Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT

for

CULVERT EXTENSIONS
REHABILITATION OF HIGHWAY 23
G.W.P. 58-00-00
PALMERSTON TO HARRISTON
TOWNS OF NORTH PERTH AND MINTO, ONTARIO

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PML Ref.: 04KF132A
Index No.: 056FIR and 057FDR
Geocres No.: 40P15-35
November 4, 2005

FOUNDATION INVESTIGATION REPORT

for

CULVERT EXTENSIONS
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G.W.P. 58-00-00
PALMERSTON TO HARRISTON
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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION REPORT
for
Culvert Extensions
Rehabilitation of Highway 23
G.W.P. 58-00-00
Palmerston to Harriston
Towns of North Perth and Minto, Ontario

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1. INTRODUCTION

Rehabilitation of the approximate 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the Towns of North Perth and Minto, Ontario is planned. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario.

Rehabilitation of the highway will involve extension of four concrete culverts at one or both ends. The culverts have been given the following reference numbers:

CULVERT No.	APPROXIMATE STATION (HIGHWAY 23 CHAINAGE)	PROPOSED WORKS
C-1	23+143 Town of North Perth	Extension of south (right) end by 3 m
C-2	23+223 Town of North Perth	Extension of north (left) end by 6 m and south (right) end by 4 m
C-3	10+084 Town of Minto	Extension of west (left) end by 3.25 m
C-12	18+588 Town of Minto	Extension of west (left) end by 4 m and east (right) end by 2 m

There is one chainage equation within the project limits:

	Station 23+267.771 =	Station 10+000.000
Highway 23 (Wallace Township, Town of North Perth)		Highway 23 (North, Town of Minto)

This report provides a summary of the factual information obtained during the field investigation conducted at the locations of the proposed culvert extensions.

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2. SITE DESCRIPTION AND GEOLOGY

Highway 23 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy areas. Land use along the study corridor is mainly agricultural with some forested/swamp areas and residential development.

The project area lies in the physiographic region known as the Teeswater Drumlin Field characterised by a complex of low, broad hills with gentle slopes. The principal soil along the study corridor is represented by the Harriston Loam, a medium textured sandy silt to silt till with good drainage. Some of the low lying areas between drumlins are swampy with poor drainage (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3rd Edition, Ontario Research Foundation, 1984).

The frost penetration depth for design purposes as outlined in the Pavement Design and Rehabilitation Manual is 1.6 m. The average annual freezing index in the area is in the order of 800 degree·days Celsius.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out in the period of May 16 to 25, 2005 and comprised a total of 12 boreholes advanced to depths of 5.8 to 9.2 m below existing grade. The approximate locations of the boreholes put down at the culvert extensions along with stratigraphic cross-sections are shown on Drawings C1, C2, C3 and C12 for the respective culverts.

The borehole numbers as well as drawings and figures are provided with prefix codes C1, C2, C3, C12 to reflect the specific culvert number for ease of reference.

The borehole layout was established in accordance with the requirements noted in the Request for Proposal. Peto MacCallum Ltd. selected the borehole locations in the field. The ground surface elevations at the boreholes were provided by the surveying company AGM.

The boreholes were advanced using continuous flight hollow stem augers, powered by a track-mounted CME-55 Bombardier drill rig, supplied and operated by a specialist drilling contractor working under the full-time supervision of a member of our engineering staff.

Representative samples of the soil were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. The ground water conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. All the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines for borehole abandonment procedures.

The recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing program consisting of moisture content determinations as well as 8 Atterberg limits tests and 21 grain size distribution analyses was carried out on selected samples. The results of the laboratory Atterberg limits testing and grain size distribution analyses are presented in figures identified with codes PC and GS respectively.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data, ground water observations and moisture content determinations. The results of laboratory Atterberg limits testing and grain size distribution analyses conducted on selected samples are also shown on the Record of Borehole sheets.

The borehole locations and stratigraphic cross-sections prepared from the borehole data are shown on Drawings C1, C2, C3 and C12. The boundaries between soil strata have been

established only at the borehole locations. Between boreholes, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations was generally consistent and typically comprised the embankment fill made up of sand and gravel or surficial sandy silt topsoil and alluvium deposits overlying clayey silt till underlain by cohesionless glacial tills varying broadly in granulometric composition between silt and gravel. It is noted that the roadside ditches at the inlet and outlet of all the culverts were dry at the time of the investigation. A description of the subsurface stratigraphy identified at each culvert is summarised in the following paragraphs.

4.1 Culvert C-1

Two boreholes were drilled on the south shoulder of the highway and at the south end of the proposed culvert extension. The subsurface stratigraphy revealed in the boreholes comprises a surficial topsoil or sandy/gravelly road embankment fill over clayey silt alluvium underlain by deposits of silt till, clayey silt till, gravelly silt till. Cobbles were encountered within the clayey silt deposit. No ground water was observed at the site.

4.1.1 Fill

Sandy/gravelly fill making up the highway embankment was present surficially in borehole C1-1 put down on the south shoulder of the highway. Composed of two layers – 0.3 m of sand and gravel over 1.1 m of gravelly sand, the fill was penetrated at elevation 396.7.

4.1.2 Topsoil

Surficial topsoil was present in borehole C1-2 advanced at the south end of the proposed culvert extension. Represented by sandy silt with an estimated low organic content, the topsoil had a thickness of 200 mm and was penetrated at elevation 397.0.

4.1.3 Clayey Silt Alluvium

Directly beneath the fill at 1.4 m depth in borehole C1-1 was a clayey silt alluvium deposit. This deposit was 700 mm thick, stiff in consistency and had a moisture content of about 23%. The clayey silt alluvium was penetrated at 2.1 m depth (elevation 396.0).

4.1.4 Silt Till

Overlain by the clayey silt alluvium in borehole C1-1 and topsoil in borehole C1-2 was cohesionless silt till. This unit had a thickness of 3.0 m in the former borehole and 2.0 m in the latter. The silt till was compact in the upper 1 m thick zone (SPT-'N' values of 18, 28) and dense to very dense underneath (up to 60 blows of hammer per 150 mm penetration). The moisture content of the unit varied between 9 and 13%. The silt till was penetrated in boreholes C1-1 and C1-2 at respective depths of 5.1 and 2.2 m (elevations 393.0 and 395.0).

The results of grain size distribution analyses performed on two samples of this material are presented in Figure C1-GS-1.

4.1.5 Clayey Silt Till

Clayey silt till was encountered below the silt till at 2.2 m depth (elevation 395.0) in borehole C1-2. This cohesive deposit was 2.2 m thick and hard in consistency, with a moisture content of about 10%. The clayey silt till contained cobbles and was penetrated at 4.4 m depth (elevation 392.8).

The results of an Atterberg limits test and grain size distribution analysis conducted on a representative sample of the cohesive material are presented in Figures C1-PC-1 and C1-GS-2 respectively. The liquid limit of the clayey silt was 18 and the plastic limit 12, with a corresponding plasticity index of 6.

4.1.6 Sandy Gravel and Silt Till

Underlying the silt till in borehole C1-1 and clayey silt till in borehole C1-2 was cohesionless sandy gravel and silt till. This unit had a minimum thickness of 4.1 m in the former borehole and 3.3 m in the latter. The sandy gravel and silt till was very dense (50 blows of hammer per 0 to 150 mm penetration). The moisture content of the unit was in a narrow range of 7 to 8%. The sandy gravel and silt till was penetrated in boreholes C1-1 and C1-2 at respective depths of 9.2 and 7.7 m (elevations 388.9 and 389.5).

The results of a grain size distribution analysis performed on this material are presented in Figure C1-GS-3.

4.1.7 Ground Water

No ground water was observed in either borehole in the course of the field work. It is noted, however, that ground water levels are subject to seasonal fluctuations and rainfall patterns.

4.2 Culvert C-2

Four boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes typically comprises a surficial fill or topsoil overlying clayey silt underlain by deposits of sandy silt till, gravelly silt till, gravel till. Cobbles/boulders were encountered at the site. Ground water was measured in all the boreholes to be at elevations 394.5 to 397.4.

4.2.1 Fill

Sand and gravel fill making up the highway embankment was present surficially in boreholes C2-2 and C2-3 put down on the road shoulders. The fill had a thickness of 1.4 m in borehole C2-2 and 1.2 m in boreholes C2-3. It was penetrated at respective elevations 397.2 and 397.4.

4.2.2 Topsoil

Surficial topsoil was present in boreholes C2-1 and C2-4 advanced at both ends of the culvert. Represented by low to very low organic sandy silt, the topsoil had a thickness of 200 mm and was penetrated at elevations 397.0 and 397.4 respectively.

4.2.3 Clayey Silt Alluvium

Directly beneath the topsoil in borehole C2-1 and fill in boreholes C2-2 and C2-3 was clayey silt alluvium. This deposit was 1.0 to 1.7 m thick, firm to stiff in consistency and had a moisture content varying between 14 and 25%. The clayey silt alluvium was penetrated at depths of 1.4 and 2.9 m (elevations 395.7 to 396.2).

The results of an Atterberg limits test and grain size distribution analysis performed on a representative sample of the alluvium are presented in Figures C2-PC-1 and C2-GS-1 respectively. The liquid limit of the clayey silt was 31 and its plastic limit 19, with a corresponding plasticity index of 12.

4.2.4 Silt

A layer of non-plastic silt was encountered below the clayey silt alluvium in borehole C2-1. This unit was 400 mm thick, loose in relative density and penetrated at 1.8 m depth (elevation 395.4).

4.2.5 Clayey Silt Till

Overlain by the fill, topsoil or silty soils at depths of 0.2 to 3.2 m (elevations 395.4 to 397.4) was clayey silt till. This deposit was 0.7 to 3.4 m thick and stiff to hard in consistency. The clayey silt till had a moisture content of 10 to 15%, locally 7%. It is worth noting that occasional cobbles were encountered in borehole C2-2. The deposit was penetrated at depths of 3.0 to 5.2 m (elevations 393.4 to 395.0).

The results of Atterberg limits testing and grain size distribution analyses conducted on the cohesive material are presented in respective Figures C2-PC-2 and C2-GS-2. The liquid and plastic limits of the clayey silt ranged from 20 to 22 and from 11 to 13 respectively, thus giving the plasticity index of 8 to 10.

4.2.6 Sandy Silt Till

Underlying the clayey silt deposit at 2.4 m depth (elevation 396.2) in borehole C2-2 and clayey silt till in boreholes C2-2 and C2-4 at depths of 3.6 and 5.2 m (elevations 393.4 and 394.0) in boreholes C2-2 and C2-4 was sandy silt till. The upper 800 mm thick stratum of this material above the clayey silt till in borehole C2-2 was compact (SPT-'N' value of 20). The sandy silt till below the clayey silt till in both boreholes was very dense (50 to 100 blows of hammer per 25 to 150 mm penetration), containing scattered cobbles/boulders, and had a minimum thickness of 2.5 m in borehole C2-2 and 4.1 m in borehole C2-4. The moisture content of these strata varied between 9 and 11%. Both boreholes were terminated within the sandy silt till at 7.7 m depth (elevations 390.9 and 389.9).

The results of a grain size distribution analysis performed on this cohesionless material are presented in Figure C2-GS-3.

4.2.7 Silt Till / Gravel Till

The clayey silt till units overlay silt till comprising silt with sand with gravel some clay at a depth of 3.6 m (elevation 395.0) in borehole C2-3. This unit was dense to very dense and had a thickness of at least 5.6 m. The moisture content of the gravelly silt till was 9 to 11%. The results of a grain size distribution analysis conducted on a representative sample of the unit are presented in Figure C2-GS-4. The borehole was terminated within the silt till at 9.2 m depth (elevation 389.4).

Gravel till comprising gravel with sand with silt trace clay was encountered below the clayey silt till at a depth of 3.0 m (elevation 394.2) in borehole C2-1. This stratum was very dense (50 to 75 blows of hammer per 50 to 150 mm penetration) and had a minimum thickness of 4.7 m. The moisture content of the gravel till ranged from 8 to 10%. The results of a grain size distribution

analysis performed on this material are presented in Figure C2-GS-5. The borehole was terminated within the stratum at 7.7 m depth (elevation 389.5).

4.2.8 Ground Water

Water was observed in all the boreholes in the course of the field work. Upon completion of drilling, ground water was measured to be at depths of 1.2 to 3.1 m (elevations 394.5 to 397.4). The observed ground water levels are subject to seasonal fluctuations and precipitation patterns.

4.3 Culvert C-3

Two boreholes were drilled on the west shoulder of the highway and at the west end of the proposed culvert extension. The subsurface stratigraphy revealed in the boreholes comprises a surficial topsoil or fill over silt alluvium, sandy silt, clayey silt till underlain by silty sand till. No ground water was observed at the site.

4.3.1 Fill

Sand and gravel fill making up the highway embankment was present surficially in borehole C3-2 put down on the west shoulder of the highway. The fill had a thickness of 1.4 m and was penetrated at elevation 396.3.

4.3.2 Topsoil

Surficial topsoil was present in boreholes C3-1 advanced at the west end of the proposed culvert extension. Represented by low organic sandy silt, the peat had a thickness of 200 mm and was penetrated at elevation 396.9.

4.3.3 Silt Alluvium

Overlain by the fill in borehole C3-2 was silt alluvium. This unit was 400 mm thick and loose in relative density. The moisture content of the silt alluvium was about 20%. The unit was penetrated at 1.8 m depth (elevation 395.9).

4.3.4 Sandy Silt

A layer of sandy silt was identified directly beneath the silt alluvium in borehole C3-2. This layer was 400 mm thick and compact in relative density. The sandy silt was penetrated at a depth of 2.2 m (elevation 395.5).

4.3.5 Clayey Silt Till

Clayey silt till was encountered below the sandy silt in boreholes C3-2. This deposit had a thickness of 1.5 m and was stiff to hard in consistency. The moisture content of the clayey silt till decreased with depth from 13 to 7%. The deposit was penetrated at 3.7 m depth (elevation 394.0).

The results of an Atterberg limits test and grain size distribution analysis conducted on a representative sample of the cohesive material are presented in Figures C3-PC-1 and C3-GS-1 respectively. The liquid limit of the clayey silt till was 19 and its plastic limit 13, with a corresponding plasticity index of 6.

4.3.6 Silty Sand Till

Underlying the topsoil in borehole C3-1 and the clayey silt till in borehole C3-2 was silty sand till. This stratum was compact to dense (SPT-'N' values of 11 to 49) in the upper 2.5 m thick portion in borehole C3-1 and very dense (50 to 87 blows of hammer per 50 to 150 mm penetration) below elevation 394.0 in both boreholes. The clayey silt till had a minimum thickness of 6.0 m in the former borehole and 4.2 m in the latter, with a moisture content varying between 8 and 13%. The

boreholes were terminated within the stratum at respective depths of 6.2 and 7.9 m (elevations 390.9 and 389.8).

The results of grain size distribution analyses performed on this cohesionless material are presented in Figure C3-GS-2.

4.3.7 Ground Water

No ground water was observed in either borehole in the course of the field work. It is noted, however, that ground water levels are subject to seasonal fluctuations and rainfall patterns.

4.4 Culvert C-12

Four boreholes were drilled along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes is complex and comprises a surficial fill and/or topsoil, clayey alluvium, sandy/silty soils underlain by deposits of silt till, clayey silt till, sandy gravel till, silt and sand till, gravel till and silty clay till. Cobbles/boulders were encountered at the west end of the culvert. Ground water was measured in all the boreholes to be at elevations 378.6 to 379.7.

4.4.1 Fill

Surficial fill was present in boreholes C12-2 and C12-3 put down on the road shoulders. Composed of sand and gravel, the embankment fill had a thickness of 1.2 m in borehole C12-2 and 1.6 m in borehole C12-3, its moisture content being about 6%. The fill was penetrated at elevation 380.1.

4.4.2 Topsoil

Low organic sandy silt topsoil was present surficially in borehole C12-4 advanced at the east end of the culvert. The sandy silt topsoil was 200 mm thick and penetrated at elevation 380.4.

Medium organic silty clay topsoil was buried below the fill in boreholes C12-2 and C12-3. The silty clay topsoil had a thickness of 400 and 500 mm, with a moisture content of 27 and 29%, and was penetrated at depths of 1.6 and 2.1 m (elevations 379.7 and 379.6) respectively.

4.4.3 Alluvium

Alluvium comprising mixed layers of clayey silt, topsoil and sand was present surficially in borehole C12-1 drilled at the west end of the culvert. Having a moisture content varying between 14 and 24% (depending on the constituent units), the alluvium was 1.4 m thick and penetrated at elevation 378.7.

Silty clay alluvium was identified at depths of 1.6 and 0.6 m (elevations 379.7 and 380.0) in boreholes C12-2 and C12-4 respectively. The silty clay alluvium was 300 mm thick and firm in consistency. The alluvium had a moisture content of about 22% and was penetrated at respective depths of 1.9 and 0.9 m (elevations 379.4 and 379.7).

4.4.4 Sand to Silt and Sand

Directly beneath the silty clay alluvium at 1.9 m depth (elevation 379.4) in borehole C12-2 was cohesionless sand. This unit was compact in relative density and had a thickness of 1.3 m. The sand was penetrated at 3.2 m depth (elevation 378.1).

The topsoil overlay strata of silt and sand at a depth of 2.1 m (elevation 379.6) in borehole C12-3 and silty sand at 0.2 m depth (elevation 380.4) in borehole C12-4. The silt and sand was 500 mm thick and compact in relative density, with a moisture content of about 14%. The silty sand had a thickness of 400 mm. These strata were penetrated at depths of 0.6 and 2.6 m (elevations 380.0 and 379.1) in boreholes C12-4 and C12-3 respectively.

4.4.5 Silt Till

Non-plastic silt till was encountered below the alluvium at a depth of 1.4 m (elevation 378.7) in borehole C12-1 and below the sand at 3.2 m depth (elevation 378.1) in borehole C12-2. This unit

had a thickness of 1.2 m in borehole C12-1 and 1.3 m in borehole C12-2. The silt till was loose to compact (SPT-'N' values of 8 to 26) and had a moisture content ranging from 10 to 19%. The unit was penetrated at respective depths of 2.6 and 4.5 m (elevations 377.5 and 376.8).

The results of grain size distribution analyses performed on two samples of the silt till are presented in Figure C12-GS-1.

4.4.6 Clayey Silt Till

Underlying the silt till in boreholes C12-1 and C12-2 at depths of 2.6 and 4.5 m and the silty clay alluvium at a depth of 0.9 m (elevation 379.7) in borehole C12-4 was clayey silt till. This deposit was 0.6 to 1.5 m thick and firm to hard in consistency. The moisture content of the clayey silt till varied between 16 and 23%. The deposit was penetrated at depths of 1.5 to 5.6 m (elevations 375.7 to 379.1).

The results of an Atterberg limits test and grain size distribution analysis conducted on a representative sample of the cohesive material are presented in Figures C12-PC-1 and C12-GS-2 respectively. The liquid limit of the clayey silt till was 33 and its plastic limit 15, with a corresponding plasticity index of 18.

4.4.7 Silt and Sand Till to Gravel Till

A 1.1 m thick layer of sandy gravel till was revealed below the silt and sand at 2.6 m depth (elevation 379.1) in borehole C12-3. This layer was compact to dense and had a moisture content of about 10%. The sandy gravel was penetrated at 3.7 m depth, elevation 378.0. The results of a grain size distribution analysis performed on this material are presented in Figure C12-GS-3.

Silt and sand till was encountered below the clayey silt till or sandy gravel till at depths of 1.5 to 5.6 m (elevations 375.7 to 379.1) in all the boreholes. This stratum was 0.4 to 4.0 m thick and compact to very dense. The moisture content of the silt and sand till ranged from 8 to 11%. The stratum was penetrated at depths of 4.5 to 6.9 m (elevations 374.8 to 375.6) in boreholes C12-1,

C12-3 and C12-4. Augering was terminated within the silt and sand till at a depth of 6.9 m (elevation 374.4) in borehole C12-2. The results of a grain size distribution analysis conducted on a representative sample of the cohesionless material are presented in Figure C12-GS-4.

Overlain by the silt and sand till at 4.5 m depth (elevation 375.6) in borehole C12-1 was gravel till. Containing scattered cobbles and boulders, this unit was very dense (60 blows of hammer per 150 mm penetration) and had a moisture content of about 8%. The borehole was terminated within the gravel till at a depth of 5.8 m (elevation 374.3) by refusal on a probable boulder. The results of a grain size distribution analysis performed on this material are presented in Figure C12-GS-5.

4.4.8 Silty Clay Till

Underlying the silt and sand till at 6.9 m depth (elevation 374.8) in borehole C12-3 and a depth of 5.5 m (elevation 375.1) in borehole C12-4 was silty clay till. This deposit was very stiff to hard in consistency and had a moisture content varying between 13 and 23%. The boreholes were terminated at respective depths of 8.2 and 7.0 m (elevations 373.5 and 373.6).

The results of an Atterberg limits test and grain size distribution analysis conducted on a representative sample of the cohesive material are presented in Figures PC-1 and GS-2 respectively. The liquid limit of the silty clay till was 35 and its plastic limit 14, with a corresponding plasticity index of 21.

4.4.9 Ground Water

Water was observed in all the boreholes in the course of the field work. Upon completion of drilling, ground water was at depths of 0.5 to 2.7 m (elevations 378.6 to 379.7). The observed ground water levels are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

The field work was carried out under the supervision of Mr. M. Rapsey and direction of Mr. P. Cullen, P.Eng., Project Engineer. The equipment was supplied by Marathon Drilling Co. Ltd.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

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GD:gd-mi

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 $\tilde{N}$.

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
F V	FIELD VANE		

STRESS AND STRAIN

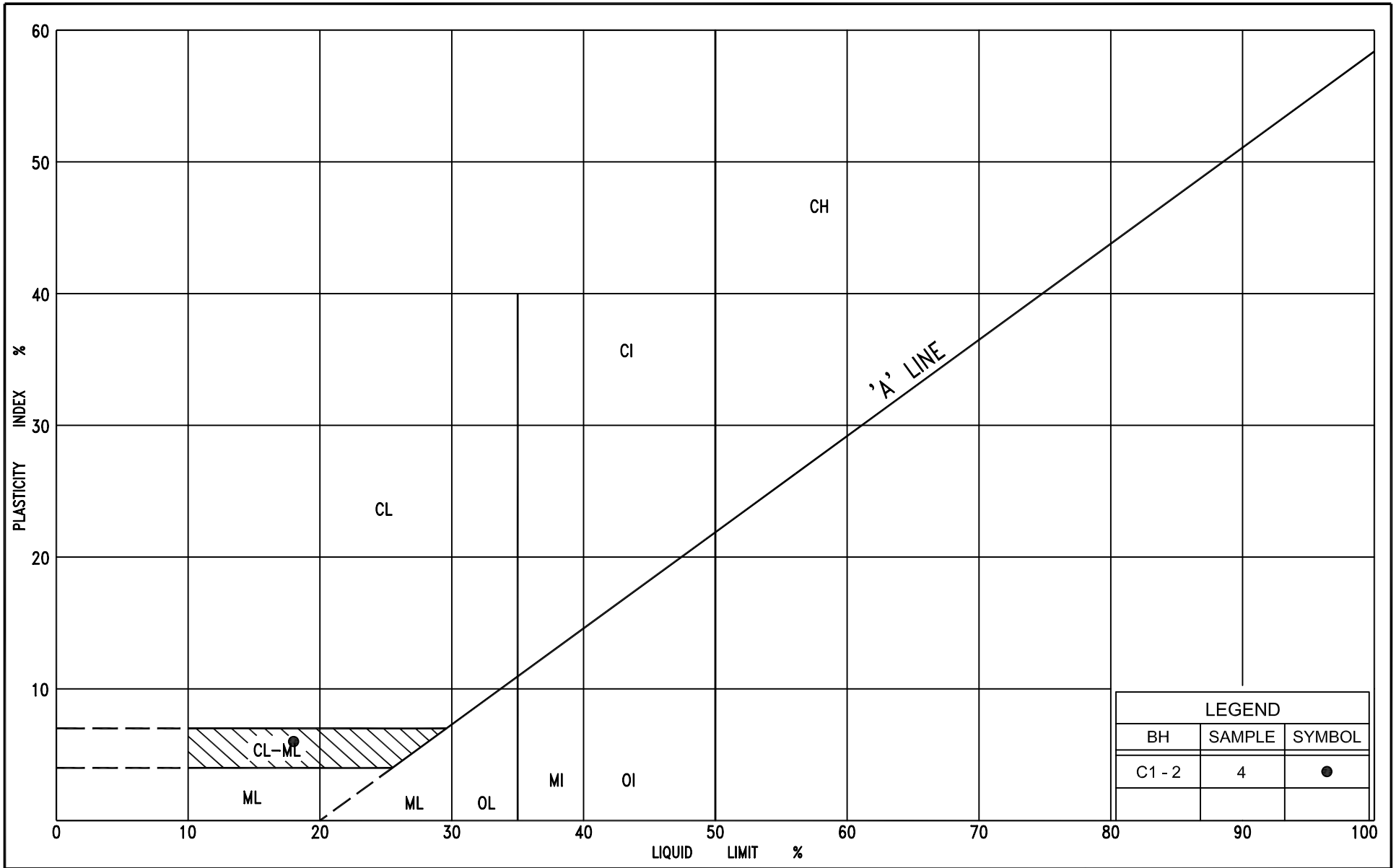
u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	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	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT
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

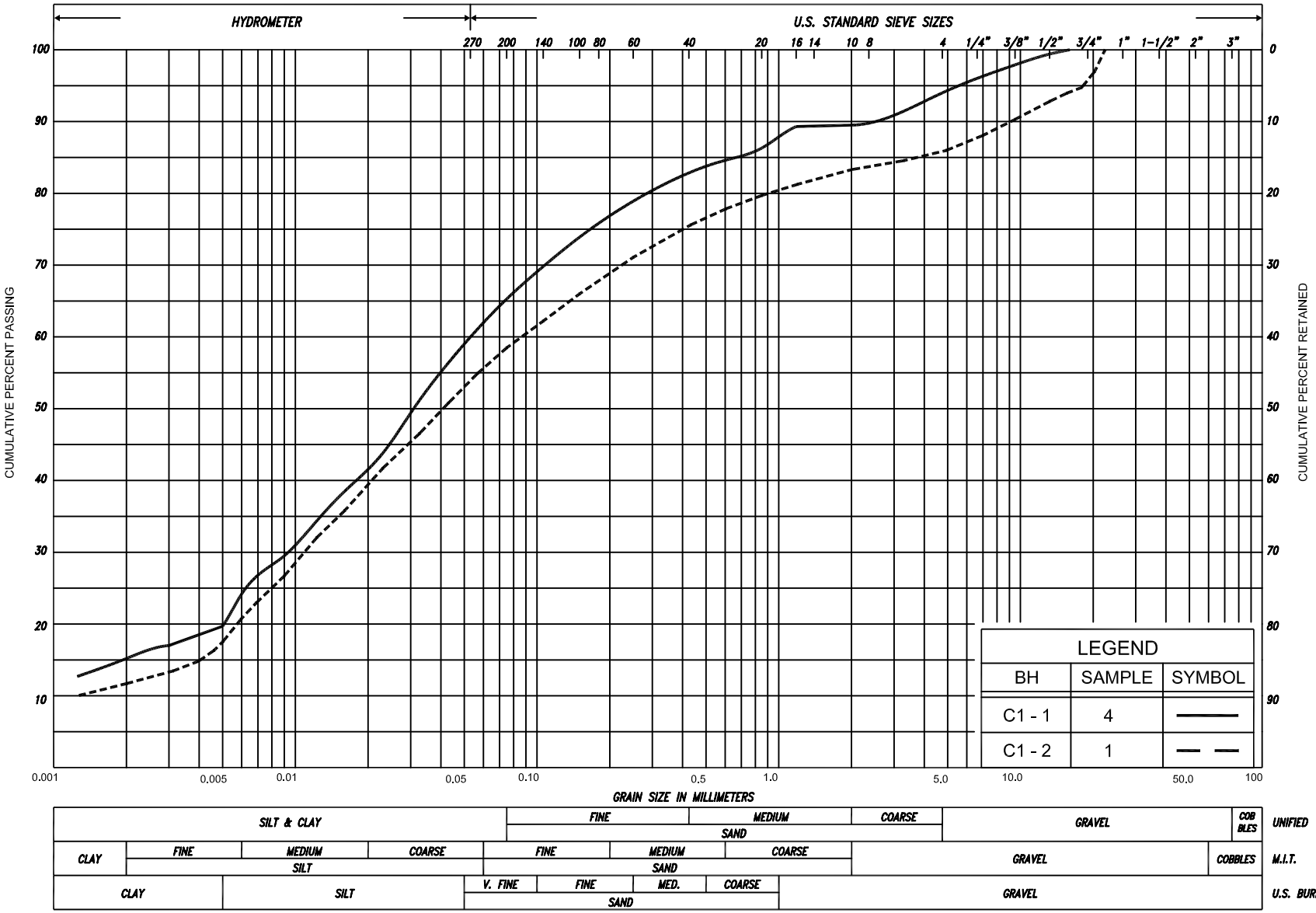


Ministry of Transportation Ontario

PLASTICITY CHART

CLAYEY SILT, with sand, with gravel
(TILL)

FIG No.	C1-PC-1
HWY	23
G.W.P. No.	58-00-00



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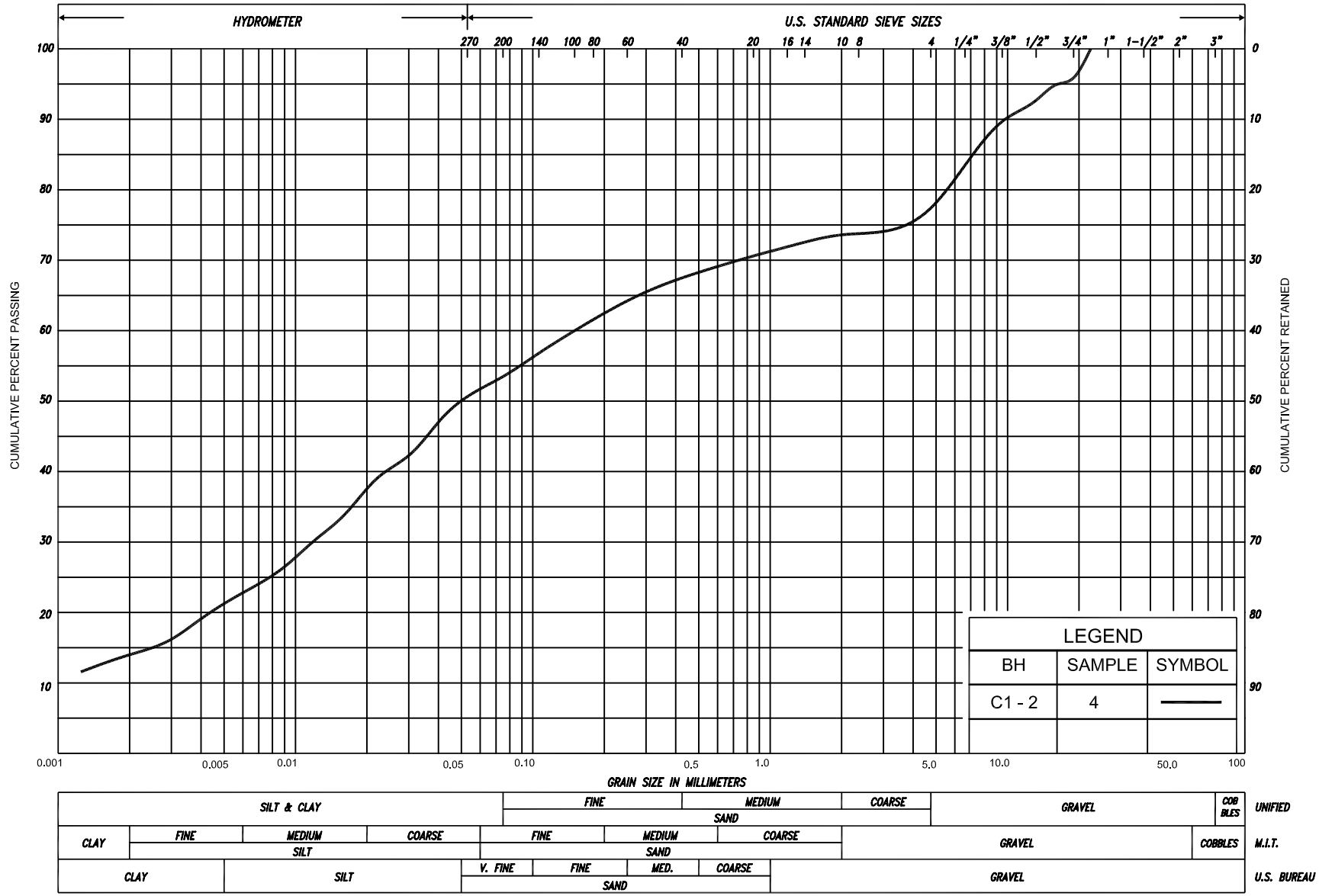
GRAIN SIZE DISTRIBUTION

SILT, with sand, some clay, trace to some gravel (TILL)

FIG No.	C1-GS-1
HWY	23
G.W.P. No.	58-00-00

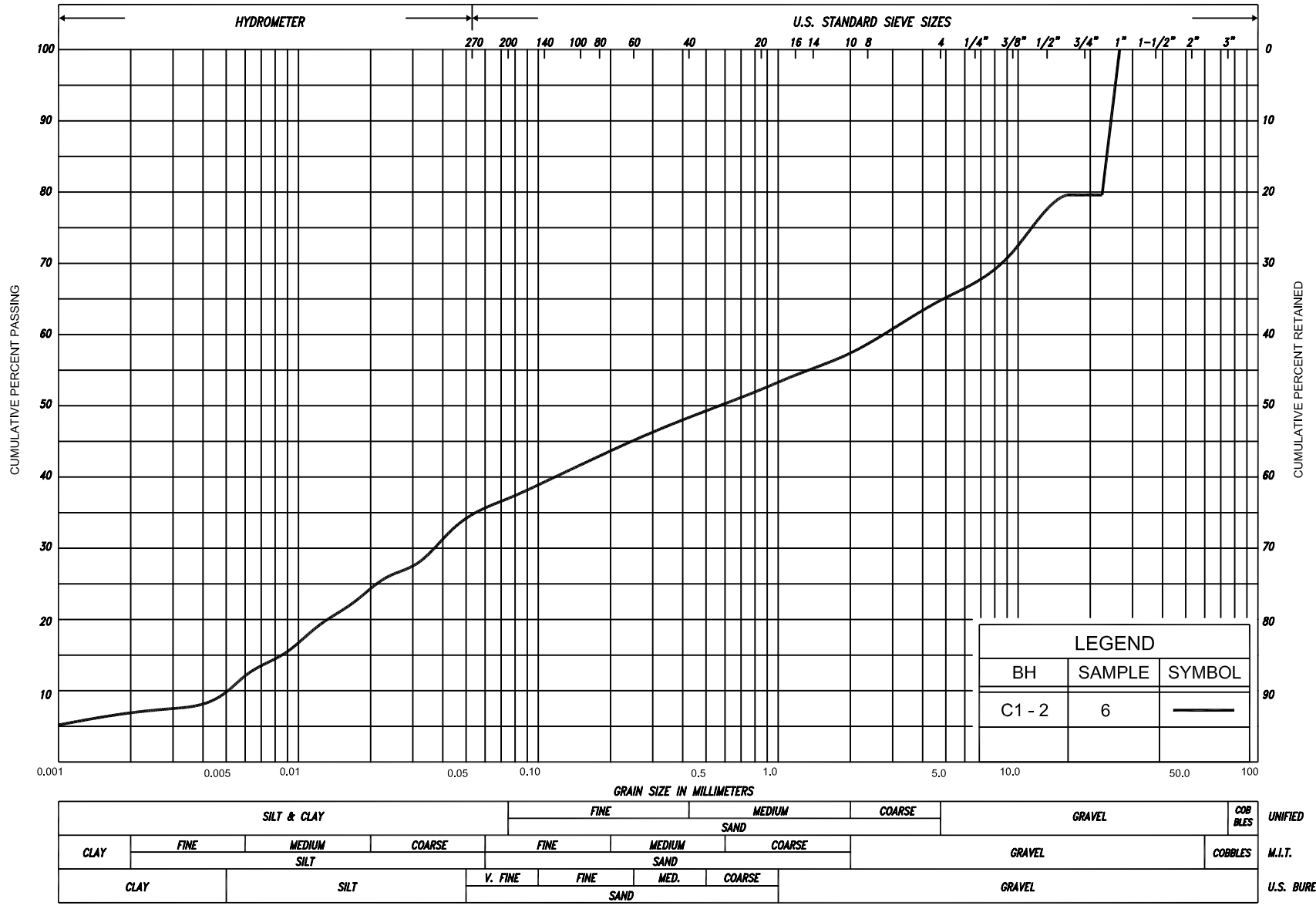


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand, with gravel
(TILL)

FIG No.	C1-GS-2
HWY	23
G.W.P. No.	58-00-00



Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SANDY GRAVEL and SILT, trace clay
(TILL)

FIG No.	C1-GS-3
HWY	23
G.W.P. No.	58-00-00

Ministry of Transportation
Ontario

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Foundation Design

RECORD OF BOREHOLE No C1-1

1 of 1

METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 562 N; 194 687 E Hwy. 23, Sta. 23+149.2 o/s 9.5m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 16, 2005 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / 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
	Ground Surface						398				
	Sand and gravel, with silt Brown Dry (FILL)										
	Gravelly sand, with silt Brown Dry (FILL)						397				
	Clayey silt, trace sand Stiff Dark olive brown Wet (Alluvium)		1	SS	12		396		○		
	Silt, with sand, some clay, trace gravel Compact to very dense Brown Moist (TILL)		2	SS	28						
			3	SS	53/15cm		395		○		
			4	SS	46		394				
			5	SS	60/15cm				○		
	Sandy gravel and silt, trace clay Very dense Brown Dry to damp (TILL)		6	SS	60/15cm		393		○		
			7	SS	50/15cm		392		○		
			8	SS	50/0cm		391				
							390				
			9	SS	50/0cm		389				
	End of borehole * Borehole dry on completion of drilling										

+ × Numbers refer to Sensitivity

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RECORD OF BOREHOLE No C1-2 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 551 N; 194 684 E Hwy. 23, Sta. 23+144.6 o/s 19.8m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 19, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
397.2	Ground Surface					*					
0.0	Topsoil						397				
0.2	Silt, with sand, some clay, some gravel Compact to dense Brown Wet to moist (TILL)		1	SS	18		396		○		14 27 47 12
395.0			2	SS	33		395		○		
2.2	Clayey silt, with sand, with gravel, cobbles Hard Brown Dry (TILL)		3	SS	50/15cm		394		⊖		22 24 40 14
392.8			4	SS	70		393				
4.4	Sandy gravel and silt, trace clay Very dense Brown Dry (TILL)		5	SS	50/15cm		392		○		35 28 30 7
389.5			6	SS	67/15cm		391				
7.7	End of borehole * Borehole dry on completion of drilling		7	SS	67/10cm		390				
			8	SS	50/8cm						

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+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE (20, 15, 5, 10)

METRIC

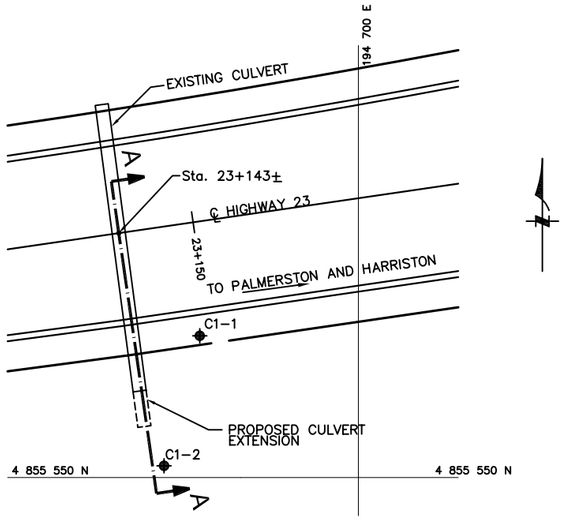
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES

CONT No
GWP No 58-00-00

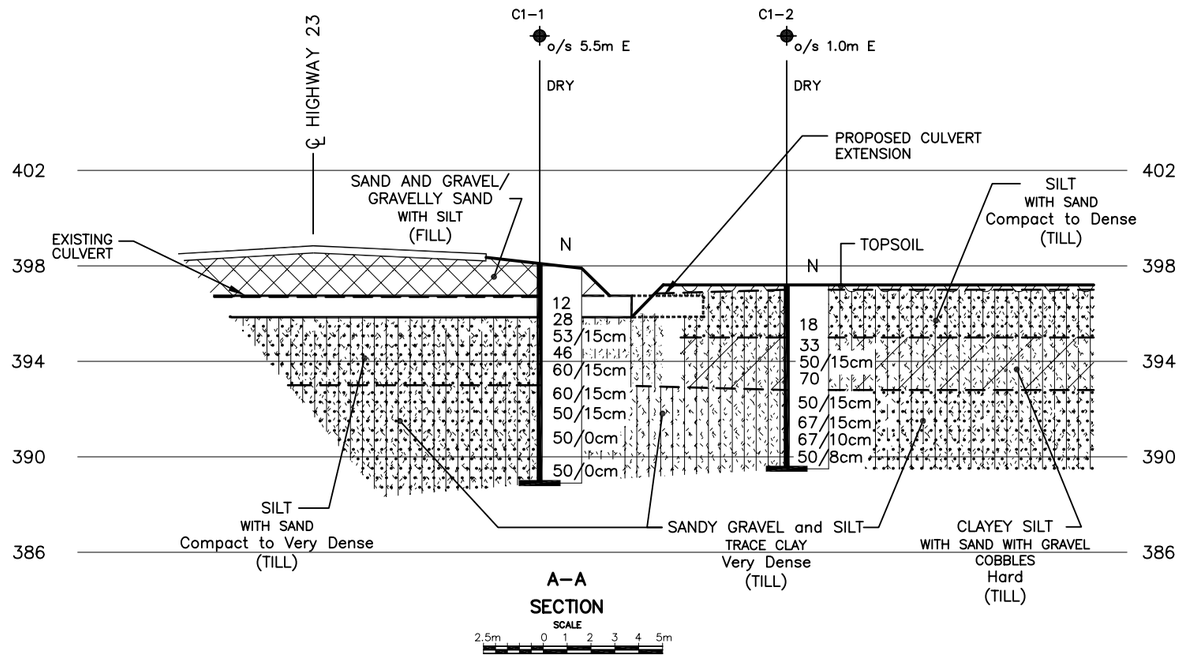
SHEET

HIGHWAY 23
CULVERT C-1, Sta. 23+143
BOREHOLE LOCATIONS & SOIL STRATA

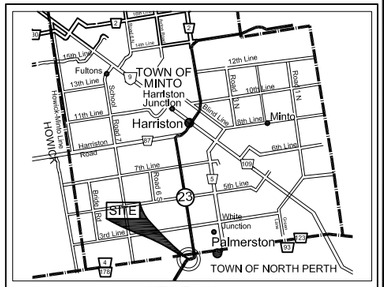
Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN
SCALE
5 0 5 10m



A-A
SECTION
SCALE
2.5m 0 1 2 3 4 5m



KEY PLAN
SCALE : 1cm : 4 km
2 1 0 2 4 6 8km

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & 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 May 2005
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C1-1	398.1	4 855 562	194 687
C1-2	397.2	4 855 551	194 684

NOTES

1. SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.
2. STATIONS REFER TO TOWN OF NORTH PERTH.

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

REVISIONS

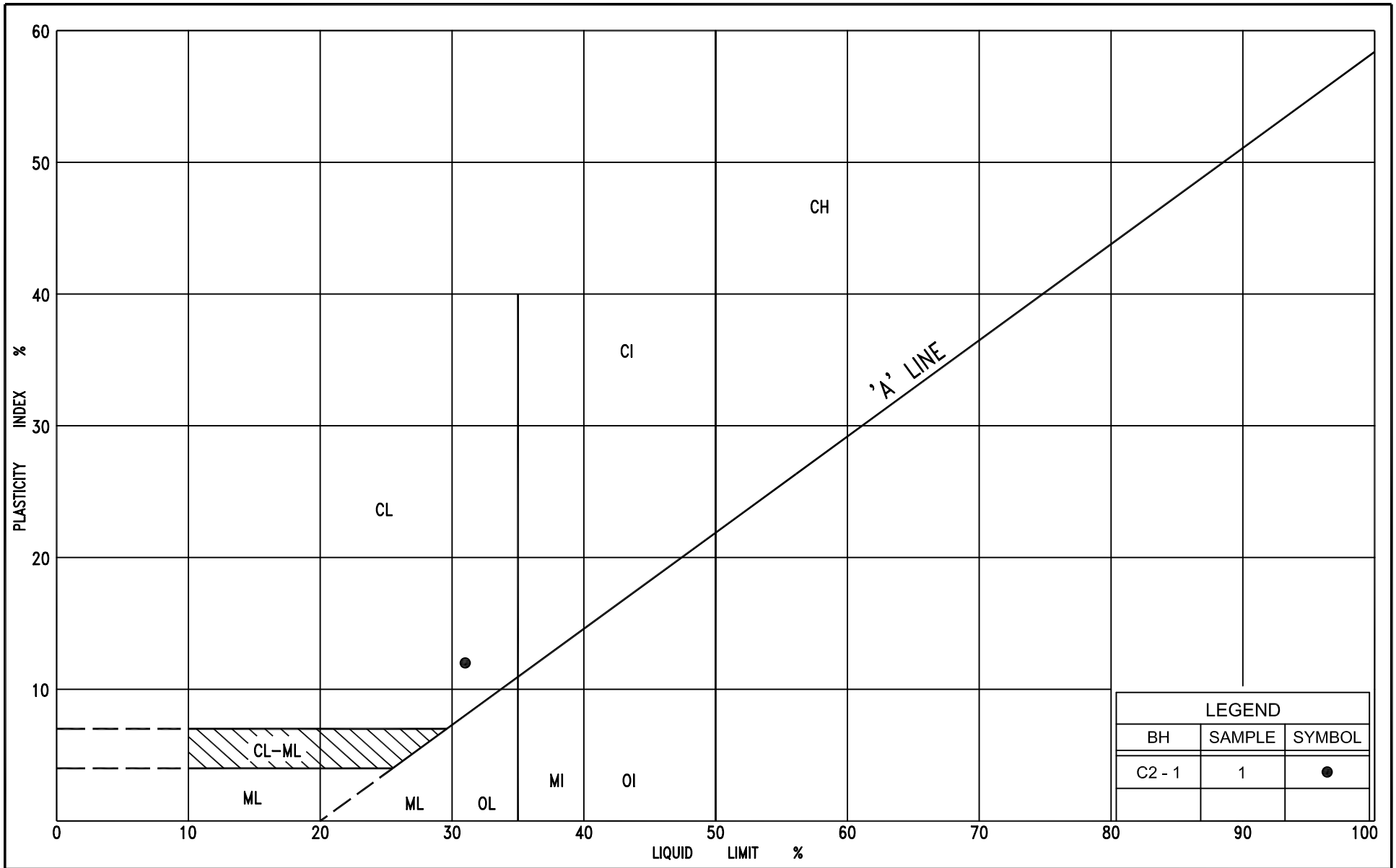
DATE	BY	DESCRIPTION

Geocres No. 40P15-35

HWY No	23					DIST	33
SUBM'D	GD	CHECKED	GD	DATE	NOV. 04, 2005	SITE	
DRAWN	NA	CHECKED	CN	APPROVED	CN	DWG	C1

REF No xbse_160210427_design.dwg DT. June 2005

BRG

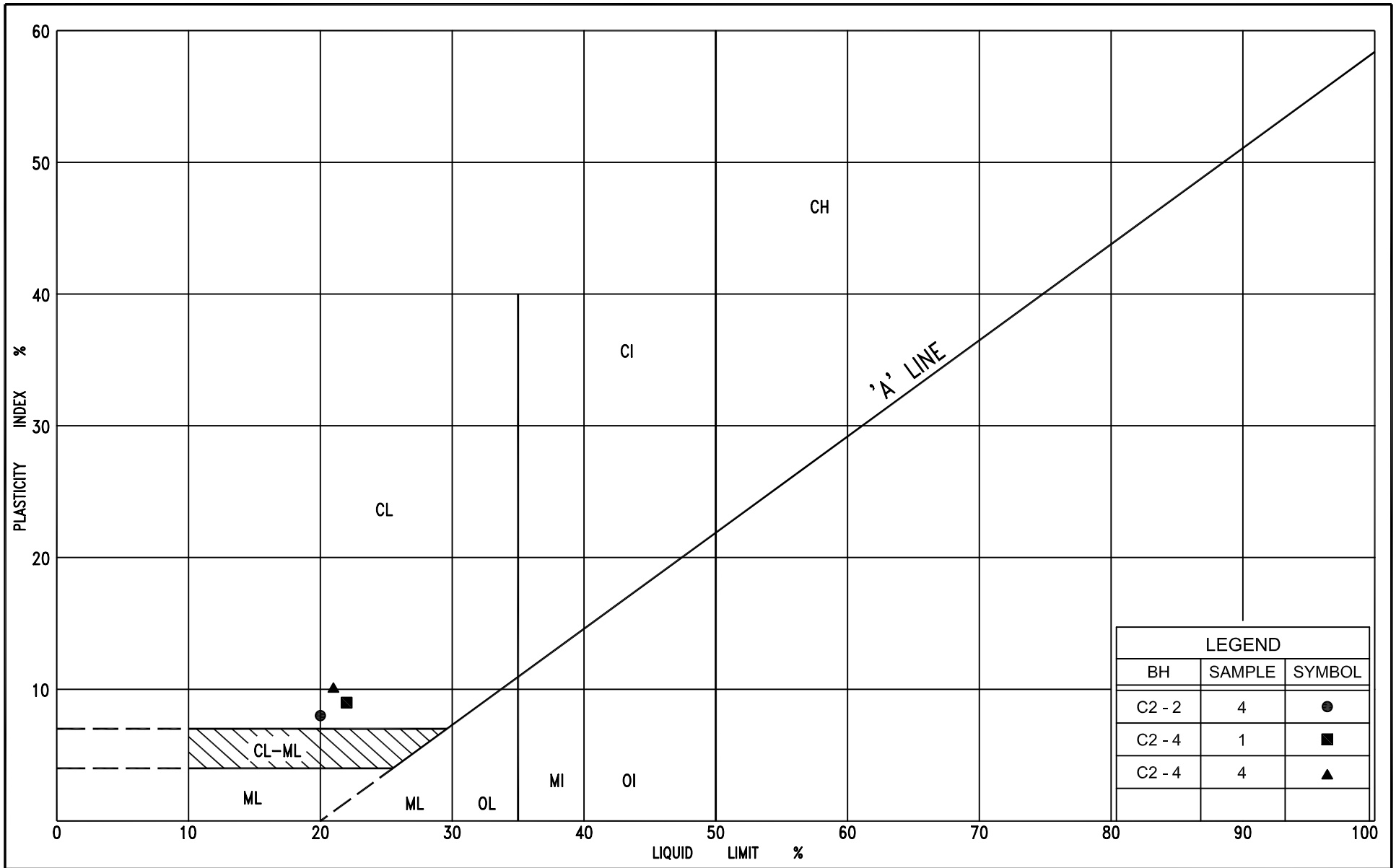


Ministry of Transportation Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand (CL)
(Alluvium)

FIG No.	C2-PC-1
HWY	23
G.W.P. No.	58-00-00

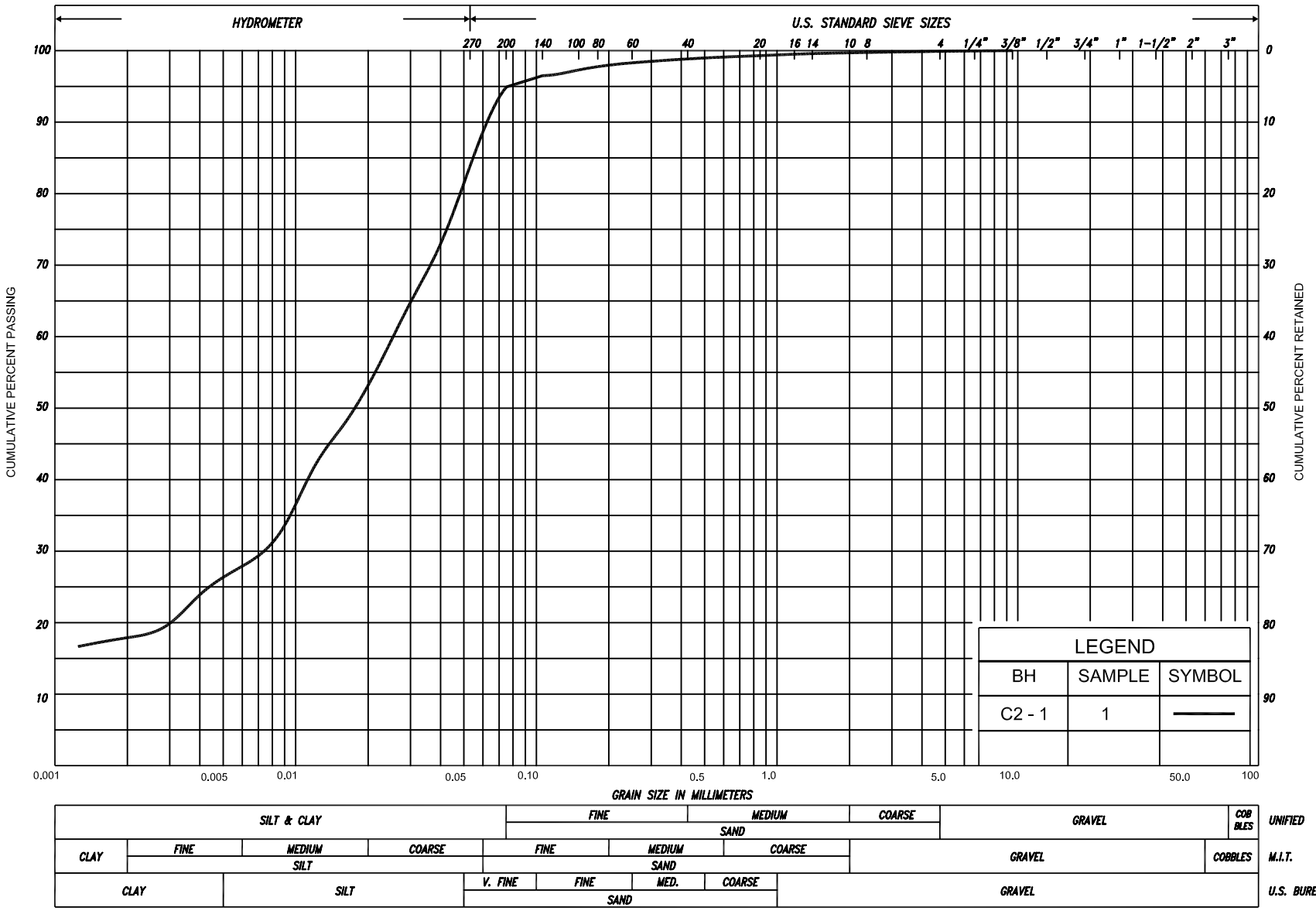


Ministry of Transportation Ontario

PLASTICITY CHART

CLAYEY SILT with sand, some gravel (CL)
(TILL)

FIG No.	C2-PC-2
HWY	23
G.W.P. No.	58-00-00

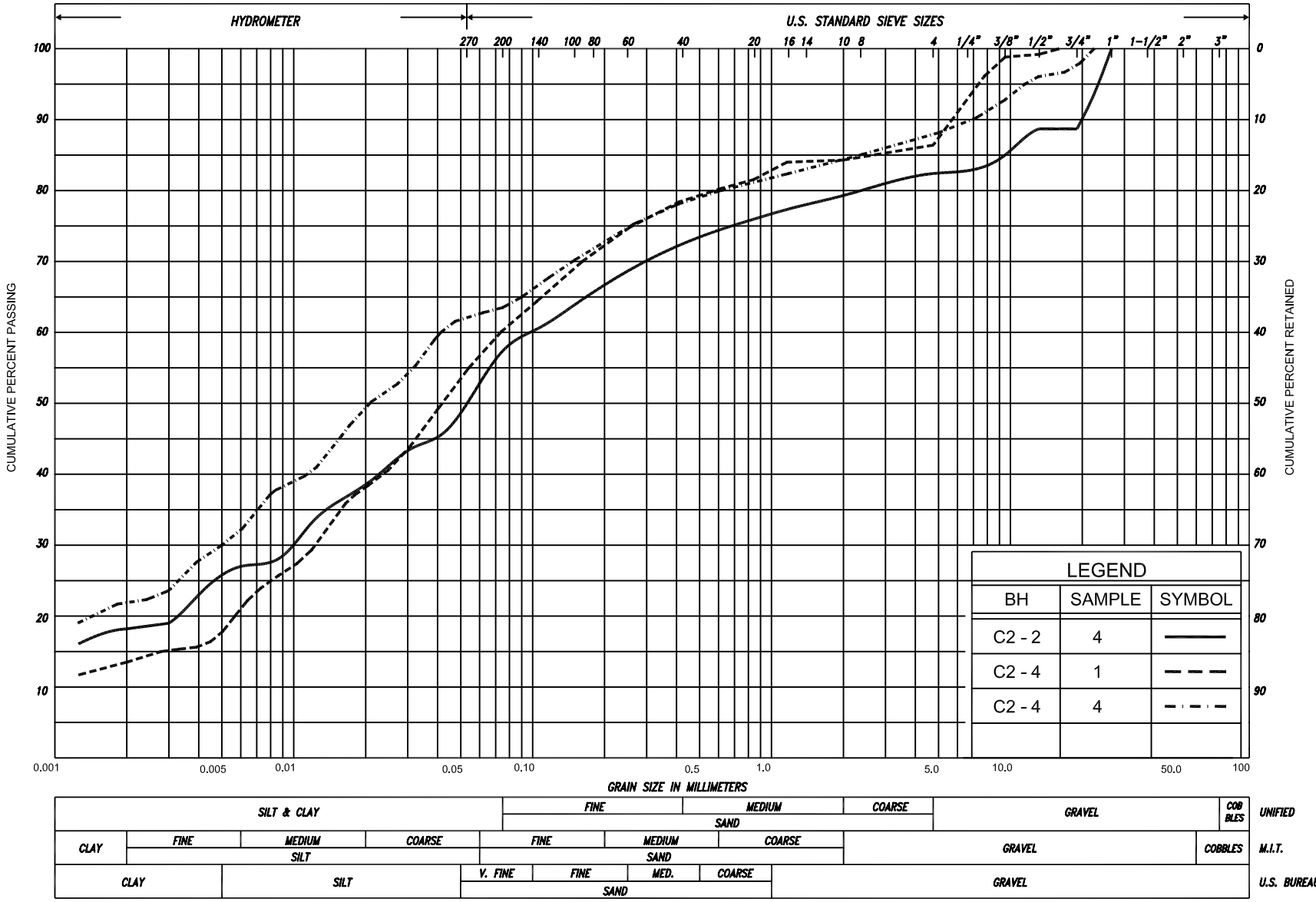


Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand (CL)
(Alluvium)

FIG No.	C2-GS-1
HWY	23
G.W.P. No.	58-00-00

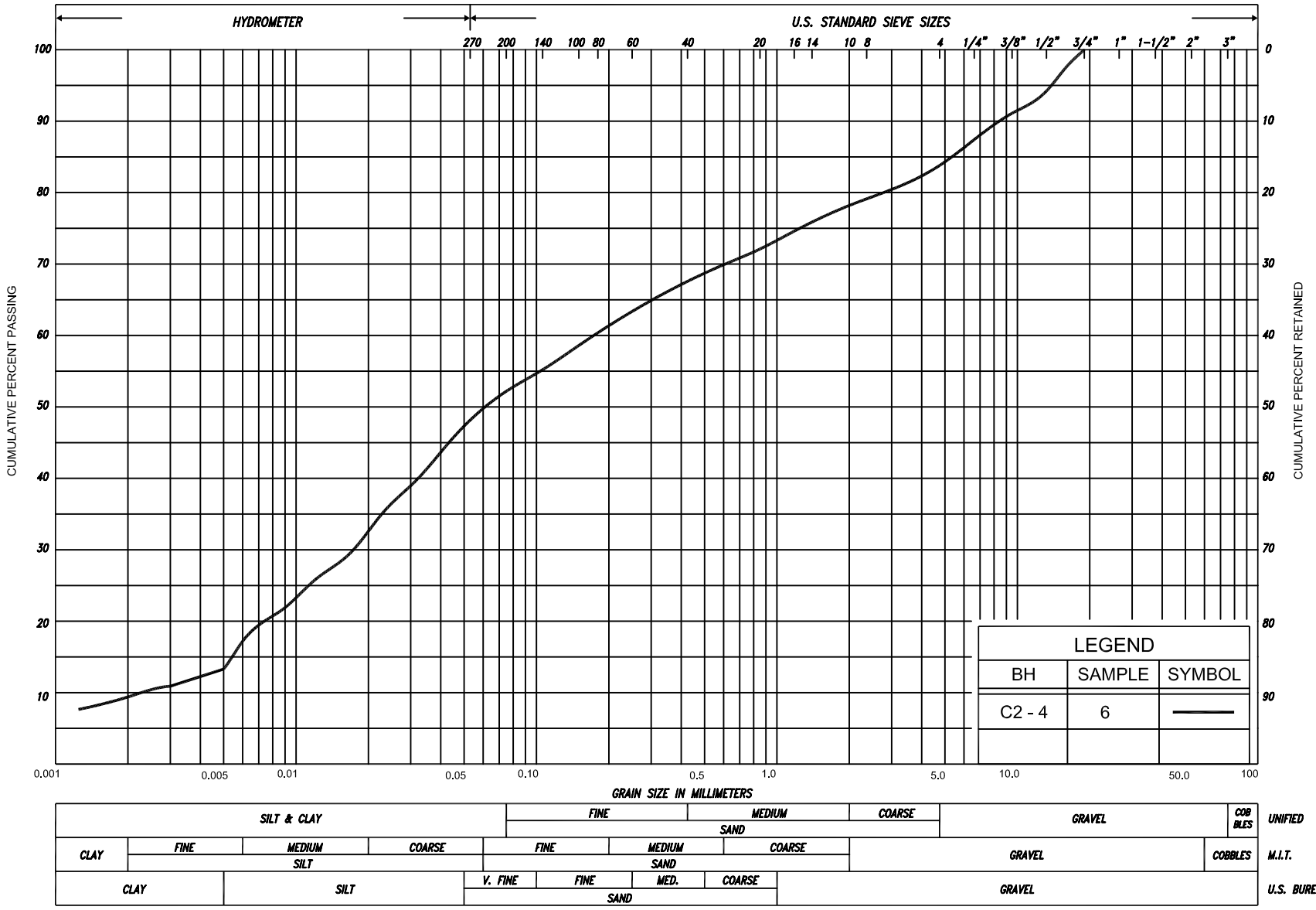


MInIstry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand, some gravel (CL)
(TILL)

FIG No.	C2-GS-2
HWY	23
G.W.P. No.	58-00-00

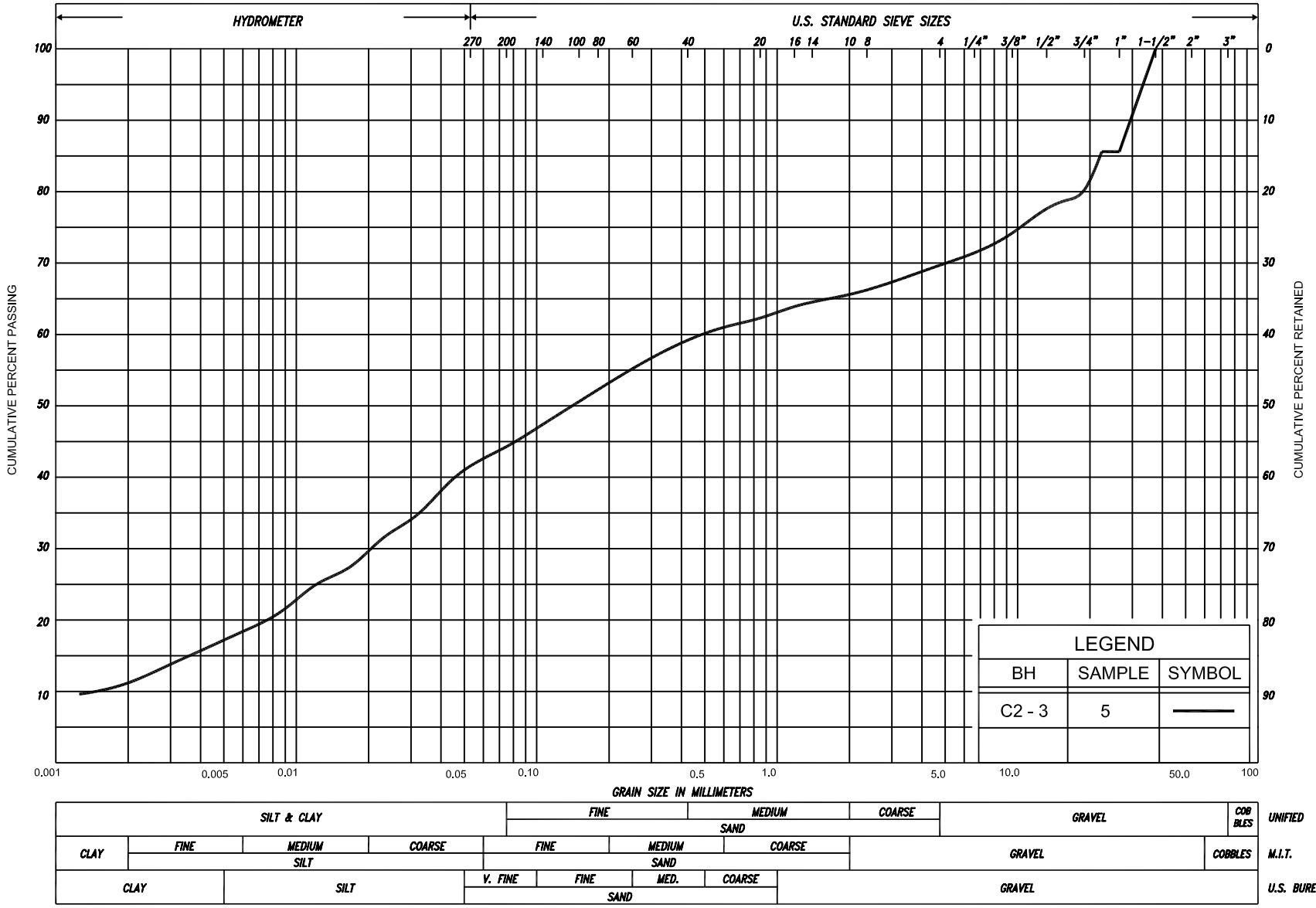


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT, some gravel, trace clay
(TILL)

FIG No.	C2-GS-3
HWY	23
G.W.P. No.	58-00-00

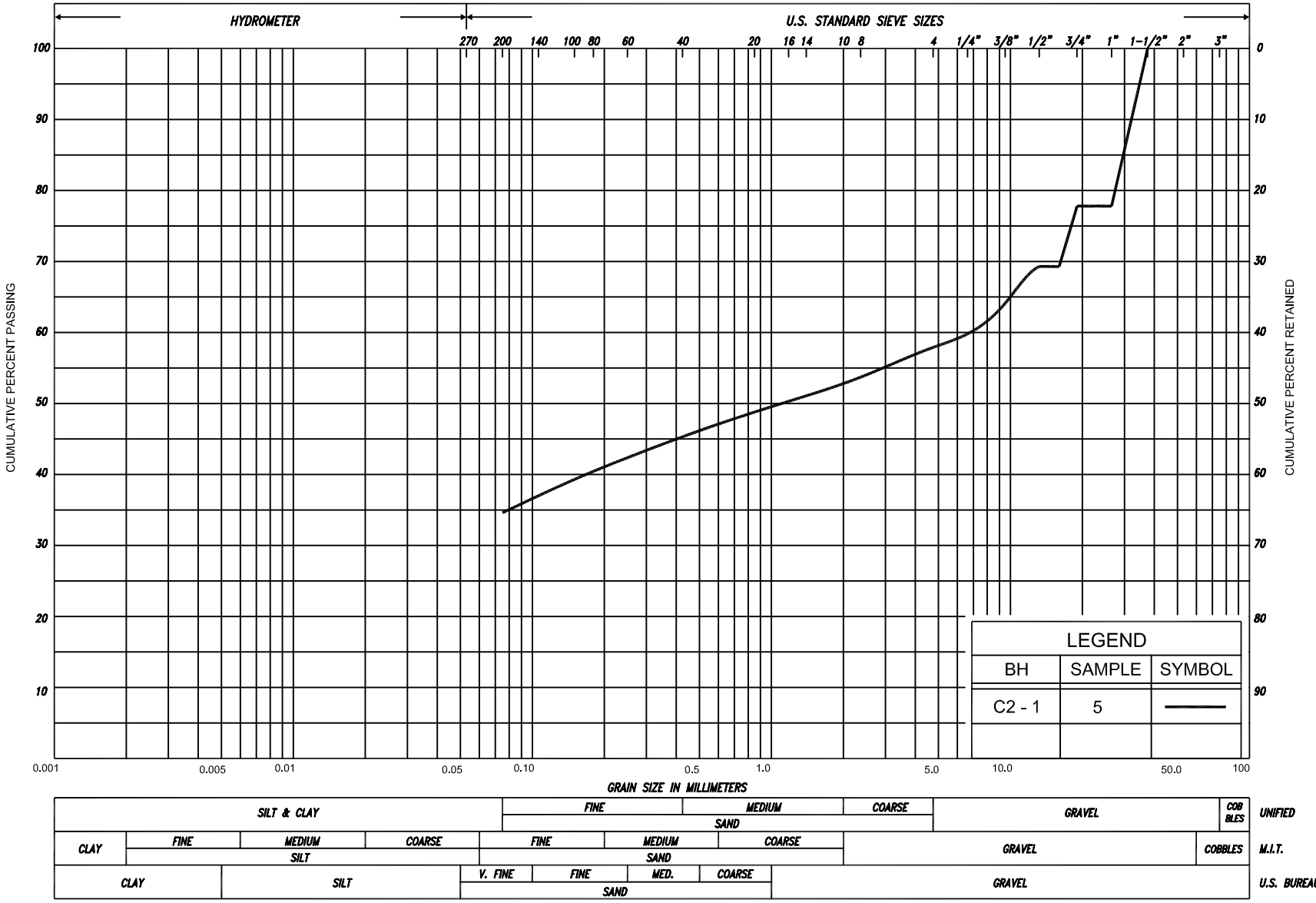


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SILT, with gravel, with sand, some clay
(TILL)

FIG No.	C2-GS-4
HWY	23
G.W.P. No.	58-00-00



Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

GRAVEL, with sand, with silt, trace clay
(TILL)

FIG No.	C2-GS-5
HWY	23
G.W.P. No.	58-00-00

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Ontario

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RECORD OF BOREHOLE No C2-1 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 608 N; 194 754 E Hwy. 23, Sta. 23+222.2 o/s 26.4m Lt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 24, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
397.2	Ground Surface											
0.0	Topsoil						397					
0.2	Clayey silt, trace sand fissured Firm Olive Wet brown		1	SS	4					○		0 5 77 18
395.8	(Alluvium)						396					
1.4	Silt, trace clay											
395.4			2	SS	11					○		
1.8	Loose Rusty brown Clayey silt, with sand, with gravel						395					
	Very stiff Brown Wet to hard moist		3	SS	42	▼*				○		
394.2	(TILL)						394					
3.0	Gravel, with sand, with silt, trace clay		4	SS	50/10cm							
	Very dense Brown Moist											
	(TILL)		5	SS	75/15cm					○		42 23 (35)
			6	SS	50/5cm		393					
							392					
			7	SS	70/15cm		391			○		
							390					
389.5			8	SS	50/5cm							
7.7	End of borehole											

* 2005 24 05

▼ Water level measured after drilling

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+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C2-2 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 594 N; 194 753 E Hwy. 23, Sta. 23+219.7 o/s 12.8m Lt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 24, 2005 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
398.6	Ground Surface										
0.0	Sand and gravel, with silt Brown Dry (FILL)										
397.2							398				
1.4	Clayey silt, with sand Stiff Olive brown Wet (Alluvium)		1	SS	11		397		○		
396.2											
2.4	Sandy silt, some gravel, trace clay Compact Brown Wet (TILL)		2	SS	20	▼*	396		○		
395.4											
3.2	Clayey silt, with sand, some gravel, cobbles Very stiff to hard Brown Wet to moist (TILL)		3	SS	19		395		○		
			4	SS	59				⊖		18 25 39 18
			5	SS	10/15cm		394		○		
393.4											
5.2	Sandy silt, some gravel, trace clay, boulders Very dense Brown Damp (TILL)		6	SS	100/15cm		393		○		
			7	SS	50/8cm						
							392				
390.9			8	SS	50/3cm		391				
7.7	End of borehole										

* 2005 05 24

▼ Water level measured after drilling

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+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C2-3 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 573 N; 194 766 E Hwy. 23, Sta. 23+229.0 o/s 9.8m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 16, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
398.6	Ground Surface										
0.0	Sand and gravel, with silt Brown Dry (FILL)					▼*	398				
397.4											
1.2	Clayey silt, some sand Stiff Khaki brown Wet (Alluvium)		1	SS	17		397		○		
			2	SS	7		396		○		
395.7											
2.9	Clayey silt, with sand, with gravel Stiff Brown Wet (TILL)		3	SS	13		395		○		
395.0											
3.6	Silt, with gravel, with sand, some clay Dense to very dense Brown Damp (TILL)		4	SS	42		394		○		
			5	SS	50/8cm				○		30 26 33 11
			6	SS	50/15cm		393				
			7	SS	50/5cm		392				
			8	SS	50/13cm		391				
							390				
389.4			9	SS	68/8cm						
9.2	End of borehole										

* 2005 05 16

▼ Water level measured after drilling

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+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C2-4 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 562 N; 194 765 E Hwy. 23, Sta. 23+226.3 o/s 20.3m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 19, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
397.6	Ground Surface										
0.0	Topsoil										
0.2	Clayey silt, with sand, some gravel Stiff to hard Brown Wet to moist (TILL)		1	SS	9		397				14 26 47 13
			2	SS	9	▼*	396				
			3	SS	59		395				
394.0			4	SS	62						12 24 42 22
3.6	Sandy silt, some gravel, trace clay with occ. cobbles Very dense Brown Dry (TILL)		5	SS	50/13cm		394				
			6	SS	70/13cm		393				16 32 43 9
			7	SS	70/15cm		392				
							391				
389.9			8	SS	50/8cm		390				
7.7	End of borehole										

* 2005 05 19

▼ Water level measured after drilling

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:13:05 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

METRIC

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

CONT No
GWP No 58-00-00

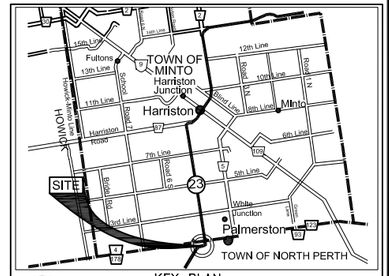
HIGHWAY 23

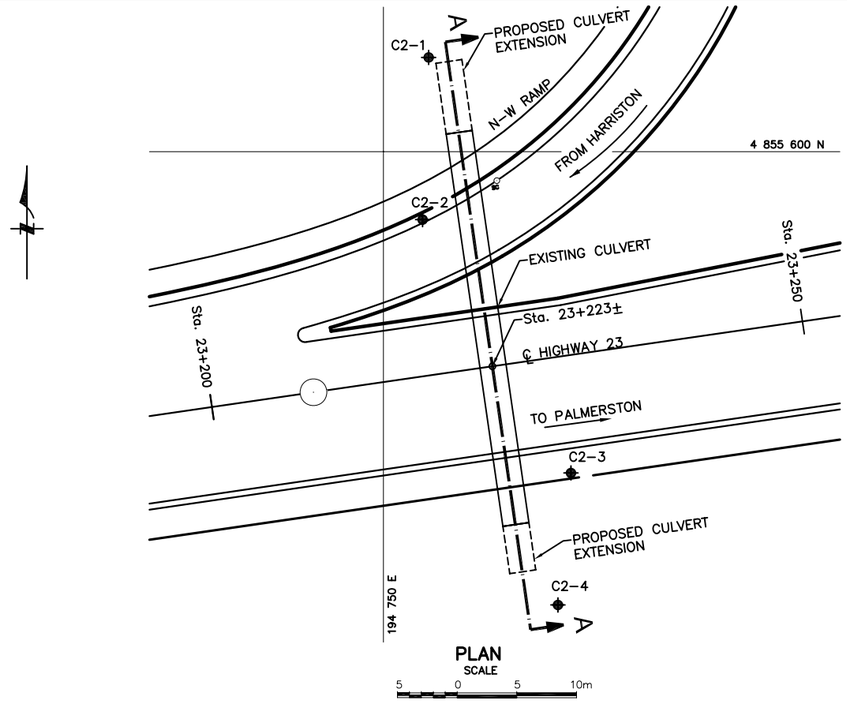
CULVERT C-2, Sta 23+223

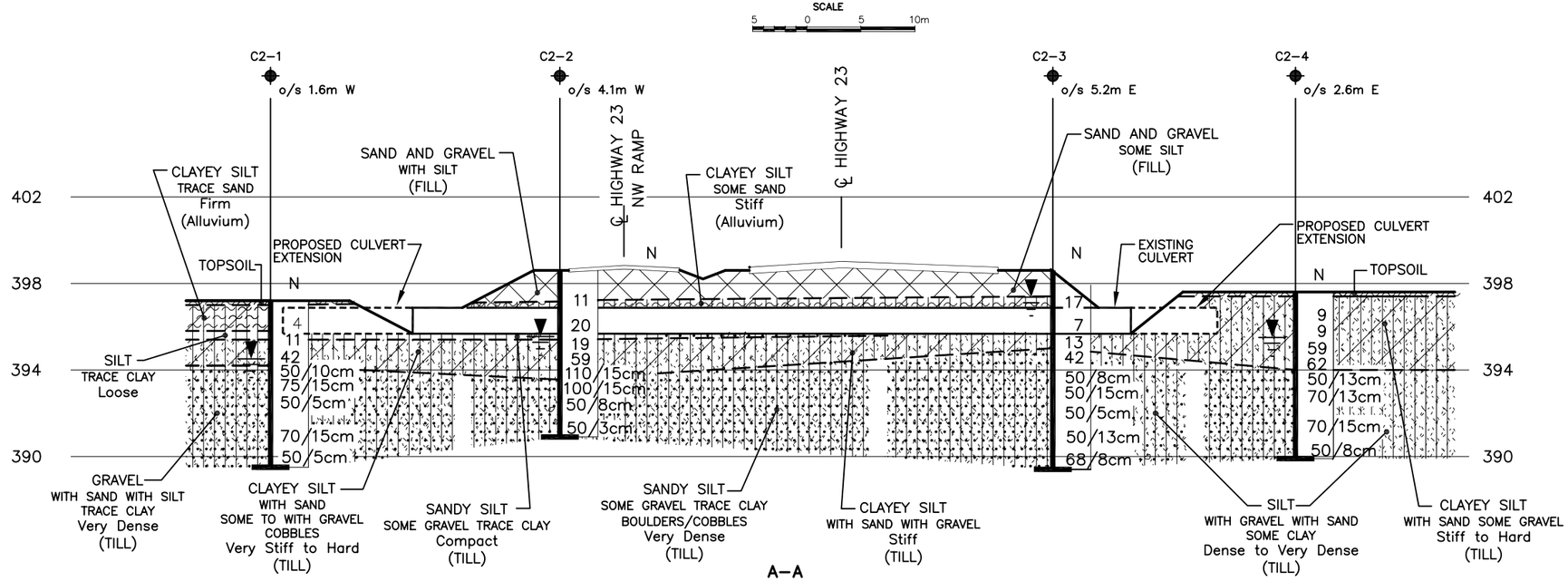
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS







LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & 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 May 2005
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C2-1	397.2	4 855 608	194 754
C2-2	398.6	4 855 594	194 753
C2-3	398.6	4 855 573	194 766
C2-4	397.6	4 855 562	194 765

- NOTE -

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

NOTES

1. SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.
2. STATIONS REFER TO TOWN OF NORTH PERTH.

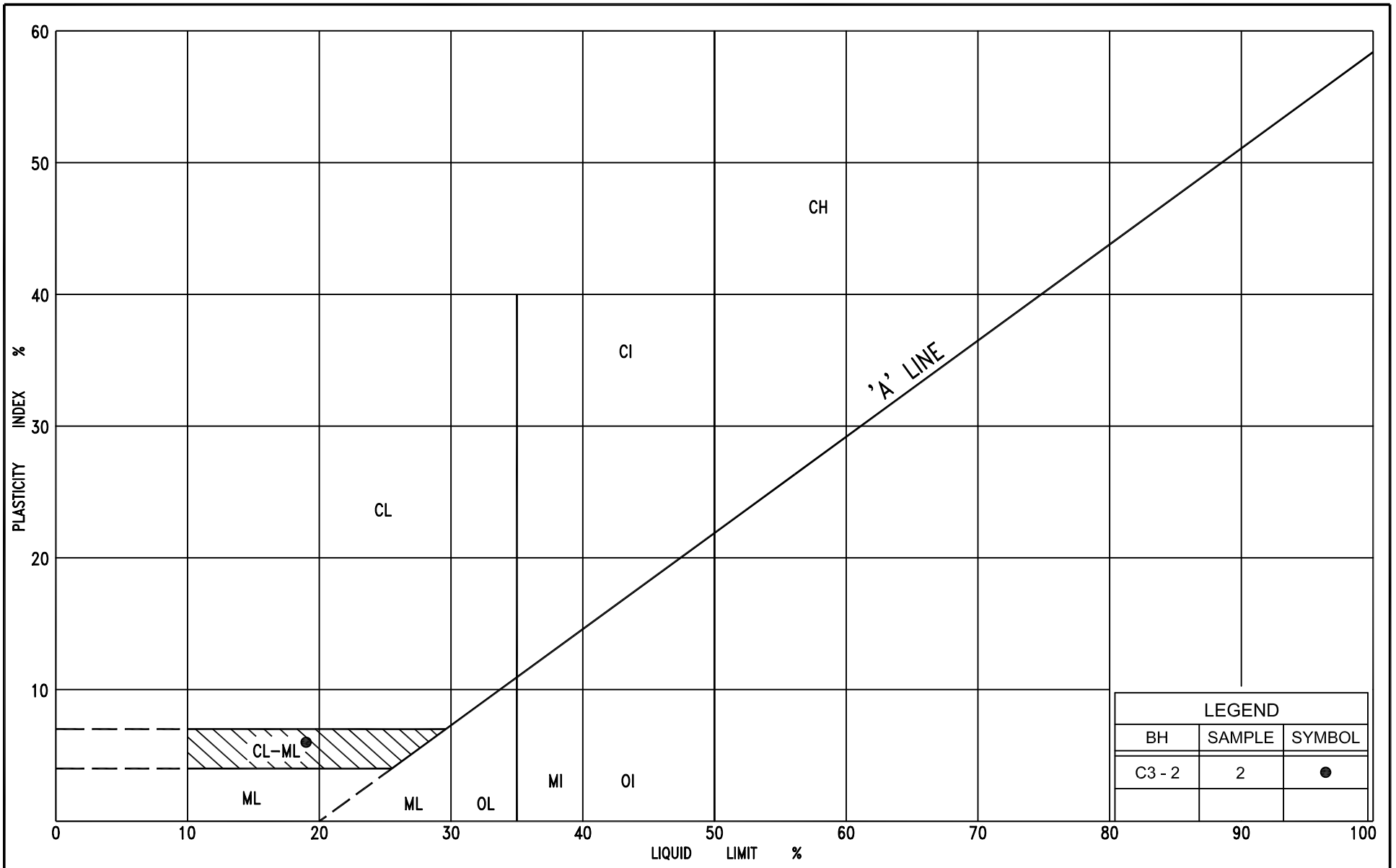
REF No xbse_160210427_design.dwg DT. June 2005

REVISIONS

DATE	BY	DESCRIPTION

Geocres No. 40P15-35

HWY No	23			DIST	33
SUBM'D	GD	CHECKED	GD	DATE NOV. 04, 2005	SITE
DRAWN	NA	CHECKED	CN	APPROVED CN	DWG C2

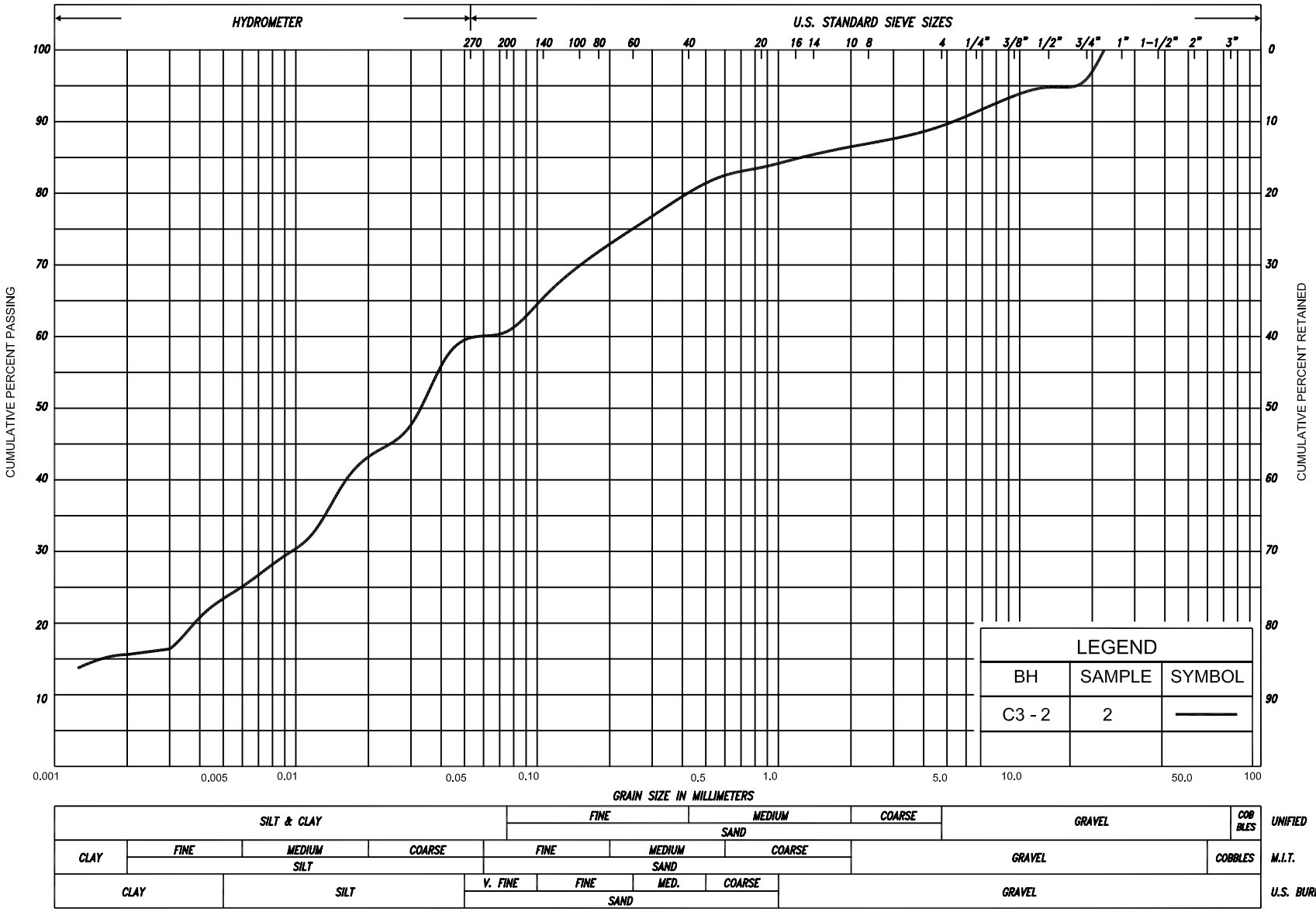


Ministry of Transportation Ontario

PLASTICITY CHART

CLAYEY SILT with sand, some gravel (CL–ML)
(TILL)

FIG No.	C3-PC-1
HWY	23
G.W.P. No.	58-00-00

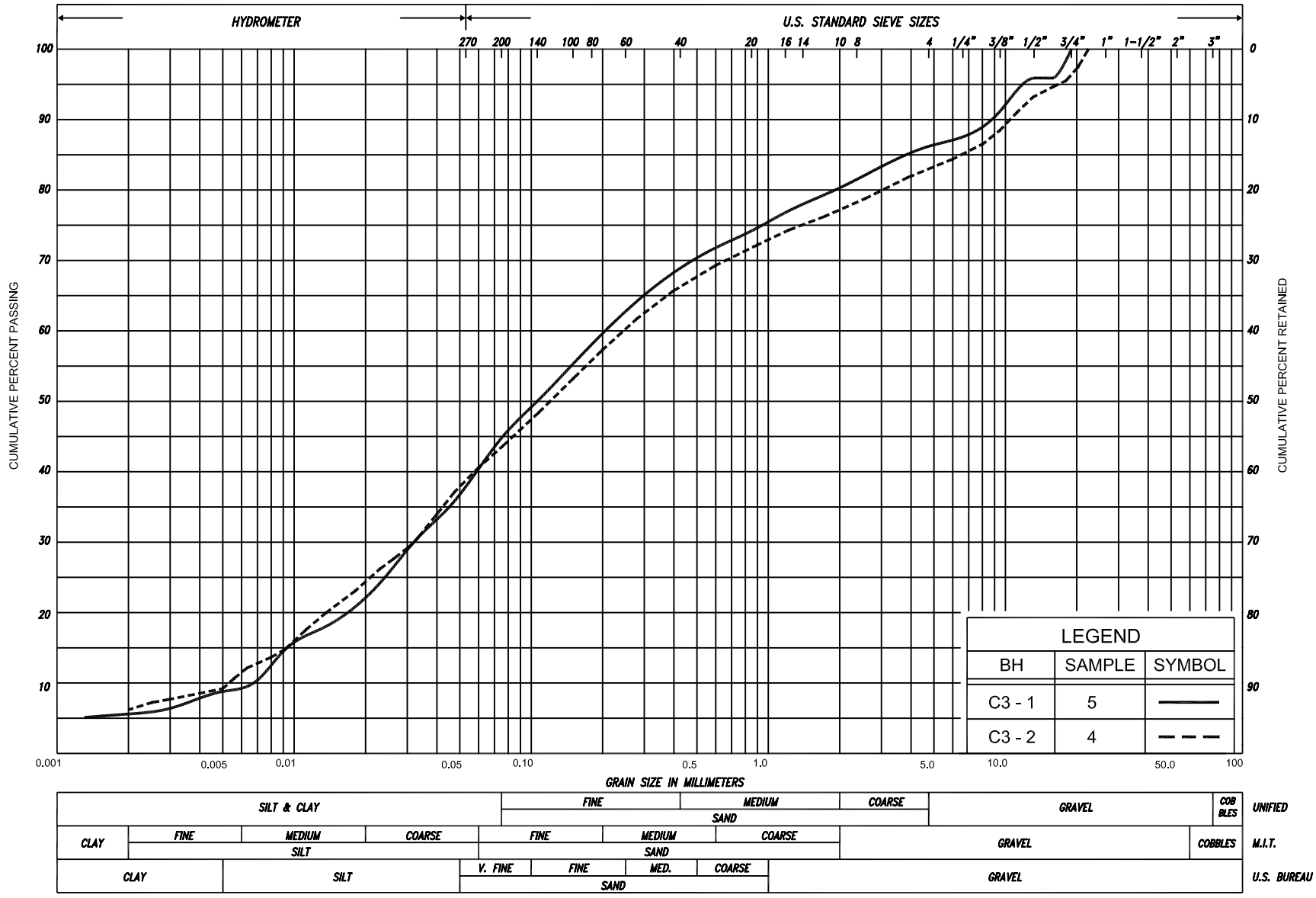


Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand, some gravel (CL–ML)
(TILL)

FIG No.	C3-GS-1
HWY	23
G.W.P. No.	58-00-00



Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SILTY SAND, some gravel, trace clay
(TILL)

FIG No.	C3-GS-2
HWY	23
G.W.P. No.	58-00-00

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C3-1

1 of 1

METRIC

G.W.P. 58-00-00 | LOCATION Co-ords: 4 855 668 N; 194 764 E Hwy. 23, Sta. 10+085.6 o/s 21.5m Lt. | ORIGINATED BY MR

DIST 33 | HWY 23 | BOREHOLE TYPE Continuous Flight Hollow Stem Augers | COMPILED BY GD

DATUM Geodetic | DATE May 24, 2005 | CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
397.1	Ground Surface					*					
0.0	Topsoil						397				
0.2	Silty sand, some gravel, trace clay Compact Brown Wet to moist (TILL)		1	SS	11		396		○		
			2	SS	17		395		○		
	Dense to very dense Damp		3	SS	49				○		
			4	SS	50/15cm		394				
			5	SS	58/15cm		393		○		14 41 39 6
			6	SS	60/15cm		392		○		
390.9			7	SS	50/5cm		391				
6.2	End of borehole * Borehole dry on completion of drilling										

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:13:08 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C3-2 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 855 671 N; 194 774 E Hwy. 23, Sta. 10+086.9 o/s 10.9m Lt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 25, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
397.7	Ground Surface					*	397				
0.0	Sand and gravel, some silt Brown Dry (FILL)										
396.3							396				
1.4 / 395.9	Silt, some sand, trace clay		1	SS	10						
1.8 / 395.5	Loose Olive brown Wet (Alluvium)										
2.2	Sandy silt, trace clay Compact Brown Moist		2	SS	13		395				11 29 44 16
	Clayey silt, with sand, some gravel Stiff to hard Brown Wet to moist		3	SS	52						
394.0	(TILL)						394				
3.7	Silty sand, some gravel, trace clay Very dense Brown Damp (TILL)		4	SS	57/ 15cm						17 40 37 6
			5	SS	75/ 15cm		393				
							392				
			6	SS	87/ 15cm						
							391				
389.8			7	SS	75/ 15cm		390				
7.9	End of borehole										

* Borehole dry on completion of drilling

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:13:11 PM

+7 , ×5 : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE (20, 15, 5, 10)

METRIC

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

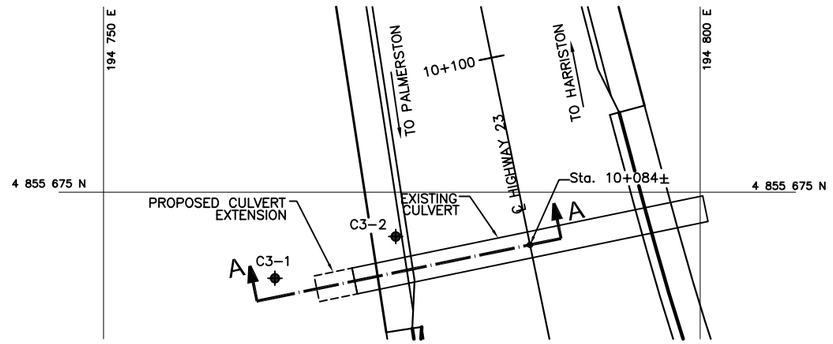
CONT No
GWP No 58-00-00

HIGHWAY 23

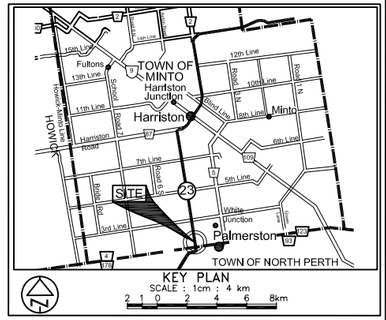
CULVERT C-3, Sta. 10+084
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

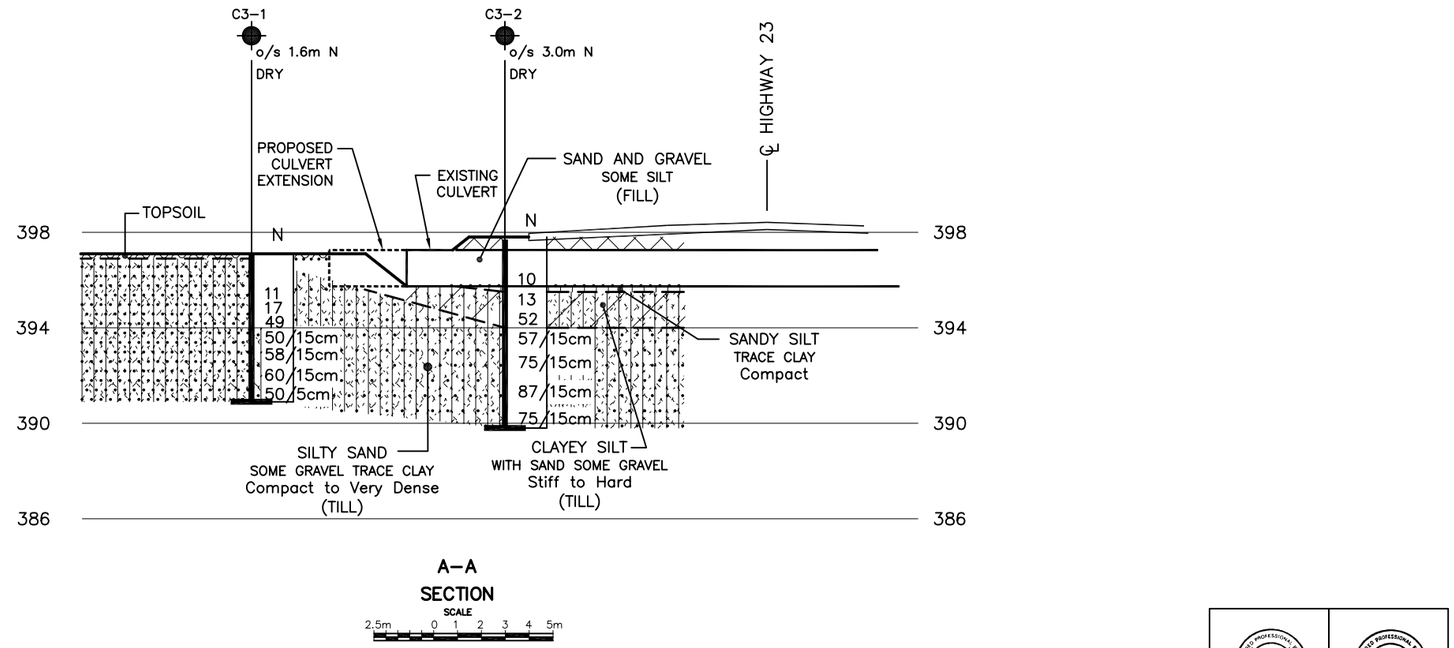
Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN
SCALE
5 0 5 10m



KEY PLAN
SCALE : 1cm = 4 km
2 1 0 2 4 6 8km



A-A
SECTION
SCALE
2.5m 0 1 2 3 4 5m

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & 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 May 2005
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C3-1	397.1	4 855 668	194 764
C3-2	397.7	4 855 671	194 774

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

NOTES:
1. SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.
2. STATIONS REFER TO TOWN OF MINTO.

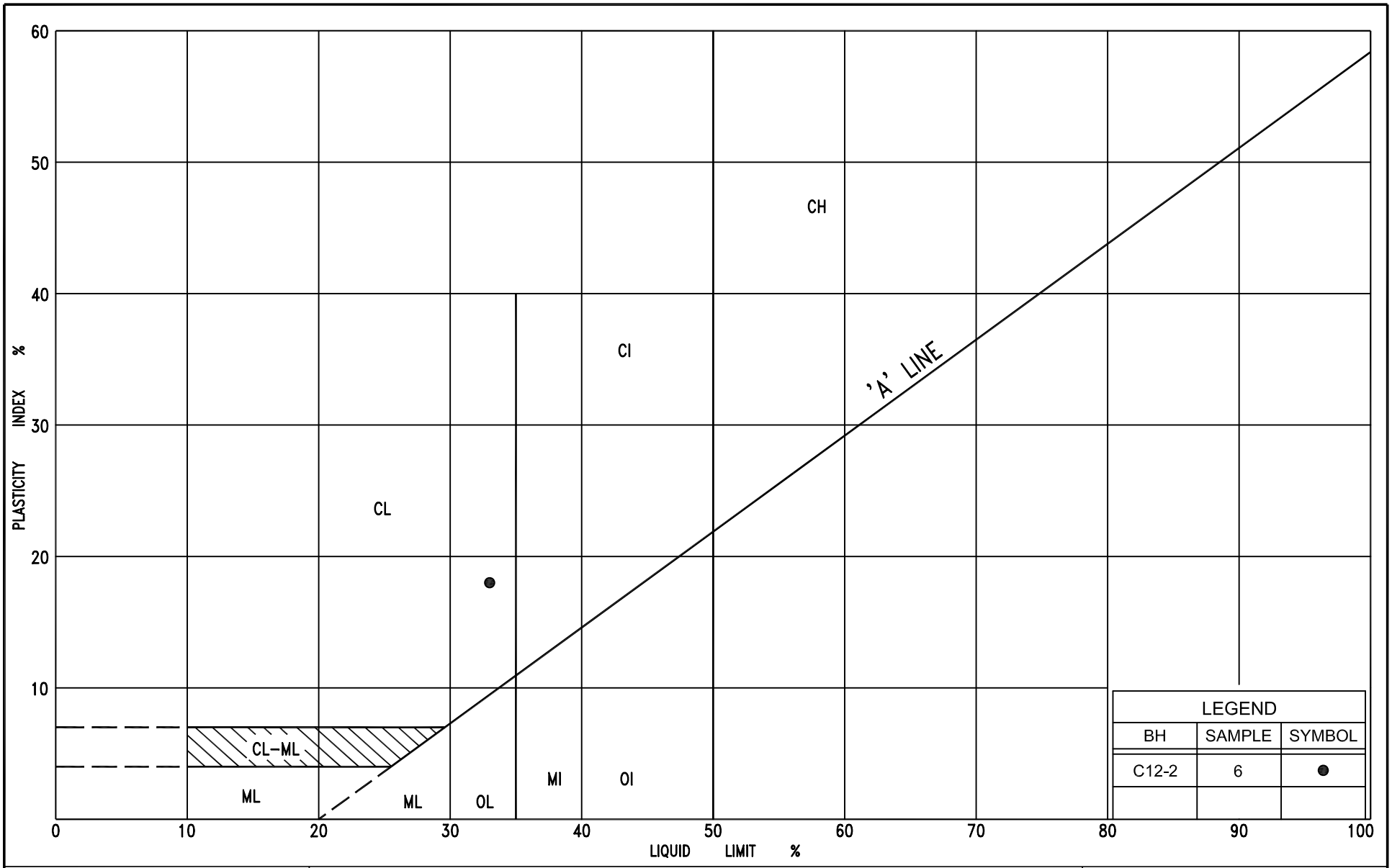
C M P Buckingham — B. R. GRAY — PROFESSIONAL ENGINEER PROVINCE OF ONTARIO

REVISIONS			
DATE	BY	DESCRIPTION	

Geocres No. 40P15-35

HWY No	23			DIST	33
SUBM'D	GD	CHECKED	GD	DATE NOV. 04, 2005	SITE
DRAWN	NA	CHECKED	CN	APPROVED CN	DWG C3

REF No xbse_160210427_design.dwg DT. June 2005

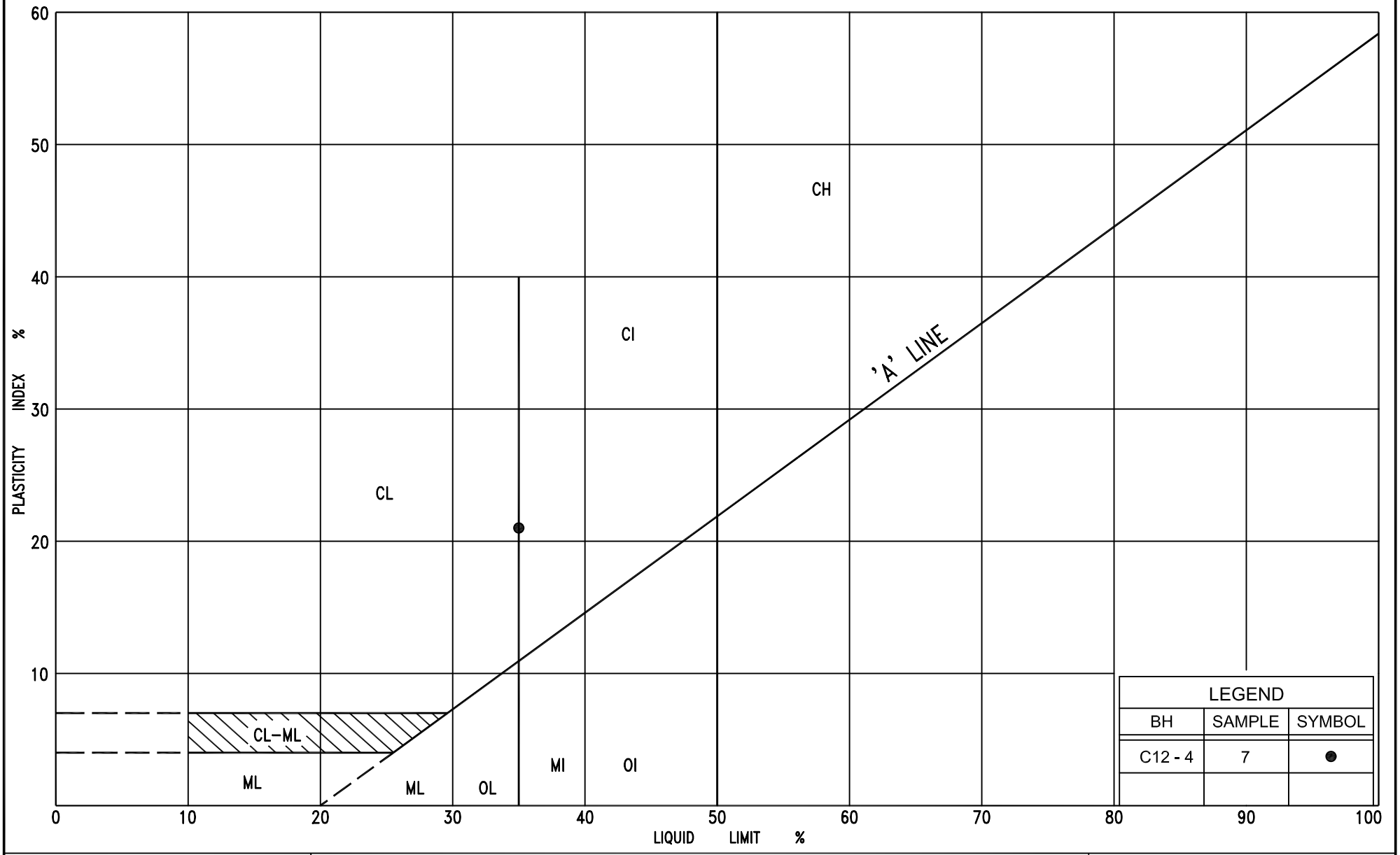


Ministry of Transportation Ontario

PLASTICITY CHART

CLAYEY SILT some sand, some gravel (CL)
(TILL)

FIG No.	C12-PC-1
HWY	23
G.W.P. No.	58-00-00

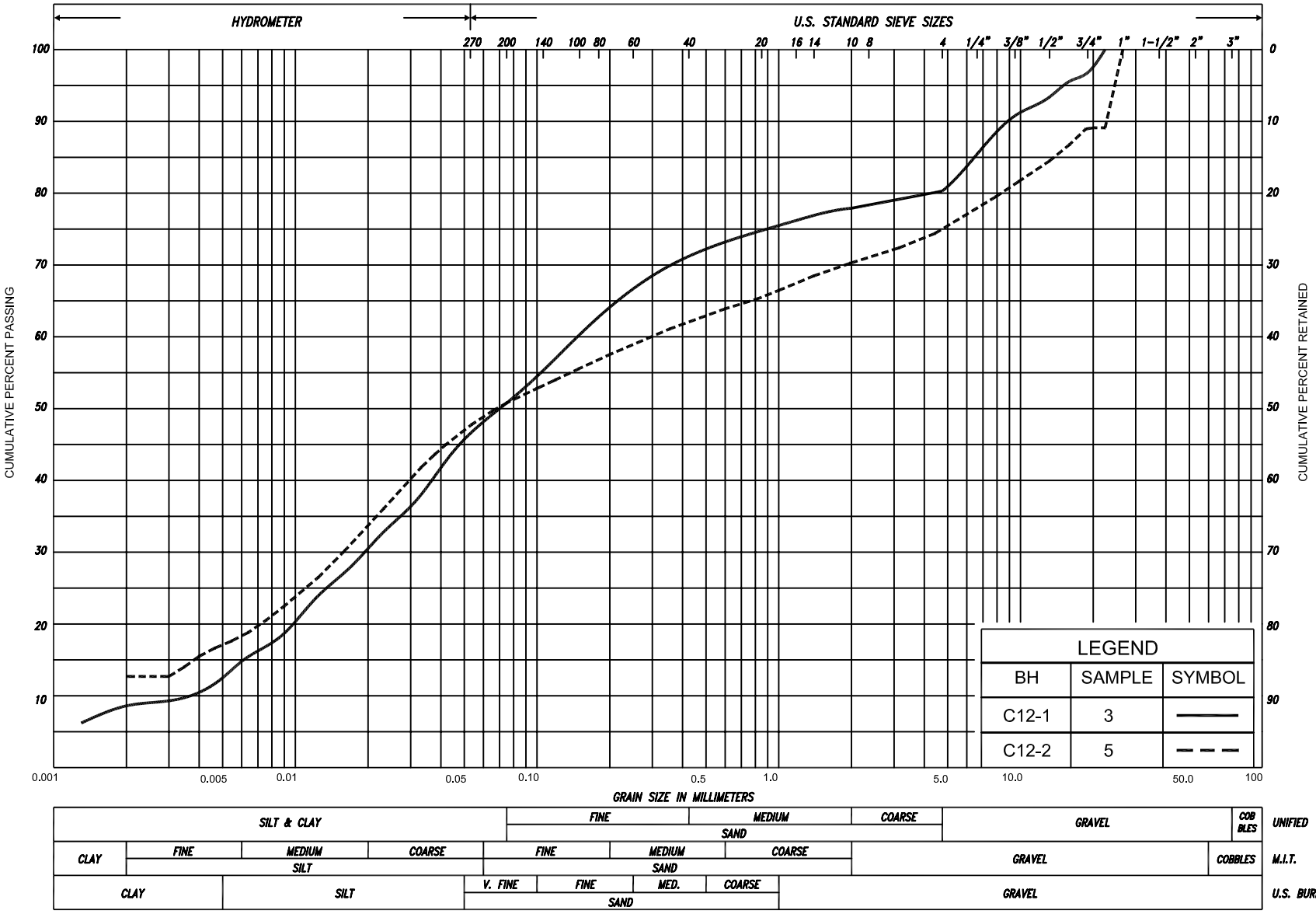


Ministry of Transportation Ontario

PLASTICITY CHART

SILTY CLAY, with gravel, some sand (CI)
(TILL)

FIG No.	C12-PC-2
HWY	23
G.W.P. No.	58-00-00

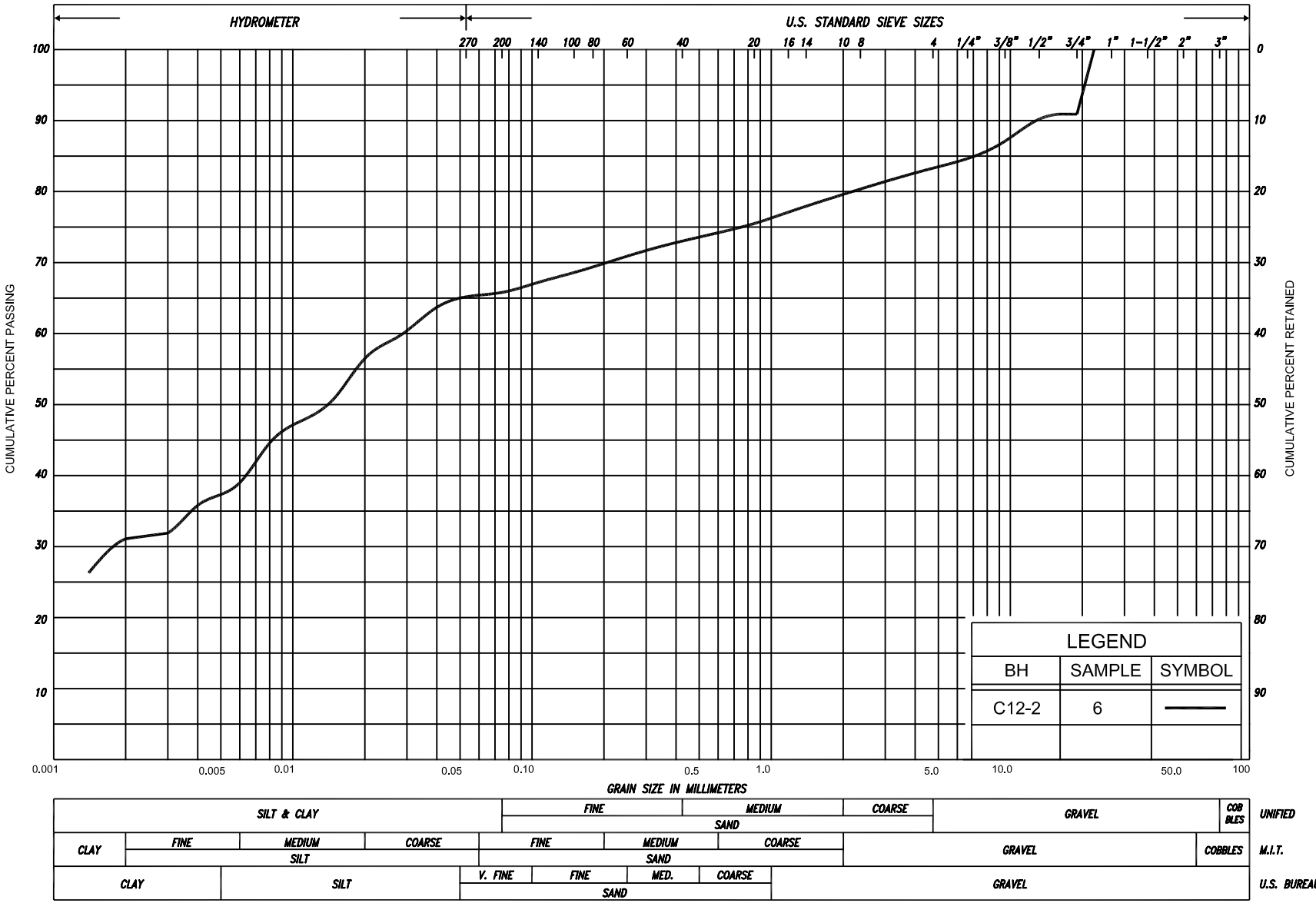


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SILT, with sand, some to with gravel, trace to some clay (TILL)

FIG No.	C12-GS-1
HWY	23
G.W.P. No.	58-00-00

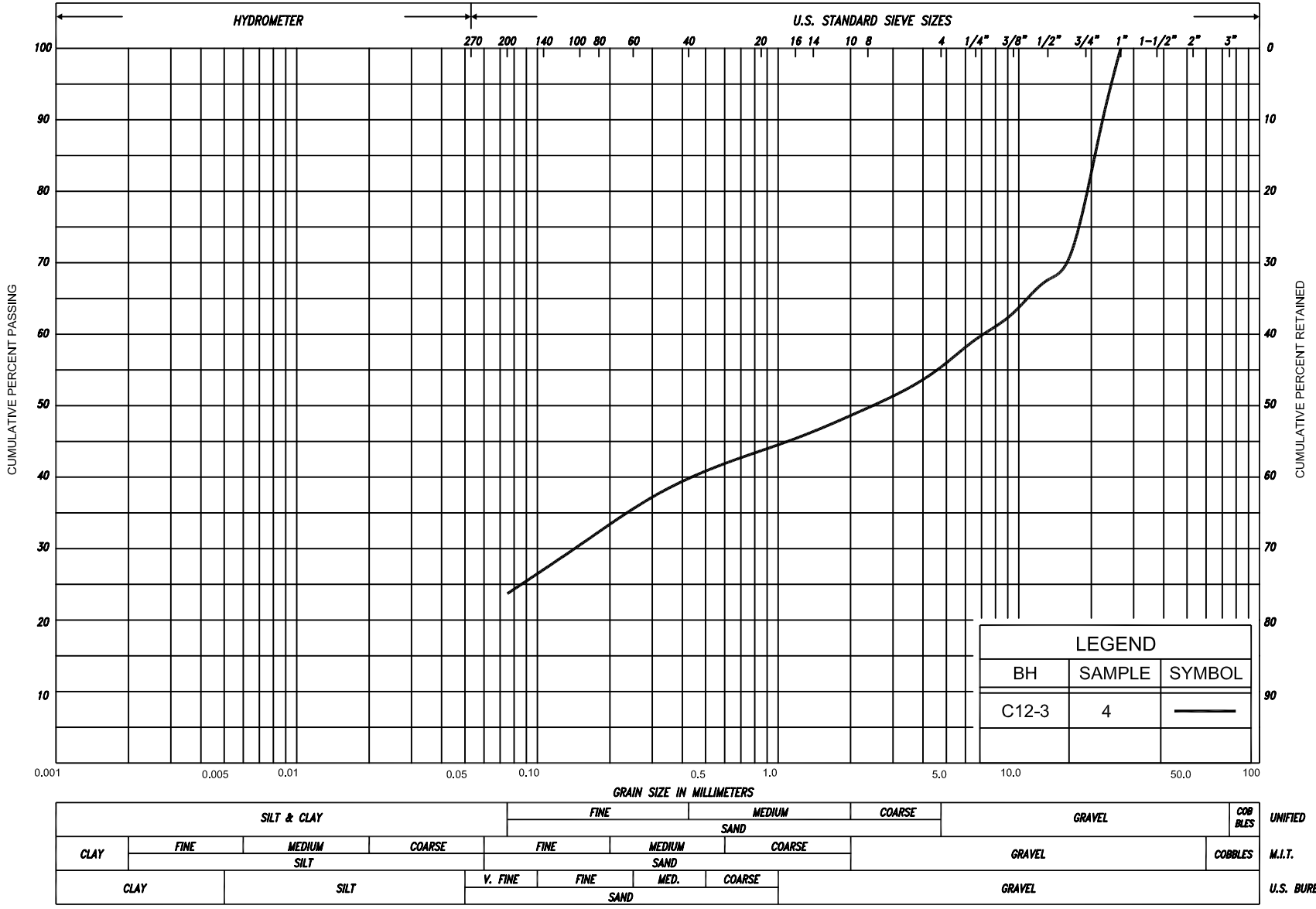


MInIstry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand, some gravel (CL)
(TILL)

FIG No.	C12-GS-2
HWY	23
G.W.P. No.	58-00-00

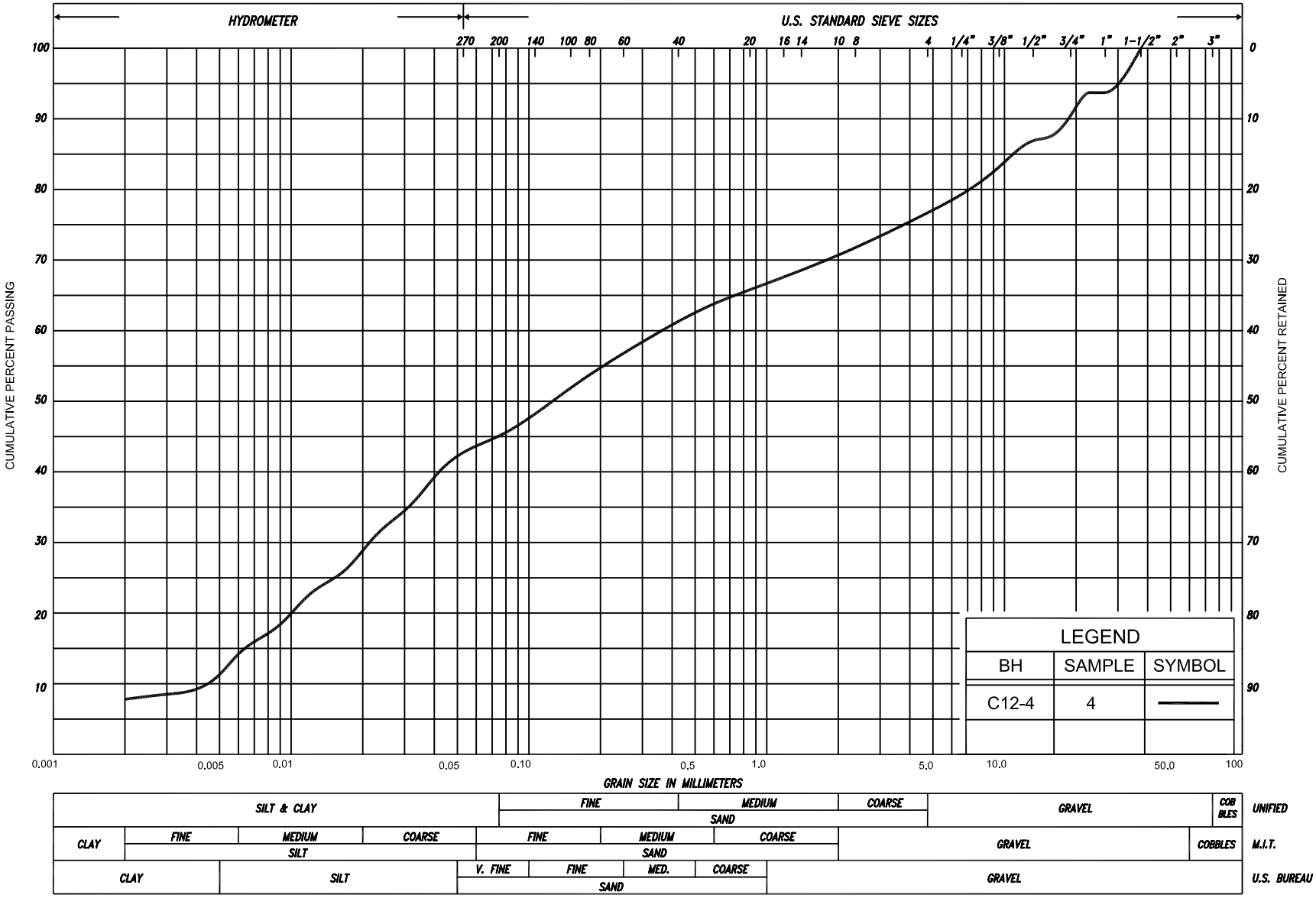


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SANDY GRAVEL, some silt, trace clay
(TILL)

FIG No.	C12-GS-3
HWY	23
G.W.P. No.	58-00-00

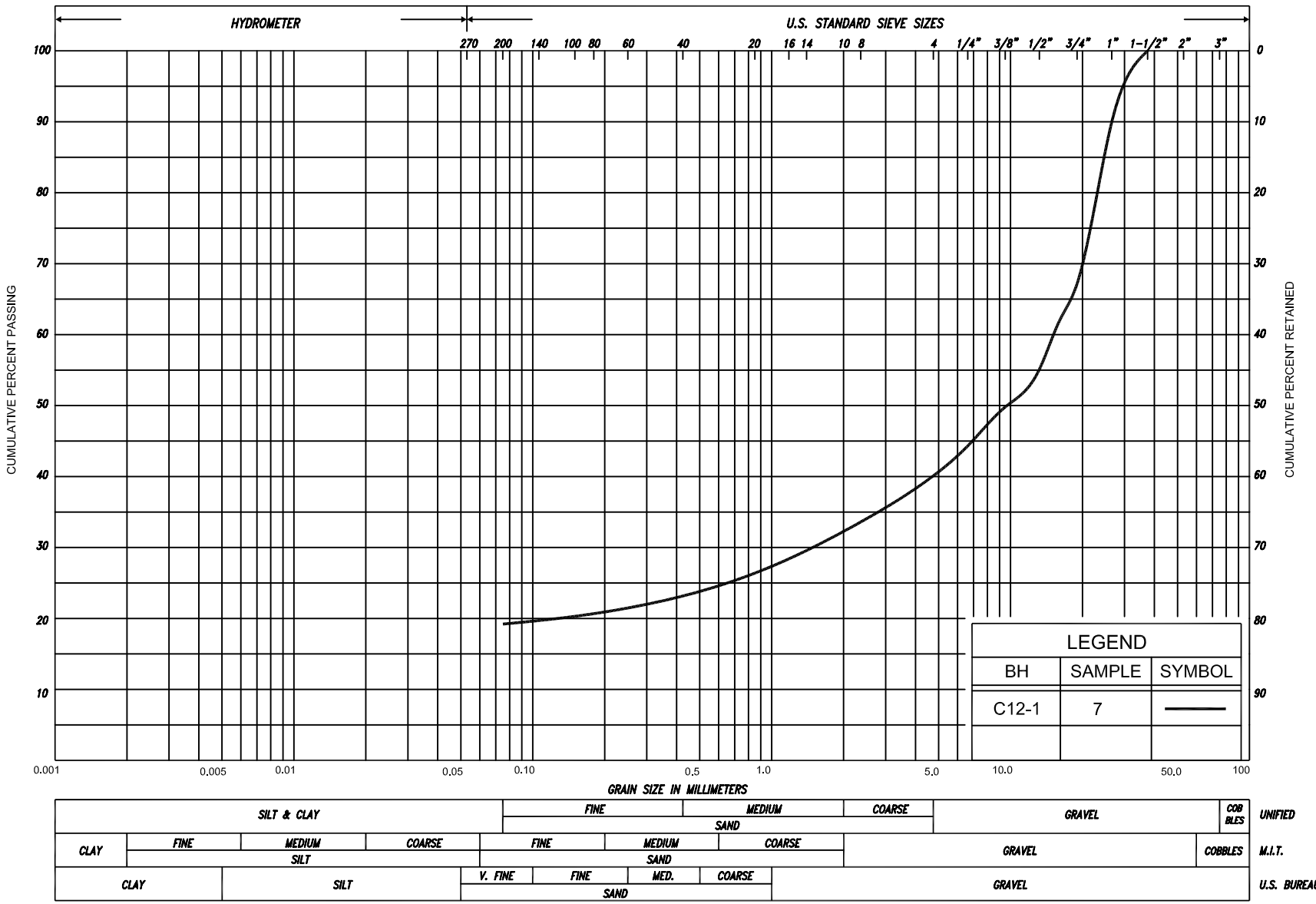


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SILT and SAND, with gravel, trace clay
(TILL)

FIG No.	C12-GS-4
HWY	23
G.W.P. No.	58-00-00

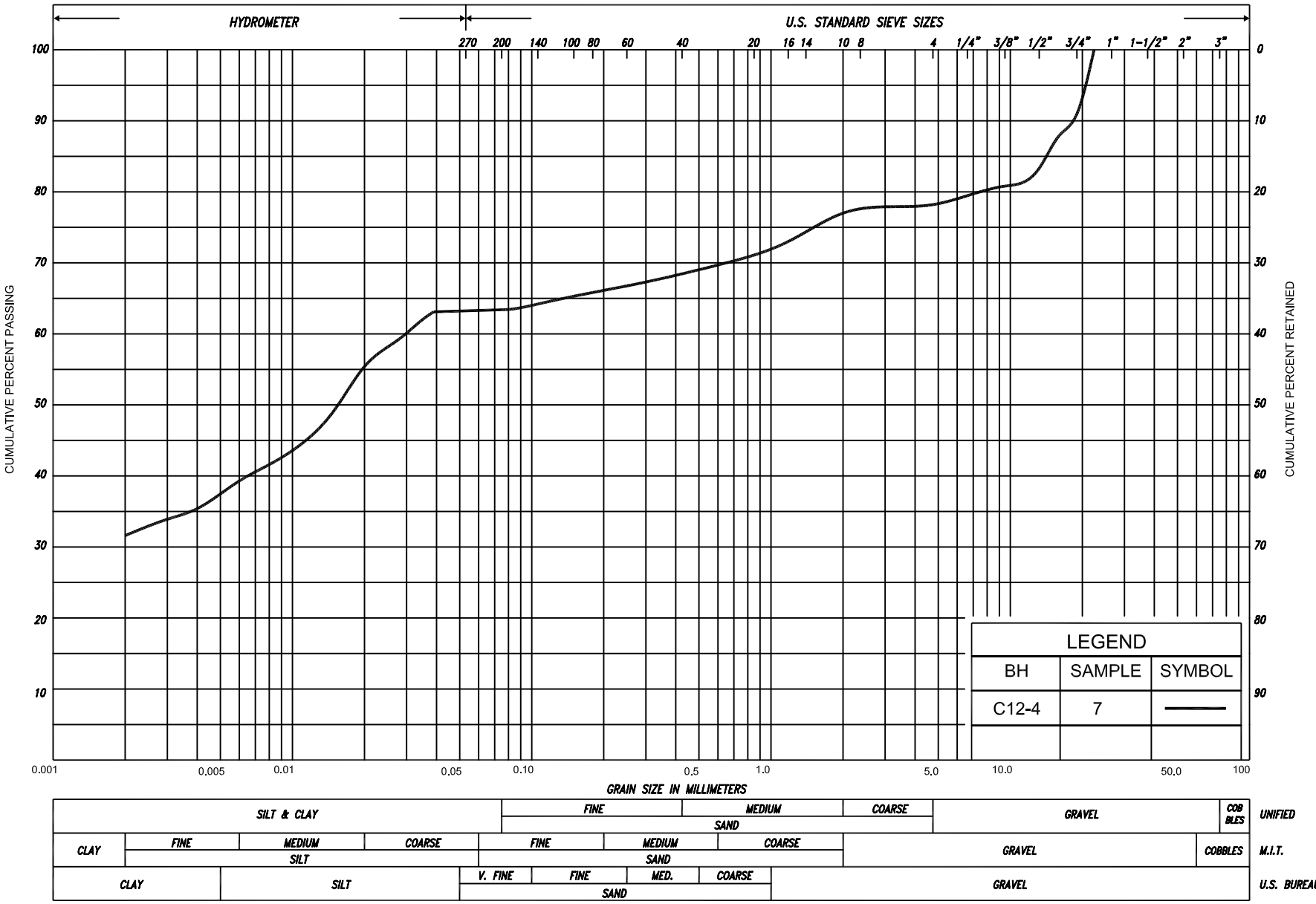


Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

GRAVEL, with sand, some silt
(TILL)

FIG No.	C12-GS-5
HWY	23
G.W.P. No.	58-00-00



Ministry of Transportation Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, with gravel, some sand (Cl)
(TILL)

FIG No.	C12-GS-6
HWY	23
G.W.P. No.	58-00-00

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C12-1 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 863 773 N; 193 917 E Hwy. 23, Sta. 18+578.9 o/s 12.4m Lt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 18, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
380.1	Ground Surface						380				
0.0	Layered clayey silt, topsoil and sand Stiff Brown/ dark brown Wet (Alluvium)		1	SS	7	▼*			○		
378.7			2	SS	10		379		○		
1.4	Silt, with sand, some gravel, trace clay Loose to compact Brown to grey Moist (TILL)		3	SS	8				○		20 29 42 9
377.5			4	SS	18		378		○ ○		
2.6	Clayey silt, some sand, some gravel Very stiff to hard Rusty brown Wet (TILL)		5	SS	29		377		○		
376.0			6	SS	30		376		○		
4.1	Silt and sand, with gravel, trace clay										
375.6			7	SS	60/15cm		375		○		60 21 (19)
4.5	Dense Brown Moist (TILL) Gravel, with sand, some silt cobbles and boulders										
374.3											
5.8	Very dense Brown Moist (TILL) End of borehole Refusal on probable boulder										

* 2005 05 18

▼ Water level measured after drilling

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:12:46 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C12-2 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 863 768 N; 193 921 E Hwy. 23, Sta. 18+580.7 o/s 6.2m Lt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 18, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.3	Ground Surface										
0.0	Sand and gravel, trace silt Brown Dry (FILL)		1	SS	23		381		○		
380.1											
1.2	Topsoil						380		○		
379.7											
1.6	Silty clay, trace sand		2	SS	7				○		
379.4							379				
1.9	Firm Olive brown Moist (Alluvium)										
	Sand, with silt, trace gravel with a 150mm layer of sandy clayey silt		3	SS	26	▼*					
378.1	Compact Brown Wet										
3.2	Silt, with sand, with gravel, some clay		4	SS	14		378		○		
	Compact Brown Moist (TILL)		5	SS	26				○		25 24 38 13
376.8							377				
4.5	Clayey silt, some sand, some gravel Very stiff Rusty brown Moist		6	SS	21				⊢●		17 17 35 31
375.7	(TILL)						376				
5.6	Silt and sand, with gravel, trace clay Very dense Brown Moist (TILL)		7	SS	50/8cm		375		○		
374.4											
6.9	End of borehole Refusal on probable boulder										

* 2005 18 05

▼ Water level measured after drilling

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:12:49 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C12-3 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 863 763 N; 193 940 E Hwy. 23, Sta. 18+595.3 o/s 6.5m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 18, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
381.7	Ground Surface										
0.0	Sand and gravel, with silt Brown Dry (FILL)		1	SS	25		381	○	○		
380.1											
1.6	Topsoil		2	SS	14	▼*	380		○		
379.6											
2.1	Silt and sand										
379.1	Compact Brown Wet		3	SS	21		379	○			
2.6	Sandy gravel, some silt, trace clay Compact Brown Wet to dense		4	SS	31			○			44 32 (24)
378.0	(TILL)						378				
3.7	Silt and sand, with gravel Dense to very dense Brown Wet (TILL)		5	SS	34			○			
			6	SS	41		377	○			
			7	SS	83/15cm		376	○			
374.8							375				
6.9	Silty clay, with gravel, trace sand Hard Rusty brown Moist (TILL)		8	SS	35		374	○			
373.5											
8.2	End of borehole * 2005 05 18 ▼ Water level measured after drilling										

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:12:52 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

Peto MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No C12-4 1 of 1 METRIC

G.W.P. 58-00-00 LOCATION Co-ords: 4 863 754 N; 193 940 E Hwy. 23, Sta. 18+591.4 o/s 14.7m Rt. ORIGINATED BY MR

DIST 33 HWY 23 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD

DATUM Geodetic DATE May 18, 2005 CHECKED BY

ELEV / DEPTH	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 ● 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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
380.6	Ground Surface										
0.0	Topsoil										
0.2	Silty sand, with gravel										
380.0	Brown Moist						380				
0.6	Silty clay, trace sand, trace gravel										
379.7			1	SS	7	▼*			○		
0.9	Firm Dark brown Wet (Alluvium)										
379.1							379				
1.5	Clayey silt, some sand, some gravel		2	SS	19				○		
	Firm Brown Wet (TILL)										
	Silt and sand, some to with gravel, trace clay		3	SS	16		378		○		
	Compact to very dense Brown Wet										
	(TILL)		4	SS	61						23 32 37 8
							377				
			5	SS	139				○		
			6	SS	50/5cm		376		○		
375.1											
5.5	Silty clay, with gravel, some sand						375				
	Very stiff Rusty brown Wet to moist										
	(TILL)										
			7	SS	24		374		⊢○⊣		22 15 32 31
373.6											
7.0	End of borehole										

* 2005 05 18

▼ Water level measured after drilling

ON_MOT VER3 04KF132A.GPJ ON_MOT.GDT 04/11/05 3:12:55 PM

+7 , ×5 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

METRIC

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

CONT No
GWP No 58-00-00

HIGHWAY 23

CULVERT C-12, Sta 18+588
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

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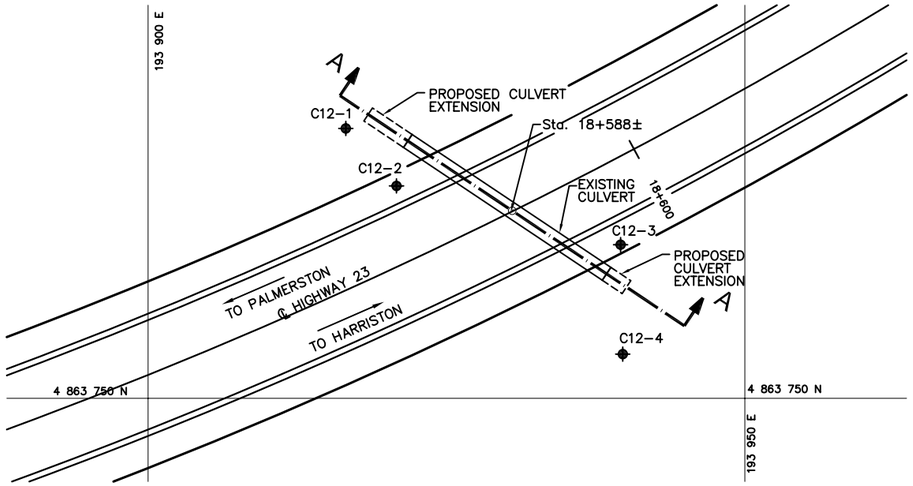
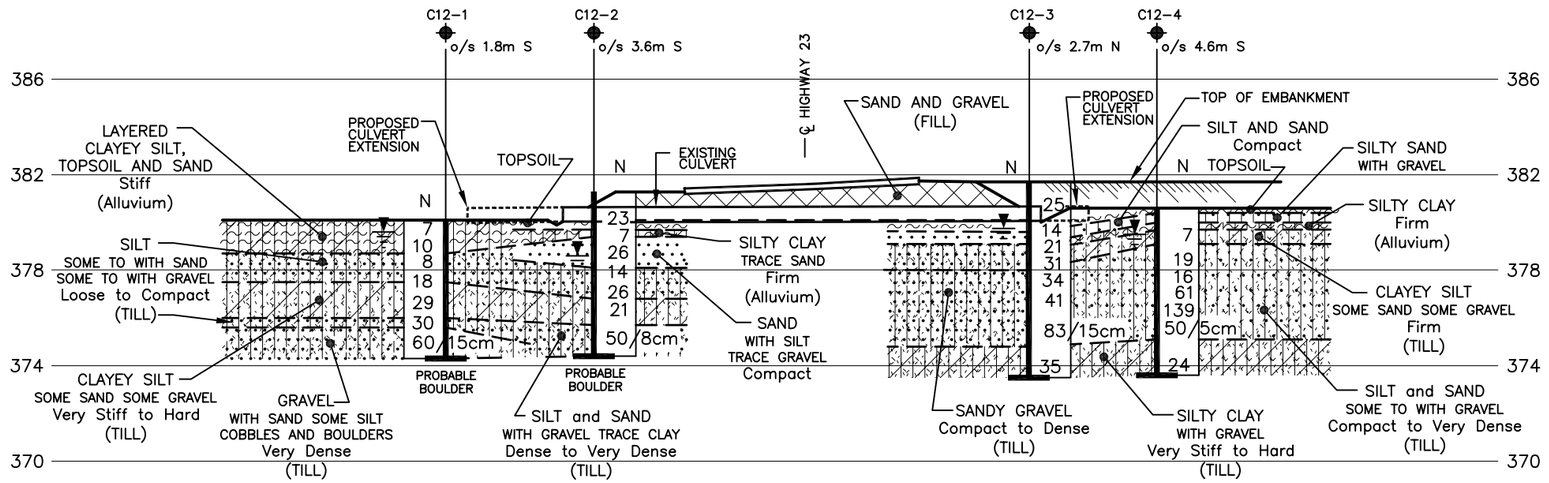
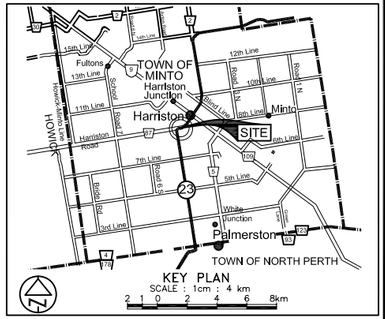


PLAN
SCALE
5 0 5 10m



A-A
SECTION
SCALE
2.5m 0 1 2 3 4 5m



LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & 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 May 2005
- Head ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES NORTH	EAST
C12-1	380.1	4 863 773	193 917
C12-2	381.3	4 863 768	193 921
C12-3	381.7	4 863 763	193 940
C12-4	380.6	4 863 754	193 940

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

NOTES:
1. SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.
2. STATIONS REFER TO TOWN OF MINTO.

REF No xbse_160210427_design.dwg DT. June 2005

REVISIONS

DATE	BY	DESCRIPTION

Geocres No. 40P15-35

HWY No	23			DIST	33
SUBM'D	GD	CHECKED GD	DATE NOV. 04, 2005	SITE	
DRAWN	NA	CHECKED CN	APPROVED CN	DWG	C12

Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT

for

CULVERT EXTENSIONS
REHABILITATION OF HIGHWAY 23
G.W.P. 58-00-00
PALMERSTON TO HARRISTON
TOWNS OF NORTH PERTH AND MINTO, ONTARIO

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PML Ref.: 04KF132A
Index No.: 057FDR
Geocres No.: 40P15-35
November 4, 2005

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN REPORT
for
Culvert Extensions
Rehabilitation of Highway 23
G.W.P. 58-00-00
Palmerston to Harriston
Towns of North Perth and Minto, Ontario

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1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed extension of four culverts while rehabilitating the approximate 9 km long section of Highway 23 that extends from Palmerston northerly to the Harriston west limits in the Towns of North Perth and Minto, Ontario. This report was prepared for Stantec Consulting Ltd. on behalf of the Ministry of Transportation of Ontario (MTO).

The culverts have been assigned reference numbers C-1, C-2, C-3 and C-12. The location, type and proposed works at each culvert are given in the following table:

CULVERT No.	APPROXIMATE STATION (HIGHWAY 23 CHAINAGE)	EXISTING CULVERT TYPE	PROPOSED WORKS
C-1	23+143 Town of North Perth	0.90 x 0.90 m Concrete Rigid Frame Open Footing	Extension of south end by 3 m
C-2	23+223 Town of North Perth	1.84 x 1.20 m Concrete Rigid Frame Box	Extension of north end by 6 m and south end by 4 m
C-3	10+084 Town of Minto	1.83 x 1.22 m Concrete Rigid Frame Box	Extension of west end by 3.25 m
C-12	18+588 Town of Minto	0.90 x 0.60 m Concrete Rigid Frame Open Footing	Extension of west end by 4 m and east end by 2 m

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This report pertains to design and construction of the proposed culvert extensions and associated bedding/backfill zones. A list of the standard specifications referenced in this report is compiled in Table 1.

Based on the road grade and ground surface elevations at the toe of slope at each culvert location, the embankment fill height at the locations of the culverts ranges from 1.0 to 1.5 m.

The subsurface stratigraphy revealed in the boreholes drilled at the culvert locations was generally consistent and typically comprised the embankment fill made up of sand and gravel or surficial sandy silt topsoil and alluvium deposits overlying clayey silt till underlain by cohesionless tills varying broadly in granulometric composition between silt and gravel.

The ground water level measured during the field investigation conducted in May 2005 was variable at the locations of Culverts C-2 and C-12, typically 1 to 2 m above the inferred founding subgrade level of the culverts. No ground water was observed at Culverts C-1 and C-3. The roadside ditches at the inlet and outlet of all the culverts were dry at the time of the investigation.

It is recommended that the proposed extensions match the design of the existing culverts.

2. FOUNDATIONS

2.1 Culvert C-1

The invert of the existing culvert is indicated to be near elevation 395.8 (ref.: Plate 180-89/5-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings provided by Stantec Consulting Ltd.). The existing subgrade founding level of the spread footings is interpreted to be near elevation 394.2, to provide the minimum 1.6 m soil cover for frost protection.

The subgrade material below this level revealed in the boreholes comprises dense to very dense silt till or hard clayey silt till. No ground water was observed at the time of the field investigation.

Based on the road grade (elevation 398.4) and ground surface elevation at the toe of slope, the embankment fill height at the culvert location is assessed to be about 1.2 m.

The new footings should be founded at the same elevation as the existing footings inferred to be at elevation 394.2. Construction of the foundations for the culvert extension on spread footings bearing on the dense to very dense silt till or hard clayey silt till encountered at the inferred foundation level is considered to be feasible.

The culvert foundations constructed on the dense to very dense silt till or hard clayey silt till should be designed using the following geotechnical resistance at ultimate and serviceability limit states (ULS and SLS) for the 0.5 m wide footing:

Factored Geotechnical Resistance at ULS = 400 kPa
Geotechnical Resistance at SLS = 275 kPa

It is noted that the depth of excavation will be 3 m beyond the toe of the existing embankment and about 3.5 m within the existing embankment fill.

In addition, the excavation will extend into the existing embankment and require road protection bracing to support the cut slopes. It is anticipated that conventional sump pumping techniques will be sufficient to control seepage of ground water into the excavation. Further comments in this regard are provided in subsequent sections of the report.

2.2 Culvert C-2

The invert of the existing culvert is indicated to be near elevation 395.6 (ref.: Plate 180-89/5-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings provided by Stantec Consulting Ltd.). The design subgrade level of the granular bedding is interpreted to be near elevation 395.1.

The subgrade material below this level revealed in the boreholes comprises stiff to hard clayey silt till underlain by dense to very dense cohesionless tills. The high ground water level at the time of the field investigation was at elevation 397.4, some 2 m above the subgrade level.

Based on the road grade (elevation 398.9) and ground surface elevation at the toe of slope, the embankment fill height at the culvert location is assessed to be about 1.5 m.

It is considered that the stiff to hard clayey silt till exposed in the boreholes at and below the design subgrade is capable of supporting the stress imposed by the embankment and culvert foundations.

The culvert foundations constructed on the stiff to hard clayey silt till should be designed using the following geotechnical resistance for the 2.2 m wide box culvert:

Factored Geotechnical Resistance at ULS = 275 kPa
Geotechnical Resistance at SLS = 175 kPa

It is noted that the depth of excavation will be 2.0 to 2.5 m beyond the toes of the existing embankment and about 3 m within the existing embankment fill.

In addition, the excavation will be some 2 m below the high ground water level and extend into the existing embankment. A positive ground water control system will be needed and road protection bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of the report.

2.3 Culvert C-3

The invert of the existing culvert is indicated to be near elevation 395.6 (ref.: Plate 180-89/6-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings provided by Stantec Consulting Ltd.). The design subgrade level of the granular bedding is interpreted to be near elevation 395.1.

The subgrade material below this level revealed in boreholes C3-1 and C3-2 comprises compact silty sand till and stiff clayey silt till respectively. No ground water was observed in either borehole at the time of the field investigation.

Based on the road grade and ground surface elevation at the toe of slope, the embankment fill height at the culvert location is assessed to be about 1.0 m.

Construction of the foundations for the culvert extension on the compact silty sand till and stiff clayey silt till is considered to be feasible.

The culvert foundations constructed on the compact silty sand till / stiff clayey silt till should be designed using the following geotechnical resistance for the 2.2 m wide box culvert:

Factored Geotechnical Resistance at ULS = 275 kPa
Geotechnical Resistance at SLS = 175 kPa

It is noted that the depth of excavation will be 2 m beyond the toe of the existing embankment and about 2.5 m within the existing embankment fill.

In addition, the excavation will extend into the existing embankment and require road protection bracing to support the cut slopes. It is anticipated that conventional sump pumping techniques will be sufficient to control seepage of ground water into the excavation. Further comments in this regard are provided in subsequent sections of the report.

2.4 Culvert C-12

The invert of the existing culvert is indicated to be near elevations 380.0 at the west end and 380.2 at the east end (ref.: Plate 180-89/19-0 of 'Highway 23 Reconstruction. Culvert Recommendations' drawings provided by Stantec Consulting Ltd.). The existing subgrade founding level of the spread footings is interpreted to be at elevations 378.4 to 378.6.

The subgrade material below this level revealed in the boreholes comprises loose to compact cohesionless soils. The high ground water level at the time of the field investigation was at elevation 379.7, over 1 m above the subgrade level.

Based on the road grade (elevation 381.4) and ground surface elevation at the toe of slope, the embankment fill height at the culvert location is assessed to be about 1.2 m.

The new footings should be founded at the same elevations as the existing footings that are inferred at elevations 378.4 and 378.6 at the west and east ends respectively. It is considered

that the generally compact cohesionless soils exposed in the boreholes at and below the design subgrade are capable of supporting the stress imposed by the embankment and culvert foundations.

The culvert foundations constructed on the compact cohesionless soils should be designed using the following geotechnical resistance for the 0.5 m wide footing:

Factored Geotechnical Resistance at ULS = 250 kPa
Geotechnical Resistance at SLS = 150 kPa

It is noted that the depth of excavation will be about 2 m beyond the toes of the existing embankment and up to 3 m within the existing embankment fill.

In addition, the excavation will be in excess of 1 m below the high ground water level and extend into the existing embankment. Cognisant of the relative permeability of the native soils present at the site, it is considered that a positive ground water control system will be needed and road protection bracing required to support the cut slopes. Further comments in this regard are provided in subsequent sections of the report.

2.5 General Comments

The resistance at SLS allows for 25 mm settlement of the founding medium. Total and differential settlements along the culvert extension length are expected to be negligible in view of the relatively low net bearing pressure exerted by the culvert foundations. Therefore, provision for camber is not considered necessary for the culvert extensions.

The topsoil revealed above the subgrade and any other deleterious soils should be excavated prior to placement of the granular base below the box culverts and replaced with compacted granular fill. Under the spread footing foundations of the open culverts, grade differences should be made up with mass concrete fill.

Preparation of the subgrade for construction of the culvert extensions should be performed and monitored in accordance with OPSS 902 and SP 902S01. This should include site review by

qualified geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the granular fill or, if required, mass concrete fill.

Fill placed under the culvert to accommodate any variation in the level of the native surface and/or replace any deleterious soils extending below the design founding level should comprise Granular A material compacted to at least 95% of the target density with conformance to OPSS 501 and SP 105S10. The limit of the granular fill zone should extend sideways a minimum 0.3 m beyond the culvert base and down to the subgrade at 45° to the horizontal and be established by a site specific survey.

Subgrade preparation, cover backfill and frost taper treatment for the culvert should be carried out in accordance with OPSD 803.010 and OPSS 422. The bedding material for a precast box culvert extension, if utilised, should comprise a minimum 150 mm thick layer of Granular A.

A frost penetration depth of 1.6 m should be employed for the design.

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with the Ontario Provincial Standard specifications and drawings (OPSD 803.010, OPSD 3504.000 and OPSS 422).

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to OPSD 808.010 for additional requirements for operation of heavy equipment near the culverts.

The culvert extensions must be designed to support the stress induced by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure imposed by the backfill adjacent to the culvert walls.

The lateral earth and water pressure, p (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the Canadian Highway Bridge Design Code (CHBDC),

CAN/CSA-S6-00, March 2001, or employing the following equation assuming a triangular pressure distribution.

$$p = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p$$

where p = lateral earth pressure (kPa)

K = lateral earth pressure coefficient

γ = unit weight of backfill material above design water level (kN/m^3)

γ' = unit weight of submerged backfill material below design water level (kN/m^3)
= $\gamma - \gamma_w$

γ_w = unit weight of water
= 9.8 kN/m^3

h_1 = depth below final grade (m), above design water level

h_2 = depth below design water level (m)

q = any surcharge load (kPa)

C_p = compaction pressure (refer to clause 6.9.3 of CHBDC)

The following parameters are recommended for design:

PARAMETER	GRANULAR A	GRANULAR B TYPE II	EXCAVATED MATERIAL
Angle of Internal Friction, degrees	35	35	30
Unit Weight, kN/m^3	22.8	22.8	20.0
Coefficient of Active Earth Pressure (K_a)	0.27	0.27	0.33
Coefficient of Earth Pressure At Rest (K_o)	0.43	0.43	0.50
Coefficient of Passive Earth Pressure (K_p)	3.69	3.69	3.00

The design should consider both the maximum water level in the stream and the stabilised ground water level condition. The ground water level encountered only at Culverts C-2 and C-12 was measured at elevations 394.5 to 397.4 and 378.6 to 379.7 respectively. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydraulic engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls.

A weeping tile system and/or weep holes should be installed at the wing walls to minimise the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 µm according to OPSS 1860) placed to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost free outlet.

4. EXCAVATION AND GROUND WATER CONTROL

The ground water level observed in the boreholes at the time of the field investigation was typically 1 to 2 m above the anticipated levels of excavation. It is anticipated that conventional sump pumping techniques will be sufficient to control seepage of ground water into the excavation at the locations of Culverts C-1 and C-3. As to the sites at Culverts C-2 and C-12, dewatering with conventional sump pumps may not be sufficient due to the presence of relatively pervious cohesionless soils and hence wells or well points may be required prior to excavation to provide a stable excavation base.

The dewatering system should be installed by a specialist dewatering contractor, with the design left to the Contractor's discretion so that the system meets a performance specification to maintain and control the ground water at least 0.6 m below the excavation base in order to provide a stable excavation.

Excavation to the anticipated founding level of the culverts is expected to extend through the fill, topsoil and native deposits of clayey silt and silty/sandy/gravelly soils. Provision for excavation of cobbles and boulders at all culvert sites should be allowed. Subject to adequate ground water control, excavation of the soil should be feasible using conventional equipment. The in situ materials are typically classified as Type 3 soils according to Occupational Health and Safety Act criteria and temporary cut slopes inclined at 1H:1V (horizontal to vertical) should be employed. Below the ground water table, the materials are classified as Type 4 soils necessitating 3H:1V slopes.

It is anticipated that a suitable roadway protection scheme following SP 539S01 will be required to support the walls of the excavation and adjacent traffic lanes during construction. Several

protection scheme alternatives such as sheet piling, sheeting supported by rakers or bracing, cantilever soldier piles and lagging may be considered. The schemes should be designed for performance level 2 provided that ground water control is in place. Otherwise, a performance level 1 system such as soldier piles and lagging with anchored tiebacks is recommended to prevent movement of the existing embankment. The contractor is responsible for preparation of a detailed design for the road protection scheme.

It will be necessary to implement measures to control water flow in the stream. Conventional procedures such as draining and/or diversion of the stream should be sufficient. Observed ground water levels are subject to seasonal fluctuations and precipitation patterns.

It is recommended that the work be carried out during the dry summer months to minimise the amount of ground water inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

All construction work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

5. EMBANKMENT FILL

It is anticipated that the embankment height at the culvert locations will not exceed 2 m.

The anticipated subgrade for the embankments typically comprises compact to very dense sandy/silty soils and/or stiff to hard clayey silt till. Topsoil was encountered in the boreholes drilled beyond the toes of the existing embankment as well as below the fill in both boreholes advanced on the road shoulders at Culvert C-12. The topsoil and other excessively loose, soft, organic or otherwise deleterious materials within the limits of the embankment fill should be subexcavated prior to fill placement. This measure is critical to minimising differential settlement between the existing and new embankment fill.

The embankment side slopes should be inclined no steeper than 2H:1V. A vegetation cover or other measures should be established to control surface runoff and minimise erosion of the embankment slopes.

It is considered that the subgrade soil is capable of supporting the embankment. Settlement of the embankment material is expected to be in the order of 25 mm. The settlement is anticipated to occur as the fill is placed and be essentially complete within one month following placement of the fill.

6. EROSION CONTROL

The protective measures noted in the OPSD 800 series (particularly OPSD 803.030 and 803.020 for open and box culverts) to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. The cut-off walls should extend to a depth at least equal to the fluctuation of the water level at each culvert location to prevent flow below the box culvert that could erode the bedding material as well as extend laterally to protect the granular material. The requirements of CHBDC clauses 1.10.5.6 and 1.10.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511 and 1004 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements (length and width of the aprons at the inlet/outlet of the culvert as well as the rock size, apron thickness and height of erosion protection on the embankment slope) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by a hydraulic engineer. A non-woven, Class II geotextile with an FOS of 75-150 µm, according to OPSS 1860, should be placed below the rip-rap to minimise the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the wing walls (if provided) should be covered with topsoil and seeded (as per OPSS 570 and 572) as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per OPSS 571) shall be

placed where it currently exists with a view to aesthetics. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor:

SOIL TYPE	K FACTOR
Sand / Gravel	0.1
Silt	0.4

7. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Foundation Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer

Carlos M. P. Nascimento, P.Eng.
Senior Foundation Engineer

Brian R. Gray, MEng, P.Eng.
MTO Designated Contact

GD:gd-mi

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

TITLE	DOCUMENT	DATE
Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	OPSS 422	April 2004
Construction Specification for Compacting	OPSS 501	February 1996
Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting	OPSS 511	November 2004
Construction Specification for Topsoil	OPSS 570	August 1990
Construction Specification for Sodding	OPSS 571	November 2001
Construction Specification for Seed and Cover	OPSS 572	November 2003
Excavation and Backfilling of Structures	OPSS 902	December 1983
Material Specification for Aggregates - Miscellaneous	OPSS 1004	November 2004
Material Specification for Geotextiles	OPSS 1860	November 2004
Construction Specification for Compaction	SP 105S10	November 2004
Construction Specification for Protection Schemes	SP 539S01	April 2004
Excavation and Backfilling of Structures	SP 902S01	September 2003
Backfill and Cover for Concrete Culverts	OPSD 803.010	November 1999
Frost Treatment - Pipe Culverts Frost Penetration Line Below Bedding Grade	OPSD 803.030	September 15, 1996
Pipe Protection against Heavy Construction Equipment	OPSD 808.010	September 15, 1996
Minimum Granular Backfill Requirements - Retaining Walls	OPSD 3504.000	April 1999