior to embankment construction.

If the culvert is constructed in the original location (11+940) following the preload period and removal of surcharge, then the magnitude of settlement expected beneath the culvert is estimated to be less than 25 mm, which can be accommodated by the standard culvert design. At this location however, excavation through the embankment will be difficult given the depth of excavation (10 m) and the proximity to the rock outcrop at Station 11+920. Effects of this construction sequence on the overall construction schedule should also be considered.

For the original culvert location (11+940) if partial sub-excavation of the compressible silty clay is carried out to a depth of about 6 m, the magnitude of settlement (including immediate and long-term settlement) would be approximately 185 mm, which is considered to be a borderline case for a standard culvert design. Again, there is not much change in the overall magnitude of settlement beneath the culvert with the sub-excavation alternative for although the magnitude of primary consolidation settlement is reduced, the magnitude of settlement of the rock fill backfill (which is end-dumped below the water table) must be considered.

For the embankment height at this location, the use of EPS fill is not considered to be economically feasible, although the magnitude of settlement would be reduced such that the culvert could likely be constructed prior to embankment construction.

Based on the above discussion, we recommend that a pre-cast box culvert be constructed at Station 12+130 prior to embankment construction and with an appropriate camber. Details for excavation, bedding and backfilling are given in Sections 5.5.8 and 5.10.

5.5.3 Differential Settlement

Depending on the method and timing of culvert construction, differential settlement of the roadway above the culvert could occur. If the culvert is built prior to embankment construction, then differential settlement of the roadway surface is not expected. However, if the culvert is built after the preload period is complete, then differential settlement between the rock fill embankment and the rock fill backfill above the culvert will occur. If standard rock fill is used, this differential could be between 25 mm and 50 mm. In order to reduce this differential settlement, consideration could be given to reducing the maximum rock fill size of the culvert backfill to less than 250 mm and reducing the lift thickness to 1 m. A non-standard special provision (NSSP) will have to be included in the Contract for this purpose and is given in Appendix I. Although the quantity of reduction of differential settlement cannot be quantified, smaller rock sizes will reduce the magnitude and time-rate of consolidation. If it is not practical to specify different rock fill grain size distributions in the contract, then the owner should be advised that additional future short-term maintenance of the road surface may be required.

5.6 Spread Footings

It is anticipated that the pre-cast box culverts will be placed on granular bedding over the properly prepared subgrade. Depending on the culvert location, the subgrade will consist of a silty clay crust (that may have been consolidated during the preload period) or by granular soils. The founding elevation is assumed to be 0.4 m lower than the invert levels given in the table in Section 5.1. The geotechnical resistance of the subgrade soils will be impacted by the height backfill above the culvert. It should be noted that no wing-walls or head-walls will be constructed as part of the culvert systems.

5.6.1 Axial Geotechnical Resistance

For the box culverts founded on the properly prepared subgrade/granular bedding (400 mm thick), the factored geotechnical resistance at Ultimate Limit States (ULS) and the geotechnical resistance at Serviceability Limits States (SLS) for 25 mm of settlement are given in the table below for the pre-cast box widths.

Culvert Location	*Proposed Box Width*	*Factored Geotechnical Resistance at ULS*	*Geotechnical Resistance at SLS*
Hwy 69 Stn 12+200	1.8 m	150 kPa	100 kPa
Hwy 69 Stn 14+100	1.2 m	150 kPa	100 kPa
Hwy 69 Stn 14+940	1.8 m	200 kPa	125 kPa
Hwy 69 Stn 16+016	1.2 m	225 kPa	150 kPa
Hwy 69 Stn 16+137	1.2 m	250 kPa	175 kPa
Hwy 69 Stn 19+845	2.4 m	150 kPa	100 kPa
Hwy 537 Stn 11+015	1.2 m	450 kPa	300 kPa
Hwy 537 Stn 12+130	1.8 m	150 kPa	100 kPa

The geotechnical resistances provided above 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 Sections 6.7.2 and 6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary.*

5.6.2 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the base of the pre-cast concrete and the granular fill should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The coefficient of friction, tan δ, may be taken as 0.5 between the pre-cast concrete footing and the granular bedding. This represents an unfactored value; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

5.7 Lateral Earth Pressures

The lateral earth pressures acting on the culvert sides will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the culvert sides. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made concerning the design of the sides of the box culverts. It should be noted that these design recommendations and parameters assume level backfill and ground surface behind the culverts. Where the ground slopes in the direction perpendicular to the culvert alignment (at grades steeper than about 10%), the coefficient of lateral earth pressure must be adjusted to account for the slope.

- In general, it is preferable that select free-draining granular fill meeting the specifications of Ontario Provincial Standard Specifications (OPSS) Granular 'A' or Granular 'B' Type II be used as backfill adjacent to the culvert sides. Other aspects of the granular backfill requirements should be in accordance with OPSD 803.010 and 803.02.

- Rock fill may be used as backfill adjacent to the culverts and the material should meet the specifications as outlined in the Northern Region Directive for backfill to structures adjacent to rock embankments, dated November 2002. Other aspects of rock backfill requirements should be in accordance with OPSD 3505.000.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert sides, in accordance with *CHBDC* Section 6.9.3 and Figure 6.9.3. Compaction equipment should be used in accordance with OPSS 501.06. Other surcharge loadings should be accounted for in the design, as required.

- Granular fill, if used, may be placed either in a zone with width equal to at least 2.0 m behind the culvert sides (Case I in Figure C6.9.1(l) of the *Commentary to the CHBDC*) or within a wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the base of the culvert (Case II in Figure C6.9.1(l) of the *Commentary to the CHBDC).*

- For Case I, the pressures are based on the proposed embankment fill materials and the existing overburden soils and the following parameters (unfactored) may be used assuming the use of rock fill:

	Rock Fill
Soil unit weight:	19 kN/m^3
Coefficients of static lateral earth pressure:	
At rest, K_o	0.38

- For Case II, the pressures are based on the rock fill as above or 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 static lateral earth pressure:		
At rest, K_o	0.43	0.43

It is expected that the culvert design will not allow lateral yielding of the sides or convergence of the sides at the culvert top and thus the concrete box structures will exhibit rigid-frame behaviour. Therefore, at-rest earth pressures should be assumed for design.

Seismic (earthquake) loading must also be taken into account in the design in accordance with Section 4.6 of the CHDBC. In this regard, the following should be taken into account in the lateral earth pressures.

- Seismic loading will result in increased lateral earth pressures. The culvert sides should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure. According to the National Building Code of Canada, this site is located in Seismic Zone 1. The site-specific zonal acceleration ratio for Sudbury is 0.05. Based on experience, for the subsurface conditions at this site, a 10 to 20 per cent amplification of the ground motion will occur, resulting in an increase in the ground surface acceleration from 0.05g to between 0.055g and 0.06g. The seismic lateral earth pressure coefficients given below have been derived based on a design zonal acceleration ratio of A = 0.06.

- For structures that do not allow lateral yielding, such as the rigid concrete box culverts, k_h is taken as 1.5 times the zonal acceleration ratio (i.e. $k_h = 0.09$). The seismic active earth pressure coefficient is also dependent on the vertical component of the earthquake acceleration, k_v. Three discrete values of vertical acceleration are typically selected for analysis, corresponding to $k_v = +2/3\ k_h$, $k_v = 0$, and $k_v = -2/3\ k_h$.

- The following seismic active pressure coefficients (K_{AE}) for the two cases (Case I and Case II) may be used in design; these coefficients reflect the maximum K_{AE} obtained using the k_h and three values of k_v as described above. It should be noted that these seismic earth pressure coefficients assume that the culvert side is vertical and the ground surface behind the wall is flat (within the grade limitations stated above).

SEISMIC ACTIVE PRESSURE COEFFICIENTS, K_{AE}

	Case I	Case II	
		Granular A	Granular B Type II
Non-yielding wall	0.37	0.30	0.30

Note : These CHBDC seismic K_{AE} values include the effect of wall friction ($\delta=\phi'/2$) and are less than the static values of K_a and K_o reported above for the very low zonal acceleration ratio for this site.

- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:

$$K \gamma' d + (K_{AE} - K) \gamma' H$$

Where

K is either the static active earth pressure coefficient (K_a) or the static at rest earth pressure coefficient (K_o);

K_{AE} is the seismic active earth pressure coefficient;

γ' is the effective unit weight of the soil (kN/m^3)

- taken as soil unit weights given above for fill materials
- taken as 20 kN/m^3 above Elev. 253 m for the native materials and 10 kN/m^3 below Elev. 253 m

d is the depth below the top of the wall (m); and

H is the height of the wall above the toe (m).

5.8 Subgrade Preparation, Bedding Requirements and Backfilling

Construction recommendations are given in the following subsections for the subgrade preparation, bedding and backfilling for the culverts at this site. Recommendations for construction of a temporary earth fill core in the culvert locations that are to be constructed after preloading are also given below.

5.8.1 Subgrade Preparation

In general, the organic/topsoil/peat deposits are to be removed from within the footprint area of the culvert. The founding soils are variable but will consist of loose to compact sandy soils or firm to very stiff silty clay (i.e. crust). These materials will be extremely sensitive to softening/disturbance due to construction traffic and ponding of water. In addition, the groundwater table is at or near ground surface at most of the culvert locations.

Where wick drains are used in the foundation treatment, consideration could be given to founding the culvert directly on the granular drainage blanket, depending on the required invert elevations. If it is necessary to excavate below the drainage blanket, special considerations will need to be given to minimizing wick drain damage. It is anticipated that continued operation of the wick drains will be facilitated by drainage into the culvert bedding materials in lieu of the drainage blanket. In this regard, any granular bedding for the culvert should be connected to the drainage blanket for the wick drains, to allow continued drainage of the underlying soils.

5.8.2 Bedding Requirements

The bedding (i.e. materials placed between the foundation soils and the bottom or invert of the culvert structure) for these culverts should be at least 400 mm in thickness and consist of Granular ‘A’ materials. The culverts should be designed for the full overburden pressure and livfe load, assuming an embankment fill unit weight of 19 kN/m^3. The bedding should be compacted in loose lifts not greater than 200 mm in thickness to 98 per cent of the material's Standard Proctor maximum dry density in accordance with OPSS 501.

Flowing water (i.e. creeks or water courses) are generally not a concern for the culverts at these sites, since the majority of the water is ponded in swampy areas or as a result of beaver dam construction. Therefore, it is not anticipated that water would flow underneath the culvert. If however, creek water is anticipated to flow either beneath the culverts (potentially causing undermining and scouring) or around the culverts (creating seepage through the embankment fill and potentially causing erosion and loss of fines), a clay seal is recommended to be provided at the upstream or inlet side of the culverts. The clay seal would be recommended at the downstream or outlet side of the culvert if flow was expected in this direction. The clay seal should have a minimum thickness of 0.3 m. It should be keyed into the natural subsoil and extend to a minimum horizontal distance of 2.0 m on either side of the culvert inlet opening and extend vertically to the high water level. The material for the clay seal shall be as per the Ministry’s standard specification OPSS 1205. As an alternative to the clay seal, a concrete apron could be also be installed around the culvert inlet to serve the same purpose.

Erosion protection should be provided to the culvert ends. Since the embankments are to be constructed out of rock fill, the rock fill should extend 2.0 m on either side of the culvert inlet and outlet (depending on flow patterns) and restricting the maximum size to 250 mm. An NSSP should be included in the contract documents for this purpose and is included in Appendix I.

5.8.3 Backfilling

Backfill to the culvert should be in accordance with OPSD 803.010 and 803.02. The fill should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 400 mm.

If the culverts are constructed prior to the embankments, the backfilling of the culvert will take place as part of the overall embankment construction. Rock fill placement should be carried out in accordance with the requirements as outlined in the Special Provision SP206S03. The rock should not be dumped in final position, but should be deposited on and pushed forward over the end of the layer being constructed. Voids and bridging shall be minimized by blading, dozing and ‘chinking’ the rock to form a dense, compact mass. In addition, any exposed rock fill surfaces should be ‘re-chinked’ prior to placing additional fill materials. An NSSP should be included in the contract documents for this purpose and is included in Appendix I.

If the culvert is constructed after the preload period, then the backfilling will take place after embankment construction. In this cases, the rock fill placement procedure becomes critical in order to reduce the settlement of the backfill above the culvert. As discussed in Section 5.4.1, consideration could also be given to reducing the maximum size of the rock fill backfill over the culvert as well as the lift thickness. An NSSP should be included in the contract documents for this purpose and is included in Appendix I. It is not recommended that granular fill be used as backfill to the culvert in this case, due to the differential settlement between the two fill types, as well as the potential for migration of fines of the granular materials into the void spaces within the rock fill. A geotextile separator fabric is not considered sufficient for long-term separation of these two materials. If granular material must be used, then consideration could be given to using a graded filter. A graded filter would consist of different sized materials extending back from the culvert towards the existing rock fill starting with the finest at the culvert and more coarse toward the rock fill.

Assuming the use of rock fill for all new embankments and for the embankment widening, final side slopes should be no steeper than 1.25H:1V.

5.8.4 Temporary Earth Fill Core

Where culverts are to be constructed after preloading is complete, excavation through the new embankment will be required to reach the founding level. In order to facilitate this excavation, it may be preferable that the embankment over the culvert area, or “temporary core” be constructed out of earth fill or Granular B Type II as such materials may be excavated more readily than rock fill. The material should be placed in accordance with in accordance with the requirements as outlined in the Special Provision SP206S03.

If constructed, the temporary core should encompass the entire width of the culvert (and temporary culvert if applicable) and bedding at the base and should extend upwards at 2H:1V from the base of the core to the top of the embankment. This requires that the rock fill slopes in the vicinity of the culvert also be formed at 2H:1V. A temporary geotextile separator should be placed between the rock fill and the granular or earth fill to prevent loss of fines into the rock fill. Since this is a short term solution, the geotextile separator should perform well in this function. A schematic of the temporary core is shown on Figure 10 for possible inclusion into the contract package.

After the preload period is complete, the culvert excavation should extend through the earth fill core should to the culvert founding level. The full earth fill core should be fully removed to the rock fill interface to maintain stability of the excavation.

5.9 Temporary Culverts

Where culverts are being constructed following the preload period, temporary culverts may be required to promote drainage during construction or to allow fish passage. Temporary culverts could consist of pre-cast culverts (box or pipe) or CSP pipes. It should be noted that significant settlements (as outlined in Table 4) are anticipated and the culvert should be sized such that the temporary culvert can still perform its intended function throughout the length of the embankment construction and preload period. Recommendations for bedding should be in accordance with the appropriate OPSD’s for the culvert type chosen and the recommendations included within this report. For pipe culverts, special attention should be paid to compacting the bedding under and around the haunches of the pipe.

The temporary culverts could be placed slightly offset from the permanent culvert location. The temporary culvert should be located within the temporary earth core (if constructed), or the temporary earth core base should be widened to accommodate the temporary culvert. Due to the potential size of the temporary culverts, it is recommended that the temporary culvert be fully removed after the permanent culvert is constructed. If it is not desirable to remove the temporary culvert, consideration could be given to backfilling the temporary culvert with “unshrinkable” fill.

5.10 Excavations and Groundwater Control

As noted throughout the report, excavation will be required below the culvert plan limits in order to remove topsoil and organic deposits as well as to place bedding material. Organic deposits at the culvert sites are typically less than about 1 m thick, except at Culvert Hwy 69 Station 19+845 (North tie-in) where the organic deposit is up to about 2 m thick. The water table is at about the ground surface, especially during periods of sustained precipitation. If necessary, ground water may be controlled by pumping from properly filtered sumps within the excavation, provided that surface flow is adequately controlled.

Excavations through the newly constructed embankments, where required for culvert construction, will extend through up to about 10 m of rock fill, earth or granular fill (as recommended in Section 5.8.4), from the crest of the embankment to the original ground. Temporary excavation side slopes within earth fill above the water table should be made at no steeper than 2H:1V. Below the original ground level (and therefore below the groundwater level), side slopes within the native materials should be made at no steeper than 3H:1V. Temporary excavation side slopes within the rock fill should be made at no steeper than 1.25H:1V.

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects.

Excavation support for roadway protection as well as space restrictions may be required at the north tie-in culvert (Hwy 69 Station 19+845). Where required, the temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 539S01. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP 539S01.

In the case of the culvert at the north tie-in (Station 19+845), and depending on the culvert construction method chosen, temporary sheeting may be required both for groundwater control and to permit construction staging. In addition, temporary earth fill berms may be required to divert water flow during culvert construction.

5.11 Closure

This report was prepared by Miss Sarah Poot, P.Eng., a senior geotechnical engineer and the technical aspects were reviewed by Mr. Storer J. Boone, P. Eng., an Associate with Golder Associates Ltd. Mr. Fintan J. Heffernan, P. Eng., a Designated MTO Contact for Golder, conducted a quality control review of the report.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
S. E. M. POOT
PROVINCE OF ONTARIO

Sarah Poot, P. Eng.,
Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
F. J. HEFFERNAN
PROVINCE OF ONTARIO

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

for Storer J. Boone, P.Eng.,
Associate

SEP/SJB/FJH/sep/stm
N:\Active\2003\1111\03-1111-011 URS Hwy 69\5000 Reporting\4-Culverts\Final Report\03-1111-011-4 RPT 05Jun Final Culvert Report.doc

REFERENCES

Bowles, J.E. 1984. Physical and Geotechnical Properties of Soils, 2nd Edition. McGraw-Hill Book Company, New York.

Kulhawy, F.H. and Mayne, P.W. 1990. Manual on Estimating Soil Properties for Foundation Design. EL-6800, Research Project 1493-6. Prepared for Electric Power Research Institute, Palo Alto, California.

Geology of Ontario. 1991. Ontario Geological Society, Special Volume 4, Part 1. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

MacFarlane, I.C., 1969. Muskeg Engineering Handbook. University of Toronto Press, Toronto.

Mesri, G. 1975. Discussion on new design procedure for stability of soft clays. ASCE Journal of the Geotechnical Engineering Division, 101 (GT4), pp. 409-412.

Peck, R.B., Hanson, W.E., and Thornburn, T.H. 1974. Foundation Engineering, 2nd Edition, John Wiley and Sons, New York.

Rutledge, P.C. and Gould, J.P. 1973. Movements of Articulated Conduits Under Earth Dams on Compressible Foundations, In: Embankment Dam Engineering – Casagrande Volume. Eds. Hirschfeld, R.C. and Poulos, S.J. John Wiley & Sons, New York.

Schmertmann, J.H. 1975. Measurement of In-Situ Shear Strength. In Proceedings, ASCE Specialty Conference on In-Situ Measurement of Soil Properties, Vol. 2, Raleigh, pp. 57-138.

U.S. Navy. 1971. Soil Mechanics, Foundations and Earth Structures. NAVFAC Design Manual DM-7, Washington, D.C.

TABLE 1
EVALUATION OF CULVERT CONSTRUCTION METHODOLOGY
HIGHWAY 69, G.W.P 327-91-00

Stability/ Settlement Mitigation Option	*Advantages*	*Disadvantages*	*Relative Costs*	*Risks/Consequences*
Alternative 1: (Preferred Alternative where settlements are small) Culvert Construction prior to Embankment Construction	• Common construction method	• Long-term settlement of subsoils below culvert; culvert needs to be articulated to account for settlement • Joint openings will occur as a result of vertical settlement and horizontal spreading of soil; short culvert segments will be required • Settlements and strains may still be too large even with short culvert segments	• Multiple joints to account for horizontal strain and camber will add to cost	• Poor drainage of culvert could occur as a result of post-construction settlement, even with a proper camber design, as a result of the variability in soil conditions along the length of the culverts • Risk of damage to culverts
Alternative 2: (Preferred Alternative) Culvert Construction following Preload Period	• Minimize post-construction settlement below the culvert • Common construction method; temporary earth fill core required to facilitate excavation	• Excavation through the new embankment will be required (between 6 and 10 m) to get to the founding level • Cannot be constructed until the preloading is complete; preload period dependant on the results of monitoring (typically 6 months to one year depending on foundation treatment)	• Excavation through new embankment will add to cost • Provision of earth fill core would add to cost	• Some differential settlement (minor) could occur between the rock fill embankment and the backfill to the culvert due to compression of the backfill itself
Alternative 3: (Preferred Alternative if limited clay thickness) Partial Sub-excavation	• Minimize post-construction settlement below the culvert • May be able to construct culvert prior to embankment construction	• Depending on the thickness of the compressible material, may not be able to practically remove enough material to reduce settlement to desirable levels • Culvert may still need to be articulated to account for settlement and horizontal strain	• Cost of sub-excavation and replacement backfill • Multiple joints to account for horizontal strain and camber will add to costs	• Poor drainage of culvert could occur as a result of post-construction settlement as a result of the variability in soil conditions along the length of the culverts • Risk of damage to culverts
Alternative 4: (Preferred Alternative where possible) Culvert Relocation	• Minimize post-construction settlement below the culvert	• Extensive bedrock blasting may be required • May not be possible from a drainage perspective	• Costs associated with blasting	• Drainage channel may not be in desired location
Alternative 5: Pile-Supported Culvert	• Minimize post-construction settlement below the culvert	• Large downdrag loads on piles from settlement of compressible soil; may require close pile spacing to obtain required load capacity • Piles lengths would range from 6 m to as deep as 37 m (120 feet) • Not common construction method	• Costs of piles/piling may be an order of magnitude higher than other foundation options, depending on the pile length and spacing	• Not recommended due to high costs and high loads • Differential settlement between embankment over culvert and embankment; leads to a “hard-point” on the roadway

TABLE 1
EVALUATION OF CULVERT CONSTRUCTION METHODOLOGY
HIGHWAY 69, G.W.P 327-91-00

Stability/ Settlement Mitigation Option	*Advantages*	*Disadvantages*	*Relative Costs*	*Risks/Consequences*
Alternative 6: Lightweight Fill	• Minimize post-construction settlement below the culvert • May be able to construct culvert prior to embankment construction • Use of EPS fill would likely reduce settlement to desirable levels	• Depending on the thickness of the embankment, use of lightweight slag fill may not reduce settlement to desirable levels • Culvert may still need to be articulated to account for settlement and horizontal strain	• Cost of EPS typically an order of magnitude higher than other options, depending on embankment thickness • Cost of slag fill much more expensive than rock fill and earth fill	• Poor drainage of culvert could occur as a result of post-construction settlement as a result of the variability in soil conditions along the length of the culverts (slag fill) option
Alternative 7: Ground Improvement (Wick Drains) (Stone Columns)	• Minimize post-construction settlement below the culvert	• Localized ground improvement beneath culvert may not tie-in with other mitigation schemes in the rest of the swamp • Culvert may still need to be construction following embankment construction depending on time rate of settlement associated with the mitigation scheme	• Cost of implementing ground improvement scheme	• Some differential settlement could occur between the rock fill embankment and the backfill to the culvert due to compression of the backfill itself
Alternative 8: Tunnelling	• Minimize differential settlement between fill types since backfilling not required	• Temporary earth fill core required to facilitate tunnelling through embankment since tunnelling through rock fill would be difficult • Not common construction method in Northern Ontario • Temporary liners may be required • Culvert may still need to be construction following embankment construction to minimize post-construction settlements	• Costs associated with tunnelling may be prohibitive; for number of culverts on this project, some cost savings may be realized	• Poor drainage of culvert could occur as a result of post-construction settlement as a result of the variability in soil conditions along the length of the culverts

TABLE 2
SUMMARY OF GEOTECHNICAL ENGINEERING PARAMETERS
HIGHWAY 69, G.W.P 327-91-00

Culvert Location (Station)	*Stratigraphic Unit*	*Top Elevation (m)*	*Thickness (m)*	γ' (kN/m^3)	ϕ' (^{o})	c' (kPa)	S_u (kPa)	C_c	C_r	$c_v^{(1)}$ (cm^2/s)	*E (MPa)*
Culvert Hwy 69 Station 12+200	Silty Clay to Clay (crust)	237 - 239	1.4 - 3.0	19	26	0	160 - 35	0.40	0.04	$5.8x10^{-3}$	-
	Clayey Silt to Silty Clay	234 - 235	2.0 - 7.6	19	25	0	40 - 25	0.40 - 0.15	0.04 - 0.02	$5.8x10^{-3}$	-
	Silty Sand to Sandy Silt	228 - 233	0.4 - 3.1	20	29	0	-	-	-	-	7
	Clayey Silt to Silty Clay	227 – 231	1.4 - 2.8	19	26.5	0	45	0.15	0.02	$5.8x10^{-3}$	-
	Silty Sand to Sandy Silt	226 – 228	0.6 - 6.1	20	29	0	-	-	-	-	7
	Silty Sand to Sand and Gravel	223 – 225	0.2 - >14.9	20	29	0	-	-	-	-	25
Culvert Hwy 69 Station 14+100	Silty Sand to Sandy Silt	237 - 238	0.7 - 2.3	20	29	0	-	-	-	-	10
	Clayey Silt to Silty Clay (crust)	236 - 237	0.8 - 3.0	19	26.5	0	140 - 50	0.50	0.05	$5.8x10^{-3}$	-
	Clayey Silt to Clay	234 - 235	6.0 - 20.6	19	23	0	70 - 35	0.55 - 0.25	0.055-0.025	$5.8x10^{-3}$	-
	Silt to Sandy Silt	216 - 223	4.4 - >8.2	20	29	0	-	-	-	-	7
	Sand and Gravel to Sand	210 - 212	-	20	29	0	-	-	-	-	25
Culvert Hwy 69 Station 14+940	Silty Clay (including crust)	241 - 244	1.5 - 10.0	19	25	0	60	0.50 - 0.10	0.05-0.01	$5.8x10^{-3}$	-
	Silty Fine Sand to Sandy Silt	237 – 239	1.0 - 6.0	20	30	0	-	-	-	-	10
	Silty Clay to Clayey Silt	233 - 235	1.0 - 4.0	19	23	0	50 - 40	0.25 - 0.10	0.02-0.01	$5.8x10^{-3}$	-
	Sandy Silt to Silty Fine Sand	230 - 233	1.5 - >8.0	20	31	0	-	-	-	-	25

TABLE 2
SUMMARY OF GEOTECHNICAL ENGINEERING PARAMETERS
HIGHWAY 69, G.W.P 327-91-00

Culvert Location (Station)	*Stratigraphic Unit*	*Top Elevation (m)*	*Thickness (m)*	γ' (kN/m^3)	ϕ' (^{o})	c' (kPa)	S_u (kPa)	C_c	C_r	$c_v^{(1)}$ (cm^2/s)	E (MPa)
Culvert Hwy 69 Station 16+000 & Station 16+150	Clayey Silt to Silty Clay	255 - 256	<4.0	19	25	0	40	0.50 - 0.10	0.05-0.01	$5.8x10^{-3}$	-
	Sandy Silt, Silty Sand, and Sand	variable	0.3 - >5.0	20	32	0	-	-	-	-	30
Culvert Hwy 69 Station 19+845	Peat	~236	0.2 - 2.9	15	15	0	-	-	-	-	1
	Clayey Silt to Clay	234 - 236	1.0 - 14.0	19	23	0	120 - 30	0.25 – 0.5	0.025-0.05	$5.8x10^{-3}$	-
	Silty Sand	223 - 228	0.5 - >6.0	20	29	0	-	-	-	-	9
Culvert Hwy 537 Station 11+020	Sand to Sand and Gravel containing Boulders	variable	0 - >5.0	20	32	0	-	-	-	-	30
Culvert Hwy 537 Station 11+940	Silty Clay to Clay (crust)	228 - 229	1.1 - 2.9	19	22	0	120 - 50	0.30	0.035	$5.8x10^{-3}$	-
	Clayey Silt to Silty Clay	226 - 227	1.6 - 9.2	19	25	0	40 - 20	0.50 - 0.10	0.05 - 0.01	$5.8x10^{-3}$	-
	Silty Sand to Sand	222 - 224	0.5 - >12.9	20	29	0	-	-	-	n/a	25

Notes: 1. Coefficient of consolidation based on average value for deposit.

TABLE 3
RESULTS OF CONSOLIDATION TESTING
HIGHWAY 69, G.W.P 327-91-00

Culvert Location	***Borehole and Sample No.***	***Elevation (m)***	σ_{vo}' ***(kPa)***	σ_p' ***(kPa)***	***OCR***	e_o	C_r	C_c	c_v^* ***(cm^2/s)***
Hwy 69 Station 12+200	BH 11, Sa#5	233.0	45	82	1.82	0.83	0.033	0.255	3.08 x 10^{-3}
	BH 17, Sa#6	231.6	59	73	1.24	0.77	0.022	0.154	1.49 x 10^{-2}
	BH 121, Sa#9	229.0	86	142	1.70	1.09	0.041	0.329	1.08 x 10^{-2}
Hwy 69 Station 14+100	BH 51, Sa#10	226.9	100	134	1.34	1.45	0.075	0.680	1.03 x 10^{-3}
	BH 122, Sa#10	225.4	116	163	1.40	1.01	0.036	0.328	1.01 x 10^{-2}
	BH 123, Sa#8	229.9	70	100	1.40	1.35	0.065	0.582	1.59 x 10^{-3}
	BH 123, Sa#12	223.8	120	146	1.20	1.68	0.107	0.812	9.92 x 10^{-4}
	103-12N, Sa#5 (1)	231.8	50	200	4.00	1.22	0.047	0.600	1.00 x 10^{-3}
	103-12N, Sa#9(1)	225.6	114	200	1.75	0.84	0.033	0.400	2.17 x 10^{-3}
	103-13S, Sa#10A(1)	223.1	95	410	4.32	1.44	0.055	0.880	2.17 x 10^{-3}
Hwy 69 Station 14+940	BH 110-2S, Sa#3(2)	239.3	32	640	20.0	0.90	0.055	0.490	7.00 x 10^{-3}
	BH 110-3S, Sa#9(2)	230.0	108	250	2.69	0.88	0.020	0.250	5.17 x 10^{-3}
Hwy 69 Station 19+845	BH 305-3N, Sa#4(2)	231.3	43	290	6.74	0.93	0.055	0.26	9.50 x 10^{-3}
Hwy 537 Station 11+940	BH 85, Sa#6	222.8	45	104	2.31	1.25	0.051	0.475	1.91 x 10^{-3}
	BH 92, Sa#5	224.7	31	242	7.81	0.94	0.035	0.287	9.36 x 10^{-3}

Note: *For stress range of $150 \leq \sigma_v' \leq 2000$ kPa (for Golder Associates test results)
For stress range of $50 \leq \sigma_v' \leq 400$ kPa (for Peto MacCallum test results)

where: σ_{vo}' is the effective overburden pressure in kPa
σ_p' is the preconsolidation pressure in kPa
OCR is overconsolidation ratio
e_o is initial void ratio
C_c is the compression index (based on void ratio)
C_r is the recompression index (based on void ratio)
c_v is the coefficient of consolidation in cm^2/s in the normally consolidated range

Notes:
1. Data obtained from Peto MacCallum Ltd. Draft Report No. 01TF003, dated August 2001.
2. Data obtained from Peto MacCallum Ltd. Final Report No. 01TF003, dated May 2003.

TABLE 4
SUMMARY OF RESULTS OF SETTLEMENT AND STABILITY ANALYSIS – CULVERTS
HIGHWAY 69, G.W.P 327-91-00

Culvert Location	*Summary of Soil Conditions*	*Proposed Embankment Height*	*Preferred Mitigation Alternative*(1)	*Estimated Preload Period*(2)	*Stability*	*Maximum Post-Construction Settlement*(4)		*Horizontal Strain* (4) *(Alternative 1)*			
					Factor of Safety(3)	**Alternative 1**(5)	**Alternative 2**(5)	**Vertical Strain**	**Estimated Ratio of Horizontal Strain to Vertical Strain (ε_h / ε_v)**	**Horizontal Strain**	**Estimated Maximum Joint Opening**(6)
Hwy 69 12+200	Up to 12 m of clay Up to 17 m of sand/silt	6.5 m	Wick Drains	8 months	> 1.3 (2m wide berm req'd)	~400 mm (See Figure 4)	< 25 mm (See Figure 4)	0.014	0.45	0.006	0.006L
Hwy 69 14+100	Up to 20 m of clay Up to 23 m of sand/silt	7 m	Wick Drains	1 year	> 1.3	~725 mm (See Figure 5)	< 25 mm (See Figure 5)	0.018	0.50	0.009	0.009L
Hwy 69 14+940	Up to 9 m of clay Up to 13 m of sand/silt	5.5 m	Wick Drains	8 months	> 1.3	~225 mm (See Figure 6)	< 25 mm (See Figure 6)	0.017	0.25	0.004	0.004L
Hwy 69 16+016	Up to 4 m of clay Up to 5 m of sand/silt	6 m	Preloading	6 months	> 1.3 (2m wide berm req'd)	~100 mm (See Figure 7A)	< 25 mm (See Figure 7A)	0.023	0.45	0.010	0.010L
Hwy 69 16+137	Up to 8 m of sand/silt	6 m	Preloading	6 months	> 1.3	~50 mm (See Figure 7B)	< 25 mm (See Figure 7B)	0.015	0.45	0.007	0.007L
Hwy 69 19+845	Up to 11 m of clay Up to 2 m of sand/silt	3 m	Preloading	6 months	> 1.3	~75 mm (See Figure 8)	~ 25 mm (See Figure 8)	0.015	0.45	0.007	0.007L
Hwy 537 11+015	Up to 10 m of sand/silt	13 m	Preloading	6 months	> 1.3	~100 mm	< 25 mm	0.010	0.60	0.006	0.006L
Hwy 537 11+940 Hwy 537 12+130	Up to 6 m of clay Up to 3 m of sand/silt	10 m 3.5 m	Wick Drains	12 months	> 1.3 (2m wide berm req'd)	~200 mm ~75 mm (See Figure 9A and 9B)	< 25 mm < 25 mm (See Figure 9A and 9B)	0.029 0.015	0.50 0.45	0.014 0.007	0.014L 0.007L

NOTES:

1. The settlement/stability mitigation alternative recommend for the swamp as discussed in the Swamp Crossings/High Fills Report (Golder, July 2005).
2. The preload period is estimated from the preliminary wick drain design (as discussed in the Swamp Crossings/High Fills Report (Golder, July 2005). The length of the preload period will ultimately be determined in the field by monitoring.
3. The global factor of safety against a deep seated failure surface as reported in the Swamp Crossings/High Fills Report (Golder, July 2004). A factor of safety of 1.3 is considered appropriate. Assumes the appropriate mitigation scheme is implemented.
4. Alternative 1 is when the culvert is constructed at the same time as the embankment construction. Alternative 2 is when the embankment is constructed following the preload period.
5. Assumes that all peat/organic material has been removed prior to culver/embankment construction.
6. Where L is the length of each culvert segment.

TABLE 5
SUMMARY OF RECOMMENDATIONS – CULVERTS
HIGHWAY 69, G.W.P 327-91-00

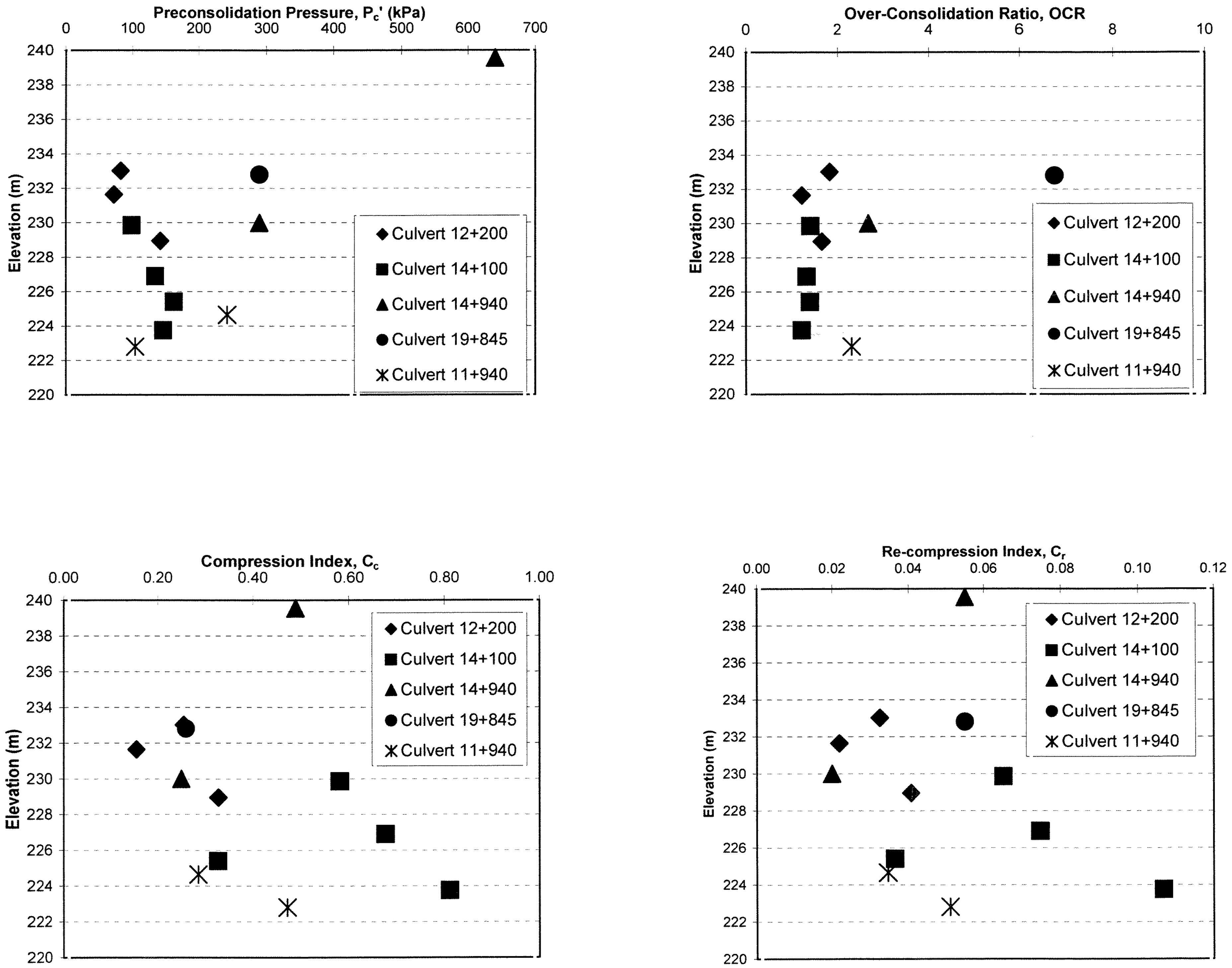
Culvert Location	*Proposed Embankment Height*	*Recommended Swamp Mitigation Alternative(1)*	*Recommendation*	*Resulting Maximum Post-Construction Settlement(2)*
Hwy 69 12+200	6.5 m	Wick Drains	Construct culvert after preload period. Use temporary earth fill core.	< 25 mm
Hwy 69 14+100	7 m	Wick Drains	Construct culvert after preload period. Use temporary earth fill core.	< 25 mm
Hwy 69 14+940	5.5 m	Wick Drains	Construct culvert after preload period. Use temporary earth fill core.	< 25 mm
Hwy 69 16+016	6 m	Preloading	Construct culvert prior to embankment construction using appropriate camber and segment lengths.	100 mm
Hwy 69 16+137	6 m	Preloading	Construct culvert prior to embankment construction using appropriate camber and segment lengths.	50 mm
Hwy 69 19+845	3 m	Preloading	Construct culvert prior to embankment construction using appropriate camber and segment lengths in widening area.	75 mm
Hwy 537 11+015	13 m	Preloading	Construct culvert prior to embankment construction using appropriate camber and segment lengths.	100 mm
Hwy 537 11+940 Hwy 537 12+130	10 m 3.5 m	Wick Drains	Relocate culvert to Station 12+230. Construct culvert prior to embankment construction.	75 mm

NOTES:

1. The settlement/stability mitigation alternative recommend for the swamp as discussed in the Swamp Crossings/High Fills Report (Golder, July 2005).
2. Assumes that all peat/organic material has been removed prior to culvert/embankment construction.

HIGHWAY 69 AND HIGHWAY 537 CULVERTS
GEOTECHNICAL ENGINEERING PARAMETER SUMMARY
COHESIVE DEPOSITS

FIGURE 1



NOTES:

1. These graphs must be read in conjunction with Section 5.0 of the accompanying report.

DRAFT
Golder Associates

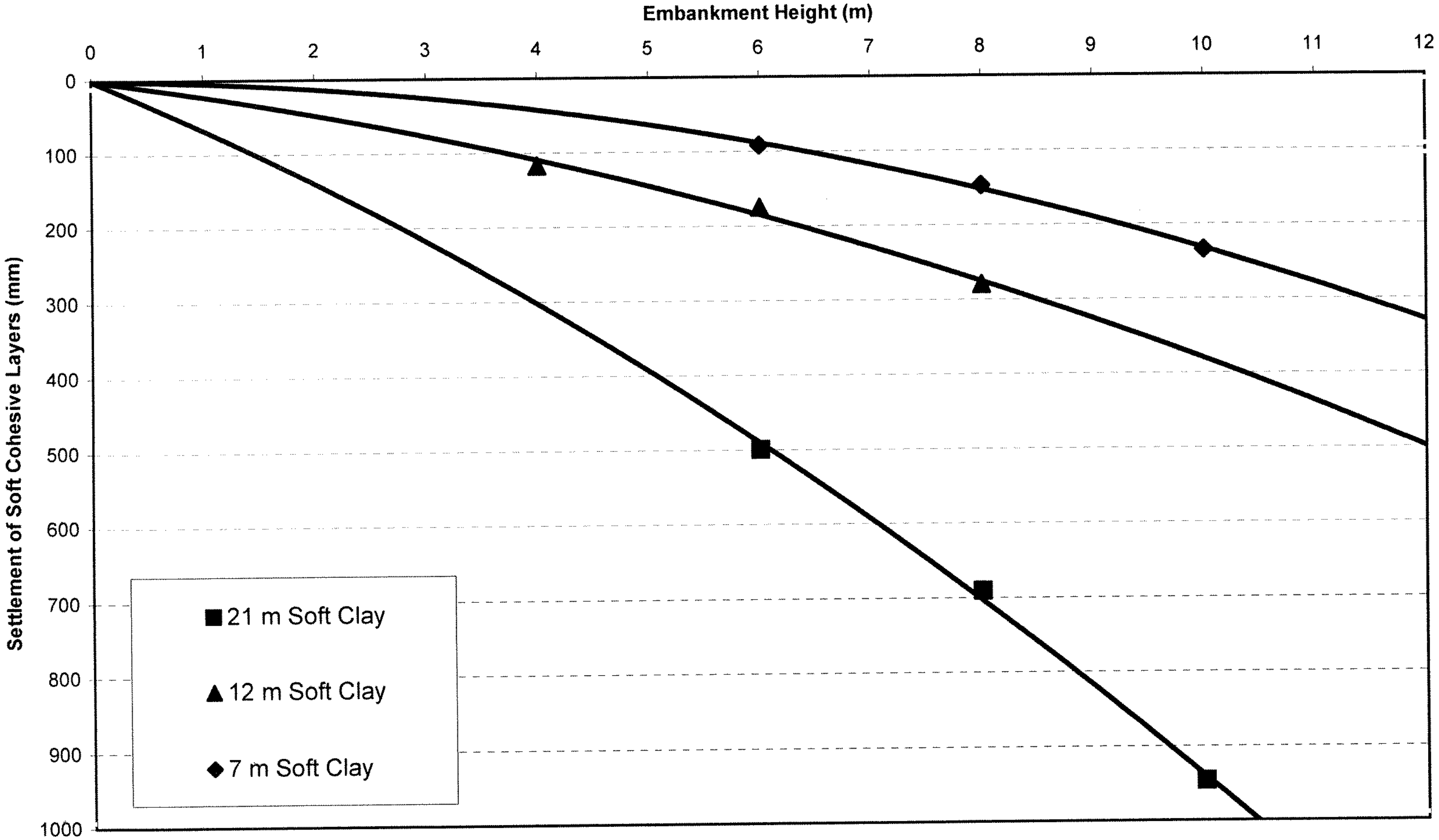
Date:	June 2005	**DB:**	SEP
Project No:	03-1111-011-4	**CHK:**	SJB

Golder Associates

C:\Documents and Settings\spoot.GOLDER\My Documents\SPOOT\Ongoing Projects\Hwy 69\Reports\Culvert\Final Report\[03-1111-011-4 FIG1 04Dec Oedometer.xls]Figure 1

SETTLEMENT FOR VARIOUS EMBANKMENT HEIGHTS AND COHESIVE LAYER THICKNESSES
HWY 69 AND HWY 537 CULVERTS

FIGURE 2

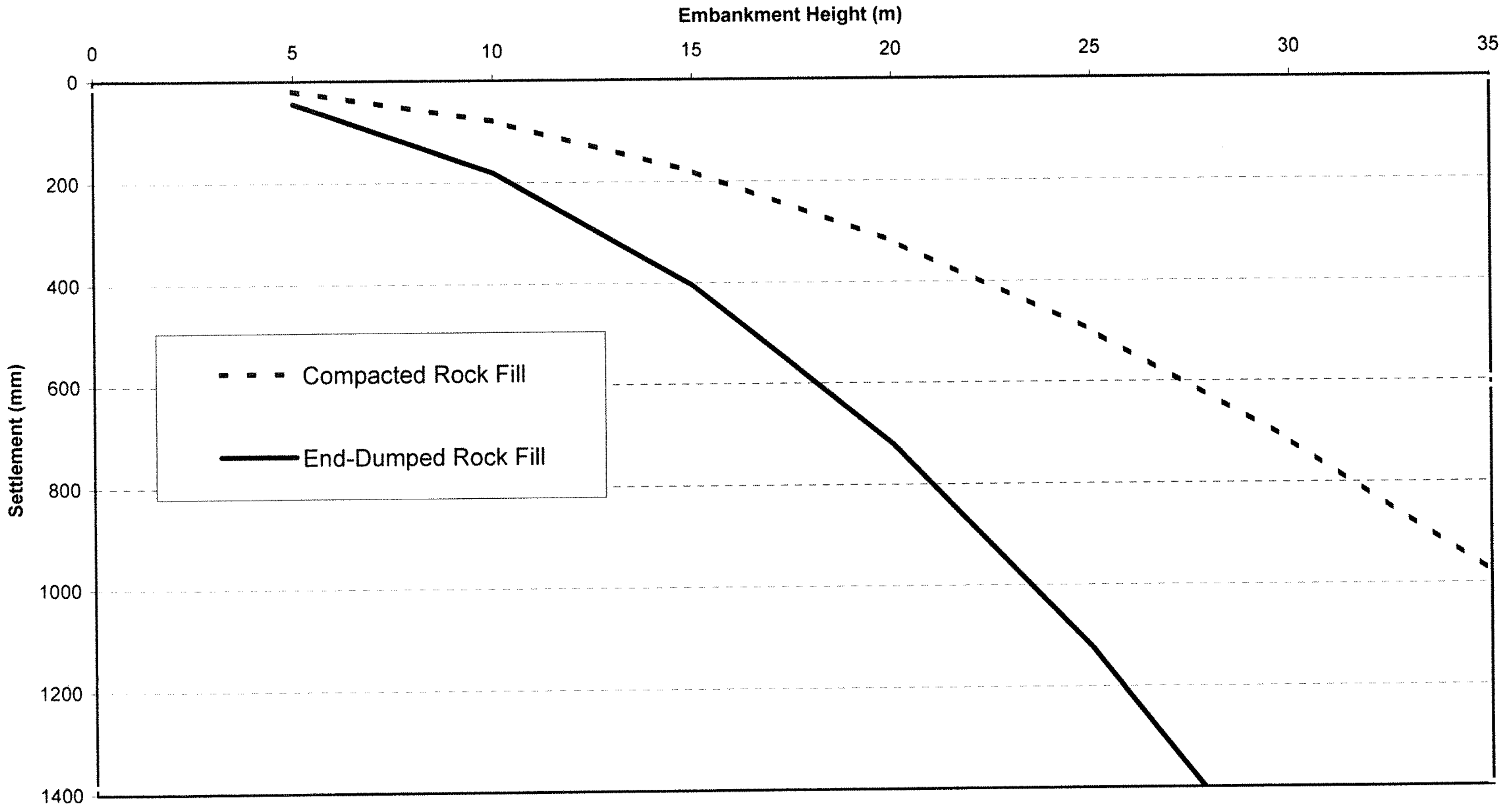


Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT OF ROCK FILL	FIGURE 3



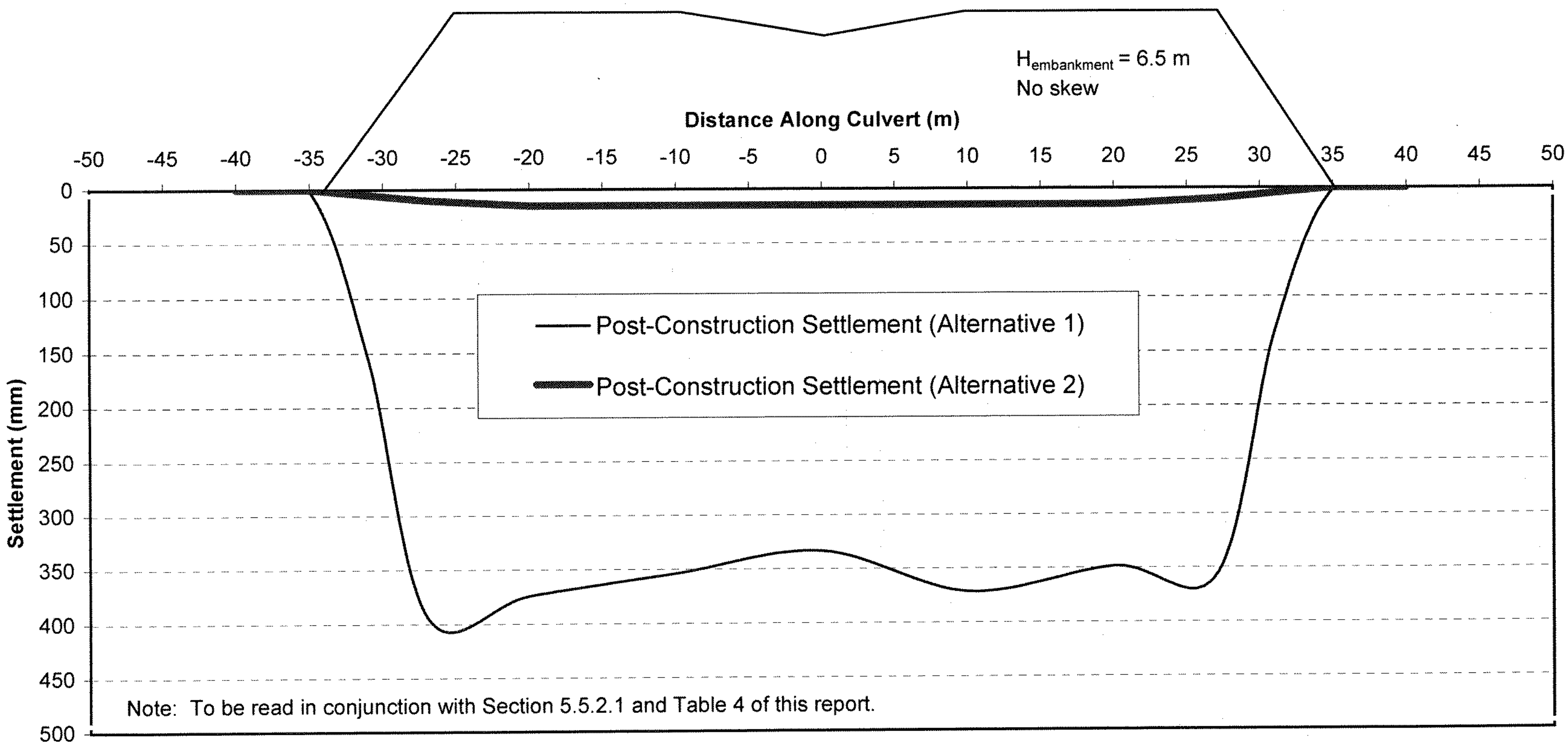
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 12+200

FIGURE 4



Note: To be read in conjunction with Section 5.5.2.1 and Table 4 of this report.

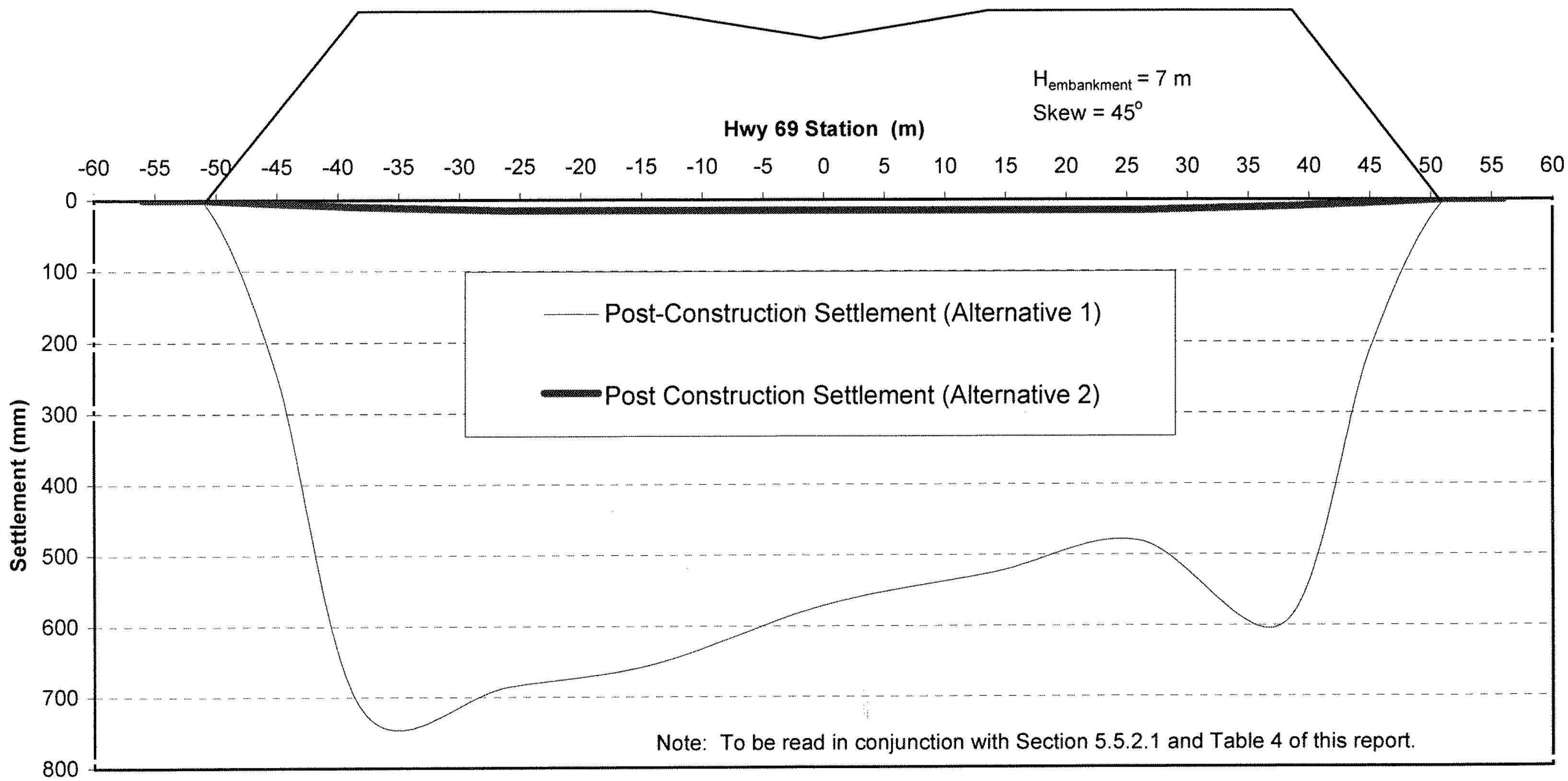
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 14+100

FIGURE 5



Note: To be read in conjunction with Section 5.5.2.1 and Table 4 of this report.

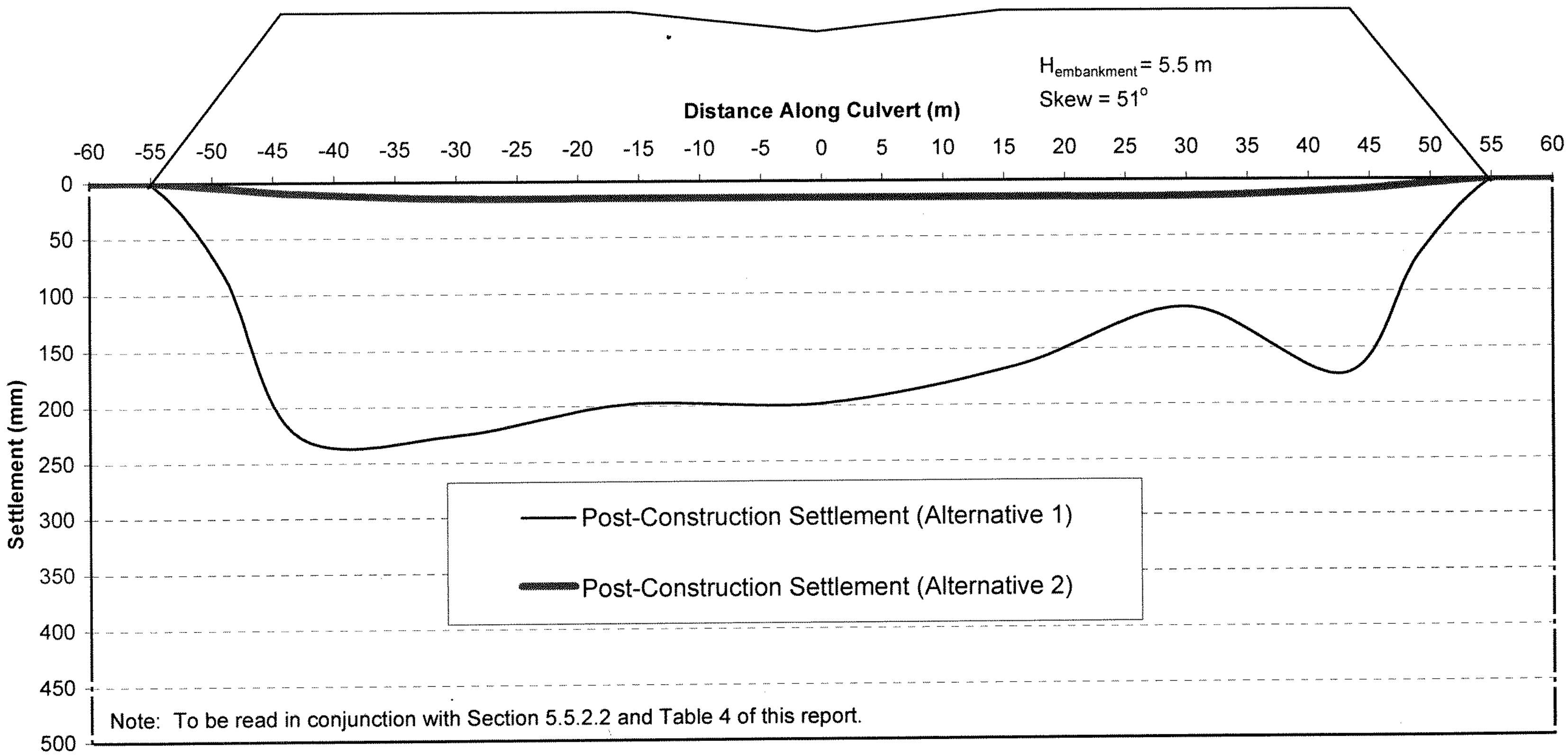
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 14+940

FIGURE 6



Note: To be read in conjunction with Section 5.5.2.2 and Table 4 of this report.

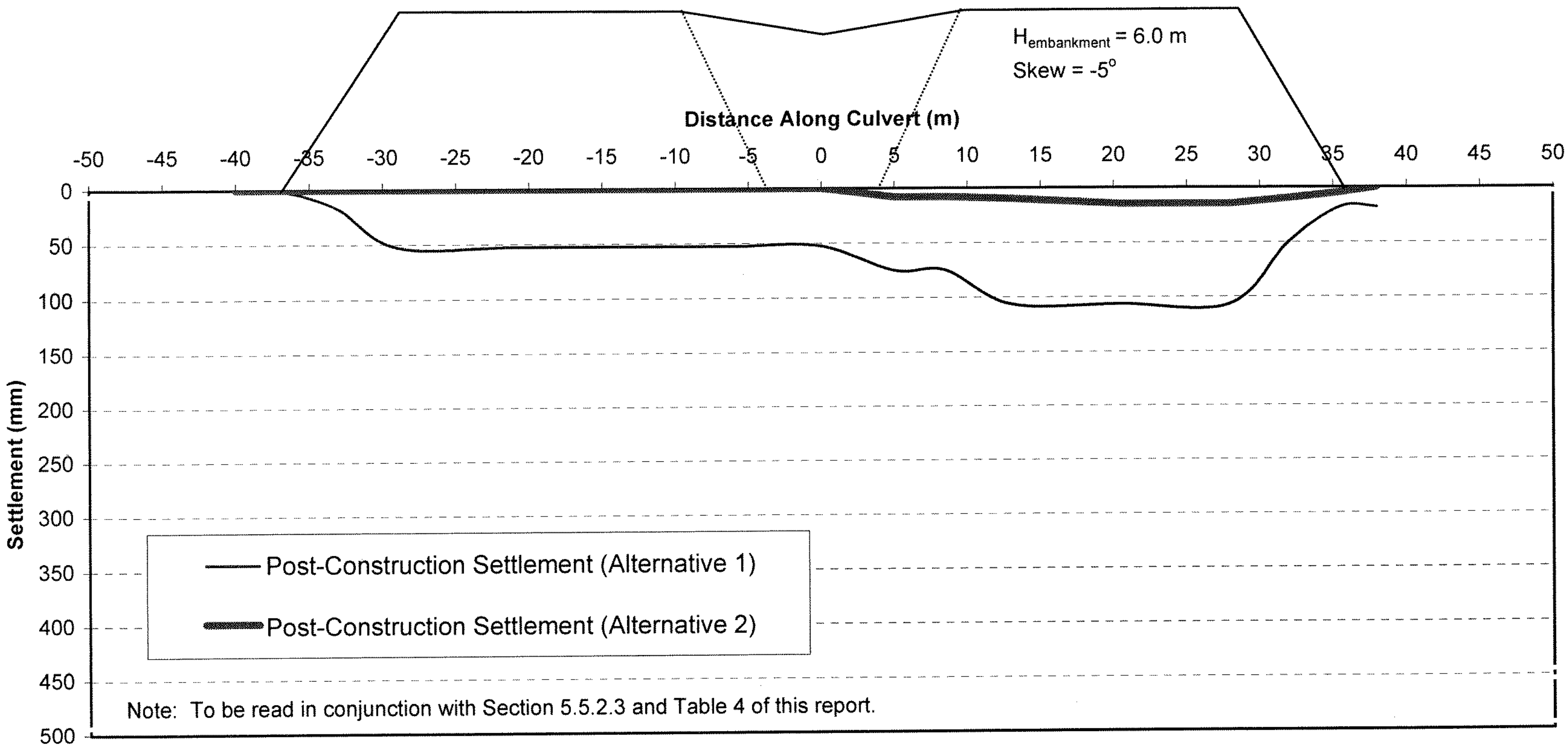
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 16+016

FIGURE 7A



Note: To be read in conjunction with Section 5.5.2.3 and Table 4 of this report.

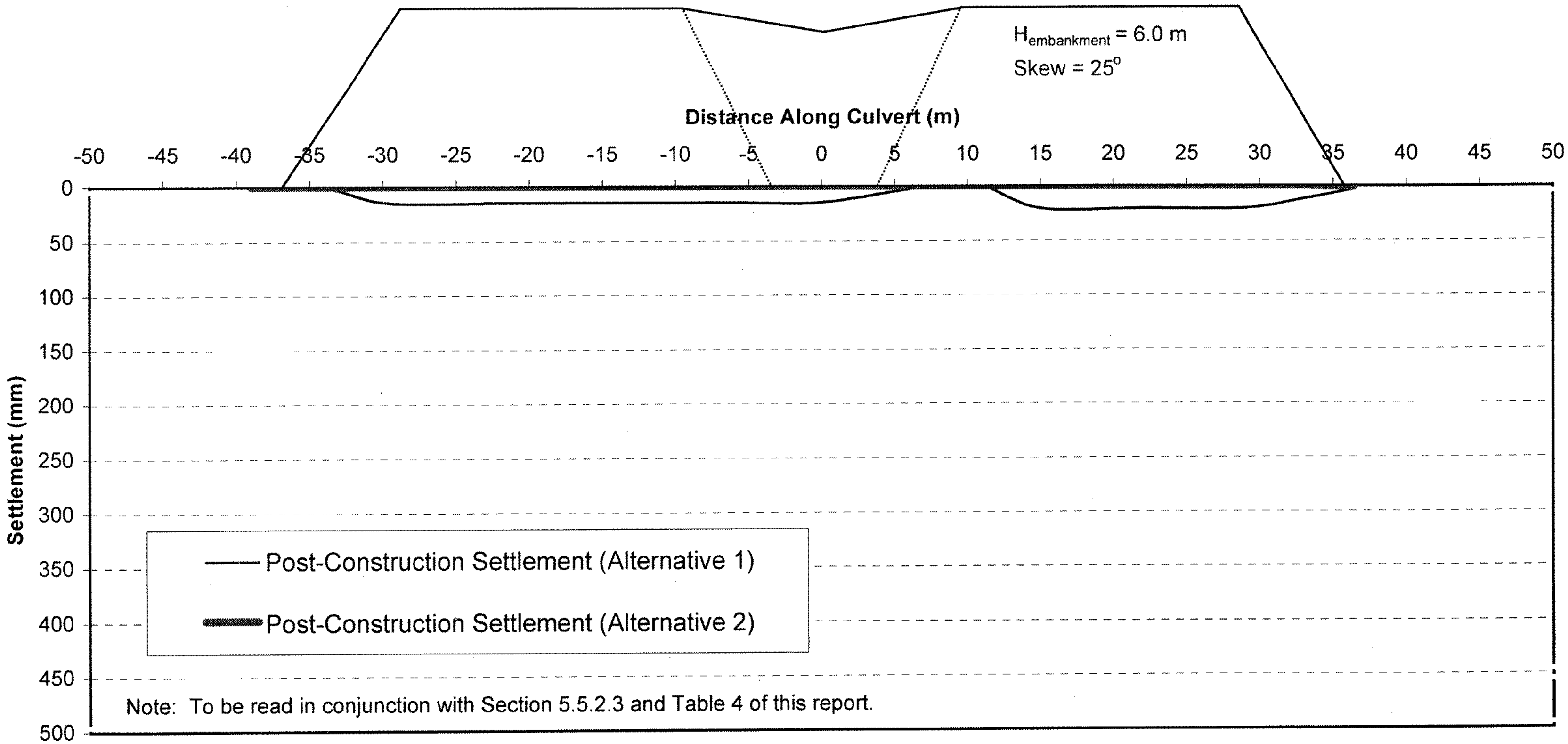
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 16+137

FIGURE 7B



Note: To be read in conjunction with Section 5.5.2.3 and Table 4 of this report.

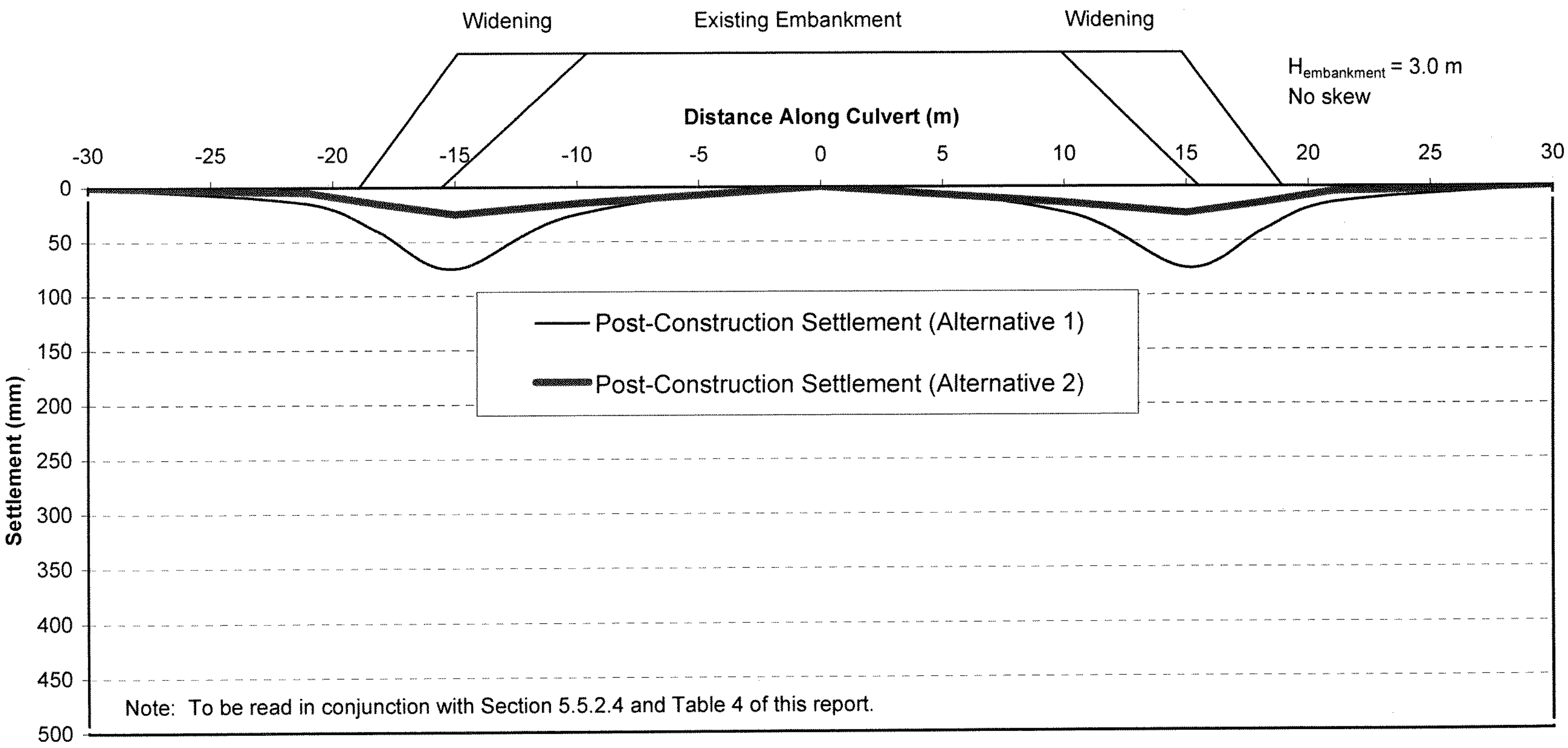
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 69 Station 19+845

FIGURE 8



Note: To be read in conjunction with Section 5.5.2.4 and Table 4 of this report.

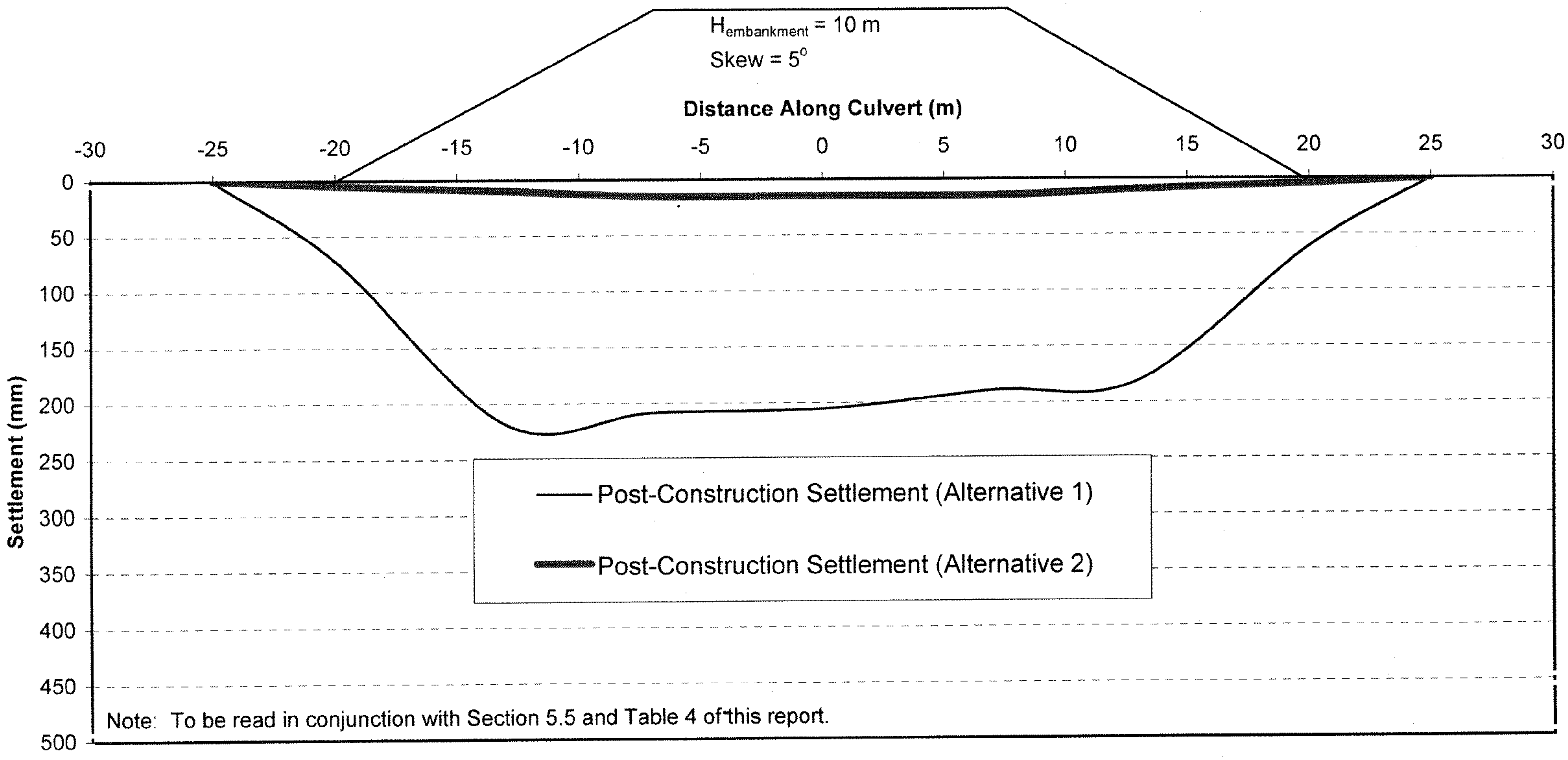
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

SETTLEMENT PROFILE
Culvert Hwy 537 Station 11+940

FIGURE 9A



Note: To be read in conjunction with Section 5.5 and Table 4 of this report.

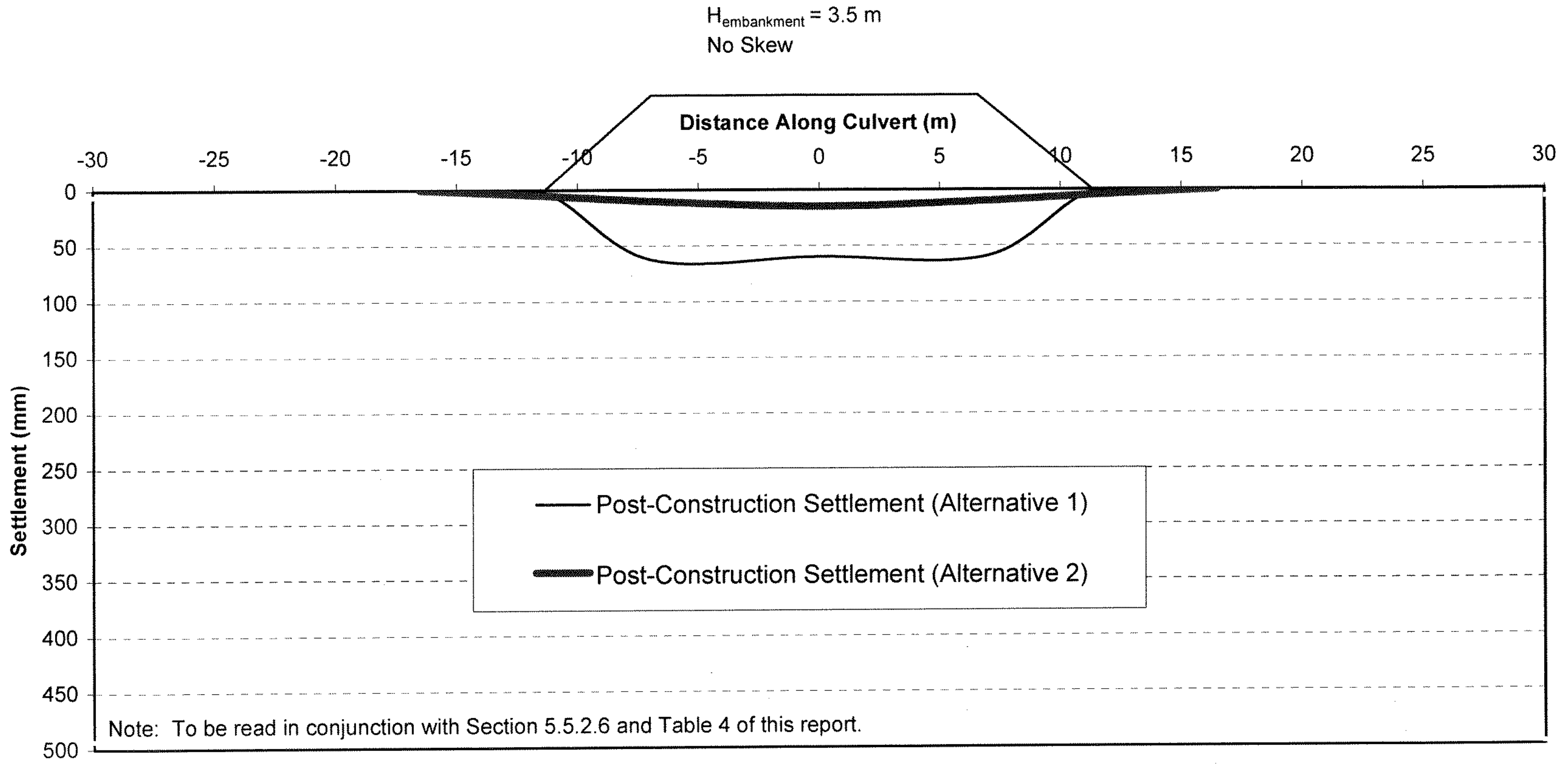
Date: June 2005
Project: 03-1111-011-4

Golder Associates

Drawn: SEP
Checked: SJB

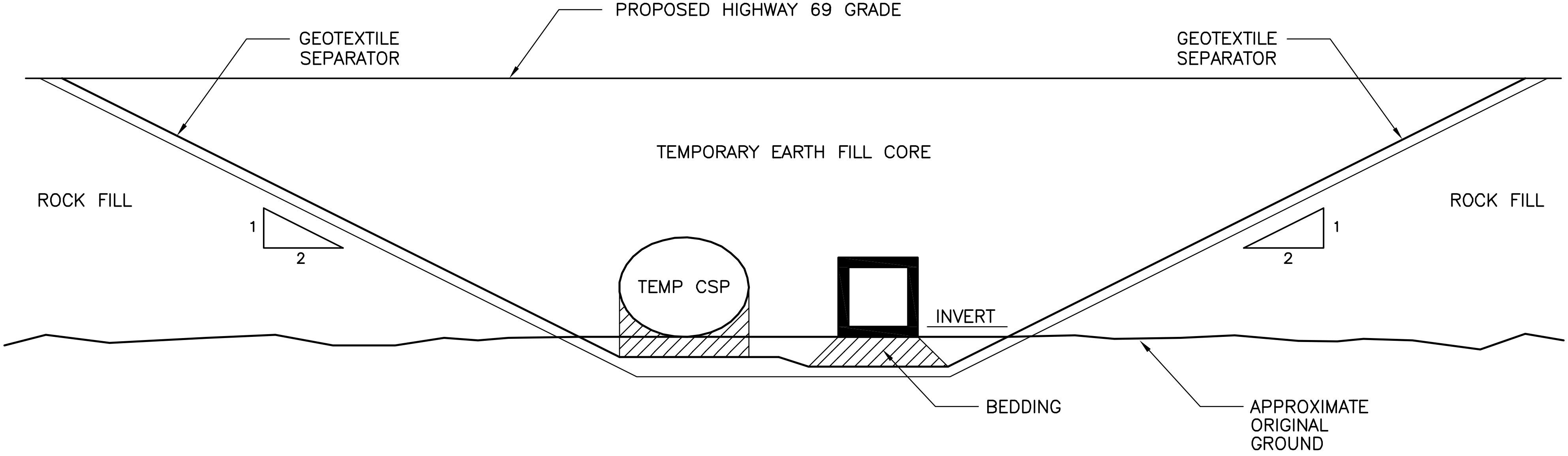
SETTLEMENT PROFILE
Culvert Hwy 537 Station 12+130

FIGURE 9B



Note: To be read in conjunction with Section 5.5.2.6 and Table 4 of this report.

Date:	June 2005		Drawn:	SEP
Project:	03-1111-011-4	**Golder Associates**	Checked:	SJB



Golder Associates
Mississauga, Ontario, Canada

SCALE	N.T.S.	TITLE	
DATE	JUNE 2005		
DESIGN			
CAD	MSM		
CHECK	SEP	FIGURE	10
REVIEW	FJH		

FILE No. 031111011JA001.dwg
PROJECT No. 03-1111-011-4 REV.

HIGHWAY 69 FOUR-LANING
FROM 0.3 KM NORTH OF HIGHWAY 537 NORTHERLY 8.8 KM

TEMPORARY EARTH FILL CORE

FIGURE 10

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

HIGHWAY 69 (NEW)
AND HIGHWAY 537 (NEW)
KEY PLAN–CULVERT LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

LEGEND

⩛	SWAMP CROSSING INVESTIGATED BY GOLDER FOUNDATION/GEOTECHNICAL
☐	HIGH FILL AREA INVESTIGATED BY GOLDER FOUNDATION/GEOTECHNICAL
■	SWAMP CROSSING INVESTIGATED BY PETO MacCALLUM LTD.
═	CULVERT LOCATIONS
▨	DEEP CUT AREA INVESTIGATION BY GOLDER FOUNDATIONS/GEOTECHNICAL

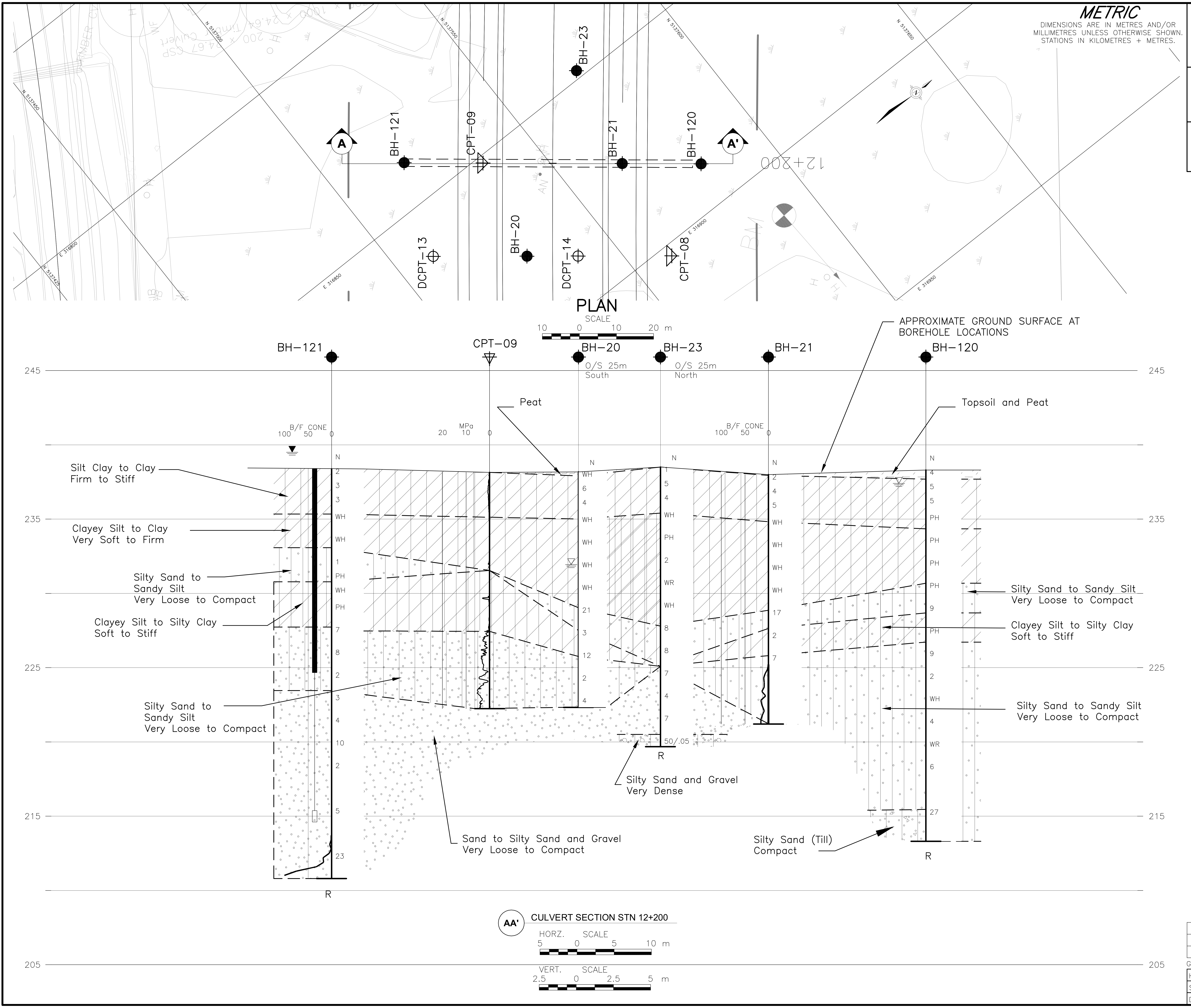
NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO.03–1111–011–4	DIST.
SUBM'D.	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JDR/MSM	CHKD. SEP	APPD. FJH	DWG. 1

PLOT DATE: June 13, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\03111101 1GC001.dwg

MINISTRY OF TRANSPORTATION, ONTARIO



METRIC

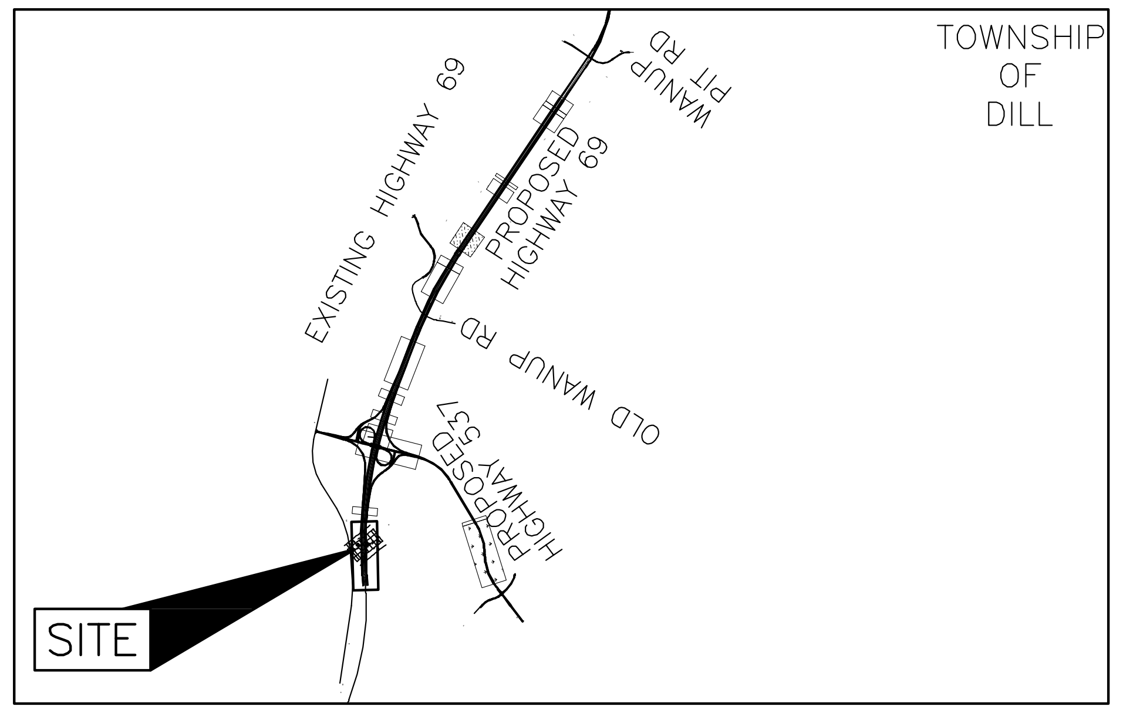
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

HIGHWAY 69
CULVERT STATION 12+200
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE
1.5 0 1.5 km

LEGEND

●	Borehole
	Cone Penetration Test
⊕	Dynamic Cone Penetration Test
	Refusal
	Seal
	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▼	WL in piezometer, measured on OCT. 5, 2004
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH-20	238.2	5137529.6	316878.9
BH-21	238.0	5137565.2	316875.3
BH-23	238.5	5137571.0	316848.0
BH-120	238.3	5137581.8	316888.5
BH-121	238.4	5137519.2	316838.6
CPT-08	238.1	5137560.2	316903.0
CPT-09	238.1	5137535.8	316851.9
DCPT-13	238.2	5137509.7	316863.3
DCPT-14	238.0	5137540.4	316887.4

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO. 03-1111-011-4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 2

PLOT DATE: June 03, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\0311111011GC002.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

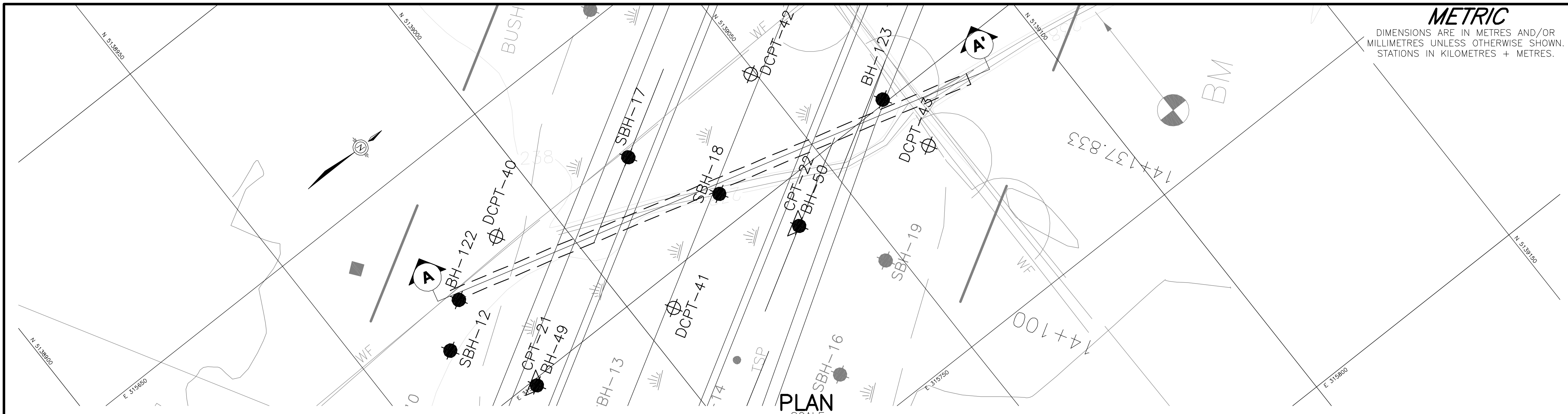
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

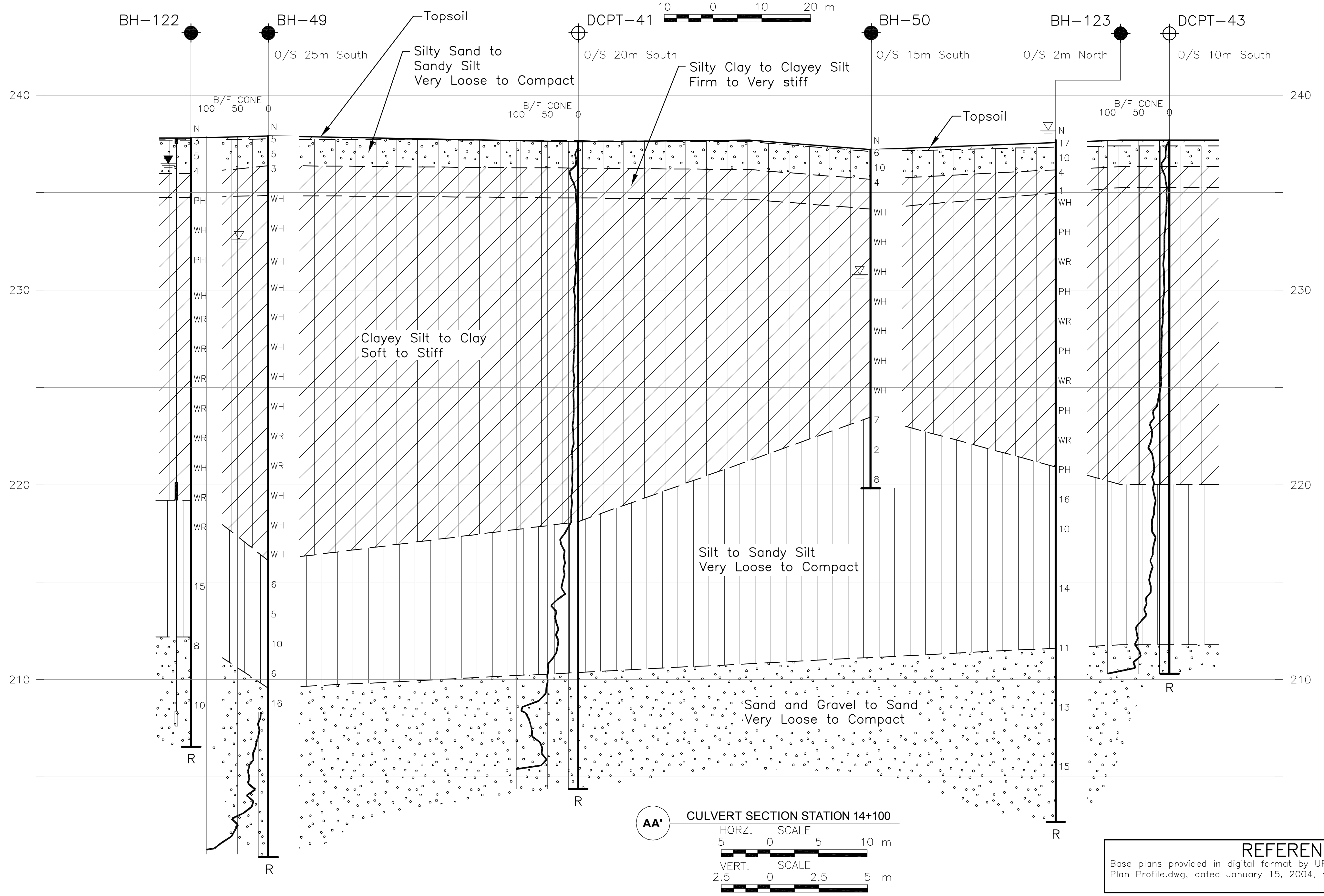
HIGHWAY 69
CULVERT STATION 14+100
BORESHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
10 0 10 20 m

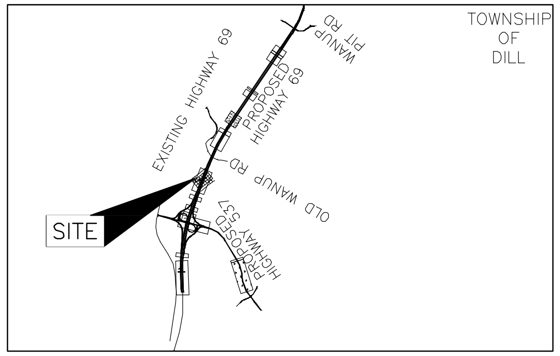


AA'

CULVERT SECTION STATION 14+100

HORZ. SCALE
5 0 5 10 m

VERT. SCALE
2.5 0 2.5 5 m



KEY PLAN

SCALE
1.5 0 1.5 km

LEGEND

●	Borehole
⊕	Cone Penetration Test
⊕	Dynamic Cone Penetration Test
R	Refusal
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▼	WL in piezometer, measured on OCT. 8, 2004
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH-49	237.9	5138975.7	315701.2
BH-50	237.2	5139037.7	315708.8
BH-122	237.8	5138974	315677.6
BH-123	237.7	5139067	315699.2
CPT-21	237.8	5138975.7	315701.2
CPT-22	237.2	5139037.7	315708.8
DCPT-40	237.5	5138982.4	315763.2
DCPT-41	237.6	5139007.3	315706.1
DCPT-42	237.6	5139068.5	315712.4
DCPT-43	237.7	5139068.5	315712.4
SBH-12	237.8	5138966.2	315684.7
SBH-17	237.7	5139019.1	315676.3
SBH-18	237.7	5139029.0	315693.4

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO. 03-1111-011-4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 3

PLOT DATE: June 03, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\03111101100003.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

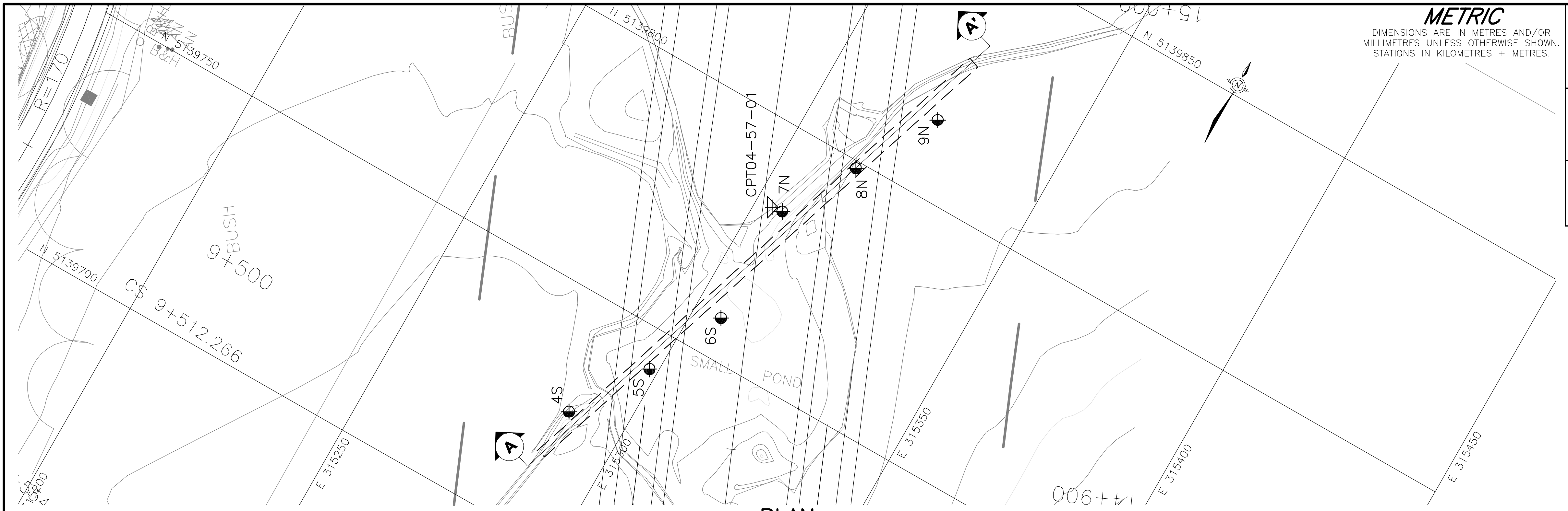
CONT No.
WP No.

SHEET

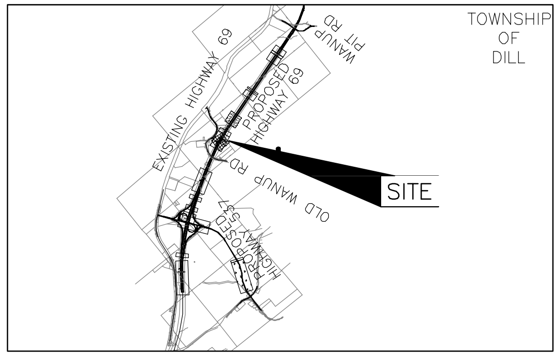
HIGHWAY 69
CULVERT STATION 14+940
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.



PLAN
SCALE
10 0 10 20 m

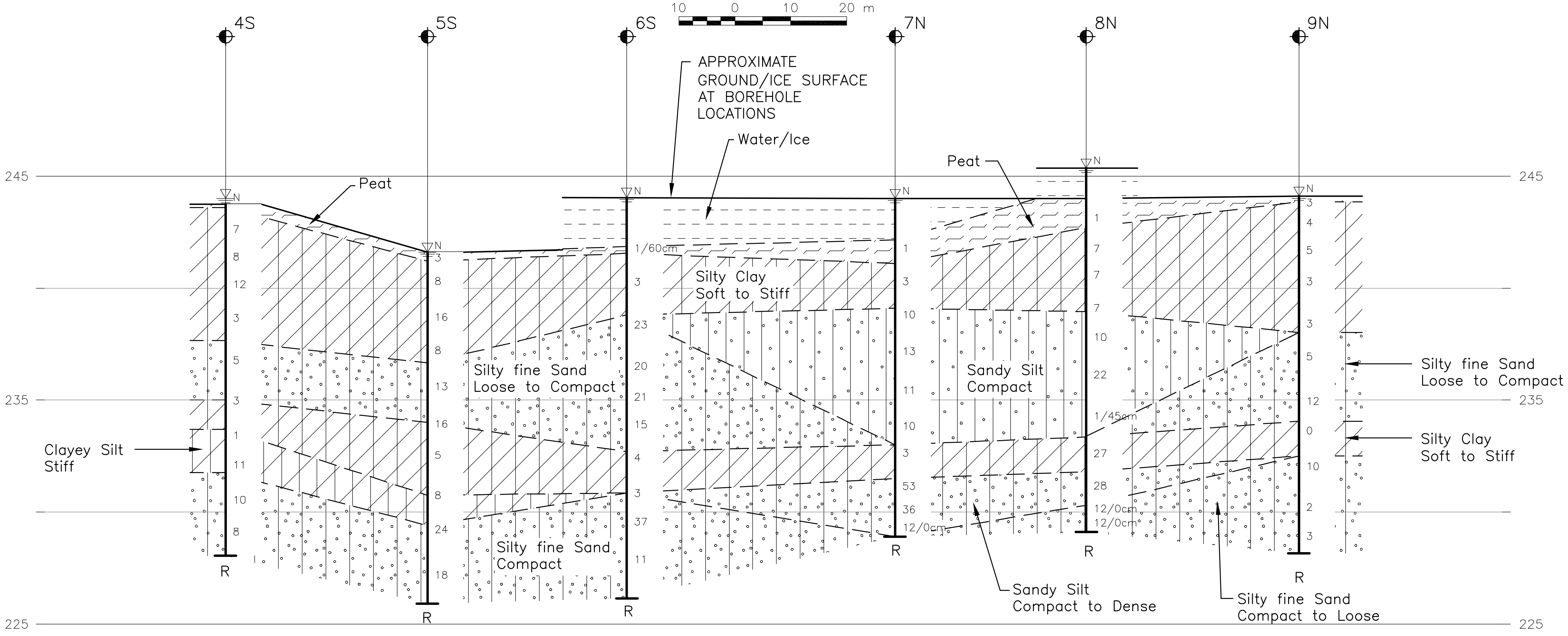


KEY PLAN
SCALE
1.5 0 1.5 km

LEGEND

⊕	Borehole – Previous Investigation (PML, May, 2003)
⊕	Cone Penetration Test – Current Investigation
R	Refusal
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
4S	243.8	5139726.2	315288.3
5S	242.0	5139742.0	315298.2
6S	244.1	5139758.3	315305.8
7N	244.0	5139783.4	315305.8
8N	245.4	5139798.6	315314.4
9N	244.1	5139815.4	315324.0
CPT04-57-01	243.5	5139783.1	315303.7



AA' CULVERT SECTION STN 14+940

HORZ. SCALE
5 0 5 10 m

VERT. SCALE
2.5 0 2.5 5 m

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

Borehole information contained in Peto MacCallum Report No. 01TF003, dated May, 2003 (PML, May, 2003). Station and Offset data adjusted for new alignment and co-ordinates determined from mapping.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO.03-1111-011-4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 4

PLOT DATE: June 01, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\0311110011GC004.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

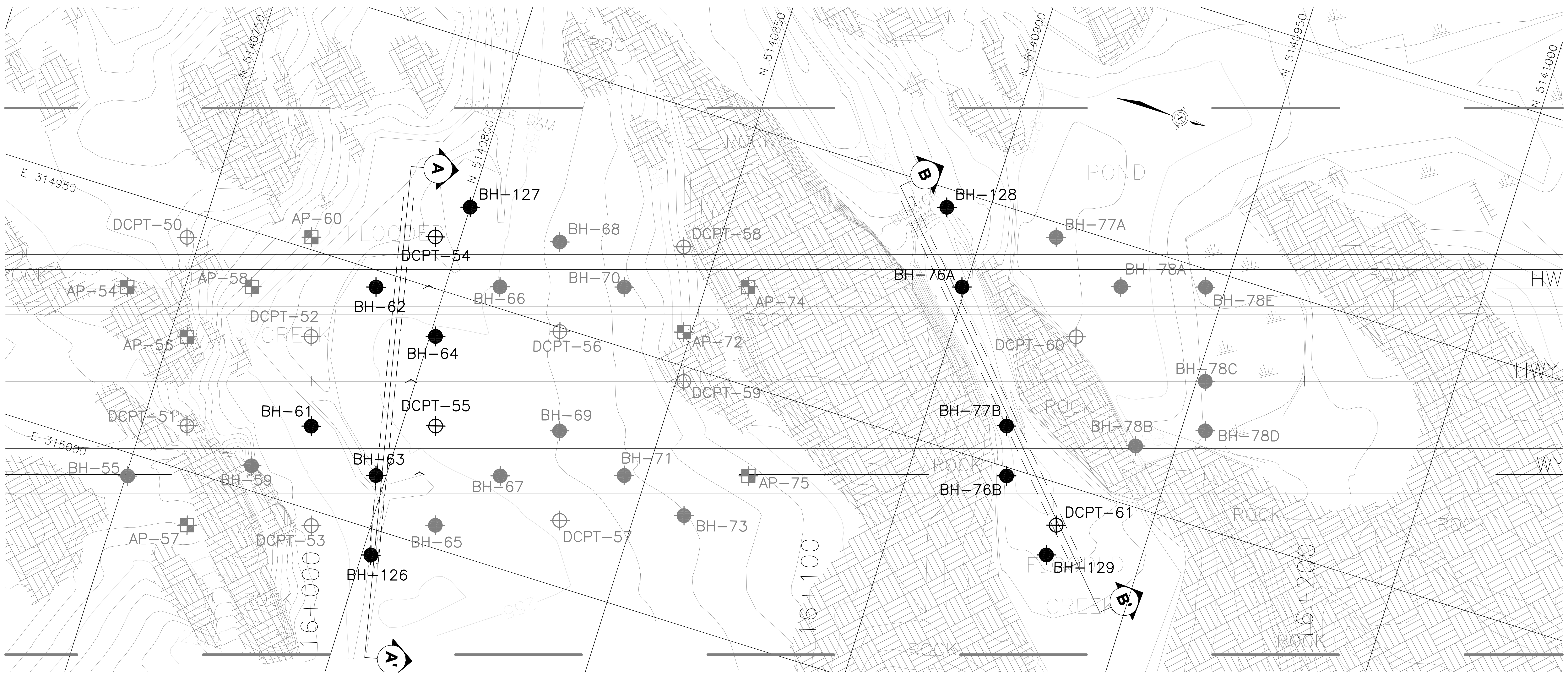
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

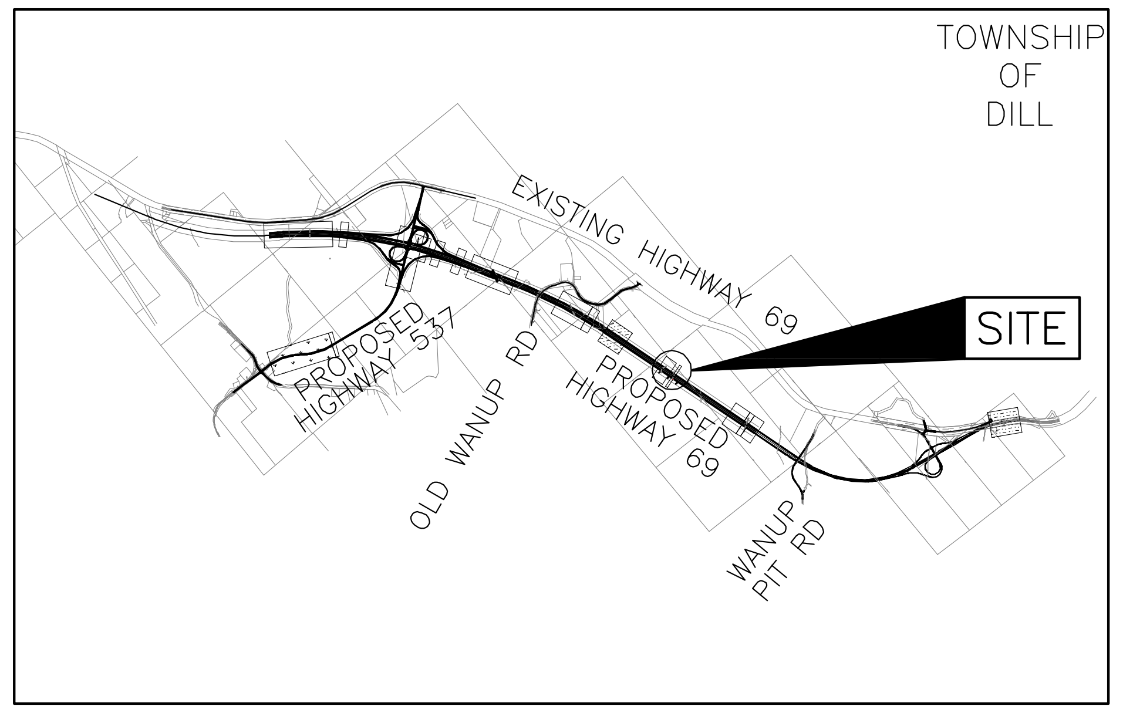
SHEET

HIGHWAY 69
CULVERT STATIONS 16+016 AND 16+137
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN
SCALE
10 0 10 20 m



KEY PLAN
SCALE
1.5 0 1.5 km

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
▚	Auger Probe
R	Refusal
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

No.	ELEVATION	CO−ORDINATES	
		NORTHING	EASTING
BH−55	261.2	5140750.3	315004.5
BH−59	255.2	5140773.5	314995.1
BH−61	254.6	5140782.6	314983.9
BH−62	255.0	5140786.7	314953.3
BH−63	255.0	5140798.0	314989.5
BH−64	255.0	5140801.1	314959.2
BH−65	255.3	5140812.4	314995.5
BH−66	255.4	5140810.5	314945.8
BH−67	255.3	5140821.9	314982.1
BH−68	255.7	5140819.3	314933.6
BH−69	255.5	5140830.6	314969.9
BH−70	255.6	5140834.4	314938.4
BH−71	255.9	5140845.7	314974.6
BH−73	255.2	5140859.6	314978.7
BH−76A	256.0	5140899.3	314918.1
BH−76B	256.0	5140919.2	314951.7
BH−77A	257.9	5140914.4	314902.9
BH−77B	256.0	5140916.2	314942.1
BH−78A	257.9	5140929.8	314908.5
BH−78B	257.9	5140942.2	314938.2
BH−78C	257.9	5140951.7	314921.6
BH−78D	257.9	5140954.7	314931.1
BH−78E	257.9	5140946.1	314903.5
BH−126	255.0	5140801.8	315005.1
BH−127	255.3	5140800.0	314932.3
BH−128	256.5	5140891.6	314903.7
BH−129	256.5	5140931.6	314964.5

No.	ELEVATION	CO−ORDINATES	
		NORTHING	EASTING
DCPT−50	259.1	5140747.4	314955.1
DCPT−51	258.5	5140758.7	314991.3
DCPT−52	254.6	5140777.2	314966.7
DCPT−53	254.6	5140788.6	315003.0
DCPT−54	254.9	5140795.1	314940.1
DCPT−55	255.2	5140806.5	314976.4
DCPT−56	255.5	5140824.7	314950.8
DCPT−57	255.3	5140836.0	314987.1
DCPT−58	258.2	5140843.4	314927.1
DCPT−59	255.8	5140854.5	314962.5
DCPT−60	257.9	5140924.2	314920.8
DCPT−61	256.0	5140931.7	314958.2
AP−54	261.5	5140738.9	314968.2
AP−56	259.5	5140753.4	314974.2
AP−57	259.9	5140764.7	315010.4
AP−58	255.3	5140762.8	314960.7
AP−60	254.8	5140771.3	314947.6
AP−72	256.6	5140848.6	314943.5
AP−74	259.9	5140858.2	314930.9
AP−75	257.4	5140869.6	314967.2

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO. 03−1111−011−4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 5A

PLOT DATE: June 14, 2005
FILENAME: T:\Projects\2003\03−1111−011 (URS, Hwy 69)\−GC− (JUNE 2005)\0311110011GC005A.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

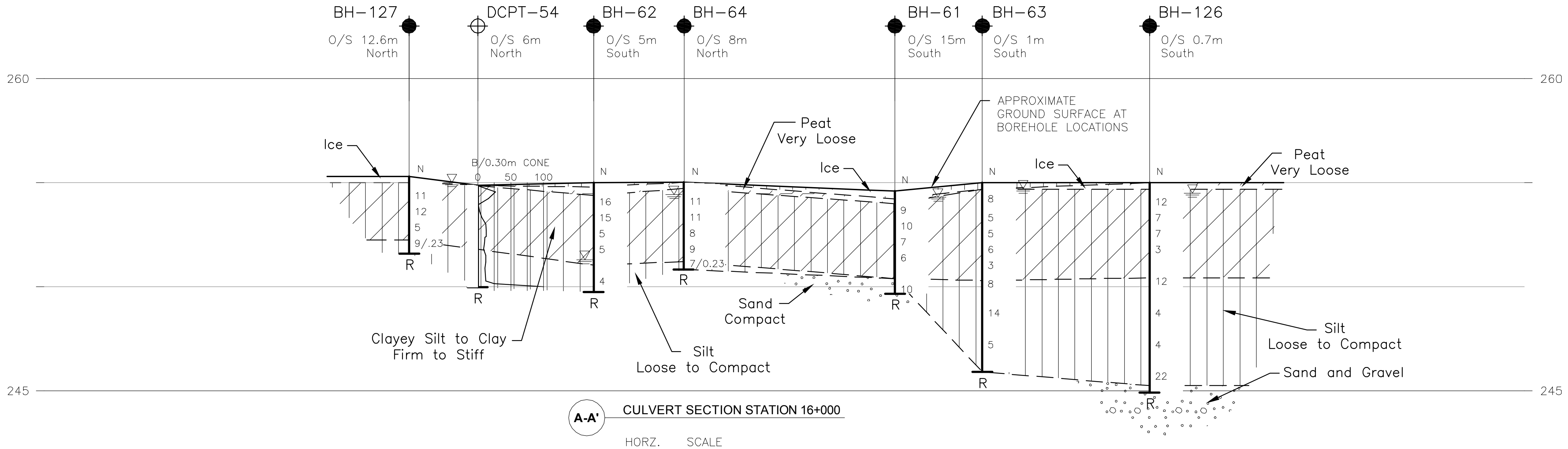
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

HIGHWAY 69
CULVERT STATIONS 16+016 AND 16+137
BOREHOLE SOIL STRATA

SHEET

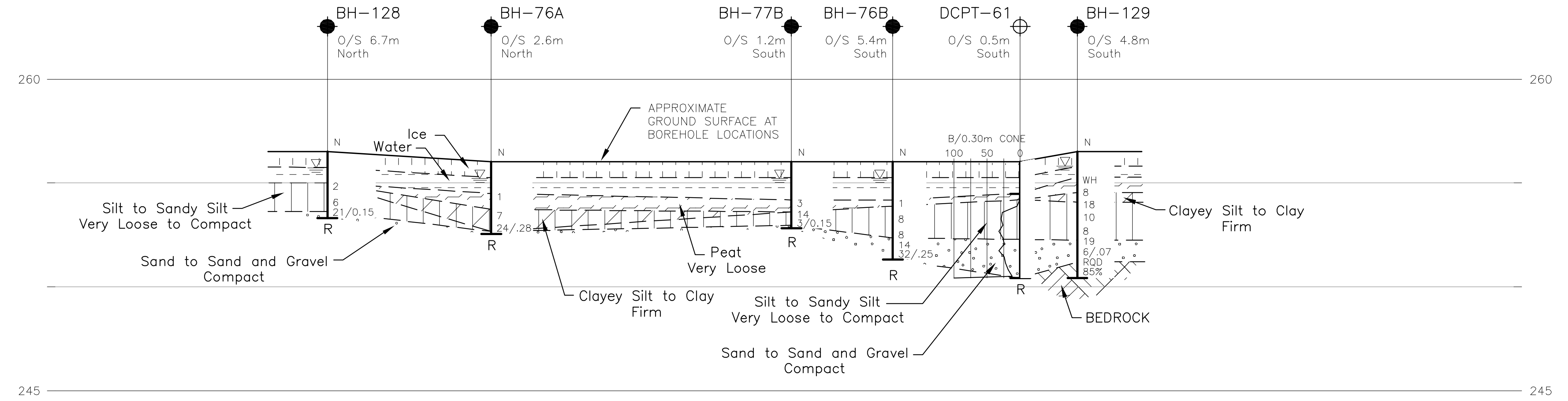
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



A-A' CULVERT SECTION STATION 16+000

HORZ. SCALE 5 0 5 10 m

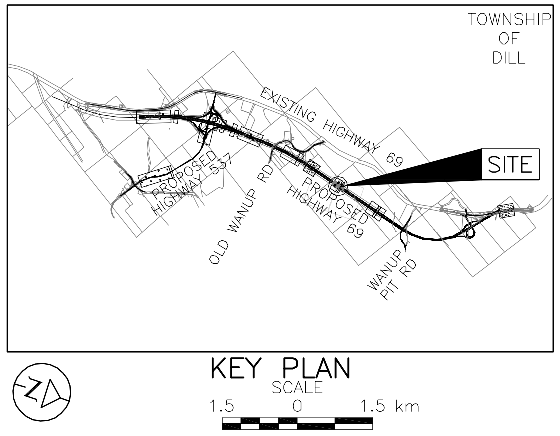
VERT. SCALE 2.5 0 2.5 5 m



B-B' CULVERT SECTION STATION 16+140

HORZ. SCALE 5 0 5 10 m

VERT. SCALE 2.5 0 2.5 5 m



KEY PLAN

SCALE 1.5 0 1.5 km

LEGEND

●	Borehole - Current Investigation
⊕	Dynamic Cone Penetration Test
R	Refusal
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH-61	254.6	5140782.6	314983.9
BH-62	255.0	5140786.7	314953.3
BH-63	255.0	5140798.0	314989.5
BH-64	255.0	5140801.1	314959.2
BH-76A	256.0	5140899.3	314918.1
BH-76B	256.0	5140919.2	314951.7
BH-77B	256.0	5140916.2	314942.1
BH-126	255.0	5140801.8	315005.1
BH-127	255.3	5140800.0	314932.3
BH-128	256.5	5140891.6	314903.7
BH-129	256.5	5140931.6	314964.5
DCPT-54	254.9	5140795.1	314940.1
DCPT-61	256.0	5140931.7	314958.2

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO. 03-1111-011-4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 5B

PLOT DATE: June 16, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\031111011GC005B.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

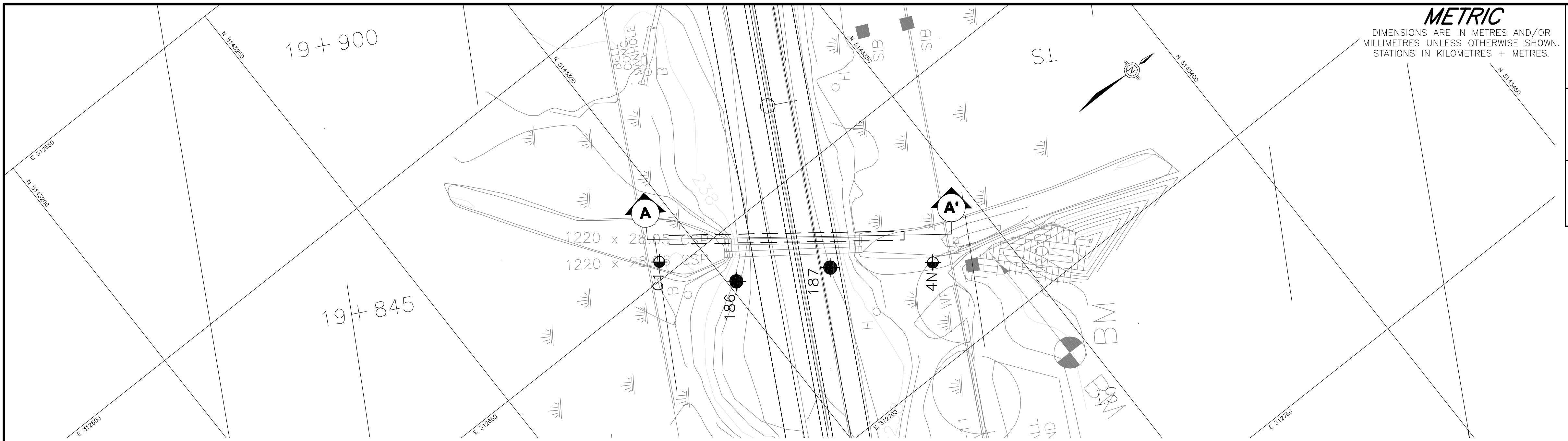
CONT No.
WP No.

SHEET

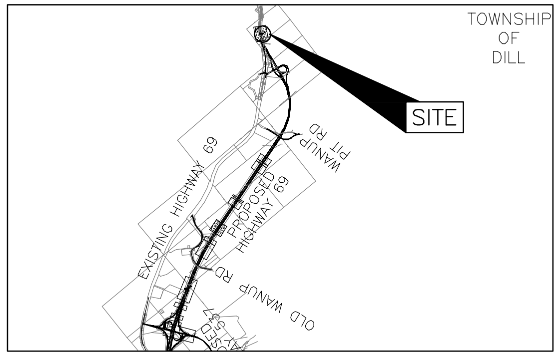
HIGHWAY 69
CULVERT STATION 19+845
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

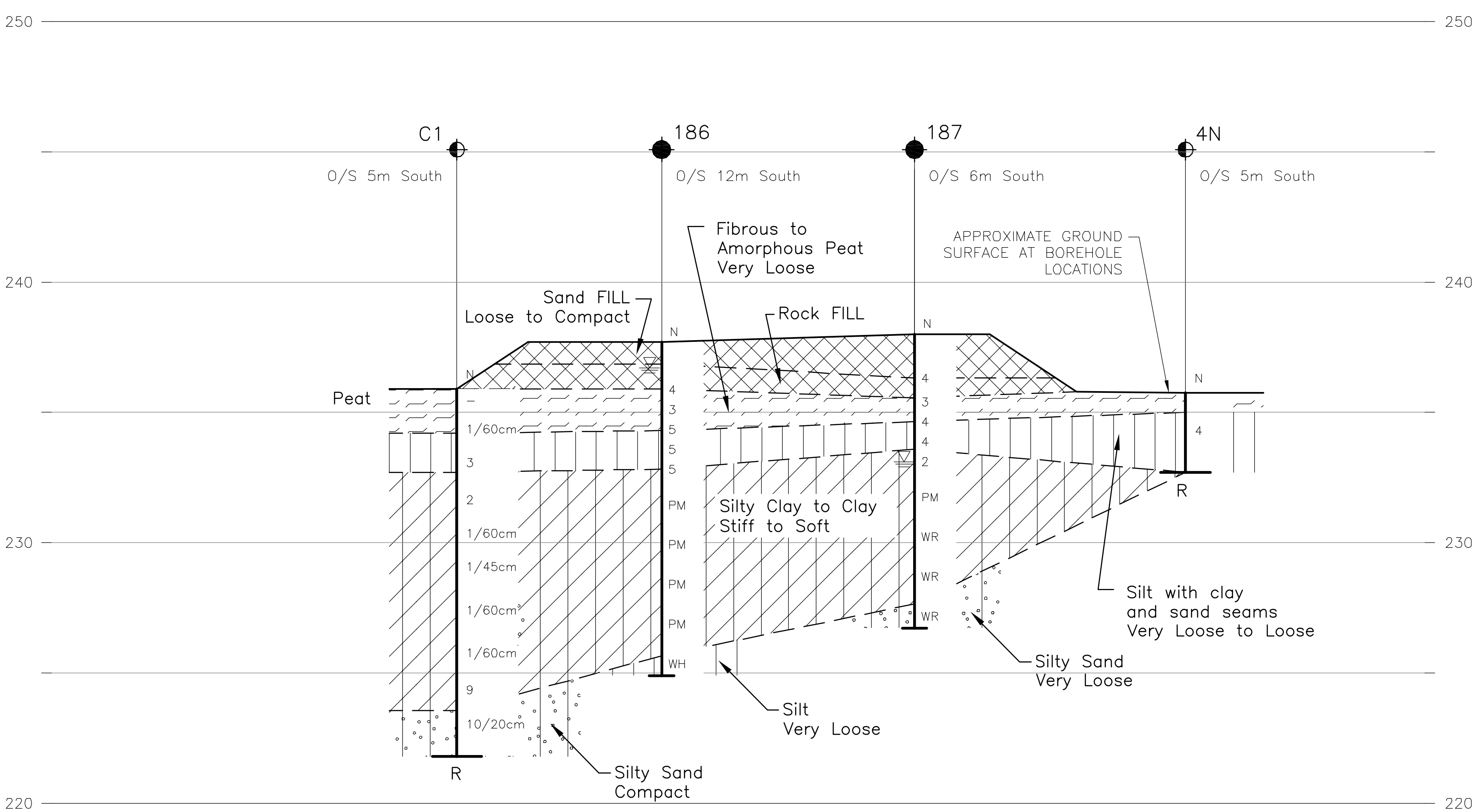
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.



PLAN
SCALE
10 0 10 20 m



KEY PLAN
SCALE
1.5 0 1.5 km



AA' CULVERT SECTION STATION 19+845

HORZ. SCALE
5 0 5 10 m
VERT. SCALE
2.5 0 2.5 5 m

LEGEND

●	Borehole – Current Investigation
⊕	Borehole – Previous Investigation (PML, May 2003)
R	Refusal
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
186	237.7	5143301.6	312659.8
187	238.0	5143318.4	312669.5
C1	235.9	5143291.7	312646.9
4N	235.8	5143335.5	312681.7

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

Boreholes C1 and 4N information contained in Peto MacCallum Report No. 01TF003, dated May, 2003 (PML, May, 2003). Station and offset data adjusted for new alignment and co-ordinates determined from mapping.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.			
HWY. 69		PROJECT NO. 03-1111-011-4	DIST.
SUBM'D. SEP	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 6

PLOT DATE: June 01, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\031111011GC006.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

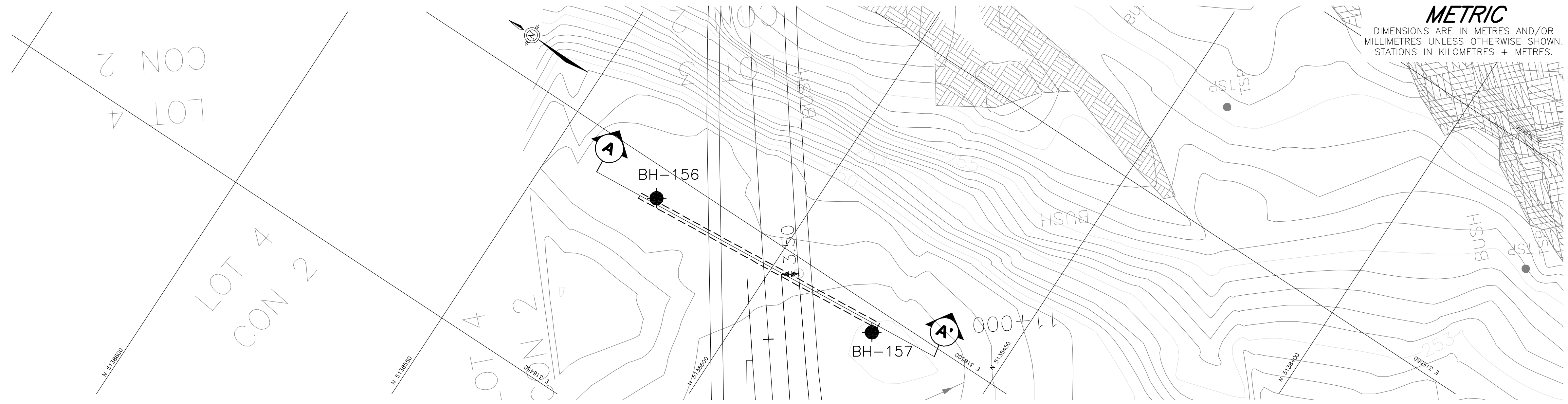
CONT No.
WP No.

SHEET

HIGHWAY 537
CULVERT STATION 11+015
BOREHOLE LOCATIONS AND SOIL STRATA

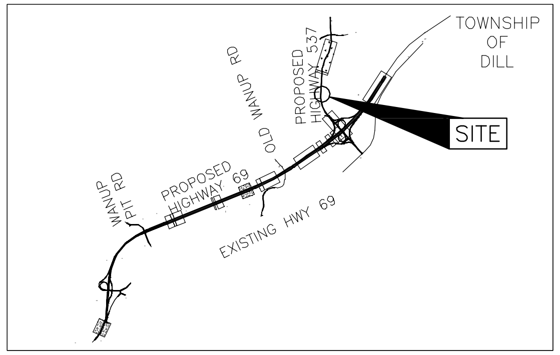
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.



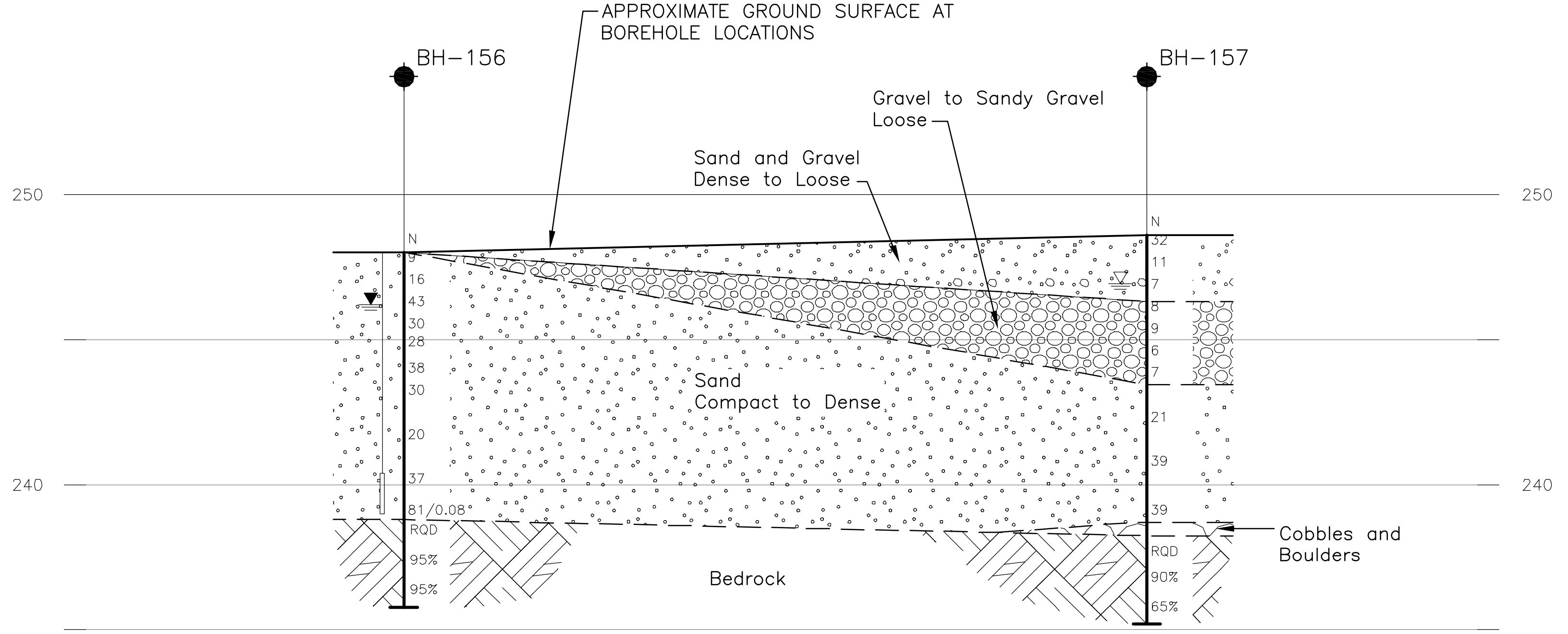
PLAN

SCALE
10 0 10 20 m



KEY PLAN

SCALE
1.5 0 1.5 km



AA' CULVERT SECTION STATIONN 11+020

HORZ. SCALE
5 0 5 10 m
VERT. SCALE
2.5 0 2.5 5 m

LEGEND

●	Borehole
▮	Seal
▯	Piezometer
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▼	WL in piezometer, measured on OCT. 6, 2004
▽	WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH-156	248.0	5138527.0	316494.2
BH-157	248.6	5138476.7	316495.5

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing file no. Hwy 69 Plan Profile.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 537		PROJECT NO.03-1111-011-4	DIST.
SUBM'D.	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 7

PLOT DATE: June 01, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\0311110011GC007.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

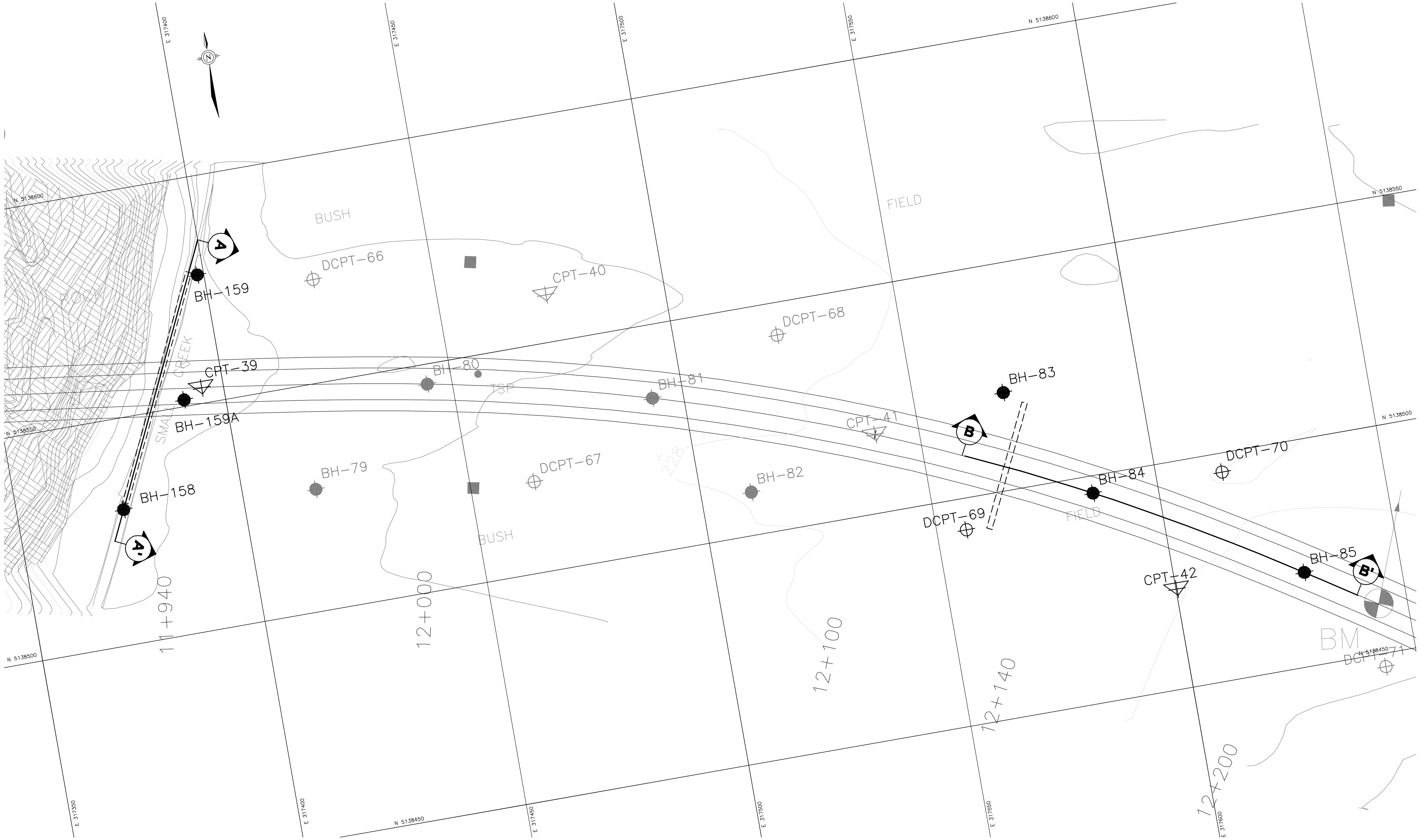
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

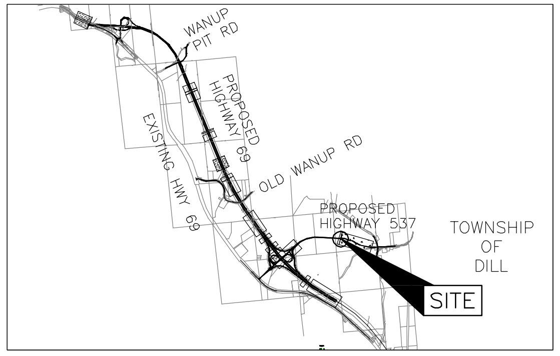
HIGHWAY 537
CULVERT STATION 11+940/12+130
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
10 0 10 20 m



KEY PLAN

SCALE
1.5 0 1.5 km

LEGEND

- ● Borehole − Current Investigation
- ⊕ Dynamic Cone Penetration Test
- ▽ Cone Penetration Test

No.	ELEVATION	CO−ORDINATES	
		NORTHING	EASTING
BH−79	228.4	5138526.9	317416.2
BH−80	228.3	5138545.6	317444.6
BH−81	227.7	5138533.8	317493.2
BH−82	227.5	5138509.5	317511.1
BH−83	227.2	5138521.6	317569.9
BH−84	227.2	5138496.2	317585.6
BH−85	227.7	5138470.7	317628.6
BH−158	229.0	5138529.9	317373.5
BH−159	228.6	5138578.2	317398.6
BH−159A	228.8	5138551.5	317390.9
CPT−39	228.4	5138553.4	317395.2
CPT−40	227.8	5138560.5	317473.9
CPT−41	227.4	5138517.3	317540.3
CPT−42	227.5	5138472.0	317600.2
DCPT−66	228.4	5138572.8	317423.7
DCPT−67	227.9	5138520.1	317464.1
DCPT−68	227.6	5138542.8	317522.8
DCPT−69	227.2	5138493.0	317556.6
DCPT−70	227.4	5138495.8	317614.6
DCPT−71	227.8	5138447.1	317642.8

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digitial format by URS, drawing file;
HWY 69 PLAN PROFILE.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 537		PROJECT NO. 03−1111−011−4	DIST.
SUBM'D.	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 8A

PLOT DATE: June 14, 2005
FILENAME: T:\Projects\2003\03−1111−011 (URS, Hwy 69)\−GC− (JUNE 2005)\03111011GC008A.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

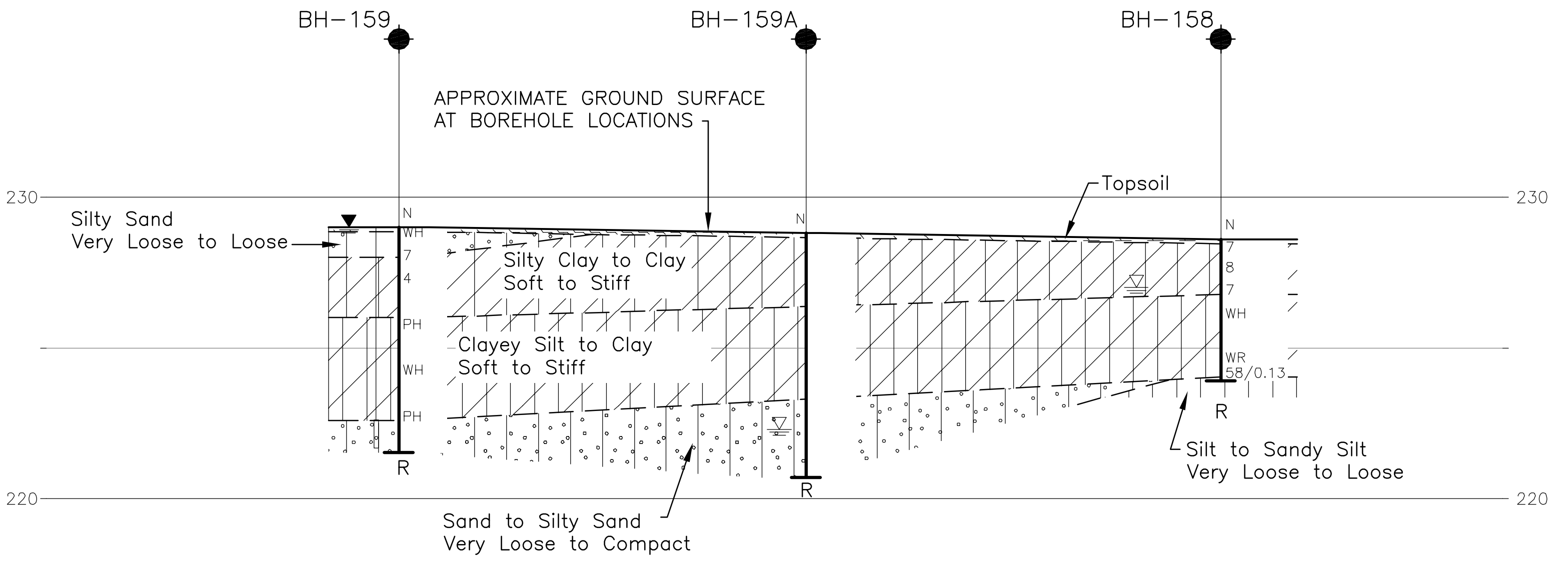
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

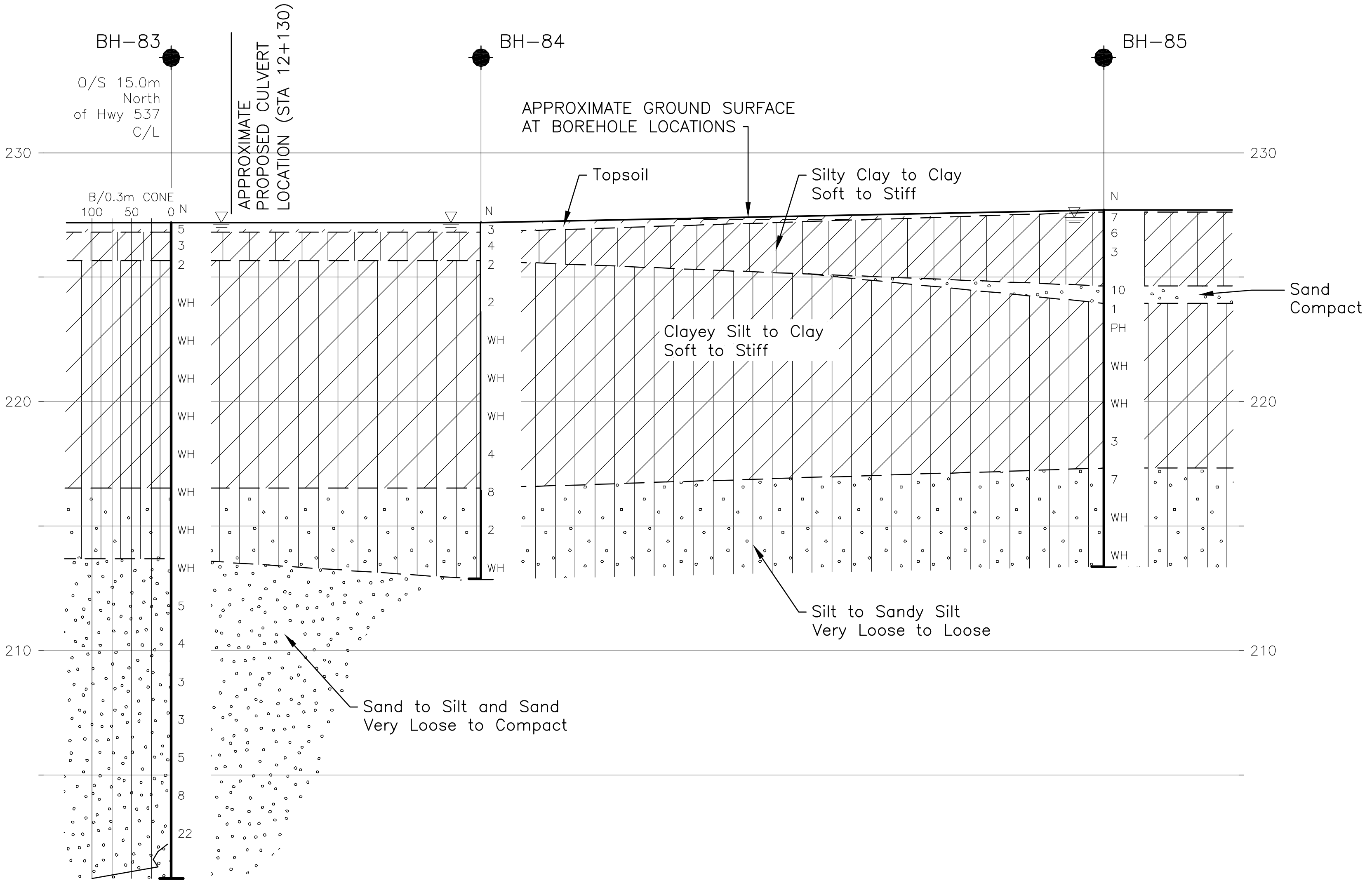
SHEET

HIGHWAY 537
CULVERT STATION 11+940/12+130
BOREHOLE SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



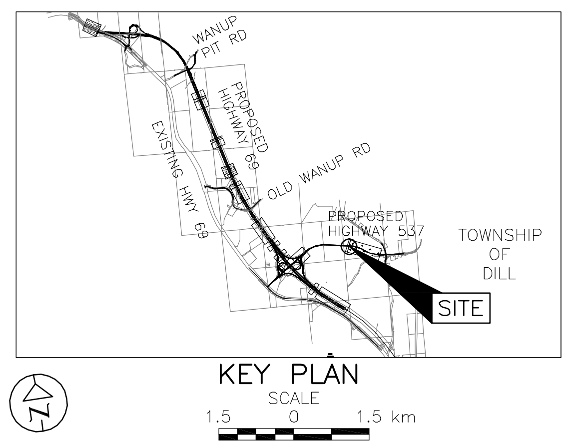
A-A' CULVERT SECTION STATION 11+940



B-B' SECTION ALONG CENTRELINE HIGHWAY 537

HORZ. SCALE
5 0 5 10 m

VERT. SCALE
2.5 0 2.5 5 m



KEY PLAN
SCALE
1.5 0 1.5 km

LEGEND

- ● Borehole – Current Investigation
- ⊕ Dynamic Cone Penetration Test
- ▽ Cone Penetration Test
- R Refusal
- ▮ Seal
- ▯ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▼ WL in piezometer, measured on OCT. 13, 2004
- ▽ WL upon completion of drilling

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
BH-83	227.2	5138521.6	317569.9
BH-84	227.2	5138496.2	317585.6
BH-85	227.7	5138470.7	317628.6
BH-158	229.0	5138333.7	317893.1
BH-159	228.6	5138338.7	317919.3
BH-159A	228.8	5138311.8	317966.3
CPT-39	228.4	5138553.4	317395.2

NOTES

This drawing is for subsurface information only. The proposed works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digitial format by URS, drawing file;
HWY 69 PLAN PROFILE.dwg, dated January 15, 2004, received January 23, 2004.

NO.	DATE	BY	REVISION

Geocres No.

HWY. 537		PROJECT NO. 03-1111-011-4	DIST.
SUBM'D.	CHKD.	DATE: JUNE 2005	SITE:
DRAWN: JFC/MSM	CHKD. SEP	APPD. FJH	DWG. 8B

PLOT DATE: June 14, 2005
FILENAME: T:\Projects\2003\03-1111-011 (URS, Hwy 69)\-GC- (JUNE 2005)\031111011GC008B.dwg

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 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

LIST OF SYMBOLS

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

I. General

π	3.1416
in 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
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma\text{-}u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (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

(a) Index Properties (continued)

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)

(b) 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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	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	over-consolidation ratio = σ'_p/σ'_{vo}

(d) 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
* density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

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

Description	Bedding Plane Spacing
Very thickly bedded	> 2 m
Thickly bedded	0.6 m to 2m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm 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

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

GRAIN SIZE

Term	Size*
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

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 and infillings are also noted.

Abbreviations

B - Bedding
FO - Foliation/Schistosity
CL - Cleavage
SH - Shear Plane/Zone
VN - Vein
F - Fault
CO - Contact
J - Joint
FR - Fracture
MF - Mechanical Fracture
∥ - Parallel To
⊥ - Perpendicular To

P - Polished
S - Slickensided
SM - Smooth
R - Ridged/Rough
ST - Stepped
PL - Planar
FL - Flexured
UE - Uneven
W - Wavy
C - Curved

APPENDIX A

LABORATORY TEST DATA

TABLE A-1
RISING HEAD TEST – BOREHOLE BH-123 (1)

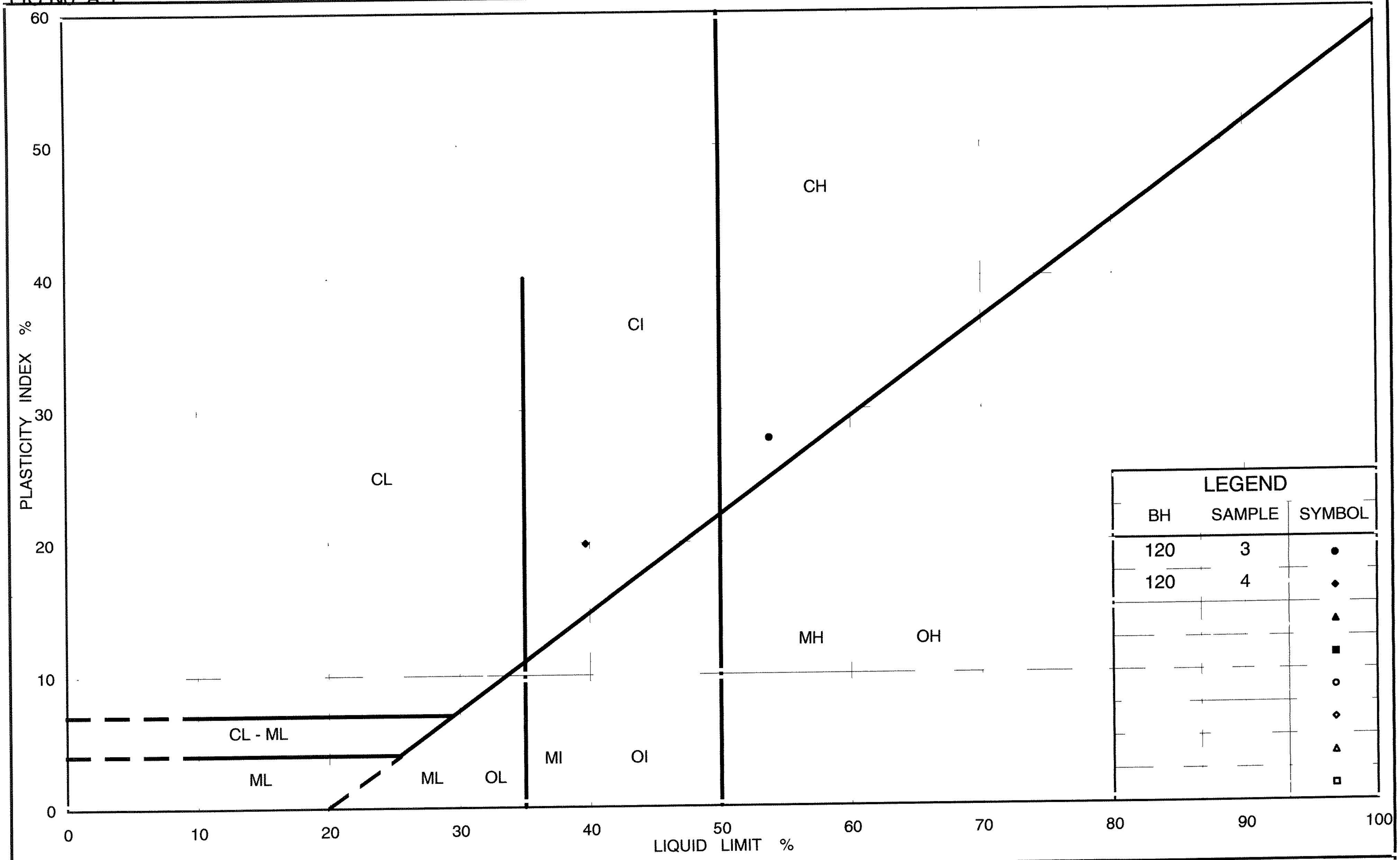
Time	*Water Level**	*Time*	*Water Level(1)*
8:02:00 AM	-1.52	8:13:30 AM	-0.14
8:02:30 AM	-1.39	8:14:00 AM	-0.1
8:03:00 AM	-1.34	8:14:30 AM	-0.05
8:03:30 AM	-1.25	8:15:00 AM	-0.01
8:04:00 AM	-1.2	8:15:30 AM	0.03
8:04:30 AM	-1.13	8:16:00 AM	0.07
8:05:00 AM	-1.05	8:16:30 AM	0.1
8:05:30 AM	-0.99	8:17:00 AM	0.12
8:06:00 AM	-0.93	8:17:30 AM	0.16
8:06:30 AM	-0.87	8:18:00 AM	0.2
8:07:00 AM	-0.79	8:18:30 AM	0.24
8:07:30 AM	-0.73	8:19:00 AM	0.27
8:08:00 AM	-0.68	8:19:30 AM	0.3
8:08:30 AM	-0.63	8:20:00 AM	0.33
8:09:00 AM	-0.57	8:20:30 AM	0.36
8:09:30 AM	-0.52	8:21:00 AM	0.38
8:10:00 AM	-0.47	8:21:30 AM	0.41
8:10:30 AM	-0.41	8:22:00 AM	0.44
8:11:00 AM	-0.36	8:22:30 AM	0.46
8:11:30 AM	-0.31	8:23:00 AM	0.48
8:12:00 AM	-0.27	8:23:30 AM	0.5
8:12:30 AM	-0.21	8:24:00 AM	0.3
8:13:00 AM	-0.18	8:24:30 AM	0.6 (3)

1. Rising head test conducted by pumping water out of augers and measuring water level over time
2. Water level measured relative to ground surface.
3. Water started flowing out of the top of the augers (about 0.6 m above the ground surface.

n:\03-1111-011\\hwy 69\reports\culvert\final\final lab testing figures\tbl a-1 bh-123 rising head test.doc

FIG No. A-1

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay to Clay

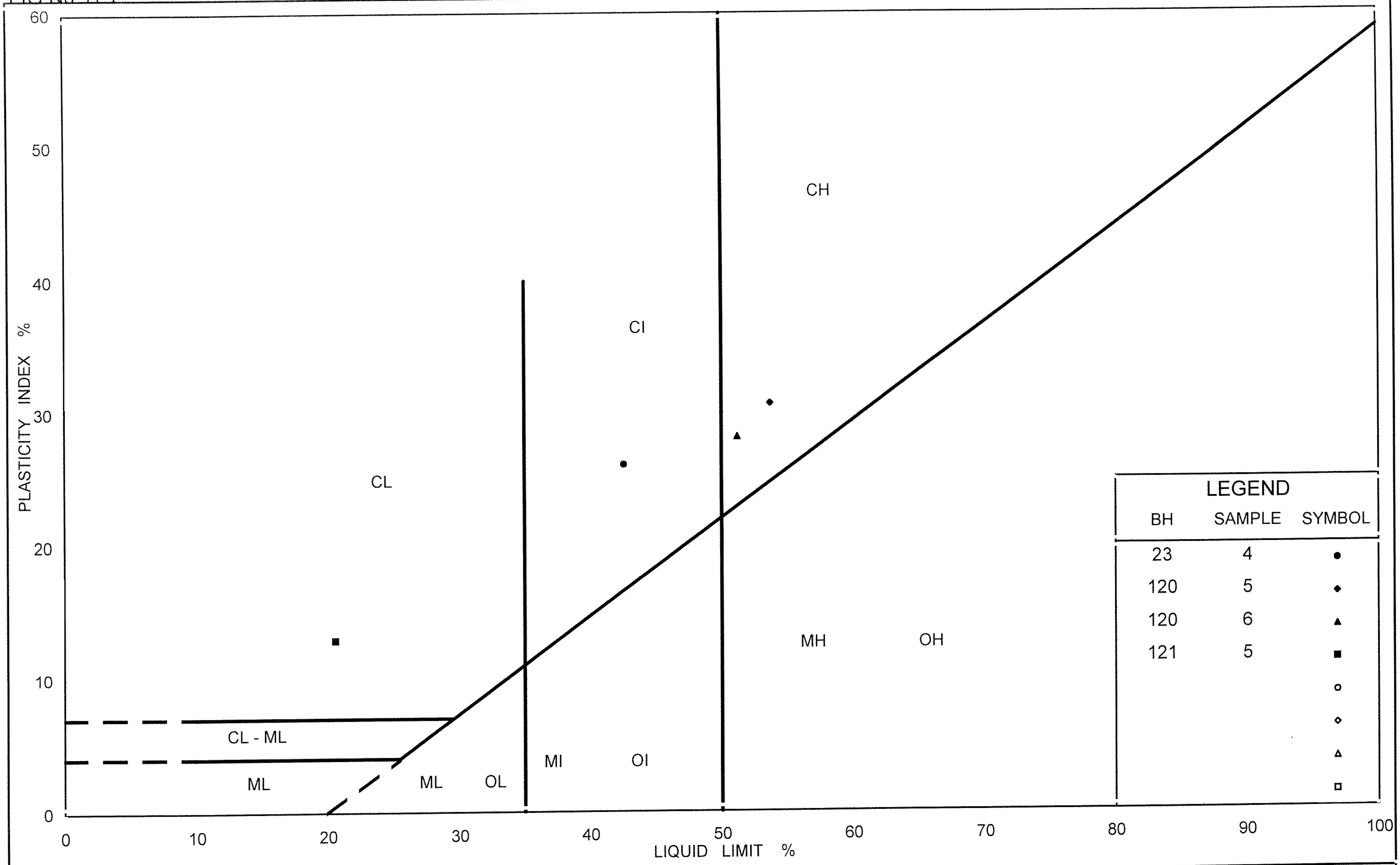
FIG No. A-1

Project No. 03-1111-011-4

Hwy 69 Culvert Sta. 12+200

FIG No. A-1

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay to Clay

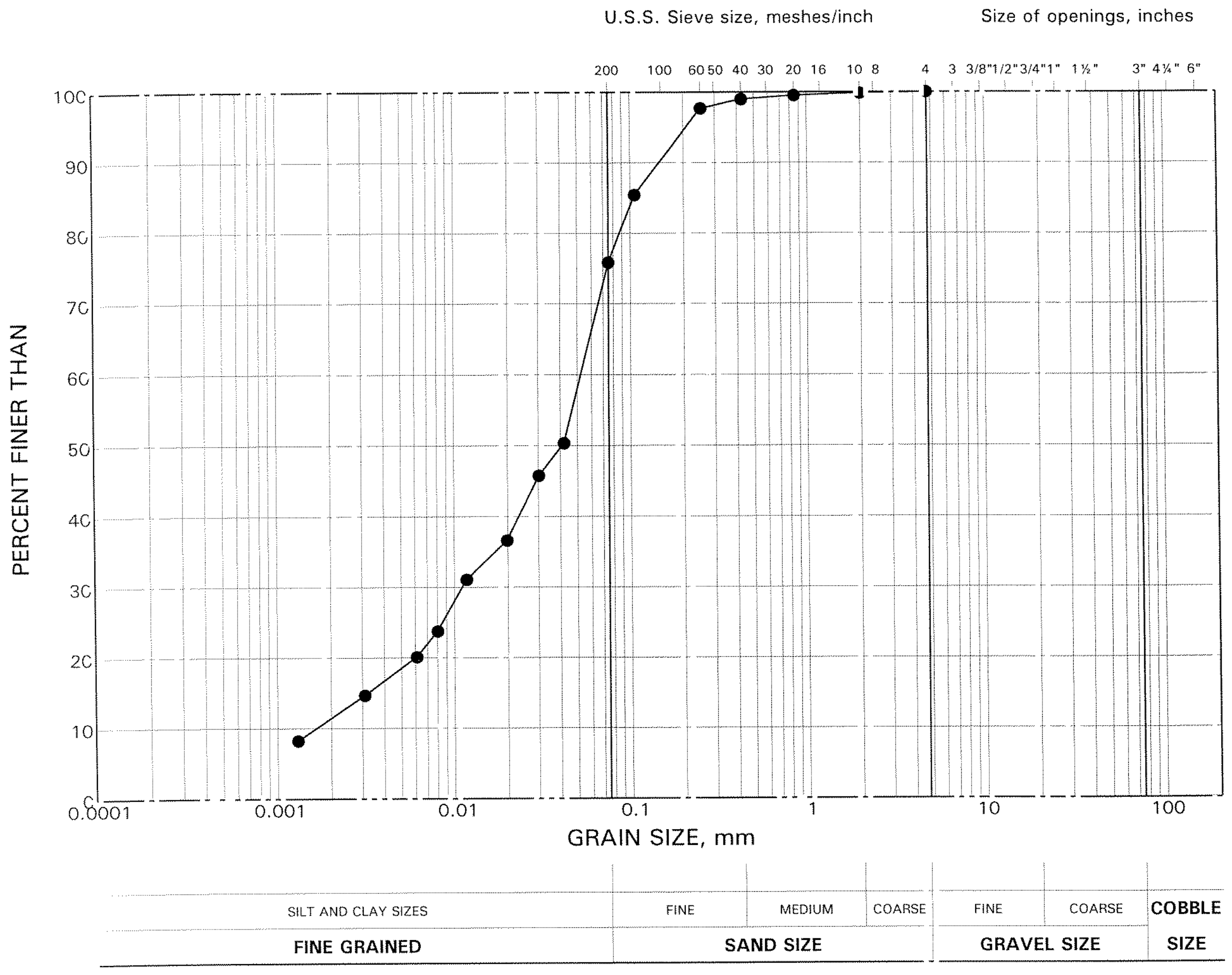
FIG No. A-2

Project No. 03-1111-011-4

Hwy 69 Culvert Sta. 12+200

GRAIN SIZE DISTRIBUTION
Clayey Silt
Culvert Hwy 69 Station 12+200

FIGURE A-3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	20	7	230.3

Date June, 2005
Project 03-1111-011-4

Golder Associates

Prepared by LG
Checked by ______

OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 12+200

FIGURE A-4
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	5
Borehole Number	BH-11	Sample Depth, m	4.6-5.2

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	11/26/2003		
Date Completed	12/07/2003		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	19.17
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	14.68
Area, cm^2	31.65	Specific Gravity, measured	2.74
Volume, cm^3	60.13	Solids Height, cm	1.038
Water Content, %	30.56	Volume of Solids, cm^3	32.85
Wet Mass, g	117.53	Volume of Voids, cm^3	27.28
Dry Mass, g	90.02	Degree of Saturation, %	100.8

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.900	0.830	1.900				
4.83	1.893	0.824	1.897	321	2.38E-03	7.63E-04	1.78E-07
9.46	1.888	0.819	1.891	225	3.37E-03	5.68E-04	1.88E-07
19.51	1.879	0.810	1.884	184	4.09E-03	4.71E-04	1.89E-07
38.91	1.865	0.797	1.872	158	4.70E-03	3.80E-04	1.75E-07
77.57	1.841	0.773	1.853	171	4.26E-03	3.27E-04	1.36E-07
154.88	1.782	0.717	1.812	242	2.87E-03	4.02E-04	1.13E-07
309.40	1.702	0.640	1.742	304	2.12E-03	2.72E-04	5.65E-08
618.76	1.631	0.571	1.667	240	2.45E-03	1.21E-04	2.90E-08
1237.35	1.560	0.503	1.596	135	4.00E-03	6.04E-05	2.37E-08
2474.60	1.491	0.436	1.526	124	3.98E-03	2.94E-05	1.14E-08
1237.35	1.500	0.445	1.496				
309.40	1.519	0.463	1.510				
77.57	1.539	0.483	1.529				
19.51	1.562	0.505	1.551				
4.83	1.591	0.533	1.577				

Notes:
k calculated using cv based on t_{90} values.

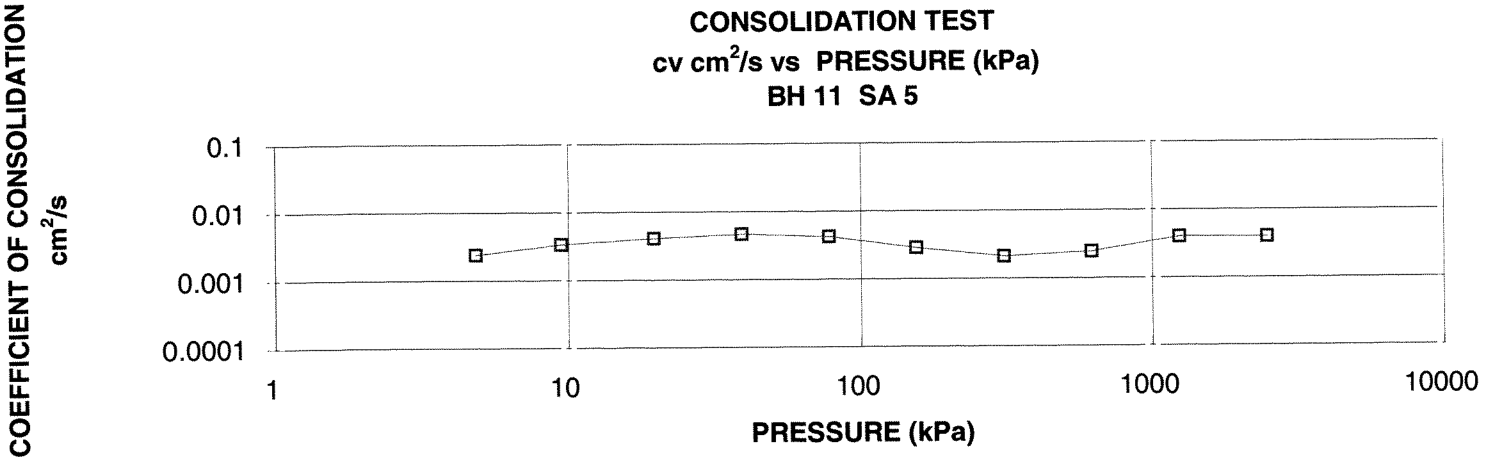
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

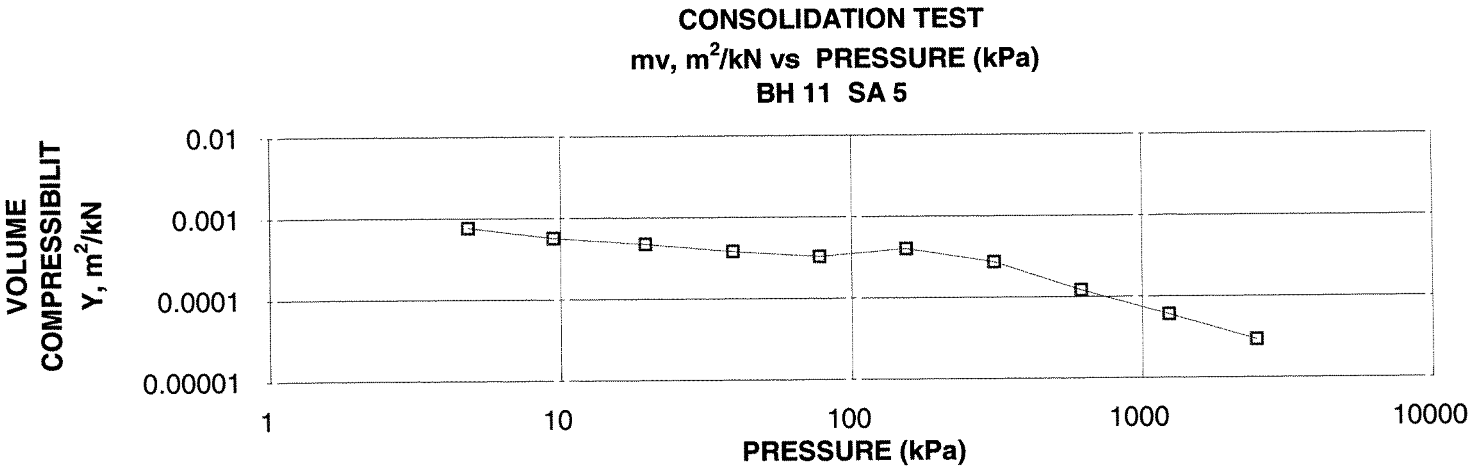
Sample Height, cm	1.59	Unit Weight, kN/m^3	21.67
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	17.53
Area, cm^2	31.65	Specific Gravity, measured	2.74
Volume, cm^3	50.35	Solids Height, cm	1.038
Water Content, %	23.63	Volume of Solids, cm^3	32.85
Wet Mass, g	111.29	Volume of Voids, cm^3	17.50
Dry Mass, g	90.02		

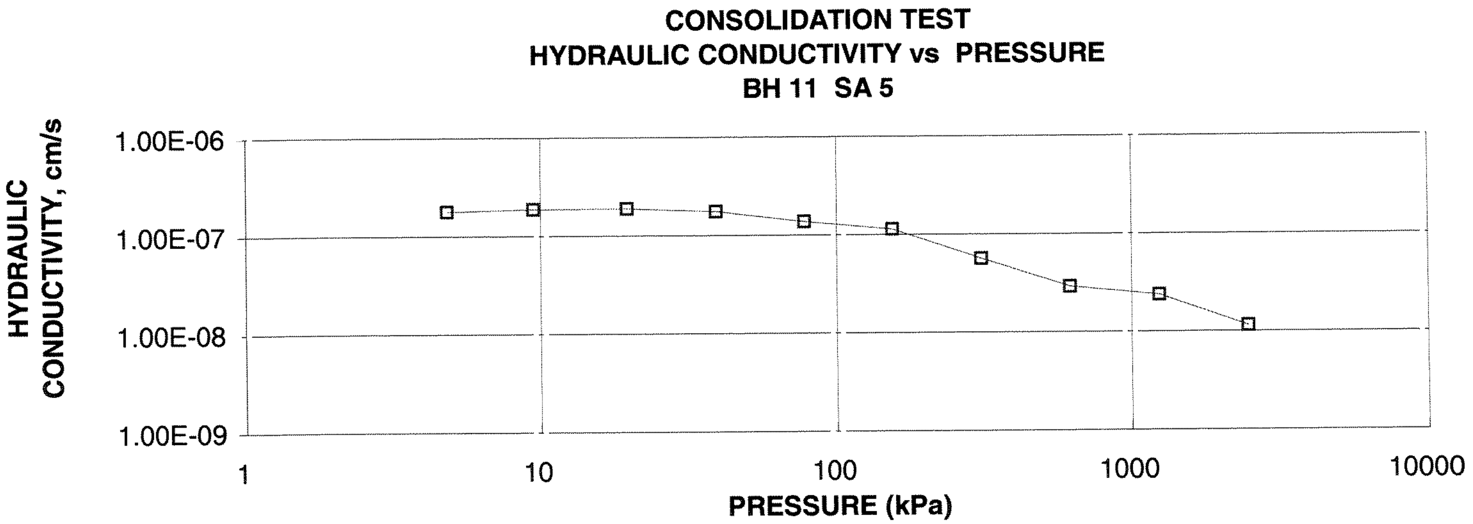
OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 12+200

FIGURE A-4
Sheet 2 of 4



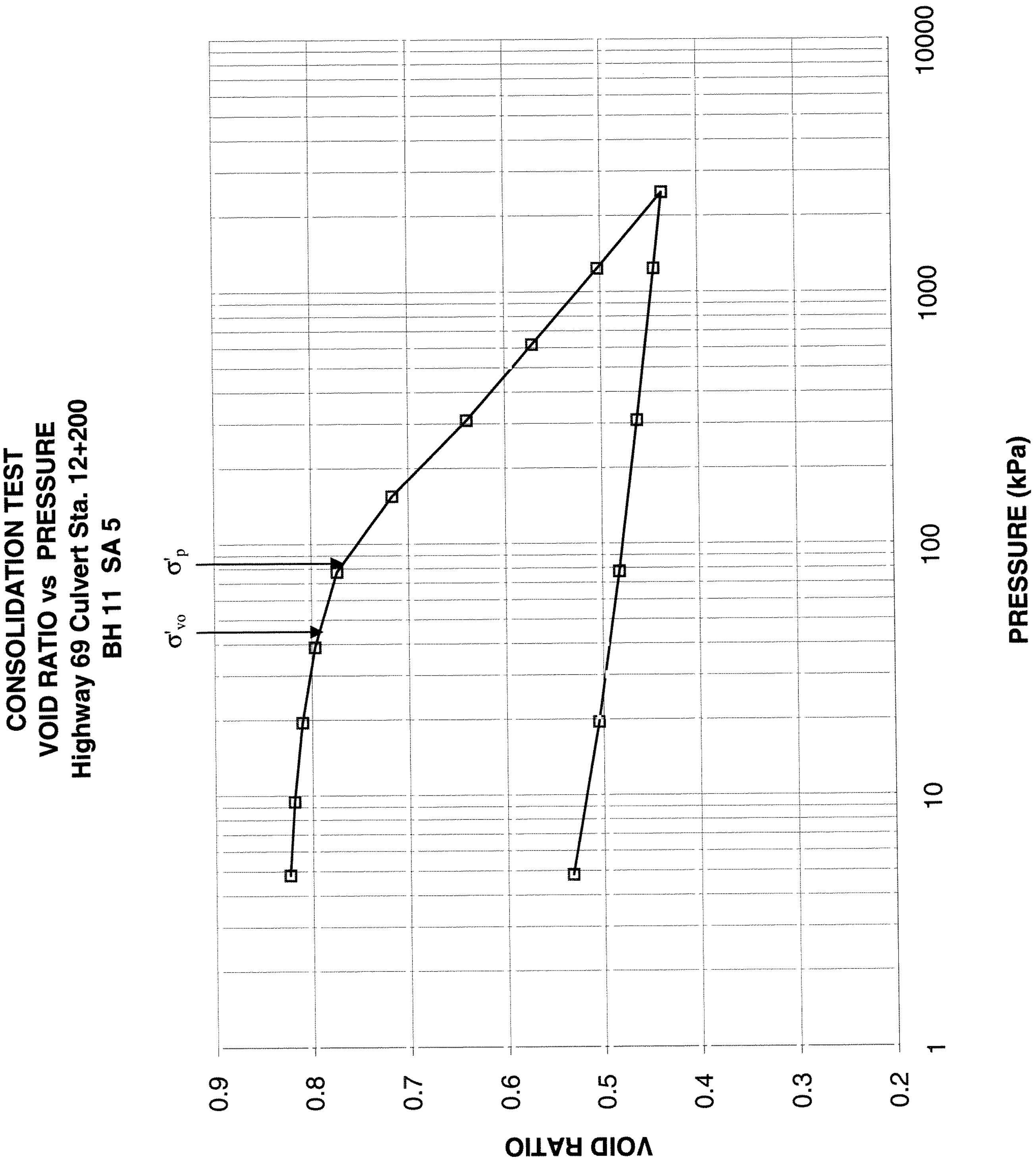




Project No. 03-1111-011-4

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

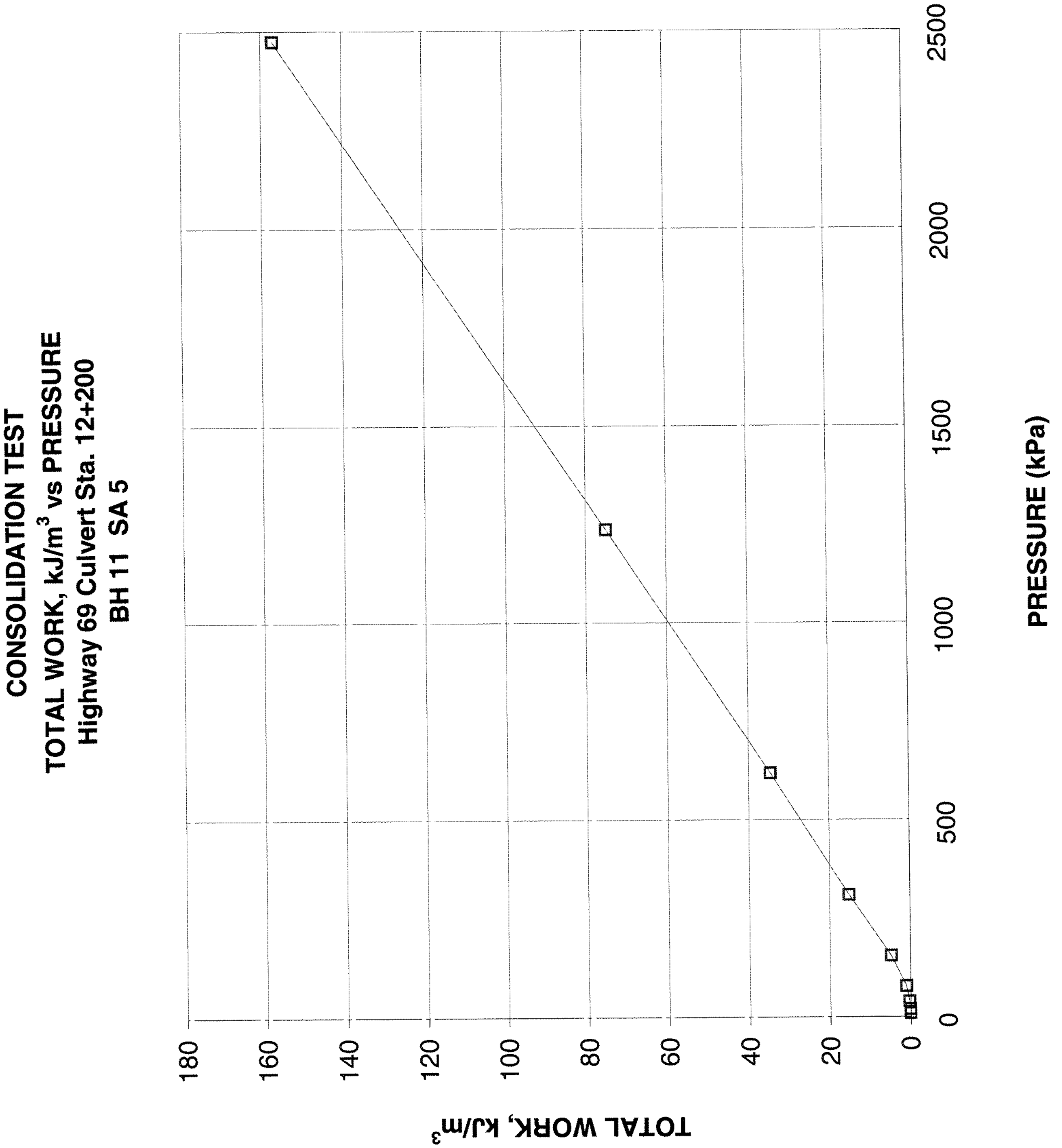
FIGURE A-4
Sheet 3 of 4



Project No. 03-1111-011-4

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

FIGURE A-4
Sheet 4 of 4



Project No. 03-1111-011-4

OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 12+200

FIGURE A-5
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	6
Borehole Number	BH-17	Sample Depth, m	6.1-6.7

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	11/27/2003		
Date Completed	12/07/2003		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.92	Unit Weight, kN/m^3	19.32
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.04
Area, cm^2	31.67	Specific Gravity, measured	2.71
Volume, cm^3	60.65	Solids Height, cm	1.084
Water Content, %	28.38	Volume of Solids, cm^3	34.33
Wet Mass, g	119.45	Volume of Voids, cm^3	26.31
Dry Mass, g	93.04	Degree of Saturation, %	100.4

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.915	0.766	1.915				
4.85	1.886	0.740	1.901	375	2.04E-03	3.12E-03	6.25E-07
9.50	1.878	0.732	1.882	197	3.81E-03	8.98E-04	3.36E-07
19.40	1.865	0.720	1.872	72	1.03E-02	6.86E-04	6.93E-07
38.64	1.846	0.703	1.856	60	1.22E-02	5.16E-04	6.15E-07
77.43	1.817	0.676	1.832	53	1.34E-02	3.90E-04	5.13E-07
154.66	1.783	0.645	1.800	60	1.14E-02	2.30E-04	2.58E-07
308.69	1.745	0.610	1.764	60	1.10E-02	1.29E-04	1.39E-07
618.07	1.704	0.572	1.725	40	1.58E-02	6.92E-05	1.07E-07
1236.00	1.662	0.533	1.683	31	1.94E-02	3.55E-05	6.74E-08
2473.04	1.617	0.492	1.640	34	1.68E-02	1.90E-05	3.12E-08
1236.56	1.625	0.499	1.621				
308.69	1.640	0.513	1.633				
77.43	1.653	0.525	1.647				
19.40	1.667	0.538	1.660				
4.85	1.689	0.558	1.678				

Notes:
k calculated using cv based on t_{90} values.

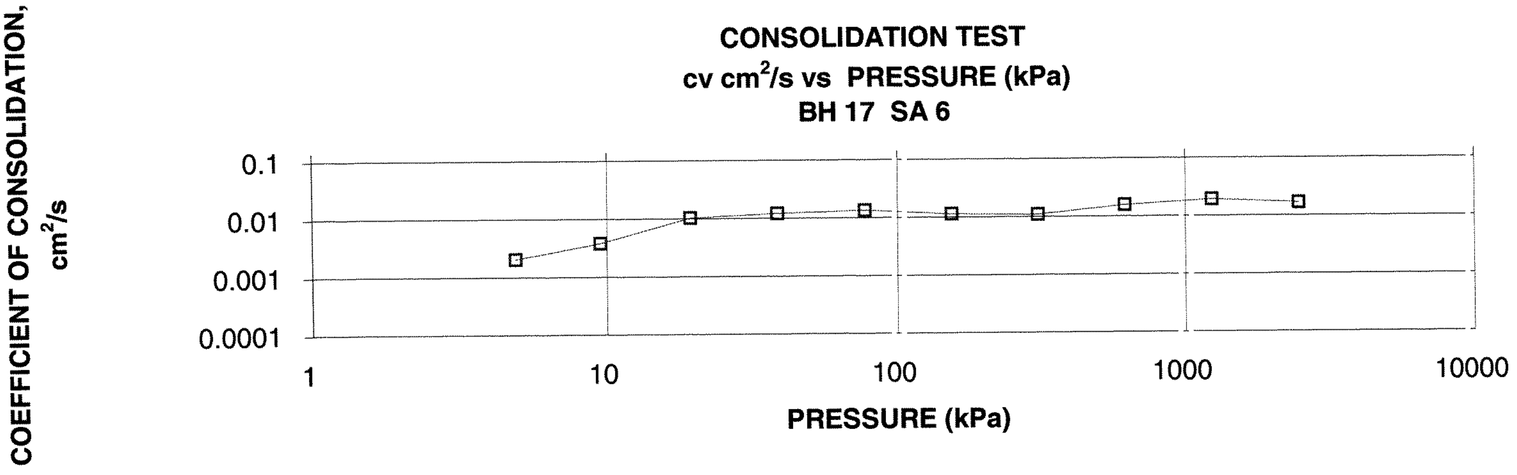
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.69	Unit Weight, kN/m^3	20.86
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	17.06
Area, cm^2	31.67	Specific Gravity, measured	2.71
Volume, cm^3	53.49	Solids Height, cm	1.084
Water Content, %	22.27	Volume of Solids, cm^3	34.33
Wet Mass, g	113.76	Volume of Voids, cm^3	19.16
Dry Mass, g	93.04		

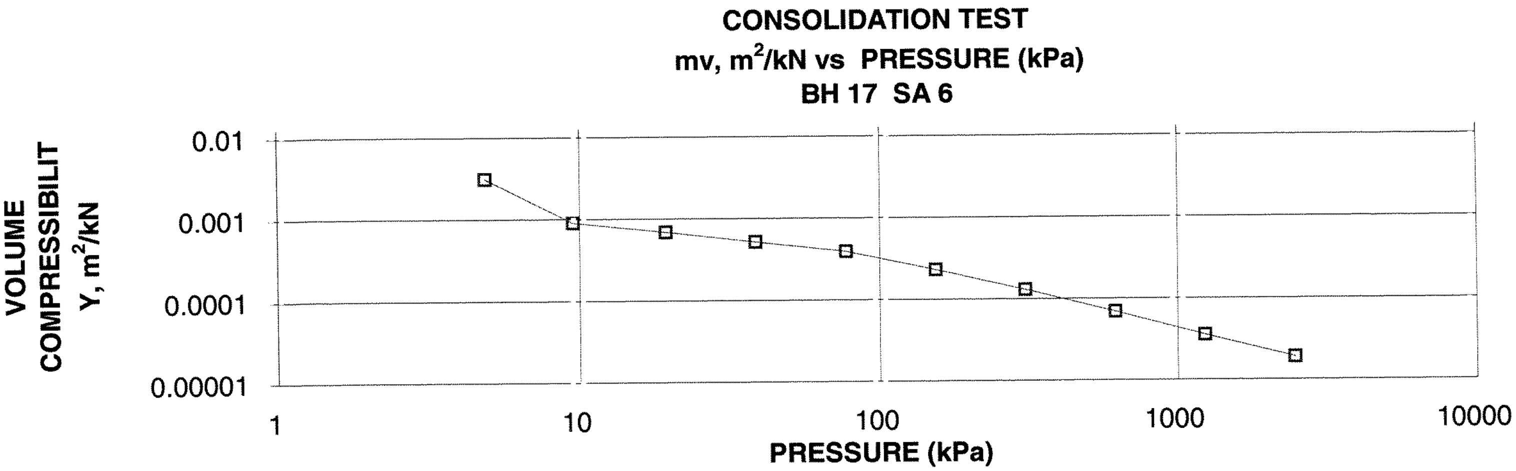
OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 12+200

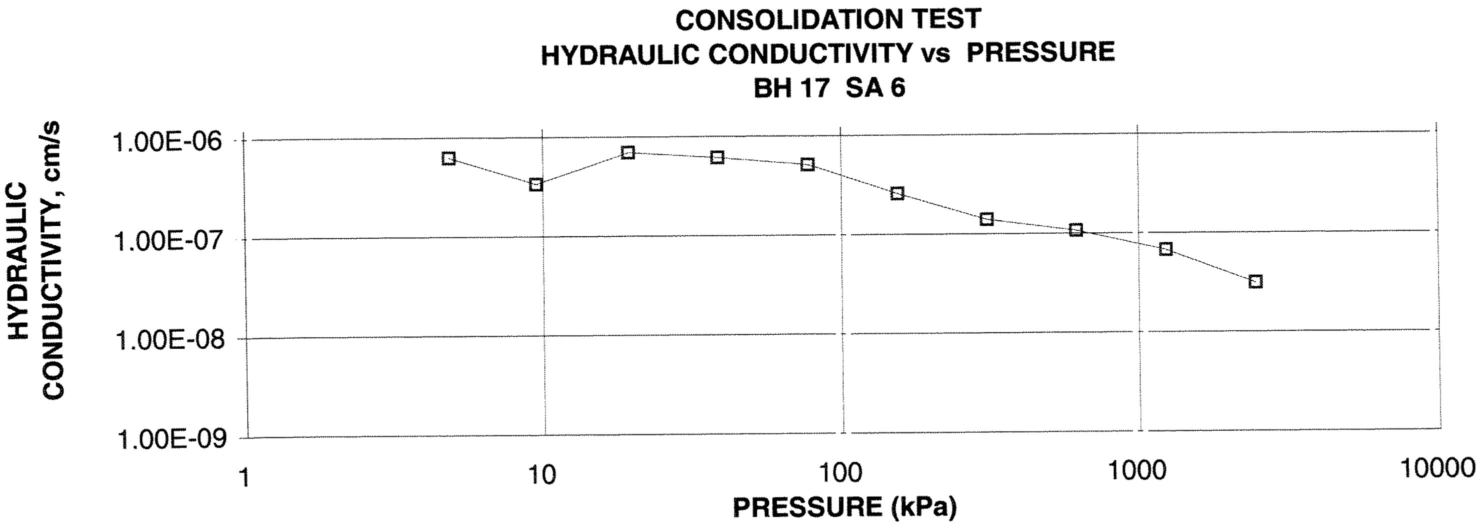
FIGURE A-5
Sheet 2 of 4



CONSOLIDATION TEST
cv cm^2/s vs PRESSURE (kPa)
BH 17 SA 6



CONSOLIDATION TEST
mv, m^2/kN vs PRESSURE (kPa)
BH 17 SA 6

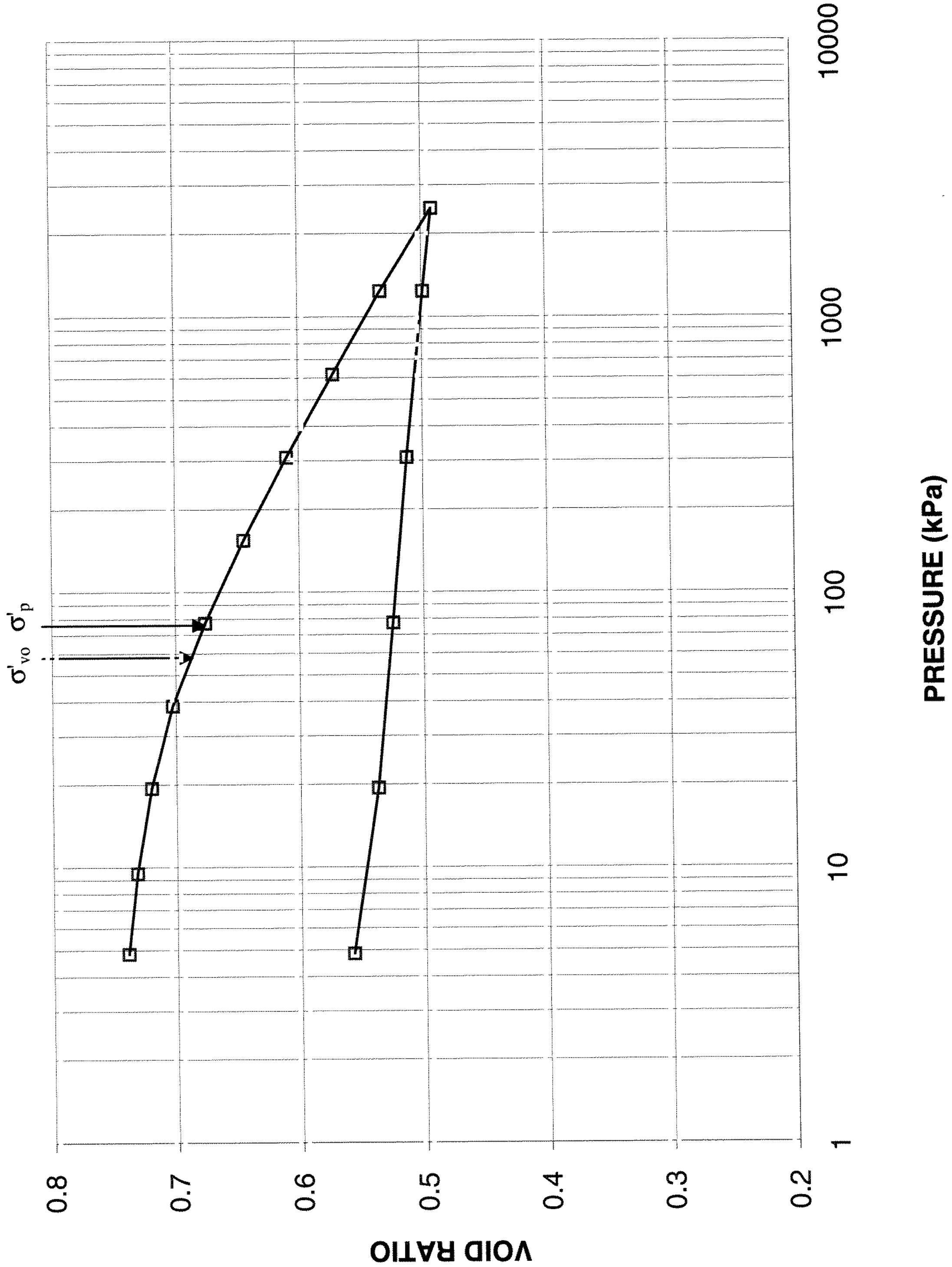


CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH 17 SA 6

Project No. 03-1111-011-4

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE A-5
Sheet 3 of 4

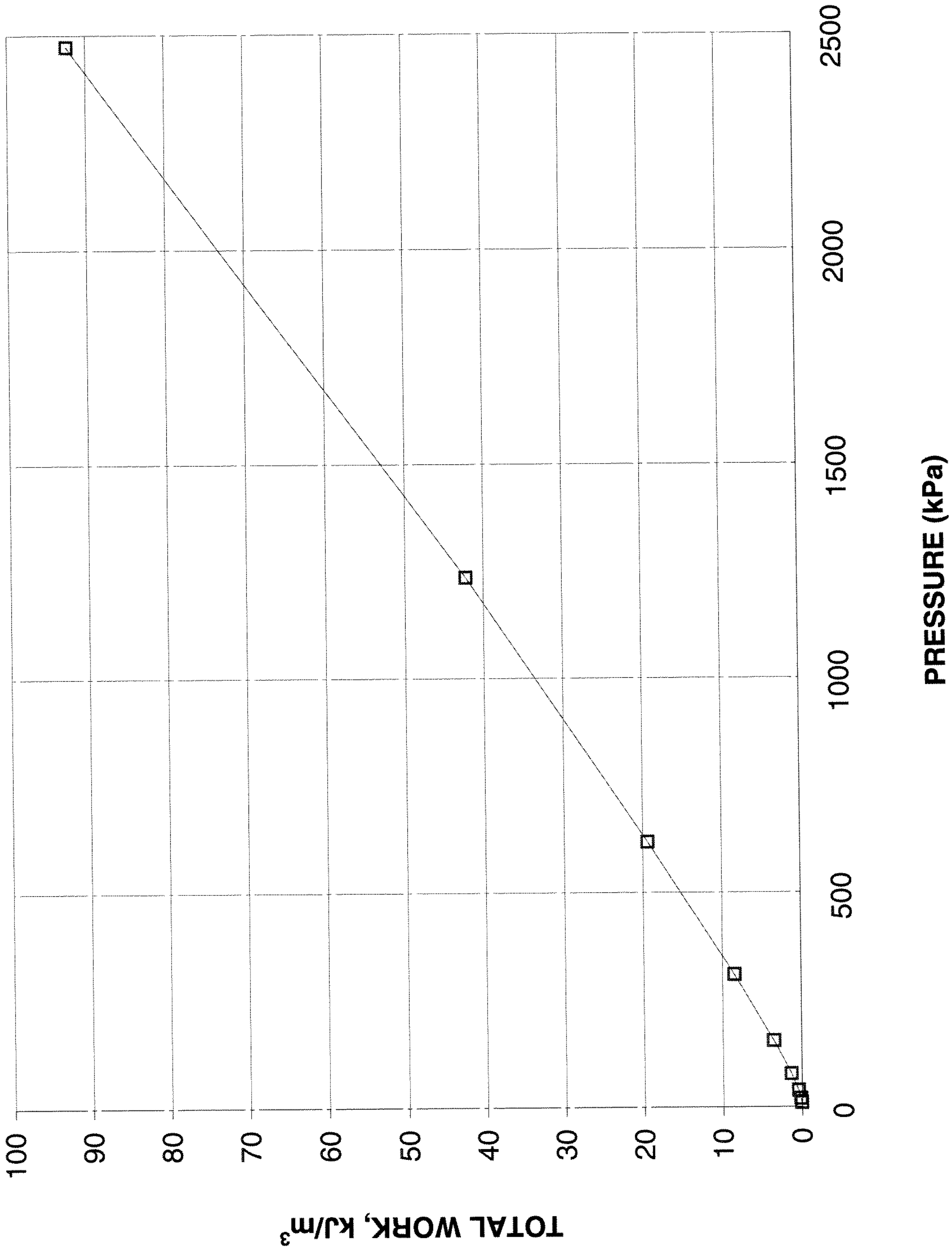


CONSOLIDATION TEST
VOID RATIO vs PRESSURE
Highway 69 Culvert Sta. 12+200
BH 17 SA 6

Project No. 03-1111-011-4

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

FIGURE A-5
Sheet 4 of 4



CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
Highway 69 Culvert Sta. 12+200
BH 17 SA 6

Project No. 03-1111-011-2 4

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Highway 69 Culvert Sta. 12+200

FIGURE A-6
Sheet 1 of 4

TEST STAGE	A	B	C
BOREHOLE NUMBER	120	120	120
SAMPLE NUMBER	6	6	6
SPECIMEN DIAMETER, cm	5.02	5.01	4.99
SPECIMEN HEIGHT, cm	10.13	10.14	10.10
WATER CONTENT BEFORE CONSOLIDATION, %	64.2	63.5	60.3
CELL PRESSURE, σ_3, kPa	185.0	285.0	385.0
BACK PRESSURE, kPa	135.0	135.0	135.0
PORE PRESSURE PARAMETER "B"	0.97	0.97	0.96
CONSOLIDATION PRESSURE, σc, kPa	50.0	150.0	250.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	2.7	12.3	18.7
WATER CONTENT AFTER CONSOLIDATION, %	61.5	51.5	42.7
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, DAYS	1	1	1
WATER CONTENT AFTER TEST, %	60.4	50.9	40.7
MAX. DEVIATOR STRESS, $(\sigma_1-\sigma_3)$, kPa	56.9	86.4	130.8
AXIAL STRAIN AT $(\sigma_1-\sigma_3)$ MAXIMUM, %	2.6	3.1	5.0
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ_1/σ_3) MAXIMUM	4.5	4.0	3.7
DEVIATOR STRESS AT (σ_1/σ_3) MAXIMUM, kPa	56.2	65.5	119.4
AXIAL STRAIN AT (σ_1/σ_3) MAXIMUM, %	3.1	14.3	15.2
PORE PRESSURE PARAMETER, Af, AT $(\sigma_1-\sigma_3)$ MAXIMUM	0.58	1.17	1.37
PORE PRESSURE PARAMETER, Af, AT (σ_1/σ_3) MAXIMUM	0.60	1.95	1.73
NATURAL WATER CONTENT, %	62.9	62.7	58.6
DRY DENSITY, Mg/m^3	1.02	1.02	1.06
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES:			
CHANGED RATE OF STRAIN, %/hr	-	-	-
AXIAL STRAIN WHERE RATE OF STRAIN WAS CHANGED, %	-	-	-
FAILURE PLANE NUMBER	1	-	-
ANGLE OF FAILURE, DEGREES	60	-	-

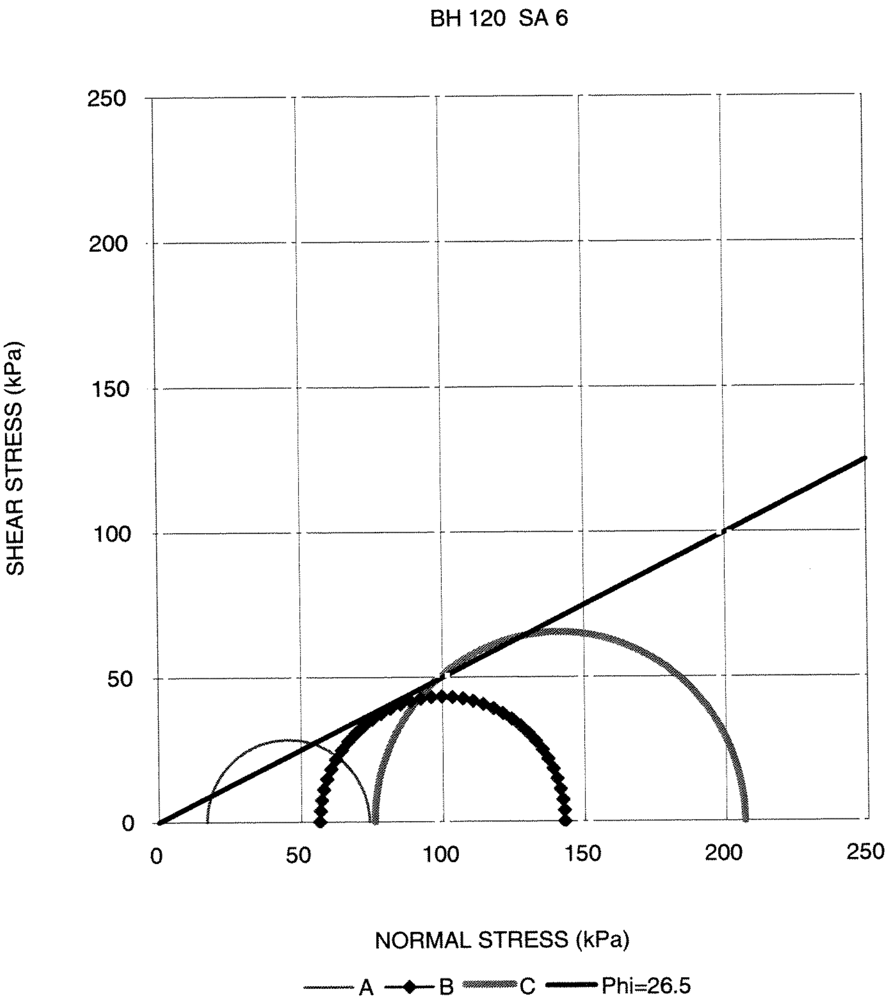
DATE: 09/27/2004

Project No. 03-1111-011-4 **Golder Associates**

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

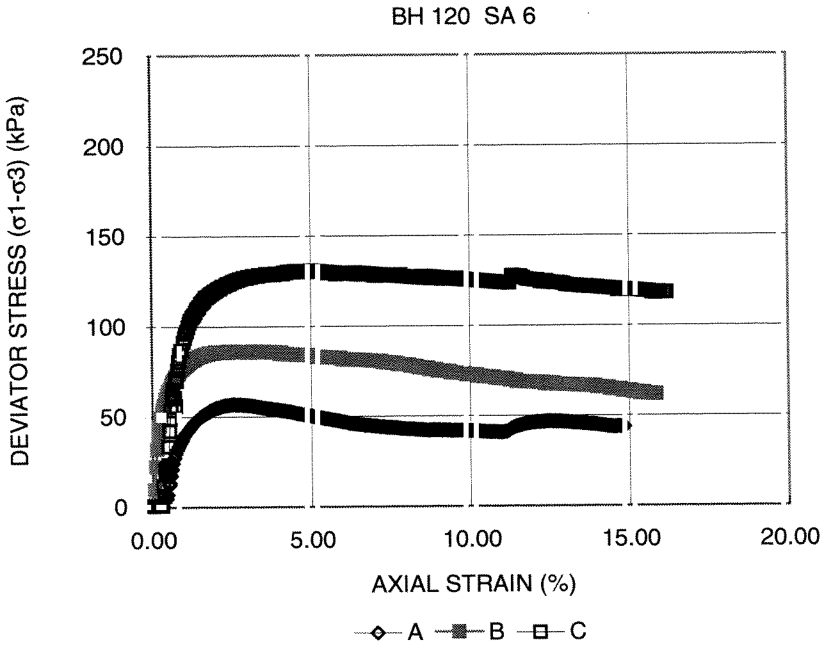
Highway 69 Culvert Sta. 12+200

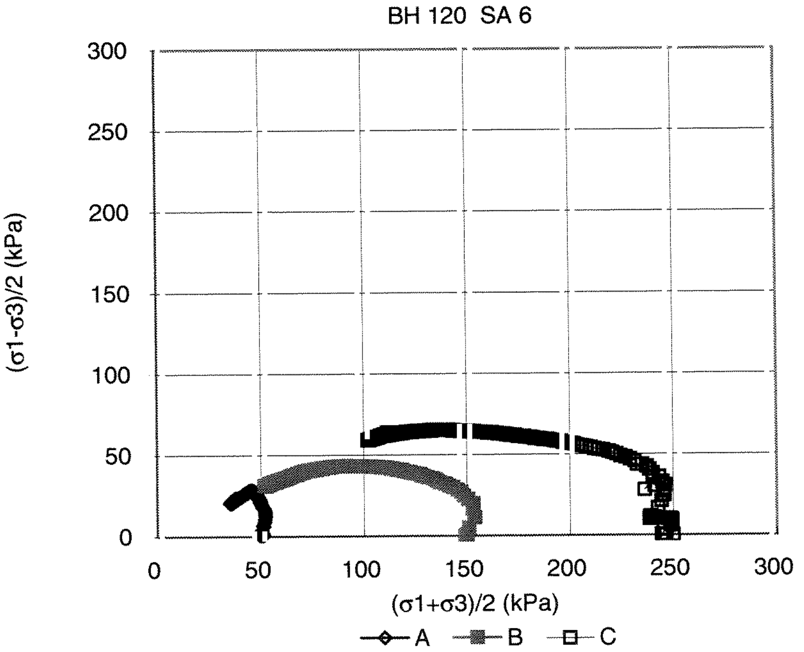
FIGURE A-6
Sheet 2 of 4



CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 12+200

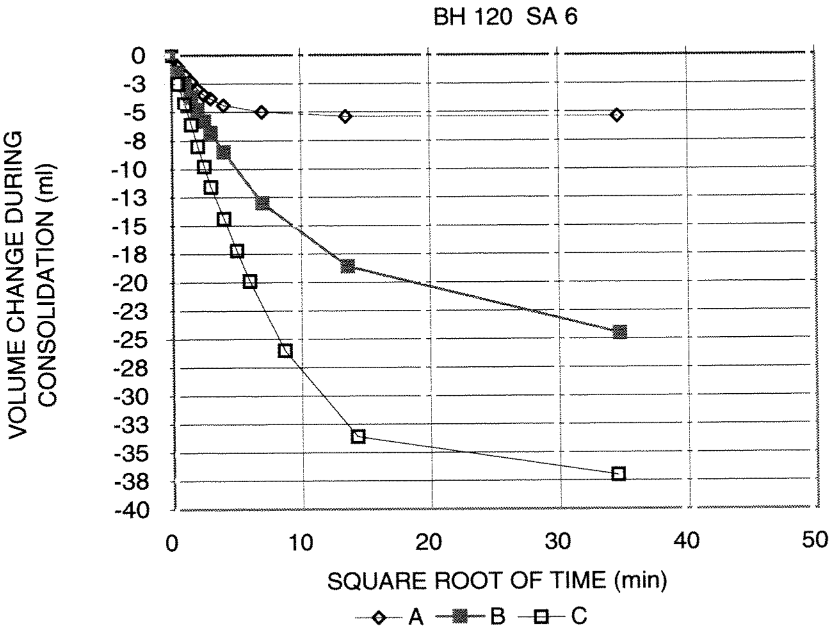
FIGURE A-6
Sheet 3 of 4

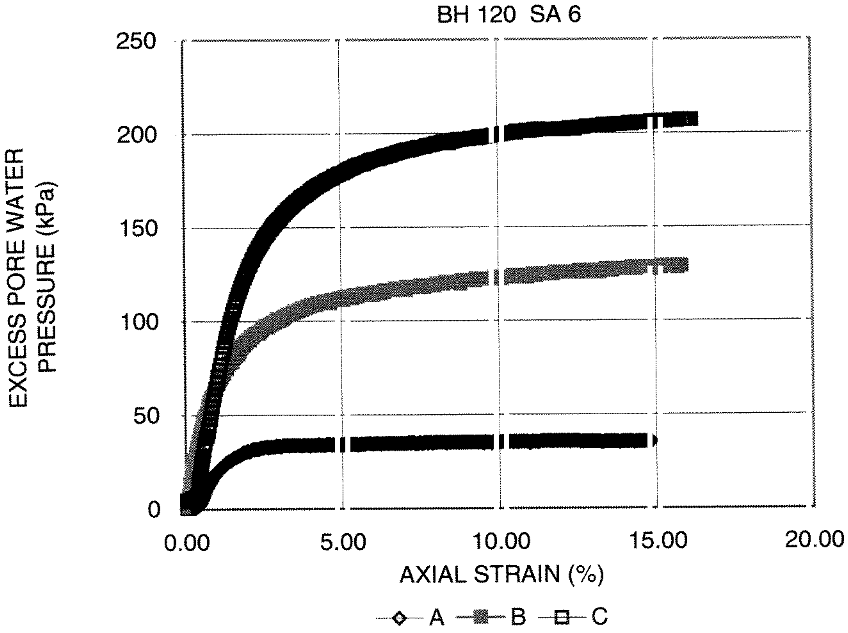




CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 12+200

FIGURE A-6
Sheet 4 of 4





Project No. 03-1111-011-4

Golder Associates

OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 12+200

FIGURE A-7
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	9
Borehole Number	121	Sample Depth, m	9.1-9.8

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	07/29/2004		
Date Completed	08/10/2004		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	17.96
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	12.82
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	60.45	Solids Height, cm	0.915
Water Content, %	40.13	Volume of Solids, cm^3	28.95
Wet Mass, g	110.73	Volume of Voids, cm^3	31.51
Dry Mass, g	79.02	Degree of Saturation, %	100.7

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.910	1.088	1.910				
4.78	1.908	1.086	1.909	60	1.29E-02	2.19E-04	2.76E-07
9.59	1.903	1.081	1.906	94	8.19E-03	5.44E-04	4.37E-07
19.50	1.893	1.070	1.898	53	1.44E-02	5.28E-04	7.46E-07
38.82	1.881	1.057	1.887	46	1.64E-02	3.25E-04	5.23E-07
77.80	1.861	1.035	1.871	46	1.61E-02	2.69E-04	4.25E-07
155.39	1.829	1.000	1.845	31	2.33E-02	2.16E-04	4.93E-07
309.65	1.723	0.884	1.776	103	6.49E-03	3.60E-04	2.29E-07
620.28	1.628	0.780	1.676	85	7.00E-03	1.60E-04	1.10E-07
1241.59	1.554	0.699	1.591	53	1.01E-02	6.24E-05	6.19E-08
2482.48	1.484	0.623	1.519	68	7.19E-03	2.95E-05	2.08E-08
1241.59	1.494	0.634	1.489				
309.65	1.517	0.659	1.506				
77.80	1.541	0.685	1.529				
19.50	1.570	0.717	1.556				
4.78	1.585	0.733	1.578				

Notes:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

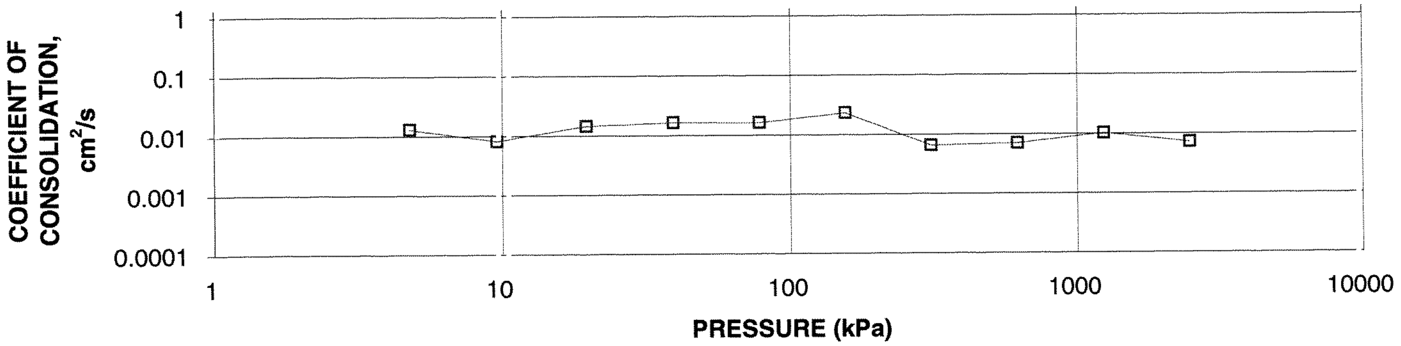
Sample Height, cm	1.59	Unit Weight, kN/m^3	16.85
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.45
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	50.16	Solids Height, cm	0.915
Water Content, %	9.09	Volume of Solids, cm^3	28.95
Wet Mass, g	86.20	Volume of Voids, cm^3	21.22
Dry Mass, g	79.02		

OEDOMETER CONSOLIDATION SUMMARY

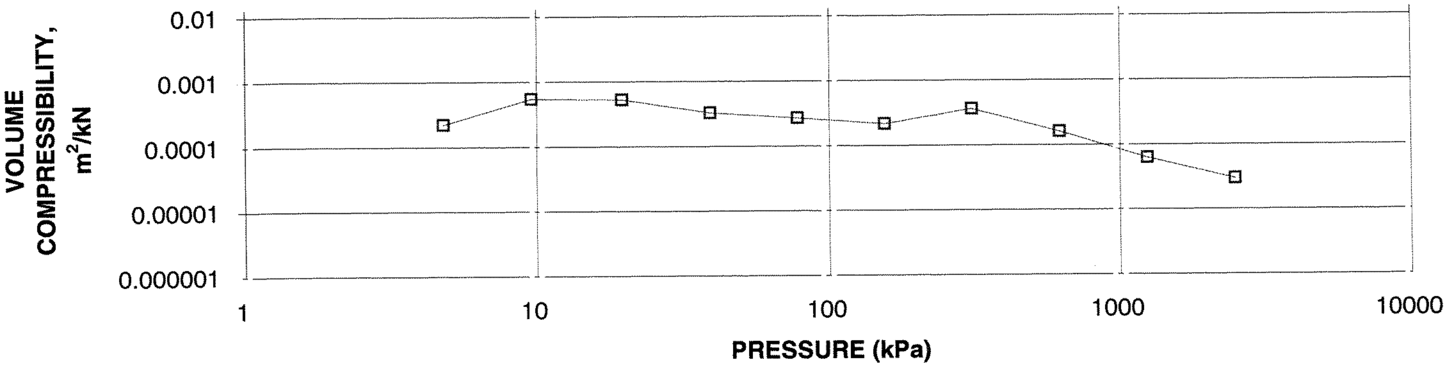
Highway 69 Culvert Sta. 12+200

FIGURE A-7
Sheet 2 of 4

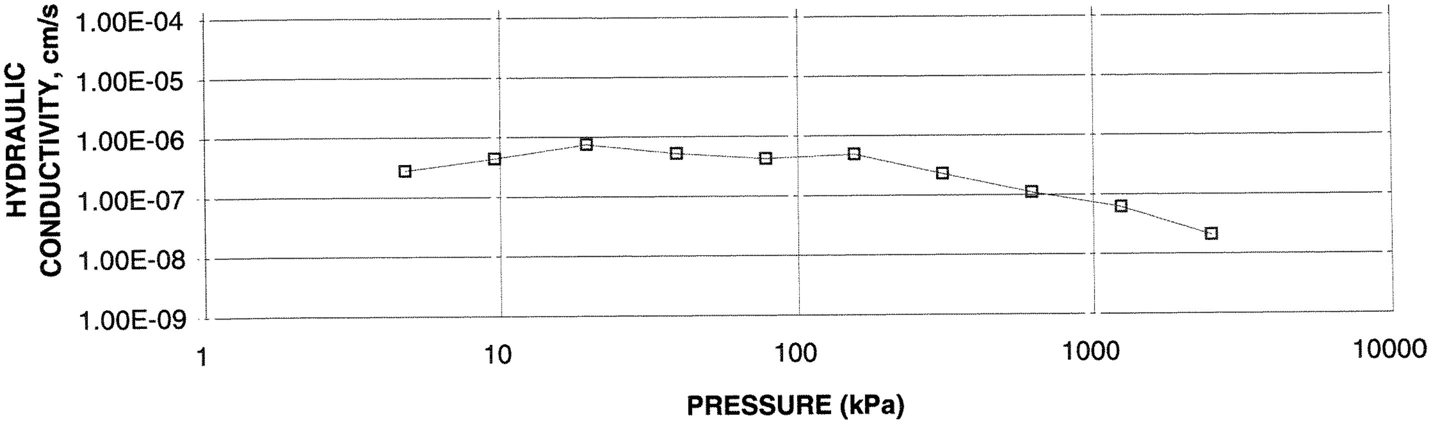
CONSOLIDATION TEST
CV cm^2/s VS PRESSURE (kPa)
BH 121 SA 9



CONSOLIDATION TEST
MV m^2/kN vs PRESSURE (kPa)
BH 121 SA 9

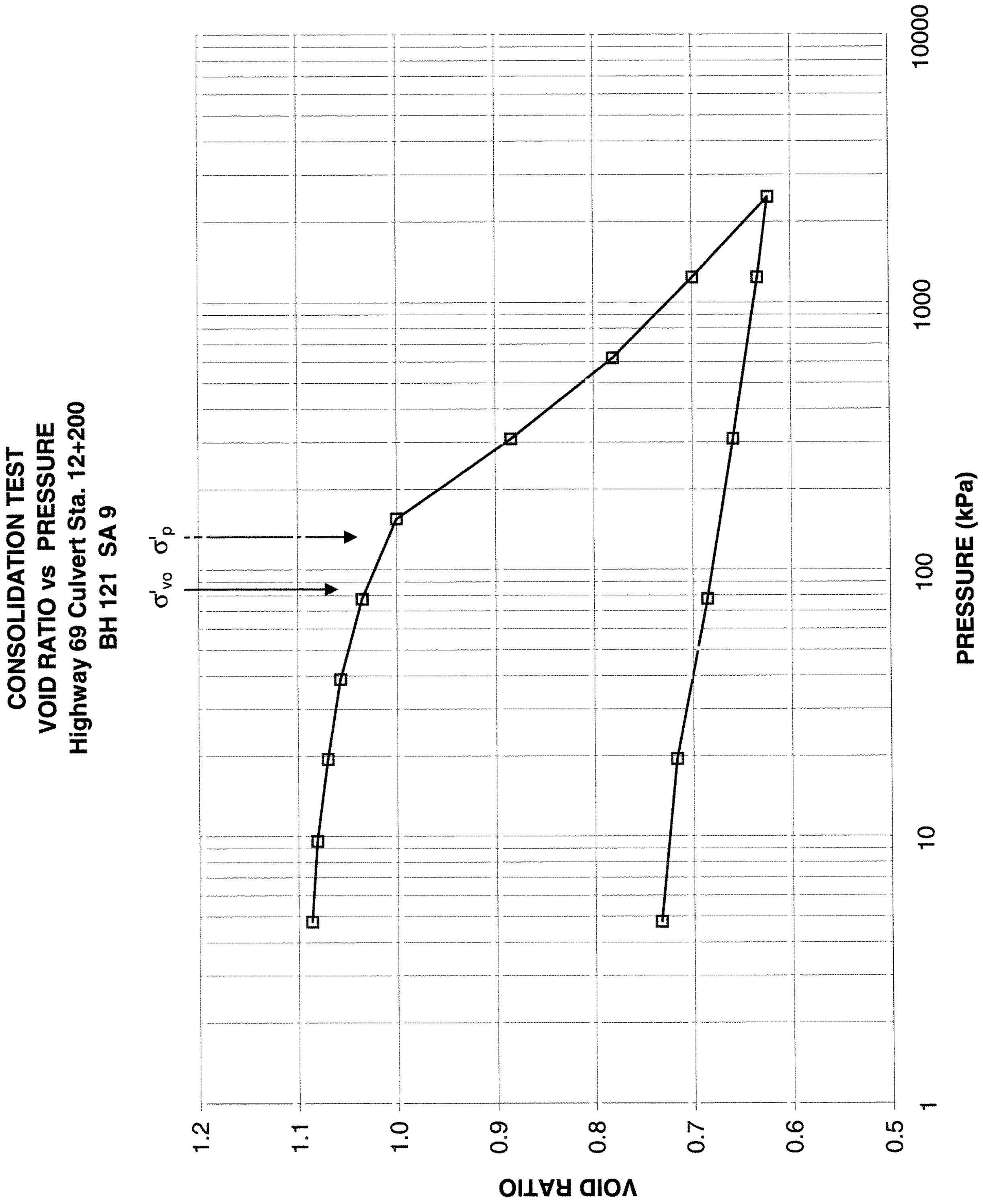


CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH 121 SA 9



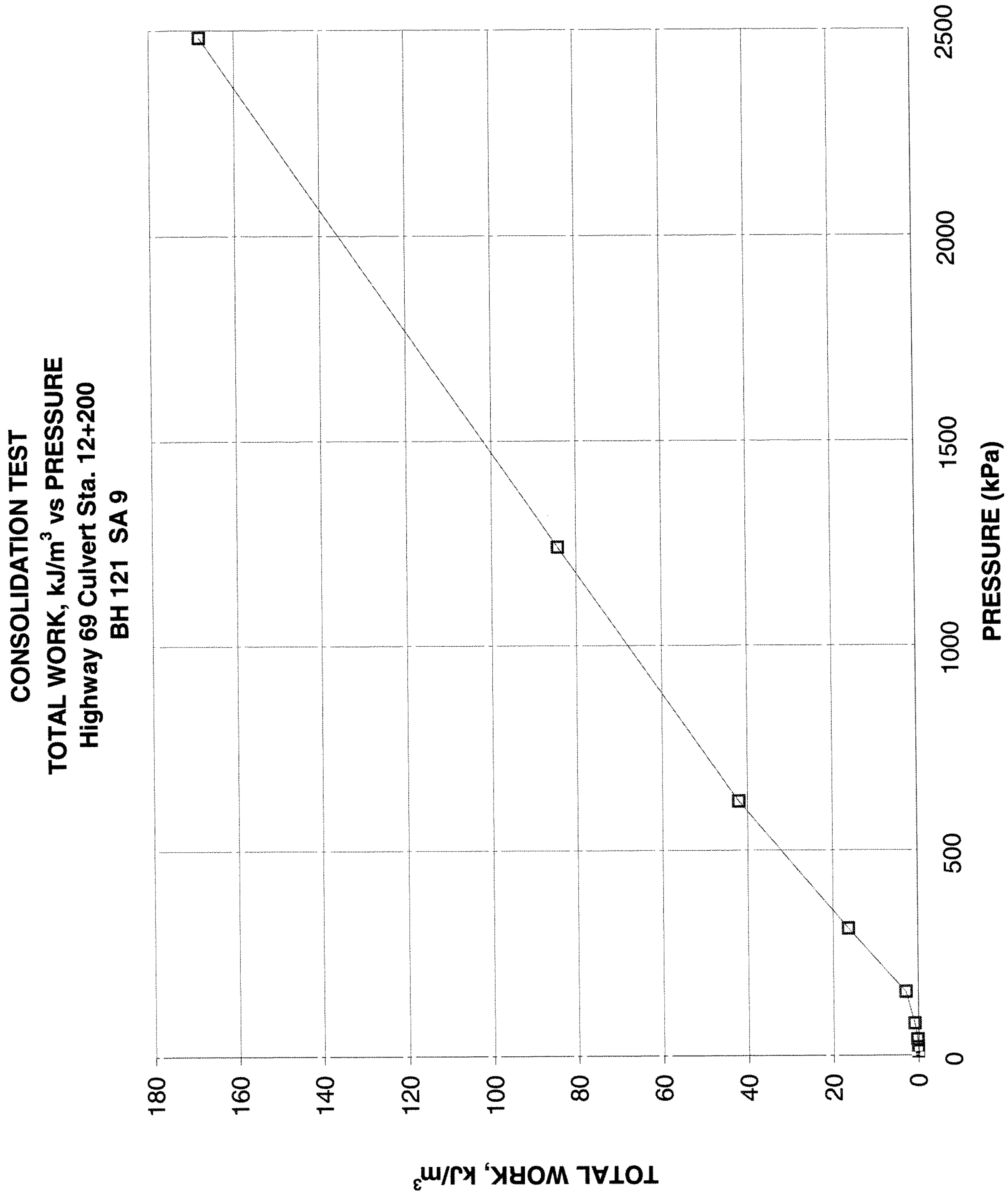
CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE
Highway 69 Culvert Sta. 12+200

FIGURE A-7
Sheet 3 of 4



CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE
Highway 69 Culvert Sta. 12+200

FIGURE A-7
Sheet 4 of 4

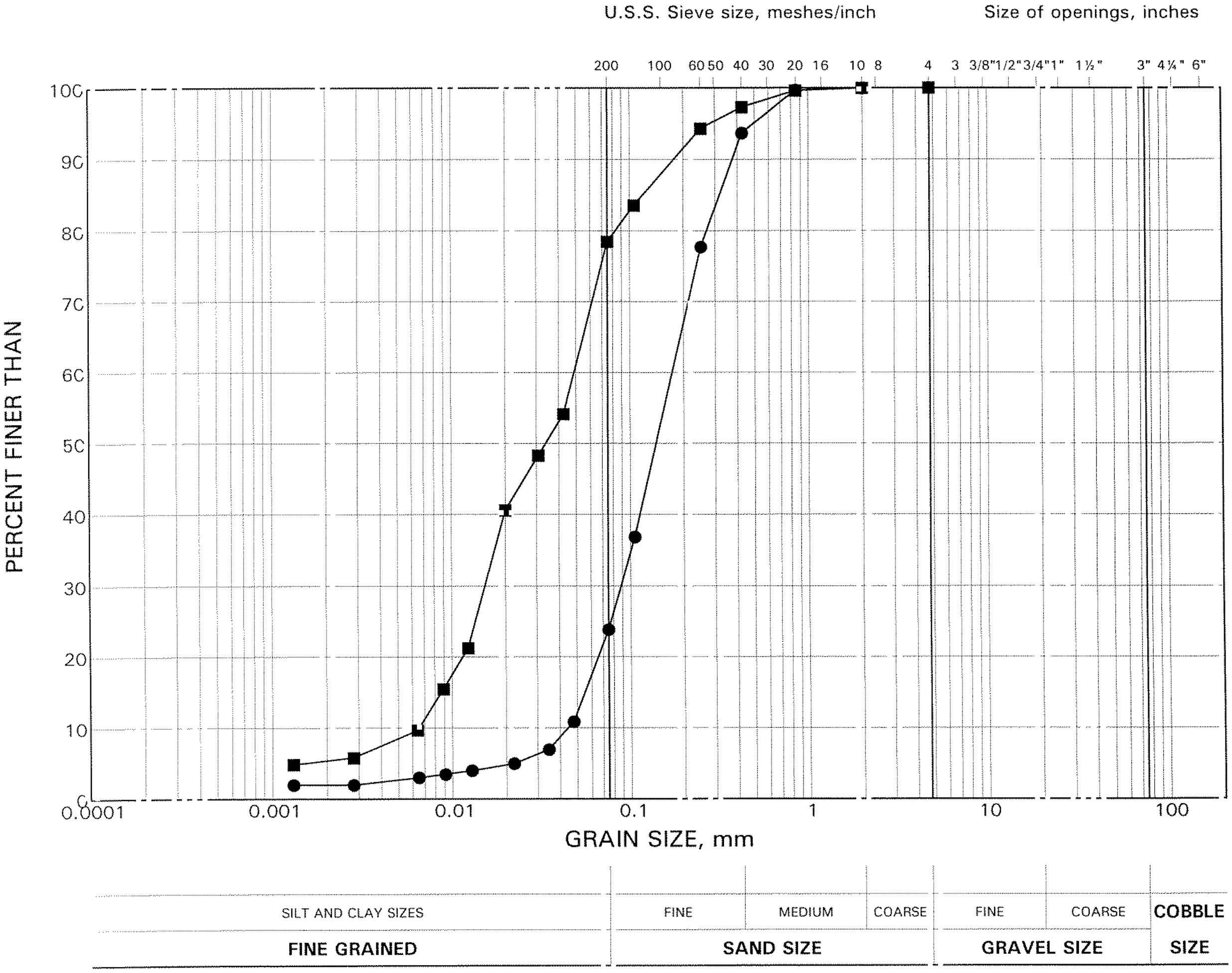


Project No. 03-1111-011-4

Golder Associates

GRAIN SIZE DISTRIBUTION
Silty Sand to Sandy Silt
Culvert Hwy 69 Station 12+200

FIGURE A-8



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	120	13	221.2
■	121	11	225.9

Date June, 2005

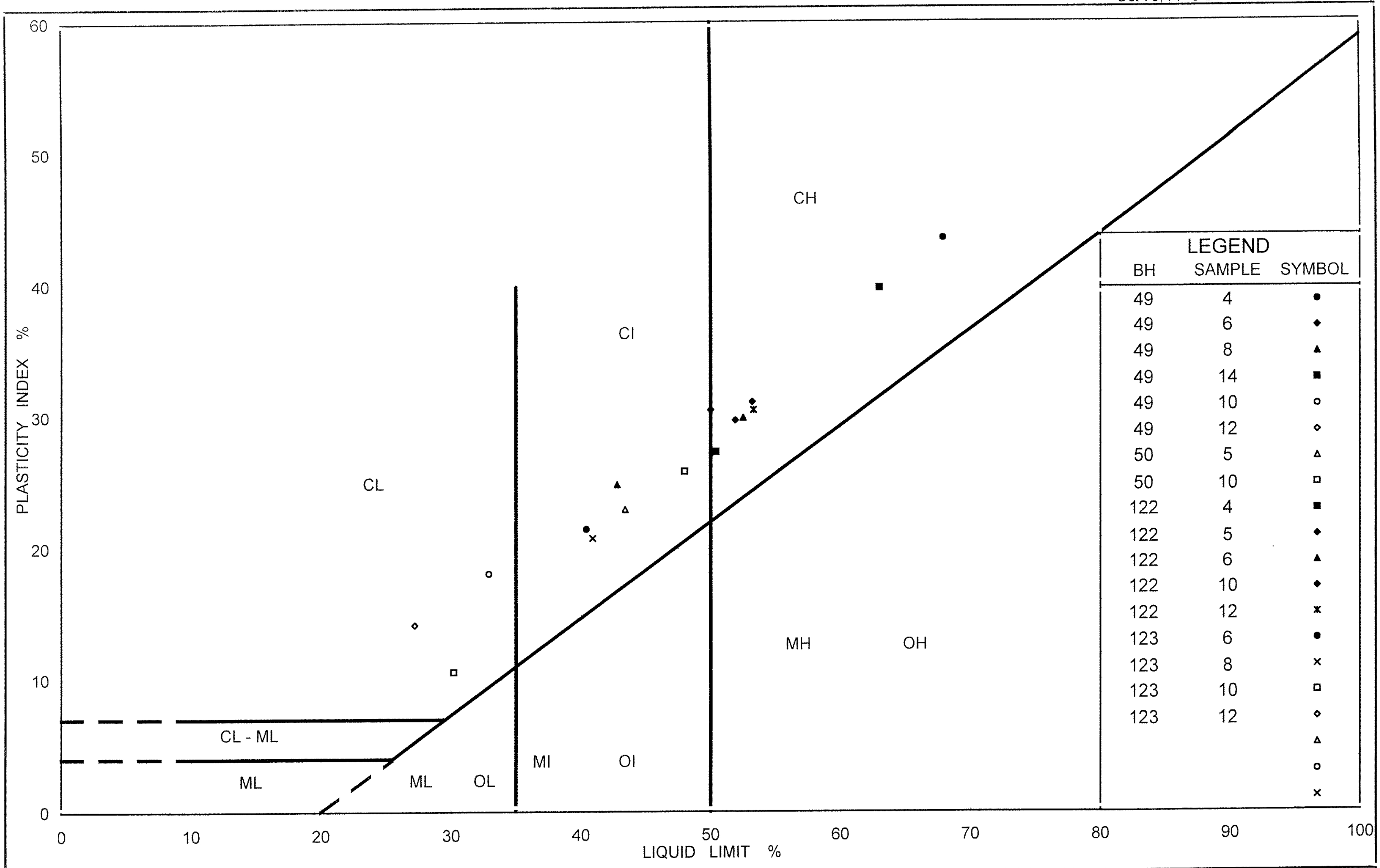
Project 03-1111-011-4

Golder Associates

Prepared by LG

Checked by ________

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Clay

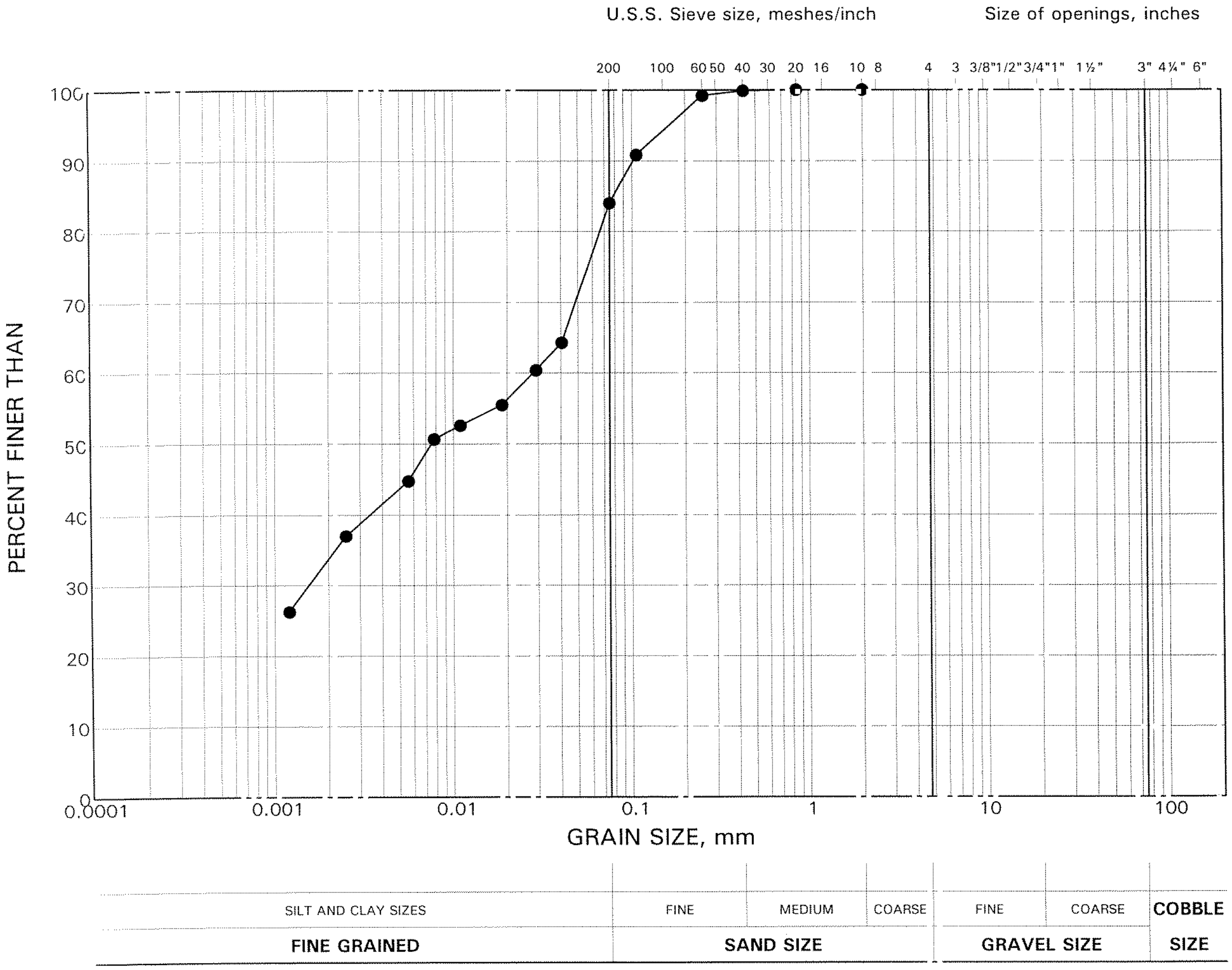
FIG No. A-9

Project No. 03-1111-011-4

Hwy 69 Culvert Sta. 14+100

GRAIN SIZE DISTRIBUTION
Clayey Silt to Clay
Culvert Hwy 69 Station 14+100

FIGURE A-10



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	49	12	222.4

Date June, 2005

Project 03-1111-011-4

Golder Associates

Prepared by LG

Checked by

OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-11
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	10
Borehole Number	122	Sample Depth, m	12.2-12.6

TEST CONDITIONS

Test Type	Quick	Load Duration, hr	(0.1-0.2)
Oedometer Number	6		
Date Started	09/25/2004		
Date Completed	09/26/2004		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	17.99
Sample Diameter, cm	6.37	Dry Unit Weight, kN/m^3	13.22
Area, cm^2	31.84	Specific Gravity, measured	2.71
Volume, cm^3	60.81	Solids Height, cm	0.950
Water Content, %	36.13	Volume of Solids, cm^3	30.24
Wet Mass, g	111.57	Volume of Voids, cm^3	30.57
Dry Mass, g	81.96	Degree of Saturation, %	96.9

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.910	1.011	1.910				
4.74	1.904	1.004	1.907	4	1.93E-01	6.63E-04	1.25E-05
9.51	1.893	0.993	1.899	10	7.64E-02	1.21E-03	9.04E-06
19.18	1.881	0.980	1.887	15	5.03E-02	6.50E-04	3.20E-06
38.53	1.868	0.967	1.875	51	1.46E-02	3.52E-04	5.03E-07
77.09	1.846	0.943	1.857	41	1.78E-02	2.99E-04	5.22E-07
154.10	1.814	0.910	1.830	42	1.69E-02	2.18E-04	3.60E-07
308.09	1.731	0.822	1.773	102	6.53E-03	2.82E-04	1.81E-07
616.03	1.635	0.721	1.683	51	1.18E-02	1.63E-04	1.88E-07
1232.29	1.560	0.642	1.598	75	7.21E-03	6.37E-05	4.50E-08
2464.90	1.490	0.569	1.525	60	8.22E-03	2.97E-05	2.39E-08
1232.29	1.501	0.580	1.496				
308.09	1.515	0.595	1.508				
77.09	1.531	0.612	1.523				
19.18	1.557	0.639	1.544				
4.74	1.584	0.668	1.571				

Notes:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

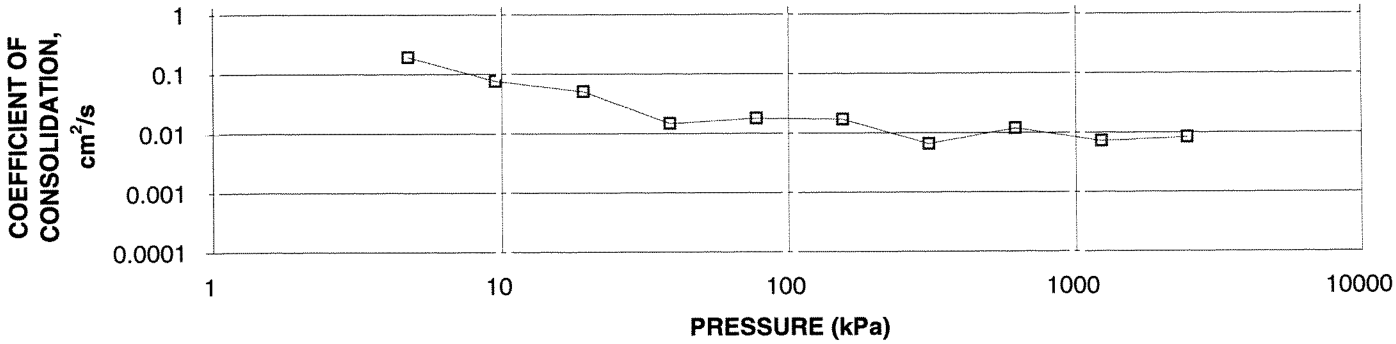
Sample Height, cm	1.58	Unit Weight, kN/m^3	19.79
Sample Diameter, cm	6.37	Dry Unit Weight, kN/m^3	15.94
Area, cm^2	31.84	Specific Gravity, measured	2.71
Volume, cm^3	50.43	Solids Height, cm	0.950
Water Content, %	24.15	Volume of Solids, cm^3	30.24
Wet Mass, g	101.75	Volume of Voids, cm^3	20.19
Dry Mass, g	81.96		

OEDOMETER CONSOLIDATION SUMMARY

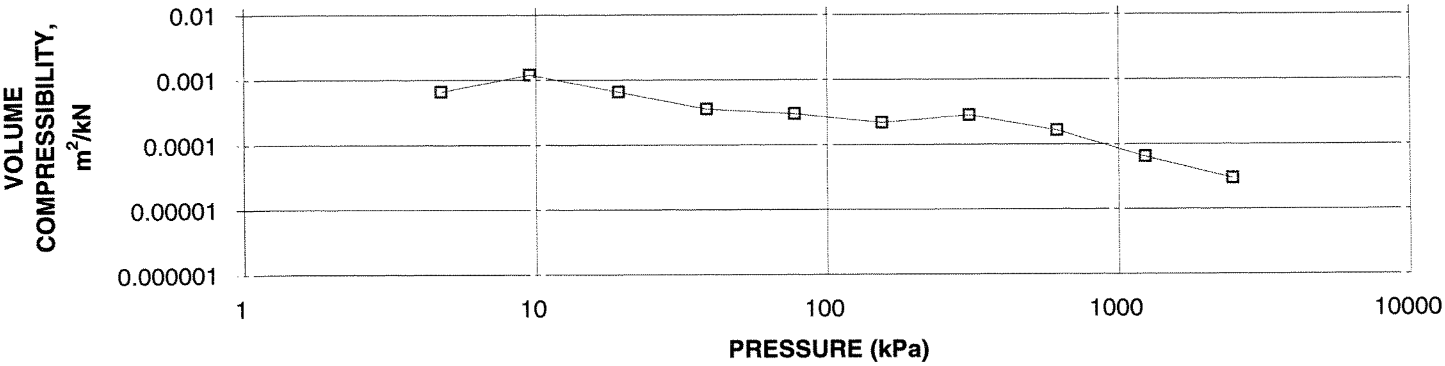
Highway 69 Culvert Sta. 14+100

FIGURE A-11
Sheet 2 of 4

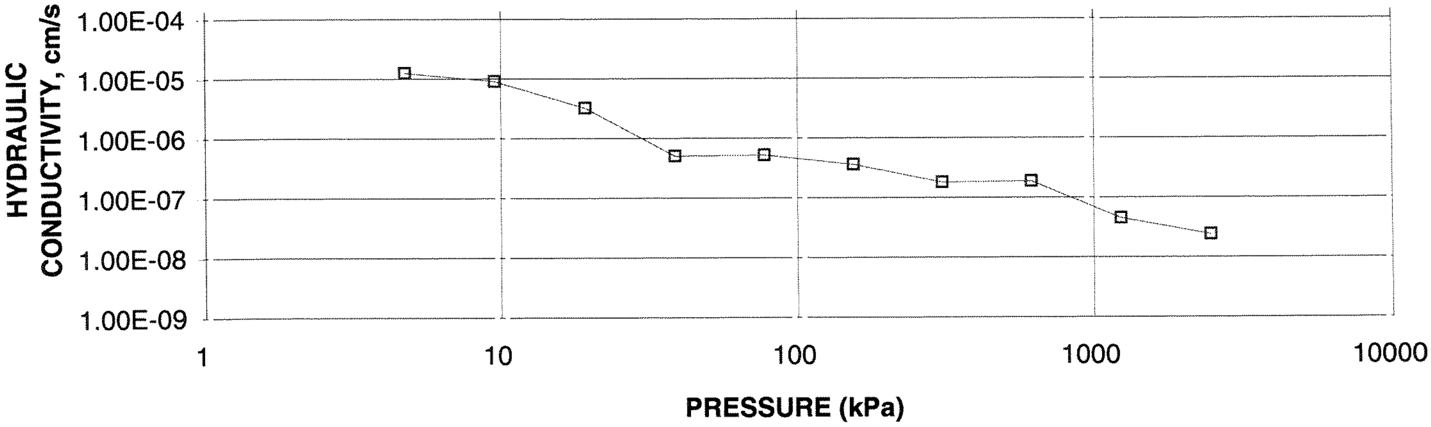
CONSOLIDATION TEST
CV cm^2/s VS PRESSURE (kPa)
BH 122 SA 10



CONSOLIDATION TEST
MV m^2/kN vs PRESSURE (kPa)
BH 122 SA 10

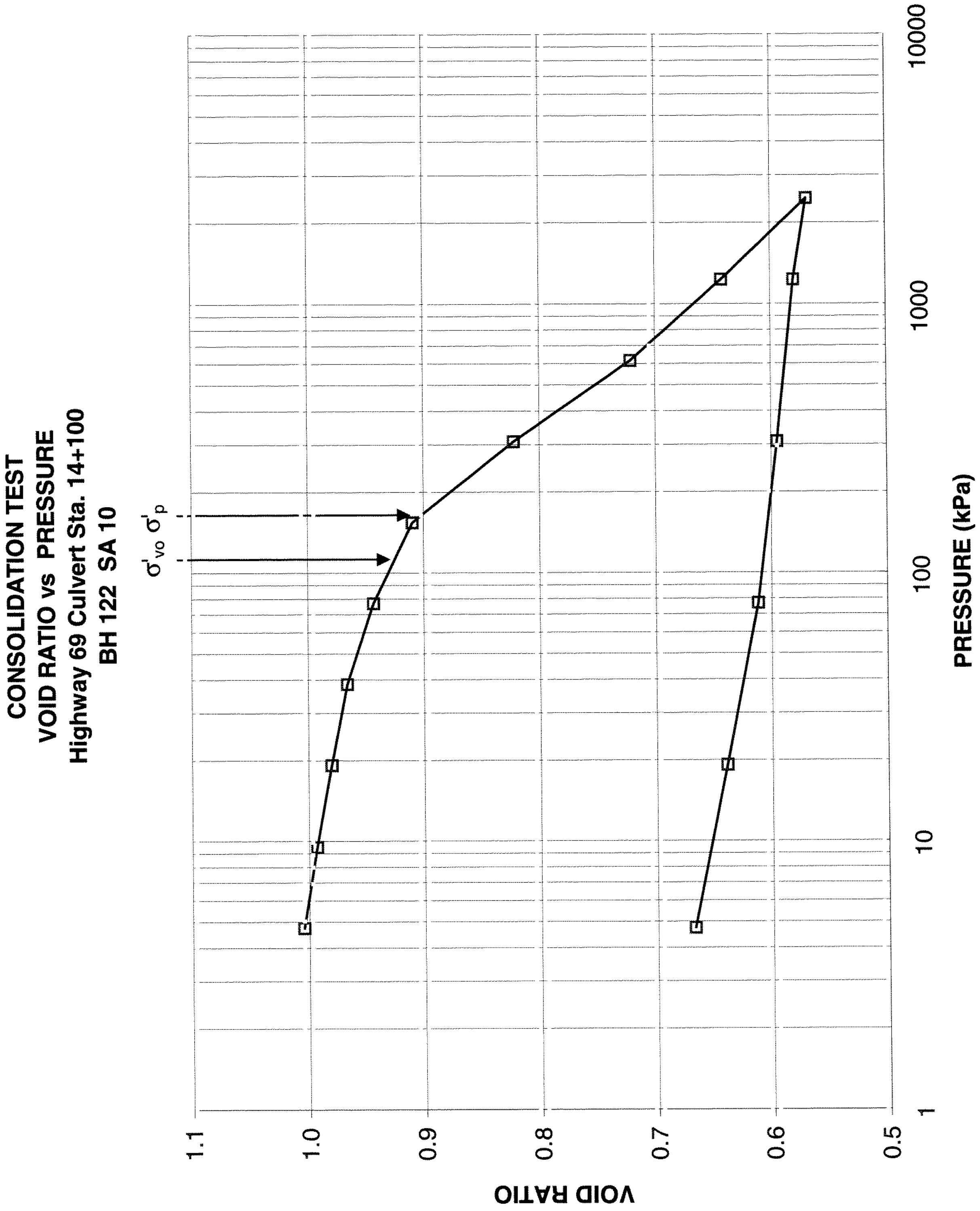


CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH 122 SA 10



CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-11
Sheet 3 of 4

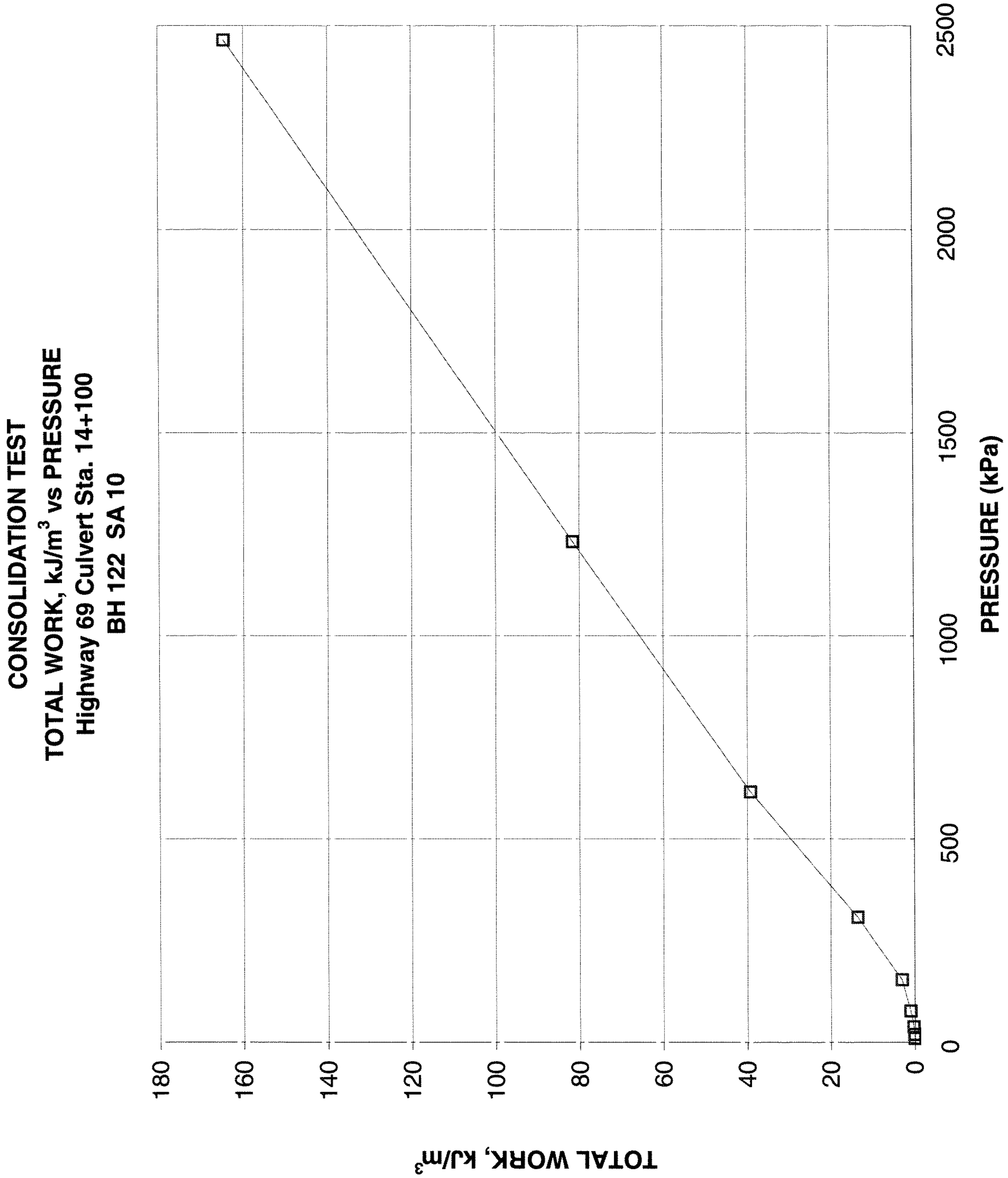


Project No. 03-1111-011-4

Golder Associates

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-11
Sheet 4 of 4



OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-12
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	8
Borehole Number	123	Sample Depth, m	7.6-8.1

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	07/29/2004		
Date Completed	08/09/2004		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	17.04
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	11.35
Area, cm^2	31.65	Specific Gravity, measured	2.72
Volume, cm^3	60.13	Solids Height, cm	0.808
Water Content, %	50.19	Volume of Solids, cm^3	25.58
Wet Mass, g	104.49	Volume of Voids, cm^3	34.56
Dry Mass, g	69.57	Degree of Saturation, %	101.1

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.900	1.351	1.900				
4.83	1.890	1.339	1.895	8	9.52E-02	1.09E-03	1.02E-05
9.46	1.885	1.333	1.888	76	9.94E-03	5.68E-04	5.54E-07
19.51	1.874	1.319	1.880	94	7.97E-03	5.76E-04	4.50E-07
38.91	1.862	1.304	1.868	124	5.97E-03	3.26E-04	1.90E-07
77.57	1.838	1.274	1.850	113	6.42E-03	3.27E-04	2.06E-07
154.88	1.709	1.115	1.774	321	2.08E-03	8.78E-04	1.79E-07
309.21	1.536	0.901	1.623	816	6.84E-04	5.90E-04	3.95E-08
618.96	1.421	0.758	1.479	496	9.34E-04	1.95E-04	1.79E-08
1237.94	1.332	0.648	1.377	287	1.40E-03	7.57E-05	1.04E-08
2475.88	1.247	0.543	1.290	124	2.84E-03	3.61E-05	1.01E-08
1237.94	1.260	0.559	1.254				
309.21	1.288	0.594	1.274				
77.57	1.325	0.640	1.307				
19.51	1.355	0.677	1.340				
4.83	1.390	0.720	1.373				

Notes:
k calculated using cv based on t_{90} values.

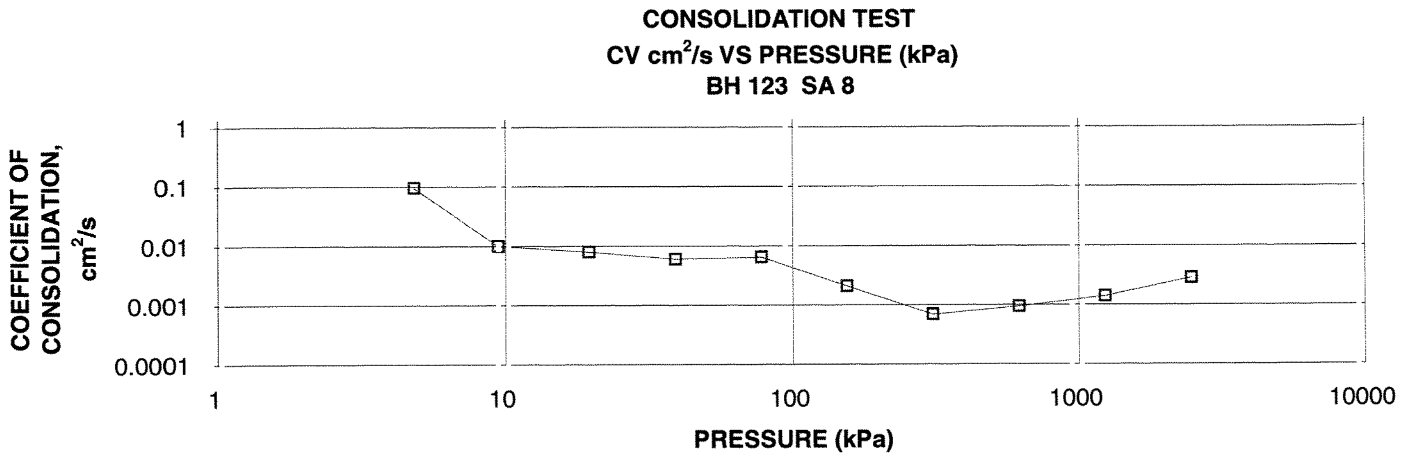
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

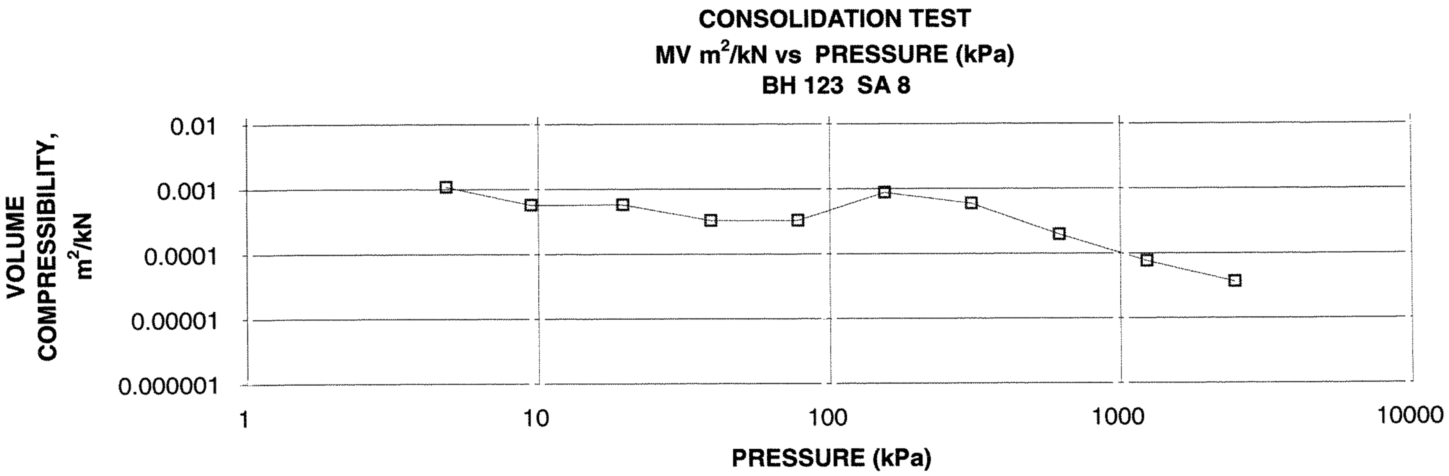
Sample Height, cm	1.39	Unit Weight, kN/m^3	19.92
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.51
Area, cm^2	31.65	Specific Gravity, measured	2.72
Volume, cm^3	43.99	Solids Height, cm	0.808
Water Content, %	28.46	Volume of Solids, cm^3	25.58
Wet Mass, g	89.37	Volume of Voids, cm^3	18.42
Dry Mass, g	69.57		

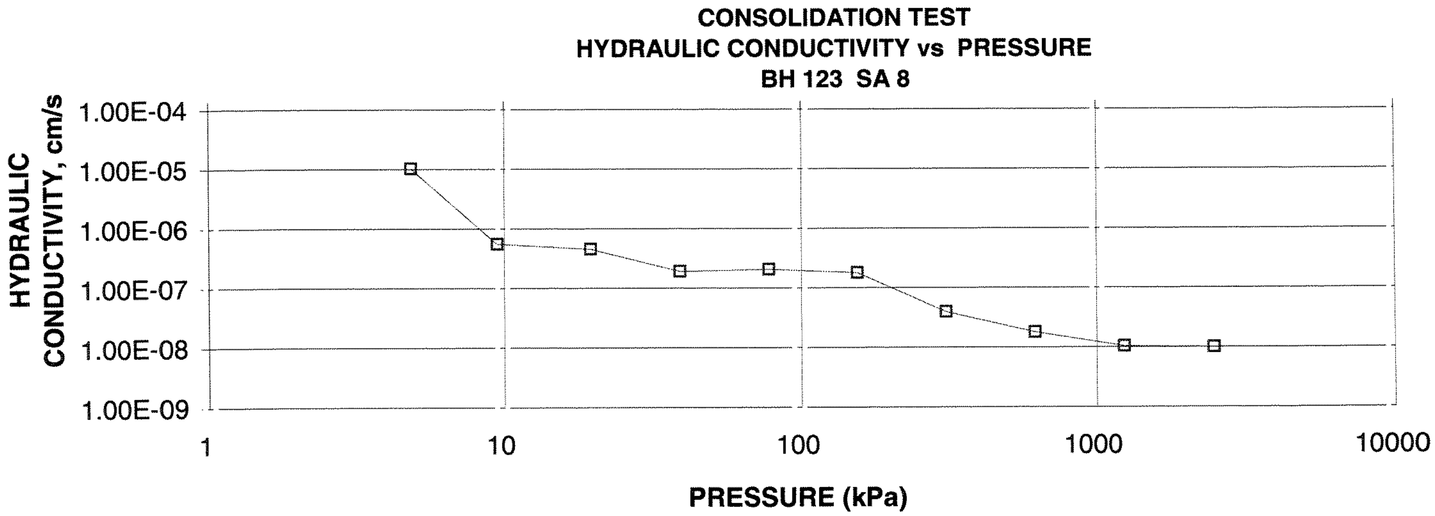
OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-12
Sheet 2 of 4

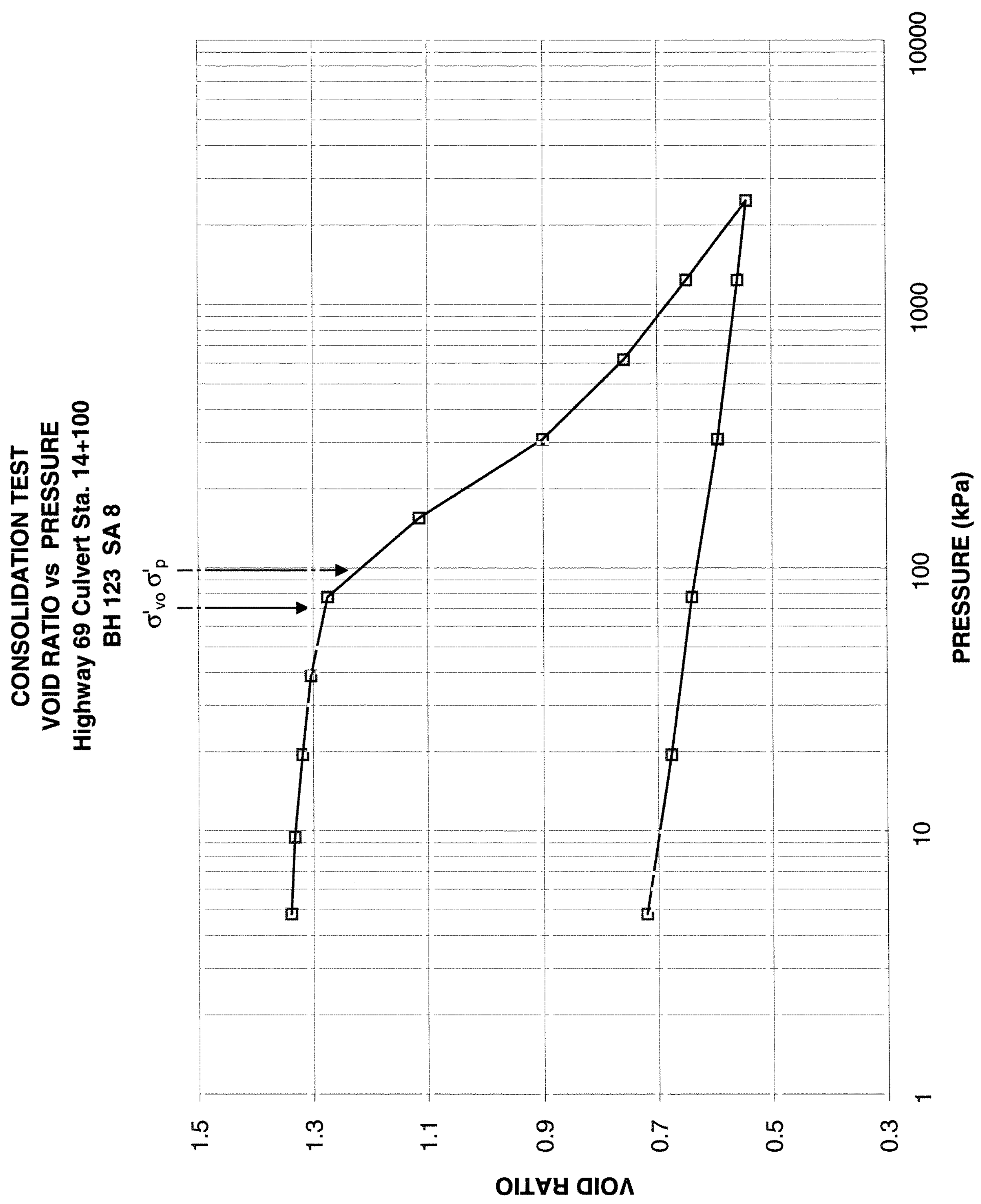






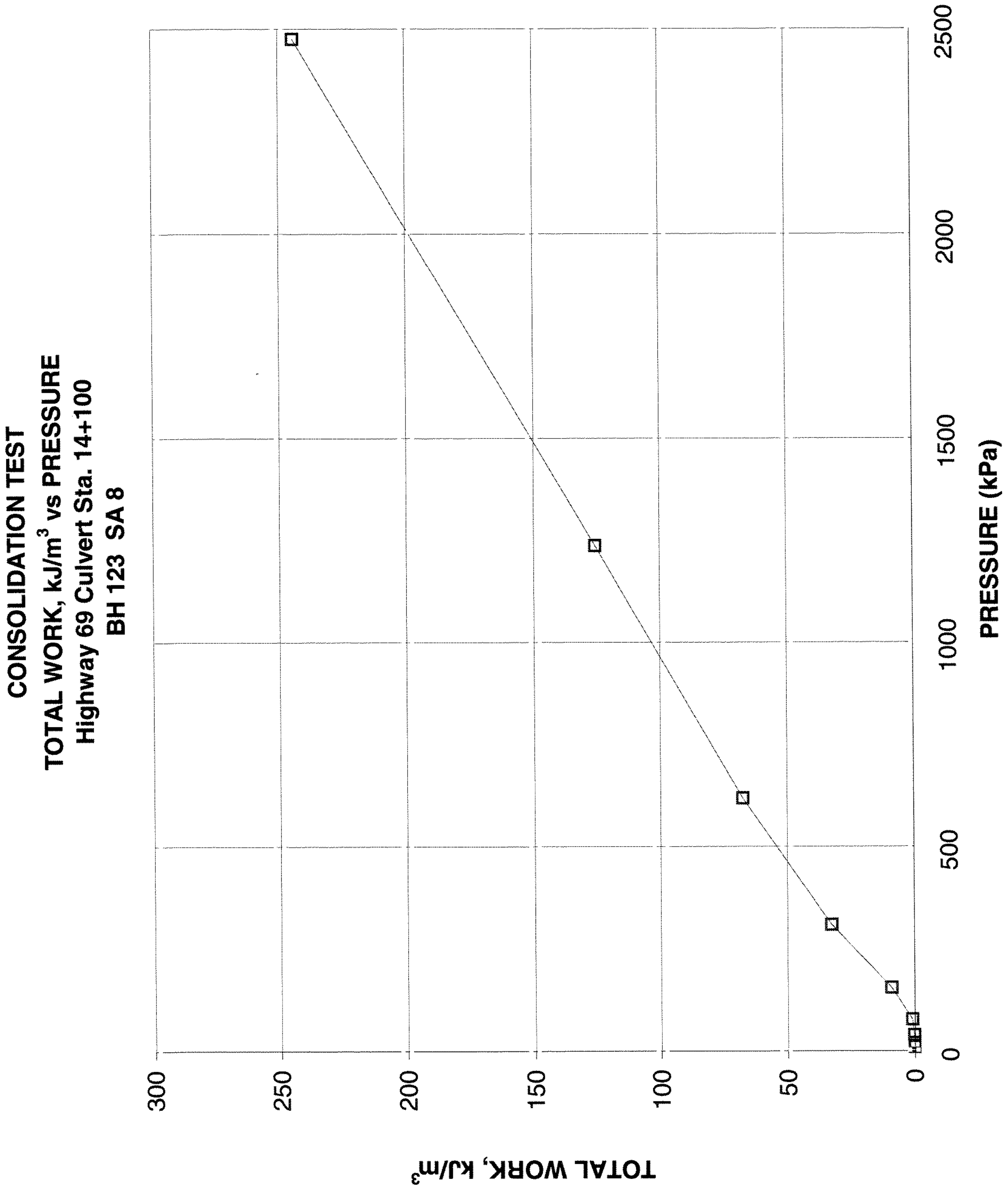
CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-12
Sheet 3 of 4



CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-12
Sheet 4 of 4



Project No. 03-1111-011-4

Golder Associates

OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-13
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	12
Borehole Number	123	Sample Depth, m	13.7-14.2

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	07/29/2004		
Date Completed	08/10/2004		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	16.30
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	9.99
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	60.45	Solids Height, cm	0.712
Water Content, %	63.22	Volume of Solids, cm^3	22.55
Wet Mass, g	100.46	Volume of Voids, cm^3	37.90
Dry Mass, g	61.55	Degree of Saturation, %	102.7

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.910	1.681	1.910				
4.70	1.907	1.677	1.909	165	4.68E-03	3.34E-04	1.53E-07
9.54	1.902	1.670	1.905	225	3.42E-03	5.41E-04	1.81E-07
19.29	1.894	1.659	1.898	197	3.88E-03	4.30E-04	1.63E-07
38.71	1.881	1.641	1.888	184	4.10E-03	3.50E-04	1.41E-07
77.44	1.859	1.610	1.870	184	4.03E-03	2.97E-04	1.17E-07
154.67	1.820	1.555	1.840	240	2.99E-03	2.64E-04	7.74E-08
309.36	1.636	1.297	1.728	1215	5.21E-04	6.23E-04	3.18E-08
618.48	1.443	1.026	1.540	1354	3.71E-04	3.27E-04	1.19E-08
1237.51	1.308	0.836	1.376	990	4.05E-04	1.14E-04	4.53E-09
2475.83	1.202	0.687	1.255	496	6.73E-04	4.48E-05	2.96E-09
1237.51	1.216	0.707	1.209				
309.36	1.265	0.776	1.241				
77.44	1.314	0.845	1.290				
19.29	1.371	0.925	1.343				
4.70	1.409	0.978	1.390				

Notes:
k calculated using cv based on t_{90} values.

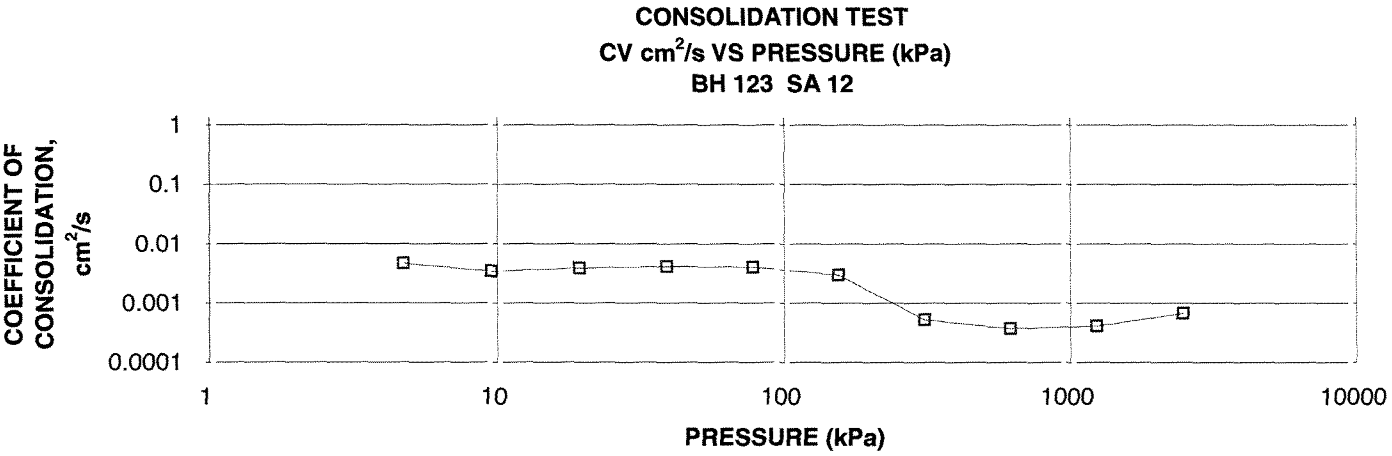
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

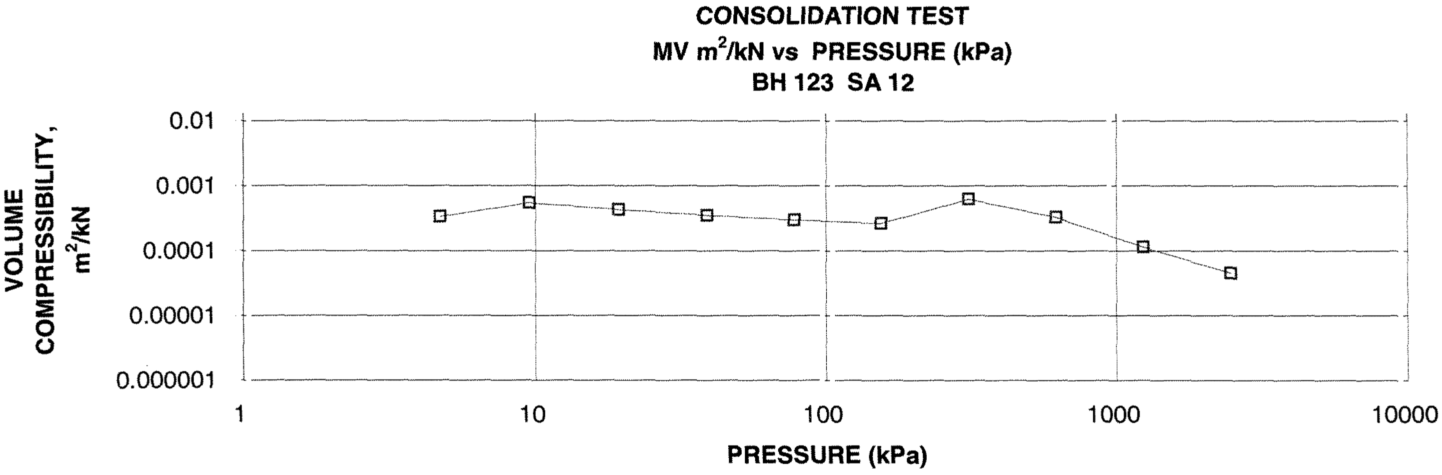
Sample Height, cm	1.41	Unit Weight, kN/m^3	18.96
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	13.54
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	44.59	Solids Height, cm	0.712
Water Content, %	40.05	Volume of Solids, cm^3	22.55
Wet Mass, g	86.20	Volume of Voids, cm^3	22.05
Dry Mass, g	61.55		

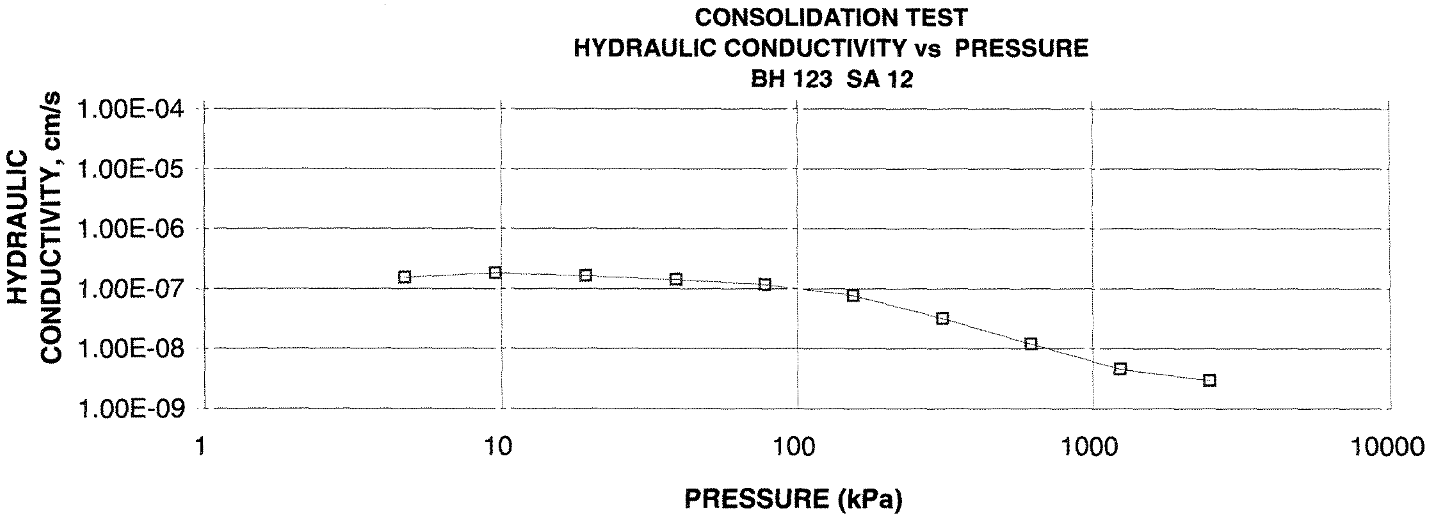
OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-13
Sheet 2 of 4

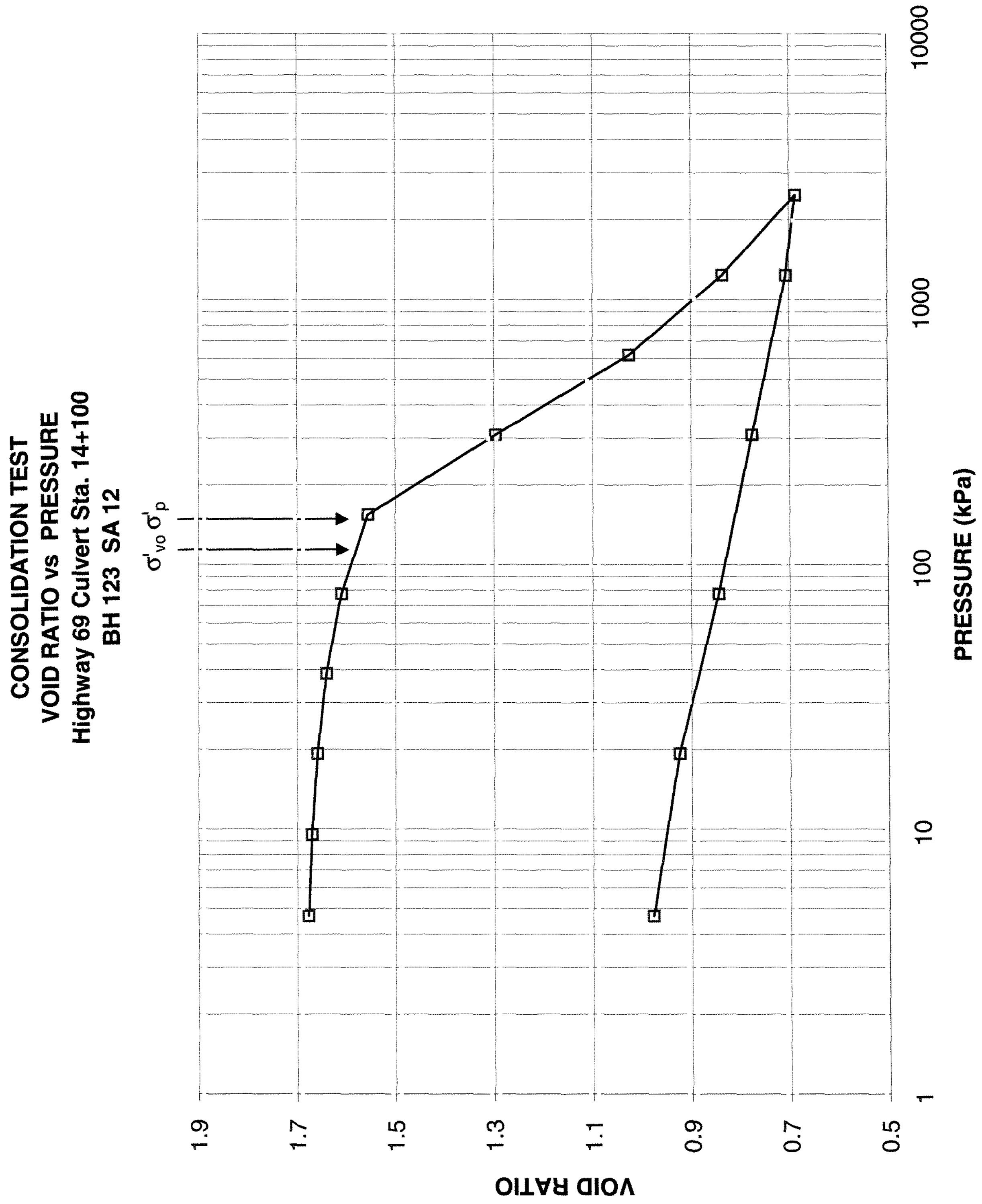






CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-13
Sheet 3 of 4

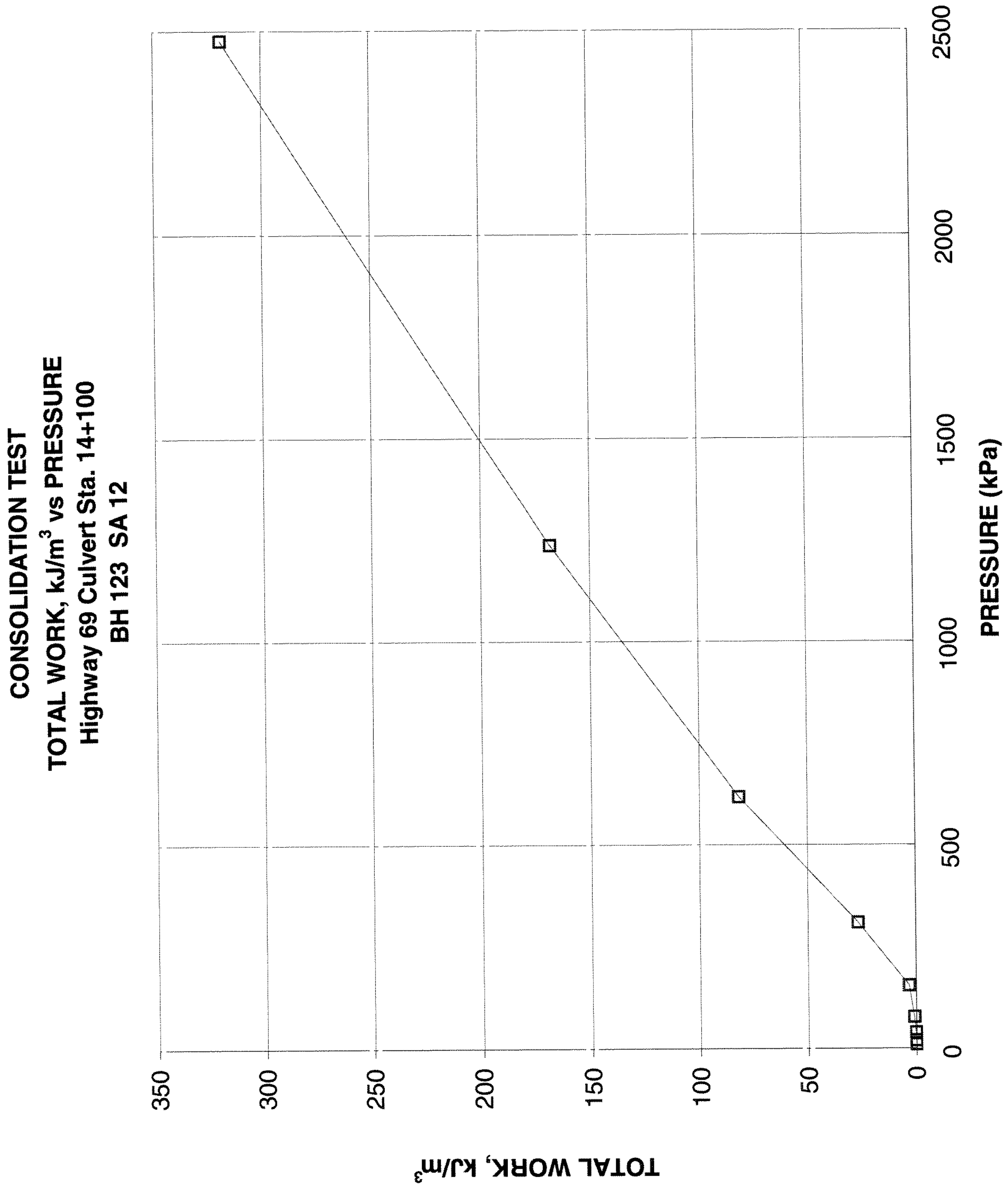


Project No. 03-1111-011-4

Golder Associates

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE
Highway 69 Culvert Sta. 14+100

FIGURE A-13
Sheet 4 of 4



OEDOMETER CONSOLIDATION SUMMARY
Highway 69 Culvert Sta. 14+100

FIGURE A-14
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	10
Borehole Number	BH-51	Sample Depth, m	10.7-11.3

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	12/8/2003		
Date Completed	12/19/2003		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	16.82
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	10.92
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	60.13	Solids Height, cm	0.775
Water Content, %	54.08	Volume of Solids, cm^3	24.52
Wet Mass, g	103.14	Volume of Voids, cm^3	35.61
Dry Mass, g	66.94	Degree of Saturation, %	101.6

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.900	1.452	1.900				
4.83	1.897	1.449	1.899	60	1.27E-02	3.27E-04	4.08E-07
9.46	1.894	1.445	1.896	103	7.40E-03	3.41E-04	2.47E-07
19.51	1.888	1.437	1.891	197	3.85E-03	3.14E-04	1.18E-07
38.91	1.877	1.423	1.883	135	5.57E-03	2.98E-04	1.63E-07
77.57	1.856	1.396	1.867	146	5.06E-03	2.86E-04	1.42E-07
154.88	1.787	1.307	1.822	540	1.30E-03	4.70E-04	6.00E-08
309.40	1.582	1.042	1.685	1318	4.56E-04	6.98E-04	3.12E-08
618.29	1.446	0.866	1.514	960	5.06E-04	2.32E-04	1.15E-08
1237.00	1.341	0.731	1.394	290	1.42E-03	8.93E-05	1.24E-08
2474.81	1.242	0.603	1.292	240	1.47E-03	4.21E-05	6.08E-09
1237.00	1.255	0.620	1.249				
309.40	1.289	0.664	1.272				
77.57	1.330	0.717	1.310				
19.51	1.364	0.761	1.347				
4.83	1.381	0.783	1.373				

Notes:
k calculated using cv based on t_{90} values.

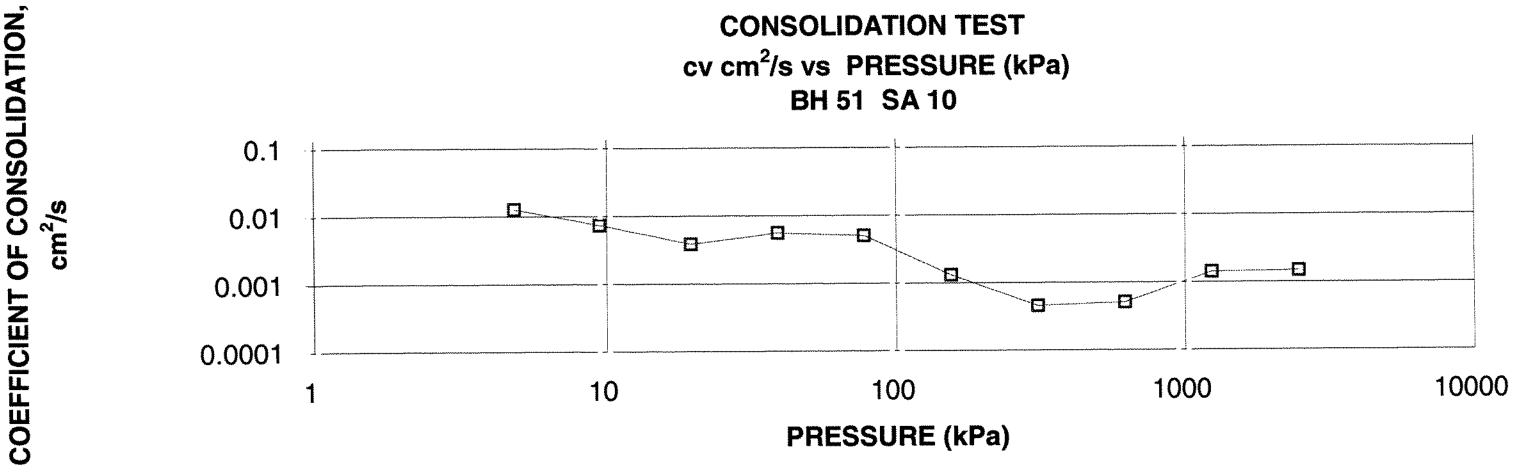
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

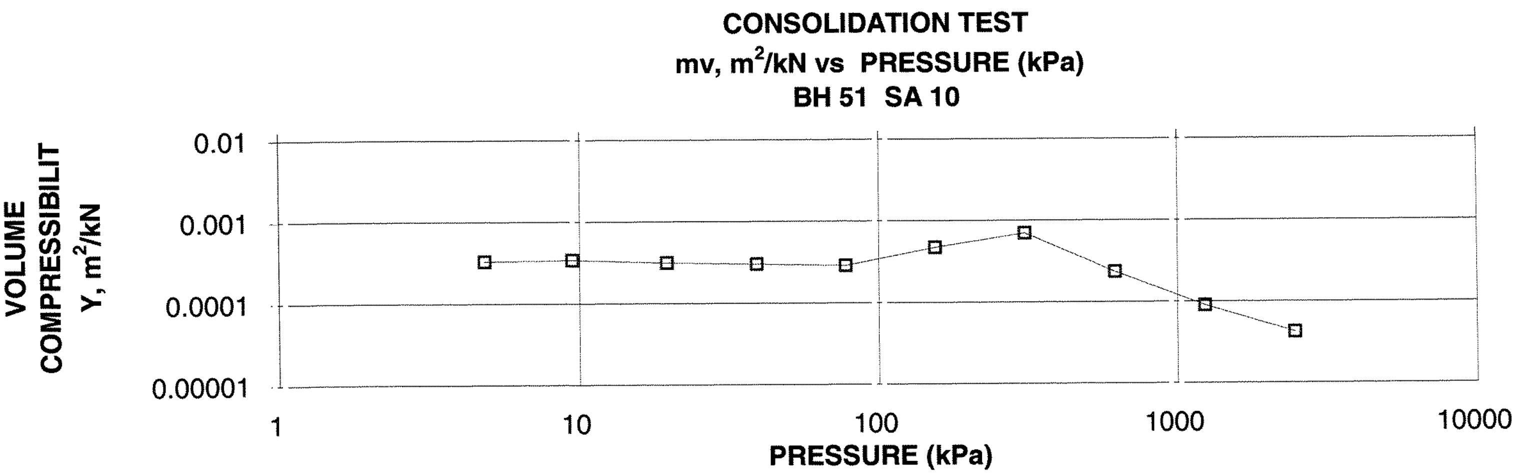
Sample Height, cm	1.38	Unit Weight, kN/m^3	19.98
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.02
Area, cm^2	31.65	Specific Gravity, measured	2.73
Volume, cm^3	43.71	Solids Height, cm	0.775
Water Content, %	33.06	Volume of Solids, cm^3	24.52
Wet Mass, g	89.07	Volume of Voids, cm^3	19.19
Dry Mass, g	66.94		

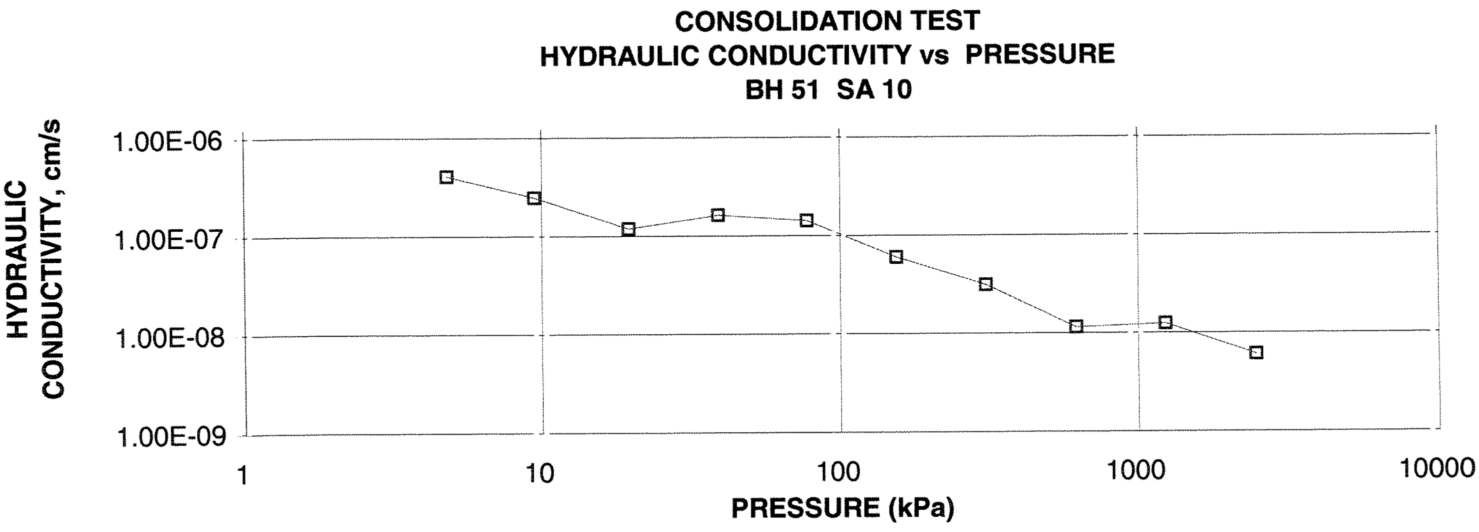
OEDOMETER CONSOLIDATION SUMMARY

Highway 69 Culvert Sta. 14+100

FIGURE A-14
Sheet 2 of 4



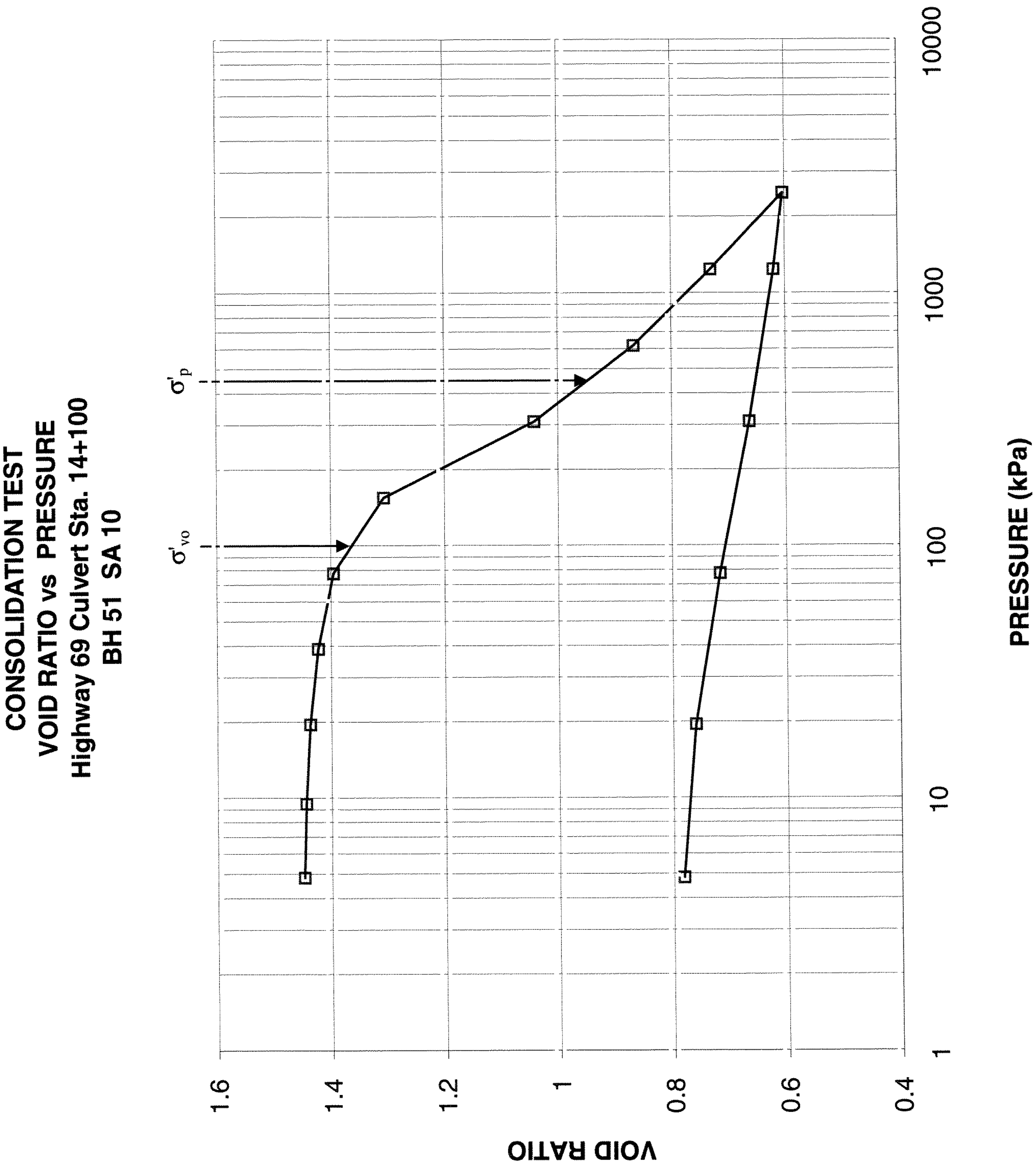




Project No. 03-1111-011-4

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

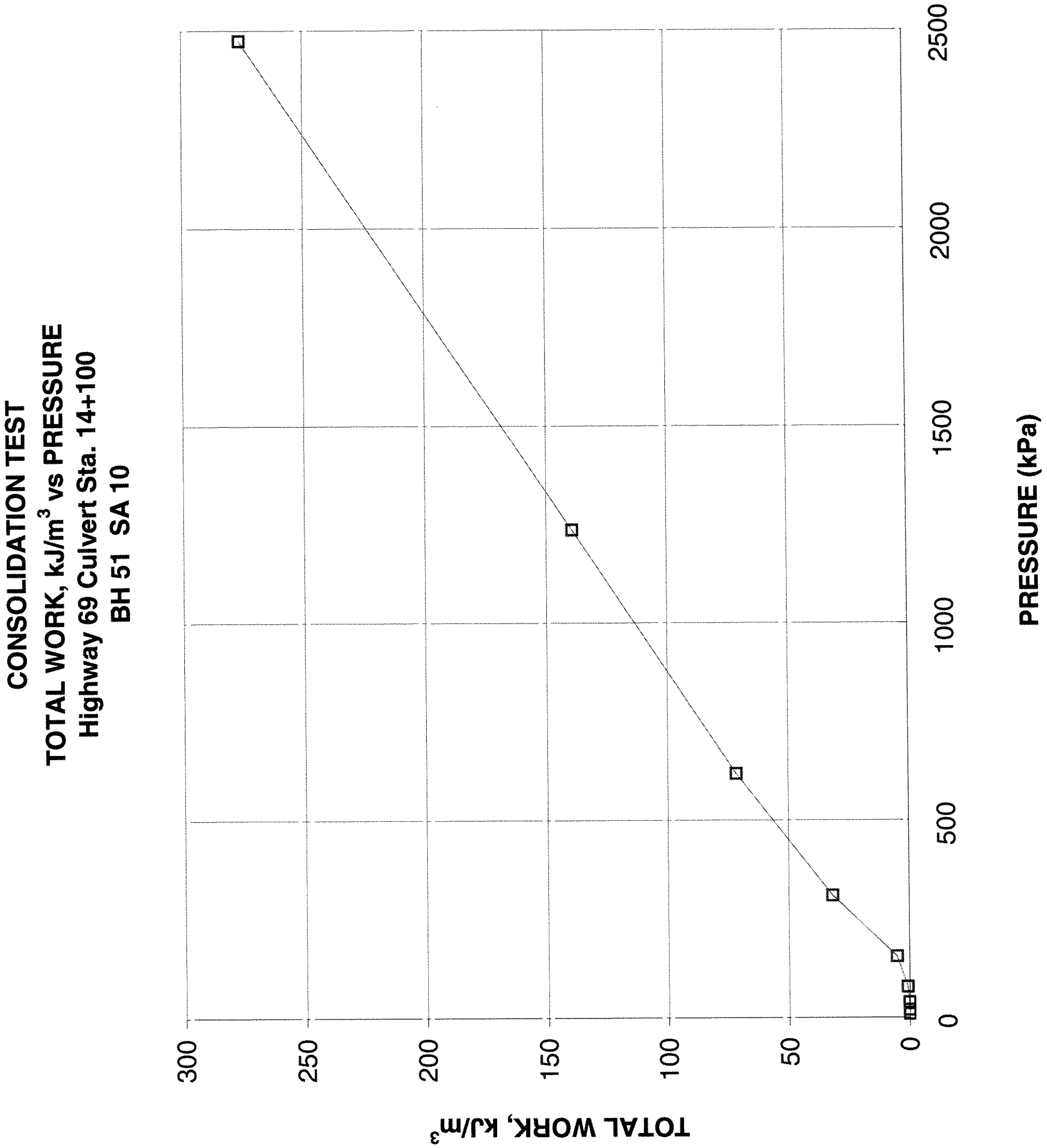
FIGURE A-14
Sheet 3 of 4



Project No. 03-1111-011-4

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

FIGURE A-14
Sheet 4 of 4



CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
Highway 69 Culvert Sta. 14+100
BH 51 SA 10

Project No. 03-1111-011-4

CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

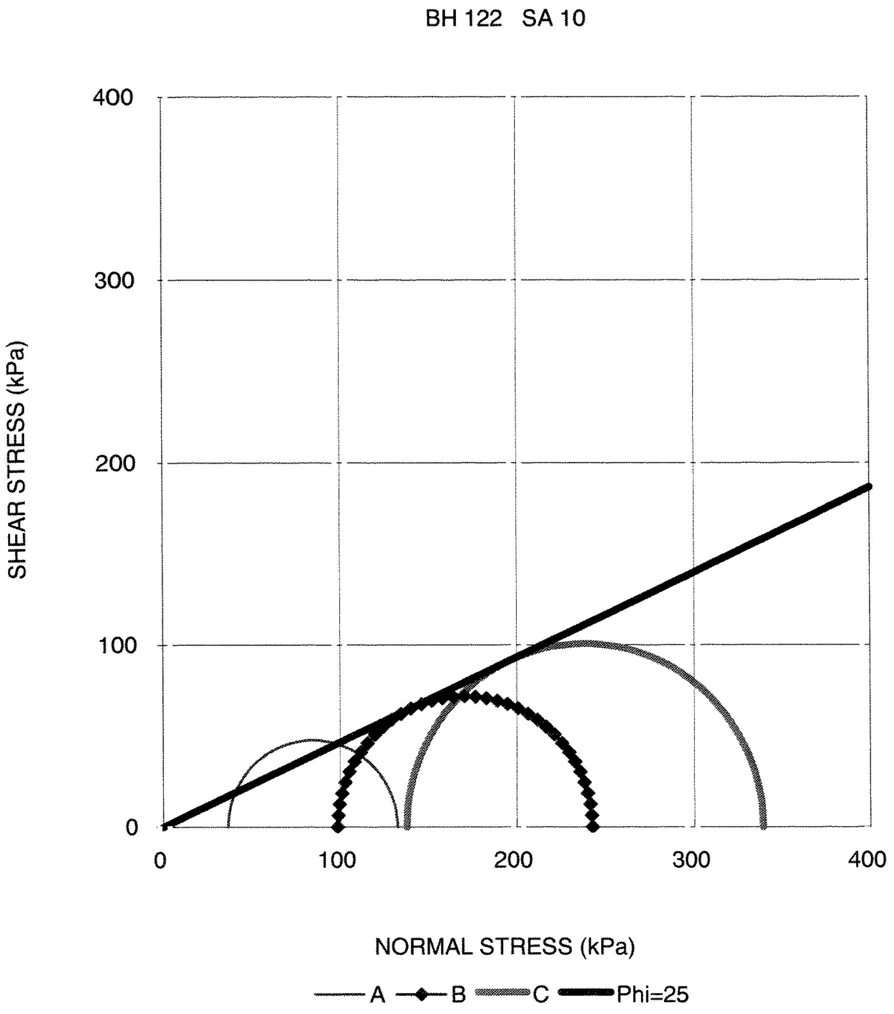
FIGURE A-15
Sheet 1 of 4

TEST STAGE	A	B	C
BOREHOLE NUMBER	122	122	122
SAMPLE NUMBER	10	10	10
SPECIMEN DIAMETER, cm	5.00	5.00	5.01
SPECIMEN HEIGHT, cm	10.14	10.05	10.11
WATER CONTENT BEFORE CONSOLIDATION, %	50.9	51.6	50.9
CELL PRESSURE, σ_3, kPa	235.0	385.0	535.0
BACK PRESSURE, kPa	135.0	135.0	135.0
PORE PRESSURE PARAMETER "B"	0.97	0.97	0.97
CONSOLIDATION PRESSURE, σc, kPa	100.0	250.0	400.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	3.3	12.6	19.7
WATER CONTENT AFTER CONSOLIDATION, %	48.0	40.7	34.0
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, DAYS	1	1	1
WATER CONTENT AFTER TEST, %	48.0	40.6	34.4
MAX. DEVIATOR STRESS, $(\sigma_1-\sigma_3)$, kPa	95.5	143.6	204.5
AXIAL STRAIN AT $(\sigma_1-\sigma_3)$ MAXIMUM, %	4.0	3.3	3.9
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ_1/σ_3) MAXIMUM	3.9	3.2	3.4
DEVIATOR STRESS AT (σ_1/σ_3) MAXIMUM, kPa	86.6	114.1	182.4
AXIAL STRAIN AT (σ_1/σ_3) MAXIMUM, %	6.6	15.9	15.0
PORE PRESSURE PARAMETER, Af, AT $(\sigma_1-\sigma_3)$ MAXIMUM	0.66	1.05	1.33
PORE PRESSURE PARAMETER, Af, AT (σ_1/σ_3) MAXIMUM	0.81	1.74	1.78
NATURAL WATER CONTENT, %	49.4	50.0	50.5
DRY DENSITY, Mg/m^3	1.16	1.16	1.16
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES:			
CHANGED RATE OF STRAIN, %/hr	0.8	0.8	0.8
AXIAL STRAIN WHERE RATE OF STRAIN WAS CHANGED, %	11.2	10.2	7.8
FAILURE PLANE NUMBER	-	-	-
ANGLE OF FAILURE, DEGREES	-	-	-

DATE: 10/06/2004

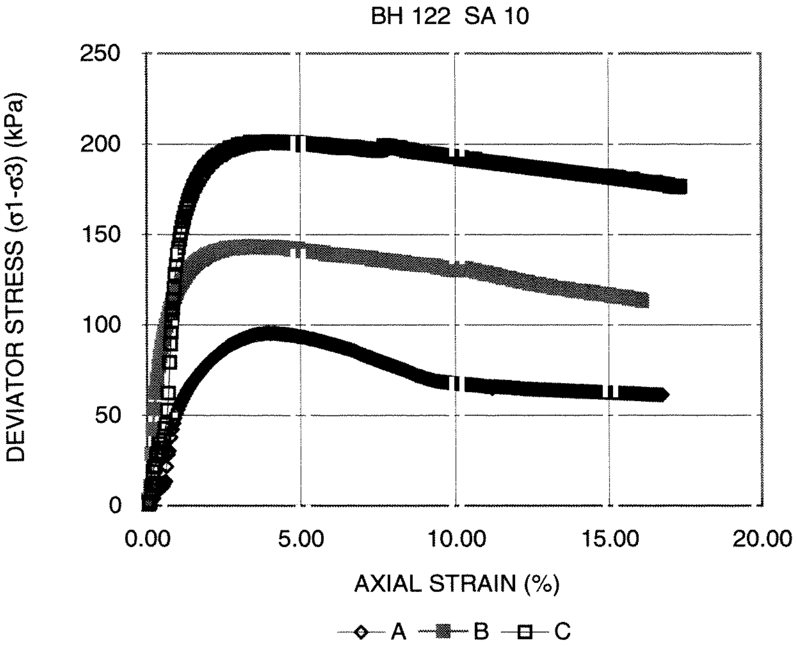
CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

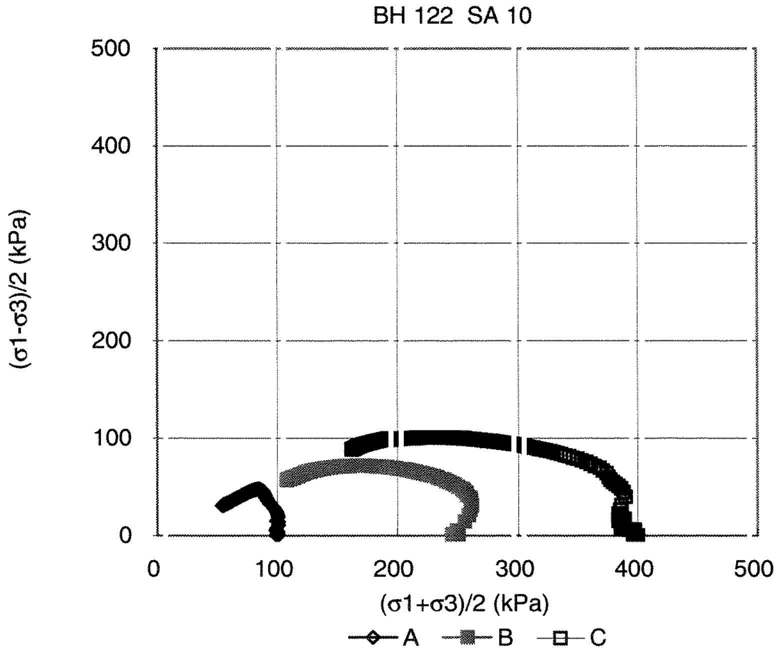
FIGURE A-15
Sheet 2 of 4



CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

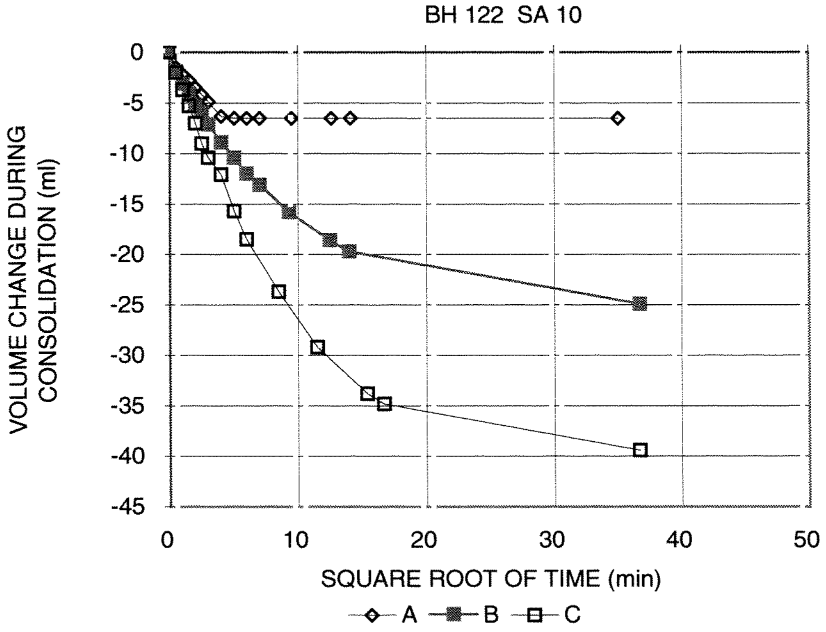
FIGURE A-15
Sheet 3 of 4

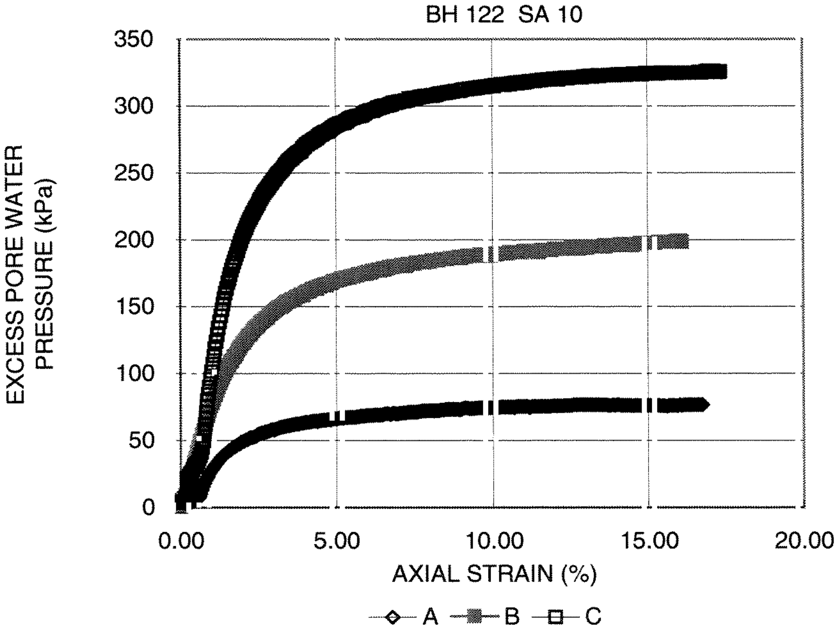




CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

FIGURE A-15
Sheet 4 of 4





Project No. 03-1111-011-2

Golder Associates

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

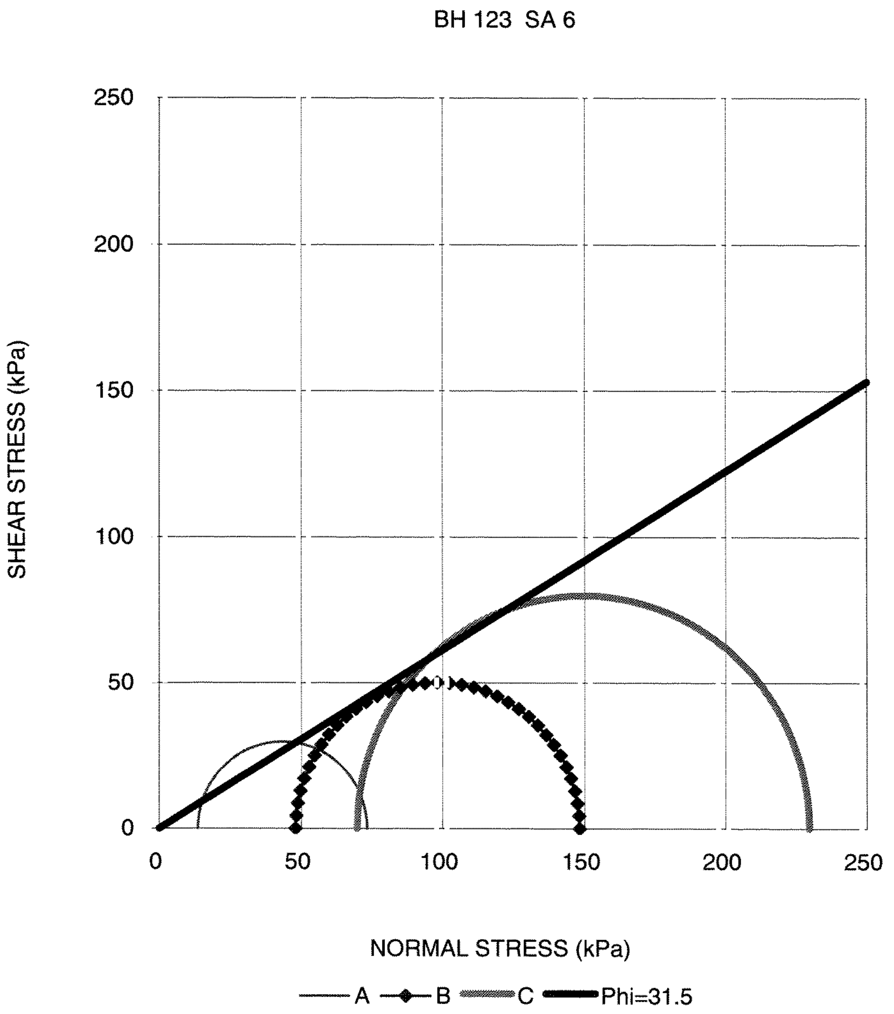
FIGURE A-16
Sheet 1 of 4

TEST STAGE	A	B	C
BOREHOLE NUMBER	123	123	123
SAMPLE NUMBER	6	6	6
SPECIMEN DIAMETER, cm	4.97	5.01	4.96
SPECIMEN HEIGHT, cm	10.11	10.11	10.11
WATER CONTENT BEFORE CONSOLIDATION, %	45.7	46.3	32.5
CELL PRESSURE, σ_3, kPa	170.0	285.0	410.0
BACK PRESSURE, kPa	135.0	135.0	135.0
PORE PRESSURE PARAMETER "B"	0.96	0.96	0.97
CONSOLIDATION PRESSURE, σc, kPa	35.0	150.0	275.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	1.6	10.5	16.0
WATER CONTENT AFTER CONSOLIDATION, %	44.4	37.7	32.5
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, DAYS	1	1	1
WATER CONTENT AFTER TEST, %	44.1	37.5	32.3
MAX. DEVIATOR STRESS, (σ_1-σ_3), kPa	59.6	100.1	159.8
AXIAL STRAIN AT (σ_1-σ_3) MAXIMUM, %	3.7	3.0	9.1
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ_1/σ_3) MAXIMUM	5.5	3.9	3.4
DEVIATOR STRESS AT (σ_1/σ_3) MAXIMUM, kPa	59.4	87.5	154.9
AXIAL STRAIN AT (σ_1/σ_3) MAXIMUM, %	3.6	17.0	13.0
PORE PRESSURE PARAMETER, Af, AT (σ_1-σ_3) MAXIMUM	0.36	0.95	1.29
PORE PRESSURE PARAMETER, Af, AT (σ_1/σ_3) MAXIMUM	0.37	1.37	1.36
NATURAL WATER CONTENT, %	44.6	45.1	43.7
DRY DENSITY, Mg/m^3	1.24	1.22	1.25
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES:			
CHANGED RATE OF STRAIN, %/hr	0.8	0.8	0.8
AXIAL STRAIN WHERE RATE OF STRAIN WAS CHANGED, %	15.7	15.1	8.5
FAILURE PLANE NUMBER	1	-	-
ANGLE OF FAILURE, DEGREES	60	-	-

DATE: 09/27/2004

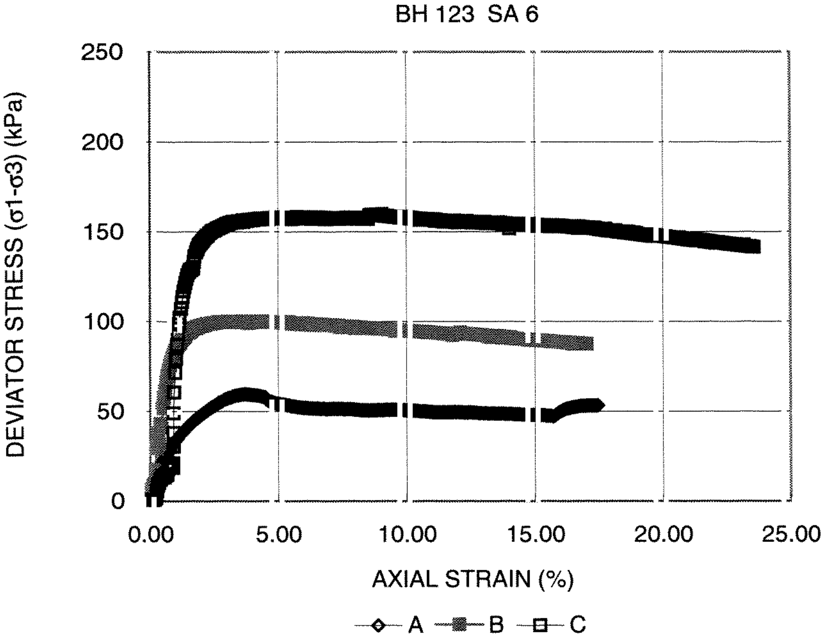
CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

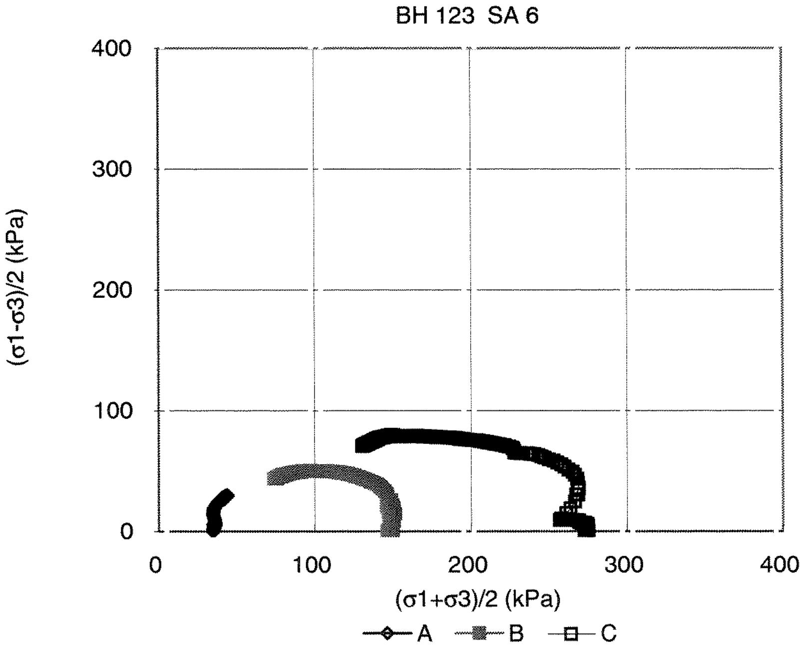
FIGURE A-16
Sheet 2 of 4



CONSOLIDATED UNDRAINED TRIAXIAL
WITH PORE PRESSURE MEASUREMENTS
Highway 69 Culvert Sta. 14+100

FIGURE A-16
Sheet 3 of 4

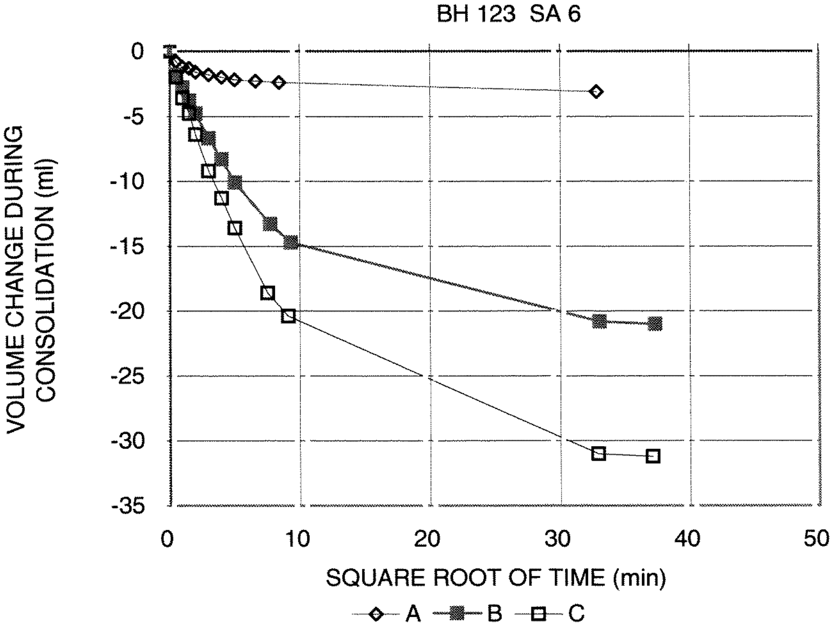


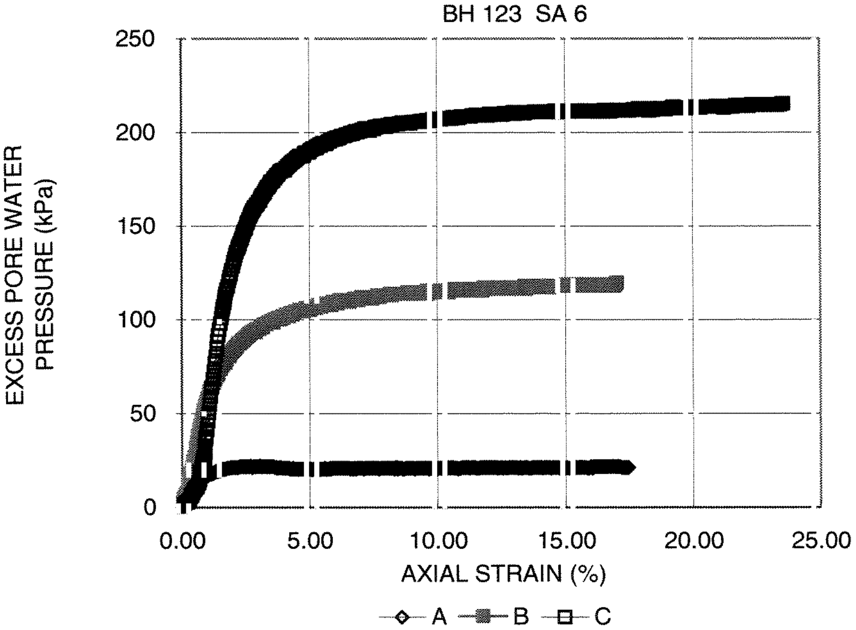


CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS

Highway 69 Culvert Sta. 14+100

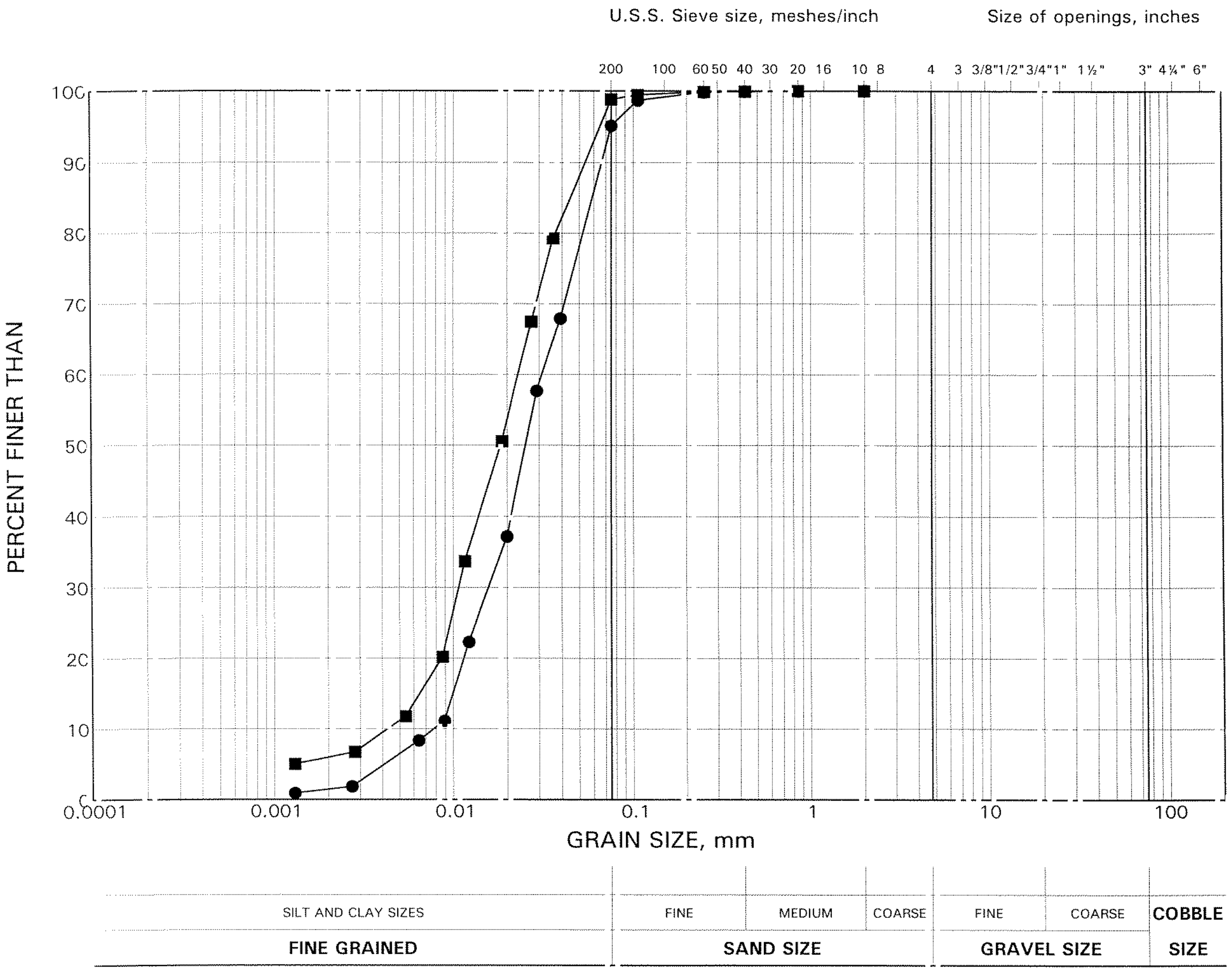
FIGURE A-16
Sheet 4 of 4





GRAIN SIZE DISTRIBUTION
Silt
Culvert Hwy 69 Station 14+100

FIGURE A-17



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	49	18	213.2
■	123	15	219.1

Date June, 2005

Project 03-1111-011-4

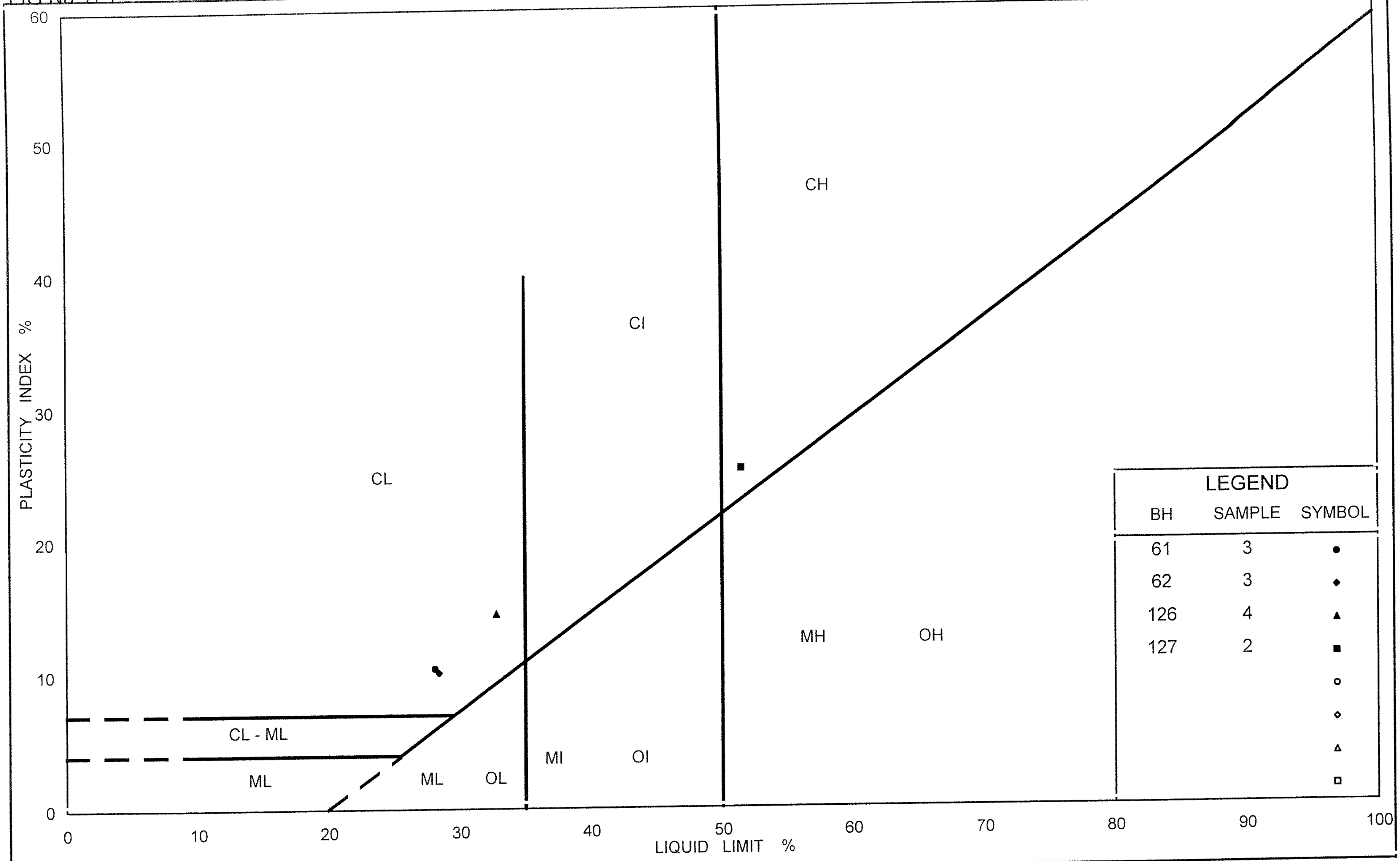
Golder Associates

Prepared by LG

Checked by

Oct 75, FF-S-21

FIG No. A-1



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Silty Clay

FIG No. A-18

Project No. 03-1111-011-4

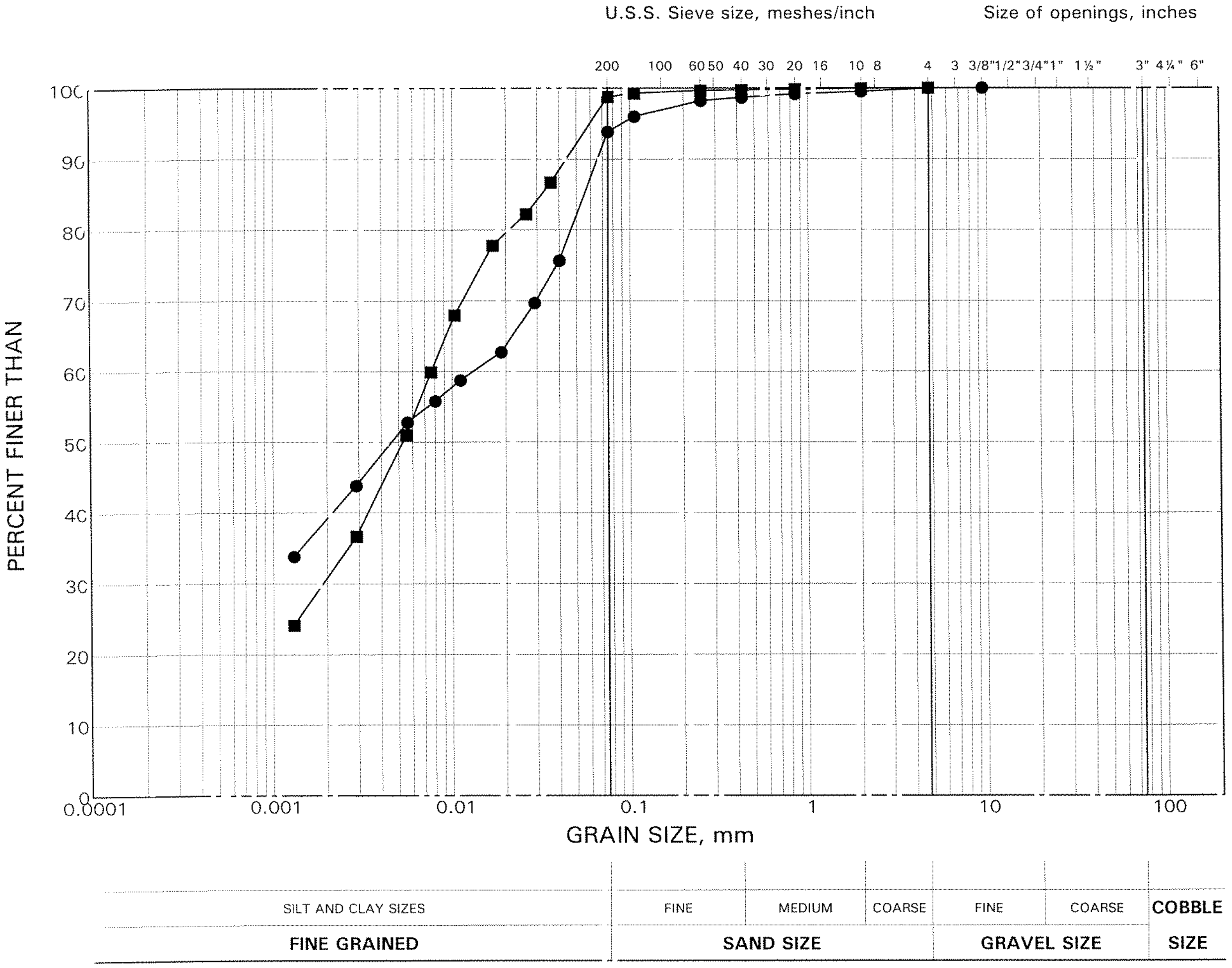
Hwy 69 Culvert Sta. 16+016 and 16+137

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clay

Hwy 69 Culvert Sta. 16+016 and 16+137

FIGURE A-19



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	61	1	253.5
■	126	2	253.2

Date June, 2005

Project 03-1111-011-4

Golder Associates

Prepared by LG

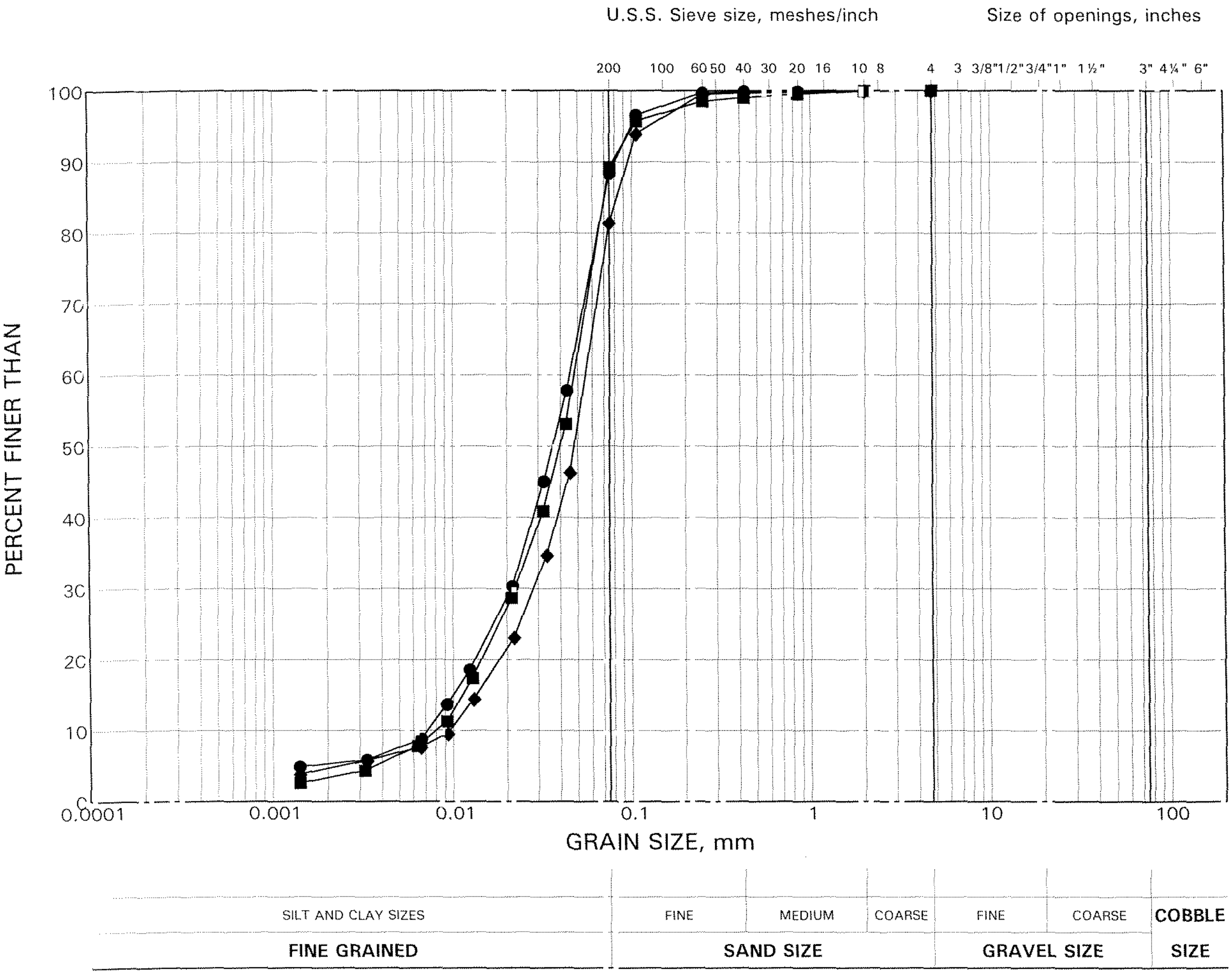
Checked by

GRAIN SIZE DISTRIBUTION

Silt

Hwy 69 Culvert Sta. 16+016 and 16+137

FIGURE A-20



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	63	7	248.5
■	126	7	247.1
◆	129	5	252.5

Date June, 2005

Project 03-1111-011-4

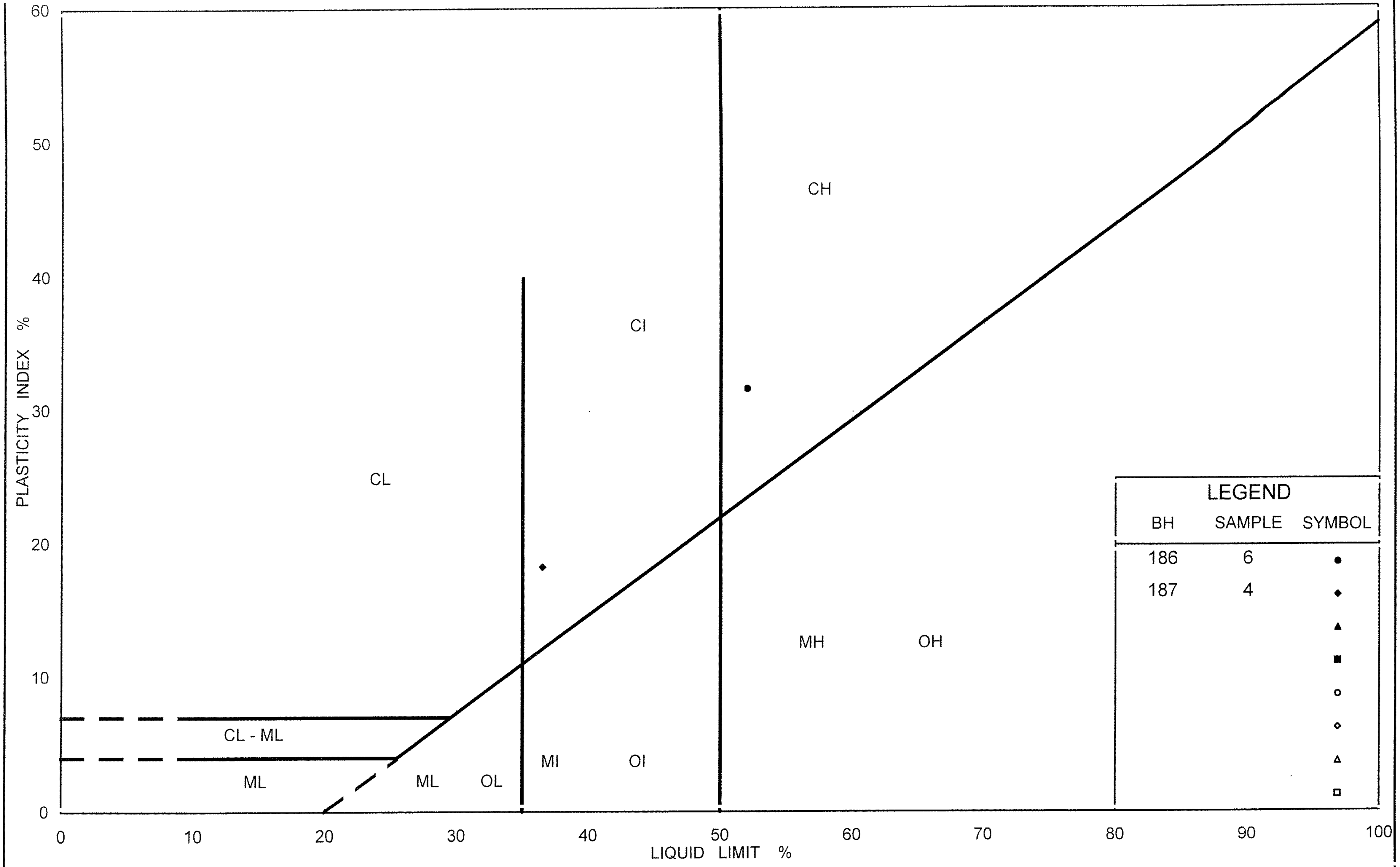
Golder Associates

Prepared by LG

Checked by

FIG No. A-1

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay to Clay

FIG No. A-21

Project No. 03-1111-011-4

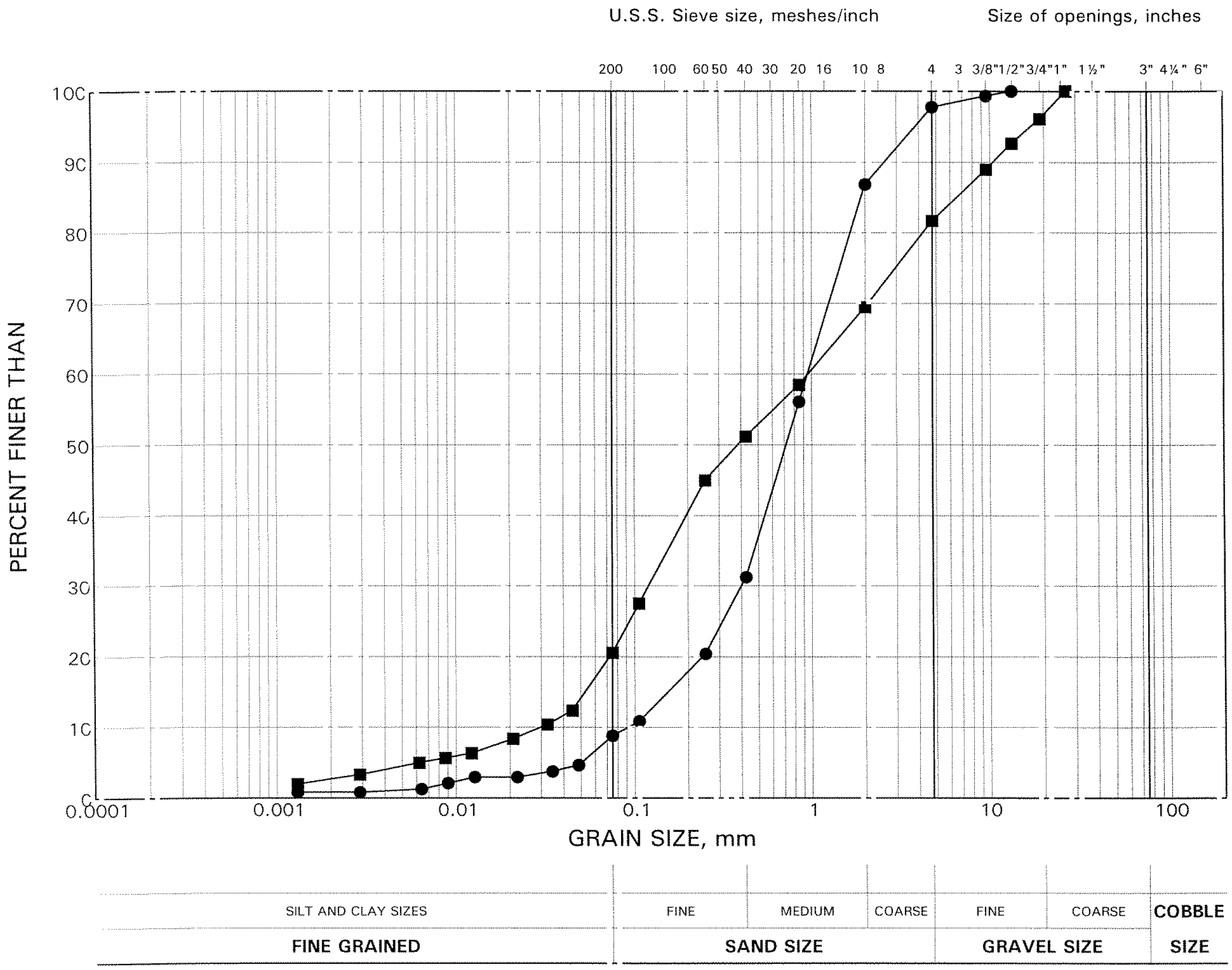
Hwy 69 Culvert Sta. 19+845

GRAIN SIZE DISTRIBUTION

Sand

Culvert Hwy 537 Station 11+015

FIGURE A-22



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	156	6	243.9
■	157	8	242.2

Date June, 2005

Project 03-1111-011-4

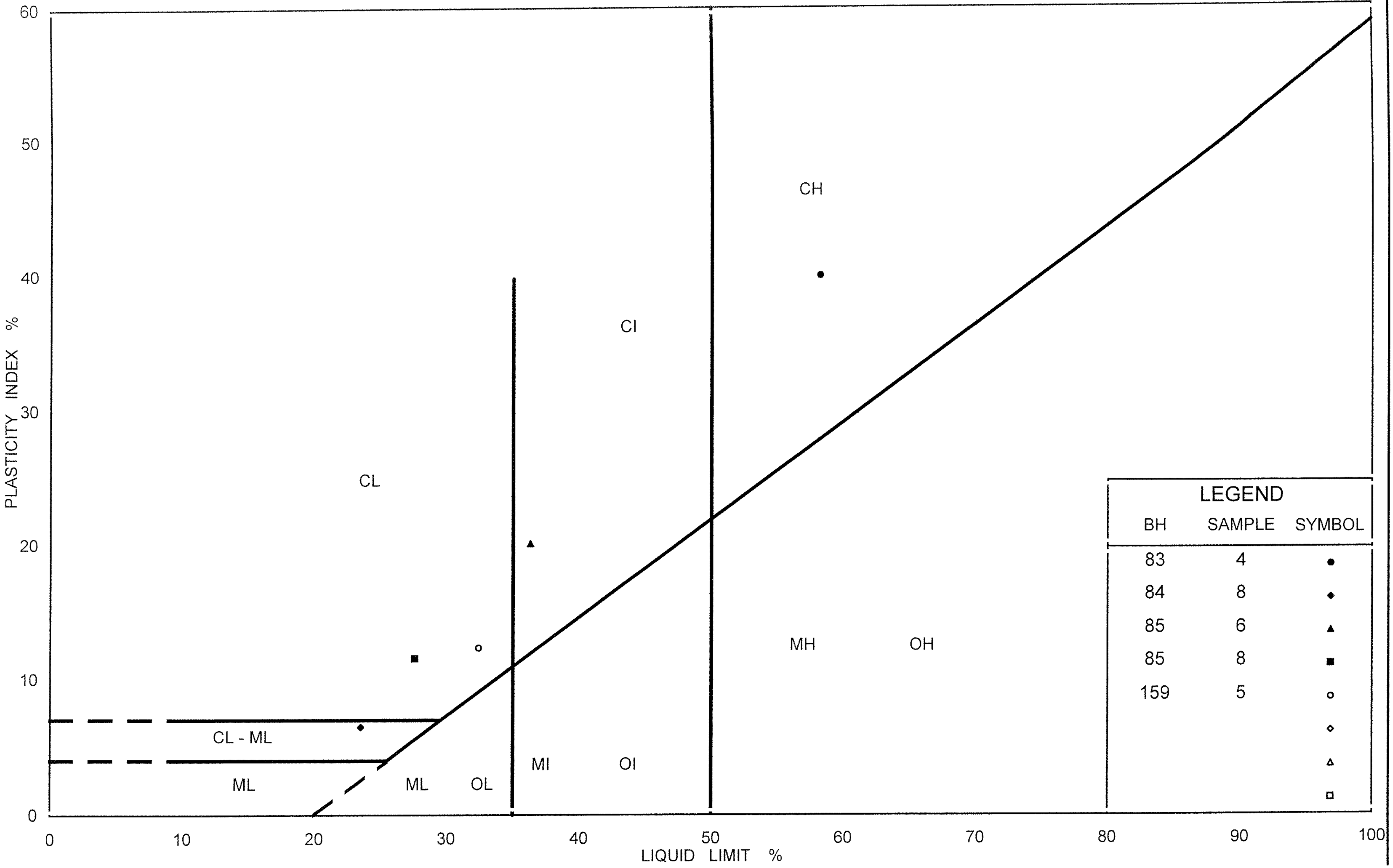
Golder Associates

Prepared by LG

Checked by

FIG No. A-1

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Clay

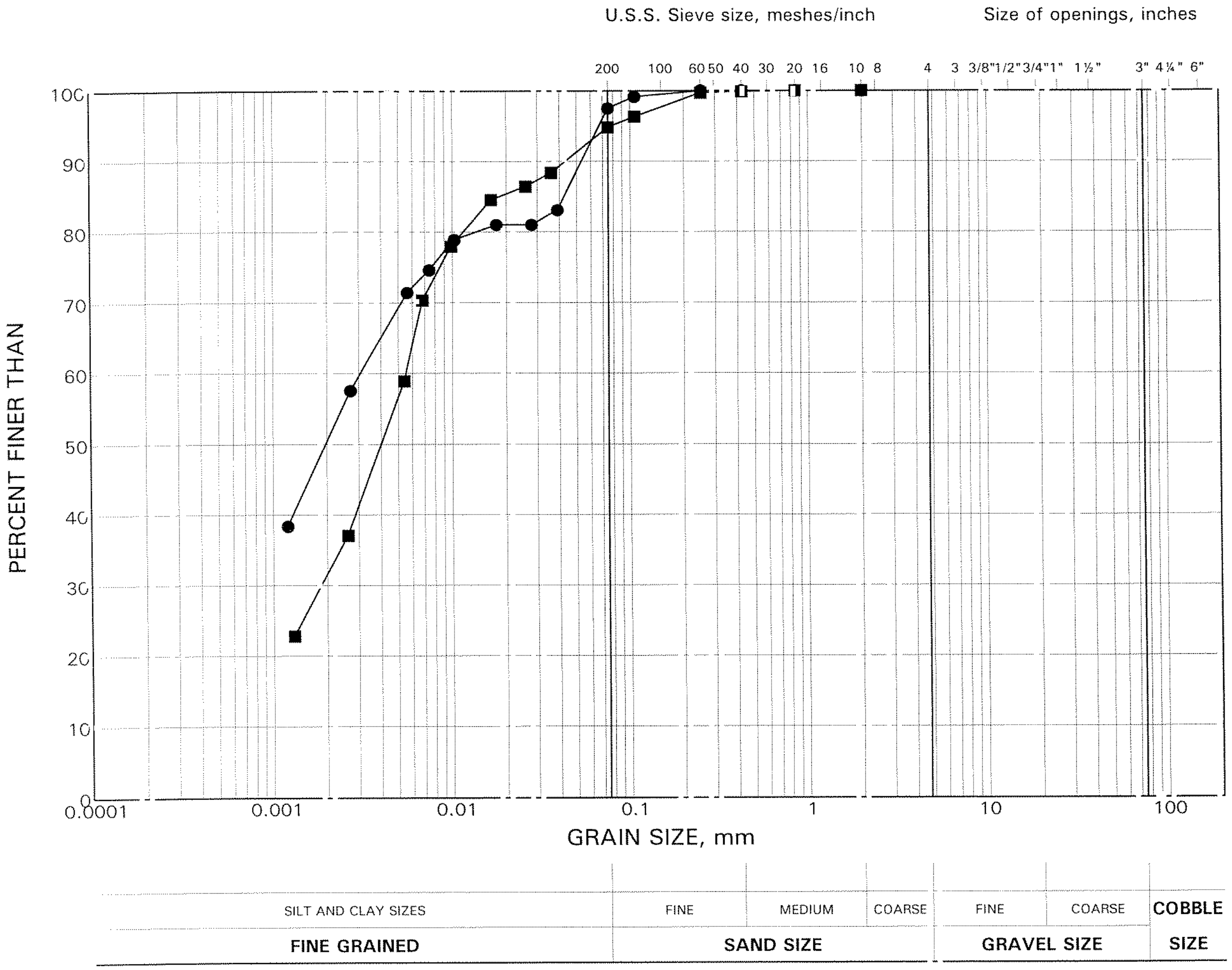
FIG No. A-23

Project No. 03-1111-011-4

Hwy 69 Culvert Sta. 11+940 and 12+130

GRAIN SIZE DISTRIBUTION
Clayey Silt to Silty Clay
Culvert Hwy 537 Station 11+940 and 12+130

FIGURE A-24



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	83	6	220.8
■	159	5	223.7

Date June, 2005
Project 03-1111-011-4

Golder Associates

Prepared by LG
Checked by

OEDOMETER CONSOLIDATION SUMMARY

Highway 537 Culvert Sta. 11+940 and 12+130

FIGURE A-25
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	6
Borehole Number	BH-85	Sample Depth, m	4.6-5.2

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	12/11/2003		
Date Completed	12/22/2003		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	17.47
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	11.96
Area, cm^2	31.65	Specific Gravity, measured	2.74
Volume, cm^3	60.13	Solids Height, cm	0.845
Water Content, %	46.14	Volume of Solids, cm^3	26.76
Wet Mass, g	107.15	Volume of Voids, cm^3	33.37
Dry Mass, g	73.32	Degree of Saturation, %	101.4

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.900	1.247	1.900				
4.70	1.890	1.235	1.895	211	3.61E-03	1.12E-03	3.96E-07
9.54	1.884	1.228	1.887	158	4.78E-03	6.52E-04	3.05E-07
19.29	1.873	1.215	1.879	321	2.33E-03	5.94E-04	1.36E-07
38.71	1.855	1.194	1.864	240	3.07E-03	4.88E-04	1.47E-07
77.44	1.820	1.153	1.838	240	2.98E-03	4.76E-04	1.39E-07
154.67	1.716	1.030	1.768	518	1.28E-03	7.09E-04	8.89E-08
309.92	1.563	0.849	1.640	960	5.94E-04	5.19E-04	3.02E-08
617.66	1.469	0.737	1.516	338	1.44E-03	1.61E-04	2.27E-08
1236.76	1.393	0.648	1.431	158	2.75E-03	6.46E-05	1.74E-08
2474.73	1.327	0.570	1.360	113	3.47E-03	2.81E-05	9.54E-09
1236.76	1.333	0.577	1.330				
309.92	1.347	0.593	1.340				
77.44	1.376	0.627	1.362				
19.29	1.418	0.677	1.397				
4.70	1.437	0.700	1.428				

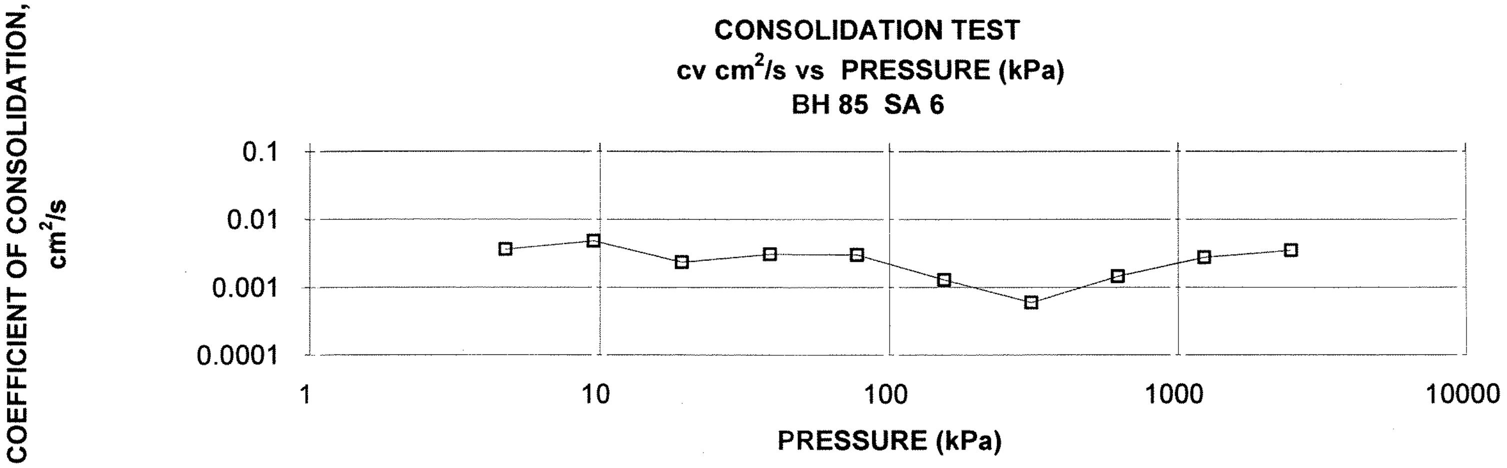
Notes:
k calculated using cv based on t_{90} values.

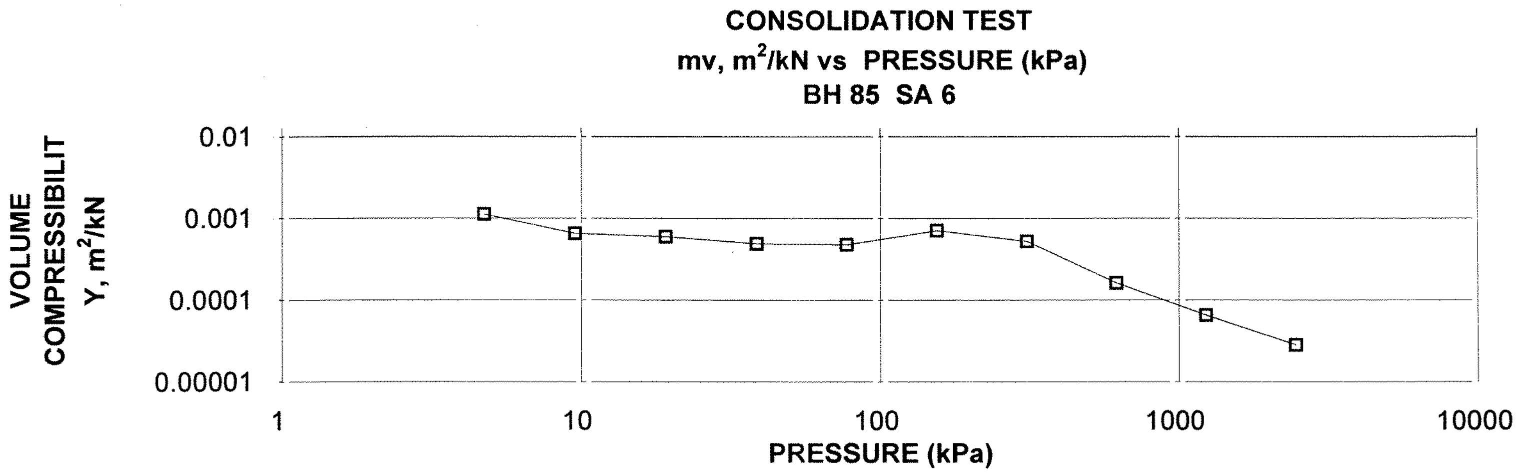
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

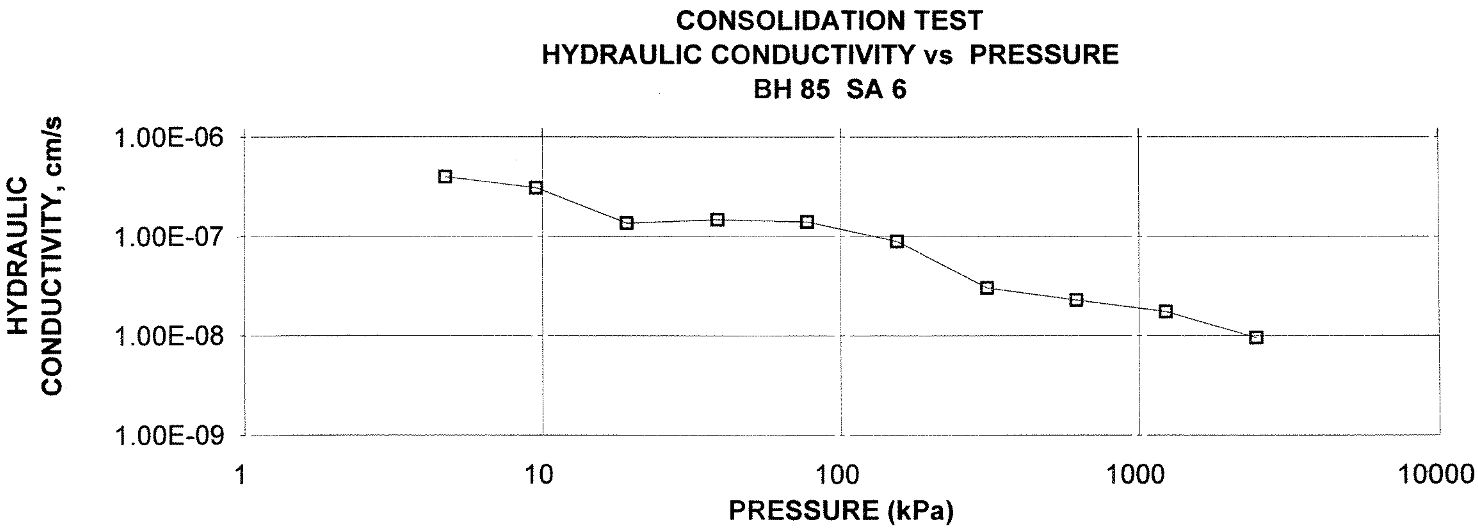
Sample Height, cm	1.44	Unit Weight, kN/m^3	20.16
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.81
Area, cm^2	31.65	Specific Gravity, measured	2.74
Volume, cm^3	45.48	Solids Height, cm	0.845
Water Content, %	27.53	Volume of Solids, cm^3	26.76
Wet Mass, g	93.50	Volume of Voids, cm^3	18.72
Dry Mass, g	73.32		

OEDOMETER CONSOLIDATION SUMMARY
Highway 537 Culvert Sta. 11+940 and 12+130

FIGURE A-25
Sheet 2 of 4



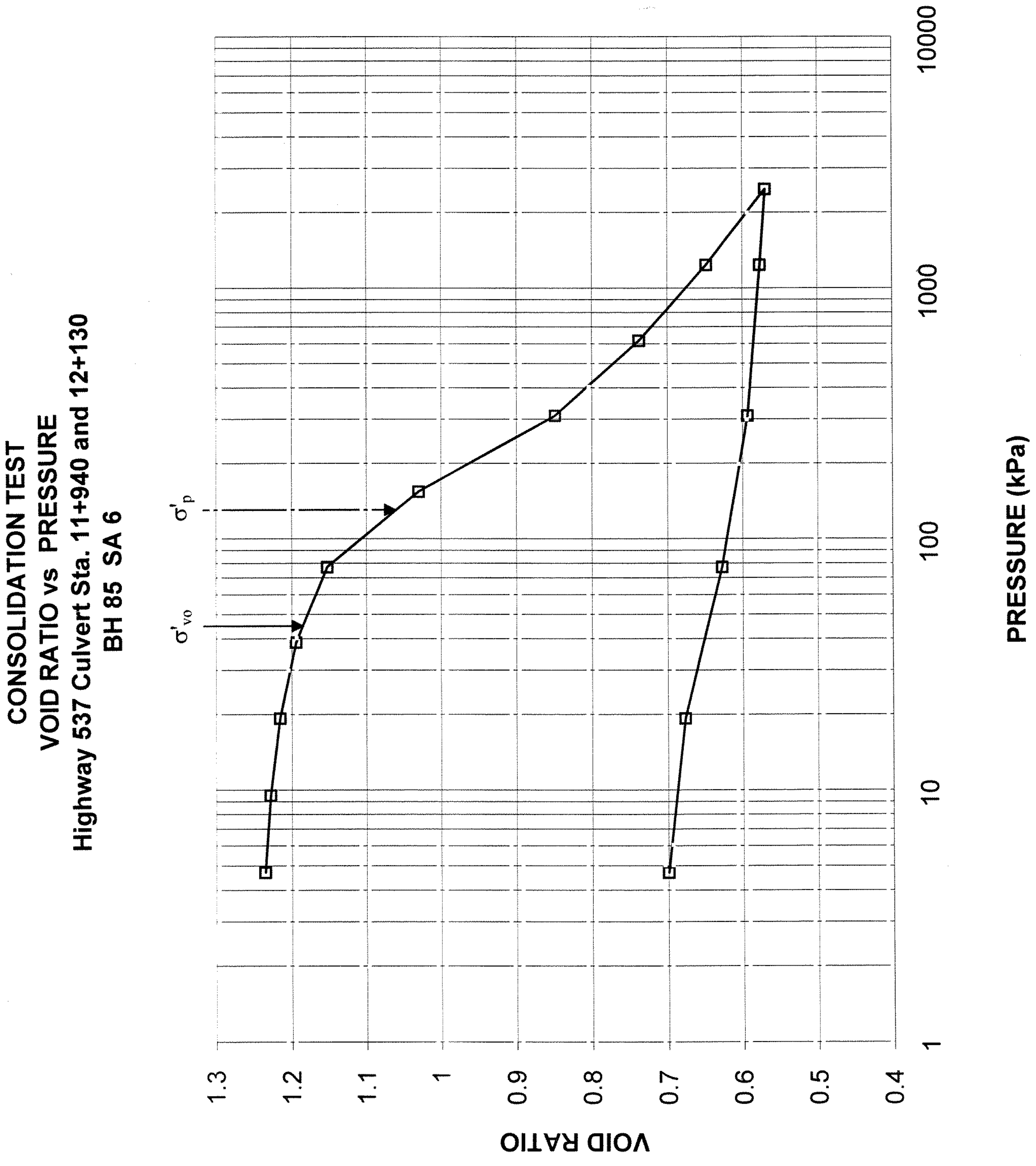




Project No. 03-1111-011-4

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

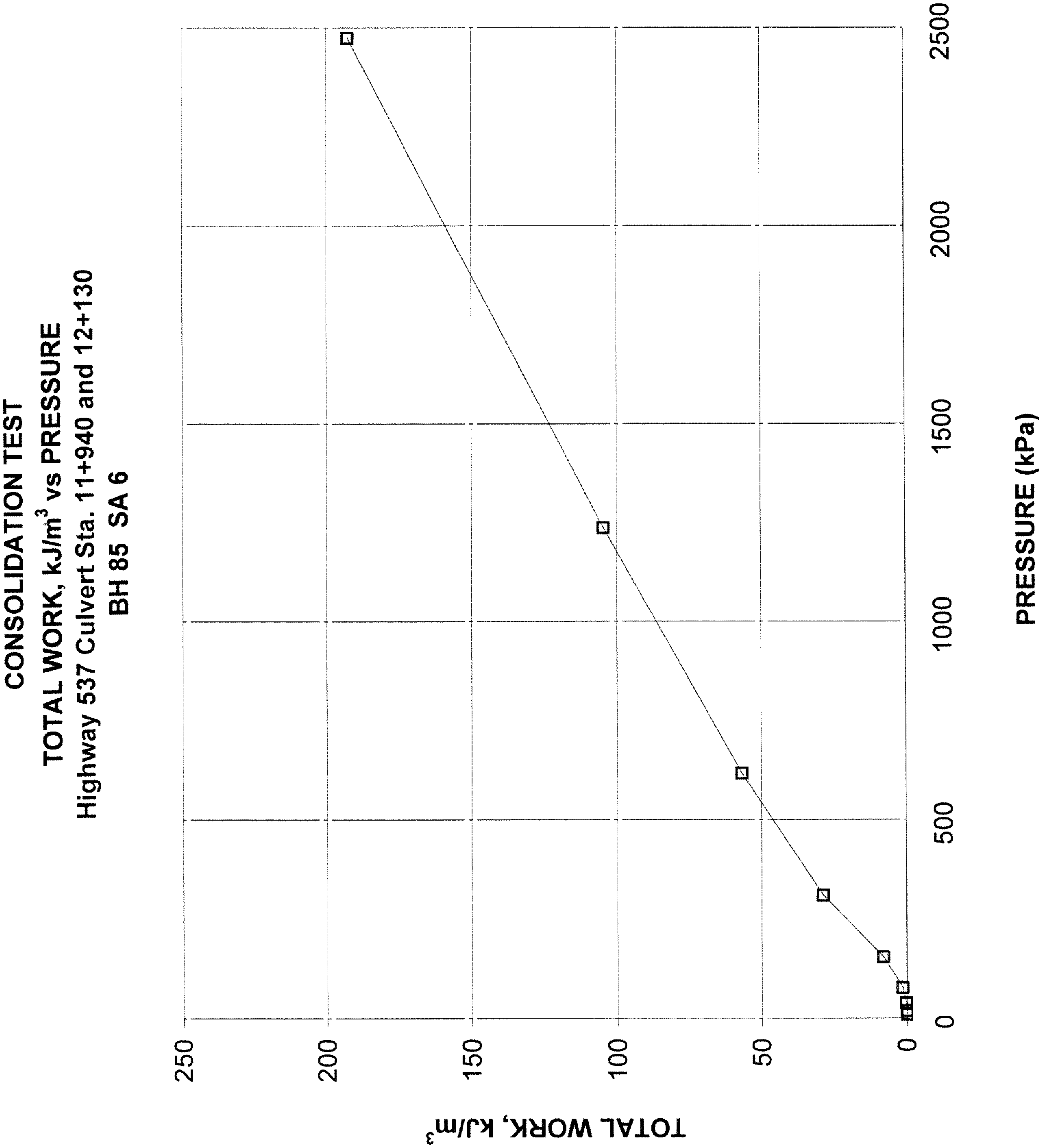
FIGURE A-25
Sheet 3 of 4



Project No. 03-1111-011-4

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

FIGURE A-25
Sheet 4 of 4



CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
Highway 537 Culvert Sta. 11+940 and 12+130
BH 85 SA 6

Project No. 03-1111-011-4

OEDOMETER CONSOLIDATION SUMMARY

Highway 537 Culvert Sta. 11+940 and 12+130

FIGURE A-26
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	03-1111-011-4	Sample Number	5
Borehole Number	BH-92	Sample Depth, m	3.0-3.7

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	12/18/2003		
Date Completed	12/29/2003		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.92	Unit Weight, kN/m^3	18.39
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	13.83
Area, cm^2	31.67	Specific Gravity, measured	2.73
Volume, cm^3	60.65	Solids Height, cm	0.989
Water Content, %	32.95	Volume of Solids, cm^3	31.33
Wet Mass, g	113.71	Volume of Voids, cm^3	29.32
Dry Mass, g	85.53	Degree of Saturation, %	96.1

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.915	0.936	1.915				
4.85	1.913	0.934	1.914	21	3.70E-02	2.15E-04	7.80E-07
9.90	1.909	0.930	1.911	255	3.04E-03	4.13E-04	1.23E-07
19.40	1.904	0.925	1.907	105	7.34E-03	2.75E-04	1.98E-07
38.64	1.894	0.915	1.899	60	1.27E-02	2.71E-04	3.39E-07
77.43	1.878	0.898	1.886	103	7.32E-03	2.15E-04	1.55E-07
154.66	1.856	0.876	1.867	60	1.23E-02	1.49E-04	1.80E-07
309.16	1.818	0.838	1.837	60	1.19E-02	1.28E-04	1.50E-07
618.37	1.740	0.759	1.779	64	1.05E-02	1.32E-04	1.35E-07
1236.55	1.661	0.679	1.701	80	7.66E-03	6.67E-05	5.01E-08
2476.21	1.592	0.609	1.627	76	7.38E-03	2.91E-05	2.10E-08
1236.55	1.600	0.617	1.596				
309.16	1.618	0.636	1.609				
77.43	1.640	0.658	1.629				
19.40	1.664	0.682	1.652				
4.85	1.690	0.708	1.677				

Notes:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

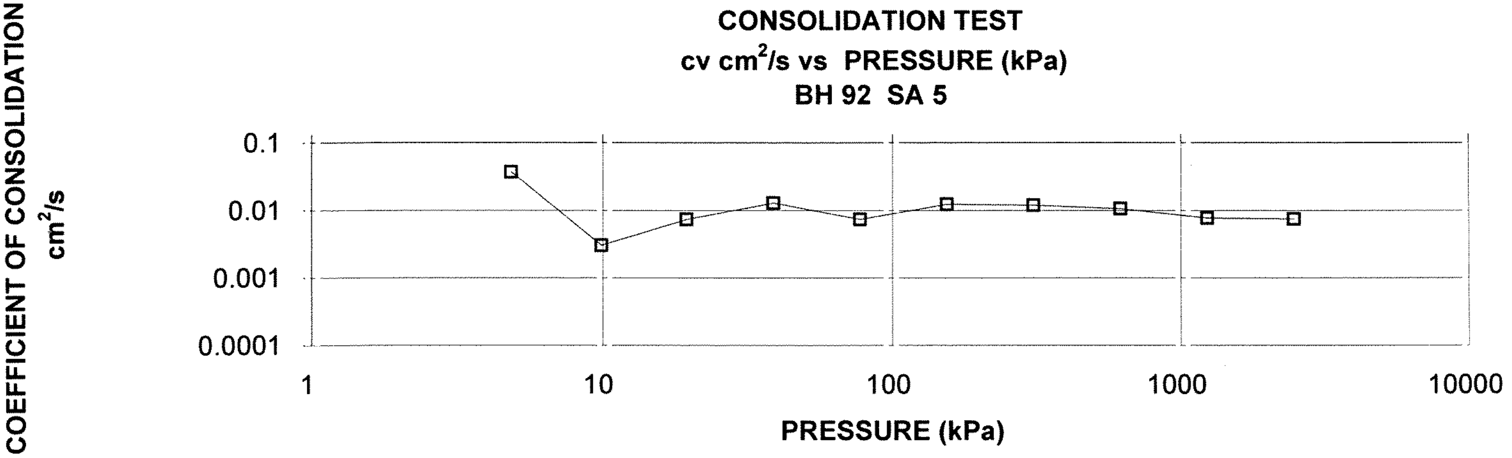
Sample Height, cm	1.69	Unit Weight, kN/m^3	19.83
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m^3	15.67
Area, cm^2	31.67	Specific Gravity, measured	2.73
Volume, cm^3	53.52	Solids Height, cm	0.989
Water Content, %	26.50	Volume of Solids, cm^3	31.33
Wet Mass, g	108.20	Volume of Voids, cm^3	22.19
Dry Mass, g	85.53		

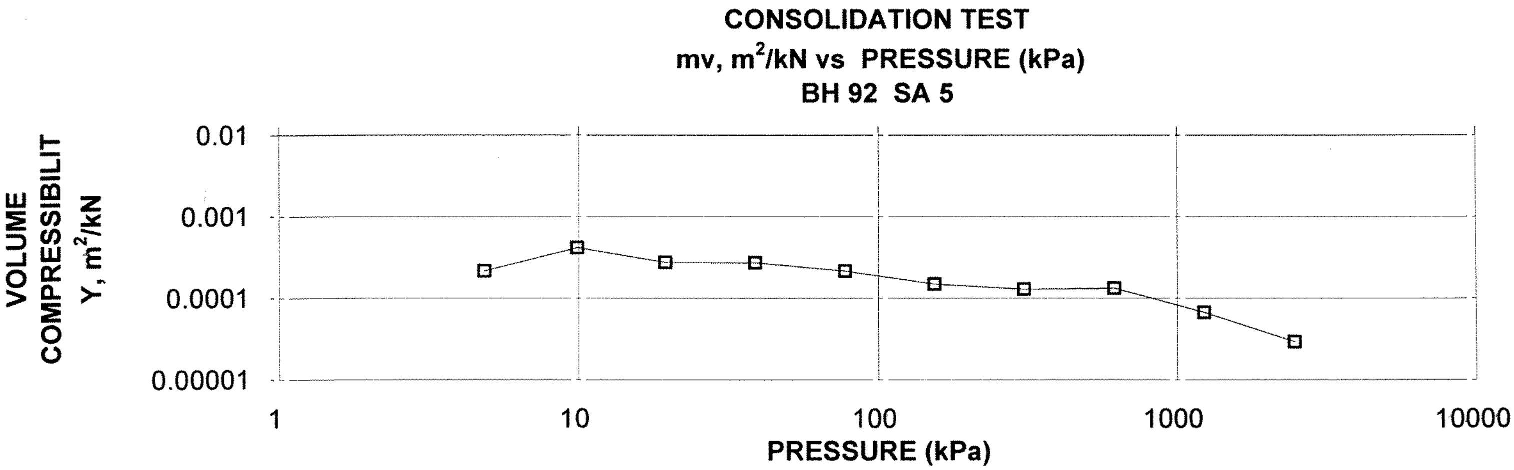
OEDOMETER CONSOLIDATION SUMMARY

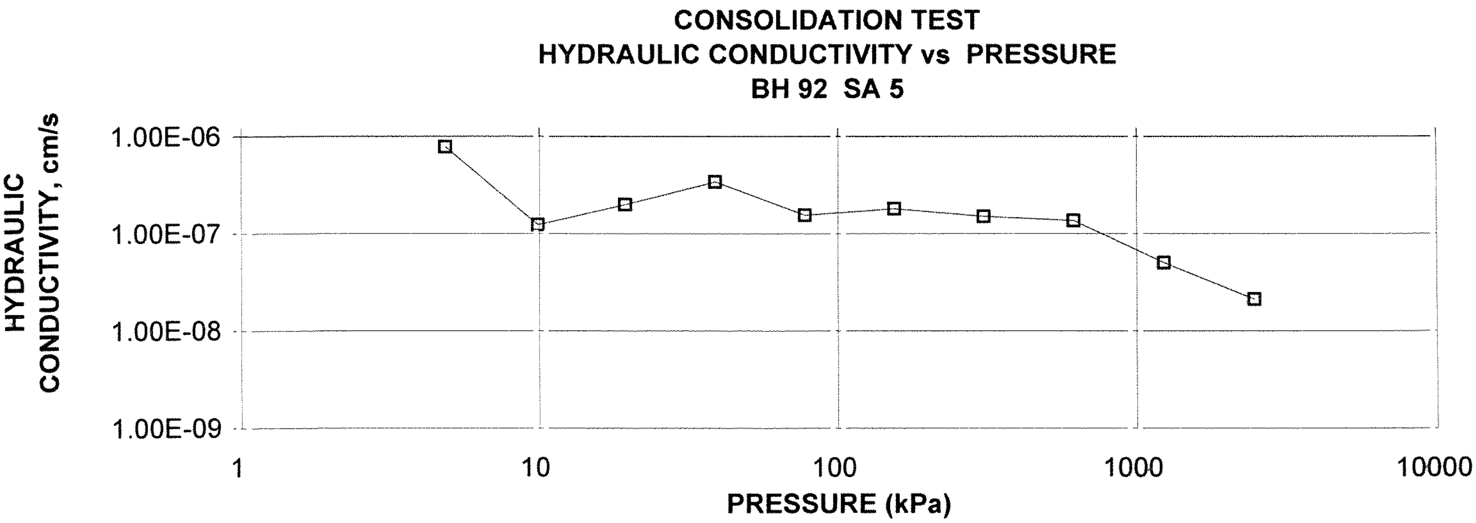
Highway 537 Culvert Sta. 11+940 and 12+130

FIGURE A-26

Sheet 2 of 4


CONSOLIDATION TEST
cv cm²/s vs PRESSURE (kPa)
BH 92 SA 5


CONSOLIDATION TEST
mv, m²/kN vs PRESSURE (kPa)
BH 92 SA 5

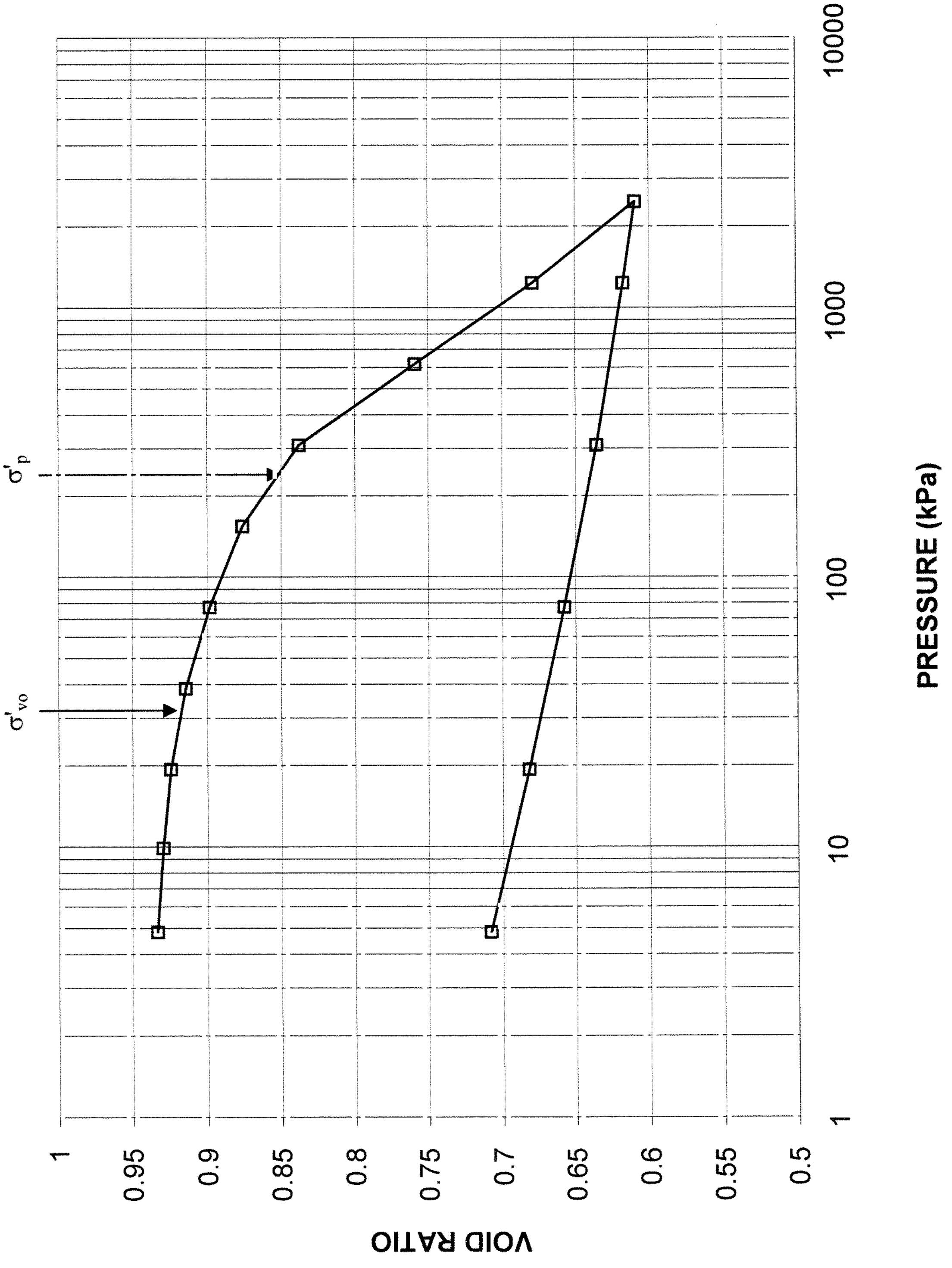

CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH 92 SA 5

Project No. 03-1111-011-4

CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE A-26
Sheet 3 of 4

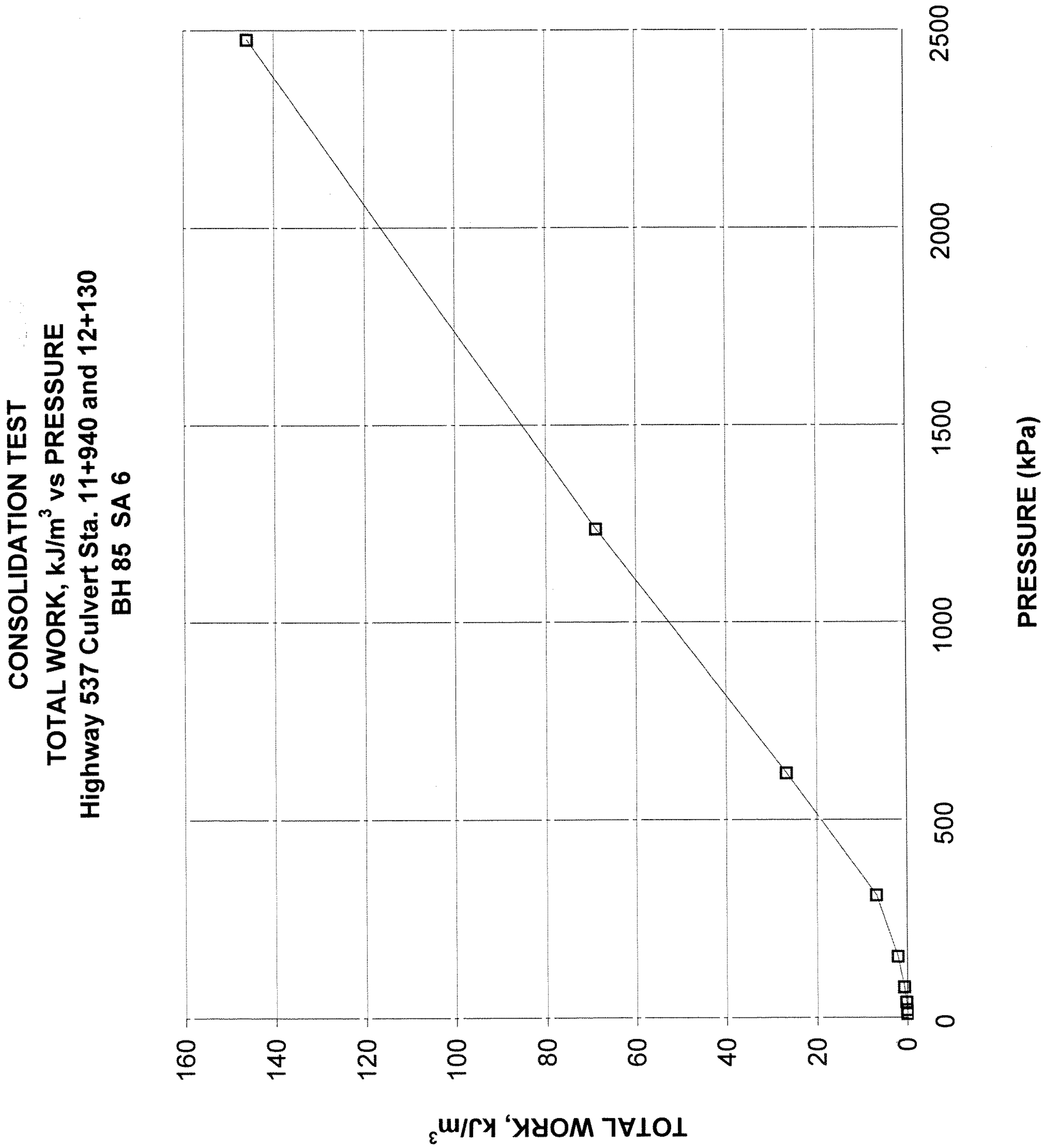
CONSOLIDATION TEST
VOID RATIO vs PRESSURE
Highway 537 Culvert Sta. 11+940 and 12+130
BH 92 SA 5



Project No. 03-1111-011-4

CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

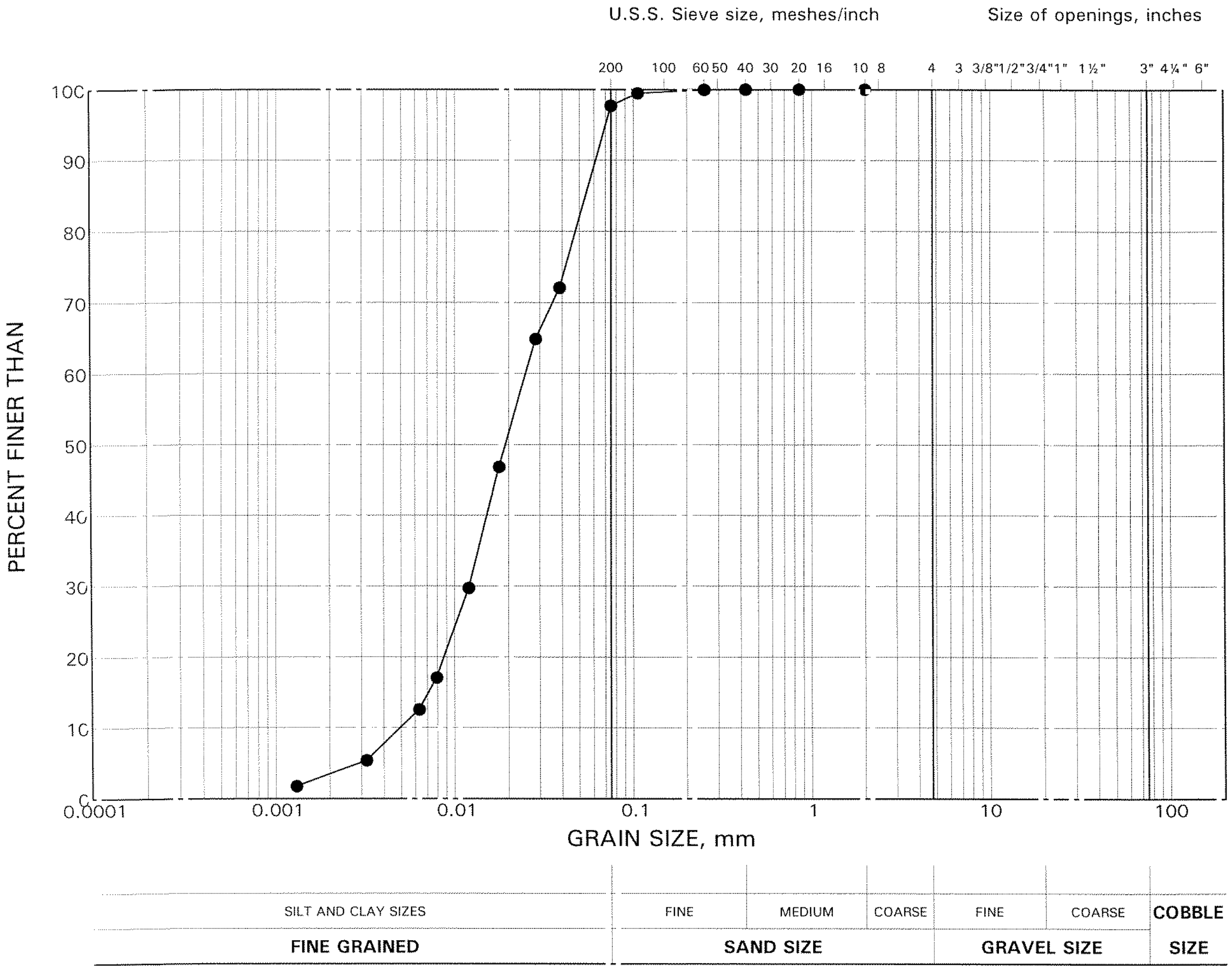
FIGURE A-26
Sheet 4 of 4



Project No. 03-1111-011-4

GRAIN SIZE DISTRIBUTION
Silt to Sandy Silt
Hwy 537 Culvert Sta. 11+940 and 12+130

FIGURE A-27



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	84	9	216.2

Date June, 2005

Project 03-1111-011-4

Golder Associates

Prepared by LG

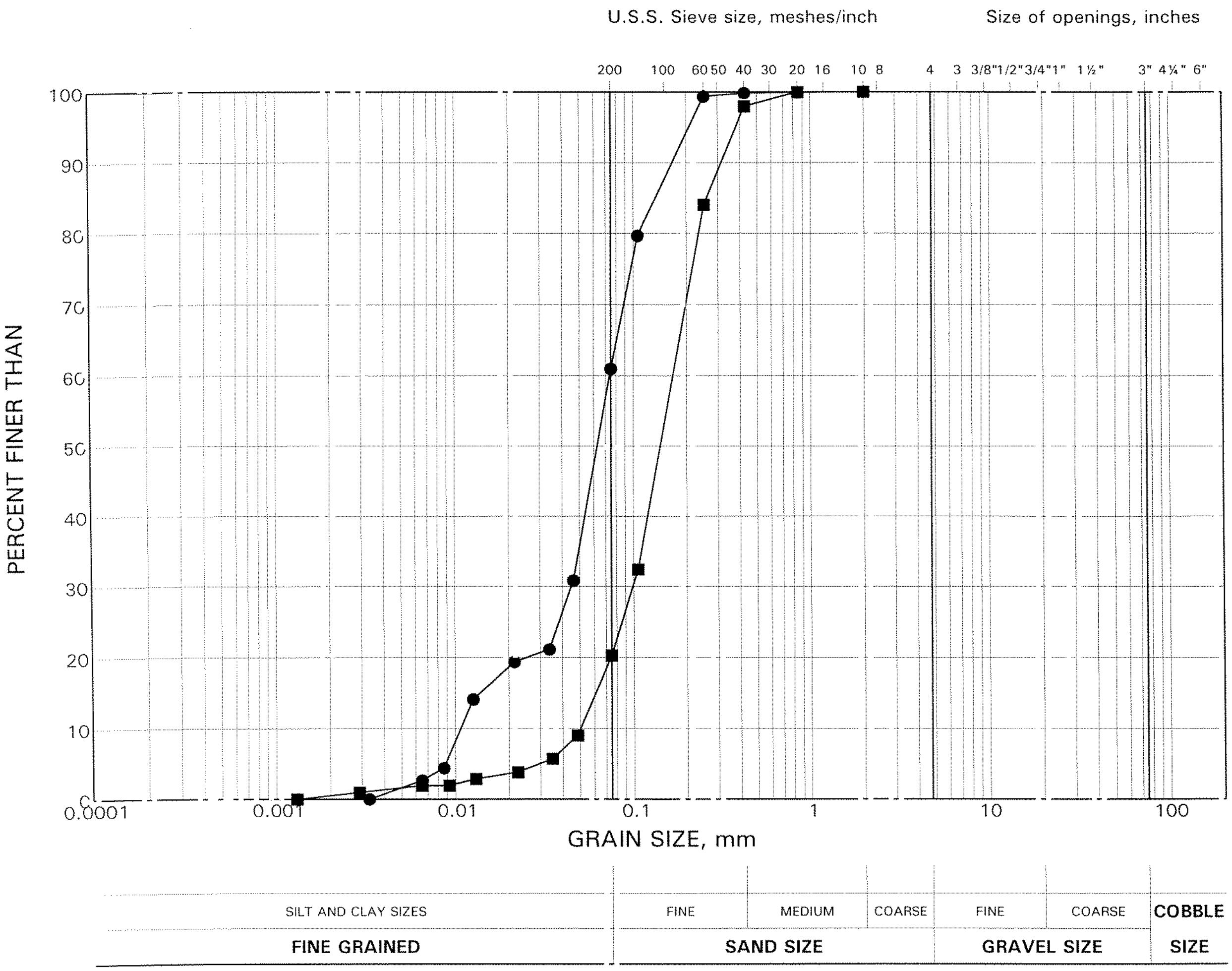
Checked by

GRAIN SIZE DISTRIBUTION

Sand to Sand and Silt

Hwy 537 Culvert Sta. 11+940 and 12+130

FIGURE A-28



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	83	12	211.7
■	83	16	205.6

Date June, 2005

Project 03-1111-011-4

Golder Associates

Prepared by LG

Checked by

APPENDIX B

RECORD OF BOREHOLE SHEETS, DYNAMIC CONE PENETRATION TEST SHEETS AND CONE PENETRATION TEST SHEETS

CULVERT HIGHWAY 69 STATION 12+200

Golder Associates

RECORD OF BOREHOLE No BH-20

1 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST

HWY 69

DATUM Geodetic

LOCATION N 5137529.6 ;E 316878.9

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

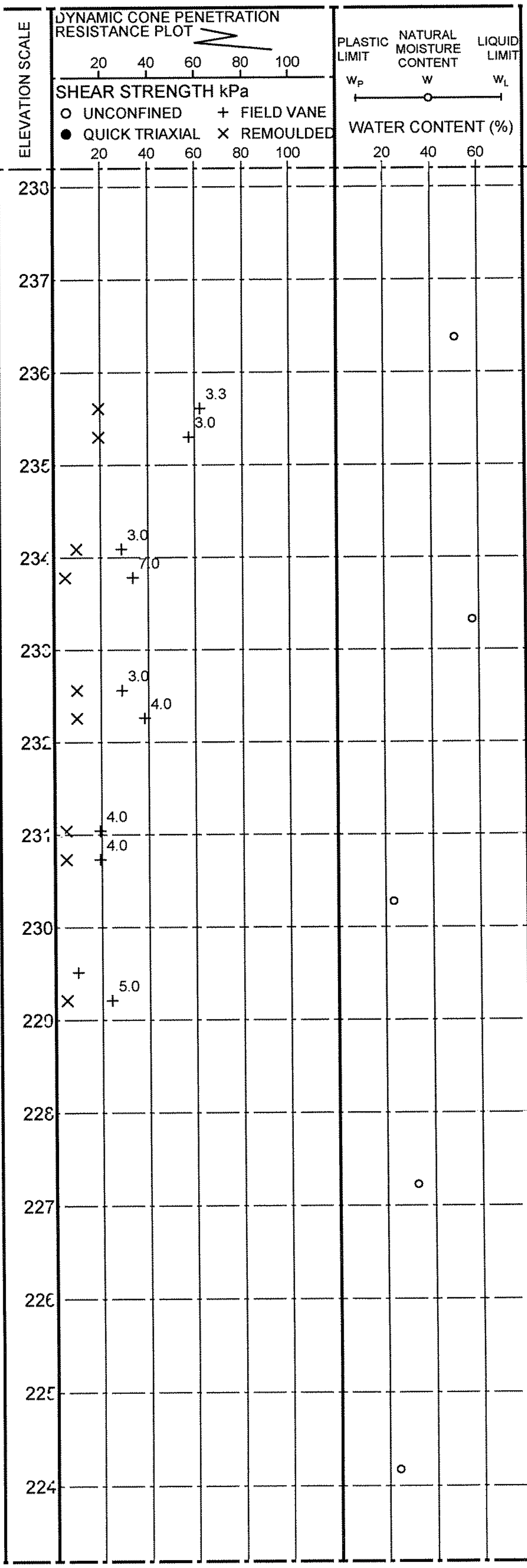
DATE Sept. 18, 2003

ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE			SAMPLES						REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
238.2	GROUND SURFACE										
0.0	TOPSOIL and PEAT										
237.9 0.3	Silty CLAY, trace to some sand and roots near surface Soft to stiff Mottled brown, reddish-brown and grey to grey Moist to wet		1	SS	WH						
			2	SS	6						
			3	SS	4						
235.1 3.1	Silty CLAY, trace sand Firm to very soft Grey Moist		4	SS	WH						
	Reddish grey varves/laminae between 4.6m and 6.7m depth		5	SS	WH						
	75mm sand seam at 6.4m depth		6	SS	WH	∇					
	Sandy silt layers below 7.6m depth		7	SS	WH			0	24	64	12
229.1 9.1	Sandy SILT, trace to some medium sand Compact Grey Wet		8	SS	21						
227.5 10.7	Clayey SILT with layers of silty sand Firm Grey Wet		9	SS	3						
226.0 12.2	Silty fine SAND, trace clay Compact to very loose Grey Wet		10	SS	12						
	Seams of grey medium sand at 13.7m depth		11	SS	2						



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

O3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-20

2 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ______ HWY 69
DATUM Geodetic
LOCATION N 5137529.6 ;E 316878.9
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Sept. 18, 2003
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	Silty fine SAND, trace clay Compact to very loose Grey Wet		12	SS	4		223				
222.4 15.9	End of Borehole Note: Water level inside augers at 6.3m depth below ground surface upon completion of drilling										

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

Golder Associates

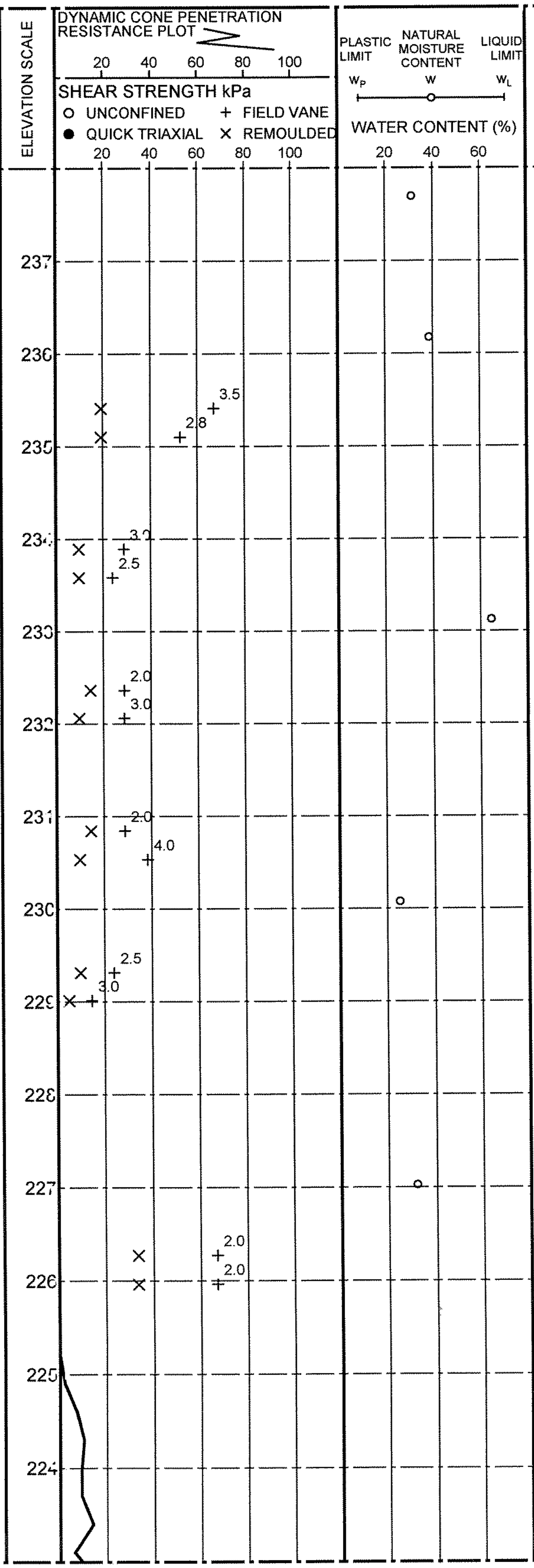
RECORD OF BOREHOLE No BH-21

1 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ____ HWY 69
DATUM Geodetic
LOCATION N 5137565.2 ;E 316875.3
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Sept. 16, 2003
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES
238.0	GROUND SURFACE			
0.1	TOPSOIL			
	Silty CLAY, trace sand and roots Firm to stiff Mottled brown, reddish-brown and grey to grey Moist	1	SS	2
		2	SS	4
		3	SS	5
234.9 / 3.1	Silty CLAY, trace to some sand Firm to soft Grey Moist	4	SS	WH
	Reddish grey varves/laminae above 4.6m depth	5	SS	WH
	Seams of silty sand below 6.1m depth	6	SS	WH
		7	SS	WH
228.9 / 9.1	Silty fine to medium SAND, trace clay Compact Grey Wet	8	SS	17
227.6 / 10.4	Clayey SILT, trace sand and thin seams of silty sand Firm Grey Moist	9	SS	2
225.8 / 12.2	Sandy SILT, trace clay Loose Grey Wet	10	SS	7
225.2	Start of Dynamic Cone Penetration Test			



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

Golder Associates

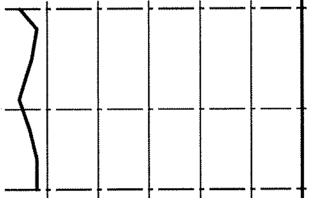
RECORD OF BOREHOLE No BH-21

2 OF 2

METRIC

PROJECT 03-1111-011			ORIGINATED BY SB
W.P. 327-91-00		LOCATION N 5137565.2 ;E 316875.3	COMPILED BY SEP
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	CHECKED BY ASP
DATUM Geodetic		DATE Sept. 16, 2003	

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
							222				
221.2 16.8	End of Dynamic Cone Penetration Test										



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

RECORD OF BOREHOLE No BH-23

1 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5137571.0 ;E 316848.0
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Sept. 16, 2003

ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE

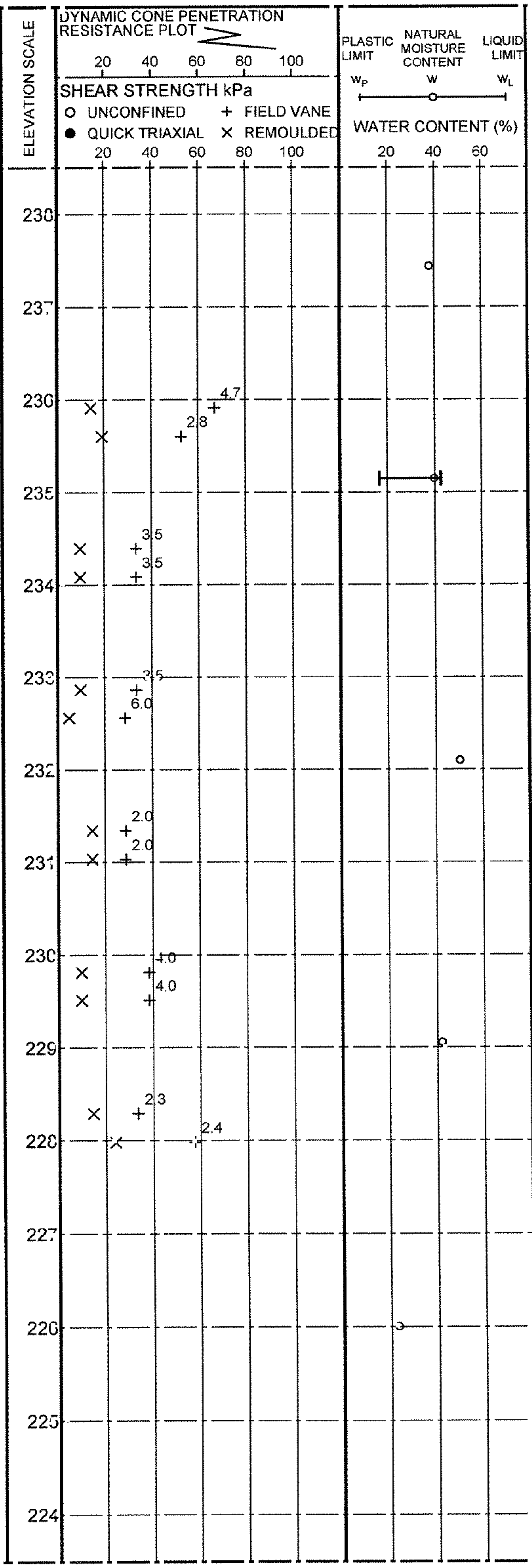
ELEV DEPTH	DESCRIPTION	STRAT PLOT
238.5	GROUND SURFACE	
0.0 0.1	TOPSOIL Silty CLAY, trace sand and roots Firm to stiff Mottled brown, reddish-brown and grey to grey Moist	▨
235.4 3.1	Silty CLAY, trace to some sand Firm to soft Grey Moist to wet Reddish grey varves/laminae at 6.1m depth 50mm sand seam at 6.4m depth Silty sand seams at 7.6m depth Becoming clayey silt below 9.1m depth with light grey and dark grey varves/laminae	▨
227.8 10.7	Silty fine SAND, trace clay Loose Grey Wet	
225.1 13.4	Fine to medium SAND, trace silt, occasional roots and organics Loose to compact Grey Wet	

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	1
2	SS	5
3	SS	4
4	SS	WH
5	TO	PH
6	SS	2
7	SS	WR
8	SS	WH
9	SS	8
10	SS	8
11	SS	7

GROUND WATER CONDITIONS



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

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

$O^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-23

2 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5137571.0 ;E 316848.0

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

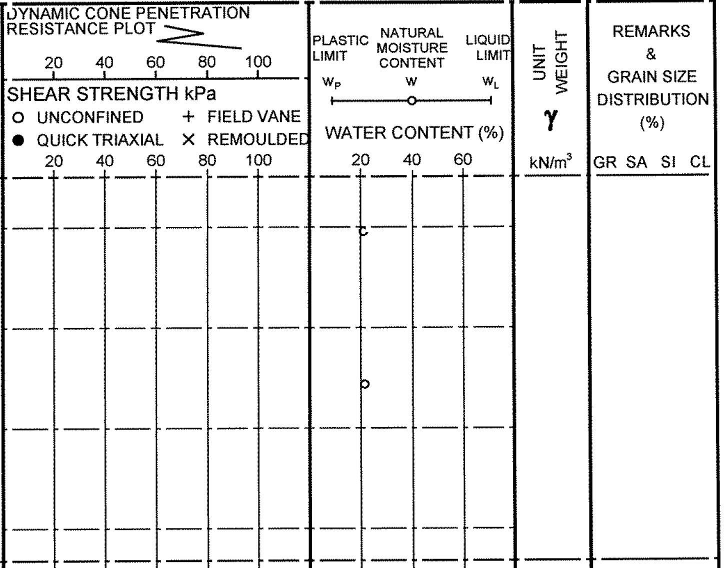
DATE Sept. 16, 2003

ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
	— CONTINUED FROM PREVIOUS PAGE —						
	Fine to medium SAND, trace silt, occasional roots and organics Loose to compact Grey Wet Seams of silty clay at 15.2m depth		12	SS	4		223
							222
			13	SS	7		
							221
220.5 18.0	Silty SAND and GRAVEL with occasional cobbles Very dense Grey Moist		14	SS	50/.05		220
219.7 18.8	End of Borehole Auger Refusal Spoon Refusal						



+3, ×3: Numbers refer to Sensitivity   O3% STRAIN AT FAILURE

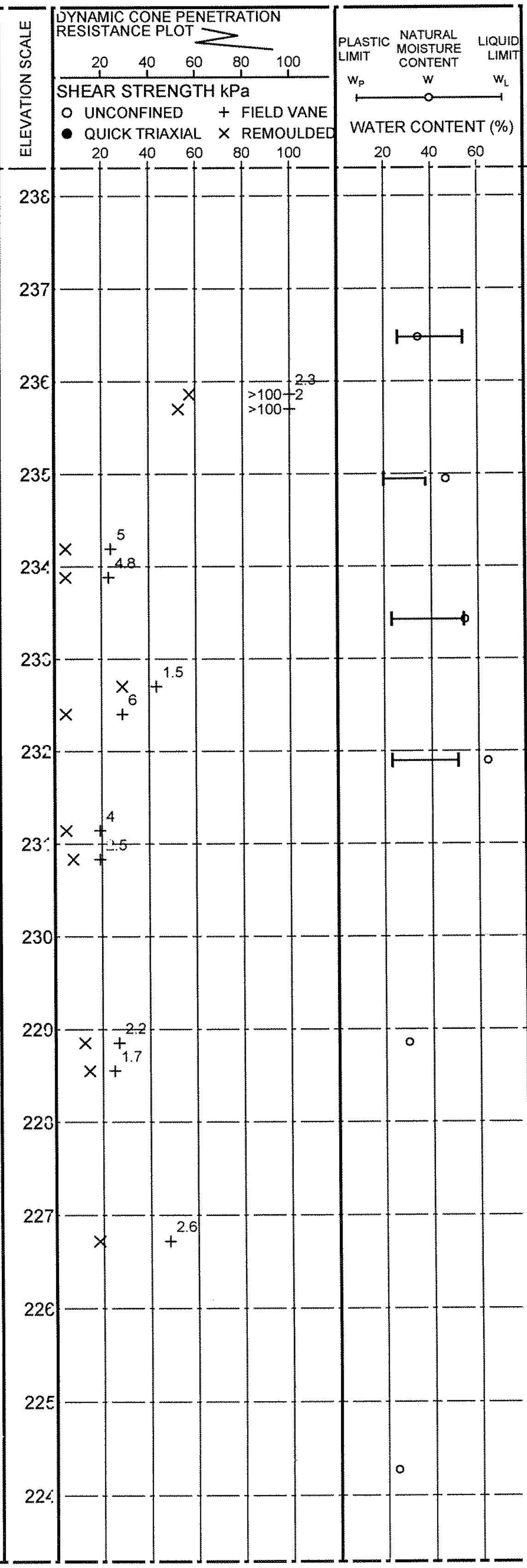
MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Golder Associates

RECORD OF BOREHOLE No BH-120 1 OF 2 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5137581.8 ;E 316888.5
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE July 9 - 10, 2004
ORIGINATED BY SB/ES
COMPILED BY SEP
CHECKED BY ASP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
238.3	GROUND SURFACE						
0.0	GRAVEL with peat	1	SS	4			
238.0	PEAT Loose Black						
237.7 0.6	Silty CLAY to CLAY, trace sand and gravel, trace organics Firm to stiff Mottled brown and grey Moist	2	SS	5	▽		
		3	SS	5			
		4	TO	PH		17.4	
234.3 4.0	Silty CLAY, trace sand and gravel, trace organics Soft to firm Grey Moist	5	TO	PH		16.8	
		6	TO	PH			
230.7 7.6	SAND to silty fine SAND Very loose Grey Wet	7	TO	PH			
		8	SS	9			
228.7 9.6	Clayey SILT to silty CLAY, trace fine sand Soft to stiff Grey Wet	9	TO	PH			
226.7 11.6	Silty SAND, trace clay Loose to very loose Grey Wet	10	SS	9			
225.2 13.1	Silty SAND to Sandy SILT, trace gravel Very loose to loose Wet	11	SS	2			



Continued Next Page

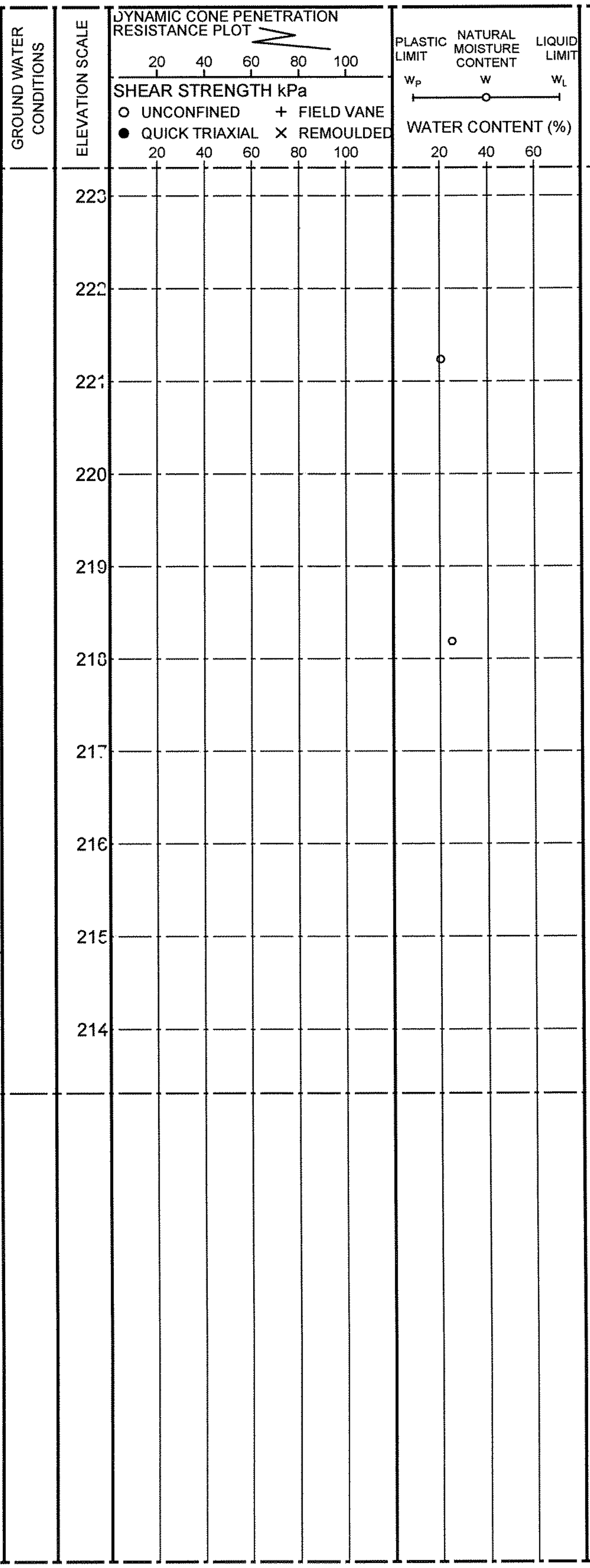
+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-120 2 OF 2 METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5137581.8 ;E 316888.5	ORIGINATED BY SB/ES
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic		DATE July 9 - 10, 2004	CHECKED BY ASP

SOIL PROFILE: ELEV / DEPTH	DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%): GR	SA	SI	CL
	— CONTINUED FROM PREVIOUS PAGE —							
	Silty SAND to Sandy SILT, trace gravel Very loose to loose Wet	12	SS	WH				
		13	SS	4	0	76	22	2
		14	SS	WR				
		15	SS	6				
215.4 22.9	Silty SAND, trace to some gravel (TILL) Compact Grey Wet	16	SS	27				
213.3 25.0	End of Borehole Auger refusal							

Notes:
1. Sample 7 lost. Sample 15 lost.
2. Sand Heave in augers below 15m depth.
3. Augers grinding from 25.0m to 25.7m depth and dipping towards the north.
4. Water level at 0.9m depth (elev. 237.4m) upon completion of drilling.
5. Borehole caved to 8.8m depth.
6. Consolidated undrained triaxial test performed on Sample 6.



UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity O3% STRAIN AT FAILURE

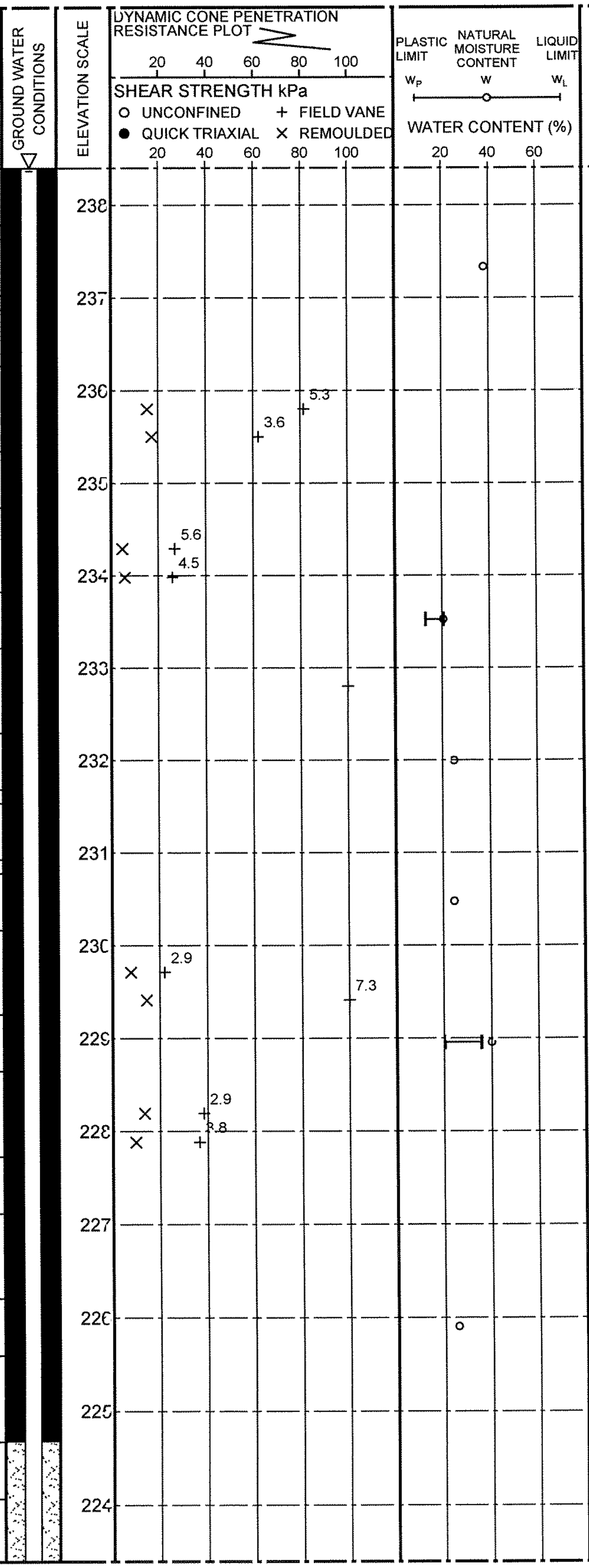
Golder Associates

RECORD OF BOREHOLE No BH-121

1 OF 3 **METRIC**

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5137519.2 ;E 316838.6
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE July 6 - 7, 2004
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
238.4	GROUND SURFACE								
0.0 0.1	Topsoil Silty CLAY to clay, trace sand and gravel, trace organics Firm to stiff Mottled brown and grey Moist to wet	1	SS	2					
		2	SS	3					
		3	SS	3					
235.3 3.1	Silty CLAY, trace sand and gravel, trace organics Soft to firm Grey Moist to wet	4	SS	WH					
	Becoming siltier at 4.6 m depth	5	SS	WH					
233.1 5.3	SAND to silty fine sand, trace to some clay Very Loose Grey Wet	6	SS	1					
		7	TO	PH					
230.8 7.6	Clayey SILT to Silty CLAY, trace to some sand Soft to stiff Grey Moist to wet	8	SS	WH					
		9	TO	PH	18.0 17.8				
227.7 10.7	Sandy SILT to Silty SAND, trace clay Loose to compact Grey Moist	10	SS	7					
		11	SS	8		0	22	73	5
		12	SS	2					
223.5									



Continued Next Page

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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Golder Associates

RECORD OF BOREHOLE No BH-121

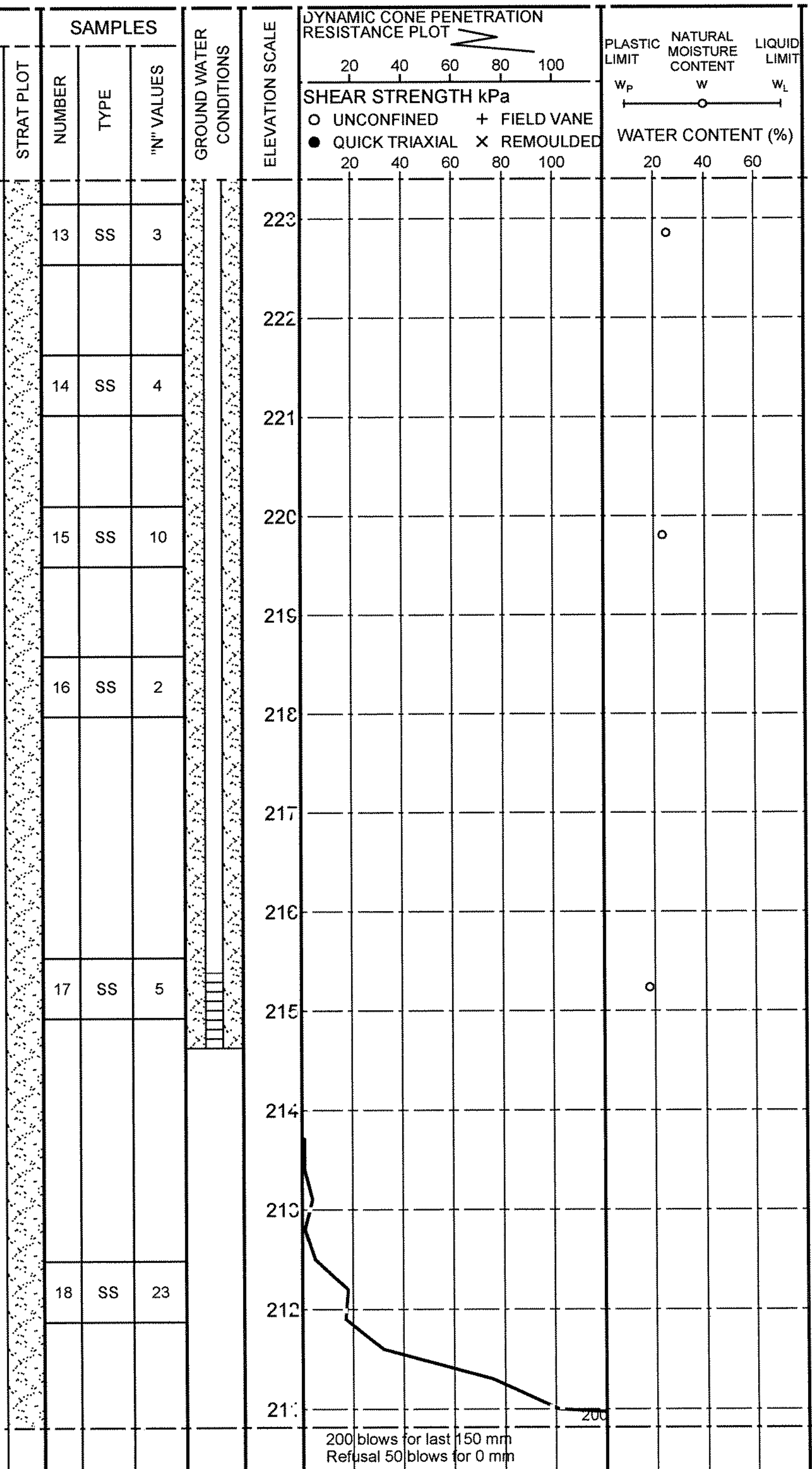
2 OF 3

METRIC

PROJECT 03-1111-011			ORIGINATED BY SB
W.P. 327-91-00	LOCATION N 5137519.2 ;E 316838.6		COMPILED BY SEP
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	CHECKED BY ASP
DATUM Geodetic	DATE July 6 - 7, 2004		

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
14.9	Medium to coarse SAND, trace gravel Loose to compact Grey Wet	13	SS	3
		14	SS	4
	Silty fine Sand below 18.3m depth	15	SS	10
		16	SS	2
		17	SS	5
	Augers grinding at 25.3m depth	18	SS	23
210.8 27.6	End of Borehole Dynamic Cone Refusal			



200 blows for last 150 mm
Refusal 50 blows for 0 mm

UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Continued Next Page

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

RECORD OF BOREHOLE No BH-121

3 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST

HWY 69

LOCATION N 5137519.2 ;E 316838.6

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATUM Geodetic

DATE July 6 - 7, 2004

ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						

Notes:

1. Sample 7 lost.

2. Sand Heave in augers below 15.2m depth.

3. Casing advanced to 30m depth to attempt sample.

4. Dynamic Cone pushed from 24.4m to 27.6m depth. Pushed through caved material from 24.4m to 26.5m depth.

5. Water level inside auger at 0.3m above ground surface. Water level at 0.6m above ground surface inside casing after completion of drilling.

6. Water level in 50mm piezometer at 0.6m above ground surface after installation. Water level on July 8, 8:00 am at 0.6m above ground surface and flowing out of pipe. Additional riser pipe added. Water level measured at 2.0m (Elev. 240.4m) above ground surface on July 8, 3:00 pm. Water level at 1.9m above ground surface on July 14, 2004. Water level in piezometer at 1.1m above ground surface (Elev. 239.5m) on October 5, 2004.

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

$\circ^{3\%}$ STRAIN AT FAILURE

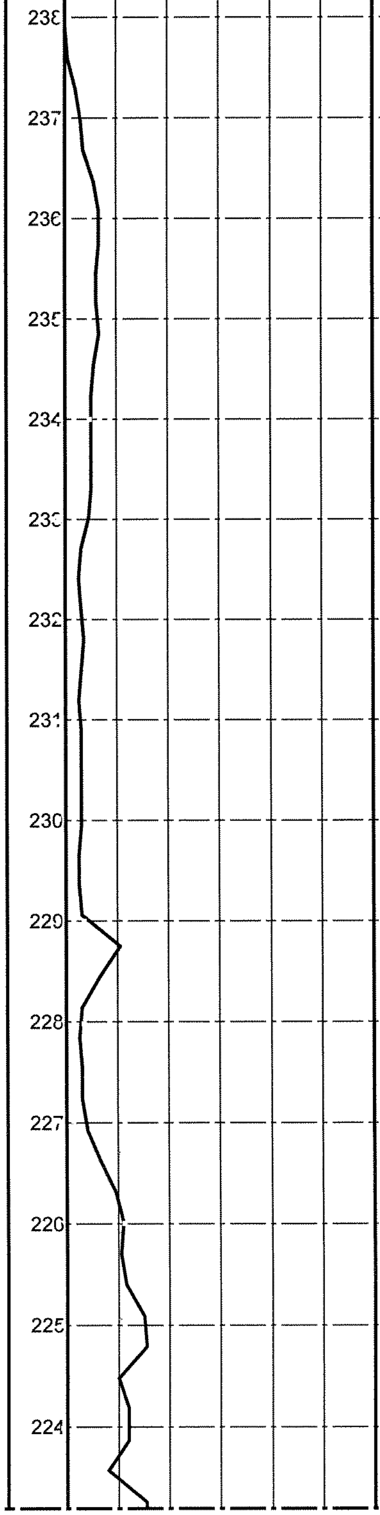
RECORD OF BOREHOLE No DCPT-13

1 OF 2

METRIC

PROJECT 03-1111-011			ORIGINATED BY SB
W.P. 327-91-00		LOCATION N 5137509.7 ;E 316863.3	COMPILED BY SEP
DIST	HWY 69	BOREHOLE TYPE Dynamic Cone	CHECKED BY ASP
DATUM Geodetic		DATE Sept. 17, 2003	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
238.2 0.0	GROUND SURFACE										



Continued Next Page

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

$O^{3\%}$ STRAIN AT FAILURE

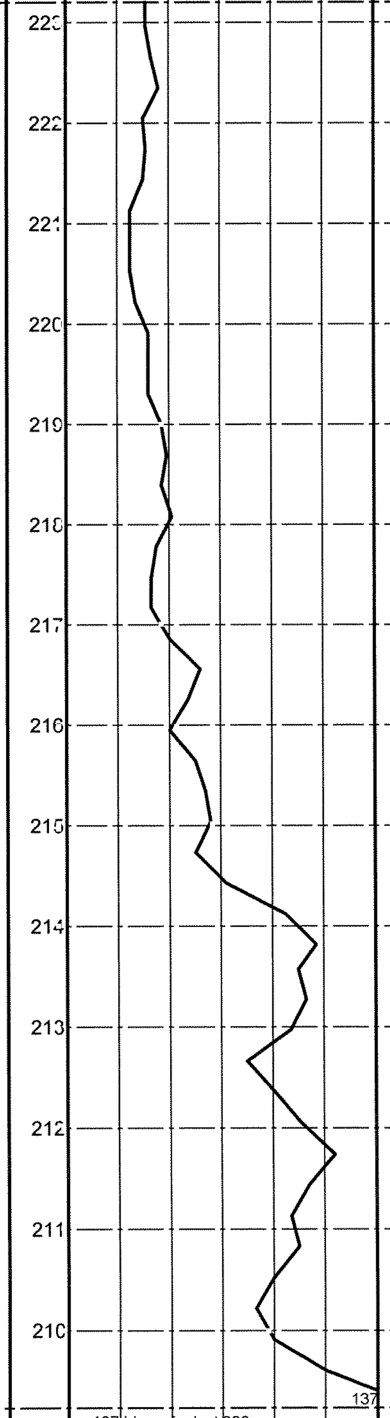
RECORD OF BOREHOLE No DCPT-13 2 OF 2 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5137509.7 ;E 316863.3
BOREHOLE TYPE Dynamic Cone
DATE Sept. 17, 2003

ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
209.2 29.0	End of dynamic cone test Refusal to penetration							137 blows for last 300 mm			



MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

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

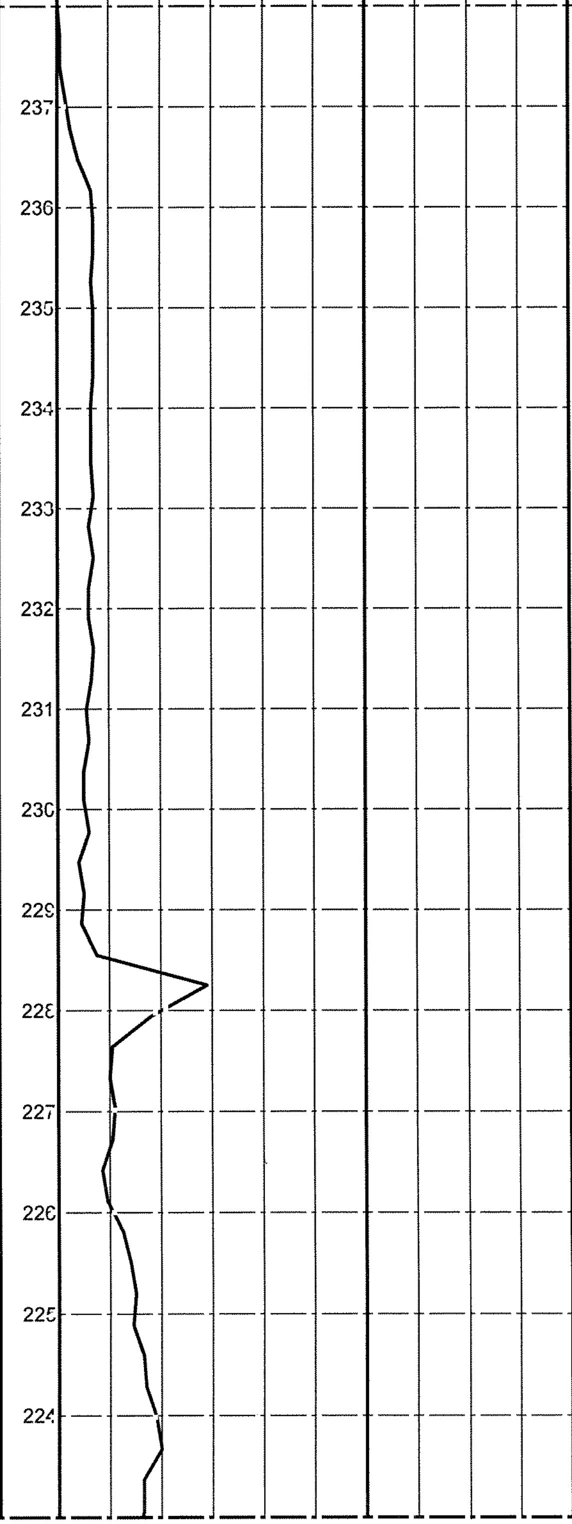
RECORD OF BOREHOLE No DCPT-14

1 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5137540.4 ;E 316887.4
ORIGINATED BY CN
DIST HWY 69
BOREHOLE TYPE Dynamic Cone
COMPILED BY SEP
DATUM Geodetic
DATE Sept. 17, 2003
CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
238.0 0.0	GROUND SURFACE										



Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

O $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No DCPT-14

2 OF 2

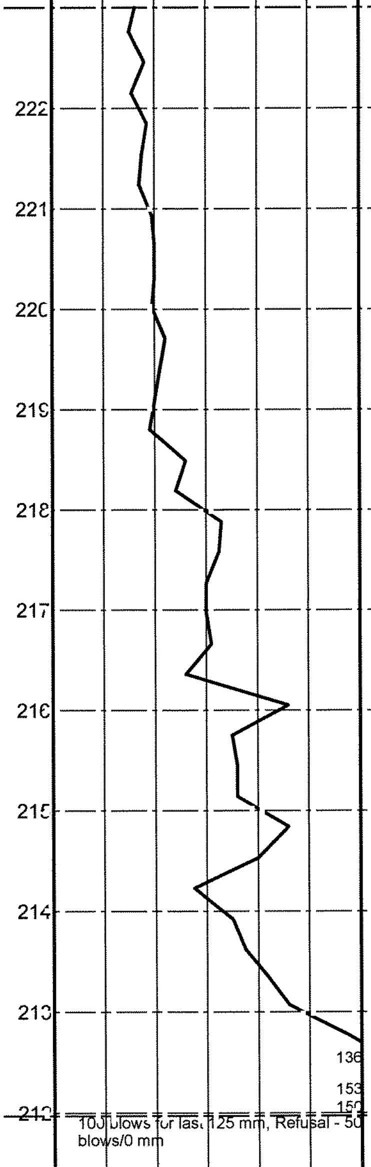
METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5137540.4 ;E 316887.4
BOREHOLE TYPE Dynamic Cone
DATE Sept. 17, 2003

ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
212.0 26.0	End of dynamic cone test Refusal to penetration										



MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

+ 3, × 3: Numbers refer to Sensitivity

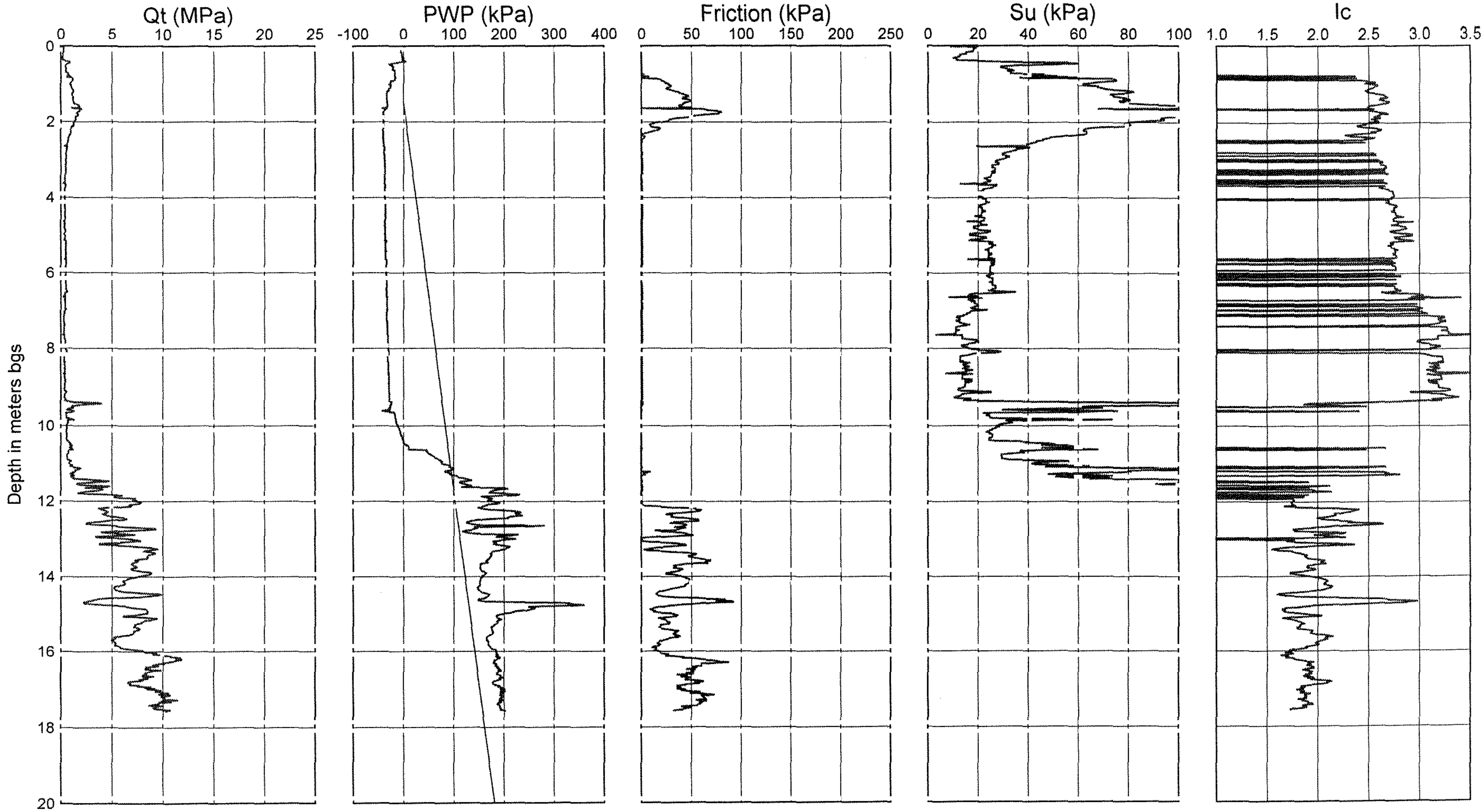
O 3% STRAIN AT FAILURE

Cone Penetration Test - CPT03-08

Test Date : September 4, 2003
Location : STA 12+175 o/s 32.1 m Rt

Operator : Golder Associates

Ground Surf. Elev. : 238.10
Water Table Depth : 1.50



Qt normalized for unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Robertson and (Fear) Wride (1998)
Ic < 1.31 - Gravelly sands
1.31 <Ic < 2.05 - Clean to silty sand
2.05 <Ic < 2.60 - Silty sand to sandy silt
2.60 <Ic < 2.95 - Clayey silt to silty clay
2.95 <Ic < 3.60 - Clays

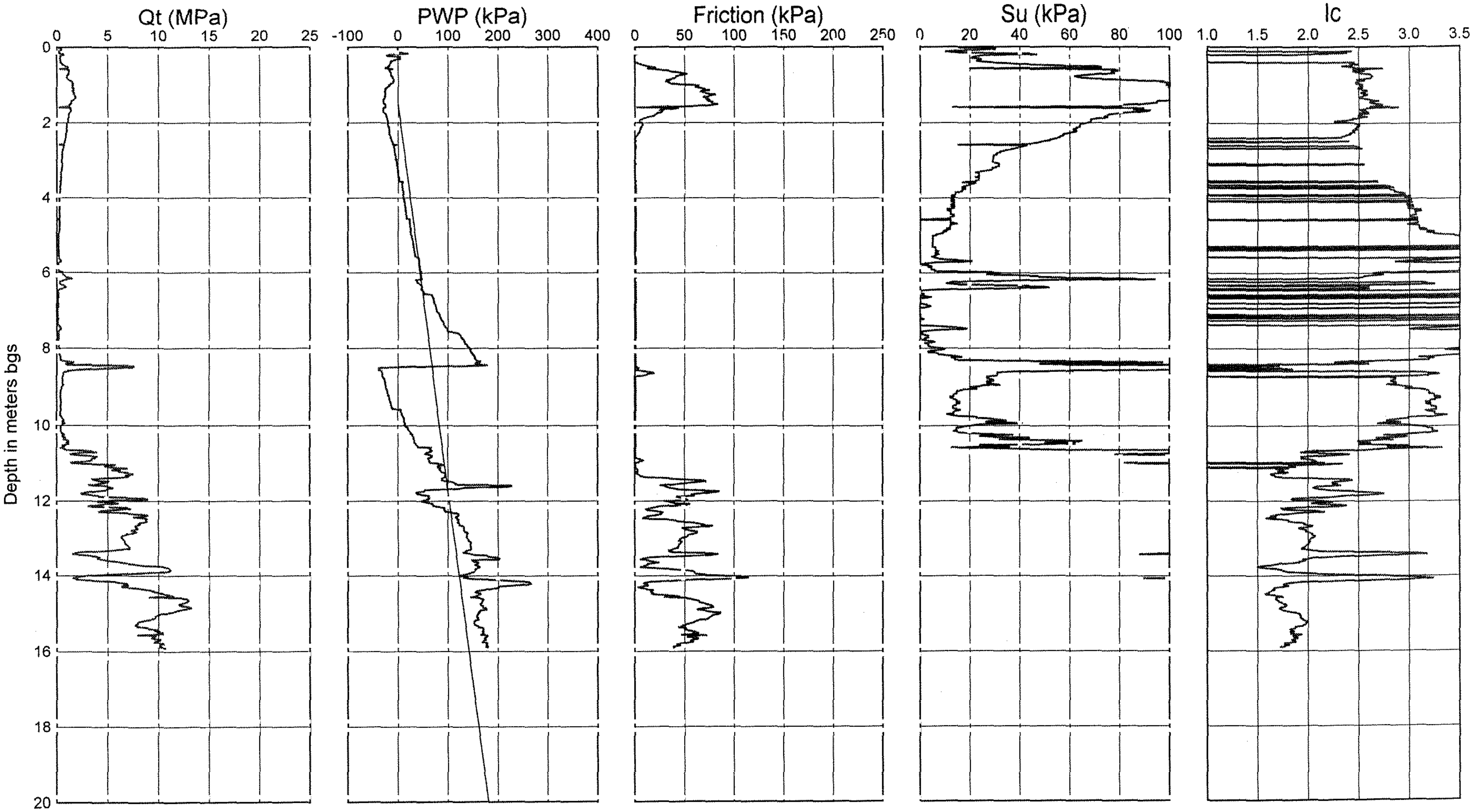
PROJECT NO. 03-1111-011 DATE: June 2004 DRAWN BY: CN

Cone Penetration Test - CPT03-09

Test Date : September 4, 2003
Location : STA 12+200 o/s 18.8 m Lt

Operator : Golder Associates

Ground Surf. Elev. : 238.10
Water Table Depth : 1.50



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Robertson and (Fear) Wride (1998)
Ic < 1.31 - Gravelly sands
1.31 <Ic < 2.05 - Clean to silty sand
2.05 <Ic < 2.60 - Silty sand to sandy silt
2.60 <Ic < 2.95 - Clayey silt to silty clay
2.95 <Ic < 3.60 - Clays

PROJECT NO. 03-1111-011 DATE: June 2004 DRAWN BY: CN

APPENDIX C

RECORD OF BOREHOLE SHEETS, DYNAMIC CONE PENETRATION TEST SHEETS AND CONE PENETRATION TEST SHEETS

CULVERT HIGHWAY 69 STATION 14+100

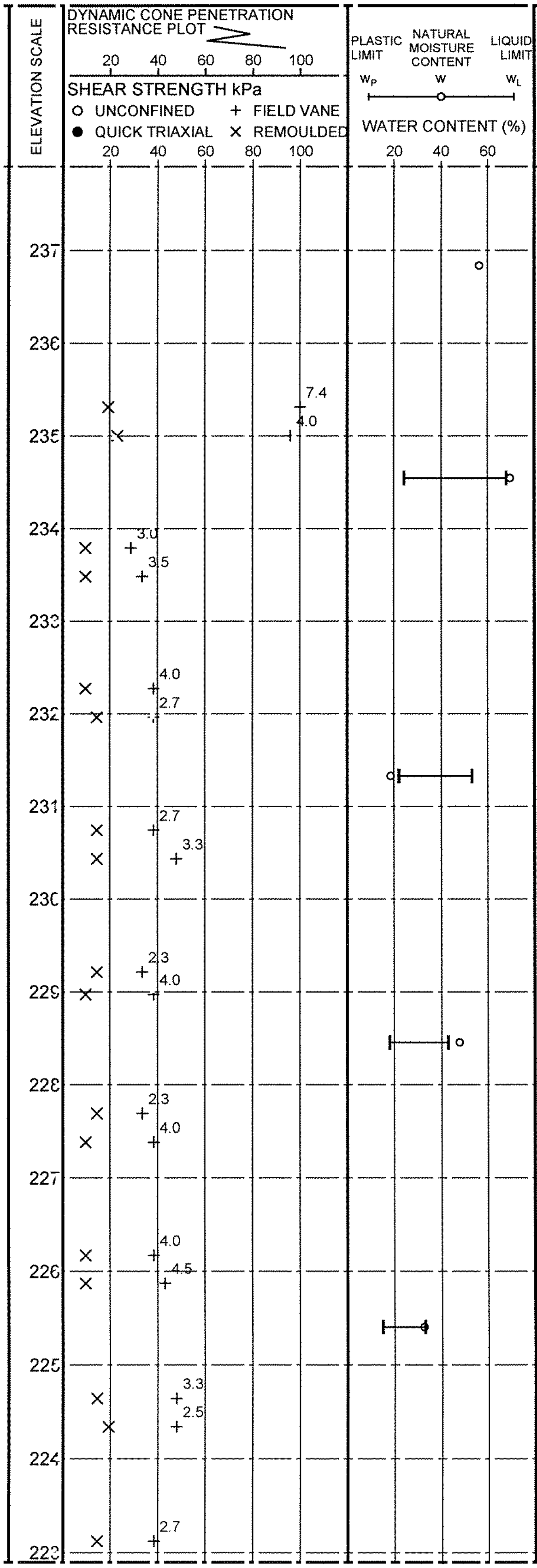
RECORD OF BOREHOLE No BH-49

1 OF 3 **METRIC**

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5138975.7 ;E 315701.2	ORIGINATED BY SB
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic		DATE Aug. 26, 2003	CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
237.9	GROUND SURFACE			
0.0	TOPSOIL			
0.2	Silty fine SAND, trace clay and roots Loose Black, brown and grey Moist Occasional pockets of brown silty clay	1 2	SS SS	5 5
236.4 1.5	Silty CLAY to Clayey SILT, trace sand and rootlets Firm to very stiff Brown and grey Moist	3	SS	3
234.9 3.1	Clayey SILT to CLAY, trace to some sand Firm to soft Grey Moist to wet Light grey to dark grey varves/laminae above 3.7m depth	4 5 6 7 8 9 10 11	SS SS SS SS SS SS SS SS	WH WH WH WH WH WH WH WH

GROUND WATER CONDITIONS: ∇ (at approx. elev. 232.7)



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

Golder Associates

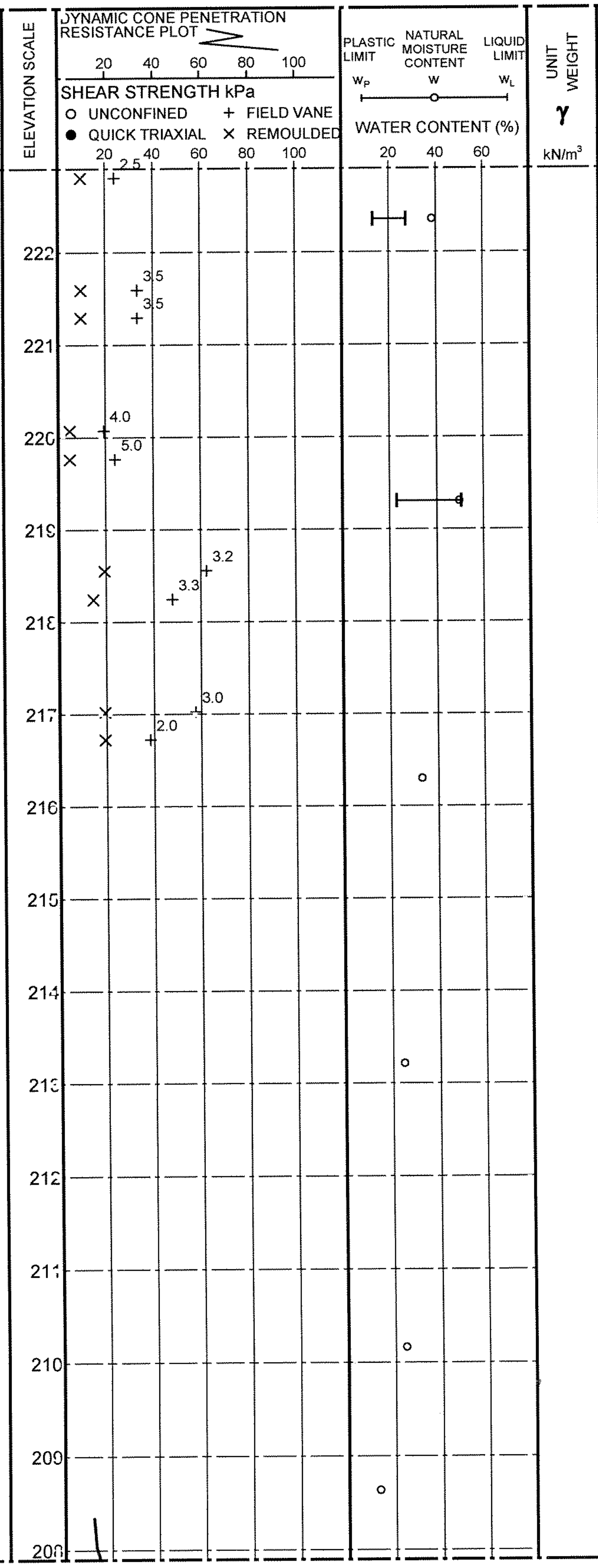
RECORD OF BOREHOLE No BH-49 2 OF 3 METRIC

PROJECT 03-1111-011
W.P. 327-91-00 LOCATION N 5138975.7 ;E 315701.2 ORIGINATED BY SB
DIST HWY 69 BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger COMPILED BY SEP
DATUM Geodetic DATE Aug. 26, 2003 CHECKED BY ASP

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	Clayey SILT to CLAY, trace to some sand Firm to soft Grey Moist to wet Seams of silty sand from 15.2m to 17.4m depth	12	SS	WR	0	16	50	34
		13	SS	WR				
		14	SS	WH		5		
	Becoming stiff below 18.9m depth Reddish grey varves/laminae below 18.9m depth	15	SS	WH				
	Becoming siltier below 21.1m depth	16	SS	WH				
216.1 21.8	SILT to Sandy SILT, trace clay Loose to compact Grey Wet	17	SS	6				
		18	SS	5	0	5	93	2
		19	SS	10				
		20	SS	6				
209.6 28.3	Coarse SAND and GRAVEL, with seams of silty fine sand Compact Grey Wet	21	SS	16				
208.3	Start of Dynamic Cone Penetration Test							

Continued Next Page



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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 20/6/05

Golder Associates

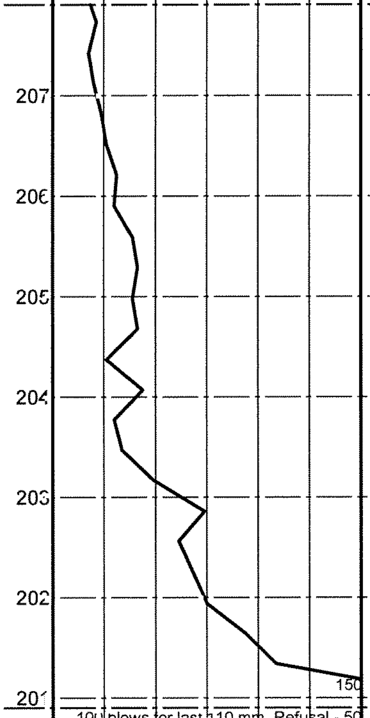
RECORD OF BOREHOLE No BH-49

3 OF 3

METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5138975.7 ;E 315701.2	ORIGINATED BY SB	
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic	DATE Aug. 26, 2003	CHECKED BY ASP	

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	--- CONTINUED FROM PREVIOUS PAGE ---										
200.9 37.0	End of Dynamic Cone Penetration Test Note: Water level in open borehole at 5.3 m depth below ground surface upon completion of drilling.							100 blows for last 110 mm. Refusal - 50 blows/0 mm			



+3, ×3: Numbers refer to Sensitivity   O3% STRAIN AT FAILURE

Golder Associates

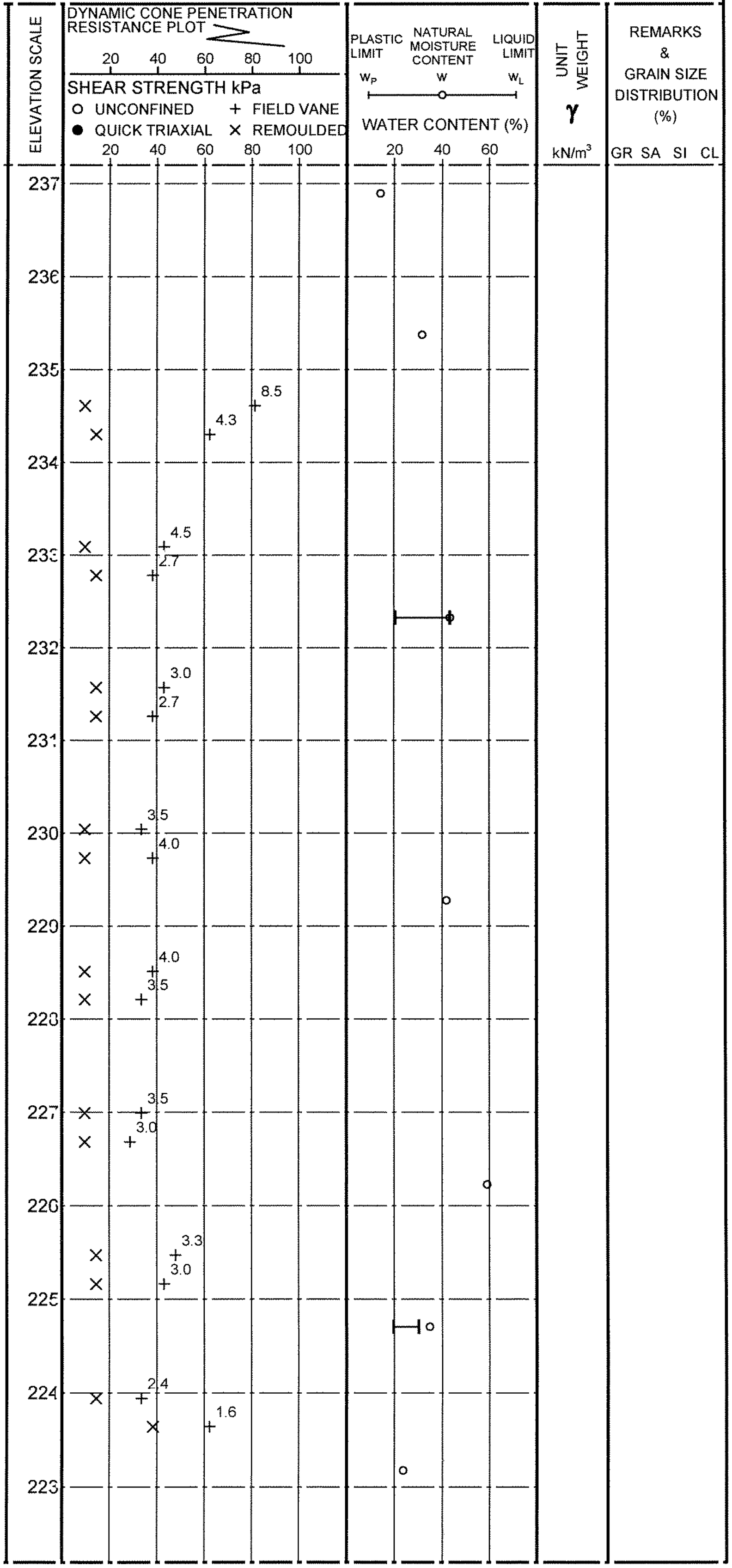
RECORD OF BOREHOLE No BH-50

1 OF 2

METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5139037.7 ;E 315708.8	ORIGINATED BY SB
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic	DATE Aug. 27, 2003	CHECKED BY ASP	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
237.2	GROUND SURFACE				
0.0	TOPSOIL				
0.1	Silty fine SAND, trace clay and roots Loose to compact Brown and grey Moist	1	SS	6	
		2	SS	10	
235.7 1.5	Silty CLAY, trace sand Stiff Mottled brown to grey Moist	3	SS	4	
234.2 3.1	Clayey SILT to CLAY, trace sand Firm Grey Moist	4	SS	WH	
		5	SS	WH	
	Faint reddish grey varves/laminae from 6.1 m to 11.3 m depth	6	SS	WH	∇
		7	SS	WH	
		8	SS	WH	
		9	SS	WH	
	Becoming siltier below 11.4 m depth				
		10	SS	WH	
223.5 13.7	Sandy SILT, trace clay Very loose to loose Grey Wet	11	SS	7	



Continued Next Page

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

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-50

2 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5139037.7 ;E 315708.8
ORIGINATED BY SB
DIST HWY 69
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
COMPILED BY SEP
DATUM Geodetic
DATE Aug. 27, 2003
CHECKED BY ASP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	--- CONTINUED FROM PREVIOUS PAGE ---										
	Sandy SILT, trace clay Very loose to loose Grey Wet	▨	12	SS	2		222		○		
		▨					221				
		▨	13	SS	8		220				
219.8 17.4	End of Borehole Note: Water level in open borehole at 6.4m depth below ground surface upon completion of drilling.										

+^{3}, ×^{3}: Numbers refer to Sensitivity

○$^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-122

1 OF 3 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5138974.0 ;E 315677.6

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

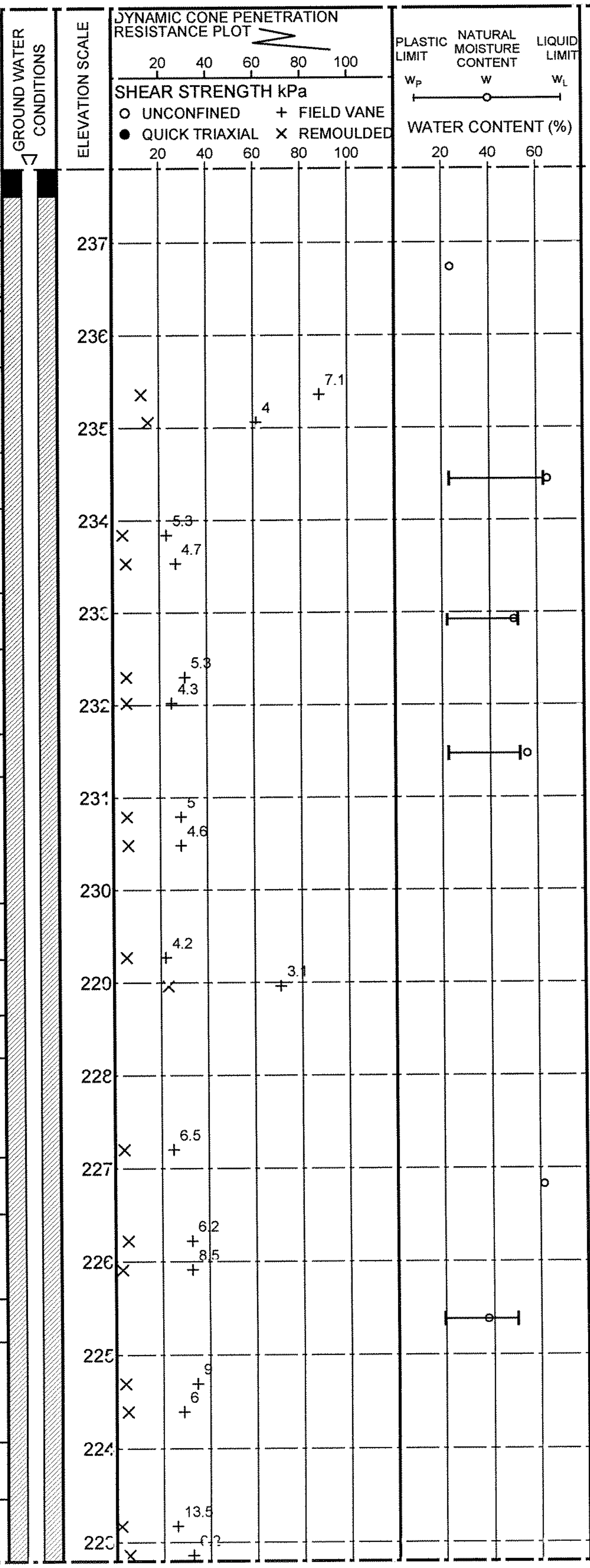
DATE July 10 - 11, 2004

ORIGINATED BY ES

COMPILED BY SEP

CHECKED BY ASP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³
237.8	GROUND SURFACE				
	Topsoil				
[illegible] 0.1	Silty fine SAND, trace clay Loose Brown, layered and mottled Moist to wet Oxidized at 0.60 m depth	1	SS	3	
		2	SS	5	
		3	SS	4	
236.0 1.8	Silty CLAY to Clayey SILT, trace fine sand, trace organics Firm to very stiff Brown				
234.8 3.1	Silty CLAY to CLAY Soft to firm Grey Wet	4	TO	PH	16.1
		5	SS	WH	
		6	TO	PH	18.0 16.6
	Reddish-grey varves/laminae below 7.6m depth	7	SS	WH	
		8	TO	WR	
	Occasional Silt seams at 10.7m depth Diagonal varves/ laminae at 10.7m depth	9	SS	WR	
		10	TO	WR	18.0
	Reddish-grey varves at 13.7m depth	11	SS	WR	



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 BH-122

2 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5138974.0 ;E 315677.6

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE July 10 - 11, 2004

ORIGINATED BY ES

COMPILED BY SEP

CHECKED BY ASP

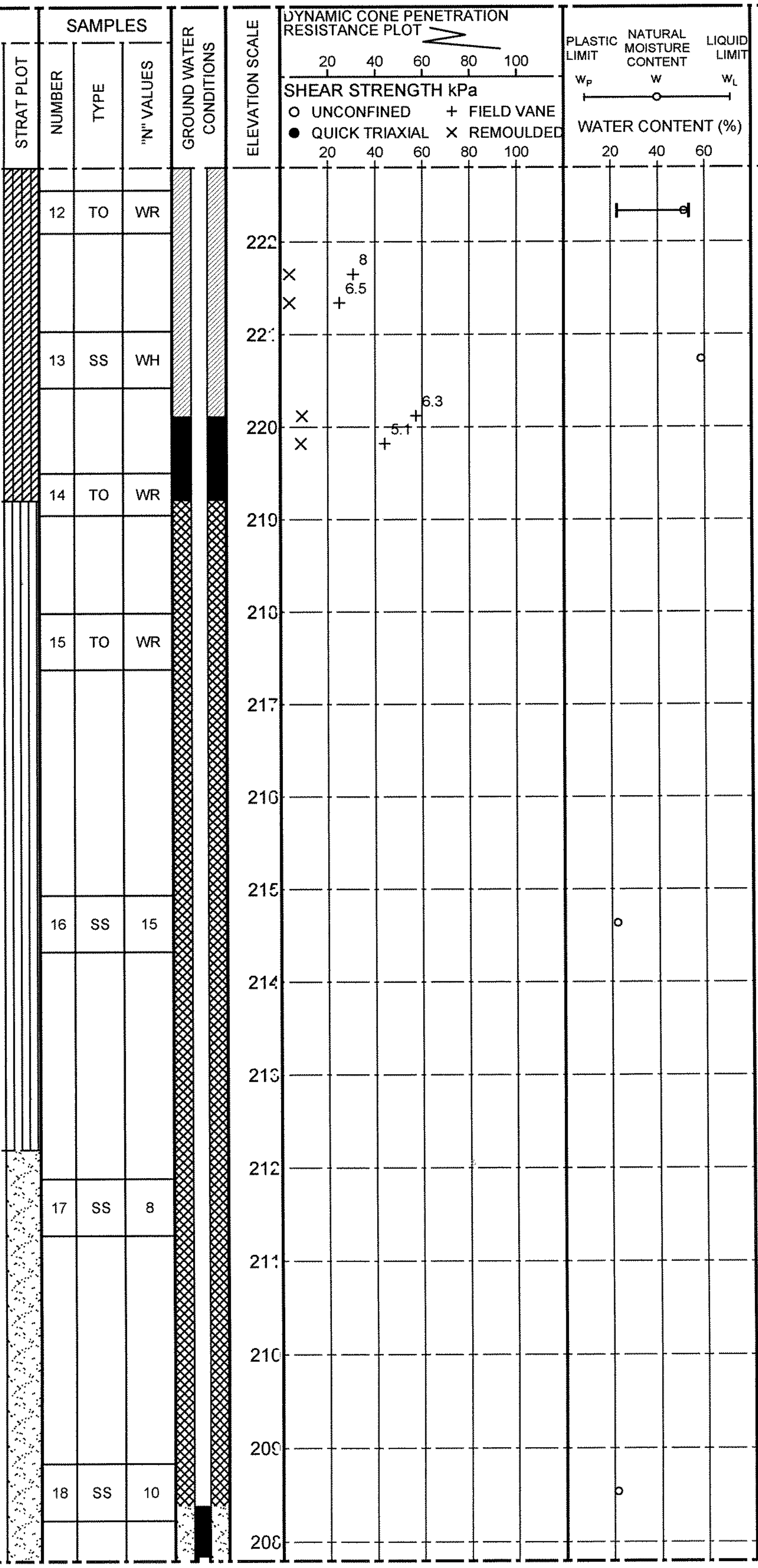
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
	--- CONTINUED FROM PREVIOUS PAGE ---
	Silty CLAY to CLAY Soft to firm Grey Wet
219.2 18.6	SILT to Sandy SILT to Silty SAND, trace gravel (occasional clay seams upper layers), occasional fine to medium sand, trace gravel seams and layers Very loose to compact, (alternating) Layered Grey Harder drilling below 19.2m depth
212.2 25.6	Fine to coarse SAND, trace to some gravel, trace silt loose to compact Layered Grey Wet Augers grinding at 25.6m depth.

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³
12	TO	WR	16.9
13	SS	WH	
14	TO	WR	
15	TO	WR	
16	SS	15	
17	SS	8	
18	SS	10	

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

O³% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-122 3 OF 3 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5138974.0 ;E 315677.6
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE July 10 - 11, 2004
ORIGINATED BY ES
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Fine to coarse SAND, trace to some gravel, trace silt loose to compact Layered Grey Wet						207				
206.6 31.2	End of Borehole Auger Refusal										

Notes:

1. Sand Heave inside augers blow 25m depth.

2. Water flowing out of augers after sample 17.

3. Water level 0.2m above ground level inside augers on July 12, 2004.

4. Water level in 50mm piezometer at 1.3m below ground surface after installation.

5. Water level in piezometer at 0.6m above ground surface on July 12, 6:00 pm ; Water level at 0.8m (Elev. 230.6m) above ground surface on July 13 and 14, 2004. Water level in piezometer at 0.5m below ground surface (Elev. 237.3m) on October 8, 2004.

6. Consolidated undrained triaxial test performed on Sample 10.

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

RECORD OF BOREHOLE No BH-123

1 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5139067.0 ;E 315699.2

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE July 12 - 14, 2004

ORIGINATED BY ES

COMPILED BY SEP

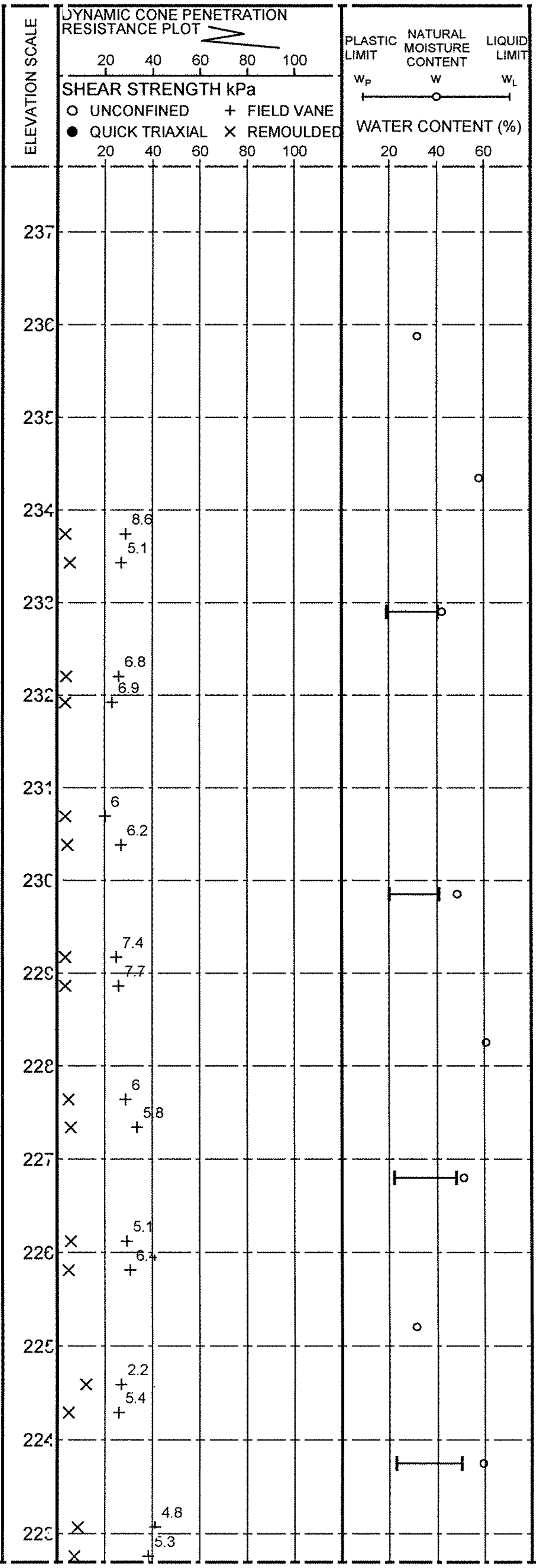
CHECKED BY ASP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
237.7	GROUND SURFACE
0.0	Topsoil
237.4 0.3	Sandy SILT, trace clay Loose to compact Mottled light brown and oxidized Wet Occasional fine sand seams and layers
236.3 1.4	Silty CLAY to Clayey SILT, trace fine sand Firm to very stiff Grey and brown mottled Wet Occasional silt layers and clay seams
235.3 2.4	Silty CLAY to CLAY, trace fine sand Very soft to firm Varved grey and reddish brown Wet Occasional seams and layers at depth
	Reddish grey varves/laminae (horizontal and/or vertical) between 6.1m and 11.1m depth.

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	17			
2	SS	10			
3	SS	4			
4	SS	1			
5	SS	WH			
6	SS	PH			
7	SS	WR			
8	SS	PH		17.0	
9	SS	WR			
10	SS	PH		16.5	
11	SS	WR			
12	TO	PH		16.3	



Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-123

2 OF 3

METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5139067.0 ;E 315699.2		ORIGINATED BY ES
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic		DATE July 12 - 14, 2004	CHECKED BY ASP

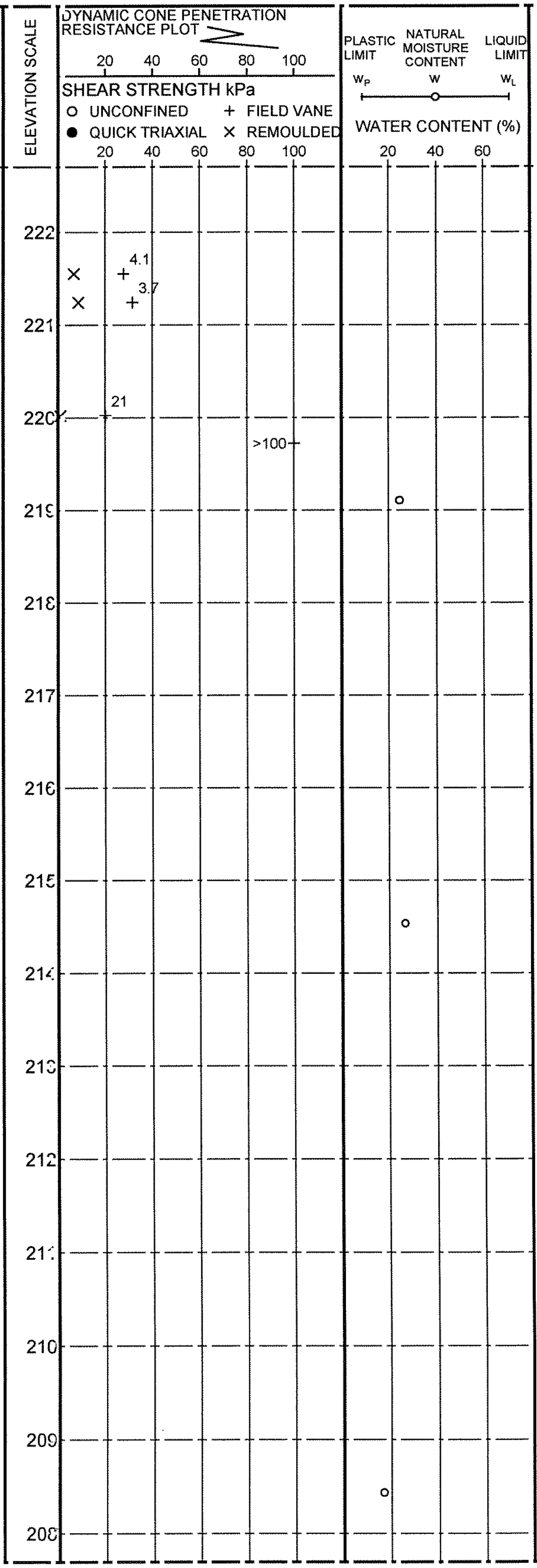
SOIL PROFILE

— CONTINUED FROM PREVIOUS PAGE —

ELEV DEPTH	DESCRIPTION
	Silty CLAY to CLAY, trace fine sand Very soft to firm Varved grey and reddish brown Wet Occasional seams and layers at depth Becoming siltier 16.8m depth
220.0 17.7	SILT to Sandy SILT, fine sand Compact Grey Wet Occasional fine to medium sand seams
211.8 25.9	Fine to medium SAND, trace to some gravel, trace silt Compact Grey Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
13	SS	WR	
14	TO	PH	
15	SS	16	0 2 92 6
16	SS	10	
17	SS	14	
18	SS	11	
19	SS	13	



Continued Next Page

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

$O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-123

3 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5139067.0 ;E 315699.2

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE July 12 - 14, 2004

ORIGINATED BY ES

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Fine to medium SAND, trace to some gravel, trace silt Compact Grey Wet						207 206				
			20	SS	15						
							205 204 203				
202.7 35.0	Hard drilling below 34.6m depth										
	End of Borehole Auger refusal										

Notes:

1. Drilling mud used below 24.3m depth to advance boreholes.

2. Minor heave (<0.6m) in augers below 29.0m depth.

3. Water level inside augers at 0.2m below ground surface on July 13, 2004.

4. Water flowing out of augers on July 14, 2004. Extra augers added and rising head test conducted.

6. Consolidated undrained triaxial test performed on Sample 6.

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

Golder Associates

RECORD OF BOREHOLE No SBH-12

1 OF 1 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5138966.2 ;E 315684.7

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE Aug. 28, 2003

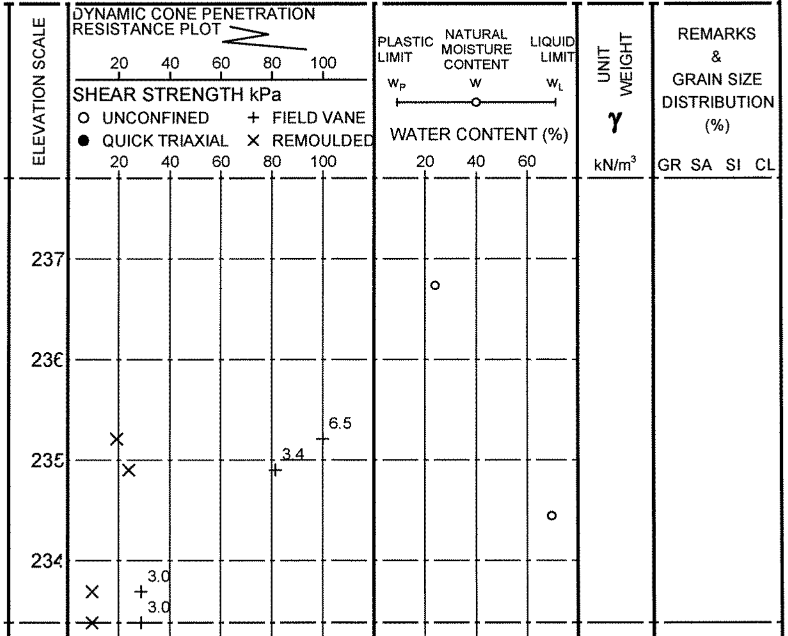
ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
237.8	GROUND SURFACE				
0.0	TOPSOIL				
0.2	Silty fine SAND, trace clay and roots Loose Brown and grey Moist	1	SS	4	
		2	SS	4	
236.3 1.5	Silty CLAY to Clayey SILT, trace sand Firm to very stiff Brown and grey Wet	3	SS	5	
					∇
234.8 3.1	Silty CLAY to CLAY, trace sand with faint grey varves/laminae Firm Grey Moist to wet	4	SS	WH	
233.4 4.4	End of Borehole				

Note:
Water level in open borehole at 2.9m depth below ground surface upon completion of drilling.



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

$\circ^{3\%}$ STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Golder Associates

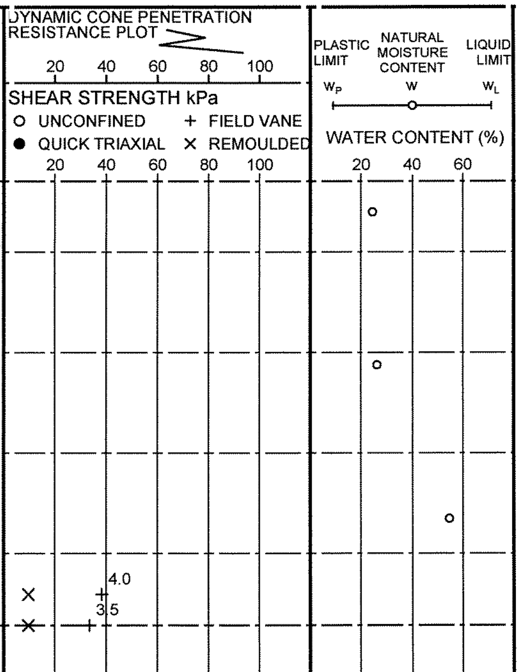
RECORD OF BOREHOLE No SBH-17

1 OF 1

METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5139019.1 ;E 315676.3	ORIGINATED BY SB
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY SEP
DATUM Geodetic		DATE Aug. 28, 2003	CHECKED BY ASP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.7	GROUND SURFACE								
0.0	TOPSOIL								
0.2	Silty fine SAND, trace clay and roots, occasional layers of silty clay Loose to compact Brown and grey Moist		1	SS	5				
			2	SS	5		237		
			3	SS	10		236		
235.4 2.3	Silty CLAY, trace sand Firm Grey mottled brown to grey Moist		4	SS	2	▽	235		
			5	SS	WH		234		
233.3 4.4	End of Borehole Note: Water level in open borehole at 2.9m depth below ground surface upon completion of drilling.								



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

$\circ^{3\%}$ STRAIN AT FAILURE

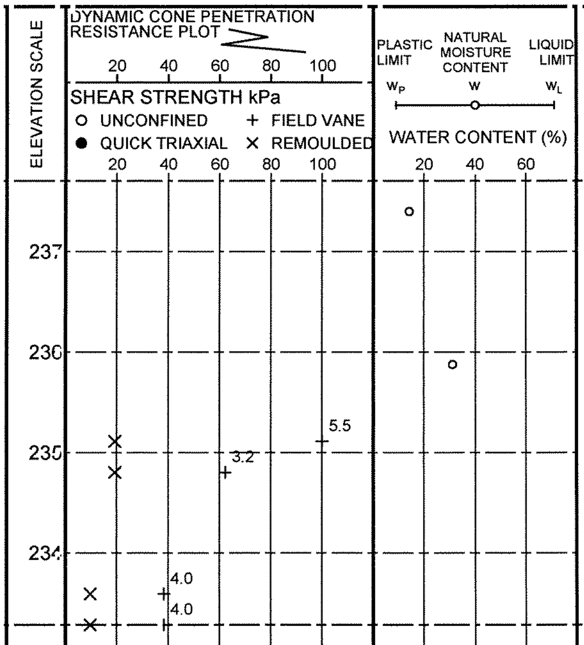
RECORD OF BOREHOLE No SBH-18

1 OF 1

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5139029.0 ;E 315693.7
ORIGINATED BY SB
DIST HWY 69
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
COMPILED BY SEP
DATUM Geodetic
DATE Aug. 21, 2003
CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
237.7	GROUND SURFACE				
0.0	TOPSOIL				
0.1	Silty SAND, trace gravel, clay and roots Loose Brown and grey Moist	1 2	SS SS	9 8	
236.2 1.5	Silty CLAY, trace sand Very stiff Brown and grey Moist	3	SS	3	▽
234.7 3.1	Silty CLAY to CLAY, trace sand Firm Grey Wet	4	SS	WH	
233.3 4.4	End of Borehole Note: Water level in open borehole at 2.6m depth below ground surface upon completion of drilling.				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

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

RECORD OF BOREHOLE No DCPT-40

1 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5138987.9 ;E 315672.3

BOREHOLE TYPE Dynamic Cone

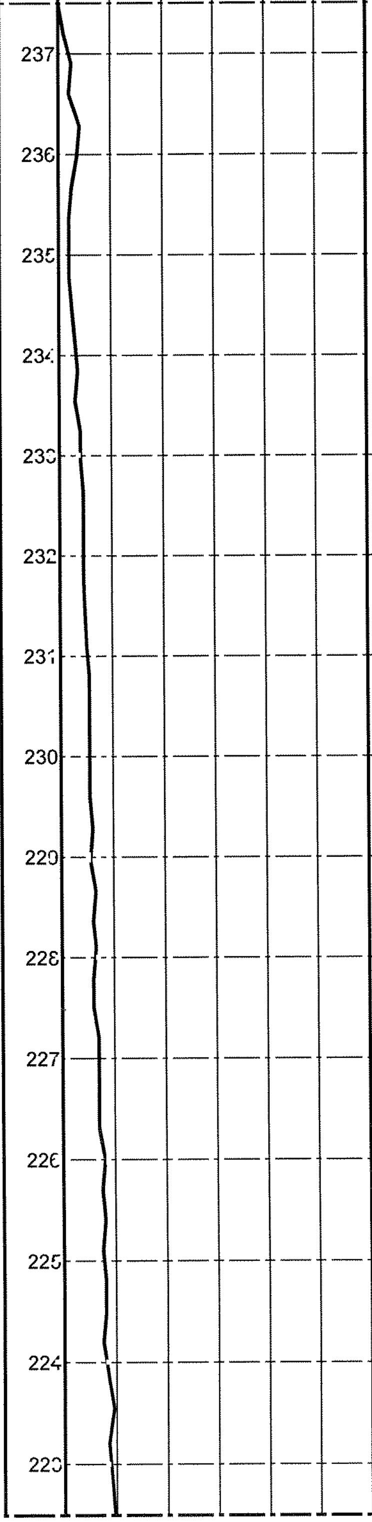
DATE Aug. 17, 2003

ORIGINATED BY CN

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
237.5 0.0	GROUND SURFACE										



Continued Next Page

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

$O^{3\%}$ STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Golder Associates

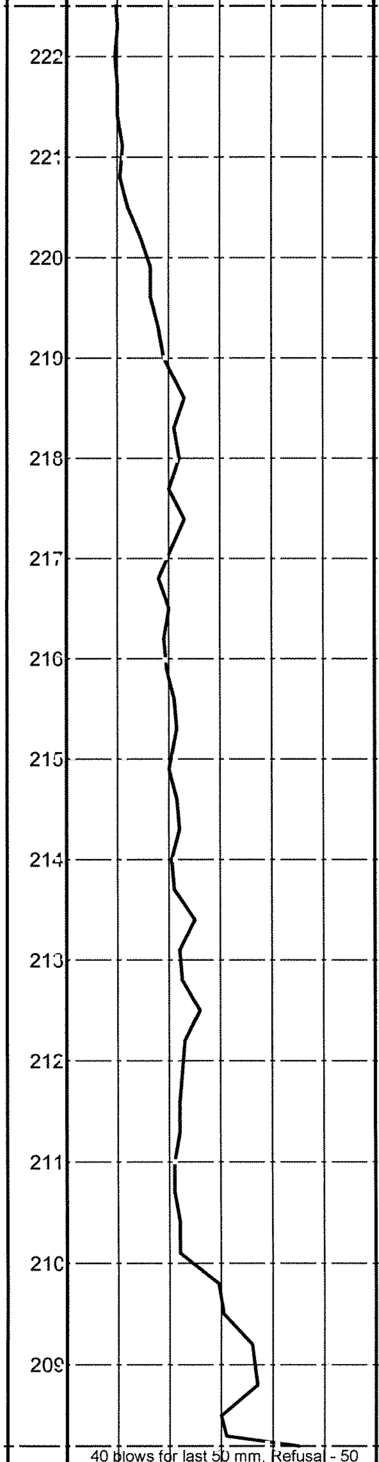
RECORD OF BOREHOLE No DCPT-40

2 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ____ HWY 69
DATUM Geodetic
LOCATION N 5138987.9 ;E 315672.3
BOREHOLE TYPE Dynamic Cone
DATE Aug. 17, 2003
ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
208.2 29.3	End of Dynamic Cone Test Refusal to Penetration							40 blows for last 50 mm, Refusal - 50 blows/0 mm			



+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No DCPT-41

1 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5139007.3 ;E 315706.1

ORIGINATED BY CN

DIST HWY 69

BOREHOLE TYPE Dynamic Cone

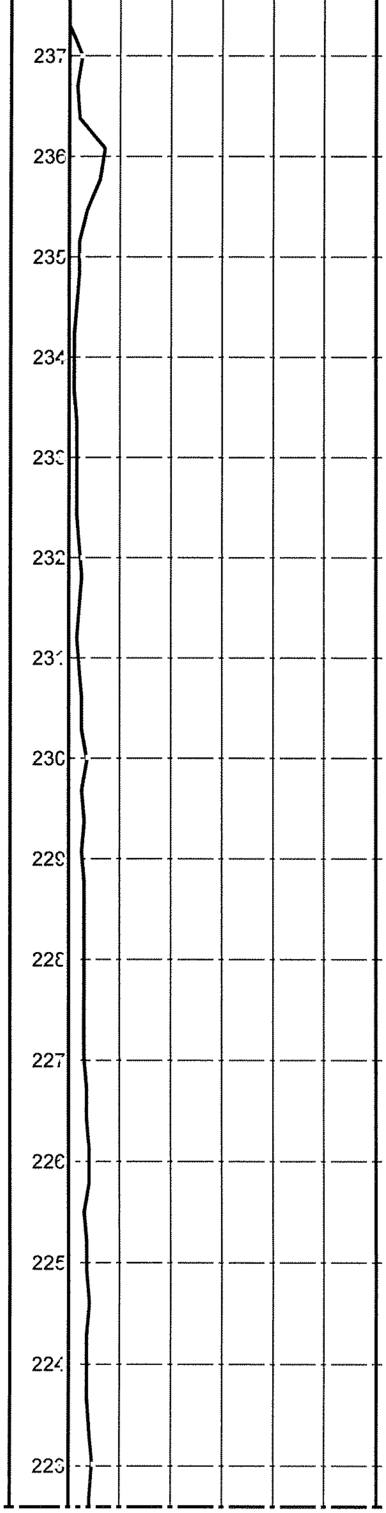
COMPILED BY SEP

DATUM Geodetic

DATE Aug. 17, 2003

CHECKED BY ASP

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT WP — NATURAL MOISTURE CONTENT W — LIQUID LIMIT WL WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.6 0.0	GROUND SURFACE										



Continued Next Page

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

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No DCPT-41

2 OF 3

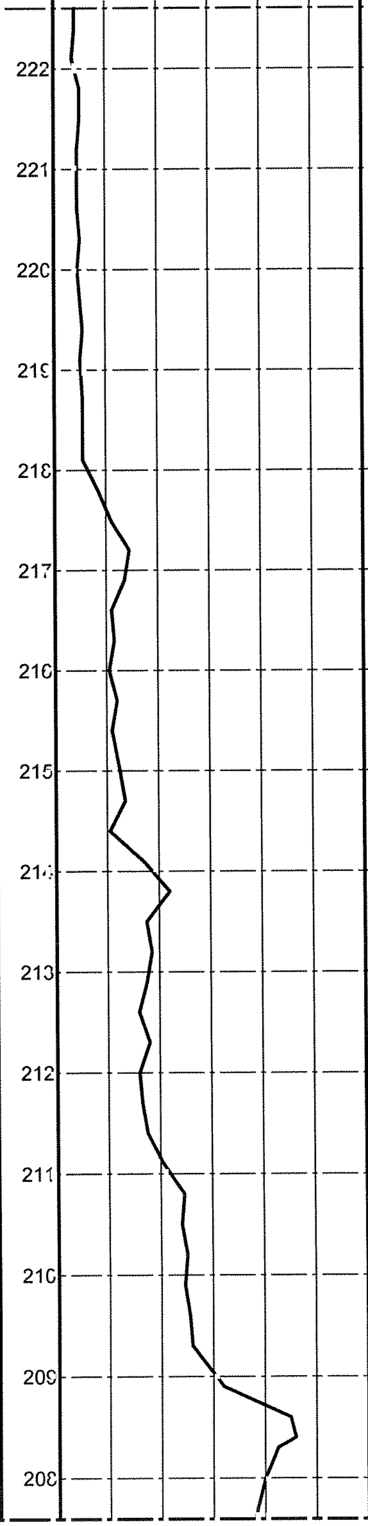
METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5139007.3 ;E 315706.1
BOREHOLE TYPE Dynamic Cone
DATE Aug. 17, 2003

ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION — CONTINUED FROM PREVIOUS PAGE —	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

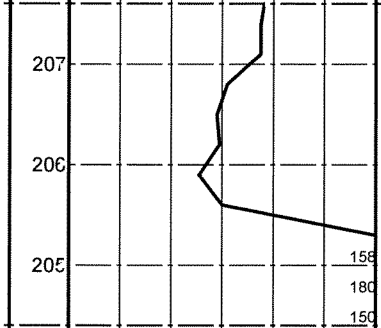
RECORD OF BOREHOLE No DCPT-41

3 OF 3

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ____ HWY 69
DATUM Geodetic
LOCATION N 5139007.3 ;E 315706.1
BOREHOLE TYPE Dynamic Cone
DATE Aug. 17, 2003
ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
							207				
							206				
							205	158 180			
204.4 33.2	End of Dynamic Cone Test Refusal to Penetration							150 100 blows for last 50 mm. Refusal - 50 blows/0 mm			



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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

Golder Associates

RECORD OF BOREHOLE No DCPT-42

1 OF 3

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5139049.1 ;E 315678.5

ORIGINATED BY CN

DIST HWY 69

BOREHOLE TYPE Dynamic Cone

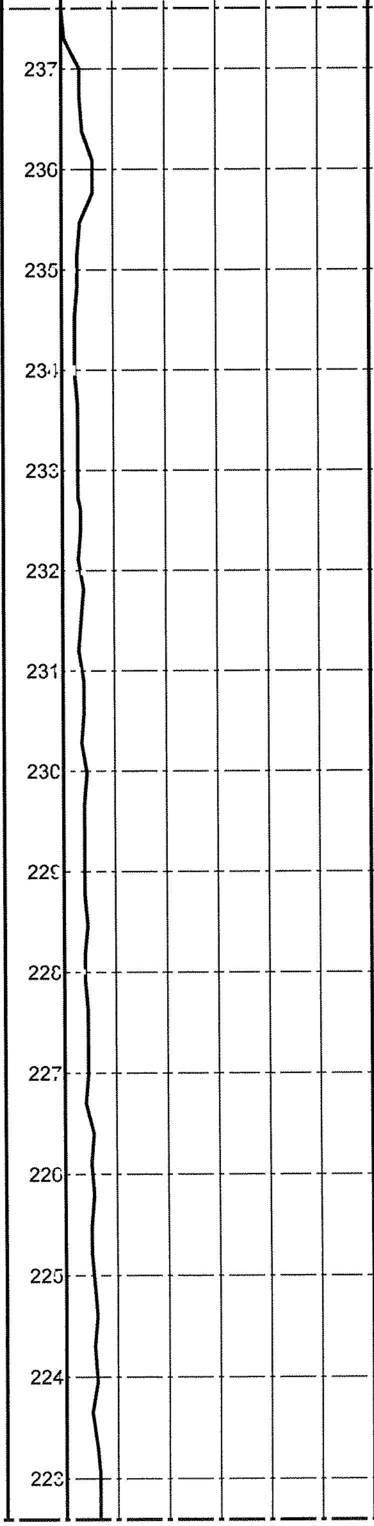
COMPILED BY SEP

DATUM Geodetic

DATE Aug. 17, 2003

CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
237.6 0.0	GROUND SURFACE										



Continued Next Page

+3, X3: Numbers refer to Sensitivity

O3% STRAIN AT FAILURE

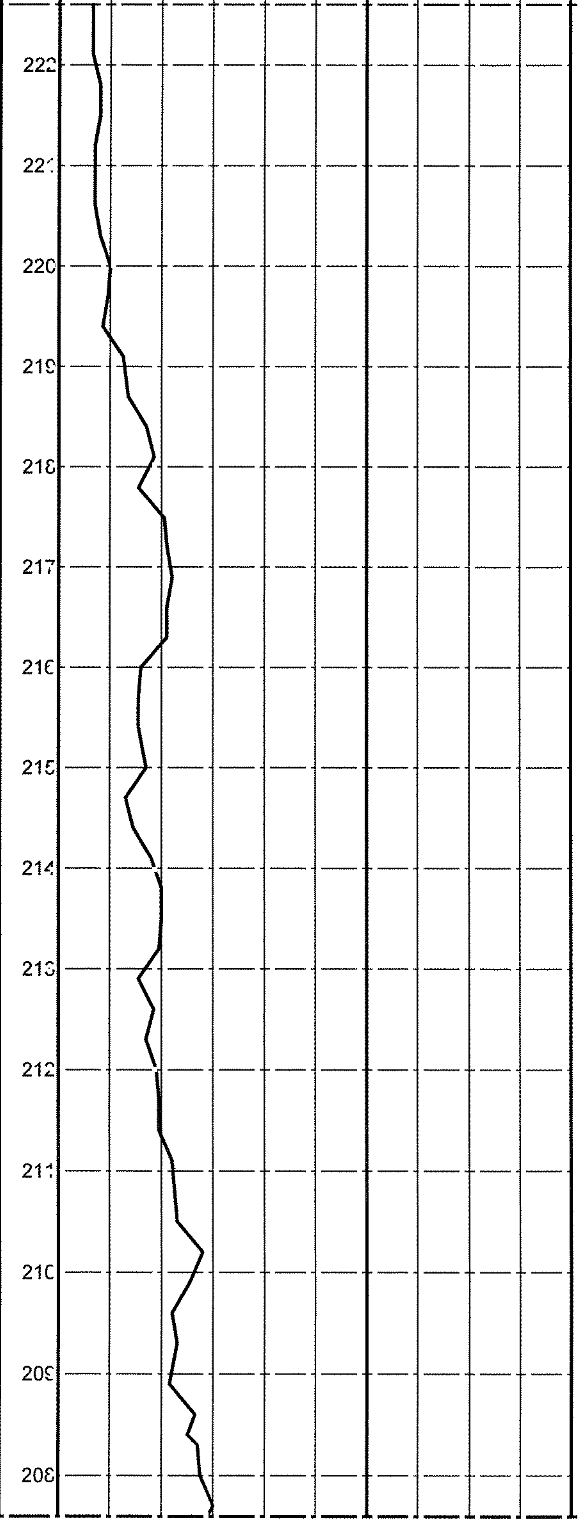
RECORD OF BOREHOLE No DCPT-42

2 OF 3

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5139049.1 ;E 315678.5
ORIGINATED BY CN
DIST ___ HWY 69
BOREHOLE TYPE Dynamic Cone
COMPILED BY SEP
DATUM Geodetic
DATE Aug. 17, 2003
CHECKED BY ASP

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	



Continued Next Page

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

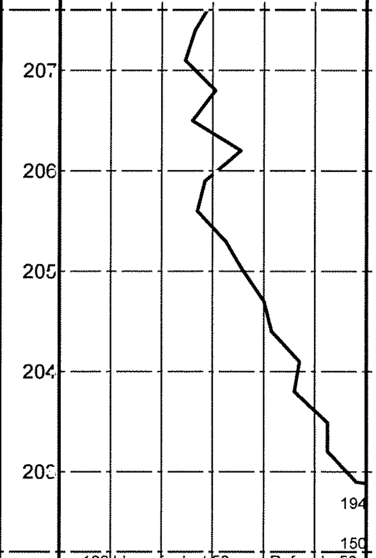
RECORD OF BOREHOLE No DCPT-42

3 OF 3 **METRIC**

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5139049.1 ;E 315678.5
BOREHOLE TYPE Dynamic Cone
DATE Aug. 17, 2003

ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP



SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
202.2 35.4	End of Dynamic Cone Test Refusal to Penetration							100 blows for last 50 mm Refusal - 50 blow/0 mm			

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

Golder Associates

RECORD OF BOREHOLE No DCPT-43

1 OF 2

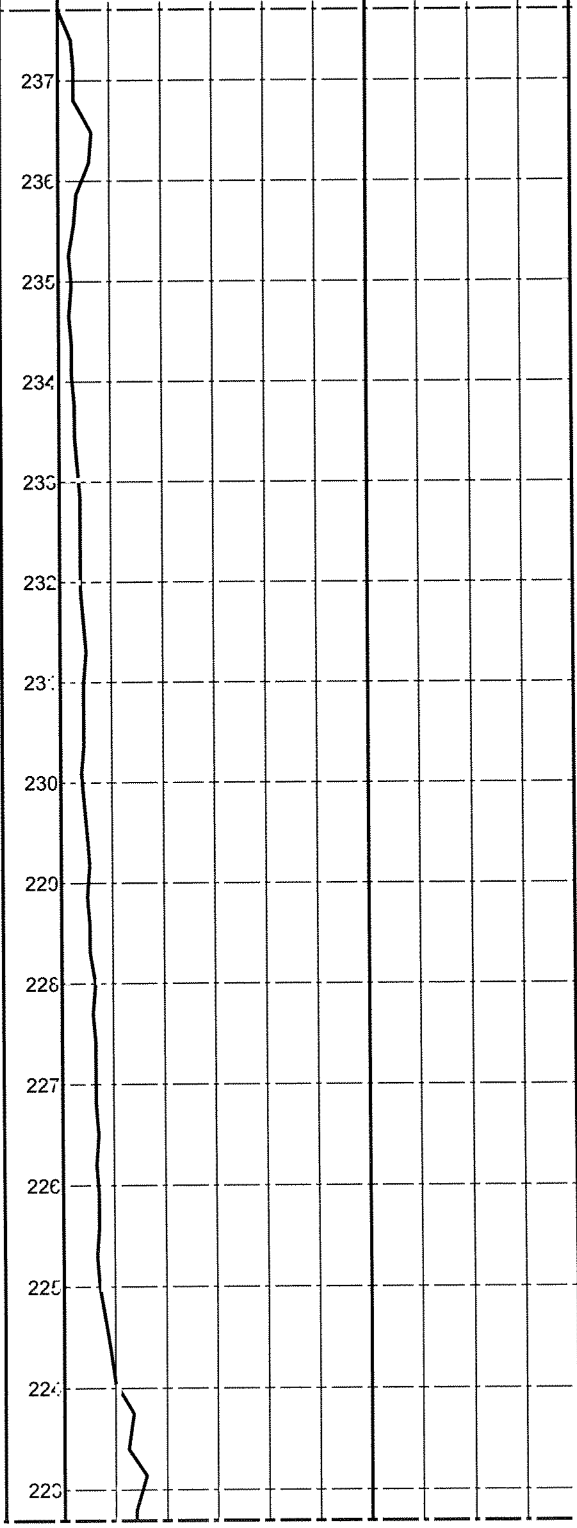
METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic

LOCATION N 5139068.5 ;E 315712.4
BOREHOLE TYPE Dynamic Cone
DATE Aug. 17, 2003

ORIGINATED BY CN
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
237.7 0.0	GROUND SURFACE										



Continued Next Page

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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

RECORD OF BOREHOLE No DCPT-43 2 OF 2 METRIC

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5139068.5 ;E 315712.4

ORIGINATED BY CN

DIST ___ HWY 69

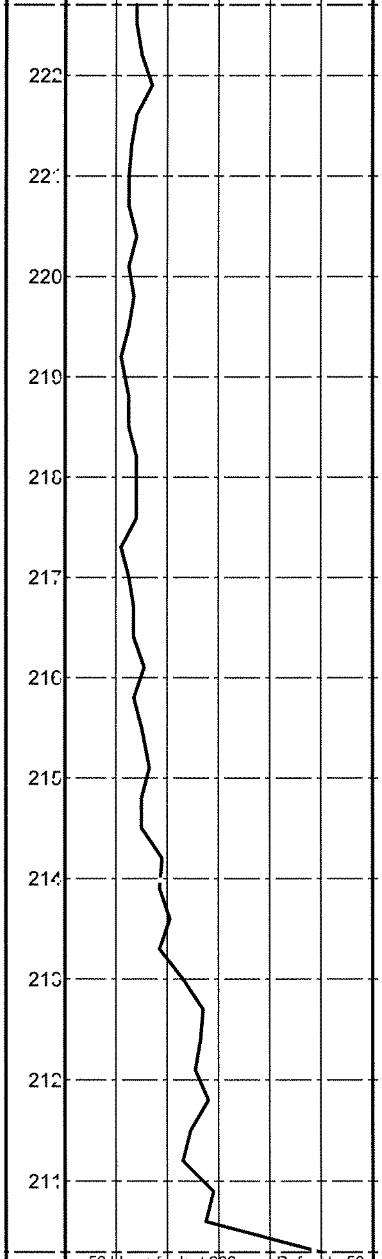
BOREHOLE TYPE Dynamic Cone

COMPILED BY SEP

DATUM Geodetic

DATE Aug. 17, 2003

CHECKED BY ASP



SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION — CONTINUED FROM PREVIOUS PAGE —	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
210.3 27.4	End of Dynamic Cone Test Refusal to Penetration							50 blows for last 300 mm, Refusal - 50 blows/0 mm				

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

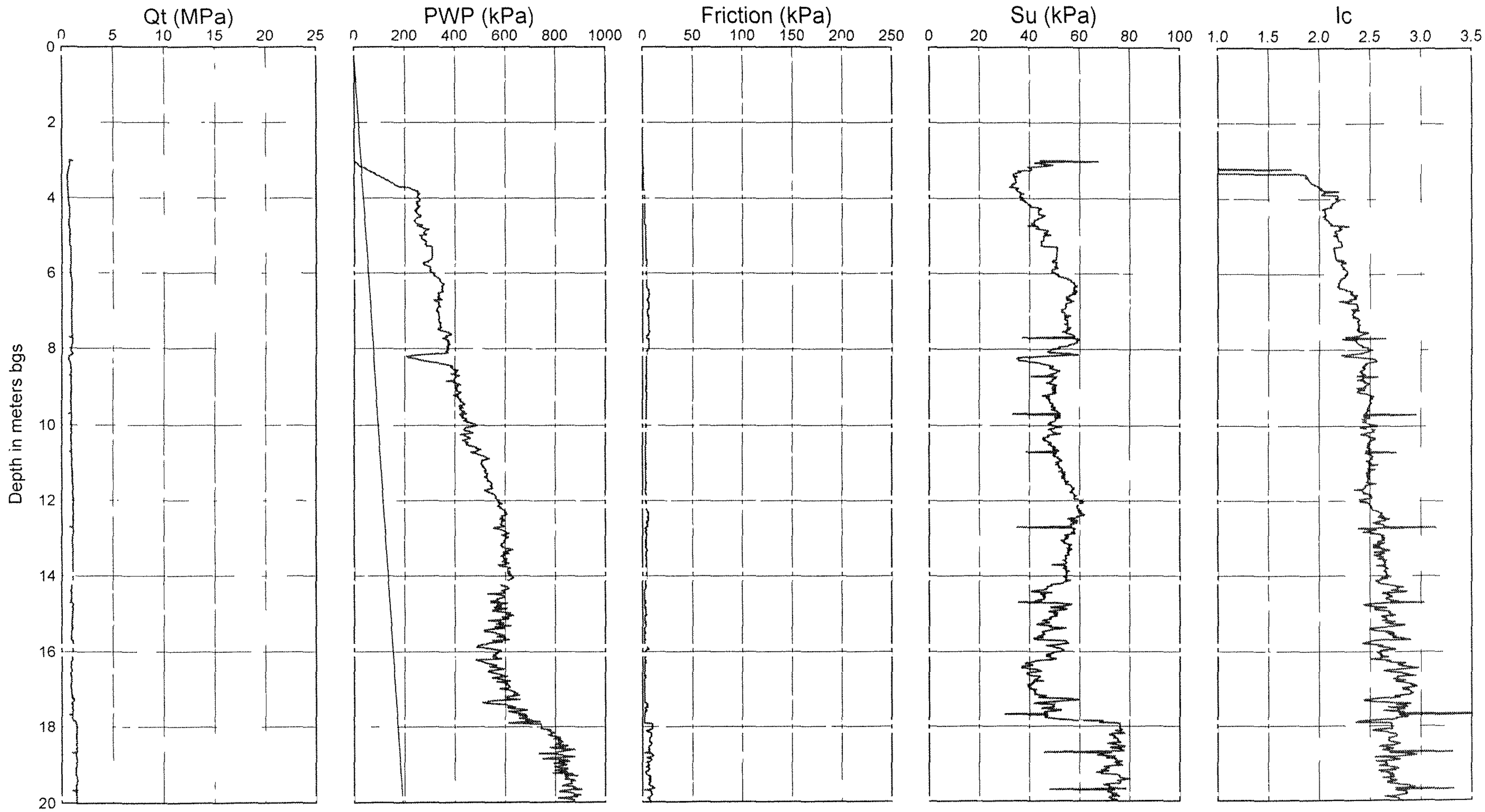
$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

Cone Penetration Test - CPT03-21R

Test Date : September 21, 2003
Location : STA 14+050 o/s 18.8 m Lt

Operator : Golder Associates

Ground Surf. Elev. : 237.80
Water Table Depth : 0.30



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

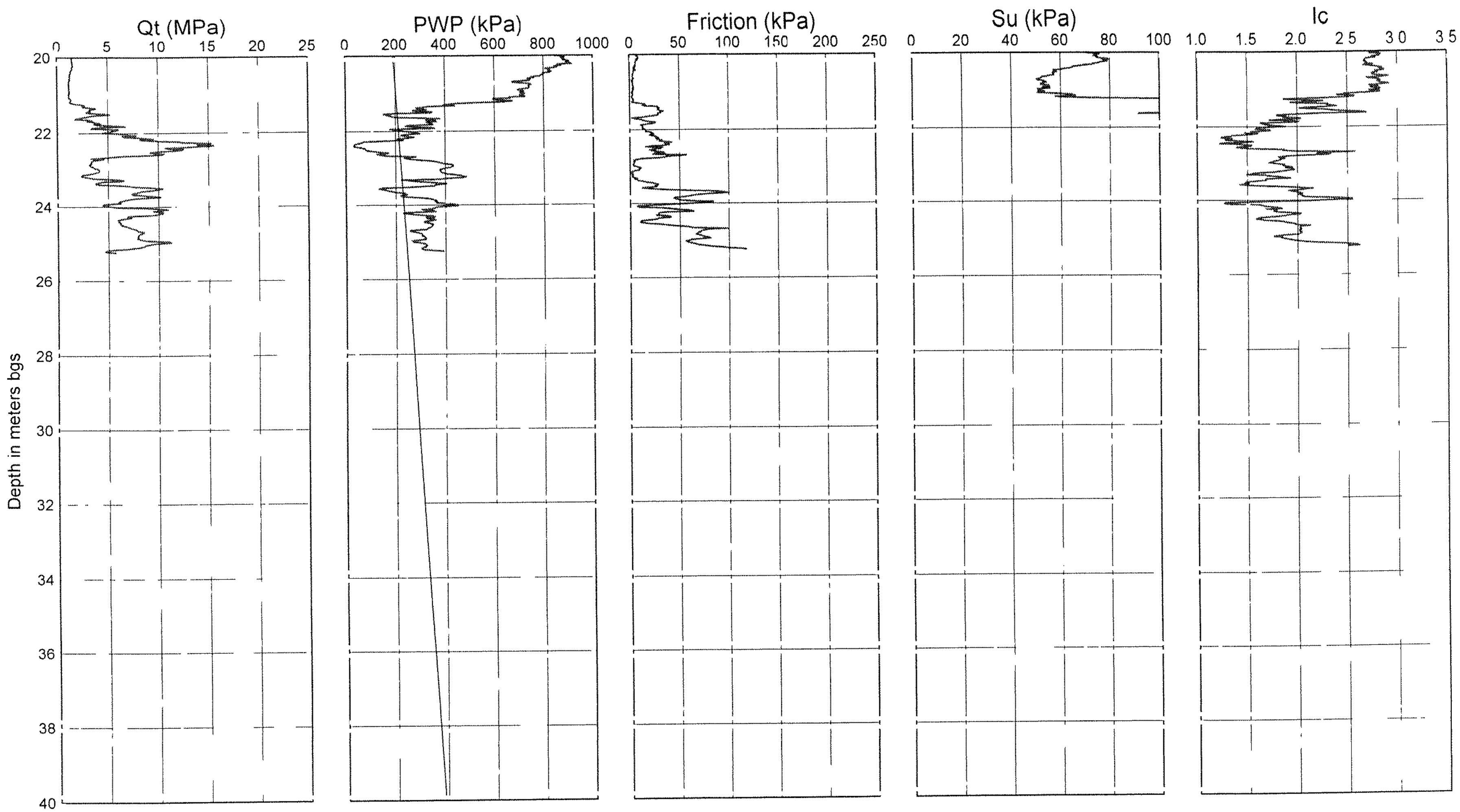
PROJECT NO 03-1111-011 DATE: DRAWN BY CN

Cone Penetration Test - CPT03-21R

Test Date : September 21, 2003
Location : STA 14+050 o/s 18.8 m Lt

Operator : Golder Associates

Ground Surf. Elev. : 237.80
Water Table Depth : 0.30



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m^3

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

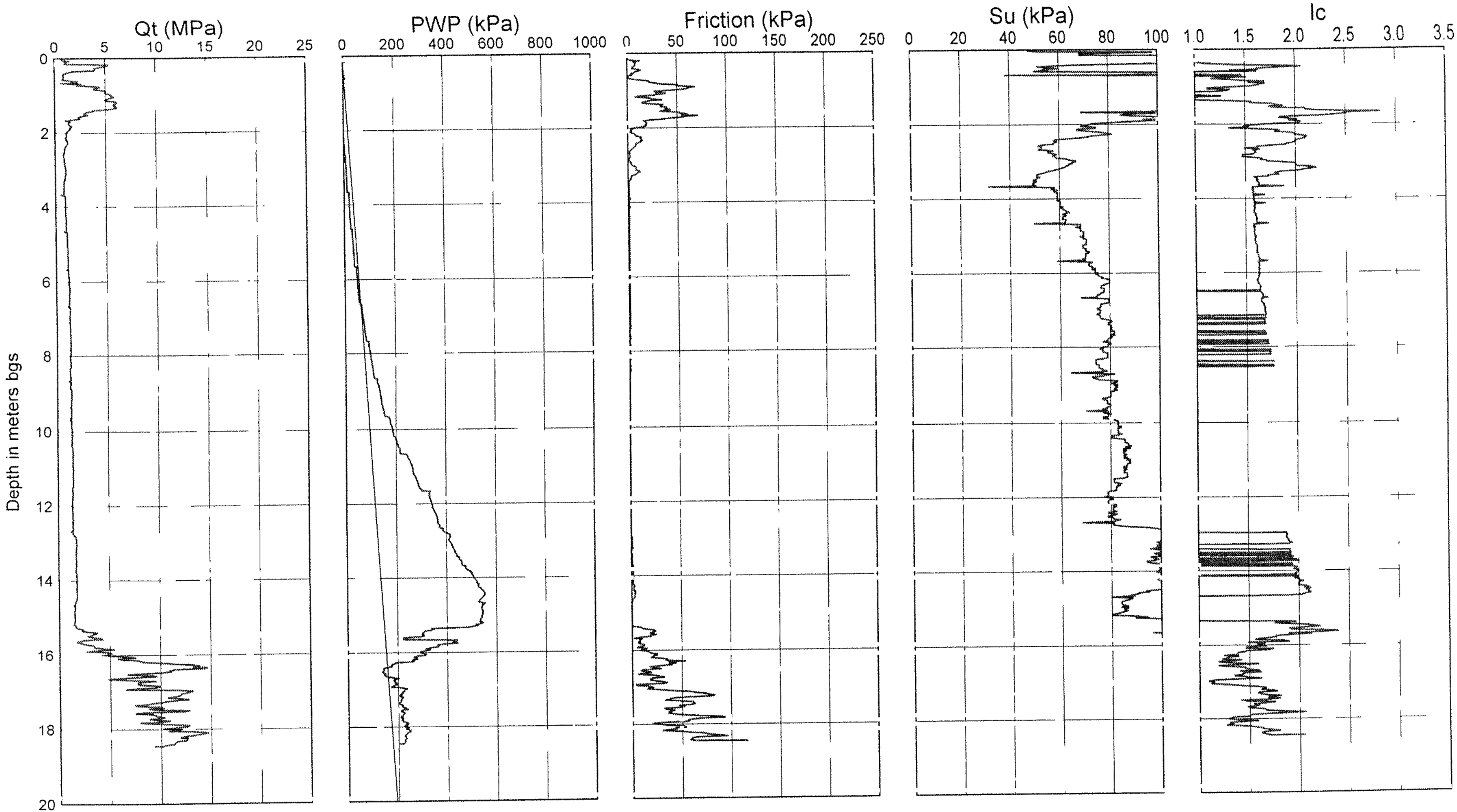
PROJECT NO 03 1111-011 DATE June 2004 DRAWN BY CN

Cone Penetration Test - CPT03-22

Test Date : August 19, 2003
Location : STA 14+100 o/s 18.8 m Rt

Operator : Golder Associates

Ground Surf. Elev. : 237.20
Water Table Depth : 0.30



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

PROJECT NO 03-1111-011 DATE: DRAWN BY. CN

APPENDIX D

RECORD OF CONE PENETRATION TEST SHEETS

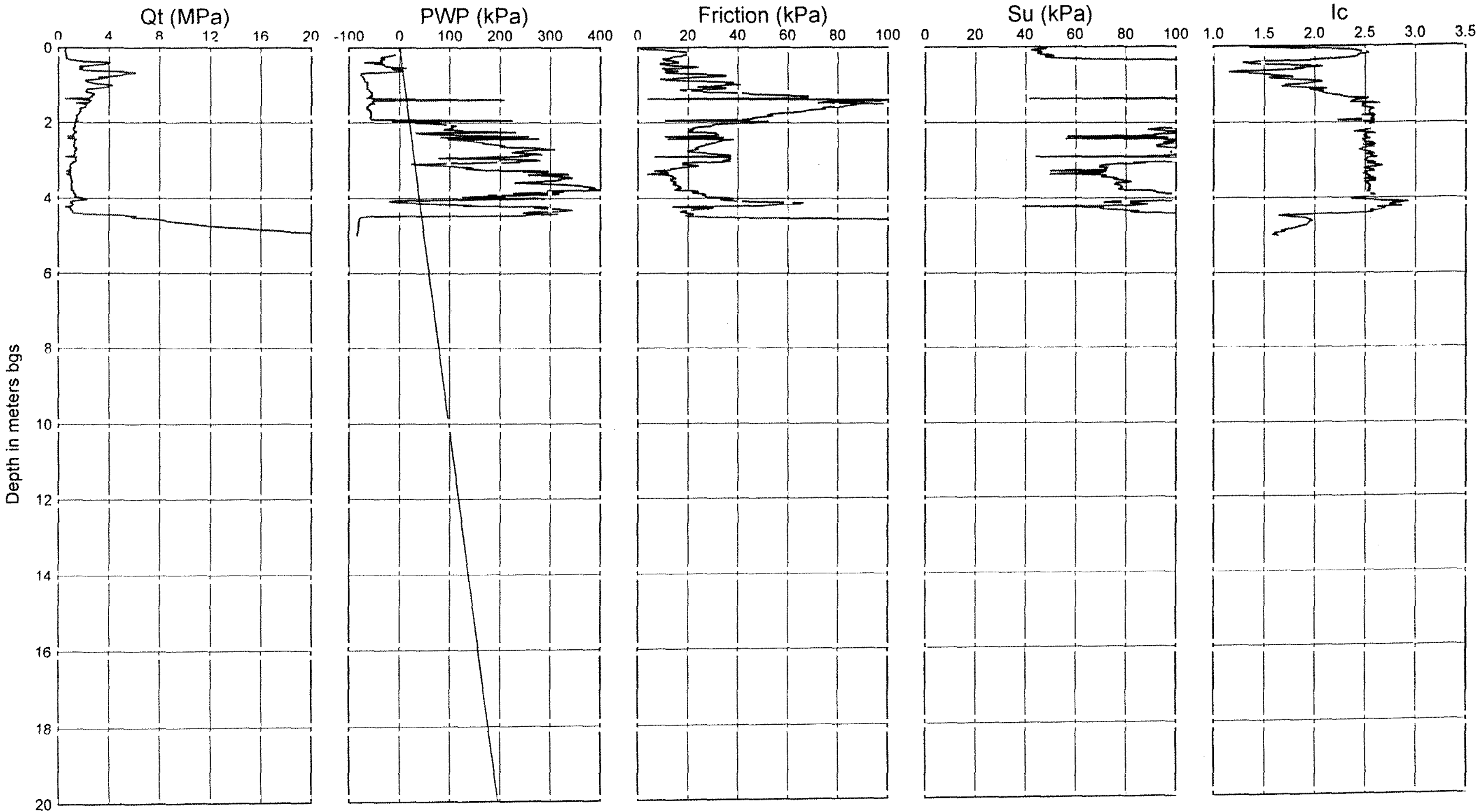
CULVERT HIGHWAY 69 STATION 14+940

Cone Penetration Test - CPT04-57-1

Test Date : October 29, 2004
Location : Highway 69 - STA 14+950 o/s 2.5 m Right

Operator : Golder Associates

Ground Surf. Elev. : 243.50
Water Table Depth : 0.00



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 12.5
Gamma = 18 kN/m³

After Robertson and (Fear) Wride (1998)
Ic < 1.31 - Gravelly sands
1.31 <Ic < 2.05 - Clean to silty sand
2.05 <Ic < 2.60 - Silty sand to sandy silt
2.60 <Ic < 2.95 - Clayey silt to silty clay
2.95 <Ic < 3.60 - Clays

PROJECT NO. 03-1111-011 DATE: April 2005 DRAWN BY: SLP

RECORD OF BOREHOLE No 110-4S

1 of 2

METRIC

G W P 327-91-00	LOCATION HWY.69 Sta. 14+870.5, o/s 35m Lt. CL Med.		ORIGINATED BY FP
DIST 54	HWY 69	BOREHOLE TYPE Continuous Flight Hollow Stem Augers	COMPILED BY FP
DATUM Geodetic		DATE March 12, 2001	CHECKED BY

SOIL PROFILE

ELEV. / DEPTH	DESCRIPTION	STRAT PLOT
243.75	Ground Surface	
0.00 / 0.15	Peat, coarse fibrous, dark brown	
	Silty clay trace sand Interbedded silty sand seams Stiff Mottled Grey/Brown Wet	▨
	Interbedded sandy silt seams	▨
237.35 / 6.10	Silty fine sand Loose Grey Wet	
235.00 / 8.75	Silty clay trace sand Stiff Grey Wet	▨
233.70 / 10.05	Clayey silt trace sand Firm Grey Wet	▨
	Stiff	▨
231.75 / 12.00	Silty fine sand trace clay Compact Grey Moist	
	Interbedded clayey silt seams Wet	
	Cont'd	

SAMPLES

NUMBER	TYPE	'N' VALUES
1	SS	7
2	SS	8
3	SS	12
4	SS	3
5	SS	5
6	SS	3
7	SS	1
8	SS	11
9	SS	10
10	SS	8

GROUND WATER CONDITIONS

ELEVATION SCALE: 243, 242, 241, 240, 239, 238, 237, 236, 235, 234, 233, 232, 231, 230, 229

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

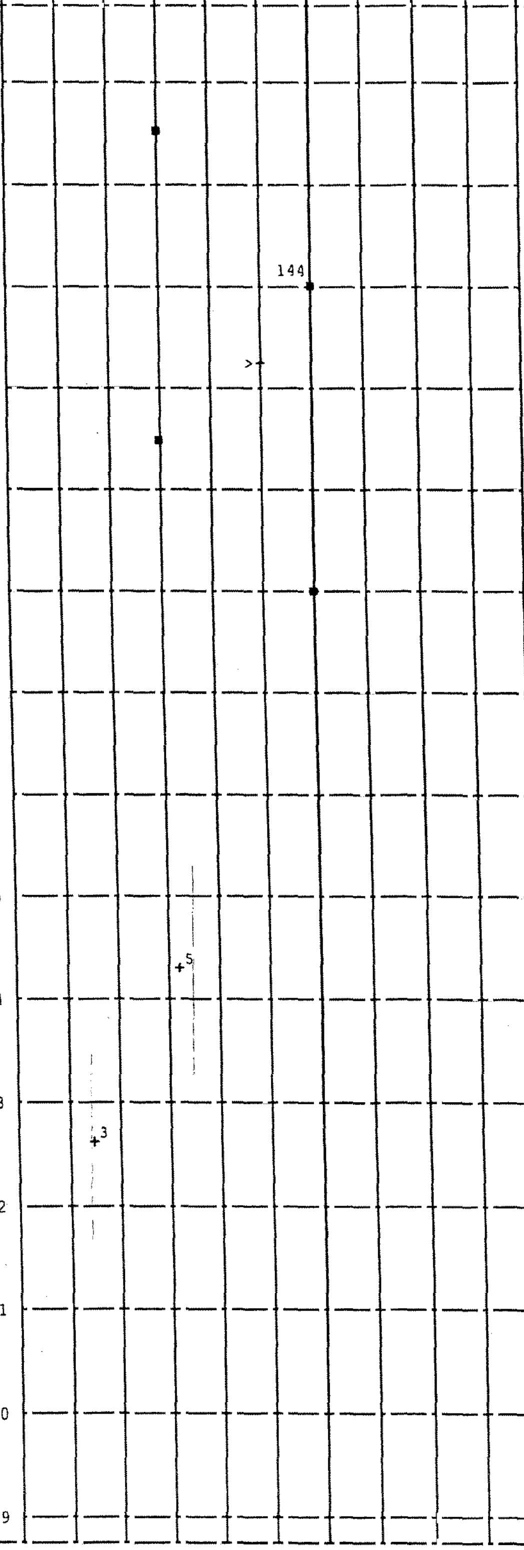
SHEAR STRENGTH (kPa)
o UNCONFINED + FIELD VANE
• QUICK TRIAXIAL X LAB VANE
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL



Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 110-4S 2 of 2 METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+870.5, o/s 35m Lt. CL Med.
ORIGINATED BY FP
DIST 54 HWY 69
BOREHOLE TYPE Continuous Flight Hollow Stem Augers
COMPILED BY FP
DATUM Geodetic
DATE March 12, 2001
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
243.75	Ground Surface										
228.05 15.70	End of borehole Auger refusal on bedrock or boulder.										

* 01 03 12

▼ WATER MEASURED AFTER DRILLING

▽ WATER OBSERVED DURING DRILLING

■ PENETROMETER

Ministry of Transportation
Ontario

Foundation Design

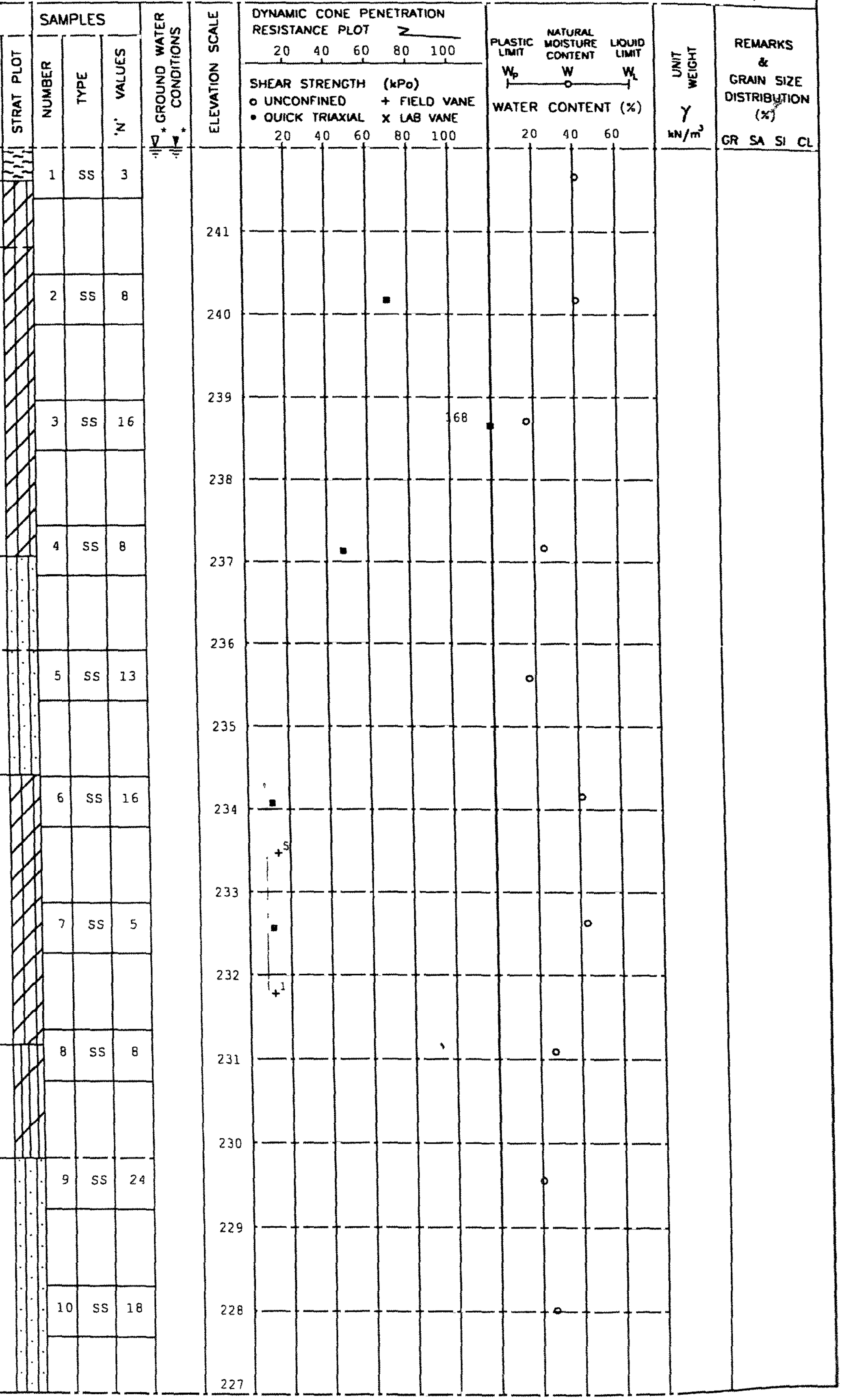
RECORD OF BOREHOLE No 110-5S

1 of 2

METRIC

G W P 327-91-00	LOCATION HWY.69 Sta. 14+883, o/s 18.75m Lt CL Med.	ORIGINATED BY FP
DIST 54 HWY 69	BOREHOLE TYPE Tripod Casing and Wash Boring	COMPILED BY FP/DH
DATUM Geodetic	DATE March 12/13, 2001	CHECKED BY

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES
242.00	Ground Surface			
0.00	Peat, amorphous Dark brown	1	SS	3
241.60 0.40	Silty clay trace sand Firm Blue/Grey Wet Stiff Grey	2	SS	8
		3	SS	16
		4	SS	8
237.05 4.95	Silty fine sand Loose Grey Wet Compact	5	SS	13
234.40 7.60	Silty clay trace sand Soft Grey wet	6	SS	16
		7	SS	5
231.15 10.85	Clayey silt trace sand Stiff Grey Wet	8	SS	8
229.80 12.20	Silty fine sand Compact Grey Wet	9	SS	24
		10	SS	18
	Cont'd			



Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 110-5S   2 of 2   METRIC

G W P 327-91-00	LOCATION HWY.69 Sta. 14+883, o/s 18.75m Lt CL Med.	ORIGINATED BY FP
DIST 54 HWY 69	BOREHOLE TYPE Tripod Casing and Wash Boring	COMPILED BY FP/DH
DATUM Geodetic	DATE March 12/13, 2001	CHECKED BY Cy

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.00	Ground Surface										
			11	SS	36				o		
226.30 15.70	End of borehole Sampler refusal on bedrock or boulder.										

* 01 03 12/13

▼ WATER MEASURED AFTER DRILLING

▽ WATER OBSERVED DURING DRILLING

■ PENETROMETER

Ministry of Transportation
Ontario

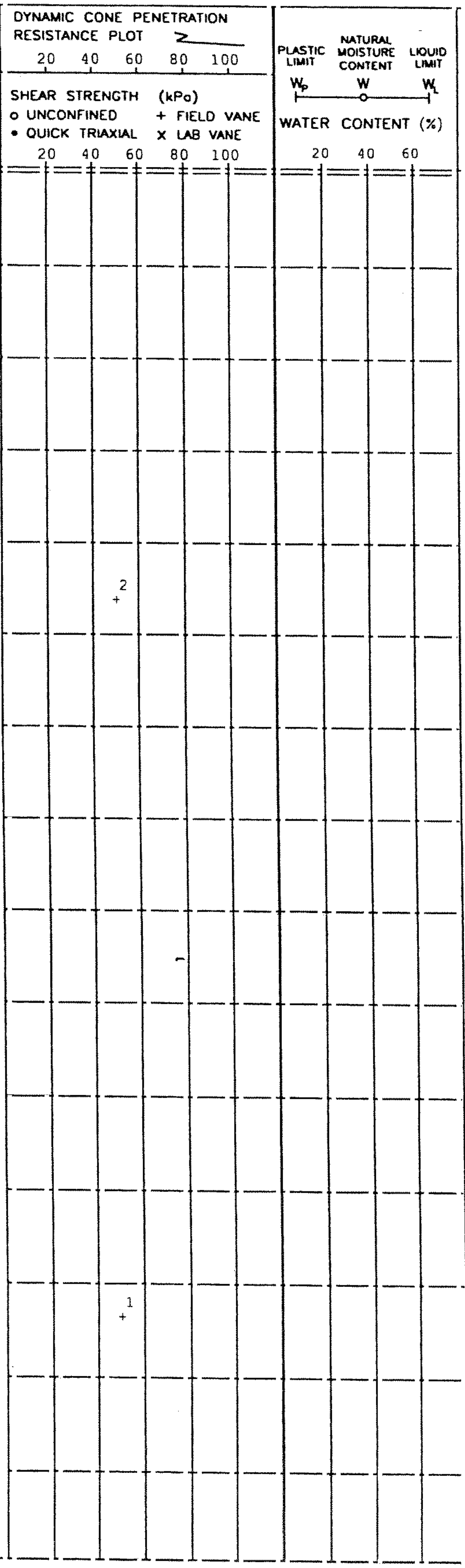
Foundation Design

RECORD OF BOREHOLE No 110-6S

1 of 2 METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+895.5, o/s 5m Lt CL Med.
ORIGINATED BY FP/DRR
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY FP/DH
DATUM Geodetic
DATE March 13 & 14, 2001
CHECKED BY ly

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.05 0.00	Top of ice						244		
							243		
241.85	Bottom of pond						242		
241.55 2.50	Peat, amorphous Dark brown Wet		1	SS	1/60cm				
	Silty clay trace sand Firm Grey Wet						241		
			2	SS	3		240		
238.8 5.25	Silty fine Sand Compact Grey Wet		3	SS	23		239		
							238		
			4	SS	20		237		
							236		
			5	SS	21		235		
			6	SS	15		234		
232.70 11.35	Silty clay trace sand Firm Grey Wet		7	SS	4		233		
							232		
230.85 13.20	Silty fine sand Compact Grey Wet		8	SS	3		231		
							230		
			9	SS	37				



RECORD OF BOREHOLE No 110-6S 2 of 2 METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+895.5, o/s 5m Lt CL Med.
ORIGINATED BY FP/DRR
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY FP/DH
DATUM Geodetic
DATE March 13 & 14, 2001
CHECKED BY

SOIL PROFILE			SAMPLES								
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.05	Top of ice						229				
			11	SS	11						
							228				
							227				
226.15 17.90	End of borehole Auger refusal on bedrock or boulder.										

* 01 02 14

▼ WATER MEASURED AFTER DRILLING

Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 110-7N

1 of 2

METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+920.5, o/s 5m Rt CL Med.
ORIGINATED BY DRR/DJB
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY DJB/DH
DATUM Geodetic
DATE March14-15, 2001
CHECKED BY

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 20 40 60 80 100
PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L
WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES		
244.00 0.00	Top of ice					
						243
	Bottom of pond					
242.15 1.85	Peat, fine fibrous Dark brown	1	SS	1		242
						241
241.10 2.90	Silty clay trace sand Soft Grey Wet	2	SS	3		
						240
239.10 4.90	Sandy silt trace clay Interbedded silty fine sand layers Compact Grey Wet	3	SS	10		239
						238
		4	SS	13		
						237
		5	SS	11		236
						235
		6	SS	10		
						234
233.00 11.00	Silty clay trace sand Firm Grey Wet	7	SS	3		233
						232
231.50 12.50	Sandy silt trace clay Dense Grey Wet	8	SS	53		231
					▽*	230
		9	SS	36		
		10	SS	12/0cm		229

$+^7, x^5$: Numbers refer to $15 \overset{20}{-\!\circ\!-} 5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 110-7N

2 of 2

METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+920.5, o/s 5m Rt CL Med.
ORIGINATED BY DRR/DJB
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY DJB/DH
DATUM Geodetic
DATE March14-15, 2001
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
244.00	Top of ice										
228.90 15.10	End of borehole Auger and sampler refusal on bedrock or boulder.										

FLOWING ARTESIAN CONDITION CONTACTED AT 12.20m; FLOWING GROUNDWATER AT SURFACE AFTER DRILLING.(3 MINUTES)

★ 01 03 14-15

▼ GROUNDWATER LEVEL MEASURED AFTER DRILLING

▽ GROUNDWATER LEVEL OBSERVED DURING DRILLING

+7 ▽5 : Numbers refer to 20 15 -+- 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Foundation Design

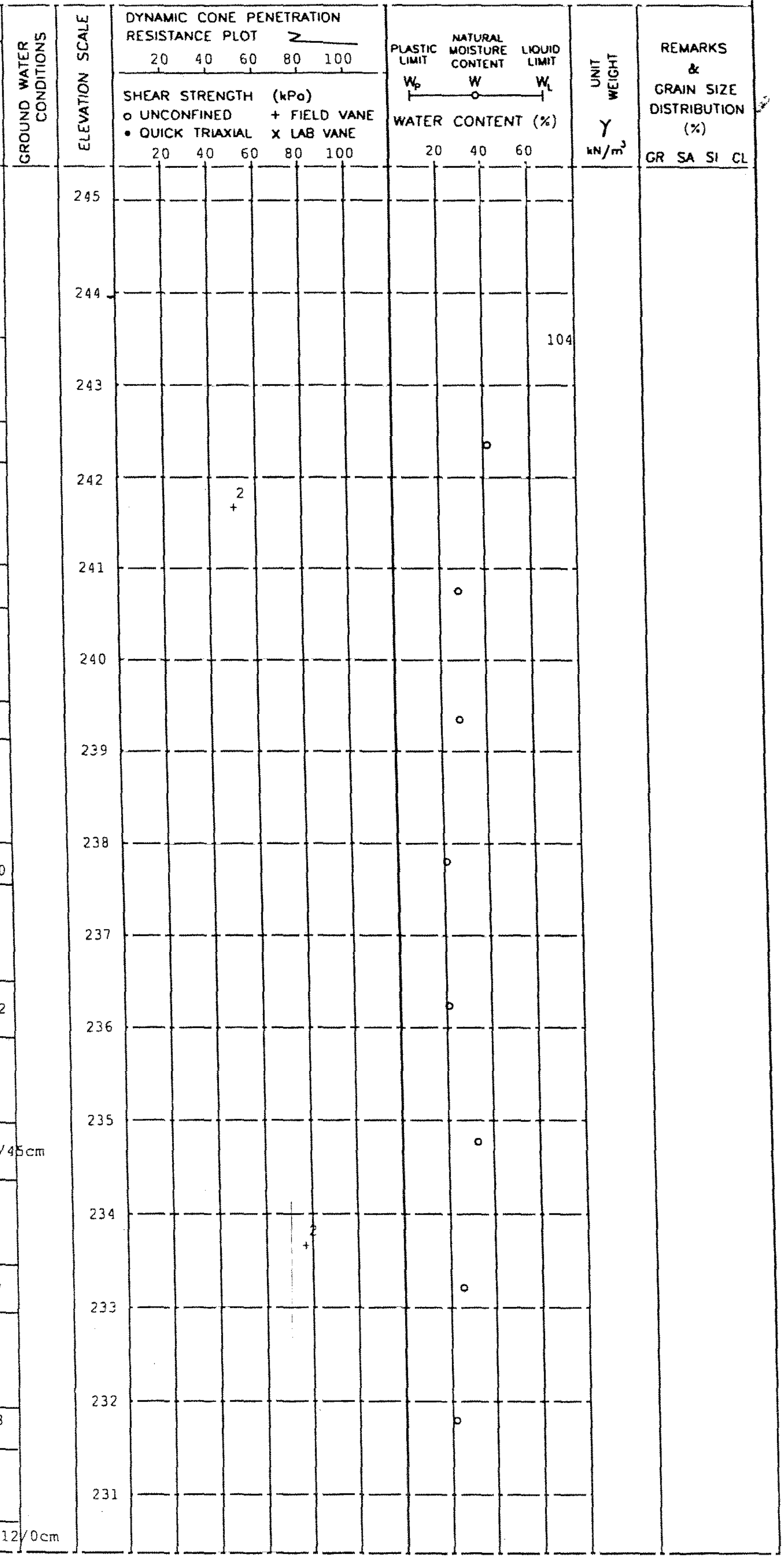
RECORD OF BOREHOLE No 110-8N

1 of 2

METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+933, o/s 18.75m Rt. CL Med.
ORIGINATED BY DJB
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY DJB
DATUM Geodetic
DATE March 15, 2001
CHECKED BY CM

SOIL PROFILE			SAMPLES		
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES
245.35 0.00	Top of ice				
244.10 1.25	Bottom of pond Peat, fine fibrous, Dark Brown		1	SS	1
243.05 2.30	Silty clay trace sand Interbedded silty fine sand seams Stiff Grey Wet		2	SS	7
			3	SS	7
			4	SS	7
239.30 6.05	Sandy silt trace clay Compact Grey Wet		5	SS	10
			6	SS	22
			7	SS	1/45cm
233.70 11.65	Silty clay trace sand Interbedded sandy silt partings Stiff Grey Wet		8	SS	27
232.15 13.20	Sandy silt trace clay Compact Grey Wet		9	SS	28
230.65 14.70	Silty fine sand Compact Grey Wet		10	SS	12/0cm



Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 110-8N 2 of 2 METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+933, o/s 18.75m Rt. CL Med.
ORIGINATED BY DJB
DIST 54 HWY 69
BOREHOLE TYPE Tripod, Casing and Wash Boring
COMPILED BY DJB
DATUM Geodetic
DATE March 15, 2001
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK TRIAXIAL X LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
245.35	Top of ice										
							229				
229.45			10	SS	12/0cm						
15.90	End of borehole Auger and sampler refusal on bedrock or boulder.										

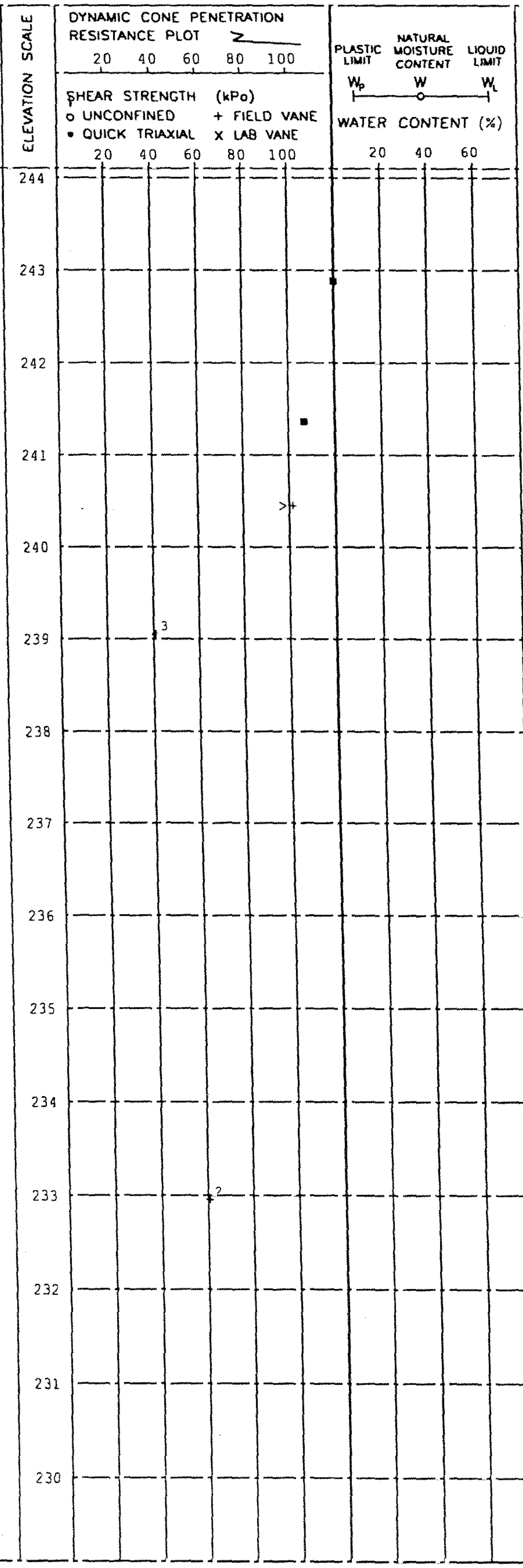
RECORD OF BOREHOLE No 110-9N

1 of 2

METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+946.5, o/s 33m Rt CL Med.
ORIGINATED BY FP
DIST 54 HWY 69
BOREHOLE TYPE Continuous Flight Hollow Stem Augers
COMPILED BY FP
DATUM Geodetic
DATE March 15, 2001
CHECKED BY Cy

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS
244.10	Ground Surface				∇*
0.00 0.25	Peat, fine fibrous Dark brown	1	SS	3	
	Silty clay trace sand Firm Grey/Brown Wet to stiff	2	SS	4	
					▼* (242)
		3	SS	5	
	Grey	4	SS	3	
	Interbedded sandy silt seams	5	SS	3	
238.00 6.10	Silty fine sand Loose Grey Wet	6	SS	5	
	Compact	7	SS	12	
234.05 10.05	Silty clay trace sand Stiff Grey Wet	8	SS	0	
232.50 11.60	Silty fine sand trace clay Compact Grey Wet	9	SS	10	
	Loose	10	SS	2	
	Trace to some clay Cont'd	11	SS	3	



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 110-9N

2 of 2

METRIC

G W P 327-91-00
LOCATION HWY.69 Sta. 14+946.5, o/s 33m Rt CL Med.
ORIGINATED BY FP
DIST 54 HWY 69
BOREHOLE TYPE Continuous Flight Hollow Stem Augers
COMPILED BY FP
DATUM Geodetic
DATE March 15, 2001
CHECKED BY

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.10	Ground Surface										
							229				
228.15 15.95	End of borehole Auger refusal on bedrock or boulder.										

* 01 03 15

▼ GROUNDWATER LEVEL MEASURED AFTER DRILLING

∇ GROUNDWATER LEVEL OBSERVED DURING DRILLING

■ PENETROMETER

APPENDIX E

RECORD OF BOREHOLE SHEETS AND DYNAMIC CONE PENETRATION TEST SHEETS

CULVERT HIGHWAY 69 STATION 16+016 AND 16+137

Golder Associates

RECORD OF BOREHOLE No BH-61

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5140782.6 ;E 314983.9

ORIGINATED BY ID

DIST ____ HWY 69

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

COMPILED BY BML

DATUM Geodetic

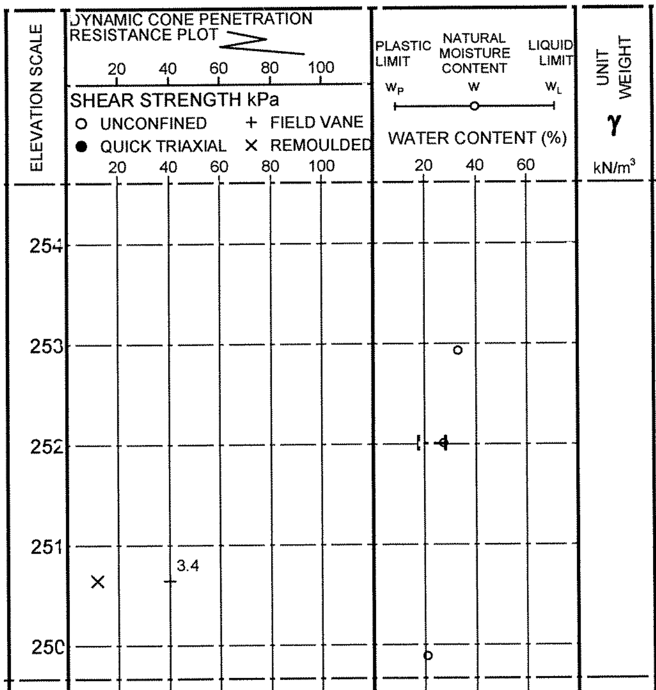
DATE Feb. 5, 2005

CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
254.6	GROUND SURFACE								
0.0	Ice				∇				
254.2	Peat, organics, roots								
0.6	Clayey Silt to Clay, trace to some sand Stiff to firm Grey with reddish varves/laminae Moist to wet	1	SS	9		0	6	55	39
		2	SS	10					
		3	SS	7					
		4	SS	6					
250.4 4.2	Fine Sand, some silt Compact Grey Wet	5	SS	10					
249.7 4.9	Auger Refusal Spoon Bouncing End of Borehole								

Note:

1. Water level at 0.3 m depth (Elev. 254.3 m) upon completion of drilling.



+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

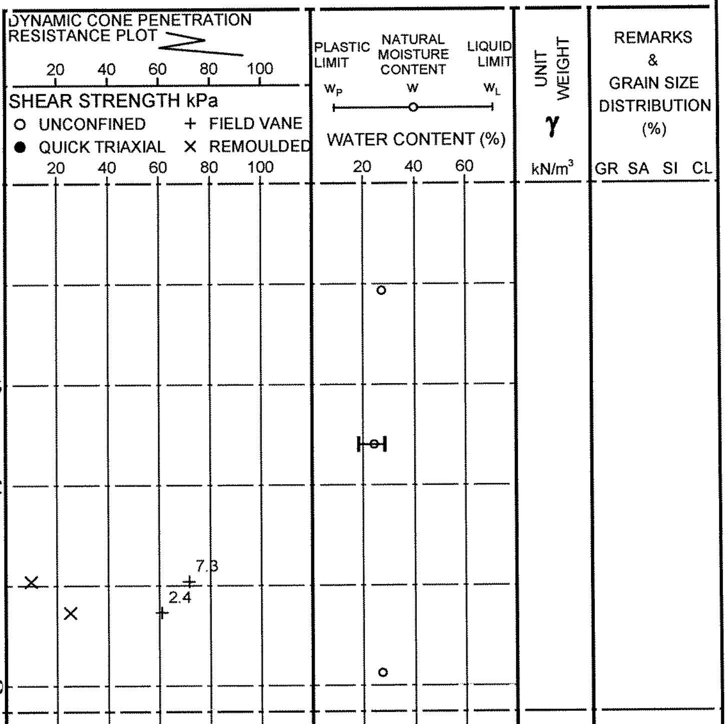
Golder Associates

RECORD OF BOREHOLE No BH-62

1 OF 1 **METRIC**

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5140786.7 ;E 314953.3		ORIGINATED BY ID
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY BML
DATUM Geodetic		DATE Feb. 4, 2005	CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
255.0	GROUND SURFACE					
0.0	Ice					
0.2	Organics Grey					
254.4 0.6	Clayey Silt to Clay, trace to some sand Stiff to firm Grey with reddish brown varves/laminae Wet Trace gravel at top of layer	1	SS	16		254
		2	SS	15		253
		3	SS	5		
		4	SS	5		252
					∇	
251.0 4.0	Silt, trace to some sand, trace to some clay Loose Grey Wet					251
		5	SS	4		250
249.7 5.3	Auger Refusal End of Borehole Note: 1. Water level at 3.7 m depth (Elev. 251.3 m) upon completion of drilling.					



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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

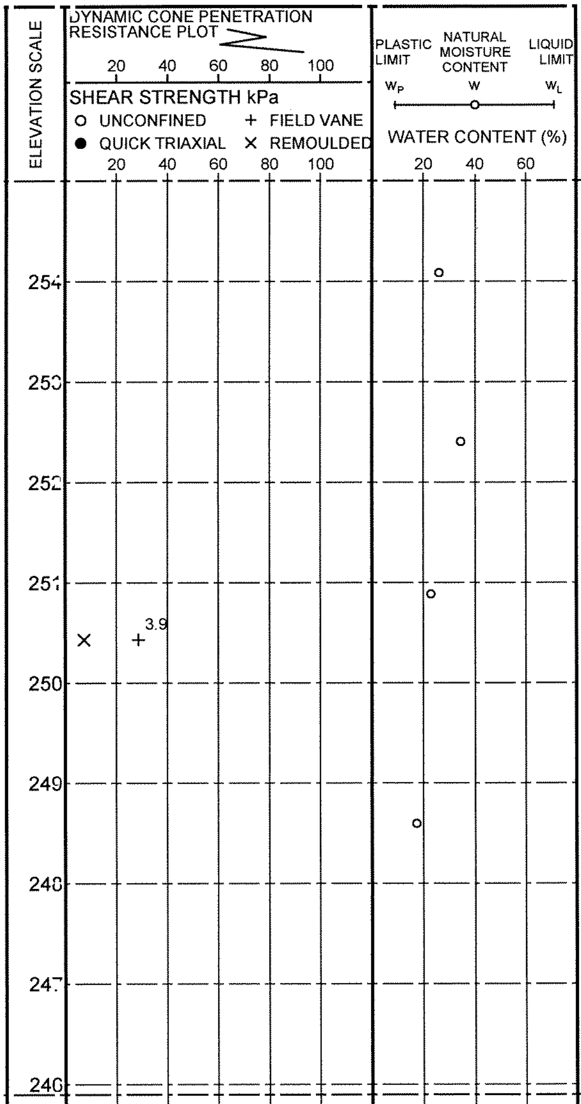
RECORD OF BOREHOLE No BH-63

1 OF 1

METRIC

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5140798.0 ;E 314989.5		ORIGINATED BY ID
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY BML
DATUM Geodetic	DATE Feb. 5, 2005		CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.0 0.0	GROUND SURFACE Ice					
254.7 0.3	Clayey Silt to Clay, trace to some sand Firm to soft Grey to brown Moist to wet Trace organics between depth 0.3 m and 1.5 m Becoming grey below 1.5 m depth	1	SS	8	∇	
		2	SS	5		
		3	SS	5		
		4	SS	6		
		5	SS	3		
250.3 4.7	Silt, trace to some sand, trace to some clay Loose to compact Grey Wet Becomes more sandy with depth	6	SS	8		
		7	SS	14		0 12 83 5
		8	SS	5		
245.9 9.1	End of Borehole Auger Refusal Note: 1. Water level at 0.3 m depth (Elev. 254.7 m) upon completion of drilling.					



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

RECORD OF BOREHOLE No BH-64

1 OF 1

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST
HWY 69
DATUM Geodetic
LOCATION N 5140801.1 ;E 314959.2
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Feb. 6, 2005
ORIGINATED BY ID
COMPILED BY BML
CHECKED BY SEP

SOIL PROFILE			SAMPLES					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
255.0	GROUND SURFACE						
0.0	Frozen, dark brown organics						
254.7 0.3	Clayey Silt to Clay, trace to some sand Stiff Light brown to grey Moist to wet					∇	
			1	SS	11		254
			2	SS	11		253
			3	SS	8		
			4	SS	9		252
251.2	Silt, trace trace to sand, trace to some clay Compact Grey Wet		5	SS	7/.23		251
250.8 4.2	Auger Refusal End of Borehole						

Note:

1. Water level at 0.6 m depth (Elev. 254.4 m) upon completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

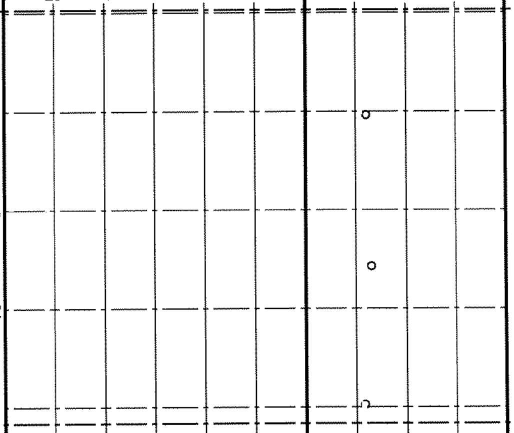
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%)
20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL



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

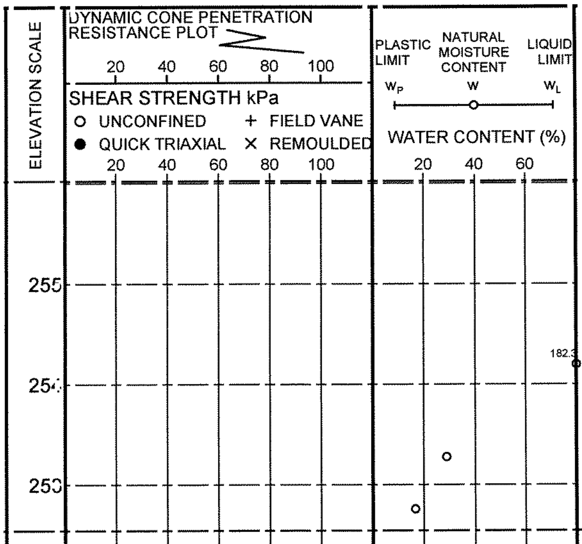
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-76A

1 OF 1 **METRIC**

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5140899.3 ;E 314918.1
BOREHOLE TYPE Wash Boring, Portable Equipment
DATE Feb. 9, 2005
ORIGINATED BY ID
COMPILED BY BML
CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.0	GROUND SURFACE						
0.0	Ice						
255.3 0.8	Water				∇		
254.5 1.5	Peat Very loose Dark brown Wet	1	SS	1			
253.7 2.3	Clayey Silt to Clay, trace to some sand Firm Dark grey to grey Wet	2	SS	7			
		3	SS	24/.28			
252.7 3.5	Silty Sand and Gravel Compact Grey Spoon Bouncing End of Borehole						



Notes:

1. Standard Penetration Testing performed with a 70 lb hammer 'N' values provided above have been converted to a full hammer weight (140 lb).

2. Water level at 0.8 m depth (Elev. 255.3 m) upon completion of drilling.

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

RECORD OF BOREHOLE No BH-76B

1 OF 1 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

DIST ____ HWY 69

DATUM Geodetic

LOCATION N 5140919.2 ;E 314951.7

BOREHOLE TYPE Wash Boring, Portable Equipment

DATE Feb. 9, 2005

ORIGINATED BY ID

COMPILED BY BML

CHECKED BY SEP

SOIL PROFILE			SAMPLES				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
256.0	GROUND SURFACE						
0.0	Ice						
255.3 0.7	Water					∇	255
254.2	Peat						254
253.9 2.1	Very loose Black Sandy Silt, trace clay Loose Grey Wet		1	SS	1		
			2	SS	8		253
			3	SS	8		
252.4 3.7	Fine to coarse Sand, trace silt, trace clay Compact to dense Grey Moist Coarse sand below 4.1 m depth		4	SS	14		252
			5	SS	32/.25		
251.3 4.7	Auger Refusal Spoon Refusal End of Borehole						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

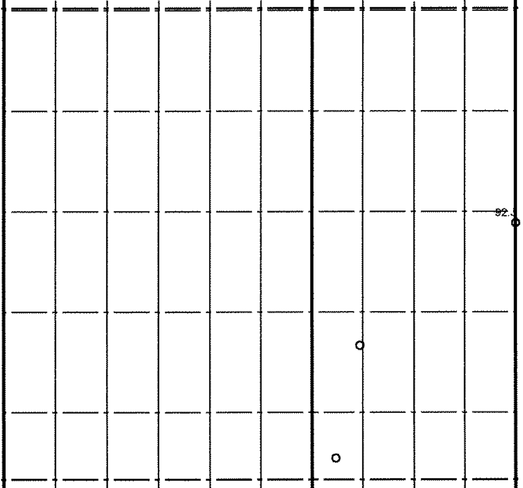
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL



Notes:

1. Standard Penetration Testing performed with a 70 lb hammer 'N' values provided above have been converted to a full hammer weight (140 lb).

2. Water level at 0.8 m depth (Elev. 255.3 m) upon completion of drilling.

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

RECORD OF BOREHOLE No BH-77B

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5140916.2 ;E 314942.1

BOREHOLE TYPE Wash Boring, Portable Equipment

DATE Feb. 9, 2005

ORIGINATED BY ID

COMPILED BY BML

CHECKED BY SEP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
256.0	GROUND SURFACE										
0.0	Ice										
255.3 0.8	Water					∇	255				
254.2 1.8	Peat Very loose Dark black		1	SS	3		254		100.3		
253.6 2.4	Silt, trace to some sand, trace to some clay, organics Compact Varved brown and grey		2	SS	14		253				
253.0 3.2	Sand and fine Gravel Loose Spoon Bouncing End of Borehole		3	SS	3/0.15						

Notes:

1. Standard Penetration Testing performed with a 70 lb hammer 'N' values provided above have been converted to a full hammer weight (140 lb).

2. Water level at 0.8 m depth (Elev. 255.3 m) upon completion of drilling.

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

Golder Associates

RECORD OF BOREHOLE No BH-126

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5140801.8 ;E 315005.1

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE Feb. 4, 2005

ORIGINATED BY ID

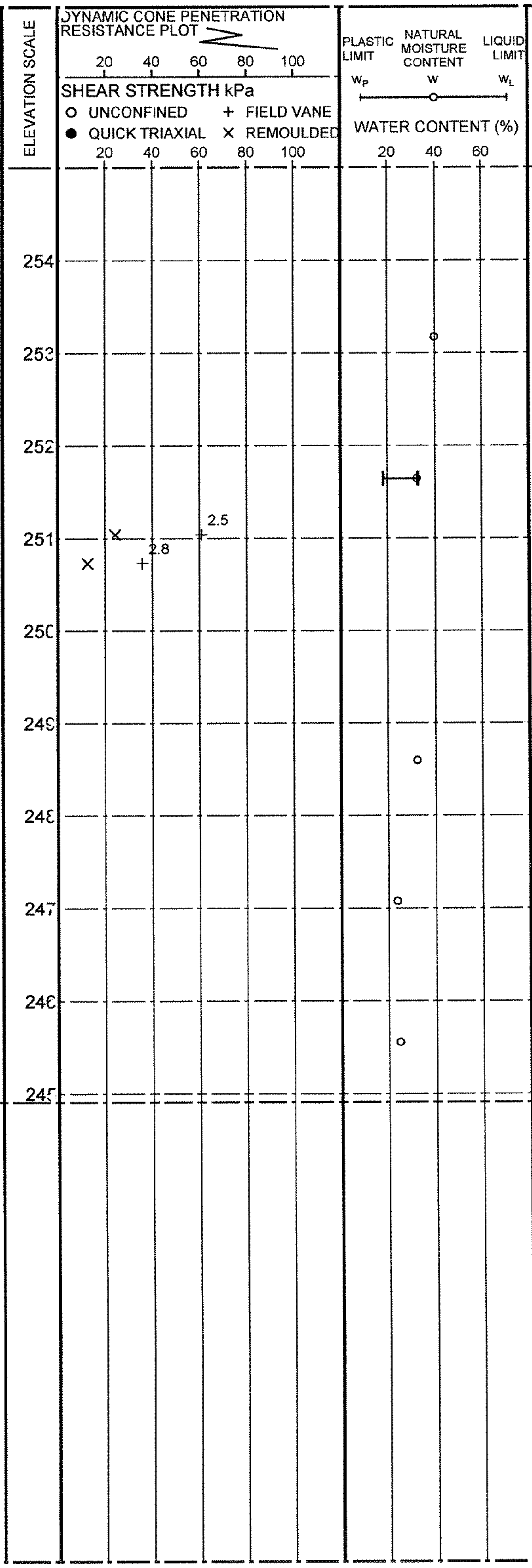
COMPILED BY BML

CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
255.0 0.0	GROUND SURFACE Peat, organics Wet								
254.7 0.3	Clayey Silt to Clay, trace to some sand, Stiff to firm Dark grey to grey with depth Wet				∇				
		1	SS	12					
		2	SS	7		0	2	67	31
	Roots and trace organics at surface	3	SS	7					
		4	SS	3					
250.4 4.6	Silt, trace to some sand, trace to some clay Loose to compact Grey Wet	5	SS	12					
		6	SS	4					
		7	SS	4		0	11	85	4
		8	SS	22					
245.3	Sand and Gravel								
244.9 10.1	Auger Refusal End of Borehole								

Note:

1. Water level at 0.5 m depth (Elev. 254.5 m) upon completion of drilling



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

$\circ^{3\%}$ STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

RECORD OF BOREHOLE No BH-127

1 OF 1 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5140800.0 ;E 314932.3

ORIGINATED BY ID

DIST HWY 69

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

COMPILED BY BML

DATUM Geodetic

DATE Feb. 4, 2005

CHECKED BY SEP

SOIL PROFILE			SAMPLES				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
255.3	GROUND SURFACE						
0.0 255.0	Ice					∇	255
0.3	Clayey Silt to Clay, trace to some sand Stiff to firm Brown and grey, varved Moist		1	SS	11		254
			2	SS	12		
			3	SS	5		253
252.3 3.1	Silt, trace to some clay, trace to some sand Compact Grey Wet		4	SS	9/.23		252
251.6 3.7	Auger Refusal End of Borehole Note: 1. Water level at 0.3 m depth (Elev. 255.0 m) upon completion of drilling.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT

20 40 60 80 100

SHEAR STRENGTH kPa

O UNCONFINED + FIELD VANE

● QUICK TRIAXIAL × REMOULDED

20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

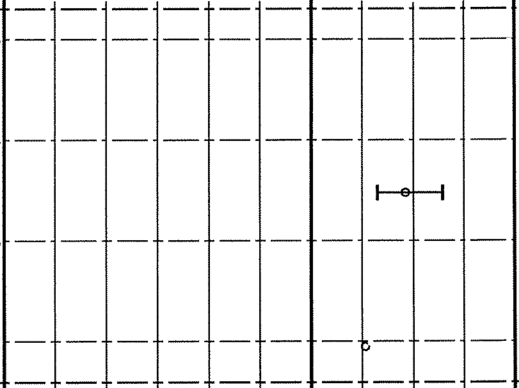
WATER CONTENT (%)

20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL



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

RECORD OF BOREHOLE No BH-128

1 OF 1 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5140891.6 ;E 314903.7

BOREHOLE TYPE Wash Boring, Portable Equipment

DATE Feb. 9, 2005

ORIGINATED BY ID

COMPILED BY BML

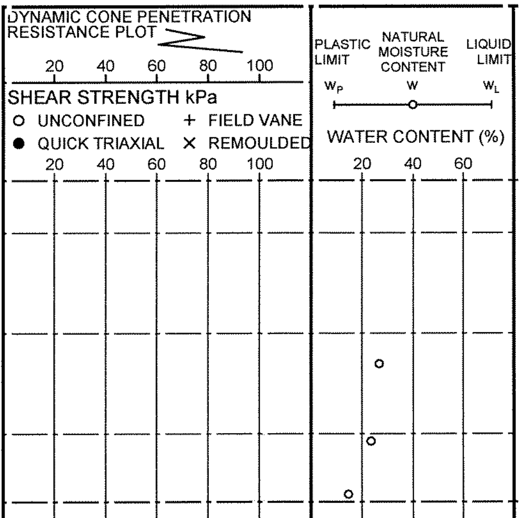
CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.5	GROUND SURFACE							
0.0	Ice					256		
255.8 0.8	Water				∇			
255.0 1.5	Silt, trace to some sand, trace to some clay, trace of organic peat Loose Black to dark grey Moist	1	SS	2		255		
		2	SS	6		254	O.C. 1.99	
253.6	Sand and Gravel, trace to some silt Grey Moist	3	SS	21/0.15				
253.3 3.2	Spoon Refusal End of Borehole							

Note:

1. Standard Penetration Testing performed with a 70 lb hammer 'N' values provided above have been converted to a full hammer weight (140 lb).

2. Water level at 0.8 m depth (Elev. 255.8 m) upon completion of drilling.



+³, ×³: Numbers refer to Sensitivity

O³% STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 20/6/05

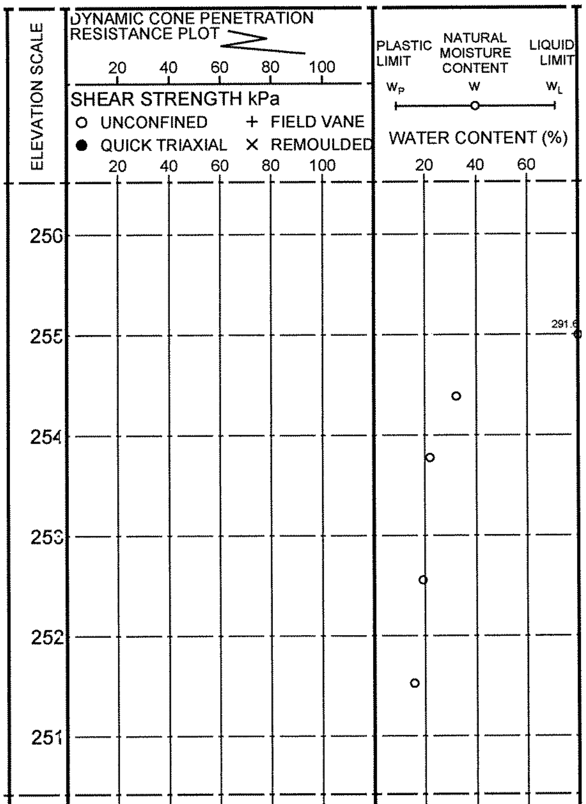
Golder Associates

RECORD OF BOREHOLE No BH-129

1 OF 1

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ______ HWY 69
DATUM Geodetic
LOCATION N 5140931.6 ;E 314964.5
BOREHOLE TYPE Wash Boring, Portable Equipment
DATE Feb. 10, 2005
ORIGINATED BY ID
COMPILED BY BML
CHECKED BY SEP



ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
256.5	GROUND SURFACE									
0.0	Ice									
255.8 / 0.7	Water				∇					
255.3 / 1.2	Peat Very loose Black Wet	1	SS	WH						
254.5 / 2.0	Clayey Silt to Clay, trace to some sand, trace organics, trace roots Stiff Dark grey	2	SS	8		O.C. 1.69				
254.1 / 2.4	Silt, trace to some sand, trace to some clay Compact Grey/light brown Wet/moist	3	SS	18						
		4	SS	10						
		5	SS	8			0	18	77	5
252.3 / 4.3	Sand, trace to some gravel Compact Grey Wet/moist	6	SS	19						
		7	SS	6/.07						
251.4	Grey Cobbles									
5.3	Fresh, dark grey to black BIOTITE SCHIST BEROCK Rock coring from 5.1 m to 6.1 m									
250.4 / 6.1	End of Borehole									

For bedrock coring details see Record of Drillhole 129

Notes:

1. Spoon bouncing at 5.1 m depth.
2. Standard Penetration Testing performed with a 70 lb hammer 'N' values provided above have been converted to a full hammer weight (140 lb).
3. Water level at 0.7 m depth (Elev. 255.8 m) upon completion of drilling.

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

PROJECT: 03-1111-011

RECORD OF DRILLHOLE: BH-129

SHEET 1 OF 1

LOCATION: N 5140931.6 ;E 314964.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 10, 2005

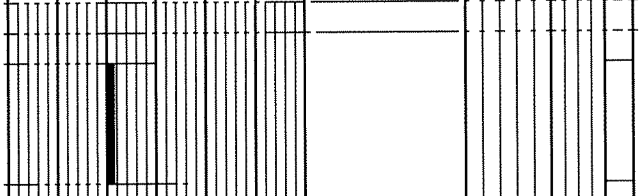
DRILL RIG: Wash Boring Portable Equipment

DRILLING CONTRACTOR: Marathon Drilling Ltd.

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	COLOUR % RETURN	FLUSH	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER 0.3 m (5 10 15 20)	DISCONTINUITY DATA B Angle (0 90 180 270)	DISCONTINUITY DATA DIP w.r.t. CORE AXIS (0 30 60 90)	TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	Diametral Point Load Index (MPa) (2 4 6)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to previous page		251.40 5.10															
		Grey Cobbles		251.20 5.30															
6		Fresh, fine to medium grained, massive to thinly foliated, dark grey to black, strong BIOTITE SCHIST with quartz veins and clasts and occasional section with felsic layers (not molted)		250.40 6.10															
		End of Borehole																	



7

8

9

10

11

12

13

14

15

DEPTH SCALE

1 : 50

LOGGED:

CHECKED:

RECORD OF BOREHOLE No DCPT-54

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ____ HWY 69

DATUM Geodetic

LOCATION N 5140795.1 ;E 314940.1

BOREHOLE TYPE Dynamic Cone

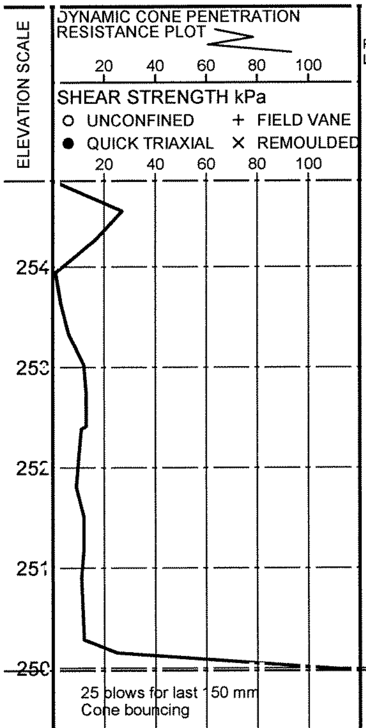
DATE Feb. 4, 2005

ORIGINATED BY ID

COMPILED BY BML

CHECKED BY SEP

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
254.9	GROUND SURFACE										
0.0											
250.0 4.9	End of dynamic cone test										



25 blows for last 150 mm
Cone bouncing

+³, ×³: Numbers refer to Sensitivity

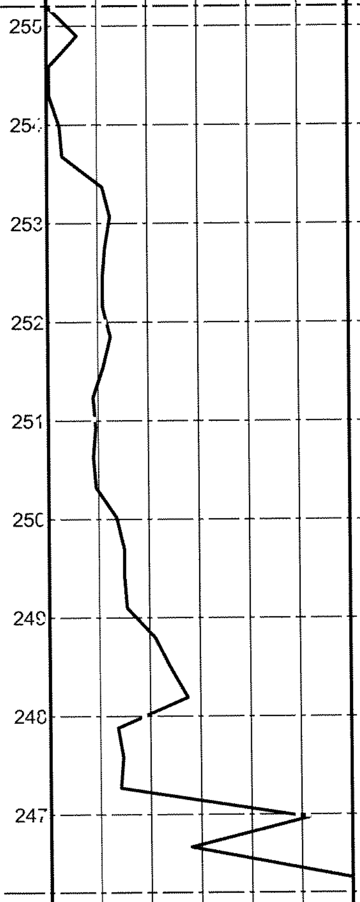
○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No DCPT-55

1 OF 1 **METRIC**

PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5140806.5 ;E 314976.4	ORIGINATED BY ID
DIST	HWY 69	BOREHOLE TYPE Dynamic Cone	COMPILED BY BML
DATUM Geodetic		DATE Feb. 6, 2005	CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
255.2 0.0	GROUND SURFACE										
246.2 9.0	End of dynamic cone test							126 blows for last 150 mm Cone bouncing			



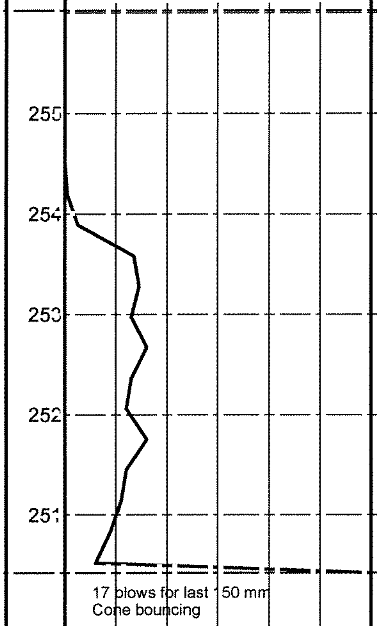
+ ³, × ³: Numbers refer to Sensitivity

○ ³% STRAIN AT FAILURE

RECORD OF BOREHOLE No DCPT-61 1 OF 1 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ___ HWY 69
DATUM Geodetic
LOCATION N 5140931.7 ;E 314958.2
BOREHOLE TYPE Dynamic Cone
DATE Feb. 9, 2005
ORIGINATED BY ID
COMPILED BY BML
CHECKED BY SEP

SOIL PROFILE			SAMPLES												
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
256.0	GROUND SURFACE													
0.0	Ice													
255.3 0.8	Water													
254.5 1.5														
250.4 5.6	End of dynamic cone test													



17 blows for last 150 mm
Cone bouncing

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

APPENDIX F

RECORD OF BOREHOLE SHEETS

CULVERT HIGHWAY 69 STATION 19+845

Golder Associates

RECORD OF BOREHOLE No BH-186

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5143301.6 ;E 312659.9

ORIGINATED BY ES

DIST HWY 69

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

COMPILED BY DD

DATUM Geodetic

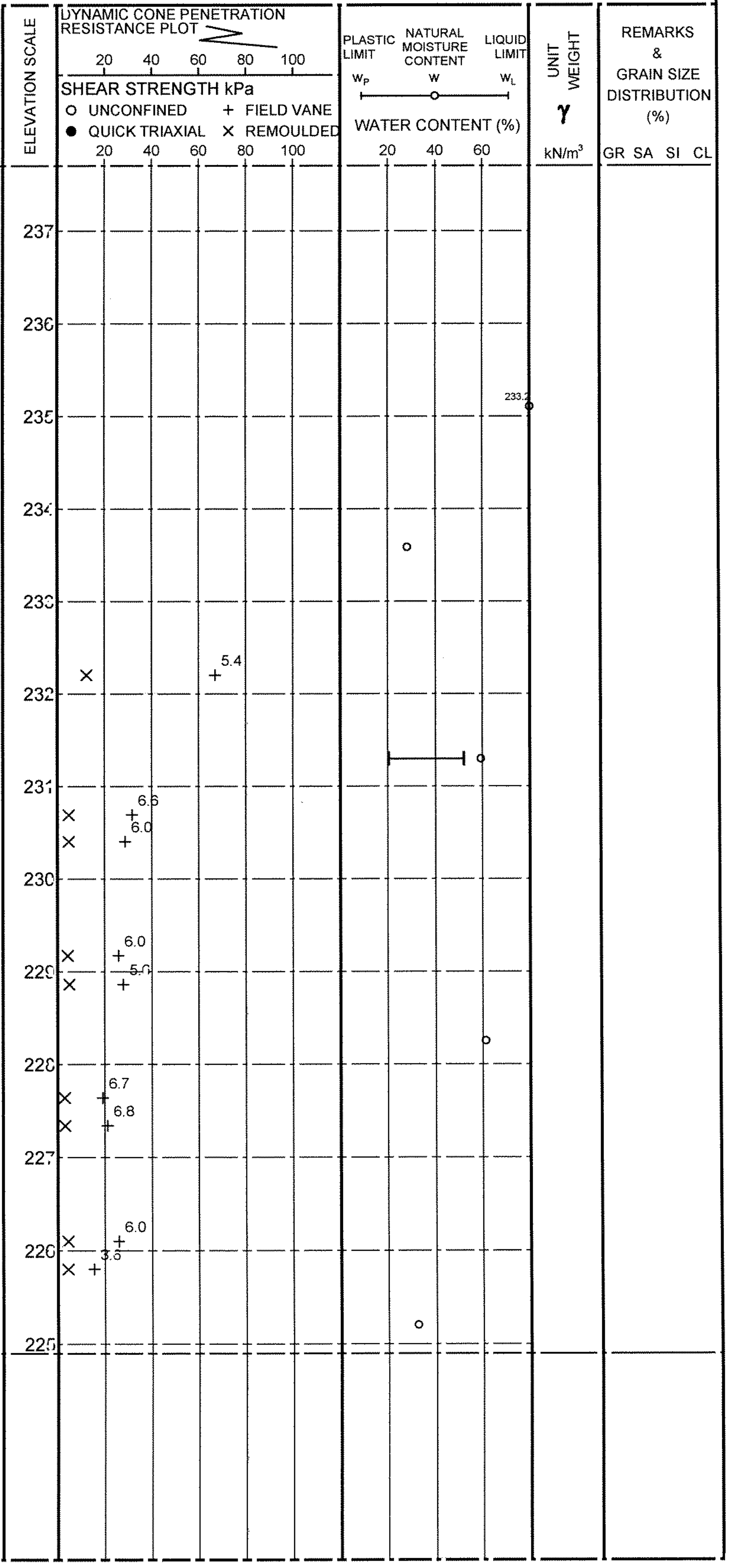
DATE Feb. 22 and 23, 2005

CHECKED BY SEP

SOIL PROFILE			SAMPLES			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
237.7	GROUND SURFACE					
0.0	Frozen , fine to medium Sand, some gravel, trace silt, cobbles (Fill) Brown					
236.9 0.8	Rock Fill Very loose Dark brown Wet					∇
235.9 1.8	Fibrous PEAT Very loose Dark brown Wet		1	SS	4	
			2	SS	3	
			3	SS	5	
234.3	SILT, trace to some clay, trace fine sand, trace organics Loose Grey Wet		4	SS	5	
			5	SS	5	
232.8 4.9	Silty CLAY to CLAY, trace fine sand, occasional vertical fine sand seams Stiff to soft Grey and dark grey Wet					
			6	SS	PM	
	Reddish-grey varves/laminae below 7.6 m depth		7	SS	PM	
			8	SS	PM	
	Frequent sand seams and silt seams below 10.4 m depth		9	SS	PM	
225.7 12.0	SILT, trace fine sand, trace clay, occasional clay seams Very loose Grey Wet		10	SS	WH	
224.9 12.8	End of Borehole					

Note:

1. Water level at 1.0 m depth (Elev. 236.7 m) upon completion of drilling.



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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 20/6/05

Golder Associates

RECORD OF BOREHOLE No BH-187

1 OF 1

METRIC

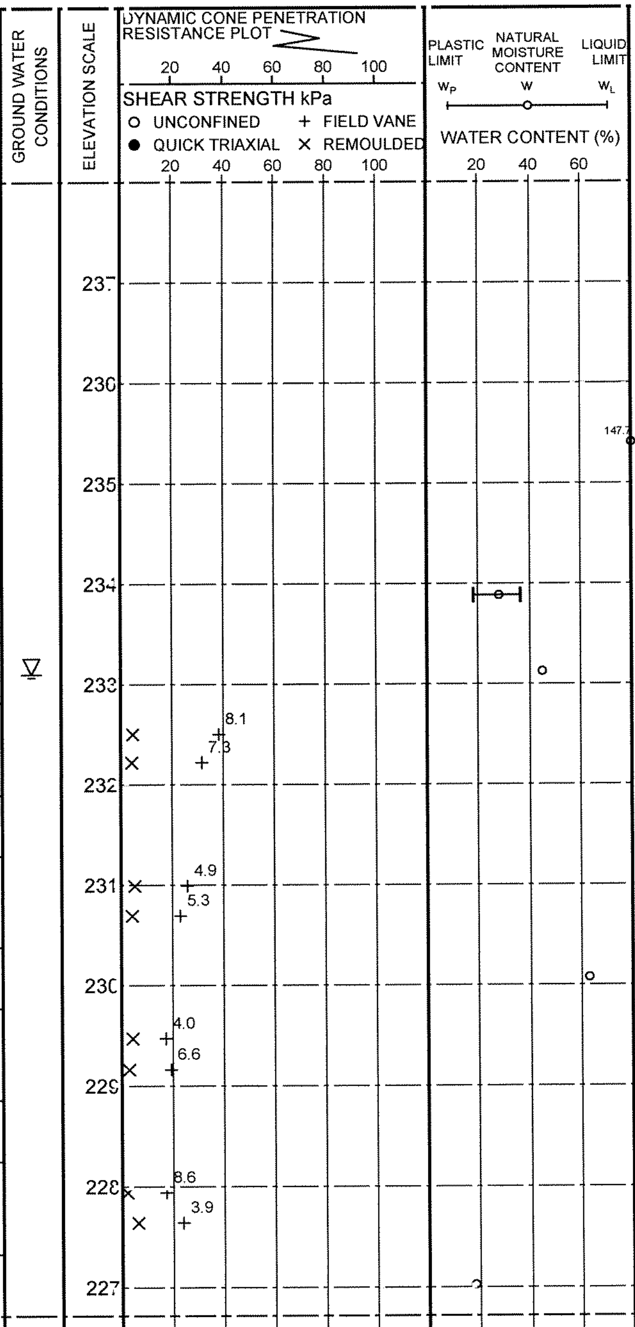
PROJECT 03-1111-011			
W.P. 327-91-00	LOCATION N 5143318.4 ;E 312669.5		ORIGINATED BY ES
DIST	HWY 69	BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger	COMPILED BY DD
DATUM Geodetic		DATE Feb. 24, 2005	CHECKED BY SEP

SOIL PROFILE / SAMPLES

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
238.0	GROUND SURFACE			
0.0	Crushed gravel (Fill) Light brown			
0.2	Sand, trace to some gravel trace silt (Fill) Loose Light brown Moist to wet			
236.3 1.7	Rock Fill	1	SS	4
235.6 2.4	Fibrous PEAT Very loose Dark brown Wet	2	SS	3
234.7 3.4	SILT, trace to some clay, trace fine sand, trace organics, frequent sand seams Very loose to loose Grey Wet	3	SS	4
		4	SS	4
233.6 4.4	Silty CLAY to CLAY, trace sand Firm to soft Grey and dark grey Wet	5	SS	2
	Reddish-grey varves/laminae below 6.1 m depth Frequent sand seams and silt seams below 6.1 m depth	6	SS	PM
		7	SS	WR
		8	SS	WR
227.6 10.4	Silty SAND, trace gravel Very loose Grey Wet	9	SS	WR
226.7 11.3	End of Borehole			

Note:

1. Water level at 4.9 m depth (Elev. 233.1 m) upon completion of drilling.
2. Water rose up to 6.1 m depth after sample 9 was taken.



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

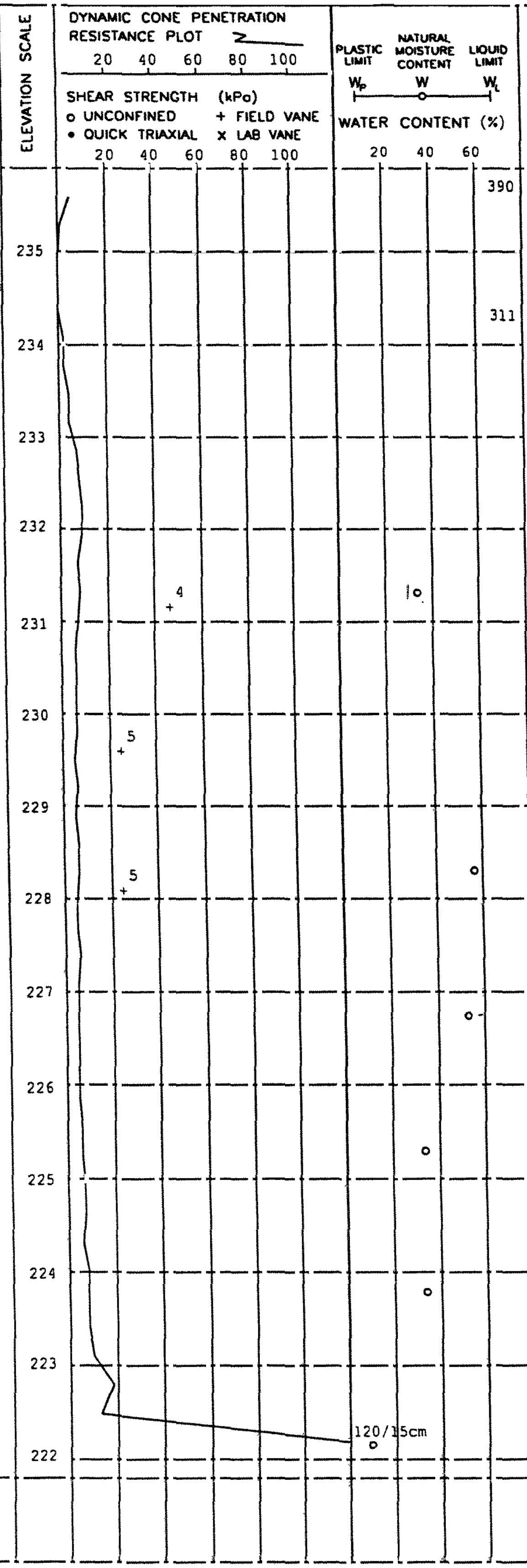
$+^3, \times^3$: Numbers refer to Sensitivity

$O^{3\%}$ STRAIN AT FAILURE

CULVERT EXTENSION BOREHOLE No 305-C1 1 of 1 METRIC

G W P 327-91-00
LOCATION HWY. 69 Sta. 12+090, o/s 26m Lt. CL med.
ORIGINATED BY DJB
DIST 54 HWY 69
BOREHOLE TYPE Continuous Flight Hollow Stem Augers
COMPILED BY DJB/DH
DATUM Geodetic
DATE March 12-13, 2001
CHECKED BY

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS
235.90	Ground Surface					*
0.00	Peat, fine fibrous, dark brown		1	AS	-	
			2	SS	1/60cm	
234.20 1.70	Silty clay with sand Interbedded fine sand and silt seams Firm Grey Wet		3	SS	3	
232.70 3.20	Clay with silt trace sand Interbedded layers of silt with clay Firm Grey Wet		4	SS	2	
	Soft		5	SS	1/60cm	
			6	SS	1/45cm	
			7	SS	1/60cm	
			8	SS	1/60cm	
	Interbedded sandy silt and silt seams		9	SS	1/60cm	
223.55 12.35	Silty sand some gravel Compact Grey Wet					
	Dense		10	SS	10/20cm	
221.80 14.10	End of borehole and dynamic cone penetration test. Refusal on bedrock or boulder.					



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

* GROUNDWATER LEVEL NOT ESTABLISHED

$+^7$, x^5: Numbers refer to 15 -o- 5 (%) STRAIN AT FAILURE (20)

RECORD OF BOREHOLE No 305-4N

1 of 1 METRIC

G W P 327-91-00
LOCATION HWY. 69 Sta. 12+080, o/s 22m Rt. CL Med.
ORIGINATED BY SH
DIST 54 HWY 69
BOREHOLE TYPE Continuous Flight Hollow Stem Augers
COMPILED BY SH/DH
DATUM Geodetic
DATE March 6, 2001
CHECKED BY Ly

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) o UNCONFINED + FIELD VANE • QUICK-TRIAXIAL x LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	* GROUND WATER CONDITIONS	ELEVATION SCALE				
235.75	Ground Surface										
0.00	Peat, amorphous, dark brown										
235.00 0.75	Silt trace sand, Interbedded clay seams Loose Grey Wet						235				
			1	SS	4		234		o		
							233				
232.70 3.05	End of borehole Auger refusal on bedrock or boulder.										

* GROUNDWATER LEVEL NOT ESTABLISHED

$+^{7}, \times^{5}$: Numbers refer to $15\overset{20}{-\!\phi\!-}5$ (%) STRAIN AT FAILURE

APPENDIX G

RECORD OF BOREHOLE SHEETS

CULVERT HIGHWAY 537 STATION 11+015

RECORD OF BOREHOLE No BH-156

1 OF 2 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5138527.0 ;E 316494.2

ORIGINATED BY ES

DIST

HWY 69

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

COMPILED BY CG

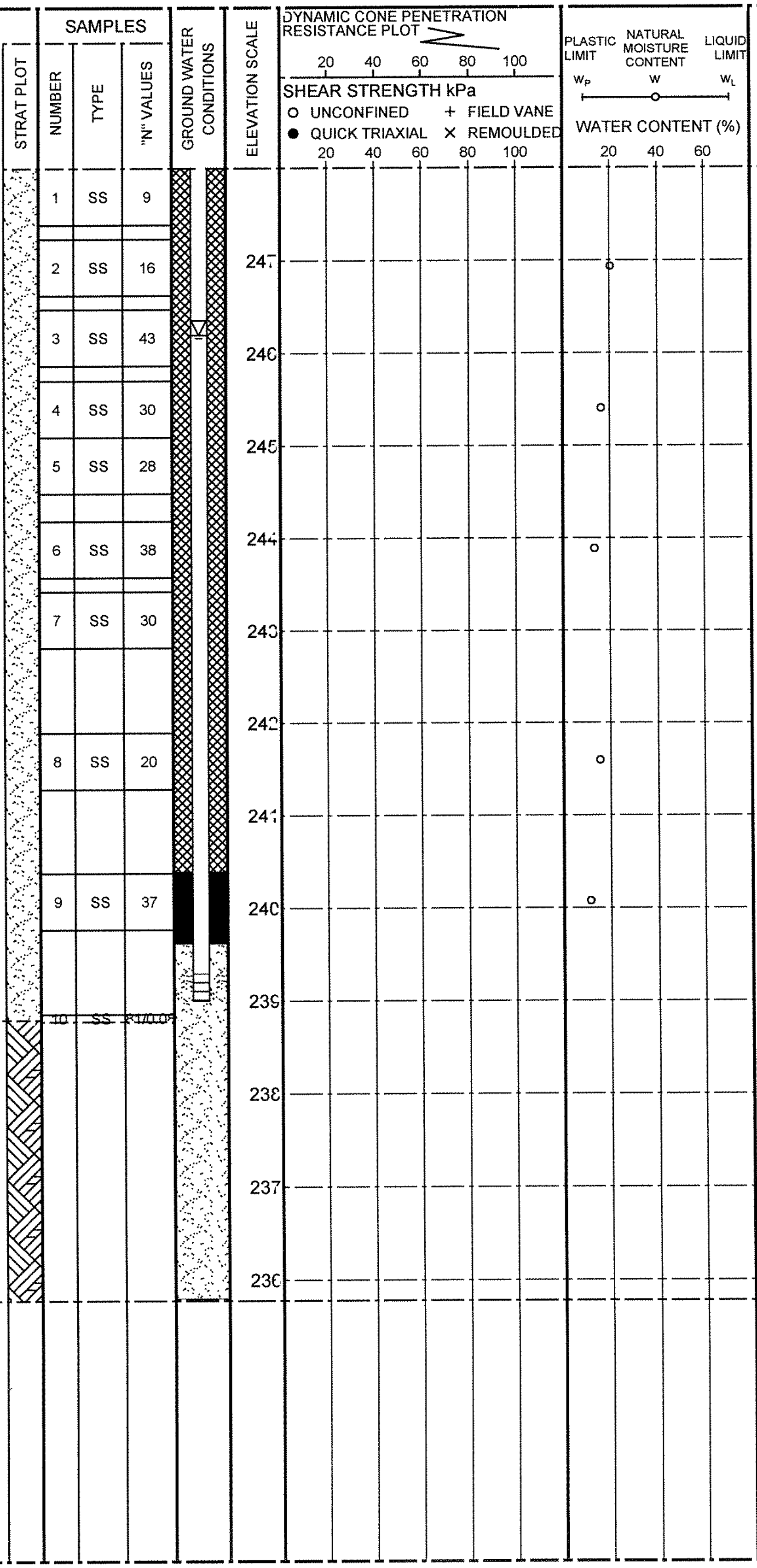
DATUM Geodetic

DATE Apr. 19, 2004

CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE – DESCRIPTION
248.0	GROUND SURFACE
0.0	Fine to medium SAND, trace gravel, trace silt Compact to dense Brown and grey Moist to wet
	Becoming medium to coarse SAND, trace to some gravel, trace silt, grey below 2.3m depth
238.8 9.2	Biotite Gneiss BEDROCK Bedrock cored from 9.2 m to 12.2 m depth For details of bedrock coring see record of Drillhole 156
235.8 12.2	

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	9	
2	SS	16	
3	SS	43	
4	SS	30	
5	SS	28	
6	SS	38	3 88 8 1
7	SS	30	
8	SS	20	
9	SS	37	
10	SS	R10/0.07	



Continued Next Page

+³, X³: Numbers refer to Sensitivity

O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-156

2 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST

HWY 69

DATUM Geodetic

LOCATION N 5138527.0 ;E 316494.2

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE Apr. 19, 2004

ORIGINATED BY ES

COMPILED BY CG

CHECKED BY SEP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	End of Borehole Notes: 1. Auger and spoon refusal at 9.2 m depth 2. Water level at 2.7 m depth upon completion of drilling 3. Water level in piezometer at 0.6 m depth (Elevation 247.4m) on April 20, 2004, at 1.3 m depth (Elevation 246.7m) on April 22, 2004, 0.5m depth (Elevation 247.5m) on June 12, 2004, and 1.8m depth (Elev. 246.2m) on October 6, 2004.										

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

$\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 03-1111-011

RECORD OF DRILLHOLE: BH-156

SHEET 1 OF 1

LOCATION: N 5138527.0 ;E 316494.2

DRILLING DATE: Apr. 19, 2004

DATUM: Geodetic

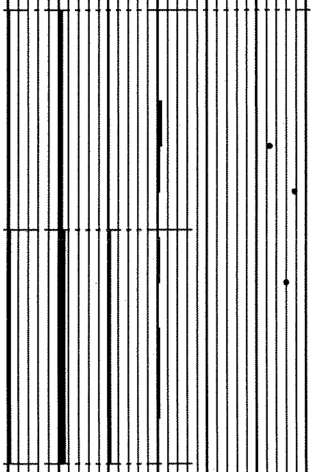
DRILL RIG: CME 55

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Marathon Drilling Ltd.

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR - Shear	CO - Contact	UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB - Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	FLUSH	COLOUR % RETURN	RECOVERY TOTAL CORE % (80 60 40 20)	RECOVERY SOLID CORE % (80 60 40 20)	R.Q.D % (80 60 40 20)	FRACT. INDEX PER 0.3 m (5 10 15 20)	DISCONTINUITY DATA B Angle (0 90 180 270)	DISCONTINUITY DATA DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	Diametral Point Load Index (MPa) (2 4 6)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to previous page																	
		BIOTITE GNEISS Medium crystalline in matic part and very coarsely in felsic part (pegmatite) Fresh Foliated Light grey to dark grey, partly pinkish grey		238.80 9.20															
10															JN,UE,Ro				
															"				
11															JN,PL,SM				
															JN,PL,Ro				
12															FO,PL,SM				
		End of Drillhole		235.80 12.20															
13																			
14																			
15																			
16																			
17																			
18																			
19																			



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: ES

CHECKED: SEP

RECORD OF BOREHOLE No BH-157

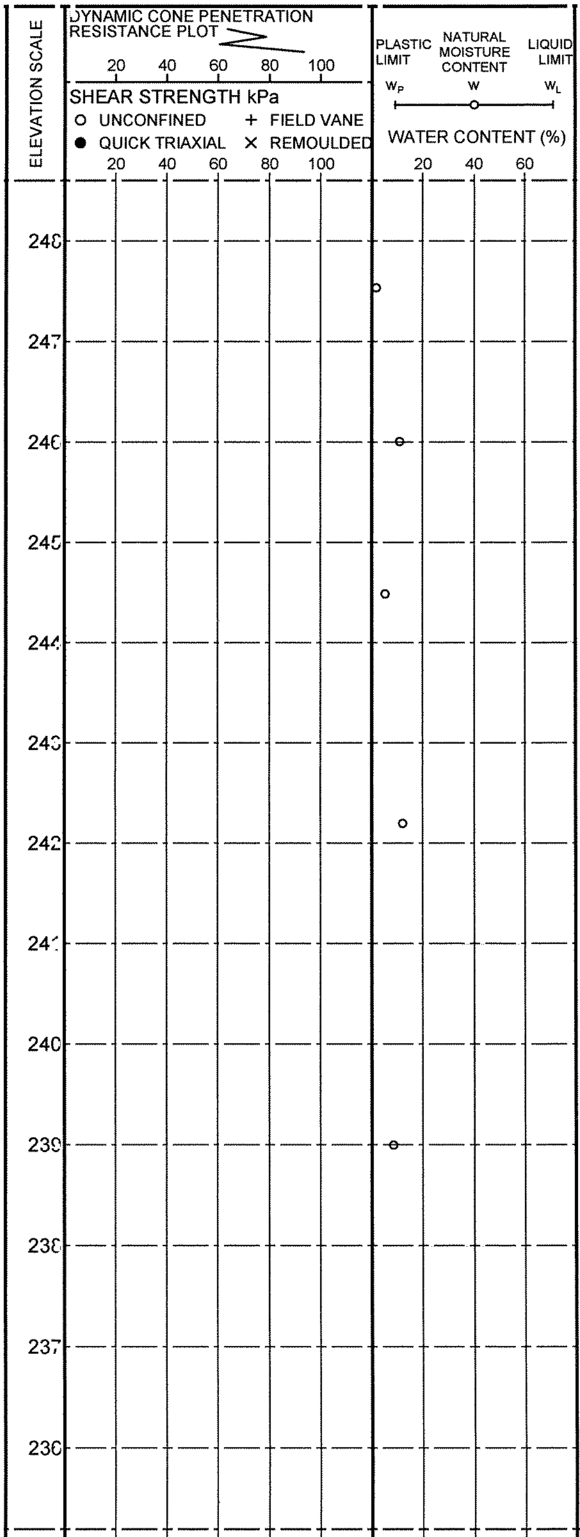
1 OF 2

METRIC

PROJECT	03-1111-011		
W.P.	327-91-00	LOCATION	N 5138476.7 ;E 316495.5
DIST	HWY 69	BOREHOLE TYPE	Power Auger 108 mm I.D. Hollow Stem Auger
DATUM	Geodetic	DATE	Apr. 17, 2004

ORIGINATED BY ES
COMPILED BY CG
CHECKED BY SEP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
248.6	GROUND SURFACE									
0.0	Fine to coarse SAND and GRAVEL, trace silt Dense to loose Brown to grey Moist	1	SS	32						
		2	SS	11						
		3	SS	7	∇					
246.3 2.3	GRAVEL, some sand, trace silt to Sandy GRAVEL, occasional cobbles Loose Grey Wet	4	SS	8						
		5	SS	9						
		6	SS	6						
		7	SS	7						
243.4 5.2	Fine to medium SAND, trace to some gravel, trace to some silt Compact to dense Light brown Wet									
		8	SS	21			18	61	18	3
		9	SS	39						
		10	SS	39						
238.7 9.9	COBBLES and BOULDERS									
238.2 10.4	Biotite Gneiss BEDROCK Bedrock cored from 10.4 m to 13.4 m depth For details of bedrock coring see record of Drillhole 157									
235.2 13.4	End of Borehole									



Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH-157 2 OF 2 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5138476.7 ;E 316495.5
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Apr. 17, 2004
ORIGINATED BY ES
COMPILED BY CG
CHECKED BY SEP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION — CONTINUED FROM PREVIOUS PAGE —	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	Notes: 1. NQ coring used to advance borehole beyond 7.2 m depth 2. Water level at 1.7 m depth (Elevation 246.9m) upon completion of drilling										

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

PROJECT: 03-1111-011

RECORD OF DRILLHOLE: BH-157

SHEET 1 OF 1

LOCATION: N 3138476.7 ;E 316495.5

DRILLING DATE: Apr. 17, 2004

DATUM: Geodetic

DRILL RIG: CME 55

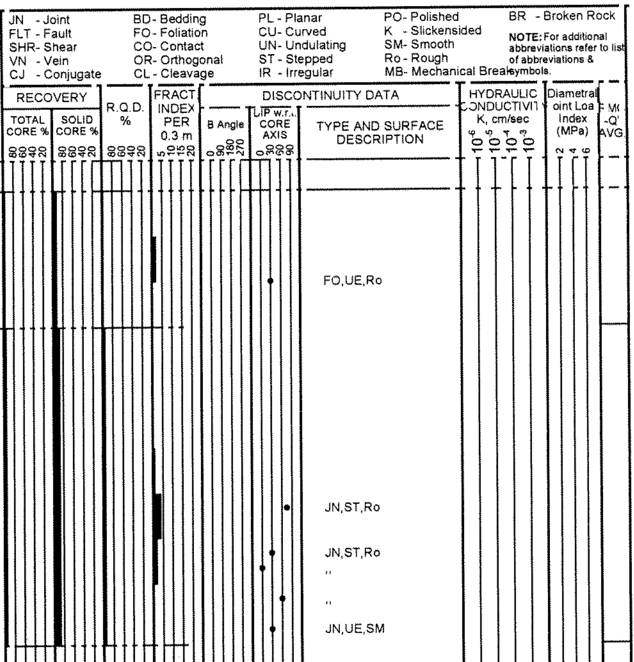
INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Marathon Drilling Ltd.

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate
BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular
PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break
BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (m/min)	FLUSH	COLOUR % RETURN	TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		Refer to previous page								
		BIOTITE GNEISS Fine to medium crystalline partly pegmatitic Fresh Slightly foliated partly, massive Mainly dark grey, partly reddish brown Reddish brown phenocrysts are developed		238.20 10.40						
11									FO,UE,Ro	
12									JN,ST,Ro JN,ST,Ro " "	
13									JN,UE,SM	
		End of Drillhole		235.20 13.40						
14										
15										
16										
17										
18										
19										
20										



DEPTH SCALE
1 : 50

Golder Associates

LOGGED: ES
CHECKED: SEP

APPENDIX H

RECORD OF BOREHOLE SHEETS, DYNAMIC CONE PENETRATION TEST SHEETS AND CONE PENETRATION TEST SHEETS

CULVERT HIGHWAY 537 STATION 11+940/12+130

Golder Associates

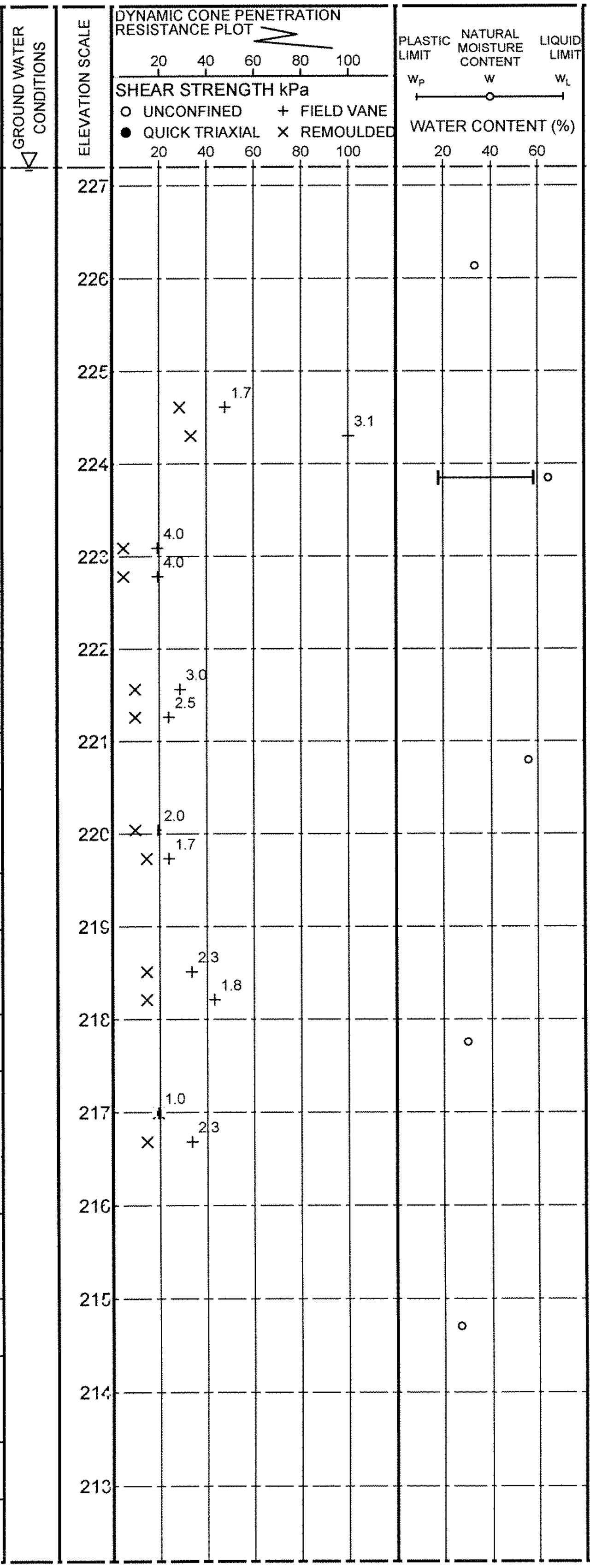
RECORD OF BOREHOLE No BH-83

1 OF 2

METRIC

PROJECT	03-1111-011
W.P.	327-91-00
DIST	
HWY	69
DATUM	Geodetic
LOCATION	N 5138521.6 ;E 317569.9
BOREHOLE TYPE	Power Auger 108 mm I.D. Hollow Stem Auger
DATE	Aug. 11, 2003
ORIGINATED BY	SB
COMPILED BY	SEP
CHECKED BY	ASP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.2	GROUND SURFACE				
0.0	Topsoil	1	SS	5	
226.8 0.4	Silty CLAY, trace sand, organics and roots Soft to firm Brown and grey Wet	2	SS	3	
225.7 1.5	Silty CLAY to CLAY, trace sand Very soft Grey Wet Fine to medium sand at 2.1 m depth	3	SS	2	
		4	SS	WH	
		5	SS	WH	
	Reddish grey varves/laminae at 6.1 m depth	6	SS	WH	0 3 47 50
	Dark grey varves/laminae at 7.6 m depth	7	SS	WH	
	Becoming siltier below 9.1 m depth	8	SS	WH	
216.5 10.7	Sandy SILT, trace clay Very loose Grey Wet	9	SS	WH	
		10	SS	WH	
213.7 13.5	Fine SAND and SILT to SAND, trace to some silt Loose to compact Grey Wet	11	SS	WH	



Continued Next Page

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-83

2 OF 2

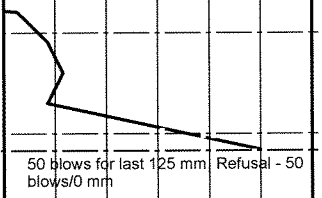
METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5138521.6 ;E 317569.9
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Aug. 11, 2003
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

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 (%): 20 40 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	Fine SAND and SILT to SAND, trace to some silt Loose to compact Grey Wet				212				
		12	SS	5		0	39	61	0
					211				
		13	SS	4	210				
					209				
		14	SS	3					
					208				
		15	SS	3	207				
					206				
		16	SS	5		0	80	19	1
					205				
		17	SS	8	204				
					203				
	Becoming siltier below 24.4 m depth	18	SS	22					
202.2 25.0	Start of dynamic cone penetration test				202				
					201				
200.8 26.4	End of dynamic cone penetration test Refusal to penetration								


50 blows for last 125 mm Refusal - 50 blows/0 mm

Note:
Water level in open borehole at ground surface upon completion of drilling

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

RECORD OF BOREHOLE No BH-84

1 OF 2 **METRIC**

PROJECT 03-1111-011

W.P. 327-91-00

LOCATION N 5138496.2 ;E 317585.6

ORIGINATED BY SB

DIST HWY 69

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

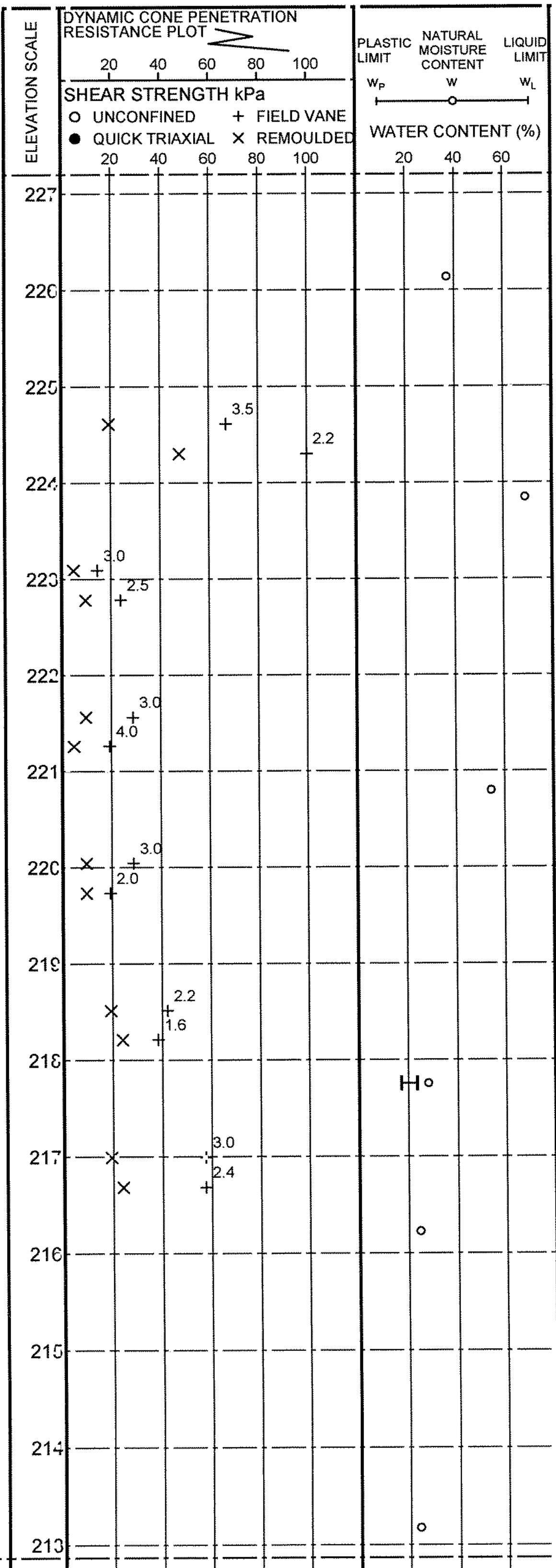
COMPILED BY SEP

DATUM Geodetic

DATE Aug. 10, 2003

CHECKED BY ASP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.2	GROUND SURFACE						
0.0	Topsoil	1	SS	3			
226.8 0.4	Silty CLAY, trace sand, roots and organics with seams of grey sand Soft to firm Mottled brown and grey Moist	2	SS	4			
225.7 1.5	Silty CLAY to CLAY, trace sand Soft to stiff Grey Moist	3	SS	2			
	Reddish grey varves/laminae and sand seams at 3.0 m depth	4	SS	2			
		5	SS	WH			
		6	SS	WH			
	Dark grey varves/laminae at 7.6 m depth	7	SS	WH			
	Becoming siltier below 9.1 m depth	8	SS	4			
216.5 10.7	SILT to Sandy SILT, trace clay Loose to very loose Grey Wet	9	SS	8			0 3 93 4
		10	SS	2			
	Becoming sandier 13.7 m depth	11	SS	WH			
212.9 14.3							



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-84

2 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5138496.2 ;E 317585.6
ORIGINATED BY SB
DIST
HWY 69
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
COMPILED BY SEP
DATUM Geodetic
DATE Aug. 10, 2003
CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	End of borehole Note: Water level in open borehole at ground surface upon completion of drilling										

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

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

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-85

1 OF 2

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ____ HWY 69
DATUM Geodetic

LOCATION N 5138470.7 ;E 317628.6
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE Aug. 10, 2003

ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.7	GROUND SURFACE						
0.0 0.1	Topsoil Silty CLAY, trace sand and roots Firm to stiff Brown and grey Moist	1	SS	7	∇		
		2	SS	6			
	Thinly layered brown, grey and red-brown silty sand at 1.5 m depth	3	SS	3			
224.7 3.0	Fine to medium SAND, trace silt and clay Compact Grey Wet	4	SS	10			
224.0 3.8	Silty CLAY to CLAY, trace sand Soft to stiff Grey Wet	5	SS	1			
	Reddish grey varves/laminae at 3.8 m and 6.1 m depth	6	TO	PH		17.5	
	Thin grey sand seams at 6.1 m depth	7	SS	WH			
	Becoming siltier below 7.6 m depth	8	SS	WH			
		9	SS	3			
217.3 10.4	Sandy SILT, trace to some clay Loose to very loose Grey Wet	10	SS	7			
	Becoming sandier below 12.2 m depth	11	SS	WH			
		12	SS	WH			
213.4 14.3							

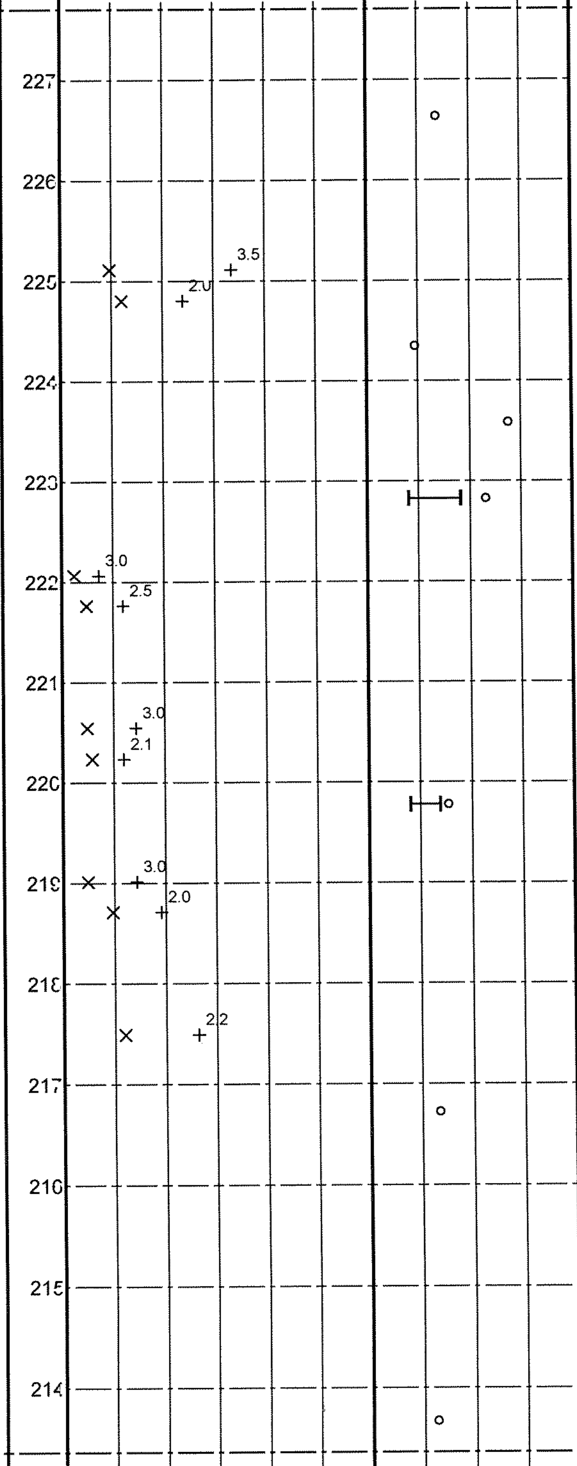
ELEVATION SCALE

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 (%) 20 40 60



Continued Next Page

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

RECORD OF BOREHOLE No BH-85

2 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5138470.7 ;E 317628.6

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE Aug. 10, 2003

ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	End of borehole Note: Water level in open borehole at 0.3m depth below ground surface upon completion of drilling										

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

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-158

1 OF 1

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ______ HWY 69
DATUM Geodetic

LOCATION N 5138529.9 ;E 317373.5
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE July 19, 2004

ORIGINATED BY ES
COMPILED BY SEP
CHECKED BY SEP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	
229.0	GROUND SURFACE					
0.0	Topsoil					
0.2	Silty CLAY to CLAY, some fine sand, trace organics, fine sand seams throughout Firm to stiff Mottled light brown Moist to wet Oxidized above 0.6m depth		1	SS	7	
			2	SS	8	
227.2 1.8	Clayey SILT to CLAY, trace fine sand Soft to firm Grey and reddish brown Wet Occasional fine sand seams, layered		3	SS	7	∇
			4	SS	WH	
	Becoming siltier below 3.8 m depth		5	TO	WR	
224.4 4.7	Sandy SILT, some gravel, trace clay, occasional cobbles Grey Wet		6	SS	8/0.1	
	Spoon Refusal Auger Refusal					

Notes:

1. Water level at 2.0m depth (Elev. 277.0) upon completion of drilling.

ELEVATION SCALE

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

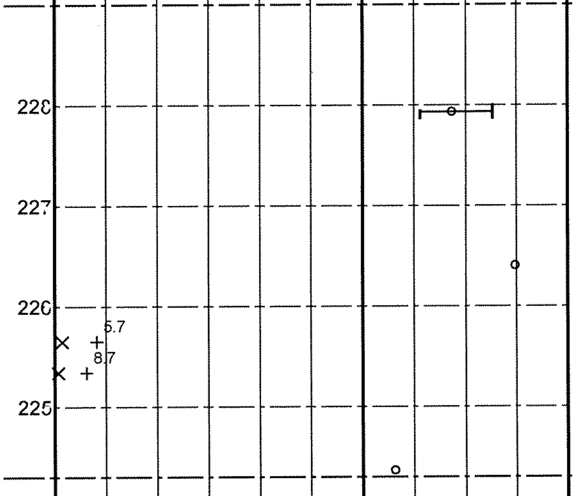
WATER CONTENT (%)

20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL



MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 20/6/05

+³, ×³: Numbers refer to Sensitivity

○^3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH-159

1 OF 1

METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST HWY 69
DATUM Geodetic
LOCATION N 5138578.2 ;E 317398.6
BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger
DATE July 19 - 20, 2004
ORIGINATED BY ES
COMPILED BY SEP
CHECKED BY SEP

SOIL PROFILE

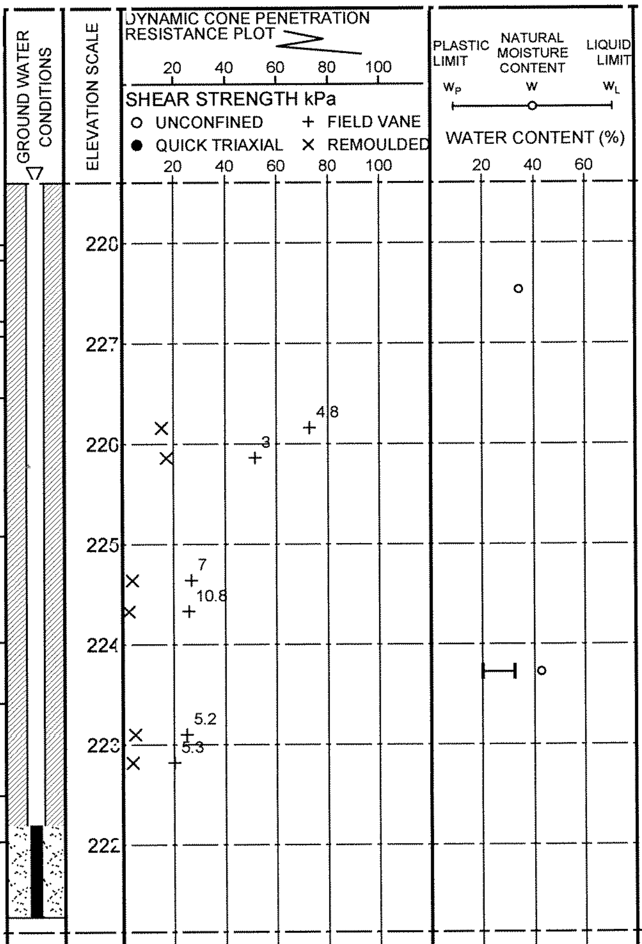
ELEV DEPTH	DESCRIPTION
228.6	GROUND SURFACE
0.0	Organics
227.6 (0.2)	Dark brown Silty SAND, trace gravel, trace organics Very loose to loose Brown and oxidized Wet
227.6 1.0	Silty CLAY, trace fine sand Firm to very stiff Light brown and grey, oxidized and reddish brown to 1.83 m depth Wet Frequent fine sand seams and silt seams above 2.1m Firm to stiff from 2.4 m to 3.1 m depth
225.6 3.0	Clayey SILT to CLAY, trace fine sand, Soft to firm Varved grey and dark grey Occasional fine sand seams
222.2 6.4	Fine to medium SAND Very loose to very dense Grey Wet Augers grinding below 6.9m depth
221.1 7.5	End of Borehole Auger refusal

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	WH				
2	SS	7				
3	SS	4				
4	SS	PH				
5	SS	WH	0	5	63	32
6	SS	PH				

Notes:

1. Augers dipping to the east at refusal.
2. Water level in piezometer at 2.0m depth after installation.
3. Water level in piezometer at ground surface (Elev. 288.6 m) on October 13, 2004.



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Golder Associates

RECORD OF BOREHOLE No BH-159A

1 OF 1

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST HWY 69

DATUM Geodetic

LOCATION N 5138551.5 ;E 317390.9

BOREHOLE TYPE Power Auger 108 mm I.D. Hollow Stem Auger

DATE July 20, 2004

ORIGINATED BY ES

COMPILED BY SEP

CHECKED BY SEP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
228.8 0.0	GROUND SURFACE No sampling										
							228				
							227				
							226				
							225				
							224				
							223				
						▽					
							222				
							221				
220.7 8.1	Augers grinding below 7.8 m depth End of Borehole Auger refusal Notes: 1. Augers dipping to the east at refusal. 2. Water level in open borehole at 6.5 m depth (Elev. 282.3 m) upon completion of drilling.										

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

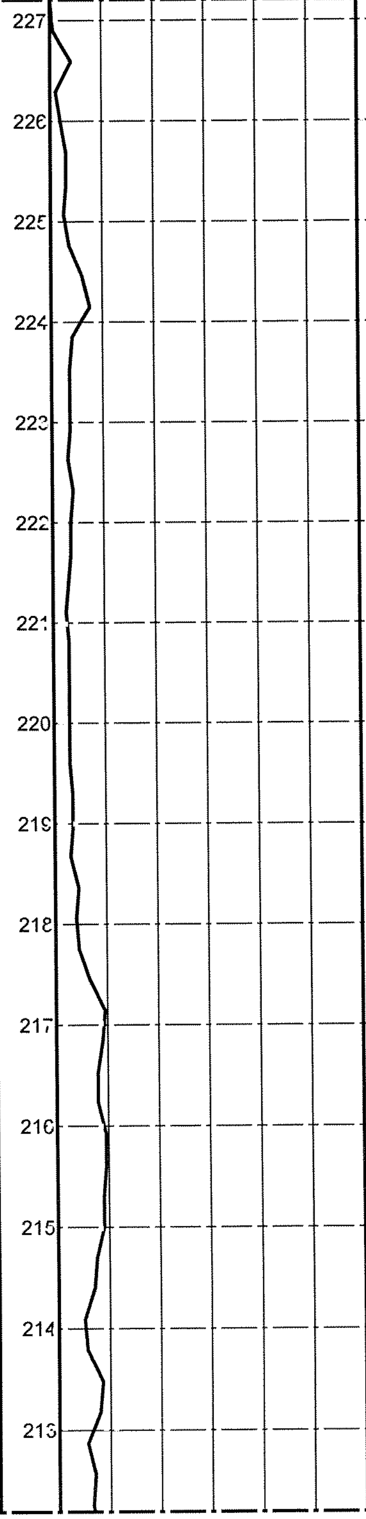
Golder Associates

RECORD OF BOREHOLE No DCPT-69

1 OF 2 **METRIC**

PROJECT 03-1111-011
W.P. 327-91-00
LOCATION N 5138493.0 ;E 317556.6
DIST HWY 69
BOREHOLE TYPE Dynamic Cone
DATUM Geodetic
DATE
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.2 0.0	GROUND SURFACE										



Continued Next Page

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

MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

RECORD OF BOREHOLE No DCPT-69

2 OF 2

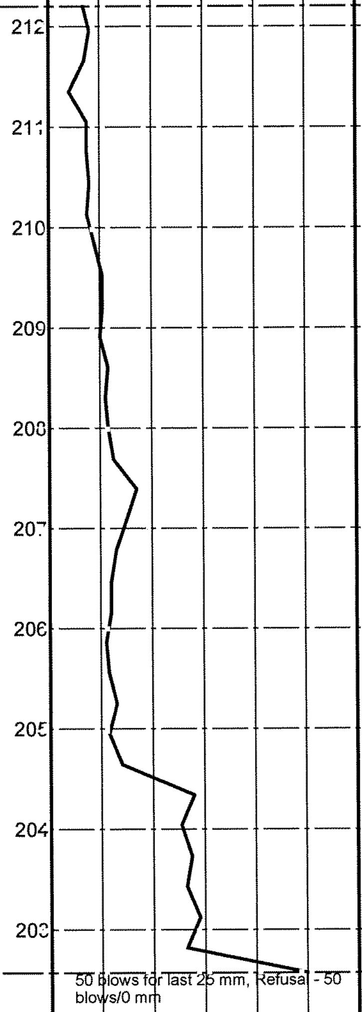
METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ______ HWY 69
DATUM Geodetic

LOCATION N 5138493.0 ;E 317556.6
BOREHOLE TYPE Dynamic Cone
DATE

ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES					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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	— CONTINUED FROM PREVIOUS PAGE —										
202.6 24.6	End of dynamic cone test Refusal to penetration							50 blows for last 25 mm, Refusal - 50 blows/0 mm			



MISS_MTO 03111011AAENV.GPJ ON_MOT.GDT 18/5/05

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

RECORD OF BOREHOLE No DCPT-70

1 OF 2

METRIC

PROJECT 03-1111-011

W.P. 327-91-00

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5138495.8 ;E 317614.6

BOREHOLE TYPE Dynamic Cone

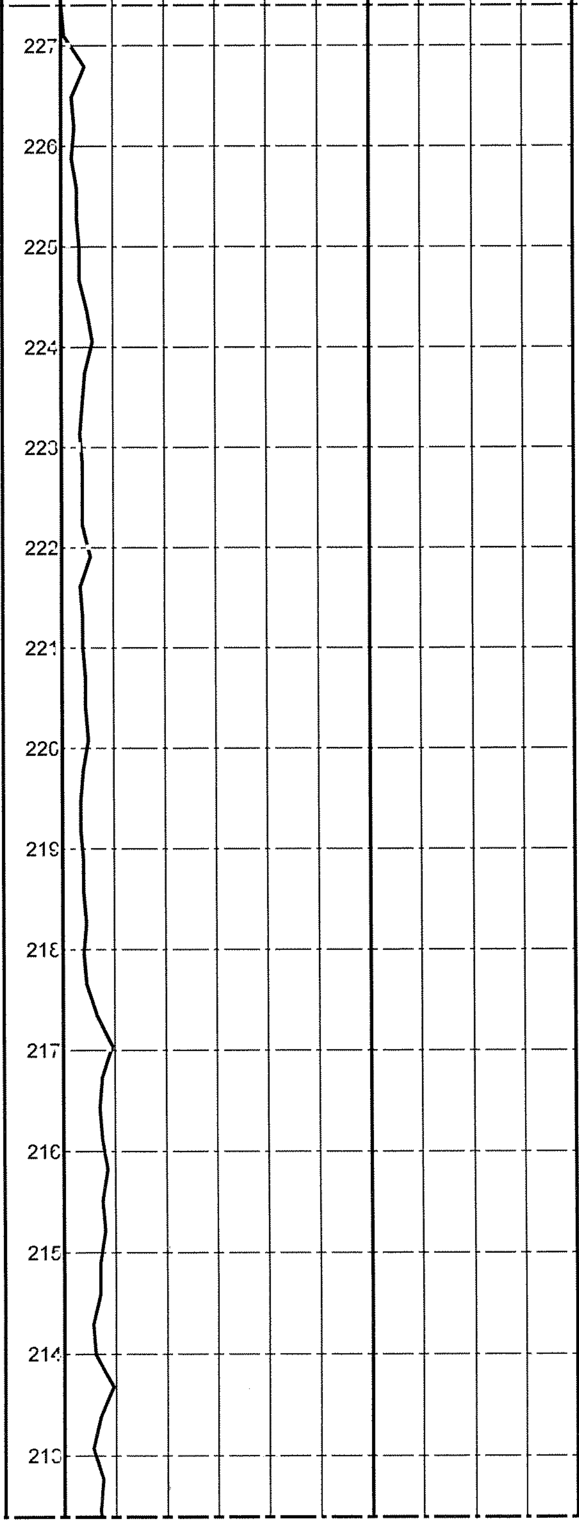
DATE

ORIGINATED BY SB

COMPILED BY SEP

CHECKED BY ASP

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.4 0.0	GROUND SURFACE										



Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

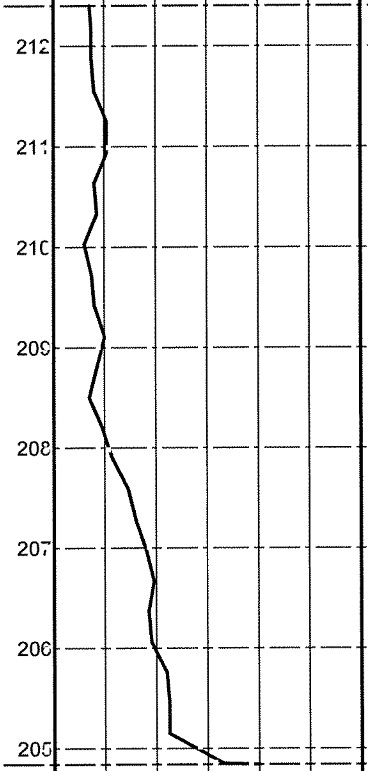
○ $^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No DCPT-70 2 OF 2 METRIC

PROJECT 03-1111-011
W.P. 327-91-00
DIST ______ HWY 69
DATUM Geodetic
LOCATION N 5138495.8 ;E 317614.6
BOREHOLE TYPE Dynamic Cone
DATE
ORIGINATED BY SB
COMPILED BY SEP
CHECKED BY ASP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
204.8 22.6	End of dynamic cone test Refusal to penetration							66 blows for last 300 mm Refusal - 50 blows/0 mm			



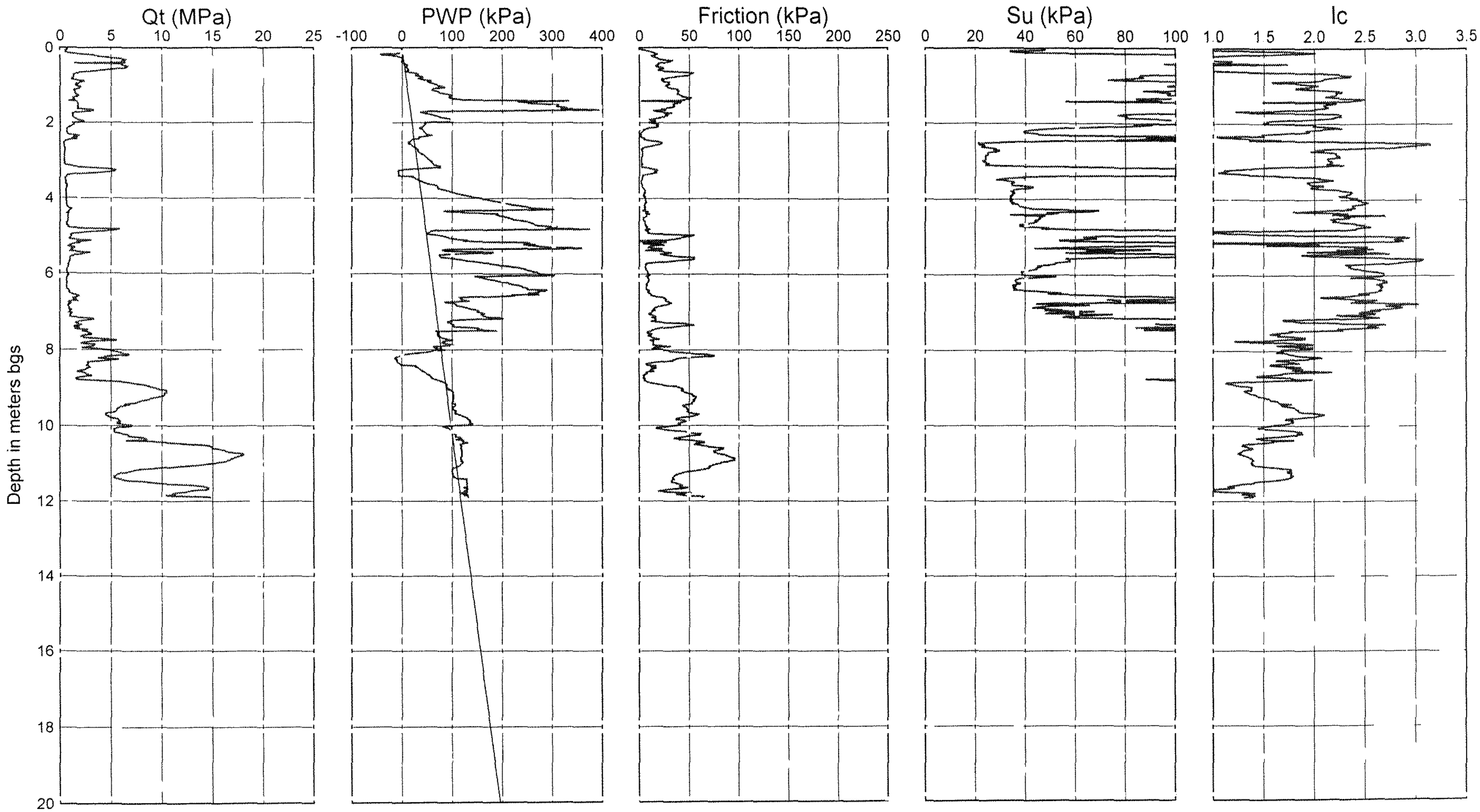
$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

Cone Penetration Test - CPT03-39

Test Date : September 3, 2003
Location : STA 11+950 CL

Operator : Golder Associates

Ground Surf. Elev. : 228.70
Water Table Depth : 0.00



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 <Ic < 1.90 - Clean to silty sand
1.90 <Ic < 2.54 - Silty sand to sandy silt
2.54 <Ic < 2.82 - Clayey silt to silty clay
2.82 <Ic < 3.22 - Clays

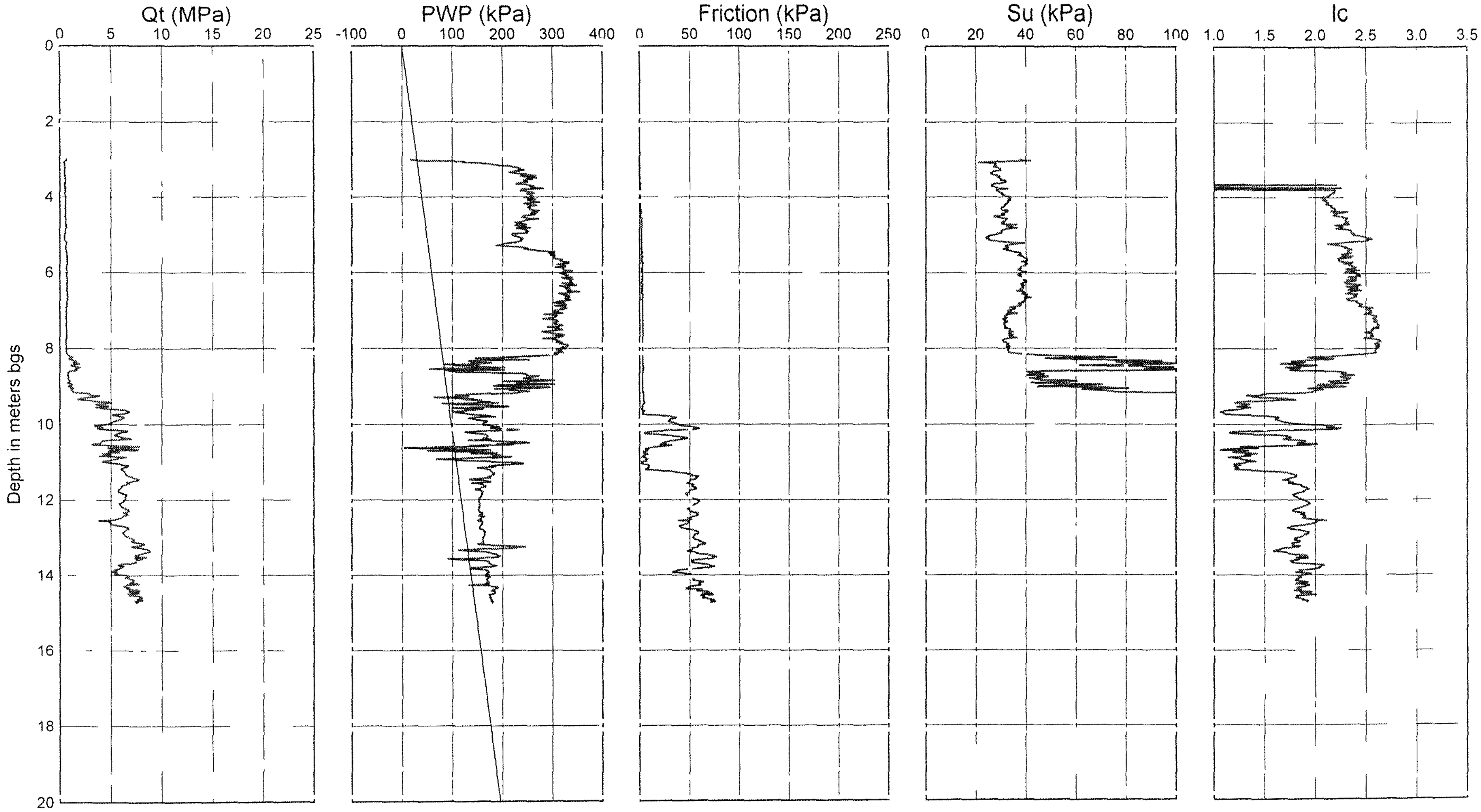
PROJECT NO 03-1111-011 DATE June 2004 DRAWN BY: CN

Cone Penetration Test - CPT03-42R

Test Date : September 22, 2003
Location : STA 12+175 o/s 13.9 m Rt

Operator : Golder Associates

Ground Surf. Elev. : 227.50
Water Table Depth : 0.00



Qt normalized for
unequal end area effects

Su = (Qt - SigmaV) / Nk
Nk = 15
Gamma = 18 kN/m³

After Jefferies and Davies (1991)
Ic < 1.25 - Gravelly sands
1.25 < Ic < 1.90 - Clean to silty sand
1.90 < Ic < 2.54 - Silty sand to sandy silt
2.54 < Ic < 2.82 - Clayey silt to silty clay
2.82 < Ic < 3.22 - Clays

PROJECT NO 03-1111-011 DATE DRAWN BY CN

APPENDIX I

NON-STANDARD SPECIAL PROVISIONS

ROCK EMBANKMENT - Item No.

Non-Standard Special Provision

Culvert Backfill

For the culverts at Highway 69 Stations 12+200, 14+100 and 14+940, the rock fill backfill over the culvert should have a maximum size of 250 mm and the maximum lift thickness should be limited to 1 m.

Erosion Protection

Where rock fill is used for erosion protection at the culvert inlets and outlets, the rock fill should have a maximum size of 250 mm.

Payment

Payment at the Contract Price for the above tender item shall include all labour, equipment, and materials required to do the work.

ROCK EXCAVATION (GRADING) - Item No.

Non-Standard Special Provision

Re-chinking Existing Rock Fills

At all locations where existing rock fills are excavated under the new roadbed, the new top of rock fill is to be re-chinked with rock fragments to form the new subgrade in accordance with OPSS 206.

Chinking Shattered Rock for Staged Construction

Prior to placing granular materials on top of shattered rock for the construction of staged areas as shown on the Contract Drawings, the temporary rock subgrade is to be chinked in accordance with OPSS 206.

Payment

Payment at the Contract Price for the above tender item shall include all labour, equipment, and materials required to do the work.