

FOUNDATION INVESTIGATION REPORT

CULVERTS FOR PHASE 2 SECTION

HIGHWAY 69 FOUR LANING FOR 21.5 km
FROM 4.5 km NORTH OF HIGHWAY 64
TO 8.7 km NORTH OF HIGHWAY 637

DISTRICT 54, SUDBURY, ONTARIO
G.W.P. NO. 5218-06-00
CONTRACT NO. 2009-5131



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DISTRICT 54, SUDBURY, ONTARIO

***PHASE 2: STA. 15+180 TO 22+346.5, TOWNSHIP OF SERVOS
STA. 10+000 TO 11+300, TOWNSHIP OF BURWASH***

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PML Ref.: 06TF055B
Index No.: 740FIR
GEOCRES No.: 41I-235
May 27, 2009



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Record of Borehole Sheets
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FOUNDATION INVESTIGATION REPORT

for
Culverts for Phase 2 Section
Highway 69 Four-Laning for 21.5 Km
From 4.5 km North of Highway 64 to 8.7 km North of Highway 637
G.W.P. 5218-06-00
District 54, Sudbury, Ontario

*Phase 2: Sta. 15+180 To 22+346.5, Township of Servos
Sta. 10+000 To 11+300, Township of Burwash*

1. INTRODUCTION

Four-Laning of a 21.5 km long section of Highway 69 that extends from 4.5 km north of Highway 64 to 8.7 km of Highway 637, about 45 km south of Sudbury, is planned. Peto MacCallum Ltd. (PML) prepared this report for AECOM on behalf of the Ministry of Transportation of Ontario (MTO).

The installation of concrete culverts is planned within the Phase 2 Section of the Highway 69 Four-Laning project. Fourteen culverts have been selected for foundation investigation. For the purpose of this report, nine of the culverts were designated by a PML reference number. These reference numbers and locations of the culverts investigated in this report are given in the following table:

PML REF. No.	APPROXIMATE STATION
New Highway 69, Servos Township	
C15	15+500 SBL and NBL
C637	10+180 (Highway 637)
C19	17+580 SBL and NBL
C20	18+156 SBL and NBL
C21	18+325 SBL and NBL
JUC	18+435 SBL and NBL
C25	20+880 SBL and 20+892 NBL
C26	21+207 SBL and 21+199 NBL
New Highway 69, Burwash Township	
C27	10+178 SBL and 10+192 NBL



In addition, five other culverts located in areas requiring wick drains were reported by Thurber Engineering Ltd. under separate cover. Other culvert sites were investigated and reported under the separate Pavements Design Report prepared by PML.

This report summarizes the results of the field investigation conducted at the locations of the above culverts. The subsurface conditions for the remaining culverts in Phase 2 section of the project are to be reported in the Pavement Design Report under separate cover.

All elevations in the report are expressed in metres.

2. SITE DESCRIPTION AND GEOLOGY

The 21.5 km long section of the existing Highway 69 to be realigned and four-laned is situated about 45 km south of Sudbury in a wooded region with open swampy areas.

The study area is located in the Precambrian Laurentian Peneplane. The topography is irregular in detail and dotted with areas of wet ground separated by steep rock ridges. The Sheppard Lake is situated to the east of the existing Highway 69 alignment. Pleistocene lacustrine/fluvial deposits and recent swamp sediments have been laid down in depressions and are probably associated with the Nipissing post-glacial stage of the Great Lakes. Soil cover over the rock outcrops is generally sparse.

Metasedimentary rocks of the Huronian Supergroup and gneisses of the Grenville Province underlie the alignment. The area has undergone considerable folding, intrusive activity, regional metamorphism and faulting.

The mineral soil cover is typically less than 1 m and may vary greatly over short distances. Locally, the depth of soil cover in swampy lands may extend to depths exceeding 30 m.



3. INVESTIGATION PROCEDURES

The field work specifically carried out for the 14 culvert sites included in this study was carried out during November and December 2008, and January and February 2009. The data was supplemented by data from subsurface investigations for the swamp crossings during the period from January, February and September 2007.

The locations of the boreholes put down along each of the culvert station are shown on the attached Drawings PML Ref. No. C15, C637, C19, C20, C21, JUC, C25, C26 and C27. The borehole logs, drawings and figures were identified with the PML reference numbers for the specific culvert stations for ease of cross reference.

The borehole locations were established in accordance with the MTO requirements indicated in the RFP and in general accordance with the requirements of the MTO Northeastern Region Pavement Design Practices and Guidelines (May 20, 1997). Sutcliffe Rody Quesnel Inc. (SRQ) laid out the reference lines of the new highway in the field and these lines were used by PML to select the borehole locations. The ground surface elevations at the boreholes were provided by Sutcliffe Rody Quesnel Inc. (SRQ).

The boreholes were advanced using continuous flight hollow and solid stem augers, powered by track-mounted D-50 and CME-55 drill rigs. The equipment was supplied and operated by a specialist drilling contractor working under the full-time supervision of members of PML engineering staff. The culvert boreholes were taken into competent native soils or where bedrock was encountered, the bedrock were extended 3.0 to 3.8 m into bedrock using rotary diamond drilling methods.



Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. Penetrometer and in-situ vane shear testing (using the MTO 'N' vane) was also performed to further assess the shear strength of the cohesive soils encountered. The penetrometer test results are typically less than the actual values due to sample disturbance. The results of the field tests and observations are reported on the appended Record of Borehole sheets.

The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open borehole. Upon completion of drilling, all the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO and MOE Reg. 903 guidelines for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. The recovered samples were returned to our laboratory for detailed visual examination and classification. The laboratory testing programme consisted of moisture content determinations, Atterberg plasticity limits tests and grain size distribution analyses. Atterberg plasticity limits were not attempted on samples deemed to be non-plastic by visual and tactile examination.

The results of the laboratory Atterberg plasticity limits and grain size distribution analyses are presented on the appended plasticity charts and grain size distribution figures, which were identified with the respective codes PC and GS.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, soil boundary elevations, standard penetration resistance values, in-situ vane shear and penetrometer test data and groundwater observations. The results of laboratory Atterberg plasticity limits tests, grain size distribution analyses and moisture content determinations are also shown on the Record of Borehole sheets.



The borehole locations are shown on Drawings C15, C637, C19, C20, C21, JUC, C25, C26, and C27. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

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

4.1 Culvert at Sta. 15+500 (SBL, NBL and Ramp S-W (Hwy 637 I/C)) (C15), Servos Township

Five boreholes designated C15-1 to C15-5 were drilled along the alignment of culvert at Sta. 15+500 (SBL, NBL and Ramp S-W (Hwy 637 I/C)) (C15). The subsurface stratigraphy revealed in the boreholes generally comprised a surficial topsoil/peat/fill units and sandy silt deposit overlying either a cohesionless sand and sandy silt soils or cohesive silty clay/clayey silt deposits which in turn mantled probable bedrock or bedrock. Locally, the cohesive silty clay is overlain by sand which in turn mantled bedrock. Bedrock/inferred bedrock was contacted at depths of 0.8 to 9.4 m (elevations 208.9 to 217.0). Groundwater was observed at 1.5 and 4.3 m depths (elevations 214.0 and 215.9) in boreholes C15-3 and C15-5.

4.1.1 Topsoil/Peat

The surficial topsoil/peat units contacted in boreholes C15-3 to C15-5 were 200 to 300 mm thick and were penetrated at elevations 217.2 and 218.0.

4.1.2 Fill

A localized fill unit was surficially found in borehole C15-1. The fill unit included sand and gravel trace silt and organics and was 600 mm thick. The fill unit extended to elevation 215.8.



4.1.3 Clayey Silt/Silty Clay

A deposit of clayey silt/silty clay was found below topsoil in boreholes C15-3 and C15-5. The clayey silt/silty clay deposit was 1.6 and 4.0 m thick and extended to bedrock at elevation 215.6 in borehole C15-3 and to the sand deposit at elevation 214.0 in borehole C15-5. Penetrometer results on samples were 15 and 150 kPa and field vane test result for one sample was 45 kPa. The low penetrometer result reflects sample disturbance.

The results of Atterberg plasticity limits testing and grain size distribution analyses conducted on a representative samples of clayey silt/clayey silt deposit are presented in Figures C15-PC-1 and C15-PC-2, and C15-GS-1 and C15-GS-2, respectively. The liquid limits of the deposit were 26 and 45 and plastic limits were 17 and 22 with plasticity index values of 9 and 23. The water contents of 14 and 32% were determined on representative samples.

4.1.4 Sandy Silt

A sandy silt deposit was surficially contacted at elevation 216.0 in borehole C15-2 and below the peat at depth of 0.2 m, elevation 217.6 in borehole C15-4. The deposits were 0.6 and 1.6 m thick and were in loose to dense condition. The N values ranged from 6 to 33. Locally at the interface with bedrock a high N value was recorded. The sandy silt deposit extended to probable bedrock at depths of 0.8 and 1.6 m (elevations 214.4 and 217.0) boreholes C15-2 and C15-4.

4.1.5 Sand

Underlying the fill unit at 0.6 m depth (elevation 215.8) in borehole C15-1, and silty clay deposit at 4.3 m depth (elevation 214.0) in borehole C15-5, a cohesionless sand deposit was contacted. The deposit was 2.1 and 5.1 m thick and extended to the underlying bedrock at 2.7 and 9.4 m depths (elevations 208.9 and 213.7). The sand deposit contains with gravel trace to some silt trace clay. The relative density of the deposit was loose to very dense. The N values ranged from 8 to 20 blows per 30 mm penetration.



The results of grain size distribution analyses conducted on representative samples of the deposit are presented in Figure C15-GS-3.

4.1.6 Bedrock

Bedrock was contacted in boreholes C15-1, C15-3 and C15-5 at depths of 1.8 to 9.4 m (elevations 208.9 to 215.6). The bedrock comprises pink and grey syenite/granite and black and white migmatite and exhibited high strength. A detailed description of the rock cores retrieved from boreholes C15-1, C15-3 and C15-5 is given in Table A appended.

The measured core recovery was in a range of 69 to 100%. The RQD determined from the rock cores was in a range of 47 to 100%, thus indicating a poor to excellent quality rock.

4.1.7 Groundwater

Groundwater was observed in boreholes C15-3 and C15-5 at depths of 1.5 and 4.3 m (elevations 214.0 and 215.9) upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.2 Culvert at Sta. 10+180 Ramp S-W and Ramp W-N (Highway 637) (C637), Servos Township

Three boreholes designated C637-1 to C637-3 were drilled along the alignment of the proposed culvert at Sta. 10+180 Ramp S-W and Ramp W-N (Highway 637) (C637). The subsurface stratigraphy revealed in the boreholes generally comprised surficial peat overlying cohesive silty clay/clayey silt deposits. Cobbles and boulders were encountered in the lower zones of the deposits. A localized thin layer of organic silty clay was contacted beneath the peat unit in one borehole. Bedrock was contacted below the silty clay/clayey silt deposits at depths of 2.6 and 5.5 m (elevations 225.1 and 227.9). Groundwater was observed at the surface (elevations 230.5 and 230.6) in boreholes C637-1 and C637-3.



Reference should be made to the previous boreholes conducted in swamp 511 (boreholes 511-18 through 511-20) that are within proximity to the culvert. Typically, the boreholes reveal consistent soil conditions with refusal on probable bedrock at elevations 224.2 to 229.8.

4.2.1 Peat

The surficial peat layer contacted in all boreholes was 200 and 500 mm thick and was penetrated at elevations 230.0 and 230.3.

A localized 400 mm thick organic silty clay layer was contacted below the peat in borehole C637-1.

4.2.2 Clayey Silt/Silty Clay

Overlain by peat at 0.3 and 0.6 m depths in all boreholes were cohesive clayey silt/silty clay deposits. The deposits extended to bedrock at depths of 2.6 and 5.5 m (elevations 225.1 and 227.9). The clayey silt/silty clay deposits were 2.0 to 5.2 m thick and were stiff in consistency with localized firm layers in borehole C637-3. The N values for the deposits were 4 and 11. Higher N values with sampler bouncing were recorded at depths where cobbles and boulders were present.

The results of Atterberg plasticity limits testing and grain size distribution analyses conducted on clayey silt/silty clay samples are presented in Figures C637-PC-1 and C637-PC-2, and C637-GS-1 and C637-GS-2, respectively. The liquid and plastic limits and plasticity index values for the material are shown on the corresponding boreholes log sheets and are summarised below.

MATERIAL	BOREHOLE NO.	SAMPLE	DEPTH (m)	WATER CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
Silty Clay	C637-1	2	0.8 – 1.4	29	47	22	25
	C637-2	2	0.8 – 1.4	30	48	21	27
	C637-3	3	1.5 – 2.1	24	42	21	21
Clayey Silt	C637-2	5	3.0 – 3.6	34	30	17	13



Natural moisture content determinations ranged from 18 to 34%, with typical values in the 24 to 29% range. The water contents were typically lower than the liquid limits of the soils indicating relatively low compressibility characteristics.

4.2.3 Bedrock

Bedrock was contacted at depths of 2.6 to 5.5 m (elevations 225.1 to 227.9) in all boreholes. The bedrock comprised light grey and black granodiorite and black biotite migmatite and exhibited medium to high strength. A detailed description of the rock cores retrieved from boreholes C637-1 to C637-3 is given in Table A, appended.

The measured core recovery was 36 and 100%. The RQD determined from the rock cores was in the range of 33 to 100%, thus indicating a very poor to excellent quality rock. Highly fractured rock with poor recovery and RQD values of 0% was locally contacted between 6.0 and 7.1 m depths in borehole C657-2.

4.2.4 Groundwater

Groundwater was observed at the ground surface in boreholes C637-1 and C637-3 (elevations 230.5 and 230.6) upon completion of drilling. During the investigation for the swamp 511 crossings in February 2008, groundwater was observed in borehole 511-18 also at the surface, elevation 230.5, upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.3 Culvert at Sta. 17+580 (SBL and NBL) (C19), Servos Township

Three boreholes designated C19-1 to C19-3 were drilled along the alignment of the culvert at station 17+580 (SBL and NBL) (C19). The subsurface stratigraphy revealed in the boreholes generally comprised surficial topsoil overlying silt and clayey silt deposits. Bedrock was contacted below the silt and clayey silt deposits at depths of 0.3 and 1.9 m (elevations 220.3 and 223.6).



Groundwater was measured at the surface and just below existing grade at elevations 221.2 and 223.9 in boreholes C19-1 and C19-3.

Reference should be made to the previous boreholes conducted in swamp 502 (boreholes 502-29 through 502-33) that are within proximity to the southbound and northbound culverts. Typically, the boreholes reveal consistent soil conditions with refusal on probable bedrock at elevations 218.2 to 224.9.

4.3.1 Topsoil

The surficial topsoil layer contacted in borehole C19-1 was 100 mm thick and was penetrated at elevation 224.1.

4.3.2 Clayey Silt/Silt

Overlain by topsoil at 0.1 m depth in borehole C19-1 and surficially in borehole C19-2 and C19-3 was a clayey silt/silt deposit. The clayey silt/silt deposits were 0.3 and 1.8 m thick and were firm in consistency. The N values for the deposits were 1 and 7. The high N values recorded at depths where the deposits contacted the bedrock. The deposits extended to bedrock at depths of 0.3 and 1.9 m (elevations 220.3 and 223.6).

The results of Atterberg plasticity limits testing and grain size distribution analysis conducted on a clayey silt sample are presented in Figures C19-PC-1 and C19-GS-1, respectively.

The liquid and plastic limits of the clayey silt were 34 and 21, respectively, with a plasticity index value of 13. A water content of 33% was found in one representative sample.

4.3.3 Bedrock

Bedrock was contacted at depths of 0.3 to 1.9 m (elevations 220.3 and 223.6). The bedrock comprised light to dark grey granitic gneiss, migmatite and migmatite/granodiorite and exhibited high strength. A detailed description of the rock cores retrieved from boreholes C19-1, C19-2 and C19-3 is given in Table A, appended.



The measured core recovery was 89 and 100%. The RQD determined from the rock cores was in a range of 68 to 100%, thus indicating a fair to excellent quality rock.

4.3.4 Groundwater

Groundwater was measured in boreholes C19-1 and C19-3 at ground surface and at depths 0.3 m (elevations 221.2 to 223.9) upon completion of drilling. During the investigation for the swamp 502 crossings in February 2007, all boreholes were dry upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.4 Culvert at Sta. 18+156 (SBL and NBL) (C20), Servos Township

Three boreholes designated C20-1 to C20-3 were drilled along the alignment of the proposed culvert at Sta. 18+156 (SBL and NBL) (C20). The subsurface stratigraphy revealed in the boreholes generally comprised surficial topsoil/peat or silty sand deposit which in turn is underlain by bedrock. Bedrock was contacted below the topsoil/peat at depths of 0.3 and 0.5 m (elevations 214.1 and 221.1), and below the silty sand deposit at depth of 1.1 m (elevation 218.2). Groundwater levels were not established upon completion of drilling.

Reference should be made to the previous boreholes conducted in swamp 503 (boreholes 503-29 through 503-33) that are within proximity of the culvert. Typically, the boreholes reveal consistent soil conditions with refusal on probable bedrock at shallow depths, elevations 216.6 to 222.2.

4.4.1 Topsoil/Peat

The surficial topsoil/peat layers contacted in boreholes C20-1 and C20-3 were 300 and 500 mm thick and were penetrated at elevations 221.1 and 214.1, respectively.

4.4.2 Silty Sand

A deposit of silty sand was found surficially in borehole C20-2. The silty sand deposit was 1.1 m thick and extended to bedrock at elevation 218.2. The deposit contains some gravel and trace clay. The N values for the deposit were 9 and 20 indicating a loose to compact condition.



4.4.3 Bedrock

Bedrock was contacted at depths of 0.3 to 1.1 m (elevations 214.1 and 221.1), sloping lower from west to east. The bedrock comprised light grey to pink with occasional dark grey to black dipping bands migmatite and granitic gneiss/migmatite and exhibited high strength. A detailed description of the rock cores retrieved from boreholes C20-1, C20-2 and C20-3 is given in Table A, appended.

The measured core recovery was 92 to 100%. The RQD determined from the rock cores was in a range of 59 to 100%, thus indicating a fair to excellent quality rock.

4.4.4 Groundwater

Groundwater table was not established in all boreholes upon completion of drilling because the boreholes were charged with water for rock coring purposes. During the investigation for the swamp 503 crossing in December 2006 and April 2007, all boreholes were dry upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.5 Culvert at Sta. 18+325 (SBL and NBL) (C21), Servos Township

Two boreholes designated C21-1, C21-2 were drilled on the west end and centreline median of the proposed culvert at Sta. 18+325 (SBL and NBL) (C21). Due to access issues to the location of the east end of the culvert, two test pits designated C21-3 and C21-3A were, at a later date, performed instead of borehole C21-3. The subsurface stratigraphy revealed in the boreholes and test pits generally included surficial fill unit and peat overlying clayey silt/silty clay deposits which in turn are underlain by a silt deposit or inferred bedrock. At the east end of the culvert, the peat unit was overlain by ice layer. Bedrock was contacted below the silt deposit at depths of 4.1 and 4.9 m (elevations 209.5 and 210.0). The inferred bedrock was contacted at depths of 1.8 and 2.6, elevations 211.5 and 212.4. Groundwater was measured at elevations 209.9 and 211.5 in boreholes C21-1 and C21-2.



Reference should also be made to the previous boreholes conducted in swamp 504 (boreholes 504-2, 504-6 through 504-9, 504-32 and 504-34) that are within proximity of the culvert. Typically, those boreholes reveal consistent soil conditions with refusal on probable bedrock at elevations 206.3 to 215.7.

4.5.1 Ice

An ice layer was surficially found in test pits C21-3 and C21-3A, and was 200 mm uniform thick. The ice layer extended to elevations 213.9 and 214.0.

4.5.2 Fill

A fill unit was surficially found in boreholes C21-1 and C21-2. The fill unit included sandy silt, silty sand and organics, and was 0.5 and 0.6 m thick. The fill unit extended to elevations 213.1 and 214.3.

4.5.3 Peat

A buried peat was found below fill unit in borehole C21-2 and below the ice layer in test pits C21-3 and C21-3A. The peat thickness ranged between 400 and 500 mm.

4.5.3 Clayey Silt/Silty Clay

Overlain by fill unit at 0.6 m depth in borehole C21-1, and below peat in borehole C21-2 and test pits C21-3 and C21-3A at depths of 0.6 to 0.9 m was a clayey silt/silty clay deposits. The clayey silt/silty clay deposits were 0.5 and 2.3 m thick and were soft to stiff in consistency. The N values for the deposits were 4 and 13. The deposits extended to silt deposit at depths of 1.4 and 2.9 m (elevations 212.0 and 212.2) and to termination depths of test pits of 1.8 and 2.6 m (elevations 211.5 and 212.4). Penetrometer results on samples were 63 to 150 kPa.

The results of Atterberg plasticity limits testing and grain size distribution analysis conducted on a clayey silt sample are presented in Figures C21-PC-1 and C21-GS-1, respectively.



The liquid and plastic limits of the clayey silt were 32 and 23, respectively, with a plasticity index value of 9. A water content of 31% was found in one representative sample.

4.5.4 Silt

Underlying the clayey silt at 1.4 and 2.9 m depths in boreholes C21-1 and C21-2 was a deposit of cohesionless loose silt, trace to some sand some to with clay trace to with gravel and cobbles and boulders, was contacted. The silt deposit ranged from 2.0 to 2.7 m in thickness and was in loose condition. The N values ranged from 6 to 9. Locally, at bedrock interface a high N value was recorded. The deposit extended to the underlying bedrock at depths of 4.1 and 4.9 m (elevations 209.5 and 210.0).

The results of grain size distribution analyses performed on the silt are presented in Figure C21-GS-2.

4.5.5 Bedrock

Bedrock was contacted at depths of 4.1 to 4.9 m (elevations 209.5 and 210.0). The Migmatite bedrock comprised light grey to pink with dark grey to black dipping bands/layers and exhibited high strength. A detailed description of the rock cores retrieved from boreholes C21-1 and C21-2 is given in Table A, appended.

The measured core recovery was 92 and 100%. The RQD determined from the rock cores was in a range of 36 to 100%, thus indicating a poor to excellent quality rock.

4.5.6 Groundwater

Groundwater was measured in boreholes C21-1 and C21-2 at depths of 3.4 and 3.7 m (elevations 209.9 to 211.5) upon completion of drilling. During the investigation for the swamp 504 crossing in December 2006 and April 2007, the groundwater was 0.3 to 5.0 m higher at levels ranging from elevations 211.8 to 214.9. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.



4.6 Culvert at Sta. 18+435 (SBL and NBL) (JUC), Servos Township

Three boreholes designated JUC-1 to JUC-3 were drilled along the alignment of the proposed culvert at Sta. 18+435 (SBL and NBL) (JUC). The subsurface stratigraphy revealed in the boreholes generally comprised surficial peat overlying sandy silt and organic clayey silt deposits. The clayey silt deposit overlays a silty sand layer. Bedrock was surficially contacted at elevation 216.2 and below the sandy silt and silty sand deposits at a common depth of 1.6 m (elevations 213.0 and 217.1). Groundwater was observed at a depth of 0.6 m in boreholes JUC-3 (elevation 214.0).

Reference should be made to the previous boreholes conducted in swamp 504 (boreholes 504-14 through 504-18) that are within proximity of the southbound and northbound culverts. Typically, the boreholes reveal consistent soil conditions with refusal on probable bedrock at elevations 210.8 to 215.1 and locally at surface, elevation 222.2, in borehole 504-17.

4.6.1 Peat

The surficial peat layer contacted in boreholes JUC-1 and JUC-3 was 300 mm thick and was penetrated at elevations 214.3 and 218.4.

A 0.3 m thick organic clayey silt unit was contacted below the peat unit at borehole JUC-3 to 0.6 m depth, elevation 214.0.

4.6.2 Sandy Silt/Silty Sand

Overlain by the peat at 0.3 m depth in borehole JUC-1 and by the organic clayey silt unit at 0.6 m depth in borehole JUC-3 were cohesionless sandy silt/silty sand soils. The cohesionless sandy silt/silty sand soils were 1.0 and 1.3 m thick and extended to bedrock at depth of 1.6 m (elevations 213.0 and 217.1). The deposits were compact to very dense in relative density. The N values for the deposits were 22 and 20 blows per 80 mm penetration. A water content of 17% was found in one sample.



4.6.3 Bedrock

Bedrock was contacted surficially (elevation 216.2) and at depth of 1.6 m (elevations 213.0 and 217.1). The bedrock comprised pink to light grey granitic gneiss and black hornblende migmatite/amphibolite and exhibited high strength. A detailed description of the rock cores retrieved from boreholes JUC-1 to JUC-3 is given in Table A, appended.

The measured core recovery was 88 to 100%. The RQD determined from the rock cores was in a range of 63 to 100%, thus indicating a fair to excellent quality rock.

4.6.4 Groundwater

Groundwater was measured in borehole JUC-3 at a depth of 0.6 m (elevation 214.0) upon completion of drilling. During the investigation for the swamp 504 crossing in February and December 2006, all boreholes were dry upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.7 Culvert at Sta. 20+880 (SBL) and 20+892 (NBL) (C25), Servos Township

Four boreholes designated C25-1 to C25-3 and C25-1A were drilled along the alignments of culverts at station 20+880 (SBL) and 20+892 (NBL) (C25), Highway 69. The subsurface stratigraphy revealed in the boreholes generally included a surficial organic clayey silt and silty clay overlying a cohesionless stratum of sand and gravel, silt, sand and silt, and sand deposits which in turn mantled probable bedrock or bedrock. Bedrock was contacted at depths of 4.6 to 6.6 m (elevations 212.0 and 213.1). Groundwater was measured 0.3 m depth (elevations 217.4 to 218.3) in all boreholes.

Referenced should be made to the previous boreholes conducted in swamp 509 (boreholes 509-6 through 509-15) that are within proximity to the southbound and northbound culverts. Typically, the boreholes reveal consistent soil conditions with refusal on probable bedrock at elevations 214.9 and 217.9 at boreholes 509-6 to 509-8, 509-10 and 509-11 and locally deeper at elevation 207.8 in borehole 509-9.



4.7.1 Organic Clayey Silt/Silty Clay

A deposit of organic clayey silt was found surficially in boreholes C25-1, C25-1A and C25-2. The organic clayey silt deposit was 2.7, 0.5 and 1.2 m thick in boreholes C25-1, C25-1A, and C25-2, respectively. The deposit extended to elevations 215.0, 217.6 and 217.2 in the respective borehole locations.

A localized 0.5 m thick organic sand and silt unit was found below the organic clayey silt in borehole C25-1.

A 0.7 m thick silty clay unit was found surficially in borehole C25-3 and penetrated at elevation 217.9.

The results of Atterberg plasticity limits testing and grain size distribution analysis conducted on a representative sample of organic clayey silt are presented in Figures C25-PC-1 and C25-GS-1, respectively. The liquid limit and plastic limit of the organic clayey silt was 28 and 19 respectively, with a plasticity index value of 9. The water content of 28% was determined in a representative sample.

4.7.2 Silt to Sand

Underlying the organic clayey silt at 0.5 and 1.2 m depth, elevations 217.2 and 217.6 in boreholes C25-1A and C25-2, and underlying the silty clay at 0.7 m depth, elevation 217.9 in borehole C25-3, cohesionless sand/sand and silt/silt soils were contacted. The deposits were 5.1 and 5.9 m thick and were in loose to compact condition. The N values ranged from 5 to 30. Locally at the interface with bedrock, low and high N values were recorded. In borehole C25-2 at a depth of 6.7 m, elevation 211.7 where SPT penetration was due to weight of rod and hammer occurred, a dynamic cone penetration was conducted and extended to a depth of 10.8 m, elevation 207.6. The encountered soil is probable sand with silt to silty and in compact to dense conditions. The silt to sand deposits extended to bedrock at depths of 5.6 and 6.6 m (elevations 212.0 and 212.5) boreholes C25-1A and C25-3.



The results of grain size distribution analyses conducted on representative samples of the deposits are presented in Figure C25 -GS-2.

4.7.3 Sand and Gravel

Underlying the organic clayey silt at 2.7 m depth (elevation 215.0) in borehole C25-1, and the silt at 3.7 m depth (elevation 214.9) in borehole C25-3 a cohesionless sand deposit with variable granulometry from sand and gravel to sand some silt with gravel deposit was contacted. The deposit was 1.9 and 2.9 m thick and extended to the underlying bedrock at 4.6 m depth (elevation 213.1). The deposit contains some silt. The relative density of the deposit was compact to very dense.

The results of grain size distribution analyses conducted on representative sample of the deposit are presented in Figure C25-GS-3.

4.7.4 Bedrock

Bedrock was contacted in boreholes C25-1, C25-1A and C25-3 at depths of 4.6 to 6.6 m (elevations 212.0 and 213.1). The bedrock comprises light grey to black migmatite and exhibited high strength. A detailed description of the rock cores retrieved from boreholes C25-1, C25-1A and C25-3 is given in Table A appended.

The measured core recovery was in a range of 88 to 100%. The RQD determined from the rock cores was in a range of 73 to 100%, thus indicating a fair to excellent quality rock.

4.7.5 Groundwater

Groundwater was observed in all boreholes at depth of 0.3 m (elevations 217.4 and 218.3) upon completion of drilling. During the investigation for the swamp 509 crossing in January 2007, the groundwater level was about 1.0 m below to the same levels and was ranging from elevations 216.6 to 218.6. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.



4.8 Culvert at Sta. 21+207 (SBL) and 21+199 (NBL) (C26), Servos Township

Three boreholes designated C26-1 to C26-3 were drilled along alignments of the culverts at Sta. 21+207 (SBL) and 21+199 (NBL) (C26) drilled on the Highway 69. The subsurface stratigraphy revealed in the boreholes generally comprised a surficial clayey silt unit overlying silt, over a sand and silt deposit except in borehole C26-3 where a clayey silt deposit was overlaid by topsoil. Groundwater was observed at depths of 1.0 m to 3.0 m (elevations 217.6 to 221.2) in all boreholes.

Reference should be made to the previous boreholes conducted in swamp 510 (boreholes 510-3 to 510-9 and N19-4) that are within proximity to the southbound and northbound culverts. Typically the boreholes reveal consistent soil conditions.

4.8.1 Topsoil

A deposit of topsoil was found surficially in borehole C26-3. The topsoil was 200 mm thick. The topsoil was penetrated at elevation 220.4.

4.8.2 Clayey Silt

Overlain by topsoil at 0.2 depth in borehole C26-3 and surficially contacted in boreholes C26-1 and C26-2 was a cohesive deposit of clayey silt. The clayey silt deposit was 0.9 and 1.4 m thick and was soft to stiff in consistency. The N values for the clayey silt ranged from 2 to 12. The deposit extended to 1.1 and 1.4 m depths (elevations 219.2 and 221.2) in all boreholes.

The results of Atterberg plasticity limits testing and grain size distribution analyses conducted on the samples of the clayey silt are presented in respected Figures C26-PC-1 and C26-GS-1, respectively. The liquid limits of the clayey silt were 28 and 33, the plastic limits were 18 and 19 with plasticity values of 9 and 15. The water contents of 23 and 29% were found for the representative samples of the clayey silt.



4.8.3 Silt

Underlying the clayey silt at 1.1 and 1.4 m depths in all boreholes was a deposit of cohesionless compact to dense silt trace sand to sandy trace to some clay was contacted. The silt deposit ranged from 5.9 to 7.9 m in thickness and was compact to dense condition. The N values ranged from 15 to 41. Locally at elevation 215.6 in borehole C26-2, a loose silt was found with N value of 9. The deposit extended to the underlying sand and silt deposit at 7.3 and 9.3 m depths (elevations 211.3 and 215.3).

The results of grain size distribution analyses performed on the samples of the silt from culverts C26 are presented in Figure C26-GS-2.

4.8.4 Sand and Silt

Underlying the silt at 7.3 and 9.3 m depths (elevations 211.3 and 215.3) in all boreholes was a cohesionless sand and silt deposit. The deposit extended to the 7.9 and 9.6 m termination depths of the boreholes (elevations 211.0 and 214.7).

The sand and silt deposit contains trace clay and trace gravel. The relative density of the sand and silt deposit was dense to very dense. N values of 47, 50 and 78 were recorded. The moisture content of a single sand and silt sample was 17%.

The result of grain size distribution analysis performed on one sample of the sand and silt deposit from culvert C26 is presented in Figure C26-GS-2.

4.8.5 Groundwater

Groundwater was observed in all boreholes at depths of 1.0 to 3.0 m (elevations 217.6 to 221.2) upon completion of drilling. During the investigation for the swamp 510 crossings in February and September 2007, the groundwater was 0.3 to 1.0 m lower at levels ranging from elevations 216.6 to 220.9. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.



4.9 Culvert at Sta. 10+178 (SBL) and 10+192 (NBL) (C27), Burwash Township

Four boreholes were drilled along the alignments of the culverts at Sta. 10+178 (SBL) and 10+192 (NBL) (C27). The subsurface stratigraphy revealed in the boreholes generally comprised a surficial cohesive soils of silty clay/clayey silt deposits overlying silt, over cohesionless soils of silty sand/sand/sand and gravel deposits in boreholes C27-2, C27-2A and C27-3. In borehole C27-1, the subsurface stratigraphy comprised a fill unit, over organic sandy silt to organic clayey silt which in turn is underlain by a silt deposit. Groundwater was observed at ground surface and at depths of 0.3 and 2.1 m at elevations 222.0 to 224.3 in all boreholes.

4.9.1 Fill

A localized fill unit was surficially found in borehole C27-1. The fill unit included silty sand some gravel trace clay and was 1.4 m thick. The fill unit extended to elevation 222.1.

4.9.2 Organic Sandy Silt to Organic Clayey Silt

Overlain by the fill unit at 1.4 depth, elevation 222.1, in borehole C27-1 was a localized organic sandy silt to organic clayey silt deposit. The organic deposit was 3.0 m thick and was soft to firm in consistency. The N values for the organic deposit ranged from 3 to 6 and the moisture content ranged between 29 and 46%. The deposits extended to 4.4 m depth (elevation 219.1). The deposit contained decayed wood and peat layers.

4.9.3 Clayey Silt/Silty Clay

Surficially in boreholes C27-2, C27-2A and C27-3, cohesive clayey silt/silty clay deposits were contacted. The cohesive soils ranged from 0.7 and 5.2 m in thickness and were very soft to very stiff in consistency. The N values ranged from 1 to 16. The deposits extended to the underlying silt deposit at depths ranging between 0.7 and 5.2 m, elevations ranging between 218.2 and 224.8.



The results of Atterberg plasticity limits testing and grain size distribution analysis conducted on one sample of the clayey silt deposit are presented in Figures C27-PC-1 and C27-GS-1, respectively.

The liquid and plastic limits of the cohesive soil were 25 and 17, respectively, giving a plasticity index value of 8. The water content of the deposits typically ranged between 18 to 24%, with locally higher values up to 42%.

4.9.4 Silt

A cohesionless silt deposit was found underlying the organic sandy silt to organic clayey silt deposits at 4.4 m depth, elevation 219.1, in borehole C27-1, and underlying the cohesive soils clayey silt/silty clay at 0.7 and 5.2 m depths (elevations 218.2 to 224.8) in boreholes C27-1A, C27-2 and C27-3.

The silt deposit was 1.4 and 6.7 m thick and contained trace to with sand, trace clay and trace gravel. The relative density of the silt was loose to compact with N values ranging between 4 and 26. The moisture content of the silt ranged between 20 and 28%. The silt extended to the 9.8 m termination depth, elevation 213.7 in borehole 27-1 and to the underlying cohesionless silty sand/sand/sand and gravel at 2.1 and 11.9 m depths, elevations 211.5 and 223.4, in boreholes C27-2, C27-2A and C27-3.

The results of grain size distribution analyses conducted on representative samples are presented in the Figure C27-GS-2.



4.9.5 Silty Sand/Sand/Sand and Gravel

Underlying the silt deposit at 2.1 to 11.9 m depths, elevations 211.5 to 223.4, in boreholes C27-2, C27-2A and C27-3 was a cohesionless sand deposit with variable silt and gravel content. These deposits were 0.6 and 3.1 m thick. The deposits extended to the maximum exploration depths of boreholes at 5.2 and 14.3 m (elevations 209.1 and 220.3). The deposits contain trace clay, silt layers and cobbles and boulders. The relative density of the deposits ranged between loose to very dense with N values ranged between 6 and 77. The low N values are believed to be related to hydraulic disturbance during the drilling and sampling operations. The moisture content of the deposits were 20 and 21%.

The results of grain size distribution analyses performed on a representative samples of the material are presented in Figure C27-GS-3.

4.9.6 Groundwater

Groundwater was observed in all boreholes at ground surface and at depths of 0.3 and 2.1 m, elevations 222.0 to 224.3, upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

5. MISCELLANEOUS

The field work was carried out under the supervision of Mr. F. Portela, Mr. M. Rapsey and Mr. J. Hagan and the direction of Mr. C.M.P. Nascimento, P.Eng., Senior Foundation Engineer. Walker Drilling Ltd. and Aardvark Drilling Inc. supplied the drilling equipment. The laboratory work was carried out in the PML laboratory in Toronto.



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Yours very truly

Peto MacCallum Ltd.

**Original copies signed
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