

SITE LOCATION MAP



COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRUCTING FEATURES.

TECHNICAL SUMMARY

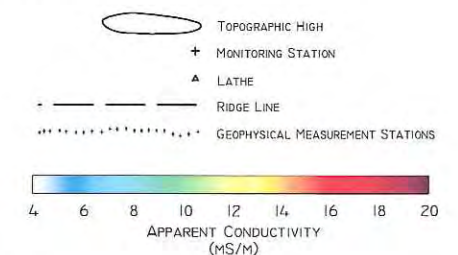
GEOPHYSICAL SPECIFICATIONS

INSTRUMENT: GEONICS EM38
 MEASURED QUANTITIES: QUADRATURE IN MS/M
 PRIMARY FIELD SOURCE (TX): INPHASE IN PPT, HS/HP
 RECEIVER (RX): SELF-CONTAINED DIPOLE TX
 INTERCOIL SPACING: SELF-CONTAINED DIPOLE RX
 OPERATING FREQUENCY: 1.0 M
 CONDUCTIVITY RANGES: 14.6 KHZ
 10 - 1000 MS/M

POSITIONING (DGPS) SPECIFICATIONS

GPS ROVER: TRIMBLE PATHFINDER POWER
 GPS BASE: TRIMBLE 4000SSI DUAL
 DATA S/A CORRECTIONS: POST-PROCESSED DIFFERENTIAL
 COORDINATE PROJECTION: UNIVERSAL TRANSVERSE MERCATOR (UTM)
 UTM ROVER ZONE: 08
 DATUM: NORTH AMERICAN DATUM 1927 (NAD27-NWT)
 BASE COORDINATE: SOPAC, INUVIK, NWT
 X: 560870E
 Y: 7577533N
 ELEV.: 51.22 M (MAE)

LEGEND



MAP 1/2 | SCALE = 1:850 | SEPTEMBER 2006 | Job No.: 1651.01

LATERAL CONDUCTIVITY DISTRIBUTION (EM38) & SITE FEATURES
 UMIAK NI6 SUMP

CLIENT: **ENCANA**

DIRECTED BY: **KWIK-ANYS Inc.**

PRODUCED BY: **Essis**

APPROVED: _____

CREATED: _____

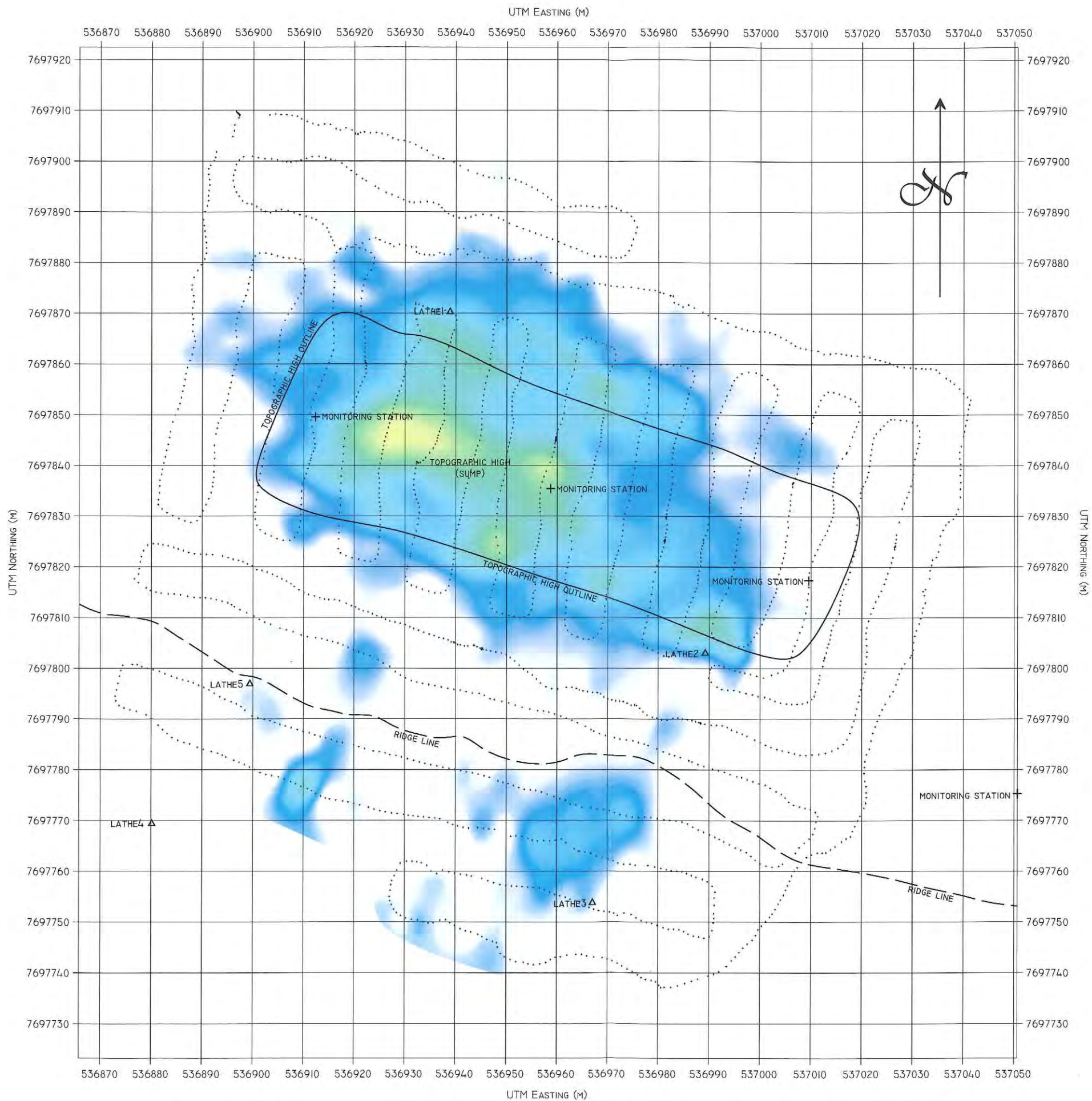
Signature: _____

Date: _____

PERMIT TO PRACTICE
 ESSIS LTD.

PERMIT NUMBER: P 6825
 The Association of Professional Engineers,
 Geologists and Geophysicists of Alberta

REDUCED VERSION



SITE LOCATION MAP



COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRUCTING FEATURES.

TECHNICAL SUMMARY

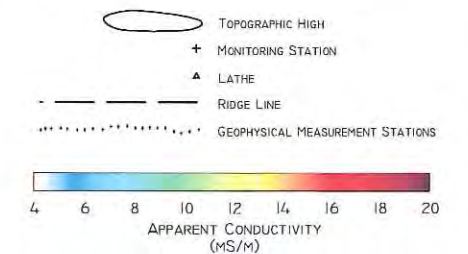
GEOPHYSICAL SPECIFICATIONS

INSTRUMENT: GEONICS EM31
 MEASURED QUANTITIES: QUADRATURE IN MS/M
 INPHASE IN PPT, HS/HP
 PRIMARY FIELD SOURCE (TX): SELF-CONTAINED DIPOLE TX
 RECEIVER (RX): SELF-CONTAINED DIPOLE RX
 INTERCOIL SPACING: 3.66 M
 OPERATING FREQUENCY: 9.8 KHZ
 CONDUCTIVITY RANGES: 10 - 1000 MS/M

POSITIONING (DGPS) SPECIFICATIONS

GPS ROVER: TRIMBLE PATHFINDER POWER
 GPS BASE: TRIMBLE 4000SSI DUAL
 DATA S/A CORRECTIONS: POST-PROCESSED DIFFERENTIAL
 COORDINATE PROJECTION: UNIVERSAL TRANSVERSE MERCATOR (UTM)
 UTM ROVER ZONE: 08
 DATUM: NORTH AMERICAN DATUM 1927 (NAD27-NWT)
 BASE COORDINATE: SOPAC, INUVIK, NWT
 X: 560870E
 Y: 757553N
 ELEV.: 51.22 M (HAE)

LEGEND



MAP 2/2 SCALE = 1:850 SEPTEMBER 2006 JOB No.: 1651 01

**LATERAL CONDUCTIVITY DISTRIBUTION (EM31)
 &
 SITE FEATURES
 UMIAK NI6 SUMP**

CLIENT:

DIRECTED BY:

PRODUCED BY:

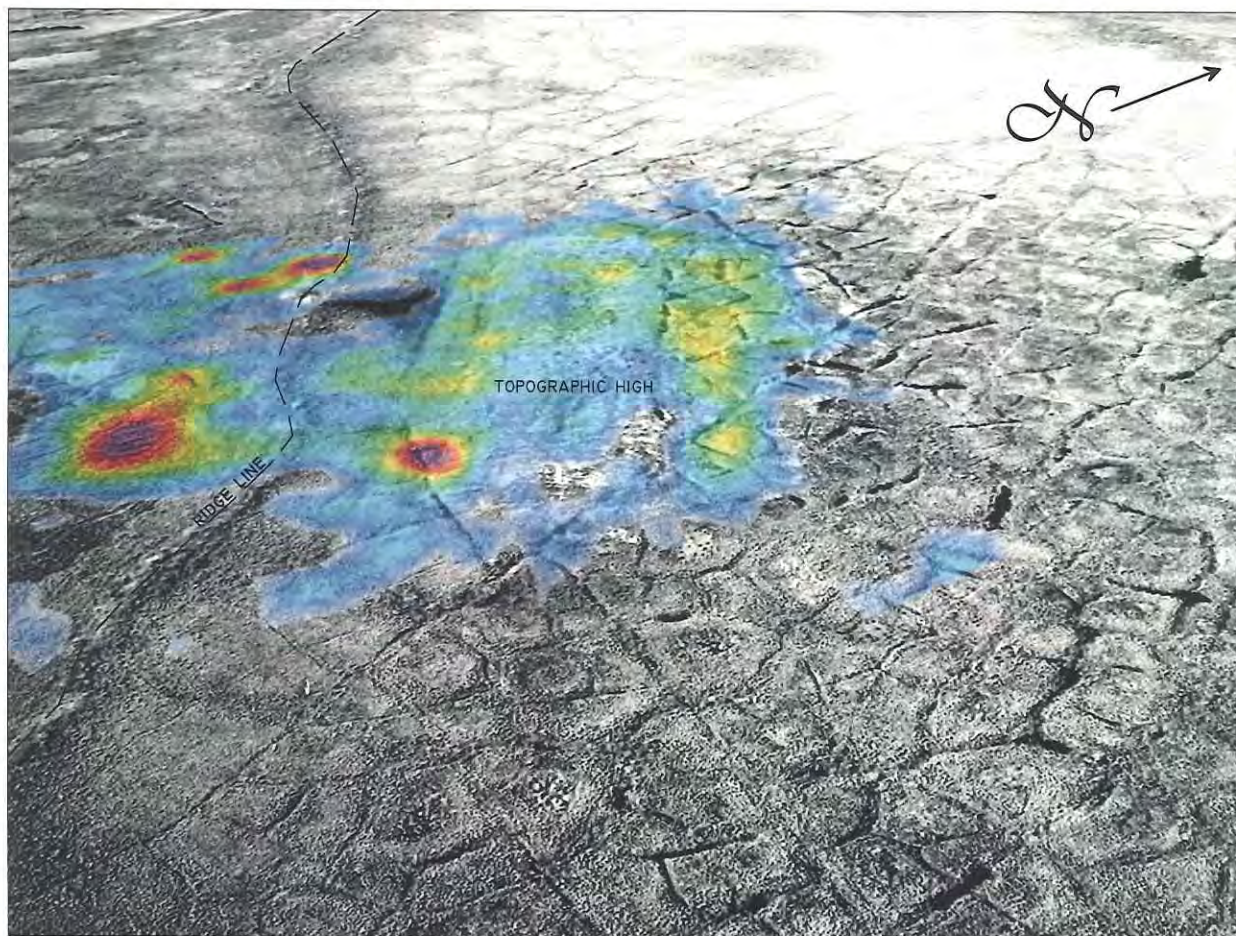
APPROVED: _____

CREATED: _____

PERMIT TO PRACTICE
 ESSIS LTD.
 Signature: _____
 Date: _____

PERMIT NUMBER: P 6825
 The Association of Professional Engineers,
 Geologists and Geophysicists of Alberta





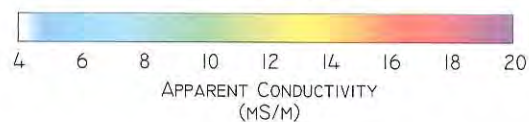
COMMENTS:

THE OVERLAY ILLUSTRATES THE CORRELATION OF EM RESPONSES TO REGIONAL FEATURES. THE PROCESS OF MERGING EM DATA WITH THE AERIAL PHOTOGRAPH GENERATES FOCAL AND PERSPECTIVE DISTORTION.

TECHNICAL SUMMARY:

GEOPHYSICAL INSTRUMENT: GEONICS EM38
 MEASURED QUANTITIES: QUADRATURE IN MS/M

AERIAL PHOTOGRAPH & EM38 OVERLAY
 UMIAK N16 SUMP



SEPTEMBER 2006

AERIAL PHOTOGRAPH #1

Job No.: 1651 01

SCALE: VARIABLE, NON-LINEAR

PRODUCED BY:



DIRECTED BY:



CLIENT:



APPENDIX A

EM38 GROUND CONDUCTIVITY METER with INPHASE CHANNEL



The EM38 measures the conductivity of the ground directly in mS/m. The EM38 also measures the inphase component of response, which enables it to be used as a metal detector or, for poorly to moderately conductive material, a magnetic-susceptibility meter.

The depth to which the EM38 measures conductivity depends solely on the orientation of the instrument. When the instrument is upright in vertical-dipole mode (as shown), depth of measurement is approximately 1.5 m. With the instrument on its side, in horizontal-dipole mode, depth of measurement is approximately 0.75m. Readings are shown on digital meters which are mounted on the top and side of the EM38, for convenient reading regardless of the orientation of the instrument.

Using EM induction, the EM38 requires no contact with the ground. As a result, surveys can cover large areas rapidly. To survey at walking speed, a special handle

allows the operator to carry the EM38 at ground level.

The EM38 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements.

The EM38 is most commonly used during soil-salinity surveys, in both dry-land and irrigated areas. Compared to resistivity, EM38 surveys offer better lateral-resolution, and much faster coverage. The EM38 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM38 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. These applications make good use of the excellent spatial resolution of the EM38. The EM38 can also be used to identify shallow metallic objects.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone (905) 670-9580*

EM38 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing:	1.0 m
Primary Field Source (Tx):	Self-Contained Dipole Tx	Operating Frequency:	14.6 kHz
Receiver (Rx):	Self-Contained Dipole Rx	Conductivity Ranges:	10-1000 mS/m

EM31 GROUND CONDUCTIVITY METER with INPHASE CHANNEL



The EM31 measures the conductivity of the ground directly in mS/m. The EM31 also measures the inphase component of response, which is useful for detecting ferrous and non-ferrous buried material.

Two meters on the front panel of the EM31 simultaneously display conductivity and inphase response. Readings can be taken at successive survey stations, or continuously along the survey line.

Using the inductive method, the EM31 operates without the ground contact required by conventional resistivity. As a result, surveys can be done over highly resistive material, such as gravel or asphalt, at the pace of a walk.

Compared to resistivity surveys, EM31 surveys yield detailed, continuous data, with better resolution of small changes in conductivity. This enables the EM31 to identify subtle changes in conductivity that can be caused by contamination, and to

delimit affected areas with precision. Depth of exploration is about 6 m, which makes the EM31 suitable for many geotechnical and environmental applications.

The EM31 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements. The EM31 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM31 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. The EM31 can map conductive contamination of soil and groundwater, and simultaneously detect buried metal, which makes this instrument the ideal tool for site assessment. It is most commonly used during soil-salinity surveys.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone (905) 670-9580*

EM31 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing: 3.66 m
Primary Field Source (Tx):	Self-Contained Dipole Tx	Operating Frequency: 9.8 kHz
Receiver (Rx):	Self-Contained Dipole Rx	Conductivity Ranges: 10-1000 mS/m

GPS Pathfinder Systems

Versatile GIS data collection and maintenance

Key Features and Benefits

- Total system solution
- Easy-to-use software
- High accuracy
- Real-time GIS data collection and maintenance
- Beacon and satellite differential capabilities
- Supports leading GIS database formats
- WAAS - capable

Trimble's GPS Pathfinder® systems are a family of high-performance GIS data collection and maintenance products. These versatile systems offer a variety of software, data collector and GPS receiver options so you'll find one that is ideal for your needs. Powerful and easy-to-use, you can quickly collect quality data for utility, urban and natural resource databases. And as the demand for high-quality position and attribute information increases, these systems allow you to update existing GIS data—ensuring that your decisions are made with the most accurate, current and reliable data available.

Easy-to-use Software

Time-saving field software is essential for productive GIS data collection and maintenance.

With Trimble's field software options, you can quickly and easily collect point, line and area features, along with their customized attribute information. Field software makes it easy to take existing data from your GIS into the field for verification and update of position and attribute information. With powerful navigation tools, the field software guides you to an existing feature or landmark using graphical display and textual messages.

Three options are available for collecting and maintaining quality data while out in the field.

Asset Surveyor® software runs on the revolutionary TSC1™ —a rugged, weatherproof, handheld data collector developed and built by Trimble.

TerraSync™ software operates on standard Pocket PC and Windows CE devices, providing the flexibility



Powerful, rapid, accurate data collection and maintenance

to choose from a wide range of devices depending on your requirements.

ASPEN® software runs on your pen or notebook computers, when extra processing power or storage is important for your field operations.

Real-time Receivers

Because you need immediate results, the GPS Pathfinder systems family includes Trimble's real-time differential GPS (DGPS) receivers. Real-time DGPS is key for relocating existing assets and for verifying that the correct feature is being updated.

The **GPS Pathfinder Pro XRS** system integrates GPS, real-time beacon, satellite differential and Wide Area Augmentation System (WAAS) capabilities.

The **GPS Pathfinder Pro XR** system integrates GPS, real-time beacon and WAAS capabilities.

The **GPS Pathfinder Power** receiver integrates GPS, real-time

satellite differential, and WAAS capabilities into a single, lightweight unit.

Efficient Planning and Processing

The powerful GPS Pathfinder Office software allows you to quickly plan your data collection and maintenance work and process your field data for use in your GIS. Important functions such as data dictionary creation, data viewing and editing, and differential correction can all be completed with ease. GPS Pathfinder Office software can process real-time DGPS data, ensuring your data is of the highest quality before exporting it to many leading GIS packages.

With powerful field and office software and integrated real-time DGPS, the GPS Pathfinder systems family meets your GIS data collection and maintenance needs today and into the future.

Trimble

GPS Pathfinder Systems

Versatile GIS data collection and maintenance

FEATURES AND OPTIONS

GPS Pathfinder Systems Standard Features

- GPS Pathfinder Office software
- Choice of GPS receiver
- Choice of field software
- Ergonomic backpack carrying system
- Rechargeable system batteries (provide 8 hours of field use)
- Battery charger and AC power supply

Optional Receiver Accessories

- Vehicle kit—includes cigarette lighter power adapter, quick release, 2 quick-release adapters and magnetic mount.
- GPS Pathfinder Centimeter Processing option
- Rangepole bipod system

Available Receivers and Standard Features

- GPS Pathfinder Pro XRS receiver
- GPS Pathfinder Pro XR receiver
- GPS Pathfinder Power receiver
- 12-channel GPS receiver
- EVEREST™ multipath rejection technology
- WAAS differential correction capabilities

Available Field Software

- Asset Surveyor software—for Trimble TSC1 data collector
- TerraSync software—for standard Pocket PC and Windows CE devices
- ASPEN software—for Windows-based pen or notebook computers

GPS PATHFINDER PRO XR AND XRS—RECEIVER & ANTENNA SPECIFICATIONS

GPS Pathfinder Pro XR

- Integrated GPS/Beacon receiver
- Integrated GPS/Beacon antenna
- RTCM input/output
- 3-meter antenna cable
- Base datalogging mode

GPS Pathfinder Pro XR receiver

General	12 channel, LI/CA code tracking with carrier phase filtered measurements and multibit digitizer
Update rate	1 Hz
Power	6 Watts (max), 10 to 32 VDC
Accuracy (RMS) (Note A)	
MCORR400 differential correction	50 cm + 1 ppm on a second-by-second basis (horizontal) Submeter + 2 ppm on a second-by-second basis (vertical)
Carrier phase processing	30 cm + 5 ppm with 5 minutes tracking satellites 20 cm + 5 ppm with 10 minutes tracking satellites 10 cm + 5 ppm with 20 minutes tracking satellites 1 cm + 5 ppm with 45 minutes tracking satellites (with Centimeter Processing option)
RTCM beacon radio transmissions	Better than 1 meter (Note B)
Time to first fix	30 seconds (typical)
Size	11.1 cm x 5.1 cm x 19.5 cm (4.4" x 2.0" x 7.7")
Weight	0.76 kg (1.68 lbs)
Temperature	-30° C to +65° C (-22° F to +149° F) (operating) -40° C to +85° C (-40° F to +185° F) (storage)
Humidity	100% fully sealed
Casing	Dustproof, splashproof, shock resistant; sealed to 5psi

GPS Pathfinder Pro XRS receiver

Specifications for the Pro XRS receiver are the same as for the Pro XR receiver with the following exceptions:

Power	7 Watts (max), 10 to 32 VDC
Accuracy (RMS) (Note A)	
RTCM satellite differential correction	Better than 1 meter (Note B)

GPS Pathfinder Pro XR antenna

General	Right-hand, circular polarized; omnidirectional; hemispherical coverage
Size	15.5 cm diameter x 10.8 cm high (6.1" x 4.2")
Weight	0.49 kg (1.08 lbs)
Operating temp	-30° C to +65° C (-22° F to +149° F)
Storage temp	-40° C to +85° C (-40° F to +185° F)
Humidity	100% fully sealed
Casing	Dustproof, waterproof, shock resistant

GPS Pathfinder Pro XRS antenna

Specifications for the Pro XRS antenna are the same as for the Pro XR antenna with the following exceptions:

Size	15.5 cm diameter x 14 cm high (6.1" x 5.5")
Weight	0.55 kg (1.2 lbs)

GPS PATHFINDER POWER RECEIVER/ANTENNA SPECIFICATIONS

- Integrated GPS/Satellite Differential receiver and antenna
- RTCM input

General	12 channel, L1/CA code tracking with carrier phase filtered measurements.
Update rate	1 Hz
Power	3.1 Watts, 9 to 32 V
Accuracy (RMS) (Note A)	
MCORR400 differential correction	Submeter + 1 ppm on a second-by-second basis (horizontal) Submeter + 2 ppm on a second-by-second basis (vertical)
Carrier phase processing	30 cm + 5 ppm with 5 minutes tracking satellites 20 cm + 5 ppm with 10 minutes tracking satellites 10 cm + 5 ppm with 20 minutes tracking satellites 1 cm + 5 ppm with 45 minutes tracking satellites (with Centimeter Processing option)
RTCM satellite differential correction	Better than 1 meter (Note B)
Time to first fix	30 seconds (typical)
Size	15.2 cm diameter x 12.7 cm high (6" x 5")
Weight	0.625 kg (1.38 lbs)
Temperature	-30° C to +60° C (-22° F to +140° F) (operating) -40° C to +80° C (-40° F to +176° F) (storage)
Humidity	100% fully sealed
Casing	Fully sealed, dustproof, waterproof, shock resistant

TRIMBLE TSC1 DATA COLLECTOR SPECIFICATIONS

Logging memory	2 MB, memory extension through user accessible Type II ATA PC card slot (Note C)
Size	26.7 cm x 11.7 cm x 4.2 cm (10.5" x 4.6" x 1.65")
Weight	0.85 kg (1.875 lbs), including rechargeable Lithium Ion battery
Operating temp	-30° C to +65° C (-22° F to +149° F)
Storage temp	-30° C to +80° C (-22° F to +176° F)
Humidity	100% fully sealed against sand, dust and moisture, buoyant, waterproof against accidental immersion
Display	240 x 200 extended temperature graphics STN LCD display
Power	<1 Watt

(footnotes)

Note A: At least 5 satellites, PDOP ≤6, signal to noise ratio ≥6, satellite elevation mask at 15 degrees.

Note B: RTCM SC-104 standard format broadcast from a Trimble reference station.

Note C: Memory extension through user-accessible Type II PC card slot. 16 MB PCMCIA Data Cards are available (33050-16)

Trimble follows a policy of continuous product improvement. Specifications are therefore subject to change without prior notice.

ORDERING INFORMATION

For further information, contact your nearest Trimble Authorized Distributor or Trimble Office. Please visit our web site at www.trimble.com

Pathfinder Office Software

GPS Data Processing Software for Microsoft Windows

Powerful software for planning and processing mapping and GIS data capture projects.

Built on the solid foundation established by PFINDER software, Pathfinder Office™ is the next generation of Trimble's GPS planning and data processing software and is an integral part of the GPS Pathfinder™ product line. The software is Microsoft Windows-based and is designed for ease-of-use and high productivity.

The software provides all of the tools to complete your projects quickly. GPS Planning software is fully integrated with Pathfinder Office. Planning your data collection sessions is a simple task that lets you make the most of field data collection time.

The Data Dictionary Editor lets you build custom data collection menus to be uploaded to your data collector. Items can be quickly added, edited, and moved within the data dictionary.

A graphic display makes the process far easier by helping you understand the structure of the data dictionary at a glance.

With Pathfinder Office's Batch Processor, you can automate your workflow. Data can be transferred from your data collector, differentially corrected, and exported to your GIS or CAD system as a single automated function. After your data has been processed, you can print it or plot it to scale using a pen plotter.

A carrier phase processing module for high accuracy positions is a standard component of the Pathfinder Office system. Using this processing system, you can achieve accuracies in the range of 10 to 75 centimeters, depending on which GPS Pathfinder product you are using.

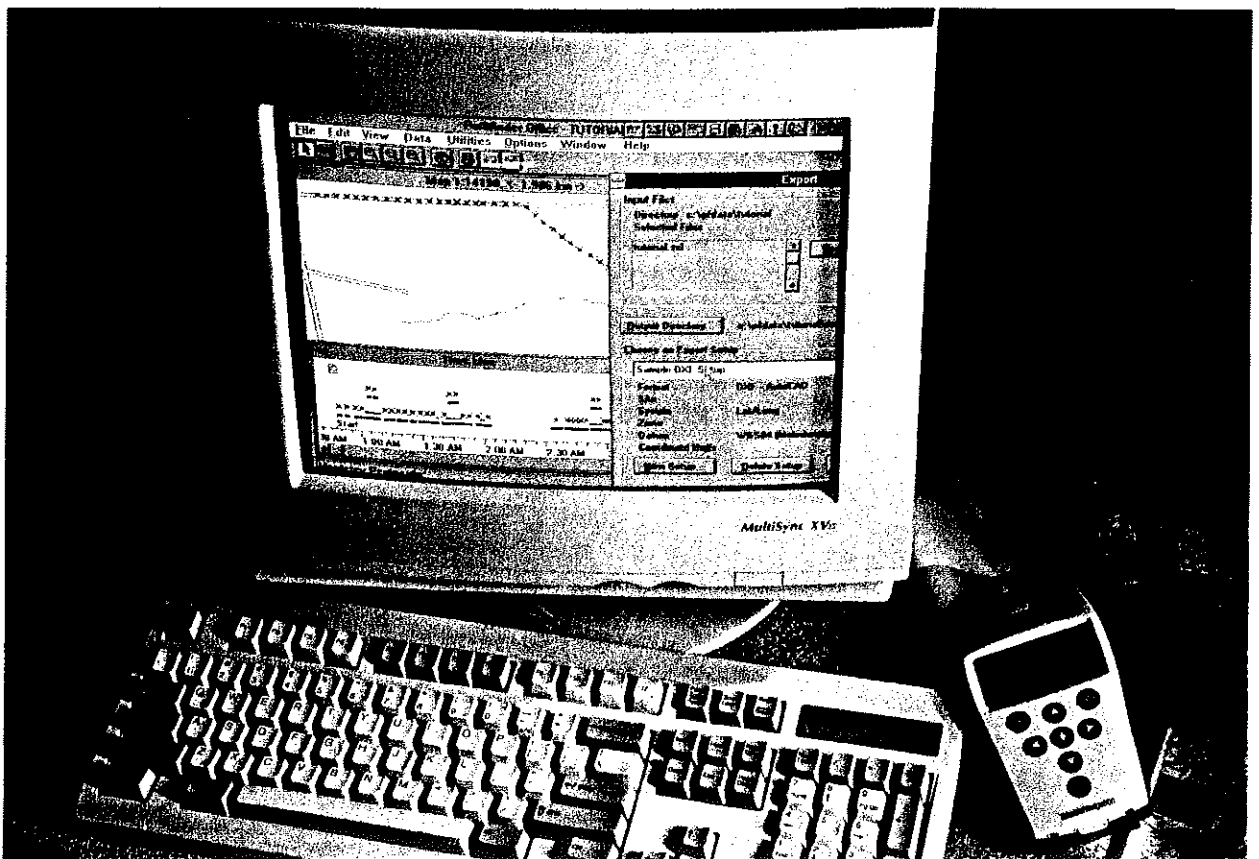
Pathfinder Office software makes exporting GPS data to your GIS or CAD system a simple process. Parameters for exporting data can be set up in the system once and saved for use

on future projects. This allows you to export data without going through setup each time.

With Pathfinder Office software, you can display a background map behind your GPS data. This allows you to see where you have collected data and how it relates to features for which you already have information, such as roads or property boundaries. Data formats for background files include DXF, Shapefile, BMP, and TIFF.

The Time Line window lets you visualize your data from a chronological point of view. For example, if you wanted to review data collected before a lunch break, you could look for that time period on the Time Line. Highlighting the feature on the Time Line also highlights it on the map display.

Pathfinder Office software sets a new standard for GPS planning and processing software. It provides all the tools needed to make your GPS data collection easy and successful.



GPS Data Processing Software for Microsoft Windows

Pathfinder Office Software Capabilities

- Automated workflow with Batch Processor
- Export to most major GIS and CAD systems
- Carrier phase processing for high accuracy positions
- Display background maps behind GPS data
- Review and edit attribute data
- Import GIS files and take them to the field
- Time Line for chronological view of GPS data
- Microsoft Windows-based—Windows 3.1 or later, Windows 95, Windows NT 3.51 or later
- Advanced data dictionary editor
- Quick Plan software for session planning
- Custom coordinate system editor
- Full project control
- Waypoint manager lets you create locations for navigation
- Support for printers and pen plotters
- Plots to scale
- Compatible with laser printers

Standard Components

- 3.5" Software Diskettes
- Software CD
- Software Security Key (not included with upgrades)
- Activation Disk
- Printed Manuals
- On-Line Help
- Tutorial and Sample Files

Ordering Information

GEO-PC to Pathfinder Office upgrade	Part Number 31307-00
PFINDER to Pathfinder Office upgrade—current PFINDER Support Agreement required	Part Number 31308-00
PFINDER to Pathfinder Office upgrade —no Support Agreement required	Part Number 31309-00

Computer Requirements

Recommended Configuration:

Computer: Pentium microprocessor with 12 MB of RAM, a 100 MB hard drive, and a CD-ROM drive
Operating System: Microsoft Windows 3.1 or later; Windows 95; or Windows NT 3.51 or later

Minimum Configuration:

Computer: 80486 microprocessor, 8 MB of RAM, and an 80 MB hard disk
Operating System: Microsoft Windows 3.1 or later



Trimble Navigation Limited
Mapping & GIS Systems Division
485 Potrero Avenue
Sunnyvale, CA 94086
1-800-545-7762 in North America
+1-408-481-8940
+1-408-481-7744 Fax
<http://www.trimble.com>

Trimble Navigation Europe Limited
Trimble House, Meridian Office Park
Osborn Way, Hook
Hampshire RG27 9HX U.K.
+44 1256-760150
+44 1256-760148 Fax

Trimble Navigation Singapore PTE Limited
300 Beach Road
#34-05 The Concourse
Singapore 199555
SINGAPORE
+65 296-2700
+65 296-8033 Fax



APPENDIX B

Table of Contents

		Page
Section I	Introduction	5
Section II	Principle of Operation	5
Section III	Instrumentation	5
Section IV	Survey Techniques and Interpretation	6
	IV. 1: Instrumental Response as a Function of Depth (Homogeneous Halfspace)	6
	IV. 2: Multi-Layered Earth Response	7
	IV. 3: Comparison with Conventional Resistivity Techniques	8
	IV. 4: Resolution of Two-Layered Earth by Varying Intercoil Spacing	8
	IV. 5: Resolution of Two-Layered Earth by Varying Instrument Height	10
Section V	Advantages and Disadvantages of Inductive Terrain Conductivity Measurements	10
	V. 1: Advantages	10
	V. 2: Disadvantages	10
Section VI	Case Histories	11
Section VII	Summary	12
Bibliography		13
Appendix	Theory of Operation at Low Induction Numbers	14



GEONICS LIMITED

1745 Meyerside Drive, Unit 8, Mississauga, Ontario, Canada L5T 1C6 Tel.: (905) 670-9580 Fax: (905) 670-9204

Technical Note TN-6

**ELECTROMAGNETIC TERRAIN
CONDUCTIVITY MEASUREMENT
at
LOW INDUCTION NUMBERS**

JD McNEILL

October, 1980

I. INTRODUCTION

The measurement of terrain resistivity to map geology has been utilized for over half a century. Several shortcomings, however, have prevented this technique from being widely accepted for engineering purposes. The first of these is that conventional galvanic resistivity surveys require a relatively large amount of manpower to execute and are thus expensive. Secondly, the actual value of resistivity itself is seldom diagnostic; it is the lateral or vertical variations of resistivity which form the basis of any interpretation. However the high cost of resistivity surveying generally means that fewer measurements are made than would be desirable, with the result that either (i) the survey area is not made large enough to establish a reasonable background against which the anomalous areas are to be delineated or (ii) the anomalous area itself is obscure and lacks definition.

An additional problem inherent to conventional resistivity techniques is that although the effective depth of exploration is determined by the selected inter-electrode spacing, resistive inhomogeneities which are small compared to this depth but which are located near the potential electrodes can cause a significant error in the measurement. Such fluctuations in the measured results are truly geological "noise" because it is not possible to determine the physical size, resistivity contrast, or location of the source. As a result of such inhomogeneities resistivity profiles carried out at constant interelectrode spacing tend to be noisy, limiting the resolution in resistivity that can be achieved, even though the instrumentation itself is capable of producing much higher accuracy.

It was an awareness of both the advantages of resistivity for engineering geophysical surveys and the disadvantages of conventional resistivity techniques that led Geonics Limited to examine the possibility of employing electromagnetic (inductive) techniques as an alternative for resistivity surveys. With the development of the EM31 and the EM34-3 it is now possible to map terrain conductivity virtually as fast as the operator(s) can walk; furthermore the sample volume is averaged in such a manner as to yield unexcelled resolution in conductivity.

These patented instruments have been designed to cover the range of depths generally useful for engineering geophysics; the EM31, one-man portable, has an effective depth of approximately 6 meters and the EM34-3, two-man portable, has stepwise selectable depths from 7.5 meters to a maximum of 60 meters.

Typical applications for the EM31 and EM34-3 instrumentation are:

- (i) Delineating regions of permafrost (frozen pore water)
- (ii) Locating gravel
- (iii) Extending known gravel deposits
- (iv) Mapping saline intrusions
- (v) Detecting cavities in carbonate rocks
- (vi) Mapping pollution plumes in groundwater
- (vii) Mapped bedrock topography
- (viii) Mapping terrain conductivity for electrical grounding
- (ix) General geological mapping (soil types, fault and fracture zones, etc.)
- (x) Archaeological exploration
- (xi) Locating pipes (EM31) and metallic-type conductors

This technical note describes both the principles and the instrumentation employed to measure terrain conductivity using electromagnetic techniques at low induction numbers. For a detailed discussion of the concept of terrain resistivity/conductivity and of the various factors that control this parameter the reader is referred to Geonics Limited Technical Note "Electrical Conductivity of Soils and Rocks".

II. PRINCIPLE OF OPERATION

The application of electromagnetic techniques to the measurement of terrain resistivity, or more properly, conductivity* is not

*Conductivity is preferred with inductive techniques since the response is generally proportional to conductivity and inversely proportional to resistivity.

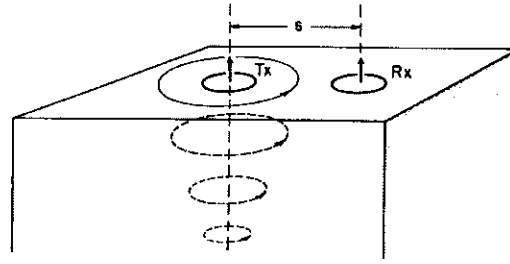


FIGURE 1. Induced current flow (homogeneous halfspace).

new and excellent descriptions of this technique are given in the literature [1], [2].

Consider Figure 1 in which a transmitter coil Tx energized with an alternating current at an audio frequency, is placed on the earth (assumed uniform) and a receiver coil Rx is located a short distance s away. The time-varying magnetic field arising from the alternating current in the transmitter coil induces very small currents in the earth. These currents generate a secondary magnetic field H_s which is sensed, together with the primary field, H_p , by the receiver coil.

In general this secondary magnetic field is a complicated function of the intercoil spacing s , the operating frequency, f , and the ground conductivity σ . Under certain constraints, technically defined as "operation at low values of induction number" (and discussed in detail in the appendix) the secondary magnetic field is a very simple function of these variables. These constraints are incorporated in the design of the EM31 and EM34-3 whence the secondary magnetic field is shown to be:

$$\frac{H_s}{H_p} \approx \frac{i\omega\mu_0\sigma s^2}{4} \quad (1)$$

where H_s = secondary magnetic field at the receiver coil

H_p = primary magnetic field at the receiver coil

$\omega = 2\pi f$

f = frequency (Hz)

μ_0 = permeability of free space

σ = ground conductivity (mho/m)

s = intercoil spacing (m)

$i = \sqrt{-1}$

The ratio of the secondary to the primary magnetic field is now linearly proportional to the terrain conductivity, a fact which makes it possible to construct a direct-reading, linear terrain conductivity meter by simply measuring this ratio. Given H_s/H_p the apparent conductivity indicated by the instrument is defined from equation (1) as

$$\sigma_a = \frac{4}{\omega\mu_0 s^2} \left(\frac{H_s}{H_p} \right) \quad (2)$$

The MKS units of conductivity are the mho (Siemen) per meter or, more conveniently, the millimho per meter.

III. INSTRUMENTATION

The EM31 (shown in Figure 2) has an intercoil spacing of 3.7 meters, which yields an effective depth of exploration of about 6 meters. The instrument can also be operated on its side, in which



FIGURE 2. EM31 in field operation.

case as will be seen in Section IV., the effective depth of exploration is reduced to approximately 3 meters. The instrument is one-man portable and can be used either in "station-by-station" mode or read continuously. The presence of layering in the earth can be detected by raising the instrument and noting the readings as a function of instrument height. If the earth is two-layered the conductivity of both layers and the upper layer thickness can be resolved.

The EM34-3 which is two-man portable has the two coils flexibly connected (Figure 3). The intercoil spacing is measured electronically so that the receiver operator simply reads a meter to accurately set the coils to the correct spacing, which can be 10, 20, or 40 meters so as to directly vary the effective depth of exploration as shown in Table 1.



FIGURE 3. EM34-3 in field operation.

TABLE 1. Exploration depths for EM34-3 at various intercoil spacings

Intercoil Spacing (meters)	Exploration Depth (meters)	
	Horizontal Dipoles	Vertical Dipoles
10	7.5	15
20	15	30
40	30	60

To measure terrain conductivity the transmitter operator stops at the measurement station; the receiver operator moves the receiver coil backwards or forwards until his meter indicates correct intercoil spacing and he reads the terrain conductivity from a second meter. The procedure takes 10 to 20 seconds. The coils are normally carried with their planes vertical (horizontal dipole mode) since in this configuration the measurement is relatively insensitive to misalignment of the coils. In the event that the greater depth of penetration resulting when the two coils are in the vertical dipole mode is desired, more care must be taken with intercoil alignment. Because of the relatively short intercoil spacing correct alignment is usually not difficult to achieve.

Both instruments are calibrated to read terrain conductivity in millimhos per meter. To convert these readings to resistivity (in ohmmeters) one simply divides them into 1,000, i.e. 50 millimhos per meter is the equivalent of 20 ohmmeters.

IV. SURVEY TECHNIQUES AND INTERPRETATION

For either the EM31 or EM34-3 it can be shown that in a homogeneous or horizontally stratified earth the current flow is entirely horizontal. Furthermore under the constraints by which the instruments are designed the current flow at any point in the ground is independent of the current flow at any other point since the magnetic coupling between all current loops is negligible. Finally, under these constraints the depth of penetration is limited only by the intercoil spacing. We say that the depth of penetration is "source" or "geometry" limited rather than "skin depth" limited since it is now controlled by the fall-off with distance of the dipolar transmitter field. For this reason all dimensions are normalized with respect to the intercoil spacing in subsequent sections of this technical note.

IV. 1. Instrumental Response as a Function of Depth (Homogeneous Halfspace)

Consider a homogeneous halfspace on the surface of which is located an EM31 or an EM34-3 transmitter as shown in Figure 4. Fixing our attention on a thin layer of thickness dz at depth z (where z is the depth divided by the intercoil spacing s) it is possible to calculate the secondary magnetic field in the receiver coil arising from all of the current flow within this or any other horizontal thin layer. One can thus construct the function $\phi_s(z)$ shown in Figure 4 which describes the relative contribution to the secondary magnetic field arising from a thin layer at any depth z . We see from this figure that material located at a depth of approximately $0.4s$ gives maximum contribution to the secondary magnetic field but that material at a depth of $1.5s$ still contributes significantly. It is interesting to note that the ground at zero depth, i.e. the near surface material,

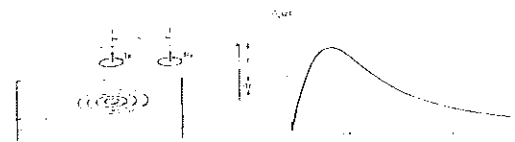


FIGURE 4. Relative response versus depth for vertical dipoles. $\phi_s(z)$ is the relative contribution to H_s from material in a thin layer dz located at (normalized) depth z .

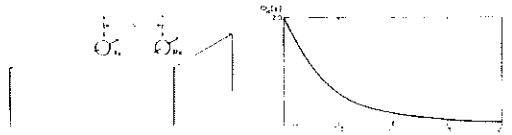


FIGURE 5. Relative response versus depth for horizontal dipoles

makes a very small contribution to the secondary magnetic field and therefore this coil configuration is insensitive to changes in near surface conductivity.

Figure 5 illustrates the function of Figure 4 for the case of both transmitter and receiver dipoles horizontal coplanar rather than vertical coplanar. For the coil configuration of Figure 5 (commonly used for the EM34-3 since it is less critical to intercoil alignment) the relative contribution from material near-surface is large and the response falls off monotonically with depth.

A comparison of the function ϕ for both coil configurations in Figure 6 emphasizes the different manner in which they respond to material at different depths. The difference is important since either instrument can be rolled over so that the vertical dipole transmitter/receiver geometry becomes a horizontal dipole transmitter/receiver geometry and vice versa. As will be seen later, this feature is useful in diagnosing and defining a layered earth. The figure also shows that for regions greater than one intercoil spacing in depth the vertical transmitter/receiver dipole gives approximately twice the relative contribution of the horizontal transmitter/receiver dipole.

To summarize, with either horizontal or vertical transmitter/receiver dipole orientation it is possible to construct a function which gives the relative response to the secondary magnetic field at the receiver from a thin layer of ground at any depth. That this is possible arises from the fact that (i) all current flow is horizontal and (ii) all current loops are independent of all other current loops. It should be noted that it is not possible to construct such functions for conventional resistivity techniques.

Finally, since as shown in Section II the definition of apparent conductivity is given in terms of the secondary magnetic field at the receiver, the functions in Figure 6 also give the relative contribution

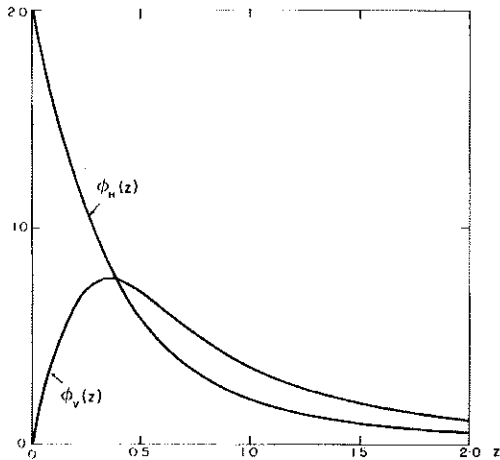


FIGURE 6. Comparison of relative responses for vertical and horizontal dipoles.

from material at different depths to the *apparent conductivity* indicated by the instrument meter. The integral of either function from zero to infinity gives the total secondary magnetic field at the receiver coil from a homogeneous halfspace which is directly related to the electrical conductivity of the halfspace by equation (1). It is therefore possible to state with great precision the relative influence of material at different depths to the indicated apparent conductivity.

IV. 2. Multi-Layered Earth Response

The functions shown in Figure 6 are useful for describing the relative sensitivity of either of the two coil configurations to material at various depths. However a function derived from them is more useful for performing calculations. It is defined as the relative contribution to the secondary magnetic field or apparent conductivity from all material below a depth z and is given by

$$R_v(z) = \int_z^\infty \phi_v(z) dz \quad (3)$$

Called the cumulative response, this function is illustrated in Figure 7 for vertical coplanar transmitter/receiver dipoles. The figure shows, for example, that for this configuration all material below a depth of two intercoil spacings yields a relative contribution of approximately 0.25 (i.e. 25%) to the secondary magnetic field at the receiver coil.

Suppose now that our homogeneous halfspace has a conductivity of 20 millimhos per meter (50 ohmmeters). The equipment having been calibrated according to equation (2), the output meter indicates 20 millimhos per meter. From Figure 7 we observed that the material below two intercoil spacings contributed 25% to the secondary magnetic field and therefore 25% to the indicated meter reading. Suppose that we replace this deep material with an infinitely resistive (zero conductivity) substance. Since we have reduced to zero the 25% that this material contributed to the meter reading the new reading will be 75% of 20, or 15 millimhos per meter. Conversely, if we leave all of the material below two intercoil spacings at 20

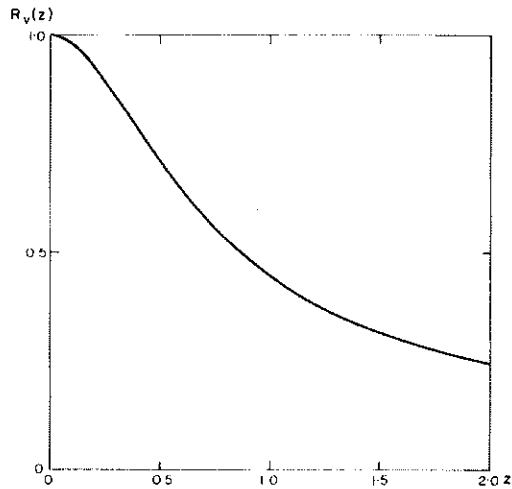


FIGURE 7. Cumulative response versus depth for vertical dipoles. $R_v(z)$ is the relative contribution to H_s from all material below a (normalized) depth z .

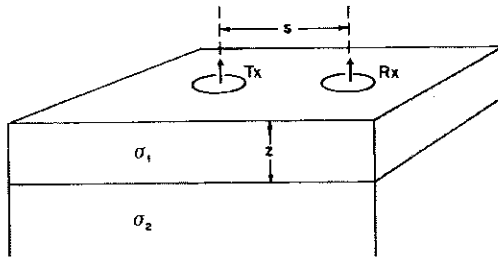


FIGURE 8. Two layer earth model.

millimhos per meter but make all material above two intercoil spacings infinitely resistive the meter reading will fall from the original 20 millimhos per meter for the homogeneous half space to 5 millimhos per meter, since, if all of the material below two intercoil spacings contributed 25% of the meter reading, all of the material above two intercoil spacings must contribute 75%; when removed the meter reading becomes 0.25×20 or 5 millimhos per meter.

From this example we see that there is a simple way to calculate the instrument reading on an arbitrarily layered earth as long as the intercoil spacing is much less than the skin depth in all of the layers. We simply add the contribution from each layer independently, weighted according to its conductivity and depth according to Figure 7. For example assume that we have a two-layer case as shown in Figure 8. The contribution from the upper layer is given by

$$\sigma_a = \sigma_1 [1 - R_V(z)] \quad (4a)$$

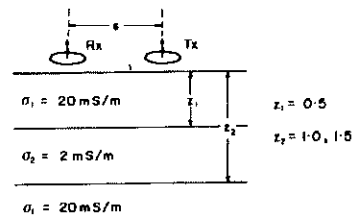
since all of the material below zero depth yields a relative contribution of unity or 100% to the meter reading. Conversely all of the material in the lower layer adds a contribution given by

$$\sigma_a = \sigma_2 R_V(z) \quad (4b)$$

and the actual instrument reading will therefore be the sum of these two quantities

$$\sigma_a = \sigma_1 [1 - R_V(z)] + \sigma_2 R_V(z) \quad (5)$$

If the earth is three-layered as shown in Figure 9 the same procedure is employed to determine the instrumental response. In this example the calculations are performed for different middle layer thicknesses.



$$\sigma_a = \sigma_1 [1 - R(z_1)] + \sigma_2 [R(z_1) - R(z_2)] + \sigma_3 R(z_2)$$

$$z_2 = 1.0, \sigma_a = 20 [1 - 0.70] + 2 [0.70 - 0.44] + 20 \times 0.44 = 15.3 \text{ mmo/m}$$

$$z_2 = 1.5, \sigma_a = 20 [1 - 0.70] + 2 [0.70 - 0.32] + 20 \times 0.32 = 13.2 \text{ mmo/m}$$

FIGURE 9. Calculation of response to three layer earth - center layer thickness varying.

8

The ease with which such calculations are performed facilitates survey preparation and interpretation. It is sometimes possible to make advance estimates of the electrical properties of the materials to be encountered during a survey or, alternatively, once on-site the operator can obtain the same information from sample measurements of the different materials. The procedures outlined above are then employed to estimate the apparent conductivity measured under various terrain conditions. Examples of such calculations for the EM31 are shown in Figure 10. As is seen in the appendix the algebraic expressions for $R(z)$ and $R_V(z)$ are very simple and are easily programmed on hand held calculators.

In Figure 10 the vertical dimensions are greatly exaggerated with respect to the horizontal dimensions. The question arises as to what degree of lateral uniformity is required before the earth can be considered as horizontally stratified or homogeneous. Survey experience indicates that if the ground conductivity does not significantly vary with horizontal distance within a radius of one intercoil spacing from the instrument the ground can be considered to be laterally uniform.

The above discussion referred to the use of vertical transmitter/receiver dipoles; it is equally possible to construct a cumulative response function for the horizontal coplanar dipole configuration and Figure 11 illustrates this function for both coil configurations. A comparison of the two curves illustrates that the vertical dipole mode of operation has approximately twice the effective exploration depth of the horizontal dipole mode.

IV. 3. Comparison with Conventional Resistivity Techniques

Many readers will be familiar with the two-layer curves employed to interpret data from conventional resistivity surveys using a Wenner array of four equally spaced electrodes. Using the techniques described in the previous section it is a simple matter to calculate two-layer curves for the electromagnetic technique; Figure 12 shows such curves for both the vertical and horizontal dipole configurations superimposed on standard Wenner curves. The general shape is similar but there are marked differences in detail. For vertical coplanar transmitter/receiver dipoles we see that when the substrate is the more resistive the response of the two systems is similar; however when the substrate is the more conductive the electromagnetic technique sees deeper in that the influence of the substrate, for a given conductivity contrast, is felt at smaller intercoil spacing than inter-electrode spacing. This is a general characteristic of electromagnetic systems which prefer to look through an insulator to a conductor rather than through a conductor to an insulator.

For the horizontal dipole configuration if the lower layer is the more resistive the effective exploration depth of the inductive technique is slightly less than the Wenner array; however, once again, in the case where the lower layer is the more conductive the exploration depth of the inductive technique is substantially greater.

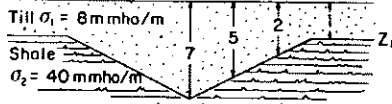
IV. 4. Resolution of Two-Layered Earth by Varying Intercoil Spacing

The principal advantage of the inductive electromagnetic technique over conventional resistivity lies in the speed and accuracy with which lateral changes of terrain conductivity can be measured. However this technique can also be used to measure the vertical variation of conductivity by expanding the intercoil spacing in a manner analogous to that in which the electrode spacing is expanded in conventional resistivity sounding techniques. The current state-of-the-art, however, is such that relatively few intercoil spacings can be employed; for example the EM34-3 can be operated with an intercoil spacing of 10, 20 or 40 meters. This feature is somewhat mitigated by the fact that the instruments can be used in either the vertical or horizontal dipole modes which, as shown in a previous section, exhibit different sensitivity to various depths thus yielding more information than would be available by simply using three spacings with one coil orientation.

To interpret a two-layer geometry the two-layer curves for both dipole configurations are superimposed on a common plot as shown

CROSS-SECTIONS

BURIED RIVER VALLEY

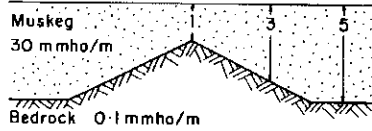


$$\frac{\sigma_a}{\sigma_1} = 1 - R(Z_1) + k_2 R(Z_1)$$

$$k_2 = \frac{\sigma_2}{\sigma_1} = \frac{40}{8} = 5$$

Z ₁ (m)	σ _a (mmho/m)
1	32.6
2	26.9
5	18.6
7	16.0

BEDROCK HIGH

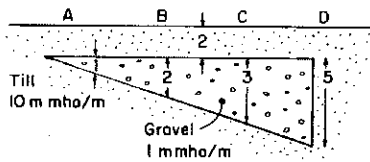


$$\frac{\sigma_a}{\sigma_1} = 1 - R(Z_1) + k_2 R(Z_1)$$

$$k_2 = \frac{\sigma_2}{\sigma_1} = \frac{0.1}{30} = 0.0033$$

Z ₁ (m)	σ _a (mmho/m)
1	6.9
3	15.9
5	20.1

GRAVEL DEPOSIT



$$\frac{\sigma_a}{\sigma_1} = 1 - R(Z_1) + k_2 [R(Z_1) - R(Z_2)] + k_3 R(Z_2)$$

$$k_2 = \frac{\sigma_2}{\sigma_1} = \frac{1}{10} = 0.10$$

$$k_3 = \frac{\sigma_3}{\sigma_1} = 1.00$$

station	σ _a (mmho/m)
A	8.9
B	8.2
C	7.7
D	6.9

FIGURE 10. EM31 calculated response across various geological features, using $R(Z)$ corrected for instrument operation at waist (1 meter) height. Coil separation $s = 3.67$ meters.

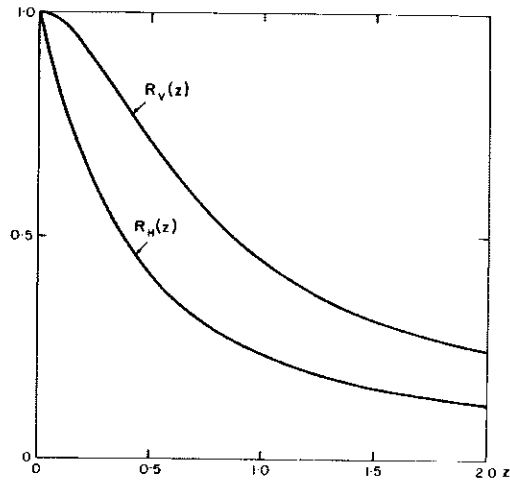


FIGURE 11. Cumulative response versus depth for vertical and horizontal dipoles.

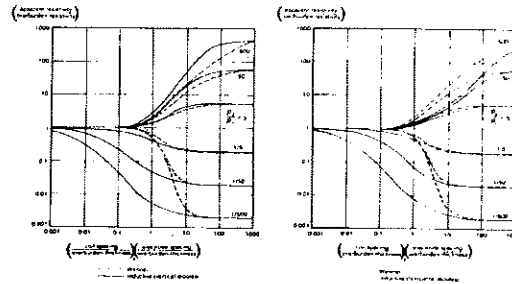


FIGURE 12. Comparison of Wenner array and inductive electromagnetic sounding curves for a two layer earth.

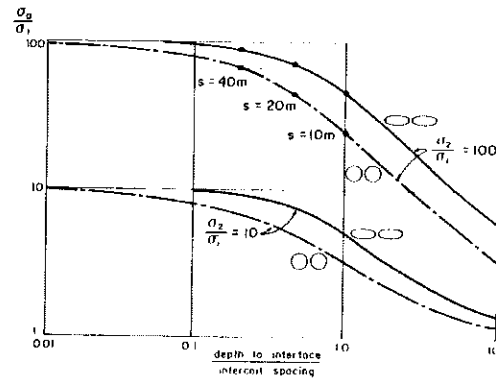


FIGURE 13. Two layer earth response curves ($\sigma_2/\sigma_1 = 10, 100$; intercoil spacing varied). Dots indicate typical survey results.

in Figure 13. The six data points obtained by making measurements with two coil orientations and three intercoil spacings are plotted to the same scale on a piece of transparent paper and are translated vertically and horizontally on the two-layer curves to ascertain whether a satisfactory fit can be achieved. In the event that such a fit can be made, the earth does exhibit two-layer characteristics and the values of conductivity for both layers and the thickness of the upper layer are directly read off.

IV. 5. Resolution of Two-Layered Earth by Varying Instrument Height

In the case of the EM31 the intercoil spacing is rigidly fixed so that the technique described above is not available to analyse a layered earth. It is, however, possible to raise the instrument above the ground, measuring the apparent conductivity as a function of instrument height for both the vertical and horizontal dipole configurations. This has the effect of shifting the response curves of Figure 6 upwards through the various regions of the earth and the variation of apparent conductivity with height is therefore of diagnostic value in determining the nature of any layering. It is a straightforward matter to calculate the response of the instrument as a function of height for various two-layered earth geometries and typical curves are shown in Figure 14b. To use the curves one simply plots the measured apparent conductivity versus height for both coil configurations on a piece of transparent paper to the same scale as Figure

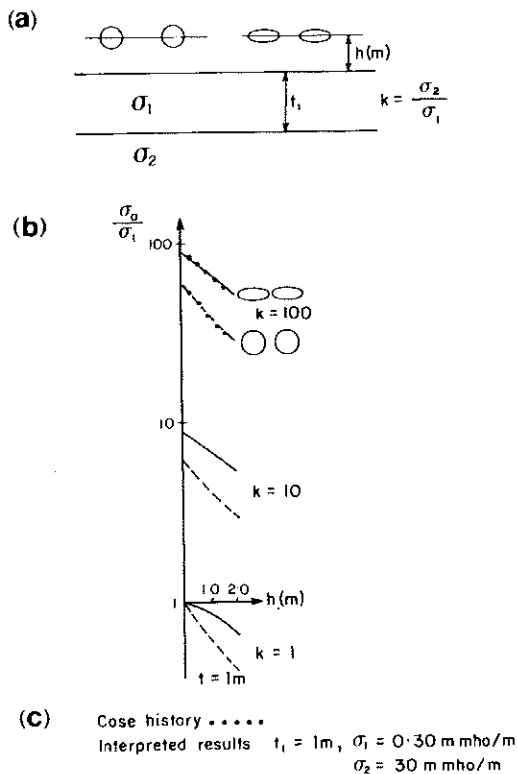


FIGURE 14. Two layer earth response curves (σ_a for $t_1 = 1, 10, 100$; instrument height varied). Dots are actual survey results.

14b and shifts the plotted data vertically until good agreement is achieved with one of the curves, whereupon the two conductivities and the upper layer thickness are immediately determined as in the illustrated case history of Figure 14c.

In the event that the conductivity of either one of the two layers is known to be much less than the other, so that its contribution to the meter reading is negligible, it is simply necessary to lay the instrument on the ground, take a reading, lay it on its side, take a second reading, and from these two values one can immediately calculate the conductivity of the more conductive layer and the thickness of the upper layer.

V. ADVANTAGES AND DISADVANTAGES OF INDUCTIVE TERRAIN CONDUCTIVITY MEASUREMENTS

V. 1. Advantages

The advantages of the use of inductive electromagnetic techniques to measure terrain conductivity are as follows:

- (i) *Excellent resolution in conductivity.* It was stated in Section 4 that a problem with conventional resistivity was that the presence of localized resistivity inhomogeneities near the potential electrodes caused large errors. If we examine the current flow in a homogeneous half-space for the inductive technique described herein we realize that in the vicinity of the transmitter the current density is very high and we might expect the presence of a conductive inhomogeneity located here to have a large effect. However where the current density is high, the radius of the current loops is small and their distance from the receiver coil large, so that these loops do not couple well magnetically with the receiver. The effect of changing this current by varying the local conductivity is consequently negligible. The lateral extent of the volume of earth whose conductivity is sensed by the inductive technique is approximately the same as the vertical depth. The result is that small changes in conductivity, for example of the order of 5% or 10%, are easily and accurately measured.
- (ii) *No current injection problems.* Since currents are magnetically induced in the earth, current injection problems encountered with conventional resistivity in materials such as gravel, bedrock, permafrost, snow and ice, etc., are not encountered with this type of instrumentation.
- (iii) *Simple multi-layered earth calculations.* This matter is dealt with at length in Section IV.
- (iv) *Easy, rapid measurements.* A problem with the conventional Wenner array is that in order to survey to an effective depth a the array must be $3a$ in length and the total length of wire required $4a$, used in four sections. This presents many opportunities for snagging and breaking the wire. Furthermore each measurement requires insertion of four electrodes and relatively careful measurement of the inter-electrode spacing. These features are avoided with the inductive electromagnetic techniques and it is no exaggeration to say that a survey can often be carried out five to ten times faster using this technique. Indeed with either the EM31 or the EM34-3 it is usually possible under average terrain conditions to survey 5 to 7 line-kilometers a day with a station spacing of 25 or 50 meters.

V. 2. Disadvantages

As with all geophysical instruments, there are some limitations and disadvantages to the use of inductive electromagnetic techniques and these are as follows:

- (i) *Limited dynamic range ($1 - 1000$ milliohms per meter).* At low values of terrain conductivity it becomes difficult to magnetically induce sufficient current in the ground to produce a detectable magnetic field at the receiver coil. Conversely at high values of conductivity the quadrature component of the received magnetic field is no longer linearly proportional to terrain conductivity as is shown in the appendix.
- (ii) *Setting and maintaining the instrument zero.* Ideally in order to set the zero the instrument would be suspended in free space

and the zero set there. The more acceptable alternative is to search out a region of very resistive ground, to accurately measure its conductivity using conventional techniques, and to set the instrumental zero at that location. This is the procedure which is actually followed.

It is necessary that this zero be accurately maintained over long periods of time and over the wide variations of temperature encountered during geophysical survey in various parts of the world. This produces tight constraints on the circuitry, with the result that the zero may be in error by up to ± 0.2 mmhos per meter. Such an error would be negligible over the usual range of terrain conductivities; however in the event that measurements are being made on highly resistive ground the zero error can become significant.

- (iii) *Limited Vertical Sounding Capability.* In theory it is possible to use a system such as the EM34-3 at a continuum of intercoil spacings to yield more information about electrical layering in the ground. To achieve a wide variety of inter-electrode spacings with conventional resistivity equipment is simple; in the case of the inductive electromagnetic technique the rapid fall-off of the magnetic field from the dipole transmitter introduces a serious dynamic range problem. In due course there will undoubtedly be instrumentation with a wider variety of spacings at the expense of additional complexity.

VI. CASE HISTORIES

This section describes several case histories obtained with the EM31 and the EM34. The surveys (i) illustrate the resolution in conductivity that can be achieved, (ii) compare the results obtained with conventional resistivity and (iii) illustrate the use of the latter for locating sand, gravel and conductive minerals, determining bed-rock topography (including locating a buried river channel) and mapping the pollution plume from a land-fill site. In some cases the indicated conductivity has been converted to resistivity to facilitate comparison with conventional resistivity survey results.

Case History #1

Location: Mississauga, Ontario

Instrument: EM31

Application: Illustrates resolution and repeatability of EM31

For this case history a Rustrak chart recorder was used to monitor the output of an EM31. A line of length 200 meters was traversed in a field in both easterly and westerly directions. Figure 15 demon-

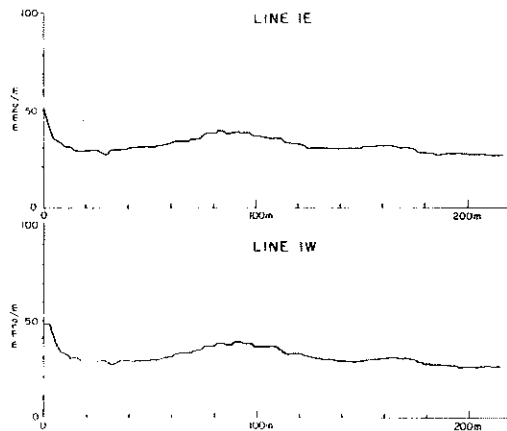


FIGURE 15.

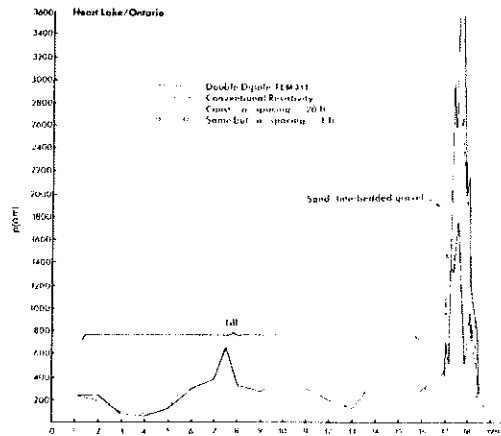


FIGURE 16. Test survey line - Heart Lake, Ont.

strates that the instrument is resolving conductivity changes of less than 1 mmho/m (1% of full scale deflection) and that the repeatability is of the same order. In fact the repeatability is limited in this case by the resolving power of the chart recorder itself. It should furthermore be noted that the instrument is detecting spatial changes in conductivity of a few meters in length - compatible with the intercoil spacing of 3.7 meters.

Case History #2

Location: Heart Lake, Ontario

Instruments: EM31

Conventional resistivity apparatus

Application: Location of sand/gravel

Comparison of EM31 and conventional resistivity

In this survey a line 1900 ft. (580 meters) in length was surveyed with a measurement interval of 100 ft. (30 meters). The survey area was generally located on a buried esker, however the last few survey stations, 17 + 00 to 19 + 00, traversed a region of exposed sand and gravel (often occurring in the form of concretions) and over this portion of the line measurements were made every 10 ft. (3.0 meters).

The conventional resistivity profile was carried out using a Wenner array with an a spacing of 20 ft. (6.1 meters) except between stations 17 + 00 and 19 + 00 where the a spacing was reduced to 1 ft. (0.30 meters).

In general the correlation between the two sets of data is excellent, and demonstrates the ability of the EM31 to generate good quantitative data even in regions of low conductivity. Over the esker the EM31 was actually read continuously down the line - the data was recorded only at the 100 ft. intervals, with the exception of the reading at station 7 + 50 which was also recorded since it was noted that a conductivity low occurred there. Such an anomaly was, of course, missed by the conventional resistivity where measurements were only made every 100 ft.

Both sets of data become rather erratic between stations 17 + 00 and 19 + 00 as a result of the very rapid lateral changes in resistivity arising from the concreted material referred to above.

Case History #3

Location: Cavendish, Ontario.

Instrument: EM31

Application: Location of metallic type conductors

This survey line, of length 2000 ft. (610 meters), is located at a site

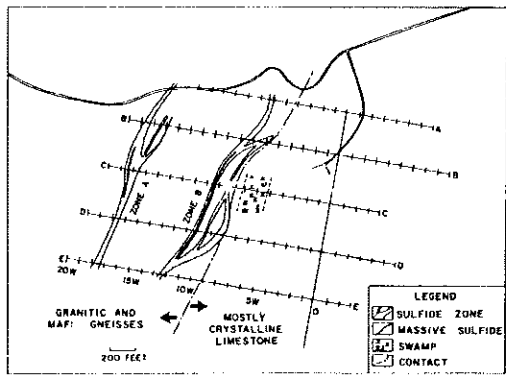


FIGURE 17. Geologic map of the Cavendish test site and the grid of traverse lines used in geophysical studies (after Ward et al [3]).

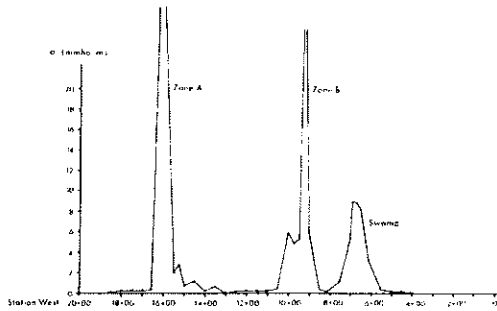


FIGURE 18. EM31 survey of Cavendish test range Line C.

in Ontario which is often used by Canadian instrumentation manufacturers to test new electromagnetic geophysical equipment. The survey, along line C, illustrates response from both the swamp and the two zones of metallic mineralization. Although measurements were only taken every 50 ft. (15 meters) both zones are well delineated and when such high responses are encountered localization to within a few meters is quickly and easily carried out.

Inasmuch as the EM31 and EM34-3 were designed to map terrain conductivity at the conductivity levels encountered in typical soils both instruments are extremely sensitive electromagnetic detectors. For example on the most sensitive scale, full scale deflection for the EM31 is 800 ppm of the primary magnetic field and for the EM34-3 it is 3800 ppm. Such sensitivity makes either instrument useful for detecting metallic type conductors at what are very low conductivity levels by normal standards.

Case History #4

Location: Mississauga, Ontario
 Instruments: EM31, EM34
 Application: Determination of bedrock topography

Total line length for this survey was 8400 ft. (2600 meters) and measurements were made every 100 ft. (30 meters) with both the EM31 and the EM34 – an earlier version of the EM34-3 which had two intercoil spacings vis. 100 ft. (30 meters) and 50 ft. (15 meters). The survey was performed to outline the cross-sectional profile of a

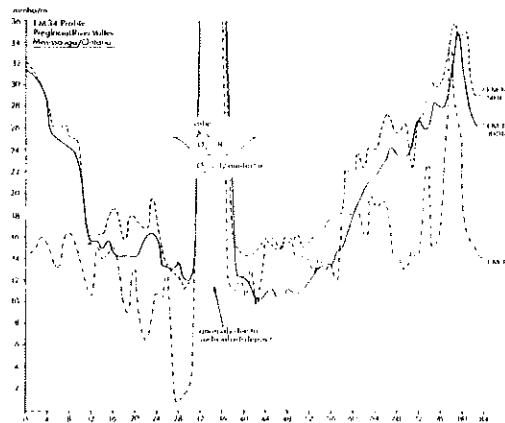


FIGURE 19. EM31 and EM34 survey line over preglacial river valley, Mississauga, Ontario.

buried preglacial river valley whose existence had been suggested from water-well data. At either intercoil spacing the time required for the EM34 profile was 1-1/2 hours, resulting in approximately one survey measurement per minute – including the time to walk the 100 feet between measurement stations. The time taken for the subsequent EM31 survey was similar.

Typical bedrock conductivity in the area is approximately 30 mmho/m, whereas an average value for the conductivity of the infilling glacial till is of the order of 8 to 12 mmho/m. Thus the EM34 at either intercoil spacing yields approximately 30 mmho/m at the valley edges where the overburden is thin and 12 to 14 mmho/m at the valley centre. The EM31 yields values of 14 to 18 mmho/m at the valley edges (slightly affected by the presence of bedrock) and approximately 10 mmho/m at the valley centre. The interpreted depth of the valley, based on the model shown in the figure, is approximately 120 feet (36 meters) which is in reasonable agreement with the water-well data value of 150 feet (45 meters), bearing in mind that the three sets of data show that a two-layer model is an over simplification.

The conductivity high which occurs between stations 32 and 38 results from a very large pile of waste furnace ash lying on the surface.

Case History #5

Location: Camp Borden, Ontario
 Instruments: EM31, EM34
 Conventional resistivity apparatus
 Application: Mapping groundwater salinity
 Comparison of EM34 and conventional resistivity

Geophysical surveys were carried out over a sanitary landfill site using, in addition to other instruments, an EM31, EM34 and conventional resistivity [4]. The survey results in the accompanying figures illustrate the good agreement between these techniques and also indicate the reduction in survey time achieved using inductive electromagnetic techniques. Particularly interesting are the vertical variations in resistivity as shown by the EM31 at 3.7 m intercoil spacing and the EM34 at 15 and 30 m spacing.

VII. SUMMARY

This technical note describes in detail the principles of mapping the electrical conductivity of the ground using magnetically induced

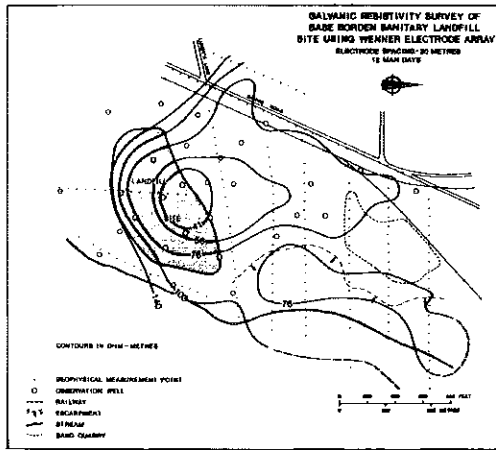


FIGURE 20(a).

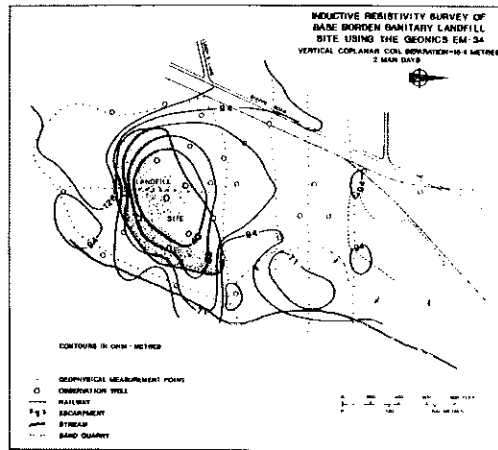


FIGURE 20(c).

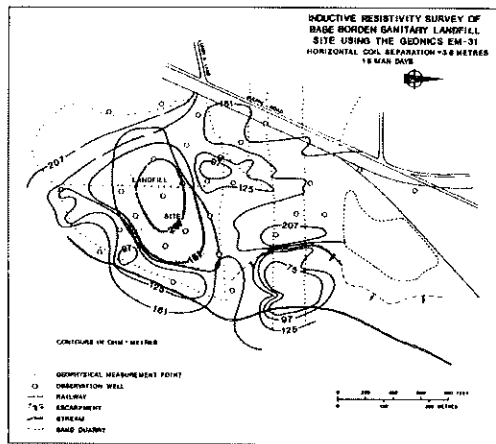


FIGURE 20(b).

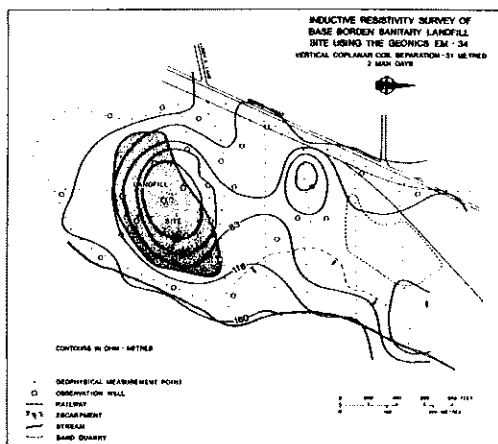


FIGURE 20(d).

currents at low frequencies. It has been shown that certain advantages can be derived from working at low values of induction number. Amongst these are excellent resolution in conductivity, a substantial reduction in man-hours necessary to carry out a conductivity survey and a simplification in the calculation of layered earth response.

Two points should be kept constantly in mind when performing surveys of this type to map geology. The first is that these instruments map only the electrical conductivity. If the conductivity does not vary significantly with the geological environment, or if parameters other than the geology also influence the conductivity, the survey results may be difficult to interpret.

The second point is that measurement of terrain conductivity, like any other geophysical measurement, must begin and end with geology. Such measurements are only an aid to help visualize geological conditions which cannot be seen. It is always necessary to interpret

geophysical data against known geology from out-crops, boreholes, or any other such "bench marks". Geophysical measurements can be very effective by allowing interpolation between such sources, or extrapolation away from them. However in every case knowledge derived from geophysical measurements must be eventually re-confirmed against known geological conditions.

BIBLIOGRAPHY

- (1) Keller, G.V., Frischknecht, F.C. Electrical Methods in Geophysical Prospecting, Pergamon Press 1966.
- (2) Wait, J.R. 1962. A Note on the Electromagnetic Response of a Stratified Earth. Geophysics V.27, pp 382-85.
- (3) Ward, S.H.; Pridmore, D.F.; Rjof, Glenn W.E. Multispectral Electromagnetic Exploration for Sulphides. Geophysics Vol. 39 No. 5 p. 666, 1974.
- (4) Survey carried out by Dr. J. Greenhouse, University of Waterloo, Waterloo, Ontario.

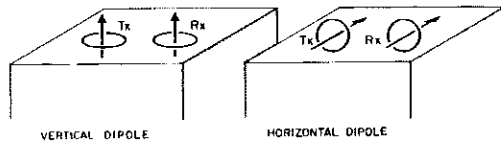


FIGURE A1. Vertical and horizontal dipole coil configurations.

APPENDIX: Theory of Operation at Low Induction Numbers

Consider the two coil configurations shown in Figure A1. In each case the transmitter coil is energized with alternating current at a frequency f Hertz. The measured quantity is the ratio of the secondary magnetic field H_s at the receiver when both coils are lying on the surface of the homogeneous half-space of conductivity σ to the primary magnetic field H_p in the absence of the half-space (i.e. as if the coils were in free space). The spacing between the coils is s meters.

The field ratios for vertical and horizontal dipole configurations are given by equations (1) and (2) respectively.

$$\left(\frac{H_s}{H_p}\right)_v = \frac{2}{(\gamma s)^3} [9 + 9\gamma s + 4(\gamma s)^2 + (\gamma s)^3] e^{-\gamma s} \quad (1)$$

$$\left(\frac{H_s}{H_p}\right)_h = 2 \left[1 - \frac{3}{(\gamma s)^2} + [3 + 3\gamma s + (\gamma s)^2] \frac{e^{-\gamma s}}{(\gamma s)^2} \right] \quad (2)$$

where $\gamma = \sqrt{i\omega\mu_0\sigma}$
 $\omega = 2\pi f$
 $f =$ frequency (Hz)
 $\mu_0 =$ permeability of free space
 $i = \sqrt{-1}$.

These expressions are complicated functions of the variable γs which is in turn a reasonably complicated (complex) function of frequency and conductivity. However, as will be shown below, under certain conditions they can be greatly simplified.

A well known characteristic of a homogeneous half-space is the electrical skin depth δ , which is defined as the distance in the half-space that a propagating plane wave has travelled when its amplitude has been attenuated to $1/e$ of the amplitude at the surface. The skin depth is given by

$$\delta = \sqrt{\frac{2}{\omega\mu_0\sigma}} = \frac{\sqrt{2i}}{\gamma} \quad (3)$$

and therefore

$$\gamma s = \sqrt{2i} \frac{s}{\delta} \quad (4)$$

The ratio s/δ , the intercoil spacing divided by the skin depth, is defined as the induction number B , whereupon

$$\gamma s = \sqrt{2i} B \quad (5)$$

Now if B is much less than unity (ie $\gamma s \ll 1$) it is a simple matter to show that the field ratios of equations (1) and (2) reduce to the simple expression

$$\left(\frac{H_s}{H_p}\right)_v \approx \left(\frac{H_s}{H_p}\right)_h \approx \frac{iB^2}{2} = \frac{i\omega\mu_0\sigma s^2}{4} \quad (6)$$

which is the equation given in Section II.

The magnitude of the secondary magnetic field is now directly proportional to the ground conductivity and the phase of the secondary magnetic field leads the primary magnetic field by 90° .

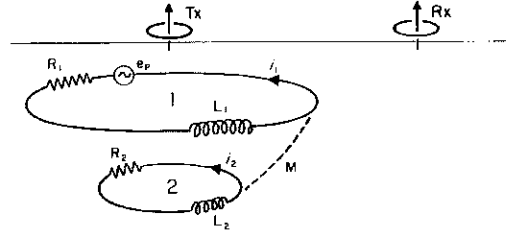


FIGURE A2. Electrical model for vertical dipoles.

To make B much less than unity we see that we must make s very much less than δ and thus

$$\omega \ll \frac{2}{\mu_0\sigma s^2} \quad (7)$$

That is, having decided on a value for s (which fixes the effective depth of penetration under the condition $B \ll 1$), the maximum probable ground conductivity is estimated and the operating frequency is chosen so that equation (7) is always satisfied.

The apparent conductivity which the instrument reads is then defined by

$$\sigma_a = \frac{4}{\omega\mu_0 s^2} \left(\frac{H_s}{H_p}\right)_{\text{quadrature component}} \quad (8)$$

To examine the reasons for this simplification let us focus our attention on the vertical dipole coil configuration shown in Figure A2 since symmetry makes this configuration the simplest to understand.

Consider current loop 1. The primary emf e_p , causing this current to flow is given (through Faraday's law) by the time rate of change of the primary magnetic flux from the transmitter through this loop. Three impedances cause the current to be limited. These arise from (i) the electrical resistance R_1 of the loop, (ii) the fact that the current i_1 generates its own magnetic field which causes a time-varying secondary magnetic flux through the loop (self-inductance, L_1), and (iii) the fact that all other current loops such as i_2 generate their own magnetic fields which in turn cause a time-varying magnetic flux to link with loop 1 (mutual-inductance, M).

The equivalent circuit for this configuration is easily derived from elementary circuit theory with the result shown in Figure A3.

The complex impedance Z incorporates all of the affects of magnetic coupling between current loop 1 and any other current loop 2. We see from this expression that Z can be made arbitrarily small by reducing $\omega = 2\pi f$, the operating frequency. When Z is thus

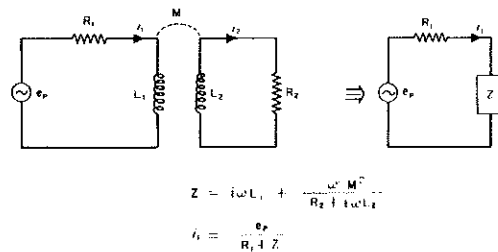


FIGURE A3. Equivalent circuit for model of Figure A2.

made much smaller than R_1 the current flow in loop 1 is simply given by

$$i_1 = \frac{e_p}{R_1} = \frac{i\omega\phi_p}{R_1} = i\omega\phi_p G_1 \quad (9)$$

where ϕ_p = primary flux linking loop 1
 G_1 = conductance of loop 1 ($G_1 = 1/R_1$)
 $i = \sqrt{-1}$

We see that the magnitude of the current is linearly proportional to the loop conductance and furthermore that the phase of the current leads the primary flux by 90° . Since the secondary magnetic field at the receiver from current i_1 is in phase with and directly proportional to i_1 it too will be directly proportional to G and will lead the primary flux by 90° . Thus

$$\left(\frac{H_s}{H_p}\right) \propto i\omega G_1 \quad (10)$$

which has the same dependence on frequency and conductance as equation (6). We infer therefore, that the condition $B \ll 1$ is equivalent to stating that for all current loops that affect the receiver output the operating frequency is so low that we can ignore any magnetic coupling between the loops. Thus the current that flows in any loop is (i) completely independent of the current that flows in any other loop since they are not magnetically coupled and (ii) is only a function of the primary magnetic flux linking that loop and of the local ground conductivity.

The lack of interaction between current loops is of great importance in simplifying the data reduction procedures. Of equally great significance is the fact that for any value of B and for any orientation of a magnetic dipole (or indeed of any magnetic source) over either a uniform halfspace or a horizontally stratified earth it can be shown that all current flow is horizontal. That this is the case for a vertical dipole is easy to see from symmetry; for a horizontal dipole it is less evident but equally true. Thus, in a horizontally layered earth no current crosses an interface which is fortunate since, if it did, changing either of the conductivities would, by virtue of refraction of the current, change the direction of the current as it flowed from one medium to the other.

If no current flow crosses an interface and if there is no magnetic coupling between current loops, changing the conductivity of any one of the layers of a horizontally stratified earth will not alter the geometry of the current flow. Varying the conductivity of any layer will proportionately vary only the magnitude of the current in that layer. To calculate the resultant magnetic field at the surface of a horizontally layered earth it is simply necessary to calculate the independent contribution from each layer, which is a function of its depth and conductivity, and to sum all the contributions.

The functions $\delta(z)$ and $R(z)$ discussed in Section II define the relative influence of current flow as a function of depth. Their derivation is involved and will not be given here. The resultant

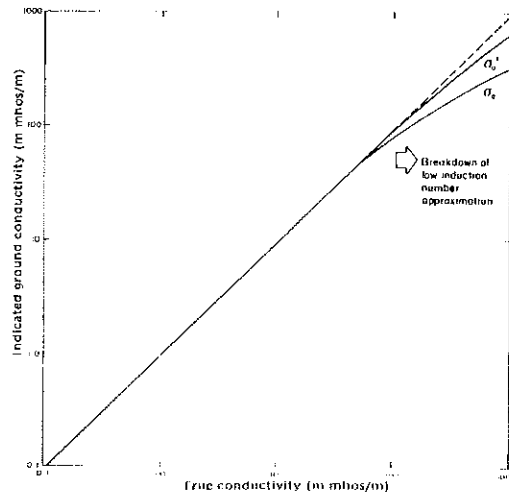


FIGURE A1V. Plot of indicated conductivity for EM31 versus true (homogeneous half-space) conductivity for both vertical (σ_v) and horizontal (σ_h) dipoles.

expressions are, however, simple and easily programmed into hand calculators:

$$\delta_v(z) = \frac{4z}{(4z^2 + 1)^{3/2}} \quad (11)$$

$$\delta_h(z) = 2 - \frac{4z}{(4z^2 + 1)^{3/2}} \quad (12)$$

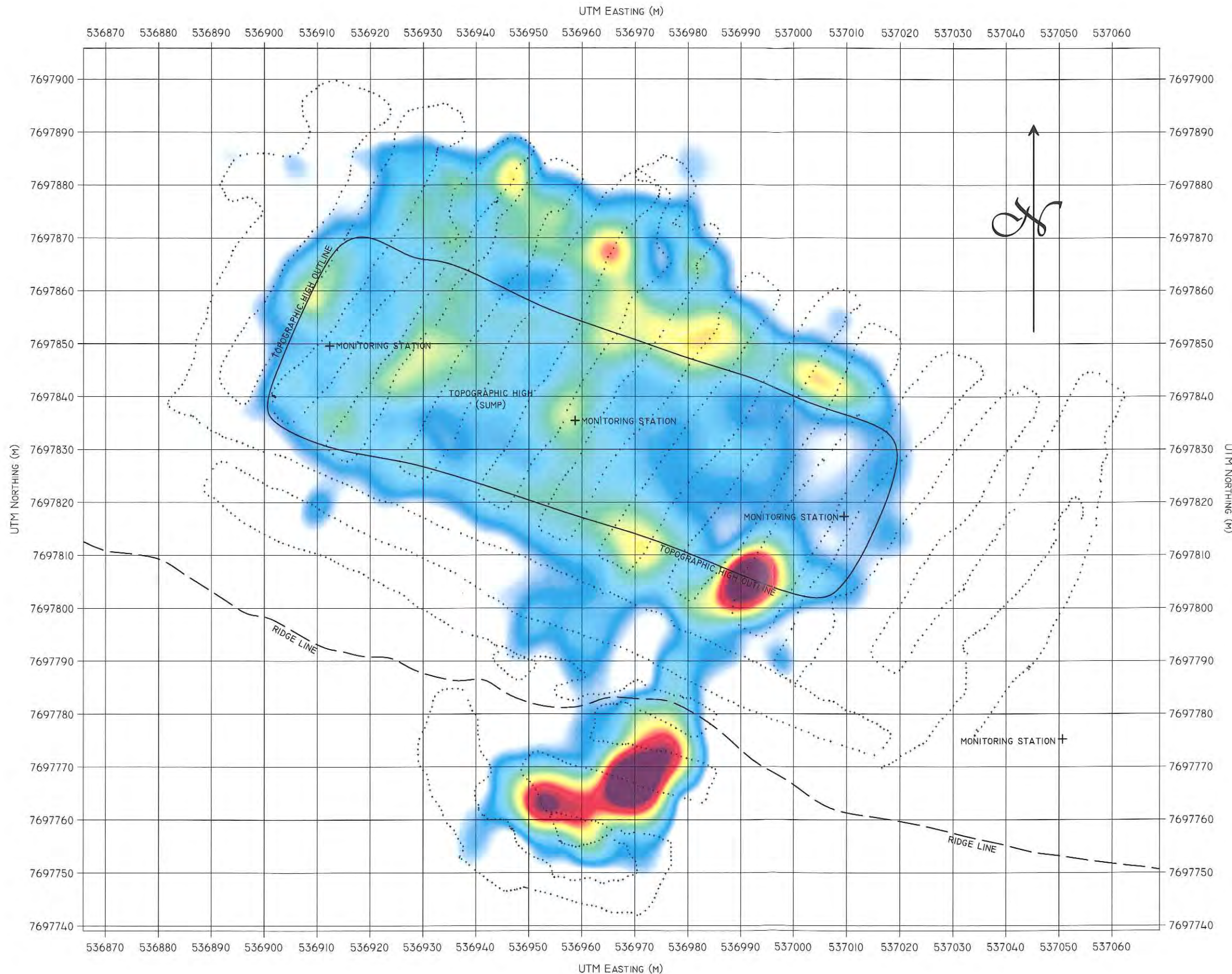
$$R_v(z) = \frac{1}{(4z^2 + 1)^{1/2}} \quad (13)$$

$$R_h(z) = (4z^2 + 1)^{1/2} - 2z \quad (14)$$

where z is the depth divided by the intercoil spacing.

Finally it should be noted that for a given frequency and intercoil spacing as the terrain conductivity increases the approximation of equation (6) eventually breaks down and the instrumental output is no longer proportional to terrain conductivity. This effect is illustrated in Figure A1V, which plots apparent (indicated) conductivity against true (homogeneous halfspace) conductivity for both vertical and horizontal transmitter/receiver dipoles for the operating parameters of the EM31. As would be expected the horizontal dipoles exhibit linearity to greater values of conductivity as a result of the reduced depth of penetration in this configuration.

APPENDIX C



SITE LOCATION MAP

COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRICTING FEATURES.

TECHNICAL SUMMARY

GEOPHYSICAL SPECIFICATIONS

INSTRUMENT:	GEONICS EM38
MEASURED QUANTITIES:	QUADRATURE IN MS/M
	INPHASE IN PPT, MS/HP
PRIMARY FIELD SOURCE (TX):	SELF-CONTAINED DIPOLE TX
RECEIVER (RX):	SELF-CONTAINED DIPOLE RX
INTERCOIL SPACING:	1.0 M
OPERATING FREQUENCY:	14.6 KHZ
CONDUCTIVITY RANGES:	10 - 1000 MS/M

POSITIONING (DGPS) SPECIFICATIONS

GPS ROVER:	TRIMBLE PATHFINDER POWER
GPS BASE:	TRIMBLE 4000SH DUAL
DATA S/A CORRECTIONS:	POST-PROCESSED DIFFERENTIAL
COORDINATE PROJECTION:	UNIVERSAL TRANSVERSE MERCATOR (UTM)
UTM ROVER ZONE:	8
DATUM:	NORTH AMERICAN DATUM 1927 (NAD27)
BASE COORDINATE:	SOPAC, INUVIK, NWT
	X: 560870E
	Y: 7577333N
	ELEV.: 46.36 M (HAE)

LEGEND

- TOPOGRAPHIC HIGH (SUMP)
- MONITORING STATION
- RIDGE LINE
- GEOPHYSICAL MEASUREMENT STATIONS

MAP 1/2 SCALE = 1:790 SEPTEMBER 2005 Job No.: 1560 02

LATERAL CONDUCTIVITY DISTRIBUTION (EM38) & SITE FEATURES

UMIAK NI6 SUMP

CLIENT:

DIRECTED BY:

PRODUCED BY:

APPROVED: _____

CREATED: _____

DATE: _____

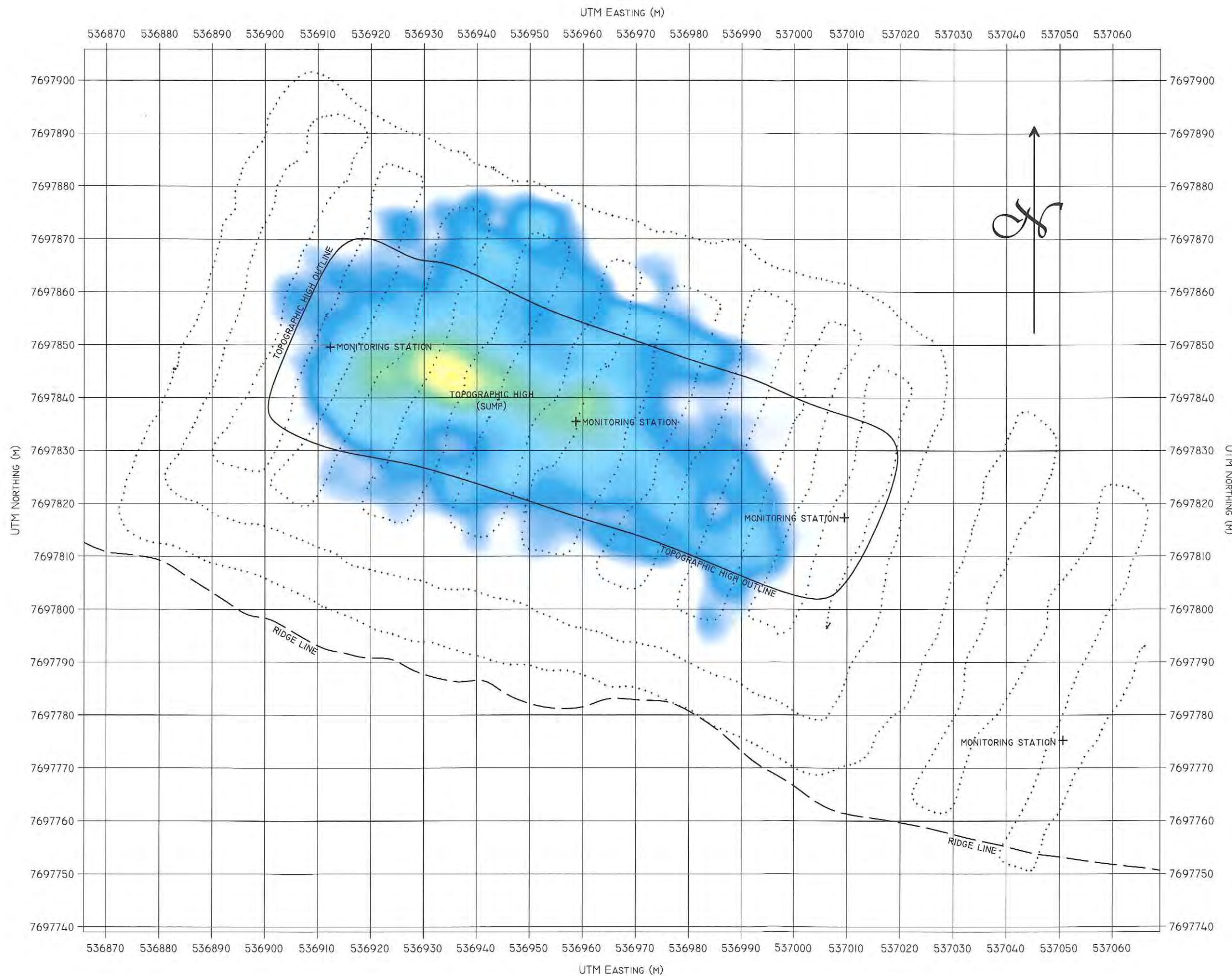
PERMIT TO PRACTICE
ESSIS LTD.

Signature: _____

Date: _____

PERMIT NUMBER: P 6825
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

REDUCED VERSION



SITE LOCATION MAP



COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRUCTING FEATURES.

TECHNICAL SUMMARY

GEOPHYSICAL SPECIFICATIONS

INSTRUMENT: GEONICS EM31
 MEASURED QUANTITIES: QUADRATURE IN mS/M
 INPHASE IN pPT, HS/HP
 PRIMARY FIELD SOURCE (TX): SELF-CONTAINED DIPOLE TX
 RECEIVER (RX): SELF-CONTAINED DIPOLE RX
 INTERCOIL SPACING: 3.66 M
 OPERATING FREQUENCY: 9.8 KHZ
 CONDUCTIVITY RANGES: 10 - 1000 mS/M

POSITIONING (DGPS) SPECIFICATIONS

GPS ROVER: TRIMBLE PATHFINDER POWER
 GPS BASE: TRIMBLE L1000SSI DUAL
 DATA S/A CORRECTIONS: POST-PROCESSED DIFFERENTIAL
 COORDINATE PROJECTION: UNIVERSAL TRANSVERSE MERCATOR (UTM)
 UTM ROVER ZONE: 8
 DATUM: NORTH AMERICAN DATUM 1927 (NAD27)
 BASE COORDINATE: SOPAC, INUVIK, NWT
 X: 560870E
 Y: 7577533N
 ELEV.: 46.36 M (HAE)

LEGEND

- TOPOGRAPHIC HIGH (SUMP)
- MONITORING STATION
- RIDGE LINE
- GEOPHYSICAL MEASUREMENT STATIONS

APPARENT CONDUCTIVITY (mS/M)

MAP 2/2 SCALE = 1:790 SEPTEMBER 2005 Job No.: 1560 02

**LATERAL CONDUCTIVITY DISTRIBUTION (EM31)
&
SITE FEATURES
UMIAK NI6 SUMP**

CLIENT:

DIRECTED BY:

PRODUCED BY:

APPROVED: _____

CREATED: _____

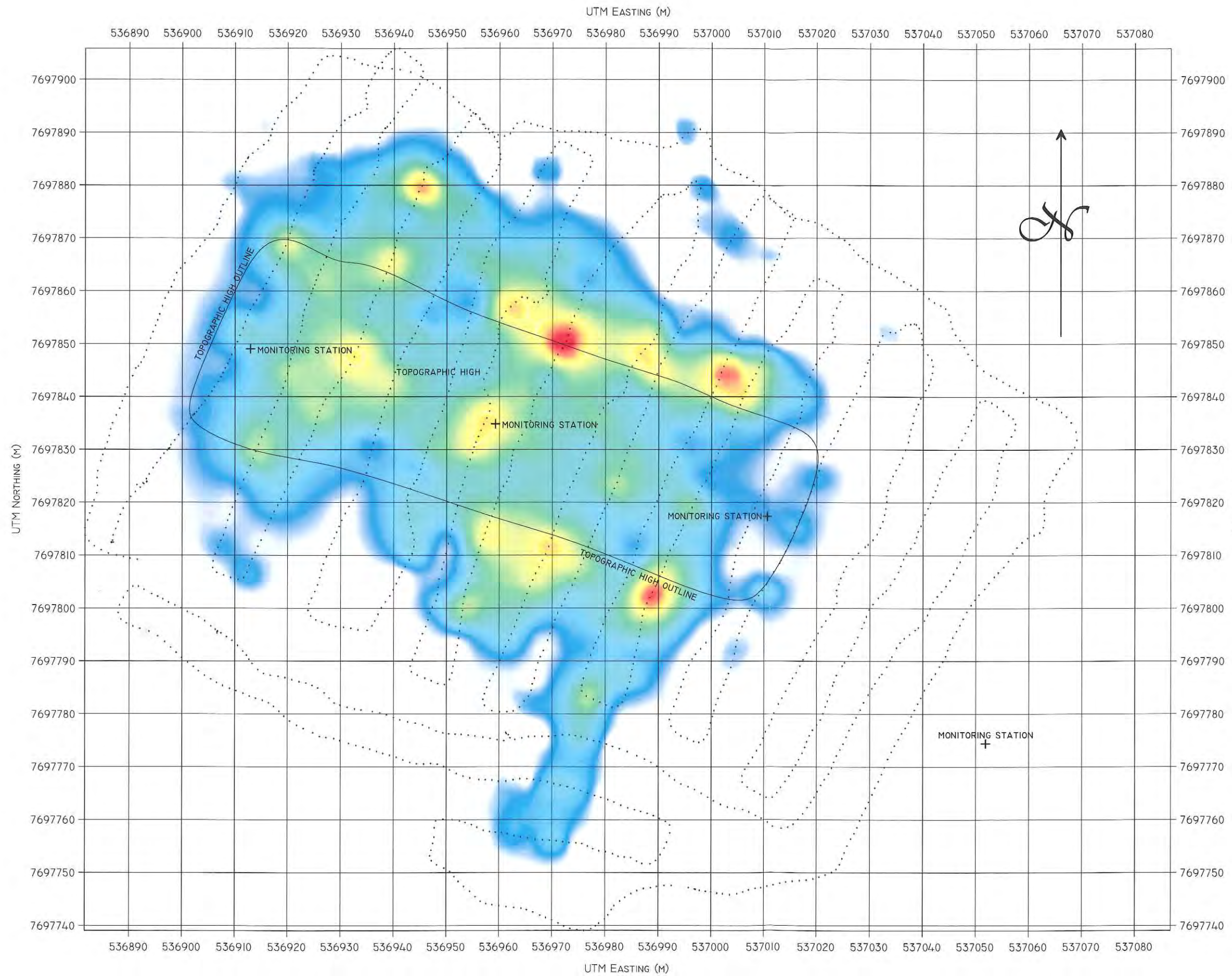
Signature: _____

Date: _____

**PERMIT TO PRACTICE
ESSIS LTD.**

PERMIT NUMBER: P 6825
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta





SITE LOCATION MAP



COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRICTING FEATURES.

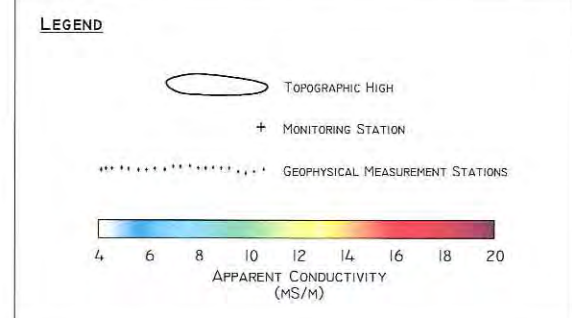
TECHNICAL SUMMARY

GEOPHYSICAL SPECIFICATIONS

INSTRUMENT: GEONICS EM38
 MEASUREMENT QUANTITIES: QUADRATURE IN MS/M
 INPHASE IN PPT, HS/HP
 PRIMARY FIELD SOURCE (TX): SELF-CONTAINED DIPOLE TX
 RECEIVER (RX): SELF-CONTAINED DIPOLE RX
 INTERCOIL SPACING: 1.0 M
 OPERATING FREQUENCY: 14.6 KHZ
 CONDUCTIVITY RANGES: 10 - 1000 MS/M

POSITIONING (DGPS) SPECIFICATIONS

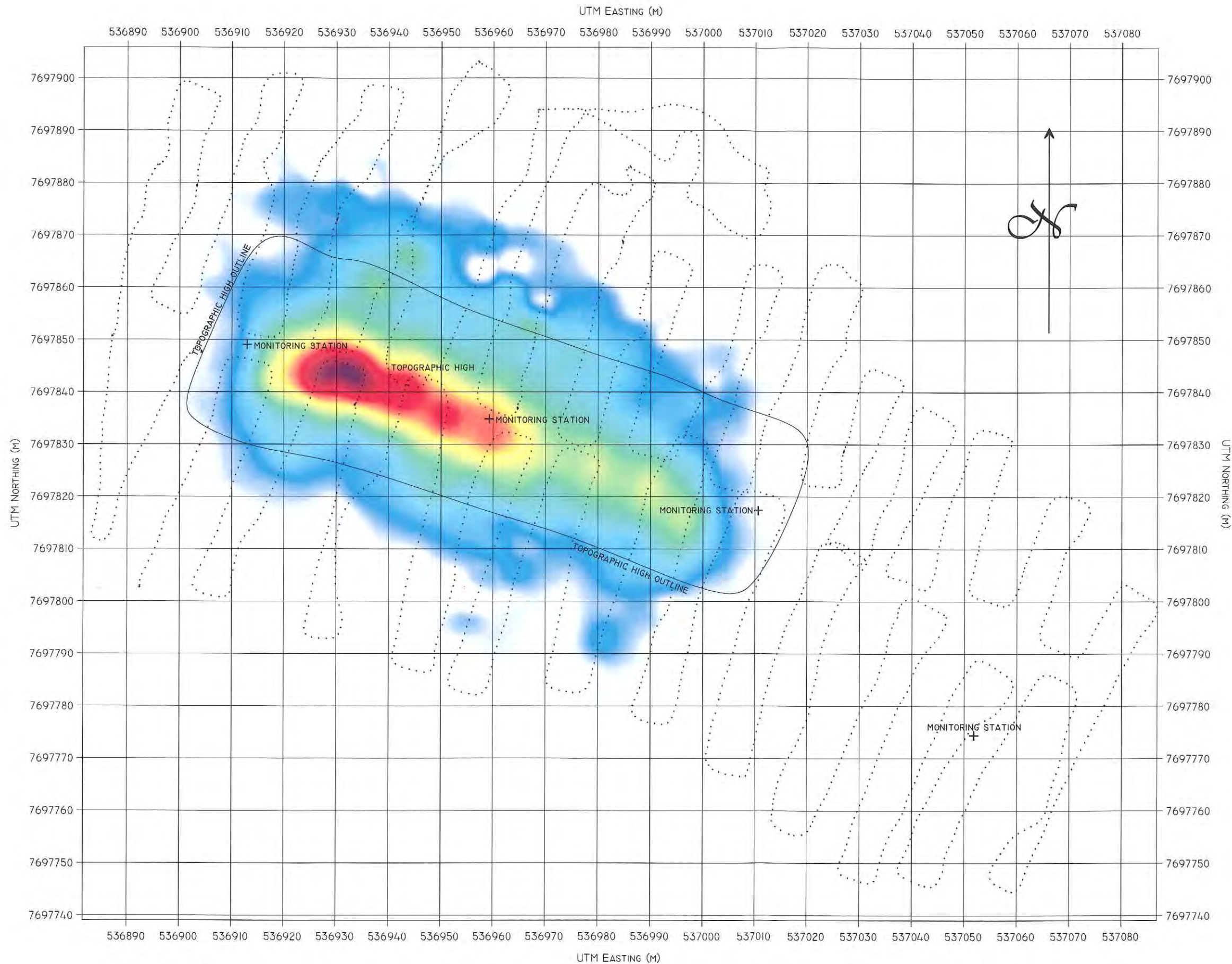
GPS ROVER: TRIMBLE PATHFINDER POWER
 GPS BASE: TRIMBLE 4000SSI DUAL
 DATA S/A CORRECTIONS: POST-PROCESSED DIFFERENTIAL
 COORDINATE PROJECTION: UNIVERSAL TRANSVERSE MERCATOR (UTM)
 UTM ROVER ZONE: 8
 DATUM: NORTH AMERICAN DATUM 1927 (NAD27)
 BASE COORDINATE: SOPAC, INUVIK, NWT
 X: 560870E
 Y: 7577533N
 ELEV.: 46.36 M (HAE)



MAP 1/2 SCALE = 1:765 AUGUST 2004 JOB No.: 1442

LATERAL CONDUCTIVITY DISTRIBUTION (EM38) & SITE FEATURES
 UMIAK NI6 SUMP

CLIENT: 	APPROVED: _____
DIRECTED BY: 	CREATED: _____
PRODUCED BY: 	PERMIT TO PRACTICE ESSIS LTD. Signature _____ Date _____
REDUCED VERSION PERMIT NUMBER: P 6825 The Association of Professional Engineers, Geologists and Geophysicists of Alberta	



SITE LOCATION MAP



COMMENTS

THE COLOUR IMAGE REVEALS THE 'APPARENT CONDUCTIVITY DISTRIBUTION' ON SITE. THE TERM 'APPARENT CONDUCTIVITY' IMPLIES THAT CONDUCTIVITY MEASUREMENTS DO NOT LINEARLY RELATE TO ACTUAL SOIL CONDUCTIVITIES.

THE PRESENTED EM DATA SHOULD BE USED QUALITATIVELY TO SELECT TARGETS FOR VERTICAL (DEPTH) GEOPHYSICAL PROFILING OR SOIL SAMPLING. GEOPHYSICAL RESULTS ARE ONLY CONCLUSIVE AFTER CORRELATION TO SOIL SAMPLE DATA (GROUND-TRUTHING). THE DEPTH RESPONSE OF THE ELECTROMAGNETIC (EM) FIELD VARIES FROM SURFACE TO A UNIQUE DEPTH, THE 'SKINDEPTH' OF THAT PARTICULAR EM SIGNAL. THE SKINDEPTH OF ANY EM SIGNAL IS STRONGLY INFLUENCED BY OVERALL SOIL CONDUCTIVITY. SINCE SOIL CONDUCTIVITY VARIES RANDOMLY, THE APPARENT CONDUCTIVITY DISTRIBUTION DOES NOT REPRESENT DATA FROM ANY PARTICULAR DEPTH.

POSTED FEATURES ARE SURVEYED USING DGPS. A POSITIONAL ACCURACY OF SEVERAL DECIMETERS IS GENERALLY POSSIBLE. POSITIONAL ACCURACY DIMINISHES NEAR LARGER BUILDINGS AND OTHER SATELLITE-OBSTRUCTING FEATURES.

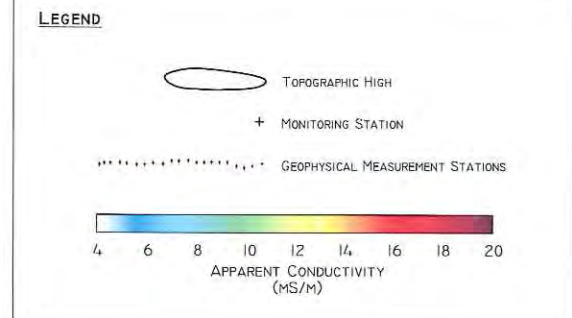
TECHNICAL SUMMARY

GEOPHYSICAL SPECIFICATIONS

INSTRUMENT: GEONICS EM31
 MEASURED QUANTITIES: QUADRATURE IN MS/M
 INFRASE IN PPT, HS/HP
 PRIMARY FIELD SOURCE (TX): SELF-CONTAINED DIPOLE TX
 RECEIVER (RX): SELF-CONTAINED DIPOLE RX
 INTERCOIL SPACING: 3.66 M
 OPERATING FREQUENCY: 9.8 KHZ
 CONDUCTIVITY RANGES: 10 - 1000 MS/M

POSITIONING (DGPS) SPECIFICATIONS

GPS ROVER: TRIMBLE PATHFINDER POWER
 GPS BASE: TRIMBLE 4000SSI DUAL
 DATA S/A CORRECTIONS: POST-PROCESSED DIFFERENTIAL
 COORDINATE PROJECTION: UNIVERSAL TRANSVERSE MERCATOR (UTM)
 UTM ROVER ZONE: 8
 DATUM: NORTH AMERICAN DATUM 1927 (NAD27)
 BASE COORDINATE: SOPAC, INUVIK, NWT
 X: 560870E
 Y: 7577533N
 ELEV.: 46.36 M (HAE)



MAP 2/2 SCALE = 1:765 AUGUST 2004 Job No.: 1442

LATERAL CONDUCTIVITY DISTRIBUTION (EM31) & SITE FEATURES

UMIAK N16 SUMP

CLIENT: ENCANA	APPROVED: _____
DIRECTED BY: KWIB AAYS Inc.	CREATED: _____
PRODUCED BY: Essis	<p>REDUCED VERSION</p> <p>PERMIT TO PRACTICE ESSIS LTD.</p> <p>Signature _____ Date _____</p> <p>PERMIT NUMBER: P 6825 The Association of Professional Engineers, Geologists and Geophysicists of Alberta</p>

Appendix E Laboratory Analysis





Environmental Division

PRELIMINARY RESULTS

AXYS ENVIRONMENTAL CONSULTING
ATTN: CHRIS REVAK
SUITE 300, 805 8 AVENUE SW
CALGARY AB T2P 1H7

Reported On: 26-SEP-06 10:10 AM

Lab Work Order #: **L434162**

Date Received: **18-SEP-06**

Project P.O. #: NA
Job Reference: NDKA9046
Legal Site Desc: UMIAK N16
CofC Numbers: 259852, 259853, 269500

Other Information:

Comments:

STEPHANIE ERIN HOEPPNER
General Manager, Calgary

For any questions about this report please contact your Account Manager:

SHANNA IRENE WIENMEYER

THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN AUTHORITY OF THE LABORATORY.
ALL SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU
REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-1	N16-S1 (0.0-0.4)							
Sampled By:	CR on 16-SEP-06 @ 16:00							
Matrix:	SOIL							
MUST PSA % > 75um	44	1		%		25-SEP-06	LK	R445781
Organic Matter	11	1		%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size								
% Sand	79	1		%		21-SEP-06	RT	R444634
% Silt	15	1		%		21-SEP-06	RT	R444634
% Clay	6	1		%		21-SEP-06	RT	R444634
Texture	0					21-SEP-06	RT	R444634
Detailed Salinity								
Chloride (Cl)	40		20	mg/L		21-SEP-06	SEL	R444589
SAR								
Calcium (Ca)	169		5	mg/L		22-SEP-06	MAT	R444736
Potassium (K)	7		2	mg/L		22-SEP-06	MAT	R444736
Magnesium (Mg)	47		3	mg/L		22-SEP-06	MAT	R444736
Sodium (Na)	42		2	mg/L		22-SEP-06	MAT	R444736
SAR	0.7			SAR		22-SEP-06	MAT	R444736
Sulphate (SO4)	303		6	mg/L		22-SEP-06	MAT	R444736
pH and EC (Saturated Paste)								
% Saturation	56.0		0.1	%		06-SEP-21	TMAR	R444365
pH in Saturated Paste	6.5		0.1	pH		06-SEP-21	TMAR	R444365
Conductivity Sat. Paste	1.03		0.03	dS m-1		06-SEP-21	TMAR	R444365
L434162-2	N16-S1 (0.4-0.8)							
Sampled By:	CR on 16-SEP-06 @ 16:00							
Matrix:	SOIL							
MUST PSA % > 75um	75	1		%		25-SEP-06	LK	R445781
Organic Matter	5	1		%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size								
% Sand	85	1		%		21-SEP-06	RT	R444634
% Silt	10	1		%		21-SEP-06	RT	R444634
% Clay	5	1		%		21-SEP-06	RT	R444634
Texture	0					21-SEP-06	RT	R444634
Detailed Salinity								
Chloride (Cl)	30		20	mg/L		21-SEP-06	SEL	R444589
SAR								
Calcium (Ca)	194		5	mg/L		22-SEP-06	MAT	R444736
Potassium (K)	10		2	mg/L		22-SEP-06	MAT	R444736
Magnesium (Mg)	55		3	mg/L		22-SEP-06	MAT	R444736
Sodium (Na)	38		2	mg/L		22-SEP-06	MAT	R444736
SAR	0.6			SAR		22-SEP-06	MAT	R444736
Sulphate (SO4)	452		6	mg/L		22-SEP-06	MAT	R444736
pH and EC (Saturated Paste)								
% Saturation	35.3		0.1	%		06-SEP-21	TMAR	R444365
pH in Saturated Paste	7.3		0.1	pH		06-SEP-21	TMAR	R444365
Conductivity Sat. Paste	1.28		0.03	dS m-1		06-SEP-21	TMAR	R444365
L434162-3	N16-S2 (0.0-0.4)							
Sampled By:	CR on 16-SEP-06 @ 16:00							
Matrix:	SOIL							
MUST PSA % > 75um	75	1		%		25-SEP-06	LK	R445781
Organic Matter	2	1		%	22-SEP-06	22-SEP-06	MMC	R445390

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters		Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-3	N16-S2 (0.0-0.4)								
Sampled By:	CR on 16-SEP-06 @ 16:00								
Matrix:	SOIL								
Particle Size									
	% Sand	81		1	%		21-SEP-06	RT	R444634
	% Silt	15		1	%		21-SEP-06	RT	R444634
	% Clay	4		1	%		21-SEP-06	RT	R444634
	Texture	0					21-SEP-06	RT	R444634
Detailed Salinity									
	Chloride (Cl)	40		20	mg/L		21-SEP-06	SEL	R444589
SAR									
	Calcium (Ca)	173		5	mg/L		22-SEP-06	MAT	R444736
	Potassium (K)	7		2	mg/L		22-SEP-06	MAT	R444736
	Magnesium (Mg)	40		3	mg/L		22-SEP-06	MAT	R444736
	Sodium (Na)	33		2	mg/L		22-SEP-06	MAT	R444736
	SAR	0.6			SAR		22-SEP-06	MAT	R444736
	Sulphate (SO4)	410		6	mg/L		22-SEP-06	MAT	R444736
pH and EC (Saturated Paste)									
	% Saturation	46.0		0.1	%		06-SEP-21	TMAR	R444365
	pH in Saturated Paste	6.5		0.1	pH		06-SEP-21	TMAR	R444365
	Conductivity Sat. Paste	1.06		0.03	dS m-1		06-SEP-21	TMAR	R444365
L434162-4	N16-S2 (0.4-0.8)								
Sampled By:	CR on 16-SEP-06 @ 16:00								
Matrix:	SOIL								
	MUST PSA % > 75um	85		1	%		25-SEP-06	LK	R445781
	Organic Matter	2		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size									
	% Sand	87		1	%		21-SEP-06	RT	R444634
	% Silt	10		1	%		21-SEP-06	RT	R444634
	% Clay	3		1	%		21-SEP-06	RT	R444634
	Texture	0					21-SEP-06	RT	R444634
Detailed Salinity									
	Chloride (Cl)	30		20	mg/L		21-SEP-06	SEL	R444589
SAR									
	Calcium (Ca)	167		5	mg/L		22-SEP-06	MAT	R444736
	Potassium (K)	28		2	mg/L		22-SEP-06	MAT	R444736
	Magnesium (Mg)	37		3	mg/L		22-SEP-06	MAT	R444736
	Sodium (Na)	34		2	mg/L		22-SEP-06	MAT	R444736
	SAR	0.6			SAR		22-SEP-06	MAT	R444736
	Sulphate (SO4)	389		6	mg/L		22-SEP-06	MAT	R444736
pH and EC (Saturated Paste)									
	% Saturation	32.0		0.1	%		06-SEP-21	TMAR	R444365
	pH in Saturated Paste	7.3		0.1	pH		06-SEP-21	TMAR	R444365
	Conductivity Sat. Paste	1.16		0.03	dS m-1		06-SEP-21	TMAR	R444365
L434162-5	N16-S3								
Sampled By:	CR on 16-SEP-06 @ 16:00								
Matrix:	SOIL								
	Organic Matter	75		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat									
	Foreign Matter (>1.70 mm)	<0.1		0.1	%		22-SEP-06	LK	R445130
	Coarse Fiber (>1.70 mm)	13.4		0.1	%		22-SEP-06	LK	R445130
	Medium Fiber (0.85-1.70 mm)	18.0		0.1	%		22-SEP-06	LK	R445130

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-5 N16-S3 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Particle Size Range of Peat Fines (<0.85 mm)	66.7		0.1	%		22-SEP-06	LK	R445130
Detailed Salinity Chloride (Cl)	220		20	mg/L		22-SEP-06	SEL	R445094
SAR Calcium (Ca)	72		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	75		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	34		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	39		2	mg/L		23-SEP-06	MAT	R445859
SAR	1.0			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	48		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste) % Saturation	400		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	4.7		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.99		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-6 N16-S4 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
MUST PSA % > 75um	29		1	%		22-SEP-06	LK	R445140
Organic Matter	81		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size % Sand	72		1	%		22-SEP-06	RT	R445018
% Silt	22		1	%		22-SEP-06	RT	R445018
% Clay	6		1	%		22-SEP-06	RT	R445018
Texture	Sandy loam					22-SEP-06	RT	R445018
Detailed Salinity Chloride (Cl)	30		20	mg/L		22-SEP-06	SEL	R445094
SAR Calcium (Ca)	19		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	5		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	8		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	14		2	mg/L		23-SEP-06	MAT	R445859
SAR	0.7			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	16		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste) % Saturation	370		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	4.7		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.22		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-7 N16-S5 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Organic Matter	51		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat Foreign Matter (>1.70 mm)	<0.1		0.1	%		22-SEP-06	LK	R445130
Coarse Fiber (>1.70 mm)	6.9		0.1	%		22-SEP-06	LK	R445130
Medium Fiber (0.85-1.70 mm)	7.3		0.1	%		22-SEP-06	LK	R445130
Fines (<0.85 mm)	81.9		0.1	%		22-SEP-06	LK	R445130
Detailed Salinity Chloride (Cl)	180		20	mg/L		22-SEP-06	SEL	R445094

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-7 N16-S5 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Detailed Salinity								
SAR								
Calcium (Ca)	75		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	32		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	24		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	31		2	mg/L		23-SEP-06	MAT	R445859
SAR	0.8			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	38		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste)								
% Saturation	296		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	5.1		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.81		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-8 N16-S6 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
MUST PSA % > 75um	77		1	%		25-SEP-06	LK	R445781
Organic Matter	11		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size								
% Sand	82		1	%		21-SEP-06	RT	R444634
% Silt	14		1	%		21-SEP-06	RT	R444634
% Clay	4		1	%		21-SEP-06	RT	R444634
Texture	0					21-SEP-06	RT	R444634
Detailed Salinity								
Chloride (Cl)	490		20	mg/L		21-SEP-06	SEL	R444589
SAR								
Calcium (Ca)	174		5	mg/L		22-SEP-06	MAT	R444736
Potassium (K)	32		2	mg/L		22-SEP-06	MAT	R444736
Magnesium (Mg)	74		3	mg/L		22-SEP-06	MAT	R444736
Sodium (Na)	54		2	mg/L		22-SEP-06	MAT	R444736
SAR	0.9			SAR		22-SEP-06	MAT	R444736
Sulphate (SO4)	103		6	mg/L		22-SEP-06	MAT	R444736
pH and EC (Saturated Paste)								
% Saturation	40.0		0.1	%		06-SEP-21	TMAR	R444365
pH in Saturated Paste	4.5		0.1	pH		06-SEP-21	TMAR	R444365
Conductivity Sat. Paste	1.83		0.03	dS m-1		06-SEP-21	TMAR	R444365
L434162-9 N16-S7 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Organic Matter	16		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat								
Foreign Matter (>1.70 mm)	<0.1		0.1	%		25-SEP-06		R445852
Coarse Fiber (>1.70 mm)	5.3		0.1	%		25-SEP-06		R445852
Medium Fiber (0.85-1.70 mm)	16.8		0.1	%		25-SEP-06		R445852
Fines (<0.85 mm)	77.4		0.1	%		25-SEP-06		R445852
Detailed Salinity								
Chloride (Cl)	2290		20	mg/L		22-SEP-06	SEL	R445094
SAR								
Calcium (Ca)	823		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	433		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	169		3	mg/L		23-SEP-06	MAT	R445859

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-11 N16-S9 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Detailed Salinity								
pH and EC (Saturated Paste)								
% Saturation	180		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	5.0		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.74		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-12 N16-S10 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Organic Matter	40		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat								
Foreign Matter (>1.70 mm)	<0.1		0.1	%		25-SEP-06		R445852
Coarse Fiber (>1.70 mm)	6.8		0.1	%		25-SEP-06		R445852
Medium Fiber (0.85-1.70 mm)	17.3		0.1	%		25-SEP-06		R445852
Fines (<0.85 mm)	75.8		0.1	%		25-SEP-06		R445852
Detailed Salinity								
Chloride (Cl)	30		20	mg/L		22-SEP-06	SEL	R445094
SAR								
Calcium (Ca)	36		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	7		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	12		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	17		2	mg/L		23-SEP-06	MAT	R445859
SAR	0.6			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	35		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste)								
% Saturation	144		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	4.5		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.28		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-13 N16-S11 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Organic Matter	80		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat								
Foreign Matter (>1.70 mm)	<0.1		0.1	%		25-SEP-06		R445852
Coarse Fiber (>1.70 mm)	13.3		0.1	%		25-SEP-06		R445852
Medium Fiber (0.85-1.70 mm)	23.3		0.1	%		25-SEP-06		R445852
Fines (<0.85 mm)	62.5		0.1	%		25-SEP-06		R445852
Detailed Salinity								
Chloride (Cl)	30		20	mg/L		22-SEP-06	SEL	R445094
SAR								
Calcium (Ca)	30		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	6		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	10		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	14		2	mg/L		23-SEP-06	MAT	R445859
SAR	0.6			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	31		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste)								
% Saturation	383		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	4.7		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.28		0.03	dS m-1		21-SEP-06	TMAR	R445091

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-14 N16-S12 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
Organic Matter	74		1	%	22-SEP-06	22-SEP-06	MMC	R445390
Particle Size Range of Peat								
Foreign Matter (>1.70 mm)	<0.1		0.1	%		25-SEP-06		R445852
Coarse Fiber (>1.70 mm)	8.1		0.1	%		25-SEP-06		R445852
Medium Fiber (0.85-1.70 mm)	20.3		0.1	%		25-SEP-06		R445852
Fines (<0.85 mm)	70.4		0.1	%		25-SEP-06		R445852
Detailed Salinity								
Chloride (Cl)	50		20	mg/L		22-SEP-06	SEL	R445094
SAR								
Calcium (Ca)	26		5	mg/L		23-SEP-06	MAT	R445859
Potassium (K)	9		2	mg/L		23-SEP-06	MAT	R445859
Magnesium (Mg)	13		3	mg/L		23-SEP-06	MAT	R445859
Sodium (Na)	24		2	mg/L		23-SEP-06	MAT	R445859
SAR	0.9			SAR		23-SEP-06	MAT	R445859
Sulphate (SO4)	32		6	mg/L		23-SEP-06	MAT	R445859
pH and EC (Saturated Paste)								
% Saturation	176		0.1	%		21-SEP-06	TMAR	R445091
pH in Saturated Paste	4.3		0.1	pH		21-SEP-06	TMAR	R445091
Conductivity Sat. Paste	0.31		0.03	dS m-1		21-SEP-06	TMAR	R445091
L434162-15 N16-H1 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
CCME BTEX, TVHs and TEHs								
CCME BTEX								
Benzene	<0.005		0.005	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Toluene	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Ethylbenzene	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Xylenes	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
CCME Total Extractable Hydrocarbons								
Prep/Analysis Dates					21-SEP-06	23-SEP-06	APR	R445335
CCME Total Hydrocarbons								
F1 (C6-C10)	<5	IPT	5	mg/kg		23-SEP-06		
F1-BTEX	<5		5	mg/kg		23-SEP-06		
F2 (C10-C16)	10		5	mg/kg		23-SEP-06		
F3 (C16-C34)	120		5	mg/kg		23-SEP-06		
F4 (C34-C50)	74		5	mg/kg		23-SEP-06		
Total Hydrocarbons (C6-C50)	200		5	mg/kg		23-SEP-06		
Chromatogram to baseline at nC50	NO					23-SEP-06		
% Moisture	17		0.1	%	21-SEP-06	22-SEP-06	ROS	R445297
L434162-16 N16-H2 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL								
CCME BTEX, TVHs and TEHs								
CCME BTEX								
Benzene	<0.005		0.005	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Toluene	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Ethylbenzene	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
Xylenes	<0.01		0.01	mg/kg	21-SEP-06	22-SEP-06	CAF	R445196
CCME Total Extractable Hydrocarbons								
Prep/Analysis Dates					21-SEP-06	23-SEP-06	APR	R445335

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-16 N16-H2 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: SOIL CCME BTEX, TVHs and TEHs CCME Total Hydrocarbons F1 (C6-C10) F1-BTEX F2 (C10-C16) F3 (C16-C34) F4 (C34-C50) Total Hydrocarbons (C6-C50) Chromatogram to baseline at nC50	<5 <5 10 200 130 340 NO	IPT	5 5 5 5 5 5	mg/kg mg/kg mg/kg mg/kg mg/kg mg/kg		23-SEP-06 23-SEP-06 23-SEP-06 23-SEP-06 23-SEP-06 23-SEP-06		
% Moisture	9.9		0.1	%	21-SEP-06	22-SEP-06	ROS	R445297
L434162-17 N16-W3 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER Routine Water Analysis Chloride (Cl) ICP metals for routine water Calcium (Ca) Potassium (K) Magnesium (Mg) Sodium (Na) Ion Balance Calculation Ion Balance TDS (Calculated) Hardness (as CaCO3) Nitrate+Nitrite-N Nitrate-N Nitrite-N Sulphate (SO4) pH, Conductivity and Total Alkalinity pH Conductivity (EC) Bicarbonate (HCO3) Carbonate (CO3) Hydroxide (OH) Alkalinity, Total (as CaCO3)	153 34.7 21.9 19.2 19 106 253 166 <0.05 <0.05 <0.05 5.6 5.6 587 <5 <5 <5 <5 33.3 9.9 2.4 6.1 12 145 68 50		0.1 0.5 0.1 0.1 1 0.05 0.05 0.05 0.5 0.1 3 5 5 5 5 0.1 5 5 5 5	mg/L mg/L mg/L mg/L mg/L % mg/L mg/L mg/L mg/L mg/L mg/L pH uS/cm mg/L mg/L mg/L mg/L mg/L mg/L mg/L	19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06	19-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 21-SEP-06 21-SEP-06 21-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 21-SEP-06 21-SEP-06 21-SEP-06	LHH MAT MAT MAT MAT LHH LHH LHH LHH GK GK GK GK GK LHH MAT MAT MAT MAT BL:INT	R443785 R444656 R444656 R444656 R444656 R443785 R443785 R443785 R443785 R443394 R443394 R443394 R443394 R443394 R443785 R444656 R444656 R444656 R444656 R444656 R443785
L434162-18 N16-W6 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER Routine Water Analysis Chloride (Cl) ICP metals for routine water Calcium (Ca) Potassium (K) Magnesium (Mg) Sodium (Na) Ion Balance Calculation Ion Balance TDS (Calculated) Hardness (as CaCO3)	33.3 9.9 2.4 6.1 12 145 68 50		0.1 0.5 0.1 0.1 1 0.1 5 5 5	mg/L mg/L mg/L mg/L mg/L % mg/L mg/L mg/L	19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06 19-SEP-06	19-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 20-SEP-06 21-SEP-06 21-SEP-06 21-SEP-06	LHH MAT MAT MAT MAT BL:INT	R443785 R444656 R444656 R444656 R444656 R443785

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-18 N16-W6 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER								
Routine Water Analysis								
Nitrate+Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrate-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Sulphate (SO4)	<0.5		0.5	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
pH, Conductivity and Total Alkalinity								
pH	6.0		0.1	pH		19-SEP-06	GK	R443394
Conductivity (EC)	170		3	uS/cm		19-SEP-06	GK	R443394
Bicarbonate (HCO3)	9		5	mg/L		19-SEP-06	GK	R443394
Carbonate (CO3)	<5		5	mg/L		19-SEP-06	GK	R443394
Hydroxide (OH)	<5		5	mg/L		19-SEP-06	GK	R443394
Alkalinity, Total (as CaCO3)	7		5	mg/L		19-SEP-06	GK	R443394
L434162-19 N16-W7 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER								
Routine Water Analysis								
Chloride (Cl)	378		0.1	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
ICP metals for routine water								
Calcium (Ca)	68.9		0.5	mg/L		20-SEP-06	MAT	R444656
Potassium (K)	120		0.1	mg/L		20-SEP-06	MAT	R444656
Magnesium (Mg)	27.3		0.1	mg/L		20-SEP-06	MAT	R444656
Sodium (Na)	42		1	mg/L		20-SEP-06	MAT	R444656
Ion Balance Calculation								
Ion Balance	93.9			%		21-SEP-06		
TDS (Calculated)	665			mg/L		21-SEP-06		
Hardness (as CaCO3)	284			mg/L		21-SEP-06		
Nitrate+Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrate-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Sulphate (SO4)	29.2		0.5	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
pH, Conductivity and Total Alkalinity								
pH	5.4		0.1	pH		19-SEP-06	GK	R443394
Conductivity (EC)	1390		3	uS/cm		19-SEP-06	GK	R443394
Bicarbonate (HCO3)	<5		5	mg/L		19-SEP-06	GK	R443394
Carbonate (CO3)	<5		5	mg/L		19-SEP-06	GK	R443394
Hydroxide (OH)	<5		5	mg/L		19-SEP-06	GK	R443394
Alkalinity, Total (as CaCO3)	<5		5	mg/L		19-SEP-06	GK	R443394
L434162-20 N16-W8 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER								
Routine Water Analysis								
Chloride (Cl)	389		0.1	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
ICP metals for routine water								
Calcium (Ca)	207		0.5	mg/L		20-SEP-06	MAT	R444656
Potassium (K)	50.1		0.1	mg/L		20-SEP-06	MAT	R444656
Magnesium (Mg)	89.9		0.1	mg/L		20-SEP-06	MAT	R444656
Sodium (Na)	74		1	mg/L		20-SEP-06	MAT	R444656
Ion Balance Calculation								
Ion Balance	99.8			%		21-SEP-06		
TDS (Calculated)	1280			mg/L		21-SEP-06		

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L434162-22 N16-W13 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER								
Routine Water Analysis								
Ion Balance Calculation								
Ion Balance	148	BL:INT		%		21-SEP-06		
TDS (Calculated)	100			mg/L		21-SEP-06		
Hardness (as CaCO3)	91			mg/L		21-SEP-06		
Nitrate+Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrate-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Sulphate (SO4)	0.6		0.5	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
pH, Conductivity and Total Alkalinity								
pH	6.5		0.1	pH		19-SEP-06	GK	R443394
Conductivity (EC)	213		3	uS/cm		19-SEP-06	GK	R443394
Bicarbonate (HCO3)	38		5	mg/L		19-SEP-06	GK	R443394
Carbonate (CO3)	<5		5	mg/L		19-SEP-06	GK	R443394
Hydroxide (OH)	<5		5	mg/L		19-SEP-06	GK	R443394
Alkalinity, Total (as CaCO3)	32		5	mg/L		19-SEP-06	GK	R443394
L434162-23 N16-W15 Sampled By: CR on 16-SEP-06 @ 16:00 Matrix: WATER								
Routine Water Analysis								
Chloride (Cl)	217		0.1	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
ICP metals for routine water								
Calcium (Ca)	113		0.5	mg/L		20-SEP-06	MAT	R444656
Potassium (K)	52.9		0.1	mg/L		20-SEP-06	MAT	R444656
Magnesium (Mg)	43.5		0.1	mg/L		20-SEP-06	MAT	R444656
Sodium (Na)	36		1	mg/L		20-SEP-06	MAT	R444656
Ion Balance Calculation								
Ion Balance	104			%		21-SEP-06		
TDS (Calculated)	683			mg/L		21-SEP-06		
Hardness (as CaCO3)	461			mg/L		21-SEP-06		
Nitrate+Nitrite-N	0.10		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrate-N	0.10		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Nitrite-N	<0.05		0.05	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
Sulphate (SO4)	143		0.5	mg/L	19-SEP-06	19-SEP-06	LHH	R443785
pH, Conductivity and Total Alkalinity								
pH	7.6		0.1	pH		19-SEP-06	GK	R443394
Conductivity (EC)	1250		3	uS/cm		19-SEP-06	GK	R443394
Bicarbonate (HCO3)	157		5	mg/L		19-SEP-06	GK	R443394
Carbonate (CO3)	<5		5	mg/L		19-SEP-06	GK	R443394
Hydroxide (OH)	<5		5	mg/L		19-SEP-06	GK	R443394
Alkalinity, Total (as CaCO3)	129		5	mg/L		19-SEP-06	GK	R443394

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier key listed:

Qualifier	Description
BL:INT	Balance Reviewed: Interference Or Non-Measured Component
IPT	Instrument performance showing response factors for C6 and C10 not within 30% of the response factor for toluene.

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
CL-CL	Water	Chloride (Cl)		APHA 4110 B-Ion Chromatography
CL-SAR-CL	Soil	Chloride (Cl) (Saturated Paste)		APHA 4500 - Cl- - E Auto'd Ferricyanide
ETL-BTX,TVH-CCME-CL	Soil	CCME BTEX		CCME CWS-PHC Dec-2000 - Pub# 1310
ETL-ROUTINE-ICP-CL	Water	ICP metals for routine water		APHA 3120 B-ICP-OES
ETL-TEH-CCME-CL	Soil	CCME Total Extractable Hydrocarbons	CCME CWS-PHC DEC2000	CCME CWS-PHC Dec-2000 - Pub# 1310
ETL-TVH,TEH-CCME-CL	Soil	CCME Total Hydrocarbons		CCME CWS-PHC Dec-2000 - Pub# 1310

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

Hydrocarbon results are expressed on a dry weight basis.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.

In samples where BTEX and F1 were analyzed, F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:

1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:

1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

IONBALANCE-CL	Water	Ion Balance Calculation		APHA 1030E
N2N3-CL	Water	Nitrate+Nitrite-N		APHA 4110 B-Ion Chromatography
NO2-CL	Water	Nitrite-N		APHA 4110 B-Ion Chromatography
NO3-IC-CL	Water	Nitrate-N		APHA 4110 B-Ion Chromatography
OM-LOI-SK	Soil	Organic Matter by LOI at 375 deg C.		CSSS (1978) p. 160
McKeague, J.A., Manual on Soil Sampling and Methods of Analysis, Canadian Society of Soil Science, 2nd Edition, 1978, P. 160.				
PH/EC/ALK-CL	Water	pH, Conductivity and Total Alkalinity		APHA 4500H,2510,2320
PREP-MOISTURE-CL	Soil	% Moisture		Oven dry 105C-Gravimetric
PSA-1-CL	Soil	Particle Size		CSSS 47.3 - Hydrometer
PSA-MUST-CL	Soil	MUST PSA D50 > 75um		ASTM D422-63
PSA-PEAT-CL	Soil	Particle Size Range of Peat		ASTM D2973-D2978,D2980,D2944
SAR-CALC-CL	Soil	SAR		CSSS 18.4-Calculation

Reference Information

SAT/PH/EC-CL	Soil	pH and EC (Saturated Paste)	CSSS, Chp. 18 - Saturation Extract
SO4-CL	Water	Sulfate (SO4)	APHA 4110 B-Ion Chromatography
SO4-SAR-CL	Soil	Sulfate (SO4)	APHA 3120 B-ICP-OES

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

259852 259853 269500

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
CL	ALS LABORATORY GROUP - CALGARY, ALBERTA, CANADA	SK	ALS LABORATORY GROUP - SASKATOON, SASKATCHEWAN, CANADA

GLOSSARY OF REPORT TERMS

Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in environmental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.

The reported surrogate recovery value provides a measure of method efficiency. The Laboratory control limits are determined under column heading D.L.

mg/kg (units) - unit of concentration based on mass, parts per million.

mg/L (units) - unit of concentration based on volume, parts per million.

< - Less than.

D.L. - The reporting limit.

N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.

UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS.

Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

ALS Laboratory Group has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, ALS Laboratory Group assumes no liability for the use or interpretation of the results.

REPORT TO:	DATE: <u>Sept 18, 2006</u>	LAB WORK ORDER # <u>NDKA 9046</u>
COMPANY: <u>Kavik Axys</u>	REPORT DISTRIBUTION ALL FINAL RESULTS WILL BE	<input checked="" type="checkbox"/> REGULAR SERVICE (DEFAULT) <input type="checkbox"/> PRIORITY SERVICE (50% SURCHARGE) <input type="checkbox"/> EMERGENCY SERVICE (100% SURCHARGE)
CONTACT: <u>Cris Revok</u>	EMAIL <input checked="" type="checkbox"/> FAX _____ MAILED	
ADDRESS: <u>Suite 30, 805 - 8th Ave SW</u>	EMAIL 1: <u>crevok@axys.net</u>	
<u>Calgary, AB</u>	EMAIL 2: _____	
PHONE: <u>530-3491</u> FAX: <u>269-5245</u>	DIGITAL EMAIL: _____	
CELLPHONE: <u>510-9231</u>	SELECT. pdf _____ digital _____ both <input checked="" type="checkbox"/>	

INVOICE TO: <u>SAMEY</u>	INDICATE BOTTLES: FILTERED/PRESERVED (F/P) <input type="checkbox"/>	ANALYSIS REQUEST			
COMPANY:	JOB # <u>NDKA9046</u>				
CONTACT:	PO/AFE: <u>N/A</u>				
ADDRESS:	LSD: <u>Umiah N16</u>				
PHONE:	QUOTE #				

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
<u>N16-W15</u>	<u>Umiah N16</u>	<u>CR/Sept 16/4:00</u>	<u>Surface</u>	<u>Water</u>				<u>23</u>

					<input type="checkbox"/> FROZEN <input type="checkbox"/> COLD <input type="checkbox"/> AMBIENT	MEAN TEMPERATURE
--	--	--	--	--	--	------------------

Failure to complete all portions of this form may delay analysis. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the reverse of the white report copy.

RELINQUISHED BY: <u>[Signature]</u>	DATE & TIME: <u>Sept 18, 3:15pm</u>	RECEIVED BY: <u>K. Flaggi</u>	DATE & TIME: <u>Sept 18/06 15:15</u>	SAMPLE CONDITION ACCEPTABLE UPON RECEIPT ? (Y/N)
-------------------------------------	-------------------------------------	-------------------------------	--------------------------------------	--

REPORT TO: Chris Revak
 COMPANY: Kavik-AXYS
 CONTACT: Chris Revak
 ADDRESS: Suite 300, 805 8th Ave SW
Calgary, AB
 PHONE: 583 3491 FAX: 269-5045
 CELLPHONE: 510-9231

REPORT DISTRIBUTION ALL FINAL RESULTS WILL BE MAILED
 EMAIL FAX _____
 EMAIL 1: crcrak@axys.net
 EMAIL 2: _____
 DIGITAL EMAIL: _____
 SELECT: pdf _____ digital _____ both

LAB WORK ORDER # NDA 9046

SERVICE REQUESTED
 REGULAR SERVICE (DEFAULT)
 PRIORITY SERVICE (50% SURCHARGE)
 EMERGENCY SERVICE (100% SURCHARGE)

INDICATE BOTTLES: FILTERED/PRESERVED (F/P)

INVOICE TO: SAME / N
 COMPANY: _____
 CONTACT: _____
 ADDRESS: _____
 PHONE: _____ FAX: _____

JOB # NDA 9046
 PO/AFE: N/A
 LSD: Umik N16
 QUOTE # _____

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	BTEX (F1-F4)	Routine	Moshm	PSA I	PSA must	Organic Meth	SAL Defect	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
N16-59	Umik N16	CR/Sept 16/4:00	Composite Soil	Soil											11
N16-S10	↓	↓	Oil	"											12
N16-S11	↓	↓	"	"											13
N16-S12	↓	↓	"	"											14
N16-H1	↓	↓	"	"											15
N16-H2	↓	↓	"	"											16
N16-W3	↓	↓	Surface	Water											17
N16-W6	↓	↓	↓	↓											18
N16-W7	↓	↓	↓	↓											19
N16-W8	↓	↓	↓	↓											20
N16-W10	↓	↓	↓	↓											21
N16-W13	↓	↓	↓	↓											22

REGULATIONS SPECIAL HANDLING OF HAZARDOUS MATERIALS

PROZEN _____ MEAN TEMPERATURE _____
 COLD _____
 AMBIENT _____

Failure to complete all portions of this form may delay analysis. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the reverse of the white report copy.

REMOVED BY: [Signature] DATE & TIME: Sept 18/3:15
 RECEIVED BY: K. Fliegel DATE & TIME: Sept 18/06
 SAMPLE CONDITION ACCEPTABLE UPON RECEIPT? (Y/N) 15:15

REPORT TO: **Chris Revak**
 COMPANY: **Kavik - AXYS**
 CONTACT: **Chris Revak**
 ADDRESS: **Suite 300, 805 Elm Ave SW Calgary, AB**
 PHONE: **538-8491** FAX: **269-5245**
 CELLPHONE: **510-9231**

DATE: **Sept 18, 2006**
 REPORT DISTRIBUTION ALL FINAL RESULTS WILL BE
 EMAIL FAX MAILED
 EMAIL 1: **crrevak@axys.net**
 EMAIL 2: _____
 DIGITAL EMAIL: _____

LAB WORK ORDER # **NDKA9046**

REGULAR SERVICE (DEFAULT)
 PRIORITY SERVICE (50% SURCHARGE)
 EMERGENCY SERVICE (100% SURCHARGE)

INVOICE TO: **SAME** N
 COMPANY: _____
 CONTACT: _____
 ADDRESS: _____
 PHONE: _____ FAX: _____

SELECT: pdf digital both

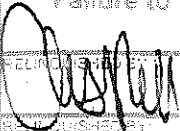
INDICATE BOTTLES: FILTERED/PRESERVED (F/P)

JOB # **NDKA9046**
 PO/A/E: **N/A**
 LSD: **Umiak NDB**
 QUOTE # _____

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	Moisture	PSA 2	PSA Must	Organic Matter	SAL Detail	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
N16-S2 (0.0-0.4)	Umiak N16	CR/Sept 16/4:00	Composite	Soil	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				1
N16-S2(0.4-0.8)													2
N16-S2(0.8-1.2)													3
N16-S2(0.0-0.4)													4
N16-S2(0.4-0.8)													5
N16-S2(0.8-1.2)													6
N16-S3													7
N16-S4													8
N16-S5													9
N16-S6													10
N16-S7													
N16-S8													

PROZEN MEAN TEMPERATURE _____
 COLD
 AMBIENT

Failure to complete all portions of this form may delay analysis. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the reverse of the white report copy.

RELINQUISHED BY:  DATE & TIME: **Sept 18, 3:15 pm**

RECEIVED BY: **K. Flagg** DATE & TIME: **Sept 18/06 15:15**

SAMPLE CONDITION ACCEPTABLE UPON RECEIPT (Y/N): _____