

FOUNDATION INVESTIGATION REPORT
PROPOSED RECONSTRUCTION OF
STRUCTURAL CULVERT - SITE 2-474-C
HIGHWAY 21 FROM KINCARDINE TO TIVERTON
G.W.P. 408-94-00
Agreement # 3005-E-0038



I.E.
C.C.



Infrastructure Engineering Group Inc.

Pavement & Construction Materials Consulting Engineers

GTA • Kitchener • London • Windsor

Corporate Office
39-69 Bessemer Road
London, Ontario
N6E 2V6
tel: (519) 680-9991
fax: (519) 680-9993
email: info@lawengineering.com

FOUNDATION INVESTIGATION REPORT
PROPOSED RECONSTRUCTION OF
STRUCTURAL CULVERT - SITE 2-474-C
HIGHWAY 21 FROM KINCARDINE TO TIVERTON

G.W.P. 408-94-00
Agreement # 3005-E-0038

Prepared for:

SNC-Lavalin Engineers & Contractors Inc.
2200 Lake Shore Boulevard West
Toronto, Ontario
Canada M8V 1A4

Mr. Bing Wong, P.Eng

Prepared by:

Infrastructure Engineering Group Inc.
39-69 Bessemer Road
London, Ontario
N6E 2V6

September 28, 2007
06-8-IEG2-474

Distribution:

9	Copies -	SNC-Lavalin Engineers & Contractors Inc.
3	Digital Copies -	SNC-Lavalin Engineers & Contractors Inc.
3	Copies -	Infrastructure Engineering Group Inc.

Geocres No.: 41A-190

TABLE OF CONTENTS

PART A – FOUNDATION INVESTIGATION	1
1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
2.1 Site Location.....	1
2.2 Physiography and Topography.....	2
3.0 INVESTIGATION PROCEDURES.....	2
3.1 Field Investigation	2
3.2 Laboratory Analysis	3
4.0 SUBSURFACE CONDITIONS	3
4.1 General Subsurface Conditions	3
4.1.1 Pavement, Fill, Topsoil.....	4
4.1.2 Sandy Silt Till	4
4.1.3 Silty Clay Till.....	4
4.2 Groundwater Conditions.....	5
5.0 STATEMENT OF LIMITATION	6

Drawings & Appendices

Drawing 1	Borehole Locations and Soil Strata	
Appendix “A”	Explanation of Terms Used in Report	
	Record of Borehole Sheets	Boreholes 2-474-C1 to 2-474-C3
Appendix “B”	Laboratory Test Results	
	Grain Size Distribution	Figures 1, 2 and 3
	Plasticity Chart	Figure 4
Appendix “C”	Limitations of Report	
Appendix “D”	Site Photographs	

PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out in September 2006 by Infrastructure Engineering Group Inc. on behalf of SNC-Lavalin Engineers & Contractors Inc.

The assignment involves the reconstruction/rehabilitation of the pavement structure on Highway 21 from 0.63 m north of the intersection with Highway 9 (north of Kincardine) northerly to 1.2 km east of the intersection with Bruce County Road 15 (west junction in the Village of Tiverton) for 12.4 km; including pavement rehabilitation/reconstruction throughout, snow drifting/storage treatments, structural culvert replacement/rehabilitation, non-structural culvert replacement, minor intersection improvements, drainage improvements and minor electrical work.

Foundation investigation and recommendations are required for the design and construction of culvert replacements as part of the improvement of Highway 21. Five (5) structural culverts and twenty-four (24) non-structural culverts are to be investigated. This report covers the site of Structure 2-474-C.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes and, based on the findings, to provide geotechnical recommendations for the foundation elements. The existing culvert is to be replaced with a new culvert.

Authorization to complete this assignment was given by Mr. Bing Wong, Project Manager, SNC-Lavalin Engineers and Constructors Inc., the TPM Consultant who is completing this assignment for MTO under Agreement # 3005-E-0038.

2.0 SITE DESCRIPTION

2.1 Site Location

Structure 2-474-C is located on Highway 21, approximately 8.3 km north of Highway 9, located at station 21+869. Photographs of this culvert site are presented in Appendix D. The existing structure is a reinforced concrete, rigid frame open footing culvert having dimensions of 3.60 m wide by 1.80 m high by 15.63 m long, with an overfill height of 1.3 m. The culvert opening dimensions were provided by AGM. Concrete headwalls exist at both ends of the culvert. Brown silty clay deposit was noted at the streambed.

The culvert site is located within a drainage valley in which the stream flows westward. The approach embankments were built on both the north and south sides of the culvert, with a maximum height of approximately 4 m. The embankment slopes are typically 2.5H to 3H:1V and are grass covered. No signs of embankment slope instability were observed at the time of this foundation investigation.

2.2 Physiography and Topography

The site is located within the Physiographic Region known as the “Huron–slope” (Chapman and Putnam, 1984) which occupies the area east of Lake Huron between Sarnia and Tobermory. The area is characterized by a flat topography, heavy textured soil and poor drainage. The surficial deposits consist of brown, calcareous clayey tills, which contain very few cobbles and boulders. The tills are known to be underlain by grey stratified clays of lacustrine origin.

The asphalt pavement surface over the existing culvert is near elevation 226.6 m while the ground surface at the base of the embankment and in the flood plain is between elevations 221.3 m and 224.1 m.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

On September 18 and 19, 2006, a CME 55 drill rig was supplied by London Soil Test Limited and used on site for drilling and Standard Penetration Testing (SPT, following the procedures of ASTM D 1586). Three (3) boreholes were drilled and sampled to obtain data for foundation design of the proposed replacement culvert. The locations of the boreholes are shown on Drawing 1.

The boreholes were numbered 2-474-C-1 to 2-474-C-3 and the depths of sampling were as follows:

Borehole No.	Depth of Sampling (m)
2-474-C-1	8.08
2-474-C-2	8.08
2-474-C-3	10.52

The boreholes were drilled using continuous flight solid stem augers. Soil samples were retrieved at selected intervals throughout the depths of the boreholes in conjunction with Standard Penetration Tests (SPT). Samples were generally taken at intervals of depth of 0.75 m to the maximum depth of exploration.

Field pocket penetrometer was used on the retrieved SPT samples to determine the undrained shear strength of the cohesive soil deposits. It should be noted that the measured shear strength value would be lower than the actual value due to sampling disturbance.

Seepage and water levels were noted in each borehole during and at the completion of drilling and sampling. All boreholes were grouted with a bentonite/cement mix at completion of sampling in accordance with Ontario Regulation 903.

Our field engineer, Mr. Ralph Billings, P. Eng., supervised the fieldwork and worked under the direction of the project engineer, Mr. Eric Chung, P. Eng. Our field staff cleared the location of buried utilities and logged the boreholes. The soil samples obtained were placed in labeled containers and transported to IEG's London laboratory for further examination and laboratory testing.

The stations, offsets and ground surface elevations at the as drilled borehole locations were surveyed by AGM London and provided to Infrastructure Engineering Group Inc. for the purpose of this report.

The results of the drilling, sampling, in-situ testing and groundwater observations are summarized on the Record of Borehole sheets and enclosed in Appendix "A".

3.2 Laboratory Analysis

Geotechnical laboratory testing consisted of natural moisture content determinations and visual classifications of all retrieved soil samples. In addition, grain size analyses, Atterberg Limit tests and unit weight tests were performed on selected samples.

The results of the laboratory testing are presented on the Record of Borehole sheets (Appendix "A"), and in the Laboratory Test Results (Figures 1 to 4, Appendix "B").

4.0 SUBSURFACE CONDITIONS

4.1 General Subsurface Conditions

Reference is made to the Record of Borehole sheets (Appendix "A") and Laboratory Test Results (Appendix "B") for detailed subsurface soil and groundwater conditions encountered in the boreholes. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, consequently, represent transitions between soil types rather than exact planes of geological change. The soil profiles depicting the subsurface conditions on Drawing 1 will vary between and beyond the borehole locations.

In general, the subsurface deposits at the site consist of loose to compact embankment fill placed on hard to stiff silty clay till.

4.1.1 Pavement, Fill, Topsoil

Borehole 2-474-C-3, located at the east edge of existing pavement in the shoulder area, encountered 1.37 m shoulder gravel. Underlying the shoulder gravel is the embankment fill material that extended to a depth of 4.04 m (elevation 222.43 m). The fill beneath the shoulder gravel consists of a mixture of silty clay and clayey silt, with some sand and gravel and occasional organic inclusions.

At Boreholes 2-474-C-1 and 2-474-C-2, topsoil was contacted to depths of 0.61 m (elevation 222.95 m) and 0.25 m (elevation 223.00 m) respectively.

Three (3) typical grain size distributions of the embankment fill are shown on Figure 1 of Appendix "B".

Standard penetration tests yielded "N"-values from 7 to 9 blows per 0.3 m. This fill is brown to grey in colour and the measured natural moisture contents range from 8 to 29%. Based on the above field and laboratory test results, together and tactile examination, the fill materials exhibited loose to compact compactness condition.

The unit weight of the fill, based on one test of the silt to clay fill, was measured to be 19.6 kN/m³.

4.1.2 Sandy Silt Till

The topsoil at Borehole 2-474-C-1 was underlain by a 1.07 m thick sandy silt till layer, which extended to a depth of 1.68 m (elevation 221.88 m). One (1) grain size analysis was performed and the results are plotted on Figure 2 of Appendix "B".

One standard penetration test yielded an "N"-value of 14 blows per 0.3 m. The natural moisture content was measured to be 10%. Based on the above field and laboratory test results, together with visual and tactile examination, the sandy silt till is considered to have compact compactness condition.

4.1.3 Silty Clay Till

A major stratum of brown to grey silty clay till was contacted below the above-mentioned soil units, and extended to the full depth of all of the borehole explorations (i.e., 8.08 m below the ground surface at Borehole 2-474-C-2, elevation 215.17 m).

Seven (7) grain size analyses were performed and the results are plotted on Figure 3 of Appendix "B". Within the silty clay till, embedded sand and gravel particles were found, as well as wet silt partings.

Standard penetration tests yielded “N”-values from 11 to 76 blows per 0.3 m. Undrained shear strength as determined from field pocket penetrometer ranged from over 225 to 25 kPa. Five (5) unit weight tests were conducted on the silty clay till and yielded results of 22.9 and 24.2 kN/m³.

Seven (7) samples were tested and exhibited the following Atterberg Limits. These results are shown in Figure 4 of Appendix “B” and summarized below:

Liquid Limit (W_L)	20 to 29%, average at 25.6%
Plastic Limit (W_P)	12 to 16%, average at 14.6%
Plasticity Index (I_p)	8 to 13%, average at 11.0%

The natural moisture contents were in the range of 10 to 32%. These results are characteristic of clayey soils of low plasticity (CL). The measured natural moisture contents are generally near or below the measured plastic limits and indicate that the deposit is pre-consolidated.

Based on the above field and laboratory test results, together with visual and tactile examination, the silty clay silt till deposit has a desiccated, very stiff to hard crust of approximately 3 to 4 m thick. Below the crust, the stratum decreases in consistency from very stiff to stiff.

4.2 Groundwater Conditions

The groundwater condition was monitored during and upon completion of sampling. On completion of drilling, groundwater levels were noted in Boreholes 2-474-C-1 and 474-C-2 at depths of 0.9 m and 4.4 m respectively below ground surface, corresponding to elevations 222.66 m and 218.85 m. The water entered the boreholes from native wet sandy silt till layer at Borehole 2-474-C-1 and from wet silt partings and seams at Borehole 2-474-C-2.

Borehole 2-474-C-3 remained dry and open throughout the sampling operations.

The water level in the creek was approximately 0.3m above the stream bed at the time of the investigation and reflected a low flow condition.

It should be noted that the groundwater level will fluctuate seasonally and in response to weather events. Under adverse conditions, water could be perched within the embankment fill and sandy silt till, and on top of the silty clay till. It is reasonable to assume that groundwater could be similar to the water level in the creek during high flow conditions.

5.0 STATEMENT OF LIMITATION

We recommend that once the details of the proposed structure are finalized, our recommendations should be reviewed for their specific applicability.

The Limitations of Report, as Quoted in Appendix “C”, is an integral part of this report.

We trust that we have completed the assignment within the Terms of Reference for this project. If there are any questions concerning this report, please do not hesitate to contact our office.

Yours truly,
Infrastructure Engineering Group Inc.

Eric Y. Chung, M.Eng., P.Eng.
Designated MTO Contact

Joseph Law, P.Eng.
Project Manager

Tom O'Dwyer, P. Eng.
Quality Review Engineer

TABLE OF CONTENTS

PART A – FOUNDATION INVESTIGATION	1
1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION	1
2.1 Site Location.....	1
2.2 Physiography and Topography	2
3.0 INVESTIGATION PROCEDURES.....	2
3.1 Field Investigation	2
3.2 Laboratory Analysis	3
4.0 SUBSURFACE CONDITIONS	3
4.1 General Subsurface Conditions	3
4.1.1 Pavement, Fill, Topsoil	4
4.1.2 Sandy Silt Till	4
4.1.3 Silty Clay Till.....	4
4.2 Groundwater Conditions.....	5
5.0 STATEMENT OF LIMITATION	6

Drawings & Appendices

Drawing 1	Borehole Locations and Soil Strata	
Appendix “A”	Explanation of Terms Used in Report	
	Record of Borehole Sheets	Boreholes 2-474-C1 to 2-474-C3
Appendix “B”	Laboratory Test Results	
	Grain Size Distribution	Figures 1, 2 and 3
	Plasticity Chart	Figure 4
Appendix “C”	Limitations of Report	
Appendix “D”	Site Photographs	

PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out in September 2006 by Infrastructure Engineering Group Inc. on behalf of SNC-Lavalin Engineers & Contractors Inc.

The assignment involves the reconstruction/rehabilitation of the pavement structure on Highway 21 from 0.63 m north of the intersection with Highway 9 (north of Kincardine) northerly to 1.2 km east of the intersection with Bruce County Road 15 (west junction in the Village of Tiverton) for 12.4 km; including pavement rehabilitation/reconstruction throughout, snow drifting/storage treatments, structural culvert replacement/rehabilitation, non-structural culvert replacement, minor intersection improvements, drainage improvements and minor electrical work.

Foundation investigation and recommendations are required for the design and construction of culvert replacements as part of the improvement of Highway 21. Five (5) structural culverts and twenty-four (24) non-structural culverts are to be investigated. This report covers the site of Structure 2-474-C.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes and, based on the findings, to provide geotechnical recommendations for the foundation elements. The existing culvert is to be replaced with a new culvert.

Authorization to complete this assignment was given by Mr. Bing Wong, Project Manager, SNC-Lavalin Engineers and Constructors Inc., the TPM Consultant who is completing this assignment for MTO under Agreement # 3005-E-0038.

2.0 SITE DESCRIPTION

2.1 Site Location

Structure 2-474-C is located on Highway 21, approximately 8.3 km north of Highway 9, located at station 21+869. Photographs of this culvert site are presented in Appendix D. The existing structure is a reinforced concrete, rigid frame open footing culvert having dimensions of 3.60 m wide by 1.80 m high by 15.63 m long, with an overfill height of 1.3 m. The culvert opening dimensions were provided by AGM. Concrete headwalls exist at both ends of the culvert. Brown silty clay deposit was noted at the streambed.

The culvert site is located within a drainage valley in which the stream flows westward. The approach embankments were built on both the north and south sides of the culvert, with a maximum height of approximately 4 m. The embankment slopes are typically 2.5H to 3H:1V and are grass covered. No signs of embankment slope instability were observed at the time of this foundation investigation.

2.2 Physiography and Topography

The site is located within the Physiographic Region known as the “Huron–slope” (Chapman and Putnam, 1984) which occupies the area east of Lake Huron between Sarnia and Tobermory. The area is characterized by a flat topography, heavy textured soil and poor drainage. The surficial deposits consist of brown, calcareous clayey tills, which contain very few cobbles and boulders. The tills are known to be underlain by grey stratified clays of lacustrine origin.

The asphalt pavement surface over the existing culvert is near elevation 226.6 m while the ground surface at the base of the embankment and in the flood plain is between elevations 221.3 m and 224.1 m.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

On September 18 and 19, 2006, a CME 55 drill rig was supplied by London Soil Test Limited and used on site for drilling and Standard Penetration Testing (SPT, following the procedures of ASTM D 1586). Three (3) boreholes were drilled and sampled to obtain data for foundation design of the proposed replacement culvert. The locations of the boreholes are shown on Drawing 1.

The boreholes were numbered 2-474-C-1 to 2-474-C-3 and the depths of sampling were as follows:

Borehole No.	Depth of Sampling (m)
2-474-C-1	8.08
2-474-C-2	8.08
2-474-C-3	10.52

The boreholes were drilled using continuous flight solid stem augers. Soil samples were retrieved at selected intervals throughout the depths of the boreholes in conjunction with Standard Penetration Tests (SPT). Samples were generally taken at intervals of depth of 0.75 m to the maximum depth of exploration.

Field pocket penetrometer was used on the retrieved SPT samples to determine the undrained shear strength of the cohesive soil deposits. It should be noted that the measured shear strength value would be lower than the actual value due to sampling disturbance.

Seepage and water levels were noted in each borehole during and at the completion of drilling and sampling. All boreholes were grouted with a bentonite/cement mix at completion of sampling in accordance with Ontario Regulation 903.

Our field engineer, Mr. Ralph Billings, P. Eng., supervised the fieldwork and worked under the direction of the project engineer, Mr. Eric Chung, P. Eng. Our field staff cleared the location of buried utilities and logged the boreholes. The soil samples obtained were placed in labeled containers and transported to IEG's London laboratory for further examination and laboratory testing.

The stations, offsets and ground surface elevations at the as drilled borehole locations were surveyed by AGM London and provided to Infrastructure Engineering Group Inc. for the purpose of this report.

The results of the drilling, sampling, in-situ testing and groundwater observations are summarized on the Record of Borehole sheets and enclosed in Appendix "A".

3.2 Laboratory Analysis

Geotechnical laboratory testing consisted of natural moisture content determinations and visual classifications of all retrieved soil samples. In addition, grain size analyses, Atterberg Limit tests and unit weight tests were performed on selected samples.

The results of the laboratory testing are presented on the Record of Borehole sheets (Appendix "A"), and in the Laboratory Test Results (Figures 1 to 4, Appendix "B").

4.0 SUBSURFACE CONDITIONS

4.1 General Subsurface Conditions

Reference is made to the Record of Borehole sheets (Appendix "A") and Laboratory Test Results (Appendix "B") for detailed subsurface soil and groundwater conditions encountered in the boreholes. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, consequently, represent transitions between soil types rather than exact planes of geological change. The soil profiles depicting the subsurface conditions on Drawing 1 will vary between and beyond the borehole locations.

In general, the subsurface deposits at the site consist of loose to compact embankment fill placed on hard to stiff silty clay till.

4.1.1 Pavement, Fill, Topsoil

Borehole 2-474-C-3, located at the east edge of existing pavement in the shoulder area, encountered 1.37 m shoulder gravel. Underlying the shoulder gravel is the embankment fill material that extended to a depth of 4.04 m (elevation 222.43 m). The fill beneath the shoulder gravel consists of a mixture of silty clay and clayey silt, with some sand and gravel and occasional organic inclusions.

At Boreholes 2-474-C-1 and 2-474-C-2, topsoil was contacted to depths of 0.61 m (elevation 222.95 m) and 0.25 m (elevation 223.00 m) respectively.

Three (3) typical grain size distributions of the embankment fill are shown on Figure 1 of Appendix "B".

Standard penetration tests yielded "N"-values from 7 to 9 blows per 0.3 m. This fill is brown to grey in colour and the measured natural moisture contents range from 8 to 29%. Based on the above field and laboratory test results, together and tactile examination, the fill materials exhibited loose to compact compactness condition.

The unit weight of the fill, based on one test of the silt to clay fill, was measured to be 19.6 kN/m³.

4.1.2 Sandy Silt Till

The topsoil at Borehole 2-474-C-1 was underlain by a 1.07 m thick sandy silt till layer, which extended to a depth of 1.68 m (elevation 221.88 m). One (1) grain size analysis was performed and the results are plotted on Figure 2 of Appendix "B".

One standard penetration test yielded an "N"-value of 14 blows per 0.3 m. The natural moisture content was measured to be 10%. Based on the above field and laboratory test results, together with visual and tactile examination, the sandy silt till is considered to have compact compactness condition.

4.1.3 Silty Clay Till

A major stratum of brown to grey silty clay till was contacted below the above-mentioned soil units, and extended to the full depth of all of the borehole explorations (i.e., 8.08 m below the ground surface at Borehole 2-474-C-2, elevation 215.17 m).

Seven (7) grain size analyses were performed and the results are plotted on Figure 3 of Appendix "B". Within the silty clay till, embedded sand and gravel particles were found, as well as wet silt partings.

Standard penetration tests yielded “N”-values from 11 to 76 blows per 0.3 m. Undrained shear strength as determined from field pocket penetrometer ranged from over 225 to 25 kPa. Five (5) unit weight tests were conducted on the silty clay till and yielded results of 22.9 and 24.2 kN/m³.

Seven (7) samples were tested and exhibited the following Atterberg Limits. These results are shown in Figure 4 of Appendix “B” and summarized below:

Liquid Limit (W_L)	20 to 29%, average at 25.6%
Plastic Limit (W_P)	12 to 16%, average at 14.6%
Plasticity Index (I_p)	8 to 13%, average at 11.0%

The natural moisture contents were in the range of 10 to 32%. These results are characteristic of clayey soils of low plasticity (CL). The measured natural moisture contents are generally near or below the measured plastic limits and indicate that the deposit is pre-consolidated.

Based on the above field and laboratory test results, together with visual and tactile examination, the silty clay silt till deposit has a desiccated, very stiff to hard crust of approximately 3 to 4 m thick. Below the crust, the stratum decreases in consistency from very stiff to stiff.

4.2 Groundwater Conditions

The groundwater condition was monitored during and upon completion of sampling. On completion of drilling, groundwater levels were noted in Boreholes 2-474-C-1 and 474-C-2 at depths of 0.9 m and 4.4 m respectively below ground surface, corresponding to elevations 222.66 m and 218.85 m. The water entered the boreholes from native wet sandy silt till layer at Borehole 2-474-C-1 and from wet silt partings and seams at Borehole 2-474-C-2.

Borehole 2-474-C-3 remained dry and open throughout the sampling operations.

The water level in the creek was approximately 0.3m above the stream bed at the time of the investigation and reflected a low flow condition.

It should be noted that the groundwater level will fluctuate seasonally and in response to weather events. Under adverse conditions, water could be perched within the embankment fill and sandy silt till, and on top of the silty clay till. It is reasonable to assume that groundwater could be similar to the water level in the creek during high flow conditions.

5.0 STATEMENT OF LIMITATION

We recommend that once the details of the proposed structure are finalized, our recommendations should be reviewed for their specific applicability.

The Limitations of Report, as Quoted in Appendix “C”, is an integral part of this report.

We trust that we have completed the assignment within the Terms of Reference for this project. If there are any questions concerning this report, please do not hesitate to contact our office.

Yours truly,
Infrastructure Engineering Group Inc.

Eric Y. Chung, M.Eng., P.Eng.
Designated MTO Contact

Joseph Law, P.Eng.
Project Manager

Tom O'Dwyer, P. Eng.
Quality Review Engineer

5.0 STATEMENT OF LIMITATION

We recommend that once the details of the proposed structure are finalized, our recommendations should be reviewed for their specific applicability.

The Limitations of Report, as Quoted in Appendix "C", is an integral part of this report.

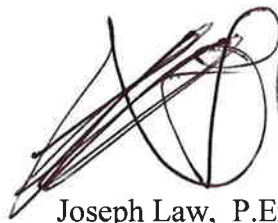
We trust that we have completed the assignment within the Terms of Reference for this project. If there are any questions concerning this report, please do not hesitate to contact our office.

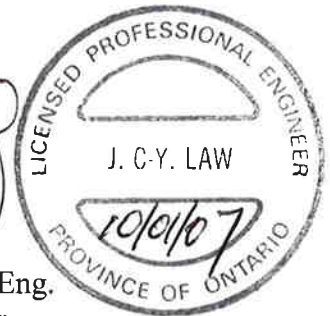
Yours truly,

Infrastructure Engineering Group Inc.


Eric Y. Chung, M.Eng., P.Eng.
Designated MTO Contact




Joseph Law, P.Eng.
Project Manager





Tom O'Dwyer, P. Eng.
Quality Review Engineer



Ministry of Transportation/SNC-LAVALIN
G.W.P. 408-94-00
Reconstruction of Highway 21 from Kincardine northerly to Tiverton
Agreement # 3005-E-0038

06-8-IEG2-474
Final Report
Drawing 1
September 28, 2007

Drawing 1
Borehole Locations
And
Soil Strata

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

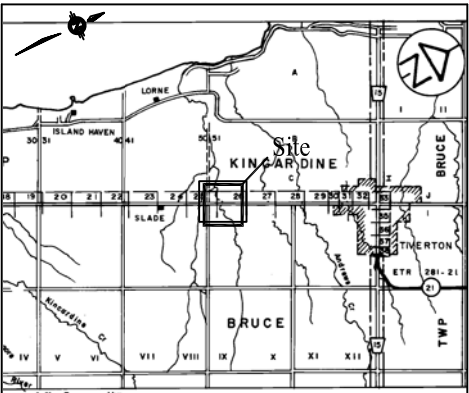
CONT No XXXX-XXXX
WP No GWP 408-94-00



Culvert # 2-474
Highway 21

SHEET
1

I.E. Infrastructure Engineering Group Inc.
Pavement & Construction Materials Consulting Engineers
GTA • Kitchener • London • Windsor

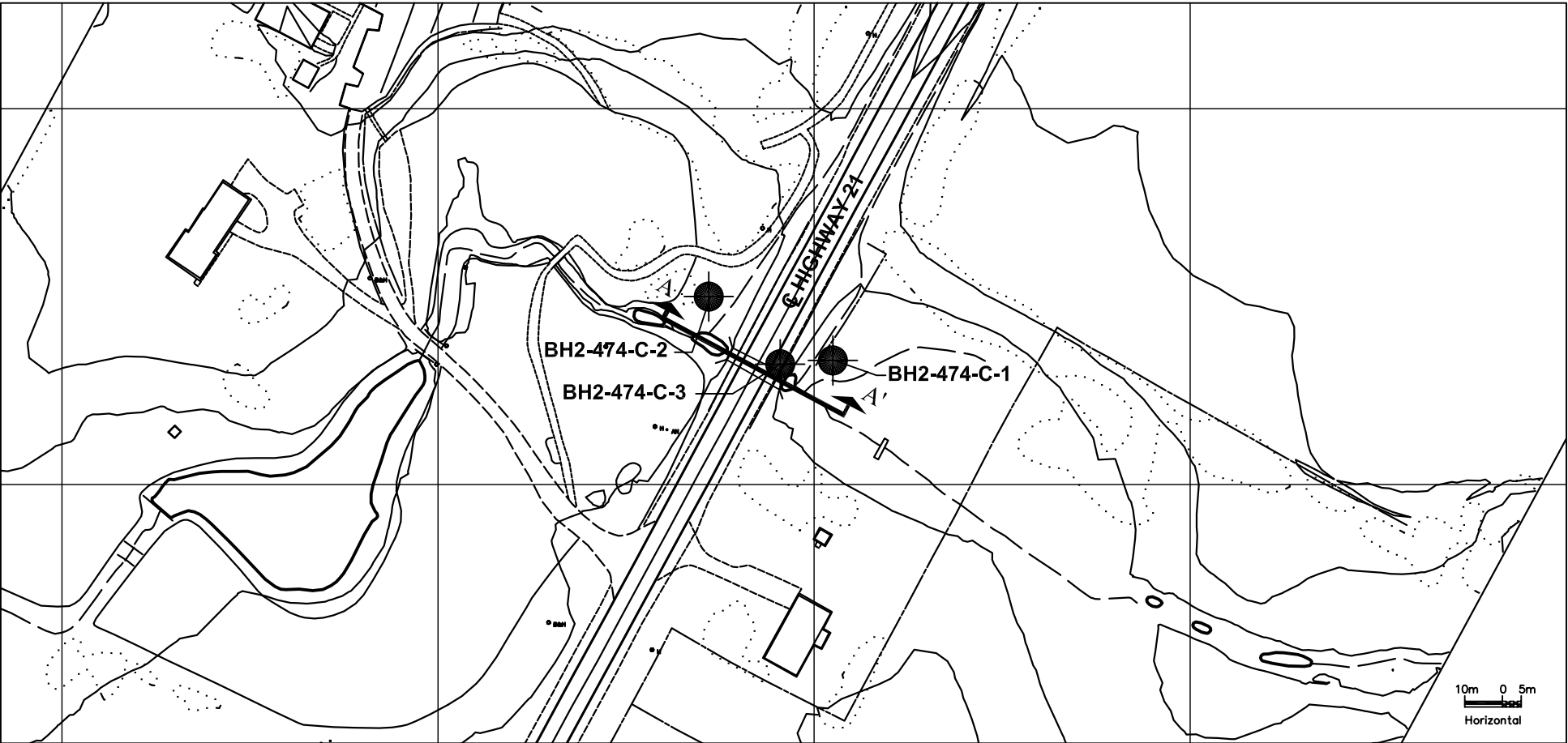


KEYPLAN

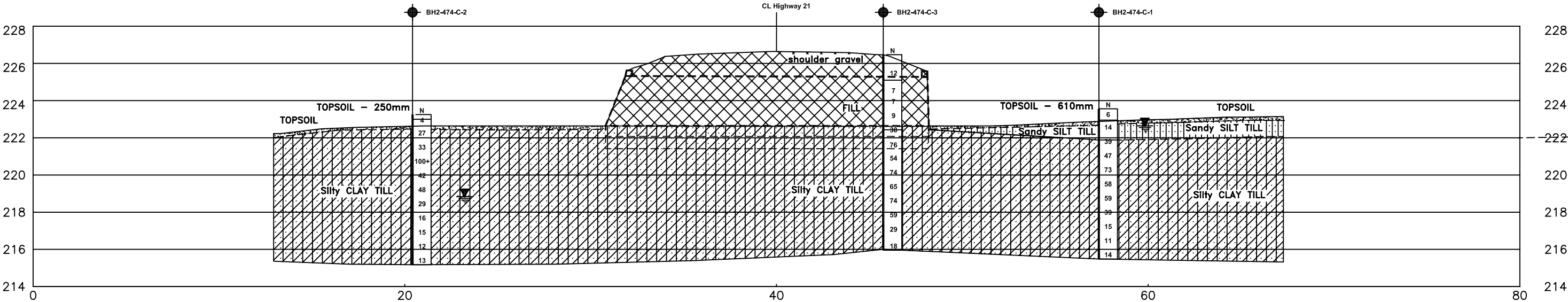
NTS

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation
- Standpipe



BOREHOLE LOCATION PLAN



SECTION A-A'
CENTERLINE OF CULVERT



REVISIONS	21/06/07	J.L.	Final
	15/01/07	J.L.	Draft
	DATE	BY	DISCRIPTION

MTO GEOCRES No. 41A-190

- NOTES
- THE COMPLETE FOUNDATION INVESTIGATION AND DESIGN REPORT FOR THIS PROJECT AND OTHER RELATED DOCUMENTS MAY BE EXAMINED AT THE ENGINEERING MATERIALS OFFICE, DOWNSVIEW. INFORMATION CONTAINED IN THIS REPORT AND RELATED DOCUMENTS ARE SPECIFICALLY EXCLUDED IN ACCORDANCE WITH THE CONDITIONS OF SECTION GC2.01 OF OPS GEN. COND.
 - THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BOREHOLE LOCATIONS. BETWEEN BOREHOLES AND BOUNDARIES ARE ASSUMED FROM GEOLOGICAL EVIDENCE.
 - SUBGRADE ELEVATION OF THE EXISTING FOOTING NOT KNOWN AND IS ESTIMATED TO BE AT 1.2m BELOW THE CREEK BED.
 - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

BOREHOLE NO.	ELEVATION	UTM CO-ORDINATES		HWY No.	HWY 21			DIST	Owen Sound
		NORTH	EAST		SUBM'D	J.L.	CHECKED E.C.		
2-474-C-1	223.56	4900233	379405	DRAWN	J.L.	CHECKED J.L.	APPROVED E.C.	DWG	1
2-474-C-2	223.25	4900250	379372						
2-474-C-3	226.47	4900232	379391						

Ministry of Transportation/SNC-LAVALIN
G.W.P. 408-94-00
Reconstruction of Highway 21 from Kincardine northerly to Tiverton
Agreement # 3005-E-0038

06-8-IEG2-474
Final Report
Appendix A
September 28, 2007

Appendix A

Explanation of Terms Used in Report

Record of Borehole Sheet

Boreholes 2-474-C1 to 2-474-C3

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 1" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T.W. ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T.W. ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_r	kPa	RESIDUAL SHEAR STRENGTH
τ_c	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_c}$

PHYSICAL PROPERTIES OF SOIL

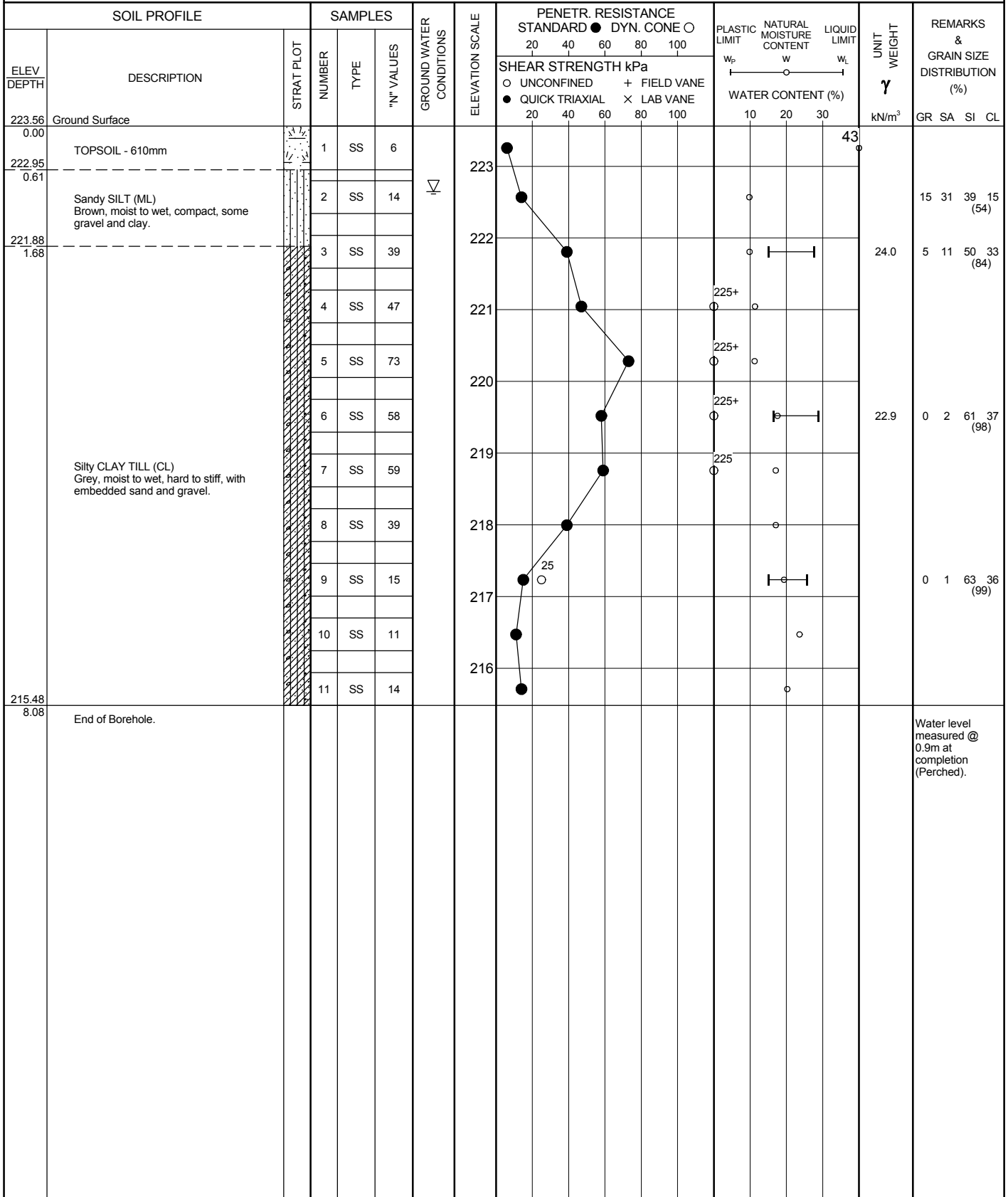
ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1. %	VOID RATIO	e_{min}	1. %	VOID RATIO IN DENSEST STATE
γ_s	kn/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1. %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1. %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kn/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kn/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kn/m ³	UNIT WEIGHT OF DRY SOIL	i_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{i_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kn/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{i_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1. %	VOID RATIO IN LOOSEST STATE	j	kn/m ³	SEEPAGE FORCE
γ'	kn/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 2-474-C-1

1 OF 1

METRIC

W.P. GWP 408-94-00 LOCATION Site No. 2-474-C Northing - 4900233, Easting - 379405 ORIGINATED BY RB
 DIST Owen Sound HWY 21 BOREHOLE TYPE 100mm SST Auger COMPILED BY JL
 DATUM Geodetic DATE 09.18.06 - 09.18.06 CHECKED BY EC



JOE MTO 06-8-IEG2.GPJ ONTARIO.MOT.GDT 09/30/07

+ 3, X 3: Numbers refer to Sensitivity

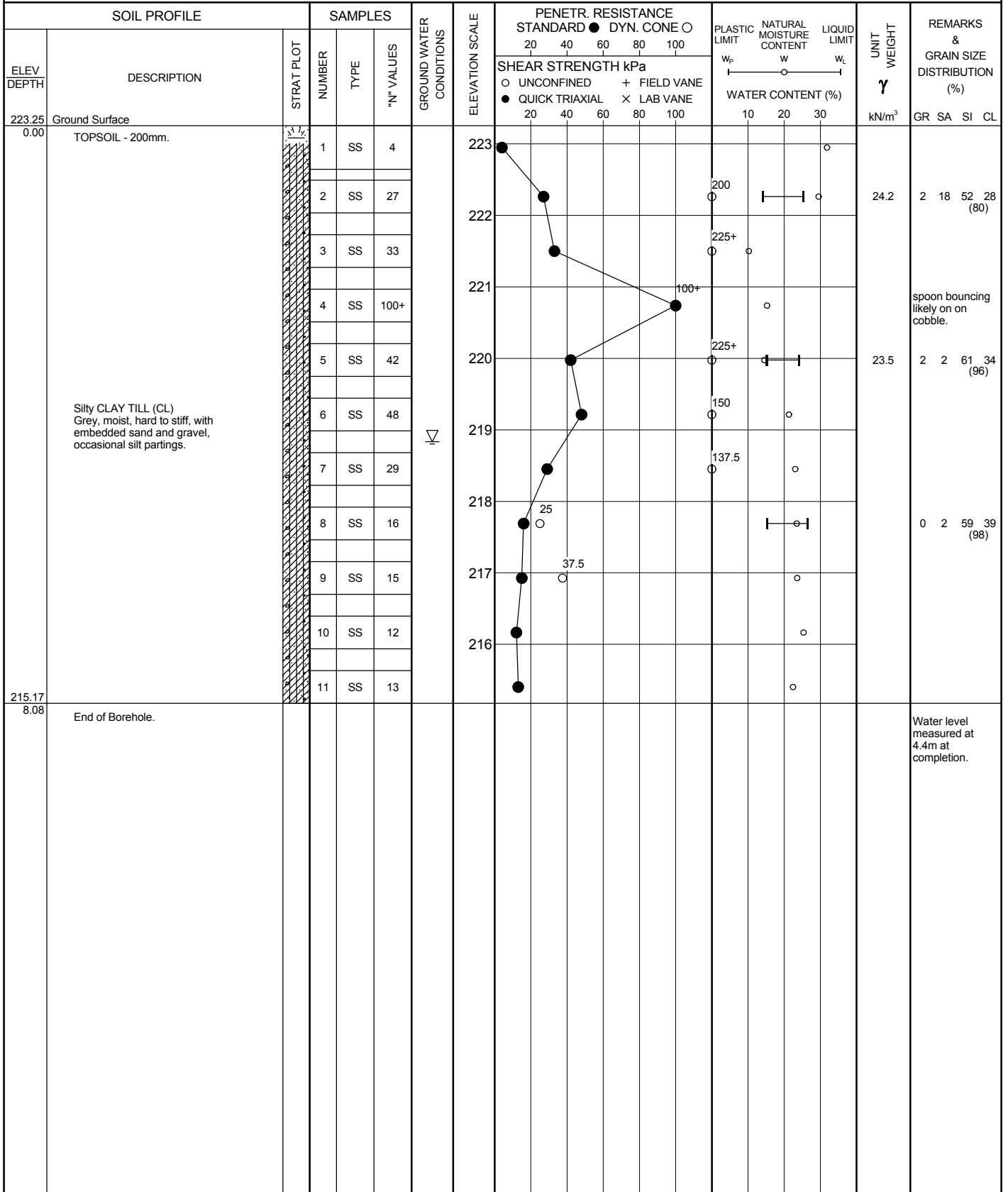
○ 150 UNCONFINED SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No 2-474-C-2

1 OF 1

METRIC

W.P. GWP 408-94-00 LOCATION Site No. 2-474-C Northing - 4900250, Easting - 379372 ORIGINATED BY RB
 DIST Owen Sound HWY 21 BOREHOLE TYPE 100mm SST Auger COMPILED BY JL
 DATUM Geodetic DATE 09.19.06 - 09.19.06 CHECKED BY EC



+ 3, × 3: Numbers refer to
Sensitivity

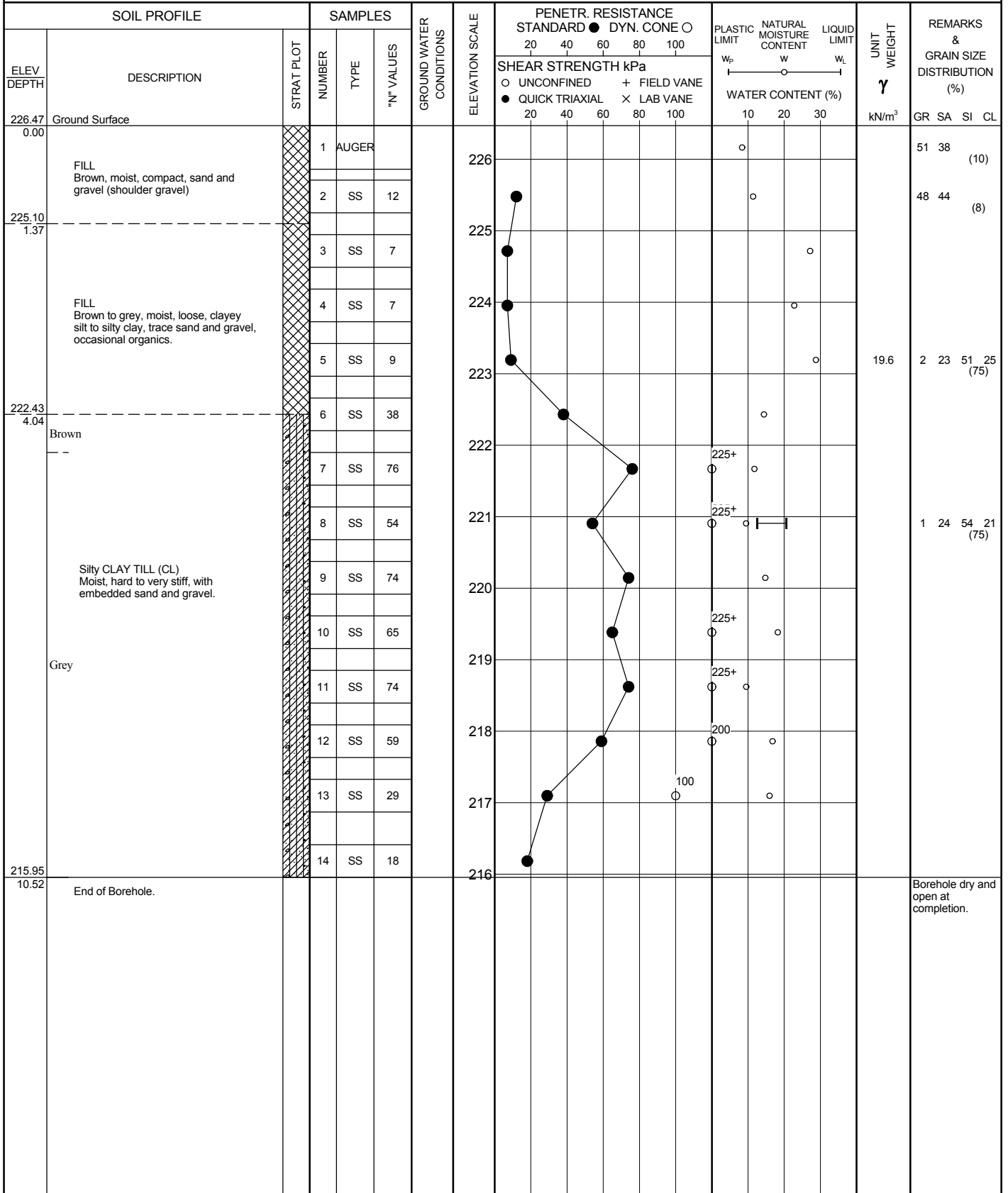
○ 150 UNCONFINED SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No 2-474-C-3

1 OF 1

METRIC

W.P. GWP 408-94-00 LOCATION Site No. 2-474-C Northing - 4900232, Easting - 379391 ORIGINATED BY RB
 DIST Owen Sound HWY 21 BOREHOLE TYPE 100mm SST Auger COMPILED BY JL
 DATUM Geodetic DATE 09.19.06 - 09.19.06 CHECKED BY EC



+³, ×³: Numbers refer to
Sensitivity

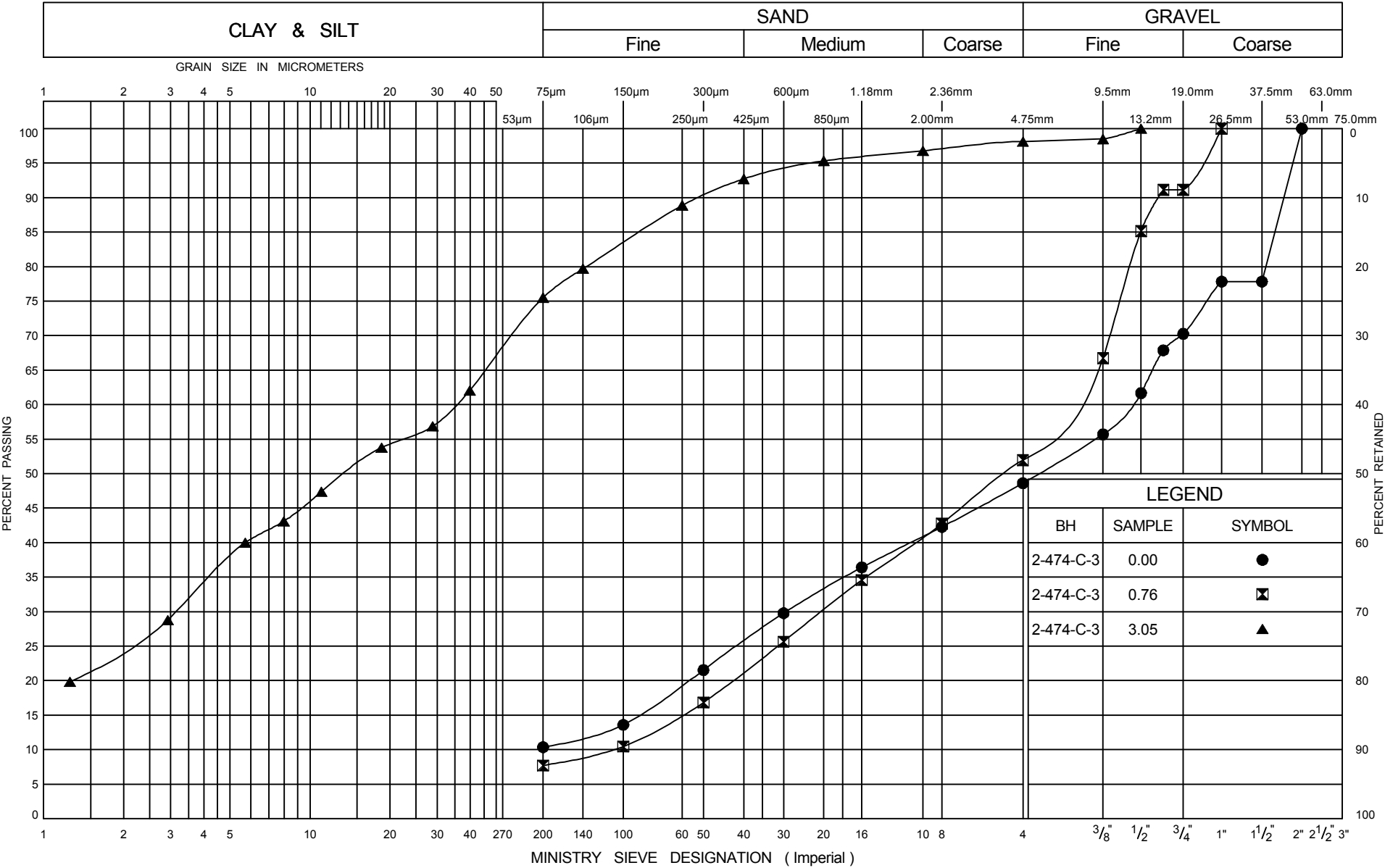
○ 150 UNCONFINED SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

Appendix B

Laboratory Test Results

Grain Size Distribution	Figures 1, 2 and 3
Plasticity Chart	Figure 4

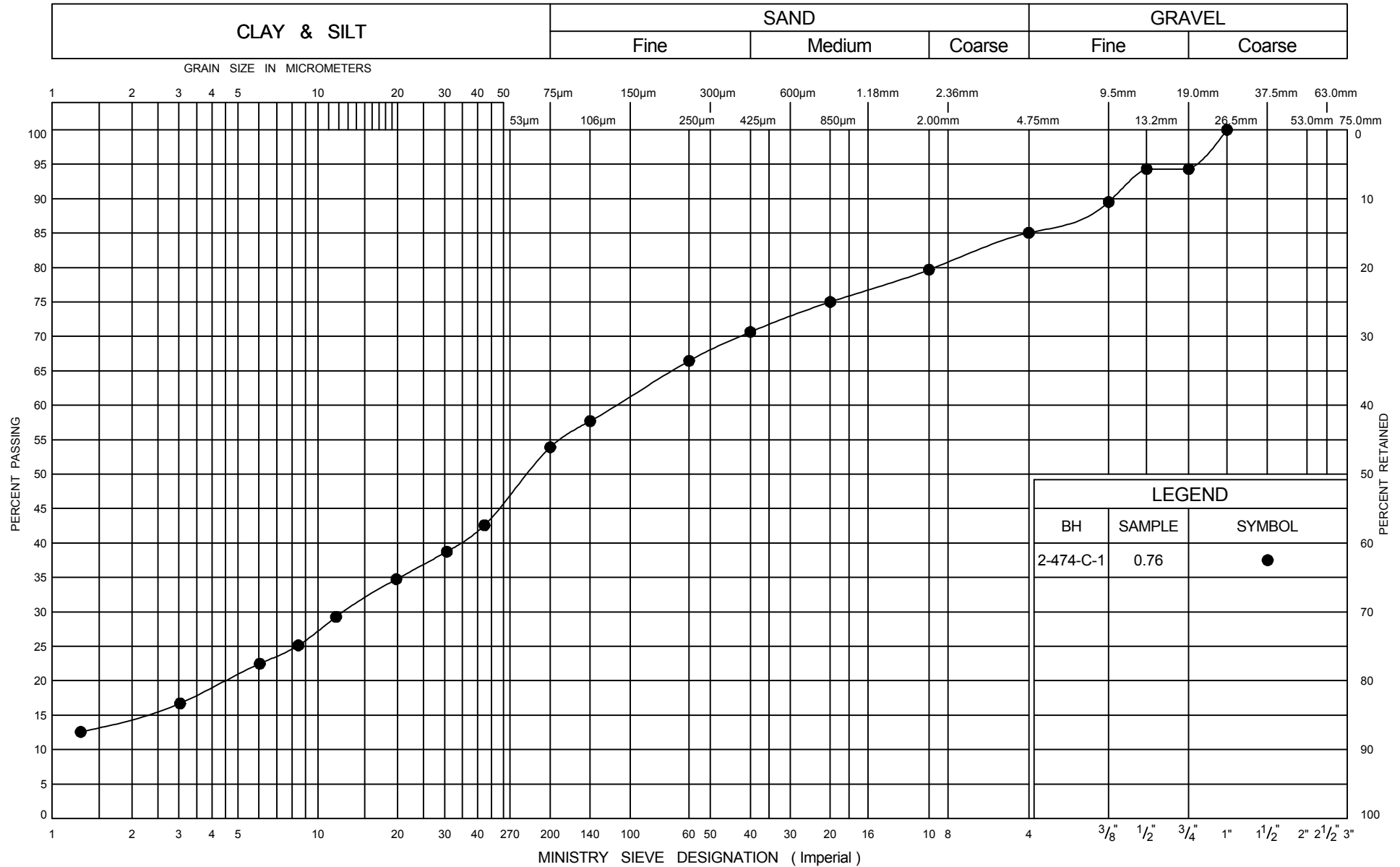
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
FILL

FIG No 1
GWP 408-94-00
Highway 21-Kincardine to Tiverton

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

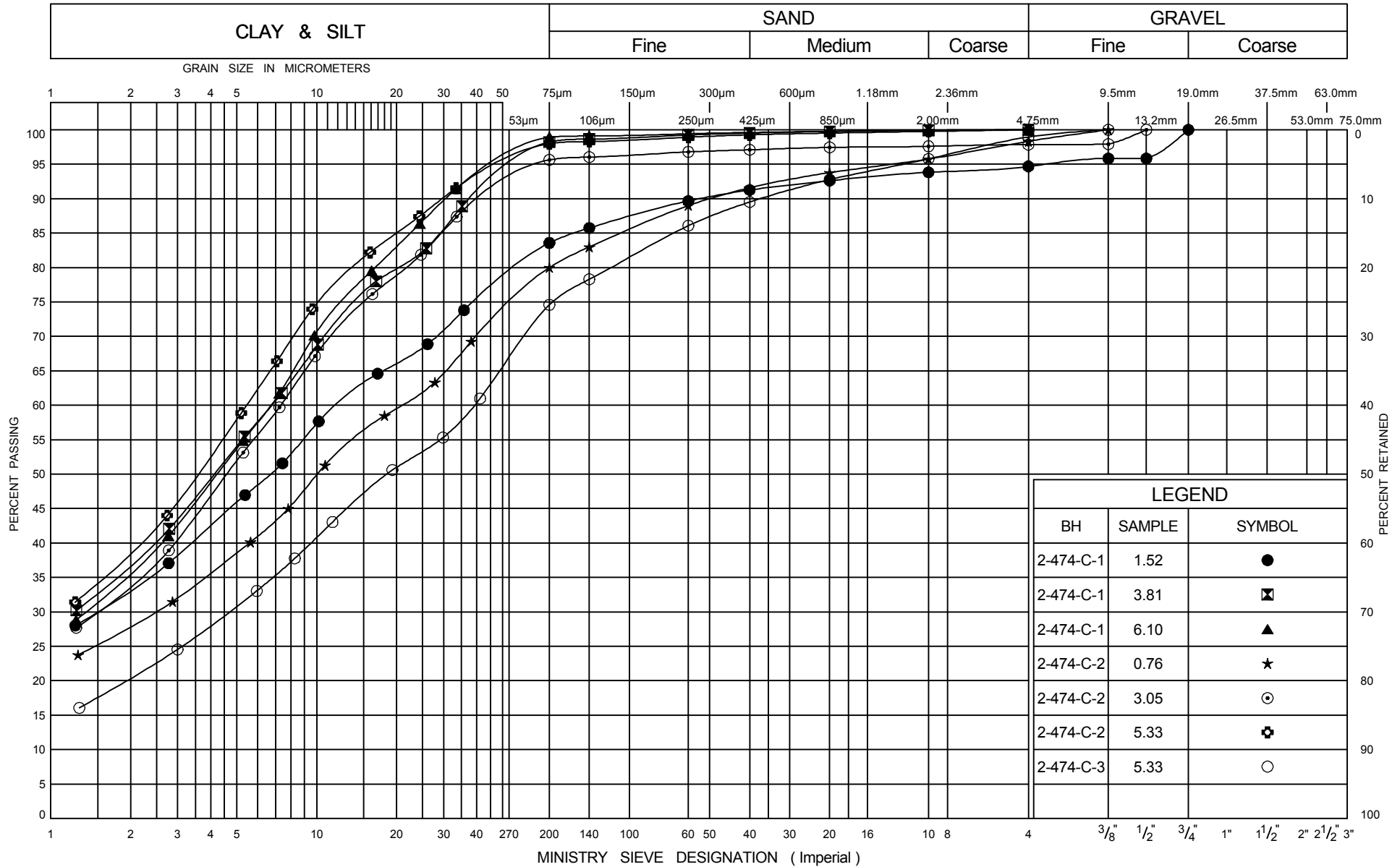
SANDY SILT (ML)

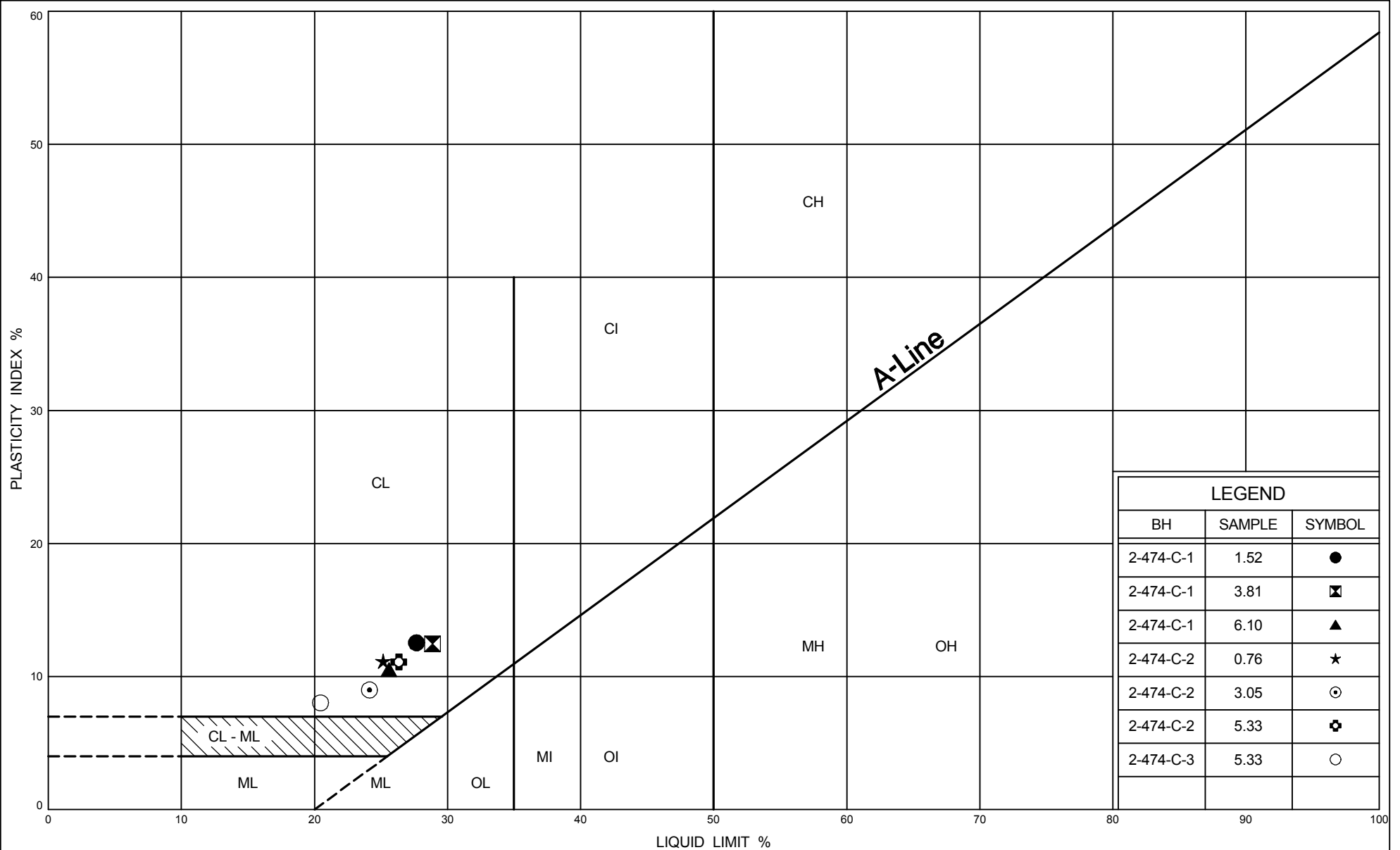
FIG No 2

GWP 408-94-00

Highway 21-Kincardine to Tiverton

UNIFIED SOIL CLASSIFICATION SYSTEM





Ministry of
Transportation

PLASTICITY CHART SILTY CLAY TILL (CL)

FIG No 4

GWP 408-94-00

Highway 21-Kincardine to Tiverton

Ministry of Transportation/SNC-LAVALIN
G.W.P. 408-94-00
Reconstruction of Highway 21 from Kincardine northerly to Tiverton
Agreement # 3005-E-0038

06-8-IEG2-474
Final Report
Appendix C
September 28, 2007

Appendix C

Limitations of Report

APPENDIX C

LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the testhole locations. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction which could not be detected or anticipated at the time of the site investigation. It is recommended practice that the Soils Engineer be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

The benchmark and elevations mentioned in this report were obtained strictly for use in the geotechnical design of the project and by this office only, and should not be used by any other parties for any other purposes.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Infrastructure Engineering Group Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report does not reflect the environmental issues or concerns unless otherwise stated in the report.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, IEG recommends that we be retained during the final design stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Ministry of Transportation/SNC-LAVALIN
G.W.P. 408-94-00
Reconstruction of Highway 21 from Kincardine northerly to Tiverton
Agreement # 3005-E-0038

06-8-IEG2-474
Final Report
Appendix D
September 28, 2007

Appendix D

Site Photographs



Culvert 2-474-C, inlet



Culvert 2-474-C, outlet