REPORT

September 22, 2015

FOUNDATION INVESTIGATION AND DESIGN REPORT

CULVERTS – CONTRACT 2
HIGHWAY 69 FOUR-LANING FROM 1.7 KM NORTH OF HIGHWAY 529 NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5404-05-00; WP 5404-05-01

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NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5404-05-00; WP 5404-05-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for two (2) culvert crossings within the Contract 2 limits of the new Highway 69 alignment to the north of the junction with Highway 529. The proposed work in Contract 2 is part of the four-laning of Highway 69 from 1.7 km north of Highway 529 northerly to 3.9 km north of Highway 522, for a total distance of 19.7 km, which includes the engineering of: high fill embankments and embankments over swamps; the Canadian National Railway (CNR) re-alignment; the Bekanon Road and Highway 522 interchanges and structures; the Still River, Straight Lake and Key River structures; the Canadian Pacific Railway (CPR) and Canadian National Railway (CNR) structures; as well as culvert crossings. The general location and extent of the various contracts as part of this assignment are shown on the Site Location Plan on Drawing 1.

The terms of reference and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated January 2009. Golder's proposal for foundation engineering services associated with the Contract 2 culvert crossings is contained in Section 6.8 of URS's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated April 19, 2010. The Base Plan showing the proposed new alignment for the Contract 2 section of Highway 69 four-laning and the General Arrangement (GA) drawings for the proposed culvert profiles were provided to Golder by URS on December 16, 2009 and August 24, 2012, respectively.

This report addresses the investigation carried out for the proposed Contract 2 culvert crossings only. A list of the Contract 2 culvert details is presented in Table 1. Separate reports address the foundation investigations for the related swamp crossings and high fill areas and bridge structures within Contract 2 of the project.

The purpose of this investigation is to establish the subsurface conditions along the proposed culvert alignments by methods of borehole drilling, rock coring, in situ testing and laboratory testing on selected samples. The culverts were located in the field by Callon Dietz Inc., a professional surveying company retained by URS. The two culverts are located within a swamp crossing (designated as Swamp 202) which was investigated by Golder Associates Ltd. The results of the swamp investigation are presented in a report titled:

- Foundation Investigation and Design Report, Swamp Crossings and High Fill Areas – Contract 2, Highway 69 Four-Laning from 1.7 km North of Highway 529 Northerly to 3.9 km North of Highway 522, Ministry of Transportation, Ontario, GWP 5404-05-00; WP 5404-05-01, Geocres No. 41H-115, dated July 2012.

2.0 SITE DESCRIPTION

The overall proposed Highway 69 alignment is oriented generally in a south-north direction spanning the Township of Wallbridge to the south, the Township of Henvey and the Township of Mowat to the north. The Contract 2 section of the new four-lane Highway 69 alignment is also oriented generally in a south-north direction within the project limits, spanning the Township of Wallbridge to the south and the Township of Henvey to the north for a total distance of 4.8 km. The proposed culverts are located within the Contract 2 highway alignment approximately 2.4 km from the southern limit of Contract 2, corresponding to approximately 1.2 km northeast of the junction between existing Highway 69 and Highway 529.

In general, the topography of the Contract 2 section of the project consists of rolling terrain, sparsely to densely treed areas, with valleys and swamps containing areas of standing water and various types of vegetation and organic soils. The ground surface along the Contract 2 culvert alignments varies between about Elevation 183 m and Elevation 181 m, referenced to Geodetic datum, and is gently sloping downward from northeast to southwest towards Georgian Bay. A detailed description of the two investigated culvert alignments is presented in Section 4.0.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The investigation for the Contract 2 culvert crossings was carried out between February 18 and March 11, 2011, during which time a total of seven (7) boreholes were advanced at or near the culvert alignments. In addition, three (3) boreholes advanced from March 3 to 13, 2011 as part of the field investigation work carried out by Golder Associates Ltd. for the Contract 2 swamp crossings and high fill areas in Swamp 202 were utilized to supplement the culvert investigation, and the methods of investigation for these supplemental additional boreholes are provided in the report referenced in Section 1.0. The boreholes associated with each culvert are summarized in Table 1 and are shown on Drawings A1 and B1 in Appendix A and Appendix B, for Culverts C201 and C202, respectively.

The field investigation was carried out using track-mounted D25 and D50 drill rigs supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced through the overburden using 127 mm outside diameter (O.D.) solid-stem augers and ‘NW’ casing with wash boring techniques. Soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm O.D. split-spoon sampler driven by automatic hammers in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test). Relatively undisturbed samples of the cohesive soils were obtained at selected locations using 76 mm O.D. thin-walled ‘Shelby’ tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling). Field vane shear tests were carried out in cohesive soils for assessment of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) using MTO Standard ‘N’ size vanes. Samples of the bedrock were obtained using an ‘NQ’ size rock core barrel. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended). Boreholes which exhibited artesian groundwater conditions during drilling were backfilled with a cement/barite grout mixture following measurement of the water level in the drill casing.

The culvert boreholes were advanced to depths up to 27.7 m below existing ground surface, generally penetrating 3 m into competent material or to refusal. In two boreholes, Dynamic Cone Penetration Tests (DCPT) were carried out from the bottom of the borehole to determine the depth to refusal. In general, the boreholes were terminated on refusal to further casing and/or split-spoon advancement or dynamic cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. In two (2) of the boreholes advanced along the Culvert C201 alignment, bedrock was cored for a depth of about 2.4 m and 3.0 m, and photographs of the recovered rock samples from the culvert borehole are provided in Appendix A.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets provided in Appendices A and B. Groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The fieldwork was observed by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil and rock core samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected samples. In addition, a one-dimensional consolidation (oedometer) test was carried out on one (1) selected sample of the cohesive deposit obtained from the culvert boreholes and the summary of the consolidation test result is presented in Section 4.0. It is noted that additional consolidation tests were carried out on samples obtained from the boreholes advanced within Swamp 202 and are provided in the report referenced in Section 1.0. The results of the laboratory testing on samples from the culvert boreholes are included in Appendices A and B.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)[1]. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2) and the strength classification of the intact rock mass based on field identification (i.e. strong to extremely strong – R4 to R6) are described in accordance with the International Society for Rock Mechanics (ISRM[2]) standard classification system.

The proposed centreline of the new highway alignment was staked in the field by Callon Dietz prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the centreline alignment and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at the centreline median and to temporary benchmarks which were then surveyed by Callon Dietz upon completion of the fieldwork. The borehole locations given in the Record of Borehole Sheets and shown on Drawings A1 and B1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole / DCPT Depth (m)
	Northing	Easting		
C201-01	5074231.7	225371.4	182.6	16.6
C201-02	5074236.3	225389.8	182.6	26.2
C201-03	5074241.2	225408.1	182.5	27.7
C201-04	5074246.9	225429.2	182.5	22.7
C202-01	5074238.2	225345.3	182.6	21.3
C202-02	5074247.4	225386.7	182.7	27.1
C202-03	5074254.7	225405.1	182.8	20.4
S202-04	5074226.7	225356.0	182.5	14.3
S202-05	5074244.1	225362.1	182.5	23.0
S202-19	5074259.4	225424.2	183.0	18.7

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[1] Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

[2] International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in The Physiography of Southern Ontario[3], this section of the new Highway 69 lies within the physiographic region known as the Georgian Bay Fringe, which extends along the east side of Georgian Bay through the Parry Sound and Muskoka areas, then eastward from Muskoka in patches into the area north of the Kawartha Lakes.

This part of the Georgian Bay Fringe physiographic region was never submerged during periods of glacial recession. As a result, the surficial soils in this area typically consist of very shallow deposits of sand, silt and clay underlain by metamorphic bedrock and numerous bare knobs and ridges of bedrock are present throughout the area. Localized low-lying swampy areas, containing peat and/or organic soils overlying soft/loose native soils, sometimes to significant depth, are present in valleys between the bedrock knobs and ridges.

The bedrock in the area consists typically of crystalline gneisses of the Britt Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in Geology of Ontario, OGS Special Volume 4[4]. Deposition of Paleozoic strata initially covered the bedrock and later erosion during glaciation exposed these Precambrian rocks.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are presented on the attached Record of Borehole sheets and the laboratory test sheets provided in Appendices A and B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The inferred soil stratigraphy as encountered in the boreholes advanced for the Contract 2 culverts are shown in profile on Drawings A2 and B2. The orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north and/or up-chainage (along the proposed Highway 69 alignment). For purposes of this report, Highway 69 is oriented north-south.

In general, the stratigraphy encountered along the two (2) culverts alignments investigated is similar and generally consists of thick deposits of cohesive soil underlain by layers of non-cohesive soils. The stratigraphy from ground surface to refusal or bedrock generally consists of:

- Surficial layers of topsoil, organic silt to organic silty sand, peat root mat;
- Non-cohesive deposit of sand;
- Thick cohesive deposits of clayey silt to clay; and,

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[3] Chapman, L.J. and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

[4] Geology of Ontario, 1991. Ontario Geological Society Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.

- Non-cohesive deposits of silt to silty sand to sand to sand and gravel, underlain by cobbles/boulders in places and underlain by granite gneiss bedrock.

Detailed descriptions of the subsurface conditions along each investigated culvert alignment is provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.3 Highway 69 SBL and NBL – STA 11+207 (Culvert 201)

The plan and profile along the Culvert 201 centreline showing the borehole locations and interpreted stratigraphy at approximately STA 11+207 in the Township of Henvey are shown on Drawings A1 and A2 in Appendix A. The culvert alignment will extend across the proposed new Highway 69 Northbound Lanes (NBL) and Southbound Lanes (SBL) embankments within Swamp 202. The proposed embankments at the culvert location are approximately 6.5 m high relative to the existing ground surface. A total of four (4) boreholes (Boreholes C201-01 to C201-04) were advanced along the length of the culvert to investigate the subsurface conditions at this culvert location. In addition, one (1) borehole (Borehole S202-04) advanced at the west toe of the proposed Highway 69 SBL embankment for the swamp crossing in the culvert area was utilized to supplement the subsurface information along the culvert alignment. The Record of Borehole sheets and associated results of the laboratory tests carried out on selected soil samples for these boreholes are included in Appendix A.

This section of the proposed Highway 69 alignment is located within the confines of tree covered valley slopes to the north and south, and consists of wet grassy areas/pasture land and a small creek traversing the valley from east to west. In general, the ground cover in the culvert area consists of a grassy field and creek bed with shrub cover and moderately treed areas and bedrock outcrops to the north and south.

The subsurface soils along the culvert alignment consist of peat and topsoil at the ground surface, underlain by deposits of organic silty sand and sand underlain in places by layers of silty clay and organic silt. These deposits are underlain by a thick deposit of clayey silt to clay, underlain by either bedrock or deposits of silt, silty sand, sand, sandy silt and sand and gravel which extends to the refusal depth. The bedrock consists of granite gneiss bedrock.

4.3.1 Peat / Topsoil

An approximately 0.2 m thick layer pf peat (root mat) was encountered at the ground surface (about Elevation 182.5 m) in Borehole S202-04, at the west end of the proposed culvert. An approximately 0.1 m to 0.3 m thick layer of topsoil was encountered at the ground surface (between about Elevation 182.6 m and 182.5 m) in Boreholes C201-01 to C201-03.

4.3.2 Organic Silty Sand

A deposit of grey organic silty sand containing rootlets was encountered locally below the peat in Borehole S202-04. The top of this deposit is at about Elevation 182.3 and the thickness of the deposit is about 0.5 m.

One SPT ‘N’-value of 1 blow per 0.3 m of penetration was recorded within this deposit, indicating a very loose relative density.

The natural water content measured on one (1) specimen of this deposit is about 46 per cent.

4.3.3 Sand

A deposit of dark grey to brown sand, some silt, containing organics, rootlets and wood fragments was encountered either at the ground surface or below the topsoil in Boreholes C201-01 to C201-04, and below the organic silty sand in Borehole S202-04. The top of this deposit ranges from about Elevation 182.5 m to 181.8 m and its thickness ranges from about 0.2 m to 1.1 m.

The SPT ‘N’-values measured within this deposit range from 0 blows (weight of hammer) to 6 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

The natural water content measured on four (4) selected samples of this deposit ranges from about 30 per cent and 93 per cent.

4.3.4 Silty Clay and Organic Silt

An approximately 0.3 m to 1.6 m thick deposit of organic silt, some sand containing layers of fibrous peat and rootlets was encountered below a 0.2 m and 0.4 m thick silty clay layer containing fibrous peat layers and wood fragments in Boreholes C201-01 and C201-04, respectively, and below the sand deposit in Borehole C201-03. The top of the organic silt deposit varies between about Elevation 181.9 m and Elevation 181.4 m.

The SPT ‘N’-values measured within the organic silt deposit range from 0 blows (weight of hammer) to 2 blows per 0.3 m of penetration, indicating a very loose relative density.

The natural water content measured on three (3) selected samples of the deposit ranges between about 57 per cent and 152 per cent. Laboratory organic testing on three (3) samples of the organic silt measured an organic content between about 13 per cent and 15 per cent. Laboratory organic testing on two (2) samples of silty clay measured an organic content of about 4 per cent.

4.3.5 Clayey Silt to Clay

A thick deposit of cohesive soil comprised of brown to grey clayey silt, silty clay and clay, some silt, trace sand and trace gravel, was encountered underlying either the sand deposit or the organic silt layer in all the boreholes. The upper 2.7 m of the cohesive deposit contains organics and/or layers of fibrous peat. The silty clay to clay portion of the cohesive deposit contains silt interlayers, up to 1.1 m thick, at various depths and the clayey silt portion of the cohesive deposit contains silty clay seams. The top of the cohesive deposit ranges from about Elevation 181.6 m to 180.3 m. The thickness of the cohesive deposit ranges from about 10.4 m to 18.4 m. The bottom of this deposit is defined by bedrock in Borehole S202-04.

The SPT ‘N’-values recorded within the cohesive deposit typically range from 0 blows (weight of hammer) to 5 blows per 0.3 m of penetration. In situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 15 kPa to 96 kPa, but typically less than 40 kPa, and the sensitivity is calculated to range from about 2 to 4. The field vane tests results indicate that the clayey silt to clay deposit has a predominantly soft to firm consistency with some higher shear strengths and stiff consistency occurring within the upper portion of the cohesive deposit.

The natural water content measured on twenty-four (24) samples of this deposit range from about 38 per cent to 87 per cent, but are typically greater than 55 per cent.

The results of grain size distribution tests completed on twelve (12) samples of the clayey silt to silty clay and clay portions of the cohesive deposit are shown on Figure A.C201-01A and A.C201-01B in Appendix A, respectively.

Atterberg limits tests were carried out on twelve (12) samples of the cohesive deposit and measured liquid limits ranging from 30 per cent to 66 per cent, plastic limits ranging from 18 per cent to 23 per cent and plasticity indices ranging from 11 per cent to 43 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure A.C201-02A and A.C201-02B in Appendix A and indicate the material is classified predominantly as a silty clay of intermediate plasticity to clay of high plasticity.

4.3.6 Silt (Interlayer)

An approximately 1.1 m thick interlayer of grey silt, trace to some clay and trace sand was encountered within the deposit of silty clay to clay in Borehole C201-04 at about Elevation 178.9 m.

One SPT ‘N’-value of 11 blows per 0.3 m of penetration was recorded in this interlayer, indicating a compact relative density.

The natural water content measured on one (1) sample of this interlayer is about 29 per cent.

The grain size distribution of one (1) sample of the silt interlayer is shown on Figure A.C201-03 in Appendix A. An Atterberg limits test on one (1) sample of the silt deposit indicates this material to be non-plastic.

4.3.7 Silt

A deposit of grey silt, trace to some sand and trace to some clay was encountered underlying the clay deposit in Boreholes C201-02 and C201-03 at approximately Elevation 165.4 m and 162.4 m, respectively. The thickness of the deposit is about 1.9 m and 2.9 m at the respective boreholes.

Two SPT ‘N’-values measured within the silt deposit are 8 blows and 10 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The natural water content measured on two (2) selected samples of the deposit is 24 per cent and 25 per cent.

The results of grain size distribution tests completed on two (2) samples of the silt to deposit are shown on Figure A.C201-04 in Appendix A. An Atterberg limits test on one (1) sample of the silt deposit indicates this material to be non-plastic.

4.3.8 Sandy Silt to Sand to Sand and Gravel

Underlying the clayey silt to clay deposit or the silt deposit, Boreholes C201-01 to C201-04 encountered a deposit of grey non-cohesive soil grading from sandy silt to silty sand to sand some silt. The deposit in places contains trace to some clay, trace to some silt and trace to some gravel. The top of the sandy silt to sand deposit ranges from about Elevation 169.6 m to 159.5 m and the thickness of the deposit ranges from about 1.2 m to greater than 4.7 m, and may be up to about 7.1 m as inferred from the refusal at a Dynamic Cone Penetration Test carried out from the bottom of Borehole C201-02. Borehole C201-03 was terminated within this deposit, where as in Boreholes C201-01 and C201-02, the bottom of this deposit was defined by bedrock and by refusal to further cone penetration, respectively.

The SPT ‘N’-values measured within this deposit range from 7 blows to 76 blows per 0.3 m of penetration, indicating a loose to very dense relative density.

The natural water content measured on three (3) samples of this deposit ranges from 14 per cent to 24 per cent.

The results of grain size distribution tests completed on one (1) sample of the sandy silt portion of the deposit and two (2) samples of the sand portion of the deposit are shown on Figure A.C201-05A and A.C201-05B, respectively, in Appendix A.

In Borehole C201-04, the non-cohesive sand deposit grades to sand and gravel containing cobbles. The top of the coarser portion of the deposit is at about Elevation 160.9 m and the thickness of this portion of the deposit is about 1.1 m. Borehole C201-04 was terminated within this deposit upon refusal to further casing advancement. One SPT ‘N’-value of 83 blows per 0.3 m of penetration was measured within the sand and gravel portion of the deposit, indicating a very dense relative density. The natural water content measured on sample of the sand and gravel deposit is 15 per cent.

4.3.9 Bedrock / Refusal

Bedrock outcrops are present to the southern and northern limits of the investigated area. The bedrock surface at the borehole locations along the culvert alignment, was proven by coring or was inferred (except in Borehole C201-03 which was terminated within the silty sand deposit) by refusal to further casing advancement or dynamic cone penetration between depths of about 11.3 m and 26.2 m below the ground surface, corresponding to between about Elevation 171.2 m and 156.4 m.

Bedrock was encountered and core samples were recovered from Boreholes S202-04 and C201-01, as shown on the photograph of the recovered core samples presented on Figure A.C201-06. The depth to the surface of the bedrock in these boreholes is about 14.2 m and 11.3 m, corresponding to Elevation 168.4 m and 171.2 m in Boreholes C201-01 and S202-04, respectively. The bedrock consists of granite gneiss and the core samples are described as fresh to slightly weathered, foliated, slightly porous, medium crystalline, strong, pink, grey and black with a mafic dyke encountered at varying intervals, as presented on the Record of Drillhole sheets in Appendix A.

The Rock Quality Designation (RQD) measured on the core samples ranges between 84 per cent and 100 per cent, indicating a rock mass of good to excellent quality, in accordance with Table 3.10 of CFEM (2006). The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of the rock core samples are between 96 per cent and 100 per cent, and between 78 per cent and 98 per cent, respectively.

4.3.10 Groundwater Conditions

In general, the soil samples taken in the boreholes were moist to wet. During drilling operations, artesian conditions were observed in all the boreholes when advanced to depths between about 19.6 m and 24.2 m below ground surface. Upon completion of drilling, artesian conditions were noted in Boreholes C201-01 and C201-02 with the groundwater levels measured in the casing at about 1.5 m and 0.5 m above ground surface, corresponding to about Elevation 184.1 m and 183.1 m, respectively. In the other boreholes, the groundwater levels measured in the open borehole ranged from about Elevation 182.5 m to 181.7 m, measured at the ground surface or to depths up to about 0.8 m below ground surface.

4.4 Highway 69 SBL and NBL – STA 11+220 (Culvert 202)

The plan and profile along Culvert 202 centreline showing the borehole locations and interpreted stratigraphy at approximately STA 11+220 in the Township of Henvey are shown on Drawings B1 and B2 in Appendix B. The culvert alignment will extend across the proposed new Highway 69 Northbound Lanes (NBL) and Southbound Lanes (SBL) embankments within Swamp 202. The proposed embankments at the culvert location are approximately 6.5 m high relative to the existing ground surface. A total of three (3) boreholes (Boreholes C202-01 to C202-03) were advanced along the length of the culvert to investigate the subsurface conditions at this culvert location. In addition, two (2) boreholes (Boreholes S202-05 and S202-19) advanced for the proposed Highway 69 NBL and SBL embankments for the swamp crossing in the culvert area was utilized to supplement the subsurface information along the culvert alignment. The Record of Borehole sheets and the associated results of the laboratory tests carried out on selected soil samples for these boreholes are included in Appendix B.

This section of the proposed Highway 69 alignment is located within the confines of tree covered valley slopes to the north and south, and consists of wet grassy areas/pasture land and a small creek traversing the valley from east to west. In general, the ground cover in the culvert area consists of a grassy field and creek bed with shrub cover and moderately treed areas and bedrock outcrops to the north and south.

The subsurface soils along the culvert alignment consist of peat and topsoil at the ground surface, underlain by near surface deposits of organic silty sand and sand, underlain by a thick deposit of clayey silt to clay. The cohesive deposit is underlain by non-cohesive deposits consisting of silty sand, sand, and sand and gravel which either extends to refusal or is underlain by cobbles and boulders deposit in places.

4.4.1 Peat / Topsoil

An approximately 0.2 m thick layer of peat (root mat) was encountered at the ground surface at about Elevation 182.5 m in Borehole S202-05. In Boreholes C202-01, C202-03 and S202-19, an approximately 0.2 m to 0.3 m thick layer of topsoil was encountered at the ground surface between about Elevation 183.0 m and 182.6 m.

4.4.2 Organic Silty Sand

A layer of dark grey to brown organic silty sand, trace clay was encountered below the peat in Borehole S202-05. The top of this deposit is at about Elevation 182.3 and the thickness of the deposit is about 0.5 m.

One SPT ‘N’-value of 1 blow per 0.3 m of penetration was recorded within this deposit, indicating a very loose relative density.

The natural water content measured on one (1) specimen of this deposit is about 39 per cent.

4.4.3 Silty Sand to Sand

A deposit of grey to brown silty sand to sand trace to some silt, containing organics, rootlets and wood fragments was encountered underlying the topsoil or at ground surface in Boreholes C202-01 to C202-03, and below the organic silty sand layer in Borehole S202-05. The top of this deposit ranges from about Elevation 182.7 m to 181.8 m and its thickness ranges from about 0.2 m to 0.9 m.

The SPT ‘N’-values measured within this deposit are 2 blows and 3 blows per 0.3 m of penetration, indicating a very loose relative density.

The natural water content measured on two (2) samples of this deposit is 37 per cent.

4.4.4 Clayey Silt to Clay

A thick deposit of cohesive soil comprised of brown to grey clayey silt, silty clay and clay, trace to some silt, trace to some sand and trace gravel was encountered underlying the sand to silty sand deposit and/or topsoil in all the boreholes. The upper portion of the cohesive deposit (to a depth of about 2.1 m below ground surface) contains organics, rootlets and fibrous peat layers. The cohesive deposit contains silt and sand and silt/sand interlayers in places. The top of the cohesive deposit ranges from about Elevation 182.7 m to 181.6 m, and the thickness of the cohesive deposit ranges from about 16.3 m to 22.0 m.

The SPT ‘N’-values recorded within the cohesive deposits range from 0 blows (weight of hammer) to 5 blows per 0.3 m of penetration. In situ field vane tests carried out within this deposit measured undrained shear strengths ranging from about 16 kPa to 85 kPa, but typically less than 40 kPa and the sensitivity is calculated to range from about 2 to 5. The field vane tests results indicate that the clayey silt to clay deposit has a predominantly soft to firm consistency with higher shear strengths and stiff consistency occurring within the upper portion of the cohesive deposit.

The natural water content measured on thirty-three (33) samples of the deposit range from about 21 per cent to 84 per cent, but are typically greater than 50 per cent.

The results of grain size distribution tests completed on fifteen (15) samples of the clayey silt, silty clay and clay portion of the cohesive deposit are shown on Figures B.C202-01A, B.C202-01B and B.C202-01C in Appendix B.

Atterberg limits tests were carried out on sixteen (16) samples of the cohesive deposit and measured liquid limits ranging from 24 per cent to 57 per cent, plastic limits ranging from 16 per cent to 21 per cent and plasticity indices ranging from 7 per cent to 38 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B.C202-02A and B.C202-02B in Appendix B and indicate the material is classified as clayey silt of low plasticity to clay of high plasticity.

A laboratory consolidation test was carried out on one (1) specimen of the silty clay deposit obtained from a Shelby tube sample in Borehole C202-02. A preconsolidation stress of about 160 kPa was estimated from the void ratio versus logarithmic pressure plot and from the total work versus pressure plot. A bulk unit weight of about 17 kN/m^3 and a specific gravity of about 2.76 were measured on the consolidation test specimen. Details of the test results are shown on Figure B.C202-03 in Appendix B, and the test results are summarized below.

Borehole Sample No.	Sample Depth / Elevation	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	C_c	C_r	e_o	c_v^* (cm^2/s)
Borehole C202-02 Sample 13	15.2 m / 167.5 m	120	160	40	1.3	0.91	0.07	1.39	8.7×10^{-4}

Note: * For stress range of between effective overburden stress and final stress due to 6.5 m high embankment, that is 120 kPa ≤ σ_v' ≤ 245 kPa

where:		
	σ_{vo}'	is the in situ vertical effective overburden stress in kPa
	σ_p'	is the preconsolidation stress in kPa
	σ_v'	is the vertical effective stress in kPa
	OCR	is overconsolidation ratio
	e_o	is initial void ratio
	C_c	is the compression index
	C_r	is the recompression index
	c_v	is the coefficient of consolidation in cm^2/s

4.4.5 Sand and Silt to Sand / Silt (Interlayers)

An approximately 1.0 m thick interlayer of grey sand and silt to sand trace silt, trace to some clay and trace gravel was encountered within the cohesive deposit in Borehole C202-02 at about Elevation 179.5 m, and an approximately 0.4 m thick interlayer of grey silt was encountered in Borehole S202-19 at approximately Elevation 179.0 m.

A single SPT ‘N’-value measured within the sand and silt to sand interlayer is 11 blows per 0.3 m of penetration indicating a compact relative density.

The natural water content measured on one (1) sample of the sand and silt portion of the interlayer is about 24 per cent.

The results of a grain size distribution test completed on one (1) sample of the sand and silt portion of the interlayer is shown on Figure B.C202-04 in Appendix B.

An Atterberg limits test was carried out on a portion of the sample of the sand and silt interlayer and measured a liquid limit of 18 per cent, a plastic limit of 16 per cent and a plasticity index of 2 per cent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B.C202-05 in Appendix B and indicates that the fines portion of the sand and silt interlayer is classified as silt of slight plasticity.

4.4.6 Silty Sand to Sand to Sand and Gravel

Underlying the clayey silt to clay deposit, all the boreholes encountered a non-cohesive deposit comprised of silty sand, sand, and sand and gravel. The sand and gravel portion of the deposit encountered in Borehole C202-01 contains cobbles. The top of the non-cohesive deposit ranges from about Elevation 166.4 m to 159.8 m and the thickness of the deposit ranges from about 0.9 m to 3.2 m, and may be up to about 4.2 m thick as inferred from the refusal of a Dynamic Cone Penetration Test carried out in Borehole C202-02. Boreholes C202-01 was terminated within this deposit, whereas the bottom of Boreholes C202-02 and S202-05, were defined by refusal to further split-spoon, casing advancement or dynamic cone penetration in this layer, respectively.

The SPT ‘N’-value measured within this deposit range from 7 blows to 93 blows per 0.3 m of penetration, indicating a loose to very dense relative density.

The natural water content measured on three (3) samples of this deposit ranges from 11 per cent and 22 per cent.

The result of a grain size distribution test completed on one (1) sample of the sand portion of the deposit is shown on Figure B.C202-06 in Appendix B. An Atterberg limits test on one (1) sample of the silty sand portion of the deposit indicates this material to be non-plastic.

4.4.7 Cobbles and Boulders

In Boreholes C202-03 and S202-19 advanced near the east end of the proposed culvert, a deposit of cobbles and/or boulders was encountered underlying the silty sand to sand and gravel deposit at about Elevation 164.0 m and 165.5 m, respectively, and cored for depths of about 1.6 m and 1.2 m, prior to termination of the boreholes.

4.4.8 Refusal

Bedrock outcrops are present to the southern and northern limits of the valley within which the culvert is located. Refusal to further split-spoon and casing advancement or dynamic cone penetration was encountered in Boreholes C202-02 and S202-05 at depths of about 27.1 m and 23.0 m, respectively, below the ground surface, corresponding to Elevation 155.6 m and 159.5 m.

4.4.9 Groundwater Conditions

In general, the soil samples taken in the boreholes were moist to wet. During drilling operation, artesian conditions were observed in all the boreholes when casing was advanced to depths between about 17.1 m and 23.9 m below ground surface. Upon completion of drilling, artesian conditions were noted in Boreholes C202-01 and C202-03 with the groundwater levels measured in the casing at about 1.8 m and 1.2 m above ground surface, corresponding to about Elevation 184.4 m and 184.0 m, respectively. In the other boreholes, the groundwater levels measured in the open borehole ranged from about Elevation 182.3 m to 179.0 m, measured at depths between 0.2 m and 4.0 m below ground surface.

5.0 CLOSURE

The drilling program was supervised by Mr. Matt Rhody, a senior technician with Golder. This report was prepared by Ms. T. Veronica Ayetan, P.Eng. with assistance provided by Mr. Billy Murphy, and was reviewed by Mr. J. Paul Dittrich, Ph.D., P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.

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PART B

FOUNDATION DESIGN REPORT
CULVERTS – CONTRACT 2
HIGHWAY 69 FOUR-LANING FROM 1.7 KM NORTH OF HIGHWAY 529 NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5404-05-00; WP 5404-05-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the geotechnical data obtained during the investigation and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as it affects their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

Golder Associates Ltd. (Golder) was retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide recommendations on foundation aspects for the detail design of structural culverts within Contract 2 along the proposed Highway 69 alignment, associated with the four-laning of Highway 69 in the Townships of Wallbridge, Henvey and Mowat. The proposed culverts are located within the Contract 2 highway alignment approximately 2.4 km to the north of the southern limit of Contract 2, corresponding to approximately 4.2 km northwest of the junction between existing Highway 69 and Highway 529. As part of this work, foundation recommendations are required for one (1) drainage culvert and one (1) cattle crossing culvert. Table 1 summarizes the locations of the proposed culverts, culvert types, dimensions and invert elevations within the Contract 2 project limits for the Highway 69 alignment that require foundation design.

This report presents geotechnical resistances for design of the culverts, as well as the results of the overlying embankment stability and settlement analyses. It provides recommendations for stable embankment geometry and embankment fill materials including implementation of mitigation alternatives that may be required as a means to reduce culvert settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical problems associated with culvert and embankment construction, sub-excavating soft/organic materials and placement of new fill materials.

6.2 Culvert Types

Based on the proposed details provided by URS on August 2, 2012, the analyses and recommendations in this report assumes that Culvert 201 at STA 11+207 will be a precast box culvert while Culvert 202 at STA 11+220 will be a cast-in-place culvert.

6.3 Culvert Construction Options

In general, the foundation soils at the culvert crossings will undergo settlement as a result of loading from the new overlying and adjacent embankments. Therefore, the timing of culvert construction is an essential factor in determining the preferred settlement mitigation option. The following alternatives for culvert construction can be considered (where applicable, giving due consideration to the recommended foundation mitigation option for the accompanying embankment swamp crossing):

- concurrent with embankment construction;
- following the embankment preload period; and
- following full sub-excavation along the culvert alignment and concurrent with embankment construction.

In areas where relatively small settlements are estimated to occur as a result of culverts being constructed within existing highway embankments or due to the presence of relatively thin, compressible foundation soils at the culvert locations, culvert construction can commence immediately following excavation of the existing embankment fill or concurrently with the proposed new embankment construction so long as any requirements for maintaining embankment stability are addressed. If required, the culvert design could include a camber.

Where relatively large settlements are estimated to occur (as is the case at this site), it is recommended that the culverts be constructed subsequent to the embankment preload period or following full sub-excavation of cohesive deposits, to reduce settlement and provide adequate long-term performance of the culvert and the associated overlying and adjacent roadway. The following sections provide a more detailed discussion on the possible alternatives for culvert construction to mitigate settlements and improve long-term performance.

6.3.1 Culvert Construction Concurrent with Embankment Construction

Culverts which are constructed concurrently with the new embankments will experience settlement (both short-term and long-term), as well as lateral spreading (or horizontal strain in the longitudinal direction) as a result of the embankment loading. The analyses of settlement and horizontal strain are discussed in Section 6.4.2 and Section 6.4.3, respectively. If the culvert structure is capable of tolerating the estimated total and differential settlements and associated strains, the culvert could be constructed with a camber (if necessary), such that once the settlement has occurred, the hydraulic flow will be maintained as originally designed. However, culvert designs which include a camber may have a relatively high risk of poor performance resulting in unfavourable drainage/surface water flow conditions at some locations. It is important to note that it is inherently difficult to predict settlements for the variable subsurface conditions along the culvert alignments with such a degree of accuracy to allow an accurate camber design. If the actual settlements are smaller than predicted, the culvert may not achieve the design grade or slope, which could impede the flow of water. If actual settlements are larger than expected, the culvert may sag below the design invert elevation and as a result some sediments may be deposited inside the culvert and could reduce the flow of water. Expansion joints should also be included along the length of the culvert to accommodate horizontal strain which will occur in conjunction with the vertical settlement. If the culvert cannot tolerate the estimated settlement and horizontal strain, consideration should be given to constructing the culvert following the preload period of the embankment (as discussed in Section 6.3.2) or following full sub-excavation of the compressible, cohesive deposits (as discussed in Section 6.3.3).

It should be noted that if either of these option is adopted as the preferred alternative for construction of any of the culverts, it is still necessary to sub-excavate all existing organic material prior to placement of any fill or culvert bedding material due to the highly compressible nature of organic soils which can undergo significant secondary (creep) settlement.

6.3.2 Culvert Construction Following Embankment Preload Period

At locations where the magnitudes of estimated total and differential settlements and horizontal strains cannot be tolerated and/or where removal of cohesive deposits and replacement with granular fill is not considered practical, the culverts should be constructed after a preload period. Preloading refers to the placement of fill to the proposed height of embankment (possibly in stages), in advance of construction of the permanent culvert, in order to consolidate the underlying compressible soils. If preloading of the embankment at the culvert location is completed prior to construction of the permanent culvert, the magnitude of total and differential settlement beneath the culvert and horizontal strain along the culvert will be reduced. However, this mitigation option requires excavation through the new embankment fill to the culvert founding elevation at the end of the preload period in order to construct the culvert. Provided that the final fill above the culvert is properly placed and compacted, the magnitude of differential settlement between the fill embankment (that has been compressed under its self-weight for the entire preload period) and the final backfill above the culvert should be acceptable.

6.3.3 Culvert Construction Following Full Sub-Excavation

Depending on the depth and thickness of any soft, compressible foundation deposit(s), the magnitude of total and differential settlement and horizontal strain could also be reduced by means of full sub-excavation and replacement along the culvert alignment to allow for permanent culvert construction prior to embankment loading (i.e. concurrent with embankment construction). At culvert locations where the compressible deposits are thick, the resulting magnitude of settlements as well as the associated horizontal strains, even with full sub-excavation, may still be too large as a result of compression of the underlying fill itself, to accommodate standard culvert construction. However, where there is a limited thickness and depth of soft, compressible soils underlying the proposed culvert, full sub-excavation and replacement is a feasible option to reduce the settlement and allow for culvert construction in conjunction with the construction of the new embankment. The costs of full sub-excavation and backfilling would have to be assessed in the cost/benefit analysis when choosing the preferred mitigation option.

Although full sub-excavation will improve the settlement performance of the culverts and embankments in close proximity of the sub-excavation, adjacent areas of the embankment may not experience the same improvements in settlement performance depending on the mitigation measures adopted for the adjacent embankment swamp crossing. As a result, the overlying embankment may experience some differential settlements along its alignment depending on the timing of embankment construction/culvert construction, type of backfill and timing of final earthworks and paving.

6.4 Stability, Settlement and Horizontal Strain

The following sections summarize the methods utilized to carry out analyses of embankment stability and settlement of the culverts and methods utilized to evaluate horizontal strains along the culverts beneath the zone of influence of the proposed embankment loading.

6.4.1 Stability

The methodology used to evaluate embankment stability at the culvert locations is described below. In addition, the parameters used in the analyses for each culvert location are also presented. The results of the analyses for each culvert location are discussed in Section 6.6.

6.4.1.1 Methodology

Embankment stability analyses were performed at each culvert location. In areas where cohesive deposits were encountered in the subsoils (as is the case at both of these culvert locations), the stability of the proposed new embankment section(s) are analyzed using limit equilibrium methods. In areas where the subsoils consist of non-cohesive soils and/or granular fill only, the stability of the proposed embankment section are assessed based on precedent experience in similar soil conditions.

All limit equilibrium slope stability analyses were performed using the commercially available program Slide (Version 6.0), produced by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety (FoS). The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum FoS of 1.3 is normally adopted for the design of embankment slopes under static conditions. This FoS is considered adequate for the embankments at these sites considering the design requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadway. The stability analyses were performed to check that the target minimum Factor of Safety was achieved for the various embankment heights and geometries at the culvert locations.

Given the presence of localized organic deposits at the proposed culvert locations, the stability analyses assume that all organic soils (i.e. topsoil peat/root mat, organic silty sand and organic silt) beneath the culvert alignment will be removed prior to construction and that granular fill will be used for replacement of sub-excavated material (as discussed in Section 6.8.1). The piezometric conditions required in the analyses were based on the groundwater levels observed during drilling which were generally located at about the level of the natural ground surface.

6.4.1.2 Parameter Selection

The simplified stratigraphy together with the associated strength and unit weight values assigned to the different native soil types at the culvert locations are plotted for the cohesive deposits on Figure 1 and summarized for all native soil layers in Table 2. The granular fill modeled in the analyses is assumed to have a unit weight of 21 kN/m^3 and an effective friction angle of 34^o and the embankments constructed with 2H:1V side slopes.

The subsoils encountered at the proposed culvert locations are composed of relative thin deposits of granular soils (silty sand to sand) overlying a thick deposit of cohesive soils (clayey silt to clay) over granular soils (silt to sand and gravel). For the granular soils, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle) for the granular soils were estimated from empirical correlations using the results of the in situ Standard Penetration Tests (SPT) (US Navy, 1986), in conjunction with engineering judgement based on experience in similar soil conditions.

For the cohesive deposits, total stress parameters were employed in the analyses assuming undrained conditions. The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were assessed based primarily on the results of in situ field vane shear tests and also inferred from the laboratory consolidation tests results (where available), and estimated from correlations with the SPT results and other laboratory test data (natural water content), if required. From the consolidation tests, the following correlation proposed by Mesri (1975) was employed to estimate the undrained shear strength:

$$s_u = 0.22\sigma'_p$$

where: s_u = average mobilized undrained shear strength (kPa)
σ'_p = preconsolidation stress (kPa)

Where appropriate, Bjerrum's correction factor was employed to estimate the average mobilized undrained shear strength from the results of the in situ field vane tests as follows:

$$s_{u(mob)} = \mu s_{u(FV)} \qquad \text{(after Bjerrum, 1973)}$$

where: $s_{u(mob)}$ = average mobilized undrained shear strength (kPa)
$s_{u(FV)}$ = undrained shear strength from field vane test (kPa)
μ = Bjerrum's correction factor based on Plasticity Index

When developing the culvert area-specific correlations of engineering parameters based on the laboratory and field test data, the results from both culvert crossings as well as the adjacent swamp crossing were combined to provide a larger set of parameters to evaluate. It is considered that both the culvert crossings and the swamp crossing exhibit sufficiently similar soil mineralogy and geology that correlations based on all of the data are justified. Having developed the area-specific correlations, the test results for each individual culvert location were examined and the design parameters developed accordingly.

6.4.2 Settlement

The following sections outline the methods used to conduct the settlement analyses at the culvert locations. The results of the analyses for each culvert location are discussed in Section 6.6.

6.4.2.1 Methodology

To estimate the magnitude of the expected settlements, analyses were carried out along the individual culvert alignments using the commercially available program Settle3D (Version 2.0) produced by Rocscience Inc. The rate of settlement/consolidation of the cohesive foundation soils was assessed using Terzaghi's one-dimensional consolidation theory.

The sources of settlement were considered to include:

- primary time-dependent consolidation of the cohesive deposits;
- secondary time-dependent (creep) consolidation of the cohesive deposits (long-term);
- immediate settlement of the native granular soils; and

- self-weight compression of the embankment fill materials beneath the culvert (where applicable).

The thickness of the compressible foundation soils and the height of the embankment vary along the proposed culvert alignments and therefore the settlements along the length of a given culvert will similarly vary. As such, settlements have been assessed at the inlet, the highway centreline median (i.e. mid-point), embankment centrelines, and outlet of each culvert location.

The settlement analyses assume that all organic soils (i.e. topsoil, peat/root mat, organic silty sand and organic silt) beneath the culvert alignment will be removed prior to construction and that granular fill will be used for replacement of sub-excavated material (as discussed in Section 6.8.1). The piezometric conditions required in the analyses are based on the groundwater levels observed during drilling and are generally located at about the level of the natural ground surface.

6.4.2.2 Parameter Selection

The simplified stratigraphy together with the associated strength and unit weight values assigned to the different native soil types at the culvert locations are plotted for the cohesive deposits on Figure 1 and summarized for all native soil layers in Table 2

The immediate compression of the very loose to very dense silt, sandy silt to silty sand, sand, and gravel layers was modeled by estimating an elastic modulus of deformation based on the SPT ‘N’-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated moduli values were compared with the typical range of expected values for similar soil types, as outlined in *Canadian Highway Bridge Design Code, CHBDC* (2006) and adjusted, if necessary.

The consolidation settlement of the cohesive deposits was assessed using the results of the laboratory consolidation tests and in situ field vane tests to estimate the stress history and deformation parameters for the cohesive deposits. It is noted that while only one (1) laboratory one-dimensional consolidation (oedometer) test was carried out on a sample obtained from a borehole specifically advanced for the culverts, the results of three (3) additional laboratory consolidation tests carried out for design of the associated embankment crossing, as described in the Foundation Investigation and Design Report, Swamp Crossings and High Fill Areas (MTO, 2012). In addition, the results of the consolidation tests were supplemented with estimates of deformation parameters (i.e. recompression and compression indices) using empirical correlations proposed in literature by Koppula (1986), Terzaghi and Peck (1967), Kulhawy and Mayne (1990) and Azzouz et al. (1976). The correlation by Koppula (1986) relating the natural water content and liquid limit to the compression index was found to be the most consistent with the results of laboratory consolidation tests for the clayey soils at this site.

The following correlation relating in situ undrained shear strength to preconsolidation stress proposed by Mesri (1975) was employed:

$$\sigma'_p = \frac{s_{u(mob)}}{0.22}$$

where:

$s_{u(mob)}$ = $\mu s_{u(FV)}$
σ'_p = preconsolidation stress (kPa)
$s_{u(mob)}$ = average mobilized undrained shear strength (kPa)
$s_{u(FV)}$ = undrained shear strength from field vane test (kPa)
μ = Bjerrum's correction factor based on Plasticity Index

The coefficient of consolidation, c_v (cm^2/s), required in the settlement time-rate analysis was established using the results of the consolidation tests (based on t_{90}) and/or estimated from the U.S. Navy (1986) correlation with liquid limits assuming normally-consolidated soils.

In addition to primary consolidation within cohesive deposits, secondary compression will also occur. Secondary compression is referred to as creep settlement and occurs over a long period of time, after full dissipation of excess pore pressure under a constant stress. The following relationship has been employed for estimating the magnitude of creep settlement over the life of the embankment following the completion of primary settlement at each location.

$$S_c = HC_{\alpha\varepsilon} log(\frac{t}{t_{EoP}})$$

where :

S_c = secondary consolidation (creep) settlement (mm)
$C_{\alpha\epsilon}$ = modified secondary compression index as estimated from laboratory consolidation tests and/or from the empirical correlation by Mesri (1973)
H = initial thickness of normally consolidated portion of compressible clay deposit (mm)
t = post-construction period of interest (20 years)
t_{EoP} = time to reach end of primary consolidation (years)

The values of modified secondary compression index ($C_{\alpha\varepsilon}$) from the empirical correlation were compared with the values of $C_{\alpha\varepsilon}$ calculated from the results of the laboratory consolidation tests, where necessary.

6.4.3 Horizontal Strain

The following sections outline the method used to estimate the horizontal strain along the culverts at both locations.

6.4.3.1 Parameter Selection

As a result of the two-dimensional nature of the proposed embankment geometry, shear stresses will be mobilized in the foundation soils (upon completion of preload embankment construction and during the preload period) causing lateral spreading of the foundation soils and new embankment fill. This, in conjunction with the non-uniform vertical settlement of the foundation soils along the proposed culvert alignment will generate horizontal straining along the newly constructed culvert. In order to maintain structural integrity of the culvert, the culvert design must incorporate a suitable allowance for extension at the joints/couplings of the culvert segments to prevent the culvert from cracking and/or failing in tension.

The research work by Rutledge and Gould (1973) on the movements on articulated conduits under earth dams on compressible foundations can be used to estimate the magnitude of the horizontal strain likely to occur as a result of the proposed embankment construction at the culvert sites. The following equations have been used to obtain a relationship between vertical settlement, vertical strain, horizontal strain and maximum joint opening as a result of settlement of the foundation soils:

$$\varepsilon_v = \frac{\delta_v}{d}$$

$$\varepsilon_h = \varepsilon_v \frac{\varepsilon_h}{\varepsilon_v}$$

$$\Delta L = \varepsilon_h L$$

where :
ΔL = maximum joint opening (m)
ε_v = maximum vertical strain
ε_h = maximum horizontal strain
$\frac{\varepsilon_h}{\varepsilon_v}$ = estimated ratio of maximum horizontal strain to maximum vertical strain from Figure 2 in Rutledge and Gould (1973)
L = length of culvert (m)
δ_v = maximum vertical settlement of culvert as a result of immediate and post-construction settlement of foundation soils and granular fill / bedding material (m)
d = thickness of compressible foundation deposits at culvert location (m)

6.5 Geotechnical Axial Resistance

Section 6.6 outlines the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS) for 25 mm of settlement for design of each culvert founded on a properly prepared subgrade/granular bedding (as discussed in Section 6.8). The geotechnical resistances provided assume that the loads will be applied perpendicular to the surface of the base of the culverts. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the *Canadian Highway Bridge Design Code (CHBDC)* and its *Commentary*.

The loading on the foundation soils below the culverts and the associated total settlement at the culvert locations will be governed by the design height of the overlying and adjacent embankment fills. As such, it is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical axial resistance at SLS in the design of the culverts. Where culverts are constructed following completion of all foundation soil settlement due to construction of embankment fills, the SLS values as provided may be used for the culvert design for settlement of 25 mm.

6.5.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of the culverts and the granular fill/bedding placed following sub-excavation of organic deposits should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following summarizes the coefficient of friction for the interface materials.

Interface Materials	Coefficient of Friction (tan δ)
Precast Concrete Box Culvert on Compacted Granular ‘A’	tan δ = 0.45
Cast-in-Place Concrete Culvert on Compacted Granular ‘A’	tan ø = 0.55

These values represent unfactored values.

6.6 Results of Analysis

The results of the stability and settlement analysis, estimated maximum vertical and horizontal strains, factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS) for 25 mm of settlement are provided for both of the proposed culvert locations in the following sections. In addition, the options and recommendations for achieving the target Factor of Safety for the stability of the required embankment geometry at the proposed culvert locations and for minimizing the time dependent, post-construction settlements are also discussed. These options take into consideration the foundation mitigation recommendations for the embankment construction at the swamp area in which the culverts are located as provided in the Foundation Investigation and Design Report, Swamp Crossings and High Fill Areas (MTO, 2012). The results of analysis and foundation recommendations for each culvert are summarized in Table 3 and Table 4, respectively.

Where the expected settlements, vertical strain and horizontal strain are relatively small, the preferred option is typically to construct the culvert concurrently with the construction of the embankment. Due to variations in the subsurface conditions along the length of the culverts, the settlements and horizontal strains may differ at different points along the culvert and this should be considered when choosing an appropriate design and construction methodology to be employed.

Where the expected settlements, vertical strain and horizontal strain are relatively large (as is the case for these culvert sites), the preferred option is to either install a temporary culvert (if necessary) and then construct the permanent culvert following the embankment preload period, or to construct the culvert following full sub-excavation of compressible deposit(s) along the culvert alignment.

6.6.1 Highway 69 SBL and NBL – STA 11+207 (Culvert 201)

The culvert crossing will extend across the proposed Highway 69 SBL and NBL embankment within Swamp 202 at about STA 11+207 in the Township of Henvey. Details of the subsurface conditions along this culvert are presented in Section 4.3 and shown on Drawing A2 in Appendix A.

Given that the proposed culvert location is within Swamp 202 and therefore subjected to the same stability and settlement issues for the adjacent embankment crossing, it is recommended that the stability and settlement mitigation recommendations for the proposed culvert location be consistent with the foundation mitigation recommendations for the embankment construction within Swamp 202.

Due to the great depth to the bottom of the cohesive deposit at this location (up to about 20 m below existing ground surface), the need for large toe berms (3 m high by 20 m wide) to satisfy a Factor of Safety (FoS) of 1.3 or greater against deep-seated failure surfaces for conventional granular fill embankments, as well as the large magnitude of consolidation settlements (up to about 1,445 mm) of the foundation soils associated with 6.5 m high fill embankments, it was recommended that the proposed embankments in Swamp 202 be constructed with lightweight fill (i.e. expanded polystyrene (EPS)).

For 6.5 m high EPS embankments constructed with 2H:1V side slopes, consisting of 1 m granular base (which includes a 300 mm thick levelling pad), 4.5 m of EPS cores and 1 m of granular protective cover/pavement structure, the stability analysis indicates that the embankments immediately adjacent to the culverts will have a FoS of 1.3 or greater for deep-seated, global failure surfaces.

In order to satisfy the embankment settlement performance criterion of 100 mm of settlement over a 20-year period following the completion of construction, the foundation recommendation for Swamp 202 is to construct 3.5 m high preload embankments comprised of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II, with temporary toe berms 1.5 m high by 2.5 m wide along the outside embankment toes, to be left in place for a minimum preload period of 130 days. It is recommended that the same foundation mitigation option and minimum preload period of 130 days be adopted to reduce settlements along the proposed culvert alignment. Temporary toe berms may not be required at the proposed culvert location if a temporary culvert is employed.

For the 3.5 m high preload embankments left in place for a minimum period of 130 days, the settlement analysis indicates that during construction preloading, a temporary culvert would undergo settlements between about 20 mm and 175 mm and that the total post-construction settlement of the foundation soils along the permanent culvert (after the preload period) will be between about 20 mm and 65 mm. Therefore, the maximum post-construction horizontal strain along the 87 m long permanent culvert is estimated to be about 0.10 per cent of the culvert length (or about 85 mm).

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement for the proposed 3.0 m wide pre-cast box culvert founded on a properly prepared subgrade/granular bedding overlying the sand, clay to clayey silt and sand and silt to sand deposits at this location is estimated to be 50 kPa and 25 kPa, respectively. The low bearing capacities are attributed to the presence of the thick, soft clay deposit within the zone of influence of the culvert foundation. The undrained shear strength of the clayey silt ot clay is about 16 kPa to 23 kPa down to Elevation 173 m, up to about 8 m to 9 m below the base of the culvert.

If higher bearing capacities are required for structural design of the culvert, consideration should be given to either supporting the culvert on piles driven to bedrock or constructing the culvert on a different alignment located further north in Swamp 202 where the thickness of the clay deposit is anticipated to be significantly thinner. If the culvert alignment is relocated to the north, settlement mitigation measures may still be required, but the type of foundation mitigation, and the corresponding ULS and SLS value for design would need to be evaluated once additional information on the subusrface conditions along the new alignment are available.

Taking into consideration that the proposed permanent culvert is a drainage culvert, it is recommended that a temporary culvert be installed prior to the preload embankment construction to maintain surface water drainage during the preload period.

Details on the requirements for excavation and replacement of the near surface organic deposits, bedding and backfilling are provided in Section 6.8.

6.6.2 Highway 69 SBL and NBL – STA 11+220 (Culvert 202)

The culvert crossing will extend across the proposed Highway 69 SBL and NBL embankment within Swamp 202 at about STA 11+220 in the Township of Henvey. Details of the subsurface conditions along this culvert are presented in Section 4.4 and shown on Drawing B2 in Appendix B.

Given that the proposed culvert location is within Swamp 202 and therefore subjected to the same stability and settlement issues for the adjacent embankment crossing, it is recommended that the stability and settlement mitigation recommendations for the proposed culvert location be consistent with the foundation mitigation recommendations for the embankment construction within Swamp 202.

Due to the great depth to the bottom of the cohesive deposit (up to about 23 m below existing ground surface), the need for large toe berms (3 m high by 20 m wide) to satisfy a Factor of Safety (FoS) of 1.3 or greater against deep-seated failure surfaces for conventional granular fill embankments, as well as the large magnitude of consolidation settlements (up to about 1,445 mm) of the foundation soils associated with 6.5 m high fill embankments, it was recommended that the proposed embankments in Swamp 202 be constructed with lightweight fill (i.e. expanded polystyrene (EPS)).

For 6.5 m high EPS embankments constructed with 2H:1V side slopes, consisting of 1 m granular base (which includes a 300 mm thick levelling pad), 4.5 m of EPS cores and 1 m of granular protective cover/pavement structure, the stability analysis indicates that the embankments immediately adjacent to the culverts will have a FoS of 1.3 or greater for deep-seated, global failure surfaces.

In order to satisfy the embankment settlement performance criterion of 100 mm of settlement over a 20-year period following the completion of construction, the recommendation for Swamp 202 is to construct 3.5 m high preload embankments comprised of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II, with temporary toe berms 1.5 m high by 2.5 m wide along the outside embankment toes, to be left in place for a minimum preload period of 130 days. It is recommended that the same foundation mitigation option and minimum preload period of 130 days be adopted to reduce settlements along the proposed culvert alignment. Temporary toe berms will be required at the proposed culvert alignment since the use of a temporary culvert is not anticipated at this location.

For the 3.5 m high preload embankments left in place forr a minimum period of 130 days, the settlement analysis indicates that during construction, the preload embankment would undergo settlements between about 20 mm and 145 mm and that the total post-construction settlement of the foundation soils along the permanent culvert (after the preload period) will be between about 40 mm and 60 mm. Therefore, the maximum post-construction horizontal strain along the 81 m long permanent culvert is estimated to be about 0.10 per cent of the culvert length (or about 80 mm).

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement for the proposed 5 m wide box culvert founded on a properly prepared subgrade/granular bedding overlying the sand, clay to clayey silt and sand and silt to sand deposits at this location is estimated to be 55 kPa and 20 kPa, respectively. The low bearing capacities are attributed to the presence of the thick, soft clay deposit within the zone of influence of the culvert foundation. The undrained shear strength of the clayey silt ot clay is about 16 kPa to 23 kPa down to Elevation 173 m, up to about 8 m to 9 m below the base of the culvert.

If higher bearing capacities are required for structural design of the culvert, consideration should be given to either supporting the culvert on piles driven to bedrock or constructing the culvert on a different alignment located further north in Swamp 202 where the thickness of the clay deposit is anticipated to be significantly thinner. If the culvert alignment is relocated to the north, settlement mitigation measures may still be required, but the type of foundation mitigation, and the corresponding ULS and SLS value for design would need to be evaluated once additional information on the subusrface conditions along the new alignment are available.

Given that the proposed permanent culvert is to be a cattle-crossing culvert, it is anticipated that a temporary culvert will not be required to be installed as part of the preload embankment construction.

Details on the requirements for excavation and replacement of the near surface organic deposits, bedding and backfilling are provided in Section 6.8.

6.7 Lateral Earth Pressures

The lateral earth pressures acting on the walls of the culverts will depend on the type and method of placement of backfill materials, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. It should be noted that these design recommendations and parameters are for level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 Aggregates Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the No. 200 (0.075 mm) sieve should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and nominally compacted. Weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).

- For box culverts, granular fill (where utilized) should be placed in a zone with the width up to 300 mm behind the back of the culvert. The pressures are based on the proposed embankment fill materials and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular ‘A’	22 kN/m^3	0.43	0.27
Granular ‘B’ Type II	21 kN/m^3	0.43	0.27

- For lightweight fill (EPS) installed behind the culvert wall, the pressure acting over the depth of the EPS may be calculated as follows:

Fill Type	Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Lightweight Fill (EPS)	0.5 kN/m^3	0.11	0.11

If the culvert structures allow for lateral yielding, active earth pressures may be used in the foundation design. If the culvert structures do not allow lateral yielding, at-rest earth pressures should be assumed for foundation design. The movement to allow active pressures to develop within the backfill may be taken as per Table C6.6 of the *Commentary to the CHBDC*.

6.8 Culverts – Construction Considerations

6.8.1 Excavation and Replacement Below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils should be stripped from the plan limits of the proposed works. Given the design invert elevations of the proposed culverts, excavations of the organic material (i.e. topsoil, peat and organic sands and silts) and overburden soils (sands and clays) up to about 2.7 m below existing ground surface is anticipated. Given the relatively thin localized organic deposits at the proposed culvert locations, it is assumed that granular fill will be used to backfill the excavations.

All excavations should be carried out in accordance with OPSS 902 (Excavating and Backfilling – Structures) and must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended).

6.8.2 Culvert Bedding and Backfill

6.8.2.1 Precast Culvert

The bedding, levelling pad, and granular backfill requirements (i.e. behind the zone of EPS) for the proposed permanent pre-cast Culvert 201 should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the near surface granular layers during excavation to invert and bedding level (see Section 6.8.4) it is recommended that Culvert 201 should be provided with at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II material. The placement of a Class II OPSS 1860 (Geotextiles) non-woven geotextile (having an FoS not greater then 212 μm) between the overburden soils and the bottom of the bedding is recommended. The bedding should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 98 percent of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 1010 (Compacting). In addition, a minimum 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 Granular ‘A’ material or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates & Concrete) should be provided as shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

6.8.2.2 Cast-in-Place Culvert

The bedding and backfill requirements for the proposed cast-in-place Culvert 202 should be in accordance with OPSS 902 (Excavating and Backfilling – Structures). The box culvert should be provided with at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' for bedding purposes and partial frost protection. The placement of a Class II OPSS 1860 (Geotextiles) non-woven geotextile between the overburden soils and the bottom of the bedding is recommended. The bedding should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 98 percent of the Standard Proctor maximum dry density of the material as specified in OPSS.PROV 501 (Compacting).

6.8.2.3 General

Backfill behind the culvert walls will consist of EPS fill and granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II, but with less than 5 percent passing the No. 200 (0.075 mm) sieve. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

Where temporary culverts are incorporated into the works and are subsequently removed after a preload period, the backfill above the permanent culvert should consist of EPS (to match the adjacent EPS fill levels), OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II to minimize differential settlements along the highway embankments in the area of the permanent culvert.

The culverts should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m^3 for OPSS.PROV 1010 Granular 'A', 21 kN/m^3 for Granular 'B' Type II and 0.5 kN/m^3 for EPS backfill above and surrounding the culvert.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

6.8.3 Erosion Protection

For the drainage culvert (i.e. C201), provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring), or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three (3) times the culvert height and along the adjacent slopes to a height of two (2) times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culverts should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culverts should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should generally follow the standard presented in OPSD 810.010, with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culverts.

6.8.4 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed culvert alignments will be required to remove organic and overburden soils prior to placement of backfill, bedding material and the actual culvert structures. As a result of the excavation, groundwater flow into the excavation can be expected to occur due to the relatively permeable near-surface subsoils and high groundwater levels observed at the culvert locations. Therefore, control of surface water and groundwater will be necessary at the culvert locations to allow for construction to be carried out in dry conditions, where required.

At Culvert 201, depending on creek flows, surface water flows and groundwater levels at the time of construction, water flow could be passed through the area by means of a temporary culvert (as discussed in Section 6.9), or diverted by pumping from behind temporary sheetpile cofferdam(s).

At Culvert 202, given that the design invert is approximately at or above existing ground surface, it is not anticipated that any specialized measures will be required to control groundwater and allow construction in the dry. Surface water should be directed away from the excavations areas to prevent ponding of water.

In addition to temporary sheet pile cofferdams, groundwater control may be required at the location of Culvert 201, as the foundation excavations to the invert level are expected to extend below the groundwater level. Excavations will be advanced through cohesive and granular soils, however, seepage into the excavation should be adequately controlled by pumping from properly filtered sumps. Dewatering of all excavation should be carried out in accordance with OPSS 517 (Dewatering).

6.9 Temporary Culverts

Where a permanent culvert will be constructed subsequent to a preload period to mitigate settlements, a temporary culvert may be required to promote drainage through the embankment fills during the preload period, such as at the location of Culvert 201. Temporary culverts may consist of precast concrete culverts (box or pipe) or corrugated steel pipe (CSP) culverts. Bedding recommendations should be in accordance with the corresponding OPSS and/or OPSD depending on the type of the temporary culvert chosen. Assuming the temporary culverts are CSPs, construction of these culverts should be in accordance with OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation).

The location of the temporary culverts could be offset from the actual alignment of the permanent culverts, provided that surface drainage paths are adequate. Due to the potential size of the temporary culverts, it is recommended that these culverts be removed following the permanent culvert construction. It is generally recommended that a temporary culvert be constructed within a temporary granular core for the ease of removal after the completion of the preload period; however, given that the 3.5 m high preload embankment will be constructed of granular fill (i.e. Granular 'B' Type II), the specification of a special granular core for the temporary culvert will not be required at this location.

If it is not desirable to remove the temporary culvert, consideration could be given to backfilling the temporary culvert with OPSS 1359 Unshrinkable Fill material.

7.0 CLOSURE

This report was prepared by Christopher Ng, P.Eng., and was reviewed by Mr. J. Paul Dittrich, Ph.D., P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, conducted an independent quality control review of the report.

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Http://capws/sites/0911116014highway69FourLaning/Contract 2/Reporting/Final/Culverts/09-1111-6014-2521 RPT 15Sep22 Highway 69 Culverts - Contract 2.docx

REFERENCES

Azzouz, A.S., Krizek, R.J., and Corotis, R.B., 1976. Regression Analysis of Soil Compressibility. Soils and Foundations, Tokyo, Vol. 16, No. 2, pp. 19-29.

Bjerrum, L., 1973. Problems of Soil Mechanics and Construction of Soft Clays and Structurally Unstable Soils. State of the art Report, Session 4. Proceedings, 8th International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol. 3, pp. 111-159.

Bowles, J.E., 1984. Physical and Geotechnical Properties of Soils, Second Edition. McGraw Hill Book Company, New York.

Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.

Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.

Chapman, L.J., and Putnam, D.F. 1984. The Physiography of Southern Ontario, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

Geology of Ontario. 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

Ministry of Transportation, Ontario. 2012. Foundation Investigation and Design Report, Swamp Crossings and High Fill Areas – Contract 2, Highway 69 Four-Laning from 1.7 km North of Highway 529 Northerly to 3.9 km North of Highway 522, GWP 5404-05-00; WP 5404-05-01, Geocres No. 41H-115 by Golder Associates Ltd.

International Society for Rock Mechanics (ISRM), 1985. Suggested Method for Determining Point Load Strength, In: International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts, Vol. 22, No. 2, pp. 53–60.

Koppula, S.D., 1986. Discussion: Statistical Estimation of Compression Index, Geotechnical Testing Journal, ASTM, Vol. 4, No. 2, pp. 68-73.

Kulhawy, F.H. and Mayne, P.W., 1990. Manual on Estimating Soil Properties for Foundation Design. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.

Mesri, G. 1973. Coefficient of Secondary Compression. ASCE Journal of the Soil Mechanics and Foundations Division, Vol. 99, SM1, pp. 123-137.

Mesri, G. 1975. Discussion on New Design Procedure for Stability of Soft Clays. ASCE Journal of the Geotechnical Engineering Division, Vol. 101, GT4, pp. 409-412.

Rutledge, P.C. and Gould, J.P. 1973. Movements of Articulated Conduits Under Earth Dams on Compressible Foundations, In: Embankment Dam Engineering – Casagramde Volume. Eds. Hirschfeld, R.C. and Poulos, S.J. John Wiley & Sons, New York.

Terzaghi, K. and Peck, R.B., 1967. Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, New York.

Unified Facilities Criteria U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587	Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil

Commercial Software:

Settle3D (Version 2.0) by Rocscience Inc.

Slide (Version 6.0) by Rocscience Inc.

Ontario Occupational Health and Safety Act:

Ontario Regulation 213	Construction Projects (as amended)

Ontario Provincial Standard Drawing:

OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets

Ontario Provincial Standard Specification:

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Compacting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specification for Aggregrates – Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Basem Subbase, Select subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1359	Material Specification for Unshrinkable Fill
OPSS 1860	Material Specification for Geotextiles

Ontario Water Resources Act:

Ontario Regulation 903	Wells (as amended)

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1 $\tau = c' + \sigma' \tan\phi'$
2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to “A” size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive Soils

Density Index Relative Density	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive) or	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

TABLES

Table 1: Summary of Culvert Details
Highway 69 Four-Laning

Culvert Designation	*Culvert Location (Associated Swamp)*	*Approximate Proposed Embankment Height[3] (m)*	*Culvert Type*	*Invert Elevations[1]*		*Culvert Dimensions[1]*			*Boreholes / DCPTs*
				East End of Culvert (m)	*West End of Culvert (m)*	*Width (m)*	*Height (m)*	*Length (m)*	
C201	Highway 69 SBL and NBL STA 11+207 (Swamp 202)	6.5	Pre-Cast Box Culvert	182.24	180.94	3	2.4	87	5 Boreholes (C201-01 to C201-04 and S202-04)
C202	Highway 69 SBL and NBL STA 11+220 (Swamp 202)	6.5	Cast-in-Place Box Culvert	183.34	182.89	5	5	81	5 Boreholes (C202-01 to C202-03, S202-05 and S202-19)

Notes 1 Invert elevations and culvert dimensions as shown on profiles drawings provided by URS on August 24, 2012.

Prepared By: TVA **Checked By:** CN/JPD **Reviewed By:** JMAC

Table 2: Summary of Foundation Engineering Parameters
Highway 69 Four-Laning

Culvert Location	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ (kN/m^3)	ϕ' ($^\circ$)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa^{-1})	E' (MPa)	c_v (cm^2/s)
Highway 69 SBL and NBL STA 11+207 (Culvert 201)	Peat/Topsoil	182.6 to 182.5	0.1 to 0.3	12 – 15	12	1	-	-	-	-	-	-	-	-
	Sand	182.5 to 181.8	0.2 to 1.1	18.5	27	0	-	-	-	-	-	-	-	-
	Organic Silt to Organic Silty Sand	182.3 to 181.4	0.3 to 0.6	12 – 15	26	0	-	-	-	-	-	-	-	-
	Upper Silty Clay	181.8	0.4	15	-	-	-	-	-	-	-	-	-	-
	Clayey Silt to Clay	181.2 to 180.3	9.7 to 18.4	16.5	-	-	16 – 41.5	77.5 – 187	1.8	0.85 – 1.4	0.085 – 0.14	-	-	1.91×10^{-3}
	Silt	165.4 to 162.4	1.9 to 2.9	18.5	27	0	-	-	-	-	-	-	4.5	-
	Sandy Silt to Sand	169.6 to 159.5	1.2 to 4.7	18 – 19	29	0	-	-	-	-	-	-	25	-
	Sand and Gravel	160.9	1.1	20 – 21	34	0	-	-	-	-	-	-	50	-
Highway 69 SBL and NBL STA 11+220 (Culvert 202)	Peat/Topsoil	183.0 to 182.5	0.2 to 0.3	12 – 15	12	1	-	-	-	-	-	-	-	-
	Silty Sand to Sand	182.7 to 182.3	0.1 to 0.9	18.5	27	0	-	-	-	-	-	-	-	-
	Organic Silty Sand	182.3	0.5	15	26	0	-	-	-	-	-	-	-	-
	Clayey Silt to Clay	182.7 to 181.8	10.7 to 22.0	16.5	-	-	16 – 41.5	77.5 – 187	1.8	0.85 – 1.4	0.085 – 0.14	-	-	1.91×10^{-3}
	Silty Sand to Sand and Gravel	166.6 to 159.8	0.9 to 3.0	19 – 21	29 – 34	0	-	-	-	-	-	-	10 – 50	-
	Cobbles and Boulders	165.5 to 164.0	1.2 to 1.6	21	-	-	-	-	-	-	-	-	75	-

Note:

1. Additional details of foundation engineering parameters for cohesive deposits (i.e. clayey silt / silty clay / clay) along Culvert 201 and Culvert 202 alignments and associated Swamp 202 are provided in Figure 1.

Prepared By: CC/TZ **Checked By:** CN/JPD **Reviewed By:** JMAC

Table 3: Summary of Settlement Analyses
Highway 69 Four-Laning

Culvert Designation (Culvert Type)	***Culvert Location (Associated Swamp)***	***Approximate Proposed Embankment Height (m)***	***Preferred Mitigation Option in Swamp for Embankment Construction***	***Estimated Total Settlement for Permanent Culvert (mm)*** [1]		***Preferred Mitigation Option for Culvert Construction*** [2]	***Founding Soil*** [3]	***Geotechnical Resistance / Reaction***	
				Culvert Construction Concurrent with Embankment Construction	***Culvert Construction Following Preload Period***			***Factored ULS (kPa)***	***SLS for 25 mm of Settlement (kPa)***
C201 (Pre-cast)	Highway 69 SBL and NBL STA 11+207 (Swamp 202)	6.5	Partial Preloading (3.5 m high for 130 days) followed by Lightweight Fill Construction (4.5 m of EPS)	δ_{West} = 55 mm δ_{SBL} = 175 mm δ_{Median} = 170 mm δ_{NBL} = 240 mm δ_{East} = 75 mm	δ_{West} = 30 mm δ_{SBL} = 20 mm δ_{Median} = 20 mm δ_{NBL} = 65 mm δ_{East} = 55 mm	Construct preload embankment (3.5 m high) with temporary culvert and replace with permanent culvert upon completion of preload period (130 days)	Granular ‘B’ Type II Bedding/Fill over Clayey Silt to Clay	50	25
C202 (Cast-in-place)	Highway 69 SBL and NBL STA 11+220 (Swamp 202)	6.5	Partial Preloading (3.5 m high for 130 days) followed by Lightweight Fill Construction (4.5 m of EPS)	δ_{West} = 65 mm δ_{SBL} = 205 mm δ_{Median} = 140 mm δ_{NBL} = 185 mm δ_{East} = 65 mm	δ_{West} = 45 mm δ_{SBL} = 60 mm δ_{Median} = 50 mm δ_{NBL} = 45 mm δ_{East} = 40 mm	Construct permanent culvert upon completion of preload period (130 days)	Granular ‘B’ Type II Bedding/Fill over Silty Sand and Clayey Silt to Clay	55	20

Notes:
1. Total settlement refers to the sum of immediate, primary and secondary/creep of the soils/rock fill below the base of the permanent culvert over a 20-year period following the completion of construction.
2. All organic soils (i.e. topsoil, peat/root mat, organic silty sand and organic silt) to be removed prior to culvert construction.
3. Bedding for the culverts should be at least 300 mm thick and consist of Special Provision 110S13 Granular ‘A’ material, plus 75 mm levelling course (uncompacted Granular ‘A’).

Prepared By: TZ **Checked By:** CN/JPD **Reviewed By:** JMAC

Table 4: Summary of Preferred Foundation Mitigation Options for Culvert Construction
Highway 69 Four-Laning

Culvert Designation (Culvert Type)	Culvert Location (Associated Swamp)	Preferred Mitigation Option for Culvert Construction[1]	Estimated Total Settlement for Permanent Culvert (mm)[2]	Founding Soil[3]	Geotechnical Resistance / Reaction		Permanent Culvert Strain				
					Factored ULS (kPa)	SLS for 25 mm of Settlement (kPa)	Estimated Vertical Strain (%)	Estimated Ratio of Horizontal Strain to Vertical Strain	Estimated Horizontal Strain (%)	Culvert Length (m)	Estimated Maximum Joint Opening (mm)
C201 (Pre-cast)	Highway 69 SBL and NBL STA 11+207 (Swamp 202)	Construct preload embankment (3.5 m high) with temporary culvert and replace with permanent culvert upon completion of preload period (130 days)	δ_{West} = 30 mm δ_{SBL} = 20 mm δ_{Median} = 20 mm δ_{NBL} = 65 mm δ_{East} = 55 mm	Granular 'B' Type II Bedding/Fill over Clayey Silt to Clay	50	25	0.25	0.45	0.10	87	85
C202 (Cast-in-place)	Highway 69 SBL and NBL STA 11+220 (Swamp 202)	Construct preload embankment (3.5 m high) and construct a permanent culvert upon completion of preload period (130 days)	δ_{West} = 45 mm δ_{SBL} = 60 mm δ_{Median} = 50 mm δ_{NBL} = 45 mm δ_{East} = 40 mm	Granular 'B' Type II Bedding/Fill over Silty Sand and Clayey Silt to Clay	55	20	0.25	0.40	0.10	81	80*

Notes: * If applicable

1 All organic soils (i.e. topsoil, peat/root mat, organic silty sand and organic silt) to be removed prior to culvert construction. For estimated settlements during preload period, refer to Sections 6.6.1 and 6.6.2.

2 Total settlement refers to the sum of immediate, primary and secondary/creep of the soils as well as granular fill below the base of the permanent culvert over a 20-year period following completion of construction.

3 Bedding for the culverts should be at least 300 mm thick and consist of Special Provision 110S13 Granular 'A' material, plus 75 mm levelling course (uncompacted Granular 'A').

Prepared By: TZ

Checked By: CN/JPD

Reviewed By: JMAC

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

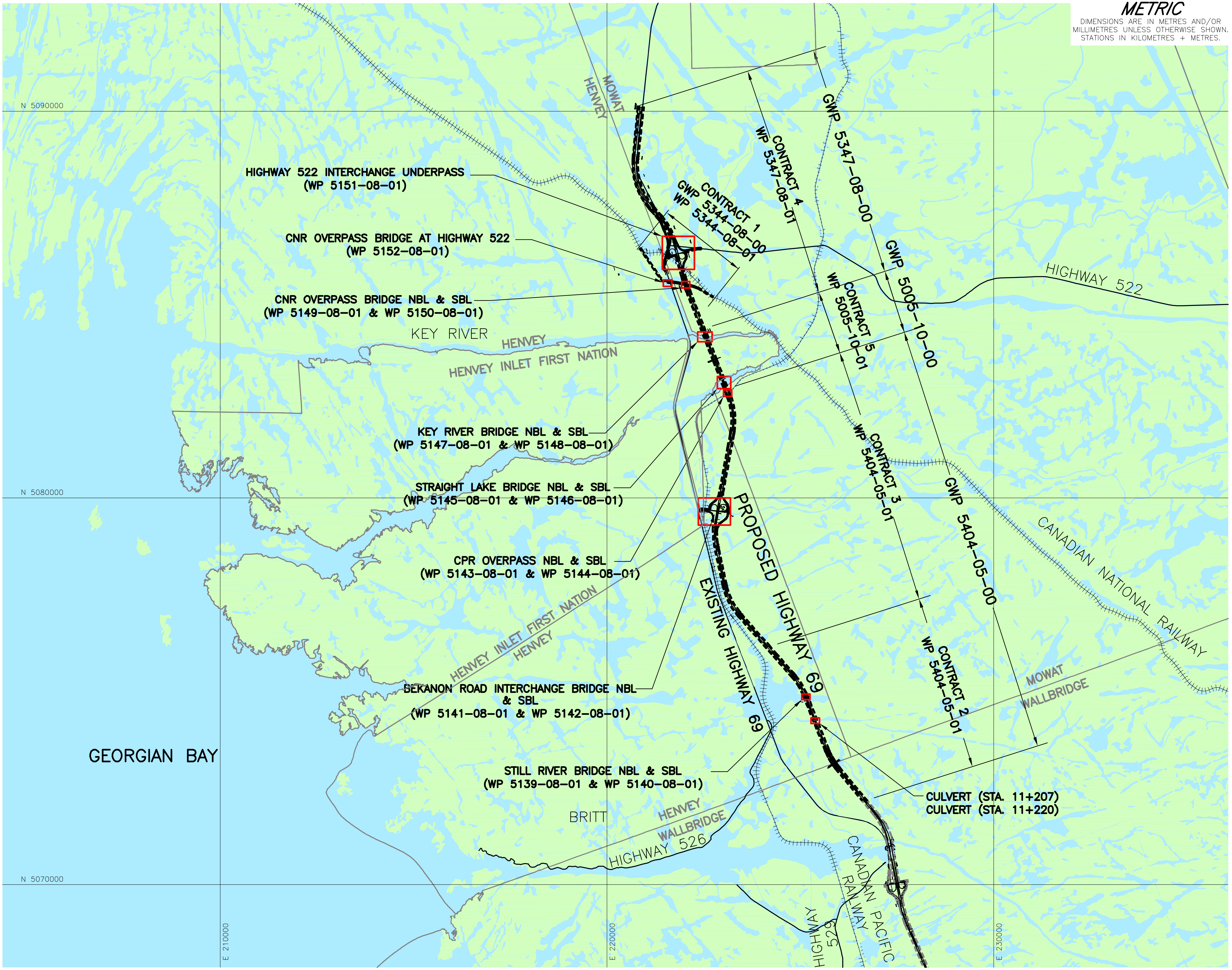
CONT No.
GWP No. 5404–05–00

SHEET

HIGHWAY 69
SITE LOCATION PLAN

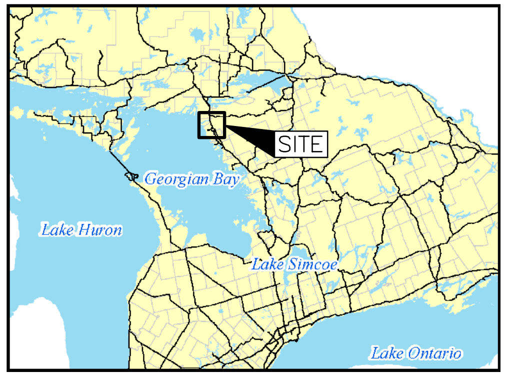
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

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



PLAN

SCALE
1 0 1 2 km



KEY PLAN
NOT TO SCALE

REFERENCE

Base Data – MNR NRVIS, obtained 2004, CANMAP v2008
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Datum : NAD 83 Projection : MTM Zone 10

NO.	DATE	BY	REVISION

Geocres No. 41H–119

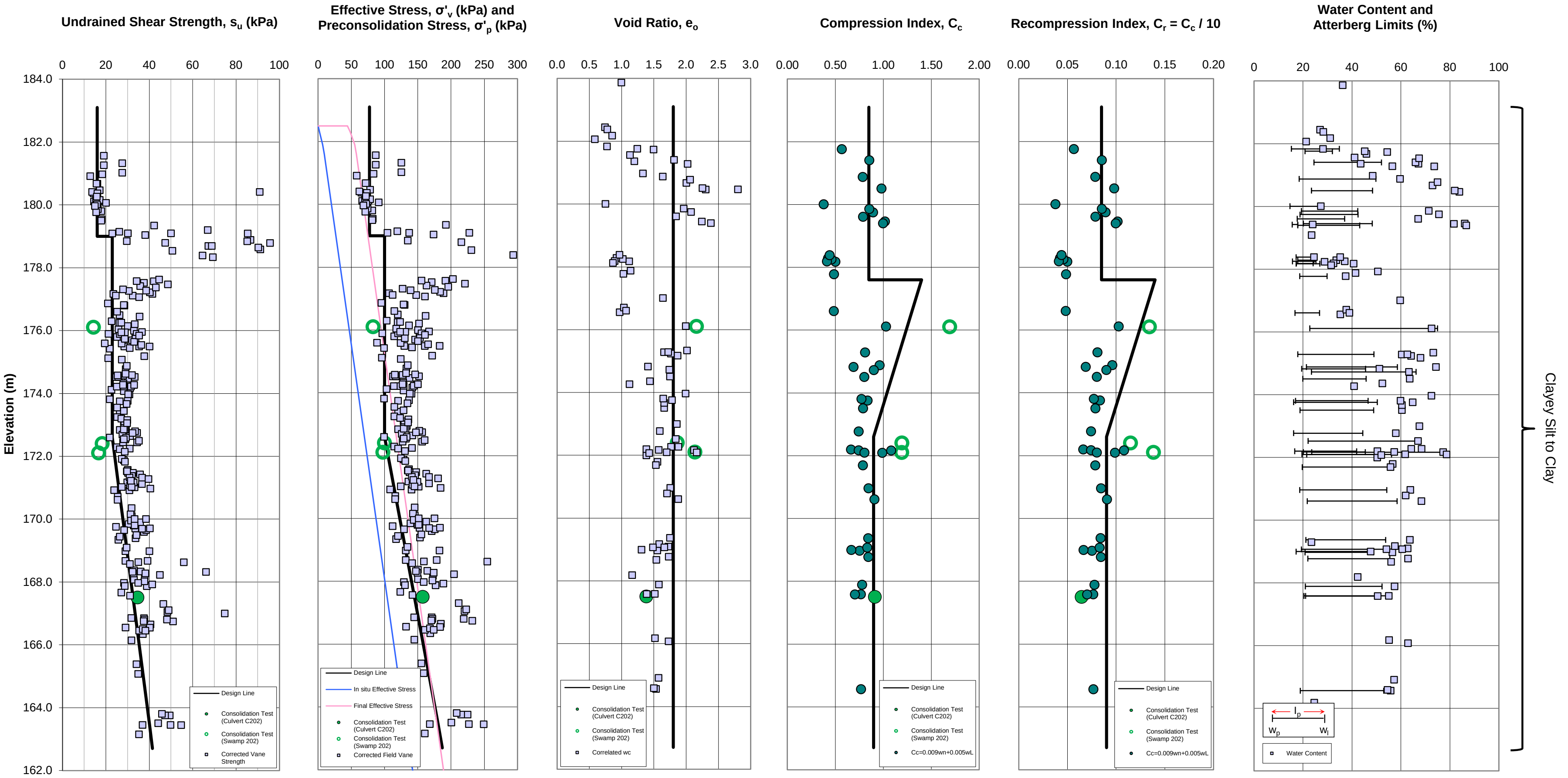
HWY. 69		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: August 2012	SITE:
DRAWN: JFC	CHKD. CN	APPD. JPD/JMAC	DWG. 1

PLOT DATE: September 22, 2015
FILENAME: T:\Projects\2009\09–1111–6014 (URS, Hwy 69, Henvey)\–FAA– CONTRACT 2 (CULVERT) – Stamped\0911116014FA001.dwg

FIGURES

SUMMARY PLOT OF ENGINEERING PARAMETERS FOR COHESIVE DEPOSITS
Highway 69 SBL and NBL - STA 11+207 (Culvert 201)
Highway 69 SBL and NBL - STA 11+220 (Culvert 202)

FIGURE 1



Date: September 2015
Project No: 09-1111-6014-2520

Prepared By: ARM/TZ
Checked By: JPD/JMAC

Golder Associates

https://capws.golder.com/sites/0911116014highway69FourLaning/Contract 2/Reporting/Final/Culverts/Tables and Figures/[09-1111-6014 FIG 1 Summary Plot (Culvert 201 and 202).xlsx]Culvert C201 Plots - Final-A1

APPENDIX A

Highway 69 SBL and NBL – STA 11+207 (Culvert 201)

MINISTRY OF TRANSPORTATION, ONTARIO

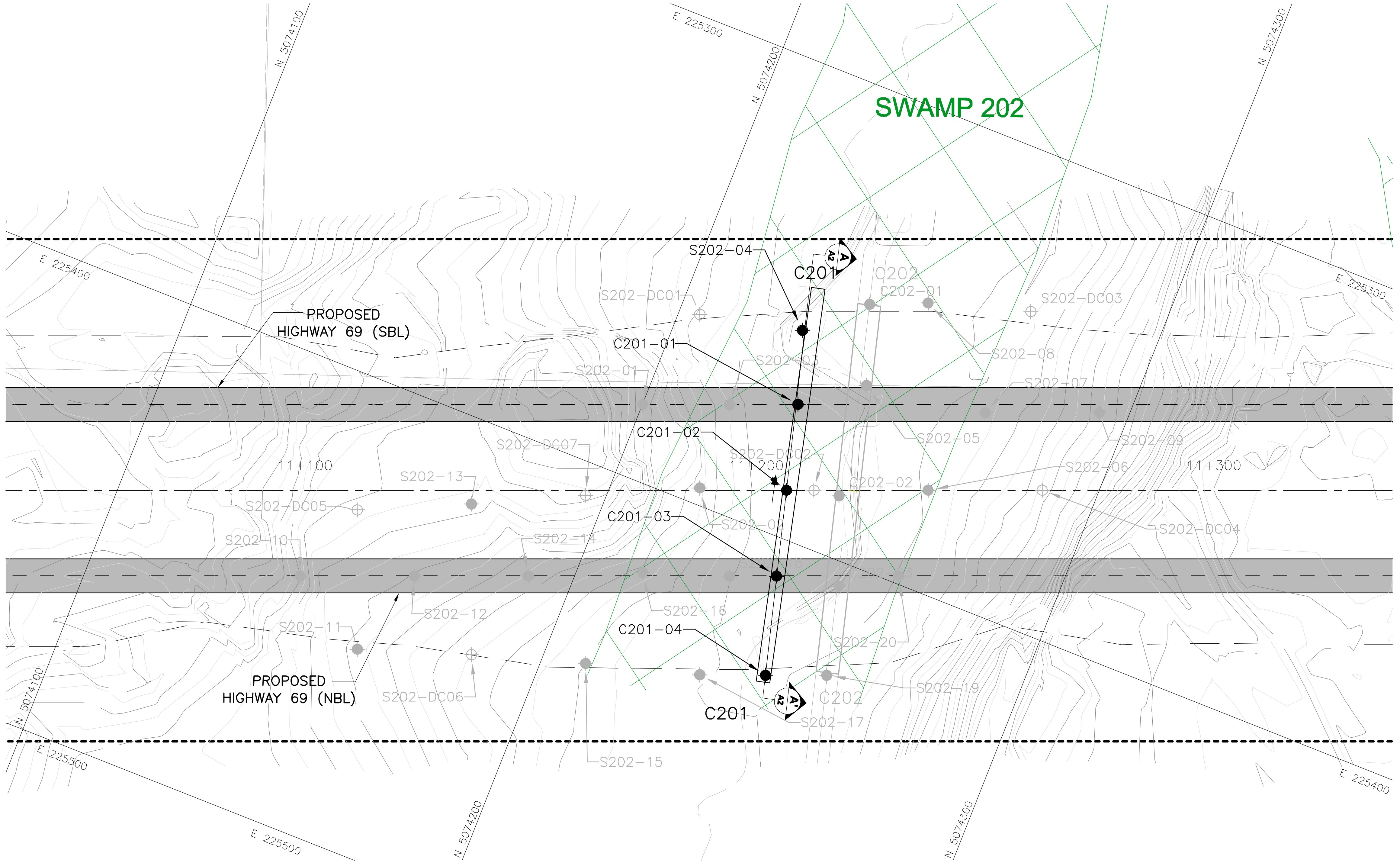
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5404–05–01

SHEET

HIGHWAY 69
CULVERT 201 STA 11+207
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
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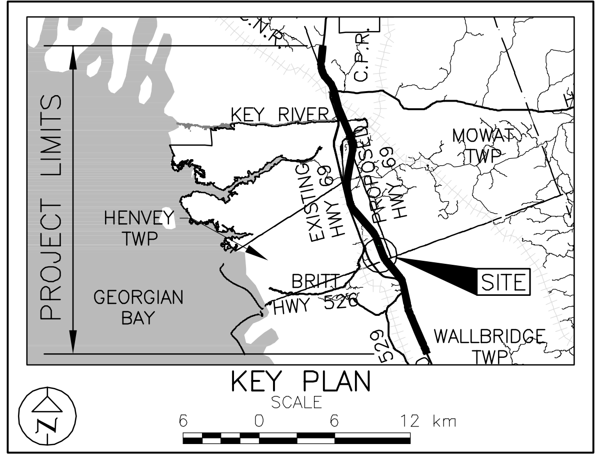


KEY PLAN
SCALE
6 0 6 12 km

LEGEND

● Borehole – Current Investigation

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
C201–01	182.6	5074231.7	225371.4
C201–02	182.6	5074236.3	225389.8
C201–03	182.5	5074241.2	225408.1
C201–04	182.5	5074246.9	225429.2
S202–04	182.5	5074226.7	225356.0

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing files Hwy69_base.dwg, Hwy69_plan.dwg, received December 16, 2009. And Contours from HWY69_Contours–Plan_C2_C3.dwg, received July 14, 2011, Location of Culvert obtained from culv 11+207 Aug 2012.dwg, received August 24 2012.

J. M. A. COSTA
Aug. 31, 2015

J.P. DITTRICH
Aug. 31, 2015

NO.	DATE	BY	REVISION

Geocres No. 41H–119

HWY. 69		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: August 2012	SITE:
DRAWN: JFC	CHKD. CN	APPD. JPD/JMAC	DWG. A1

PLOT DATE: September 22, 2015
FILENAME: T:\Projects\2009\09–1111–6014 (URS, Hwy 69, Henvey)\–FAA– CONTRACT 2 (CULVERT) – Stamped\09111160 14FA0A1.dwg

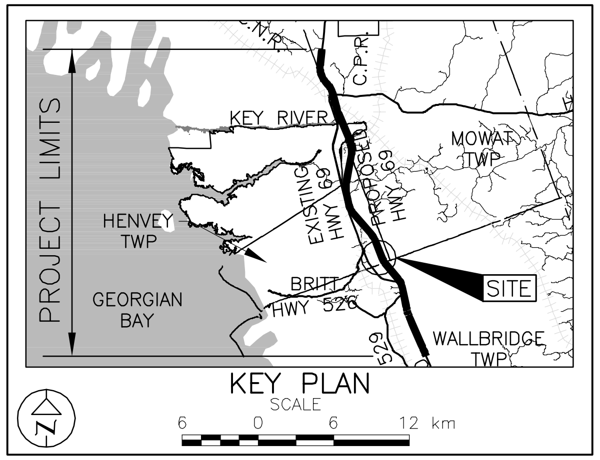
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5404–05–01

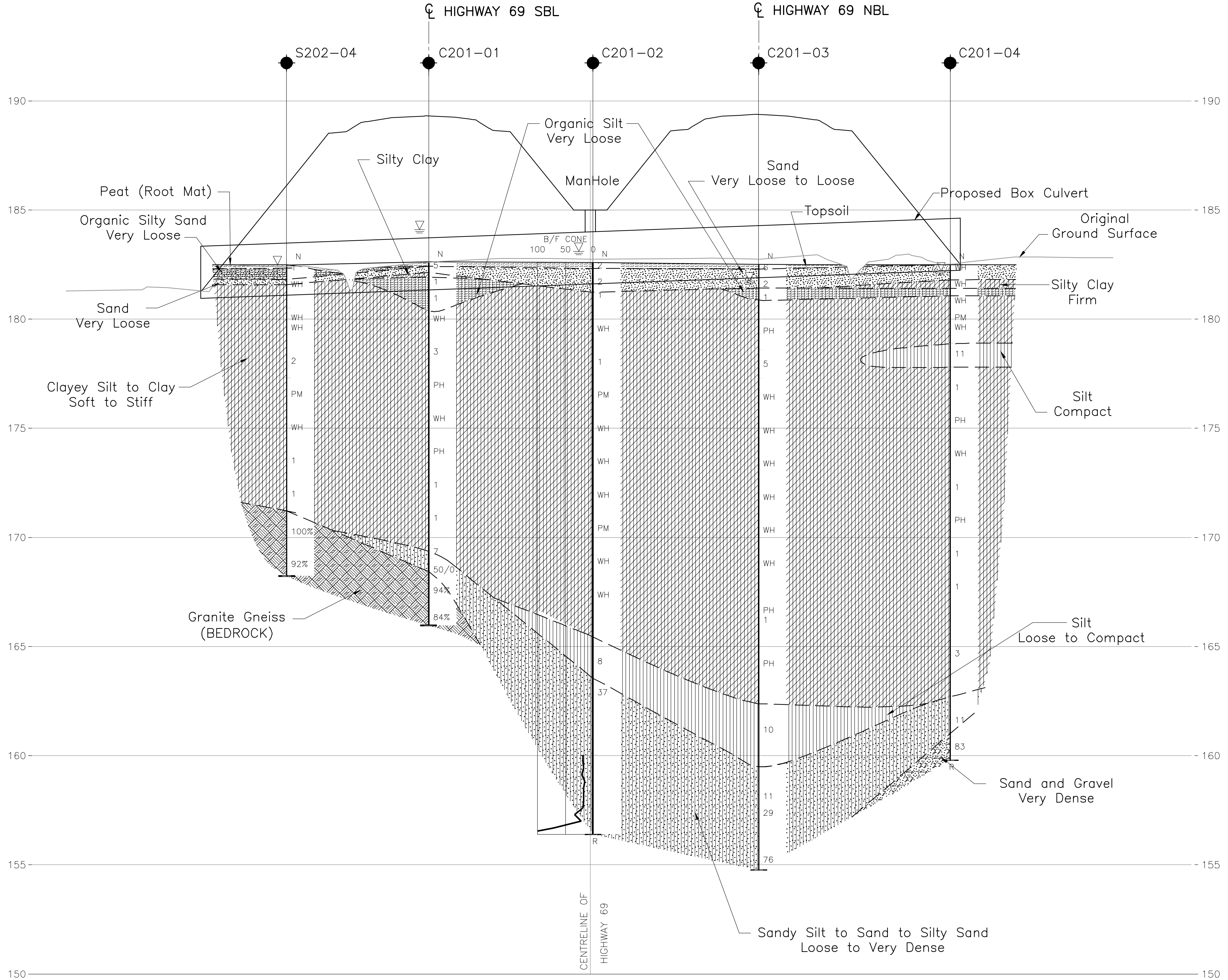
SHEET

HIGHWAY 69
CULVERT 201 STA 11+207
SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
SCALE
6 0 6 12 km



A-A'
A1

CULVERT 201 AT STA 11+207
HIGHWAY 69

HORIZONTAL SCALE
5 0 5 10 m
2 0 2 4 m
VERTICAL SCALE

LEGEND

●	Borehole – Current Investigation
N 16	Standard Penetration Test Value Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling
R	Refusal

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
C201–01	182.6	5074231.7	225371.4
C201–02	182.6	5074236.3	225389.8
C201–03	182.5	5074241.2	225408.1
C201–04	182.5	5074246.9	225429.2
S202–04	182.5	5074226.7	225356.0

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing files Hwy69_base.dwg, Hwy69_plan.dwg, received December 16, 2009. Cross–Section drawing obtained from culv 11+207 Aug 2012.dwg, received August 24, 2012.

J. M. A. COSTA
Aug. 31, 2015

J.P. DITTRICH
Aug. 31, 2015

NO.	DATE	BY	REVISION

Geocres No. 41H–119

HWY. 69		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: August 2012	SITE:
DRAWN: JFC	CHKD. CN	APPD. JPD/JMAC	DWG. A2

PLOT DATE: September 22, 2015
FILENAME: T:\Projects\2009\09–1111–6014 (URS, Hwy 69, Henvey)\–FAA– CONTRACT 2 (CULVERT) – Stamped\0911116014FA0A2.dwg

RECORD OF BOREHOLE No C201-01

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014

W.P. 5404-05-01

DIST HWY 69

DATUM Geodetic

LOCATION N 5074231.7 ;E 225371.4

BOREHOLE TYPE NW Casing, Wash Boring

DATE February 27 and 28, 2011

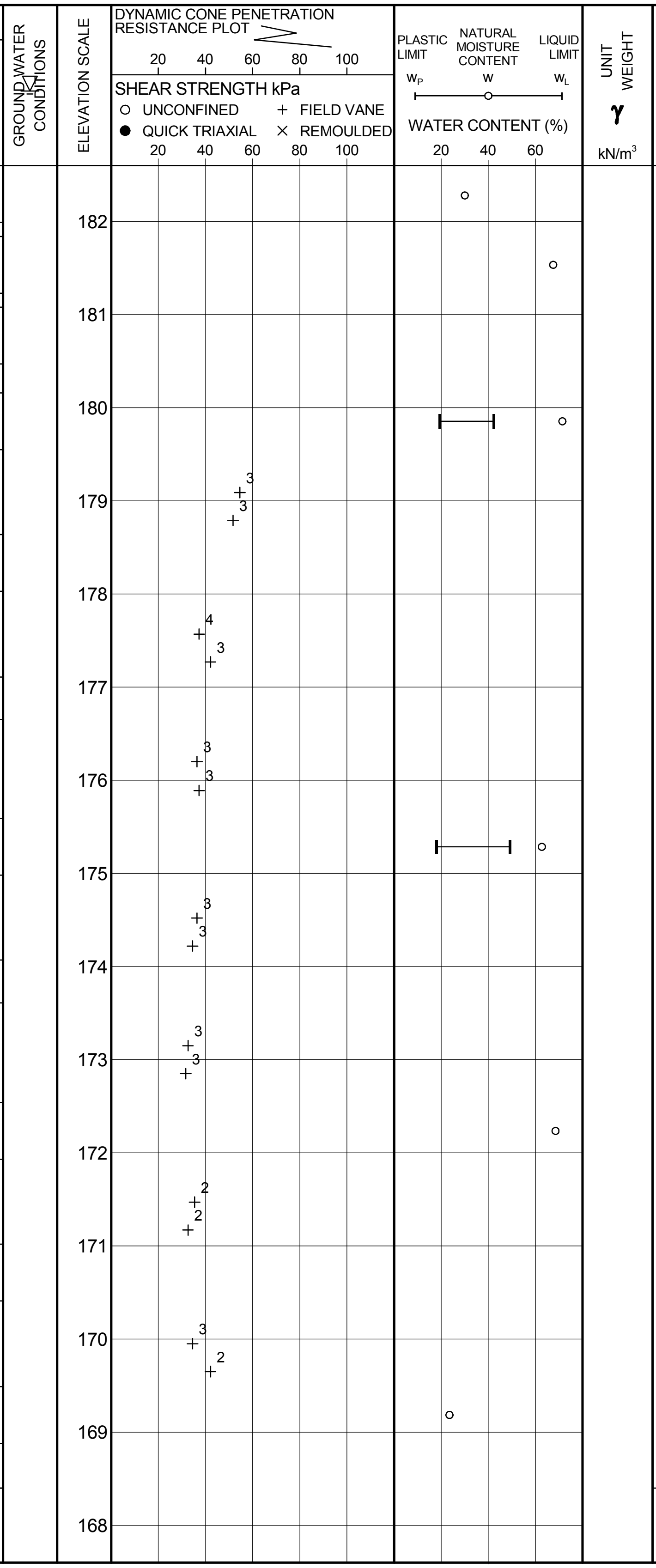
ORIGINATED BY MR

COMPILED BY MAS/SB

CHECKED BY TVA

ELEV DEPTH	SOIL PROFILE – DESCRIPTION
182.6	GROUND SURFACE
0.0	TOPSOIL
182.1	SAND, some silt, containing organics and rootlets Loose Brown Moist to wet
0.7	SILTY CLAY, containing organics and rootlets Very soft Grey Moist
	Organic SILT, containing layers of fibrous peat Very loose Dark grey to dark brown Moist
180.3 2.3	SILTY CLAY, trace sand Firm to stiff Brown to grey Moist to wet Containing grey silt interlayers between depths of 4.0 m and 4.6 m
169.6 13.0	Sandy SILT, trace to some clay Loose Grey Wet
169.0 13.6	Silty SAND, trace gravel, containing sandy silt layers Grey Wet
168.4 14.2	

SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1A 1B 1C	SS	5				
2	SS	1				
3	SS	1	OC=15%			
4	SS	WH	0	1	56	43
5	SS	3				
6	TO*	PH				
7	SS	WH	0	1	40	59
8	TO	PH				
9	SS	1				
10	SS	1				
11A 11B	SS	7	0	23	71	6
12	SS	50/0.0				
1	NQ RC	REC 97%	RQD = 94%			



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C201-01

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014			
W.P. 5404-05-01	LOCATION N 5074231.7 ;E 225371.4	ORIGINATED BY MR
DIST ___ HWY 69	BOREHOLE TYPE NW Casing, Wash Boring	COMPILED BY MAS/SB
DATUM Geodetic	DATE February 27 and 28, 2011	CHECKED BY TVA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- *CONTINUED FROM PREVIOUS PAGE* ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Granite Gneiss (BEDROCK) Bedrock cored from depths of 14.2 m to 16.6 m For bedrock coring details, refer to Record of Drillhole C201-01		1	NQ RC	REC 97%		167				
166.0			2	NQ RC	REC 100%						RQD = 84%
16.6	END OF BOREHOLE NOTES: *Unable to recover a Shelby tube sample between depths of 5.5 m and 5.9 m. 1. Water level in casing at 0.8 m above ground surface upon completion of drilling (Elev. 183.7 m). Water level in casing at 1.5 m above ground surface (Elev. 184.1 m) measured at about 7:15 a.m. on February 28, 2011 - Artesian Condition. Casing set at a depth of 14.3 m below ground surface (Elev. 168.3 m) at the time of water level measurement.						166				

+^{3}, ×^{3}: Numbers refer to Sensitivity ○$^{3\%}$ STRAIN AT FAILURE

PROJECT: 09-1111-6014

RECORD OF DRILLHOLE: C201-01

SHEET 1 OF 1

LOCATION: N 5074231.7 ;E 225371.4

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: February 27 and 28, 2011

DRILL RIG: D25 Bombardier

DRILLING CONTRACTOR: Walker Drilling

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO- Polished	BR - Broken Rock
FLT - Fault	FO - Foliation	CU- Curved	K - Slickensided	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
SHR- Shear	CO- Contact	UN- Undulating	SM- Smooth	
VN - Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.
		Continued from Record of Borehole C201-01		168.4															
	NW Casing February 27, 2011	GRANITE GNEISS Slightly weathered, foliated, strong, pink, dark grey and black with mafic dyke between depths of 15.5 m and 15.8 m.		14.2	1								JN,PL,RO	1.5	1				
													JN,UN,RO	3	1				
15	NQRC February 28,2011												JN,PL,SM JN,PL,SM JN,PL,RO	1.5 1 1.5	1 2 1				
					2								JN,CU,SM JN,IR,RO JN,CU,SM JN,IR,SM JN,PL,SM	2 3 1 1 1	1 1 2 2 1				
16													JN,PL,SM	1	2				
				166.0									JN,PL,SM	1	1				
		END OF DRILLHOLE		16.6															
17																			
18																			
19																			
20																			
21																			
22																			
23																			
24																			

GTA-RCK 023 T:\PROJECTS\2009\09-1111-6014 (URS, HWY 69, HENVEY)\LOG\09-1111-6014.GPJ GAL-GTA.GDT 8/31/15

DEPTH SCALE

1 : 50

Golder Associates

LOGGED:

CHECKED: MAS/TVA

Golder Associates

Foundation Design

RECORD OF BOREHOLE No C201-02

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
DIST
HWY 69
DATUM Geodetic
LOCATION N 5074236.3 ;E 225389.8
BOREHOLE TYPE NW Casing, Wash Boring
DATE February 18,22 and 23, 2011
ORIGINATED BY MR
COMPILED BY MAS/SB
CHECKED BY TVA

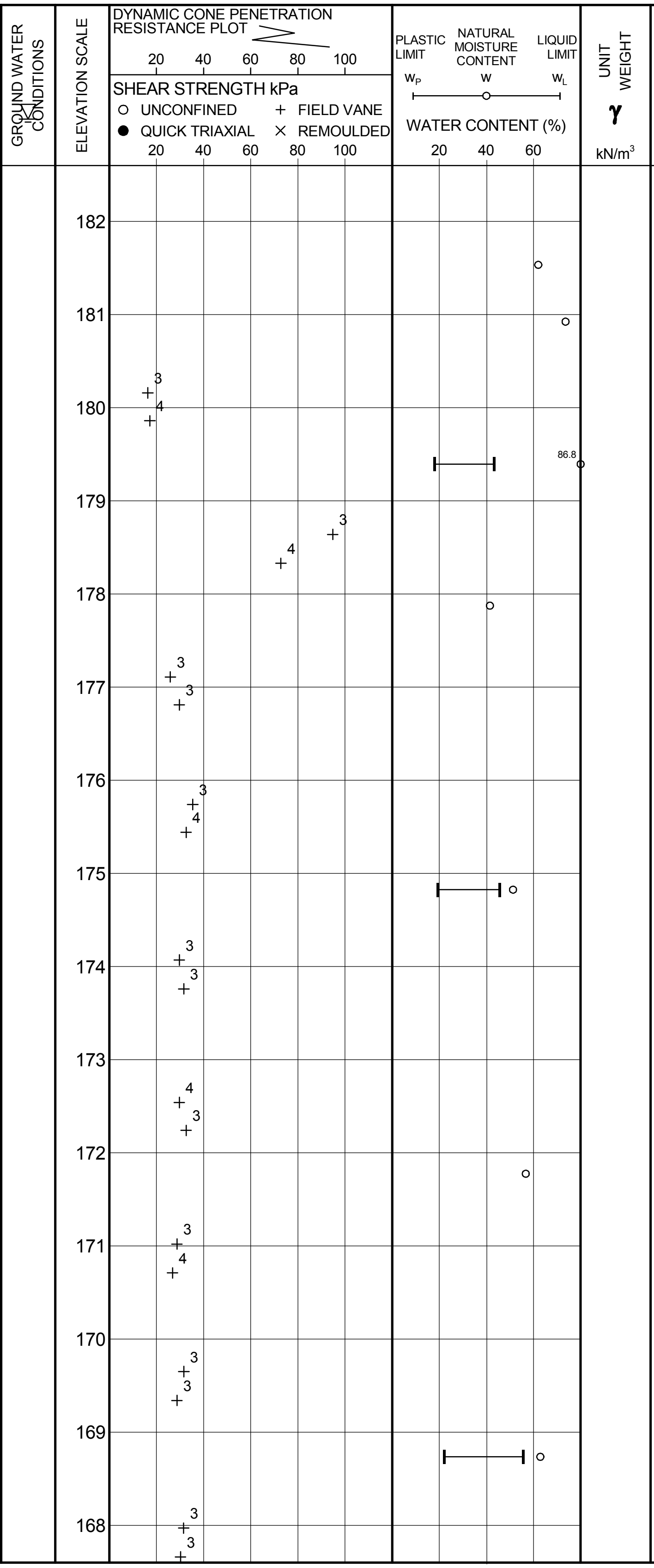
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.6	GROUND SURFACE
0.0	TOPSOIL
182.3 0.3	SAND, some silt, containing rootlets Very loose Brown Wet
181.2 1.4	SILTY CLAY, trace sand, containing organics Soft Grey Wet
180.2 2.4	SILTY CLAY, trace sand Soft to stiff Grey Wet Containing silt interlayers between depths of 4.4 m and 8.1 m
169.2 13.4	CLAY, some silt, trace sand, containing silt interlayers Firm Grey Wet

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	2				
2	SS	2				
3	SS	1	OC=4%			
4	SS	WH	0	2	55	43
5	SS	1				
6	TO	PM				
7	SS	WH	0	2	40	58
8	SS	WH				
9	SS	WH				
10	TO	PM				
11	SS	WH	0	1	33	66



+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

GTA-MTO 001 T:\PROJECTS\2009\09-1111-6014 (URS, HWY 69, HENVEY)\LOG\09-1111-6014.GPJ GAL-GTA.GDT 8/31/15

RECORD OF BOREHOLE No C201-02

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
DIST
HWY 69
DATUM Geodetic
LOCATION N 5074236.3 ;E 225389.8
BOREHOLE TYPE NW Casing, Wash Boring
DATE February 18,22 and 23, 2011
ORIGINATED BY MR
COMPILED BY MAS/SB
CHECKED BY TVA

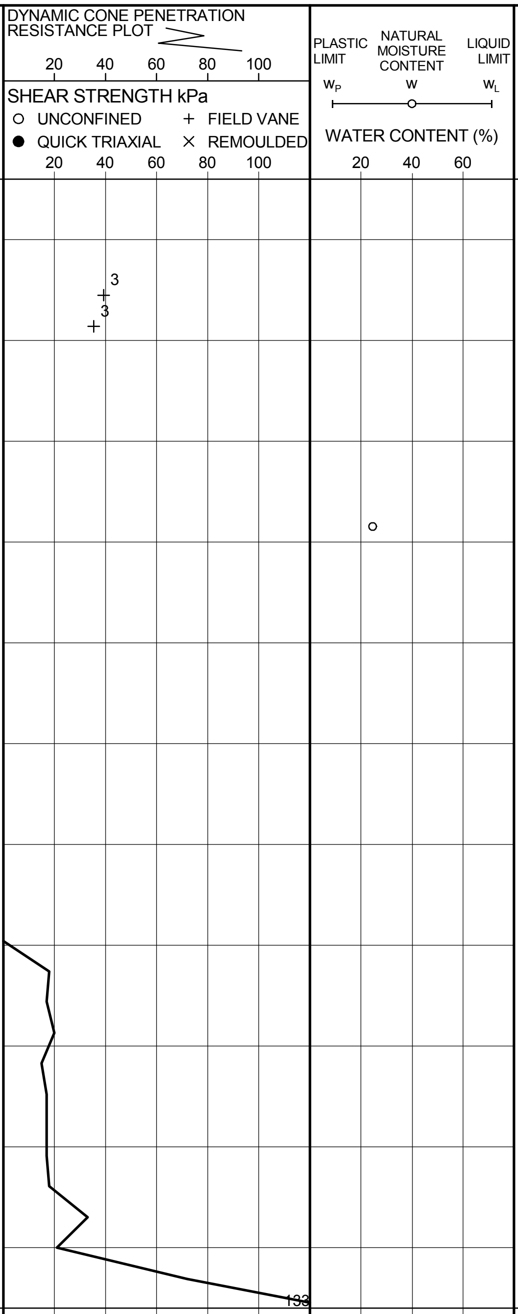
--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY, some silt, trace sand, containing silt interlayers Firm Grey Wet	▨	12	SS	WH		
165.4 17.2	SILT, some sand, trace clay Loose Grey Wet		13	SS	8		Non-Plastic 0 15 83 2
163.5 19.1	SAND, trace to some silt Dense Grey Wet		14	SS	37		
160.0 22.6	END OF BOREHOLE						
156.4 26.2	END OF DCPT Refusal to Further Penetration (133 Blows/0.3m)						

NOTES:

*Water flowing from top of casing when advanced to a depth of 19.6 m below ground surface (Elev. 163.0 m).

1. Water level in casing at 0.5 m above ground surface (Elev. 183.1 m) measured about 13 min. after completion of drilling - Artesian Condition.



+3, ×3: Numbers refer to Sensitivity   ○3% STRAIN AT FAILURE

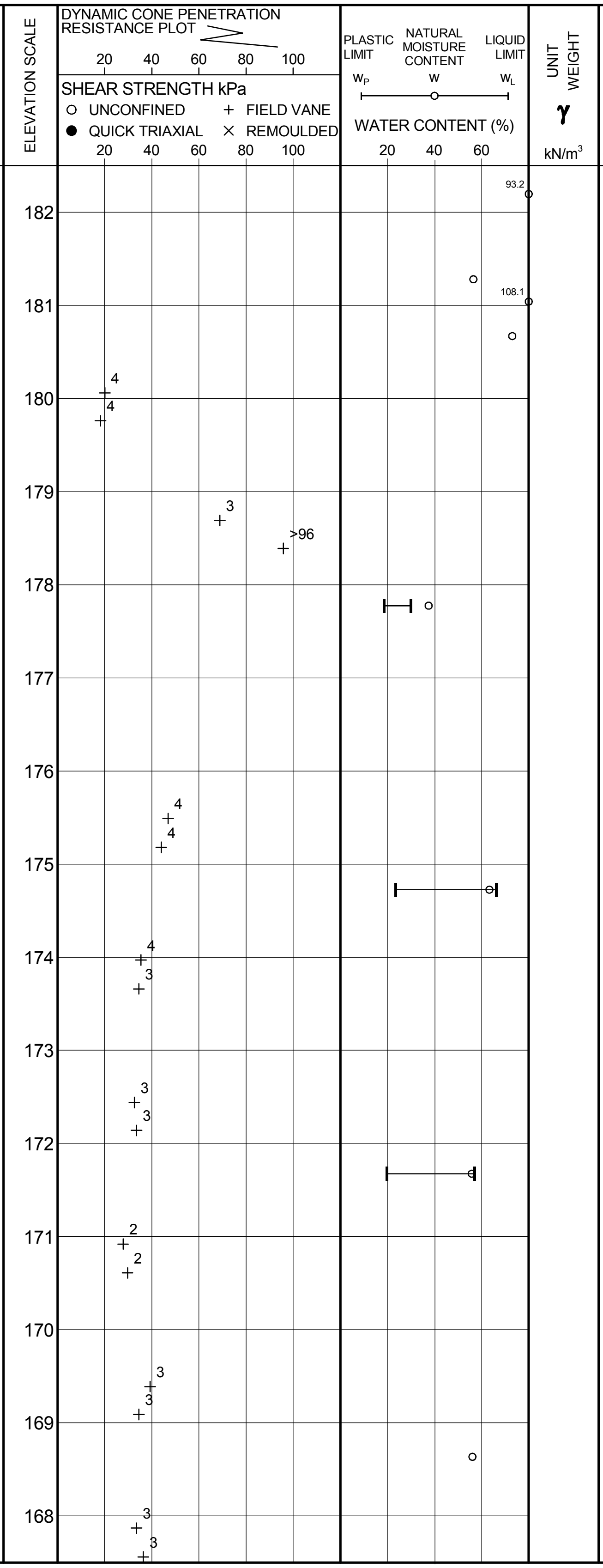
RECORD OF BOREHOLE No C201-03

SHEET 1 OF 3

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074241.2 ;E 225408.1
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE NW Casing, Wash Boring
COMPILED BY ARM/SB
DATUM Geodetic
DATE February 24, 2011
CHECKED BY TVA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES		GR	SA	SI	CL
182.5	GROUND SURFACE								
0.0	TOPSOIL								
0.2	SAND, some silt, containing organics Very loose to loose Brown to grey Wet	1	SS	6	∇				
		2A 2B	SS	2					
181.4 1.1	Organic SILT, some sand, containing rootlets Very loose Dark grey to brown Moist	3A 3B	SS	1		OC=13%			
180.8 1.7	SILTY CLAY, trace sand, containing organics to a depth of 2.6 m Soft to stiff Grey Moist	4	TO	PH					
178.6 3.9	CLAYEY SILT, trace sand, containing silt seams Stiff Grey Wet	5	SS	5		0	1	75	24
177.3 5.2	CLAY, some silt, trace sand Firm Grey Moist to wet Containing silt layers between depths of 5.2m and 6.7 m	6	SS	WH					
		7	SS	WH		0	2	36	62
		8	SS	WH					
		9	SS	WH		0	1	48	51
		10	SS	WH					
		11	SS	WH					



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C201-03

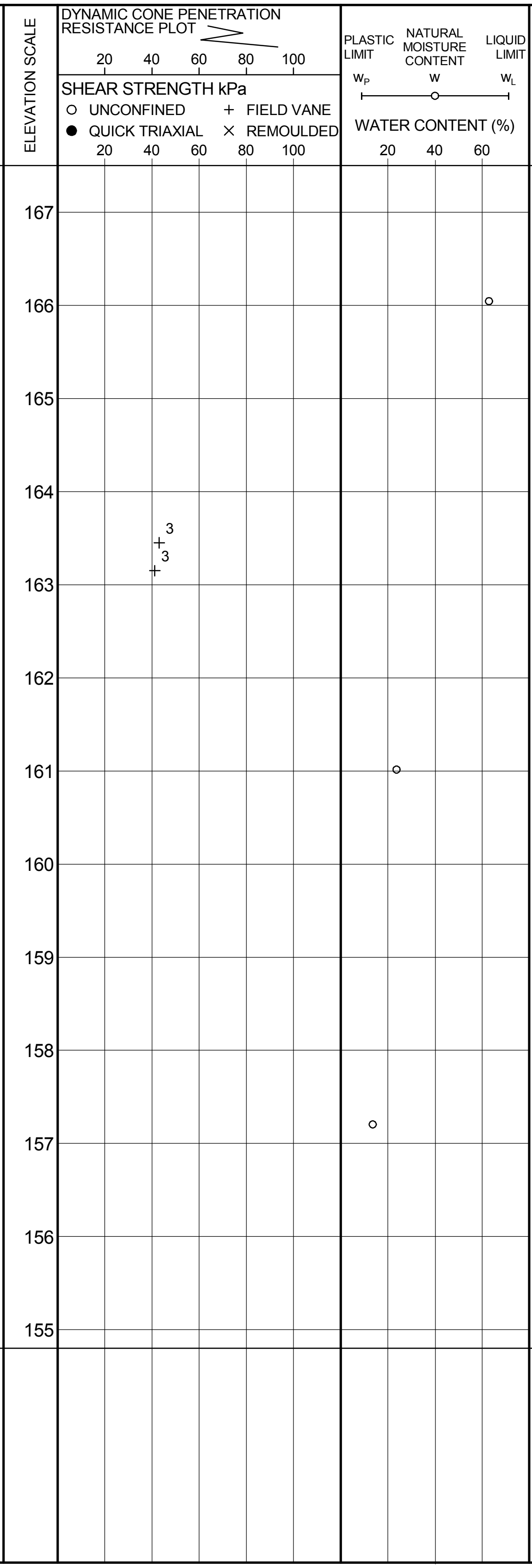
SHEET 2 OF 3

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074241.2 ;E 225408.1
ORIGINATED BY MR
DIST HWY 69
BOREHOLE TYPE NW Casing, Wash Boring
COMPILED BY ARM/SB
DATUM Geodetic
DATE February 24, 2011
CHECKED BY TVA

--- *CONTINUED FROM PREVIOUS PAGE* ---

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	CLAY, some silt, trace sand Firm Grey Moist to wet	12	TO	PH						
		13	SS	1						
		14	TO	PH						
162.4 20.1	SILT, trace to some clay, trace sand Compact Grey Moist	15	SS	10			0	3	89	8
159.5 23.0	SAND, some gravel, trace to some silt Compact to very dense Grey Wet	16	SS	11						
		17	SS	29			17	77	6	0
		18A	SS	76						
155.1	Silty SAND Very dense Grey Wet	18B								
154.8 27.7										



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+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C201-03

SHEET 3 OF 3

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
DIST
HWY 69
DATUM Geodetic
LOCATION N 5074241.2 ;E 225408.1
BOREHOLE TYPE NW Casing, Wash Boring
DATE February 24, 2011
ORIGINATED BY MR
COMPILED BY ARM/SB
CHECKED BY TVA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- *CONTINUED FROM PREVIOUS PAGE* ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	END OF BOREHOLE NOTES: 1. Water flowing from top of casing when advanced to a depth of 24.2 m below ground surface (Elev. 158.3 m). Water level in open borehole at a depth of 0.8 m below ground surface (Elev. 181.7 m) upon completion of drilling.										

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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C201-04

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014

W.P. 5404-05-01

DIST ______ HWY 69

DATUM Geodetic

LOCATION N 5074246.9 ;E 225429.2

BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring

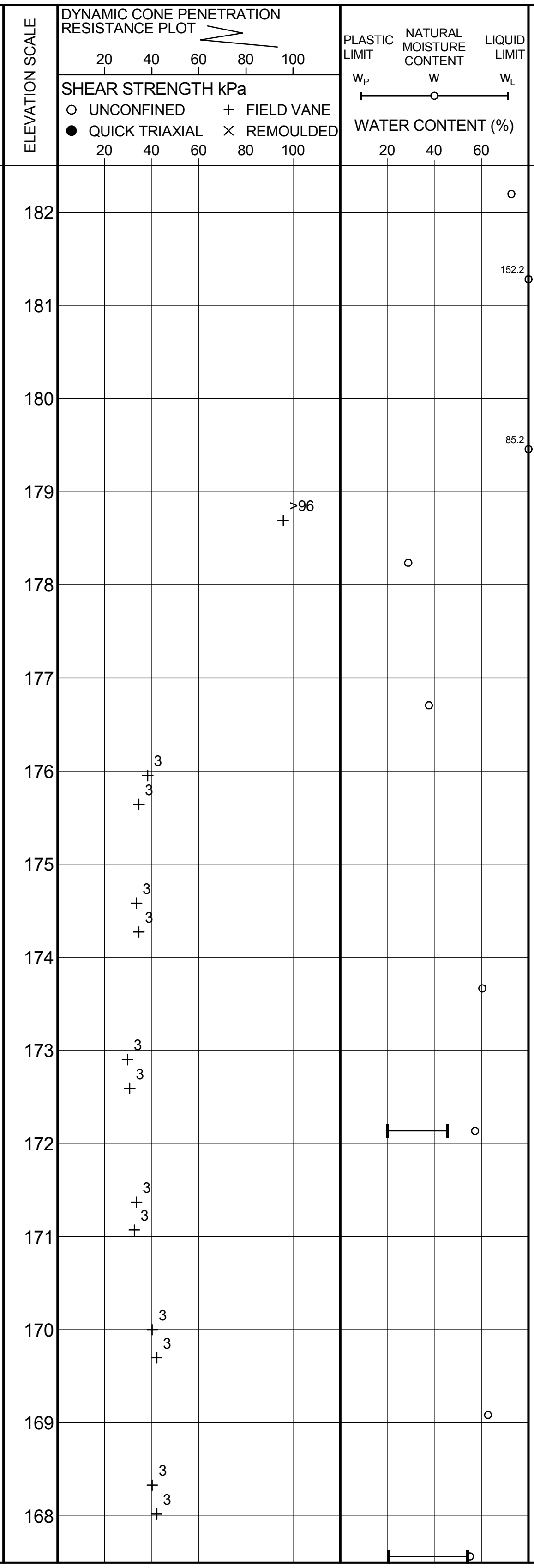
DATE March 1 and 2, 2011

ORIGINATED BY MR

COMPILED BY ARM/SB

CHECKED BY TVA

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.5	GROUND SURFACE					
0.0	SAND, containing organics and rootlets Very loose Dark grey Wet	1	AS	WH	▽	
181.8	SILTY CLAY, containing fibrous peat layers Very soft Dark grey Moist	2A 2B	SS	WH		OC=13%
181.4 181.1 1.4	Organic SILT, containing rootlets Very loose Dark brown Moist	3	SS	WH		
	SILTY CLAY, trace sand, containing layers of fibrous peat to a depth of 2.7 m Very soft Grey Wet	4 5	TO* SS	PM WH		
178.9 3.6	SILT, trace sand, trace to some clay Compact Grey Moist	6	SS	11		Non-Plastic 0 2 89 9
177.8 4.7	SILTY CLAY, trace sand, containing silt layers to a depth of 6.1 m Firm Grey Moist	7 8 9 10 11	SS TO SS SS TO	1 PH WH 1 PH		 0 2 38 60
169.5 13.0	CLAY, some silt, trace sand, trace gravel, containing silt interlayers Firm to stiff Grey Wet	12 	SS SS	1 1		 1 5 35 59



UNIT WEIGHT γ kN/m³

Continued Next Page

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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C201-04

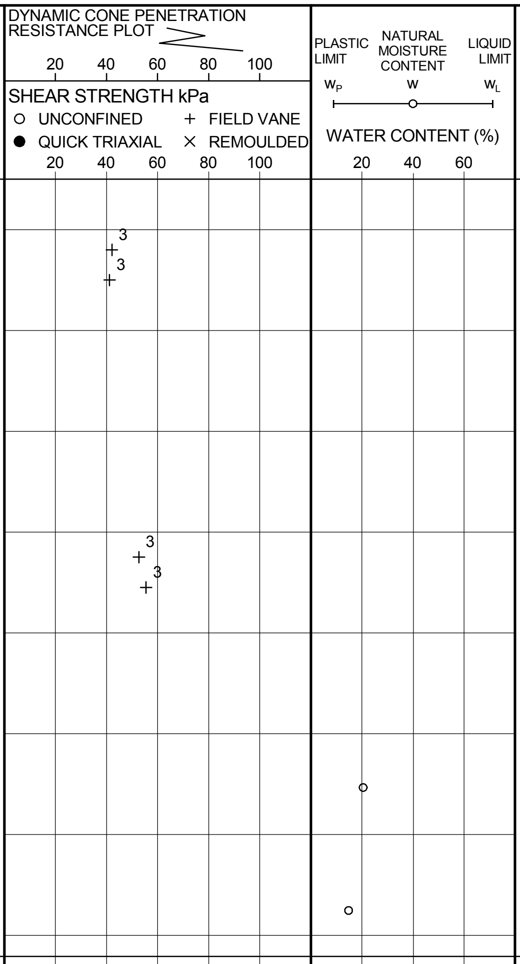
SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
DIST
HWY 69
DATUM Geodetic
LOCATION N 5074246.9 ;E 225429.2
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
DATE March 1 and 2, 2011
ORIGINATED BY MR
COMPILED BY ARM/SB
CHECKED BY TVA

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	CLAY, some silt, trace sand, trace gravel, containing silt interlayers Firm to stiff Grey Wet	13						
		14	SS	3				
162.7 19.8	SAND, some gravel, trace silt, trace clay Compact Grey Wet	15	SS	11	16	76	5	3
160.9 21.6	SAND and GRAVEL, containing cobbles Very dense Grey Wet	16	SS	83				
		17	SS	50/0				
159.8 22.7	END OF BOREHOLE CASING REFUSAL							



NOTES:

* Unable to recover a Shelby tube between depths of 2.3 m and 2.7 m.

1. Water flowing from top of casing when advanced to a depth of 20.7 m below ground surface (Elev. 161.8 m).

Water level in open borehole at a depth of 0.3 m below ground surface (Elev. 182.2 m) upon completion of drilling.

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No S202-04

SHEET 1 OF 2

METRIC

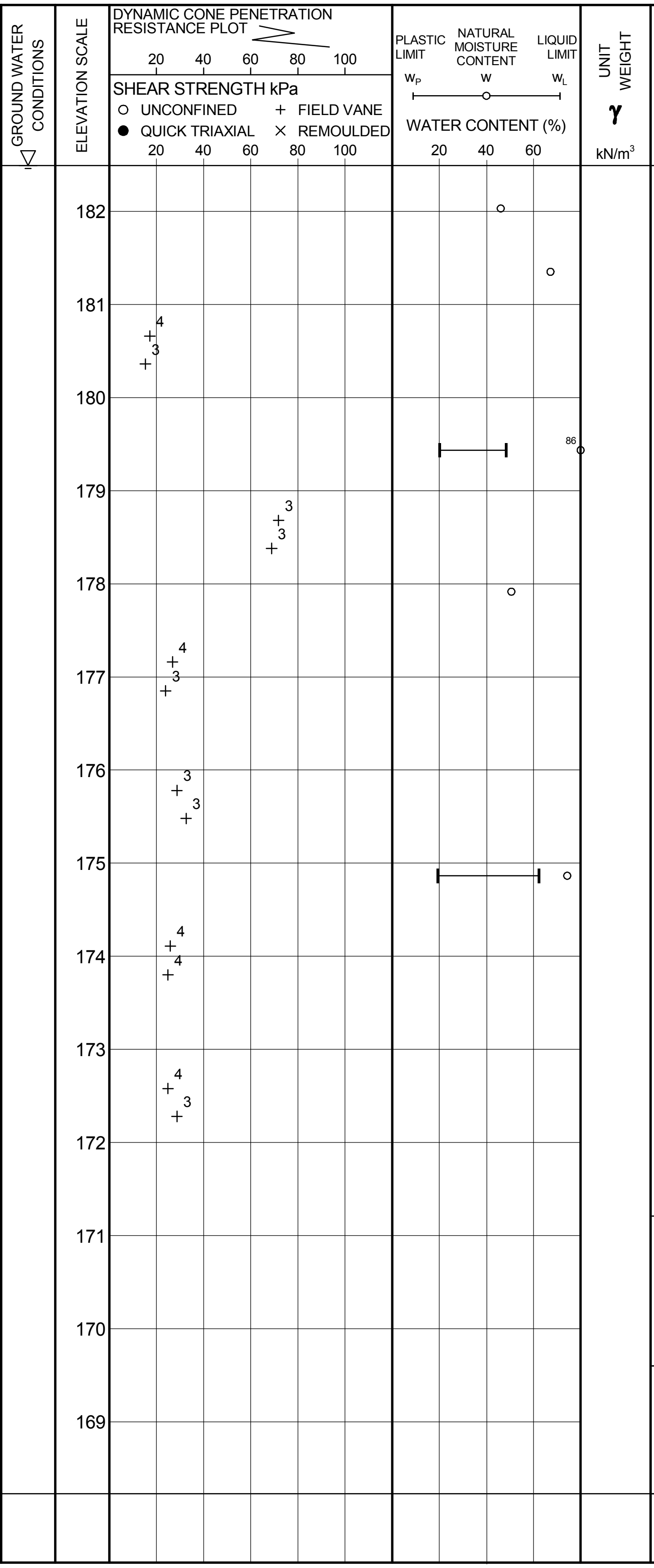
PROJECT 09-1111-6014
W.P. 5404-05-01
DIST ____ HWY 69
DATUM Geodetic
LOCATION N 5074226.7 ;E 225356.0
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
DATE March 12, 2011
ORIGINATED BY MR
COMPILED BY ARM
CHECKED BY TVA

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.5	GROUND SURFACE
0.0	Peat (Root Mat)
0.2	Organic Silty SAND, containing rootlets Very loose Grey Wet
181.8 0.9	SAND, containing wood fragments Very loose Grey Wet
180.5 2.0	SILTY CLAY, containing organics and fibrous peat layers Soft Grey Wet
	SILTY CLAY, trace sand Soft to stiff Grey Wet Containing silt layers between depths of 3.7 m and 5.2 m
177.3 5.2	CLAY, some silt, trace sand Soft to firm Brown to grey Wet
171.2 11.3	Granite Gneiss (BEDROCK) Bedrock cored from depths of 11.3 m to 14.3 m For bedrock coring details refer to Record of Drillhole S202-04
168.2 14.3	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1A 1B	SS	1	
2A 2B	SS	WH	
3	SS	WH	
4	SS	WH	0 1 50 49
5	SS	2	
6	TO	PM	
7	SS	WH	0 1 37 62
8	SS	1	
9	SS	1	
1	NQ RC	REC 100%	RQD = 100%
2	NQ RC	REC 96%	RQD = 92%



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+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S202-04

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074226.7 ;E 225356.0
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY ARM
DATUM Geodetic
DATE March 12, 2011
CHECKED BY TVA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION --- *CONTINUED FROM PREVIOUS PAGE* ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	NOTE: 1. Water level in open borehole at ground surface (Elev. 182.5 m) upon completion of drilling.										

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

PROJECT: 09-1111-6014

RECORD OF DRILLHOLE: S202-04

SHEET 1 OF 1

LOCATION: N 5074226.7 ;E 225356.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE:

DRILL RIG: D25 Bomb

DRILLING CONTRACTOR: Walker Drilling

DATUM: Geodetic

JN - Joint	BD - Bedding	PL - Planar	PO - Polished	MB - Mechanical Break
FLT - Fault	FO - Foliation	CU - Curved	K - Slickensided	BR - Broken Rock
SH - Shear	CO - Contact	UN - Undulating	SM - Smooth	**NOTE:** For additional abbreviations refer to list of abbreviations & symbols.
VN - Vein	OR - Orthogonal	ST - Stepped	RO - Rough	
CJ - Conjugate	CL - Cleavage	IR - Irregular	VR - Very Rough	

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN / FLUSH	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES
		Continued from Record of Borehole C201-1		171.21																
12	NW Casing March 12, 2011	GRANITE GNEISS Fresh, foliated, slightly porous, medium crystalline, strong, pink, grey and black with mafic dyke between depths of 11.3 m and 11.8 m; and between depths of 12.0 m and 12.1 m.		11.28	1								JN,PL,SM JN,PL,SM			2				
13	NQRC March 12, 2011				2								JN JN,PL,SM JN,PL,SM			4				
14				168.23									JN,PL,SM							
		END OF BOREHOLE		14.26																
15																				
16																				
17																				
18																				
19																				
20																				
21																				

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

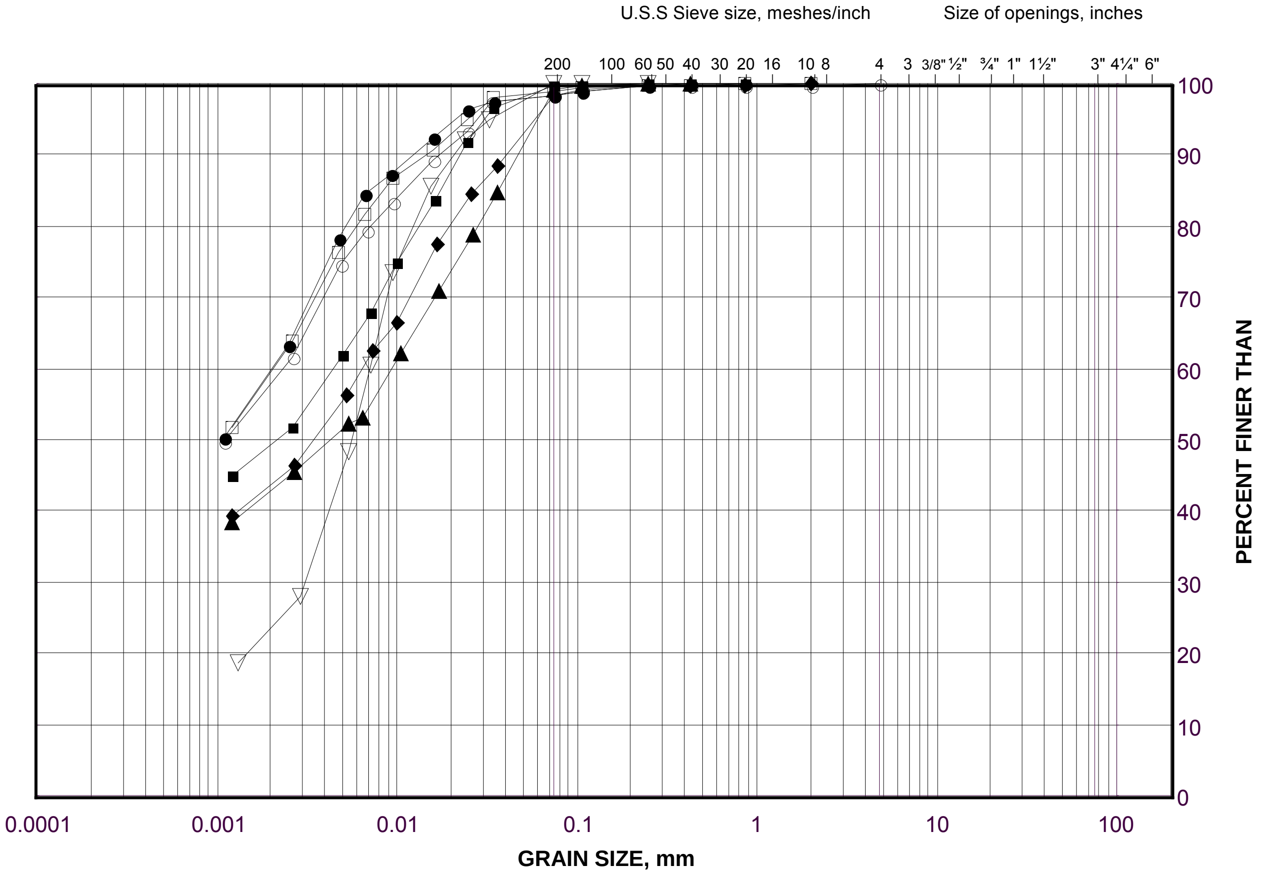
CHECKED: TVA

GRAIN SIZE DISTRIBUTION

Clayey Silt to Silty Clay

Highway 69 (SBL and NBL) Culvert C201 at STA 11+207

FIGURE A.C201-01A



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-04	10	172.2
■	S202-04	4	179.6
◆	C201-02	4	179.4
▲	C201-01	4	179.8
▽	C201-03	5	177.8
○	C201-02	7	174.8
□	C201-01	7	175.3

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

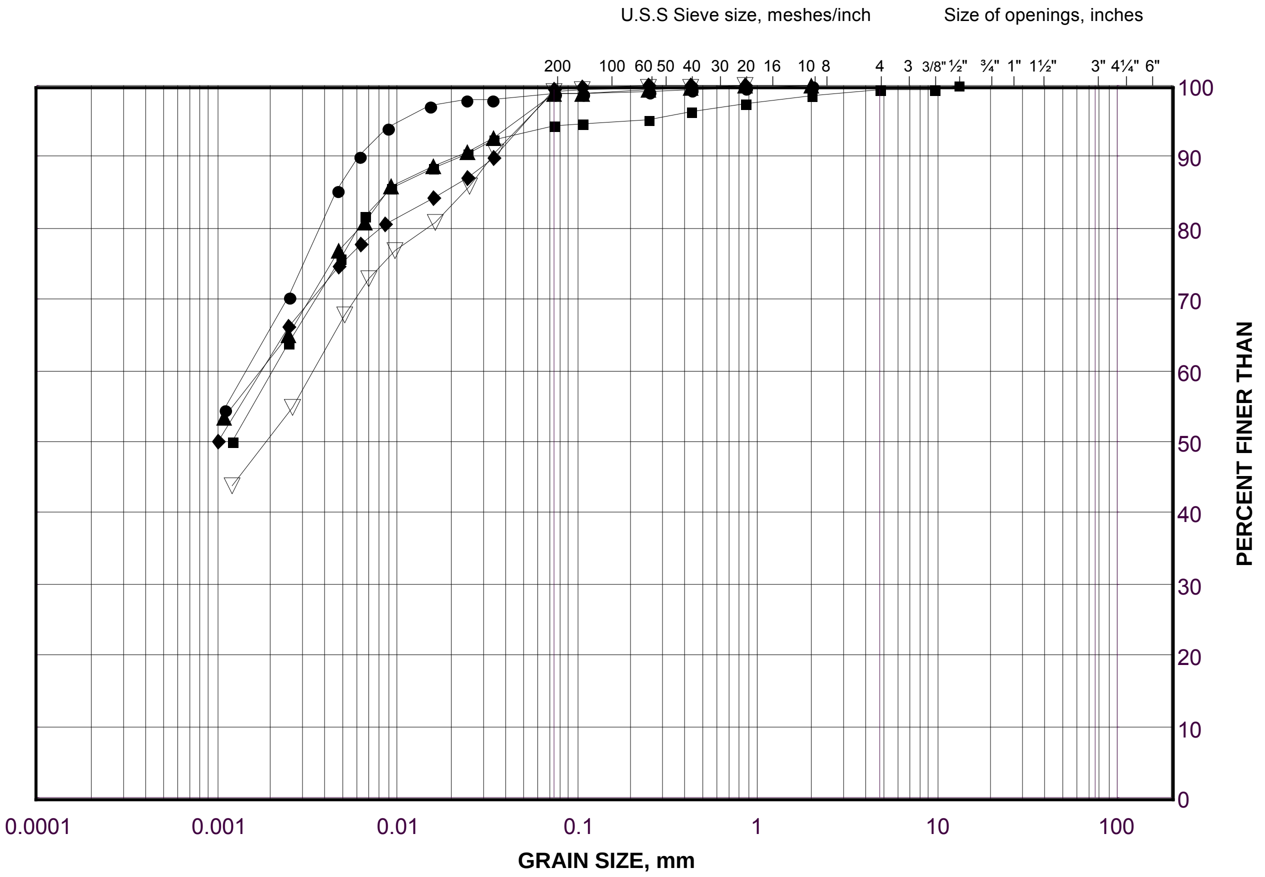
Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION

Clay

Highway 69 (SBL and NBL) Culvert C201 at STA 11+207

FIGURE A.C201-01B



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-02	11	168.7
■	C201-04	13	167.6
◆	S202-04	7	174.8
▲	C201-03	7	174.7
▽	C201-03	9	171.7

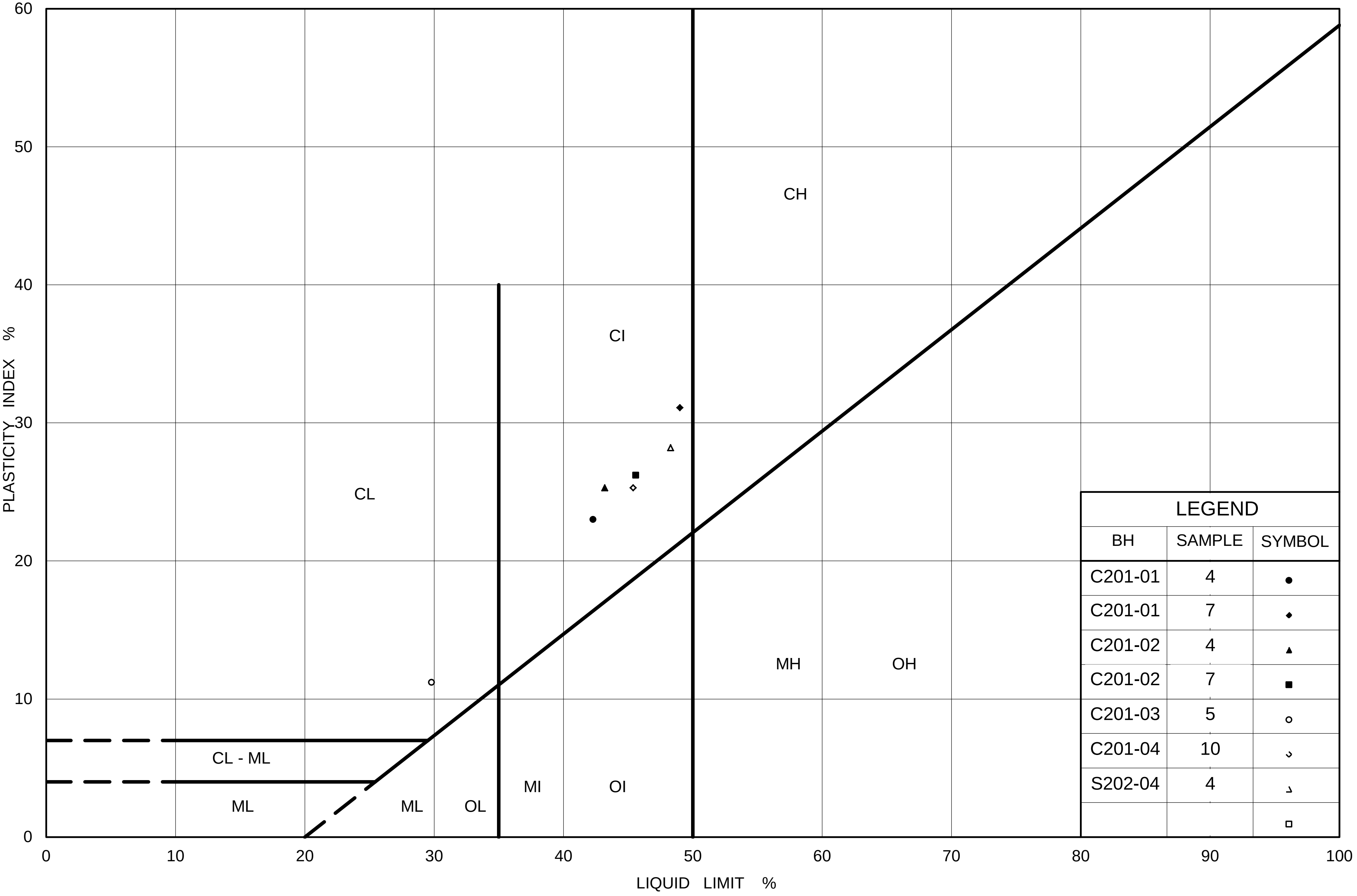
Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

Date: 03-Feb-12

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
C201-01	4	●
C201-01	7	◆
C201-02	4	▲
C201-02	7	■
C201-03	5	○
C201-04	10	◇
S202-04	4	△
		□

Ministry of Transportation

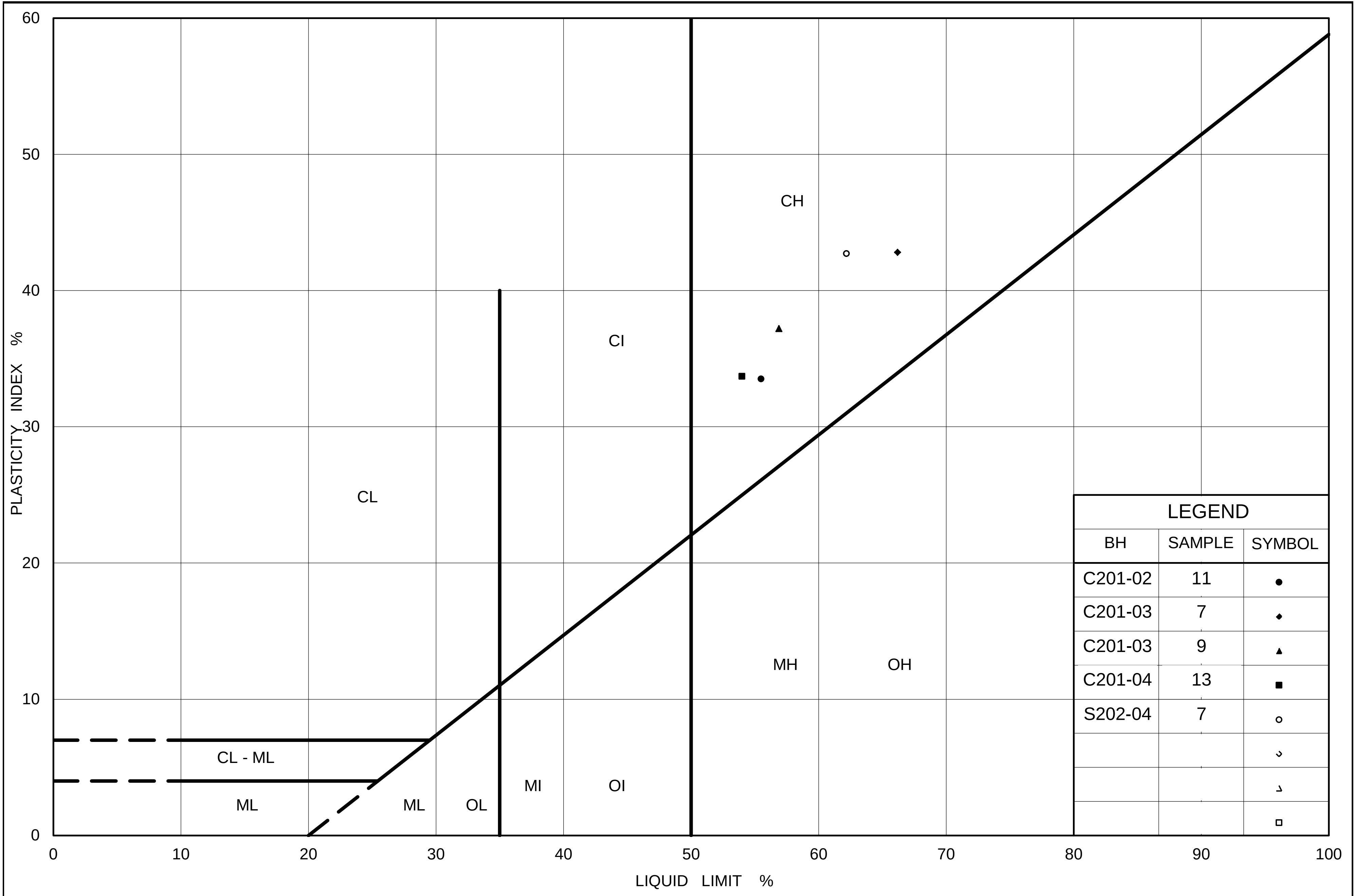
Ontario

PLASTICITY CHART
Clayey Silt to Silty Clay
Highway 69 (SBL and NBL) Culvert C201 at STA 11+207

Figure No. A.C201-02A

Project No. 09-1111-6014

Checked By: JPD



LEGEND		
BH	SAMPLE	SYMBOL
C201-02	11	●
C201-03	7	◆
C201-03	9	▲
C201-04	13	■
S202-04	7	○
		□

Ministry of Transportation

Ontario

PLASTICITY CHART
Clay
Highway 69 (SBL and NBL) Culvert C201 at STA 11+207

Figure No. A.C201-02B

Project No. 09-1111-6014

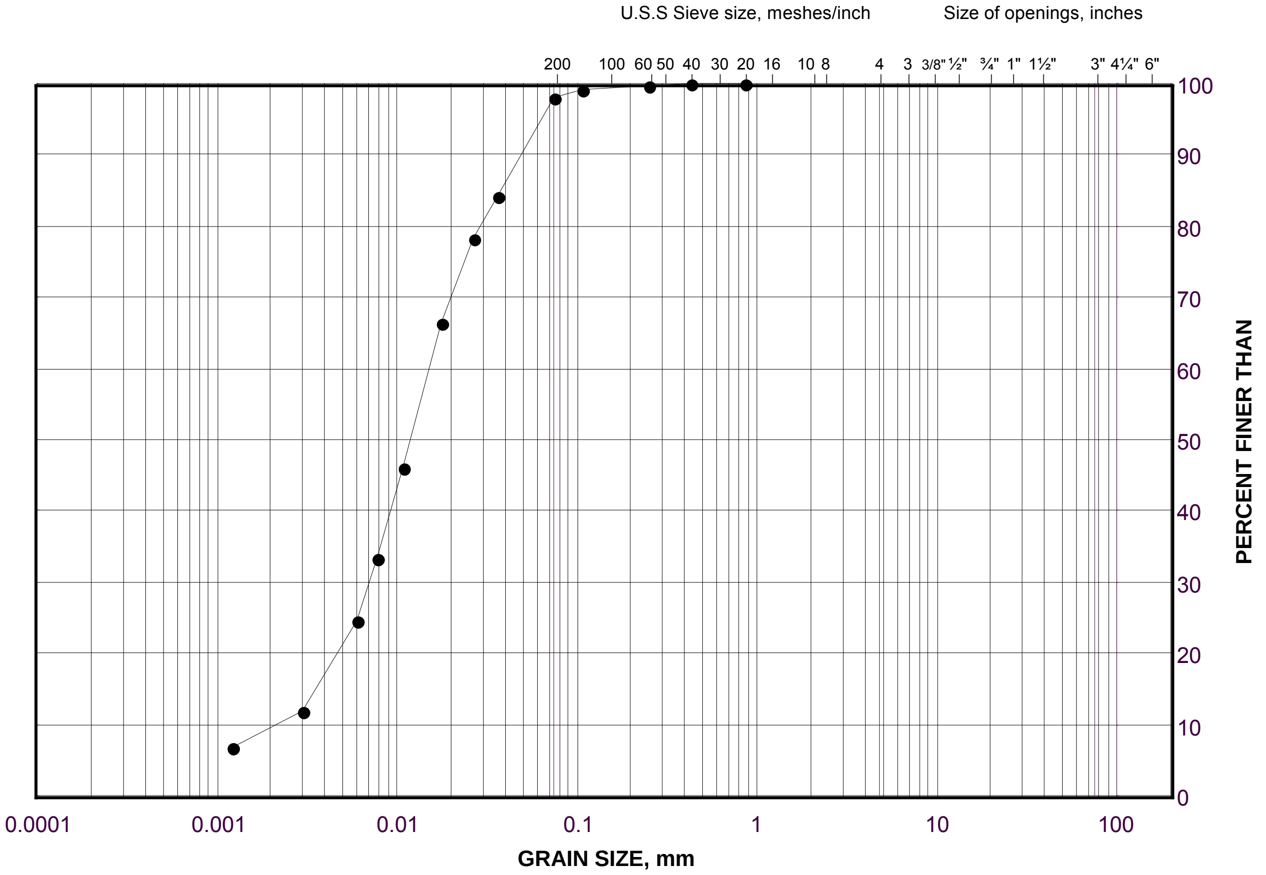
Checked By: JPD

GRAIN SIZE DISTRIBUTION

Silt (Interlayer)

Highway 69 (SBL and NBL) Culvert 201 at STA 11+207

FIGURE A.C201-03



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-04	6	178.2

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

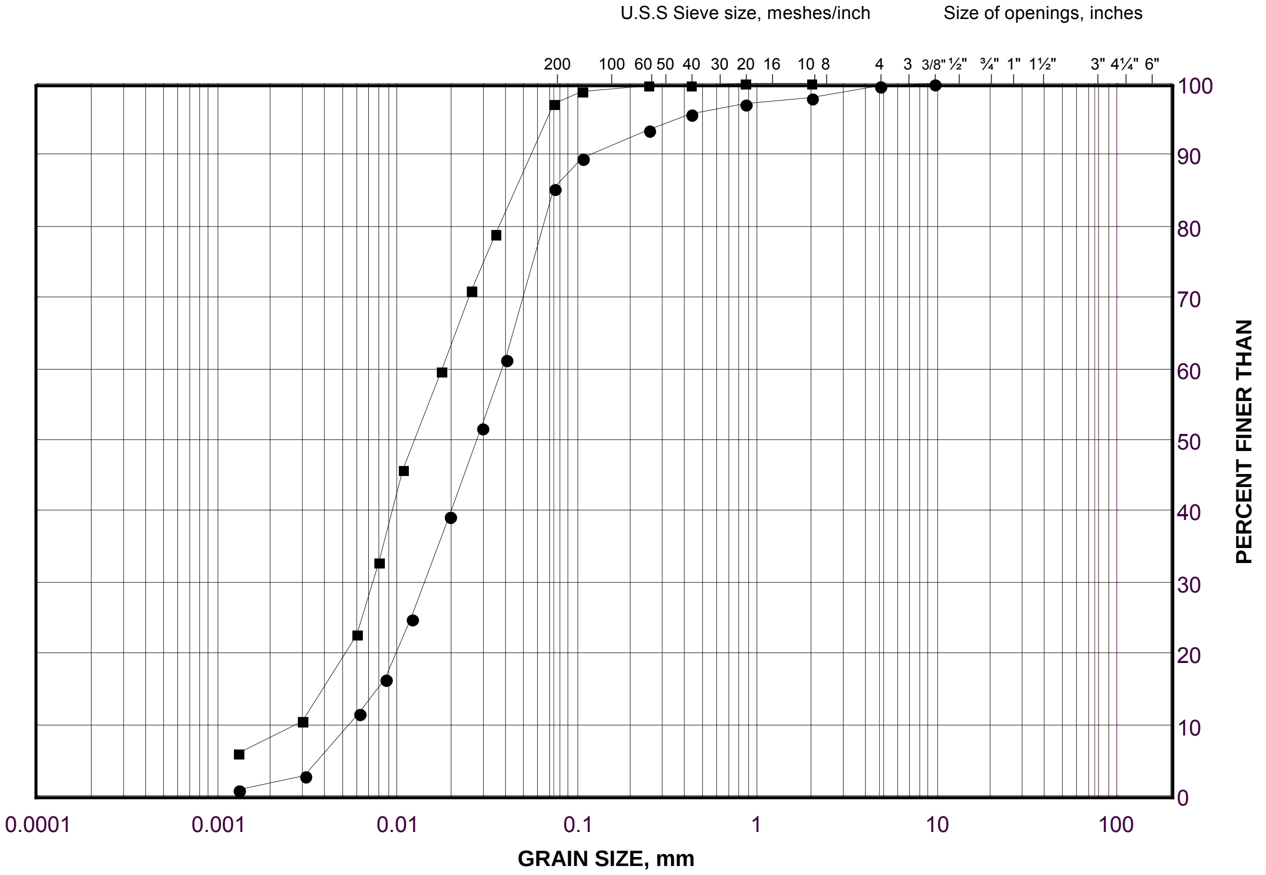
Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION

Silt

Highway 69 (SBL and NBL) Culvert C201 at STA 11+207

FIGURE A.C201-04



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-02	13	164.2
■	C201-03	15	161.0

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

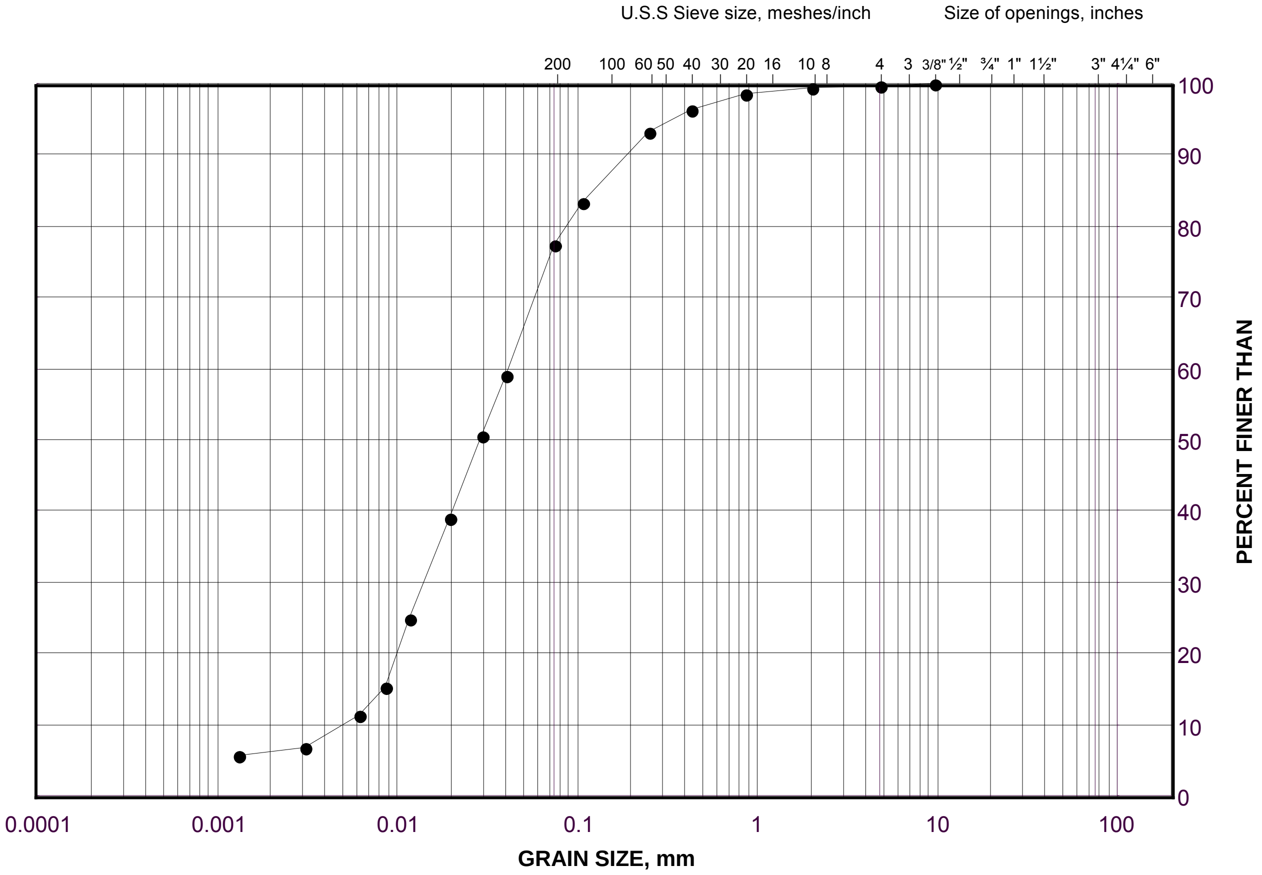
Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION

Sandy Silt

Highway 69 (SBL and NBL) Culvert 201 at STA 11+207

FIGURE A.C201-05A



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-01	11A	169.2

Project Number: 09-1111-6014

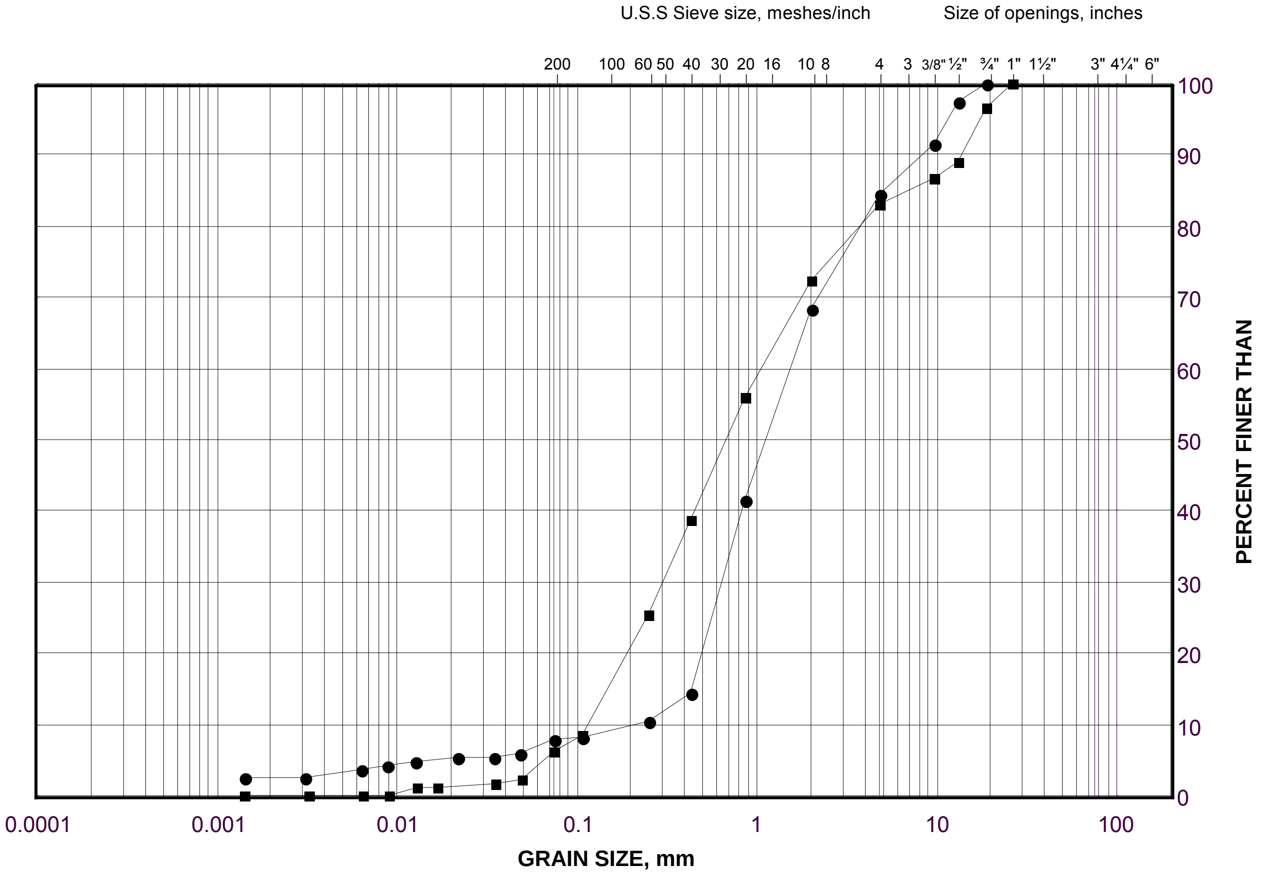
Checked By: TVA

Golder Associates

Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION
Sand
Highway 69 (SBL and NBL) Culvert 201 at STA 11+207

FIGURE A.C201-05B



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C201-04	15	161.5
■	C201-03	17	157.2

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

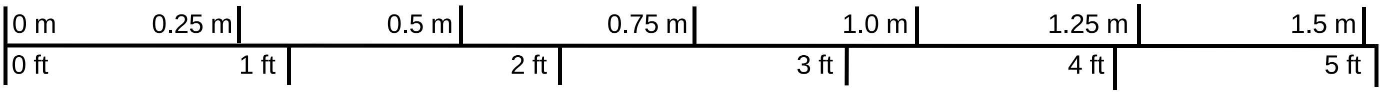
Date: 03-Feb-12

Borehole C201-01

Box 1: 14.17 m – 16.60 m

Borehole S202-04

Box 1: 11.28 m – 14.26 m



Scale

PROJECT
Culverts
Highway 69 Four-Laning
GWP 5402-05-00; WP 5402-05-01

TITLE
Bedrock Core Photographs – Culvert 201
Highway 69 (SBL and NBL) STA 11+207

Golder Associates

PROJECT No.	09-1111-6014		FILE No.	----
DESIGN	AT		SCALE NTS	REV.
CADD	--		**FIGURE A.C201-06**	
CHECK	AT			
REVIEW	TVA			

REVISION DATE: April 13, 2011 BY: AT Project: 09-1111-6014

APPENDIX B

Highway 69 SBL and NBL – STA 11+220 (Culvert 202)

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

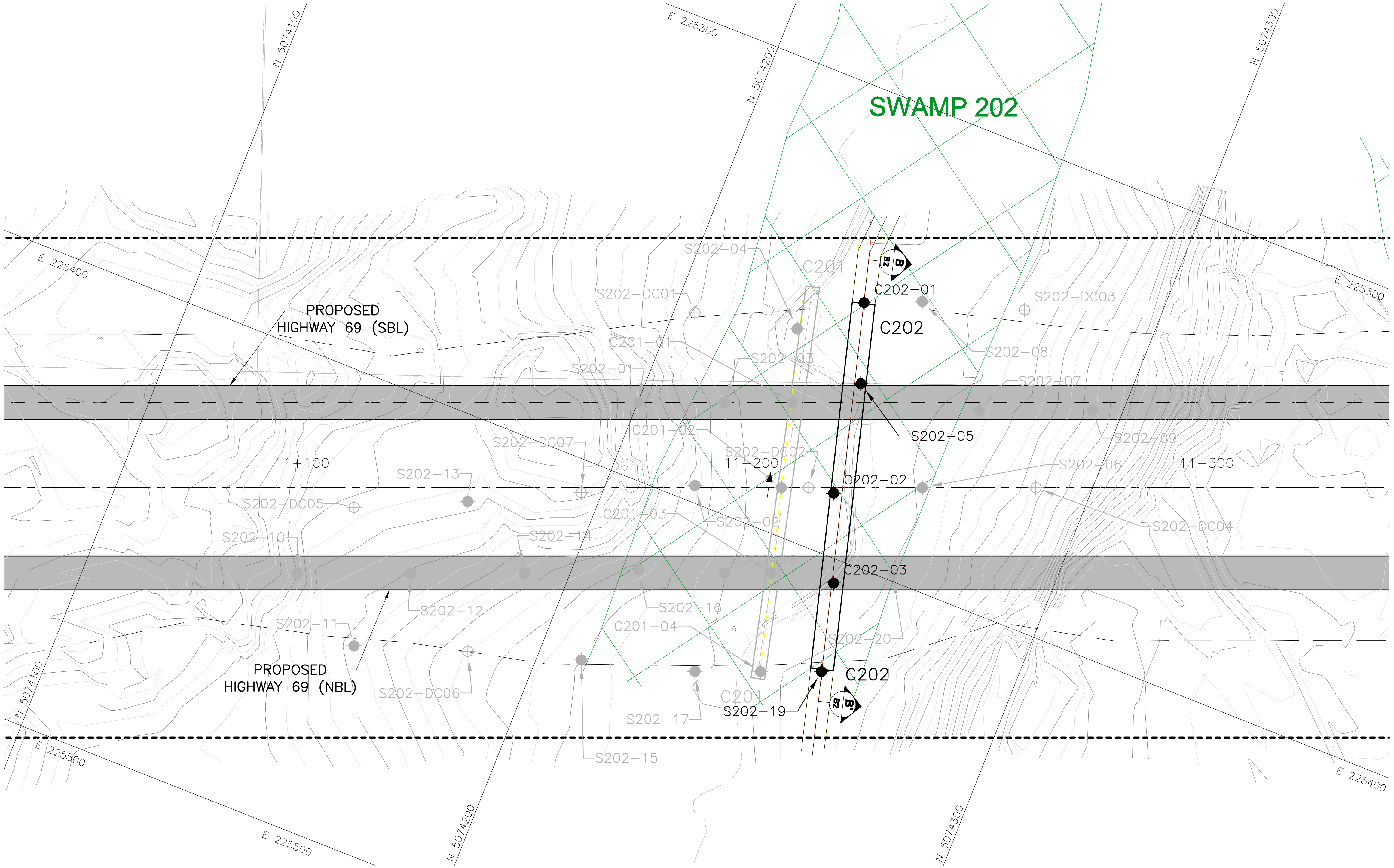
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5404–05–01

SHEET

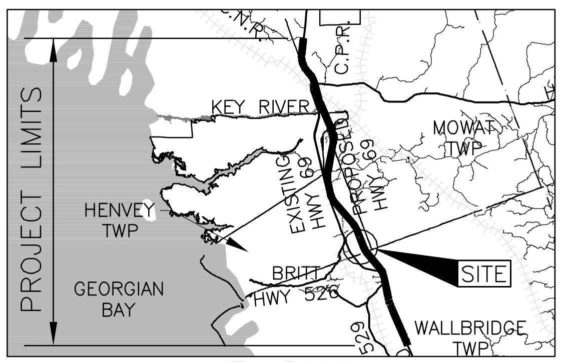
HIGHWAY 69
CULVERT 202 STA 11+220
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE
10 0 10 20 m



KEY PLAN
SCALE
6 0 6 12 km

LEGEND

● Borehole – Current Investigation

BOREHOLE CO–ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C202–01	182.6	5074238.2	225345.3
C202–02	182.7	5074247.4	225386.7
C202–03	182.8	5074254.7	225405.1
S202–05	182.5	5074244.1	225362.1
S202–19	183.0	5074259.4	225424.2

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing files Hwy69_base.dwg, Hwy69_plan.dwg, received December 16, 2009. And Contours from HWY69_Contours–Plan_C2_C3.dwg, received July 14, 2011, Culvert Location obtained from culv 11+220 aug 2012.dwg, received August 24, 2012.

J. M. A. COSTA
Aug. 31, 2012

J.P. DITTRICH
Aug. 31, 2012

NO.	DATE	BY	REVISION

Geocres No. 41H–119

HWY. 69		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: August 2012	SITE:
DRAWN: JFC	CHKD. CN	APPD. JPD/JMAC	DWG. B1

PLOT DATE: September 22, 2015
FILENAME: T:\Projects\2009\09–1111–6014 (URS, Hwy 69, Henvey)\–FAA– CONTRACT 2 (CULVERT) – Stamped\0911116014FA0B1.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

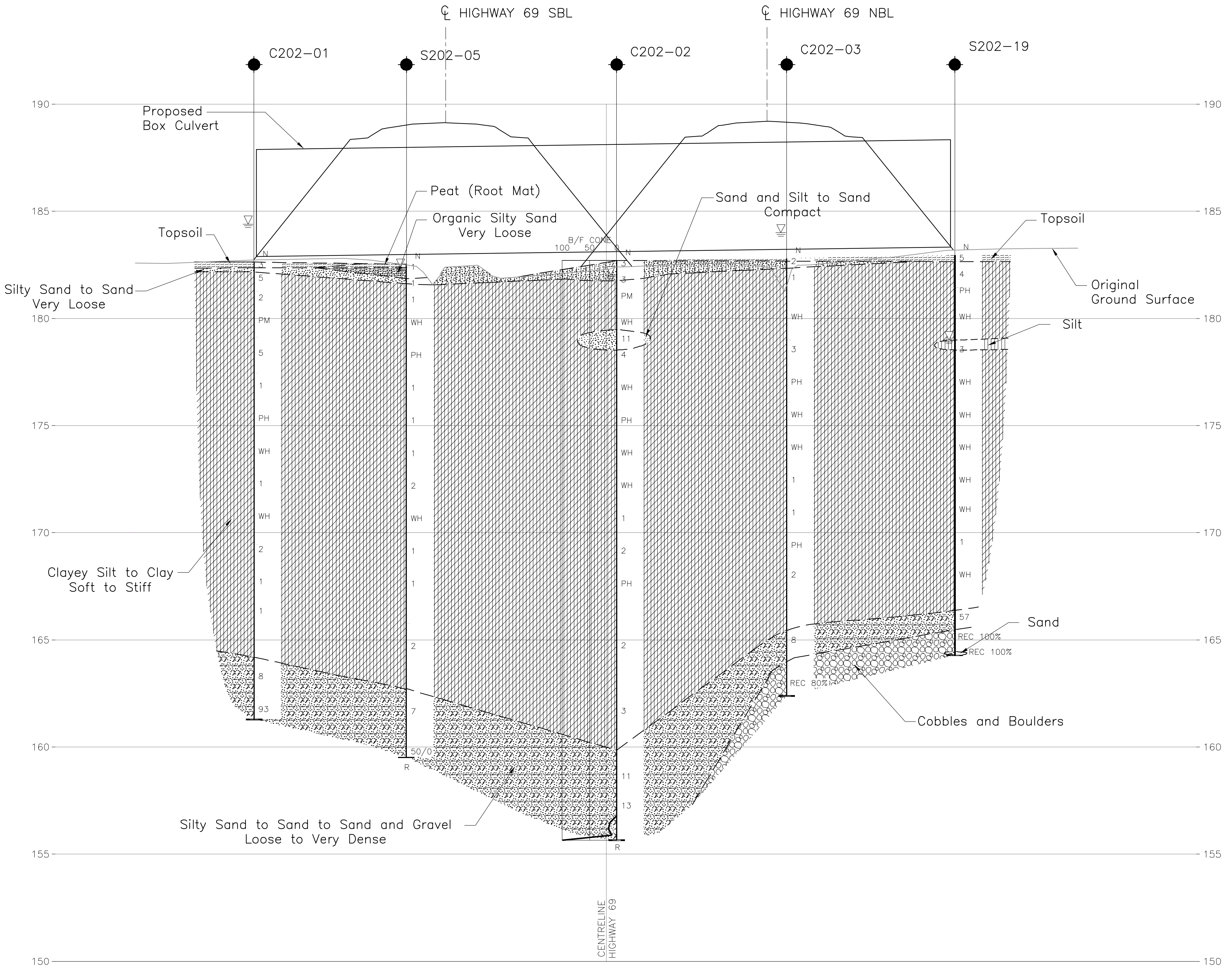
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5404-05-01

HIGHWAY 69
CULVERT 202 STA 11+220
SOIL STRATA

SHEET

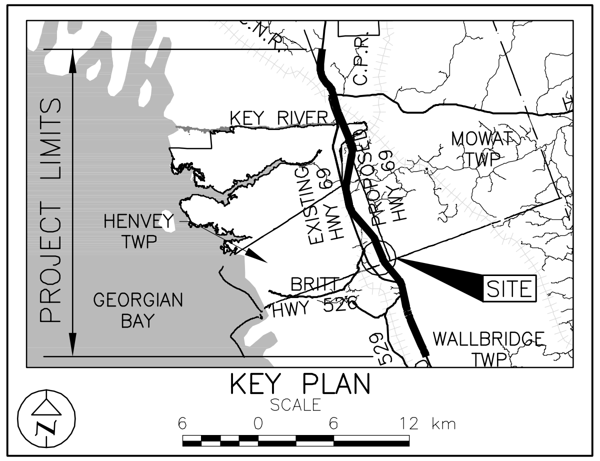
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



B-B' / B1

CULVERT 202 AT STA 11+220
HIGHWAY 69

HORIZONTAL SCALE 5 0 5 10 m
VERTICAL SCALE 2 0 2 4 m



KEY PLAN
SCALE
6 0 6 12 km

LEGEND

●	Borehole – Current Investigation
N 16	Standard Penetration Test Value Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
▽	WL upon completion of drilling
REC	Recovery (%)
R	Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
C202-01	182.6	5074238.2	225345.3
C202-02	182.7	5074247.4	225386.7
C202-03	182.8	5074254.7	225405.1
S202-05	182.5	5074244.1	225362.1
S202-19	183.0	5074259.4	225424.2

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by URS, drawing files Hwy69_base.dwg, Hwy69_plan.dwg, received December 16, 2009.
Cross-Section drawing obtained from culv 11+220 aug 2012.dwg, received August 24, 2012.

J. M. A. COSTA
Aug. 31, 2015

J.P. DITTRICH
Aug. 31, 2015

NO.	DATE	BY	REVISION

Geocres No. 41H-119

HWY. 69		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. TVA	CHKD. TVA	DATE: August 2012	SITE:
DRAWN: JFC	CHKD. CN	APPD. JPD/JMAC	DWG. B2

PLOT DATE: September 22, 2015
FILENAME: T:\Projects\2009\09-1111-6014 (URS, Hwy 69, Henvey)\-FAA- CONTRACT 2 (CULVERT) - Stamped\0911116014FA0B2.dwg

RECORD OF BOREHOLE No C202-01

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
DIST
HWY 69
DATUM Geodetic
LOCATION N 5074238.2 ;E 225345.3
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
DATE March 10 and 11, 2011
ORIGINATED BY MR
COMPILED BY MAS/SB
CHECKED BY TVA

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.6	GROUND SURFACE
0.0	TOPSOIL
182.3 0.5	SAND, trace to some silt, containing organics and rootlets Very loose Brown Moist
181.2 1.4	CLAYEY SILT, some sand, containing rootlets Firm Brown Moist
	SILTY CLAY, trace sand, containing rootlets to a depth of 2.1 m Soft Grey Moist
179.1 3.5	CLAYEY SILT, trace sand Firm Grey Wet
177.4 5.2	SILTY CLAY, trace sand Soft to firm Grey Moist
169.4 13.2	CLAY, some silt, trace to some sand, trace gravel, containing silt interlayers Firm Grey Wet

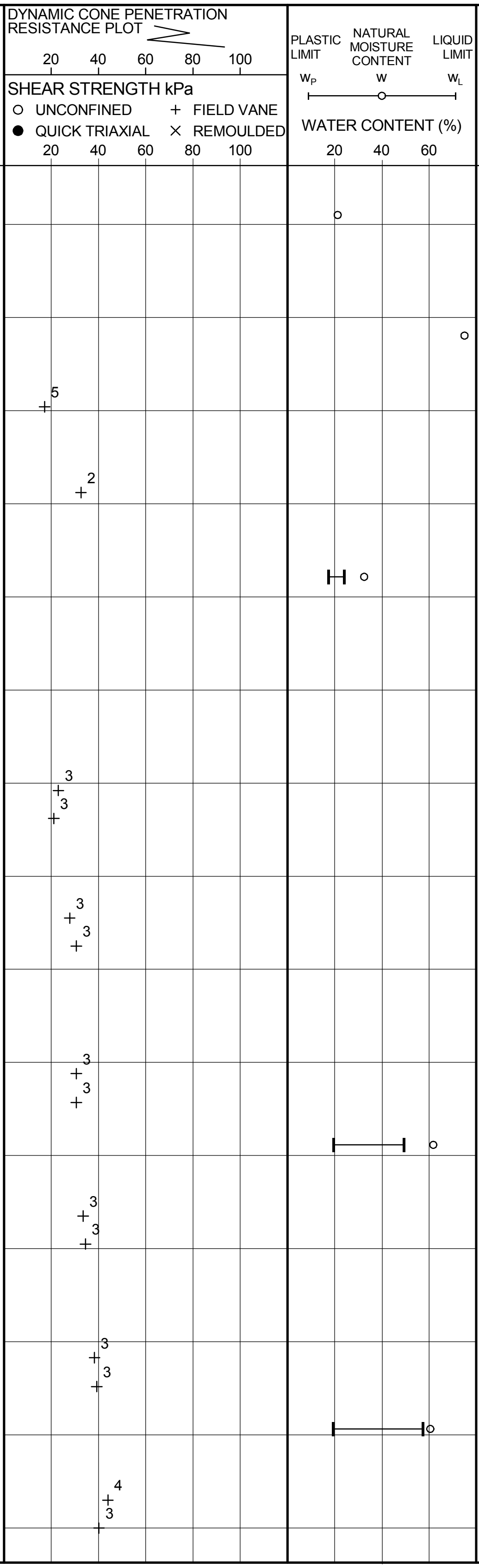
SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1A 1B 1C	SS	3				
2	SS	5				
3	SS	2				
4	TO*	PM				
5	SS	5	0	1	79	20
6	SS	1				
7	TO	PH				
8	SS	WH				
9	SS	1	0	1	42	57
10	SS	WH				
11	SS	2	3	6	33	58

GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)



Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No C202-01

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014			
W.P. 5404-05-01	LOCATION N 5074238.2 ;E 225345.3	ORIGINATED BY MR	
DIST	HWY 69	BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring	COMPILED BY MAS/SB
DATUM Geodetic	DATE March 10 and 11, 2011	CHECKED BY TVA	

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY, some silt, trace to some sand, trace gravel, containing silt interlayers Firm Grey Wet	▨	12	SS	1		
			13	SS	1		
164.2 18.4	Silty SAND, trace to some gravel Loose Grey Wet		14	SS	8		Non-Plastic
162.3 20.3	SAND and GRAVEL, containing cobbles Very dense Grey Wet		15	SS	93		
161.3 21.3	END OF BOREHOLE						

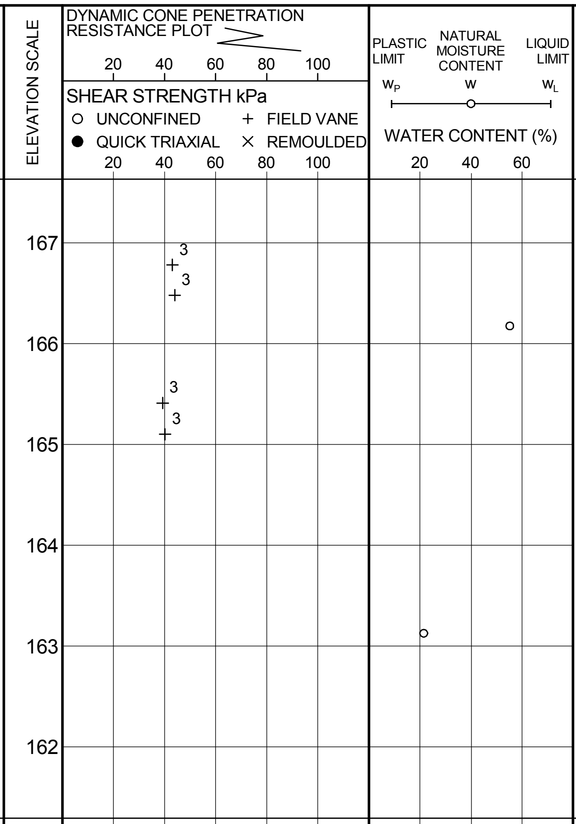
NOTES:

* Unable to recover Shelby tube sample between depths of 2.6 m and 3.0 m.

1. Water flowing from top of casing when advanced to a depth of 20.7 m below ground surface (Elev. 161.9 m).

Water level in casing at a depth of 0.8 m below ground surface (Elev. 181.8 m) at about 6:30 pm on March 10, 2011. Casing set at a depth of 20.7 m below ground surface (Elev. 161.9 m) at the time of water level measurement.

Water level in casing at 1.8 m above ground surface (Elev. 184.4 m) measured at about 7:15 am on March 11, 2011 - Artesian Condition. Casing set at a depth of 20.7 m below ground surface (Elev. 161.9 m) at the time of water level measurement.



UNIT WEIGHT γ kN/m³

$+^3$, $\times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No C202-02

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074247.4 ;E 225386.7
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY MAS/SB
DATUM Geodetic
DATE February 28 and March 1, 2011
CHECKED BY TVA

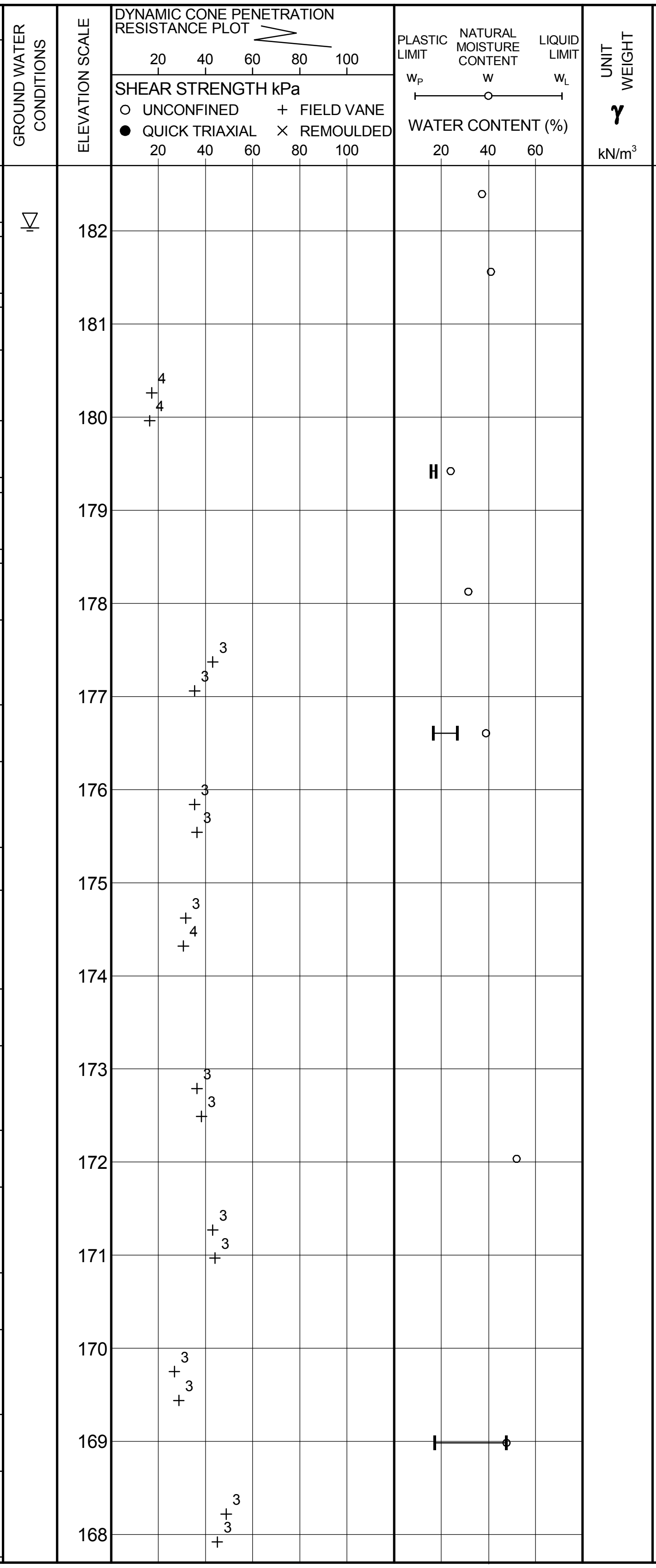
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.7	GROUND SURFACE
0.0	Silty SAND, containing organics and wood fragments Very loose Dark brown Moist
181.8 0.9	SILTY CLAY, trace sand Soft Grey Moist
179.5 3.4	SAND and SILT, trace to some clay, trace gravel Grey Wet SAND, trace silt, trace gravel Compact Grey Wet
178.5 4.2	CLAYEY SILT, trace sand Firm Grey Moist Containing silt layers below a depth of 5.3 m
175.7 7.0	SILTY CLAY, trace sand Firm to stiff Grey Moist

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	3				
2A 2B	SS	3				
3	TO	PM				
4A 4B	SS	WH	1	46	44	9
5	SS	11				
6	SS	4				
7	SS	WH	0	1	74	25
8	TO	PH				
9	SS	WH				
10	SS	WH				
11	SS	1				
12	SS	2	0	2	44	54

REMARKS & GRAIN SIZE DISTRIBUTION (%)



Continued Next Page

+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No C202-02

SHEET 2 OF 2

METRIC

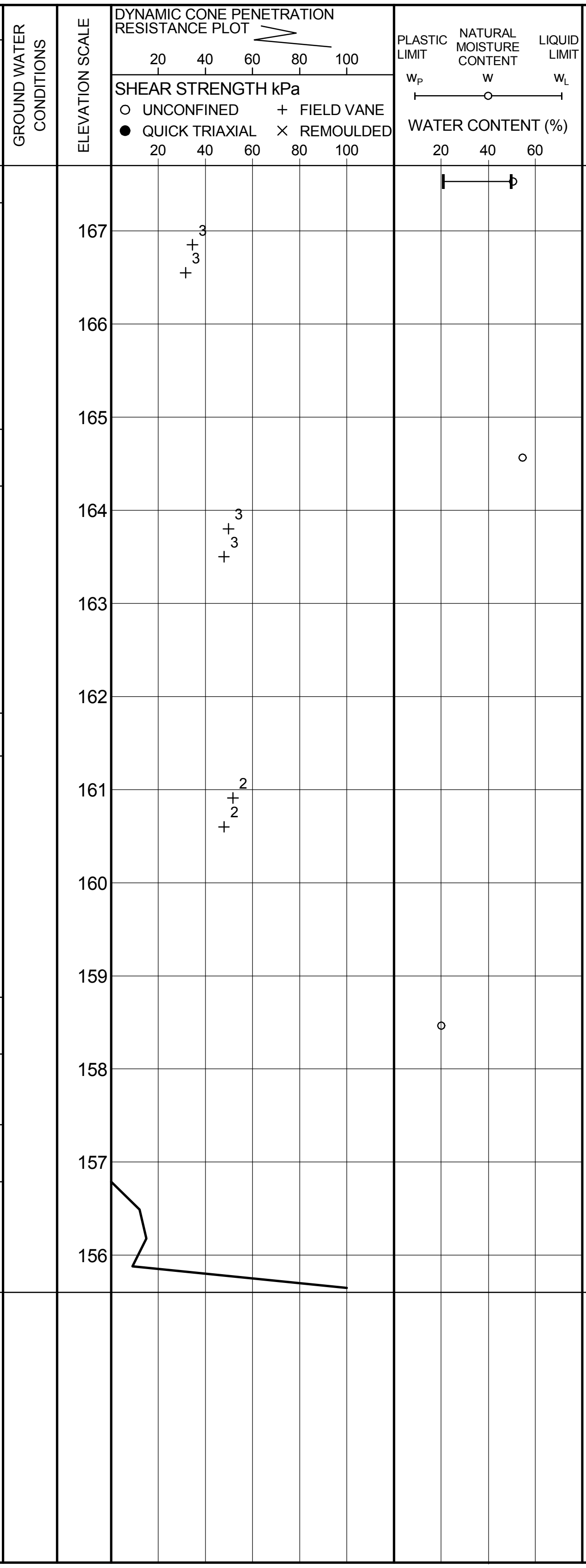
PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074247.4 ;E 225386.7
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY MAS/SB
DATUM Geodetic
DATE February 28 and March 1, 2011
CHECKED BY TVA

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	--- *CONTINUED FROM PREVIOUS PAGE* ---								
	SILTY CLAY, trace sand Firm to stiff Grey Moist	13	TO	PH	17.1				
		14	SS	2					
	Containing silt layers below a depth of 19.7 m	15	SS	3					
159.8 22.9	SAND, trace to some silt, trace clay, trace gravel Compact Grey Wet	16	SS	11		4	89	6	1
		17	SS	13					
156.8 25.9	END OF BOREHOLE								
155.6 27.1	END OF DCPT Refusal to Further Penetration (100 Blows/0.2 m)								

NOTES:

1. Water flowing from top of casing when advanced to a depth of 23.9 m below ground surface (Elev. 158.8 m).

Water level in open borehole at a depth of 0.7 m below ground surface (Elev. 182.0 m) upon completion of drilling.



+³, ×³: Numbers refer to Sensitivity   ○³% STRAIN AT FAILURE

GTA-MTO 001 T:\PROJECTS\2009\09-1111-6014 (URS, HWY 69, HENVEY)\LOG\09-1111-6014.GPJ GAL-GTA.GDT 8/31/15

RECORD OF BOREHOLE No C202-03

SHEET 1 OF 2

METRIC

PROJECT	09-1111-6014		
W.P.	5404-05-01	LOCATION	N 5074254.7 ;E 225405.1
DIST		HWY	69
BOREHOLE TYPE	127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring		
DATUM	Geodetic	DATE	March 8, 2011
ORIGINATED BY	MR	COMPILED BY	MAS/SB
CHECKED BY	TVA		

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
182.8	GROUND SURFACE
0.0	TOPSOIL
182.3 / 0.7	SAND, containing organics and rootlets Very loose Grey Moist
	CLAYEY SILT, trace sand, trace gravel Grey Moist
	SILTY CLAY, trace sand, containing organics and rootlets to a depth of 2.0 m Soft Grey Moist
179.0 / 3.8	CLAYEY SILT, trace sand, containing silt layers Firm to stiff Grey Moist
176.1 / 6.7	SILTY CLAY, trace sand Firm Grey Moist
168.3 / 14.5	

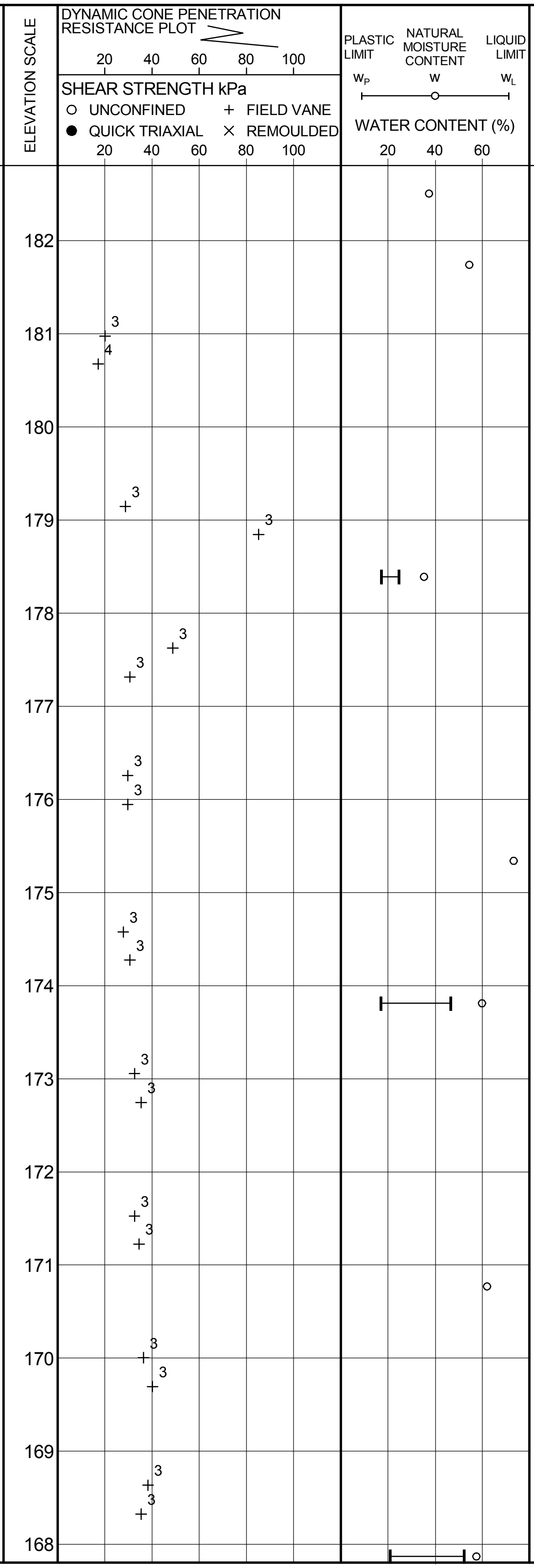
Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS	GR	SA	SI	CL
1A							
1B	SS	2					
1C							
2	SS	1	OC=4%				
3	SS	WH					
4	SS	3		0	2	75	23
5	TO	PH					
6	SS	WH					
7	SS	WH		0	2	38	60
8	SS	1					
9	SS	1					
10	TO*	PH					
	SS	2		2	2	38	58

GROUND WATER CONDITIONS

UNIT WEIGHT γ kN/m³



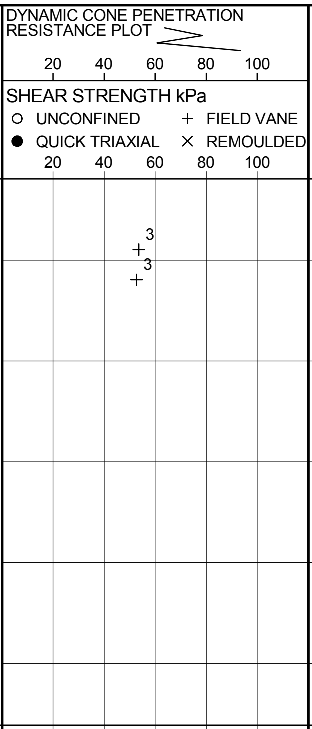
+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

PROJECT	09-1111-6014	**RECORD OF BOREHOLE No C202-03**	SHEET 2 OF 2	**METRIC**	
W.P.	5404-05-01	LOCATION	N 5074254.7 ;E 225405.1	ORIGINATED BY	MR
DIST		HWY	69		
		BOREHOLE TYPE	127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring	COMPILED BY	MAS/SB
DATUM	Geodetic	DATE	March 8, 2011	CHECKED BY	TVA

--- CONTINUED FROM PREVIOUS PAGE ---

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	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
	CLAY, some silt, trace sand, trace gravel, containing silt interlayers Stiff Grey Wet	▨	11				167 166				
165.4 17.4	SAND and GRAVEL Loose Grey Wet		12	SS	8		165				
164.0 18.8	Cobbles and Boulders, containing sand interlayers		13	SC	REC 80%		164 163				
162.4 20.4	END OF BOREHOLE										



NOTES:

* Unable to recover Shelby tube sample between depths of 13.3 m and 13.9 m.

1. Water flowing from top of casing when advanced to a depth of 17.7 m below ground surface (Elev. 165.1 m).

Water level in casing at 1.2 m above surface (Elev.184.0 m) measured at about 30 min. after completion of drilling - Artesian Condition.

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

Golder Associates

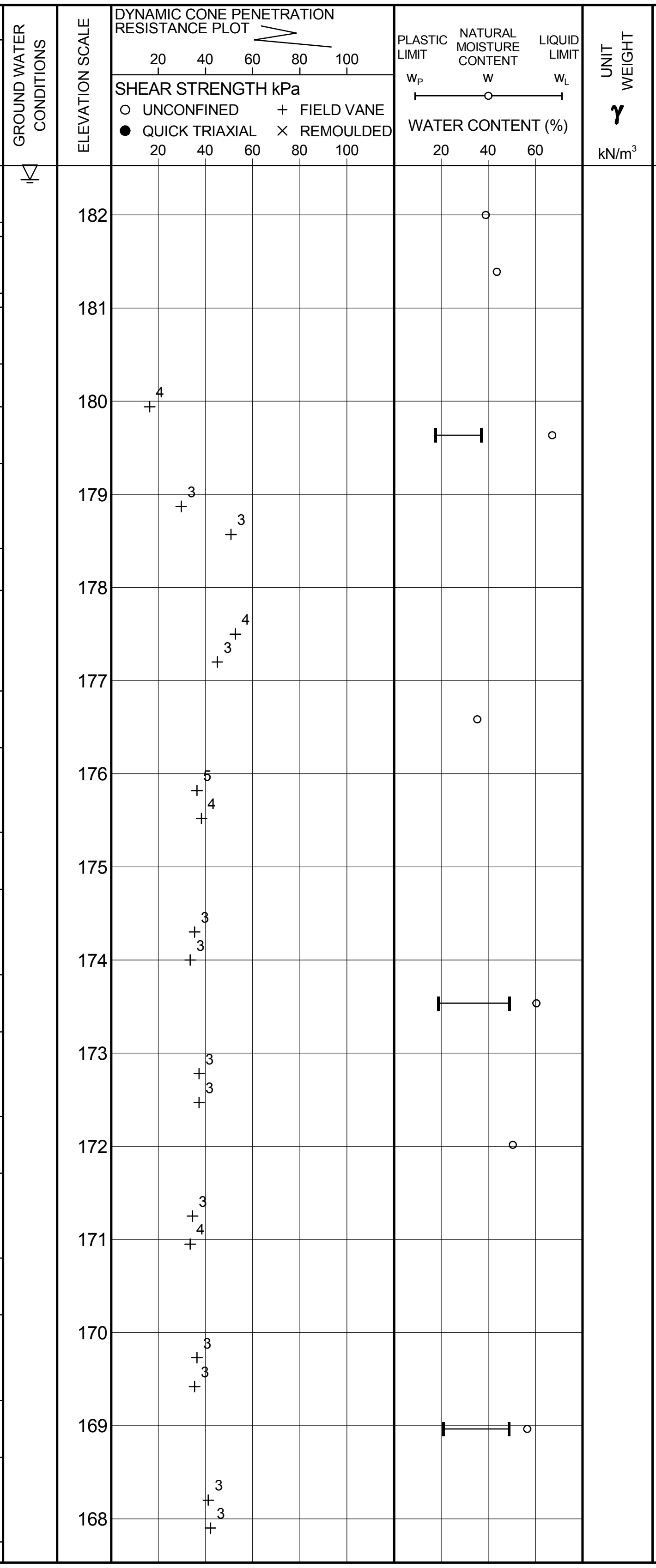
RECORD OF BOREHOLE No S202-05

SHEET 1 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074244.1 ;E 225362.1
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY MAS
DATUM Geodetic
DATE March 13, 2011
CHECKED BY TVA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
182.5	GROUND SURFACE							
0.0	Peat (Root Mat)							
0.2	Organic Silty SAND, trace clay Very loose Dark grey to brown Wet	1A 1B	SS	1				
181.8 0.9	SAND, containing organics Brown Wet	2A 2B	SS	1				
181.1 1.4	SILTY CLAY, containing organics Very soft Brown and grey Wet	3	SS	1				
	SILTY CLAY, trace to some sand Soft to stiff Grey Wet	4	SS	WH	0	2	66	32
		5	TO	PH				
		6	SS	1				
	Brown between depths of 6.9 m and 7.8 m	7	SS	1				
		8	SS	1	0	1	41	58
		9	SS	2				
		10	SS	WH				
		11	SS	1	0	13	37	50



REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

Golder Associates

Foundation Design

RECORD OF BOREHOLE No S202-05

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074244.1 ;E 225362.1
ORIGINATED BY MR
DIST
HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY MAS
DATUM Geodetic
DATE March 13, 2011
CHECKED BY TVA

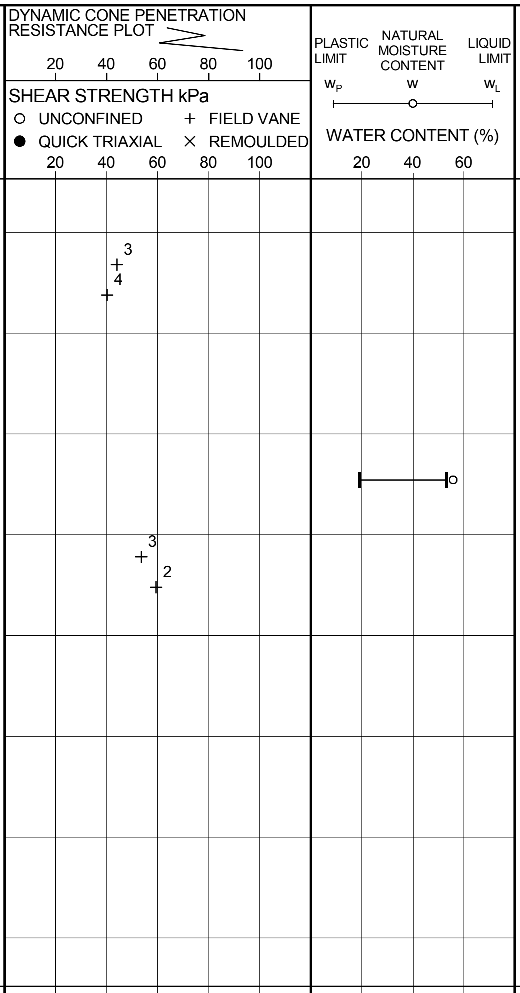
--- CONTINUED FROM PREVIOUS PAGE ---

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	SILTY CLAY, trace to some sand Soft to stiff Grey Wet	12	SS	1	167				
165.7 16.8	CLAY, some silt, containing grey silt layers Stiff Brown Wet	13	SS	2	166 165 164	0	0	37	63
162.7 19.8	SAND, some silt Loose Grey Wet	14	SS	7	163 162 161 160				
159.5 23.0	END OF BOREHOLE SPOON AND CASING REFUSAL	15	SS	50/0.0					

NOTES:

1. Water flowing from top of casing when advanced to a depth of 20.7 m below ground surface (Elev. 161.8 m).

Water level in open borehole at a depth of 0.2 m below ground surface (Elev. 182.3 m) upon completion of drilling.



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

$\circ^{3\%}$ STRAIN AT FAILURE

GTA-MTO 001 T:\PROJECTS\2009\09-1111-6014.GPJ GAL-GTA.GDT 9/22/15

RECORD OF BOREHOLE No S202-19

SHEET 1 OF 2

METRIC

PROJECT	09-1111-6014				
W.P.	5404-05-01	LOCATION	N 5074259.4 ;E 225424.2	ORIGINATED BY	MR
DIST		HWY 69			
		BOREHOLE TYPE	127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring	COMPILED BY	MAS
DATUM	Geodetic	DATE	March 3, 2011	CHECKED BY	TVA

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
183.0	GROUND SURFACE
0.0	TOPSOIL
182.7 0.3	CLAYEY SILT, trace sand, containing organics and rootlets Soft to firm Brown to grey
181.5 1.5	SILTY CLAY, trace sand, containing organics and fibrous peat layers to a depth of 2.0 m Soft Grey Moist
179.0 4.0	SILT, trace clay, trace sand Grey Wet
178.6 4.4	CLAYEY SILT, trace sand, containing silt layers Firm Grey Moist
176.1 6.9	CLAY, some silt, trace sand Firm Grey Moist
168.2 14.8	

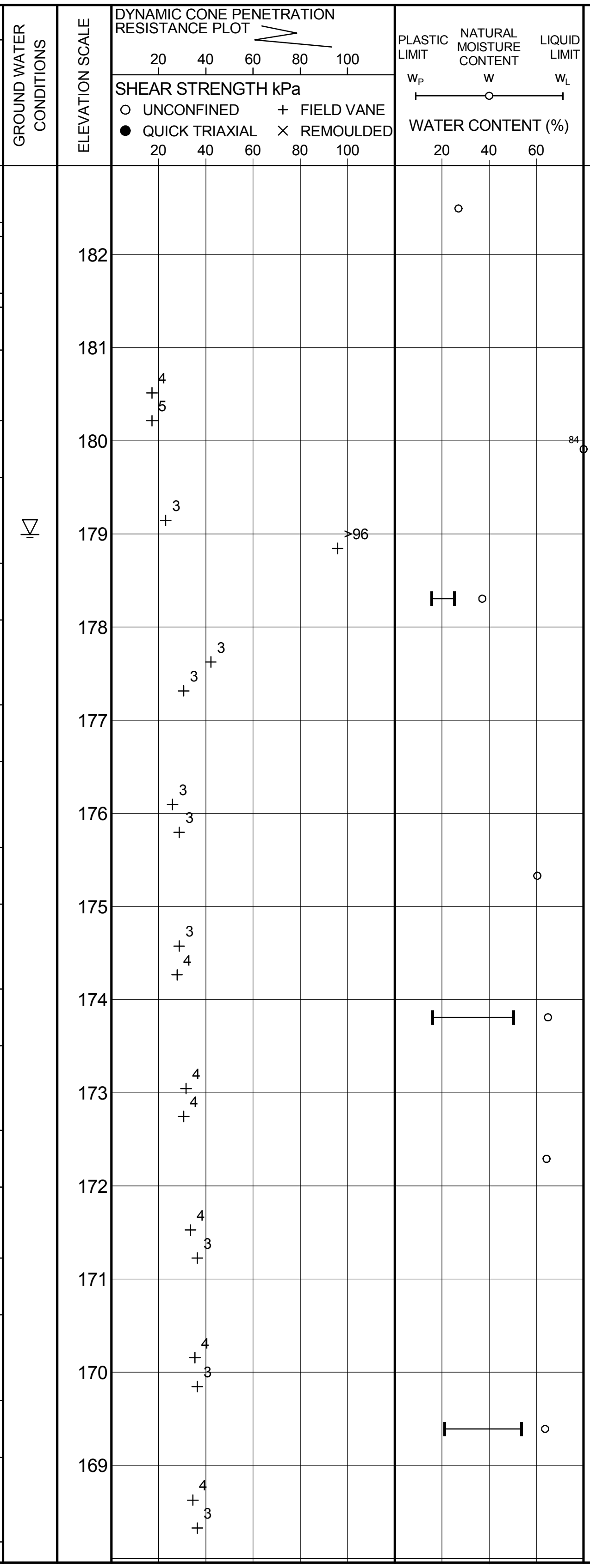
Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1A 1B	SS	5				
2	SS	4				
3	TO	PH				
4	SS	WH				
5A 5B	SS	3	0	2	72	26
6	SS	WH				
7	SS	WH				
8	SS	WH	0	1	42	57
9	SS	WH				
10	SS	WH				
11	SS	1	0	2	36	62

REMARKS & GRAIN SIZE DISTRIBUTION (%)

UNIT WEIGHT γ kN/m³



+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No S202-19

SHEET 2 OF 2

METRIC

PROJECT 09-1111-6014
W.P. 5404-05-01
LOCATION N 5074259.4 ;E 225424.2
ORIGINATED BY MR
DIST HWY 69
BOREHOLE TYPE 127 mm O.D. Continuous Flight Solid Stem Augers, NW Casing, Wash Boring
COMPILED BY MAS
DATUM Geodetic
DATE March 3, 2011
CHECKED BY TVA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SILTY CLAY, trace sand, containing grey silt interlayers Stiff Brown Moist		12	SS	WH		167	+ 2 + 2			
166.4 16.6	Silty SAND, some gravel, containing cobbles Very dense Grey Wet		13	SS	57		166		○		
165.5 17.5	Boulder Dark grey with reddish pink bands		14	SC	REC 100%		165				
164.5	SAND		15	SC	REC 100%						
18.7	COBBLE Dark grey										

END OF BOREHOLE

NOTES:

1. Water flowing from top of casing when advanced to a depth of 17.1 m below ground surface (Elev. 165.9 m), height of casing at about 0.7 m above ground surface.

Water level in open borehole at a depth of 4.0 m below ground surface (Elev. 179.0 m) upon completion of drilling.

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

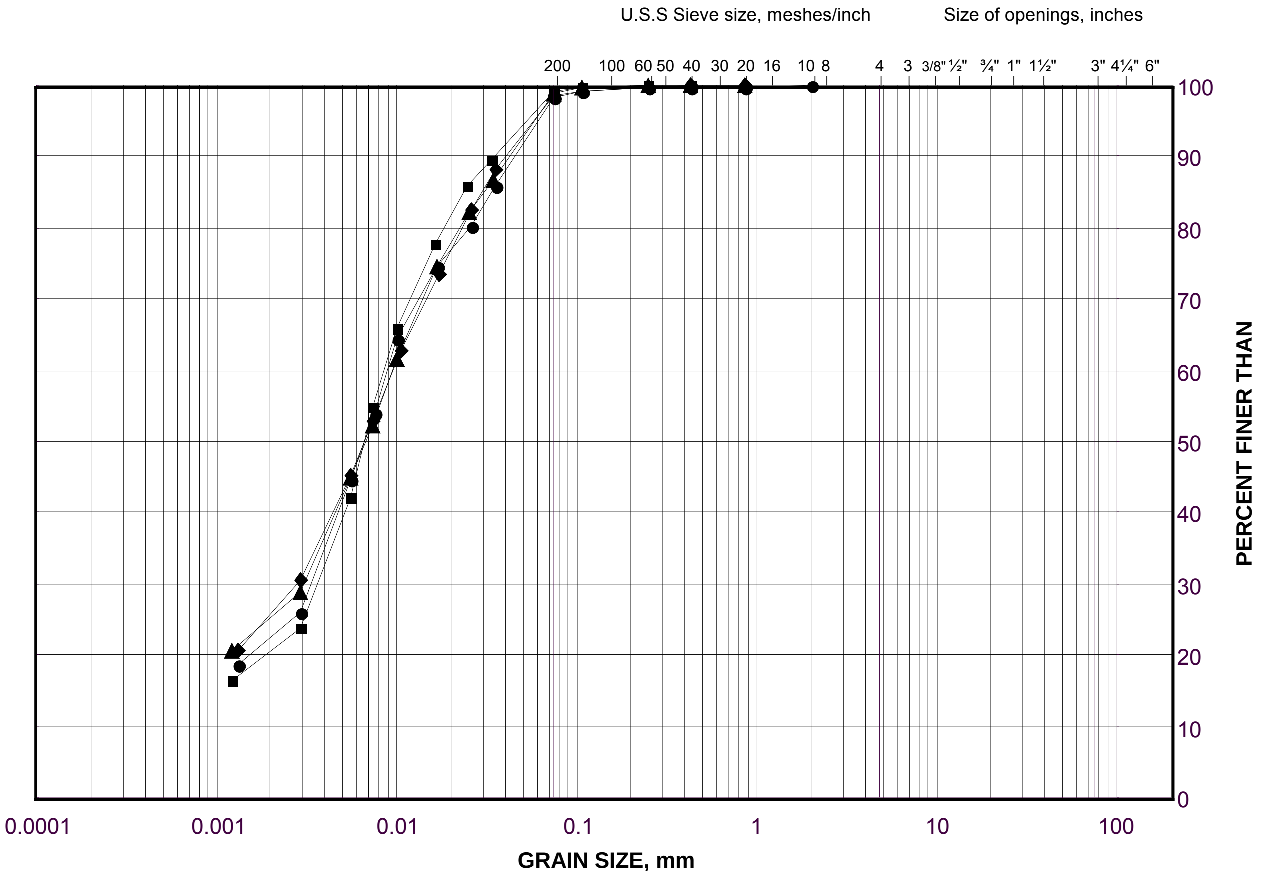
$\bigcirc^{3\%}$ STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION

Clayey Silt

Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-01A



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C202-03	4	178.4
■	C202-01	5	178.2
◆	S202-19	5B	178.3
▲	C202-02	7	176.6

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

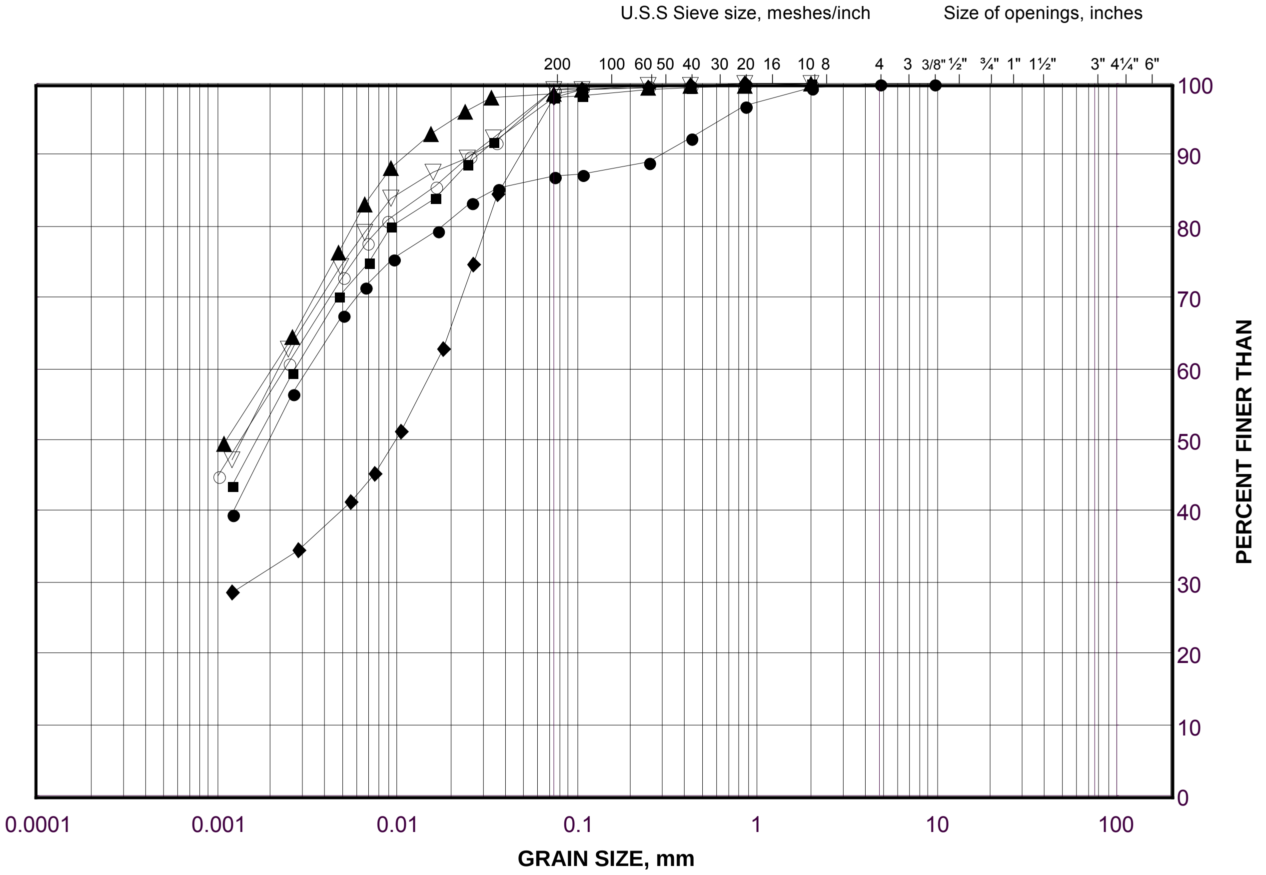
Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION

Silty Clay

Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-01B



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	S202-05	11	168.9
■	C202-02	12	169.0
◆	S202-05	4	179.6
▲	C202-03	7	173.8
▽	S202-05	8	173.5
❍	C202-01	9	172.1

Project Number: 09-1111-6014

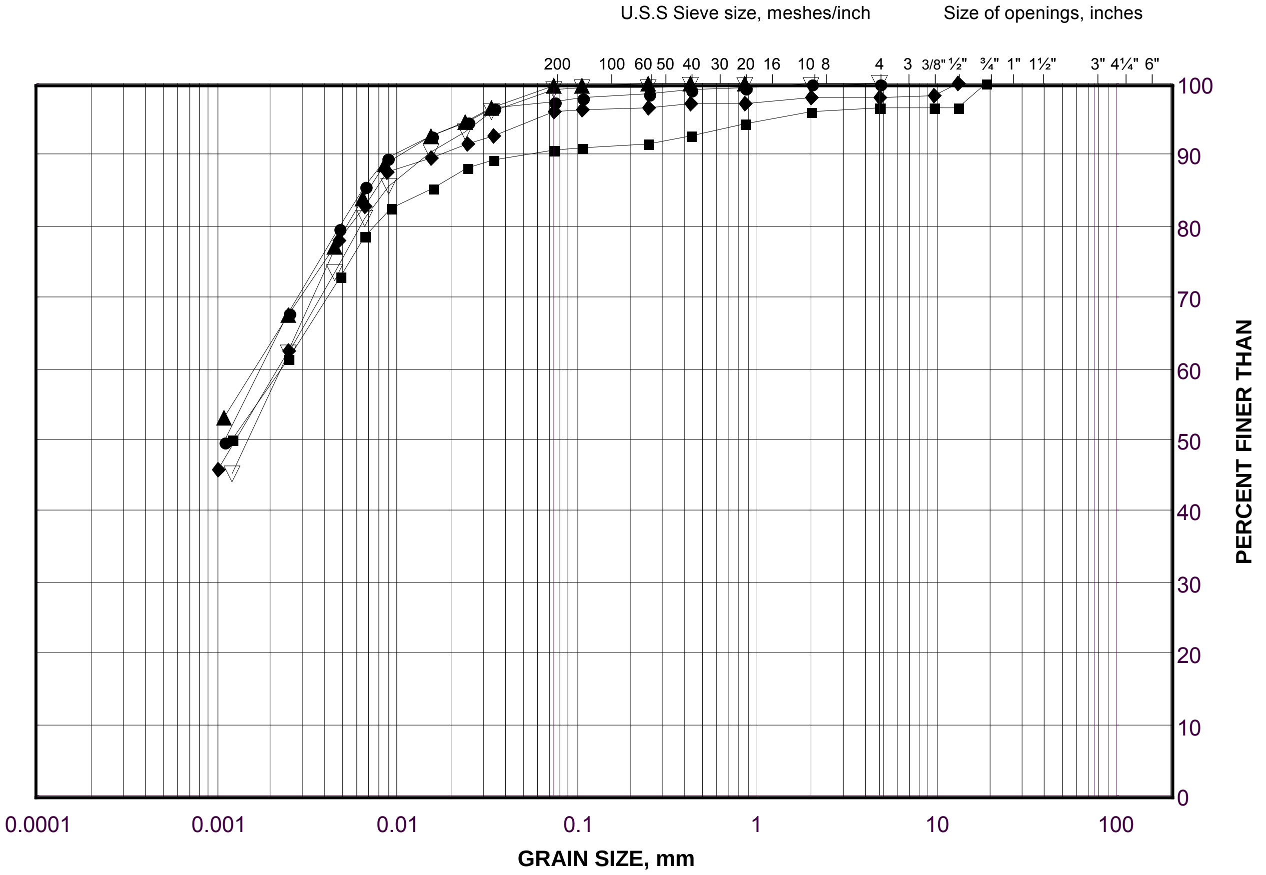
Checked By: TVA

Golder Associates

Date: 03-Feb-12

GRAIN SIZE DISTRIBUTION
Clay
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-01C



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	S202-19	11	169.4
■	C202-01	11	169.1
◆	C202-03	11	167.9
▲	S202-05	13	164.5
▽	S202-19	8	173.8

Project Number: 09-1111-6014

Checked By: TVA

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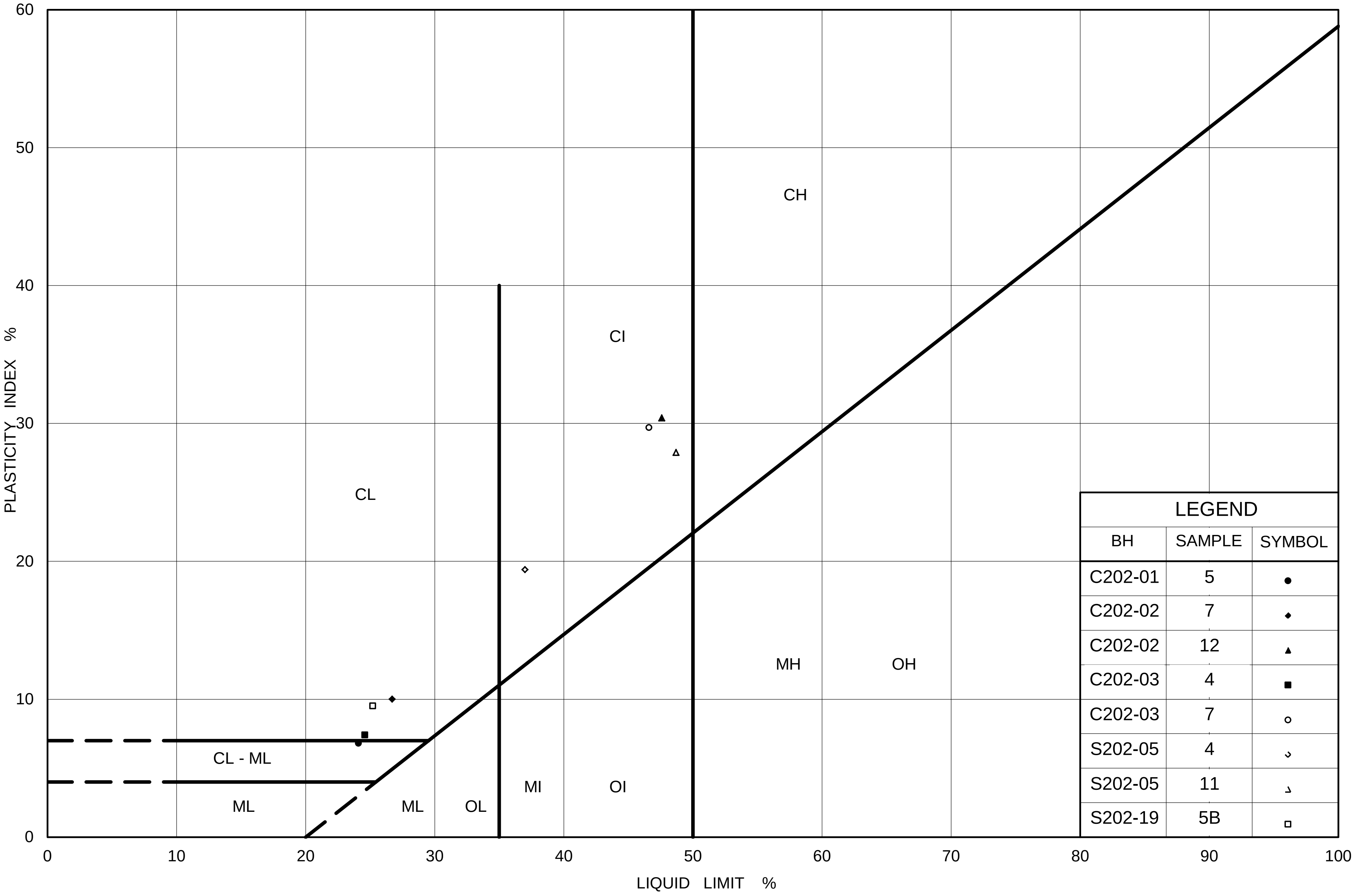
Date: 03-Feb-12

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
C202-01	5	●
C202-02	7	◆
C202-02	12	▲
C202-03	4	■
C202-03	7	○
S202-05	4	◇
S202-05	11	△
S202-19	5B	□

Ministry of Transportation

Ontario

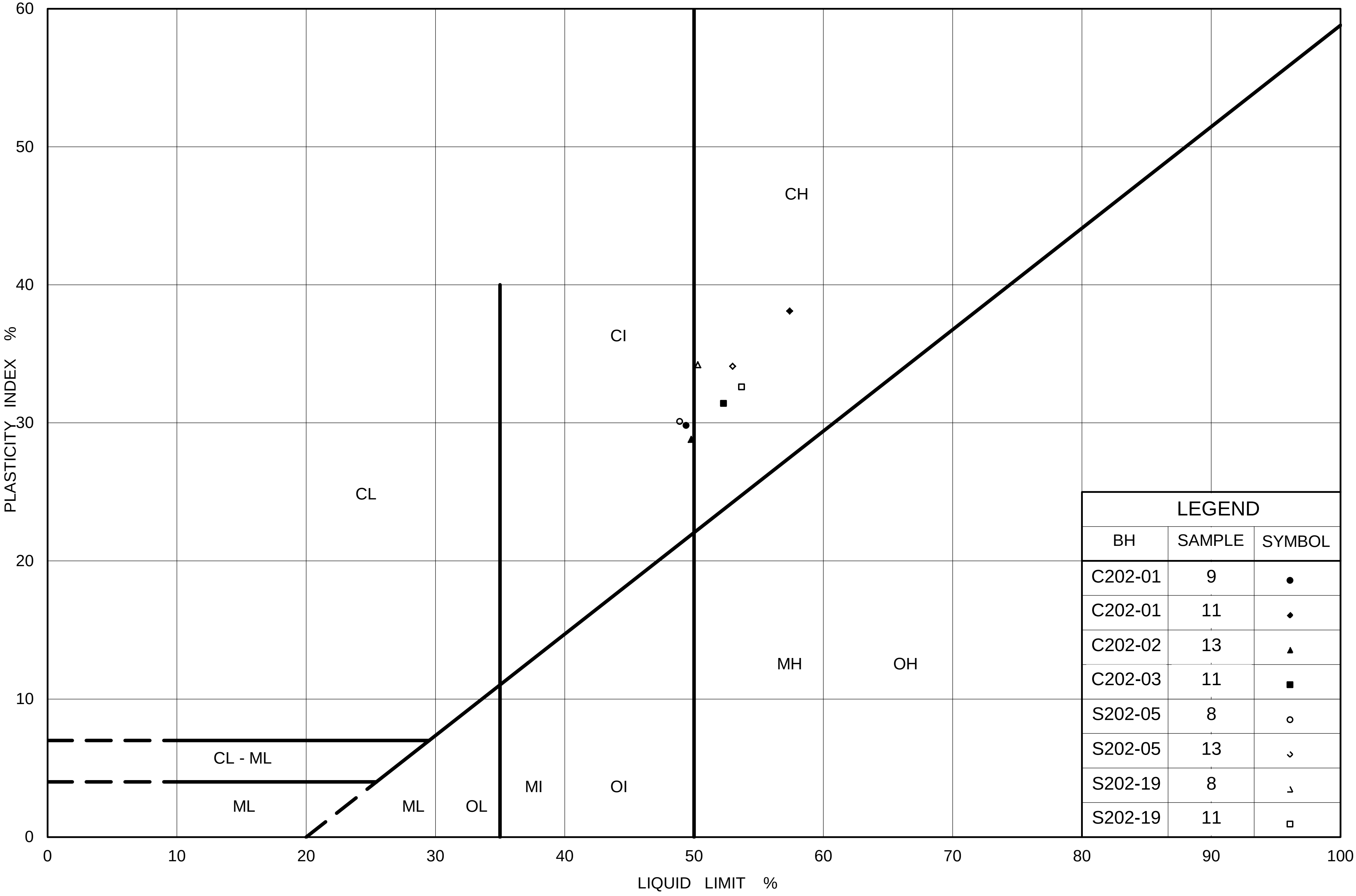
PLASTICITY CHART
Clayey Silt to Silty Clay
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

Figure No. B.C202-02A

Project No. 09-1111-6014

Checked By: JPD

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
C202-01	9	●
C202-01	11	◆
C202-02	13	▲
C202-03	11	■
S202-05	8	○
S202-05	13	◇
S202-19	8	△
S202-19	11	□

Ministry of Transportation

Ontario

PLASTICITY CHART
Silty Clay to Clay
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

Figure No. B.C202-02B

Project No. 09-1111-6014

Checked By: JPD

CONSOLIDATION TEST SUMMARY
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-03
Sheet 1 of 4

SAMPLE IDENTIFICATION

Project Number	09-1111-6014	Sample Number	13
Borehole Number	C202-02	Sample Depth, m	15.2

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	5/02/2011		
Date Completed	5/15/2011		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	17.09
Sample Diameter, cm	6.32	Dry Unit Weight, kN/m^3	11.35
Area, cm^2	31.40	Specific Gravity, measured	2.76
Volume, cm^3	59.91	Solids Height, cm	0.800
Water Content, %	50.56	Volume of Solids, cm^3	25.12
Wet Mass, g	104.38	Volume of Voids, cm^3	34.79
Dry Mass, g	69.33	Degree of Saturation, %	100.7

TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	c_v cm^2/s	m_v m^2/kN	k cm/s
0.00	1.908	1.385	1.908				
5.00	1.910	1.388	1.909	1	7.73E-01		
10.00	1.909	1.386	1.910	38	2.03E-02	1.05E-04	2.09E-07
20.00	1.907	1.384	1.908	118	6.54E-03	9.96E-05	6.38E-08
39.97	1.896	1.370	1.901	540	1.42E-03	2.99E-04	4.16E-08
79.74	1.875	1.344	1.886	254	2.97E-03	2.68E-04	7.78E-08
157.62	1.830	1.288	1.853	623	1.17E-03	3.05E-04	3.49E-08
317.01	1.634	1.042	1.732	1124	5.66E-04	6.46E-04	3.58E-08
630.61	1.510	0.887	1.572	406	1.29E-03	2.07E-04	2.61E-08
1252.71	1.410	0.762	1.460	240	1.88E-03	8.42E-05	1.55E-08
2500.15	1.322	0.652	1.366	194	2.04E-03	3.70E-05	7.39E-09
1252.71	1.331	0.664	1.326				
317.01	1.355	0.694	1.343				
79.74	1.386	0.733	1.371				
20.00	1.425	0.782	1.406				
5.00	1.453	0.816	1.439				

Note:
k calculated using cv based on t_{90} values.
Specimen swelled under 10kPa

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.45	Unit Weight, kN/m^3	19.46
Sample Diameter, cm	6.32	Dry Unit Weight, kN/m^3	14.91
Area, cm^2	31.40	Specific Gravity, measured	2.76
Volume, cm^3	45.61	Solids Height, cm	0.800
Water Content, %	30.52	Volume of Solids, cm ^{3}	25.12
Wet Mass, g	90.49	Volume of Voids, cm ^{3}	20.49
Dry Mass, g	69.33		

Prepared By: LFG

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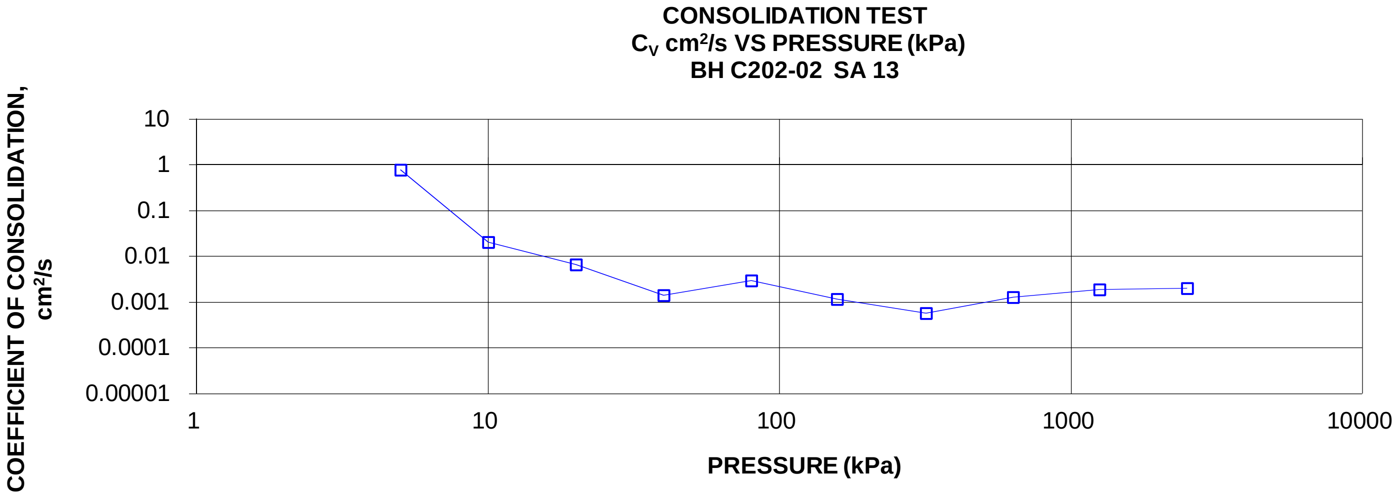
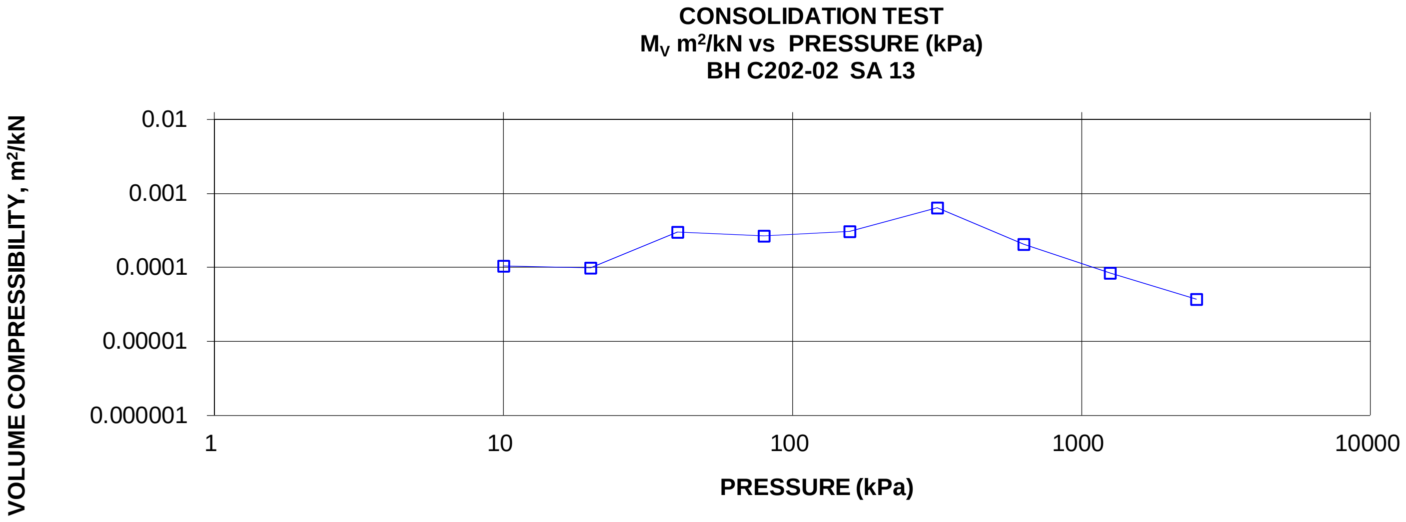
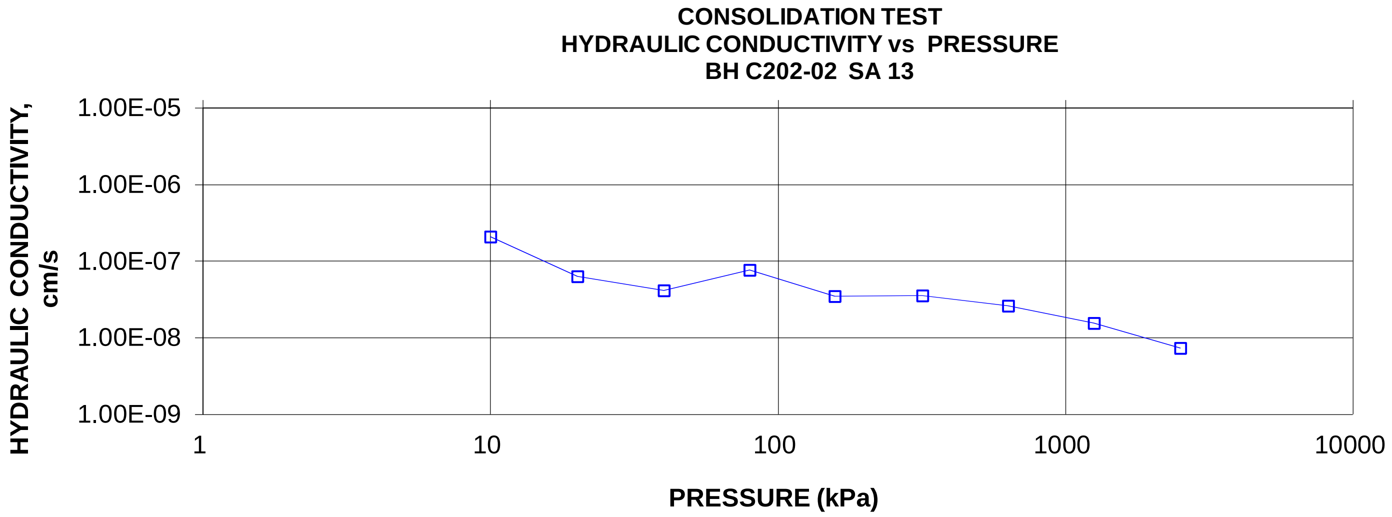
CONSOLIDATION TEST SUMMARY
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-03
Sheet 2 of 4







Project No. 09-1111-6014

Prepared By: LFG

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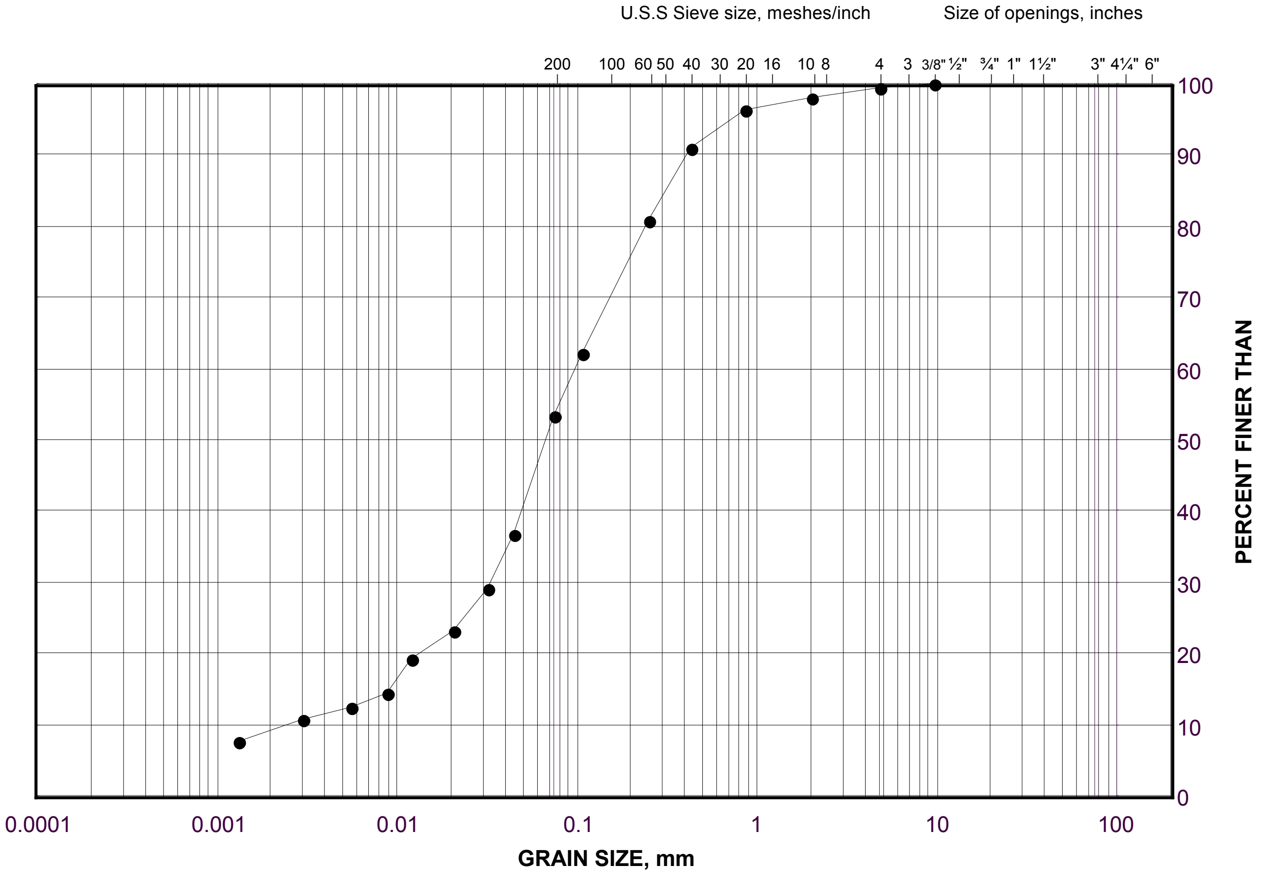
GRAIN SIZE DISTRIBUTION
Sand and Silt (Interlayer)
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-04



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C202-02	4B	179.4

Project Number: 09-1111-6014

Checked By: TVA

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Date: 03-Feb-12

Project No. 09-1111-6014
Prepared By: LFG

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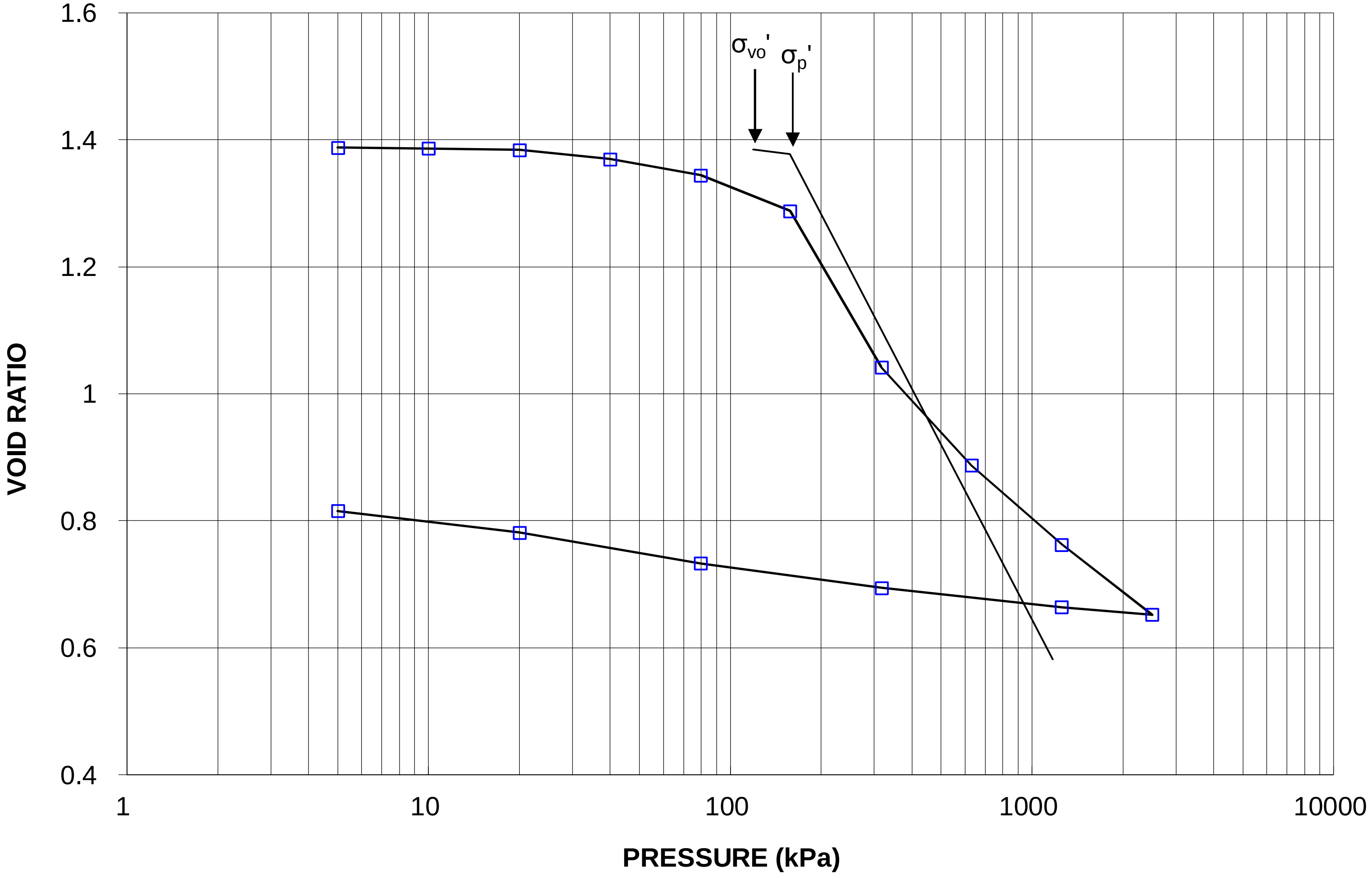
CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH C202-02 SA 13



CONSOLIDATION TEST
VOID RATIO VS LOG PRESSURE

FIGURE B.C202-03
Sheet 3 of 4

Project No. 09-1111-6014
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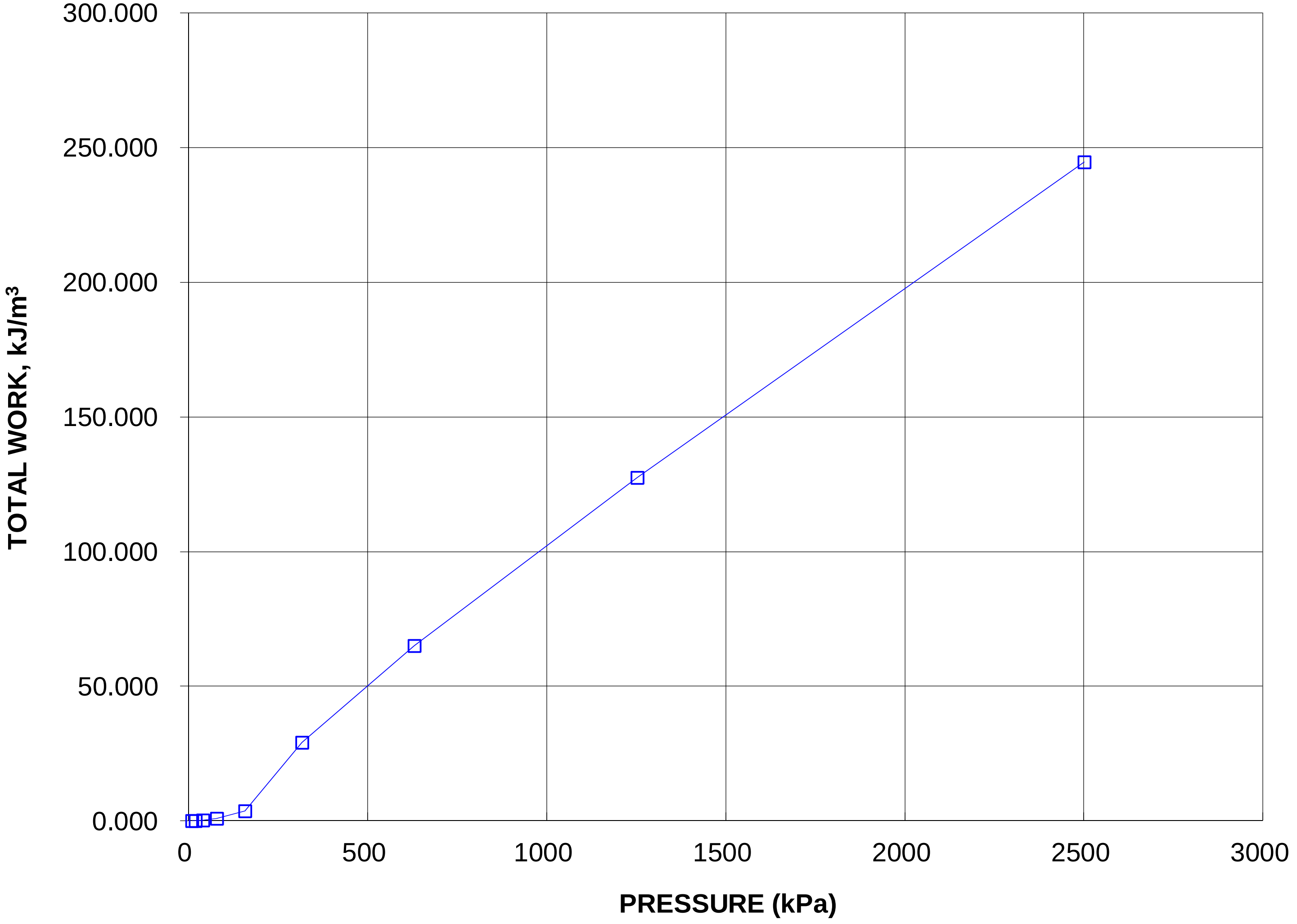
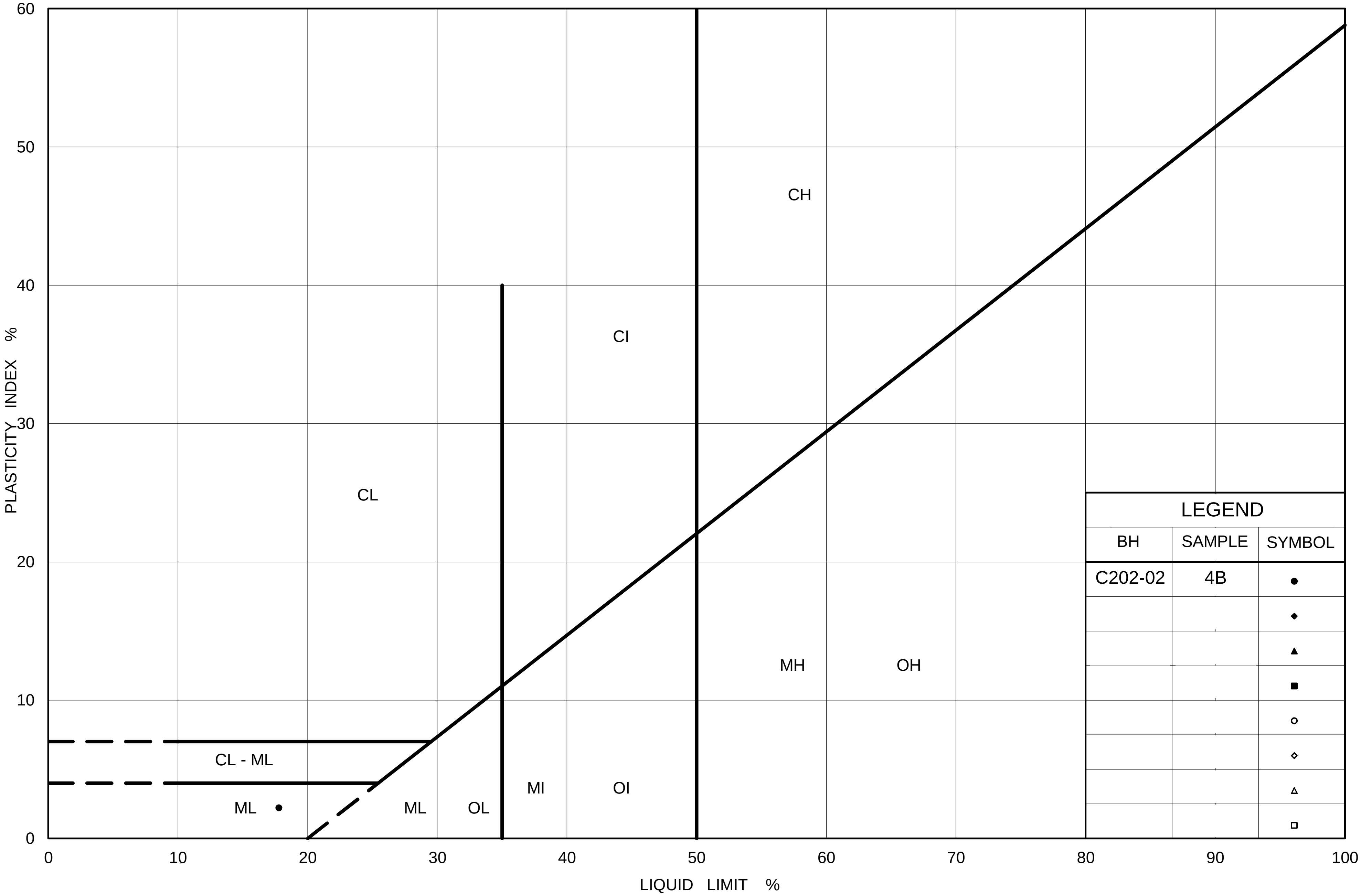
CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs PRESSURE
BH C202-02 SA 13



CONSOLIDATION TEST
TOTAL WORK VS PRESSURE

FIGURE

Oct 75, FF-S-21



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PLASTICITY CHART
Sand and Silt (Interlayer)
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

Figure No. B.C202-05

Project No. 09-1111-6014

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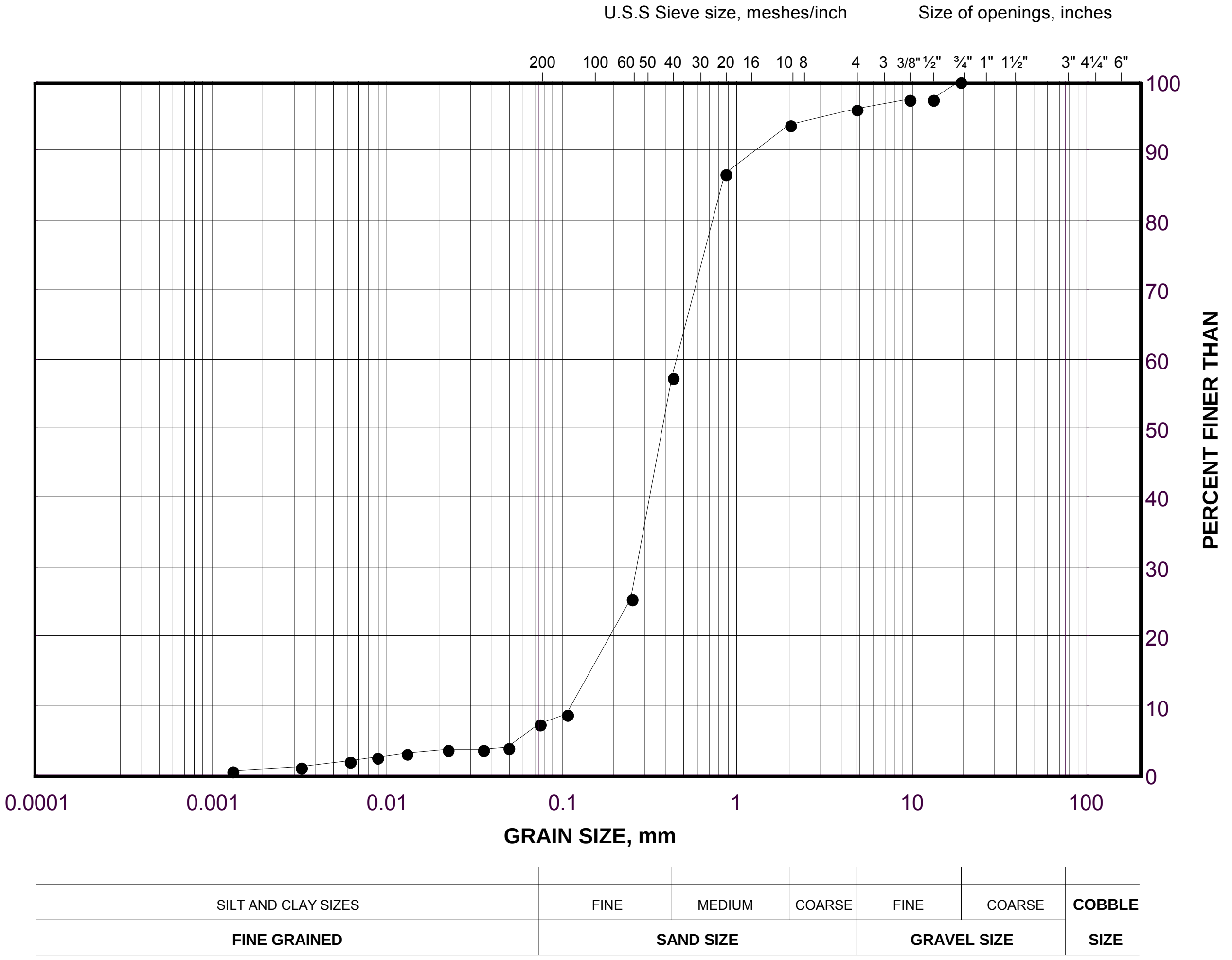
GRAIN SIZE DISTRIBUTION
Sand
Highway 69 (SBL and NBL) Culvert C202 at STA 11+220

FIGURE B.C202-06



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C202-02	16	158.5

Project Number: 09-1111-6014

Checked By: TVA

Golder Associates

Date: 03-Feb-12

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