



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**EXTENSION AND REPLACEMENT OF SIX CULVERTS**

**FROM STA. 22+616 TO STA. 29+089**

**IMPROVEMENT OF HIGHWAY 6 FROM ARTHUR (WELLS STREET)**

**NORTHERLY TO SOUTH OF MOUNT FOREST**

**G.W.P. 342-97-00**

**TOWNSHIP OF ARTHUR**

**WELLINGTON NORTH COUNTY, ONTARIO**

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PML Ref.: 05KF104D3  
Index No.: 201FIR and 202FDR  
Geocres No.: 40P15-43  
June 14, 2007



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#### Explanation of Terms Used in Report

##### Culvert C-15 at Sta. 22+616

Figures C15-PC-1 – Results of Atterberg Limits Testing  
Figures C15-GS-1 to GS-3 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C15-1 to C15-3  
Drawing C15-1 – Borehole Locations

##### Culvert C-16 at Sta. 23+065

Figures C16-PC-1 to PC-3 – Results of Atterberg Limits Testing  
Figures C16-GS-1 to GS-5 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C16-1 to C16-4  
Drawing C16-1 – Borehole Locations

##### Culvert C-17 at Sta. 23+218

Figures C17-GS-1 to GS-3 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C17-1 to C17-4  
Drawing C17-1 – Borehole Locations

##### Culvert C-18 at Sta. 28+116

Figures C18-PC-1 – Results of Atterberg Limits Testing  
Figures C18-GS-1 and GS-2 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C18-1 to C18-3  
Drawing C18-1 – Borehole Locations

##### Culvert C-19 at Sta. 28+319

Figure C19-PC-1 to PC-3 – Results of Atterberg Limits Testing  
Figures C19-GS-1 to GS-4 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C19-1 to C19-3  
Drawing C19-1 – Borehole Locations

##### Culvert C-20 at Sta. 29+089

Figures C20-PC-1 – Results of Atterberg Limits Testing  
Figures C20-GS-1 and GS-2 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C20-1 to C20-3  
Drawing C20-1 – Borehole Locations

**FOUNDATION INVESTIGATION REPORT**  
for  
Extension and Replacement of Six Culverts  
From Sta. 22+616 to Sta. 29+089  
Improvement of Highway 6  
From Arthur (Wells Street) Northerly  
to South of Mount Forest  
G.W.P. 342-97-00  
Township of Arthur  
Wellington North County, Ontario

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**1. INTRODUCTION**

Planned under this project is the improvement of an approximate 18 km long section of Highway 6 that extends from Arthur (Wells Street) northerly to south of Mount Forest in the Township of Arthur, Wellington North County, Ontario. This report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario.

Improvement of the highway will involve either extension or replacement of twenty one culverts less than 3 m wide. This report deals with six culverts that are located between Sta. 22+616 and Sta. 29+089 and listed in the following table. Peto MacCallum Ltd. (PML) identified the culverts by numbers C-15 to C-20 for ease of reference in this report.

<b>PML Ref. No.</b>	<b>APPROXIMATE STATION</b>
C-15	22+616
C-16	23+065
C-17	23+218
C-18	28+116
C-19	28+319
C-20	29+089

This report provides a summary of the factual information obtained during the field investigation conducted at the locations of the existing six culverts listed above. The factual information for the remaining culverts is reported separately.



## **2. SITE DESCRIPTION AND GEOLOGY**

Highway 6 within the project limits is primarily situated in a rural setting with rolling terrain containing streams and swampy areas. The six culverts dealt with in this report are located from south of Kenilworth to north of Riverstown. Land use along the study corridor is mainly agricultural with some forested/swamp areas, local residential development and gravel pit explorations. The direction of water flow through the culverts as inferred from the existing invert levels was indicated on the attached drawings.

The project area lies in the physiographic region known as the Dundalk Till Plain characterised by a gently undulating till plain. The principal surficial soil along the study corridor is a shallow medium textured sandy silt and locally sand and gravel. Typically, the surficial soils overlay clay tills. Some of the low lying and valley areas are swampy with poor drainage (L.J.Chapman & D.F.Putnam, *The Physiography of Southern Ontario*, 3<sup>rd</sup> Edition, Ontario Research Foundation, 1984).

The bedrock in this section of the project belongs to the Salina Formation comprising dolostone, shale, gypsum and salt. The bedrock in the area is at approximate 20 to 57 m depths.

The frost penetration depth for foundation design purposes as shown on the OPSD 3090.101 is 1.6 m.

## **3. INVESTIGATION PROCEDURES**

The field work for this study was carried out in the period of May 17 to July 19, 2006 and comprised a total of 20 boreholes and 4 dynamic cone penetration tests. The explorations advanced with drill rig equipment were extended to depths of 5.8 to 15.2 m below existing grade. One borehole put down off the west shoulder of the highway at culvert C-16 was advanced with a tripod to 2.8 m depth due to access and permission to enter restrictions. The approximate locations of the boreholes put down at each culvert are shown on Drawings C15-1 to C20-1.



The borehole numbers and figures are provided with prefix codes C15 to C20 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. PML selected the borehole locations in the field. The co-ordinates and ground surface elevations at the boreholes were provided by MRC. All elevations in this report are expressed in metres.

The boreholes were advanced using continuous flight solid stem augers, powered by a truck or track-mounted drill rig or with a motorized tripod, 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 0.75 and 1.5 m 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. Four dynamic core penetration tests were advanced at the bottom of boreholes C15-1, C15-3, C16-1 and C16-2. Penetrometer tests were carried out on cohesive split-spoon soil samples. These test results are typically lower than the actual values due to sample disturbance.

Soils were identified visually in the field in accordance with the MTO Soil Classification procedures. The groundwater 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 and MOE (Reg. 903) 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 17 Atterberg limits tests and 37 grain size distribution analyses was carried out on selected samples. Atterberg limits were not determined on samples deemed to be non-plastic by visual and tactile examination. 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 and dynamic cone penetration test data, groundwater 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 are shown on Drawings C15-1 to C20-1. 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 and/or surficial topsoil overlying sandy/silty soils and clayey silt till/silty clay till. Cobbles and boulders were encountered within the glacial till deposits at the culvert locations. Groundwater was at variable depths of 0.0 to 5.2 m upon completion of drilling. The level of water flowing through the culverts ranged from up to 200 mm deep after heavy rainfalls to a negligible amount between rain events.

A description of the subsurface stratigraphy identified at each culvert is summarised in the following subsections of the report.

##### **4.1 Culvert C-15 at Sta. 22+616**

Three boreholes were drilled along the alignment of this culvert. Two dynamic cone penetration tests were performed in boreholes C15-1 and C15-3. The explorations extended to depths of 6.7 to 10.5 m. The subsurface stratigraphy revealed in the boreholes comprised a road embankment fill or surficial topsoil underlain by clayey silt till and/or sandy/silty soils. Groundwater was observed in all the boreholes.

###### **4.1.1 Fill**

The road shoulder pavement comprised about 250 mm of sand and gravel fill encountered at the surface in borehole C15-1.





Variable fill soils making up the existing highway embankment were present below the gravel shoulder fill in borehole C15-1 advanced to the east of the road centreline. Gravel mixed with sand and silt was 1.9 m thick and compact to loose in relative density. Overlain by the gravel fill was firm silty clay 800 mm in thickness. The fill soils were penetrated at 3.0 m depth (elevation 446.3). The standard penetration test N-values in the fill ranged from 6 to 13.

The results of one grain size distribution analysis performed on the mixed gravel fill are presented in Figure C15-GS-1. The moisture content of the fill materials varied between 11 and 15%.

#### 4.1.2 Topsoil

Surficial topsoil was present in boreholes C15-2 and C15-3 put down at both ends of the culvert. The topsoil had a thickness of about 300 mm.

#### 4.1.3 Clayey Silt Till

Directly beneath the topsoil in boreholes C15-2 and C15-3 was a cohesive clayey silt till deposit. Being stiff to very stiff in consistency, with a range in N-values of 7 to 21, this deposit was 2.2 m thick in the former borehole and 0.6 m in the latter. The clayey silt till was penetrated at 2.5 m depth (elevation 445.1) in borehole C15-2 drilled at the west end of the culvert and a depth of 0.9 m (elevation 446.6) at the east end.

The results of one Atterberg limits testing and one grain size distribution analysis on a representative sample of the cohesive deposit are shown in respective Figures C15-PC-1 and C15-GS-2. The liquid and plastic limits of the clayey silt till were 26 and 15 respectively (plasticity index of 11). The moisture content of the clayey silt till was 12 to 15%.

#### 4.1.4 Silty Sand to Sand

Underlying the clayey silt till in boreholes C15-2 and C15-3 was cohesionless silty sand. This unit was 0.4 m thick and dense (N-value of 47) at the west end of the culvert; 1.3 m thick and compact



(N-values of 14 and 20) at the east end. The silty sand was penetrated at respective depths of 2.9 and 2.2 m (elevations 444.7 and 445.3).

Cohesionless sand was revealed below the fill in borehole C15-1 or silty sand in the remaining boreholes at depths of 2.2 to 3.0 m (elevations 444.7 to 446.3). This stratum was typically compact to very dense, with N-values ranging from 11 to 58 and one isolated value of 9. The results of the dynamic cone penetration test obtained in the sandy soils were 16 to 73. The sand was 5.7 m thick and penetrated at 8.7 m depth (elevation 440.6) in the borehole put down on the road shoulder. The stratum extended to termination depths of 6.7 and 7.6 m (elevations 440.9 and 439.9) in boreholes C15-2 and C15-3 respectively.

The envelope of the results of four grain size distribution analyses performed on these materials is presented in Figure C15-GS-3. The moisture content of the sandy soils varied between 17 and 22%.

#### 4.1.5 Sandy Silt

Very dense sandy silt (N-value of 51) was identified below the sand at 8.7 m depth (elevation 440.6) in borehole C15-1. Dynamic cone penetration test values of 62 to over 120 blows were obtained in the sandy silt. This unit was not penetrated at the termination depth of 10.5 m (elevation 438.8). The sandy silt had a moisture content of about 20%.

#### 4.1.6 Groundwater

Water was observed in all the boreholes in the course of the field work. In the process of augering, it was detected at a depth of 1.5 m (elevation 446.1) in borehole C15-2 and 0.9 m depth (elevation 446.6) in borehole C15-3. Groundwater was measured in all the boreholes to be at depths of 1.1 to 2.4 m (elevations 445.8 to 446.9) upon completion of drilling.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.



## **4.2 Culvert C-16 at Sta. 23+065**

Four boreholes were drilled along the alignment of this culvert. Two dynamic cone penetration tests were performed in boreholes C16-1 and C16-2. The explorations extended to depths of 2.8 to 15.2 m. The subsurface stratigraphy revealed in the boreholes comprised a road embankment fill and/or topsoil underlain by gravelly/sandy soils, silt and silty clay. Probable boulder was encountered at the termination depth of one borehole. Groundwater was observed in all the boreholes.

### **4.2.1 Fill**

The highway gravel shoulder pavement comprised sand and gravel of 1350 mm thickness in borehole C16-1 and 280 mm in borehole C16-2.

Mixed clayey silt, silty clay, gravel fill was present surficially in borehole C16-3 and below the gravel shoulder in boreholes C16-1 and C16-2. The standard penetration test values in the fill ranged from 5 to 25. The fill extended to a depth of 5.6 m under the pavement of the highway and was penetrated at elevation 436.9. At the east end of the culvert, the fill was 300 mm thick and penetrated at elevation 439.8.

The results of one Atterberg limits test and one grain size distribution analysis conducted on the cohesive portion of the fill are shown in respective Figures C16-PC-1 and C16-GS-1. The liquid and plastic limits of the clayey silt fill were 25 and 14 respectively (plasticity index of 11). The results of one grain size distribution analysis performed on the cohesionless fill material are presented in Figure C16-GS-2. The moisture content of the fill was in a range of 5 to 15%.

### **4.2.2 Topsoil**

Topsoil was present surficially in borehole C16-4 and buried under the fill at 0.3 m depth (elevation 439.8) in borehole C16-3. The topsoil had a thickness of 400 mm in the borehole advanced at the east end of the culvert extending to 0.7 m depth (elevation 439.4) and 800 mm at the west end (elevation 438.4).



#### 4.2.3 Gravel/Sand

Discontinuous gravelly/sandy soils were encountered below the topsoil or silty clay at depths of 0.7 and 1.4 m (elevations 439.4 and 437.8) in boreholes C16-3 and C16-4 respectively. The gravelly sand to gravel with sand soils revealed at the east end of the culvert were 3.4 m thick, compact in relative density (N-values of 23 and 24) and penetrated at 4.1 m depth (elevation 436.0). The sand with gravel and gravelly sand soils identified at the west end of the culvert were loose to dense and not penetrated at the termination depth of 2.8 m (elevation 436.4) due to refusal on probable boulder.

The results of three grain size distribution analyses performed on these materials are presented in Figure C16-GS-3. The gravelly/sandy soils had a moisture content ranging from 5 to 14%.

#### 4.2.4 Silt

Silt was encountered below the fill at a depth of 5.6 m (elevation 436.9) in the boreholes put down on the shoulders of the highway and below the silty clay till at 5.2 m depth (elevation 434.9) in borehole C16-3. Having a thickness of 4.9 m in borehole C16-1 and 4.6 m in borehole C16-2, this unit was penetrated at respective depths of 10.5 and 10.2 m (elevations 432.0 and 432.3). Borehole C16-3 was terminated in the silt at 5.8 m depth (elevation 434.3). The unit was compact to dense (N-values of 11 to 33).

The results of two Atterberg limits tests and two grain size distribution analyses performed on representative samples of this material are shown in respective Figures C16-PC-2 and C16-GS-4. The silt had liquid limits of 17 and 18, plastic limits of 13 and 14, with a corresponding plasticity index of 4. The silt had a moisture content of 11 to 16%.

#### 4.2.5 Silty Clay

Silty clay was encountered below the topsoil, gravelly soils or silt at variable depths of 0.8 to 10.5 m (elevations 432.0 to 438.4). This deposit was firm to hard in consistency, with a range in N-values of 7 to 32 and penetrometer test results indicating a shear strength of 138 to 175 kPa.



The silty clay was 1.1 m thick and penetrated at a depth of 5.2 m (elevation 434.9) in borehole C16-3, 0.6 m in thickness and penetrated at 1.4 m depth (elevation 437.8) in borehole C16-4. The remaining boreholes were terminated in the deposit at depths of 14.9 and 15.2 m (elevations 427.6 and 427.3).

The results of one Atterberg limits testing and one grain size distribution analysis on a representative sample of the cohesive deposit are shown in respective Figures C16-PC-3 and C16-GS-5. The liquid and plastic limits of the silty clay were 43 and 18 respectively (plasticity index of 25). One moisture content determination on the deposit was about 23%.

#### 4.2.6 Groundwater

Water was observed in all the boreholes in the course of the field work. In the process of augering, it was detected at depths of 0.0 to 4.0 m (elevations 438.5 to 439.5). Groundwater was measured at depths of 0.0 to 5.2 m (elevations 437.3 to 440.4) upon completion of drilling.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

### 4.3 Culvert C-17 at Sta. 23+218

Four boreholes were drilled to depths of 5.8 to 9.8 m along the alignment of this culvert. The subsurface stratigraphy revealed in the boreholes comprised a road embankment fill and/or topsoil underlain by sandy/gravelly soils, silt, clayey silt and silty clay. Cobbles were encountered in one of the boreholes. Groundwater was observed in all the boreholes.

#### 4.3.1 Fill

The highway gravel shoulder pavement encountered in boreholes C17-1 and C17-2 comprised sand and gravel of 940 mm thickness in borehole C17-1 and 250 mm in borehole C17-2.

Mixed gravelly sand to gravel trace sand, clayey silt fill with silty clayey, organic inclusions was present surficially in borehole C17-3 and below the gravel shoulder materials in boreholes C16-1



and C16-2. The standard penetration test values in the fill ranged from 5 to 51. The fill extended to depths of 3.0 to 4.0 m under the pavement of the highway and was penetrated at elevations 437.0 to 438.0. At the east end of the culvert, the fill was 200 mm thick and penetrated at elevation 439.5.

The results of two grain size distribution analyses conducted on the cohesionless portion of the fill are presented in Figure C17-GS-1. The moisture content of the fill materials varied between 5 and 10%.

#### 4.3.2 Topsoil

Topsoil was present surficially in western borehole C17-4 and buried under the fill at 0.2 m depth (elevation 439.5) in eastern borehole C17-3. The topsoil had a thickness of 400 mm in the borehole advanced at the west end of the culvert and 800 mm at the east end where the unit extended to 1.0 m depth, elevation 438.7.

#### 4.3.3 Sand and Gravel to Gravel with Sand

Gravelly/sandy soils were contacted below the fill and/or topsoil at depths of 0.4 to 3.0 m (elevations 438.0 to 439.0) in boreholes C17-1, C17-3 and C17-4. These soils were 2.0 to 4.1 m thick and loose to very dense (N-values of 8 to 71). Cobbles were encountered within the gravelly soils at the west end of the culvert. The gravelly/sandy soils were penetrated at depths of 3.0 to 5.5 m (elevations 434.9 to 436.7).

The envelope of the results of four grain size distribution analyses performed on these materials is presented in Figure C17-GS-2. The gravelly/sandy soils had a moisture content ranging from 4 to 10%.

#### 4.3.4 Silt

Non-plastic silt was revealed below the sand and gravel, clayey silt or silty clay at depths of 5.5 to 8.6 m (elevations 432.4 to 435.5) in boreholes C17-1, C17-2 and C17-4. This unit was 3.2 m thick and penetrated at 8.7 m depth (elevation 432.3) in borehole C17-1. The other two boreholes were



terminated in the silt at depths of 6.6 and 9.6 m (elevations 432.8 and 431.4). This unit was dense to very dense (N-values of 33 to 56).

The results of two grain size distribution analyses conducted on this material are presented in Figure C17-GS-3. The moisture content of the silt was about 14%.

#### 4.3.5 Clayey Silt

Overlain by the silt in borehole C17-1 and fill in borehole C17-2 at respective depths of 8.7 and 4.0 m (elevations 432.3 and 437.0) was a clayey silt unit. This deposit was very stiff to hard in consistency, with a range in N-values of 18 to 51 and penetrometer test results indicating a shear strength of 212 to 225 kPa. The clayey silt had a thickness of 4.6 m and was penetrated at 8.6 m depth (elevation 432.4) in borehole C17-2. The deposit was not penetrated upon termination of drilling at a depth of 9.8 m (elevation 431.2) in borehole C17-1. The clayey silt had a moisture content of about 16%.

A layer of clayey silt till was also identified below silty clay at 5.2 m depth (elevation 434.5) in borehole C17-3. This layer was very stiff and not penetrated at the termination depth of 5.8 m (elevation 433.9).

#### 4.3.6 Silty Clay

Underlying the gravelly soils at 4.5 m depth (elevation 434.9) in borehole C17-4 and at 3.0 m depth (elevation 436.7) in borehole C17-3 was silty clay. This deposit was 1.3 to 2.2 m thick and stiff to hard in consistency. The silty clay was penetrated at a depth of 5.8 m (elevation 433.6) in borehole C17-4 and at a depth of 5.2 m (elevation 434.5) in borehole C17-3.

The range of N-values was 10 to 50 and penetrometer resistance indicated a shear strength of about 160 kPa in borehole C17-3.

#### 4.3.7 Groundwater

Water was observed in all the boreholes in the course of the field work. In the process of augering, it was detected at depths of 0.6 to 2.1 m (elevations 438.7 to 438.9). Groundwater was measured at depths of 0.6 to 2.1 m (elevations 438.4 to 439.2) upon completion of drilling.



The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

#### **4.4 Culvert C-18 at Sta. 28+116**

Three boreholes were drilled along the alignment of this culvert to depths of 6.5 to 7.9 m. The subsurface stratigraphy revealed in the boreholes comprised a road embankment fill and/or surficial topsoil underlain by clayey silt till and silty clay till interbedded with silt and sandy gravel. Occasional cobbles and boulders were encountered in one of the boreholes. Groundwater was observed in all the boreholes.

##### **4.4.1 Fill**

The road shoulder pavement comprised about 400 mm of gravelly sand fill encountered at the surface in borehole C18-1 advanced to the west of the road centreline.

Variable fill soils making up the existing highway embankment were present below the gravel shoulder fill in borehole C18-1. The fill comprised clayey silt mixed or layered with gravelly sand and was 1.1 m thick and firm to stiff or compact. The fill soils were penetrated at a depth of 1.5 m (elevation 430.2). The standard penetration test N-value in the fill was 13.

The results of one grain size distribution analysis performed on the cohesionless portion of the fill are presented in Figure C18-GS-1. The moisture content of the clayey silt fill was about 27%.

##### **4.4.2 Topsoil**

Topsoil was present surficially in the boreholes put down at both ends of the culvert and buried under the fill at 1.5 m depth (elevation 430.2) in borehole C18-1. Having a moisture content of about 28%, the topsoil had a thickness of 300 to 500 mm and was penetrated at depths of 0.3 to 2.0 m (elevations 429.3 to 429.7).





#### 4.4.3 Clayey Silt Till

Clayey silt till was encountered below the topsoil, silt or silty clay till at depths of 0.3 to 5.9 m (elevation 423.7 – lower of two zones in borehole C18-2 – to 429.7) in all the boreholes. This deposit was 1.2 to 5.2 m thick where penetrated and typically stiff to hard in consistency, with a range in N-values of 12 to 64 and penetrometer resistance indicating a shear strength of 75 to 225 kPa. The upper layer of the clayey silt till in borehole C18-2 was firm to stiff (N-value of 6 and penetrometer tests over 100 kPa in similar soils in borehole C18-3). The clayey silt till was penetrated at 7.2 m depth (elevation 424.5) in borehole C18-1 and the upper zone of the clayey silt till at 1.5 m, elevation 428.1 in borehole C18-2. The remaining boreholes were terminated within the deposit at a depth of 6.5 m (elevations 423.1 and 423.2). The clayey silt till contained occasional cobbles and boulders.

The results of Atterberg limits testing and grain size distribution analyses conducted on four samples of this material are presented in respective Figures C18-PC-1 and C18-GS-2. The liquid and plastic limits of the clayey silt till ranged from 20 to 28 and from 12 to 15 respectively, thus giving the plasticity index values of 8 to 13. The deposit had a moisture content of 8 to 22%.

#### 4.4.4 Silty Clay Till

Silty clay till underlay the upper zone of the clayey silt till or sandy gravel at depths of 1.5 and 3.2 m (elevations 428.1 and 426.5) in boreholes C18-2 and C18-3 respectively. This deposit was 1.4 m thick and very stiff in the former borehole, 1.2 m thick and hard in the latter. Penetrometer tests indicated a shear strength of about 225 kPa. The silty clay till had a moisture content of about 14% and was penetrated at depths of 2.9 and 4.4 m (elevations 426.7 and 425.3).

#### 4.4.5 Silt/Silt Till

Non-plastic silt was encountered below the topsoil or sandy gravel at depths of 0.3 and 4.4 m (elevations 429.4 and 425.2) at both ends of the culvert. This unit was 1.5 m thick and dense (N-value of 41) in borehole C18-2, 0.4 m thick and very loose (N-value of 3) in borehole C18-3. The silt was penetrated at respective depths of 5.9 and 0.7 m (elevations 423.7 and 429.0). The moisture content of the unit was about 18%.



A layer of silt till was also identified below clayey silt till at 7.2 m depth (elevation 424.5) in borehole C18-1. This layer was very dense (N-value of 50 blows for 100 mm penetration) and not penetrated at the 7.9 m termination depth of the borehole (elevation 423.8). The silt till had a moisture content of about 16%. The layer contained occasional cobbles and boulders.

#### 4.4.6 Sandy Gravel

Underlying the silty clay till or clayey silt till at 2.9 m depth (elevations 426.7 and 426.8) at both ends of the culvert was a sandy gravel unit. Being dense, this stratum had a thickness of 1.5 m in borehole C18-2 and 0.3 m in borehole C18-3 and was penetrated at respective depths of 4.4 and 3.2 m (elevations 425.2 and 426.5). The sandy gravel had a moisture content of about 11%.

#### 4.4.7 Groundwater

Water was observed in all the boreholes in the course of the field work at depths of 2.3 to 2.9 m (elevations 426.7 to 429.4). Groundwater was measured to be at depths of 1.8 to 4.9 m (elevations 426.8 to 427.9) upon completion of drilling.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

### 4.5 Culvert C-19 at Sta. 28+319

Three boreholes were drilled along the alignment of this culvert to depths of 6.2 to 7.9 m. The subsurface stratigraphy revealed in the boreholes generally comprised a road embankment fill and/or surficial topsoil underlain by clayey silt till and silt till. Cobbles and boulders were encountered in one of the boreholes. Groundwater was observed in all the boreholes.

#### 4.5.1 Fill

The road shoulder pavement comprised about 500 mm of gravelly sand fill encountered at the surface in borehole C19-1 advanced to the west of the road centreline.



Variable fill soils making up the existing highway embankment were present below the gravel shoulder fill in borehole C19-1. The mixed clayey silt and gravelly sand fill was 1.2 m thick and stiff/compact. The fill soils were penetrated at a depth of 1.7 m (elevation 429.8). The standard penetration test N-value in the fill was 17. At the east end of the culvert, a surficial layer of silty sand fill was 300 mm thick and penetrated at elevation 429.8.

The results of one grain size distribution analysis conducted on the cohesionless portion of the mixed fill are presented in Figure C19-GS-1. The moisture content of the gravelly sand fill was about 5%.

#### 4.5.2 Topsoil

Topsoil was present surficially in borehole C19-2 and buried beneath the fill at depths of 0.3 and 1.7 m (elevation 429.8) in the remaining boreholes. Having a moisture content of 28 to 30%, the topsoil was 200 to 500 mm in thickness and penetrated at depths of 0.2 to 2.2 m (elevations 429.3 to 429.7).

#### 4.5.3 Clayey Silt / Silty Clay

Overlain by the topsoil at depths of 0.2 and 0.7 m (elevations 429.7 and 429.4) in the boreholes advanced at both ends of the culvert was clayey silt or silty clay. These deposits were firm to soft in consistency, with a range in N-values of 2 to 6. The cohesive soils had a thickness of 0.8 to 1.2 m and were penetrated at depths of 1.5 and 2.4 m (elevations 428.6 and 428.5).

The results of Atterberg limits testing and grain size distribution analysis performed on a representative sample of the clayey silt are shown in respective Figures C19-PC-1 and C19-GS-2. The liquid and plastic limits of this soil were 33 and 17 respectively, with a corresponding plasticity index of 16. The moisture content of the cohesive soils varied between 17 and 19%.



#### 4.5.4 Clayey Silt Till

Underlying the topsoil, silty clay or clayey silt at depths of 1.4 to 2.2 m (elevations 428.5 to 429.3) in all the boreholes was clayey silt till. The stratum was interbedded with gravelly sand in boreholes C19-2 and C19-3 and with a silt till layer in borehole C19-3. This deposit was 1.2 to 2.1 m thick where the upper layers of the deposit were penetrated and stiff to hard in consistency, with a range in N-values of 9 to 63 and penetrometer resistance indicating a shear strength of 60 to 225 kPa. The upper layers of the clayey silt till were penetrated at depths of 4.3, 2.4 and 2.7 m (elevations 427.2, 427.5 and 427.4) in boreholes C19-1, C19-2 and C19-3, respectively. The lower layer in borehole C19-3 extended from 4.5 to 5.9 m depths, elevations 425.6 to 424.2. Borehole C19-2 was terminated within the deposit at 6.5 m depth (elevation 423.4).

The results of Atterberg limits testing and grain size distribution analyses conducted on two samples of this material are presented in respective Figures C19-PC-2 and C19-GS-3. The liquid limits of the clayey silt till were 25 and 28, the plastic limits 13 and 15, thus giving the plasticity index values of 12 and 13. The deposit had a moisture content of 8 to 19%.

#### 4.5.5 Gravelly Sand

A layer of gravelly sand was identified below the clayey silt till at depths of 2.4 and 2.7 m (elevations 427.5 and 427.4) in boreholes C19-2 and C19-3 respectively. This unit was 400 and 500 mm thick and compact in relative density (N-value of 13). The gravelly sand had a moisture content of about 13% and was penetrated at depths of 2.9 and 3.1 m (elevation 427.0).

#### 4.5.6 Silt Till

Silt till was encountered below the clayey silt till at 4.3 m depth (elevation 427.2) in borehole C19-1 or gravelly sand at a depth of 3.1 m (elevation 427.0) in borehole C19-3. A lower layer was found in borehole C19-3 at 5.9 m depth, elevation 424.2. This unit was compact to very dense (N-values of 16 to 82 with values also in excess of 50 for less than 300 mm penetration) and not penetrated at respective depths of 7.9 and 6.2 m (elevations 423.6 and 423.9) upon termination of boreholes C19-1 and C19-3. Cobbles and boulders were contained within the silt till.



The results of Atterberg limits testing and grain size analysis performed on a representative sample of this material are shown in respective Figures C19-PC-3 and C19-GS-4. Two samples were non-plastic. The liquid and plastic limits of the silt till were 15 and 11 (plasticity index of 4). The moisture content of the unit ranged from 8 to 13%.

#### 4.5.7 Groundwater

Water was observed in all the boreholes in the course of the field work at depths of 1.5 to 2.7 m (elevations 427.4 to 430.0). Groundwater was measured to be at depths of 1.8 to 2.4 m (elevations 427.5 to 429.4) upon completion of drilling.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

### 4.6 Culvert C-20 at Sta. 29+089

Three boreholes were drilled along the alignment of this culvert to depths ranging from 6.5 to 8.2 m. The subsurface stratigraphy revealed in the boreholes generally comprised a road embankment fill and/or surficial topsoil underlain by clayey silt till and silty clay till. Cobbles and boulders were encountered in two of the boreholes. Groundwater was observed in all the boreholes.

#### 4.6.1 Fill

Fill was present surficially in borehole C20-1 and buried under topsoil at a depth of 0.3 m (elevation 428.3) in borehole C20-3. Sandy gravel fill in the former borehole was 1.7 m thick, compact in relative density (N-value of 16) and penetrated at elevation 428.4. Silty clay fill in the latter borehole was 0.4 m thick, firm in consistency (N-value of 7) and penetrated at 0.7 m depth (elevation 427.9).

The results of grain size distribution analysis conducted on the sandy gravel fill are presented in Figure C20-GS-1. The moisture content of the fill units was 4 and 13%.



#### 4.6.2 Topsoil

Topsoil was present surficially in the boreholes put down at both ends of the culvert and buried below the fill at a depth of 1.7 m (elevation 428.4) in borehole C20-1 drilled on the shoulder of the highway. The thickness of the topsoil was 900 mm in borehole C20-1 and 300 mm in the other boreholes. The topsoil had a moisture content of about 30% and was penetrated at 0.3 to 2.6 m depths, elevations 427.5 to 428.3.

#### 4.6.3 Silty Clay

A layer of silty clay was identified below the topsoil at 0.3 m depth (elevation 427.7) in borehole C20-2 advanced at the west end of the culvert. This layer was 400 mm thick and stiff in consistency. The silty clay had a moisture content of about 23% and was penetrated at a depth of 0.7 m (elevation 427.3).

#### 4.6.4 Clayey Silt Till

Underlying the topsoil or silty clay at depths of 0.7 to 2.6 m (elevations 427.3 to 427.9) in all the boreholes was clayey silt till. This deposit was stiff to hard, with a range in N-values of 8 to 41 and penetrometer test results indicating a shear strength of 75 to 225 kPa. The clayey silt till was 3.9 m thick and penetrated at 4.6 m depth (elevation 424.0) in borehole C20-3. The remaining boreholes were terminated in the deposit at depths of 6.5 and 8.2 m (elevations 421.5 and 421.9). Cobbles and boulders were encountered within the clayey silt till.

The results of Atterberg limits testing and grain size distribution analyses conducted on four samples of this material are presented in respective Figures C20-PC-1 and C20-GS-2. The liquid and plastic limits of the clayey silt till ranged from 25 to 29 and 12 to 14 respectively, thus giving the plasticity index of 13 to 15. The moisture content of the deposit typically varied between 11 and 15%. An isolated value of 23% in borehole C20-3 at about 2.5 m depth was also obtained.



#### 4.6.5 Silty Clay Till

Silty clay till was revealed below the clayey silt till at 4.6 m depth (elevation 424.0) in borehole C20-3 drilled at the east end of the culvert. This deposit was very stiff, with N-values of 26 and 29 and penetrometer resistance indicating a shear strength of 187 kPa. The deposit had a moisture content of 12 to 17% and was not penetrated at a depth of 6.5 m (elevation 422.1) upon completion of drilling.

#### 4.6.6 Silty Sand

Silty sand was contacted within the clayey silt till at 2.5 m depth (elevation 425.5) in borehole C20-2 put down at the west end of the culvert. This unit was 500 mm thick, dense (N-value of 30) and penetrated at a depth of 3.0 m (elevation 425.0).

#### 4.6.7 Groundwater

Water was observed in all the boreholes in the course of the field work at depths of 3.1 m (elevation 427.0) in borehole C20-1 and 2.1 m (elevation 425.9) in borehole C20-2. Groundwater was measured in the same boreholes at respective depths of 4.3 and 2.7 m (elevations 425.8 and 425.3) upon completion of drilling. Water was at the surface in borehole C20-3 due to surface water run-off.

The observed groundwater levels are subject to seasonal fluctuations and precipitation patterns.

## 5. CLOSURE

The field work was carried out under the supervision of Messrs. G. Idzik, BASc, and F. Portela and direction of Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. The soil drilling equipment was supplied by Geo-Environmental Drilling Inc.

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

Yours very truly

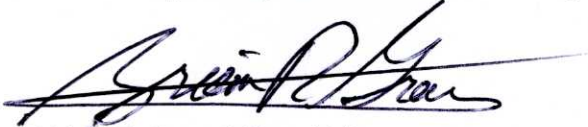
Peto MacCallum Ltd.



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



Carlos M. P. Nascimento, P.Eng.  
Senior Project Engineer and Project Manager



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

GD/CN:lr-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  $\bar{N}$ .

**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 (RQD), 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
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	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
$C_\alpha$	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
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$kg/m^3$	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE
$\gamma_s$	$kN/m^3$	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\rho_w$	$kg/m^3$	DENSITY OF WATER	$S_r$	%	DEGREE OF SATURATION	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\gamma_w$	$kN/m^3$	UNIT WEIGHT OF WATER	$w_L$	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
$\rho$	$kg/m^3$	DENSITY OF SOIL	$w_p$	%	PLASTIC LIMIT	$D_n$	mm	n PERCENT - DIAMETER
$\gamma$	$kN/m^3$	UNIT WEIGHT OF SOIL	$w_s$	%	SHRINKAGE LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\rho_d$	$kg/m^3$	DENSITY OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$	$kN/m^3$	UNIT WEIGHT OF DRY SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	$m^3/s$	RATE OF DISCHARGE
$\rho_{sat}$	$kg/m^3$	DENSITY OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
$\gamma_{sat}$	$kN/m^3$	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
$\rho'$	$kg/m^3$	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$	$kN/m^3$	UNIT WEIGHT OF SUBMERGED SOIL	WTPL		WETTER THAN PLASTIC LIMIT	j	$kN/m^3$	SEEPAGE FORCE
e	1, %	VOID RATIO						

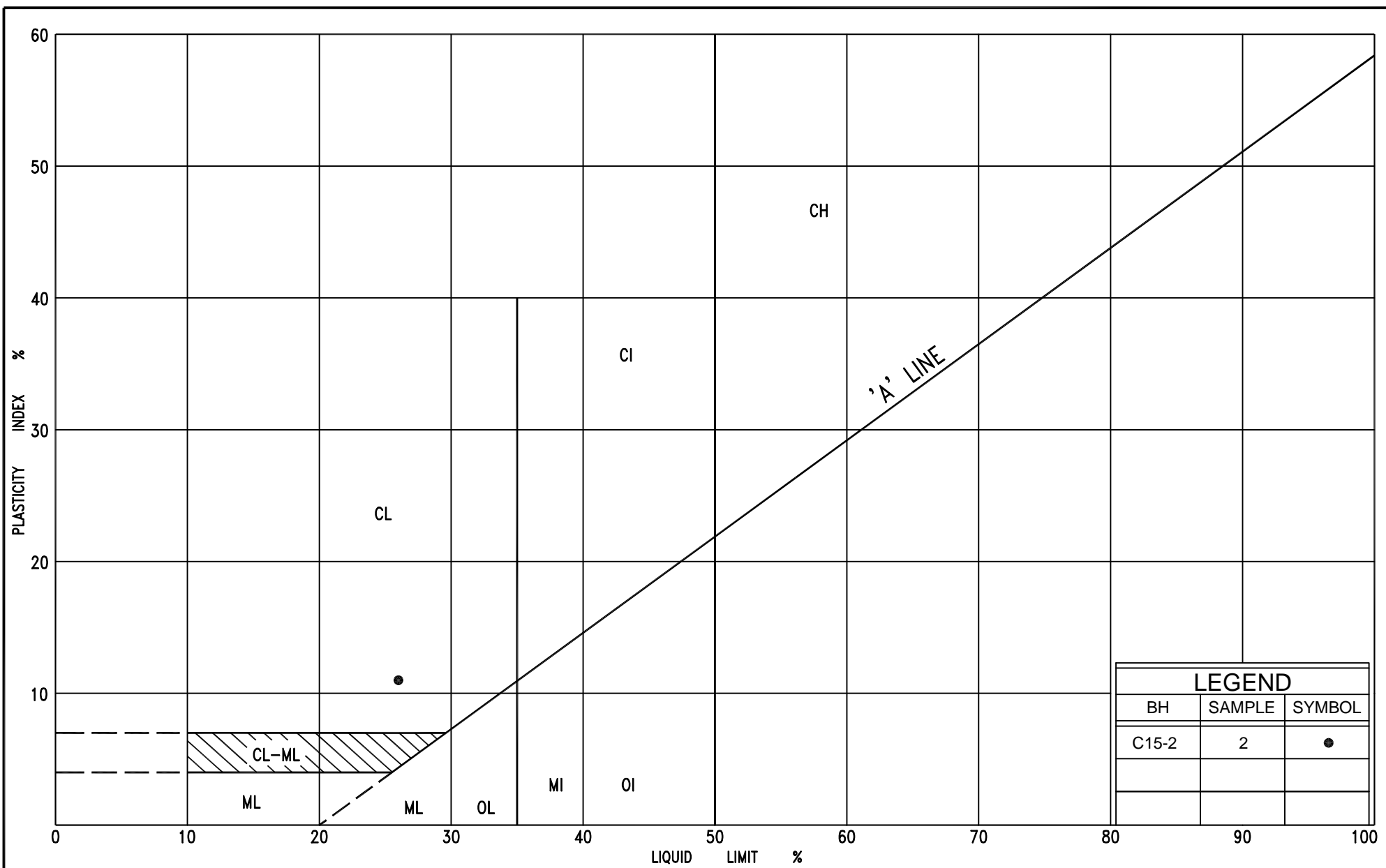
### Culvert C-15 at Sta. 22+616

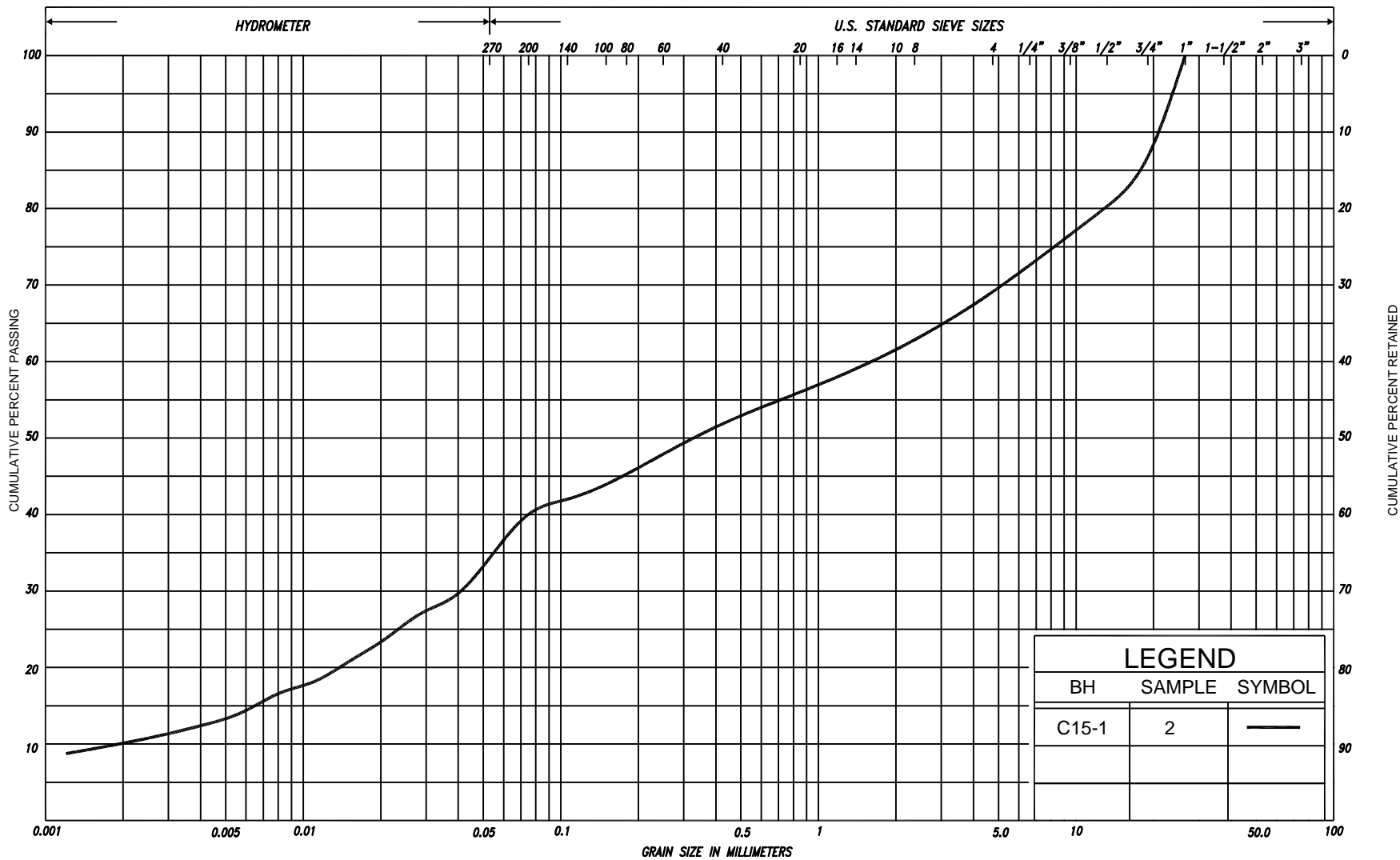
Figures C15-PC-1 – Results of Atterberg Limits Testing

Figures C15-GS-1 to GS-3 – Results of Grain Size Distribution Analyses

Record of Borehole Sheets C15-1 to C15-3

Drawing C15-1 – Borehole Locations





LEGEND		
BH	SAMPLE	SYMBOL
C15-1	2	—

SILT & CLAY				FINE SAND			MEDIUM SAND		COARSE SAND		GRAVEL		COBBLES
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL			COBBLES			UNIFIED
													M.I.T.
CLAY	SILT			V. FINE	FINE	MED.	COARSE	GRAVEL			COBBLES		U.S. BUREAU

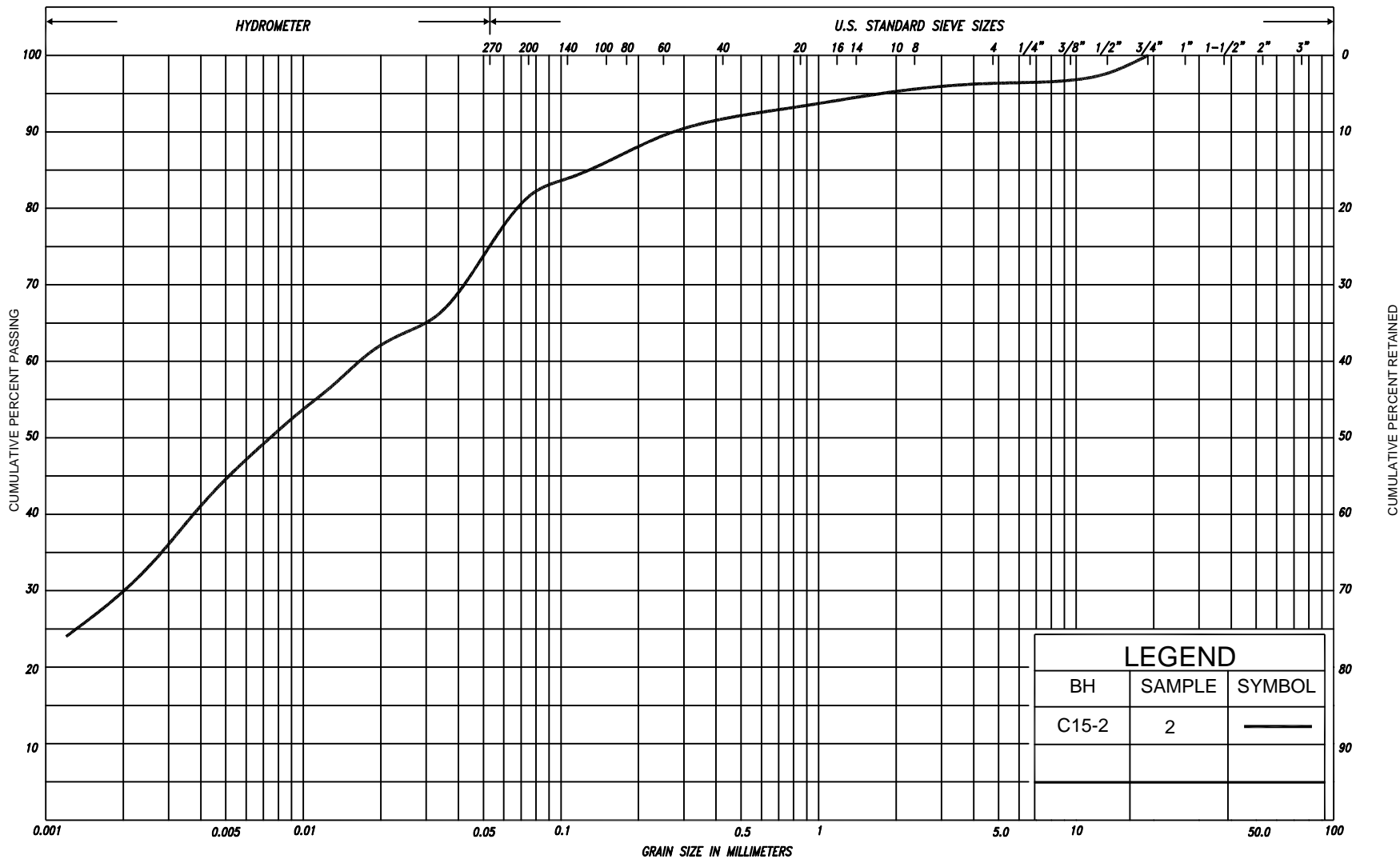
# GRAIN SIZE DISTRIBUTION Mixed gravel with sand with silt , trace clay (FILL)

FIG No. C15-GS-1

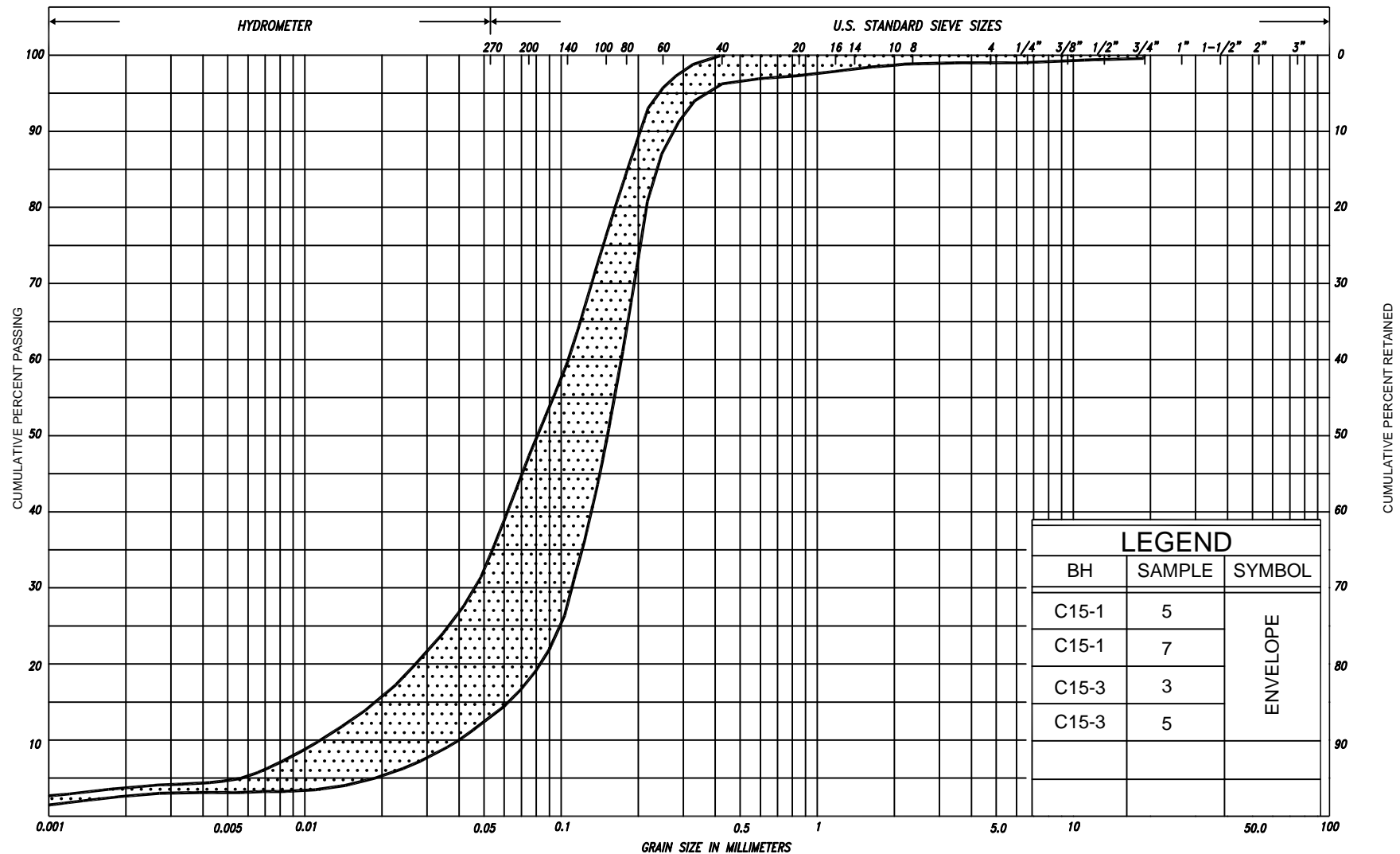
HWY 6

G.W.P. No. 342-97-00





SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED					
					SAND															
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.			
	SILT												GRAVEL				U.S. BUREAU OF SOILS			
CLAY		SILT			V. FINE	FINE	MED.	COARSE												
					SAND															



SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL				COB BLES	UNIFIED			
				SAND														
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL				COBBLES	M.I.T.
	SILT																	
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL								U.S. BUREAU	
				SAND														

## 1 of 1

METRIC

## Foundation Design

LOCATION

Co-ords. 4 863 482 N; 213 168 E  
Hwy. 6 Sta. 22+612, o/s 5.4m Rt.

ORIGINATED BY F.P.

BOREHOLE TYPE

C. F. S. S. A. + Dynamic Cone Penetration Test

COMPILED BY G.D.

DATE \_\_\_\_\_

May 24, 2006

CHECKED BY C.N.

ON MOT VER3 05KF104D.GPJ ON MOT.GDT 6/13/2007 9:30:38 AM

**+<sup>7</sup>, ×<sup>5</sup>:** Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No C15-2

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 863 472 N; 213 149 E  
 DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers  
 DATUM Geodetic DATE July 11, 2006

ORIGINATED BY F.P.

COMPILED BY F.P.

CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+	FIELD VANE							
447.6	Ground surface						20	40	60	80	100						
0.0	Topsoil		1	SS	7									○			
0.3	Clayey silt some sand, trace gravel																
	Very stiff Brown Moist		2	SS	21									○			
	with sandy silt lenses																
	Wet (TILL)		3	SS	16									○			
445.1	Silty sand		4	SS	47									○			
2.5	Dense Brown Moist																
444.7	Sand trace to with silt		5	SS	25									○			
2.9	Compact Brown Moist to wet very dense																
			6	SS	58									○			
			7	SS	23									○			
440.9	End of borehole																
6.7																	
		</															

\* 2006 07 11

▽ Water level observed during drilling

▽ Water level measured after drilling



## 1 of 1

METRIC

## Foundation Design

G.W.P. 342-97-00

LOCATION

Co-ords: 4 863 489 N; 213 170 E  
Hwy. 6, Sta. 22+615, o/s 11.7m Rt.

ORIGINATED BY F.P.

DIST Owen Sound HWY 6

BOREHOLE TYPE

C.F.S.S.A. + Dynamic Cone Penetration Test

COMPILED BY F.P.

DATUM Geodetic

DATE \_\_\_\_\_

July 13, 2006

CHECKED BY C.N.

ON MOT VER3 05KF104D-JULY 2006.GPJ ON MOT.GDT 6/13/2007 9:37:50 AM

$+$ <sup>7</sup>,  $\times$ <sup>5</sup>: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

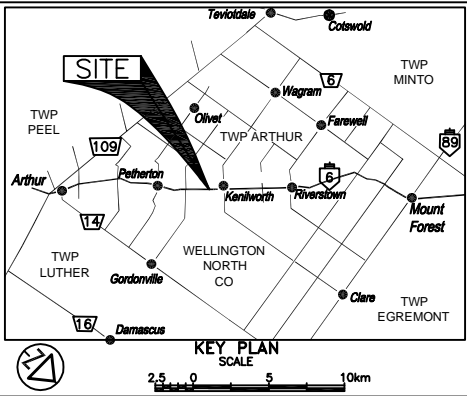
METRIC

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

CONT No  
WP No 342-97-00  
HIGHWAY 6  
CULVERT AT STA. 22+616  
BOREHOLE LOCATIONS



SHEET



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 2006 to July 2006
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C15-1	449.3	4 863 482	213 168
C15-2	447.6	4 863 472	213 149
C15-3	447.5	4 863 489	213 170

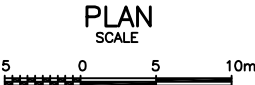
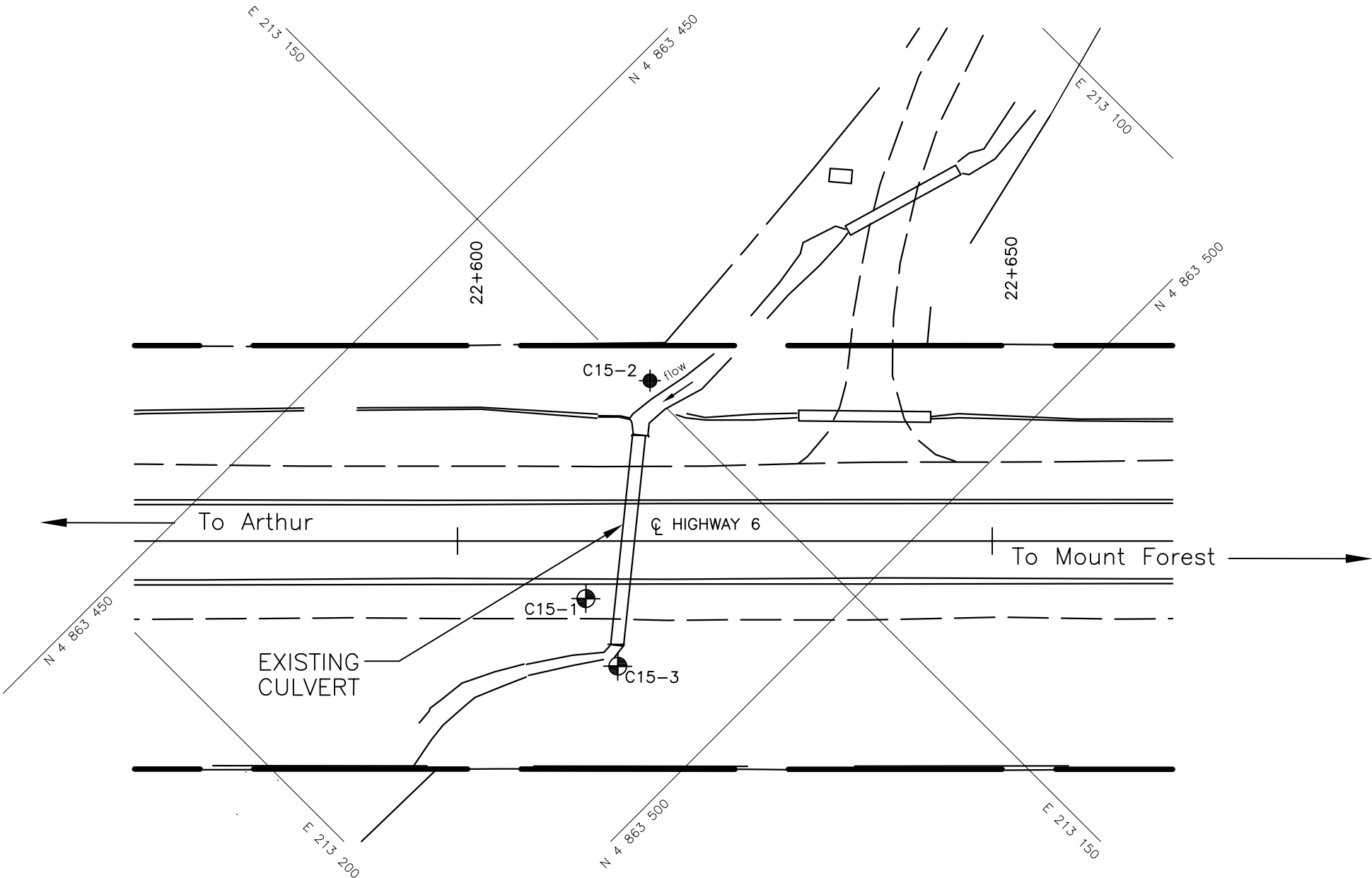
NOTE

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

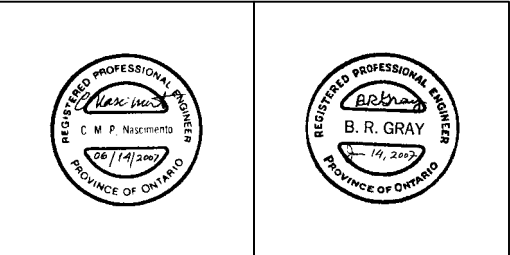
Geocres No. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	---
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C15-1



NOTE:

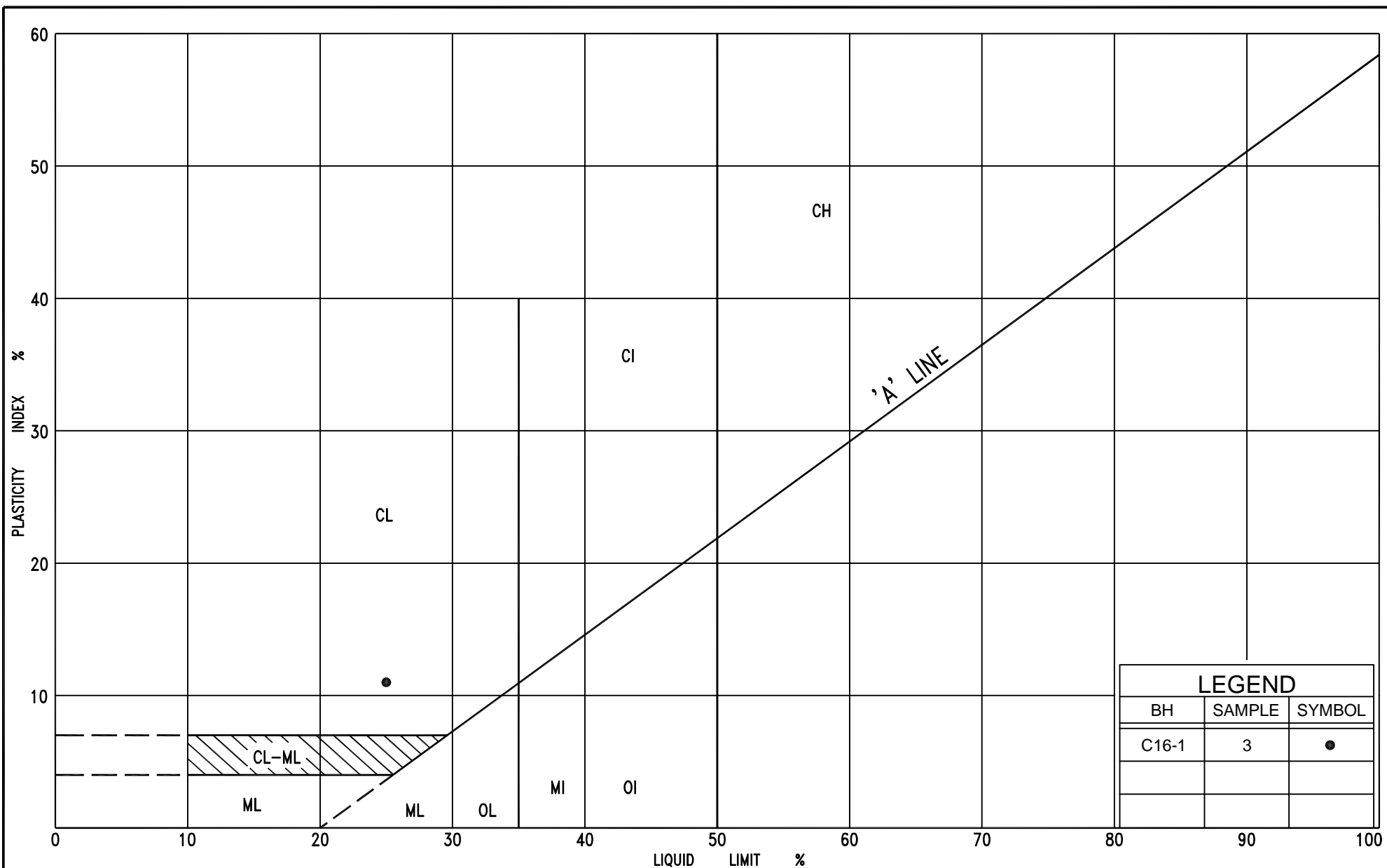
THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE  
DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.



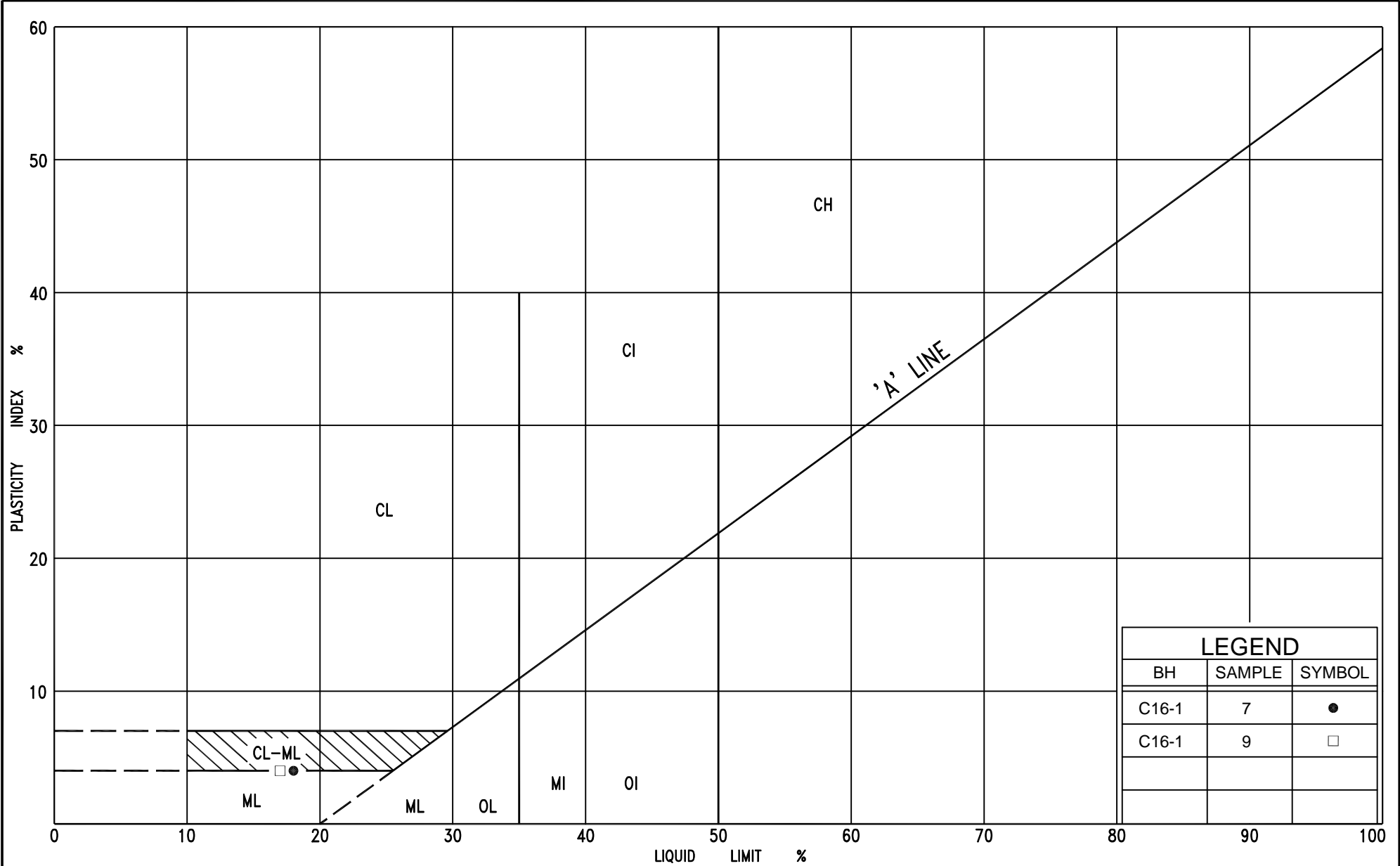
REF. No.: Drawing H6258xb01 provided by MRC dated February 2006

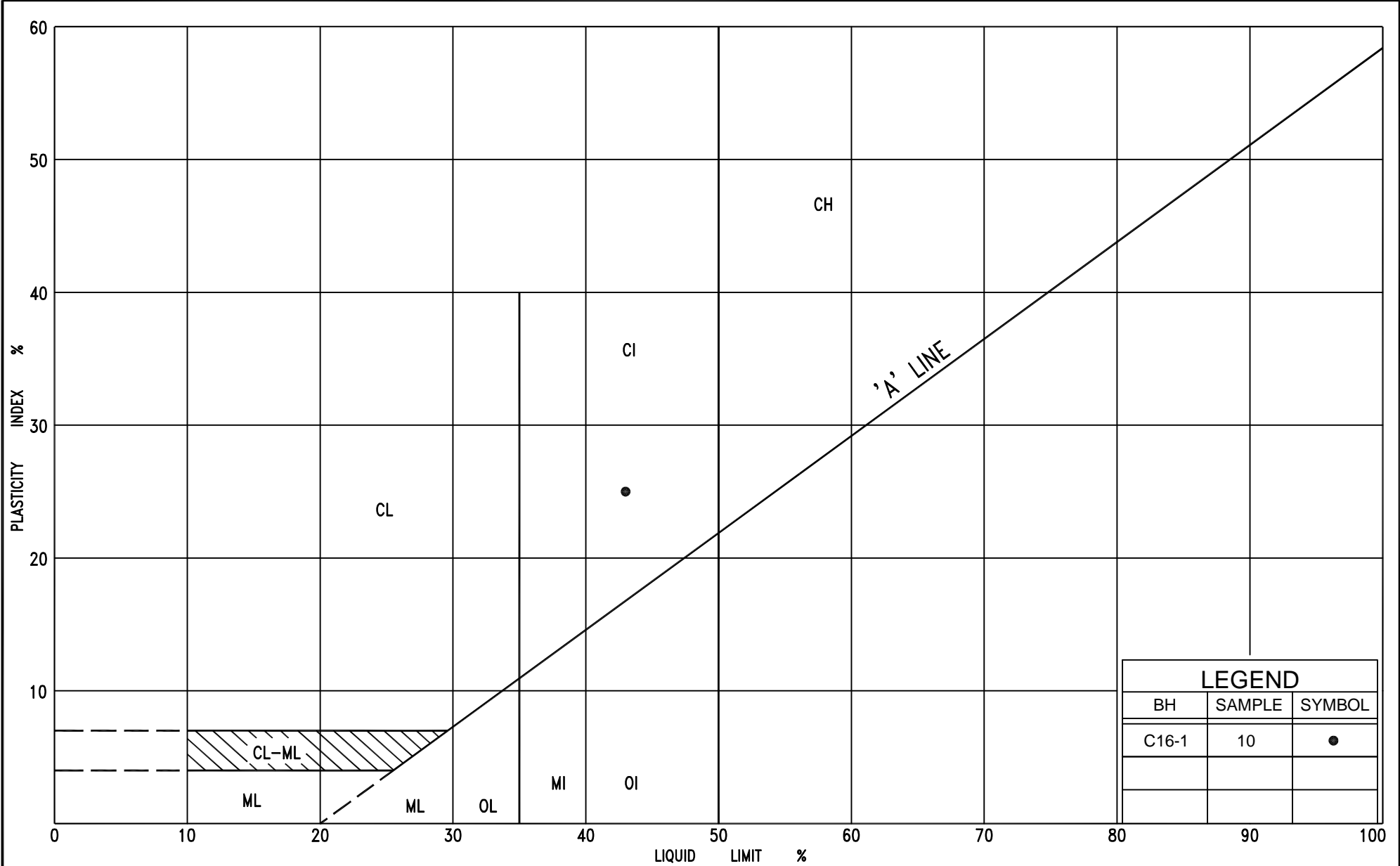
### Culvert C-16 at Sta. 23+065

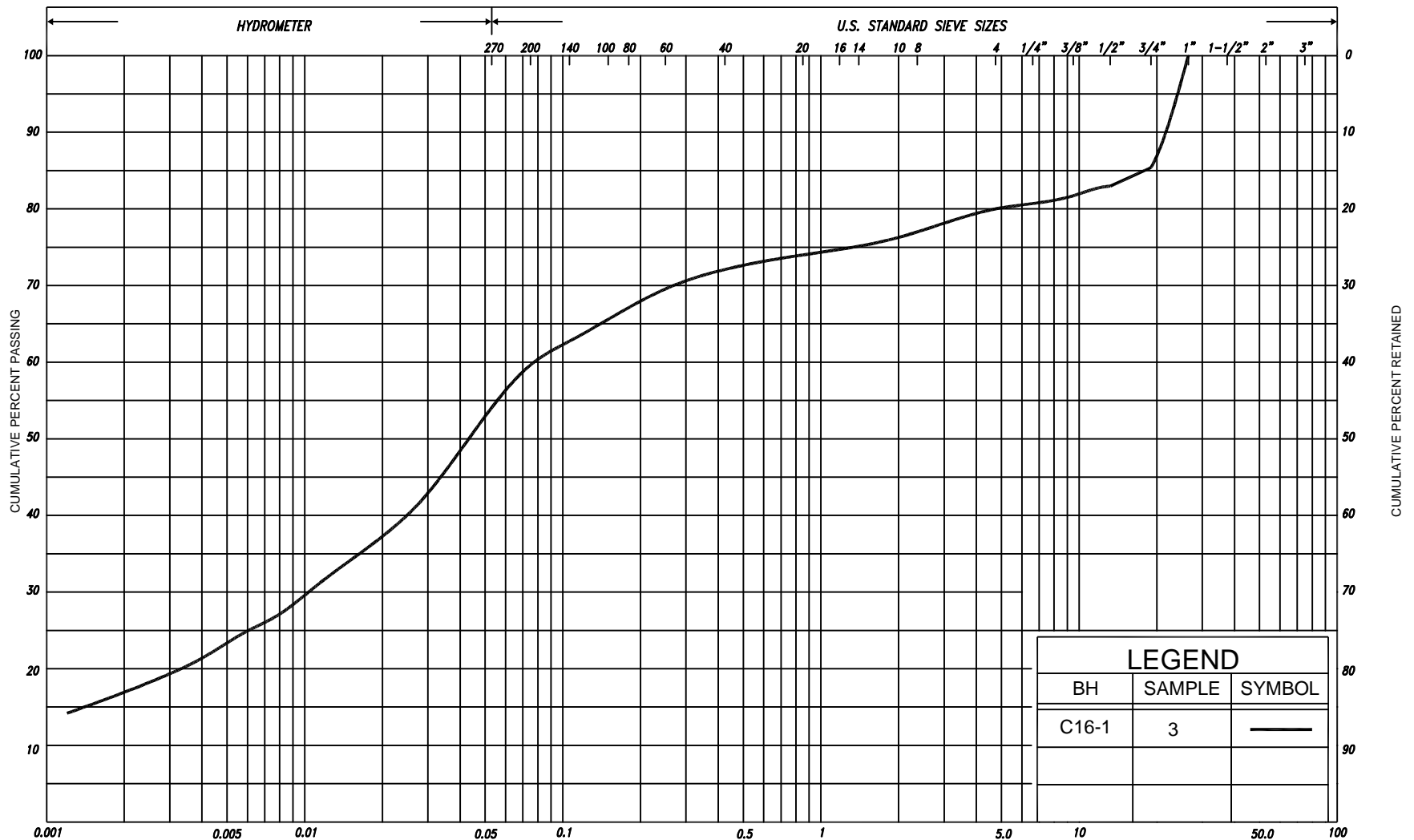
Figures C16-PC-1 to PC-3 – Results of Atterberg Limits Testing  
Figures C16-GS-1 to GS-5 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C16-1 to C16-4  
Drawing C16-1 – Borehole Locations



LEGEND		
BH	SAMPLE	SYMBOL
C16-1	3	●

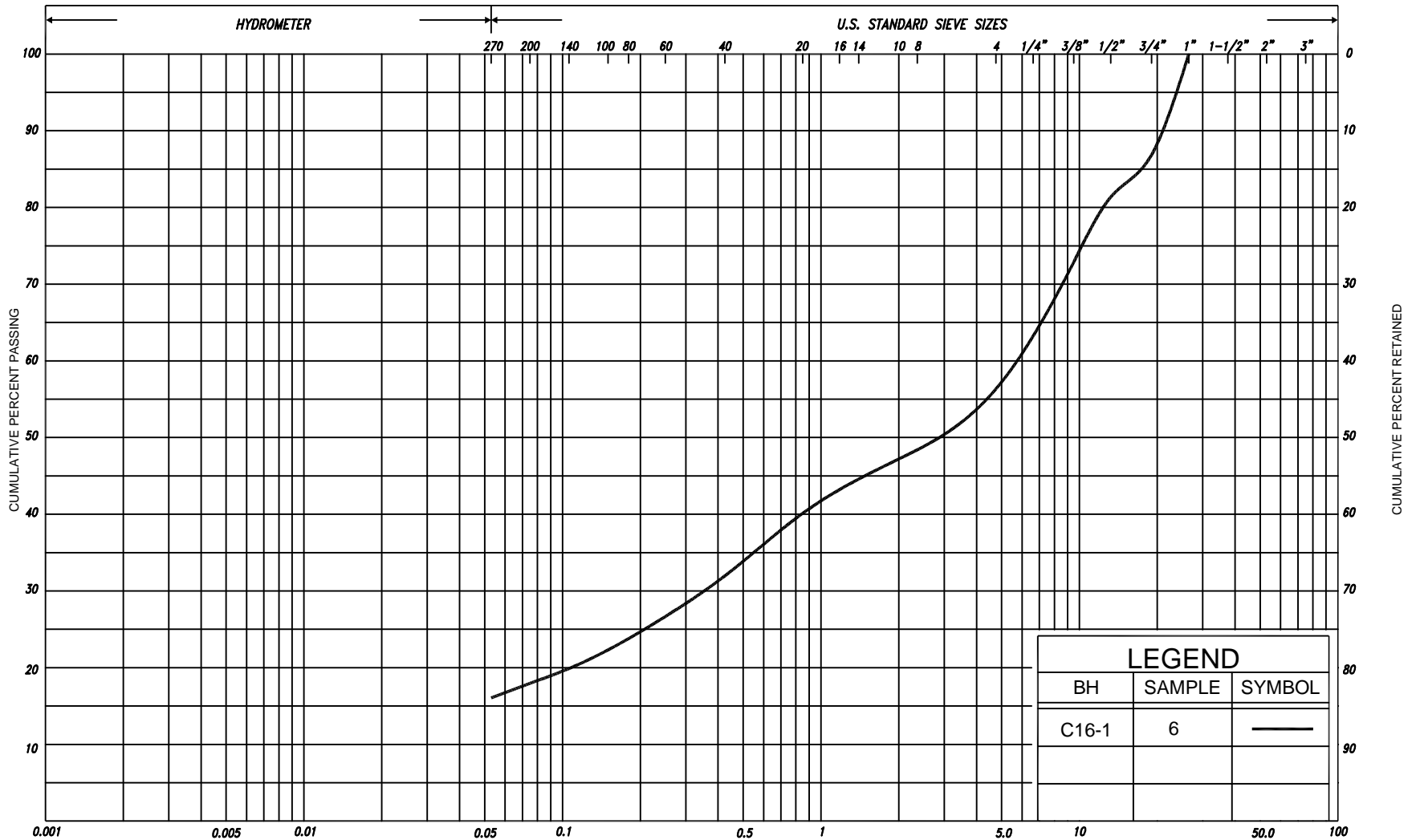






LEGEND		
BH	SAMPLE	SYMBOL
C16-1	3	—

SILT & CLAY				SAND			GRAVEL		COBBLES	UNIFIED
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
CLAY	SILT			Y. FINE	FINE	MED.	COARSE	GRAVEL		U.S. BUREAU
				SAND						



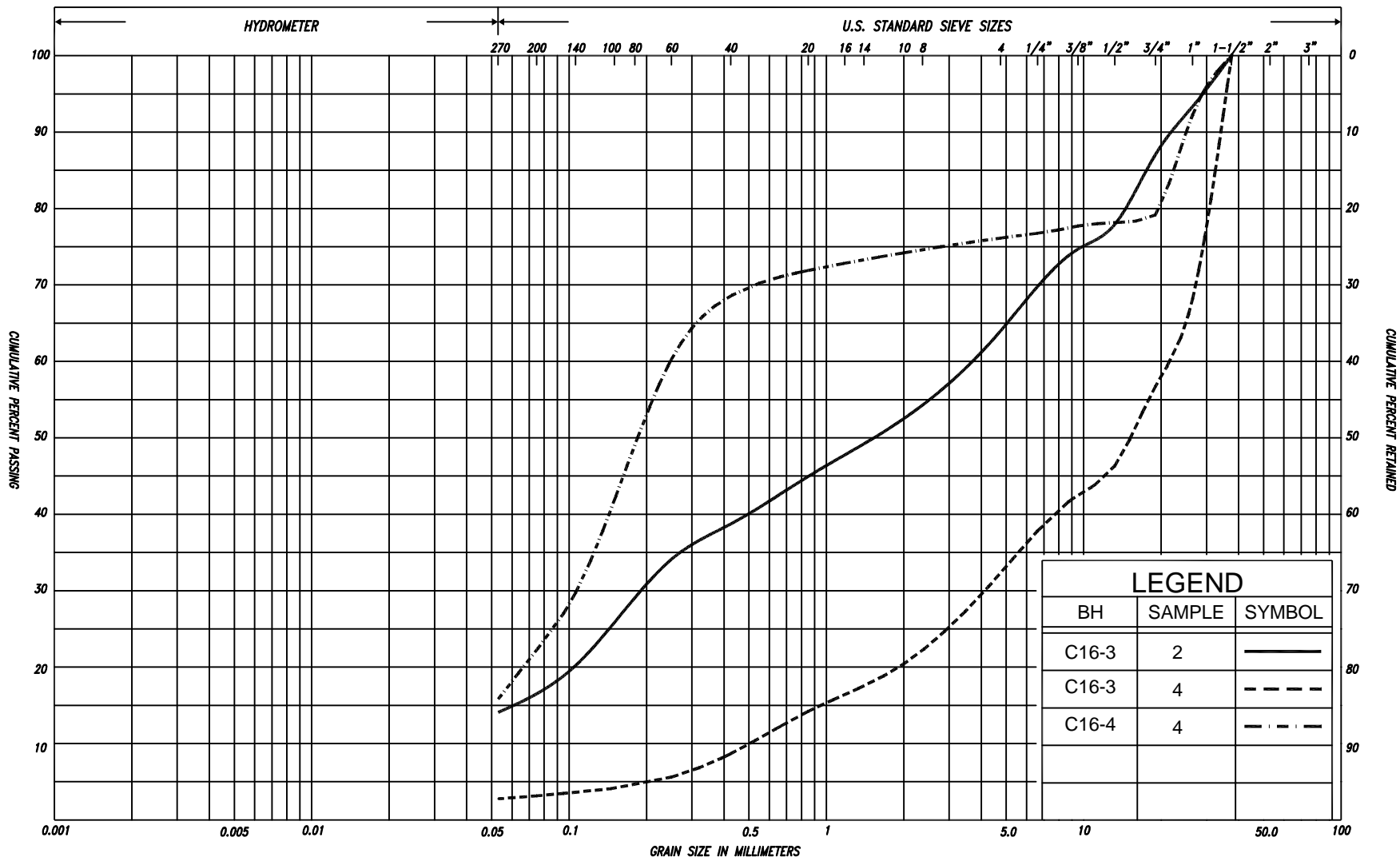
LEGEND		
BH	SAMPLE	SYMBOL
C16-1	6	—

SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL		COBBLES	UNIFIED
				SAND								
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
	SILT				SAND							
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL				U.S. BUREAU OF SOILS
				SAND								

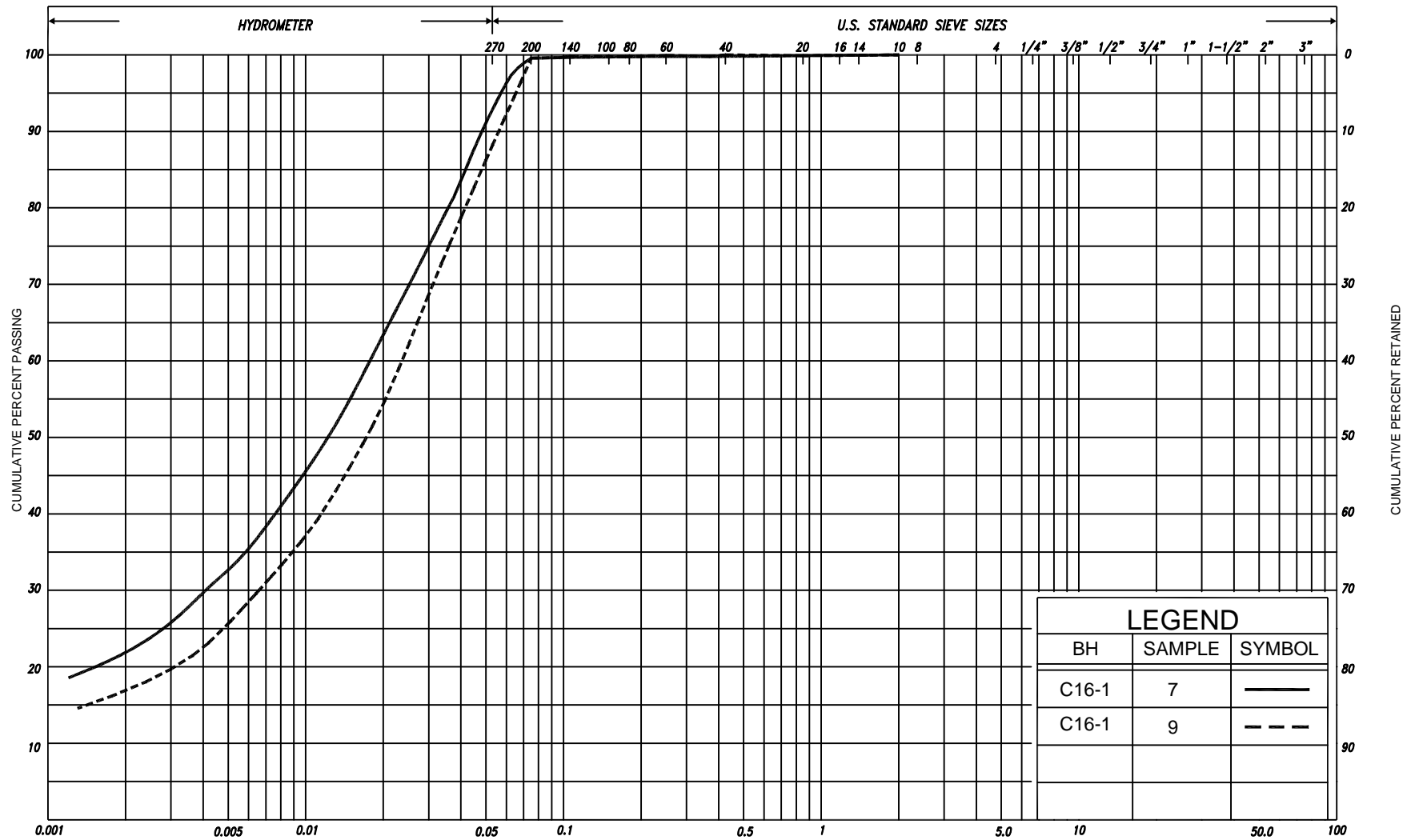
# GRAIN SIZE DISTRIBUTION SAND and GRAVEL, some silt, trace clay (FILL)

FIG No.	C16-GS-2
HWY	6
G.W.P. No.	342-97-00





SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COB BLES	UNIFIED	
				SAND										
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT				SAND									
CLAY		SILT		V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU
				SAND										



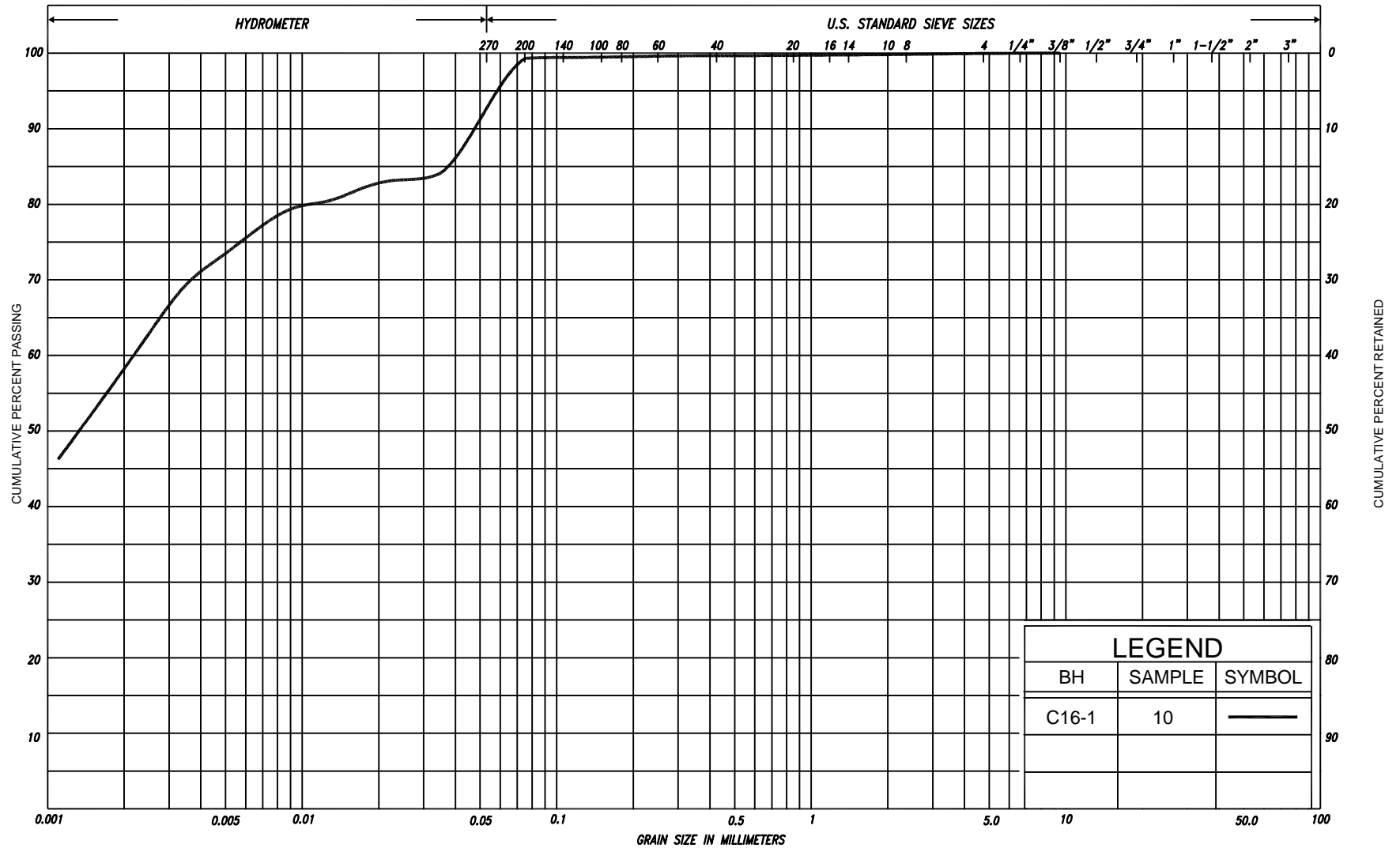
LEGEND		
BH	SAMPLE	SYMBOL
C16-1	7	—
C16-1	9	- - -

SILT & CLAY				SAND			GRAVEL		COBBLES	UNIFIED
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL		COBBLES	M.I.T.
		SILT			SAND					
CLAY	SILT			V. FINE	FINE	MED.	COARSE	GRAVEL		U.S. BUREAU
				SAND						



GRAIN SIZE DISTRIBUTION  
SILT, some to with clay, trace sand

FIG No. C16-GS-4  
HWY 6  
G.W.P. No. 342-97-00



LEGEND		
BH	SAMPLE	SYMBOL
C16-1	10	—

SILT & CLAY				FINE SAND			MEDIUM SAND		COARSE SAND	GRAVEL		COBBLES	UNIFIED
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE				GRAVEL		COBBLES	M.I.T.
		SILT		V. FINE	FINE	MED.	COARSE			GRAVEL			U.S. BUREAU
CLAY		SILT		SAND									

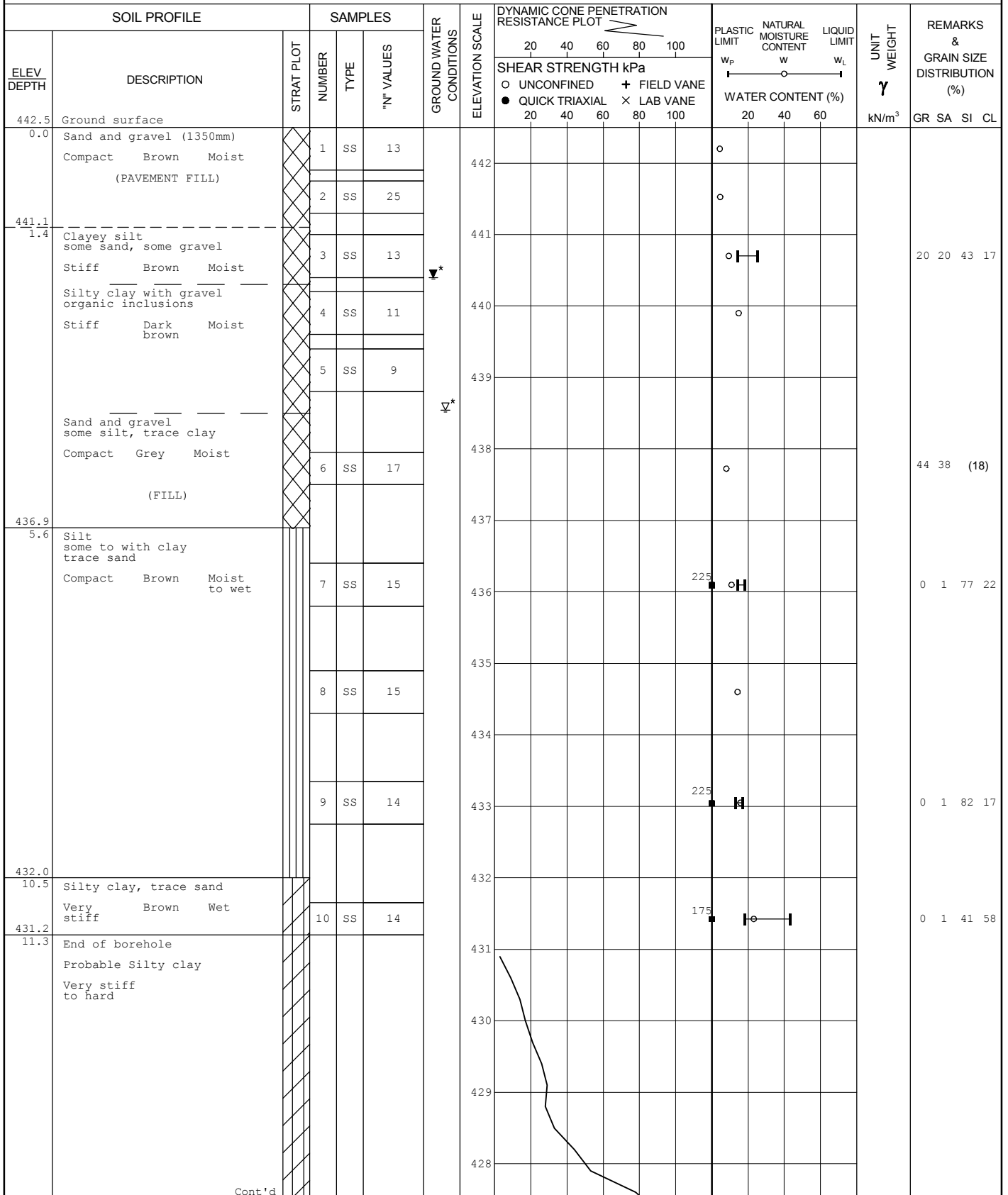
# RECORD OF BOREHOLE No C16-1

1 of 2

METRIC

G.W.P. 342-97-00 LOCATION Co-ords. 4 863 793 N; 212 842 E  
DIST Owen Sound HWY 6 BOREHOLE TYPE C.F.S.S.A. + Dynamic Cone Penetration Test  
DATUM Geodetic DATE May 23, 2006

ORIGINATED BY F.P.  
COMPILED BY G.D.  
CHECKED BY C.N.



# RECORD OF BOREHOLE No C16-1

2 of 2

METRIC

G.W.P. 342-97-00

LOCATION

Co-ords. 4 863 793 N; 212 842 E  
Hwy. 6 Sta. 23+062, o/s 5.7m Lt.

ORIGINATED BY F.P.

DIST Owen Sound HWY 6

BOREHOLE TYPE

## C.F.S.S.A. + Dynamic Cone Penetration Test

COMPILED BY G.D.

DATUM Geodetic

DATE \_\_\_\_\_

May 23, 2006

CHECKED BY C.N.

[illegible]

**RECORD OF BOREHOLE No C16-2**

1 of 2

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords. 4 863 805 N; 212 846 E  
DIST Owen Sound HWY 6 BOREHOLE TYPE C.F.S.S.A. + Dynamic Cone Penetration Test  
DATUM Geodetic DATE May 24, 2006

ORIGINATED BY F.P.  
COMPILED BY G.D.  
CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE								○		
								● QUICK TRIAXIAL		× LAB VANE								○		
442.5	Ground surface						20	40	60	80	100	20	40	60						
0.0	Sand and gravel (280mm)																			
0.3	Compact Brown Moist (PAVEMENT FILL)		1	SS	10															
	Clayey silt, with gravel organic inclusions																			
	Stiff Brown Moist		2	SS	11															
			3	SS	10															
	Silty clay, with gravel organic inclusions																			
	Firm Brown Moist		4	SS	6															
			5	SS	5															
	Gravel (crushed limestone)																			
	Loose Brown Moist																			
	(FILL)		6	SS	7															
436.9																				
5.6	Silt trace to with clay																			
	Compact Brown Moist to wet		7	SS	20															
	Sandy silt layers																			
	Grey																			
			8	SS	16															
			9	SS	11															
432.3																				
10.2	Silty clay, trace sand silt partings																			
	Very Brown Moist stiff		10	SS	19															
431.2																				
11.3	End of borehole																			
	Probable Silty clay																			
	Very stiff to hard																			
427.6																				

<b>RECORD OF BOREHOLE No C16-2</b>															<b>2 of 2</b>		<b>METRIC</b>	
G.W.P. 342-97-00			LOCATION			Co-ords. 4 863 805 N; 212 846 E Hwy. 6 Sta. 23+068, o/s 5.5m Rt.					ORIGINATED BY F.P.							
DIST Owen Sound HWY 6			BOREHOLE TYPE			C.F.S.S.A. + Dynamic Cone Penetration Test					COMPILED BY G.D.							
DATUM Geodetic			DATE			May 24, 2006					CHECKED BY C.N.							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub> W W <sub>L</sub>					
427.5								20	40	60	80	100						
14.9	End of dynamic cone penetration test   * 2006 05 24  ▽ Water level observed during drilling ▼ Water level measured after drilling ■ Penetrometer test  C.F.S.S.A. - denotes Continuous Flight Solid Stem Augers																	

## 1 of 1

METRIC

## Foundation Design

LOCATION

Co-ords. 4 863 812 N; 212 855 E  
Hwy. 6 Sta. 23+066, o/s 17.0m Rt.

ORIGINATED BY F.P.

BOREHOLE TYPE

Continuous Flight Solid Stem Augers

COMPILED BY G.D.

DATUM Geodetic

DATE June 22, 2006

CHECKED BY C.N.

ON MOT VER3 05KF104D.GPJ ON MOT.GDT 6/13/2007 9:32:18 AM

**+<sup>7</sup>, ×<sup>5</sup> :** Numbers refer to Sensitivity

(%) STRAIN AT FAILURE



## METRIC

(%) STRAIN AT FAILURE

METRIC

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

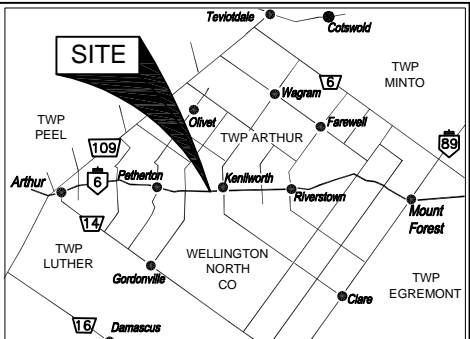
CONT No  
WP No 342-97-00

HIGHWAY 6  
CULVERT AT STA. 23+065  
BOREHOLE LOCATIONS



SHEET

PML 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 2006 to July 2006
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C16-1	442.5	4 863 793	212 842
C16-2	442.5	4 863 805	212 846
C16-3	440.1	4 863 812	212 855
C16-4	439.2	4 863 790	212 833

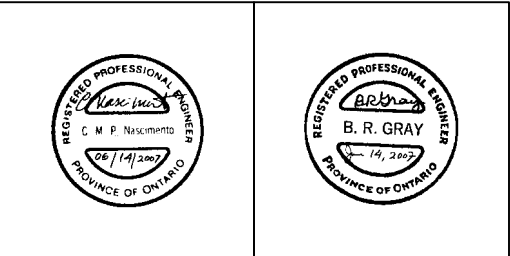
NOTE

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. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	--
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C16-1



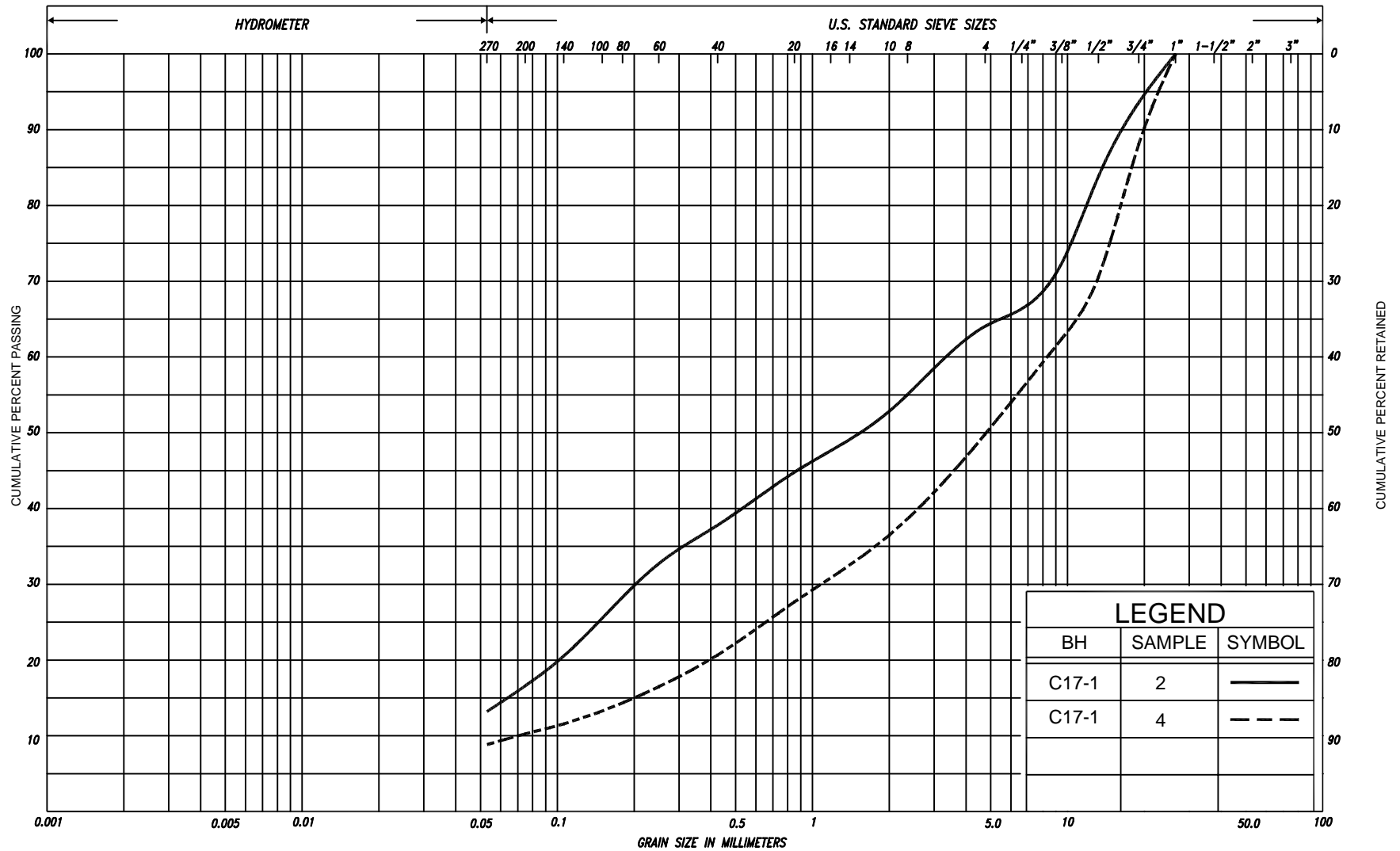
REF. No.: Drawing H6258xb01 provided by MRC dated February 2006

NOTE:

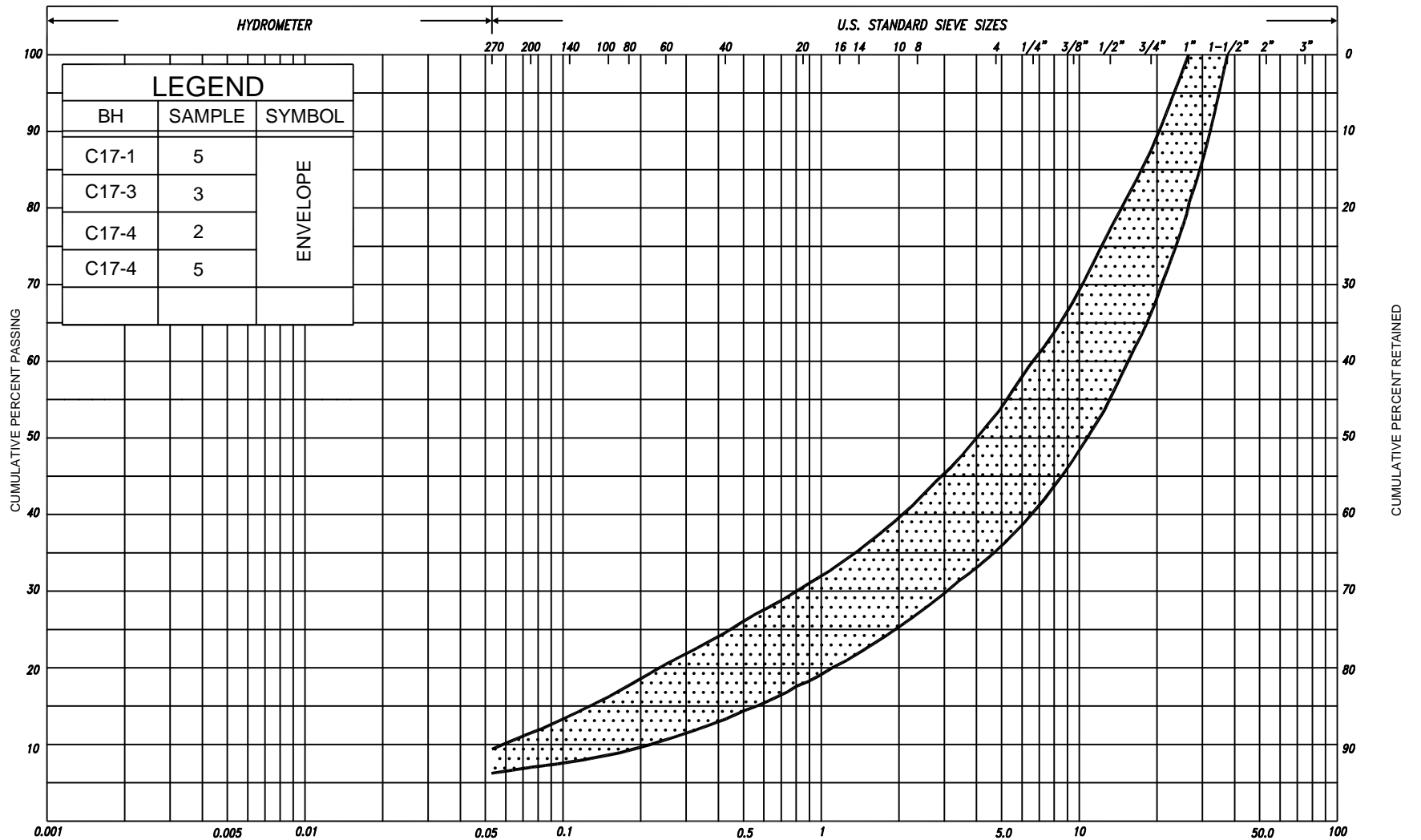
THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

### Culvert C-17 at Sta. 23+218

Figures C17-GS-1 to GS-3 – Results of Grain Size Distribution Analyses  
Record of Borehole Sheets C17-1 to C17-4  
Drawing C17-1 – Borehole Locations



SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL				COBBLES	UNIFIED
CLAY	FINE		MEDIUM		COARSE	SAND			GRAVEL			COBBLES		M.I.T.		
	SILT				FINE		MEDIUM		COARSE		GRAVEL				COBBLES	M.I.T.
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL						U.S. BUREAU	
SAND																



SILT & CLAY			FINE			MEDIUM			COARSE			GRAVEL			COB BLES	UNIFIED
						SAND										
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.
		SILT														U.S. BUREAU
CLAY				SILT		V. FINE		FINE		MED.		COARSE		GRAVEL		
						SAND										



**RECORD OF BOREHOLE No C17-1**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords. 4 863 906 N; 212 730 E  
Hwy. 6 Sta. 23+221, o/s 5.6m Lt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
DATUM Geodetic DATE May 23, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
441.0	Ground surface							20	40	60	80	100								
0.0	Sand and gravel (940mm) Compact    Brown    Moist (PAVEMENT FILL)		1	SS	12									○						
440.1	Gravelly sand to Sand and Gravel trace to some silt		2	SS	12									○			36 47 (17)			
0.9	Compact    Brown    Moist to very dense		3	SS	51									○						
	Grey (FILL)		4	SS	49									○			50 40 (10)			
438.0	Sand and Gravel some silt		5	SS	19									○			46 42 (12)			
3.0	Compact    Brown    Wet																			
	Very dense		6	SS	66									○						
435.5	Silt trace sand, some clay																			
5.5	Dense    Brown    Moist		7	SS	33									○			0 2 82 16			
			8	SS	56									○						
	Very dense    Grey																			
432.3	Clayey silt																			
8.7	Hard    Brown    Moist		9	SS	51									○						
431.2	End of borehole																			
9.8																				
	  *    2006   05   23  ▽    Water level observed during drilling  ▼    Water level measured after drilling																			

# RECORD OF BOREHOLE No C17-2

1 of 1

METRIC

G.W.P. 342-97-00

LOCATION

Co-ords. 4 863 910 N; 212 741 E  
Hwy. 6 Sta. 23+216, o/s 5.3m Rt.

ORIGINATED BY F.P.

DIST Owen Sound HWY 6

BOREHOLE TYPE

Continuous Flight Solid Stem Augers

COMPILED BY G.D.

DATUM Geodetic

DATE

May 24, 2006

CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+	FIELD VANE										
441.0	Ground surface						20	40	60	80	100									
0.0	Sand and gravel (250mm)		1	SS	19															
0.3	Compact Brown Moist (PAVEMENT FILL) Clayey silt gravel inclusions Stiff Brown Moist Silty clayey organics Firm Dark brown Moist Gravel, trace sand Dense Grey Moist (FILL)		2	SS	9															
			3	SS	5															
				4	SS	47														
			5	SS	27															
437.0	Clayey silt																			
4.0	Very Brown Moist stiff		6	SS	18							212								
			7	SS	24							225								
			8	SS	27							225								
432.4	Silt, trace clay																			
8.6	Dense Brown Moist																			
431.4			9	SS	34															
9.6	End of borehole																			
<div>* 2006 05 24</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																				



**RECORD OF BOREHOLE No C17-3**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords. 4 863 917 N; 212 747 E  
Hwy. 6 Sta. 23+217, o/s 14.2m Rt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
DATUM Geodetic DATE June 22, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED	+	FIELD VANE								
						● QUICK TRIAXIAL	×	LAB VANE	WATER CONTENT (%)									
						20	40	60	80	100								
439.7	Ground surface																	
0.0	Clayey silt with gravel inclusions		1	SS	4													
0.2	Brown (FILL)																	
438.7	Topsoil		2	SS	8													
1.0	Gravelly sand																	
438.3	Loose to Brown Wet compact																	
1.4	Gravel with sand trace silt		3	SS	71													
	Very Brown Wet dense to dense		4	SS	42													
436.7	Silty clay trace sand, trace gravel																	
3.0	Stiff Grey Moist to hard		5	SS	10													
			6	SS	34													
434.5	Clayey silt trace sand, trace gravel																	
5.2	Very Grey Moist stiff		7	SS	25													
433.9	(TILL)																	
5.8	End of borehole																	
<div>* 2006 06 22</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																		

<b>RECORD OF BOREHOLE No C17-4</b>										<b>1 of 1</b>		<b>METRIC</b>	
G.W.P. 342-97-00			LOCATION			Co-ords: 4 863 896 N; 212 723 E Hwy. 6, Sta. 23+219, o/s 17.2m Lt.			ORIGINATED BY F.P.				
DIST Owen Sound HWY 6			BOREHOLE TYPE			Continuous Flight Solid Stem Augers			COMPILED BY F.P.				
DATUM Geodetic			DATE			July 19, 2006			CHECKED BY C.N.				

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
439.4	Ground surface																
0.0	Topsoil		1	SS	41												
439.0																	
0.4	Sandy gravel trace silt, cobbles to Sand and Gravel		2	SS	43												
	Dense Brown Wet																
	Compact		3	SS	15												
			4	SS	24												
	cobbles																
	Dense		5	SS	39												
434.9																	
4.5	Silty clay with sand and gravel inclusions		6	SS	50												
	Hard Brown Wet																
433.6																	
5.8	Silt some clay, trace sand																
	Dense Brown Moist		7	SS	33												
432.8																	
6.6	End of borehole																
<div style="display: flex; justify-content: space-between;"> <div> <p>* 2006 07 19</p> <p>▽ Water level observed during drilling</p> <p>▼ Water level measured after drilling</p> <p>■</p> </div> <div> <p>Numbers refer to Sensitivity</p> <p>(%) STRAIN AT FAILURE</p> </div> </div>																	

METRIC

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

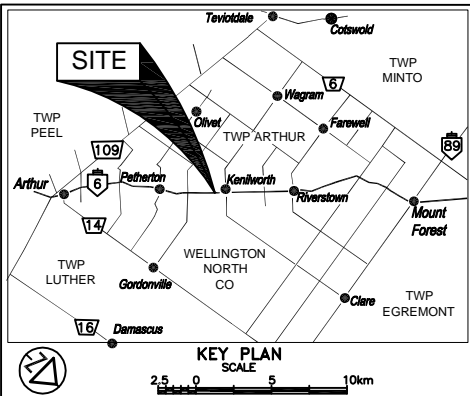
CONT No  
WP No 342-97-00

HIGHWAY 6  
CULVERT AT STA. 23+218  
BOREHOLE LOCATIONS



SHEET

PML 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 2006 to July 2006
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C17-1	441.0	4 863 906	212 730
C17-2	441.0	4 863 910	212 741
C17-3	439.7	4 863 917	212 747
C17-4	439.4	4 863 896	212 723

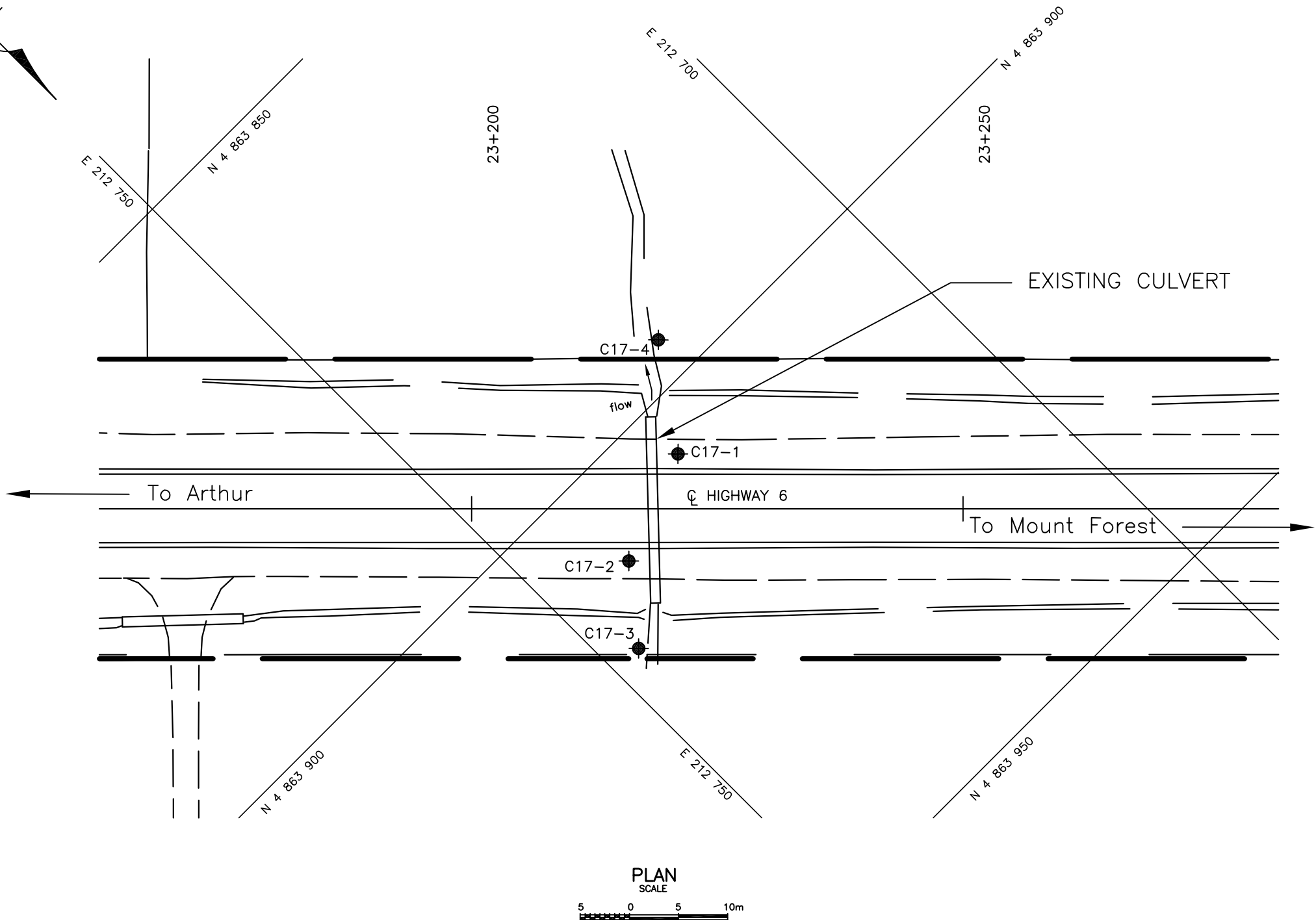
NOTE

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. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	--
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C17-1

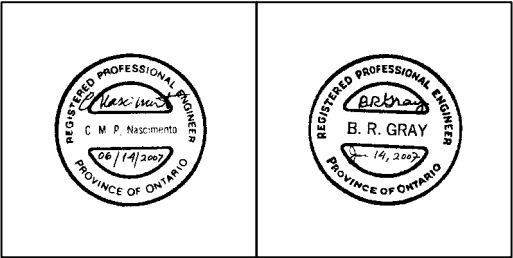


PLAN SCALE



NOTE:

THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.



REF. No.: Drawing H6258xb01 provided by MRC dated February 2006

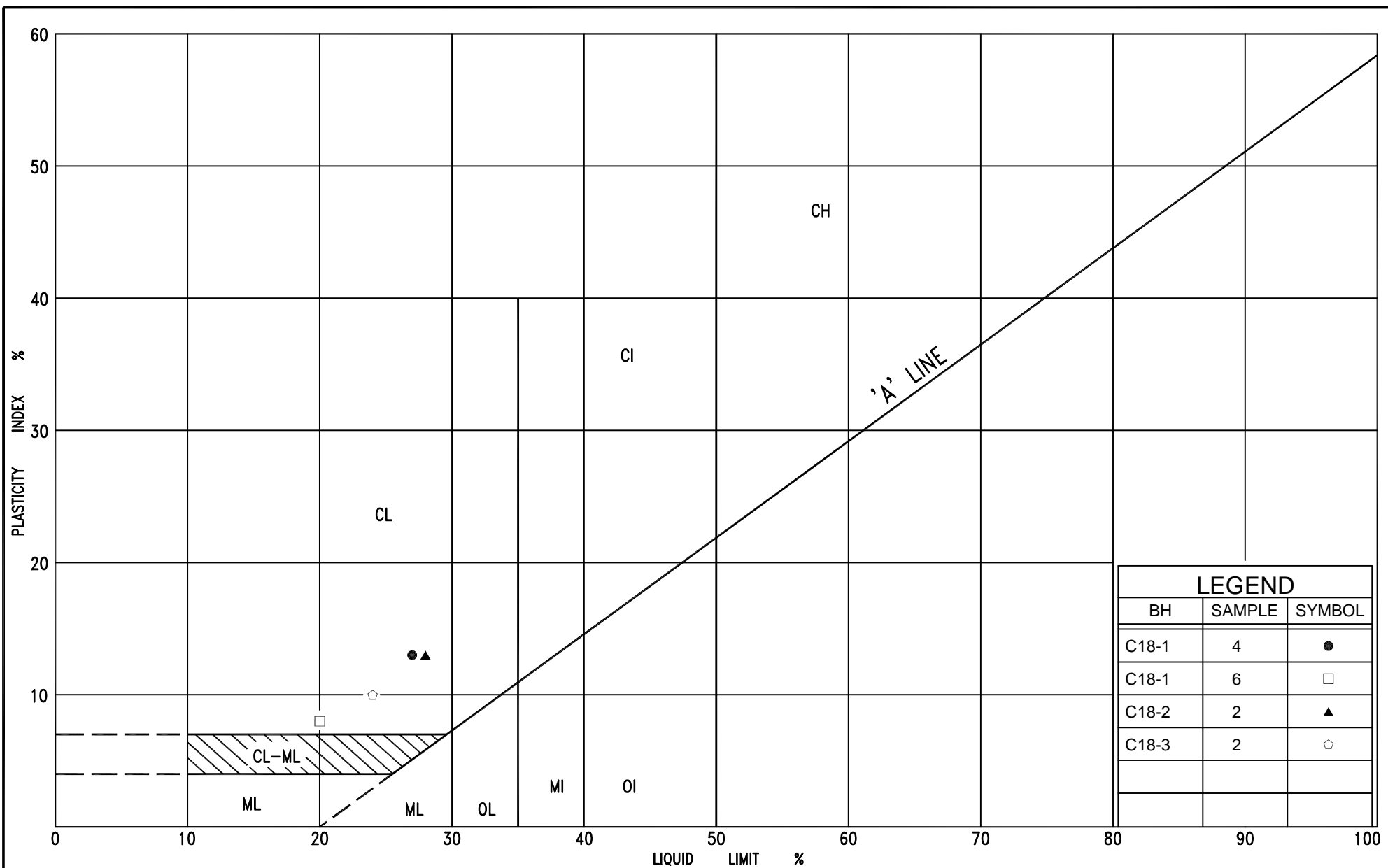
### Culvert C-18 at Sta. 28+116

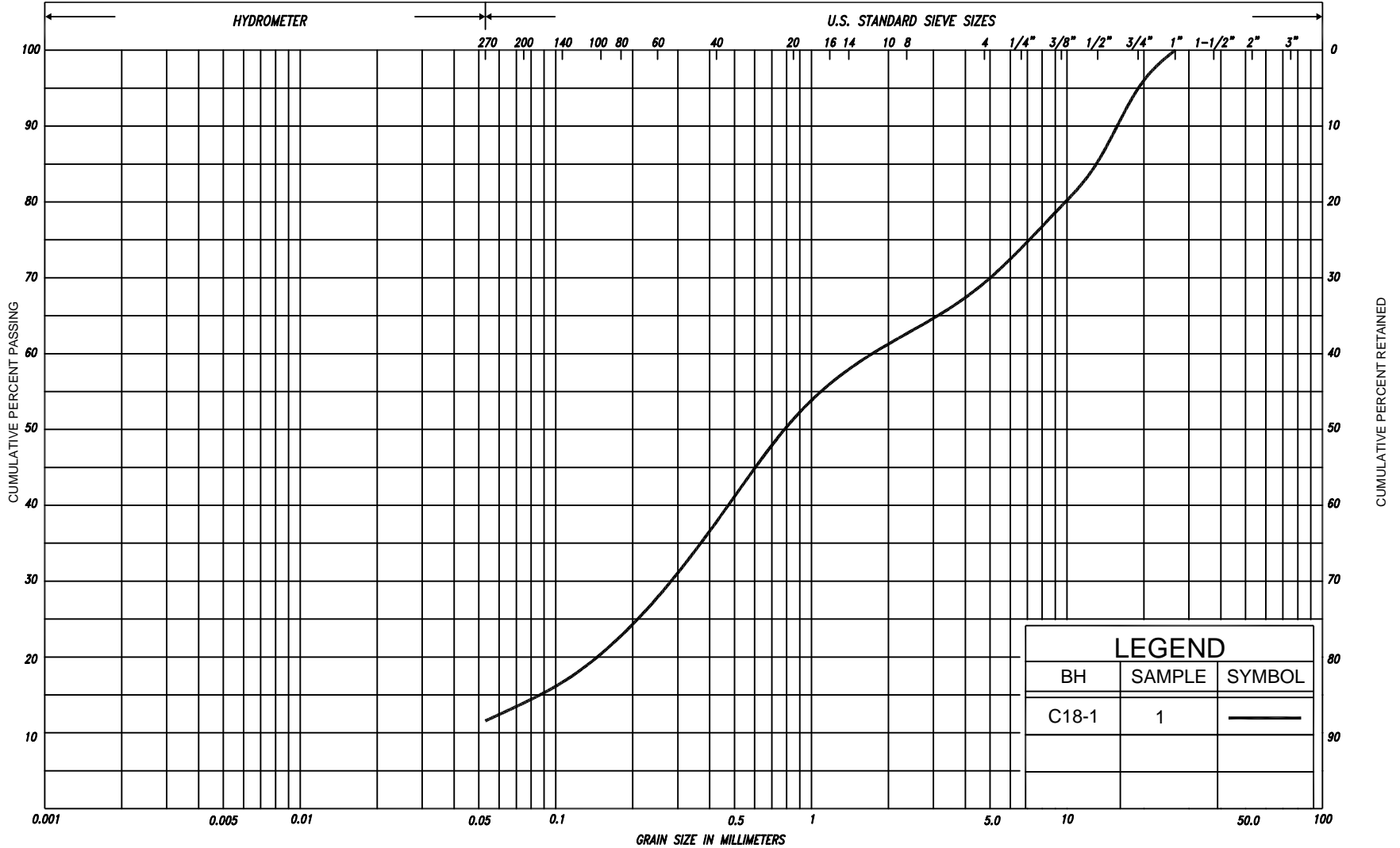
Figures C18-PC-1 – Results of Atterberg Limits Testing

Figures C18-GS-1 and GS-2 – Results of Grain Size Distribution Analyses

Record of Borehole Sheets C18-1 to C18-3

Drawing C18-1 – Borehole Locations





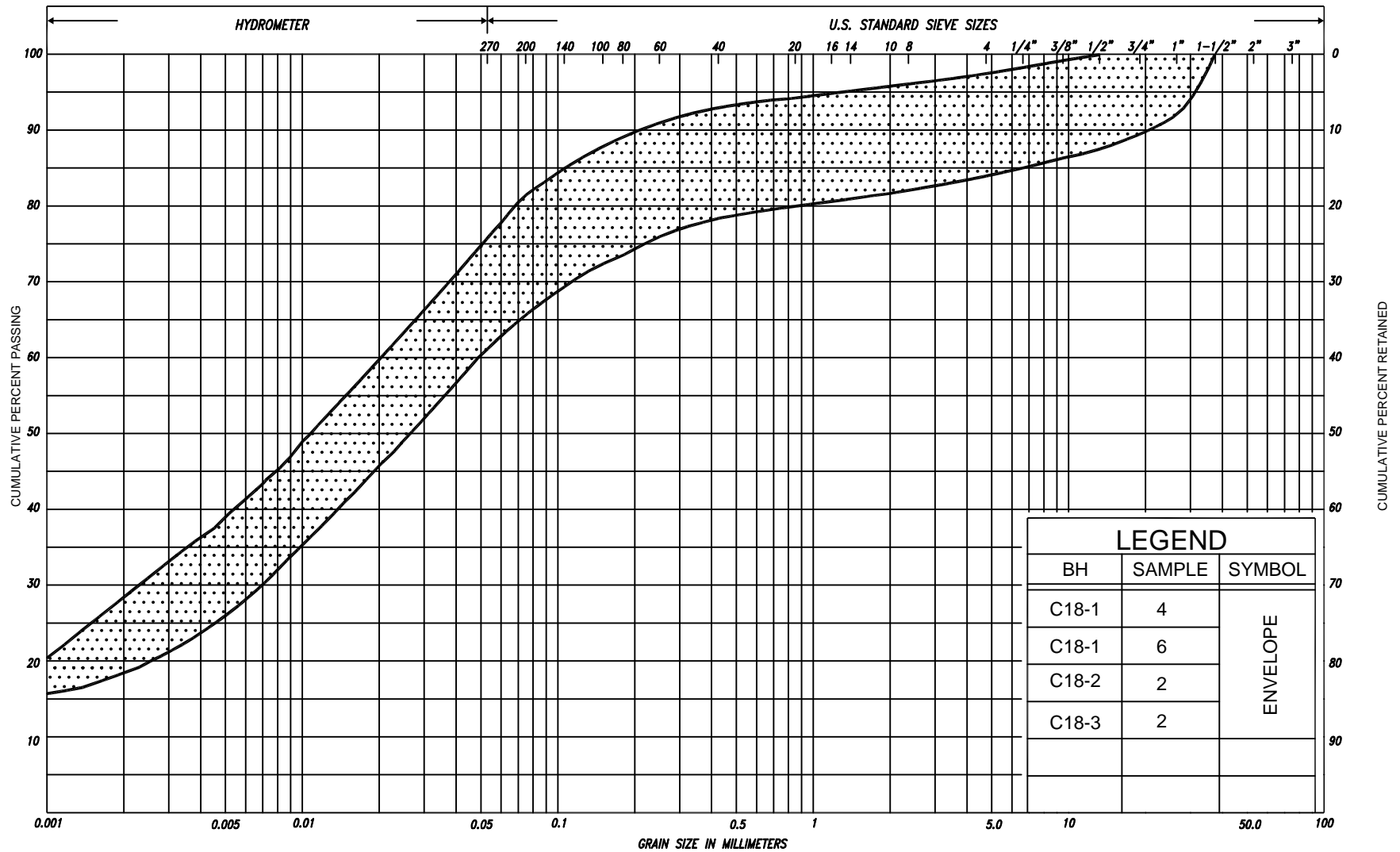
LEGEND		
BH	SAMPLE	SYMBOL
C18-1	1	—

SILT & CLAY			FINE			MEDIUM			COARSE			GRAVEL			COBBLES	UNIFIED
CLAY			FINE			MEDIUM			COARSE			GRAVEL			COBBLES	M.I.T.
CLAY			SILT			SAND			GRAVEL			GRAVEL			COBBLES	U.S. BUREAU
CLAY			SILT			SAND			GRAVEL			GRAVEL			COBBLES	U.S. BUREAU



**GRAIN SIZE DISTRIBUTION**  
 GRAVELLY SAND, some silt, trace clay  
 (FILL)

FIG No. C18-GS-1  
 HWY 6  
 G.W.P. No. 342-97-00



SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED		
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.
	SILT				SAND				GRAVEL				COBBLES	U.S. BUREAU	
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL				U.S. BUREAU	
					SAND										

# RECORD OF BOREHOLE No C18-1

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 866 965 N; 209 082 E  
Hwy 6 Sta. 28+113, o/s 5.4m Lt. ORIGINATED BY GI  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY GD  
DATUM Geodetic DATE May 17, 2006 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
431.7	Ground Surface																
0.0	Gravelly sand, some silt Compact Brown Moist (PAVEMENT FILL)																
431.3																	
0.4	Clayey silt some sand, trace gravel Firm Dark Moist brown		1	SS	13									o			31 55 (14)
430.2	Gravelly sand some silt, trace clay Compact Brown Moist																
1.5	Clayey silt with sand, trace gravel Stiff Dark Moist brown (FILL)		2	SS	10									o			
429.7																	
2.0	Topsoil		3	SS	12									o			
	Clayey silt some sand, trace gravel																
	Stiff Brown Wet occ. cobbles and boulders		4	SS	21									200	o		3 15 54 28
	Very stiff																
</																	



**RECORD OF BOREHOLE No C18-2**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 866 962 N; 209 077 E  
Hwy. 6, Sta. 28+116, o/s 11.1m Lt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY F.P.  
DATUM Geodetic DATE July 11, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE								○		
						● QUICK TRIAXIAL	× LAB VANE													
429.6	Ground surface						20	40	60	80	100									
0.0	Topsoil																			
0.3	Clayey silt with sand, trace gravel		1	SS	3												5 21 50 24			
	Firm Brown Wet (TILL)		2	SS	6															
428.1																				
1.5	Silty clay trace sand, trace gravel		3	SS	22							225								
	Very Brown Moist stiff grey (TILL)		4	SS	21							225								
426.7																				
2.9	Sandy gravel with silty clay lenses		5	SS	30															
	Dense Brown Wet																			
425.2																				
4.4	Silt, trace fine sand																			
	Dense Grey Moist		6	SS	41															
423.7																				
5.9	Clayey silt trace sand, trace gravel																			
423.1	Hard Grey Moist (TILL)		7	SS	64															
6.5	End of borehole																			
<div><div>*</div><div>2006 07 11</div></div> <div><div>▽</div><div>Water level observed during drilling</div></div> <div><div>▼</div><div>Water level measured after drilling</div></div> <div><div>■</div><div>Penetrometer test</div></div>																				

**RECORD OF BOREHOLE No C18-3**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 866 981 N; 209 088 E  
Hwy. 6, Sta. 28+116, o/s 11.2m Rt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY F.P.  
DATUM Geodetic DATE July 11, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED		+ FIELD VANE							
						● QUICK TRIAXIAL	× LAB VANE			WATER CONTENT (%)							
429.7	Ground surface						20	40	60	80	100						
0.0	Topsoil																
0.3	Silt, trace sand		1	SS	3												
429.0	Very loose Brown Wet																
0.7	Clayey silt some sand, some gravel		2	SS	14							162				16 18 44 22	
	Stiff Brown Wet Very stiff Moist		3	SS	18							225					
	Grey		4	SS	17							150					
426.8	(TILL)																
2.9	Sandy gravel																
426.5	Dense Grey Wet		5	SS	46												
3.2	Silty clay trace sand, trace gravel																
	Hard Grey Wet																
425.3	(TILL)																
4.4	Clayey silt trace sand, trace gravel		6	SS	45												
	Hard Grey Moist (TILL)																
423.2			7	SS	48												
6.5	End of borehole																
			</														

\* 2006 07 11

▽ Water level observed  
during drilling

▽ Water level measured  
after drilling

■ Penetrometer test

METRIC

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

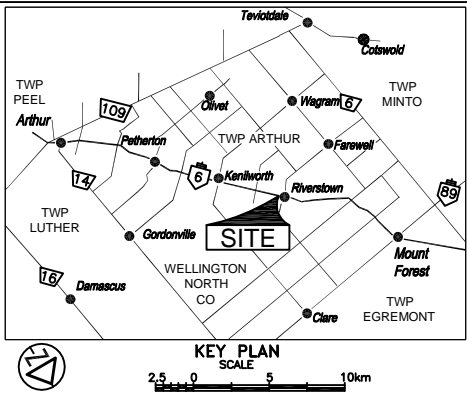
CONT No  
WP No 342-97-00

HIGHWAY 6  
CULVERT AT STA. 28+116  
BOREHOLE LOCATIONS

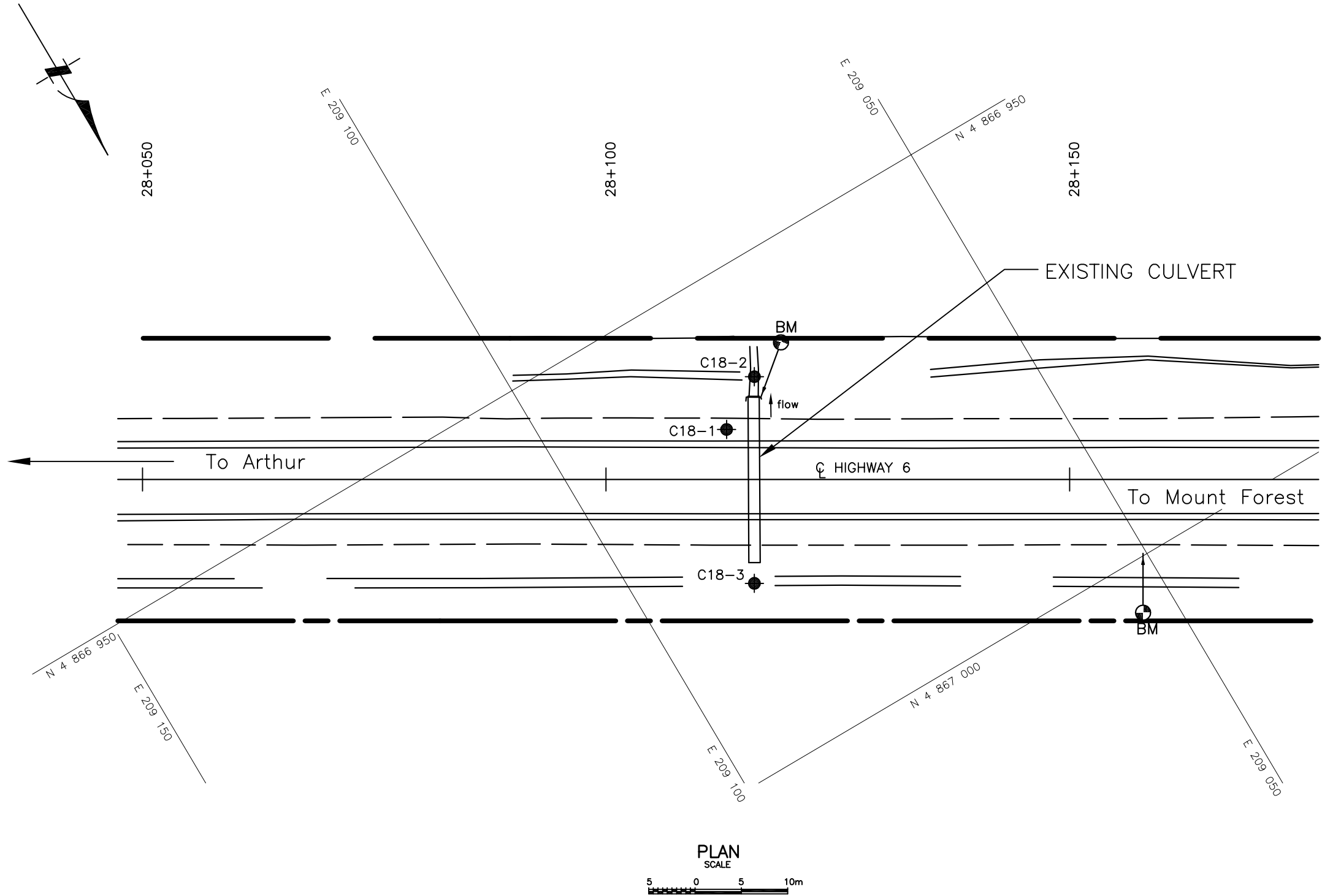


SHEET

PMI 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 2006 to July 2006		
	Head		
	ARTESIAN WATER Encountered		
	PIEZOMETER		
		CO-ORDINATES	
BH No	ELEVATION	NORTH	EAST
C18-1	431.7	4 866 965	209 082
C18-2	429.6	4 866 962	209 077
C18-3	429.7	4 866 981	209 088



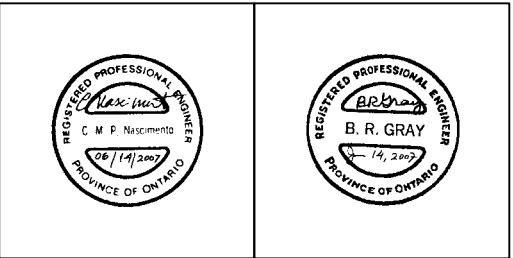
PLAN  
SCALE  
5 0 5 10m

NOTE:

THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE  
DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

- NOTE -

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



REF. No.: Drawing H6258xb01 provided by MRC dated  
February 2006

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	--
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C18-1

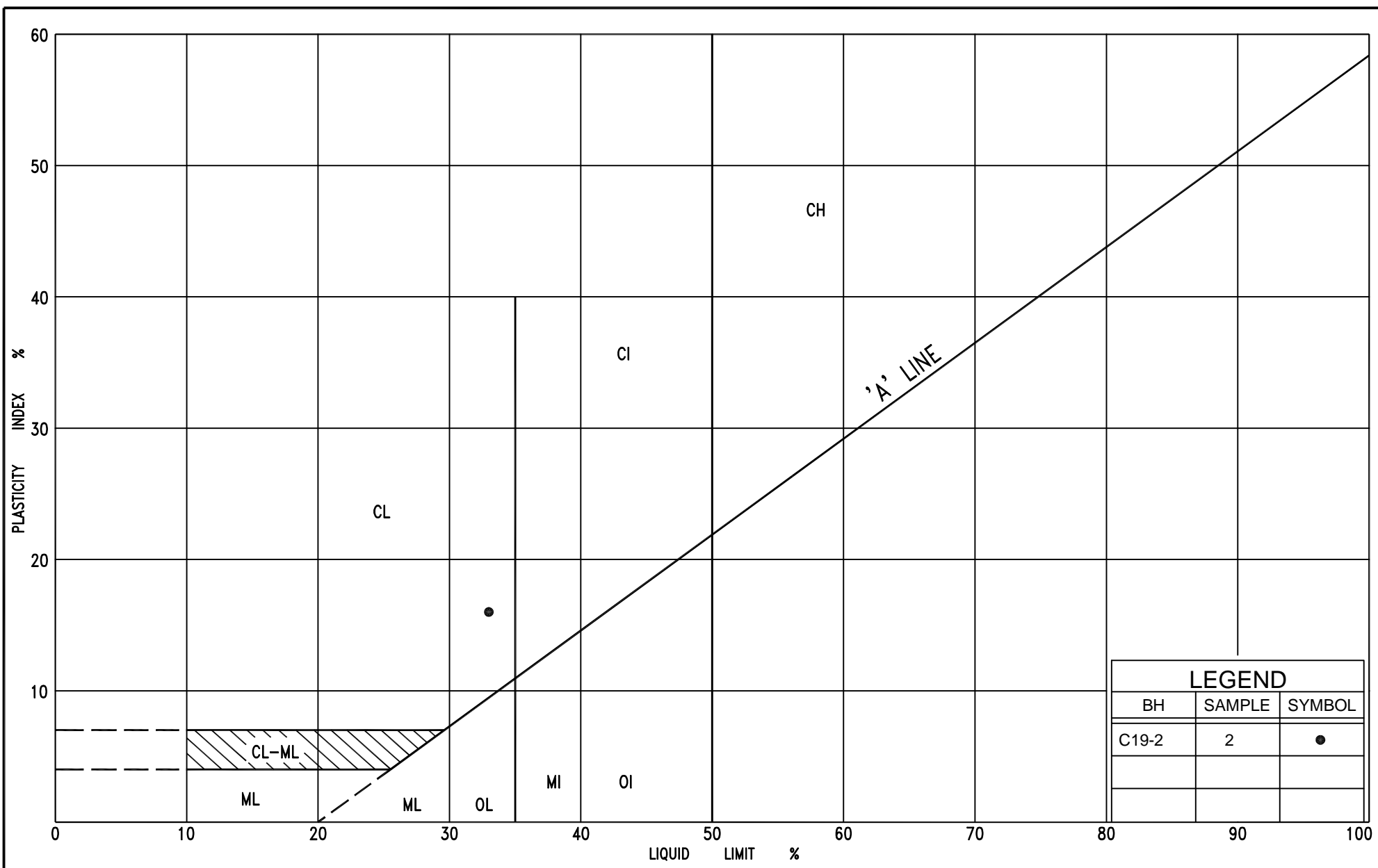
### Culvert C-19 at Sta. 28+319

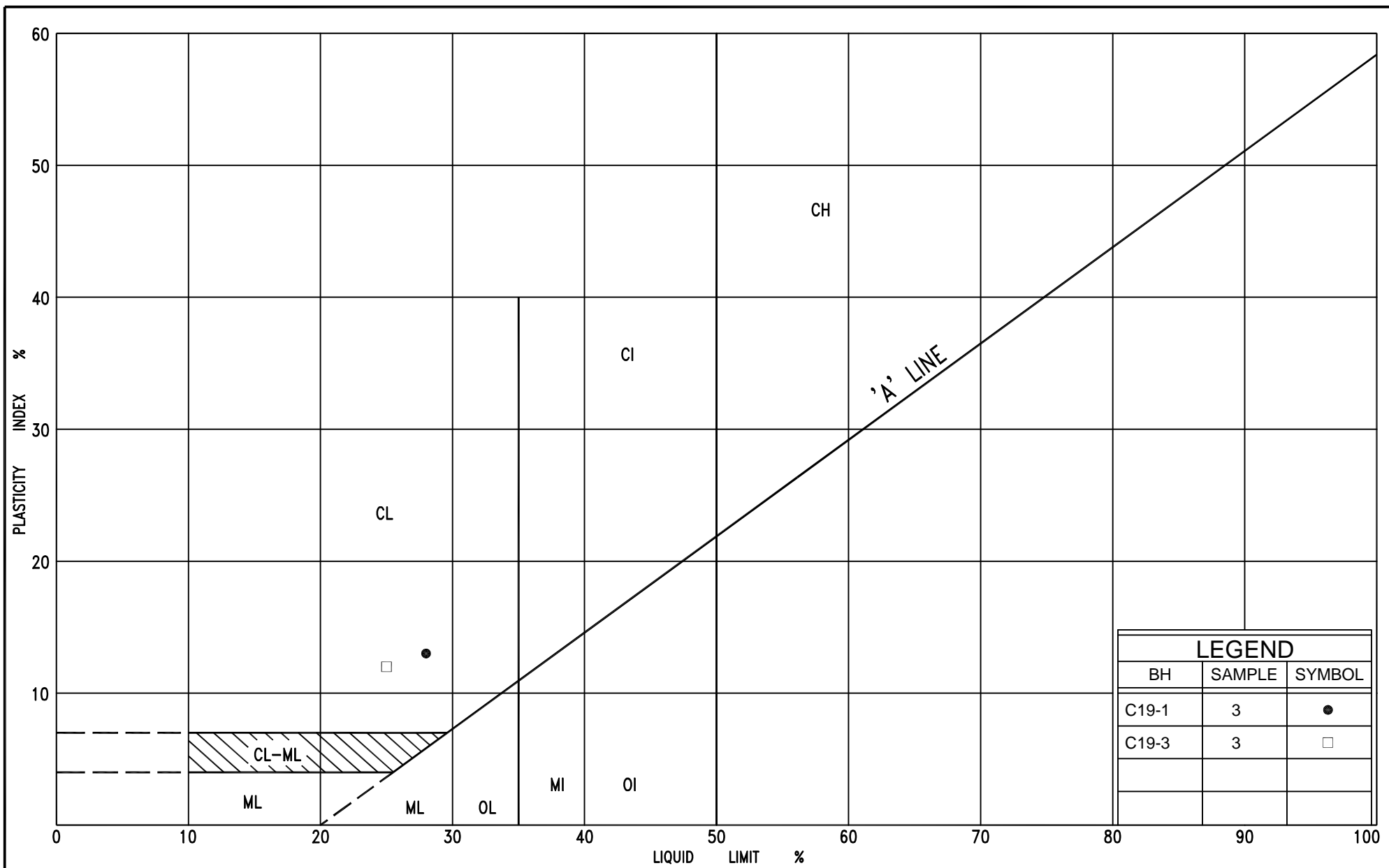
Figure C19-PC-1 to PC-3 – Results of Atterberg Limits Testing

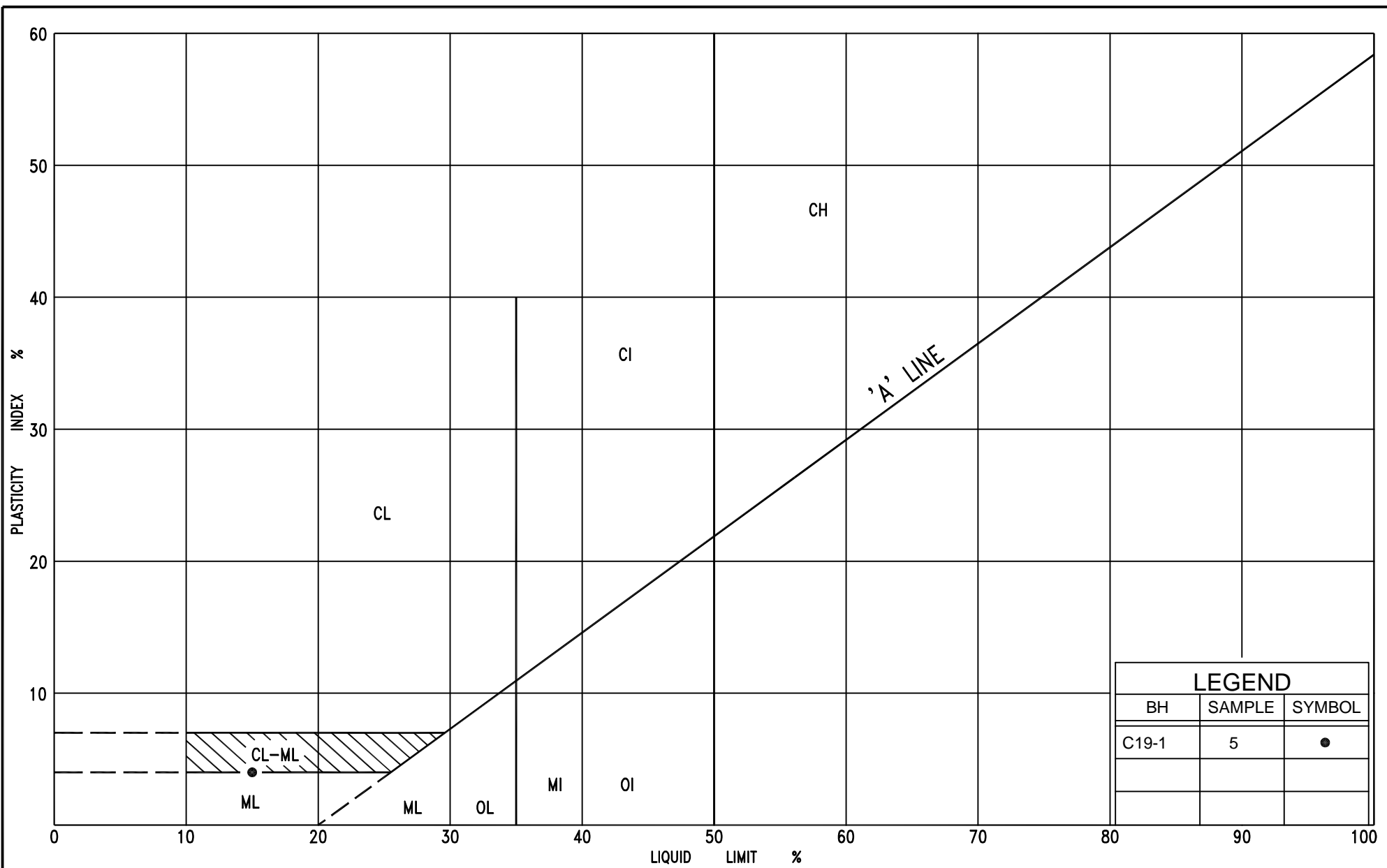
Figures C19-GS-1 to GS-4 – Results of Grain Size Distribution Analyses

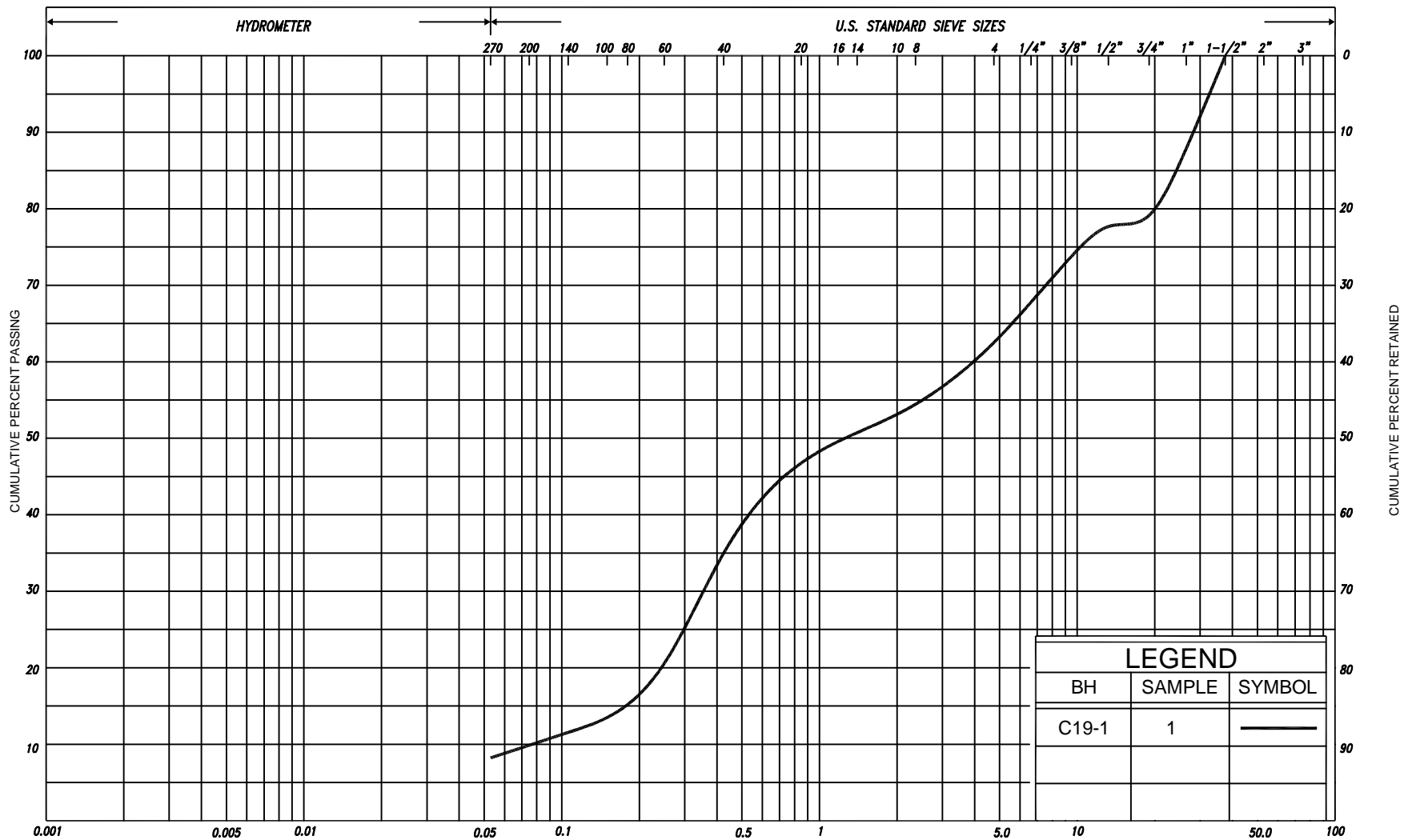
Record of Borehole Sheets C19-1 to C19-3

Drawing C19-1 – Borehole Locations





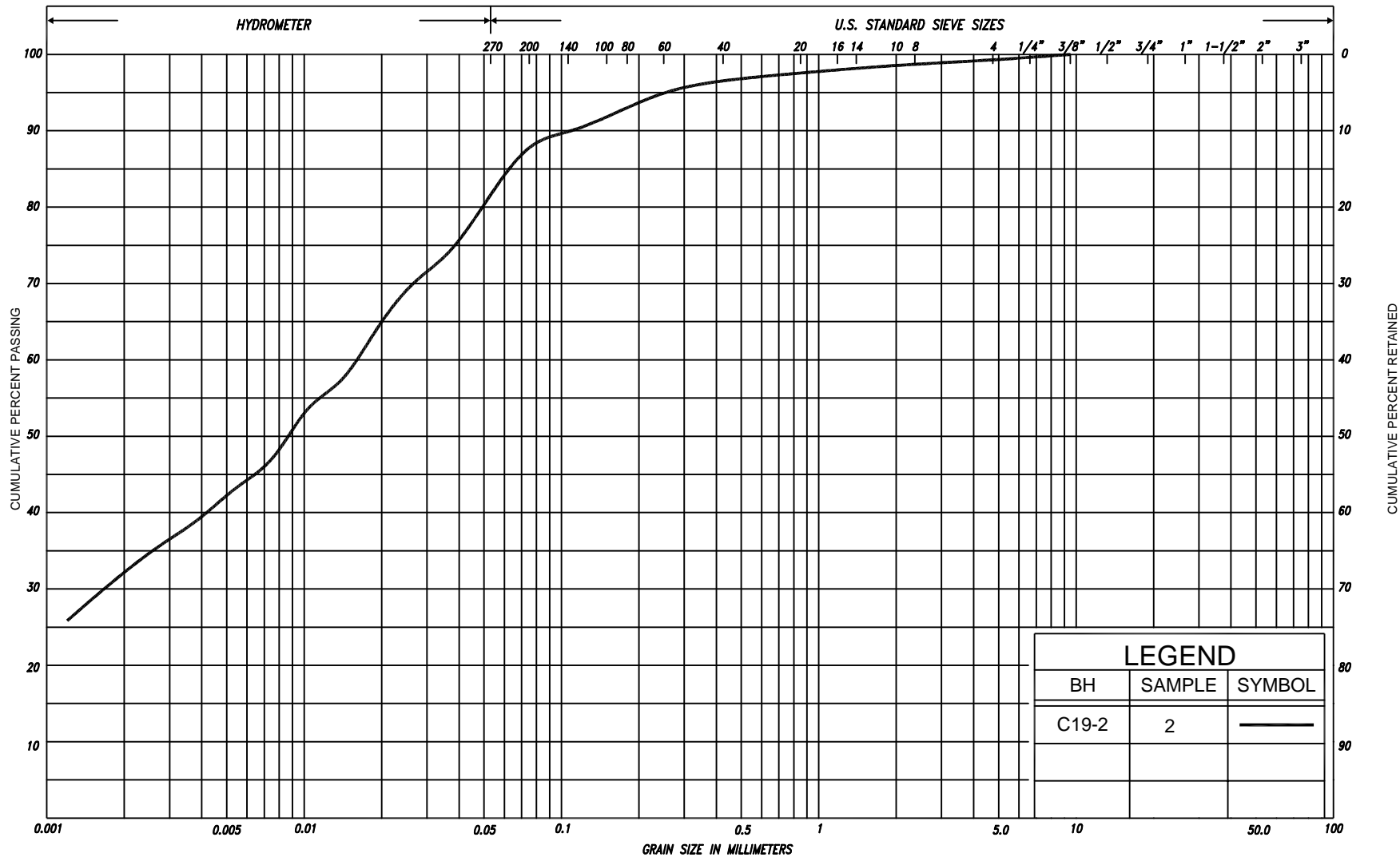




LEGEND		
BH	SAMPLE	SYMBOL
C19-1	1	—

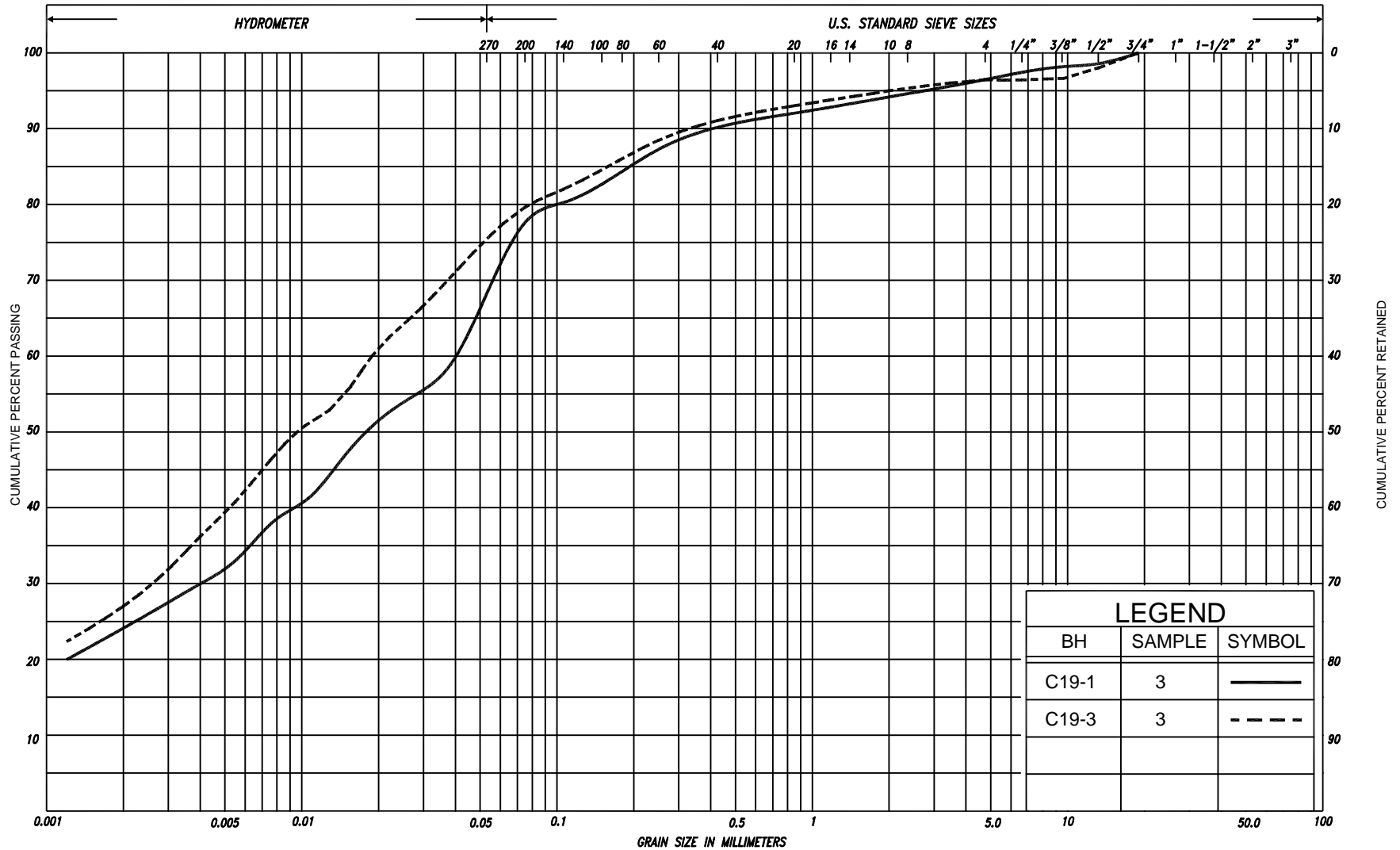
SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL			COBBLES	UNIFIED			
				SAND													
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL	COBBLES	M.I.T.		
	SILT																
CLAY			SILT			V. FINE		FINE		MED.		COARSE		GRAVEL		U.S. BUREAU	
						SAND											



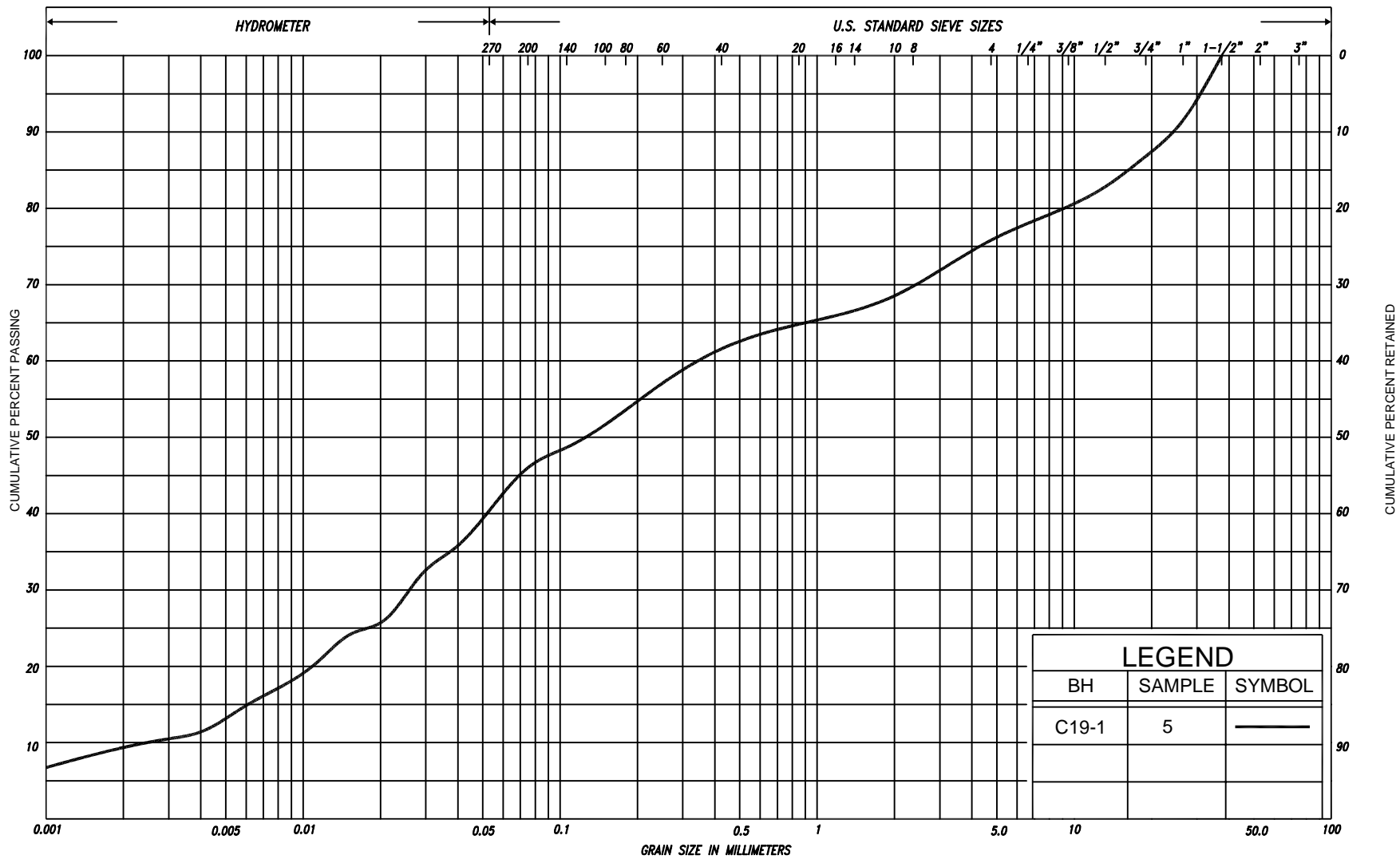


LEGEND		
BH	SAMPLE	SYMBOL
C19-2	2	

SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COB BLES	UNIFIED	
				SAND										
CLAY	FINE	MEDIUM		COARSE	FINE		MEDIUM	COARSE		GRAVEL			COBBLES	M.I.T.
	SILT													
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU
					SAND									



SILT & CLAY			FINE			MEDIUM			COARSE			GRAVEL			COBBLES	UNIFIED
CLAY			FINE			MEDIUM			COARSE			GRAVEL			COBBLES	M.I.T.
CLAY			SILT			SAND			GRAVEL			GRAVEL			U.S. BUREAU	
CLAY			SILT			SAND			GRAVEL			GRAVEL			U.S. BUREAU	
CLAY			SILT			SAND			GRAVEL			GRAVEL			U.S. BUREAU	
CLAY			SILT			SAND			GRAVEL			GRAVEL			U.S. BUREAU	



LEGEND		
BH	SAMPLE	SYMBOL
C19-1	5	

SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED		
					SAND											
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT															
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL							U.S. BUREAU
					SAND											

**RECORD OF BOREHOLE No C19-1**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 867 069 N; 208 907 E  
Hwy 6 Sta. 28+317, o/s 5.4m Lt. ORIGINATED BY GI  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY GD  
DATUM Geodetic DATE May 17, 2006 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>					
431.5	Ground Surface															
0.0	Gravelly sand, some silt Compact Brown Moist (PAVEMENT FILL)															
431.0	Clayey silt with sand, trace gravel Stiff Dark Moist brown		1	SS	17											38 52 (10)
0.5	Gravelly sand trace silt, trace clay															
429.8	Compact Brown Moist (FILL)		2	SS	8											
1.7	Topsoil															
429.3	Clayey silt some sand, trace gravel Stiff Brown Moist to very stiff  (TILL)		3	SS	9											3 19 54 24
2.2			4	SS	25											
427.2	Silt, with sand with gravel, trace clay cobbles and boulders Very dense Brown Moist (TILL) Grey		5	SS	82											24 30 37 9
4.3			6	SS	50/ 13cm											
423.6			7	SS	50/ 13cm											
7.9	End of borehole															
<div>* 2006 05 17</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																

# RECORD OF BOREHOLE No C19-2

1 of 1

METRIC

G.W.P. 342-97-00

LOCATION

Co-ords: 4 867 066 N; 208 902 E  
Hwy. 6, Sta. 28+319, o/s 10.9m Lt.

ORIGINATED BY F.P.

DIST Owen Sound HWY 6

BOREHOLE TYPE

Continuous Flight Solid Stem Augers

COMPILED BY F.P.

DATUM Geodetic

DATE \_\_\_\_\_

July 11, 2006

CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  W <sub>p</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL						× LAB VANE		
429.9	Ground surface																			
0.0	Topsoil																			
0.2	Clayey silt, some sand trace gravel, organics		1	SS	6								○							
	Firm Brown Wet to Soft		2	SS	2								■	■		1 11 56 32				
428.5																				
1.4	Clayey silt trace sand, trace gravel		3	SS	26								○							
	Very stiff Brown Moist (TILL) to wet																			
427.5	Gravelly sand		4	SS	13								○							
427.0	Compact Brown Wet																			
2.9	Clayey silt trace sand, trace gravel		5	SS	63								○							
	Hard Grey Moist (TILL)																			
	_____																			
	Grey		6	SS	50/ 15cm								○							
	_____																			
	with sandy silt lenses																			
	Wet		7	SS	47								○							
423.4	End of borehole																			
6.5																				

**RECORD OF BOREHOLE No C19-3**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 867 084 N; 208 913 E  
Hwy. 6, Sta. 28+319, o/s 10.5m Rt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY F.P.  
DATUM Geodetic DATE July 11, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE										
							20	40	60	80	100									
430.1	Ground surface																			
0.0	Silty sand, topsoil inclusions		1	SS	2															
0.3	Very loose Brown Moist																			
429.4	(FILL)																			
0.7	Topsoil		2	SS	4															
	Silty clay trace sand, trace gravel																			
428.6	Firm Brown Wet		3	SS	20															
1.5	Clayey silt some sand, trace gravel																			
	Very stiff Brown Moist		4	SS	26															
427.4	(TILL)																			
2.7	Gravelly sand																			
427.0	Compact Grey Wet		5	SS	16															
3.1	Silt trace sand, trace gravel																			
	Compact Grey Wet																			
425.6	(TILL)																			
4.5	Clayey silt trace sand, trace gravel		6	SS	56															
	Hard Brown Moist																			
	(TILL)																			
424.2	Silt trace clay, trace sand		7	SS	50/8cm															
5.9	Very dense Grey Moist																			
423.9	(TILL)																			
6.2	End of borehole																			
<div>* 2006 07 11</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																				

\* 2006 07 11

▽ Water level observed  
during drilling

▽ Water level measured  
after drilling

■ Penetrometer test

METRIC

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

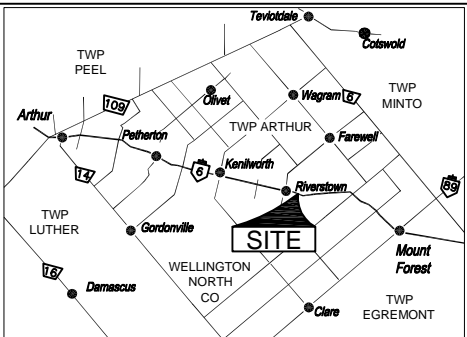
CONT No  
WP No 342-97-00

HIGHWAY 6  
CULVERT AT STA. 28+319  
BOREHOLE LOCATIONS



SHEET

PML Peto MacCallum Ltd.  
CONSULTING ENGINEERS



KEY PLAN  
SCALE  
2.5 0 5 10km

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 2006 to July 2006
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C19-1	431.5	4 867 069	208 907
C19-2	429.9	4 867 066	208 902
C19-3	430.1	4 867 084	208 913

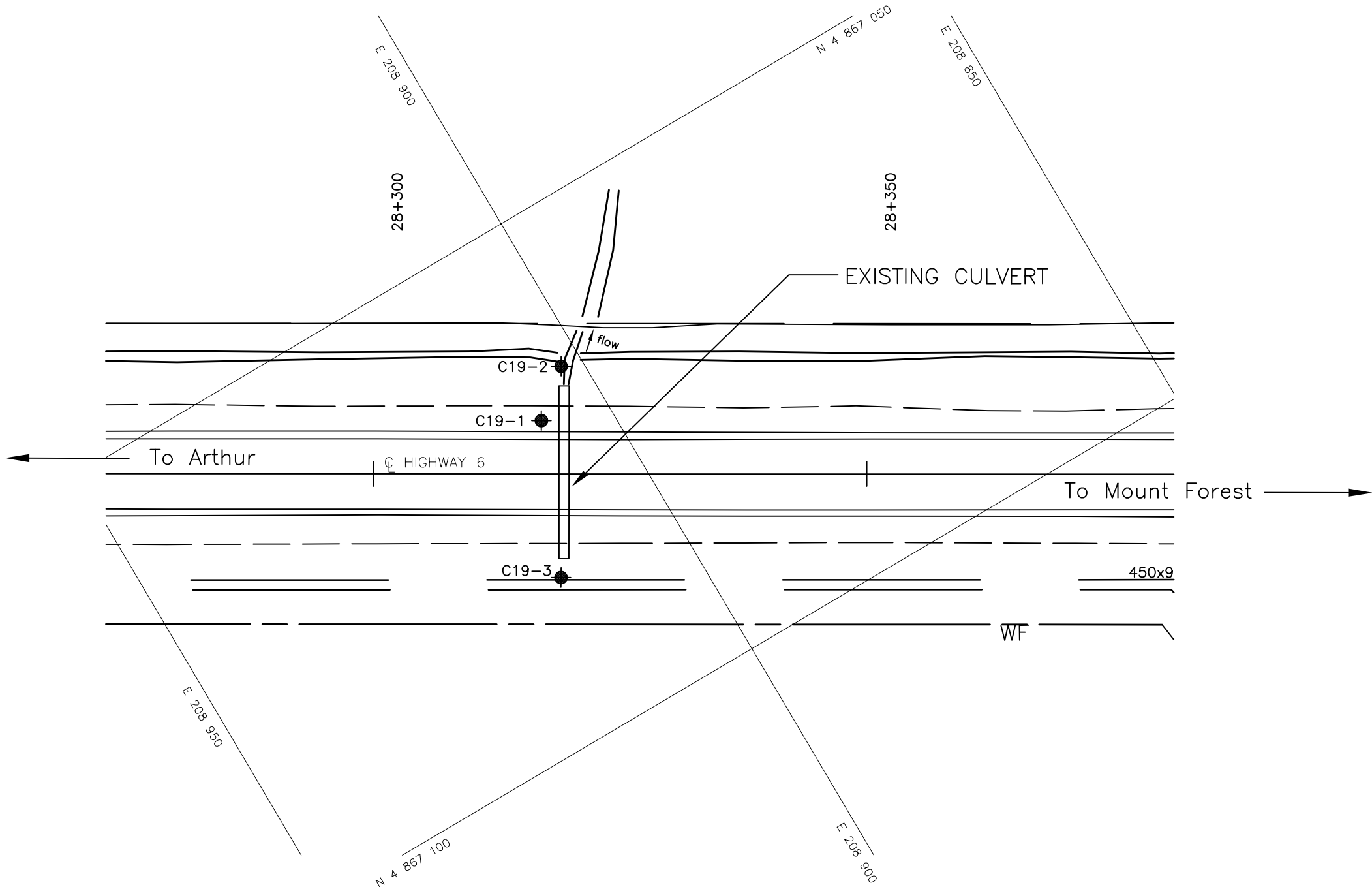
NOTE

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. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	---
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C19-1



PLAN  
SCALE

10 0 10 20m

NOTE:

THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE  
DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.



REF. No.: Drawing H6258xb01 provided by MRC dated February 2006

### Culvert C-20 at Sta. 29+089

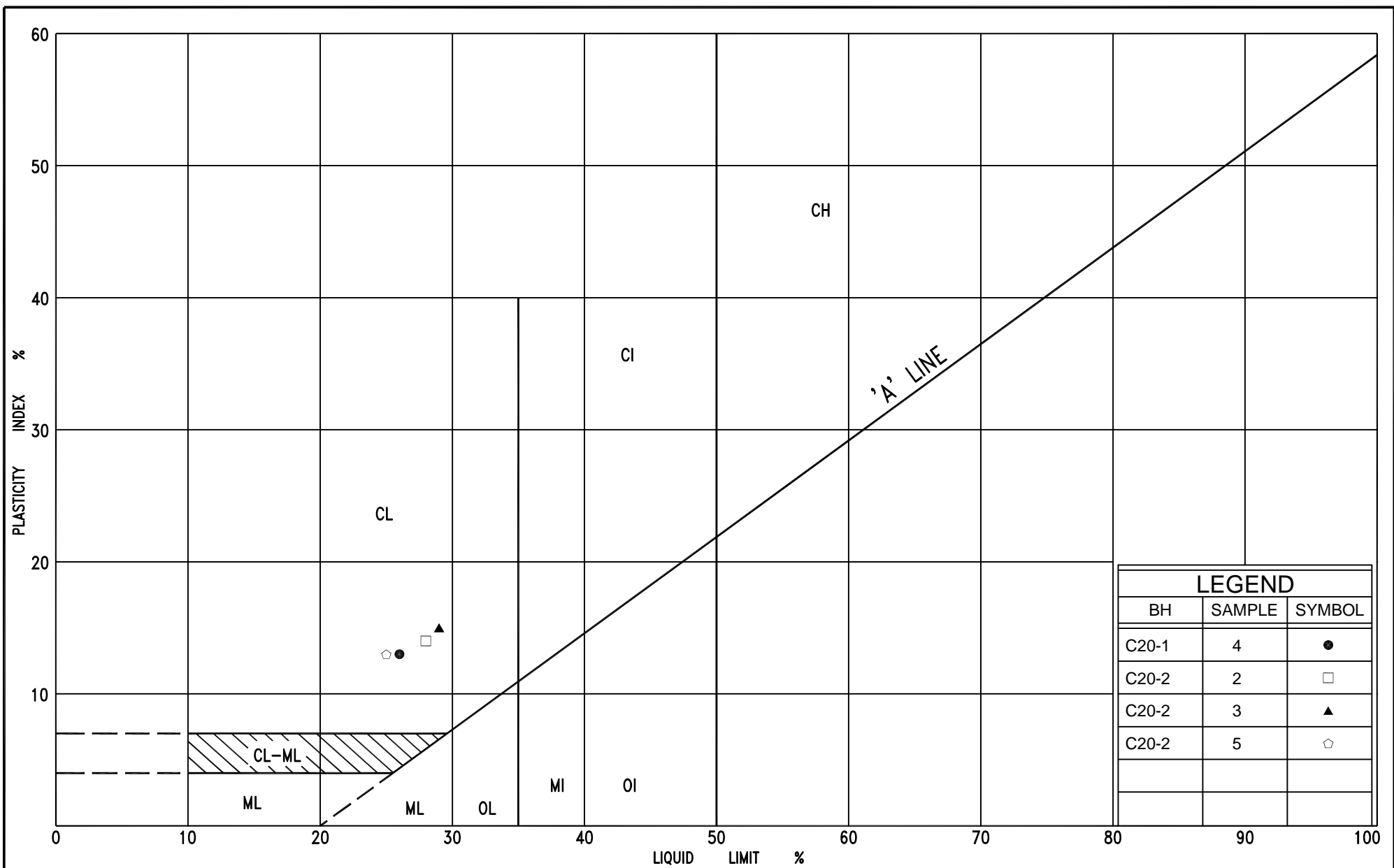
Figures C20-PC-1 – Results of Atterberg Limits Testing

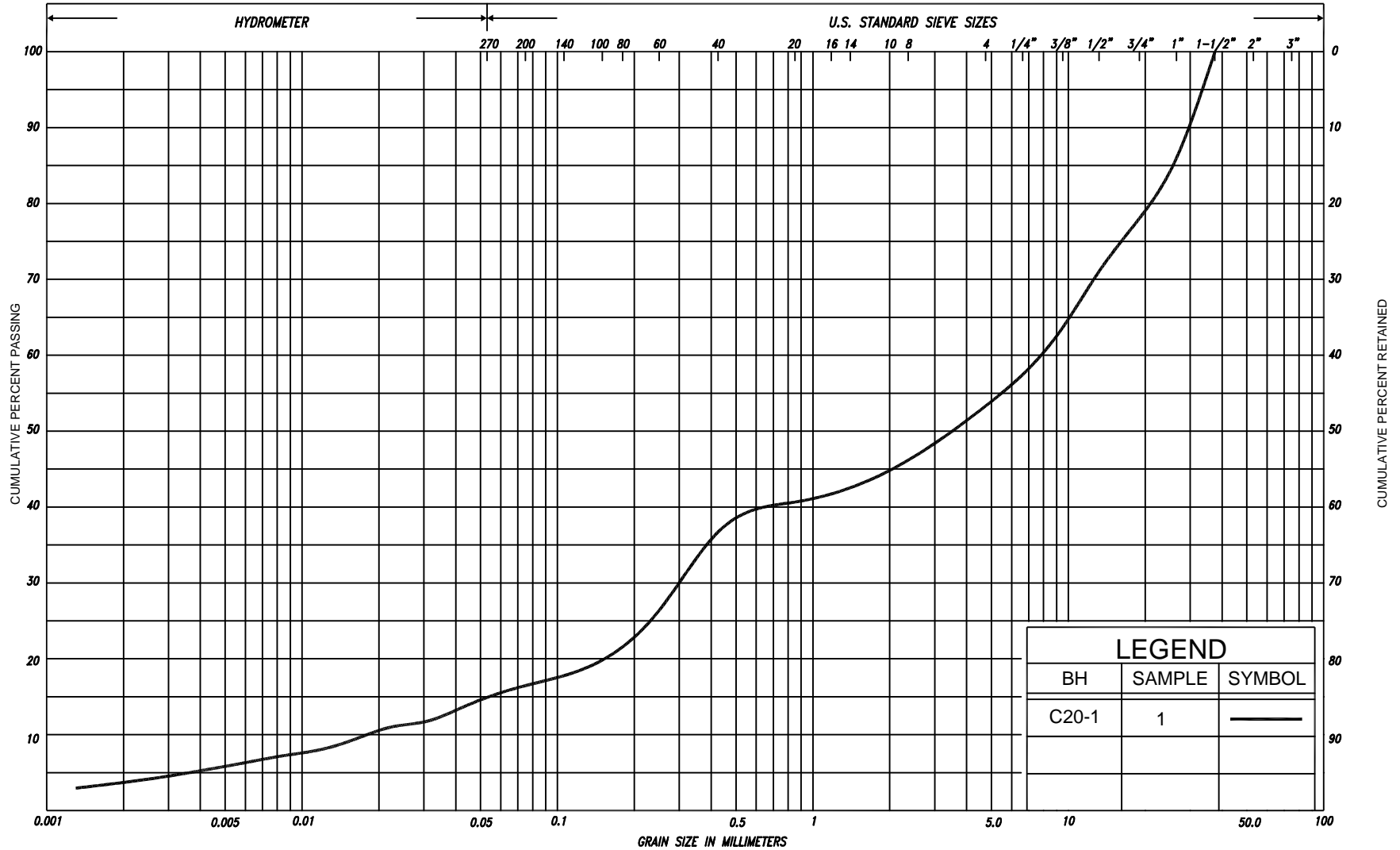
Figures C20-GS-1 and GS-2 – Results of Grain Size Distribution Analyses

Record of Borehole Sheets C20-1 to C20-3

Drawing C20-1 – Borehole Locations







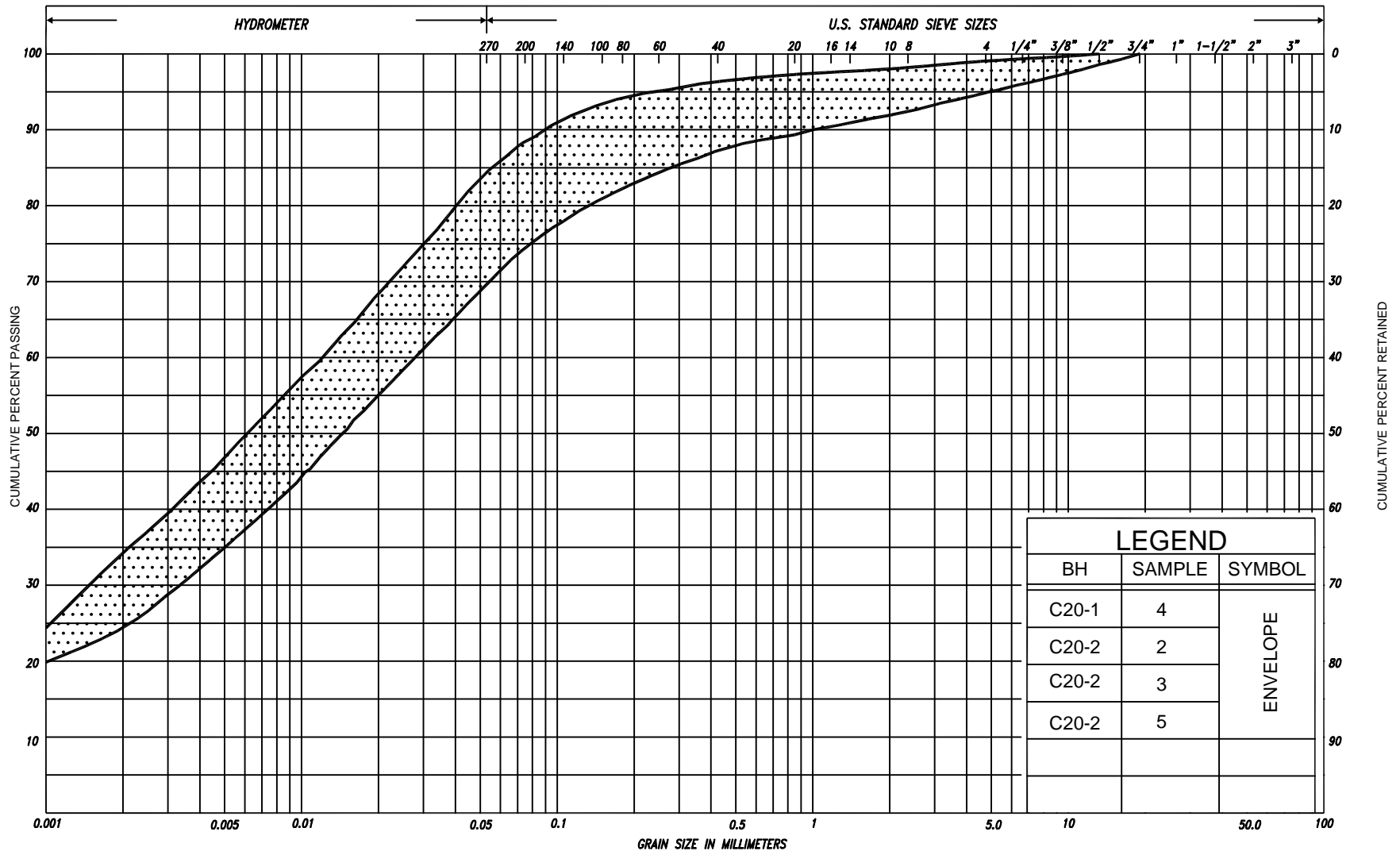
LEGEND		
BH	SAMPLE	SYMBOL
C20-1	1	—

SILT & CLAY				FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED						
				SAND															
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.		
				SILT														COBBLES	
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL								U.S. BUREAU	
				SAND															








GRAIN SIZE DISTRIBUTION  
SANDY GRAVEL, some silt, trace clay  
(FILL)

FIG No.	C20-GS-1
HWY	6
G.W.P. No.	342-97-00



SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COB BLES	UNIFIED	
					SAND										
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE		GRAVEL		COBBLES	M.I.T.
	SILT							SAND							
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL					U.S. BUREAU
					SAND										

RECORD OF BOREHOLE No C20-1										1 of 1	METRIC					
G.W.P. 342-97-00			LOCATION Co-ords: 4 867 460 N; 208 244 E Hwy 6 Sta. 29+086, o/s 5.4m Lt.			ORIGINATED BY GI										
DIST Owen Sound HWY 6			BOREHOLE TYPE Continuous Flight Solid Stem Augers			COMPILED BY GD										
DATUM Geodetic			DATE May 17, 2006			CHECKED BY CN										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa									WATER CONTENT (%)
430.1	Ground Surface						20	40	60	80	100					
0.0	Sandy gravel some silt, trace clay cobbles  Compact Brown Moist  (FILL)		1	SS	16											47 36 14 3
428.4	Topsoil		2	SS	4											
427.5	Clayey silt some sand, trace gravel Stiff Brown Moist to very stiff (TILL)		3	SS	8											
426.5			4	SS	13	▽*										
425.5	layer of sand and gravel at 4.6m depth		5	SS	27	▽*										
424.5	cobbles and boulders Hard Grey		6	SS	41											
423.5																
421.9			7	SS	37											
421.9	End of borehole															
8.2	* 2006 05 17 ▽ Water level observed during drilling ▼ Water level measured after drilling ■ Penetrometer test															

**RECORD OF BOREHOLE No C20-2**

1 of 1

**METRIC**

G.W.P. 342-97-00 LOCATION Co-ords: 4 867 453 N; 208 237 E  
Hwy. 6, Sta. 29+089, o/s 15.2m Lt. ORIGINATED BY F.P.  
DIST Owen Sound HWY 6 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY F.P.  
DATUM Geodetic DATE July 11, 2006 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
428.0	Ground surface							20	40	60	80	100								
0.0	Topsoil		1	SS	9															
0.3	Silty clay, organics																			
427.3	Stiff Brown Wet																			
0.7	Clayey silt some sand, trace gravel		2	SS	13															
	Stiff Brown Moist																			
	Very stiff		3	SS	20															
	(TILL)																			
425.5	Silty sand		4	SS	30															
2.5	Dense Brown Wet																			
425.0	Clayey silt some sand, trace gravel		5	SS	25															
3.0	Very Grey Moist stiff																			
	(TILL)																			
	Hard		6	SS	36															
											</									

\* 2006 07 11

▽ Water level observed  
during drilling

▼ Water level measured  
after drilling

■ Penetrometer test

## 1 of 1

METRIC

## Foundation Design

G.W.P. 342-97-00

LOCATION

Co-ords: 4 867 474 N; 208 253 E  
Hwy. 6, Sta. 29+086, o/s 11.2m Rt.

ORIGINATED BY F.P.

DIST Owen Sound HWY 6

BOREHOLE TYPE

Continuous Flight Solid Stem Augers

COMPILED BY F.P.

DATUM Geodetic

DATE \_\_\_\_\_

July 13, 2006

CHECKED BY C.N.

ON MOT VER3 05KF104D-JULY 2006.GPJ ON MOT.GDT 6/13/2007 9:40:04 AM

$+$ <sup>7</sup>,  $\times$ <sup>5</sup>: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

METRIC

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

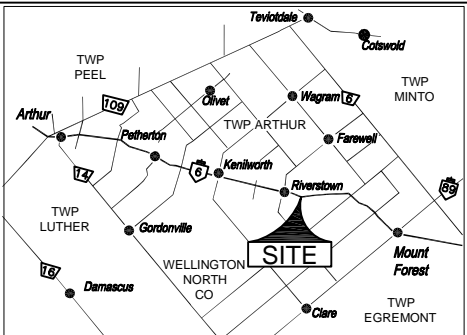
CONT No  
WP No 342-97-00

HIGHWAY 6  
CULVERT AT STA. 29+089  
BOREHOLE LOCATIONS



SHEET

**PML Peto MacCallum Ltd.**  
CONSULTING ENGINEERS



KEY PLAN  
SCALE  
2.5 0 5 10km

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 2006 to July 2006
- Head
- ARTESIAN WATER Encountered
- PIEZOMETER

BH No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
C20-1	430.1	4 867 460	208 244
C20-2	428.0	4 867 453	208 237
C20-3	428.6	4 867 474	208 253

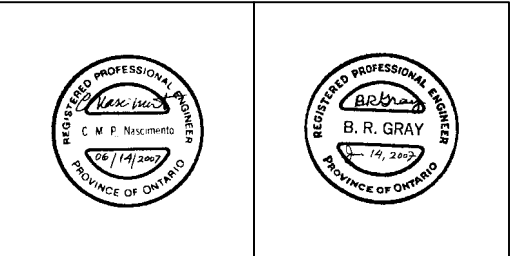
NOTE

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. 40P15-43

HWY No	6	DIST	Owen Sound
SUBM'D	GD	CHECKED	CN
DATE	JUNE 14, 2007	SITE	---
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	C20-1



REF. No.: Drawing H6258xb01 provided by MRC dated February 2006

PLAN  
SCALE



NOTE:

THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE  
DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.



## **FOUNDATION DESIGN REPORT**

**for**

**EXTENSION AND REPLACEMENT OF SIX CULVERTS**

**FROM STA. 22+616 TO STA. 29+089**

**IMPROVEMENT OF HIGHWAY 6 FROM ARTHUR (WELLS STREET)  
NORTHERLY TO SOUTH OF MOUNT FOREST**

**G.W.P. 342-97-00**

**TOWNSHIP OF ARTHUR**

**WELLINGTON NORTH COUNTY, ONTARIO**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
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### **Distribution:**

- 5 cc: McCormick Rankin Corporation for distribution to MTO,  
Project Manager + one digital copy (PDF format)
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Pavements and Foundations Section + one digital copy  
(PDF format), and Drawings (AutoCAD format)
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PML Ref.: 05KF104D3  
Index No.: 202FDR  
Geocres No.: 40P15-43  
June 14, 2007





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TABLE 1 – List of Standard Specifications Referenced in Report

**FOUNDATION DESIGN REPORT**  
for  
Extension and Replacement of Six Culverts  
From Sta. 22+616 to Sta. 29+089  
Improvement of Highway 6  
From Arthur (Wells Street) Northerly  
to South of Mount Forest  
G.W.P. 342-97-00  
Township of Arthur  
Wellington North County, Ontario

---

**1. INTRODUCTION**

This report provides foundation engineering comments and recommendations for the proposed extension or replacement of six of the twenty-one culverts less than 3 m wide while improving an approximate 18 km long section of Highway 6 that extends from Arthur (Wells Street) northerly to south of Mount Forest in the Township of Arthur, Wellington North County, Ontario. The six culverts dealt with in this report are located between Sta. 22+616 and Sta. 29+089. Foundation engineering comments and recommendations for the remaining thirteen culverts are provided separately. The report was prepared for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

Peto MacCallum Ltd. (PML) identified the culverts by PML reference numbers C-15 to C-20 for ease of reference in this report. The location, type and required work at each culvert are given in the following table:

**CULVERT DETAILS**

<b>PML Ref. No.</b>	<b>APPROXIMATE STATION</b>	<b>EXISTING CULVERT TYPE</b>	<b>WORK REQUIRED</b>
C-15	22+616	1.2 x 0.9 m Concrete Open Footing	Replacement
C-16	23+065	1.5 x 0.9 m Concrete Open Footing	New west headwall and extension of east end by 3 m
C-17	23+218	0.9 x 0.9 m Concrete Open Footing	Extension of west end by 3 m and east end by 3 m
C-18	28+116	1.2 x 1.2 m Concrete Open Footing	Replacement
C-19	28+319	0.6 m Diameter Corrugated Steel Pipe	Replacement
C-20	29+089	0.6 m Diameter Corrugated Steel Pipe	Replacement

Note: MRC provided the final scope of work at each culvert in January 2007.



This report pertains to design and construction of the proposed culvert extension or replacement and associated bedding/backfill zones.

Based on the proposed road grade and inferred invert levels of the culverts, the embankment fill height at the culvert locations ranges from 1.7 to 3.5 m.

The subsurface stratigraphy revealed in the boreholes drilled at the locations of the culverts was generally consistent and typically comprised the embankment fill and/or surficial topsoil overlying sandy/silty soils and clayey silt till/silty clay till. Locally, the boreholes encountered gravelly soils. Cobbles and boulders were encountered within the glacial till deposits at the culvert locations.

The groundwater level measured during the field investigation conducted in the period of May to July 2006 was variable at the culvert locations. Groundwater was measured in all the boreholes at depths of 0.0 to 5.2 m upon completion of drilling. The higher levels represented surface water run-off or perched water conditions. It was observed that the level of water flowing through the culverts varied from 200 mm deep after heavy rainfalls to a negligible amount between the rain events.

The foundation frost penetration for the site is 1.6 m as shown on OPSD 3090.101.

It is recommended that the proposed extension match the design of the existing culverts. For culvert replacement, both the open footing and box culvert options are considered feasible.

We also note that the alignment of the replacement culverts may be changed from the existing alignments. Consequently the new footings (in the open footing option) may not be located over the founding subgrade of the existing footings.

Excavations should allow for the presence of boulders. Road protection schemes involving augered or driven piles or sheet piles should also allow for these obstructions. Driven piles or sheet piles should be equipped with driving shoes.



It is noted that no responsibility or liability is assumed by the consultants for alerting the contractor and “red-flagging” all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the contractor.

A list of the standard specifications referenced in this report is compiled in Table 1. All elevations in this report are expressed in metres.

## **2. FOUNDATIONS**

### **2.1 Culvert C-15 at Sta. 22+616**

Replacement of this culvert is contemplated. The invert of the existing open footing culvert is inferred to be near elevation 447.0 at the east end and 447.1 at the west end (ref.: Plate 156-6/26-0 of 'Arthur to Mount Forest. Highway 6' Preliminary Design drawings). The existing subgrade founding level of the spread footings is interpreted to be at elevations 445.4 to 445.5 to account for the minimum 1.6 m soil cover for frost protection.

The subgrade material revealed in the boreholes just below the subgrade level comprises compact sand/silty sand or very stiff clayey silt till. The groundwater level at the time of the field investigation was at elevations 445.8 to 446.9, about 0.3 to 1.5 m above the inferred subgrade level.

Based on the proposed road grade (elevation 449.5) and invert levels of the culvert, the embankment fill height at the culvert location is assessed to be about 2.5 m. A 0.6 m road grade raise is planned.

The replacement culvert may be an open footing culvert founded at or below the 1.6 m frost protection depth, elevations 445.4 to 445.5. Also feasible is a precast or cast-in-place concrete box culvert placed at the design invert level. The founding subgrade of the precast box culvert is estimated to be at elevations 446.6 to 446.7, i.e. 0.4 m lower than the invert level to accommodate the thickness of the concrete culvert base slab, bedding thickness (150 mm) and levelling course (75 mm). The alternative cast-in-place box culvert may be placed at about elevations 446.8 to 446.9 since the bedding and levelling course are not considered to be required. The grades under the road



should be subexcavated to elevation 446.3 to remove the silty clay fill with organic inclusions encountered in borehole C15-1.

It is recommended that the existing culvert footings be removed and fill or disturbed subgrade soils resulting from the removal of the existing culvert and present below the new box culvert founding levels subexcavated to facilitate the preparation of the founding subgrade. The excavation levels should be restored to the new foundation levels using engineered fill, mass concrete or unshrinkable fill upon approval by the geotechnical engineer.

It is considered that compact sand/silty sand and very stiff clayey silt till found in the boreholes within the zone of influence of the new foundations are capable of adequately supporting the stress imposed by the embankment and culvert foundation loads. The high water levels measured in the boreholes necessitate elaborate groundwater control measures (see Section 5).

The replacement culvert foundations constructed on the sand/silty sand or clayey silt till should be designed using the following geotechnical resistances at the ultimate and serviceability limit states (ULS and SLS) assuming the groundwater to be at about elevation 446.9 and the minimum 0.5 m wide footing or 1.2 m wide replacement box culvert:

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Open Footing	Compact sand/silty sand or	375	200
	Very stiff clayey silt till	450	250
Box Culvert	Compact sand or	375	200
	Stiff to very stiff clayey silt till	250	150

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.



PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	COMPACT SAND / SILTY SAND	CLAYEY SILT TILL	
			STIFF	VERY STIFF
Friction Angle, degrees	35	32	0	0
Cohesion, kPa	0	0	100	150
Unit Weight, kN/m <sup>3</sup>	22.8	20.5	19.0	20.0

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.

## 2.2 Culvert C-16 at Sta. 23+065

A new headwall at the west end and extension at the east end are planned for culvert C-16 at Sta. 23+065.

The invert of the existing open footing culvert is inferred to be near elevation 439.4 at both ends (ref.: Plate 156-6/27-0 of 'Arthur to Mount Forest. Highway 6' Preliminary Design drawings). The existing subgrade founding level of the spread footings is interpreted to be at elevation 437.8 to account for the minimum 1.6 m soil cover for frost protection.

The subgrade material revealed in the boreholes just below the subgrade level comprises gravelly fill or compact sand/gravel. The groundwater level at the time of the field investigation was at elevations 437.3 to 439.2, about 0.5 m below to 1.4 m above the inferred subgrade level. Perched water was also present in the embankment fill at about 2.6 m (elevation 440.4) above the founding level of the culvert.

Based on the proposed road grade (elevation 442.7) and inferred invert levels of the culvert, the embankment fill height at the culvert is assessed to be up to 3.3 m. A road grade raise of 0.3 m is planned.

It is recommended that the culvert eastern extension matches the open footing type of the existing culvert to minimise potential erosion or differential settlement problems between the existing and new sections of the culvert.



The new footings should be founded at the same elevation as the existing footings inferred to be at elevation 437.8 at both the east and west ends of the culvert. Construction of the foundations for the culvert extension on spread footings bearing on the compact sand/gravel found in the boreholes within the zone of influence of the new foundations is considered to be feasible. It is noted that positive groundwater control measures will be necessary due to the high groundwater levels at the site; see Section 5 for more detail. Particular care should be exercised during excavation to ensure stability of the existing footings.

The culvert foundations constructed on the sand/gravel should be designed using the following geotechnical resistances for the minimum 0.5 m wide footing and assuming the groundwater level at elevation 439.2, about 1.4 m above the founding levels:

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Open Footing	Compact sand/gravel	400	250

Note: Box culverts are not recommended for extension of open footing type culverts.

It is noted that the depth of excavation for construction of new footings will be 1.5 to 2.5 m beyond the toes of the existing embankment and about 4.5 m within the existing embankment fill.

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	COMPACT SAND / GRAVEL
Friction Angle, degrees	35	34
Cohesion, kPa	0	0
Unit Weight, kN/m <sup>3</sup>	22.8	20.5

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.



### **2.3 Culvert C-17 at Sta. 23+218**

Extensions at both ends of culvert C-17 at Sta. 23+218 are planned. The invert of the existing open footing culvert is inferred to be near elevation 439.2 at the west end and 439.3 at the east end (ref.: Plate 156-6/27-0 of 'Arthur to Mount Forest. Highway 6' Preliminary Design drawings). The existing subgrade founding level of the spread footings is interpreted to be at elevations 437.6 to 437.7 to account for the minimum 1.6 m soil cover for frost protection.

The subgrade material revealed in the boreholes just below the subgrade level comprises gravel fill or generally compact sandy gravel/gravelly sand soils. The groundwater level at the time of the field investigation was at elevations 438.4 to 439.2, about 0.7 to 1.6 m above the inferred subgrade founding level.

Based on the proposed road grade (elevation 441.2) and invert levels of the culvert, the embankment fill height at the culvert location is assessed to be about 2.0 m. A road grade raise of 0.3 m is planned.

It is recommended that the culvert extensions match the open footing type of the existing culvert to minimise potential erosion or differential settlement problems between the existing and new sections of the culvert.

The new footings should be founded at the same elevation as the existing footings inferred to be at elevations 437.6 to 437.7. Construction of the foundations for the culvert extension on spread footings bearing on the compact sandy gravel/gravelly sand soils found in the boreholes within the zone of influence of the new foundations is considered to be feasible. The high water levels measured in the boreholes require elaborate groundwater control measures (see Section 5). Particular care should be exercised during excavation to ensure stability of the existing footings.

The culvert foundations constructed on the sandy gravel/gravelly sand soils should be designed using the following geotechnical resistances for the minimum 0.5 m wide footing and assuming a groundwater level at about elevation 439.2.





CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Open Footing	Compact sandy gravel/gravelly sand	400	250

Note: Box culverts are not recommended for extension of open footing type culverts.

It is noted that the depth of excavation for construction of new footings will be about 2.0 m beyond the toes of the existing embankment and up to 3.5 m within the existing embankment fill.

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	COMPACT GRAVELLY SOILS
Friction Angle, degrees	35	34
Cohesion, kPa	0	0
Unit Weight, kN/m <sup>3</sup>	22.8	21.5

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.

## 2.4 Culvert C-18 at Sta. 28+116

Replacement of C-18 at Sta. 28+116 culvert is contemplated.

The invert of the existing open footing culvert is inferred to be near elevation 429.3 at its both ends (ref.: Plate 156-6/35-0 of 'Arthur to Mount Forest. Highway 6' Preliminary Design drawings). The existing subgrade founding level of the spread footings is interpreted to be at elevation 427.7 to account for the minimum 1.6 m soil cover for frost protection.



The subgrade material revealed in the boreholes just below the subgrade level comprises very stiff clayey silt till/silty clay till. The groundwater level at the time of the field investigation was at elevations 426.8 to 427.9, about 0.9 m below to 0.2 m above the inferred subgrade founding level.

Based on the existing road grade (elevation 431.9) and invert level of the culvert, the embankment fill height at the culvert location is assessed to be some 2.6 m. It is planned to maintain the existing road grades.

The replacement culvert may be an open footing culvert founded at or below the 1.6 m frost protection depth, elevation 427.7. Also feasible is a precast or cast-in-place concrete box culvert placed at the design invert level. The founding subgrade of the precast box culvert is estimated to be at elevation 428.9, i.e. 0.4 m lower than the invert level to accommodate the thickness of the concrete culvert base slab, bedding thickness (150 mm) and levelling course (75 mm). The alternative cast-in-place box culvert may be placed at about elevation 429.1 since the bedding and levelling course are not considered to be required. The grades at the east end of the cast-in place box culvert should be subexcavated to elevation 429.0 to remove the very loose silt encountered in borehole C18-3.

It is recommended that the existing culvert footings be removed and fill or disturbed subgrade soils resulting from the removal of the existing culvert and present below the new box culvert founding levels subexcavated to facilitate the preparation of the founding subgrade. The excavation levels should be restored to the new foundation levels using engineered fill, mass concrete or unshrinkable fill upon approval by the geotechnical engineer. These materials may also be used to bring up the grades below the founding levels where required east of the highway.

It is considered that very stiff clayey silt till/silty clay till found in the boreholes within the zone of influence of the new foundations are capable of adequately supporting the stress imposed by the embankment and culvert foundation loads. The wet firm to stiff clayey silt should be protected with a 75 mm thick skim slab of lean concrete upon excavation to minimise disturbance during construction activities and post-construction settlement. Cognisant of the permeability characteristics of the clayey silt till/silty clay till, it is anticipated that the groundwater levels observed do not pose problems with dewatering and conventional sump pumping techniques will be sufficient to control seepage of groundwater into the excavations.



The replacement culvert foundations constructed on the clayey silt till/silty clay till should be designed using the following geotechnical resistances assuming groundwater at elevation 427.9, and the minimum 0.5 m wide footing or 1.2 m wide replacement box culvert:

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Open Footing	Very stiff clayey silt till / silty clay till	400	250
Box Culvert	Firm to stiff clayey silt	150	100

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	VERY STIFF CLAYEY SILT TILL / SILTY CLAY TILL	FIRM TO STIFF CLAYEY SILT
Friction Angle, degrees	35	0	0
Cohesion, kPa	0	150	50
Unit Weight, kN/m <sup>3</sup>	22.8	20.0	19.0

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.

## 2.5 Culvert C-19 at Sta. 28+319

Replacement of the CSP culvert C-19 at Sta. 28+319 is planned.

The invert of the existing 0.6 m diameter 17.5 m long CSP culvert is inferred to be near elevation 429.5 at the west end and 429.8 at the east end (ref.: Plate 156-6/36-0 of 'Arthur to Mount Forest. Highway 6' Preliminary Design drawings). The existing subgrade founding level of the culvert is interpreted to be at elevations 429.3 to 429.6 to account for about 150 mm of bedding thickness.



The subgrade material revealed in the boreholes immediately below the founding subgrade levels comprises firm clayey silt. The groundwater level at the time of the field investigation was at elevations 427.5 to 429.4, about 0.2 to 2.0 m below the inferred subgrade level.

Based on the existing/proposed road grade (elevation 431.7) and inferred culvert invert levels, the embankment fill height at the culvert location is assessed to be 1.9 to 2.2 m. It is planned to maintain the existing road grades.

The replacement culvert may be a CSP pipe or a precast concrete pipe culvert of the same 0.6 m diameter as the existing CSP culvert. The new CSP or concrete pipe should be founded at the same elevation as the existing culvert inferred to be at elevations 429.5 and 429.8 at the west and east ends respectively. The grades should be subexcavated where required to remove any topsoil that may be encountered at the subgrade level.

Both the open footing and box culvert options are also considered feasible for culvert replacement. The founding subgrade of the precast box culvert is estimated to be at elevations 429.1 to 429.4, i.e. 0.4 m lower than the invert level to accommodate the thickness of the concrete culvert base slab, bedding thickness (150 mm) and levelling course (75 mm). The alternative cast-in-place box culvert may be placed at elevations 429.3 to 429.6 since the bedding and levelling course are not considered to be required. The cast-in-place box culvert construction will require the provision of a 50 mm thick skim slab of lean concrete to protect the subgrade from disturbance and minimize post-construction settlement.

The founding subgrade of the open footing culvert should be 1.6 m below the invert levels for frost protection. These levels are assessed to be at elevations 427.9 to 428.2, with the soils immediately below the subgrade consisting of very stiff clayey silt till/silty clay till.

Construction of the new replacement CSP or box culvert bearing on the firm to stiff clayey silt/silty clay found in the boreholes is considered to be feasible. The open footing alternative at the required levels is feasible provided that care is taken with potential groundwater problems from the gravelly sand layer encountered in boreholes C19-2 and C19-3 about 0.4 to 0.8 m below the founding level. The replacement culvert constructed on the clayey silt/silty clay should be



designed using the following geotechnical resistances assuming groundwater at about elevation 429.4:

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
CSP, Concrete Pipe or Box Culvert	Firm to stiff clayey silt / silty clay	150	100
Open Footing	Very stiff clayey silt till / silty clay till	400	250

The following parameters should be used for sliding resistance at the culvert site. These parameters are applicable to cast-in-place concrete structures or CSP. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	FIRM TO STIFF CLAYEY SILT / SILTY CLAY	VERY STIFF CLAYEY SILT TILL / SILTY CLAY TILL
Friction Angle, degrees	35	0	0
Cohesion, kPa	0	50	150
Unit Weight, kN/m <sup>3</sup>	22.8	19.0	20.0

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.

## 2.6 Culvert C-20 at Sta. 29+089

Replacement of the CSP culvert C-20 at Sta. 29+089 is planned.

The invert of the existing 0.6 m diameter 18.5 m long CSP culvert is inferred to be near elevation 427.9 at both ends (ref.: Plate 156-6/37-0 of 'Arthur to Mount Forest. Highway 6')



Preliminary Design drawings). The existing subgrade founding level of the culvert is interpreted to be at elevation 427.7 to account for about 150 mm of bedding thickness.

The subgrade material revealed in the boreholes immediately below the subgrade level comprises topsoil in the borehole drilled on the shoulder of the highway, stiff silty clay or very stiff clayey silt till. The groundwater level at the time of the field investigation was at elevations 425.3 to 425.8, some 2 m below the inferred subgrade level.

Based on the existing road grade (elevation 430.3) and inferred culvert invert levels, the embankment fill height at the culvert location is assessed to be about 2.4 m. It is planned to maintain the existing road grades.

The replacement culvert may be a CSP pipe or a precast concrete pipe culvert of the same 0.6 m diameter as the existing CSP culvert. The new CSP or concrete pipe should be founded at the same elevation as the existing culvert inferred to be at elevation 427.9. The grades should be subexcavated to the level of the stiff to very stiff clayey silt till (elevation 427.5) to remove the topsoil encountered at the founding level in borehole C20-1.

For culvert replacement, both the open footing and box culvert options are also considered feasible. The founding subgrade of the precast box culvert is estimated to be at elevation 427.5, i.e. 0.4 m lower than the invert level to accommodate the thickness of the concrete culvert base slab, bedding thickness (150 mm) and levelling course (75 mm). The alternative cast-in-place box culvert may be placed at elevation 427.7 since the bedding and levelling course are not considered to be required.

The founding subgrade of the open footing culvert should be 1.6 m below the invert level for frost protection. This level is assessed to be at elevation 426.3, with the soils immediately below the subgrade consisting of very stiff clayey silt till.

Construction of the new replacement culvert bearing on the stiff silty clay to very stiff clayey silt till found in the boreholes is considered to be feasible. The replacement culvert constructed on the



silty clay/clayey silt till should be designed using the following geotechnical resistances, assuming the groundwater level at about elevation 427.9, the culvert invert level.

CULVERT TYPE	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
CSP, Concrete Pipe or Box Culvert	Stiff silty clay to very stiff clayey silt till	250	150
Open Footing	Very stiff clayey silt till	400	250

The following parameters should be used for sliding resistance at the culvert site. These parameters are applicable to cast-in-place concrete structures or CSP. The friction angle for precast concrete culverts should be reduced by a factor of 0.67.

PARAMETER	GRANULAR A OR GRANULAR B, TYPE II	STIFF SILTY CLAY	STIFF TO VERY STIFF CLAYEY SILT TILL
Friction Angle, degrees	35	0	0
Cohesion, kPa	0	75	150
Unit Weight, kN/m <sup>3</sup>	22.8	19.0	20.0

The structural designer should incorporate a factor of 0.8 on the tabled angle of friction and cohesion values for the sliding resistance check.

## 2.7 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 extension foundations. Therefore, provision for camber is not considered necessary for the culvert extension or replacement.



Preparation of the subgrade for construction of the culvert extension or replacement 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.

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

Granular fill placed under the box culverts 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. Where the existing open footing culverts will be replaced with precast box culverts on precast pipe culverts the existing footing may be removed and replaced with compacted engineered fill on unshrinkable fill. Alternatively, the footings maybe cut down to the level of the bedding material. If the new culvert will cross over the existing footing, however, that section of footing(s) should be cut down further, to a level at least 0.5 m below the bedding material. 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.

The geometry of the subgrade preparation, cover backfill and frost taper treatment for the open footing or box culverts should be carried out in accordance with OPSD 803.010, OPSS 422 and SP 422S01. The granular base/bedding material for a precast box culvert should comprise a minimum 150 mm thick layer of Granular A material. The pipe culvert should be placed in accordance with OPSD 803.030 and 803.031 and SP 421S01.

Where the excavations extend into the existing embankment, road protection will necessitate bracing to support the cut slopes. It is anticipated that conventional sump pumping techniques will be sufficient to control seepage of groundwater into the excavations at culverts C-18 to C-20, with





more positive groundwater control measures at the remaining culvert locations. Further comments in this regard are provided in subsequent sections of the report.

### 3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSD 3121.150, OPSS 422, SP 421S01 and SP 422S01.

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) should be restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction.

The replacement culverts and culvert extensions must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted 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) 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

$\gamma$  = unit weight of backfill material above design water level (kN/m<sup>3</sup>)

$\gamma'$  = unit weight of submerged backfill material below design water level (kN/m<sup>3</sup>)

$$= \gamma - \gamma_w$$

$\gamma_w$  = unit weight of water

$$= 9.8 \text{ kN/m}^3$$

$h_1$  = 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 OR GRANULAR B TYPE II	EXCAVATED MATERIAL (*)
Angle of Internal Friction, degrees	35	30
Unit Weight, kN/m <sup>3</sup>	22.8	20.0
Coefficient of Active Earth Pressure ( $K_a$ )	0.27	0.33
Coefficient of Earth Pressure At Rest ( $K_o$ )	0.43	0.50
Coefficient of Passive Earth Pressure ( $K_p$ )	3.69	3.00

(\*) Assumes that excavated materials used for backfill are inorganic cohesionless soils.

The design should consider both the maximum water level in the stream and the stabilised groundwater level conditions. The groundwater level measured during the field investigation was variable at the culvert locations and ranged from 2.0 m below to 1.5 m above the founding subgrade level. The water levels at all culverts may vary seasonally. 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 to minimise the build-up of hydrostatic pressure behind walls. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150  $\mu$ m 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. HEADWALLS AND WINGWALLS**

If headwalls and wing walls are utilised, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be utilised for design of the foundations. The wall founding levels should match those of the respective culverts where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established 1.6 m below the culvert invert level for adequate frost protection.

The design of the walls should be checked for sliding resistance using the geotechnical parameters provided in Section 2 for cast-in-place concrete foundations.

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind the walls as indicated in the previous section of the report.

#### **5. EXCAVATION AND GROUNDWATER CONTROL**

Excavation to the anticipated founding level of the culvert replacement or extension is expected to extend through the fill and/or topsoil into the native deposits of cohesionless gravelly/sandy/silty soils and cohesive clayey silt till/silty clay till. Provision for excavation of cobbles and boulders at all culvert sites should be allowed. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the in situ firm to stiff clayey silt till/silty clay till and compact gravelly/sandy/silty soils as well as fill materials are typically classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). The native very stiff clayey silt till or silty clay till are considered Type 2 soils. The OHSA requires that the slopes be cut to the requirements of the soil type with the highest number that is present in the slope. The need to excavate flatter sideslopes below the groundwater table or if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should also be considered.



It is anticipated that a suitable roadway protection scheme following SP 105S19 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 or anchored soldier piles and lagging may be considered. The driven sheet piles should be equipped with driving shoes in view of potential boulders in the native soils. The schemes should be designed for performance level 2 provided that groundwater control is in place. Otherwise, a performance level 1a system is recommended to prevent movement of the existing embankment. The contractor is responsible for the selection, preparation and performance of a detailed design for the road protection scheme.

The groundwater level observed in the boreholes at the time of the field investigation was 2.0 m below to 1.5 m above the anticipated levels of excavation. It is anticipated that dewatering with conventional sump pumps will be sufficient to control seepage of groundwater into the excavations for installation of culverts C-18 to C-20. The construction of open footing culvert foundation for culvert C-19 may require careful control of groundwater due to local high water levels found in a gravelly sand layer 0.4 to 0.8 m below the anticipated founding levels. More positive groundwater control measures such as wells or well points need to be implemented at the locations of culverts C-15 to C-17 to ensure the integrity of the existing embankment and maintain basal stability.

The dewatering system should be installed by a specialist dewatering contractor. The design of the dewatering system should be left to the Contractor's discretion so that the system meets a performance specification to maintain and control the groundwater at least 0.6 m below the excavation base.

It will be necessary to implement measures to control water flow in the streams. Conventional procedures such as dam and pump and/or temporary diversion of the stream should be sufficient. Observed groundwater levels are subject to seasonal fluctuations and precipitation patterns, which likely influence water flows in the relatively more pervious gravelly/sandy deposits. At these locations (culverts C-15, C-16, C-17 and C-19) a short cofferdam may be required upstream and downstream of the excavations to effectively control the groundwater flow and provide for



construction in the dry. Sheet piles should be provided with driving shoes to minimize damage due to buried boulders.

It is recommended that the work be carried out during the dry summer months to minimise the amount of groundwater 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 and with local/MTO regulations.

## **6. EMBANKMENT FILL**

The height of embankment at the culvert locations is envisaged to vary between about 1.7 and 3.5 m.

The anticipated subgrade for the embankments typically comprises compact sandy/silty soils or stiff to very stiff clayey silt till/silty clay till with localised firm zones. Topsoil was present in the boreholes drilled beyond the toes of the existing embankment and encountered below the fill in the boreholes advanced on the road shoulders at culverts C-18 to C-20. The construction specifications for grading in SP 206S03 should be followed. In particular, 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 benching of the earth slopes should follow the OPSD 208.010 procedures and geometry. The new embankment fill should be placed and compacted in accordance with OPSS 501 and SP 105S10. The material should comprise native soils compacted to at least 95% of the target density.

It is considered that the subgrade soils are capable of supporting the 1.7 to 3.5 m high embankments. The maximum total settlement of the embankment platform surface is assessed to be in the order of 25 mm (5 to 10 mm from the settlement of new fill and up to 15 mm from the settlement of the subsoil). The settlement is expected to be essentially complete within one to three months following fill placement.



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.

## **7. EROSION CONTROL**

The protective measures noted in the OPSD 800 series 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 materials. The cut-off walls should extend below the upper edge of the new box culverts and to a depth at least equal to the fluctuation of the water level at the culvert location to prevent flow below the culvert that could erode the granular base/bedding material as well as extend laterally to protect the granular backfill 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 and OPSD 810.010 is recommended to prevent erosion adjacent to the culverts as well as scour that could undermine the culverts 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  $\mu\text{m}$ , 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 headwalls and 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:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
Sand	0.2
Silt	0.3
Clayey Silt Till	0.5
Silty Clay Till	0.5

## **8. DISCUSSION OF FOUNDATION ALTERNATIVES**

### **8.1 Advantages and Disadvantages of Foundation Alternatives**

It is considered that the foundation schemes for extension of culverts C-16 (Sta. 23+065) and C-17 (Sta. 23+218) should match the existing culvert types to prevent post-construction erosion and/or settlement problems between the existing culvert and the extension sections. Care should be exercised during excavation to preclude undermining or disturbance of the subgrade soils of the existing footings.

The foundation options for replacement of CSP culverts C-19 and C-20 may be of similar configuration – a CSP pipe or a precast concrete pipe culvert. The replacement of these culverts with an open footing or box culvert is also feasible.



The following table summarises the advantages, disadvantages and inferred risks/consequences of the open footing and box culvert alternatives for replacement of culverts C-15, C-18 to C-20:

**COMPARISON OF THREE OPTIONS FOR REPLACEMENT OF CULVERTS  
AT STATIONS 22+616, 28+116, 28+319 AND 29+089**

CULVERT LOCATION	OPEN FOOTING		PRECAST CONCRETE BOX CULVERT OR PRECAST PIPE		CAST-IN-PLACE CONCRETE BOX CULVERT	
	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
C-15 Sta. 22+616	Cut-off walls not required between footings  Design incorporates full frost protection	Erosion control of soil between footings is required	Concrete base provides erosion protection	Only partial frost protection is incorporated – frost tapers are required	Concrete base provides erosion protection	Only partial frost protection is incorporated – frost tapers are required
C-18 Sta. 28+116		Relatively longer construction schedule than precast concrete culvert construction  Deeper founding levels typically require more sophisticated groundwater control	Shorter construction schedule than cast-in- place concrete culvert construction .	Cut-off walls are required	Cast-in-place concrete provides higher sliding resistance than precast concrete	Cut-off walls are required  Longer construction schedule than precast concrete culvert construction
C-19 Sta. 28+319						
C-20 Sta. 29+089						

The precast concrete option constructed at the design invert level is considered to be less costly than cast-in-place concrete alternatives since construction will be expedited due to elimination of the forming and setting time required for cast-in-place concrete construction. It is expected, however, that the construction of cut-off walls will offset some of the cost advantages of the box culvert construction.

## **8.2 Preferred Foundation Option Considerations**

From the foundation perspective, any of the alternative types of culvert (open footing, precast or cast-in-place concrete box culvert) is feasible. However, the box culverts provide a more effective erosion protection of the culvert invert materials. For replacement of the CSP culverts, a CSP





pipe or a precast concrete pipe culvert as well as any of the above mentioned alternative types of culvert is feasible.

It is noted that the culvert type selection also depends on other considerations such as potential fish habitat and commercially available (off the shelf) precast culvert sizes. These facets are to be evaluated by MRC.

## 9. CLOSURE

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

Yours very truly

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**TABLE 1**  
**LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT**

<b>DOCUMENT</b>	<b>TITLE</b>	<b>DATE</b>
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Culverts in Open Cut	April 2004
OPSS 501	Construction Specification for Compacting	November 2005
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting	November 2004
OPSS 570	Construction Specification for Topsoil	August 1990
OPSS 571	Construction Specification for Sodding	November 2001
OPSS 572	Construction Specification for Seed and Cover	November 2003
OPSS 902	Excavation and Backfilling of Structures	November 2002
OPSS 1004	Material Specification for Aggregates – Miscellaneous	November 2006
OPSS 1860	Material Specification for Geotextiles	November 2004
SP 105S10	Construction Specification for Compaction	November 2004
SP 105S19	Construction Specification for Protection Systems	November 2006
SP 206S03	Construction Specification for Grading	November 2006
SP 421S01	Construction Specification for Pipe Culverts	November 2006
SP 422S01	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers	April 2000
SP 902S01	Excavation and Backfilling of Structures	June 2006
OPSD 208.010	Benching of Earth Slopes	November 2003
OPSD 803.010	Backfill and Cover for Concrete Culverts	November 2006
OPSD 803.030	Frost Treatment - Pipe Culverts, Frost Penetration Line Below Bedding Grade	November 2005
OPSD 810.010	Rip-Rap Treatment for Culvert Outlets	November 2001
OPSD 803.031	Frost Treatment - Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade	November 2005
OPSD 3090.101	Foundation Frost Depth for Southern Ontario	November 2005
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls	November 2005