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PHASE I & II DRAFT REPORT

Geophysical Survey to Map Ground Type Strata Information Between Pauingassi and Little Grand Rapids, MB

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REPORT

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Table of Contents

1.0 INTRODUCTION **1**

2.0 METHODOLOGY **1**

2.1 Ground Penetrating Radar 1

2.2 Capacitively-coupled Electrical Resistivity Imaging 1

2.3 Wenner Profile Electrical Resistivity Imaging 2

3.0 FIELD WORK **3**

3.1 Site Access & Positional Data 3

3.2 GPR Data 5

3.3 Capacitively-coupled ERI Data 6

3.4 Wenner Profile ERI Data 6

4.0 ANALYSIS AND RESULTS **8**

4.1 GPR Data Analysis 8

4.2 Capacitively-coupled ERI Data Analysis 9

4.3 Wenner Profile ERI Data Analysis 9

4.4 Interpretation and Results 10

4.4.1 Phase I 10

4.4.2 Phase II 10

5.0 CONCLUSION & RECOMMENDATIONS **11**

6.0 LIMITATIONS OF USE **11**

IMAGES

Image 1: GPR System in Data Acquisition Mode. 5

Image 2: Ohm-Mapper ERI in Data Acquisition Mode. 6

Image 3: Syscal ERI setup. 7

List of Tables

Table 1: Factors Affecting Data Acquisition

Table 2: GPR Data Acquisition Parameters

Table 3: ERI Data Acquisition Parameters

Table 4: Tabulated GPR Interpreted Bedrock Depth Data

DRAFT

List of Figures

Figure 1: Site Map Showing ASR Alignment

Figure 2: Example of Ohm-Mapper and GPR Cross-Sections

Figure 3: Interpreted Cross-Sections

Figure 4: Interpreted ERI Line 1 Root Creek Crossing

Figure 5: Interpreted ERI Lines 2 and 3 Berens River Crossing

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Manitoba Floodway & East Side Road Authority (ESRA) to conduct a geophysical investigation along a proposed all-season road (ASR) alignment between Pauingassi and Little Grand Rapids First Nations Reserve Lands (FN) in Manitoba. The objective was to map the overburden soil type and bedrock profile along the entire alignment to assist with the design of the ASR.

2.0 METHODOLOGY

Based on the work required Golder proposed to complete this investigation in two phases using three different geophysical techniques as follows:

- Phase I – Ground penetrating radar and capacitively-coupled Electrical Resistivity Imaging along the entire alignment (where accessible); and
- Phase II – Wenner array Electrical Resistivity Imaging at two river crossings.

Golder designed the geophysical program to investigate bedrock up to depths of 10 metres below ground surface based on the Manitoba Geological Survey Quaternary Map indicating the Precambrian bedrock to be close to or at the surface over the majority of the alignment. The following sections describe the methodology of the geophysical equipment used to meet the objective of this investigation.

2.1 Ground Penetrating Radar

A Ground Penetrating Radar (GPR) system consists of two antennae (transmitter and receiver), control console, power supply, connecting cables and a computer for real-time, graphic display and data recording. In reflection profiling mode, the antennae, separated a fixed distance, are moved stepwise along a traverse and readings are taken at discrete intervals. At each step, pulses of radar frequency electromagnetic energy (megahertz range) are transmitted and reflections received where there is an abrupt change in the subsurface material dielectric permittivity such as at the interface between stratigraphic horizons or overburden and bedrock. The amplitude of received radar energy is recorded as a function of time, processed in real-time for display purposes, and the raw data recorded digitally for later processing and presentation.

GPR sections are presented as time-sections, with the position of each trace recorded as the horizontal axis across the top of the section and the GPR travel time (in nanoseconds, increasing downward) as the principal vertical axis. A second vertical axis is included to provide an estimate of depth or elevation and is calculated assuming a constant GPR velocity for the subsurface, which is obtained either through common-midpoint tests, comparison with ground-truth data such as borehole data or curve-matching on hyperbolic reflections.

The received GPR signal strength is strongly attenuated when travelling through conductive materials such as fine silts or clays. The depth of investigation of a GPR system is strongly affected by the electrical conductivity of the materials it travels through (the greater the conductivity, the shallower the depth of penetration).

2.2 Capacitively-coupled Electrical Resistivity Imaging

The Ohm-Mapper survey instrument is a capacitively-coupled Electrical Resistivity Imaging (ERI) system manufactured by Geometrics Inc. The transmitter and receiver array are towed behind the operator by snowmobile or on foot. Data are recorded by means of a digital data logger through a fibre-optic cable

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connected to the receiver array. Multiple passes can be made along the same survey line using different spacings (1, 2.5, 5 and/or 10 metre spacings) between the transmitter and receiver array to provide varying depths of investigation. Investigation depth is largely controlled by the transmitter-receiver separation and the electrical properties of the ground; increasing the distance between the transmitter and receiver increases penetration depth. The maximum possible transmitter-receiver separation is controlled by the ground conductivity, where an increase in ground conductivity (reciprocal of resistivity) tends to reduce the maximum separation and so reduces the maximum depth of investigation. Clay-rich soils and groundwater high in total dissolved solids can limit signal penetration.

The Ohm-Mapper is designed to measure subsurface resistivity, both laterally and vertically, without the use of electrodes traditionally employed in direct current resistivity systems. The technique is, therefore, not susceptible to many of the limitations encountered by electrode-based direct current systems, such as problems resulting from the high contact resistance that commonly occurs between the electrodes and frozen soils. The ERI system consists of an ungrounded transmitter, an array of 5 receivers and a data logger. An alternating current is coupled to the ground by the transmitter, inducing a current to flow within the ground. This secondary current, in turn, couples a current to the receiver array. The voltage that is measured by the receivers is proportional to the resistivity of the earth between the transmitter and receiver array.

2.3 Wenner Profile Electrical Resistivity Imaging

The electrical resistivity imaging (ERI) technique measures the electrical resistivity (reciprocal of conductivity) of the subsurface to infer rock/soil types, stratigraphy and soil conditions. The physical principles for this technique are the same as that established for direct-current (DC) resistivity, in which the apparent resistivity of the subsurface is calculated for increasing electrode separations by applying a current to the ground using two electrodes and measuring the potential difference (voltage) between two different electrodes.

Apparent resistivity is calculated from the potential to current ratio multiplied by a constant. This constant is a function of the electrode spacing and geometry. The depth of investigation possible is also a function of the electrode separation. Thus, with larger electrode separations, information from greater depths can be acquired, but at the cost of decreased resolution.

ERI differs from traditional DC sounding techniques in that a “spread” of electrodes (typically 56, 72 or more) are staked along a survey line and connected to a resistivity meter by a cable fitted with multiple take-outs. The resistivity meter is a computer-controlled device consisting of a current supply capable of producing a constant (+/-) current and a high impedance voltmeter.

A software sequencing routine on the resistivity meter switches current to the electrodes on and off as required throughout the measurement process. This equipment and procedure allows for automated collection of high density data along the entire spread. As the line of resistivity coverage is continued, cables from the start of the electrode array are moved (rolled) to the end and measurements are continued. By “leap-frogging” the array system along the survey line, a semi continuous pseudo-section of apparent resistivity values versus apparent depth beneath the profile line can be generated. These data are then inverted to calculate a two-dimensional resistivity model for the profile with modelled true depths and resistivity. RES2DINV is the computer program that is used to invert the survey data to determine two-dimensional resistivity models for the subsurface.

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The ERI survey results present an interpretable electrical resistivity model of the subsurface. Vertical and horizontal fractures or dissolution features within the bedrock are manifest on the interpreted results as zones of low resistivity within the bedrock.

The key difference between the two ERI systems deployed is regarding mobility. The Ohm-Mapper is a towed system providing much more rapid coverage suitable for large projects and alignments; whereas, the Syscal system requires electrodes to be hammered into the ground and static readings taken from one central measurement point more suitable for smaller specific areas and for deeper soundings.

3.0 FIELD WORK

The field work was carried out by personnel from the Golder Mississauga office in two separate trips. The Phase I work was completed from March 20 to April 3, 2014 and Phase II from July 29 to 31, 2014. The area of investigation was located along the ASR alignment that was cut recently in some areas and in previous years in other areas. The next section provides details regarding the condition of the alignment and positional control for this geophysical investigation.

3.1 Site Access & Positional Data

The initial intent was to collect continuous data with both the GPR and ERI systems along the entire 38 Km ASR. During Phase I, site and access conditions were not as expected or planned for. The crew attempted to collect data where snow cover was adequate to allow for quicker and greater ease of transport before tackling the more difficult areas. The end-result was a modified data acquisition plan that was not as productive as anticipated. The items below summarize these challenges in the order of impact on the geophysical survey.

Table 1: Factors Affecting Data Collection

Item	Issue	Impact/Consequence	Solution
1.	Inadequate snow cover: a) Presence of bare ground, rocks and stumps made it too rough to tow equipment by snowmobile. b) Snowmobiles overheating 5-10 times per day when travelling on sections without adequate snow-cover. c) Branches and 'bungy' stumps on ground with thin snow cover catch and damage cables.	Wasted days trying to collect data with snowmobile and costs incurred. Productivity about half what was expected.	a) Towing equipment by hand instead of snowmobiles (however, the friction on non-snow covered ground was much greater slowing the pace considerably). b) Frequent stops to cool snowmobile engines. c) Slow down

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Item	Issue	Impact/Consequence	Solution
2.	Only 3 access points to the entire ASR.	Half the day spent travelling to/from the work areas resulting in daily productivity about half what was expected.	
3.	No trails along north end of ASR.	Deep snow prevented ~3,700 line metres from being accessed.	Crew tried to collect more on foot in one area and ran back and forth with snowmobiles to try and create a packed down trail without success.
4.	Incomplete line-cutting: a) Middle Section –cut line impassable because of large branches, boulders and stumps at Maman Lake. b) South Section –only got to Cook Creek.	Could not collect data for ~1,700 line metres of the alignment from Maman Lake to Berens River. No data acquisition along ~9,200 line metres remaining south of Cook Creek.	
5.	Sharp turns along actual cut line that did not follow proposed ASR.	Slowed down ERI surveying by a factor of 4.	Long receiver array of ERI very difficult to navigate.
6.	No chainage markers along ASR to tie to geophysical surveys.	Discrepancies between proposed ASR chainage and GPS distances measured.	Crew collected geophysical data and cumulative distances based on computations from GPS data acquired simultaneously.
7.	Actual cut line not same as proposed ASR.	Some areas of ASR not surveyed. Actual chainage different than proposed chainage.	

All positional data regarding the geophysical surveys described below were captured using a Trimble GeoXH differential GPS system. Although the initial intent was to tie into a known monument and also to the chainage along the ASR, neither were possible because there were no control points along the alignment nor within the communities of Little Grand Rapids and Pauingassi. There were no marked pickets along the ASR present at the time of survey that could be picked up by our GPS system. The result is that the positional control of the data is based solely on GPS data and is therefore susceptible to the errors inherent to this type of data acquisition. In general, the GPS accuracy was on the order of 1 meter throughout the Phase I project although the range varied from ±0.2 to 5 metres. There were some stretches where no GPS signal was available resulting in interpolation between know locations.

As a result, the following items should be considered regarding positional information using the chainage:

1. The GPR and ERI data were acquired on separate days following very similar paths; however, the actual paths traversed may have deviated as much as a few metres given the width of the corridor.
2. The GPR and ERI were collected with a chainage starting at the south end of the ASR and increases going north. This is opposite to the chainage provided which starts at Pauingassi and heads south to LGR. Both chainage axes are provided on the drawings for reference.

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A sketch of the survey area showing surface features and the approximate location of the GPR survey lines is shown in Figure 1.

3.2 GPR Data

A total of 21 GPR line segments covering 20,777 line-metres were acquired during Phase I. The GPR data were acquired using a Sensors and Software pulseEKKO Pro GPR system with 100 MHz antennae sampling in time-based mode towed in a sled behind the operator (see Image 1).

Image 1: GPR System in Data Acquisition Mode.

The data were reviewed by the operator on site for quality control by means of the real-time visual display of data traces. The data acquisition parameters summarized in Table 2 below.

Table 2: GPR Data Acquisition Parameters

Parameter	GPR Antennae
System Centre Frequency	100 MHz
Antenna Separation	0.5 metres
Step Size along Line	0.03 to 0.50 metres
Number of Stacks	16
Antenna Orientation	Parallel to survey line

3.3 Capacitively-coupled ERI Data

A total of 22 ERI line segments covering 23,930 line-metres were acquired during Phase I. The ERI data were acquired using a Geometrics Ohm-Mapper X5 with one dipole separation and two different transmitter-receiver separator ropes for the single transmitter and 5 receiver array (see Image 2). Typically, data were acquired with one rope separation going in one-direction, then with the longer rope separation returning in the opposite direction.

Image 2: Ohm-Mapper ERI in Data Acquisition Mode.

The data acquisition parameters shown in Table 3 below were used to acquire the data:

Table 3: ERI Data Acquisition Parameters

Parameter	GPR Antennae
Dipole Length	5 metres
Tx-Rx Rope Separations	2.5 and 15 metres
Measurement Interval	1 second intervals

3.4 Wenner Profile ERI Data

The field work for the ERI surveys at Root Creek and at the Berens River Channel crossings consisted of a total of 3 ERI line segments covering 420 line-metres. The survey design and line layout was carried out using a Trimble GeoXH dGPS for positioning in the field. The lines were located using UTM coordinates provided by East Side Road Authority and are presented as insets on Figures 4 and 5. The elevation change along the resistivity lines were extracted from the topographic maps provided by the client.

Image 3: Syscal ERI setup.

The ERI data were collected using a SYSCAL R1 Plus Switch 72 channel resistivity system (manufactured by IRIS Instruments, France). The resistivity data were collected using a Wenner type electrode array which consists of equally spaced current and potential electrodes. The minimum electrode separation ('a' spacing) used was 2 metres at the Root Creek crossing and at the east side of the Berens River Channel crossing. The maximum 'a' spacing was 48 metres yielding a maximum depth of investigation of approximately 20 m below ground surface.

The electrode spacing used along the west side of the Berens River Channel crossing was reduced to 1 m because of the limited access available, yielding a maximum depth of investigation of 6 metres. Prior to starting each ERI survey line, continuity and contact resistance checks were made for all electrodes. Contact resistances at the electrodes during the survey were typically 10-15 K-ohms or less, which is considered acceptable. Because bedrock was at surface at a lot of locations, the electrodes were covered with moss and soaked with water to keep the contact resistances to an acceptable level.

Generally, the resistivity system was setup to pass enough current between the current electrodes to generate a measurable voltage at the potential electrodes in the range of 300 mV in order to yield data with the highest

possible signal to noise ratio. The resistivity data were analyzed for quality control in the field, at the time of the data collection. The weather was dry at the time of the survey.

At the Root Creek crossing, the bedrock slab was very close to surface as determined by visual observation (exposed bedrock) or electrode refusal (stakes hitting bedrock). No electrode refusal was noted along the north side of the Root Creek crossing. At the Berens River Channel, Golder was only able to survey on land on both sides of the river. The water level was too high along the east side and the current too strong to safely survey the river. Several attempts were made to deploy a rope across the river starting along the north side of the west river bank, but without success. Bedrock was observed at or near surface along most of Line 2 located on the west side of the channel. A large bedrock outcrop was observed about 10 m west of Line 2. Bedrock was not directly observed along the east side of the river but electrode refusal along most of the west part suggested shallow bedrock.

4.0 ANALYSIS AND RESULTS

The geophysical data were transferred from field data loggers, collated and sorted into files for further data processing as outlined in the sections below. The GPR data were processed and interpreted to map the bedrock topography whereas the ERI data were used to correlate the GPR data and to map near surface soil types.

4.1 GPR Data Analysis

The GPR data were processed and analyzed using the Reflex software package (Sandmeier). GPR data is most often presented as cross-sections showing energy reflections in time. A GPR velocity of 0.11 metres/nanosecond was used to calculate the depth/elevation scales. This velocity was estimated by fitting a theoretical hyperbola to a well-defined point source reflection in the data and is consistent with values for soils encountered at similar sites. An example GPR profile is shown in Figure 2 showing some of the features identified.

Data processing consisted of the following:

- Remove poor quality traces;
- Interpolate small (<2 metre) gaps;
- Smooth the data both temporally and spatially with a simple 3-point running average;
- ‘Dewow’ the data to remove low frequency saturation;
- Apply GPS positioning (X and Y) to the data traces;
- Apply topography (Z) from the digital elevation model data provide by LiDAR;
- Stitch together the GPR sections; and
- Apply a spreading exponential compensation gain.

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Soil and bedrock interfaces are manifested within GPR data as a continuous reflector that mimics the actual horizon. The GPR response from weathered/glaciated bedrock is often comprised of a series of continuous hyperbolic reflections given the blocky, fractured nature of the near surface.

The following summarizes the GPR data acquired during Phase I of this geophysical investigation:

- GPR signal penetration ranged between 3 and 15 metres below ground surface;
- Many fractures within the bedrock could be seen in the GPR data particularly when bedrock was near the ground surface;
- The above-ground hydro wires could be seen in the data at certain locations (often mimicking a subsurface reflector); and
- High-frequency reverberations are present in the GPR profiles where water was at or near surface.

4.2 Capacitively-coupled ERI Data Analysis

The ERI data were initially edited and smoothed using MagMap2000 v4.92 manufactured by Geometrics. Data were de-spiked to remove spurious data points and then passed through a spline filter to smooth the data curves. The elevations along the resistivity lines were extracted from the topography data provided by ESRA, using the GPS positions collected along each resistivity line at the time of the survey. The elevation data were combined with the resistivity data to include topography along the lines in the model results. The resistivity results were modelled using the inversion program RES2DINV, an industry standard software package developed by Dr. M. H. Loke. A least-squares finite-element inversion (Loke and Barker, 1996) was applied to the edited data to convert apparent resistivity data to “true” resistivity resolved at “true” depth. No constraints were put on the model during the inversion process since borehole data were not available. The ERI models were contoured using the Surfer Surface Mapping System (Golder Software) using a Kriging algorithm. The contoured models were then imported to AutoCAD (Autodesk) for interpretation and presentation.

The resultant resistivity sections were then plotted as cross-sections using the Golden Software’s Surfer v10 surface mapping program. An example ERI profile is shown in Figure 2 showing some of the features identified.

An overburden soil legend was established based on the range of resistivity observed in the ERI data and broken down into four basic soil types as follows:

- Interpreted Sandy Soil or Shallow Bedrock (high resistivity - highlighted in yellow)
- Interpreted Sandy-Silt (moderate resistivity - highlighted in brown)
- Interpreted Silty and Clayey Soil (low resistivity - highlighted in green)
- Interpreted Clayey Soil (very low resistivity - highlighted in blue)

4.3 Wenner Profile ERI Data Analysis

The ERI data were initially processed to remove spurious data points. Spurious data points can be caused by several factors, including, the presence of localized buried metal objects (wires, fences, utilities), poor coupling of electrodes to the ground, and the influence of infrastructure. Less than 0.5% of the readings along the ERI survey line were removed from the data set.

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The ERI data were modelled using RES2DINV (an inversion algorithm coded by M.H. Loke and distributed by Geotomo Software) to produce true depth versus resistivity sections. The elevation data were combined with the ERI data to include topography along the line in the model results. These model results were then contoured (using Surfer by Golden Software) in section to generate the sections presented on the attached figures. The RMS errors associated with the final resistivity inversions were on average about 4% after 5 iterations.

4.4 Interpretation and Results

4.4.1 Phase I

For the Phase I investigation, the combined interpretation of the GPR and ERI data is presented in Figures 3A through 3F. It is presented in sections approximately 5,000 metres long with chainage (the proposed ASR) and distance (the geophysical linear chainage) horizontal axes and metres above sea level (masl) as a vertical axis. Each figure shows the GPR cross-section with the surface topography and interpreted bedrock topography superposed. Key maps indicate where along the ASR alignment the sections are from. No borehole information, necessary to correlate the lithology of the site with the resistivity and GPR sections, was available at the time of this draft report. As such, results should be considered preliminary pending the availability and cross-correlation of intrusive investigations.

The bedrock topography undulates along the entire alignment with a range of interpreted minimum and maximum bedrock thickness of 0.9 and 13.6 metres respectively. Note that there were many locations where bedrock was exposed at surface yet the geophysical interpretation indicates a bedrock depth otherwise. This is an result of the inability to track a GPR reflector less than approximately 1 metre below ground surface because of interference with the transmit pulse between the transmitting and receiving antennas. Also, there are several gaps where the bedrock depth was not mapped because GPR data were not acquired for the reasons discussed in Section 3.1. These gaps (and plans to acquire data along them) are addressed in the next section of this report.

The overburden soils (shown interpreted across the chainage axis) loosely correlate with the interpreted bedrock topography. Where the bedrock is shallow, the resistivity was higher due to the presence of either sandy or sandy-slity overburden soils or near surface bedrock, and; where the bedrock is deep, the resistivity was lower due to the presence of silty or clayey overburden soils.

Table 4 attached tabulates the bedrock elevation at 100 metre intervals using the proposed ASR alignment chainage values provided. The values were calculated using a running average using equal weighting for ±50 metres either side of each and every data point.

4.4.2 Phase II

For the Phase II investigation, the interpreted results of the ERI data at Root Creek and Berens River Channel are shown on Figures 4 and 5 respectively. The depth to bedrock along the resistivity line is interpreted based on field observations, and on the very high resistivity of granitic bedrock and assumes that the bedrock composition is relatively consistent along the survey lines. The interpreted bedrock is presented as a high resistivity layer at the top part of the bedrock with values greater than 2,000 Ohm-metres with typical values around 10,000 Ohm-metres.

At Root Creek (ERI Line 1), except for a small overburden pocket located near chainage 60, the results along the south side of the river indicate that bedrock is within 0.1 metres from the surface. Along the north side, the

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bedrock surface appears to be deeper to a maximum of 7 metres below ground between chainage 155 and 180. The bedrock surface appears to become shallow again north of chainage 190, an observation that is corroborated by the presence of a bedrock outcrop at approximately 10 metres north of the line. A few lower resistivity pockets within the bedrock like the one just below the river are interpreted to indicate the presence of fractured/weathered zones.

Along the west side of the Berens River (ERI Line 2), bedrock is interpreted to be within 0.1 metres of surface. Along the east side of the river (ERI Line 3), bedrock is also interpreted to be near surface along most of the line. A small zone between chainage 85 and 120 indicates the presence a thin layer of overburden. There is also a lower resistivity layer at depth with values less than 1,000 Ohm-metres between chainage 70 and 120. Without borehole data, it is unknown what this represents at this time.

Water depth was measured at two locations within the Berens River Channel. The water was 3.5 and 4.0 metres deep at UTM locations 331,145E / 5,770,466N, and 331,137E / 5,770,466N respectively.

5.0 CONCLUSION & RECOMMENDATIONS

This geophysical investigation was able to successfully map the overburden strata and bedrock depth profile along approximately 23,930 line-metres of the ASR alignment.

The potential work remaining is as follows:

- Collect additional GPR data along gaps and near the river crossings (where access permits) along approximately 8,500 line-metres of the ASR. This does not include the southern leg of the portion into Little Grand Rapids FN.
- Collect additional ERI data along gaps (where access permits) at approximately 5,000 line-metres of the ASR. This does not include the southern leg of the portion into Little Grand Rapids FN.
- Collect additional ERI data Across the Berens River Channel during shallow water level season.

6.0 LIMITATIONS OF USE

The geophysical interpretation presented in this report is based on the use of geophysical surveying. As with any geophysical method, interpretation presented in this report should be confirmed by intrusive methods (boreholes, test pits, etc.)

Assumptions made in the geophysical interpretation have been stated, where applicable, throughout the report.

This geophysical survey was carried out in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practising under similar conditions, subject to the time limits and financial and physical constraints applicable to the services provided. This report provides a professional opinion and therefore no warranty is either expressed, implied, or made as to the conclusions, advice, and recommendations offered.

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Any use of the information within this report made by a third party, or any reliance on, or decisions to be made based on it, are the sole responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this letter.

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TABLE 4

Tabulated GPR Interpreted Bedrock Depth Data

(Chainage 0+500 to 26+300)

Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)
0+500	1.5	4+500	-	8+500	2.6	12+500	1.9
0+600	4.0	4+600	-	8+600	4.4	12+600	3.4
0+700	2.9	4+700	-	8+700	4.0	12+700	2.5
0+800	8.1	4+800	-	8+800	4.0	12+800	1.7
0+900	10.8	4+900	-	8+900	4.1	12+900	1.5
1+000	3.0	5+000	-	9+000	4.4	13+000	2.6
1+100	13.6	5+100	-	9+100	3.2	13+100	2.4
1+200	3.4	5+200	-	9+200	2.3	13+200	2.9
1+300	2.6	5+300	-	9+300	3.7	13+300	2.7
1+400	3.0	5+400	-	9+400	2.8	13+400	2.1
1+500	4.4	5+500	-	9+500	3.4	13+500	1.8
1+600	4.5	5+600	-	9+600	3.1	13+600	1.9
1+700	2.3	5+700	-	9+700	3.3	13+700	1.9
1+800	2.6	5+800	-	9+800	3.5	13+800	2.0
1+900	4.0	5+900	-	9+900	3.7	13+900	1.8
2+000	1.9	6+000	-	10+000	4.4	14+000	2.7
2+100	5.2	6+100	-	10+100	4.9	14+100	2.2
2+200	1.5	6+200	-	10+200	3.6	14+200	1.8
2+300	4.9	6+300	-	10+300	3.3	14+300	2.6
2+400	3.4	6+400	1.1	10+400	3.4	14+400	3.6
2+500	1.5	6+500	3.3	10+500	2.1	14+500	1.6
2+600	1.9	6+600	3.0	10+600	1.5	14+600	1.5
2+700	2.0	6+700	2.3	10+700	2.0	14+700	1.9
2+800	-	6+800	3.0	10+800	1.5	14+800	3.6
2+900	-	6+900	3.2	10+900	5.0	14+900	5.1
3+000	-	7+000	2.0	11+000	2.8	15+000	3.4
3+100	-	7+100	1.5	11+100	1.7	15+100	2.7
3+200	-	7+200	1.7	11+200	1.6	15+200	2.4
3+300	-	7+300	2.9	11+300	1.4	15+300	4.2
3+400	-	7+400	1.5	11+400	1.9	15+400	5.4
3+500	-	7+500	1.4	11+500	1.8	15+500	2.5
3+600	-	7+600	1.3	11+600	2.0	15+600	2.3
3+700	-	7+700	1.1	11+700	2.6	15+700	2.3
3+800	-	7+800	0.9	11+800	1.9	15+800	1.9
3+900	-	7+900	1.4	11+900	1.8	15+900	1.7
4+000	-	8+000	1.5	12+000	2.0	16+000	1.4
4+100	-	8+100	1.6	12+100	2.0	16+100	4.0
4+200	-	8+200	2.8	12+200	2.5	16+200	5.0
4+300	-	8+300	4.0	12+300	4.5	16+300	3.4
4+400	-	8+400	2.5	12+400	2.1	16+400	4.7

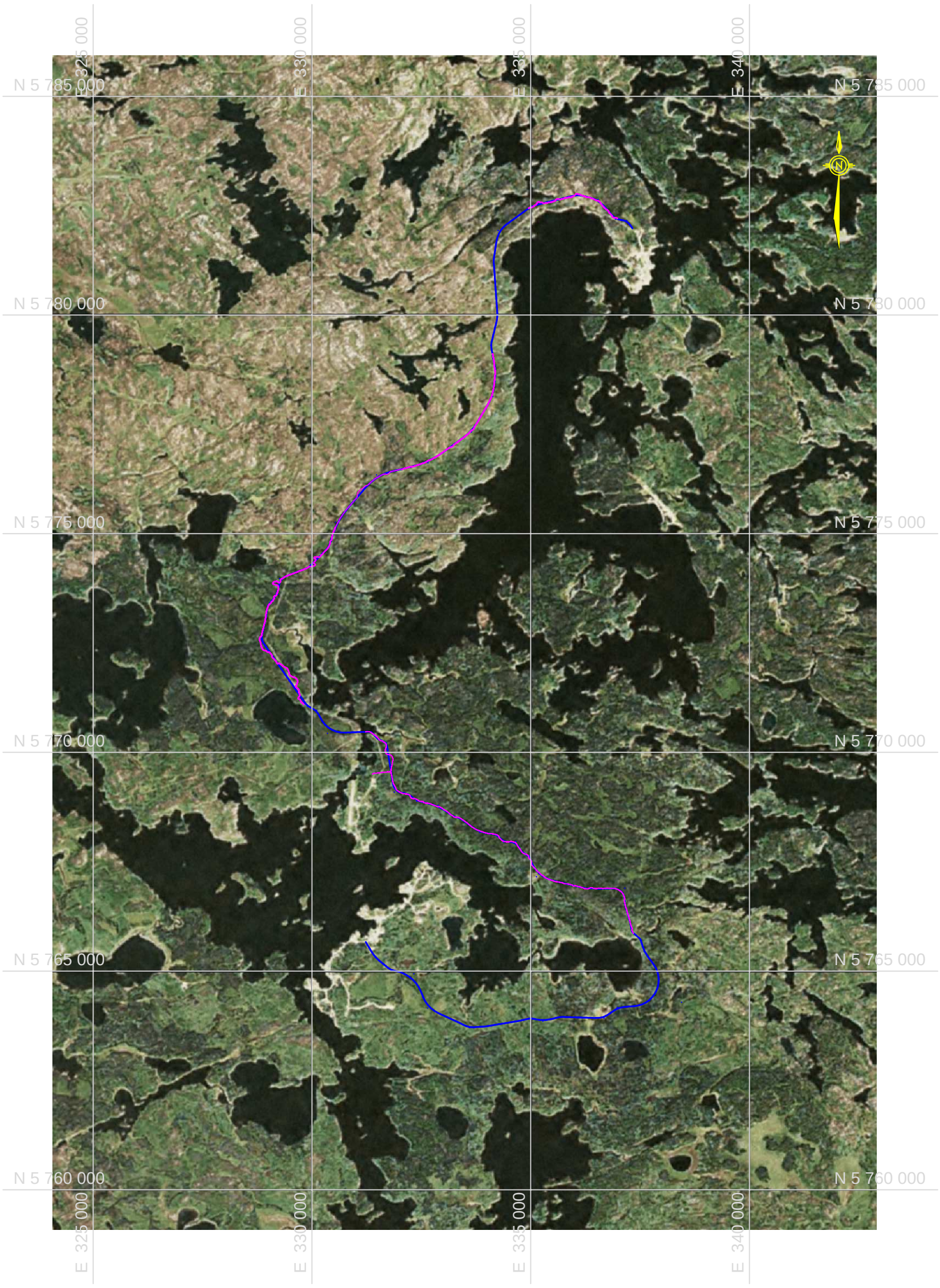
TABLE 4

Tabulated GPR Interpreted Bedrock Depth Data

(Chainage 0+500 to 26+300)

Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)	Survey Chainage (m)	Average Bedrock Depth (m)
16+500	5.2	20+600	4.8	24+600	2.8		
16+600	3.3	20+700	10.0	24+700	1.6		
16+700	2.5	20+800	5.9	24+800	1.7		
16+800	3.0	20+900	1.7	24+900	2.0		
16+900	2.8	21+000	1.8	25+000	2.0		
17+000	3.1	21+100	1.2	25+100	2.2		
17+100	1.8	21+200	1.7	25+200	3.2		
17+200	2.7	21+300	1.6	25+300	1.4		
17+300	3.8	21+400	2.0	25+400	1.4		
17+400	-	21+500	1.5	25+500	2.6		
17+500	-	21+600	1.9	25+600	2.5		
17+600	-	21+700	1.6	25+700	3.8		
17+700	-	21+800	2.0	25+800	1.3		
17+800	-	21+900	1.6	25+900	2.4		
17+900	-	22+000	0.9	26+000	1.9		
18+000	-	22+100	-	26+100	3.3		
18+100	-	22+200	-	26+200	4.3		
18+200	-	22+300	-	26+300	2.6		
18+300	-	22+400	-	26+400	-		
18+400	-	22+500	-	26+500	-		
18+500	-	22+600	-	26+600	-		
18+600	-	22+700	-	26+700	-		
18+700	-	22+800	-	26+800	-		
18+800	-	22+900	3.1	26+900	-		
18+900	-	23+000	2.3	27+000	-		
19+000	-	23+100	2.0	27+100	-		
19+100	-	23+200	3.8	27+200	-		
19+200	-	23+300	1.6	27+300	-		
19+400	2.5	23+400	2.3	27+400	-		
19+500	3.0	23+500	3.1	27+500	-		
19+600	2.5	23+600	1.7				
19+700	2.5	23+700	2.8				
19+800	2.1	23+800	4.5				
19+900	1.8	23+900	2.9				
20+000	2.3	24+000	5.7				
20+100	1.5	24+100	1.5				
20+200	1.7	24+200	3.5				
20+300	3.1	24+300	2.5				
20+400	4.8	24+400	2.4				
20+500	3.1	24+500	3.6				

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 1_Site Map.dwg



Legend

Ohm-Mapper Line

Proposed Alignment

Notes

1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the proposed alignment provided by the client

0 1500 3000 4500 metres

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Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	MAY 2014
DESIGN	SS
CAD	SS
CHECK	PG
REVIEW	CRP

FILE No. Figure 1_Site Map.dwg
PROJECT No. 14-1165-0002 REV.

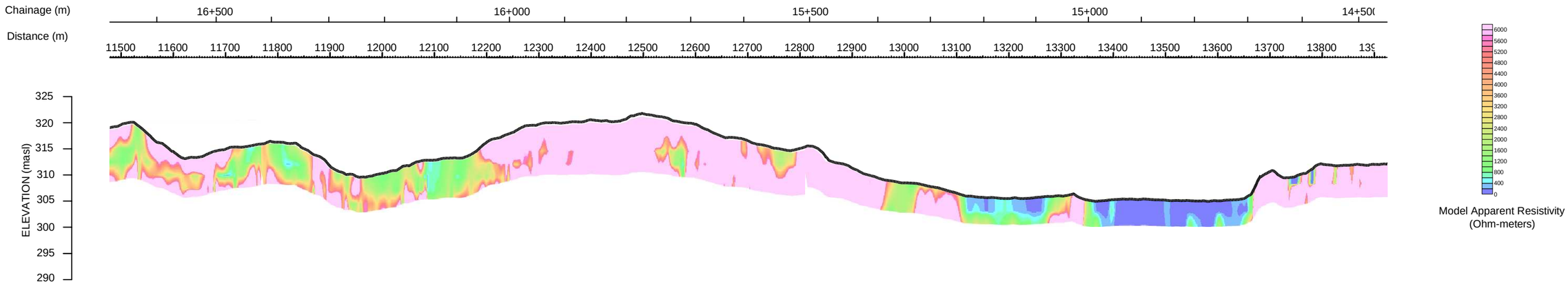
TITLE

SITE MAP SHOWING ASR ALIGNMENT

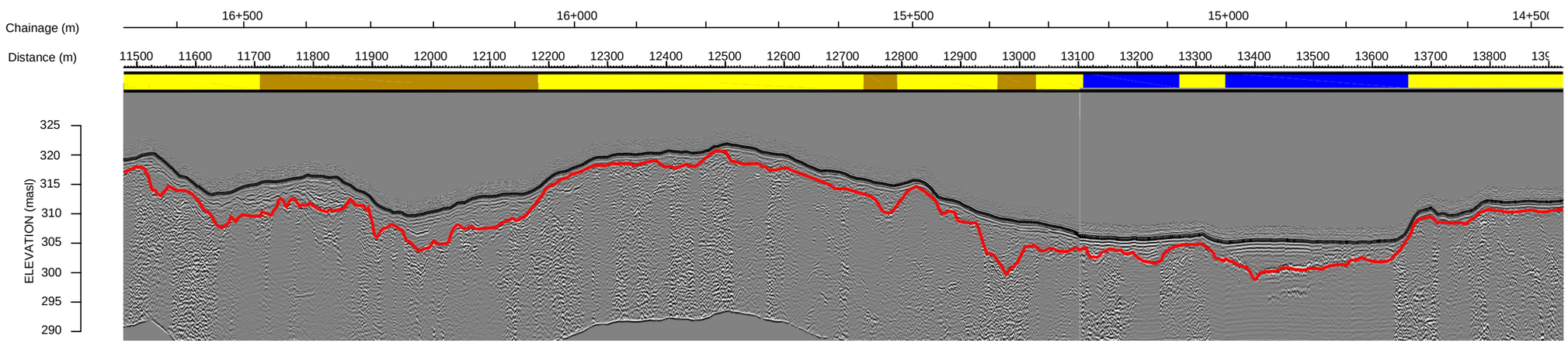
East Side Road Authority

FIGURE 1

OHM.MAPPER - SURVEY RESULTS



GPR - SURVEY RESULTS



Legend

- Ohm-Mapper line
- Proposed Alignment

Notes

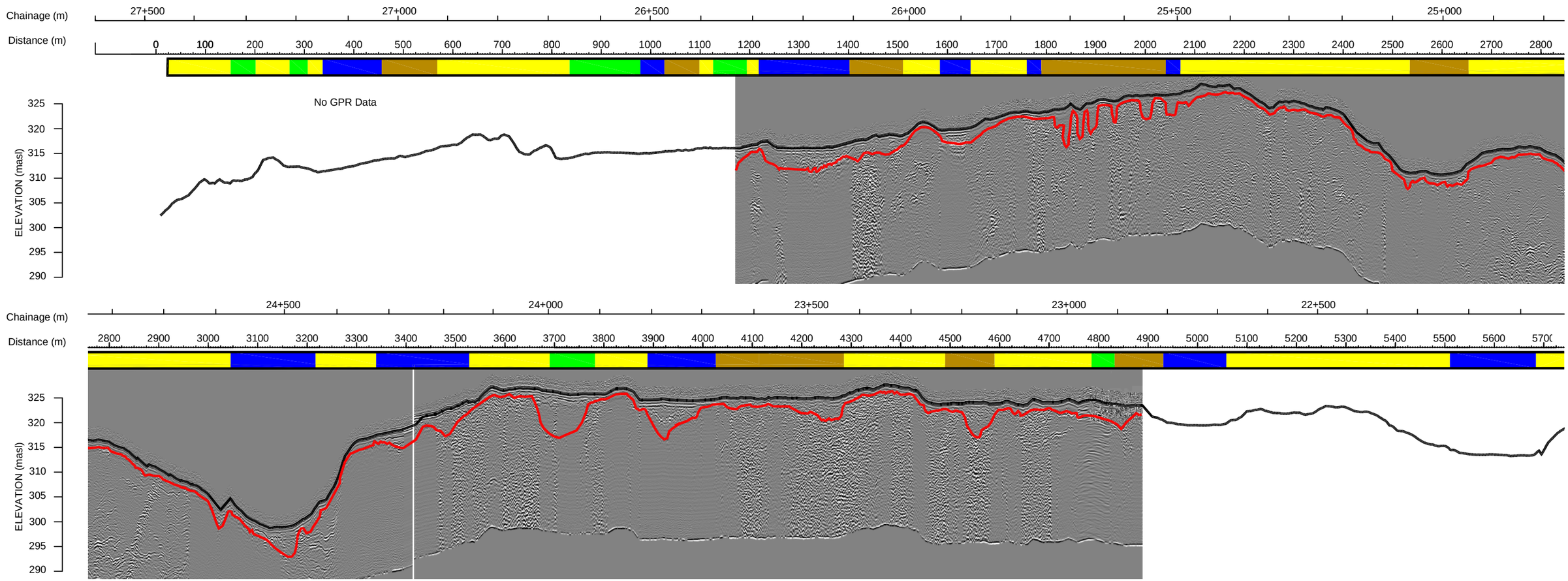
1. Data presented in NAD83 UTM Zone 15N (metric)

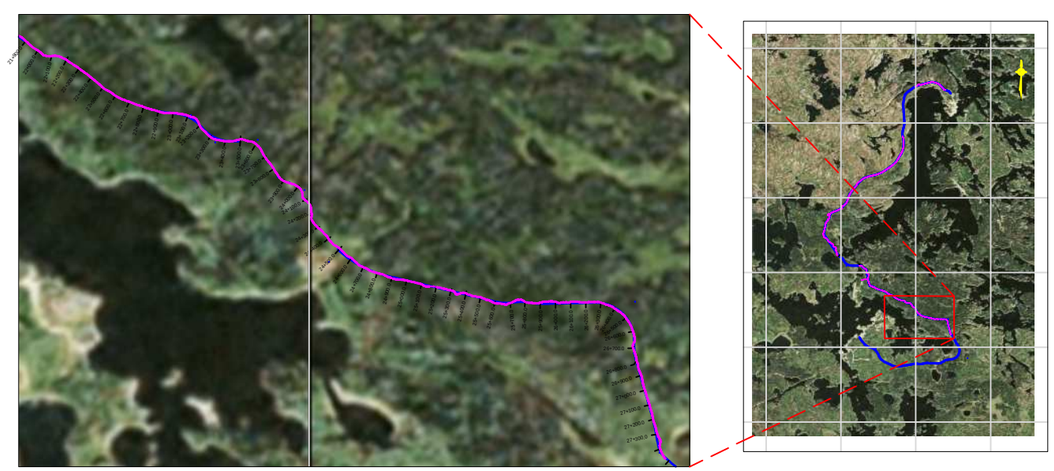
Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Golder Associates, Mississauga, Ontario, Canada	SCALE AS SHOWN	TITLE	
	DATE MAY 2014	EXAMPLE OF OHM-MAPPER ERI AND GPR SECTIONS	
	DESIGN SS		
	CAD SS		
FILE No. Figure 2_Example.dwg	CHECK PG	East Side Road Authority	FIGURE 2
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 2_Example.dwg





Legend

- Ohm-Mapper Line
- Proposed Alignment
- Ground Surface
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Notes

1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

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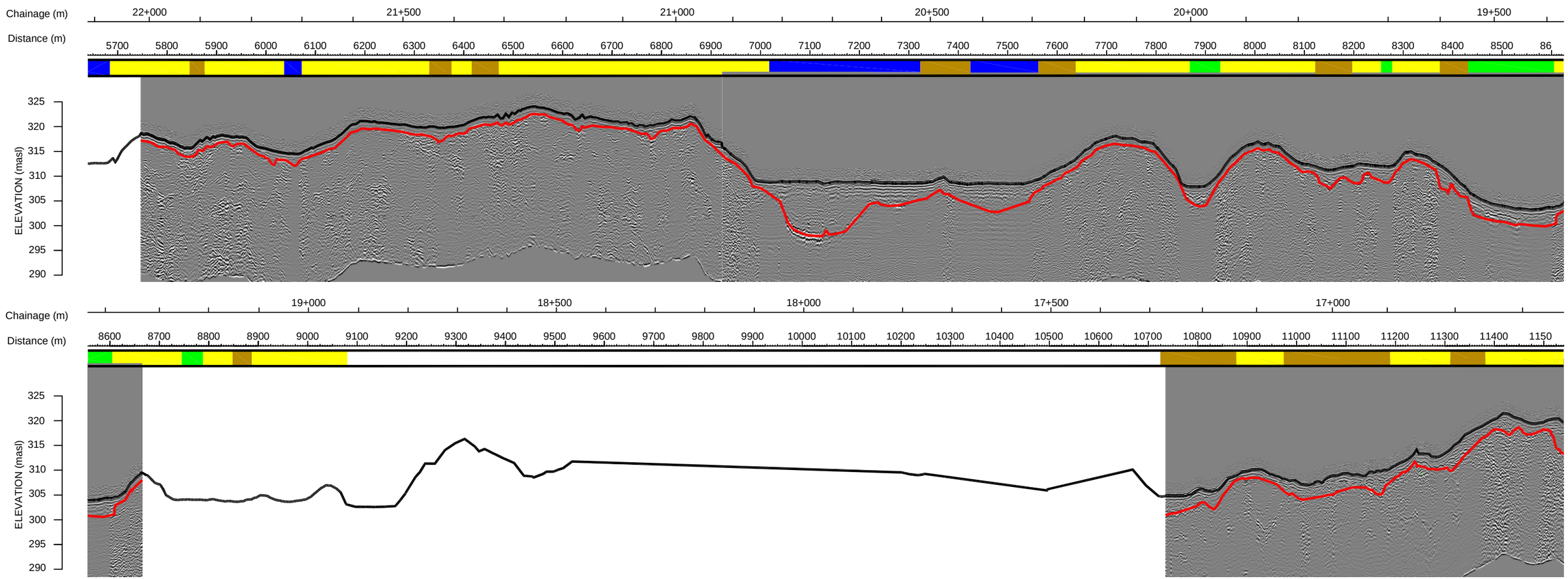
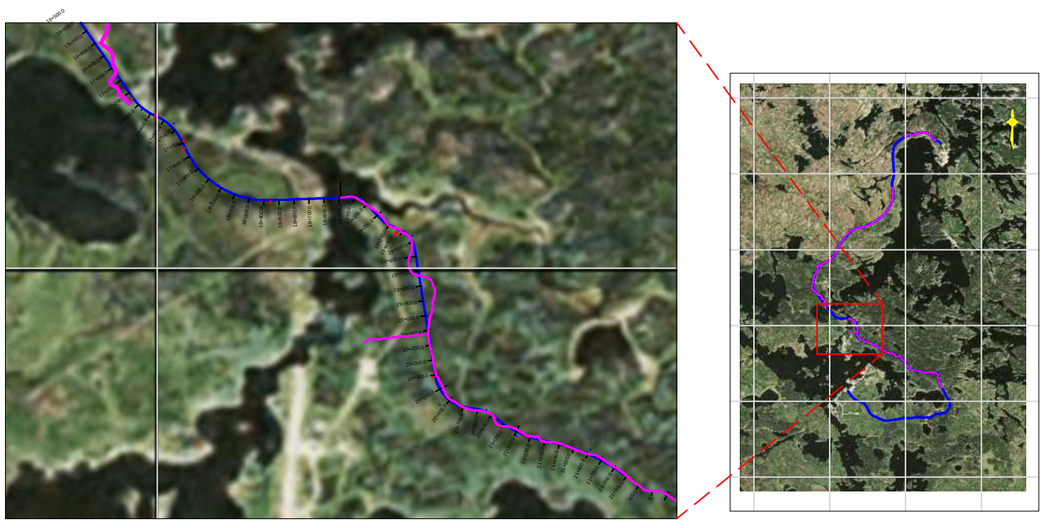
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	INTERPRETED CROSS-SECTION CHAINAGE 27+500 to 22+100
DATE	MAY 2014		
DESIGN	SS		
CAD	SS		
FILE No. Figure 3_Data_v7.dwg	CHECK PG	East Side Road Authority	FIGURE 3A
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg





Legend

- Ohm-Mapper Line
- Ground Surface
- Proposed Alignment
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Notes

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2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

Golder Associates
Mississauga, Ontario, Canada

FILE No. Figure 3_Data_v7.dwg		SCALE	AS SHOWN
		DATE	MAY 2014
		DESIGN	SS
		CAD	SS
PROJECT No. 14-1165-0002	REV.	CHECK	PG
		REVIEW	CRP

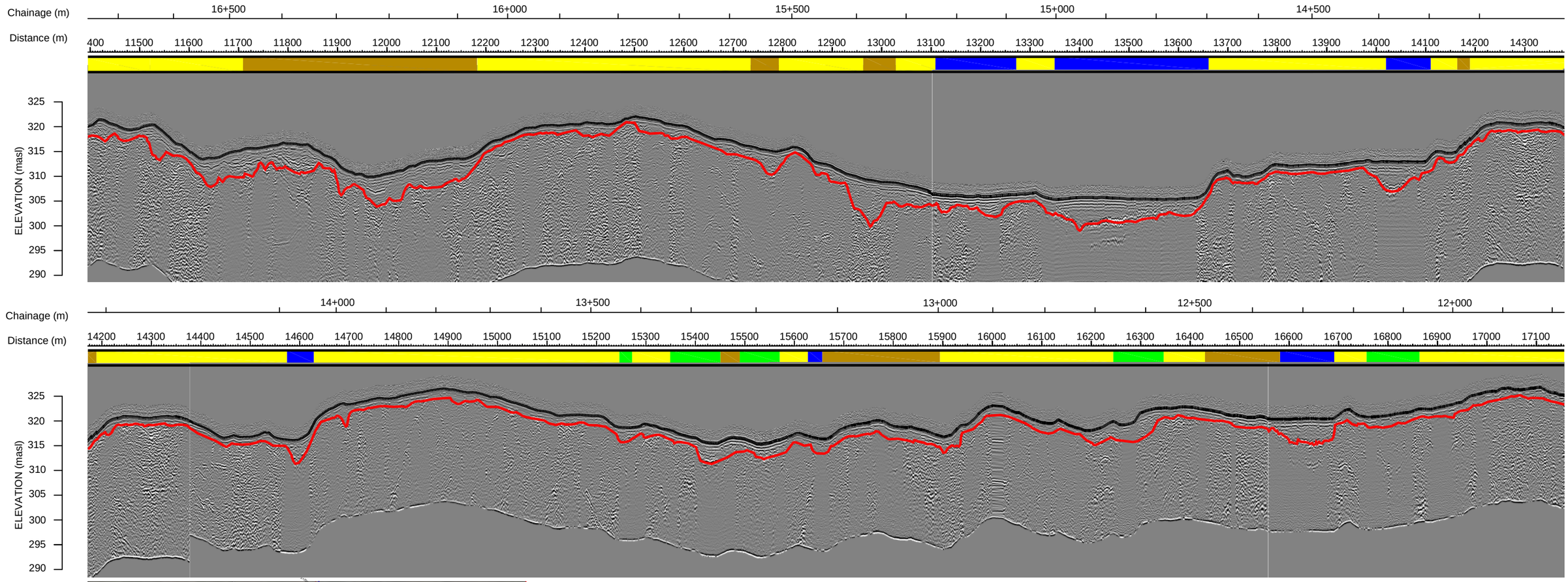
TITLE

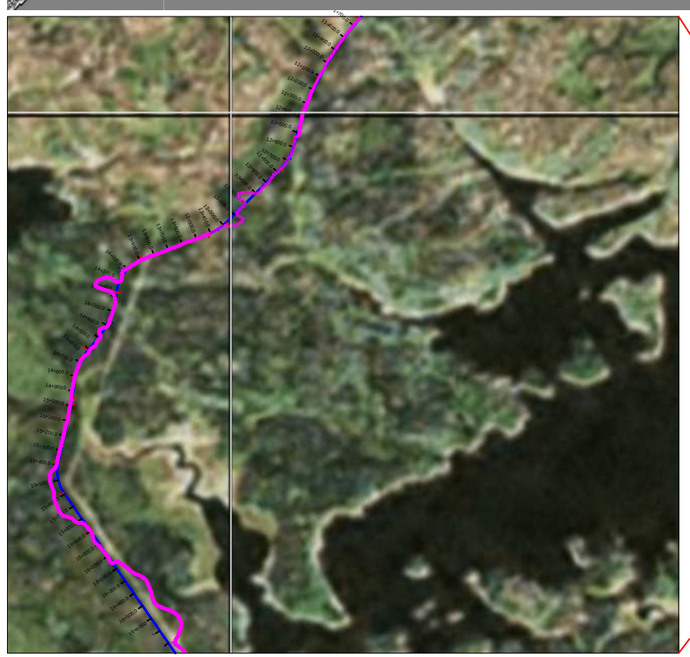
INTERPRETED CROSS-SECTION CHAINAGE 22+100 to 16+700

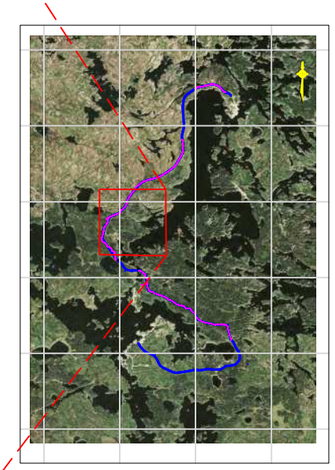
East Side Road Authority

FIGURE **3B**

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg







Legend

- Ohm-Mapper Line
- Ground Surface
- Proposed Alignment
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Notes

1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

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Mississauga, Ontario, Canada

FILE No.	Figure 3_Data_v7.dwg	SCALE	AS SHOWN
PROJECT No.	14-1165-0002	REV.	
		DATE	MAY 2014
		DESIGN	SS
		CAD	SS
		CHECK	PG
		REVIEW	CRP

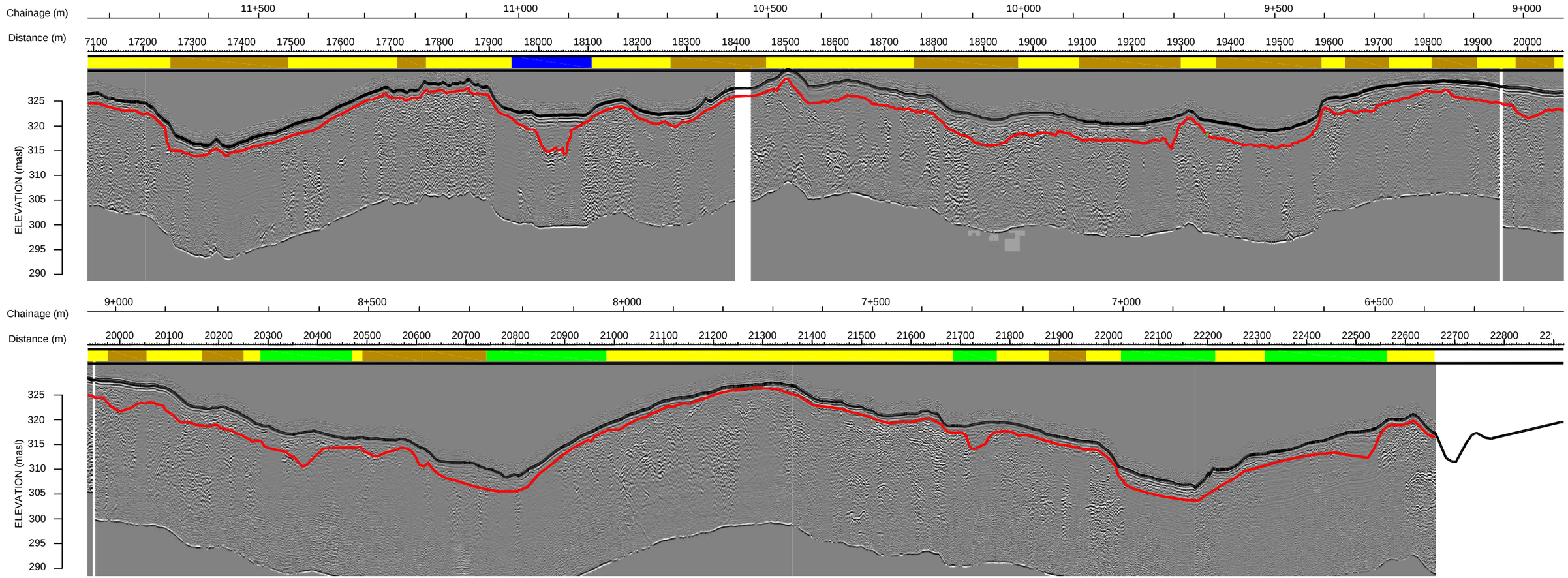
TITLE

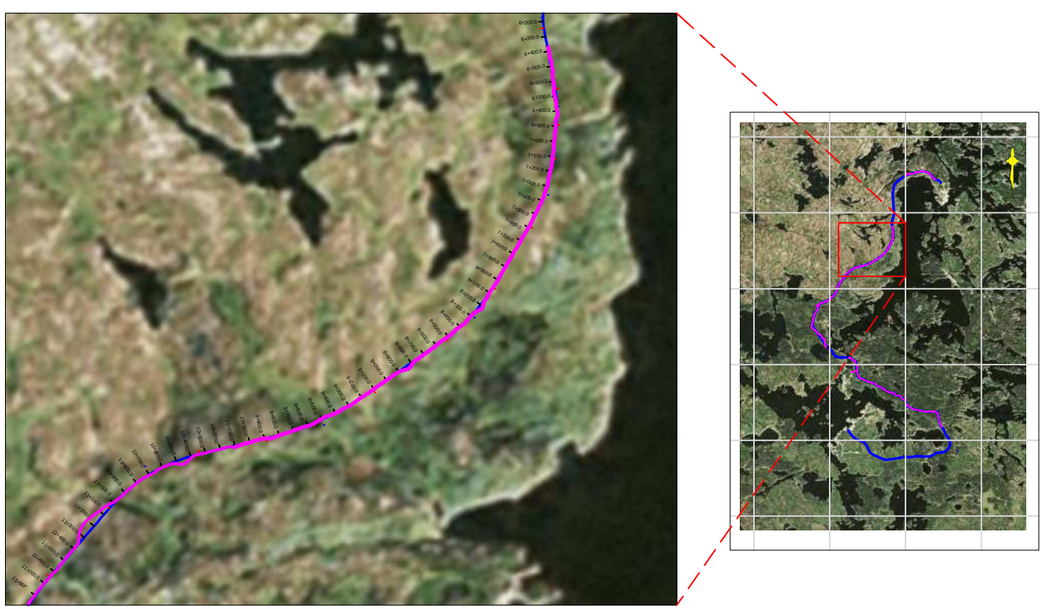
INTERPRETED CROSS-SECTION CHAINAGE 16+700 to 11+800

East Side Road Authority

FIGURE 3C

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg





Legend

- Ohm-Mapper Line
- Ground Surface
- Proposed Alignment
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Notes

1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

Golder Associates
Mississauga, Ontario, Canada

FILE No.	Figure 3_Data_v7.dwg	SCALE	AS SHOWN
PROJECT No.	14-1165-0002	REV.	
		DATE	MAY 2014
		DESIGN	SS
		CAD	SS
		CHECK	PG
		REVIEW	CRP

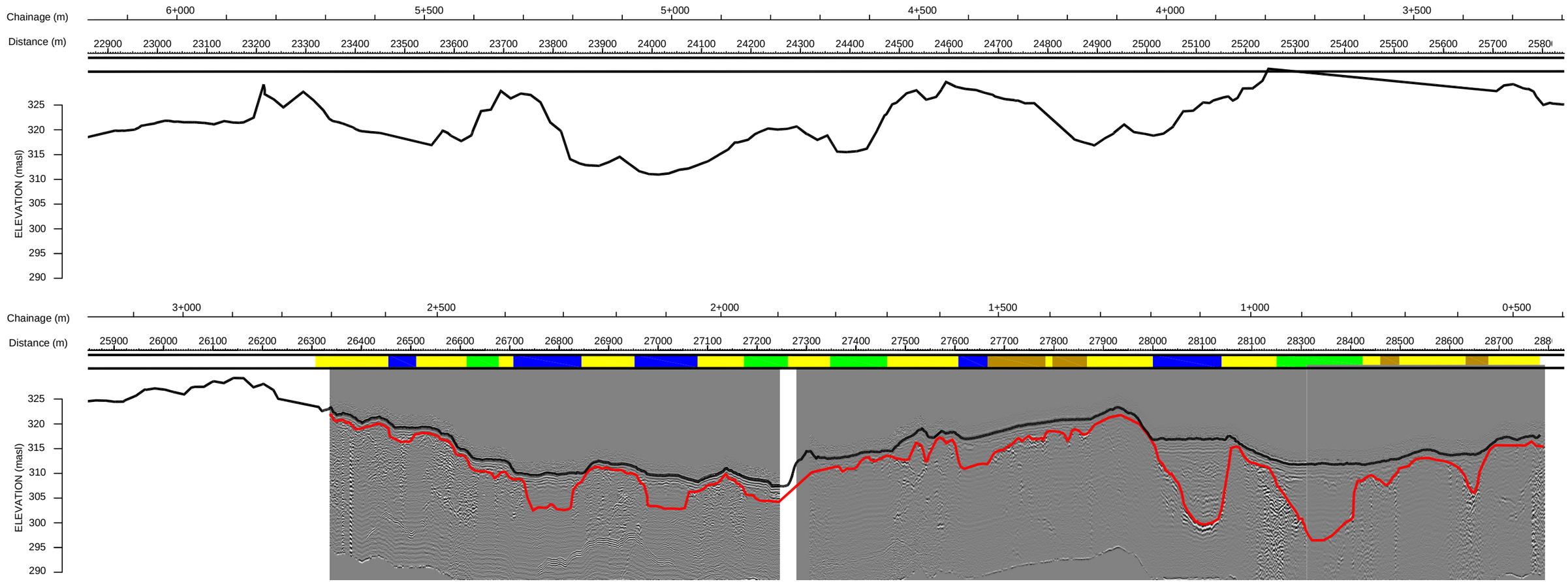
TITLE

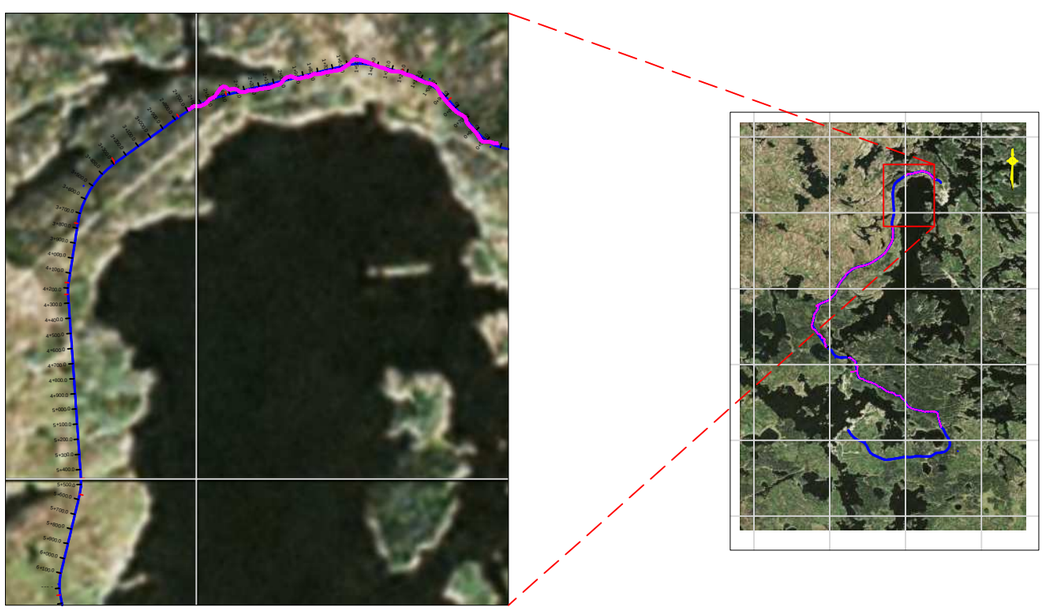
INTERPRETED CROSS-SECTION CHAINAGE 11+800 to 6+200

East Side Road Authority

FIGURE **3D**

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg





Legend

- Ohm-Mapper Line
- Ground Surface
- Proposed Alignment
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

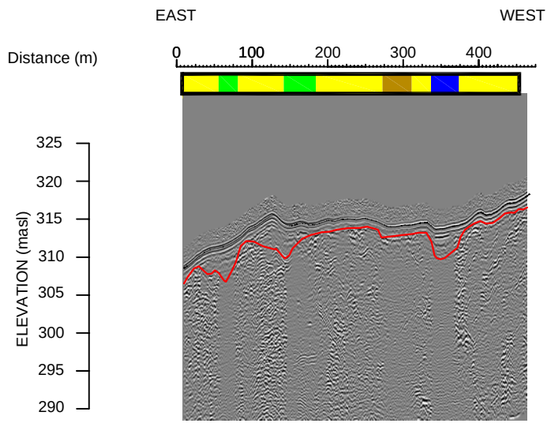
Notes

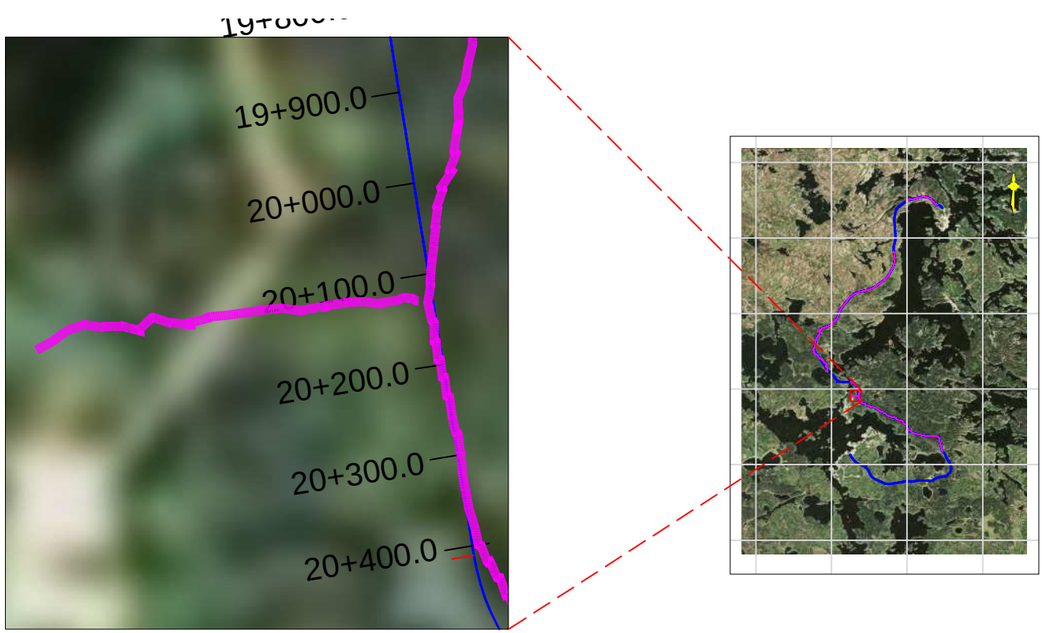
1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	INTERPRETED CROSS-SECTION CHAINAGE 6+200 to 0+400
DATE	MAY 2014		
DESIGN	SS		
CAD	SS		
FILE No. Figure 3_Data_v7.dwg	CHECK PG	East Side Road Authority	FIGURE 3E
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg





Legend

- Ohm-Mapper Line
- Ground Surface
- Proposed Alignment
- Interpreted Bedrock Surface

Overburden Legend

- Interpreted Sandy Soil or Shallow Bedrock
- Interpreted Sandy-Silty Soil
- Interpreted Silty-Clayey Soil
- Interpreted Clayey Soil

Notes

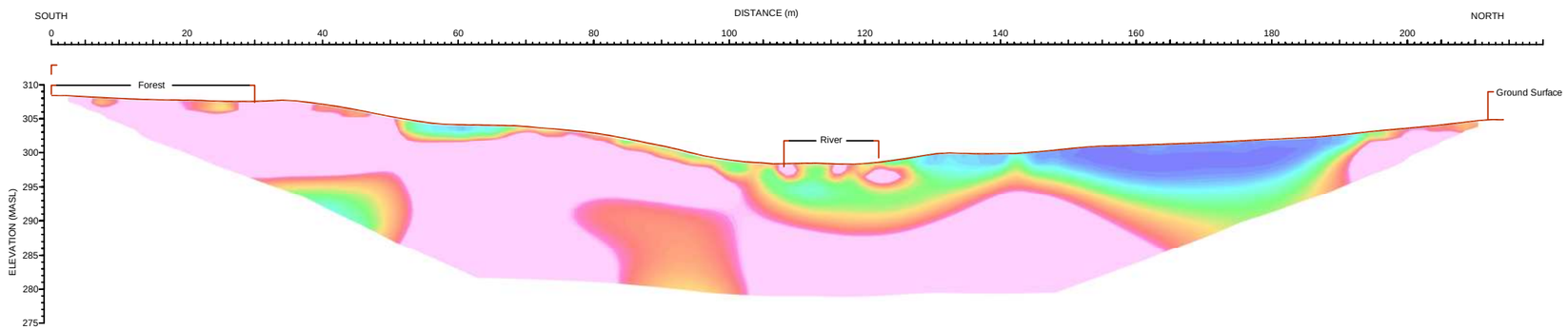
1. This figure should be read in conjunction with the accompanying report
2. Data presented in NAD83 UTM Zone 15N (metric)
3. Geophysical lines located using dGPS
4. Location of the chainage along proposed alignment provided by client

Golder Associates
Mississauga, Ontario, Canada

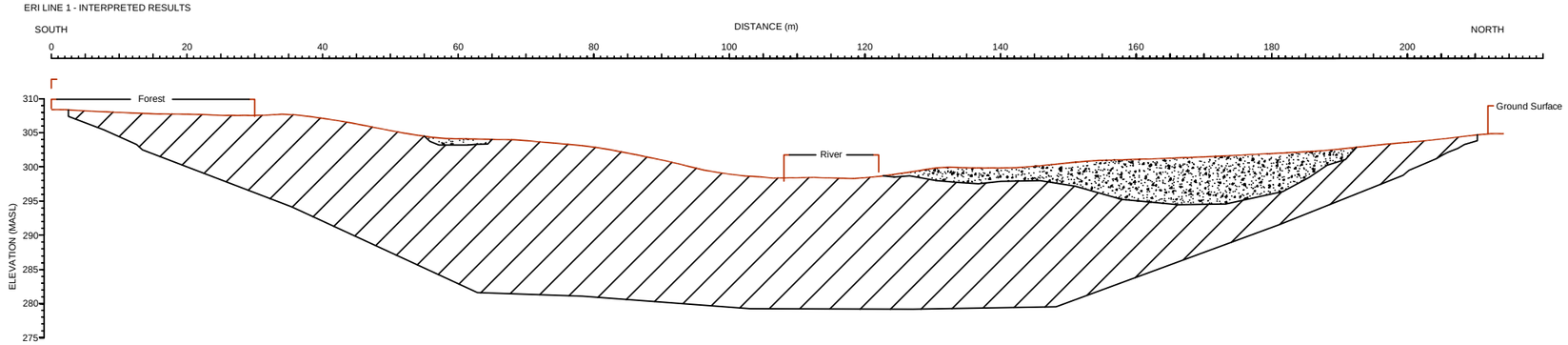
SCALE	AS SHOWN	TITLE	INTERPRETED CROSS-SECTION ON WESTERLY SPUR AT CHAINAGE 20+129
DATE	MAY 2014		
DESIGN	SS		
CAD	SS		
FILE No. Figure 3_Data_v7.dwg	CHECK PG	East Side Road Authority	FIGURE 3F
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

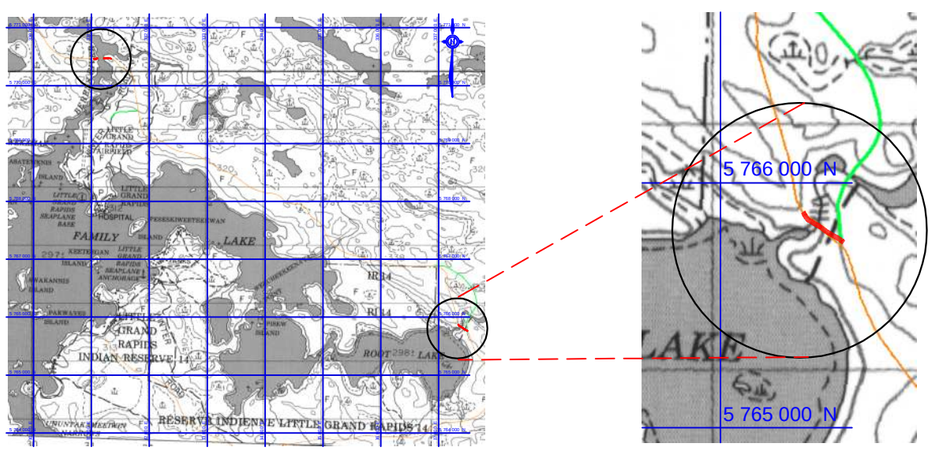
PLOT DATE: June 03, 2014
FILENAME: \\golder.gds\gal\Mississauga\Active\2014\1165\14-1165-0002 MFESRA Geophysics\Reporting\CAD\Figure 3_Data_v7.dwg

ERI LINE 1 - SURVEY RESULTS



ERI LINE 1 - INTERPRETED RESULTS





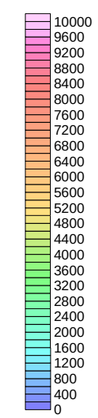
LEGEND SECTIONS

- Interpreted Unconsolidated Layer
- Interpreted Bedrock Layer
- ERI LINE

NOTES

1. This Figure is to be analyzed in conjunction with the accompanying report.
2. ERI data collected using an Iris Instruments SYSCAL R1 Plus resistivity meter.
3. ERI section generated using the Res2D Software Package.
4. Elevations of the ERI lines presented based on topographic data provided by East Side Road Authority.

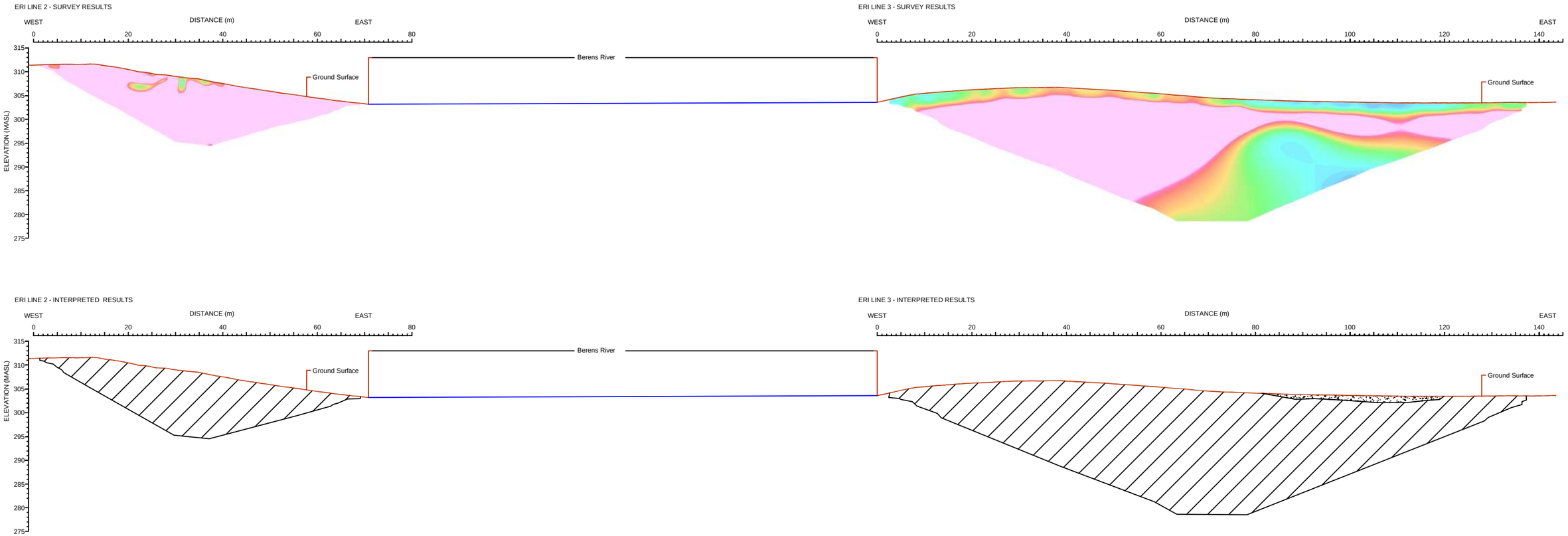
10 0 10 20
SCALE METRES

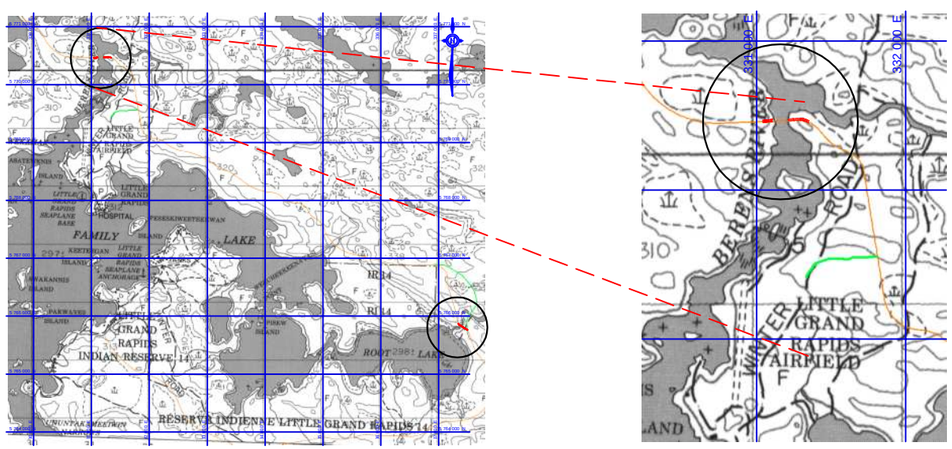


Model Apparent Resistivity (Ohm-m)

Golder Associates, Mississauga, Ontario, Canada	SCALE AS SHOWN	TITLE	**INTERPRETED ERI LINE 1 ROOT CREEK CROSSING**
	DATE AUGUST 2014		
	DESIGN SS		
	CAD SS		
FILE No. Figure 4-5_River Crossings.dwg	CHECK PG	East Side Road Authority	FIGURE 4
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

PLOT DATE: August 26, 2014
FILENAME: N:\Active\2014\1165\14-1165-0002 MFESRA Geophysics\2014 JULY\Processing\CAD\Figure 4-5_River Crossings.dwg





LEGEND SECTIONS

- Interpreted Unconsolidated Layer
- Interpreted Bedrock Layer
- ERI LINE

NOTES

1. This Figure is to be analyzed in conjunction with the accompanying report.
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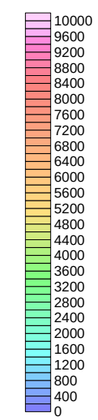
3. ERI section generated using the Res2D Software Package.
4. Elevations of the ERI lines presented based on topographic data provided by East Side Road Authority.

10 0 10 20
SCALE METRES



Model Apparent Resistivity (Ohm-m)

Golder Associates, Mississauga, Ontario, Canada	SCALE AS SHOWN	TITLE	
	DATE AUGUST 2014	INTERPRETED ERI LINES 2 AND 3 BERENS RIVER CROSSING	
	DESIGN SS		
	CAD SS		
FILE No. Figure 4-5_River Crossings.dwg	CHECK PG	East Side Road Authority	FIGURE 5
PROJECT No. 14-1165-0002 REV.	REVIEW CRP		

PLOT DATE: August 26, 2014
FILENAME: N:\Active\2014\1165\14-1165-0002 MFESRA Geophysics\2014 JULY\Processing\CAD\Figure 4-5_River Crossings.dwg

Report Signature Page

We trust that this report meets your needs at the present time. If you have any questions regarding this investigation, please contact the undersigned.

GOLDER ASSOCIATES LTD.

Peter Giamou, B.Sc., P.Geo.
Geophysicist

Christopher Phillips, M.Sc., P.Geo.
Senior Geophysicist, Associate

PG/CP/pg/sp

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DRAFT

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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South America	+ 55 21 3095 9500

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DRAFT

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T: +1 (204) 489 9600

Golder Associates

W.L. Gibbons & Associates Inc.
64 St. Andrew Road Winnipeg, MB R2M 3H6

Technical Memorandum

Date: September 16, 2014

To: Nelson Ferreira, P.Eng.

From: Steve Wiecek, P.Geo., P.Eng.

Subject: ESRA Project 7A – Summary of August 19-20, 2014 Potential Quarry Site Inspections

W.L. Gibbons & Associates Inc. (WLG) is pleased to provide the following summary of the results of the potential quarry site inspections completed on August 19-20, 2014. During this site visit, brief visual inspections were made at the potential quarry locations identified by ESRA that were accessible by helicopter. Inspections were made of potential quarries Q1 through Q8, and Q10 and Q11. Potential quarries Q9, 12 through 14 were not accessible. Detailed geologic mapping of the areas and the collection of samples for laboratory analysis were not included in this inspection trip. The locations of the quarries selected by ESRA are shown on Drawing No. 01, which also provides the compilation of the bedrock geology based on provincial mapping.

General Overview

The majority of the proposed road alignment and the potential quarries are underlain by predominantly tonalite bedrock. Granite bedrock is present between potential quarries Q4 and Q5, and granitic dikes intrude the tonalite on the margins of the granite intrusives. This includes the areas around potential quarries Q1, 2, 4, 5 and 6. Quarries established at those locations will produce a mixture of tonalite and granite.

Tonalite is an intrusive igneous rock comprised predominantly of plagioclase feldspar, quartz, hornblende and biotite. Granites are also intrusive igneous rocks comprised predominantly of alkali and plagioclase feldspars, quartz, hornblende and biotite. The mineralogic composition of the two types of intrusives are very similar with that alkali feldspar content being higher in the granites. As the mineralogic composition is very similar, there is only a marginal difference in the preference for the use of these rock types to produce aggregate for the road. In general, there would be a slight preference towards the use of the tonalite bedrock primarily due to its generally lower quartz content. However, the differences are relatively minor and it is expected that the selection of quarry locations will be based primarily on the logistics of setting up the quarries (access, etc.) and the economics of hauling the produced aggregate from the quarry to the road location.

The visual inspection of the bedrock in the area did not find evidence of the presence of any sulphide or other minerals that might result in the formation of acidic drainage or other potential contaminants of concern.

Quarry Q1

Quarry Q1 is a large area of outcrop located immediately east of the Pauingassi FN boundary at approximately 1+500. Bedrock in this area consists predominantly of tonalite with numerous granitic dikes. The bedrock is massive to weakly fractured (Photos 1 and 2). The fracture sets are oriented at 350 and 310 degrees. A weak foliation at 330 degrees is also present.

Quarry Q2

Quarry Q2 is located at approximately 4+250. The bedrock is predominantly tree and moss covered (Photo 3). Bedrock in this area consists of tonalite with numerous granitic dikes. The bedrock is massive to weakly foliated at 010 degrees. A weak fracture set oriented at 270 and 300 degrees is present.

Quarry Q3

Quarry Q3 is located at approximately 5+500. The bedrock is predominantly tree and moss covered (Photo 4). Bedrock in this area consists of tonalite which is massive. A weak fracture set oriented at 050 and 300 degrees is present.

Quarry Q4

Quarry Q4 is located at approximately 7+500. Bedrock in this area consists of granite, and the bedrock is massive (Photo 5).

Quarry Q5

Quarry Q5 is located at approximately 13+000. Bedrock in this area consists of tonalite with numerous pegmatitic dikes at 290 degrees (Photo 6). Granitic dikes are also present in the area. The bedrock is massive and a weak fracture set oriented at 290 and 340 degrees is present.

Quarry Q6

Quarry Q6 is located at approximately 14+750. The quarry was not accessed and the bedrock outcrops in the nearby area of the CH6 culvert crossing were inspected. Bedrock in this area consists predominantly of tonalite with numerous granitic dikes oriented at 290 degrees. The bedrock is massive to weakly foliated at 290 degrees.

Quarry Q7

Quarry Q7 is located at approximately 15+500. Bedrock in this area consists of tonalite which is massive to weakly brecciated in places (Photo 7). Numerous granitic dikes are present across the area.

Quarry Q8

Quarry Q8 is located at approximately 18+500 and is immediately north of the Berens River crossing . The area consists of large bedrock outcrops with only a minor amount of tree and moss cover. Bedrock in this area consists predominantly of tonalite with numerous granitic dikes at 350 degrees (Photo 8). The bedrock is massive to weakly foliated at 350 degrees. A fracture set oriented at 025 and 350 degrees is present.

Quarry Q9

Quarry Q9 is located at approximately 20+250. The Quarry Q9 area was inaccessible and only viewed from that air. The area was found to be heavily forested and significant bedrock outcrops were not visible.

Quarry Q10

Quarry Q10 is located at approximately 20+750. The bedrock is predominantly tree and moss covered (Photo 9). Bedrock in this area consists of tonalite. The bedrock is massive to foliated at 320 degrees. A fracture set oriented at 020 and 050 degrees is present.

Quarry Q11

Quarry Q11 is located at approximately 21+100. The bedrock is predominantly tree and moss covered (Photo 10). Bedrock in this area consists of tonalite. The bedrock is massive to foliated at 320 degrees. A fracture set oriented at 020 and 050 degrees is present.

Quarries Q12 to Q14

Quarries Q12 to Q14 were not accessible and the areas were only viewed from the air. Significant amounts of bedrock outcrop were observed at all three areas (Photos 11 to 13).

Photo 1 – Quarry Q1 – Massive tonalite outcrop with granitic dikes

Photo 2 – Quarry Q1 – Tonalite outcrop with granitic dikes

Photo 3 – Quarry Q2 – Tonalite outcrop with granitic dikes

Photo 4 – Quarry Q3 – Tonalite outcrop

Photo 5 – Quarry Q4 – Massive granite outcrop

Photo 6 – Quarry Q5 – Tonalite outcrop with pegmatite dikes

Photo 7 – Quarry Q7 – Tonalite outcrop, massive to slightly brecciated

Photo 8 – Quarry Q8 – Tonalite outcrop with granitic dikes

Photo 9 – Quarry Q10 – Quarry location in background

Photo 10 – Quarry Q11 – outcrop area in front of helicopter

Photo 11 – Quarry Q12 – Overhead view

Photo 12 – Quarry Q13 – Overhead view

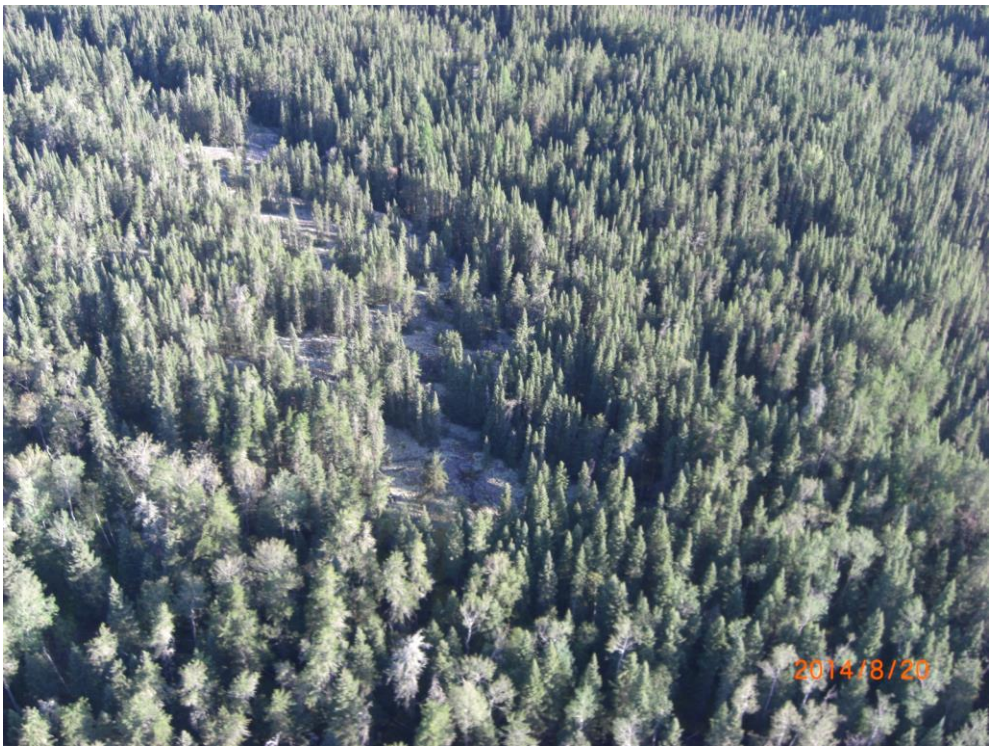

Photo 13 – Quarry Q14 – Overhead view

TREK GEOTECHNICAL

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Dillon Consulting Ltd.
ESRA Project 7a

Tabloid (279mm x 432mm)

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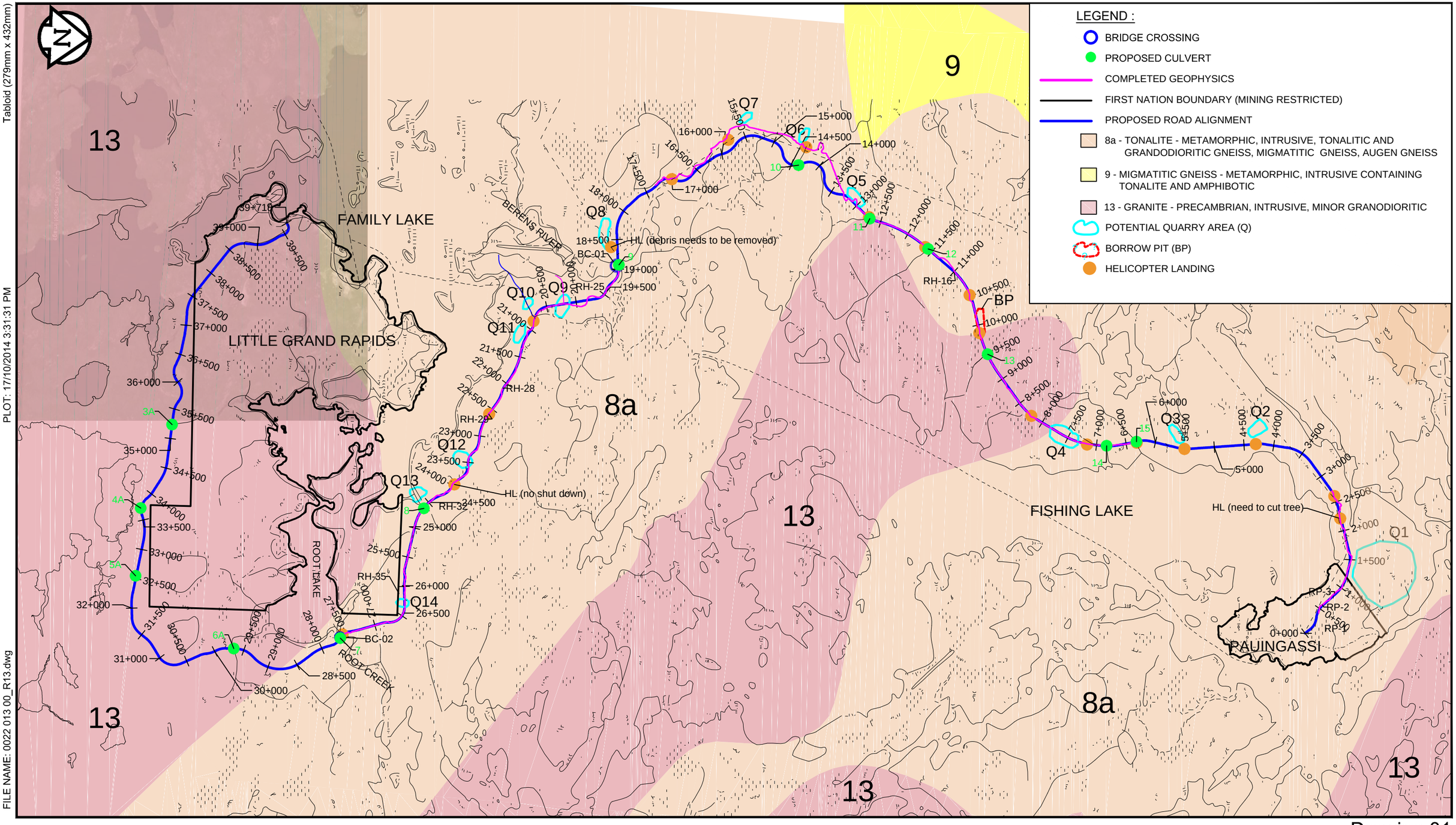

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SCALE : 1:60 (279mm x 432mm)
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Drawing 01
Bedrock Geology Map