THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF STRUCTURAL CULVERT No 30-676/C
HIGHWAY 12, 75 m EAST OF CONCESSION ROAD 10
ORILLIA, ONTARIO
G.W.P. 2183-13-00

GEOCRES Number: 31D-594

SUBMITTED TO
McINTOSH PERRY CONSULTING ENGINEERS LTD.

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at Structural Culvert 30-676/C located on Highway 12 approximately 12 km east of Orillia, Ontario. Thurber carried out the investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) under Agreement No. 2013-E-0053.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, to provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

The culvert is located on Highway 12, approximately 75 m east of Concession Road 10, near Orillia, Ontario. It is noted that for project orientation purposes Highway 12 within the project limits, will be assumed to run east-west. The location of Culvert 30-676/C is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

Within the project limits Highway 12 is a two-lane, undivided highway with a rural cross-section, 3.75 m wide lanes and 3m wide granular shoulders. The maximum height of the road embankment is approximately 3 m in the area of the culvert and the existing side slopes are graded at approximately 3H:1V.

The existing culvert has been identified as having been constructed in 1953 and consists of an open footing (rigid frame) cast-in-place culvert with a length of approximately 21 m, interior width of 3.66 m, approximate opening height of 1.5 m and cover of 890 mm. The top of the stream bed is at approximately elevation 222.3 m. Flow through the culvert is from north to south.

The lands surrounding the roadway are typically agricultural with some residential and agricultural buildings. Storm water drainage in the area is to ditches and culverts. Typical site photographs are presented in Appendix D.

The site is located within a Physiographic Region known as the Simcoe Lowlands (Chapman and Putnam, 1984). This region was flooded by the glacial Lake Algonquin and is bordered by shorecliffs, beaches and boulder terraces and as such is characterized by a mixture of sand, silt and clay deposits.

3 BACKGROUND – PREVIOUS INVESTIGATION

A Foundation Investigation was carried out for a possible rehabilitation of Culvert 30-676/C by Infrastructure Engineering Group Inc. (IEG). The results of that investigation are presented in a Foundation Investigation Report (GEOCRES Report No. 31D-488, dated November 2009). A copy of this report is provided in Appendix E for reference.

The investigation consisted of two sampled boreholes and two dynamic cone penetration tests (DCPT). The boreholes were advanced through the existing roadway shoulders, and DCPT test holes (not sampled) advanced near the inlet and outlet of the culvert.

For reference, the IEG report indicates that the stratigraphy in the area of the culvert structure is generally characterized by granular fill related to the highway pavement structure, over a silty clay fill over very soft silty clay and/or very loose to loose sand and silt over a compact to very dense silty sand (till-like), underlain by very strong limestone bedrock. One of the boreholes advanced by IEG was extended into the underlying bedrock by coring. The bedrock surface in this borehole was identified at elevation 217.47 m.

The results of the IEG investigation were reviewed and considered when planning the current investigation.

4 SITE INVESTIGATION AND FIELD TESTING

Prior to carrying out the drilling investigation, a site visit was conducted by Thurber personnel and the locations of the proposed boreholes were laid out on site.

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to clear the borehole locations of underground utilities.

The field investigation for this site was carried out on October 6th and 7th, 2014, and included drilling three boreholes. The approximate locations of the boreholes are shown on the Borehole Location and Soil Strata drawing in Appendix A and summarized in Table 4-1.

Table 4-1: Borehole Summary

Borehole	Location	Ground Surface Elevation (m)	Depth (m)
14-1	Near south (outlet) end of culvert	223.8	6.0
14-2	Edge of pavement eastbound lane	224.9	7.5
14-3	Near north (inlet) end of culvert	223.5	6.0

The inlet and outlet boreholes were advanced using portable drilling equipment. A CME75 truck mounted drill equipped with hollow stem augers was used for the edge of pavement borehole. The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes while conducting Standard Penetration Tests (SPTs), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof bags, the bags were labelled, and the samples returned to Thurber's Ottawa geotechnical laboratory for further examination and testing.

Groundwater levels were measured on completion of drilling in the open boreholes prior to backfilling.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on October 7, 2014. The geodetic ground surface elevation at the top of pavement at the culvert location was used as a benchmark.

5 LABORATORY TESTING

Geotechnical laboratory testing was carried out in the Thurber geotechnical laboratory in Ottawa, Ontario, and consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analysis and Atterberg limit testing were also carried out on selected samples to MTO and ASTM standards.

The laboratory test results are presented on the Record of Borehole sheets in Appendix B and the Figures in Appendix C.

6 DESCRIPTION OF SUBSURFACE CONDITIONS

6.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert site is presented on the Borehole Locations and Soil Strata Drawing in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy in the area of the culvert structure is generally characterized by fill material (pavement structure, culvert backfill, embankment fill), over firm to stiff clay/silty clay, over very loose to compact silty sand to silt with sand, over compact to very dense silty sand with gravel. All boreholes were terminated on inferred bedrock.

6.2 Fill: Silty Sand with Gravel

A fill layer consisting predominantly of silty sand with gravel was encountered beneath the 50 mm thick asphalt surface in Borehole 14-2. The top of this layer was at elevation 224.8 m and the layer had a thickness of 1.4 m. The standard penetration test (SPT) 'N' values for this layer range from 2 to 21 blows per 0.3 m of penetration; indicating a very loose to compact state.

The moisture content of a sample tested was 5%. The results of grain size analysis conducted on one sample of the granular fill material are presented on Fig. No. 1 in Appendix C. The results are summarized in Table 6-1.

Table 6-1: Gradation Results for Silty Sand with Gravel Fill

Soil Particles	%
Gravel	20
Sand	55
Silt and Clay	25

6.3 Fill: Silty Clay with Sand

A fill layer consisting predominantly of silty clay with sand with some wood fragments was encountered beneath the granular fill layer is Borehole 14-2. The top of the fill layer was at elevation 223.5 m and the layer had a thickness of 1.6 m. The SPT ‘N’ value for this layer was 3 blows per 0.3 m of penetration, indicating a soft consistency.

The moisture content of a sample tested was 31%. The results of grain size analysis conducted on a sample of this fill material are presented on Fig. No. 2 in Appendix C. The results are summarized in Table 6-2.

Table 6-2: Gradation Results for Silty Clay with Sand Fill

Soil Particles	%
Gravel	2
Sand	20
Silt and Clay	78

Atterberg Limit testing was completed on one sample. The test results are illustrated on Figure No. 6 in Appendix C and are summarized in Table 6-3. The results indicate that the material exhibits intermediate plasticity.

Table 6-3: Atterberg Limits Test Results

Borehole	Sample	LL	PL	PI	Classification
14-2	SS-3	38	17	21	CI

6.4 Clay (CH) with Sand / Silty Clay (CI) trace Sand

A deposit of clay to silty clay with varying amounts of sand was encountered beneath the surficial vegetation in Boreholes 14-1 and 14-3, located near the outlet and inlet, respectively.

The top of this stratum ranged in elevation from 223.5 to 223.8 m and the thickness of the layer was 1.8 m in both boreholes. The SPT ‘N’ values for this stratum ranged from 3 to 9 blows per 0.3 m of penetration indicating a soft to stiff consistency.

The moisture content of the samples tested ranged from 18% to 45%. The results of grain size analysis conducted on two samples of the clay/silty clay material are presented on Fig. No. 3 in Appendix C. The results are summarized in Table 6-4.

Table 6-4: Gradation Results for Clay

Soil Particles	%
Gravel	0
Sand	6 to 23
Silt	54 to 55
Clay	23 to 39

Atterberg Limit testing was completed on two samples. The test results are illustrated on Figure No. 6 in Appendix C and are summarized in Table 6-5. The results indicate that the material ranged from high to intermediate plasticity.

Table 6-5: Atterberg Limits Test Results

Borehole	Sample	LL	PL	PI	Classification
14-1	SS-1	52	27	25	CH
14-1	SS-3	37	15	22	CI

6.5 Silty Sand (SM) to Silt (ML) with Sand

A layer of silty sand (SM) to silt (ML) with sand was encountered in all boreholes. The top of this stratum ranged from elevation 221.7 to 222.0 m and the material had a thickness ranging from 2.0 to 4.2 m. The SPT 'N' values for this stratum range from 1 to 20 blows per 0.3 m of penetration indicating a very loose to compact condition.

The moisture content of the samples tested ranged from 11% to 23%. The results of grain size analysis conducted on three samples of this deposit are presented on Fig. No. 4 in Appendix C. The results are summarized in Table 6-6.

Table 6-6: Gradation Results for Silty Sand to Silt

Soil Particles	%
Gravel	0 to 10
Sand	23 to 51
Silt	36 to 73
Clay	4 to 9

The results of the Atterberg Limits testing indicate that fines content of this stratum is comprised of a non-plastic silt.

6.6 Silty Sand (SM) with Gravel

The silty sand to silt with sand material in Boreholes 14-1 and 14-2 was underlain by a deposit of silty sand with gravel. The top of this stratum was encountered at elevations ranging from 219.6 m to 220.0 m and the thickness was 2.2 m. The SPT 'N' values for this stratum ranged from 5 to 88 blows per 0.3 m of penetration indicating a loose to very dense condition but typically a loose to compact condition

The moisture content of the samples tested ranged from 8% to 12%. The results of grain size analysis conducted on two samples of the material are presented on Fig. No. 5 in Appendix C. The results are summarized in Table 6-7.

Table 6-7: Gradation Results for Silty Sand

Soil Particles	%
Gravel	16 to 30
Sand	36 to 42
Silt	26 to 32
Clay	8 to 10

Atterberg Limit testing was completed on one sample. The test results are illustrated on Figure No. 6 in Appendix C and are summarized in Table 6-8. The results indicate that the material has low plasticity (CL-ML).

Table 6-8: Atterberg Limits Test Results

Borehole	Sample	LL	PL	PI	Classification
14-2	SS-10	18	11	7	CL-ML

6.7 Bedrock

All three boreholes were terminated on inferred bedrock based on SPT refusal at elevations ranging from 217.4 m to 217.8 m. Bedrock coring was outside the scope of work for this investigation. Bedrock was proven by coring in Borehole C28-3 during the previous investigation at this site and was identified at elevation 217.47 m.

6.8 Groundwater Conditions

Groundwater levels were measured on completion of drilling in the open boreholes prior to backfilling. Free water was observed at depths below existing grade of 1.4 m to 2.4 m; corresponding to elevations ranging from 222.1 m to 222.5 m.

The values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level will be influenced by the water level in the stream and ditches and may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

McIntosh Perry reported a water level in the creek of approximately 222.1 m on November 5, 2014.

7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and provided the northing and easting coordinates and ground surface elevations. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario supplied and operated both the portable and track-mounted CME 75 drill rigs to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full time basis by Ms. Katrina Young of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. and Paul Carnaffan, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents a foundation assessment and geotechnical evaluation of feasible methods for replacement of the culvert beneath Highway 12, approximately 75 m east of Concession Road 10 near Orillia, Ontario.

The existing culvert has been identified as having been constructed in 1953 and consisting of an open footing (rigid frame) cast-in-place culvert with a length of approximately 21 m, interior width of 3.66 m, approximate opening height of 1.5 m and cover of 890 mm. Flow through the culvert is from north to south. The width and founding elevation of the existing footings are not known, however, it is estimated that the footings extend to elevation 220.8 m.

The top of pavement at the Highway 12 centreline above the culvert is at approximately elevation 225.0 m. The slopes of the existing embankment are inclined at approximately 3H:1V and are between approximately 1.5 and 3 m high. The existing roadway cross-section includes two 3.75 m lanes and 3.0 m wide shoulders. The AADT is reported to be 9,000 (2008 data, MTO iCorridor).

Groundwater levels in the boreholes were observed at elevations ranging from 222.1 m to 222.5 m. The water level in the creek was observed to be at elevation 222.1 m on November 5, 2014.

It is noted that the need for replacement was identified based on its current condition rather than a need to increase hydraulic capacity. The General Arrangement Drawing of July 2015 indicates that the culvert will be replaces along the existing alignment and that the proposed closed box culvert is to have a span of 6.0 m, an interior height of 1.8 m and an invert elevation of 221.99 m (inlet end). The total length of structure is to be 22 m. In addition, the design includes a concrete cutoff wall, at both the inlet and outlet of the proposed culvert. The design of the proposed box culvert does not include wing walls

The frost penetration depth at this site is 1.6 m (OPSD 3090.101).

The following sections address the replacement of the existing culvert. The discussions and recommendations presented in this report are based on our understanding of the project and on the factual data obtained during the course of this investigation.

9 SEISMIC CONSIDERATIONS

In accordance with Table A3.1.1 of the Canadian Highway Bridge Design Code (CHBDC) the following seismic parameters should be used for design:

- Velocity Related Seismic Zone (Zv) = 1
- Zonal Velocity Ratio, (V) = 0.05
- Acceleration Related Seismic Zone (Za) = 1
- Zonal Acceleration Ratio, (A) = 0.05

This site is classified as a Soil Profile Type I in accordance with Section 4.4.6 of the CHBDC.

Based on the combination of the grain size distribution, relative density of the overburden soils, and low zonal acceleration, the overburden soil at this site is classified as "not susceptible" to liquefaction during the design earthquake event.

10 FOUNDATION ASSESSMENT

10.1 General

The following sections address replacement of the existing culvert.

10.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below and a comparison of feasible alternatives, based on their respective advantages and disadvantages, is included in Appendix F.

<u>Circular Pipes (CSP or Concrete)</u>

Circular pipes are technically feasible from a foundation engineering standpoint, however, due to the shallow cover, several parallel pipes would likely be required to provide an equivalent hydraulic section.

<u>Concrete Box (Closed) Culvert</u>

It is understood based on the General Arrangement Drawing of July 2015 that the existing culvert could be replaced with a closed box culvert with a span of 6.0 m, an interior height of 1.8 m and an invert elevation of 221.836 m to 221.993 m. Assuming a base slab thickness of 350 mm, the underside of the culvert would be at approximately elevation 221.5 to 221.6 m. Subgrade preparation should consist of excavation and removal of existing foundations (estimated to extend to approximately elevation 220.8 m). The base of the concrete cut-off walls ranges from 220.586 m to 220.743 m.

From a foundations perspective both pre-cast and cast-in-place concrete box (closed) culverts are considered feasible at this site, although a pre-cast culvert is preferred from an ease of construction point of view.

Concrete, Open Footing Culvert

The replacement culvert is to have span of 6.0 m, and an interior height of 1.8 m. The underside of footings would be at approximately elevation 220.8 m.

A concrete, open footing culvert is feasible, however, very loose to loose silt and sand deposits are present at the conventional founding depth and deeper footings or removal of the very loose to loose deposits and replacement with engineered fill would be required to achieve adequate geotechnical resistance. This would result in increased costs for excavation, backfill, protection systems and dewatering. Dewatering would be critical to allow footing construction in the dry.

10.3 Construction Methodology Alternatives

This section presents discussions on alternative construction methods for replacement of the culvert.

Trenchless Techniques

Although trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, the presence of a loose, saturated cohesionless soil within the tunnel diameter brings significant risk of tunnel face instability during construction. In addition, there is a very limited amount of cover over the new installation. Furthermore, several parallel pipes would be required to provide an equivalent section. Trenchless techniques are not considered suitable for the site conditions.

Open Cut with Road Closure

Installation of a new culvert using open cut techniques during a full road closure is the preferred alternative from a foundation perspective. This option would allow for an expedient construction schedule and reduced costs associated with roadway protection, and avoid the need for platform widening, however, it is understood that a road closure is not feasible from a traffic operations perspective.

Open Cut with Staged Construction & Roadway Protection

The culvert could be replaced using open cut techniques with staged construction (half and half) and roadway protection in order to keep one lane of traffic open throughout the construction period.

Open Cut with Staged Construction & Platform Widening/Lowering

Given the limited amount of cover over the existing and proposed culverts, it is not feasible to widen the roadway platform by temporarily lowering the profile. Widening the platform would require increasing the embankment footprint which may in turn require a temporary culvert extension. In addition, the proximity of the culvert to the intersection with Concession Road 10 (50 to 75 m) may impact the ability to shift the alignment.

10.4 Recommended Approach

From a foundation engineering perspective, replacement of the culvert with a concrete closed box structure using open cut techniques with staged construction and temporary protection systems is considered the best alternative. The discussion and recommendations provided below are based on the culvert replacement consisting of a closed box constructed in a half and half manner facilitated by roadway protection.

There are significant construction timing advantages of precast boxes in comparison to cast-in-place concrete construction, thus it is recommended that a precast box culvert be utilized for this project.

11 RECOMMENDATIONS

Foundation recommendations for a closed concrete box culvert are provided in the following sections. Construction of pre-cast concrete box culverts should be carried out in accordance with OPSS 422.

11.1 Subgrade Preparation

The base of the box culvert is expected to be at approximately elevation 221.6 m which is below the water level in the stream and within the very loose to compact silty sand to silt with sand. The subgrade will be easily disturbed by construction activities and will offer relatively low geotechnical resistance. It is also noted that the footings for the existing open culvert likely extend to approximately elevation 220.8 m.

The base of the concrete cut-off walls will be as low as elevation 220.586 m.

After removal of the existing culvert foundations and excavation to a uniform undisturbed base, the exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. As noted above, the subgrade is expected to consist of very loose to compact silty sand. Construction equipment should not be permitted to travel on the exposed subgrade. In addition, compaction of granular bedding directly above the subgrade is likely to result in disturbance of the material with, pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include:

- Placement of a Class II non-woven geotextile over the full extent of the subgrade as a separation layer prior to placement of granular pad a minimum of 300 mm thick consisting of OPSS Granular A (the granular pad is in addition to the bedding to be placed above it). The granular pad should be levelled and tamped but not compacted.
- Lowering the groundwater level to at least 0.5 m below the proposed underside of the granular pad.

Culvert construction and subgrade preparation must be carried out in the dry. This work should be carried out in accordance with OPSS 902. Dewatering will be required.

11.2 Box Culvert Foundations

Foundation bearing resistance recommendations for the box culvert founded at approximately elevation 221.5 m to 221.6 m following subgrade preparation as described in the section above are provided below.

Table 11-1: Geotechnical Bearing Reactions and Resistances for Box Culvert Design

Box Culvert Width (m)	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa)
4 to 7	250	100

The factored geotechnical resistance at ultimate limits states (ULS) includes a resistance factor of 0.5.

The bearing pressure at serviceability limit states (SLS) corresponds to the sustained net pressure increase resulting in 25 mm of total settlement.

The frost penetration depth at this site is 1.6 m (OPSD 3090.101).

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

11.3 Culvert Bedding and Backfill

Culvert bedding should consist of 300 mm of OPSS Granular A.

Backfill and cover for the culverts must satisfy structural requirements but as a minimum should be carried out with backfill similar to OPSD 3121.150.

Culvert backfill should consist of free-draining granular material conforming to OPSS Granular A, Granular B Type II or Granular B Type I specifications.

The backfill should be placed and compacted in simultaneous, equal lifts on both sides of the culvert. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501.

11.4 Lateral Earth Pressures

In general, earth pressures acting on the culvert walls may be assumed to impose a triangular distribution governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K(\gamma h + q)$$

where: P_h = horizontal pressure on the wall at depth h (kPa)
K = earth pressure coefficient
γ = bulk unit weight of retained soil (kN/m^3)

h = depth below top of fill where pressure is computed (m)
q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert are dependent on the material used as backfill. Recommended unfactored values are shown in the following table. As the design is based on a closed box culvert the walls will be braced at top and bottom and the at-rest coefficient should be used to assess the lateral earth pressures.

Table 11-2: Geotechnical Design Parameters for Lateral Earth Pressures

Parameter	Existing Embankment Fill	Silty Sand / Silt with Sand	Granular B Type I	Granular A and Granular B Type II
Soil Unit Weight (kN/m^3)	20.0	18.0	21.2	22.8
Angle of Internal Friction, ϕ'	30°	29°	32°	35°
Walls with Horizontal Backfill				
Coefficient of Earth Pressure At-Rest, K_o	0.50	0.52	0.47	0.43
Coefficient of Active Earth Pressure, K_a	0.33	0.35	0.31	0.27
Coefficient of Passive Earth Pressure, K_p	3.0	2.9	3.2	3.7

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or at a depth of 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

11.5 Embankment Design and Construction

Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS 206. The embankment material should consist of imported Granular A or B Type II material. Excavated granular fill may also be reused as backfill provided there is no organic matter within the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction.

The existing embankment is sloped at approximately 3H:1V and exhibits no signs of instability. Provided the subgrade is prepared as described in Section 11.1 and the embankment is reinstated as per the relevant OPSS requirements, embankment side slopes of 3H:1V or flatter should remain stable.

It is understood that the culvert will be replaced along the same alignment as the existing culvert and that the hydraulic opening does not change significantly from that of the existing culvert. Therefore, the proposed work will not result in any appreciable stress increase in the soil beneath the culvert and no significant settlement is anticipated provided the subgrade is protected from disturbance during construction.

11.6 Excavation

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The existing embankment fill is considered Type 3 soil as per the OHSA. For the purposes of the OHSA, the native silty sand to silt with sand below the water level are considered Type 4 soil.

Excavations for culvert replacement will typically be carried out through the existing embankment fill and extend into the underlying native soils and below the surface water and groundwater levels. Protection systems will be required to facilitate the proposed construction staging. Protection systems should be designed by a licensed Professional Engineer experienced in such designs and should be coordinated with the proposed dewatering and creek diversion methods. Earth pressure parameters are provided in Table 11-2. OPSS 539 “Construction Specifications for Protection Systems” must be referenced in the contract documents. It is recommended that Performance Level 2, as per Clause 539.04.02.01 (maximum horizontal displacement of 25 mm), be specified for this culvert replacement site. Due to the presence of the low SPT N-value silt and sand subgrade soils, sheet piles and steel H-piles should be driven into place and not vibrated.

11.7 Groundwater Control

It is expected that groundwater and surface water will accumulate in the excavations during culvert construction. Surface water and creek flow should be diverted away from the excavation through cofferdams and diversions. The groundwater level is expected to be largely governed by the water level in the creek and seasonal weather patterns. The Contractor must also make provisions to control any groundwater seepage, surface runoff and ponding by measures including the use of sump pumps and protection systems to maintain dry excavations during the course of construction (e.g. sheet piles and pumping from multiple sump pits or well points). Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Design of appropriate dewatering measures is the responsibility of the contractor.

An NSSP should be included in the contract alerting bidders to possible disturbance of the subgrade if the groundwater is not lowered prior to excavation. Suggested NSSP wording is provided in Appendix F.

11.8 Erosion Control

Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which surface water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic clay liner may be used as a clay seal.

12 CONSTRUCTION CONCERNS

The planned construction methodology includes staged construction with protection systems in order to maintain traffic flow across the culvert area. Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of excavation on the existing pavement surface. Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining the level of remedial action that is required.
- Implementation of an adequate and effective surface water management and dewatering plan to construct the replacement culvert and subgrade in the dry and to reduce the risk of disturbance of the subgrade.
- The base of excavations for the culverts will be within soils that are easily disturbed.
- Due to the presence of the low SPT N-value silt and sand subgrade soils, sheet piles and steel H-piles should be driven into place and not vibrated.
- Confirmation that the culvert backfill is adequately placed and compacted to specifications.

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

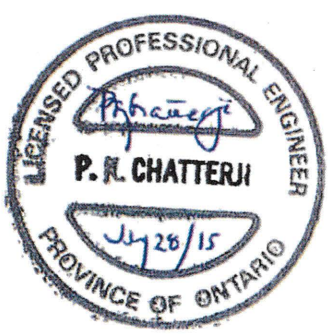
The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

13 CLOSURE

Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Paul Carnaffan, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

Paul Carnaffan, M.Eng., P.Eng.
Associate, Senior Geotechnical Engineer

Fred Griffiths, P.Eng.
Associate, Senior Geotechnical Engineer



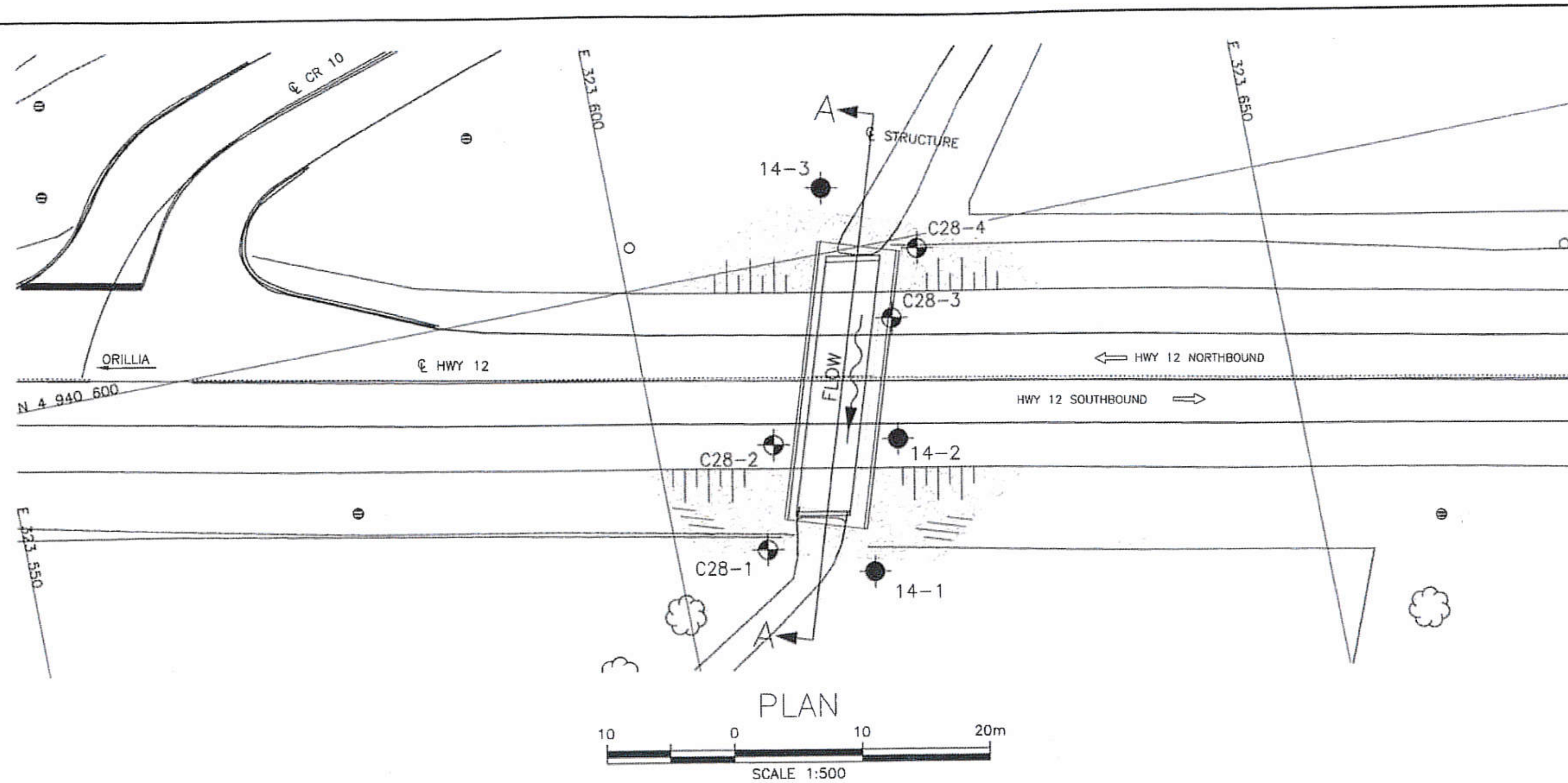
P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

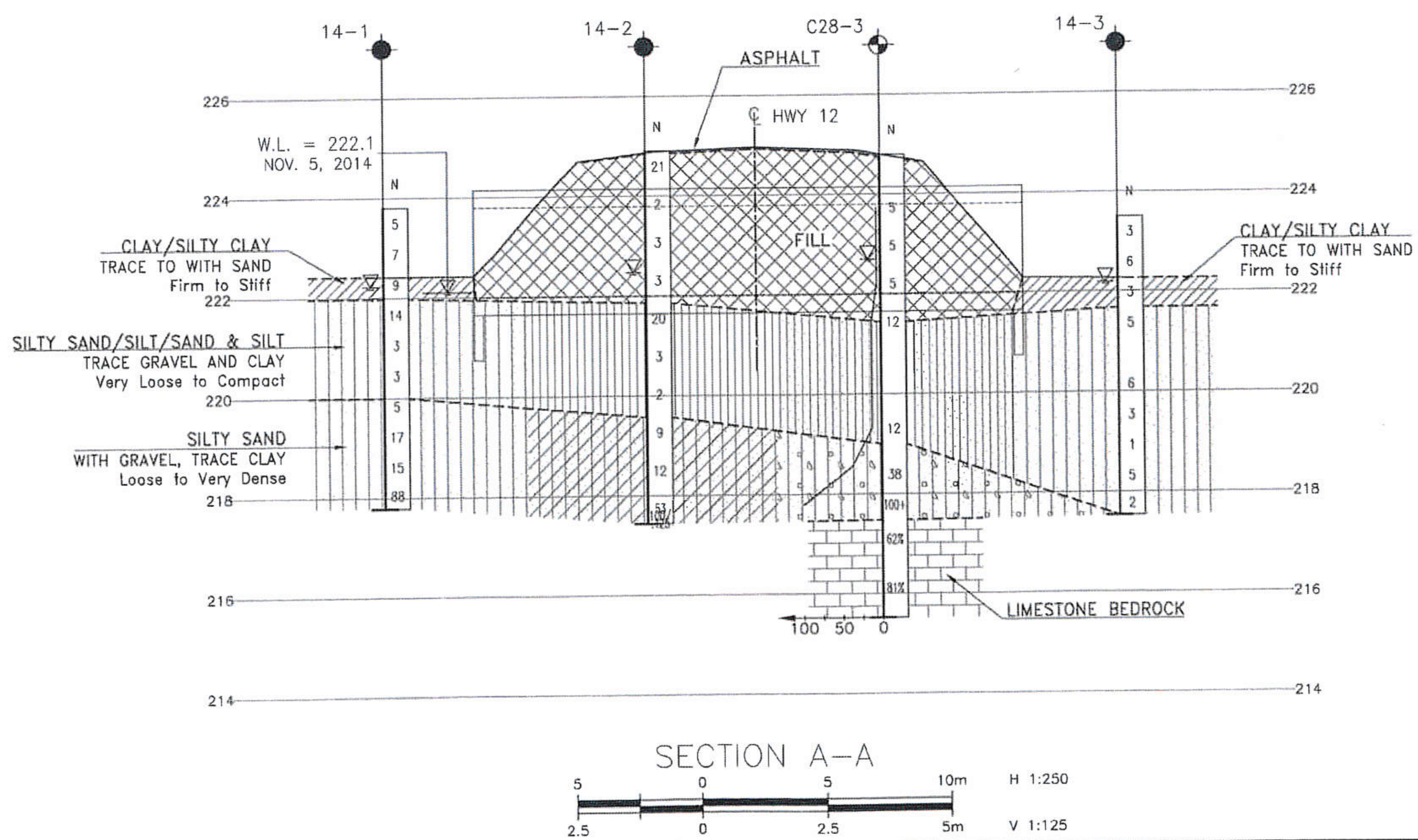
Appendix A

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN





CONT No

WP No 2183-13-00

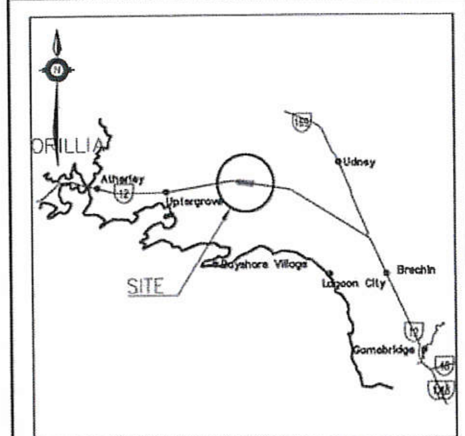
SHEET

HIGHWAY 12
CULVERT 30-676/C

BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole (Current Investigation)
⊕	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
14-1	223.8	4 940 574.7	323 614.9
14-2	224.9	4 940 584.6	323 618.7
14-3	223.5	4 940 605.1	323 616.5
C28-1	222.9	4 940 578.0	323 607.0
C28-2	224.7	4 940 586.0	323 609.0
C28-3	224.8	4 940 594.0	323 620.0
C28-4	224.0	4 940 599.0	323 623.0

-NOTES-

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

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31D-594

REVISIONS DATE	BY	DESCRIPTION			
DESIGN CM	CHK PC	CODE	LOAD	DATE JUL 2015	
DRAWN MFA	CHK PC	SITE	STRUCT	DWG 1	

FILENAME: H:\Drafting\18\3405\5\Ves4055-PlanAndProfile(Hwy12).dwg
PLOTDATE: 7/23/2015 12:19 PM

Appendix B

Record of Borehole Sheets

THURBER

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

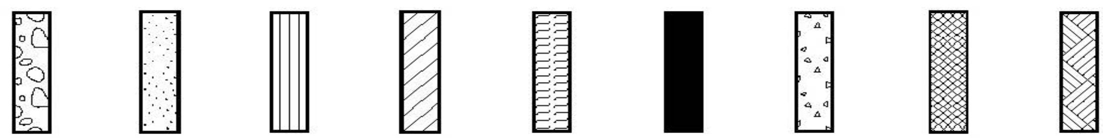
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an “A” size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

THURBER

STRATA PLOT:
Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

THURBER

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L= Liquid Limit

THURBER

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 14-1

METRIC

GWP# 2183-13-00 LOCATION Highway 12 & Mara Concession Road 10 N 4 940 574.7 E 323 614.9 ORIGINATED BY KMY

HWY 12 BOREHOLE TYPE Portable COMPILED BY KMY

DATUM Geodetic DATE 2014.10.06 - 2014.10.06 CHECKED BY PC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
223.8 / 0.0	**CLAY (CH)** with sand, firm to stiff, brown, dry	1	SS	5			0	23	54	23
		2	SS	7		223				
222.6 / 1.2	**SILTY CLAY (CI)** trace sand, stiff, brown, wet	3	SS	9	▽		0	6	55	39
222.0 / 1.8	**Silty SAND (SM)** trace gravel trace clay, very loose to compact, grey, saturated	4	SS	14		222	2	51	40	7
		5	SS	3		221				
		6	SS	3						
220.0 / 3.8	**Silty SAND (SM)** with gravel trace clay, loose to very dense, grey, saturated	7	SS	5		220				
		8	SS	17		219				
		9	SS	15			16	42	32	10
		10	SS	88		218				
217.8 / 6.0	END OF BOREHOLE At 6.0 m on inferred bedrock									

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 14-2

METRIC

GWP# 2183-13-00 | LOCATION Highway 12 & Mara Concession Road 10 N 4 940 584.6 E 323 618.7 | ORIGINATED BY KMY

HWY 12 | BOREHOLE TYPE Truck-Mount | COMPILED BY KMY

DATUM Geodetic | DATE 2014.10.07 - 2014.10.07 | CHECKED BY PC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
224.9					
0.0 / 0.1	**50 mm ASPHALT**				
	Silty sand with gravel, brown, dry, **FILL**	1	SS	21	20 55 25 (SI+CL)
		2	SS	2	
223.5 / 1.4	Silty clay with sand, brown, moist, some wood fragments, **FILL**	3	SS	3	2 20 54 24
		4	SS	3	
221.9 / 3.0	**SILT (ML)** with sand trace clay, very loose to compact, grey, saturated	5	SS	20	
		6	SS	3	0 23 73 4
		7	SS	2	
219.6 / 5.3	**Silty SAND** with gravel, compact to very dense, grey, wet	8	SS	9	
		9	SS	12	
		10	SS	53	30 36 26 8
217.4 / 7.5		11	SS	100/125mm	
	END OF BOREHOLE At 7.5 m on inferred bedrock				

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (224, 223, 222, 221, 220, 219, 218); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 14-3

METRIC

GWP# 2183-13-00 | LOCATION Highway 12 & Mara Concession Road 10 N 4 940 605.1 E 323 616.5 | ORIGINATED BY KMY

HWY 12 | BOREHOLE TYPE Portable | COMPILED BY KMY

DATUM Geodetic | DATE 2014.10.06 - 2014.10.06 | CHECKED BY PC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
223.5 / 0.0	**CLAY (CH)** with sand, firm to stiff, brown, dry		1	SS	3			
			2	SS	6		223	
222.3 / 1.2	**SILTY CLAY (CI)** trace sand, soft, brown, wet		3	SS	3	∇	222	
221.7 / 1.8	**Silty SAND (SM)** trace gravel trace clay, very loose to compact, grey, saturated		4	SS	5		221	
			5	SS	6		220	10 45 36 9
			6	SS	3			
			7	SS	1		219	
			8	SS	5		218	
			9	SS	2			
217.5 / 6.0	SPT blows for SS9 were 1, 1, 1 and 100 for 25 mm. END OF BOREHOLE At 6.0 m on inferred bedrock							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

+3, ×3: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Appendix C

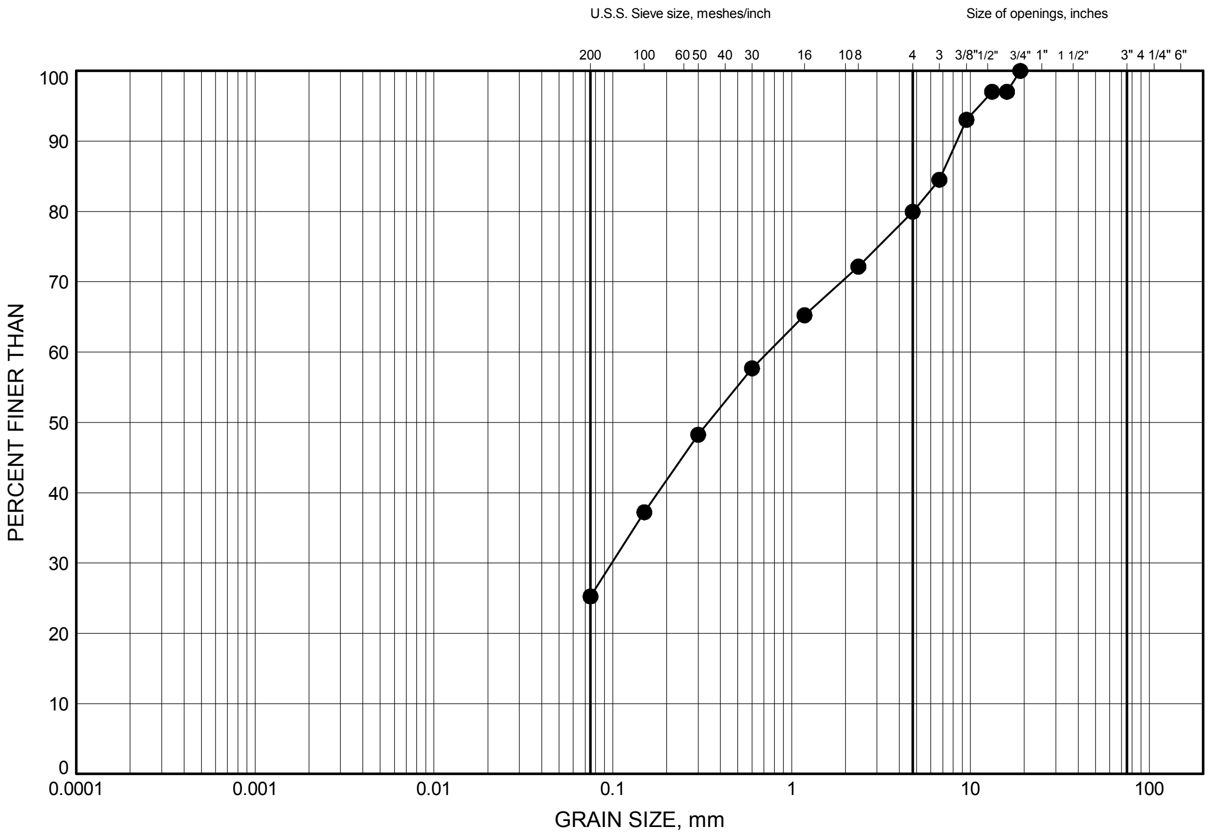
Laboratory Test Results

Highway 12 & Mara Concession Road 10

GRAIN SIZE DISTRIBUTION

FIGURE 1

FILL: Silty Sand with Gravel



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-2	0.30	224.59

Date January 2015

GWP# 2183-13-00

THURBER

Prep'd CM

Chkd. PC

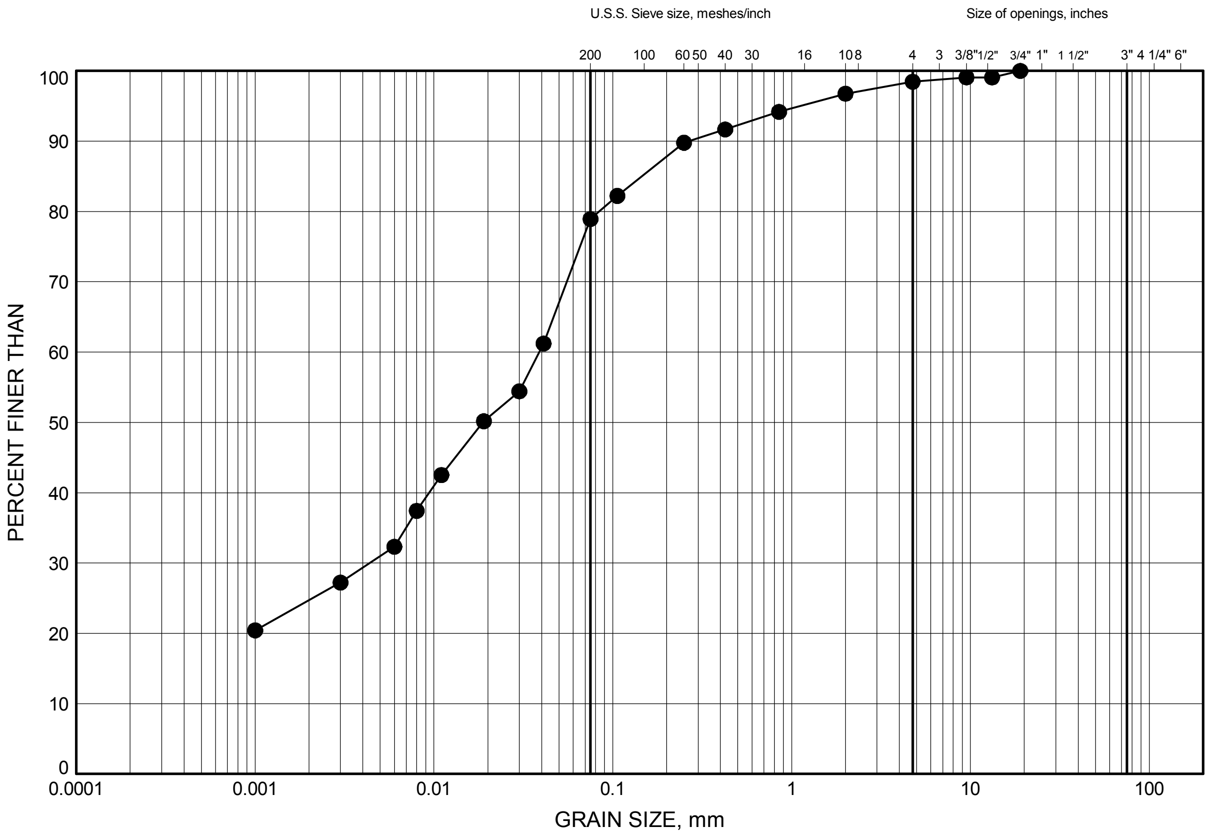
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 12 12112014.GPJ 13/1/15

Highway 12 & Mara Concession Road 10

GRAIN SIZE DISTRIBUTION

FIGURE 2

FILL: Silty Clay with Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-2	1.83	223.07

Date January 2015

GWP# 2183-13-00

THURBER

Prep'd CM

Chkd. PC

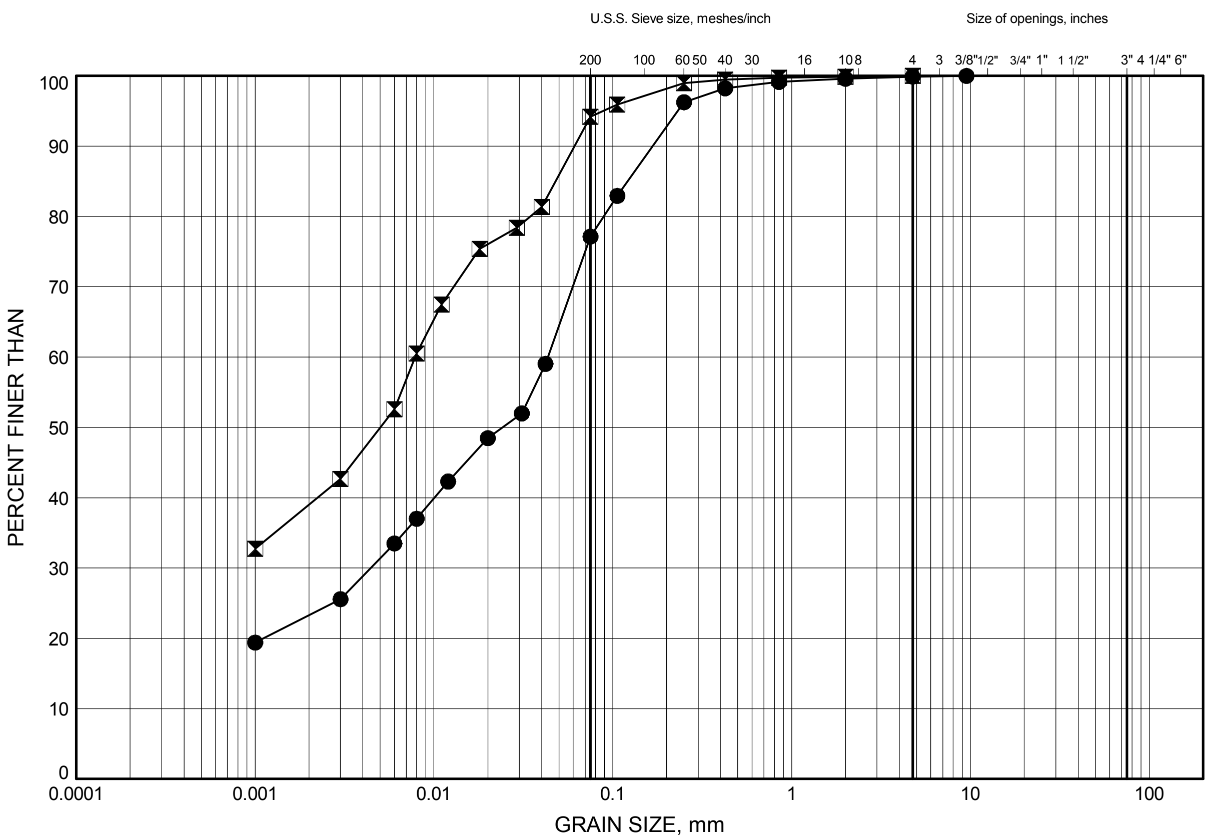
GRAIN SIZE DISTRIBUTION - THURBER 19-3405-5 HWY 12 12112014.GPJ 13/1/15

Highway 12 & Mara Concession Road 10

GRAIN SIZE DISTRIBUTION

FIGURE 3

Clay / Silty Clay



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-1	0.30	223.49
⧗	14-1	1.52	222.28

Date January 2015

GWP# 2183-13-00

THURBER

Prep'd CM

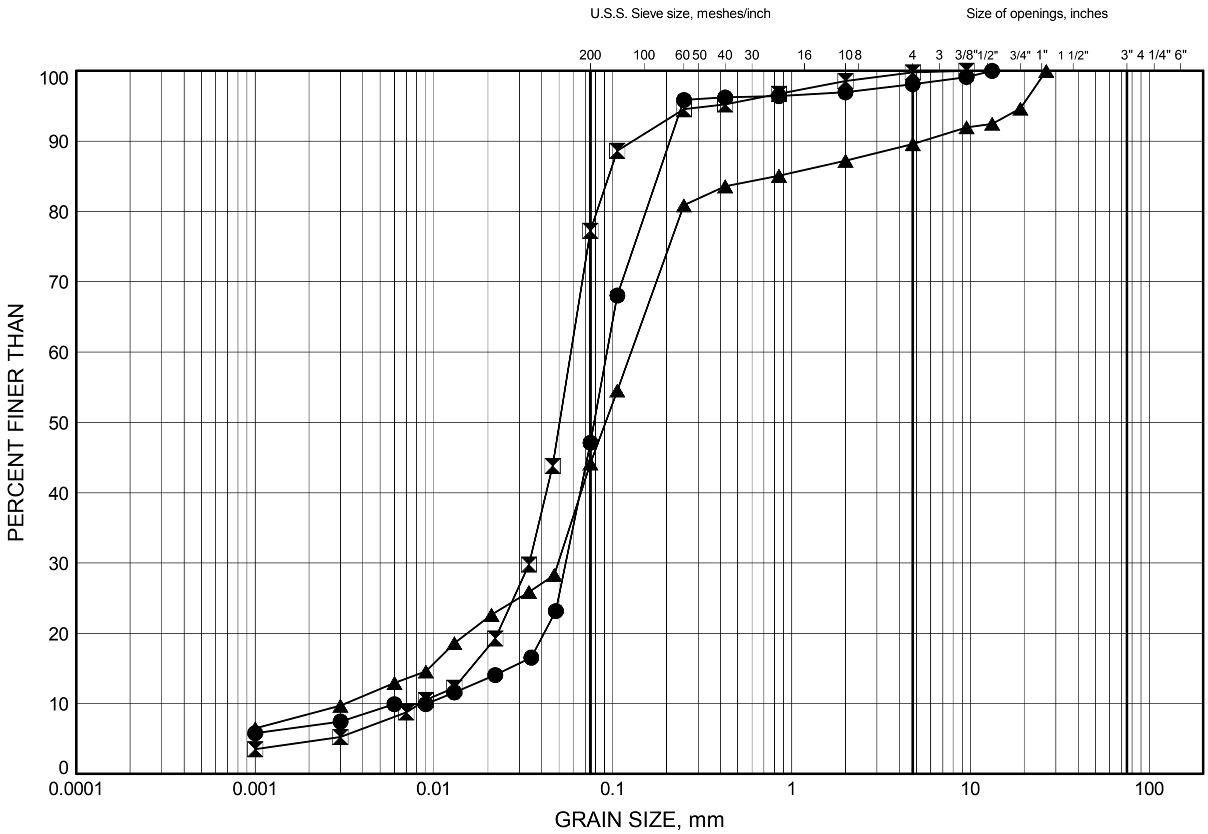
Chkd. PC

Highway 12 & Mara Concession Road 10

GRAIN SIZE DISTRIBUTION

FIGURE 4

Silty Sand / Silt with Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-1	2.13	221.67
⧗	14-2	4.11	220.78
▲	14-3	3.35	220.15

Date January 2015

GWP# 2183-13-00

THURBER

Prep'd CM

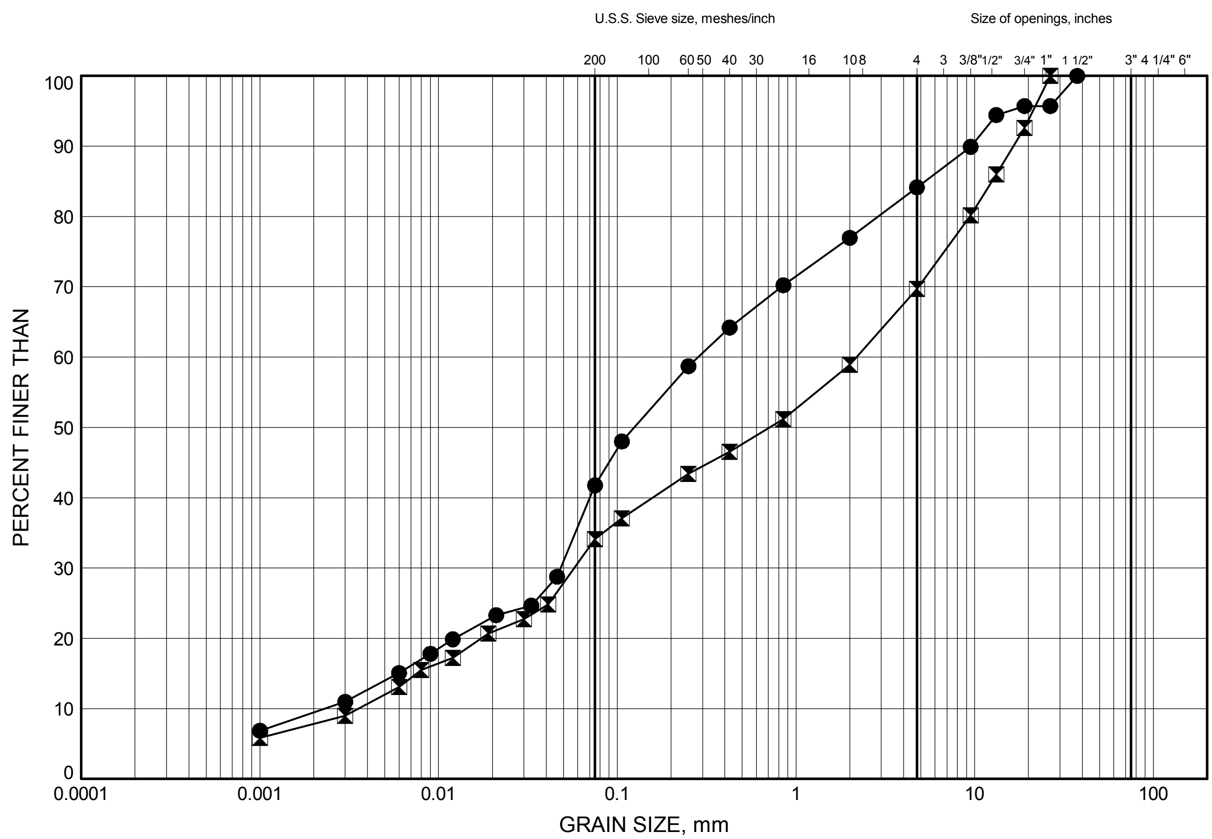
Chkd. PC

Highway 12 & Mara Concession Road 10

GRAIN SIZE DISTRIBUTION

FIGURE 5

Silty Sand with Gravel



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-1	5.18	218.62
⧗	14-2	7.16	217.74

Date January 2015

GWP# 2183-13-00

THURBER

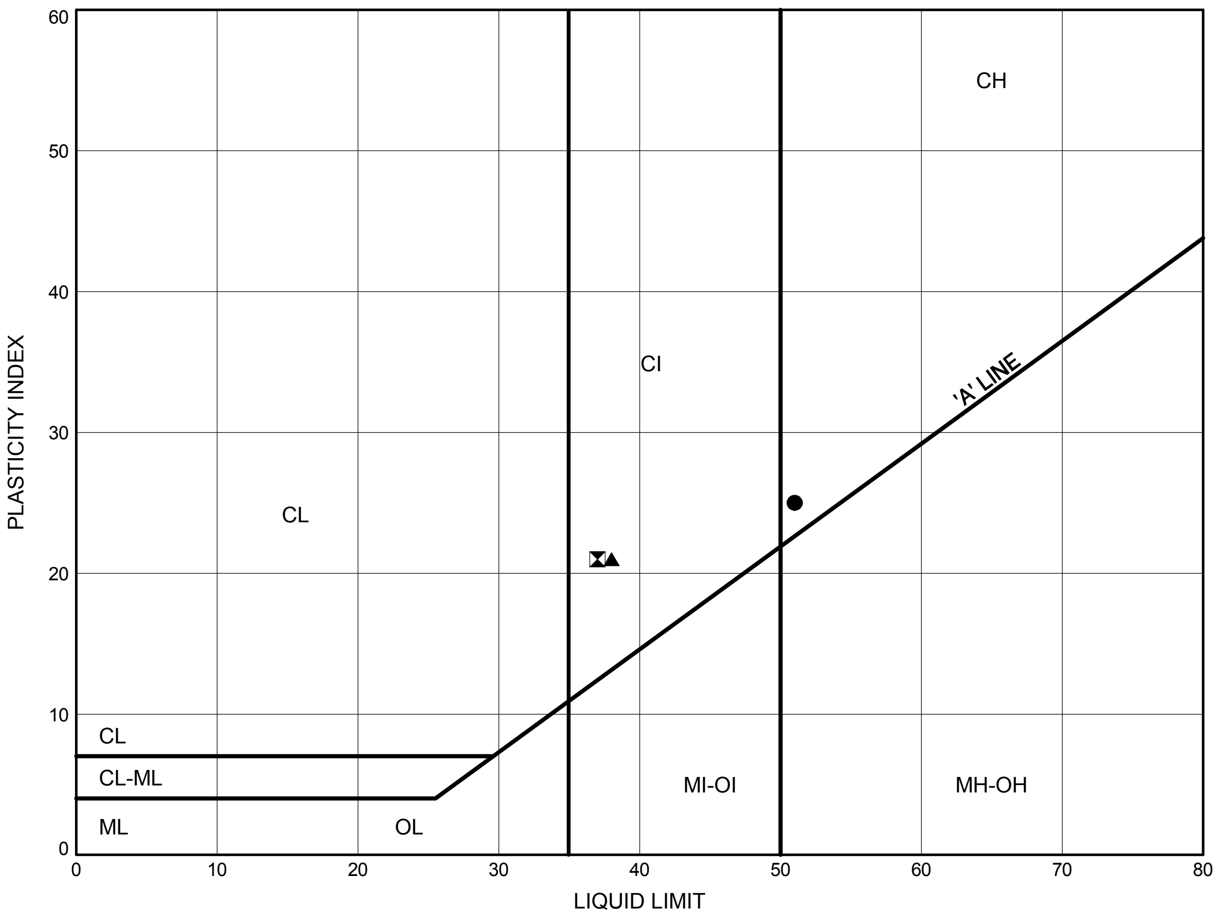
Prep'd CM

Chkd. PC

Highway 12 & Mara Concession Road 10

ATTERBERG LIMITS TEST RESULTS

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-1	0.30	223.49
⧗	14-1	1.52	222.28
▲	14-2	1.83	223.07

Date January 2015

GWP# 2183-13-00

THURBER

Prep'd CM

Chkd. PC

THURBALT 19-3405-5 HWY 12 12112014.GPJ 16/1/15

Appendix D

Selected Photographs of Culvert Location

Photo 1: Looking west at culvert alignment and intersection with Concession Rd 10.

Photo 2: North end – existing culvert outlet.

Appendix E

Existing GEOCRES Report

FOUNDATION INVESTIGATION REPORT

PROPOSED REHABILITATION OF
STRUCTURAL CULVERT SITE NO. 30-676/C
TOWNSHIP OF RAMA
HIGHWAY 12 FROM GAMEBRIDGE TO RAMA ROAD 25

W.P. 365-98-00
Agreement # 2004-E-0070

I.E.
Group

Geocres No.: 31D-488

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

FOUNDATION INVESTIGATION REPORT

PROPOSED REHABILITATION OF
STRUCTURAL CULVERT SITE NO. 30-676/C
TOWNSHIP OF RAMA
HIGHWAY 12 FROM GAMEBRIDGE TO RAMA ROAD 25

W.P. 365-98-00
Agreement # 2004-E-0070

Prepared for:
Morrison Hershfield Limited
Suite 600
255 Yorkland Blvd.
Toronto, Ontario M2J 1T1

Mr. Stanley Ma, Project Manager

Prepared by:

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

November 6, 2009

08-1-IEG6-30-676/C

Distribution:

5	Copies -	Morrison Hershfield Limited
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Geocres No.: 31D-488

TABLE OF CONTENTS

Drawings & Appendices

PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out in December 2008 and February 2009 by Infrastructure Engineering Group Inc. (IEG) on behalf of Morrison Hershfield Limited (Morrison Hershfield).

This assignment involves the rehabilitation of approximately 24 km of Highway 12, from Rama Road to Gamebridge. The original scope of the rehabilitation is based on addressing the immediate and short term deficiencies identified in the Ministry's Highway Assessment Report for W.O. #03-20019 (February 2005). The scope of work may include extension or replacement of seven (7) non-structural culverts and four (4) structural culverts.

Foundation investigation and recommendations are required for the design and construction of culvert replacements and/or extension as part of the improvement of Highway 12. Seven (7) non-structural culverts and four (4) structural culverts are to be investigated. The scope of work was subsequently changed to include rehabilitation/replacement of non-structural Culvert C03, and rehabilitation of structural Culvert C28, and no work to be done on structural Culverts C14, C15 and C25.

This report covers the site of Structural Culvert No. 30-676/C, also described as C28 in this report, and in the culvert summary as Culv 28.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes and, based on the findings, to provide geotechnical recommendations for the foundation elements.

Based on the information presented in the Preliminary Drawings provided by Morrison Hershfield, and verbal discussion with the project team, it is understood this culvert will be rehabilitated and will not be replaced. The rehabilitation will consist of concrete repairs and installation of tie-back anchors near the toe of the culvert walls.

Authorization to complete this assignment was given by Mr. Stanley Ma, P. Eng., of Morrison Hershfield, the TPM Consultant who is completing this assignment for MTO under Agreement # 2004-E-0070.

2.0 SITE DESCRIPTION

2.1 Site Location

The project alignment starts in Gamebridge, at Station 10+000 and extends northerly to approximately Station 19+200 just south of County Road 169, then extends north westerly to approximately Station 24+800 just before Side Road 15, then extends westerly to Station 34+000 just east of Rama Road 25. For the purpose of description, standard MTO conventional description will be used, i.e. a site north pointing in the direction of increasing chainage. When facing the direction of increasing chainage, the right hand side is referred to as east, and the left hand side is referred to as west. Any directions with clarifications in brackets (e.g., north-west) are given with reference to the true north direction.

Structure 30-676/C is located on Highway 12, approximately 16.5 km north of the south limit of this Contract at Gamebridge (Station 10+000), located at Station 26+514. Photographs of this culvert site are presented in Appendix "D". The Culvert Summary provided by Morrison Hershfield indicates that the existing structure is a reinforced concrete, rigid frame open footing culvert with a span of 3.66 m, a height of 1.8 m, a length of 20.6 m (3.66 m span by 1.53 m height in accordance with ETR Plate No. 205-12/55-0), with an overfill height of approximately 0.9 m. The culvert opening dimensions were obtained from the Culvert Summary provided by Morrison Hershfield and compared with the ETR drawings provided in the RFP.

This culvert is located within a drainage valley in which the stream easterly (northerly). The approach embankments were built on both the east and west sides of the culvert, with a maximum height of approximately 2.9 m. The embankment slopes are typically 3H:1V or flatter and are grass covered. No signs of embankment slope instability were observed at the time of this foundation investigation.

There are no headwalls for this culvert and the ends of the culvert protrude beyond the road embankment. The water levels were observed above the bottom of the creek, at an approximate Elevation of 222.6 m on December 17, 2008, likely reflecting a normal flow condition.

Photographs taken on March 1, 2002, as shown in Appendix B of the Highway Assessment Study Report indicate that water level was slightly lower than those observed during the field work.

2.2 Physiography and Topography

The project alignment except for the extreme western portion is located within the Simcoe Lowlands physiographic region (Chapman and Putnam, 1984). This area was previously flooded by glacial Lake Algonquin. The portion of the alignment located east of the Atherley Narrows (narrows between Lakes Couchiching and Simcoe) is comprised of an elevated, drumlinized till plain comprised primarily of undifferentiated sand to sandy silt (Chapman and Putnam, 1984). The character of local topography and soils in proximity to the highway corridor elsewhere are predominantly comprised of clay plain with interspersed elongated drumlins comprised of calcareous till (kame moraine) (Chapman and Putnam, 1984). There is a large patch of peat/muck located on the east shore of Lake Simcoe associated with several of the wetland features located along the lakeshore. There is also a section of Carden limestone plain located north of the Talbot River at the south end of the study area. This area is characterized as limestone overlaid with a very shallow overburden (Chapman and Putnam, 1984).

The topography of the study area is primarily flat with scattered drumlin features. The area slopes gently down towards Lake Simcoe. There are numerous headwater areas of small size that traverse the ROW of Highway 12. Movement of shallow ground water is confined by the tight till and clay soils and would follow surficial topography towards Lake Simcoe.

There are six provincially significant wetlands (PSW) located in part within the project alignment. From west to east, they include the Orillia Filtration Swamp, Victoria Point Wetland, Atherley Wetlands, Mud Lake Wetland, Barnstable Bay Wetland, and the Lagoon City Wetland.

The asphalt pavement surface over the existing culvert is near Elevation 224.9 m while the ground surface at the base of the embankment at the stream bed is at approximate Elevation 221.9 m.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

Between December 3, 2008 and February 18, 2009, a CME 55 truck-mounted drill rig was supplied by London Soil Test Ltd. and used on site for drilling and Standard Penetration Testing (SPT, following the procedures of ASTM D 1586). Two (2) boreholes (Boreholes C28-2 and C28-3) were drilled and sampled to obtain data for foundation design of the proposed rehabilitation work and potential culvert replacement. Rock coring was carried out on February 18, 2009 in Borehole C28-3 to provide geotechnical data as per the requirements of our proposal for this work. Hand-drilled boreholes cannot be completed at the location of Borehole C28-1 and C28-4 due to inundation of the area, and a series of dynamic cone penetration tests were carried out instead. The locations of the boreholes are shown on Drawing 1.

The culvert borehole numbering system was established from the Culvert Summary spreadsheet provided by Morrison Hershfield. The subject Culvert was identified as Culv 28, with a Structure Number 30-676/C as presented in the Culvert Summary. The boreholes for this culvert are numbered C28-1 to C28-4 accordingly.

The boreholes were numbered C28-1 to 28-4 for the subject culvert and the depths of sampling were as follows:

Borehole No.	Depth of Sampling (m)
C28-1 (DCP only)	3.76
C28-2	7.32
C28-3 (with rock coring)	9.27
C28-4 (DCP only)	4.39

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

The undrained shear strength was obtained by shear vane test, with the sensitivity measured. Field pocket penetrometer was used on the retrieved SPT samples, where applicable, to determine the undrained shear strength of the cohesive soil deposits. These undrained shear strengths are used to supplement the properties of the cohesive soils. It is noted that the measured shear strength value on the retrieved SPT samples would be slightly lower than the actual value due to sampling disturbance.

Rock cores were retrieved using NQ core assembly (47.6 mm ID). The rock core samples were identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock cores were placed in wooden core boxes and transported to our laboratory for further examination, to confirm the field logging, and laboratory testing.

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

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

The stations, offsets and ground surface elevations at the as drilled borehole locations were provided by Morrison Hershfield to IEG for the purpose of this report.

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

3.2 Laboratory Analysis

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

A section of the rock core (at 8.47 m depth from Borehole C28-3) was selected for unconfined compressive strength testing in accordance with ASTM 2938. The testing was performed by Trow Associates Inc. of Brampton and the results are presented as Figure 8 in Appendix B.

The results of the laboratory testing are presented on the Record of Borehole sheets (Appendix “A”), and Laboratory Test Results (Figures 1 to 8, Appendix “B”).

4.0 SUBSURFACE CONDITIONS

4.1 General Subsurface Conditions

Reference is made to the Record of Borehole sheets (Appendix “A”) and Laboratory Test Results (Appendix “B”) for detailed subsurface soil and groundwater conditions encountered in the boreholes. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, consequently, represent transitions between soil types rather than exact planes of geological change. The soil profiles depicting the subsurface conditions on Drawings 1 and 2 will vary between and beyond the borehole locations.

In general, the subsurface deposits at the site consist of loose embankment fill, placed on very soft silty clay or loose to compact sand and silt to sandy silt deposits to depths of 5.03 m (Elevation 219.71 m at Borehole C28-2) and 5.79 m (Elevation 219.00 m at Borehole C28-3). These very soft/loose to compact deposits were underlain by a compact to very dense silty sand stratum to depths of 7.32 m (Elevation 217.42 m at Borehole C28-2) and 7.32 m (Elevation 217.47 m at Borehole C28-3). The silty sand was further underlain by limestone bedrock.

4.1.1 Pavement, Fill

Boreholes C28-2 and C28-3, located at the edge of existing pavement in the shoulder areas, encountered 360 mm shoulder gravel. Underlying the shoulder gravel is the embankment fill material that extended and to depths of 3.05 to 3.35 m, respective Elevations of 221.69 m and 221.44 m at Boreholes C28-2 and C28-3. The fill beneath the shoulder gravel consists of a mixture of silt, sand and gravel with cobbles and silty clay lumps.

Two (2) grain size distribution analyses of the embankment fill is shown on Figure 1 of Appendix “B”. The results of an Atterberg Limit test are provided in Figure 2.

Standard penetration tests yielded “N”-values from 4 to 12 blows per 0.3 m. This fill is brown to dark brown in colour and the measured natural moisture contents range from 10 to 42%. The higher moisture contents reflect the presence of organic matters and clay lumps. Based on one sample, the unit weight of the fill was measured to be 22.1 kN/m^3.

Based on the above field and laboratory test results, together with visual and tactile examination, the fill beneath the shoulder gravel consists of a mixture of silt, sand and gravel with cobbles and silty clay lumps and has a loose to compact compactness condition.

4.1.2 Silty Clay

A 0.76 m thick layer of brown to grey silty clay was contacted below the embankment fill at Borehole C28-2 and extended to a depths of 3.81 m below the existing ground surface (at Elevations 220.93 m). The silty clay also contains organic inclusions.

A single grain size analysis was performed and the results are presented on Figure 3 of Appendix "B". The same sample was tested for Atterberg Limits and the results in Figure 4 of Appendix "B" and summarized below:

Liquid Limit (W_L)	25%
Plastic Limit (W_P)	14%
Plasticity Index (I_p)	11%
Natural Moisture Content (W)	49%

A standard penetration test yielded an "N"-value of 1 blow per 0.3 m. The low N-value could also be attributed by disturbance from the drilling operations. Based on the above field and laboratory test results, together with visual and tactile examination, the silty clay deposit is considered to have a very soft consistency and can be classified as a clay of low plasticity (CL).

4.1.3 Sand and Silt

The silty clay at Borehole C28-2 and the embankment fill at C28-3 were underlain by a sand and silt deposit that extended to depths of 5.03 to 5.79 m, at Elevations of 219.71 m and 219.00 m in Boreholes C28-2 and C28-3, respectively.

Three (3) grain size analyses were performed and the results are presented on Figure 5 of Appendix "B". One (1) sample was tested and exhibited the following Atterberg Limits. These results are shown in Figure 6 and summarized below:

CL-ML, Sample at 5.33 m from Borehole C28-3

Liquid Limit (W_L)	16%
Plastic Limit (W_P)	10%
Plasticity Index (I_p)	6%
Natural Moisture Content (W)	9%

The natural moisture contents were in the range of 9 to 24%, indicative of wet to saturated moisture condition. The results of the grain size and Atterberg Limit tests indicate that the sand and silt is generally non-plastic to slightly plastic and can be classified as a SM-ML material with occasional clayey pockets (CL-ML).

Standard penetration tests yielded “N”-values between 2 and 12 blows per 0.3 m, indicative of very loose to compact compactness condition.

4.1.4 Silty Sand (Till-like)

The sand and silt to sandy silt were underlain by a silty sand deposit which has a till-like structure.

A single grain size analysis was performed and the results are presented on Figure 7 of Appendix “B”.

The natural moisture contents of the silty sand were in the range of 8 to 16%, indicative of damp to moist moisture condition. Standard penetration tests yielded “N”-values 20 and over 100 blows per 0.3 m. Based on the above field and laboratory test results, together with visual and tactile examination, the silty sand till-like deposit exhibited a compact to very dense compactness condition.

4.1.5 Limestone Bedrock

The silty sand till-like stratum was further underlain by a grey to tan limestone bedrock at depths of 7.32 m (Elevation 217.42 m at Borehole C28-2) and 7.32 m (Elevation 217.47 m at Borehole C28-3). The appearance of the rock core sample is fossiliferous with sections that are coralliferous, with close to wide bedding planes.

Recovery of the rock core sample was at 100%. Rock Quality Designation (RQD) varied from 62 to 81%, indicative of a fair to good quality.

A single uniaxial compressive strength determination carried out on a section of rock core samples yielded a result of 128 MPa. The uniaxial compressive strength test report is presented in Figure 8.

4.2 Groundwater Conditions

The groundwater condition was monitored during and upon completion of sampling. On completion of drilling, groundwater was observed in Boreholes C28-2 and C28-3 at depths of 2.3 and 2.1 m, corresponding to Elevations 222.44 and 222.69 m.

The water levels were observed above the bottom of the creek, at an approximate Elevation of 222.6 m on December 17, 2008, likely reflecting a normal flow condition.

Photographs taken on March 1, 2002, as shown in Appendix B of the Highway Assessment Study Report indicate that water level was slightly lower than those observed during the field work.

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

5.0 STATEMENT OF LIMITATION

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

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

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

Yours truly,
Infrastructure Engineering Group Inc.

LICENSED PROFESSIONAL ENGINEER
E.Y. CHUNG
8345506
Nov 6, 09
PROVINCE OF ONTARIO

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

Joseph Law, P.Eng.
Project Manager

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

LICENSED PROFESSIONAL ENGINEER
J.L.
J. C-Y. LAW
NOV. 6/09
PROVINCE OF ONTARIO

Drawings 1 & 2

Borehole Locations

And

Soil Strata

MINISTRY OF TRANSPORTATION, ONTARIO

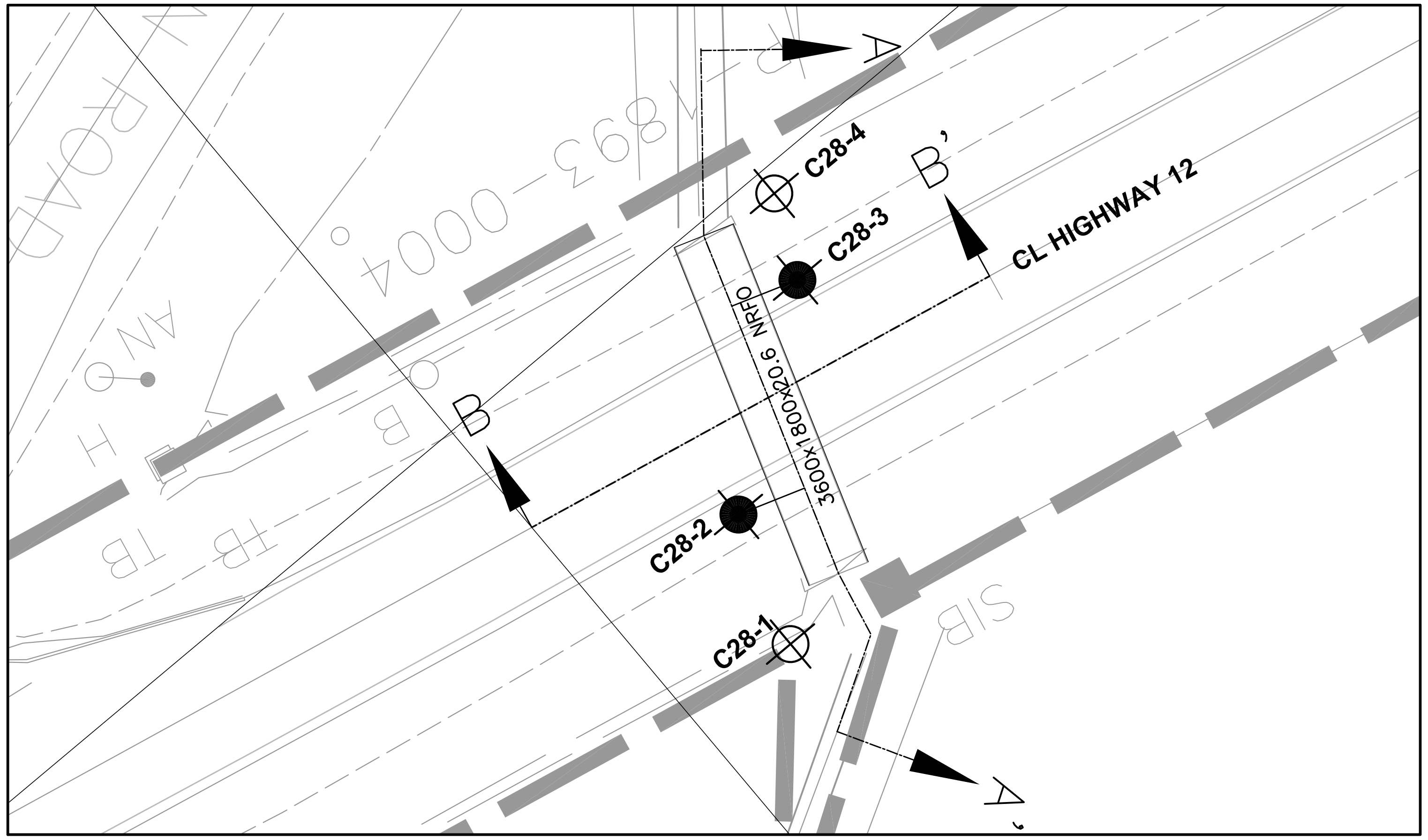
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No xxxx–xxxx
WP No GWP 365–98–00

Structural Culvert 30–676/C
Highway 12
BOREHOLE LOCATION PLAN & PROFILE

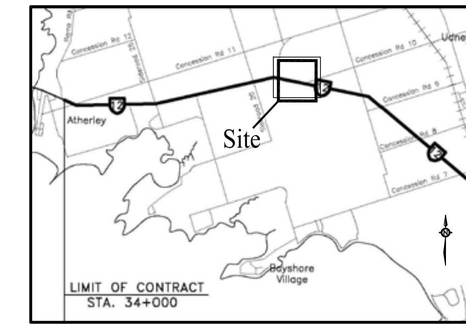
SHEET 1

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



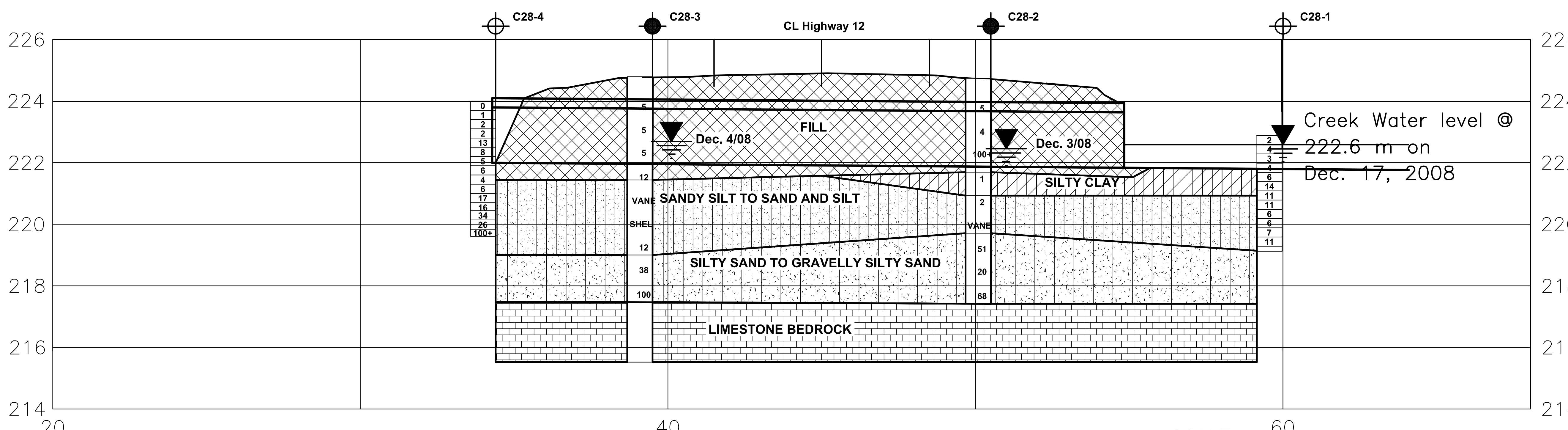
BOREHOLE LOCATION PLAN

KEYPLAN NTS



LEGEND

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



SECTION A-A' - CENTERLINE OF CULVERT

SCALE
5m 0 2m
Horizontal and Vertical

REVISIONS		
05/09/09	J.L.	Final Report
18/05/09	J.L.	Draft
DATE	BY	DISCRIPTION

NOTES

1. THE COMPLETE FOUNDATION INVESTIGATION AND DESIGN REPORT FOR THIS PROJECT AND OTHER RELATED DOCUMENTS MAY BE EXAMINED AT THE ENGINEERING MATERIALS OFFICE, DOWNSVIEW. INFORMATION CONTAINED IN THIS REPORT AND RELATED DOCUMENTS ARE SPECIFICALLY EXCLUDED IN ACCORDANCE WITH THE CONDITIONS OF SECTION GC2.01 of OPS GEN. COND.
2. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BOREHOLE LOCATIONS. BETWEEN BOREHOLES AND BOUNDARIES ARE ASSUMED FROM GEOLOGICAL EVIDENCE.
3. SUBGRADE ELEVATION OF THE EXISTING FOOTING NOT KNOWN AND IS ESTIMATED TO BE AT 1.6m BELOW THE CREEK BED.
4. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

BOREHOLE NO.	ELEVATION	UTM CO–ORDINATES NORTH	UTM CO–ORDINATES EAST
C28–1	222.44	4940578	323607
C28–2	224.74	4940586	323609
C28–3	224.79	4940594	323620
C28–4	223.99	4940599	323623

Geocres : 31D–488

HWY No. HWY 12			DIST CENTRAL
SUBM'D J.L.	CHECKED E.C.	DATE 25/03/09	SITE 30–676/C
DRAWN J.L.	CHECKED J.L.	APPROVED E.C.	DWG 1

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

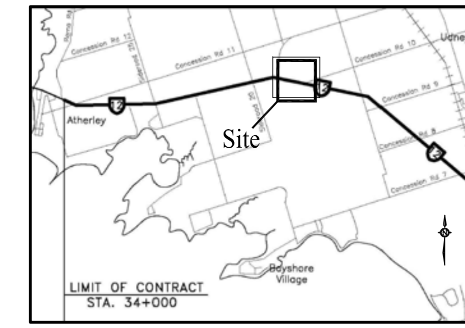
CONT No xxxx–xxxx
WP No GWP 365–98–00

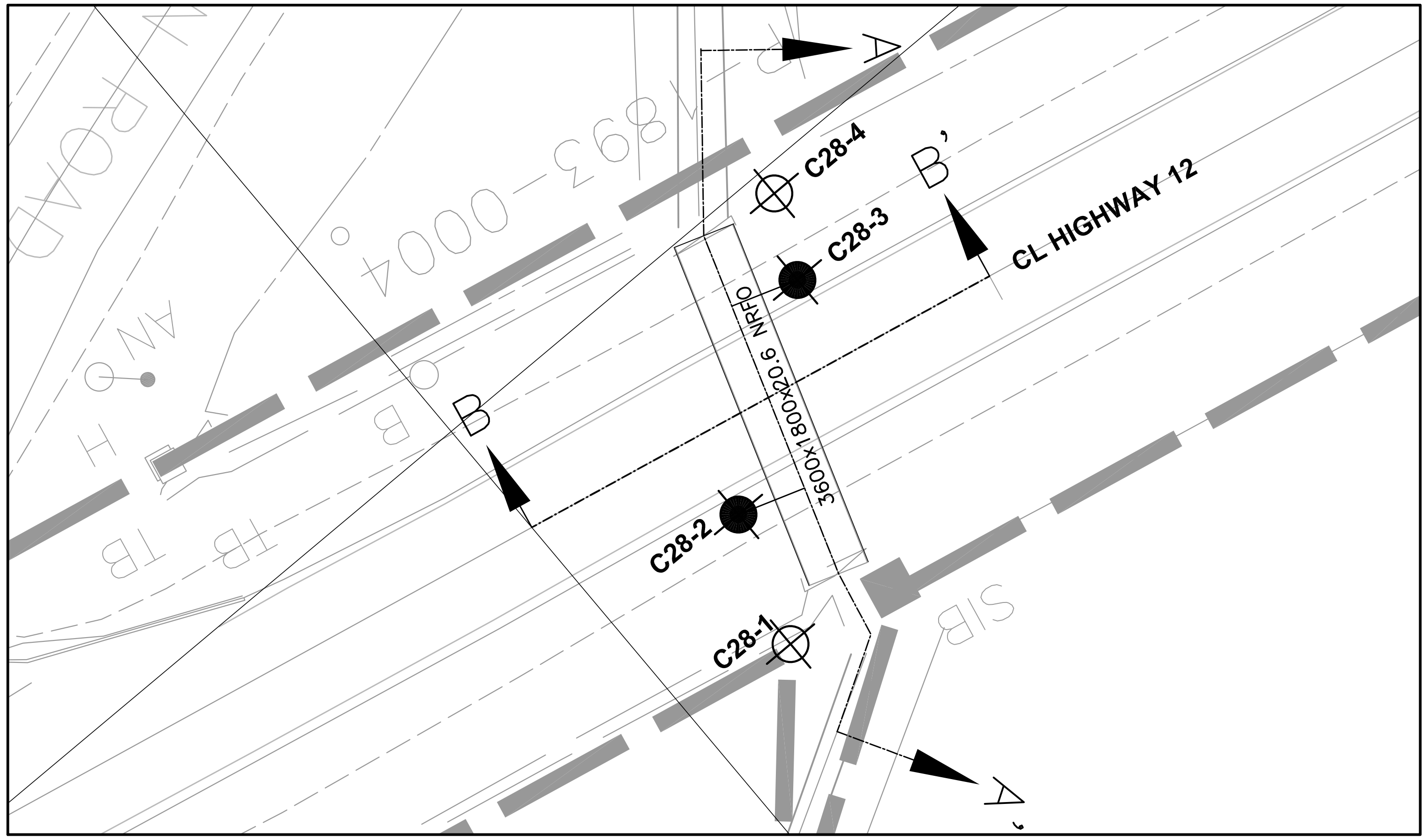
Structural Culvert 30–676/C
Highway 12
BOREHOLE LOCATION PLAN & PROFILE

SHEET 2

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

KEYPLAN NTS



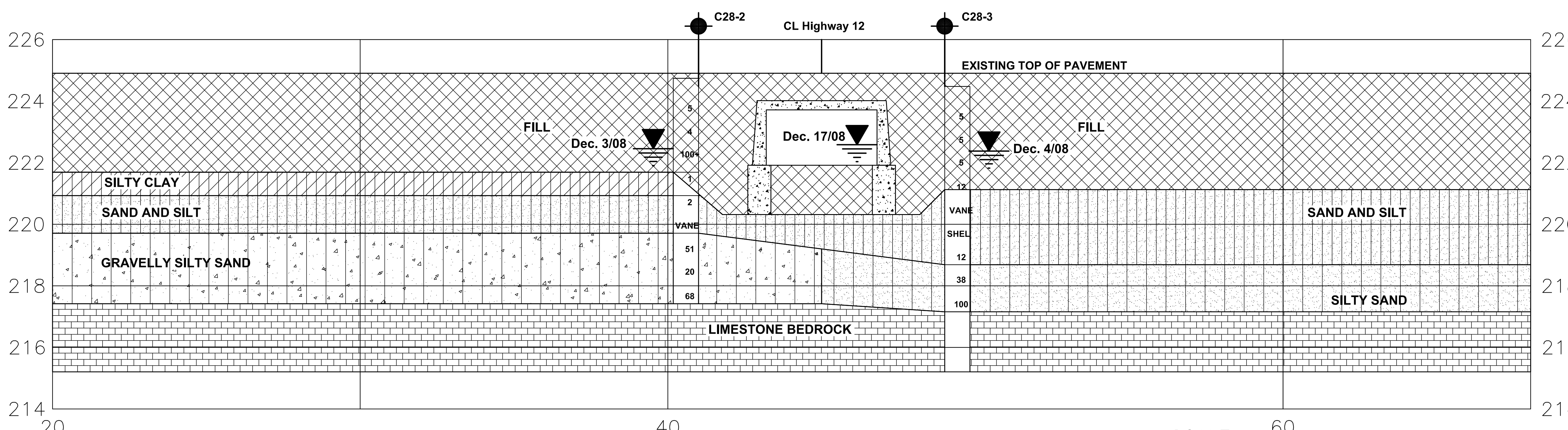


SCALE
20m 0 10m

BOREHOLE LOCATION PLAN

LEGEND

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



SECTION B-B' - CENTERLINE OF CULVERT

SCALE
5m 0 2m
Horizontal and Vertical

NOTES

1. THE COMPLETE FOUNDATION INVESTIGATION AND DESIGN REPORT FOR THIS PROJECT AND OTHER RELATED DOCUMENTS MAY BE EXAMINED AT THE ENGINEERING MATERIALS OFFICE, DOWNSVIEW. INFORMATION CONTAINED IN THIS REPORT AND RELATED DOCUMENTS ARE SPECIFICALLY EXCLUDED IN ACCORDANCE WITH THE CONDITIONS OF SECTION GC2.01 of OPS GEN. COND.
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3. SUBGRADE ELEVATION OF THE EXISTING FOOTING NOT KNOWN AND IS ESTIMATED TO BE AT 1.6m BELOW THE CREEK BED.
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BOREHOLE NO.	ELEVATION	UTM CO-ORDINATES NORTH	EAST
C28–1	222.44	4940578	323607
C28–2	224.74	4940586	323609
C28–3	224.79	4940594	323620
C28–4	223.99	4940599	323623

REVISIONS DATE	BY	DISCRIPTION
05/09/09	J.L.	Final Report

Geocres : 31D–488

HWY No. HWY 12			DIST CENTRAL
SUBM'D J.L.	CHECKED E.C.	DATE 05/09/09	SITE 30–676/C
DRAWN J.L.	CHECKED J.L.	APPROVED E.C.	DWG 2

Appendix A

Explanation of Terms Used in Report

Record of Borehole Sheet

Boreholes C28-1 TO C28-4

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

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

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

RECORD OF BOREHOLE No C28-1

METRIC

W.P. WP 365-98-00	LOCATION Northing - 4940578, Easting - 323607	ORIGINATED BY RB
DIST Central Region HWY Highway 12	BOREHOLE TYPE Dynamic Cone	COMPILED BY JL
DATUM Geodetic	DATE 12.17.08 - 12.17.08	CHECKED BY EC

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE (STANDARD ● DYN. CONE) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.89	Ground										
0.00						∇	222, 221, 220				31.75 Kg (70lbs.) hammer used for driving dynamic cone. Nc values corrected for standard 63 kg (140 lbs.) hammer. W.L. @ 0.3m @ completion.
219.13 / 3.76	End of Borehole.										Dynamic Cone refusal @ 3.76 m on confirming stratum.

+ 3, × 3: Numbers refer to Sensitivity

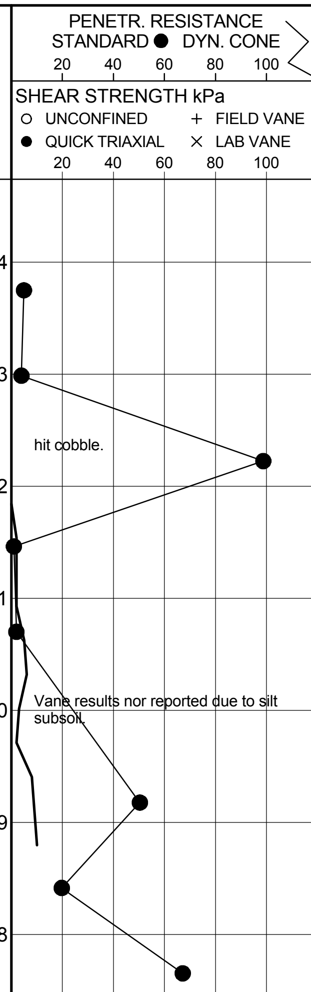
○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No C28-2

METRIC

W.P. WP 365-98-00	LOCATION Northing - 4940586, Easting - 323609		ORIGINATED BY RB
DIST Central Region HWY Highway 12	BOREHOLE TYPE S/S Augering 110 mm Dia.		COMPILED BY JL
DATUM Geodetic	DATE 12.03.08 - 12.03.08		CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
224.74	Ground								
0.00 / 224.38 / 0.36	360 mm Shoulder GRAVEL	1	GRAB						18 51 20 11 (31)
						224			
	FILL Dark brown to brown, damp to wet, loose, consisting of silty clay, sand, some organics, occasional cobbles or concrete pieces.	2	SPT	5					
		3	SPT	4		223			
					∇				
		4	SPT	100+					W.L. @ 2.3m @ completion of drilling.
221.69 / 3.05						222			
220.93 / 3.81	Silty CLAY, CL Brown to grey, wet, very soft, with organic inclusions.	5	SPT	1			49		1 40 39 20 (60)
						221			
	SAND & SILT, SM-ML Grey, saturated, loose to very loose, slight plasticity.	6	SPT	2					0 43 51 6 (57)
219.71 / 5.03		7	VANE			220			
	Gravelly Silty SAND, SW-SM Grey, damp, to moist, compact to very dense, trace clay, till like.	8	SPT	51				28.1	
						219			
		9	SPT	20					
						218			
217.42 / 7.32		10	SPT	68					31 44 20 6 (26)
	End of Borehole								Auger refusal @ 7.32 m on presumed bedrock.



PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

+3, ×3: Numbers refer to Sensitivity ○150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

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Foundation Design

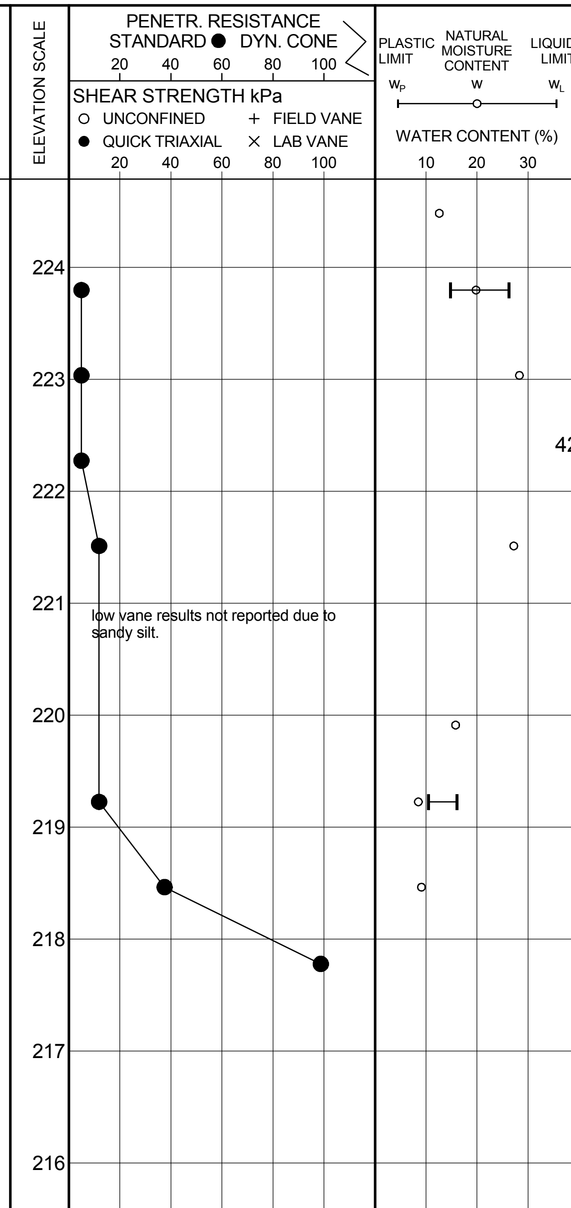
RECORD OF BOREHOLE No C28-3

METRIC

W.P.	WP 365-98-00	LOCATION	Northing - 4940594, Easting - 323620	ORIGINATED BY	RB
DIST	Central Region HWY Highway 12	BOREHOLE TYPE	H/S Augering 110 mm Dia.	COMPILED BY	JL
DATUM	Geodetic	DATE	12.04.08 - 12.18.08	CHECKED BY	EC

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
224.79	Ground						
0.00 / 224.43 / 0.36	360 mm Shoulder GRAVEL	1	GRAB				
	FILL Dark brown to brown, wet, loose to compact, consisting of mixed silty clay, sand and gravel, some organics.	2	SPT	5			31 33 26 9 (36)
		3	SPT	5	▽	22.1	
		4	SPT	5			W.L. @ 2.1m @ completion of drilling.
221.44 / 3.35		5	SPT	12			
	SAND & SILT, SM-ML Grey, wet to saturated, loose to compact, slight plasticity, occasional clayey silt pocket with trace gravel.	6	VANE				
		7	SH				0 30 67 3 (70)
	clayey pocket	8	SPT	12			14 42 31 14 (45)
219.00 / 5.79	Silty SAND, SM Grey, wet, dense to very dense, some gravel, slight plasticity, till like.	9	SPT	38			
		10	SPT	100+			
217.47 / 7.32	LIMESTONE BEDROCK Tan to grey, fossiliferous, very strong, fair to good quality, close to wide bedding plane.	11	CORE	NQWL			Rock core with NQ wireline. Recovery - 100%, RQD - 62%
		12	CORE	NQWL			Recovery - 100%, RQD - 81% Uniaxial Compressive Strength = 128.6 MPa
215.52 / 9.27	End of Borehole						



+³, ×³: Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

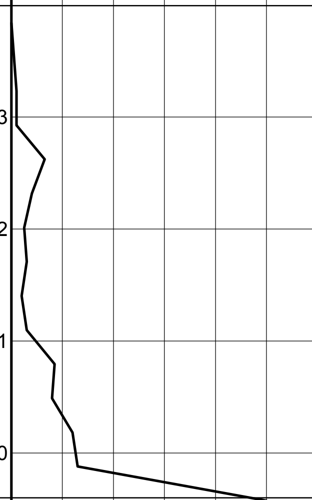
RECORD OF BOREHOLE No C28-4

METRIC

W.P. WP 365-98-00 | LOCATION Northing - 4940599, Easting - 323623 | ORIGINATED BY RB

DIST Central Region HWY Highway 12 | BOREHOLE TYPE Dynamic Cone | COMPILED BY JL

DATUM Geodetic | DATE 02.18.09 - 02.18.09 | CHECKED BY EC

SOIL PROFILE		SAMPLES						PENETR. RESISTANCE / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	STANDARD ● DYN. CONE 20 40 60 80 100; ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	w_P w w_L; WATER CONTENT (%) 10 20 30	γ kN/m³	GR SA SI CL
223.99	Ground										
0.00							223, 222, 221, 220				31.75 Kg (70lbs.) hammer used for driving dynamic cone. Nc values corrected for standard 63 kg (140 lbs.) hammer.
219.60 / 4.39	End of borehole.										Dynamic cone refusal @ 4.39 m on presumed bedrock.

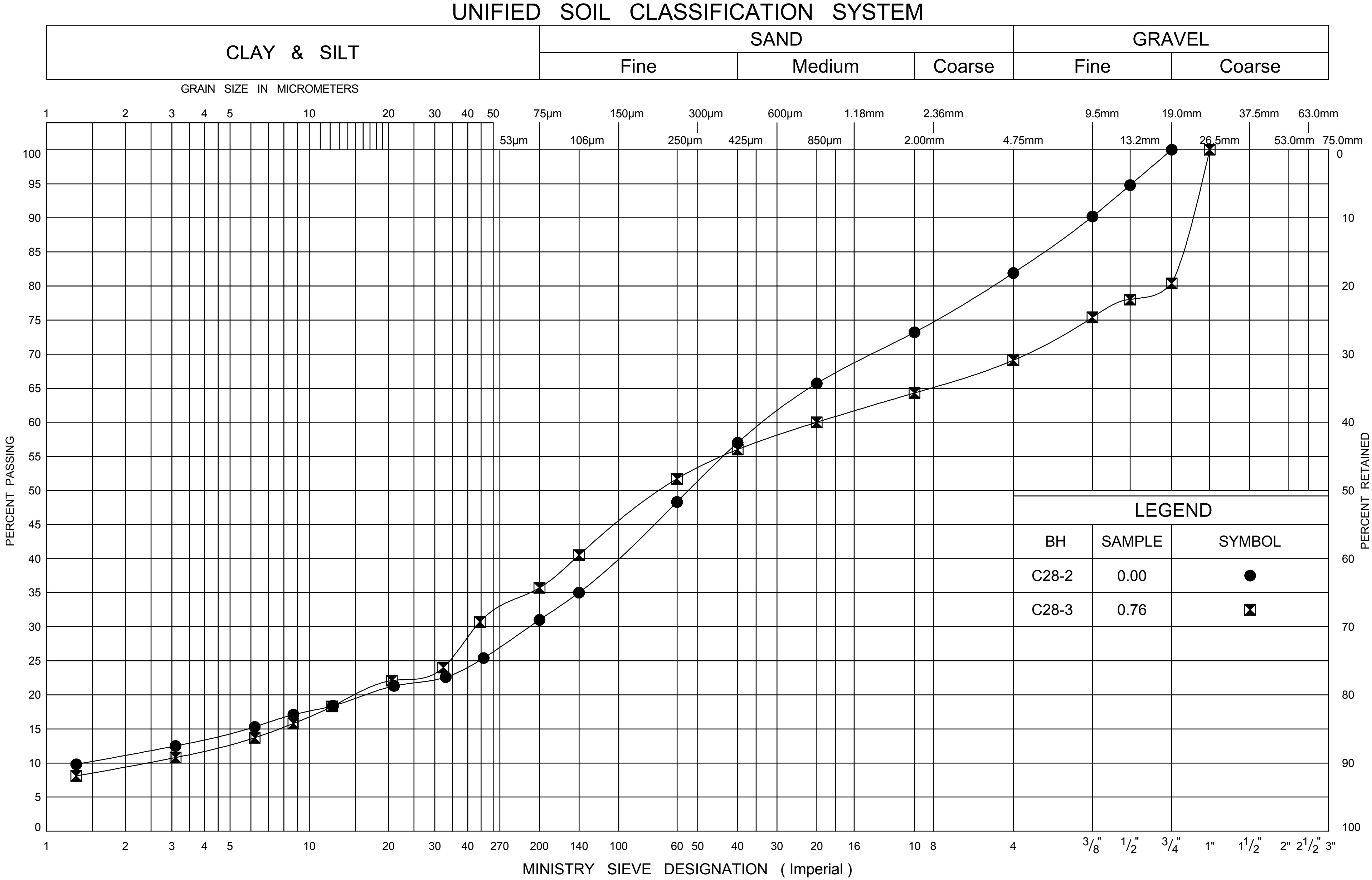
$+^{3}, \times^{3}$: Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

Appendix B

Laboratory Test Results

Grain Size Distribution	Figures 1, 3, 5 and 7
Plasticity Chart	Figures 2, 4 and 6
Rock Core Report	Figure 8



BH	SAMPLE	SYMBOL
C28-2	0.00	●
C28-3	0.76	⧗

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GRAIN SIZE DISTRIBUTION

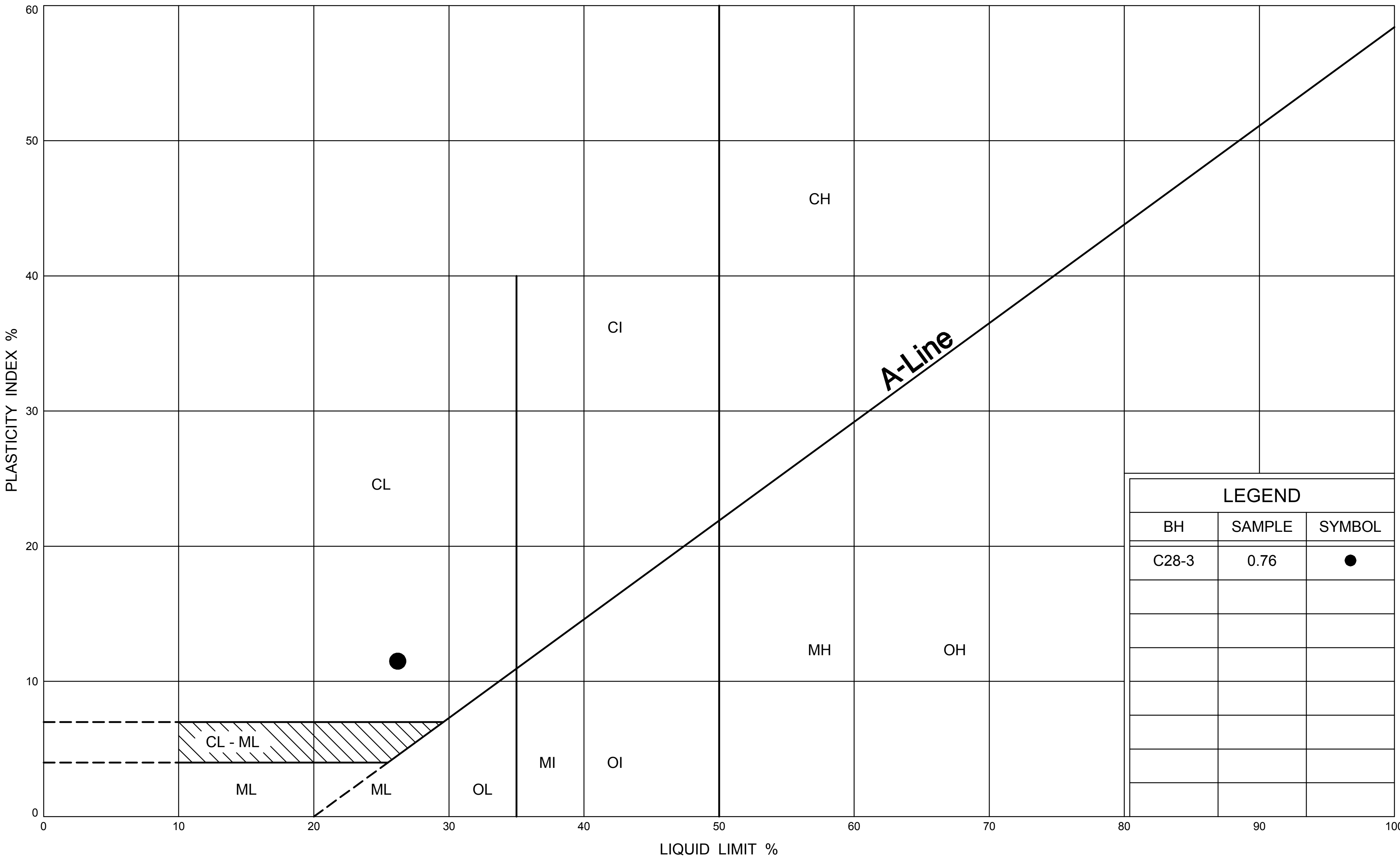
FILL

FIG No 1

GWP 365-98-00

Highway 12, Rama Road to Gamebridge

Oct 75, FF - S - 21



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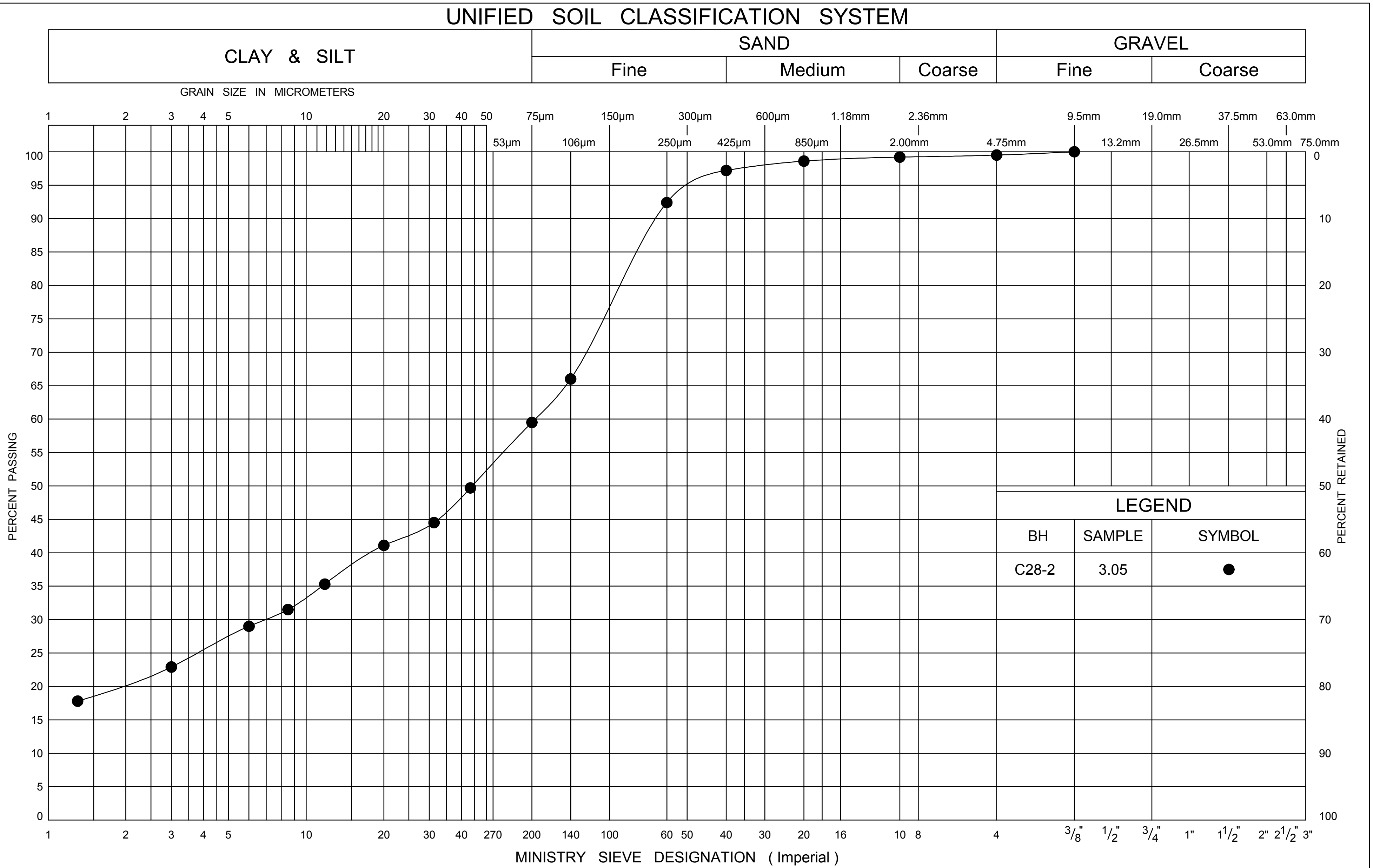
PLASTICITY CHART
FILL

FIG No 2

GWP 365-98-00

Highway 12, Rama Road to Gamebridge

78 12 M



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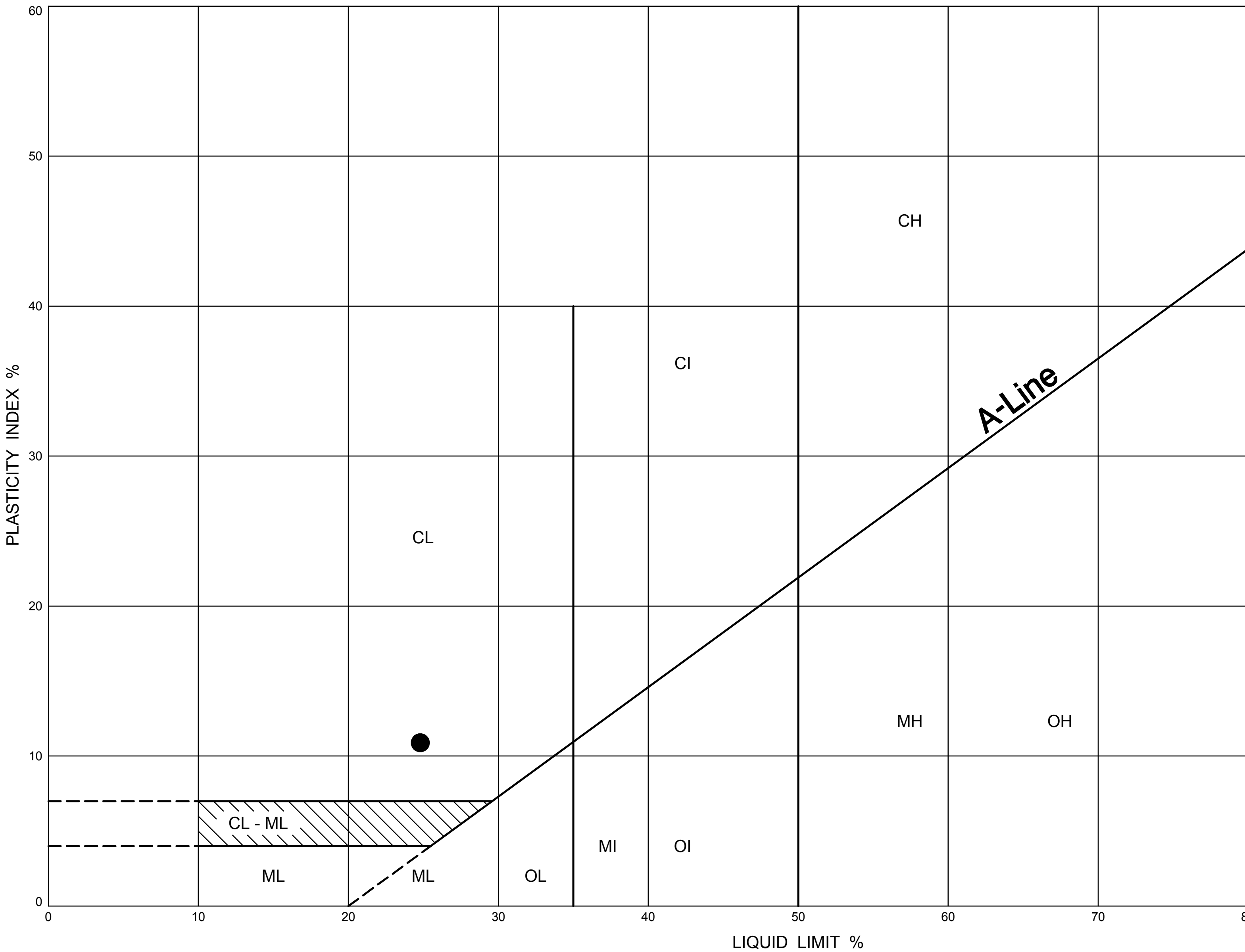
GRAIN SIZE DISTRIBUTION

SILTY CLAY, CL

FIG No 3

GWP 365-98-00

Highway 12, Rama Road to Gamebridge



LEGEND		
BH	SAMPLE	SYMBOL
C28-2	3.05	●

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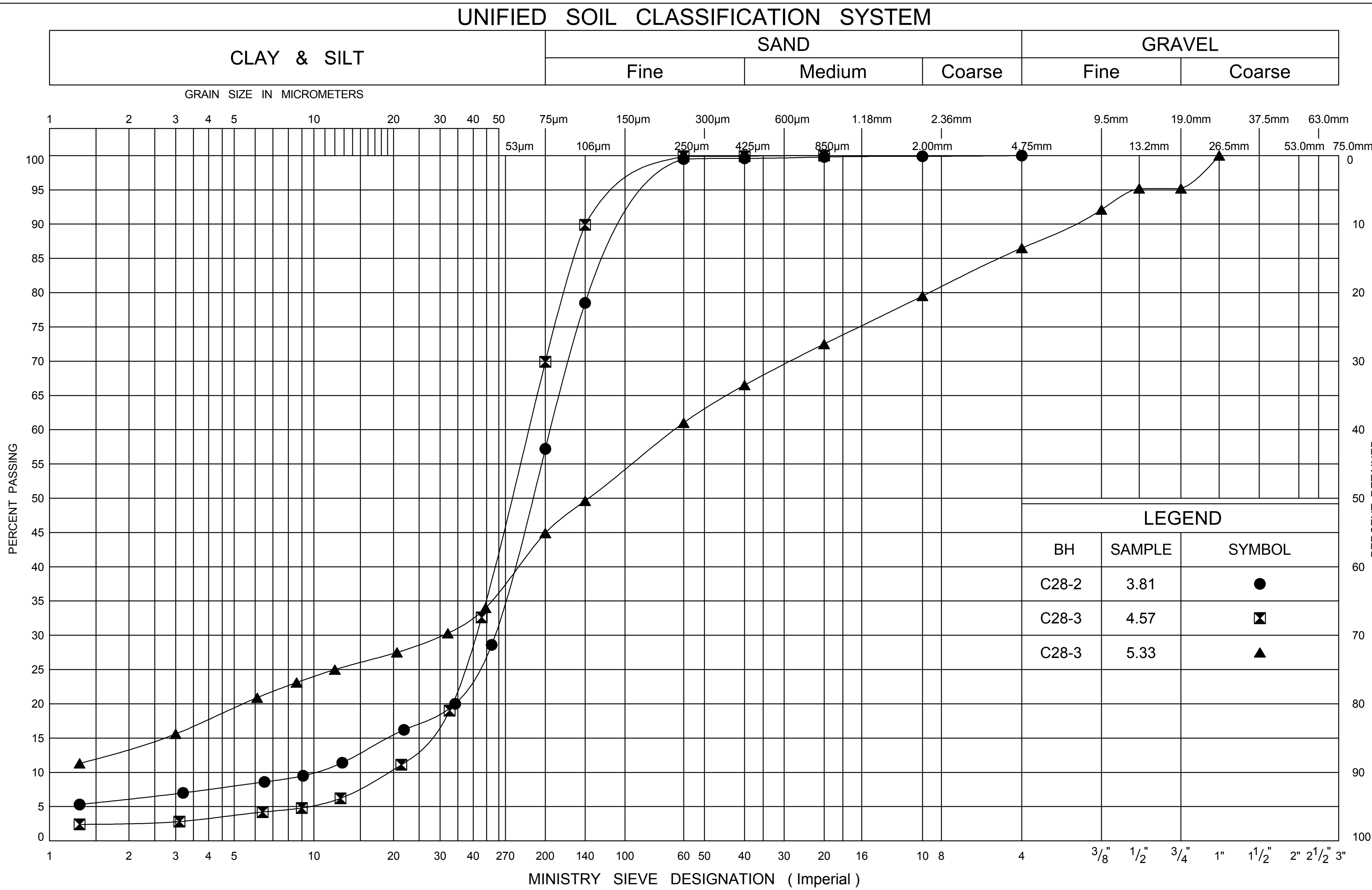
PLASTICITY CHART
SILTY CLAY, CL

FIG No 4

GWP 365-98-00

Highway 12, Rama Road to Gamebridge

78 12 M



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GRAIN SIZE DISTRIBUTION

SILTY SAND, SAND AND SILT, SANDY SILT, SM TO ML

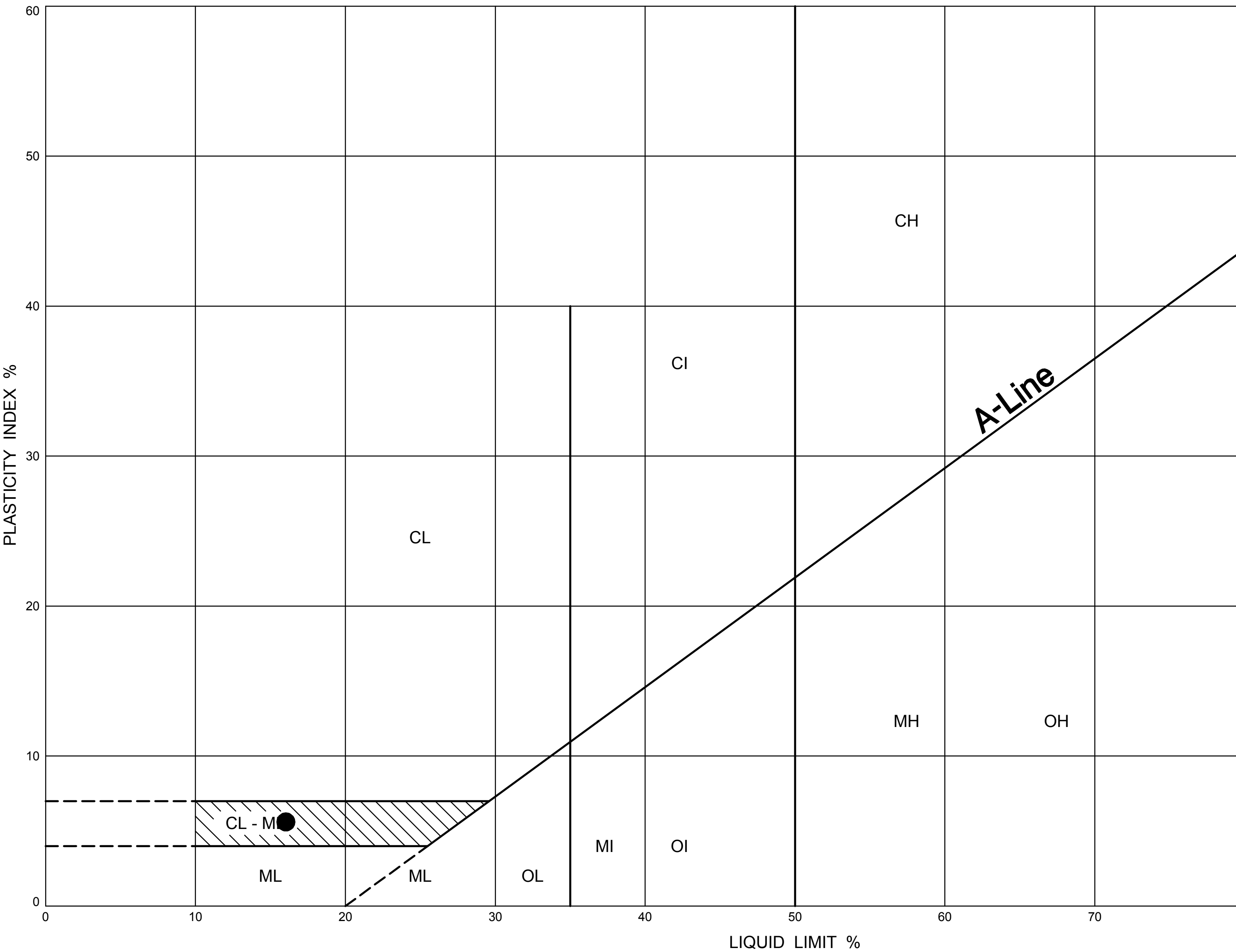
FIG No 5

GWP 365-98-00

Highway 12, Rama Road to Gamebridge

ONTARIO MOT GRAIN SIZE LARGE CULVERTS 08-1-IEG6 CULVERTS.GPJ ONTARIO MOT.GDT 03/30/09

Oct 75, FF - S - 21



LEGEND		
BH	SAMPLE	SYMBOL
C28-3	5.33	●

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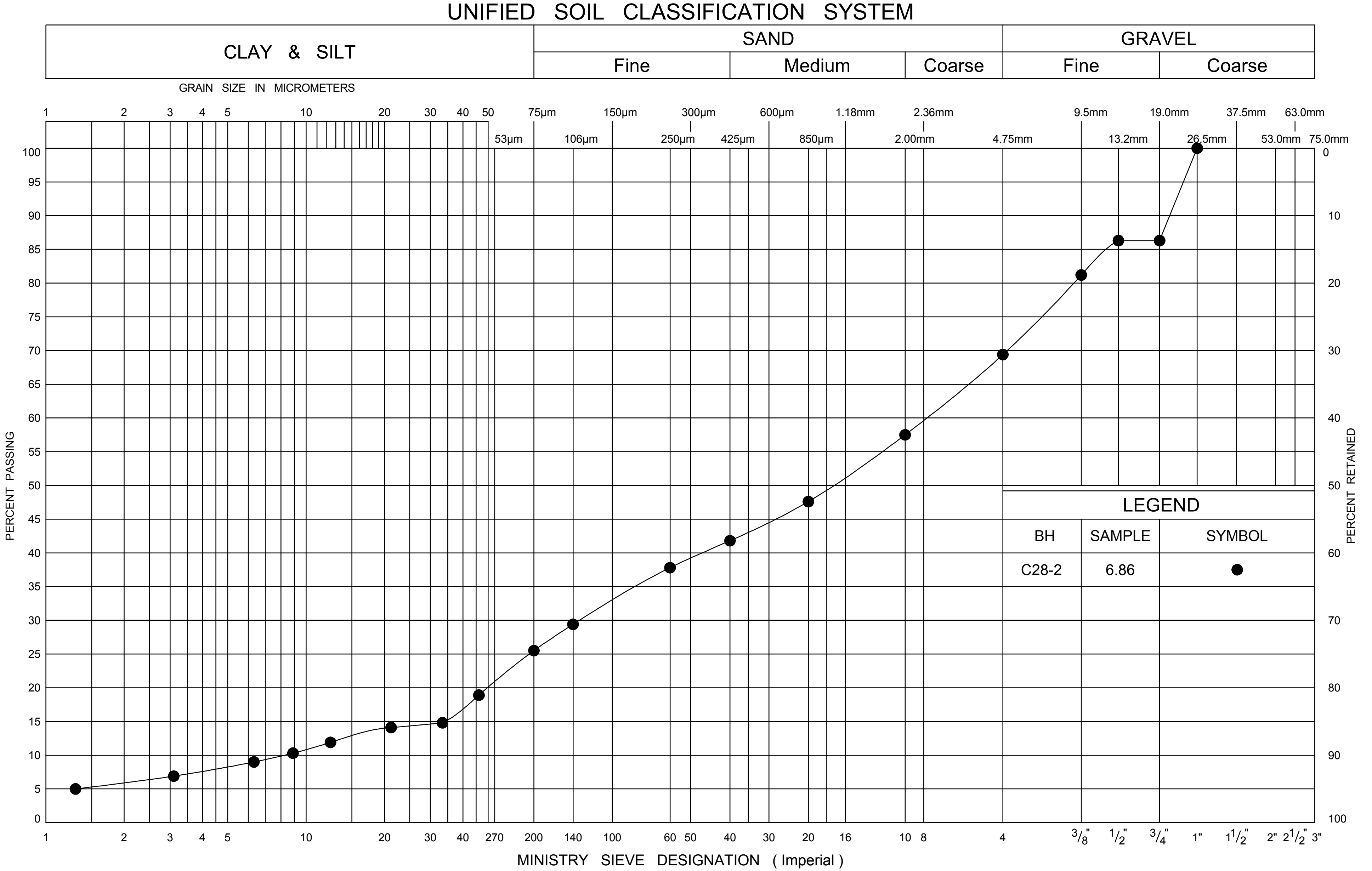
PLASTICITY CHART

SILTY SAND, SAND AND SILT, SANDY SILT, SM TO ML

FIG No 6

GWP 365-98-00

Highway 12, Rama Road to Gamebridge



ONTARIO MOT GRAIN SIZE LARGE CULVERTS 08-1-IEG6 CULVERTS.GPJ ONTARIO MOT.GDT 03/30/09

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Ontario

GRAIN SIZE DISTRIBUTION

GRAVELLY SILTY SAND, SW-SM

FIG No 7

GWP 365-98-00

Highway 12, Rama Road to Gamebridge

Trow 50 YEARS

Rock Core Test Report

Project No.: LAGM00289085C **Project Name:** Hwy 12 – 03/20019

Core No.	BH C28-3
Location	27'10"-28'6"
Date Cored	
Date Tested	April 7, 2009
Height - (mm)	126.5
Average Diameter - (mm)	46.2
Corrected Compressive Strength - (MPa)	128.6

Testing Laboratory Representative Signature
Ammanuel Yousif

Date April 8/09

Appendix C

Limitations of Report

APPENDIX C

LIMITATIONS OF REPORT

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

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

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

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

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

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

Appendix D

Site Photographs

C28 - Station 26+514 - Looking North

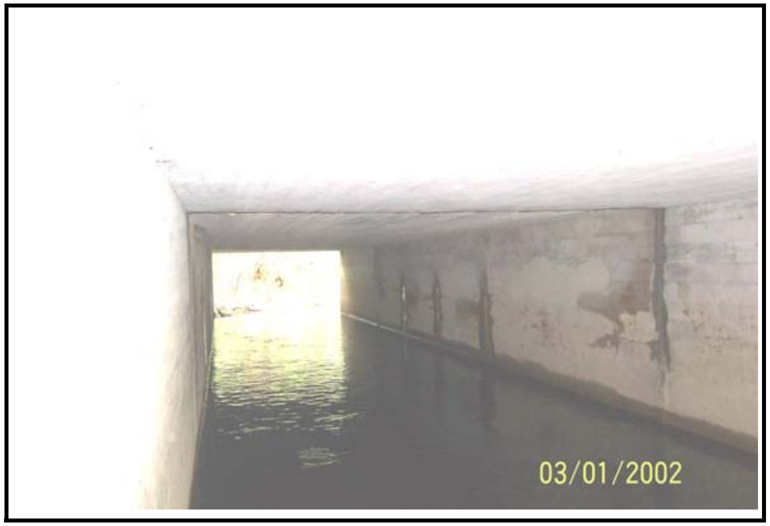
C28 - Station 26+514 - Downstream

C28 - Station 26+514 - Upstream

SITE PHOTOGRAPHS **SITE NO.:30-676/C**

C28 Photo 1 **Roadway Above Culvert / North Approach Roadway**

C28 Photo 2 **West Elevation**



C28 Photo 3 **Culvert Barrel from West**

C28 Photo 4 **Embankment Erosion at Northwest Corner**

Appendix F

Foundation Alternatives Comparisons

Suggested Wording for NSSP

List of Referenced Specifications

THURBER

COMPARISON OF CULVERT ALTERNATIVES

Comment	Circular Pipe	Concrete - Open Footing Culvert	Concrete Box (closed) Culvert
Advantages	Quick installation	NA	Quick installation procedure due to use of pre-cast sections Wider base provides better load distribution and higher bearing resistance.
Disadvantages	Multiple pipes required to provide equivalent hydraulic opening	Low bearing resistance	NA
Risks/ Consequences	NA	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
Relative Cost	lowest	moderate	moderate
	NOT RECOMMENDED	**FEASIBLE**	**RECOMMENDED**

THURBER

COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS

Comment	**Open Cut with Full Road Closure**	**Staged Open Cut with Roadway Protection**	**Staged Open Cut with embankment widening/lowering**	**Trenchless**
Advantages	Quick installation Simple construction	Quick installation	Quick installation Simple construction	Avoids open cut. Less traffic impacts.
Disadvantages	Significant traffic impacts Requires water/groundwater control	Traffic impacts Requires roadway protection system Requires water/groundwater control	Traffic impacts on Hwy 12 and may impact Concession Rd 10 Requires temporary extensions to culverts Requires water/groundwater control	High mobilization costs Potential face instability due to very loose saturated cohesionless soil. Requires water/groundwater control Requires multiple pipes to achieve hydraulic capacity.
Risks / Consequences	Dewatering challenges / extended closure of highway	Lowest risk option	Pockets of organics within footprint of embankment widening/ increase in subgrade preparation costs	Disturbance to pavement surface due to limited cover
Relative Cost	low	moderate	moderate	high
	FEASIBLE	**RECOMMENDED**	**FEASIBLE**	**NOT FEASIBLE**

THURBER

NSSP Wording

"Dewatering shall be provided by the Contractor during structure excavation and backfilling as per OPSS 902. The Contractor is advised that the soils underlying this site include very loose to compact cohesionless soil and that the planned excavation will extend below the groundwater level. Excavation below the groundwater level is expected to lead to instability and slough of the sides of the excavation and softening of the base, accompanied by loss in geotechnical resistance of the soils. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, so as to preserve the stability of the excavation and to allow the work to proceed in a dry and stable condition."

List of Referenced Specifications

OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement
OPSS 206	Construction Specification for Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS 1205	Material Specification for Clay Seal