FOUNDATION INVESTIGATION REPORT
PROPOSED RECONSTRUCTION OF
NON-STRUCTURAL CULVERTS 05A and 20A
TOWNSHIP OF ST. VINCENT
HIGHWAY 26 FROM MEAFORD TO THORNBURY

G.W.P. 57-00-00
Agreement # 3006-E-0002

I.E. Group

MTO GEOCRES No. 41A-205

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Prepared for:

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March 13, 2009
07-6-IEG-A-STVNSCR

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PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out in July and September 2007 by Infrastructure Engineering Group Inc. (IEG) on behalf of Stantec Consulting Ltd. (Stantec).

This assignment involves the rehabilitation of the pavement structure on Highway 26 from 0.2 km east of the Thornbury west limit (Peel Street) westerly 10.06 km to the Town of Meaford east limit.

It includes the rehabilitation and extension of two existing structural culverts, as well as many non-structural culvert extensions and replacements. The project also includes intersection realignments, intersection improvements, construction of two new 1.5 km long passing lanes, minor horizontal and vertical alignment improvements and electrical work. The original assignment included the re-alignment of the Blue Mountains/Meaford Town Line which has been deleted from the assignment.

Foundation investigation and recommendations are required for the design and construction of culvert replacements and extension as part of the improvement of Highway 26. Two (2) structural culverts, twenty-four (24) non-structural culverts, two shale bin replacements, and a high cut area are to be investigated. There is a change in the scope of work to include two additional culvert extensions which were not part of the original scope of work for foundation investigations, and re-allocation of the foundations investigation work for three (3) CSP culverts to the geotechnical investigation portion of this assignment. This report covers the site of Culverts 05A and 20A in the St. Vincent Township.

Two (2) non-structural culverts are listed in the following table for replacements as per the information supplied by the RFP documents. There is no work required for Culvert 05A as the project develops and as per the final culvert recommendations provided by Stantec. The foundation data and information for Culvert 05A are left in this report for future reference. The locations of these structures are shown in Appendix A, Borehole Location Plan, Drawing 1.

Table 1
Summary of location, structure type, dimensions

Culvert #	New Chainage (m)	Existing Culvert Type and Size, W X H	Existing Overfill (m)	Recommended Replacement Culvert Type and Size	Length (m)	U/S Culvert Invert (m)	D/S Culvert Invert (m)
05A	24+766	Concrete 2.4m X 0.9m	2.0	No Work Required	Not Applicable	Not Applicable	Not Applicable
20A	28+940	Concrete 1.5m X 0.9m	1.0	Precast Concrete Box 2.40 m x 0.90 m & Shale Bin	17.79	233.181	233.178

The existing Culvert 20A is to be replaced with a new culvert, with box culverts being the preferred structures as per the PDR report. The temporary shale bin at the upstream (south) end of Culvert 20A is to be replaced with new permanent shale bin. 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 work presented herein was undertaken under MTO G.W.P. 57-00-00, Agreement No. 3006-E-0002.

Authorization to complete this assignment was given by Mr. Dan Green, P. Eng., of Stantec Consulting Ltd., the TPM Consultant who is completing this assignment for MTO under Agreement # 3006-E-0002.

2.0 SITE DESCRIPTION

2.1 Site Location

The two (2) non-structural culverts are located on Highway 26, approximately 1.6 km and 5.7 km east of Meaford town limit (STA 23+206), respectively for Culvert 05A and 20A. Table 1 summarizes the locations, structure types and dimensions of the existing and replacement culverts as recommended by the PDR and provided in the RFP documents. Locations of the individual non-structural culverts are illustrated in the Borehole Location Plan, Drawing 1 presented in Appendix A. The existing concrete Culvert 20A, although in a good condition, is hydraulically under capacity.

These non-structural culvert sites are generally located within drainage valleys or surface water flow paths. The overfill heights range approximately between 1.0 m at Culvert 20A and 2.0 m at Culvert 05A. The shale bin at the inlet of Culvert 20A is constructed of precast concrete blocks (600 X 600 X 1200 mm), with a narrow opening covered by a metal screen. At the time of site visit after a period of rain, water was backed up from the shale bin.

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. Site photographs taken during a site visit in March 2006 by Stantec are provided in Appendix C.

2.2 Physiography and Topography

The Town of Meaford is situated at the mouth of the Bighead River where the river enters Nottawasaga Bay, part of the Georgian Bay of Lake Huron.

The subsurface of the Town of Meaford is comprised of predominately silty clay, and smooth to gently sloping topography. Pockets of sand and gravelly sands exist which also exhibit smooth to gently sloping topography.

The Town is located on the coastal plain left by glacial Lake Algonquin. East of Meaford, the Algonquin shore cliff coincides with the base of the Niagara Escarpment. The coastal plain in this area consists of sand and gravel beach terraces overlying the bedrock. Overburden thickness is generally less than 5 m.

Bedrock consists of the shale and limestones of the Georgian Bay Formation. Grey, impure carbonate beds (limestone and dolomite) alternate with grey and blue/grey shale.

West of Meaford, the coastal plain consists of the same beach deposits as found in the east. To the west away from the Lake, overburden becomes a glacio-lacustrine derived silt to clayey till. Numerous drumlins of calcareous till with red shale inclusions are found in the Meaford area.

Progressing west on Highway 26 toward Owen Sound and the Niagara Escarpment, the bedrock types progress from Queenston shales, the Clinton and Cataract shales and dolomites to the cap rock of the Amabel dolomites and limestones. Overburden thickness can be as much as 15 m, but is generally less than 5 m.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

Between July 25 and September 17, 2007, a Bombardier-mounted Dietriech drill rig and a truck-mounted CME 55 drill rig, supplied and operated by London Soil Test Ltd. of London, was used on site for drilling and Standard Penetration Testing (SPT, following the procedures of ASTM D 1586). Three (3) boreholes at each site were drilled and sampled to obtain data for foundation and bedding design of the proposed replacement culverts. The boreholes were drilled to a minimum depth of 3.0 m (or deeper if required) below the culvert inverts to provide sufficient subsurface information for the evaluation of bearing resistances or support of bedding material for the proposed culvert and shale bin replacements.

The boreholes were advanced 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.

The culvert locations are described as 05A and 20A. The culvert borehole numbering system was established from the catchment area numbering system used in the Drainage Report of this project, as agreed with Stantec. A letter "A" or "B" was also added after the culvert numbers to delineate Part A or Part B of this assignment.

For the purpose of proper management of the Borehole Logs within gINT, the borehole logging software, a preceding 0 was added to the culverts numbered 1 to 9, with a letter "A" or "B" also added after the culvert numbers to delineate Part A or Part B of this assignment, and the last number being the borehole number at the culvert site, i.e., "05A-1" refers to Borehole 1 at the location of Culvert 05A, etc.

Field pocket penetrometer was used on the retrieved SPT samples, where applicable, to determine the undrained shear strength of the cohesive soil deposits. These undrained shear strengths are used to supplement the properties of the cohesive soils. It is noted that the measured shear strength value would be slightly 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., working under the direction of the project engineer, Mr. Eric Chung, P. Eng., supervised the fieldwork. 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 our London Office 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 B.

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 and in the respective figures presented in Appendix B.

4.0 SUBSURFACE CONDITIONS

Reference is made to the respective appendix of each culvert site for the Record of Borehole sheets 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 the respective Borehole Locations will vary between and beyond the borehole locations.

In general, the subsurface deposits encountered in the boreholes put down on the shoulder area at the two (2) culvert sites consist of loose to dense embankment fill placed on dense to very dense sand and gravel over silty clay till at Culvert 05A. At Culvert 20A, a stiff to hard clayey silt over silty clay till was encountered.

4.1 Fill, Topsoil

The boreholes at the shoulders generally encountered a 0.46 and 0.76 m thick layer of granular fill (shoulder gravel). The shoulder gravel is underlain by mixed sand, gravel, silt and clayey silt fill materials with localized zones of organic inclusions, and extended to or slightly below the bottom of the culverts.

The boreholes near the ends of the existing culverts generally encountered a 0.1 to 0.2 m thick layer of topsoil.

Standard penetration tests taken in the mixed fill yielded “N”-values from 2 to 30 blows per 0.3 m, indicative of typically compact compactness condition with localized very loose and dense layers. The measured natural moisture contents of the mixed fill ranged from 9 to 18%.

Grain size distributions of these fill materials are shown on the first figure of the corresponding culvert site in Appendix B, e.g. Figure 05A.1 refers to the first figure of Culvert 05A, etc.

Table of Figures of Laboratory Test Results

Culvert Number	Grain Size Figure
05A	C-05A.1
20A	C-20A.1

Unit weight of the fill was not determined due to the disturbance of the soil samples during sampling and sample retrieval.

4.2 Sandy Silt (ML)

At Culvert 05A, the topsoil layer at the ends of the culvert was underlain by a sandy silt stratum which extended to depths of 1.37 to 1.68 m. Standard penetration tests taken within the sandy silt yielded "N"-values of 22 and 33 blows per 0.3 m, indicative of compact to dense compactness condition. The natural moisture contents were 6 and 19%.

4.3 Clayey Silt Till (ML to CL-ML)

At Culvert 20A, the topsoil layer at the ends of the culvert and the embankment fill were underlain by a clayey silt till stratum which extended to depths of 1.37 to 4.86 m. Standard penetration tests taken within the clayey silt till yielded "N"-values of between 6 and 15 blows per 0.3 m. The natural moisture contents were between 14 and 22%.

Grain size analyses and Atterberg Limits determinations were performed and the results are plotted on the following figures of Appendix B.

Table of Figures of Laboratory Test Results

Culvert Number	Grain Size Figure	Atterberg Limits Figure
20A	20A.2	C-20A.3

A single Atterberg Limits determination carried out on the clayey silt till (CL-ML to CL) yielded the following results:

Atterberg Limits	%
Liquid Limit (W_L)	27.0
Plastic Limit (W_P)	20.0
Plasticity Index (I_p)	7.0

Undrained shear strength of the clayey silt till as determined from field pocket penetrometer ranged from 75 to over 225 kPa, which generally increased with increasing depths. A firm layer of limited thickness (less than 0.8 m) was encountered immediately below the embankment fill.

Based on the above field and laboratory test results, together with visual and tactile examination, the clayey silt till deposit generally exhibited very stiff to hard consistency with localized firm condition.

4.4 Silty Clay Till (CL-ML, CL to CI)

At Culvert 20A, the clayey silt till layer was underlain by a silty clay till stratum which extended to the full depths of the boreholes. Standard penetration tests taken within the silty clay till yielded "N"-values of between 13 and over 100 blows per 0.3 m. The natural moisture contents were between 9 and 23%.

At Culvert 05A, the sandy silt layer at the ends of the culvert was underlain by an upper silty clay till stratum of 0.6 to 0.7 m thick. Further, a lower silty clay till stratum was encountered below the sand and gravel deposit, and then extended to the full depths of the boreholes. Within the sand and gravel deposit, silty clay layers were encountered.

Grain size analyses and Atterberg Limits determinations were performed and the results are plotted on the following figures of Appendix B.

Table of Figures of Laboratory Test Results

Culvert Number	Grain Size Figure	Atterberg Limits Figure
05A	C-05A.2 C-05A.5 C-05A.7	C-05A.3 C-05A.6 C-05A.8
20A	C-20A.4	C-20A.5

Atterberg Limits determinations on the silty clay till (CL-ML, CL to CI) yielded the following results:

Atterberg Limits	Minimum	Maximum	Average
Liquid Limit (W_L)	17.0	42.0	30.6
Plastic Limit (W_P)	11.0	24.0	16.8
Plasticity Index (I_p)	7.0	19.0	12.5

Standard penetration tests taken within the silty clay till yielded "N"-values of between 12 and over 100 blows per 0.3 m, and generally increasing with increasing depths. The measured natural moisture contents of the silty clay till ranged from 9 to 23%. Undrained shear strength of the silty clay till as determined from field pocket penetrometer were generally over 200 kPa, which generally increased with increasing depths. The unit weight of the silty clay till was measured to be between 21.6 and 24.5 kN/m^3.

Based on the above field and laboratory test results, together with visual and tactile examination, the silty clay till deposit generally exhibited very stiff to hard consistency.

4.5 Sand and Gravel to Gravelly Sand

At Culvert 05A, a major stratum of sand and gravel to gravelly sand deposit lies underneath the embankment fill and between the upper and lower silty clay till stratum. Within the sand and gravel deposit, silty clay layers were encountered. The sand and gravel to gravelly sand deposit contain some silt and trace of clay and displays a till-like structure.

A grain size analysis was performed and the results are plotted on the following figure of Appendix B.

Table of Figures of Laboratory Test Results

Culvert Number	Grain Size Figure
05A	C-20A.4

Standard penetration tests yielded "N"-values from 21 to over 100 blows per 0.3 m. The measured natural moisture contents ranged from 8 to 21%. The unit weight of a single sample was measured to be 25.5 kN/m^3.

Based on the above field and laboratory test results, together with visual and tactile examination, the sand and gravel to gravelly sand deposit exhibited compact to very dense compactness condition.

4.6 Groundwater

The groundwater condition was monitored during and upon completion of sampling. On completion of drilling, groundwater levels noted in the boreholes are summarized in the following table.

Culvert Number	Groundwater Levels - Depth/Elevation (m)		
	Borehole 1	Borehole 2	Borehole 3
05A	4.30/223.16	6.10/222.76	3.30/222.91
20A	BD&O	2.60/232.32	4.20/229.00

Note: BD&O means borehole dry and open at completion

In general, the groundwater was encountered as perched condition within the upper fill materials and in the wet to saturated sand and gravel deposit. The observed groundwater table represented the shallow groundwater condition at these culvert sites.

The groundwater condition will fluctuate seasonally and in response to weather events.

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 D, 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

Appendix A

Drawing 1

Borehole Location Plan

METRIC

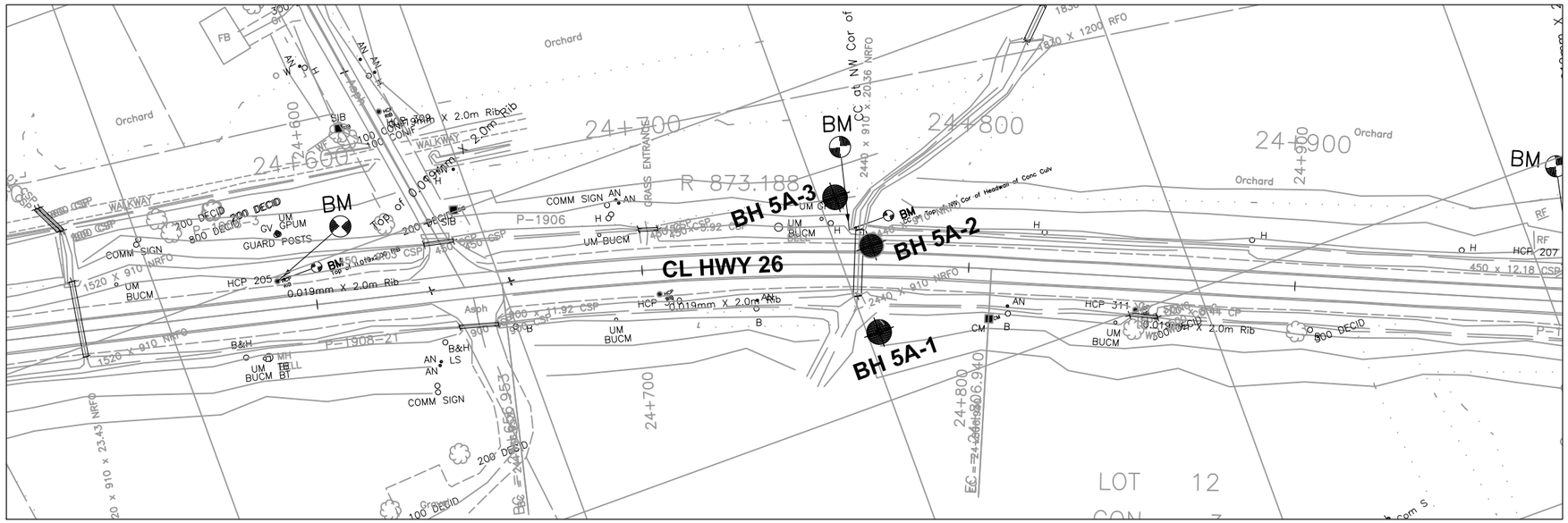
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

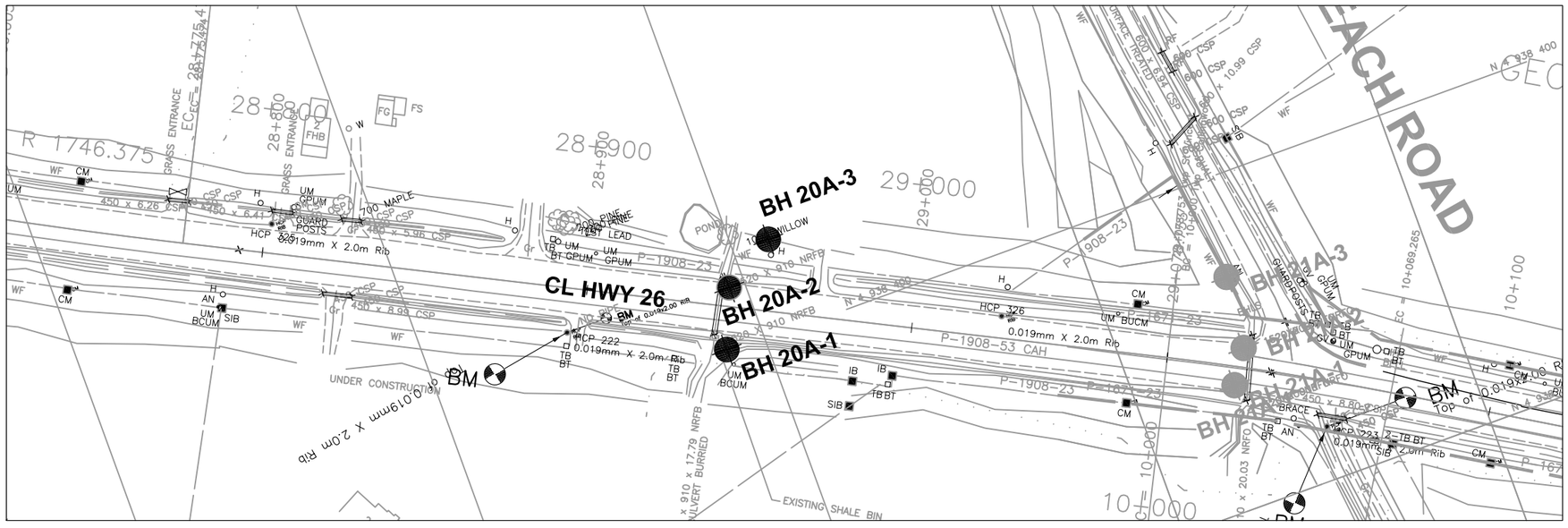
CONT No xxxx–xxxx
WP No GWP 57–00–00

Culvert # C05A & C20A
Highway 26
BOREHOLE LOCATION PLAN

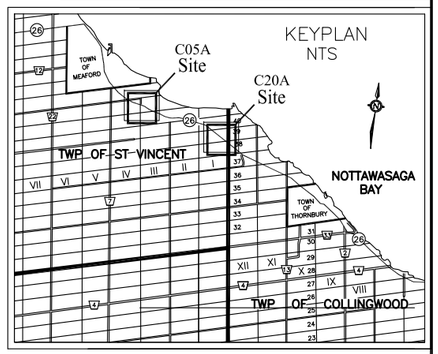
SHEET 1

I.E. Group — 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

NOTES

1. 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.

BOREHOLE NO.	ELEV.	UTM CO–ORDINATES NORTH	UTM CO–ORDINATES EAST	BOREHOLE NO.	ELEV.	UTM CO–ORDINATES NORTH	UTM CO–ORDINATES EAST
05A–1	227.46	4939421	220304	C20A–1	233.71	4938401	224288
05A–2	228.86	4939447	220310	C20A–2	234.92	4938419	224295
05A–3	226.21	4939464	220305	C20A–3	233.20	4938428	224311

SCALE
100m 0 50m

REVISIONS	DATE	BY	DISCRIPTION
	10/03/09	J.L.	Final
	15/01/08	J.L.	Draft

MTO GEOCRES No. 41A–205

HWY No.	HWY 26		DIST	Owen Sound
SUBM'D J.L.	CHECKED E.C.	DATE 15/01/08	SITE	C05A & C20A
DRAWN J.L.	CHECKED J.L.	APPROVED E.C.	DWG	1

Appendix B

Explanation of Terms Used in Report
Record of Borehole Sheet
Laboratory Test Results

Culvert Site	Borehole Logs	Grain Size	Atterberg Limits
05A	05A-1 to 3	Figures C-05A.1, 2, 4, 5 and 7	Figure C-05A.3, 6 and 8
20A	20A-1 to 3	Figures C-20A.1, 2 and 4	Figures C-20A.3 and 5

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 'A' 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_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_s	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C		CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE

e_{min}	1, %	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

RECORD OF BOREHOLE No 05A-1

1 OF 1 **METRIC**

W.P. GWP 57-00-00 LOCATION Northing - 4939421, Easting - 220304 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia. COMPILED BY JL

DATUM Geodetic DATE 07.31.07 - 07.31.07 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE / SHEAR STRENGTH kPa (O UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.46 Ground											
0.00 / 227.26 / 0.20	200 mm TOPSOIL										
	Sandy SILT, ML Brown, moist, dense, trace to some gravel.		1	SPT	33						
225.78 / 1.68	Upper Silty CLAY TILL, CI Brown, moist, stiff, with embedded sand and gravel.		2	SPT	12						1 8 48 44 (91)
225.17 / 2.29	Gravelly SAND, SW Brown, moist to wet, compact to very dense, some silt, trace clay, till like.		3	SPT	21						45 26 18 10 (29)
			4	SPT	48						
			5	SPT	70	▽					Water level measured @ 4.3m @ completion.
			6	SPT	68						26 48 18 8 (26)
			7	SPT	88					25.5	
221.36 / 6.10	Silty CLAY to Clayey SILT TILL, CL to CL-ML Grey, moist, hard, with embedded sand, gravel and cobbles.		8	SPT	100+						7 36 41 16 (57)
			9	SPT	100+						9 36 40 16 (55)
219.54 / 7.92	End of borehole.		10	SPT	100+						

+ 3, × 3: Numbers refer to Sensitivity

O 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

JOE MTO 07-6-1EG1.GPJ ONTARIO MOT.GDT 03/10/09

RECORD OF BOREHOLE No 05A-2

1 OF 1 **METRIC**

W.P. GWP 57-00-00 LOCATION Northing - 4939447, Easting - 220310 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia. COMPILED BY JL

DATUM Geodetic DATE 07.31.07 - 07.31.07 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
228.86	Ground										
0.00	760 mm sand and gravel FILL										
228.10											
0.76	FILL Brown, moist, dense to loose, consisting of a mixture of sand and gravel and clayey silt, trace to some organics, buried topsoil layer.		1	SPT	20		228				51 24 16 8 (25)
			2	SPT	30		227				
			3	SPT	6						28 33 27 12 (40)
			4	SPT	11		226				
	buried topsoil layer		5	SPT	10		225				
224.44											
4.42	Gravelly SAND, SW Brown, wet, dense to very dense, some silt, trace clay, with silty clay to clayey silt seams and layers, till like.		6	SPT	57		224				42 32 18 8 (26)
	silty clay layer		7	SPT	58						35 33 21 11 (32)
223.07							223				
5.79			8	SPT	49	▽					Water level measured @ 6.1m @ completion.
			9	SPT	48		222				26 49 19 6 (25)
			10	SPT	100+		221				
			11	SPT	59						
219.56			12	SPT	100+		220				
9.30	End of borehole.										

+ 3, × 3: Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

JOE MTO 07-6-IEG1.GPJ ONTARIO MOT.GDT 05/10/09

RECORD OF BOREHOLE No 05A-3

1 OF 1 **METRIC**

W.P. GWP 57-00-00 LOCATION Northing - 4939464, Easting - 220305 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia COMPILED BY JL

DATUM Geodetic DATE 07.31.07 - 07.31.07 CHECKED BY EC

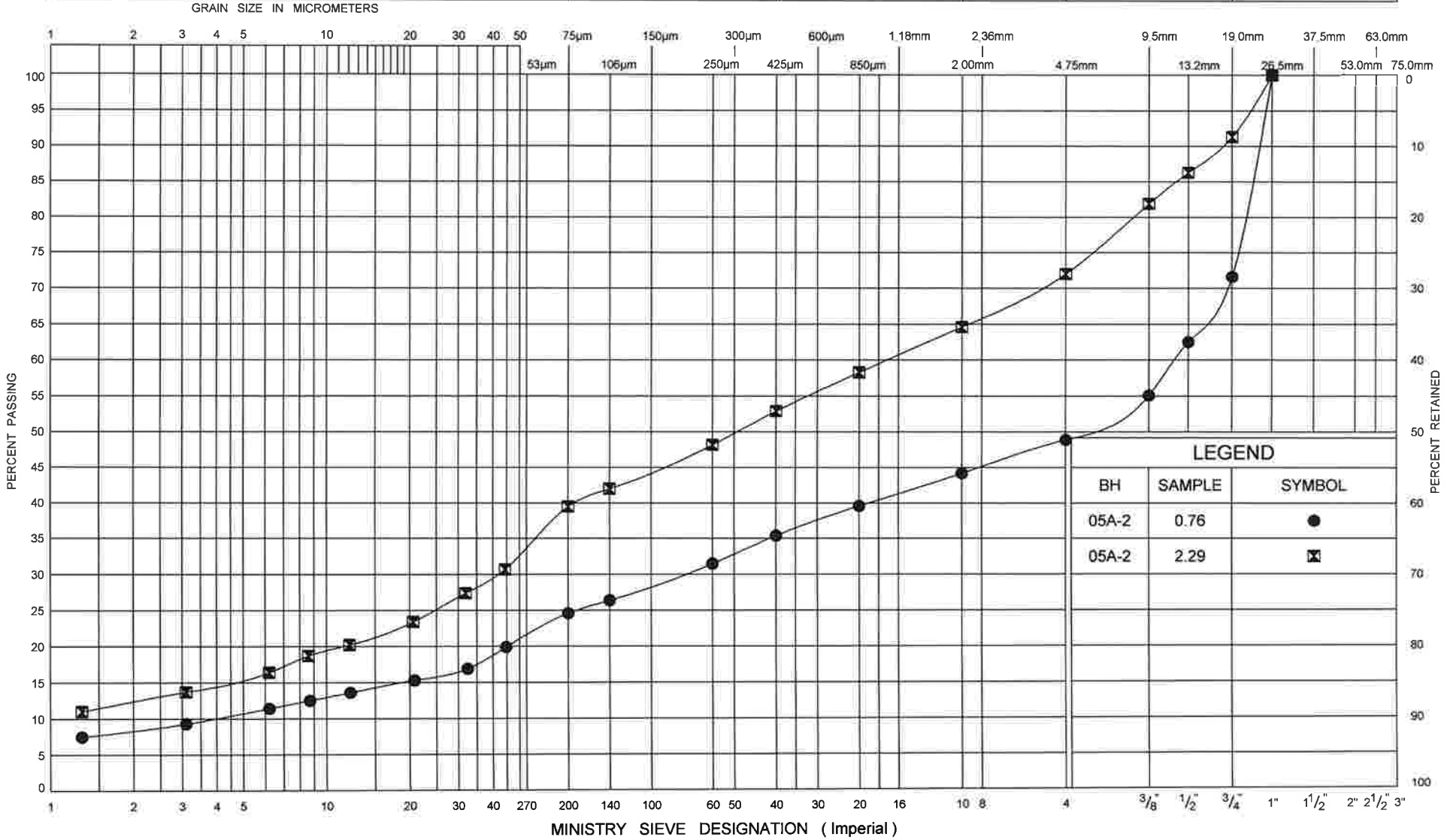
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
226.21 Ground											
0.00 / 226.01 / 0.20	200 mm TOPSOIL						226				
	Sandy SILT, ML Brown, moist, dense, trace to some gravel and cobbles, with occasional clayey silt to silty clay layers		1	SPT	22		225				
224.84 / 1.37	Silty CLAY TILL, CL-CI Brown, moist, hard, with embedded sand and gravel.		2	SPT	33						9 29 38 24 (62)
224.08 / 2.13	SAND & GRAVEL, SW-GW Brown, wet to saturated, dense to very dense some silt to silt, trace clay, till like.		3	SPT	79		224				38 37 16 9 (25)
			4	SPT	100+	▽	223				hit cobbles Water level measured @ 3.3m @ completion.
			5	SPT	41		222				43 35 15 7 (22)
221.33 / 4.88			6	SPT	64						28 34 27 11 (38)
	Silty CLAY to Clayey SILT TILL, CL to CL-ML Brown to grey, moist, hard, with embedded sand and gravel.		7	SPT	100+		221				7 29 45 19 (64)
219.96 / 6.25	End of borehole.		8	SPT	100+		220			24.5	

+ 3, × 3. Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

FILL

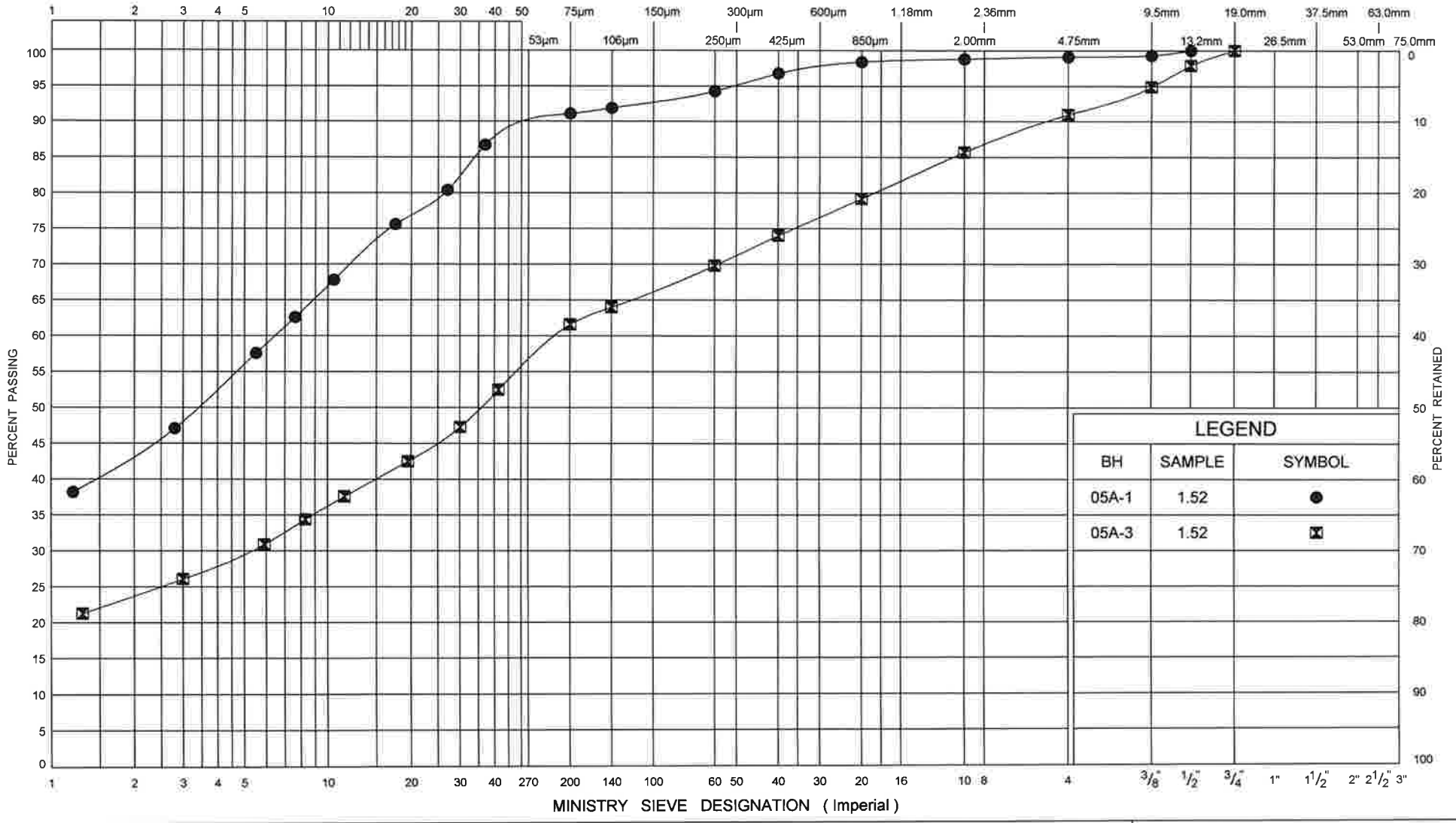
FIG No C- 05A.1

GWP 57-00-00

HWY 26, Thornbury to Meaford

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

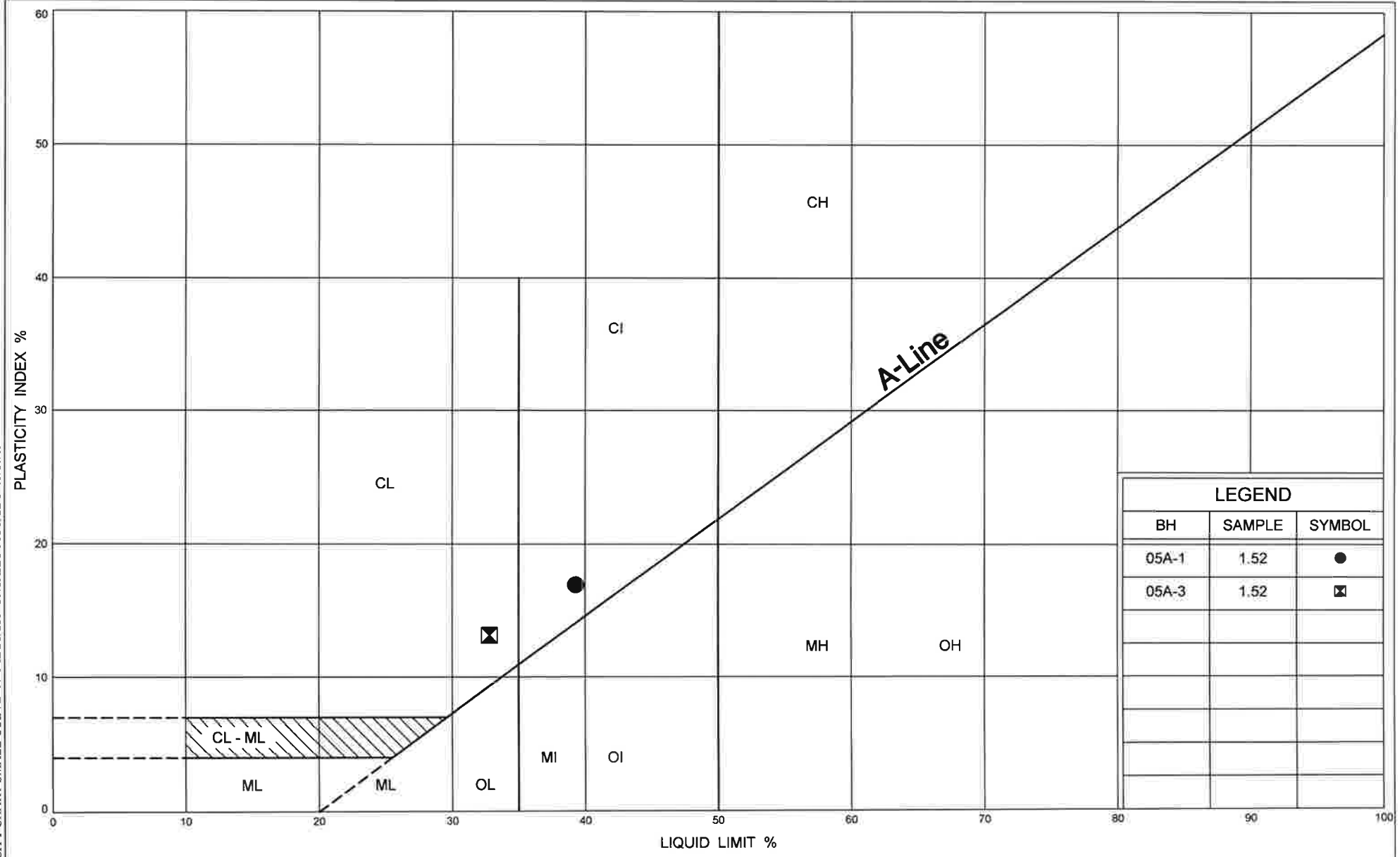
UPPER SILTY CLAY TILL, CL-CI

FIG No C- 05A.2

GWP 57-00-00

HWY 26, Thornbury to Meaford

Oct 75, FF - S - 21



Ministry of Transportation
Ontario

PLASTICITY CHART

UPPER SILTY CLAY TILL, CL-CI

FIG No C- 05A.3

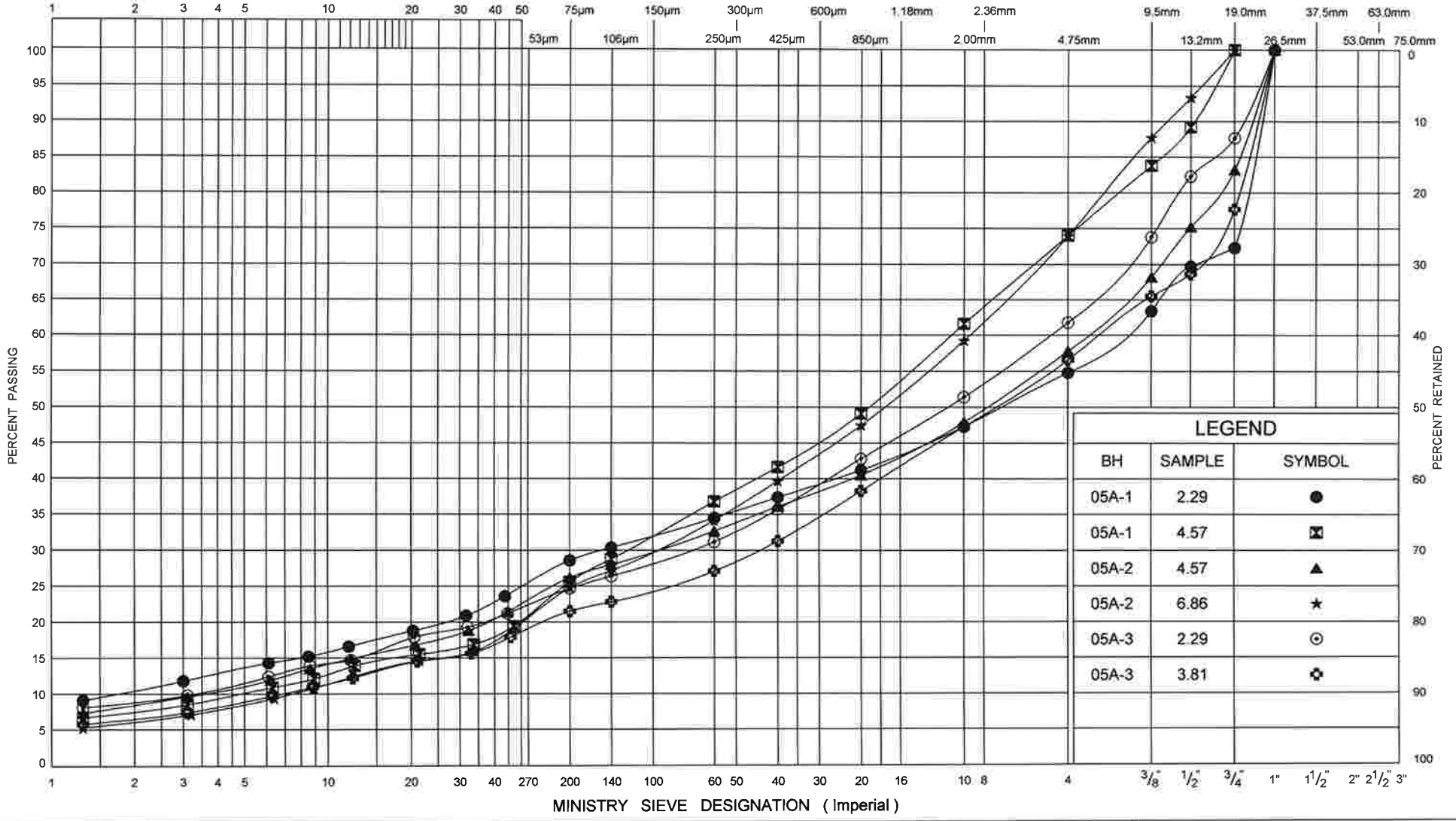
GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT PLASTICITY CHART SMALL CULVE 07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

SAND AND GRAVEL TO GRAVELLY SAND, GW-SW

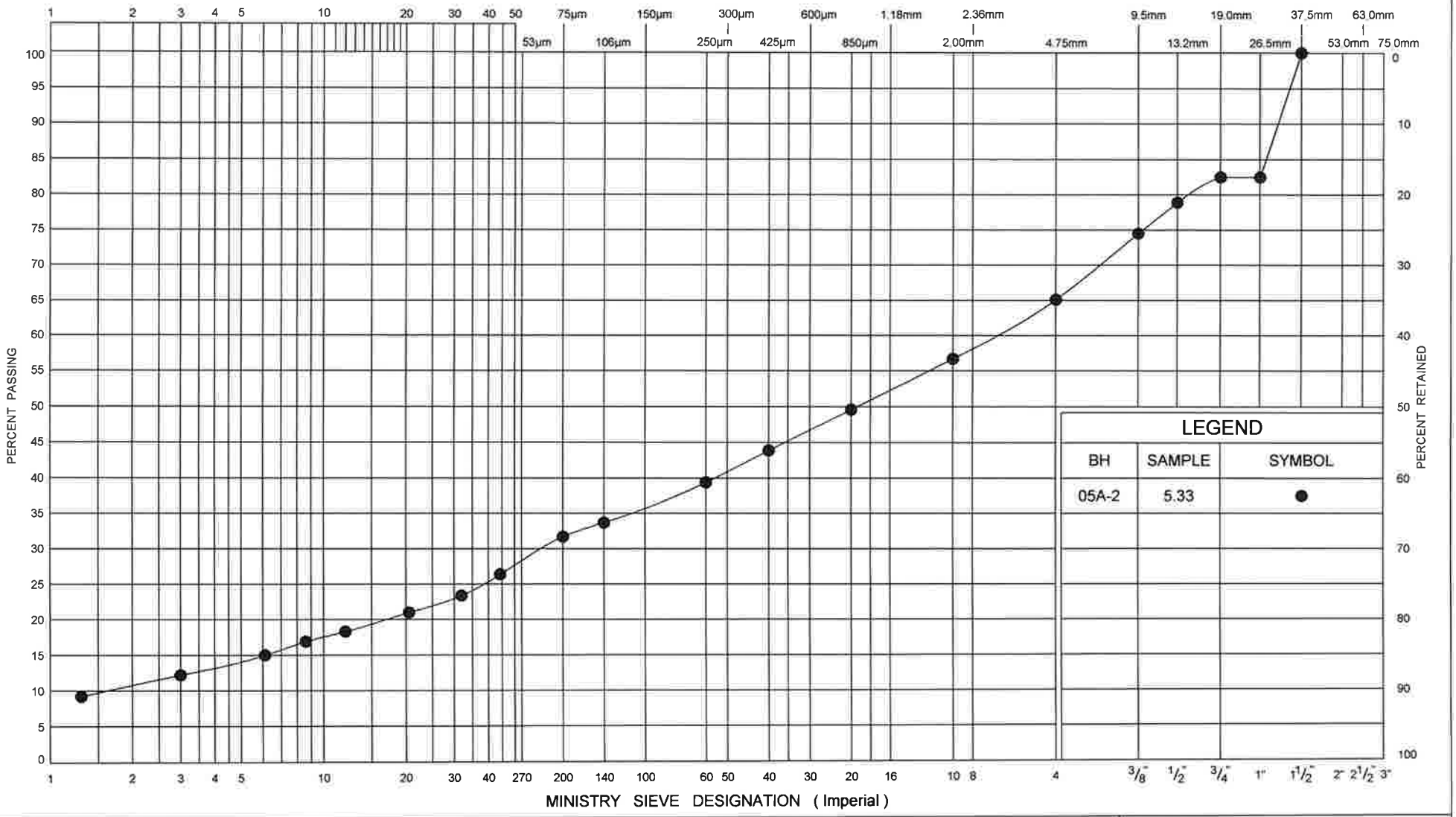
FIG No C- 05A.4

GWP 57-00-00

HWY 26, Thornbury to Meaford

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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GRAIN SIZE DISTRIBUTION

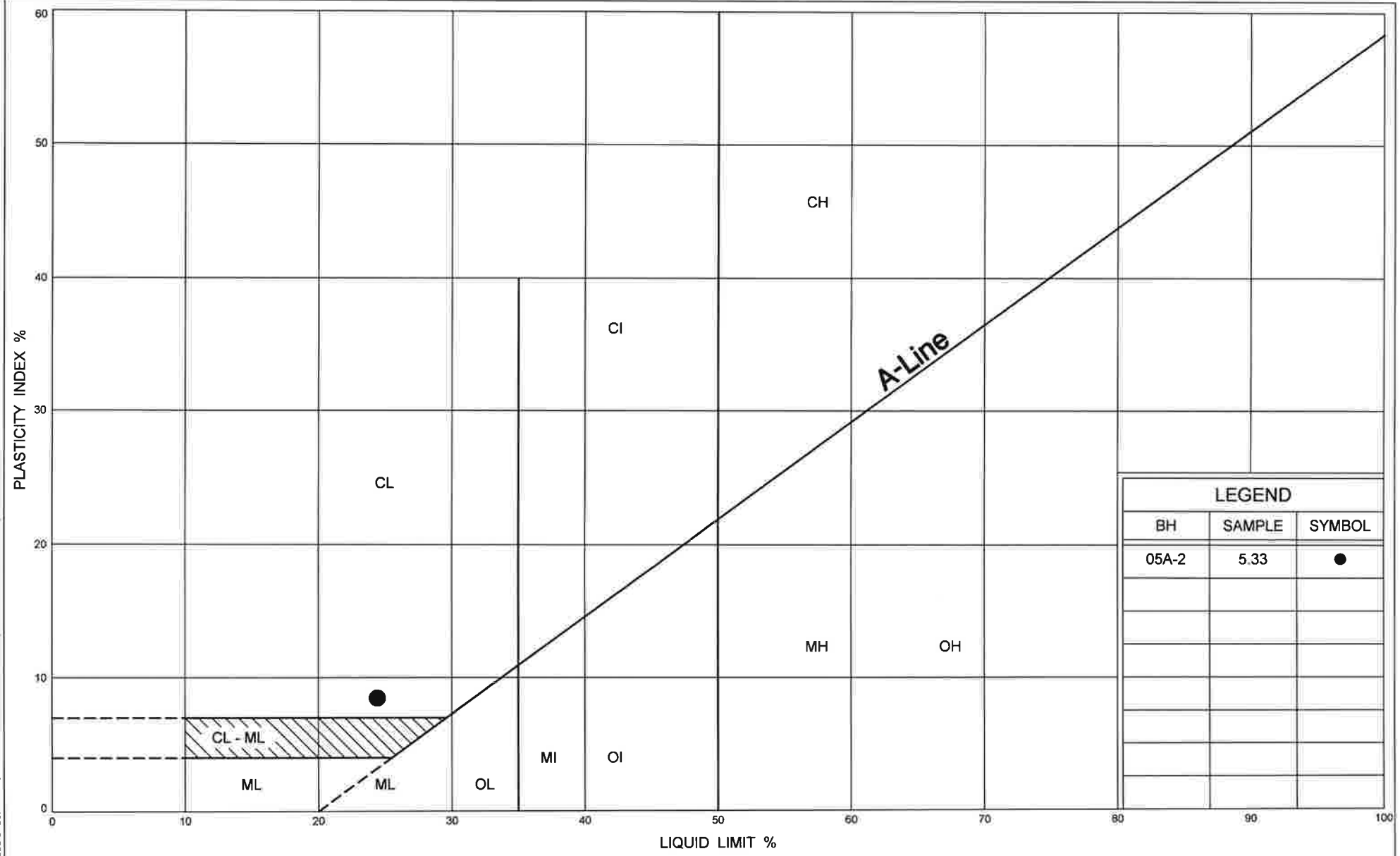
SILTY CLAY LAYER, CL

FIG No C- 05A.5

GWP 57-00-00

HWY 26, Thornbury to Meaford

Oct 75, FF - S - 21



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Ontario

PLASTICITY CHART

SILTY CLAY LAYER, CL

FIG No C- 05A.6

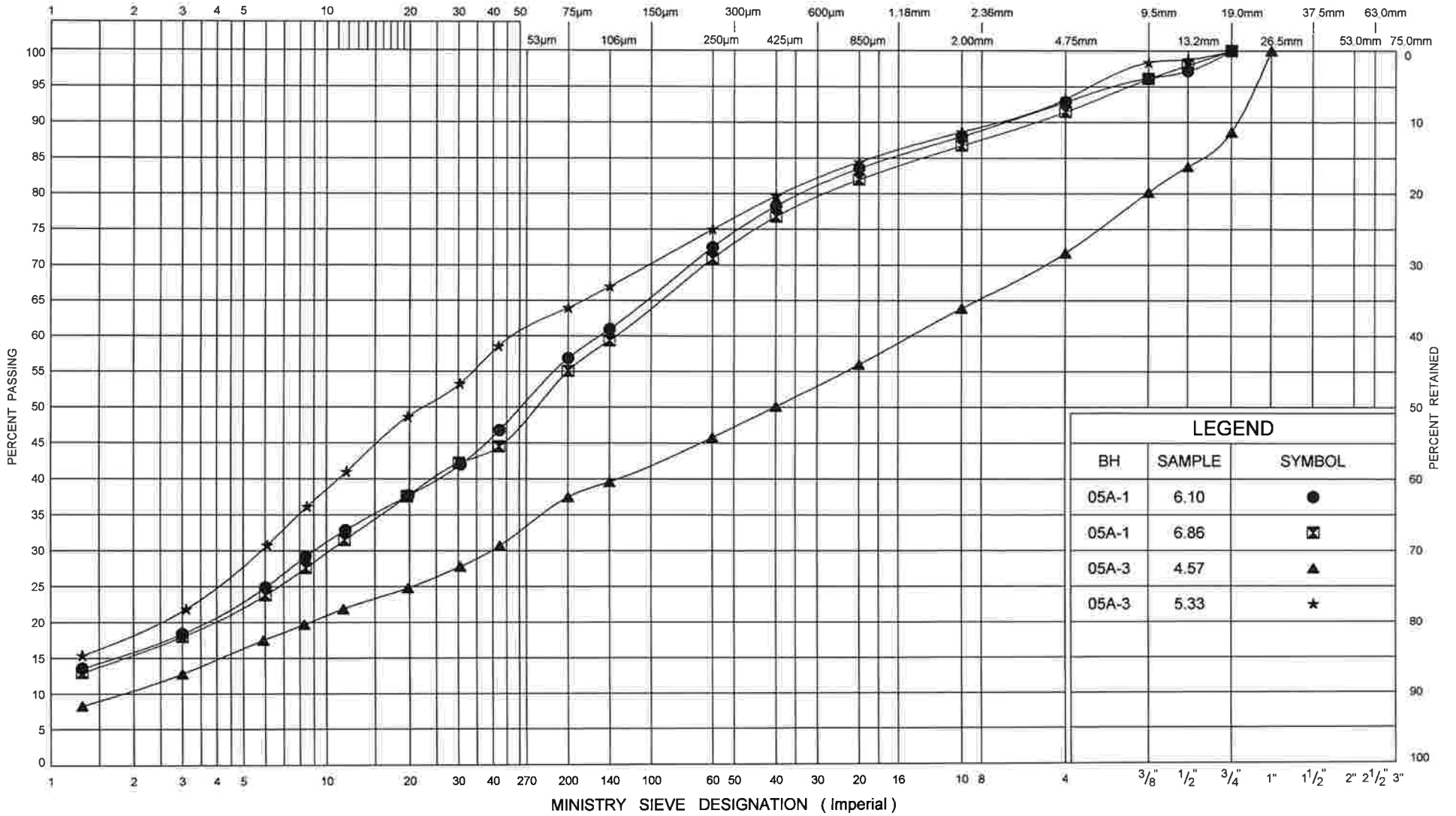
GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT PLASTICITY CHART SMALL CULVE 07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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Ontario

GRAIN SIZE DISTRIBUTION

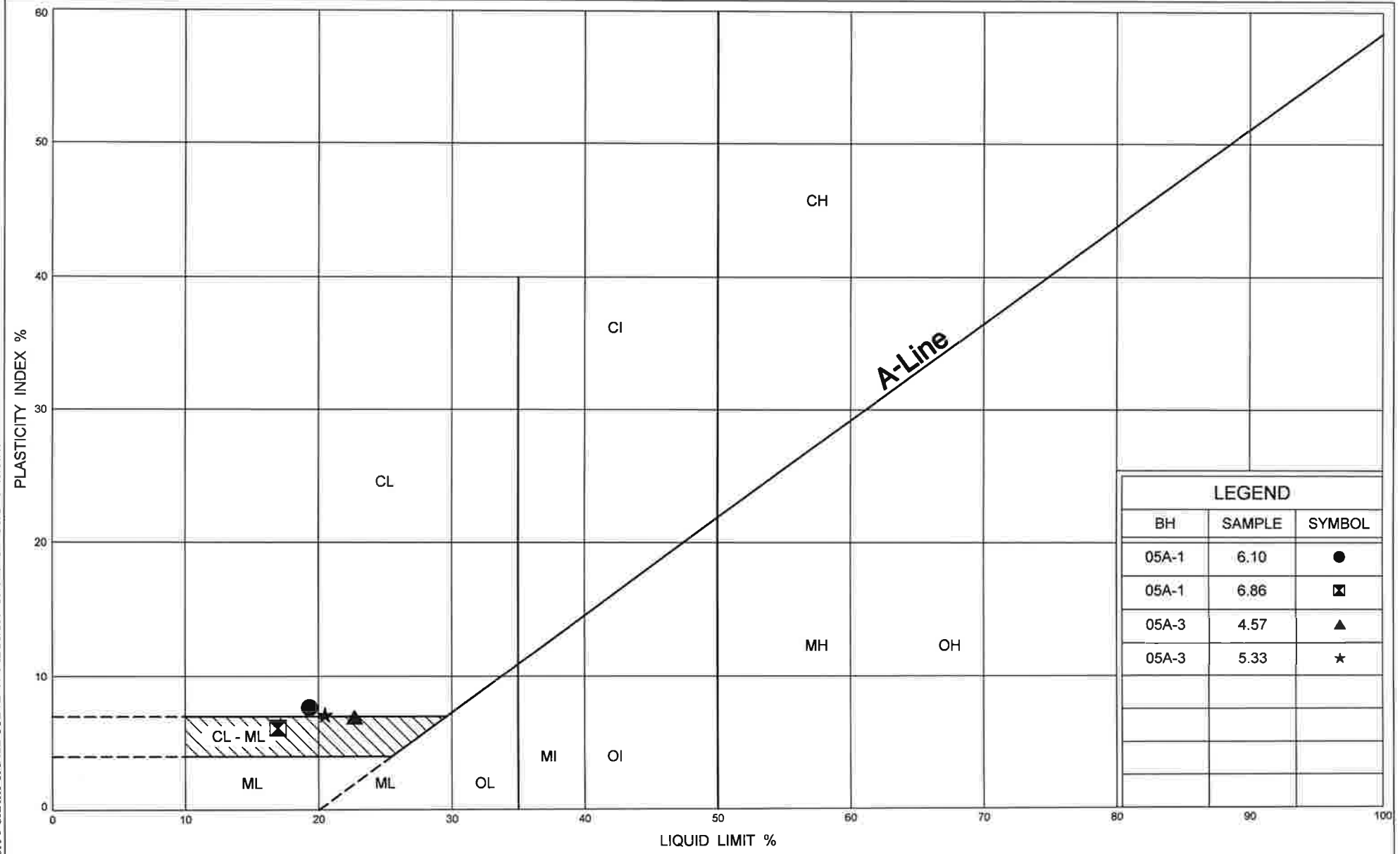
LOWER SILTY CLAY TO CLAYEY SILT TILL, CL TO CL-ML

FIG No C- 05A.7

GWP 57-00-00

HWY 26, Thornbury to Meaford

Oct 75, FF - S - 21



LEGEND		
BH	SAMPLE	SYMBOL
05A-1	6.10	●
05A-1	6.86	⊠
05A-3	4.57	▲
05A-3	5.33	★

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Ontario

PLASTICITY CHART

LOWER SILTY CLAY TO CLAYEY SILT TILL, CL TO CL-ML

FIG No C- 05A.8

GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT PLASTICITY CHART SMALL CULVE 07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

RECORD OF BOREHOLE No 20A-1

1 OF 1 **METRIC**

W.P. GWP 57-00-00 LOCATION Northing - 4938401, Easting - 224288 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia COMPILED BY JL

DATUM Geodetic DATE 07.25.07 - 07.25.07 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
233.71 Ground											
0.00	100mm TOPSOIL										
	Clayey SILT (CL-ML) Reddish brown, moist, stiff, some sand, gravel and clay		1	SPT	14		233		225+		18 12 52 18 (71)
			2	SPT	15		232		187.5		
231.58											
2.13	Brown		3	SPT	17		231				
	Silty CLAY TILL (Cl) Moist, very stiff to hard, embedded sand and gravel.		4	SPT	26				225+		22.8
	Grey						230				
			5	SPT	58					41	6 5 50 38 (89)
229.44											
4.27	End of Borehole										Borehole dry and open @completion

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

O^{150} UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No 20A-2 1 OF 1 METRIC

W.P. GWP 57-00-00 LOCATION Northing - 4938419, Easting - 224295 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia COMPILED BY JL

DATUM Geodetic DATE 07.25.07 - 07.25.07 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
234.92 Ground								20 40 60 80 100	10 20 30		
0.00 / 234.46	460 mm sand and gravel FILL.										
0.46	FILL Brown, moist, very loose to compact, consisting of sand and gravel, silt and clay.		1	SPT	18		234				
			2	SPT	12		233				41 46 9 3 (12)
232.02			3	SPT	2	▽					Water level measured @ 2.6m @ completion.
2.90	Clayey SILT to SILT (ML to CL-ML) Brown, moist, firm to very stiff, some sand and gravel.		4	SPT	6		232				17 26 42 16 (58)
			5	VANE			231				vane refusal
230.04			6	SPT	27		230				8 8 50 35 (84)
4.88	Silty CLAY TILL (Cl) Grey, moist, very stiff to hard, embedded sand and gravel.		7	SPT	45						8 5 55 31 (86)
229.13											
5.79	End of Borehole										

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

$\circ^{150}$ UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

JOE MTO_07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

RECORD OF BOREHOLE No 20A-3

1 OF 1 **METRIC**

W.P. GWP 57-00-00 LOCATION Northing - 4938428, Easting - 224311 ORIGINATED BY JL

DIST Owen Sound HWY 26 BOREHOLE TYPE S/S Augering, 110 mm dia COMPILED BY JL

DATUM Geodetic DATE 09.17.07 - 09.17.07 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
233.20 Ground								20 40 60 80 100	10 20 30		
0.00 / 233.00	200mm TOPSOIL						233				
0.20	Clayey SILT TILL (CL-ML) Brown, moist, stiff, embedded sand and gravel		1	SPT	12			75			3 9 69 18 (88)
231.83							232				
1.37	Brown		2	SPT	13				212.5 / 41		1 5 47 47 (94)
			3	SPT	20		231			21.6	
	Silty CLAY TILL (Cl) Moist, stiff to hard, embedded sand and gravel		4	SPT	36				42		0 1 57 42 (99)
	Grey		5	SPT	100+	▽	230				
228.48			6	SPT	100+		229				
4.72	End of Borehole										Water level measured @ 4.2m @ completion.

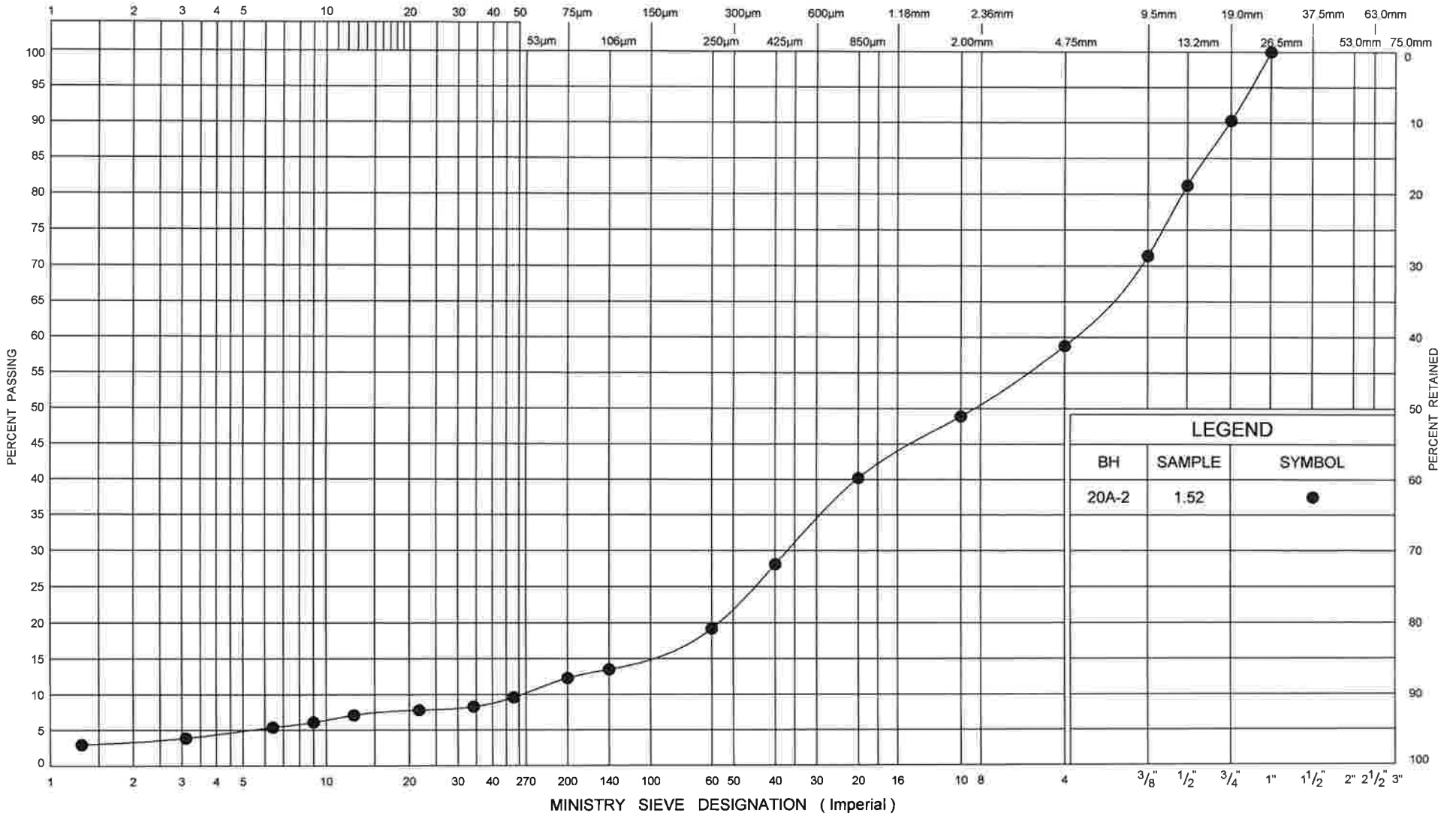
+ 3, × 3: Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

JOE MTO 07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

FILL

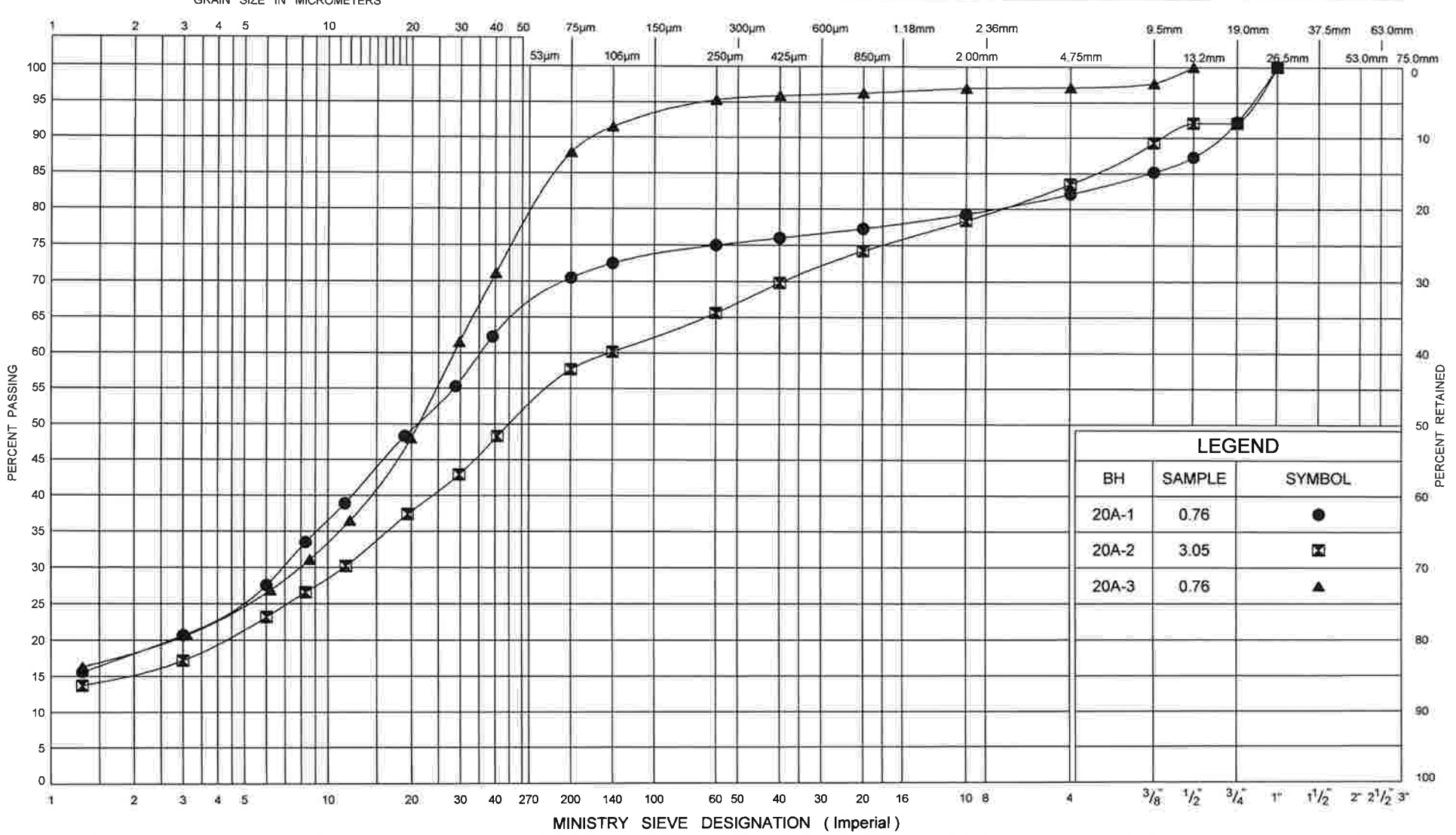
FIG No C- 20A.1

GWP 57-00-00

HWY 26, Thornbury to Meaford

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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GRAIN SIZE DISTRIBUTION

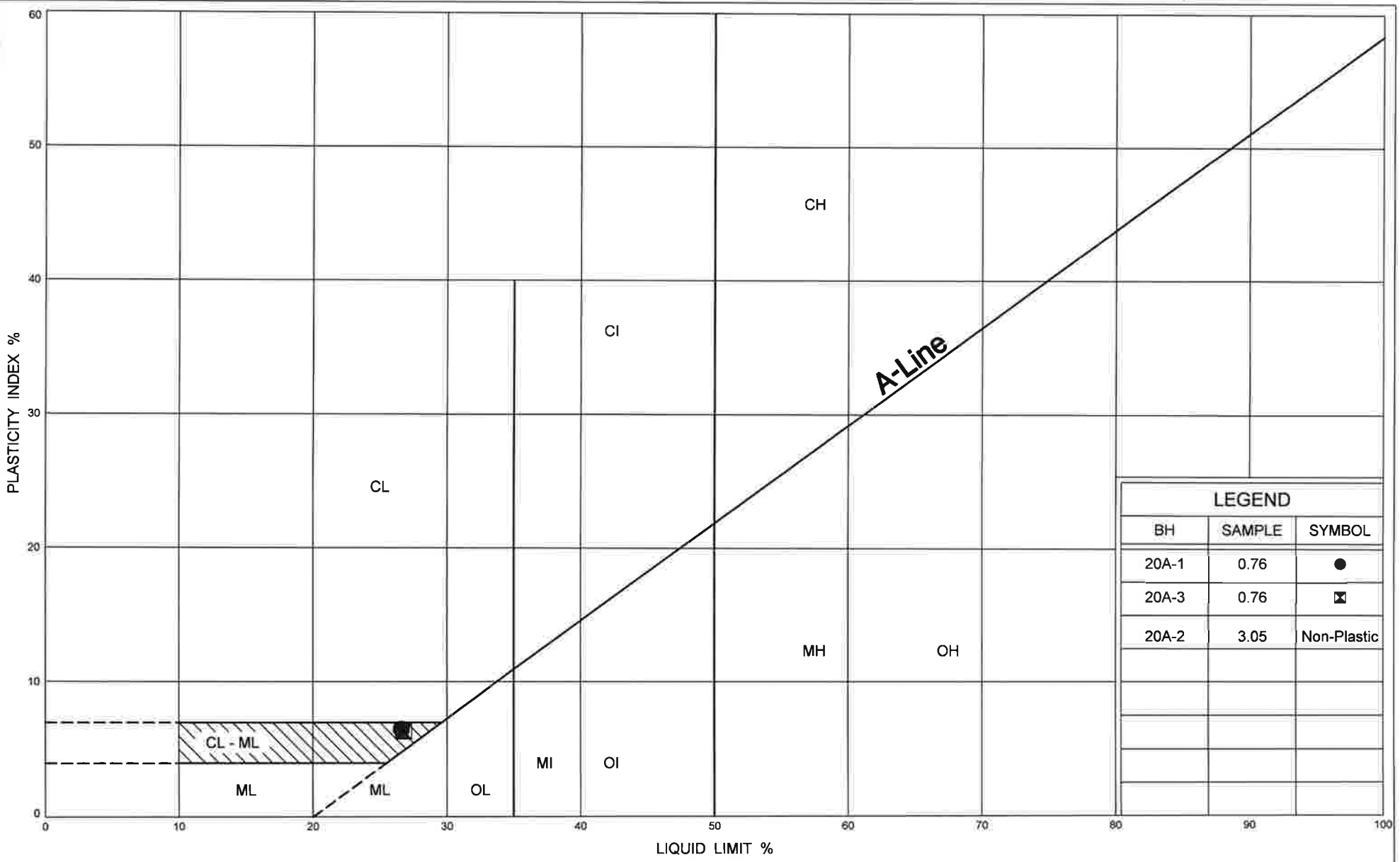
CLAYEY SILT, CL-ML TO ML

FIG No C- 20A.2

GWP 57-00-00

HWY 26, Thornbury to Meaford

Oct 75, FF - S - 21



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Ontario

PLASTICITY CHART

CLAYEY SILT, CL-ML TO ML

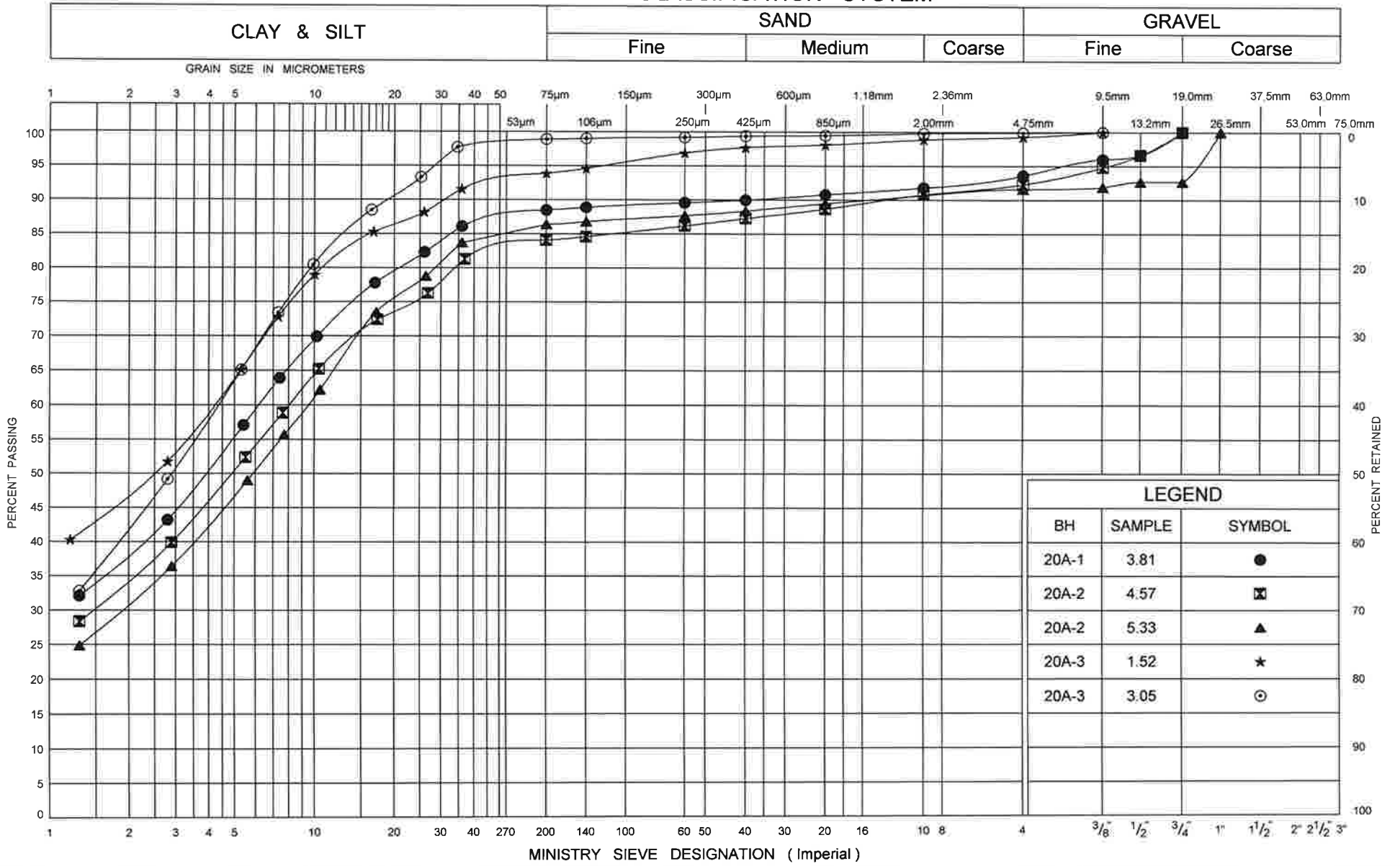
FIG No C- 20A.3

GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT PLASTICITY CHART SMALL CULVE 07-6-JEG1.GPJ ONTARIO MOT.GDT 03/10/09

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

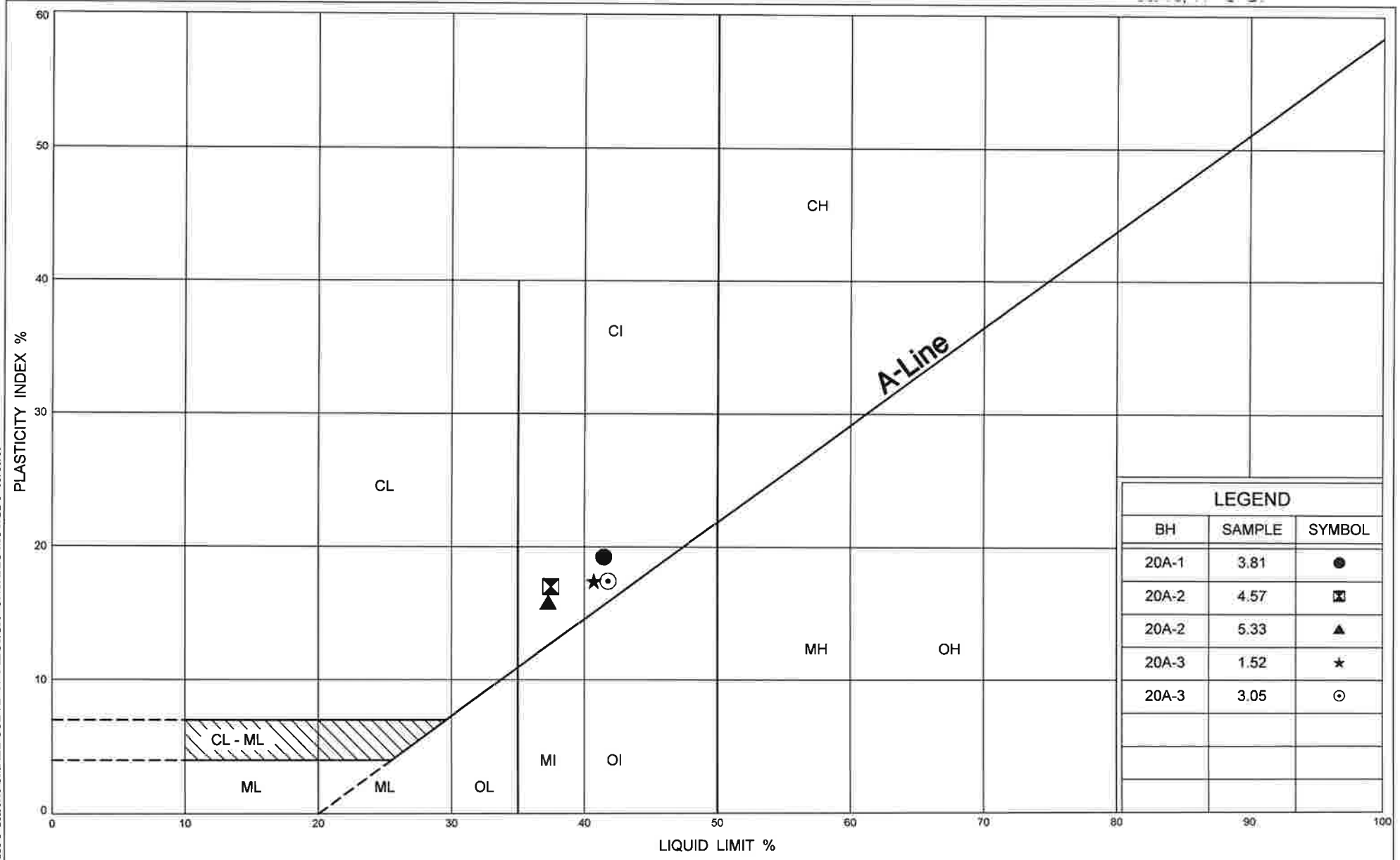
SILTY CLAY TILL, CI

FIG No C- 20A.4

GWP 57-00-00

HWY 26, Thornbury to Meaford

Oct 75, FF - S - 21



LEGEND		
BH	SAMPLE	SYMBOL
20A-1	3.81	●
20A-2	4.57	⊠
20A-2	5.33	▲
20A-3	1.52	★
20A-3	3.05	⊙

Ministry of Transportation
Ontario

PLASTICITY CHART
SILTY CLAY TILL, CI

FIG No C- 20A.5

GWP 57-00-00

HWY 26, Thornbury to Meaford

ONTARIO MOT PLASTICITY CHART SMALL CULVE 07-6-IEG1.GPJ ONTARIO MOT.GDT 03/10/09

Appendix C

Site Photographs

Station 24+766 – Looking downstream (north)

Station 24+766 – Downstream end (north)

Station 24+766 – Looking upstream (south)

Station 24+766 – Upstream end (south)

Station 28+940 – Looking downstream (north)

Station 28+940 – Downstream end (north)

Station 28+ 940 – Looking upstream (south)

Station 28+940 – Upstream end (south)

Appendix D

Limitations of Report

APPENDIX D

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.