REPORT

January 17, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C
TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5465-09-00, WP 5466-09-01

Submitted to:
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192 Hickson Avenue
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GEOCRES NO: 41G-16

Report Number: 12-1191-0014-R06

Distribution:

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Golder Associates

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FOUNDATION INVESTIGATION REPORT

HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C

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Golder Associates

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the east end of the existing culvert at Mud Creek (Site 49-68/C) located at STA 20+045 on Highway 540, in the Township of Billings on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the location of the culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Mud Creek culvert is located in the Township of Billings on Highway 540, approximately 5.8 km west of Highway 551. The land use in the area is generally rural with a few residences in the vicinity of the site.

The topography in the area of the overall project limits is generally flat. The creek banks are vegetated with grass and small trees. The creek was dry at the time of our investigation.

The existing highway grade at the culvert is at about Elevations 220.8 m with the bottom of Mud Creek located about 2.1 m below the existing highway grade. The existing structure is a 3.0 m span by 0.8 m high by 15.8 m long open footing concrete culvert under approximately 0.8 m of fill. We understand the original open footing culvert, which was constructed in 1964, was approximately 6.2 m in length. Since the original construction, the culvert has been extended about 7.7 m to the west and 1.9 m the east. The construction date of the extensions is not known. The existing inlet (west) and outlet (east) inverts are at Elevation 218.7 m and 218.8 m, respectively.

A 2010 structural inspection indicated severe scaling, delaminations and medium stained cracks. The base of the south wall of the east culvert extension was noted to be rotating inwards. Based on the 2012 inspection performed by McIntosh Perry, the north side of the east culvert extension has also rotated inward at the base of the wall.

Photographs taken at the site are included following the text of the report.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on July 8 and 9, 2013, during which time a total of four boreholes (M1 to M4) were advanced at the culvert location. The locations of the boreholes are shown on Drawing 1.

The field investigation was carried out using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m, using a 50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using

NW casing and NQ size rock core barrels in each of the boreholes. The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling, sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury 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 contents and grain size distributions) was carried out on selected soil samples and uniaxial compressive strength (UCS) testing was carried out on specimens of the recovered bedrock core. The geotechnical laboratory testing was completed according to applicable MTO LS standards. The results of the laboratory testing are included on the Record of Borehole sheets in Appendix A and in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
M1	5078730.0	326590.3	220.5	5.6
M2	5078736.4	326590.3	220.6	5.5
M3	5078730.0	326598.7	220.6	4.7
M4	5078736.7	326605.3	218.8	3.3

As part of the foundation investigation, an excavator was used to expose the foundation at the northeast corner of the culvert extension. As shown in Photograph #3 following the text of the report, the wall of the culvert extension is bearing directly on the exposed bedrock.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)[1], the site is located within limestone plains bordering with clay plains and drumlin formations.

[1] Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.

Based on geological mapping in the area (Ministry of Northern Development and Mines)[2], the bedrock in the area consists typically of sandstone, shale, dolostone and siltstone from the Amabel Formation from the Silurian Period of the Paleozoic Era.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix 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. 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 based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill overlying bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Sand and Gravel Fill

A 1.8 m to 2.1 m thick layer of brown, moist, sand and gravel fill, trace to some silt, trace clay was encountered from ground surface (between Elevation 220.6 and 220.5 m) in Boreholes M1 to M3, which were advanced from the existing highway shoulders. The augers were noted to be grinding on cobbles within the fill generally at a depth of about 0.6 m below the existing ground surface (about Elevation 220.0 m).

Standard Penetration Test (SPT) 'N'-values measured within the sand and gravel fill range from 11 blows to 38 blows per 0.3 m of penetration indicating a compact to dense relative density.

Grain size distribution tests were carried out on five samples of the sand and gravel fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on five samples of the sand and gravel fill ranges from 3 per cent to 5 per cent.

4.2.2 Silty Organics

A 0.2 m thick layer of brown, moist, silty organics, trace to some sand, trace gravel was encountered from ground surface (Elevation 218.8 m) in Borehole M4, which was advanced beyond the embankment toe of slope near the culvert inlet.

[2] Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.

4.2.3 Gravelly Silty Sand

A 0.4 m thick deposit of brown, wet gravelly silty sand, trace organics, was encountered below the sand and gravel fill in Borehole M1. The surface of this deposit was encountered at Elevation 218.7 m.

The SPT 'N'-value measured within the gravelly silty sand deposit is 14 blows per 0.3 m penetration, indicating a compact relative density.

The natural water content measured on one sample of the gravelly silty sand is 20 per cent.

A grain size distribution test was carried out on a sample of the gravelly silty sand and the results are shown on Figure B2 in Appendix B.

4.2.4 Bedrock

Bedrock was cored in Boreholes M1 to M4. The bedrock surface/refusal depths and elevations are presented below.

Borehole No.	Depth to Bedrock (m)	Bedrock Surface Elevation (m)	Notes
M1	2.2	218.3	Bedrock Cored for 3.4 m
M2	2.1	218.5	Bedrock Cored for 3.4 m
M3	1.8	218.8	Bedrock Cored for 2.9 m
M4	0.2	218.6	Bedrock Cored for 3.1 m

The retrieved bedrock core is described as a fine grained, fresh to slightly weathered, grey, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B3 in Appendix B.

The Total Core Recovery (TCR) during bedrock coring ranged from 97 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the core samples ranges from 58 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

Laboratory UCS testing was carried out on two core samples of the bedrock. The UCS values are presented below and the test results indicate the bedrock is very strong as per Table 3.5 of the CFEM (2006).

Borehole	Elevation (m)	UCS (MPa)
M2	217.9	229
M3	216.8	183

4.2.5 Groundwater Conditions

The boreholes were noted to be dry upon completion of drilling prior to bedrock coring.

The creek was dry at the time of the investigation in July 2013. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program was Mr. Mathew Riopelle. This report was prepared by Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.

Report Signature Page

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http://capws.golder.com/sites/p211910014mtohwy542and655manislandtimmins/reports/final/mud creek site 49-68/12-1191-0014-r06 rpt 14jan17 mud creek site 49-68 - fir.docx

PART B

FOUNDATION DESIGN REPORT

HIGHWAY 540 – MUD CREEK CULVERT, SITE 49-68/C

TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and conclusions 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 such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The existing Mud Creek culvert is a 3.0 m span by 0.8 m high by 15.8 m long open footing concrete culvert under about 0.8 m of fill. The original culvert, which was constructed in 1964, was about 6.2 m long. Since the original construction, the culvert has been extended about 7.7 m to the west and 1.9 m the east. The culvert extension consists of a three sided structure with concrete walls along the north and south sides with a top slab/cover. Based on the structural reviews performed by the MTO and McIntosh Perry, we understand that the north and south walls of the east extension are rotating inwards at the base. It appears as though the culvert or the extensions were not constructed with footings but with the wall placed directly on the bedrock surface.

The subsoils within the embankment platform generally consist of sand and gravel fill overlying bedrock, with the bedrock surface encountered between Elevation 218.8 m and 218.6 m at the east side of the culvert. Based on the drawings provided by McIntosh Perry, the invert of the east culvert extension is at about Elevation 218.8 m. Given the subsurface information, the culvert extension is founded directly on the bedrock. This has been confirmed by exposing the base of the wall at the northeast corner of the culvert extension with an excavator.

The culvert extension walls are sliding along the bedrock surface towards the inside of the culvert likely as a result of:

- potential frost heaving of the low frost susceptible backfill material and native gravelly silty sand (i.e., between 11 per cent and 31 per cent passing the no. 200 sieve) pushing against the wall;
- earthquake forces;
- lateral earth pressures exerted by the approximately 2 m high granular fill embankment potentially exceeding the available lateral sliding resistance between the concrete wall and the bedrock surface; and
- hydrostatic forces as wall backfill is not free draining.

It is likely that dowels were not installed during construction of the extension resulting in a relatively low available frictional resistance.

Due to the relatively low embankment height with the embankment constructed directly on bedrock, embankment stability and settlement are not a concern at this site. Further, as the culvert and extension are founded on bedrock, settlement and horizontal strain of the culvert and extension is also not a concern.

Due to the shallow bedrock at this site, frost protection is not required for culvert foundations.

6.2 Culvert Extension Replacement Options

Based on discussions with McIntosh Perry, we understand that the existing east culvert extension may be partially or completely replaced. Partial replacement will consist of replacing the north and south walls of the extension (leaving the top slab in place) with either gabion baskets, concrete blocks or cast-in-place concrete. Alternatively, the entire extension (including the top cover) may be replaced with a cast-in-place concrete extension.

6.3 Recommendations

The recommendations provided below assume the proposed replacement culvert extension walls will be founded directly on the bedrock surface and that any existing fill, organic material and/or native soil will be sub-excavated prior to construction the culvert extension.

6.3.1 Geotechnical Resistance

A factored geotechnical axial resistance at Ultimate Limit States (ULS) of 1,000 kPa may be used for design for culvert extension walls bearing directly on the bedrock surface.

For walls bearing directly on bedrock, the geotechnical axial resistance at Serviceability Limit States will be equal to or greater than the factored geotechnical resistances at ULS and, therefore, the ULS values will govern for design.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of wall. Where loads are not applied perpendicular to the base of the wall, 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 Code (CHBDC) and its Commentary.

6.3.2 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of the replacement culvert extension walls and the bedrock surface should be calculated in accordance with Section 6.7.5 of the CHBDC. Depending on the type of extension selected (i.e., gabion baskets, concrete block), the design resistance will be the responsibility of the designer. For a cast in place concrete extension, the coefficient of friction is tan ϕ = 0.7 and for a precast culvert extension the coefficient of friction is tan ϕ = 0.6.

To provide additional sliding resistance, we recommend that dowels be incorporated into the design, or the bedrock be sub-excavated a minimum of 150 mm to “key” the base of the extension into the bedrock surface.

6.3.3 Lateral Earth Pressures

The lateral earth pressures acting on the culvert extension walls will depend on the type and method of placement of backfill materials, the nature of 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 extension walls. It should be noted that these design recommendations and parameters are applicable to 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 requirements of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the retaining walls, in accordance with CHBDC Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compaction). Other surcharge loadings should be accounted for in the design as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.6 m behind the back of the wall (in accordance with Figure C6.20(a) of the Commentary to the CHBDC). For unrestrained walls, granular fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the Commentary to the CHBDC). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	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

If the culvert extension walls allows for lateral yielding, active earth pressures may be used in the geotechnical design of the wall. If the walls do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

6.4 Culvert Construction Considerations

6.4.1 Excavations and Subgrade Preparation

Given the relatively shallow excavation depths (i.e., about 2 m below the existing grade), it is anticipated that temporary open-cut excavations are considered feasible for the proposed culvert extension replacement.

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). When referencing OHSA, the granular fill, organics and native soils at this site should be considered as "Type 3 Soil" and temporary excavation side slopes should be made no steeper than 1 horizontal (H) to 1 vertical (V).

Care must be taken by the Contractor during excavation adjacent to the highway to minimize impact to the existing roadway. A provision for traffic control measures should be included in the Contract Documents to maintain the safe operation of Highway 540 during excavations and culvert extension replacement.

Prior to placing the proposed culvert extension walls, any existing fill, organic matter or native soils should be excavated to expose the bedrock surface within the plan limits of the walls.

6.4.2 Control of Groundwater and Surface Water

The existing culvert flows (if any) will need to be diverted/piped during construction. Surficial water seepage and seepage from the granular fills, native soils and the bedrock should be expected and will be heavier during periods of sustained precipitation. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within the excavation.

7.0 CLOSURE

This report was prepared by Mr. David Muldowney, P.Eng and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact, carried out a quality control review and reviewed the technical aspects of the report.

Report Signature Page

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http://capws.golder.com/sites/p211910014mtohwy542and655manislandtimmins/reports/final/mud creek site 49-68/12-1191-0014-r06 rpt 14jan17 mud creek site 49-68.docx

REFERENCES

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

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

Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.

Ministry of Northern Development and Mines, 1991. Bedrock Geology of Ontario, Southern Sheet, Map 2544.

STANDARDS

ASTM International:

ASTM D1586-08a	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Occupational Health and Safety Act

Ontario Regulation 213/91	Construction Projects
Ontario Regulation 443/09	Amendment to Ontario Regulation 213/91

Ontario Provincial Standard Drawing

OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

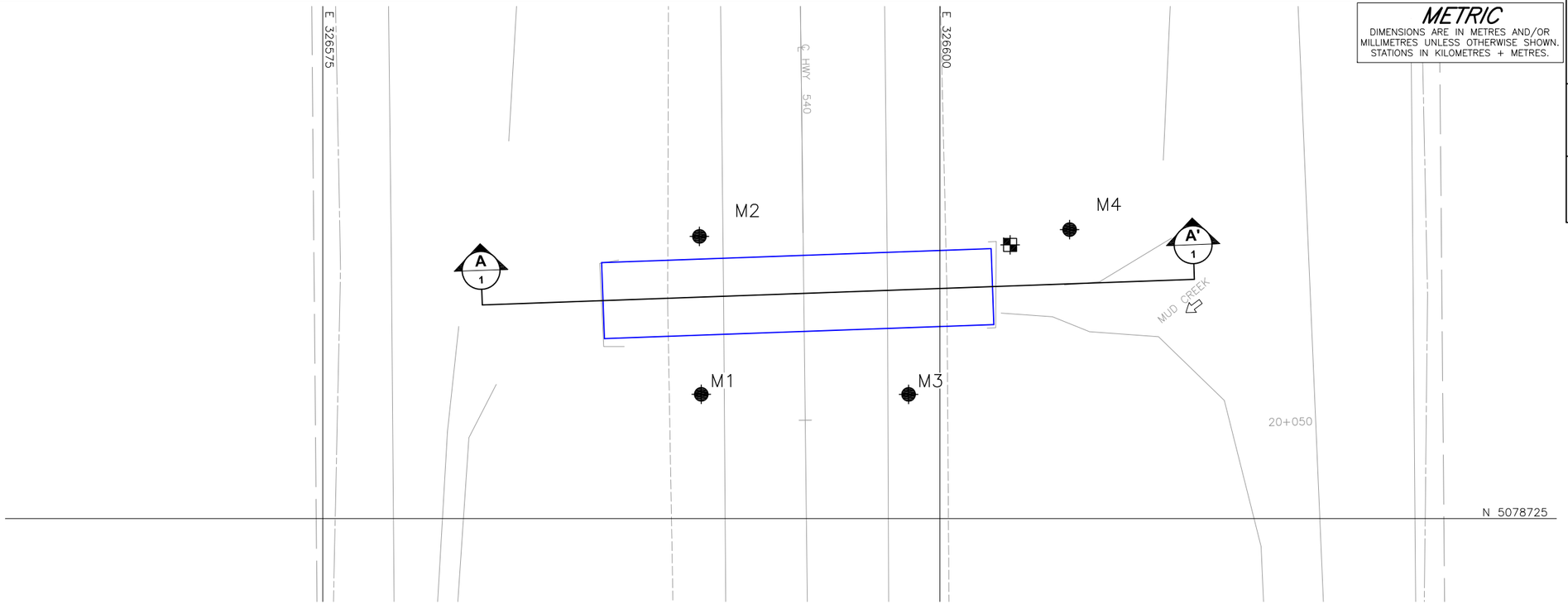
Ontario Provincial Standard Specification

OPSS 501	Construction Specification for Compacting
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

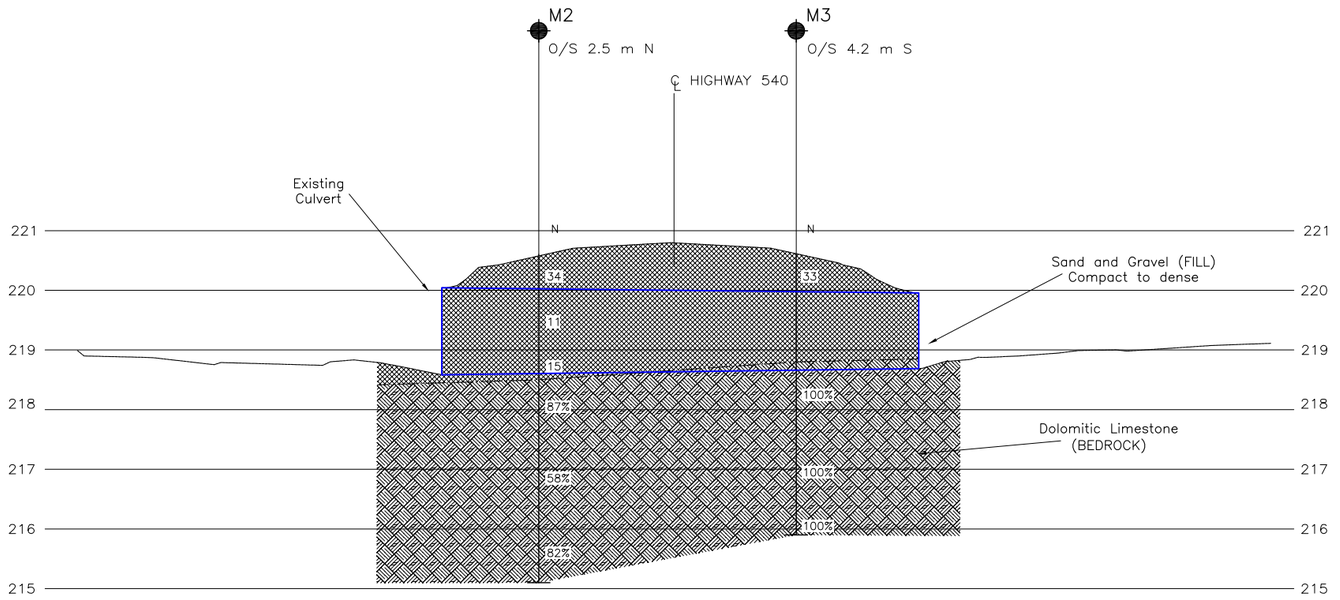
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE

2 0 2 4 m



A–A' / 1 CULVERT PROFILE STA. 20+045

HIGHWAY 540

HORIZONTAL SCALE

2 0 2 4 m

VERTICAL SCALE

1 0 1 2 m

METRIC

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

CONT No.

WP No. 5466–09–01

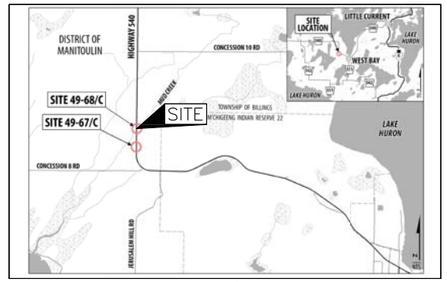
HIGHWAY 540

MUD CREEK CULVERT SITE 49–68/C

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN

LEGEND

- Borehole
- Test Pit
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% — Rock Quality Designation (RQD)

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
M1	220.5	5078730.0	326590.3
M2	220.6	5078736.4	326590.3
M3	220.6	5078730.0	326598.7
M4	218.8	5078736.7	326605.3

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 McIntosh Perry, drawing file no. 11–684–Mud Creek Xref.dwg, received Aug 20, 2013. Coss–section file no. 11–684–Mud Creek – Typical Sections – C3D.dwg, received July 19, 2013. Key plan drawing file no. KM11684 – 49–68 and 49–67 Location Map – June 26 2012.jpg, received August 24, 2012.

LICENSED PROFESSIONAL ENGINEER — A.J.K. BOM — 100075715 — JAN 17, 2014 — PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER — F. J. HEFFERNAN — JAN 17, 2014 — PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41G–16

HWY. 540	PROJECT NO. 12–1191–0014		DIST.
SUBM'D. DAM	CHKD.	DATE: JAN 2014	SITE: 49–68/C
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 1

PLOT DATE: January 17, 2014
FILENAME: \\golder.gds\GAL\Sudbury\CAD–QS\CAD\Projects\2012\12–1191–0014 Manitoulin and Timmins\Mud Creek\12119100144A001 Mud Cr.dwg

Photograph 1: Looking southeast from culvert inlet (October 2012)

Photograph 2: Looking south at east culvert extension
(From McIntosh Perry by email Feb 25, 2013)

Photograph 3: Looking north at exposed east culvert extension following excavation of test pit (July 2013)

Photograph 4: Looking at north wall of east extension (From McIntosh Perry by email Feb 25, 2013)

APPENDIX A

Record of Boreholes and Drillholes

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 (Cohesionless) 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	c_u, s_u 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 (cohesionless)) or With (cohesive)	Sand and Gravel / 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^{o} 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

Golder Associates

RECORD OF BOREHOLE No M1

1 OF 1 **METRIC**

PROJECT 12-1191-0014 | W.P. 5466-09-01 | LOCATION N 5078730.0; E 326590.3 | ORIGINATED BY MR

DIST | HWY 540 | BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring | COMPILED BY DAM

DATUM GEODETIC | DATE July 8, 2013 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
220.5	GROUND SURFACE										
0.0	Sand and gravel, some silt, trace clay (FILL) Compact to dense Brown Moist Augers grinding on cobbles between 0.6 m and 0.9 m depth and between 1.4 m and 1.5 m depth.		1	SS	38		220		○		38 44 16 2
			2	SS	11				○		43 39 15 3
218.7			3a 3b	SS	14		219		○		28 41 28 3
218.3	Gravelly Silty SAND, trace clay, trace organics Compact Brown Wet										
2.2	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 2.2 m depth to 5.6 m depth. For coring details see Record of Drillhole M1.		1	RC	REC 97%		218				RQD = 78%
			2	RC	REC 100%		217				RQD = 96%
			3	RC	REC 100%		216				RQD = 99%
214.9							215				
5.6	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M1

SHEET 1 OF 1

LOCATION: N 5078730.0 ;E 326590.3

DRILLING DATE: July 8, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF ROCK		218.3																
3	July 8, 2013 NW NQ Coring	DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh		2.2	1	GREY 100%							JNIRRo JNIRRo JNIRRo MB MB JNIRRo							
													JNIRRo							
													JNIRRo JNIRRo JNIRRo MB							
4					2	GREY 100%							JNIRRo MB							
													JNIRRo							
													MB MB							
5					3	GREY 100%							JNIRRo							
				214.9									JNIRRo JNIRRo							
		END OF DRILLHOLE		5.6																
6																				
7																				
8																				
9																				
10																				
11																				
12																				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: MR
CHECKED: AB

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No M2

1 OF 1 **METRIC**

PROJECT 12-1191-0014
W.P. 5466-09-01
LOCATION N 5078736.4; E 326590.3
ORIGINATED BY MR
DIST HWY 540
BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY DAM
DATUM GEODETIC
DATE July 8, 2013
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
220.6	GROUND SURFACE										
0.0	Sand and gravel, trace to some silt (FILL) Compact to dense Brown Moist Augers grinding on cobbles between 0.6 m and 0.8 m depth and between 1.2 m and 1.5 m depth.		1	SS	34		220				
			2	SS	11				○		56 33 (11)
218.5			3	SS	15		219		○		39 49 (12)
2.1	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 2.1 m depth to 5.5 m depth. For coring details see Record of Drillhole M2.		1	RC	REC 100%		218				RQD = 87%
			2	RC	REC 100%		217				RQD = 58%
			3	RC	REC 100%		216				RQD = 82%
215.1											
5.5	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M2

SHEET 1 OF 1

LOCATION: N 5078736.4 ;E 326590.3

DRILLING DATE: July 8, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF ROCK		218.5																
3	July 8, 2013 NQ Coring NW	DOLOMITIC GNEISS Fine grained Very strong Grey Slightly weathered		2.1	1	GREY 100%							JNIRRo JNIRRo MB MB MB MB MB MB JNIRRo							UCS = 229 MPa
4		Broken rock between 3.1 m and 3.2 m depth.			2	GREY 100%							JNIRRo JNIRRo JNIRRo BR JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo MB MB JNIRRo					
5		Broken rock between 4.8 m and 4.9 m depth.			3	GREY 100%							MB MB JNIRRo JNIRRo BR							
				215.1									JNIRRo JNIRRo							
		END OF DRILLHOLE		5.5																

DEPTH SCALE

1 : 50

LOGGED: MR

CHECKED: AB

Golder Associates

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No M3

1 OF 1 **METRIC**

PROJECT 12-1191-0014 | W.P. 5466-09-01 | LOCATION N 5078730.0; E 326598.7 | ORIGINATED BY MR

DIST | HWY 540 | BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring | COMPILED BY DAM

DATUM GEODETIC | DATE July 9, 2013 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	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
220.6	GROUND SURFACE										
0.0	Sand and gravel, some silt, trace clay (FILL) Dense Brown Moist Augers grinding on cobbles between 0.5 m and 0.8 m depth. Split spoon attempted at 0.8 m depth, hammer bouncing on cobbles. Switched to NW Casing. A 150 mm coble encountered at 0.9 m and 1.3 m depths, respectively.		1	SS	33		220	○			34 46 17 3
218.8							219				
1.8	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 1.8 m depth to 4.7 m depth. For coring details see Record of Drillhole M3.		1	RC	REC 100%		218				RQD = 100%
			2	RC	REC 100%		217				RQD = 100%
215.9			3	RC	REC 100%		216				RQD = 100%
4.7	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M3

SHEET 1 OF 1

LOCATION: N 5078730.0 ;E 326598.7

DRILLING DATE: July 9, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

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

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF ROCK		218.8																
2	July 9, 2013 NQ Coring NW	DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh		1.8	1	GREY 100%							JNIRRo							
													JNIRRo							
													JNIRRo							
													JNIRRo							
3													JNIRRo							
					2	GREY 100%							JNIRRo							UCS = 183 MPa
4													MB							
													JNIRRo							
					3	GREY 100%							MB							
				215.9																
		END OF DRILLHOLE		4.7																
5																				
6																				
7																				
8																				
9																				
10																				
11																				

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

CHECKED: AB

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No M4

1 OF 1 **METRIC**

PROJECT 12-1191-0014 | W.P. 5466-09-01 | LOCATION N 5078736.7; E 326605.3 | ORIGINATED BY MR

DIST | HWY 540 | BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring | COMPILED BY DAM

DATUM GEODETIC | DATE July 9, 2013 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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
218.8	GROUND SURFACE										
0.0	Silty ORGANICS, trace to some sand, trace gravel, Brown, Moist										
0.2	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 0.2 m depth to 3.3 m depth. For coring details see Record of Drillhole M4.		1	RC	REC 100%		218				RQD = 84%
			2	RC	REC 100%		217				RQD = 100%
215.5			3	RC	REC 100%		216				RQD = 100%
3.3	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M4

SHEET 1 OF 1

LOCATION: N 5078736.7 ;E 326605.3

DRILLING DATE: July 9, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU- Curved; UN- Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF ROCK		218.6																
1	July 9, 2013 NQ Coring NW	DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh		0.2	1	GREY 100%							MB MB JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo JNIRRo MB MB							
2					2	GREY 100%							JNIRRo JNIRRo							
3					3	GREY 100%							MB MB							
		END OF DRILLHOLE		215.5 3.3																
4																				
5																				
6																				
7																				
8																				
9																				
10																				

DEPTH SCALE

1 : 50

Golder Associates

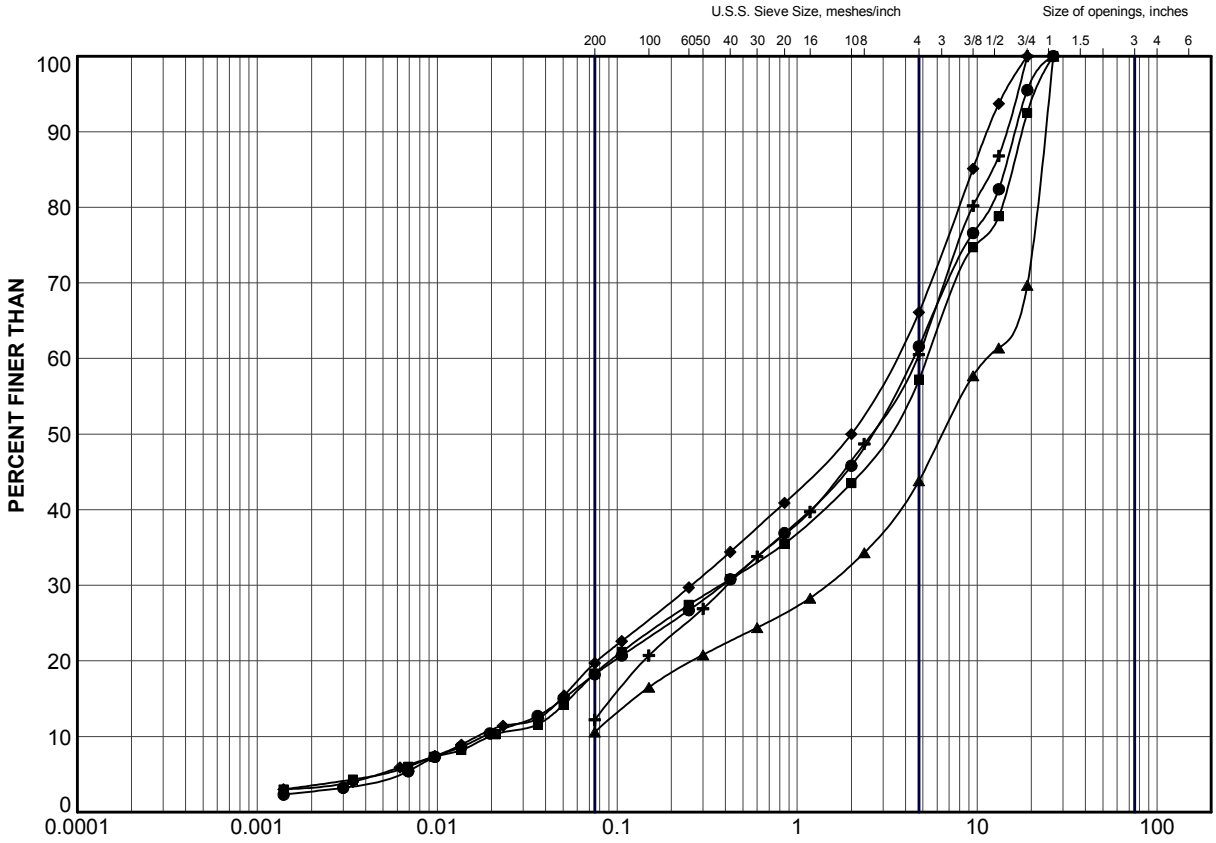
LOGGED: MR

CHECKED: AB

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	M1	1	220.2
■	M1	2	219.4
▲	M2	2	219.5
+	M2	3	218.8
◆	M3	1	220.3

PROJECT

HIGHWAY 540
MUD CREEK CULVERT

TITLE

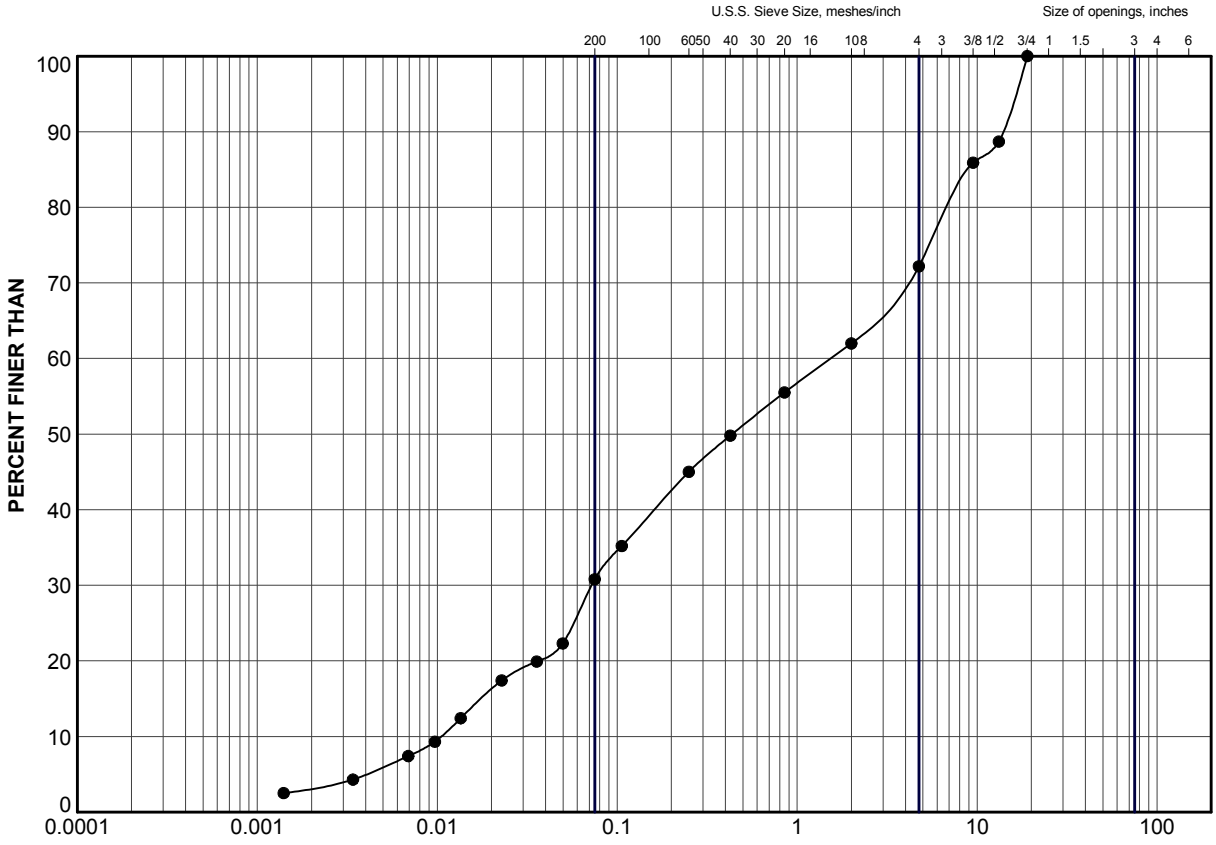
GRAIN SIZE DISTRIBUTION

SAND and GRAVEL (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	12-1191-0014		FILE No.	1211910014.5000.GPJ
DRAWN	JJL	Aug 2013	SCALE N/A	REV.
CHECK	AB	Aug 2013		
APPR		Aug 2013	**FIGURE B1**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	M1	3b	218.5

PROJECT

HIGHWAY 540
MUD CREEK CULVERT

TITLE

GRAIN SIZE DISTRIBUTION

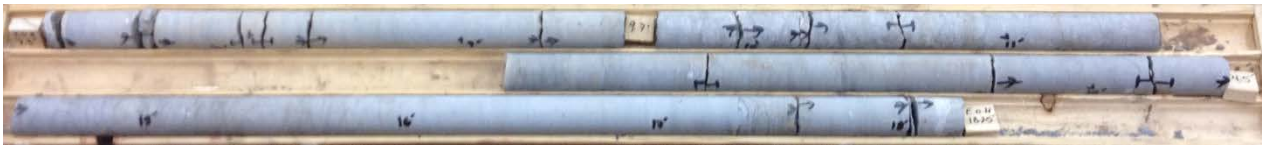
GRAVELLY SILTY SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	12-1191-0014		FILE No.	1211910014.5000.GPJ
DRAWN	JJL	Aug 2013	SCALE N/A	REV.
CHECK	AB	Aug 2013		
APPR		Aug 2013	**FIGURE B2**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT

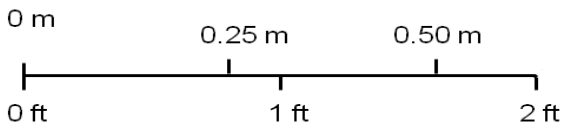
Borehole M1
Elevation 218.3 m to 214.9 m



Borehole M2
Elevation 218.5 m to 215.1 m

Borehole M3
Elevation 218.8 m to 215.9 m

Borehole M4
Elevation 218.6 m to 215.5 m



PROJECT
HWY 540
MUD CREEK CULVERT

TITLE
BEDROCK CORE

Golder Associates

PROJECT No. 12-1191-0014			FILE No. ----	
DESIGN	DAM	Aug. 2013	SCALE AS SHOWN	REV.
CADD	--		**FIGURE B3**	
CHECK	AB	Aug. 2013		
REVIEW				

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