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Time Domain Electromagnetic Survey of the Mud Lake Area in South Bay, Ontario

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Project:

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Introduction:

The bedrock depth in area immediately North of Mud Lake may vary from as deep as 20 m to very shallow level. The soil in the area consists of wet, organic rich, fine grain organic material, with possible addition of clay which underlines Mud Lake.

Various geophysical methods were reviewed as a possible techniques to investigate depth to bedrock in this area. Ground Penetrating Radar or Sledge-hammer Seismic investigations were initially proposed as tools to investigate depth of the bedrock in area located North of Mud Lake. The penetration depth of the Ground Penetrating Radar system is dependent upon the effective conductivity and dielectric constant of the earth material being probed. Previous electromagnetic EM34-3 surveys in the area indicated relatively high soil conductivity, possibility of the presence of clay material, and conductive surface water. Based on these information Ground Penetrating Radar would have relatively small depth of penetration in the northern portion of Mud Lake. However it may provide satisfactory results in area of gravel pit and in areas adjacent to bedrock outcrops.

Seismic method appears to be the most suitable and accurate geophysical method in this type of investigations, however sledge hammer or other mechanical devices used as an energy source seem to be too weak in area of very soft, organic rich and wet soils. To investigate depth up to 20 m in above described conditions dynamite would have to be used as a sufficient source of energy. This would cause disturbance of sensitive soft soils leading to a possible cross contamination of the subsurface.

Due to above concerns the time domain electromagnetic (TEM) soundings or resistivity method using direct current (DC soundings) remained available techniques to investigate depth to bedrock in area North of Mud Lake. Since DC soundings can not be conducted in frozen ground and in the presence of substantial snow cover the TEM soundings were chosen to be conducted during this project.

Time Domain Electromagnetic Method

In the TEM method the transmitter loop is energized by current pulses. During time-on the current is constant in the loop and the magnetic field is invariant with time. No eddy currents are induced in the surrounding medium. When the transmitter current is switched off eddy currents arise in the ground due to rapid changes of the primary magnetic field in accordance with Faraday's Law. The secondary magnetic field caused by these eddy currents is measured at the surface in the receiver coil. The behaviour of the eddy currents changes a function of time. In the first instant after the transmitter current is switched off, the eddy currents are mainly concentrated near the ground surface under the transmitter loop. The electromotive force in the receiver coil depends then mainly on the conductivity of the upper layer. With the increasing time the current maximum occurs at greater depths. As a result, the electromotive force measured in the receiver will be affected by the

properties of deeper layers. The depth of investigation thus increases as a function of time. The TEM sounding technique is well suited for mapping the vertical distribution of the electrical properties from the ground surface. It may be especially efficient when electromagnetic data can be correlated with available drill hole logs in the area.

The TEM measurements were taken using Geonics EM47 transient system. A 5 m by 5 m single wire square loop was used as a transmitter. The vertical component of magnetic field was measured 12.5 m off the centre of the transmitter loop using a standard receiver coil with an effective area of 31.4 sq. m. The measurements were taken using a basic frequency of 315Hz which provided a measurement range of 7 uS to 800 uS.

Field Procedures

Prior to taking measurements, survey lines which were used during former EM34 surveys were reconstructed. Measurements were carried out at stations separated by 20 m. This interval was reduced to 10 m whenever the operator of the instrument noticed more substantial changes in readings at neighbouring stations. In general three measurements were performed at each station. Repeatability of readings was generally very good, at some stations where repeatability of obtained data was excellent only two readings were taken. Data were taken along seven survey lines (200N, 400N, 500N, 600N, 700N, 750N, and 800N) in the northern portion of Mud Lake and along one line (0N) in Confederation Lake area.

Results

The survey results for area located in the northern portion of Mud Lake are given in Figure A-1. This figure presents pseudo-sections of apparent conductivity (measured conductivity values verse EM47 time gate) for each station. The image shown by presented pseudosections may be related to vertical distribution of soil conductivity. Figure A-1 shows consistent behaviour of conductivity values along each survey line with expected high conductivity values at stations located over Mud Lake water. However, inversion technique applied to each separate station which was supposed to provide depth to highly resistive layer (bedrock) did not provide reasonable results. This may be an effect of not sufficient horizontal layering of soil and bedrock interface. An additional effect may be provided by too conductive overburden especially in areas adjacent to Mud Lake waters.
Ground probing was performed at several locations in the EM47 survey area in September 1997. Results of this survey are shown in Figure A-1 as magenta (depth to bedrock) and pink (depth to bedrock greater than shown) square symbols. In this case vertical axes present depth in metres. Normally it is expected that the bedrock surface would follow pattern of pseudosections, especially its resistive portion (blue areas). This agrees somehow along the western portion of line 750N and to certain degree at the western end of line 700N, while ground probing data taken in the centre of line 750N (stations 300E to 340E) and at the eastern end of line 800N do not follow this pattern. The EM47 data taken at the central portion of line 750N may be strongly distorted by extremely conductive environment at this location, while electromagnetic measurement at line

800N may be affected be relatively conductive soil and possibly by a lack of horizontal layering of subsurface. The results obtained in the western section of line 750N (stations 420E to 500E) may indicate increase of conductivity with depth. This anomaly may be associated with deposits of highly conductive clays or with conductive, possibly contaminated soils.

Results of measurements in Confederation Lake area did not provide satisfactory results. In the portion of line over lake water strong cultural interferences affected quality of data. The most probable source of these interferences is old steel dock located in this area. The EM47 data obtain in the lake and shore interface area show more uniform distribution of measured conductivity, however modelling did not produce any reasonable results due to possible lack of horizontal layering of the subsurface in this area.

Recommendations

Based on results of electromagnetic survey which show complicated distribution of conductivity in the subsurface of the northern portion of Mud Lake area it is suggested that depth to bedrock and vertical stratigraphy of subsurface should be investigated using acoustic methods. Acoustic methods (basically seismic techniques) are entirely independent on electrical parameters of soil. In this relatively high conductive area high variations of soil conductivity appear to screen geological changes. Since the Mud Lake site is secluded and there are no potential interferences (mainly vibrations originated by highway traffic, trains, heavy industry, etc.) for seismic method it may be possible to find a method of measurements and instrumentation that would use extended digital stacking of data to obtain enough signal to noise ratio while using mechanical devices (no dynamite blasting).

Additional electromagnetic survey (EM34-3 and EM31) or DC soundings carried out along finer grid in area located at line 750N between stations 400E and 500E may provide additional information about distribution of soil conductivity in this area.