FOUNDATION INVESTIGATION AND DESIGN REPORT
SWAMP AND HIGH FILL CROSSINGS

for

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. 5379-02-00
DISTRICT 54, SUDBURY, ONTARIO

PHASE 1, STA. 12+200 TO 15+400
TOWNSHIP OF SERVOS

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PML Ref.: 06TF053A
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Geocres No.: 41I-206
July 30, 2007

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Peto MacCallum Ltd.
CONSULTING ENGINEERS

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for
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Phase 1, Sta. 12+200 to 15+400
Township of Servos

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1. INTRODUCTION

Realignment and four-laning of the 21.5 km long section of Highway 69 that extends from 4.5 km north of Highway 64 to 8.7 km north of Highway 637, south of Sudbury, is planned. This report was prepared for Totten Sims Hubicki Associates Limited (TSH) on behalf of the Ministry of Transportation of Ontario (MTO).

The study corridor for phase 1 of the project extends from Station 12+200 to 15+400 in the Township of Servos, new Highway 69 centreline. A total of 3 swamp and high fill crossings were identified in the Request for Proposal (RFP) for foundation investigation within the phase 1 limits. For ease of reference, the crossings were designated sequential numbers in the 400 series from 401 to 403. The identification number and location of each crossing are provided in Table 1 and shown on Drawing 1.

This report summarises the results of the field investigation conducted at the swamp and high fill crossings for phase 1 of the project. The subsurface conditions along the sections of the alignment identified in RFP for geotechnical investigation are provided in the Pavement Design Report under separate cover.

2. SITE DESCRIPTION AND GEOLOGY

The 21.5 km long section of Highway 69 to be realigned is situated south of Sudbury in a wooded region with open swampy areas. Land use includes forestry exploration and isolated cottage sites.

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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. 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. Gravel and sand deposits were also encountered. 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 bedrock outcrops at many locations throughout the project section.

3. INVESTIGATION PROCEDURES

The field work for the foundation investigation within the phase 1 limits involved a total of 84 boreholes and 10 dynamic cone penetration tests carried out during the period of November 21, 2006 to March 12, 2007. (Two boreholes and one dynamic cone penetration test advanced in the swamp 401 area in March 2004 are also included.) The test locations and drawings for each crossing are identified by a prefix identical to the crossing number. Numbered sequentially from left to right in the direction of increasing chainage, the test locations at each crossing are shown on corresponding Drawings. The records of the test holes are appended.

Except for nine programmed locations where bedrock was exposed, the test holes were advanced to depths ranging from 0.1 to 11.4 m below existing grade with termination in most cases due to refusal on probable bedrock (boulder at nine locations in swamp 401). Some test holes were terminated in competent materials (typically silty/sandy soils).

The test hole 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). SRQ Inc. (SRQ) laid out the reference lines of the new highway in the field and these lines were used to locate the programmed test holes. Geodetic elevations were provided by SRQ.

The test holes were advanced using a combination of methods including track-mounted drill rigs, excavators, power augering and manual hand sampling. The motorised portable power auger utilized during the field work allowed for investigation to deeper levels than with a manual auger but had no capability to carry out standard penetration tests and retrieve samples. The equipment was supplied and operated by contractors working under the full-time supervision of members of our engineering staff.

Representative samples of the soils 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. In situ vane shear and penetrometer testing was also performed to further assess the shear strength of the cohesive soils encountered. The results of the field tests and observations are reported on the 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, the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. The soil samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determination. Atterberg limits tests (12) and grain size distribution analyses (28) were largely performed on selected soil samples from swamps 402 and 403 (refer to the appended corresponding figures) where a significant thickness of clayey soils was identified. Organic content was determined on a sample of peat from swamp 403. The laboratory test results are appended.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole and Record of Penetration Test sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard

and dynamic cone penetration test data, in situ vane and penetrometer undrained shear strength values as well as groundwater observations. The results of laboratory Atterberg limits, grain size distribution analyses and natural moisture content determination are also shown on the Record of Borehole sheets.

The stratigraphic profiles along the centreline of the new Highway 69 alignment and the toe of embankment slopes (established from profile in RFP) as well as characteristic cross-sections at selected locations at each swamp are presented on the corresponding Drawings. 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 general description of the subsurface conditions encountered at the swamp and high fill crossings is provided in Table 1. The shear strength/consistency of the cohesive soils noted on the Record of Borehole sheets and in the subsequent sections of the report is primarily based on in situ vane shear testing (using the MTO 'N' vane according to the procedure described in the Northern Region Pavement Design Practices and Guidelines dated May 1997) and penetrometer tests on recovered samples. Less consideration was given to Standard Penetration Test (SPT) N-values since the shear strength indicated by this technique is less reliable in very soft to soft clayey soils. It is also noted that penetrometer tests typically provide lower shear strength values due to sample disturbance during sampling. A brief highlight of the findings is given below.

4.1 Swamp 401

A total of 43 test holes comprising 39 boreholes and 4 dynamic cone penetration tests were carried out in swamp 401. At the preliminary design stage, 2 other boreholes and 1 dynamic cone penetration test numbered N12-1 to N12-3 were advanced on the west side of the swamp. The toe of the SBL alignment crosses a low-lying swamp section between Sta. 12+950 and 13+310. The alignments of the NBL and SBL are located over high hilly terrain.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat underlain by predominantly cohesionless silty/sandy soils extending to bedrock. Cobbles and boulders were encountered in 17 boreholes. Exposed at four borehole

locations, the bedrock surface was contacted at depths of 0.1 to 7.1 m. Groundwater was at elevation 199.6 to 201.2 upon completion of drilling.

4.1.1 Topsoil / Peat

Topsoil was identified surficially in 30 boreholes. The silty topsoil was 100 to 500 mm thick and penetrated at elevation 201.8 to 226.2.

A surficial deposit of peat was present in boreholes 401-8, 401-19, 401-31, N12-1 and N12-3. The peat was fine fibrous to amorphous and contained occasional cobbles in borehole 401-8. This deposit had a thickness of 0.9 to 4.8 m and moisture content of 185 to 379%. The peat was penetrated at elevation 196.2 to 200.7.

4.1.2 Silty Clay / Clayey Silt

Layers of silty clay and/or clayey silt were encountered below the topsoil, peat or within silt at depths of 0.2 to 1.1 m (elevation 200.7 to 217.3) in boreholes 401-1, 401-38 and N12-3. The silty clay in borehole N12-3 was firm in consistency as indicated by in situ vane testing that gave an undisturbed shear strength value of 26 kPa (soil sensitivity of 5). The cohesive soils had a total thickness of 0.6 to 4.0 m and were penetrated at depths of 0.9 to 4.9 m (elevation 199.3 to 204.9). It is noteworthy that numerous cobbles and boulders were revealed within the clayey silt in borehole 401-1.

The results of Atterberg limits testing and grain size distribution analysis performed on a cohesive sample from borehole N12-3 are presented in respective Figures 401-PC-1 and 401-GS-1. The liquid and plastic limits of the silty clay were 36 and 19 respectively, thus giving the plasticity index of 17. The moisture content of the silty clay varied between 41 and 48%.

4.1.3 Silt to Sandy Gravel

Present at surface in borehole 401-37 and typically overlain in most boreholes by the topsoil or peat at depths of 0.1 to 4.9 m (elevation 196.2 to 226.2) were cohesionless soils of various

granulometric composition (silt, sandy silt, silty sand, sand, gravelly sand, sand and gravel, sandy gravel). These strata were 0.4 to 4.6 m thick where penetrated and very loose to dense. The moisture content of the sand / gravelly sand ranged from 13 to 15%. Containing cobbles and boulders in 17 boreholes, the strata extended to the termination depth of 0.5 to 6.1 m (elevation 195.2 to 225.2).

4.1.4 Bedrock

Exposed at elevation 209.8 to 224.9 in boreholes 401-2, 401-10, 401-16 and 401-23, bedrock was inferred by refusal at depths of 0.1 to 7.1 m (elevation 194.2 to 225.2) in most test holes with the exception of boreholes 401-1, 401-6, 401-9, 401-12, 401-14, 401-17, 401-20, 401-26, 401-32, 401-35, 401-38 to 401-42 terminated at depths of 0.0 to 4.0 m (elevation 198.0 to 216.5).

4.1.5 Groundwater

In the course of the field work, groundwater was observed in boreholes 401-8, 401-19, 401-31 and N12-1. During and upon completion of drilling, groundwater was at depths of 0.3 to 0.6 m (elevation 199.6 to 201.2). No water was observed in the remaining boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.2 Swamp 402

A total of 33 test holes comprising 30 boreholes and 3 dynamic cone penetration tests were carried out in swamp 402. The alignment crosses a low-lying swamp section between Sta. 14+187.5 and 14+330.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying cohesive silty clay underlain by cohesionless silt or sand extending to bedrock. Cobbles and boulders were encountered in one borehole. Exposed at three borehole locations, the bedrock surface was contacted at depths of 0.1 to 7.7 m. Groundwater was at elevation 197.9 to 202.9 upon completion of drilling.

4.2.1 Fill

Fill composed of sand and gravel was present surficially in borehole 402-4. The fill had a thickness of 300 mm and was penetrated at elevation 204.7.

4.2.2 Topsoil / Peat

Surficial topsoil was identified in 14 boreholes. The silty topsoil had a thickness of 50 to 300 mm, locally 650 mm, and was penetrated at elevation 200.2 to 210.4.

A surficial deposit of peat was present in 8 boreholes. The fine to coarse fibrous peat was 100 to 300 mm thick and penetrated at elevation 200.1 to 204.1.

4.2.3 Silty Clay

Present at surface in boreholes 402-15, 402-18, 402-24 and encountered below the fill, peat or topsoil at depths of 0.1 to 0.3 m (elevation 200.1 to 204.8) in 16 boreholes was silty clay. This deposit contained occasional thin layers of clayey silt and was 0.3 to 5.2 m in thickness (at least 5.3 m in borehole 402-21). The silty clay was firm to very stiff, typically stiff in consistency. The results of in situ vane testing carried out in the deposit yielded the undisturbed shear strength values in a range of 48 to 56 kPa (soil sensitivity of 2 to 4). Penetrometer tests on samples of the silty clay indicated a shear strength varying between 62 and 175 kPa. The deposit was penetrated at depths of 0.4 to 5.9 m (elevation 195.2 to 202.4).

The results of Atterberg limits testing and grain size distribution analyses conducted on five samples of the cohesive soil are presented in respective Figures 402-PC-1 and 402-GS-1. The liquid and plastic limits of the silty clay were 35 to 42 and 22 to 24 respectively, thus giving the plasticity index of 12 to 18. The silty clay had a moisture content in a typical range of 27 to 42% and specific gravity of about 2.76.

4.2.4 Silt

Underlying the topsoil at 0.3 m depth (elevation 202.6) in borehole 402-3 or silty clay at depths of 0.4 to 5.9 m (elevation 195.2 to 200.9) in boreholes 402-14 to 402-16 and 402-21 was non-plastic silt. This unit was 0.4 to 1.8 m thick and very loose to compact in relative density (SPT N-values of 0 to 18), its moisture content varying between 24 and 28%. The silt extended to the termination depth on probable bedrock of 1.7 to 7.7 m (elevation 193.4 to 201.1).

The results of grain size distribution analyses performed on 5 samples of the unit are presented in Figure 402-GS-2.

4.2.5 Sand

Directly beneath the silty clay at depths of 1.0 to 5.5 m (elevation 196.4 to 199.6) in boreholes 402-5, 402-11, 402-22 and 402-24 was sand. Being very loose to compact (SPT N-values of 1 to 20), this stratum had a thickness of 0.2 to 2.0 m and moisture content of 18%. Occasional cobbles and boulders were detected in the sand in borehole 402-22. The stratum extended to the termination depth on probable bedrock of 1.2 to 7.5 m (elevation 196.2 to 199.4).

The results of grain size distribution analysis performed on a representative sample of the sand are presented in Figure 402-GS-3.

4.2.6 Bedrock

Exposed at elevation 208.4 to 209.6 in boreholes 402-1, 402-31 and 402-33, bedrock was inferred by refusal at depths of 0.1 to 7.7 m (elevation 193.4 to 210.4) in the remaining test holes with the exception of 402-8 and 402-28 terminated at respective depths of 5.8 and 1.5 m (elevation 197.1 and 200.9).

4.2.7 Groundwater

In the course of the field work, groundwater was observed in boreholes 402-4, 402-5, 402-7, 402-10, 402-11, 402-14, 402-16 and 402-21. In the process of augering, water was detected at depths of 0.6 to 6.8 m (elevation 194.3 to 202.9). Upon completion of drilling, groundwater was measured to be at depths of 0.6 to 5.2 m (elevation 197.9 to 202.9). No water was observed in the remaining boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.3 Swamp 403

A total of 18 test holes comprising 15 boreholes and 3 dynamic cone penetration tests were advanced in swamp 403. The alignment crosses a low-lying swamp section between Sta. 15+120 and 15+180.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying cohesive clayey silt and/or silty clay underlain by cohesionless silty/sandy soils extending to bedrock. Cobbles and boulders were encountered in 5 boreholes. Exposed at two borehole locations, the bedrock surface was contacted at depths of 0.1 to 11.4 m. Groundwater was at elevation 192.7 to 204.1 upon completion of drilling.

4.3.1 Topsoil / Peat

Topsoil was identified surficially in most boreholes. The silty topsoil was 100 to 300 mm thick and penetrated at elevation 194.5 to 205.4.

A surficial deposit of peat was present in boreholes 403-4 and 403-6 (covered with some 300 mm of snow and ice in the latter borehole). The peat was fine fibrous and had an organic content of about 6.5%. The peat was 200 mm thick and penetrated at elevation 195.5 in borehole 403-4 and 194.1 in borehole 403-6.

4.3.2 Clayey Silt

Present at surface in boreholes 403-9, 403-12 and encountered below the topsoil or peat at 0.2 m depth (elevation 194.5 to 197.0) in boreholes 403-1, 403-4, 403-14 was a distinctive layer of clayey silt. This layer was 1.0 to 1.6 m in thickness and firm to stiff in consistency (penetrometer testing indicated a shear strength of about 75 kPa). The unit was penetrated at depths of 1.1 to 1.8 m (elevation 193.2 to 195.4). It is noted that clayey silt layers were also revealed within a deposit of silty clay underneath.

The results of four Atterberg limits tests and grain size distribution analyses conducted on this material are presented in respective Figures 403-PC-1 and 403-GS-1. The liquid and plastic limits of the clayey silt ranged from 31 to 34 and from 20 to 21 respectively, with the plasticity index of 10 to 13. The moisture content in the clayey silt layer was 26 to 32%.

4.3.3 Silty Clay

Overlain by the peat or clayey silt at depths of 0.5 to 1.5 m (elevation 193.2 to 194.9) in boreholes 403-1, 403-4, 403-6, 403-9 and 403-12 was silty clay. Containing layers of clayey silt, this deposit was 1.5 to 3.2 m thick and soft to stiff, typically firm. The results of in situ vane testing carried out in the silty clay yielded the undisturbed shear strength values in a range of 20 to 48 kPa (soil sensitivity of 2 to 4). Penetrometer tests on samples of the deposit indicated a shear strength varying between 25 and 137 kPa. The silty clay was penetrated at depths of 2.7 to 4.4 m (elevation 190.3 to 193.4).

The results of Atterberg limits testing and grain size distribution analysis conducted on a sample of the deposit are presented in respective Figures 403-PC-2 and 403-GS-2. The liquid and plastic limits of the silty clay were 35 and 21 respectively, thus giving the plasticity index of 14. The silty clay had a moisture content in a range of 27 to 37%.

4.3.4 Silty/Sandy Soils

Underlying the topsoil, clayey silt or silty clay at depths of 0.2 to 4.4 m (elevation 190.3 to 205.4) in most boreholes were silty/sandy soils of various granulometric composition. These units were very loose to dense (SPT N-values of 0 to 37), their moisture content varying between 10 and 22%. The silty/sandy soils had a total thickness of 0.5 to 9.4 m and were penetrated at depths of 0.8 to 10.8 m (elevation 184.3 to 203.5), except for borehole 403-8 terminated within the silty sand at elevation 204.2. It is noteworthy that cobbles and boulders were encountered within the units in boreholes 403-6, 403-8, 403-12, 403-15 and 403-16.

The results of 11 grain size distribution analyses performed on samples of the silty/sandy soils are presented in Figures 403-GS-3 and 403-GS-4.

4.3.5 Bedrock

Exposed in boreholes 403-17 and 403-18 at respective elevation 199.7 and 203.7, bedrock was inferred by refusal at depths of 0.1 to 11.4 m (elevation 183.5 to 205.0) in the remaining test holes with the exception of borehole 403-8 terminated in a silty sand layer with cobbles and boulders at 1.5 m depth (elevation 204.2).

4.3.6 Groundwater

In the course of the field work, groundwater was observed in boreholes 403-1, 403-3, 403-4, 403-6, 403-9, 403-12 and 403-15. In the process of augering, water was detected at depths of 0.6 to 4.1 m (elevation 192.4 to 194.9, locally 204.1). Upon completion of drilling, groundwater was measured in boreholes 403-3, 403-4, 403-6, 403-9, 403-12 and 403-15 to be at depths of 0.6 to 4.6 m (elevation 192.7 to 195.2, locally 204.1). No water was observed in the remaining boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

Messrs. F. Portela, N. Lee-Bun and N. Rahman carried out most of the field investigation for this study under the supervision of Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and direction of Mr. B.R. Gray, MEng, P.Eng., MTO Designated Principal Contact. The equipment was supplied by Walker Drilling Ltd. and Marathon Drilling Co. Ltd. The laboratory testing of the selected soil samples was carried out at the PML laboratory in Toronto.

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

Yours very truly,

Peto MacCallum Ltd.

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CN/BRG/GD:gd-mi-lr/lnr

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

SWAMP NO.	LOCATION	NO. OF TEST HOLES	TOPSOIL/PEAT THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
401	Sta. 12+950 to 13+310 Township of Servos	43	0.0 – 0.5, locally 0.9 – 4.8	0.0 – 4.9	0.0 – 7.1 (El. 194.2 – 225.2)	Exposed bedrock in 4 boreholes. Topsoil or peat present in most boreholes overlies predominantly cohesionless silty/sandy soils extending to bedrock
402	Sta. 14+187.5 to 14+330 Township of Servos	33	0.0 – 0.3, locally 0.7	0.0 – 5.9	0.0 – 7.7 (El. 193.4 – 210.4)	Exposed bedrock in 3 boreholes located at both ends of the crossing. Topsoil or peat present in most boreholes overlies cohesive silty clay underlain by cohesionless silt or sand extending to bedrock
403	Sta. 15+120 to 15+180 Township of Servos	18	0.0 – 0.3	0.0 – 4.4	0.0 – 11.4 (El. 183.5 – 205.0)	Exposed bedrock in 2 boreholes located at the north end of the crossing. Topsoil or peat present in most boreholes overlies cohesive clayey silt and/or silty clay underlain by cohesionless silty/sandy soils extending to bedrock

NOTES:

1. Test holes include boreholes and dynamic cone penetration tests.
2. Thickness of topsoil / peat and depth to bottom of cohesive deposits is based on borehole data only.
3. Depth to probable bedrock is based on both borehole and dynamic cone penetration test data.