

**GEOPHYSICAL INVESTIGATION REPORT
FOR STRATIGRAPHY MAPPING ACROSS TWO SWAMP LOCATIONS
STATION 10+000 TO 10+300 COX TOWNSHIP, AND 18+720 TO 19+000 SERVOS
TOWNSHIP, HIGHWAY 69 FOUR LANING FROM 4.5 KM NORTH OF HIGHWAY 64
TO 8.7 KM NORTH OF HIGHWAY 637, DISTRICT 54, SUDBURY, ONTARIO**

GWP 5379-02-00

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1. Introduction

Peto MacCallum Ltd. on behalf of Totten Sims Hubicki Associates Ltd. commissioned Geophysics GPR International Inc. to execute a geophysical investigation for stratigraphy mapping across two swamps along Highway 69, south of Sudbury, Ontario (Figure 1).

The primary objective of the investigation was to resolve as much geologic detail from the surface down to and including the bedrock contact in both Area 1 (Cox Township 10+000 to 10+300) and Area 2 (Servos Township 18+720 to 19+000).

Resistivity data were collected along eight profiles (Area 1 and 2) for a total of approximately 1780 m of bedrock profiles. Seismic data were collected along seven profiles (Area 1 and 2) for a total of 1250 m. Georadar data were collected along five profiles (Area 1) for a total of approximately 860 m.

This report deals with the various aspects of the survey including field techniques, interpretation techniques, statistics and finally a culmination of the interpretation in the form of interpreted electrical resistivity, ground penetrating radar and seismic profiles.

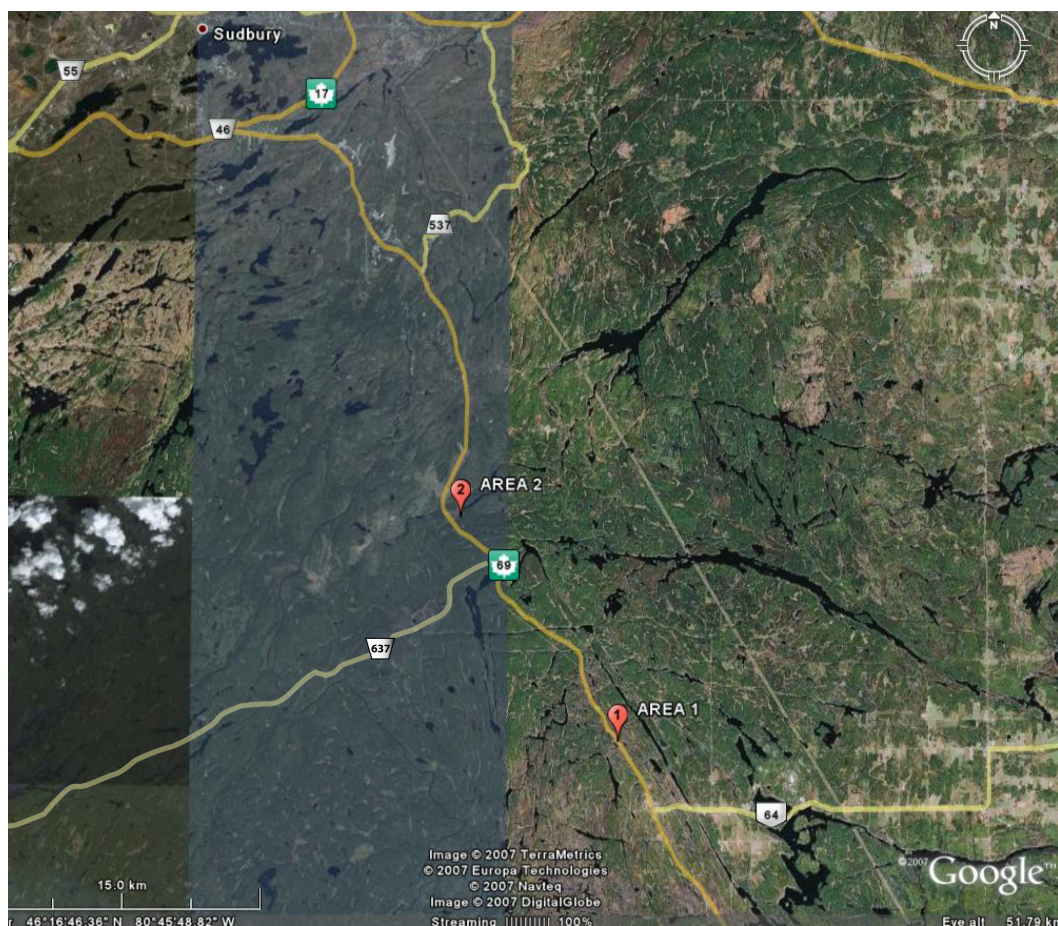


Figure 1: Approximate site locations (Area 1 and Area 2)

2. Basic Data

Details pertaining to the organization of the survey including mobilization, site, crew, equipment are described in this section.

2.1. *Investigation Site*

The investigation sites are located at two separate locations (Areas 1 and 2), which are about 55 km and 40 km along Highway 69, south of Sudbury respectively. Area 1 includes a portion of the existing Highway 69, while Area 2 was about 1.5 kilometres east of the highway and was accessible by an ATV.

2.2. *Mobilization*

The resistivity, seismic and radar surveys for Area 1 were performed October 24 to 27, 2006.

For Area 2, resistivity and seismic surveys were performed November 2 to 6, 2006.

2.3. *Personnel and Equipment*

The GPR field personnel involved in this project and the dates that they were on-site are outlined below:

Table 1: Field personnel and survey dates

Employee	Title	Dates On-Site
Ben McClement, P.Eng.	Geophysicist/Operator	October 24 to 27, 2006
Riaz Mirza,	Geophysicist	October. 24 to 27 and November. 2 to 6, 2006
Tomas Westerblom	Geoph. Tech.	October 24 to 27, 2006
Nicholas Zenhenko	Assistant	November. 2 to 6, 2006

The principal equipment involved in this project includes the following;

- An ABEM SAS1000 terrameter with the ES10-64 were used for the resistivity measurements.
- The ABEM Terraloc Mark VI, 24-channel seismograph.
- A GSSI SIR3000 and 100 MHz and 270 MHz antennas for ground penetrating radar survey were used.

A more detailed description of the equipment used is presented in Appendices A, B and C.

3. Methodology

The basic operating principles and methodology of the geophysical techniques utilized during this investigation are outlined in the sections that follow.

3.1. Positioning, Topography and Units of Measurement

The start and end points of each survey line along with stakes at even intervals were put in place by Sutcliffe Rody Quesnel Inc. (SRQ) land surveyors prior to commencing the investigation. All chainages of surveyed profiles are given in Tables 2 and 3 and are indicated in plan view maps in Figure 2.

There is a difference in Area 1 between the proposed survey chainages and the actual survey coverage. There are two reasons for the change in coverage. The first is the bedrock exposures were more extensive than expected such that the coverage was unnecessary. The second reason was anticipated, as the use of electrical resistivity along the roadway is not possible/practical. A fourth profile was added to the seismic refraction profiles.

The land surveyors collected topography data after the geophysical surveys at the locations of the stakes every 10 m. Topographic and positional data have been interpolated between these stakes were necessary and extrapolated for profiles that extended beyond the survey limits.

All geophysical measurements were collected in SI units.

Table 2: Area 1 Cox Township Surveyed Profile Chainages.

Profiles (W to E)	Ground Penetrating Radar	Electrical Resistivity	Seismic Refraction
1	10+000 to 10+150	10+130 to 10+310	10+150 to 10+294
2	10+000 to 10+130	10+120 to 10+280	10+130 to 10+274
3	10+000 to 10+240	-----	10+050 to 10+194
4	10+000 to 10+250	-----	-----
5	10+160 to 10+250	10+000 to 10+160	10+000 to 10+144

Table 3: Area 2 Servos Township Surveyed Profile Chainages

Profiles (W to E)	Ground Penetrating Radar	Electrical Resistivity	Seismic Refraction
1	-----	18+715 to 18+955	18+715 to 18+940
2	-----	18+710 to 18+950	-----
3	-----	18+710 to 18+950	18+745 to 18+970
4	-----	18+720 to 19+000	18+745 to 18+970
5	-----	18+720 to 19+000	-----

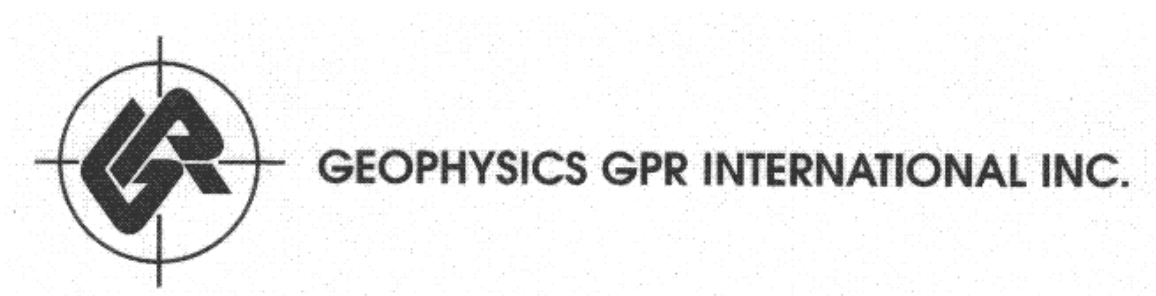


Figure 2: Plan View Map Indicating Profile Locations and Method Chainages

3.2. *Electrical Resistivity Method*

Basic Theory

The electrical resistivity method involves measuring the variation in potential (ΔV) at the surface due to the current flow through the subsurface. Individual readings involve injecting current (I) into two outer probes and measuring the potential (ΔV) across two inner probes. Different combinations of outer and inner electrodes are used along the array to sample from varying depths and positions. The resistance is given by:

$$R = \Delta V / I$$

The measured resistance (R) is then converted into an apparent resistivity (ρ_a). This apparent resistivity is an average of the different true resistivities crossed by the current over the investigated volume. It provides a good indication of the variation of resistivity with depth as the electrode spacing increases. The apparent resistivity (for a Wenner array) at each station is given by:

$$\rho_a = 2\pi a R$$

where 'a' is the electrode spacing and 'R' is the measured resistance. Figure 3 shows the operating principle of an entire array.

Survey Design

A series of 4 cables are laid out with a total of 60 connectors and probes. Software and a control unit select combinations of electrodes to produce readings at various locations and various electrode separations, thus at varying depths of investigation.

The Wenner configuration was applied for this project. This means that the spacing between the four electrodes involved in a given reading is equal. If every permutation of equally spaced electrodes is used then about 345 readings are taken. There were other configurations that could have been used for this project, such as Schlumberger, which would have allowed more readings to a greater depth of modeling. The Wenner array was chosen because the depth of investigation was known to be relatively shallow and this configuration has a better signal/noise ratio.

The resistivity profiles for Area 1 used a minimum electrode separation of 2.25 m for Profile 1 and 2.0 m for Profiles 2 and 5. The resistivity profiles for Area 2 used a minimum electrode separation of 3.0 m for Profiles 1, 2 and 3 and 3.5 m for Profiles 4 and 5. For a further description of the technique and the type of information obtained, see Appendix A.

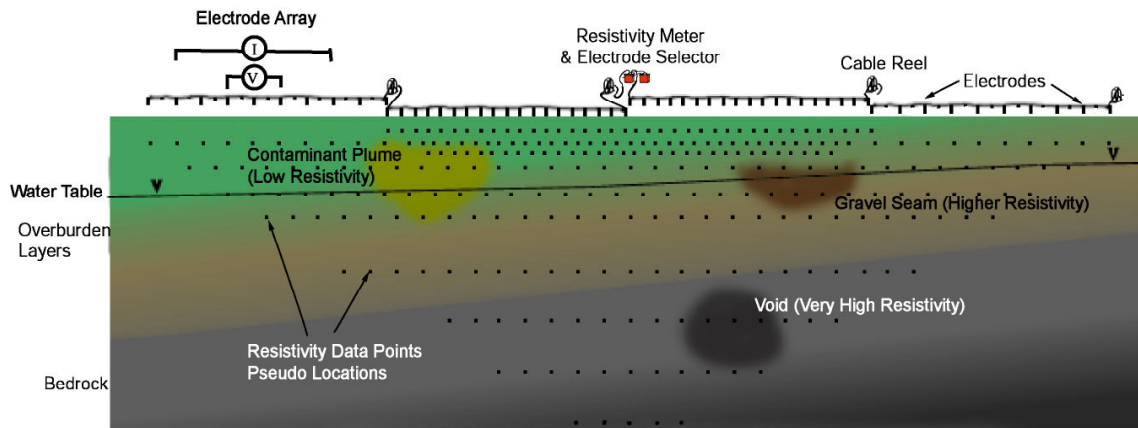


Figure 3: Resistivity Profiling Operating Principle

Interpretation Method and Accuracy of Results

Processing of the resistivity data involves running a 2D inversion routine to generate an inversion model with resistivity values and depths. The main processing sequence was completed using the Res2Dinv© software package for 2D inversion and plotting of the resistivity data. The 2D resistivity profiles are presented in Appendix D. The top pseudo-section on each figure is a plot of the measured resistivity values, the raw data. Through an inversion process a physical model with depths and resistivity values is generated. This model is presented as the third pseudo-section of each figure. The middle pseudo-section represents the calculated resistivity values based on the inversion model. How well the calculated apparent resistivity data compares with the measured apparent resistivity data is calculated as the root mean square (RMS) error. Lower RMS errors indicate a better fitting model.

All five profiles for area 2 had an RMS error in the range of 2.9% to 4.5%, which is considered excellent, while for Area 1 this percentage is ranging from 9% to 18%, which is also considered a very good match. As mentioned above, the higher RMS errors imply that the resistivity values based on the inversion model do not match the raw data as well. This typically occurs where there is noise in the data that cannot be fit by the inversion. This does not necessarily imply that the final interpretation is any less accurate.

The calculated inversion model is a resistivity model and must be interpreted in terms of geologic units or subsurface features. Geological materials will have different resistivities based primarily on variations in water content and the dissolved ions in the water (a table of typical values is enclosed in Appendix A). The interpretation will not extend the entire length of the profile because of the geometry. The depth of the readings decreases towards the ends of the profiles such that there are no readings directly beneath the end electrodes. There are other instances where the interpretation is ended when the contacts reach the surface. The interpreted models are presented in the drawings enclosed in Appendix F.

In regards to the accuracy of the results, it is difficult to assign a true error estimate. The following factors must be considered when interpreting 2D inversion models:

- 1) 3D geology – The process is assuming a 2D subsurface model. Larger electrode separations are influenced not only by deeper features but also by features offset horizontally from the profile line. Variations in the subsurface perpendicular to the survey line can distort the results.
- 2) Non-uniqueness – The inversion process is inherently non-unique, that is, different models can be generated from similar data sets. In general however, the main features of the models will be similar. Constraints can be placed on the inversion process given knowledge of the geology. At this particular site for example, the inversion process was allowed to generate sharp contrasts in resistivities that are likely present between the rock and water saturated soils.
- 3) The resolving power of the resistivity method decreases exponentially with depth.

3.2.1 Resistivity Quality Control

Electrodes (400 mm steel rods) are usually planted to a depth of 200 mm. The electrodes are attached to the cables and a connectivity test is run to check for contact resistance. If the contacts are adequate then the system initiates data collection. If there is a poor contact then a warning is given to improve the contacts by various means including adding the following:

- Add Water
- Sink the rods deeper into the ground
- Use two or more electrodes
- Add water, salt and dish soap

Consecutive readings are taken automatically and the resistivity meter averages the measured results continuously. Measurement cycles are taken until the standard deviation falls below a preset threshold (typically 2%) or until a maximum number of readings are taken.

Contact resistance was not a problem at these sites for the majority of electrodes as the soils were very wet; however, some of the electrodes on or near the end of each spread were planted with little to no soil cover. Although the bedrock depths are not critical at the actual electrode location the electrode is needed to obtain readings further into the spread. There were two issues when the outside electrodes were in a soil condition where the contact resistance is moderate to high. Firstly if an electrode cannot be properly grounded then it affects up to 30 readings so it is critical that every attempt be made to ensure every electrode is grounded. Secondly an electrode can be grounded but it can still produce a reading with moderate to poor repeatability. During the editing process a cursory screening of the raw data set is critical to extract the noisy data. This data is apparent when the values are usually extremely high when compared to adjacent readings.

3.3. Seismic Refraction

Basic Theory

The seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the shot-point to each geophone. The fastest seismic waves are the compressional (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival, such as reflected waves and transverse (S) waves, is not considered under routine seismic refraction interpretation. Figure 4 illustrates the basic operating principle for refraction surveys. A further description of the method can be found in Appendix B.

Survey Design

The seismic investigation for both sites was specifically designed for analysis of the refracted seismic waves. The parameters used were ideal for the survey (e.g. geophone spacing, energy source).

A seismic spread typically consists of 24-vibration monitoring devices (geophones) connected in-line (spread) to a seismograph (ABEM Terraloc Mark VI) by two 12-connector cables. Seismic pulses (shots) are then generated at various locations with respect to the spread. Spacing between geophones was 6.25 m for Area 1 profiles and 5 m for Area 2 profiles. Typically seven shots were executed: three shots within the profile to obtain the lateral velocity variation in the overburden, two end shots and two off-end shots on either side of the spread to provide the true velocity and depth of the bedrock surface.

Soil conditions in Area 1 were not ideal for the seismic refraction method due to trapped gases in the swamp. Gases can be compressed so the transmission of P-wave energy is attenuated. Fortunately, the length of the seismic spreads was short and the bedrock depths relatively shallow, thus the available energy source was adequate.

The energy source used for this investigation was a buffalo gun. A buffalo gun is an ideal seismic energy source for shallow to intermediate (less than 20 m) bedrock depths. It produces excellent signal and recordings of high quality in such areas. A sledgehammer or drop-weight can be used in areas of shallower bedrock. Had the depth to bedrock been more than 20 m and/or the spacing between geophones been greater than dynamite would have been the best option for a seismic source.

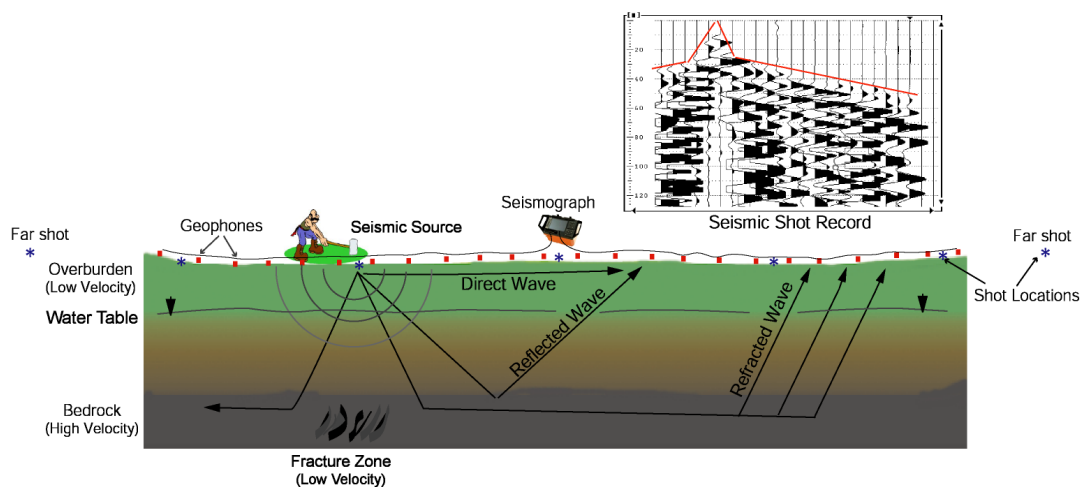


Figure 4: Seismic Refraction Operating Principle

Interpretation Method and Accuracy of Results

Interpretation of the seismic data was done using Hawkins' method and crosschecked by the critical distance method. The Hawkins' method allows the computation of rock depth at every geophone. This method provides information on the thickness of the various overburden layers, depth to bedrock and rock quality. It is based on the closure times of the inner shots. It calculates the true velocities of the rock using the apparent velocities, with the information provided by the outer shots. A brief description of both Hawkins' and the critical distance methods is presented in Appendix B. An in-depth description of the method can be found in the paper *The Reciprocal Method of Routine Shallow Seismic Refraction Investigations*, L.V. Hawkins, Geophysics, Volume 26, Issue 6, pp. 806-819 (December 1961).

The seismic refraction method allows the determination of the bedrock profile with a precision of 10% or better for depths greater than 10 m and a precision of 1 m for depths less than 10 m. The precision in the determination of rock velocities is plus or minus 3%. The vertical contacts (lateral velocity change), usually associated with faults and deep valleys, are generally accurate to within 5 m in width; although, this is somewhat site specific.

3.3.1. Seismic Quality Control

Throughout the surveys, a strict procedure for quality control including fieldwork and interpretation was followed. The purpose of the following measures is to ensure a superior quality in the acquisition of seismic refraction data:

- The first arrival times on each seismic record must be clean and precise. The quality of the records is increased if the geophones are firmly planted;
- No more than two traces should be absent;
- No end traces (Geophone G1, G2, G23, G24) which are used for the time-distance curve closure should be absent;
- Closure times should be within ± 2 ms;
- Each successive profile overlaps the previous profile by two geophones. This overlap allows the correlation of arrival times at the same point from two different set-ups.
- Two different methods were applied to the interpretation. The first one being the reverse time-distance technique (Hawkins' method) and the second using a critical distance method.
- Senior quality assurance personnel reviewed the results of the seismic investigations.

3.4. Ground Penetrating Radar

Survey Objective

The purpose of using georadar in certain areas was to emphasize its strength of quick and accurate data collection in areas of shallow bedrock where the geology is conducive to radar signal penetration. There was a secondary objective in the use of larger antennas on the existing road base, which was to possibly verify the existence of peat material between the road base and the bedrock.

Ground penetrating radar was a tertiary technique used for mapping the depth to bedrock with seismic refraction and electrical resistivity methods. The georadar technique was also used to provide additional information in areas, where the other two methods were not practical or not accessible.

Basic Theory

Georadar utilizes radar technology to obtain a near-continuous profile of the subsurface. The basic principle is to emit an electromagnetic impulse into the ground. This pulse will travel through the sub-surface and reflect off the boundaries of materials with differing dielectric constants (contrasts of EM impedances). The reflected pulse returns to the surface and is recorded by a receiver. Examples of radar reflecting boundaries included air/water (water table); water/earth (bathymetry); earth/metal, PVC, or concrete (pipe locating); and differing earth materials (stratigraphic profiles, including bedrock profiles). Figure 5 illustrates the basic operating principle for Georadar surveys. More information on the georadar operating principle can be found in Appendix C.

Survey Design

Impulses are emitted at a predetermined frequency rate of 10 to 80 scans/second. Only by moving the antennas along a profile directly over the targets can the locations and depths be determined.

Data were collected with two antennas corresponding to frequencies of 100-MHz and 270-MHz. Lower frequency antenna provides greater depth penetration at the expense of resolution. The use of these two frequencies of antennas provided the optimum results over the range of investigation depths. These particular antennas are usually the most appropriate for shallow to intermediate depth penetration (0 to 10 m) and resolution of stratigraphic layers.

The method was used only in Area 1 on the existing roadbed (Profiles 3 and 4) and on a portion of Profiles 1, 2 and 5 where the bedrock is very shallow (less than 3 m). Profiles 3 and 4 were collected with the 100-MHz and 270-MHz antennas, while Profiles 1, 2 and 5 were collected with the 270-MHz antenna.

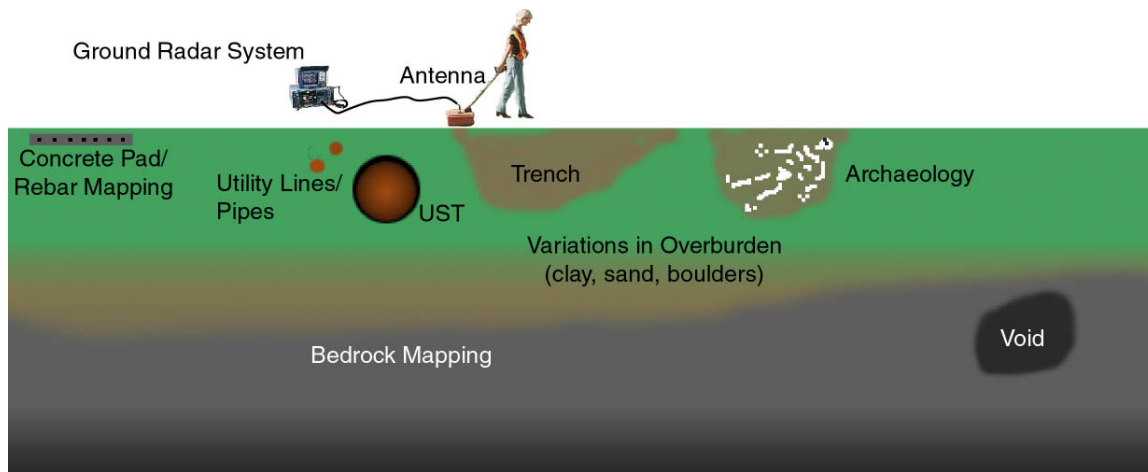


Figure 5: Ground Penetrating Radar Operating Principle

Interpretation Method

Prior to interpretation, the georadar data were filtered and stacked to improve signal-to-noise ratio, to remove hi/low-frequency noise, to decrease ringing and to improve the resolution of reflected events. Interpretation of the data is based primarily on the qualitative analysis of two characteristics of radar reflections: continuity and amplitude.

Positioning for the georadar survey was controlled by inserting fix marks into the data along each of the profile lines. The georadar data is then normalized to these fix markers and the positions of individual readings are interpolated between the fix marks. Readings were taken approximately every 50 to 100 mm and then the interpreted results were averaged over 500-mm intervals and values were output at 1-m intervals.

3.4.1 Georadar Quality Control

Quality control revolves around a well-planned survey design.

The antenna choices have to emphasize the balancing of resolution and depth of penetration. It is common to use more than one frequency of antenna when there are multiple areas of interest in the survey.

There are data collection settings that will also emphasize the area of interest particularly for the shallow bedrock mapping. The time windows should not be too large otherwise the shallow bedrock details become too fine to identify.

The site preparation is critical in terms of chaining the site with regular intervals of stakes, as this is the means of relating the radar images to real positions.

4. Results

The results from the georadar, resistivity and seismic profiles are presented in Drawings T06902-A1-1, T06902-A1-2, T06902-A2-2 and T06902-A2-2 (enclosed in Appendix F) in the form of cross-sections. Each cross-section is a compilation of one or all the methodologies used depending upon the profile. Included on the drawings are plan view maps indicating the profile locations and geophysical methods used.

4.1 Land Surveys

Sutcliffe Rody Quesnel Inc. (SRQ) Land Surveyors provided the topographic data and profile coordinates. The coordinates are in the Universal Transverse Mercator Geographic Coordinate System. The coordinates for the start and end of the profile lines for areas 1 and 2 are provided in Table 4. Coordinates in brackets have been extrapolated past the end of the survey stakes.

Table 4: Profile Line Coordinates for Area 1: Cox Township

Area 1: Cox Township				
	<i>Start</i>		<i>End</i>	
<i>Profile</i>	<i>Northing</i>	<i>Easting</i>	<i>Northing</i>	<i>Easting</i>
Profile 1	5111154.6	328459.1	5111400.7	328273.9
Profile 2	(5111161.2)	(328469.3)	5111385.6	328306.9
Profile 3	5111169.6	328483.3	5111366.8	328346.6
Profile 4	(5111183.3)	(328506.1)	5111386.3	328355.0
Profile 5	5111191.0	328517.6	5111401.2	328373.4

Table 5: Profile Line Coordinates for Area 2: Servos Township

Area 2: Servos Township				
	<i>Start</i>		<i>End</i>	
<i>Profile</i>	<i>Northing</i>	<i>Easting</i>	<i>Northing</i>	<i>Easting</i>
Profile 1	(5122973.7)	(320329.8)	5123134.8	320151.1
Profile 2	(5122983.3)	(320345.1)	5123143.8	320166.7
Profile 3	(5122997.1)	(320357.6)	5123170.9	320164.1
Profile 4	5123018.4	320362.3	5123205.4	320154.9
Profile 5	5123033.9	320375.7	5123221.4	320169.2

4.2 Area 1 Cox Township (10+000 to 10+310)

Profile 1

The interpreted depth to bedrock along Profile 1 ranged from outcrop to a depth of 7.6 m (elevation 199.2 to 186.0 m). The overburden stratigraphy is interpreted to be dominated by clay and peat based on the low seismic velocities (400 m/s) and the low resistivity values ($< 75 \Omega\cdot\text{m}$).

There are differences between the seismic contact and the resistivity contact. The seismic contact is based on the change in P-wave velocity and is interpreted to represent the overburden/bedrock contact. The resistivity contact is based on the gradient increase in modelled resistances and may not always represent the overburden/bedrock contact because a coarse sand/gravel/boulder material can have a similar resistivity to bedrock.

The seismic contact between chainages 10+218 to 10+255 is approximately 1.5 m deeper than the resistivity contact. This could indicate the presence of a sand/gravel/boulder material overlying the bedrock in this area. The presence of sand/gravel is supported by borehole N1-2 located along Profile 5.

The seismic contact between chainages 10+162 to 10+182 is up to 6 m shallower than the resistivity contact. Some of the difference could be attributed to the seismic velocities but likely most of this difference is related to geometry limitation of the seismic method. It is not possible to measure steeply dipping contacts greater than 45° with the seismic refraction method. In this area the resistivity contact may be more representative of the bedrock contact.

Penetration test DCPT N1-3 (Appendix E) was located at approximate chainage 10+226 of Profile 1 based on the GPS coordinates indicated on the log. The depth to refusal of this penetration test was 7.1 m (elevation 186.9 m). This correlates well with the interpreted seismic contact at a depth of 6.6 m (elevation 187.2 m).

Georadar data collection was intended for areas of shallow bedrock. However, along this profile the sections where georadar data were collected had little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

Profile 2

The interpreted depth to bedrock along Profile 2 ranged from outcrop to a depth of 6.6 m (elevation 186.9 m). The overburden stratigraphy is interpreted to be dominated by clay and peat, based on the low seismic velocities (400 m/s) and the low resistivity values ($< 75 \Omega\cdot\text{m}$), and underlain in some areas by a sand/gravel layer.

Similar to Profile 1, there are differences between the seismic and resistivity contacts. The seismic contact is deeper than the resistivity contact towards the middle of the profile suggesting up to 2 m of sand/gravel.

Georadar data collection was intended for areas of shallow bedrock. However, along this profile the sections where georadar data were collected had little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

Profile 3

The interpreted depth to bedrock along Profile 3 ranged from outcrop to a depth of 4.9 m (elevation 196.0 to 189.6 m). The overburden stratigraphy is interpreted to be dominated by clay and peat based on the low seismic velocities (400 m/s) with sand/gravel towards the north end of the profile (based on the georadar images)

Georadar and seismic data were collected. They are not in perfect agreement but georadar can excel with more accuracy in the shallow areas, 10+000 to 10+130. The seismic data is likely more reliable for the remainder of the profile.

Georadar data collection was intended for areas of shallow bedrock. However, along this profile the sections where georadar data were collected had little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

Profile 4

The interpreted depth to bedrock along Profile 4 ranged from 1.4 m to 7.1 m (elevation 196.9 to 190.1 m). The topography/elevation data is assumed from chainage 10+000 to 10+180. The overburden stratigraphy is interpreted to consist of very coarse fill material based on the georadar images.

Only Georadar data were collected along this profile because the centreline was along the existing centreline of Highway 69. This was anticipated so for the sake of safety the georadar was collected along the eastern shoulder of the roadway. There were many reflectors visible on the images (examples in Appendix C.) A bedrock contact has been interpreted on the profile; however, the confidence level in this contact is not high. Very large boulders in the base of the road obscure the bedrock/overburden contact. Had there been only coarse fill material over bedrock it is anticipated that the bedrock contact would be readily apparent. It is possible that there may be a small amount of fine material sandwiched between the road base and the bedrock.

Georadar data collection was intended for areas of shallow bedrock. However, along this profile the sections where georadar data were collected had little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

Profile 5

The interpreted depth to bedrock along Profile 5 ranged from outcrop to a depth of 9.8 m (elevation 202.3 to 184.0 m). The overburden stratigraphy is interpreted to consist of clay and peat, based on the low seismic velocities (400 m/s) and the low resistivity values ($< 75 \Omega\cdot\text{m}$), underlain by a sand/gravel layer (higher resistivities).

Borehole N1-2 (Appendix E) was located at approximate chainage 10+083 (offset 5 m to the east) of Profile 5. The depth to refusal of this borehole was 6.9 m (elevation 187.7 m). The interpreted seismic bedrock/overburden contact is at a depth of 7.4 m (elevation 186.7 m). The resistivity contact is at a depth of 3.1 m (elevation 191.1 m). The resistivity contact correlates well with a sand/gravel layer identified in the borehole logs at a depth of 3.8 m (elevation 190.8 m).

Georadar data collection was intended for areas of shallow bedrock. However, along this profile the sections where georadar data were collected had little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

4.3 Area 2 Servos Township (18+715 to 19+000)

Profile 1

The interpreted depth to bedrock along Profile 1 ranged from outcrop to a depth of 14 m (elevation 221.5 to 198.4 m). The overburden stratigraphy is interpreted to consist of water saturated clay and peat (resistivities $< 75 \Omega \cdot \text{m}$) underlain in some areas by a sand/gravel layer (higher resistivities).

Based on the differences between the seismic and resistivity contacts, the sand/gravel layer could be up to 3.6 m thick.

Profile 2

Only resistivity data were collected along Profile 2. Based on the resistivity contact, the interpreted bedrock/overburden contact ranges in depth from outcrop to 14.8 m (elevations 214.4 to 198.9 m); however, as appears to be evident by the adjacent profiles and comparison with borehole data, the identified resistivity contact may not always represent the overburden/bedrock contact as a coarse sand/gravel/boulder material can have a similar resistivity to bedrock.

The resistivity values of ($<75 \Omega \cdot \text{m}$) suggest that the majority of the overburden material is clay and/or peat material.

Profile 3

The interpreted depth to bedrock along Profile 3 ranged from outcrop to a depth of 16.9 m (elevation 218.2 to 195.7 m). The overburden stratigraphy is interpreted to consist of water saturated clay and peat (resistivity $<75 \Omega \cdot \text{m}$) underlain in some areas by a sand/gravel layer (higher resistivities).

Borehole N17-2 (Appendix E) was located at approximate chainage 18+875 of this profile. The depth to refusal of this borehole was 13.6 m (elevation 196.3 m). The interpreted seismic bedrock/overburden contact at this chainage is at a depth of 13.3 m (elevation 198.6 m). The resistivity contact is at a depth of 10.5 m (elevation 201.5 m). The resistivity contact correlates well with a sand/gravel layer identified in the borehole logs at a depth of 11.0 m (elevation 198.9 m).

Profile 4

The interpreted depth to bedrock along Profile 4 ranged from outcrop to a depth of 18.1 m (elevation 216.3 to 195.0 m). The overburden stratigraphy is interpreted to consist of water saturated clay and peat (resistivities $< 75 \Omega\cdot\text{m}$) underlain in some areas by a sand/gravel layer (higher resistivities).

Based on the differences between the seismic and resistivity contacts, the sand/gravel layer could be up to 7.1 m thick.

Profile 5

Only resistivity data were collected along this profile. Based on the resistivity contact, the interpreted bedrock/overburden contact ranges in depth from outcrop to 13.0 m (elevations 213.2 to 200.2 m); however, as appears to be evident by the adjacent profiles and comparison with borehole data, the identified resistivity contact may not always represent the overburden/bedrock contact as a coarse sand/gravel/boulder material can have a similar resistivity to bedrock.

The resistivity values of ($<75 \Omega\cdot\text{m}$) suggest that the majority of the overburden material is clay and/or peat material.

5. Conclusions

The results from the resistivity, seismic and georadar profiles are presented in Drawings T06902-A1-1, T06902-A1-2, T06902-A2-1 and T06902-A2-2 in the form of cross-sections. Each cross-section is a compilation of all the methodologies used. In general, the seismic contact is interpreted to best represent the bedrock/overburden contact with the exception of the ends of the profiles where the bedrock may be steeply dipping. In these areas, the resistivity contact is interpreted to be the more accurate of the two.

The Drawings also contain a second set of cross-sections that intersect the five profiles. Drawing T06902-A1-2 has three additional cross-sections at chainages 10+230, 10+150 and 10+080. Drawing T06902-A2-2 has two additional cross-sections at chainages 18+800 and 18+900.

Three bedrock reference points were available for each of the two areas. Of these six reference points, three were close enough to the profiles to be used for correlation (N1-2, N1-3 and N17-2). The reference points for the bedrock were used to verify that the seismic velocities used for the calculations were accurate. This can be critical in swampy areas as the overburden velocity can vary greatly depending on the trapped gas/water ratio. The interpreted depth to bedrock based on the seismic results was well within the expected 10% accuracy. When the elevations of the interpreted bedrock are compared to the elevations indicated on the borehole logs the error is greater. This is attributed to the precision of the elevations readings taken at the boreholes, as there is a difference in surface elevation.

The borehole data were also used to identify the potential overburden materials that may be present in the areas. Although not directly used in the interpretation of the resistivity data, the contact identified in the resistivity data was within +/- 1 m of a sand/gravel layer identified on the two borehole logs.

Resistivity data were collected along three profiles in Area 1 and five profiles in Area 2 for a total of approximately 500 m and 1280 m respectively. Appendix A contains further information on the equipment and methodology of resistivity. Appendix D contains all of the inversion models.

The quality of the data is excellent. The data sets had excellent repeatability and the inversion data set matched the actual data set to within 20% for Area 1 and within 5% for Area 2.

There were two profiles in Area 1 where data collection was not possible/practical. Profile 4 was along the centreline of the existing road while Profile 3 was along the downward slope of the road base where the surface material was largely very coarse gravel.

The electrical resistivity method has both strengths and weaknesses. Strengths include:

- Logistically simpler than seismic refraction, 30 to 40% lower in cost per metre.
- Can model steep vertical contacts
- Can discriminate between peat/clay material and granulars such as sands and gravels.

Weaknesses of the resistivity method include:

- At these particular sites the method does not seem able to discriminate between the sand/gravel layer and the bedrock.
- Very dry surface conditions (including shallow bedrock) can make it difficult to achieve proper electrode grounding.

Seismic data were collected along four profiles in Area 1 and three profiles in Area 2 for a total of approximately 575 m and 675 m respectively. Appendix B contains further information on the seismic equipment and methodology.

The quality of the data for both areas is considered good. The energy source was sufficient as the bedrock depth was relatively shallow (< 20 m). Had the bedrock in Area 1 been deeper, there could have been difficulties as the swamp areas had some trapped gas which will attenuated compressional waves.

The overburden material in Area 1 has been measured to have a velocity of approximately 400 m/s; however, it is apparent on site that the area is water saturated at surface. The measured velocity of 400 m/s is slow for saturated sediments, which are typically 1500 m/s. The slower measured values are indicative of trapped gases in the sediments, not unusual for peat-rich swamps. The 400 m/s velocity is an average value but there may be velocity variations that could not be measured. Material with less trapped gas (more water) would have a significantly higher velocity resulting in an increase to the depth of the interpreted bedrock/overburden contact. This potential for large velocity variations in the overburden material decreases the accuracy of the seismic method in swampy areas.

The seismic refraction method has both strengths and weaknesses. Strengths include:

- Most accurate method regardless of overburden material particularly if depths exceed 5 m.
- Can map weak zones in the bedrock.

Weaknesses include:

- Gases trapped in the swamps will require larger energy sources
- Cannot accurately map steeply dipping rock (> 45°)
- Localized velocity variations in the overburden of swampy areas can decrease the accuracy.

Ground penetrating radar (Georadar) data was collected in Area 1 along five profiles for a total of 860 m. Appendix C contains further information on the equipment and methodology of ground penetrating radar.

Generally the georadar method was used only in areas where seismic and resistivity data were not collected. Georadar data collection was intended for areas of shallow bedrock where the accuracy of the other two methods would be limited; however, along most such areas there was little to no soil cover. Given the antenna frequencies interpreted depths of less than 1 m may be outcrop.

Georadar was also used on Profiles 3 and 4 where access/conditions, along the existing road, were observed to be poor/impractical for resistivity and seismic refraction. There were many reflectors identified on the images (examples in Appendix C) but some of the features were interpreted to be very large boulders that compose the core of the road base. A bedrock contact has been interpreted in the data set of Profiles 3 and 4 however the level of confidence is low. If there had been only coarse fill material over bedrock it is anticipated that the bedrock contact would be readily apparent. It is possible that very fine material may be sandwiched between the road base and the bedrock.

Georadar has the strength of being very fast and excelling where the ground conditions are favourable. Typically, dry soils, fresh water saturated sands and gravels and peat are conducive to good radar images. Clay-rich overburden material will severely limit the effective depth of penetration of the radar signal regardless of antenna frequency.

Georadar could also have been used along the same areas that resistivity and seismics were used. The objective would have been to map the peat and clay contact in Area 1. It was logistically too difficult to achieve smooth movement of the antennas. There was too much water to walk and not enough for a boat. If this contact is considered critical then it is recommended that this data be collected over the frozen swamps in the winter.

Interpretation of the resistivity and georadar data was performed by Milan Situm. Interpretation of the seismic refraction data was performed by Micheline Poulin. This report has been written by Ben McClement, P.Eng. and Milan Situm, P.Geo.

Ben McClement, P.Eng.

Milan Situm, P.Geo.
Manager

APPENDIX A:
RESISTIVITY EQUIPMENT AND INFORMATION SHEETS

Terrameter LUND Imaging System – INFORMATION SHEET



Automatic System for Resistivity and IP Imaging

- ABEM Terrameter LUND Imaging System – designed for optimum versatility in infrastructure projects and environmental studies.
- Built-in quality control and feedback to operator.
- Supports arbitrary cable arrangements and electrode arrays (including Wenner, Schlumberger, gradient, dipole-dipole, pole-dipole, pole-pole, square array, borehole etc.) via user defined cable description and protocol files.
- Automated roll-along capability for 2D and 3D surveys.
- High productivity rate thanks to speed-optimised software (particularly in 4 channel version).
- Software includes data transfer from instrument to PC, protocol generation software, file conversion software and pseudosection plotting.

Electrical Imaging

Electrical imaging has emerged as a prime method for infrastructure projects and environmental studies in recent years, and the demand for better information is expected to continue. In such applications the following essential:

- High resolution at shallow depths
- Automated data acquisition for cost effectiveness
- Superior area coverage through at least two-dimensional information
- Output presented in easily interpretable form.

The ABEM Terrameter LUND Imaging System, developed in cooperation with Dept. of Engineering Geology, Lund University, provides fast, accurate and automated resistivity

imaging in 2D and 3D. The entire data handling process is automated as far as possible, including data acquisition, processing, interpretation and presentation. This is made possible by utilising state of the art technology.

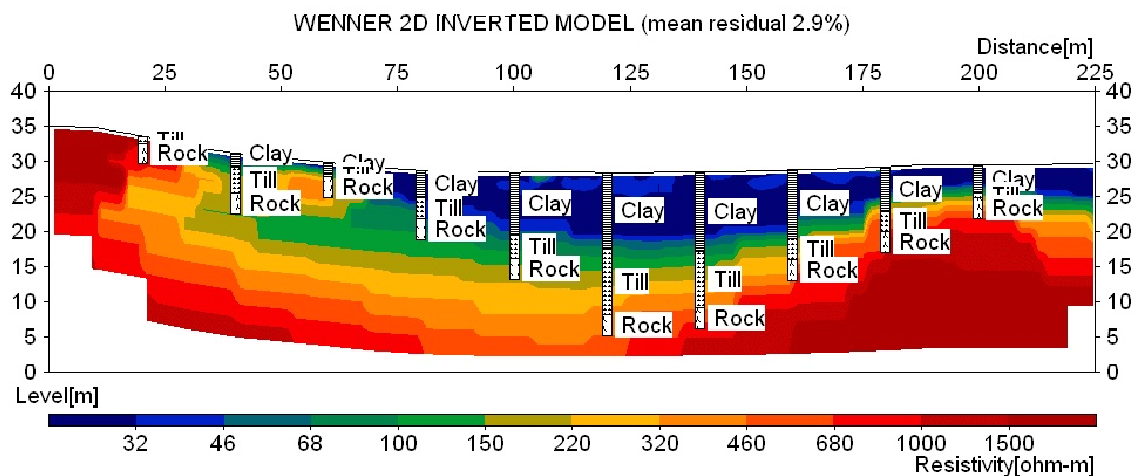
Key features of the LUND Imaging

System include:

- Integrated roll-along function.
- Automatic electrode contact test.
- Option to measure IP.

System Components

- Terrameter SAS1000 (single channel) or SAS4000 (four channel) resistivity and IP instrument, with integrated PC for full control of data acquisition process and storage of data. Built-in transmitter with maximum ± 400 V (800 V peak-to-peak) and 1000 mA output. 12 V DC power supply.
- Electrode Selector ES10-64e or ES10-64 connects to the Terrameter through a single robust cable. Power supply via the Terrameter.
- Terrameter and Electrode Selector housed in rugged water-proof (IP66) aluminium housing for reliable performance during harsh field conditions.
- Field cable set with electrodes and cable jumpers. Highly durable multi-conductor cable, terminated both ends with military standard connectors.
- User-friendly acquisition and presentation software for standard or user defined arrays.



2D resistivity image with geotechnical information.

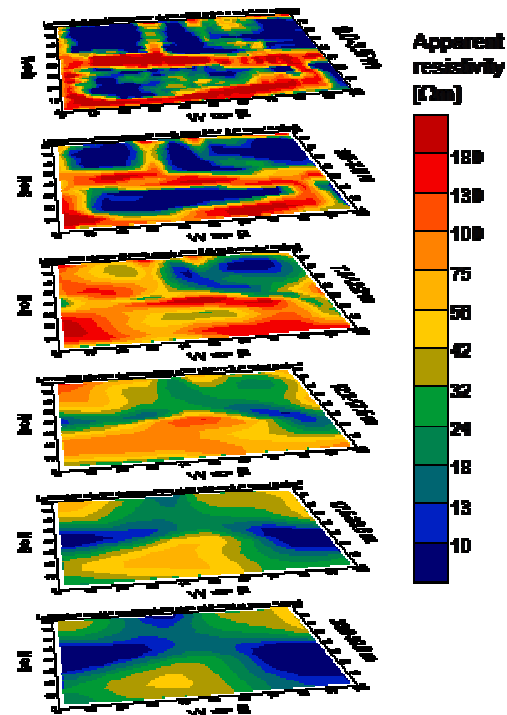
Note the good correlation between low resistivity areas and clay layer.

A major advantage of the method is that it produces continuous images of the variation in properties in the subsurface. Electrical imaging can serve as an excellent basis for planning detail investigations via for example a drilling and sampling programme with optimized sampling locations. The detail investigation results can then in turn be used as a base for a refined interpretation of the electrical imaging data, leading to a

comprehensive and reliable model of the underground.

Typical areas of application include:

- Groundwater resource management and vulnerability assessment,
- Mapping and monitoring of contaminated ground/groundwater
- Geotechnical pre-investigation
- Geological mapping
- Mapping/prospecting of natural resources
- Geothermal prospecting
- Sub-bottom mapping at sea and in lakes
- Mapping of frozen ground/permafrost.
- Archaeology



3D resistivity model outlining a buried sludge deposit and migration of contaminants towards depth.

Resistivity imaging is a robust method, which often produces good results even close to for example power lines and railways, in contrast to EM methods that are mostly useless near such installations. It is, however, important to realise that disturbances can occur, and that false anomalies can arise from for example metal pipes or other conductive objects in the ground.

The method is well suited for long term monitoring. A series of measurements taken at different times can give information about variations in water content, movement of pollutants in the ground, seepage through embankment dams etc.

Automated data acquisition allows a field crew to carry out complementary investigations during measurement (e.g. levelling, GPS positioning). However, the 4 channel version of the system offers very high field productivity; in standard electrical imaging it means that the major limiting factor is the pace of work of the field crew rather than the equipment.

BASIC PRINCIPLES FOR RESISTIVITY SURVEYING

The SAS 4000 / 1000 measures different parameters that characterizes the ground:

- Resistivity
- Induced Polarization
- Self Potential

The electrical resistivity varies between different geological materials, dependent mainly on variations in water contents and dissolved ions in the water. Resistivity investigations can thus be used to identify zones with different electrical properties, which can then be referred to different geological strata. Resistivity is also called specific resistance, which is the inverse of conductivity or specific conductance.

The most common minerals forming soils and rocks have very high resistivity in a dry condition, and the resistivity of soils and rocks is therefore normally a function of the amount and quality of water in pore spaces and fractures. The degree of connection between the cavities is also important. Consequently, the resistivity of a type of soil or rock may vary widely, as shown in figure 9-a. However, the variation may be more limited within a confined geological area, and variations in resistivity within a certain soil or rock type will reflect variations in physical properties. For example: the lowest resistivities encountered for sandstones and limestones mean that the pore spaces in the rock are saturated with water, whereas the highest values represent strongly consolidated sedimentary rock or dry rock above the groundwater surface. Sand, gravel and sedimentary rock may also have very low resistivities, provided the pore spaces are saturated with saline water, which is not indicated in figure 9-a. Fresh crystalline rock is highly resistive, apart from certain ore minerals, but weathering commonly produces highly conductive clay-rich saprolite. The variations in characteristics within one type of geological material makes it necessary to calibrate resistivity data against geological documentation, from for example surface mapping, test pits or drilling. However, this applies to all geophysical methods.

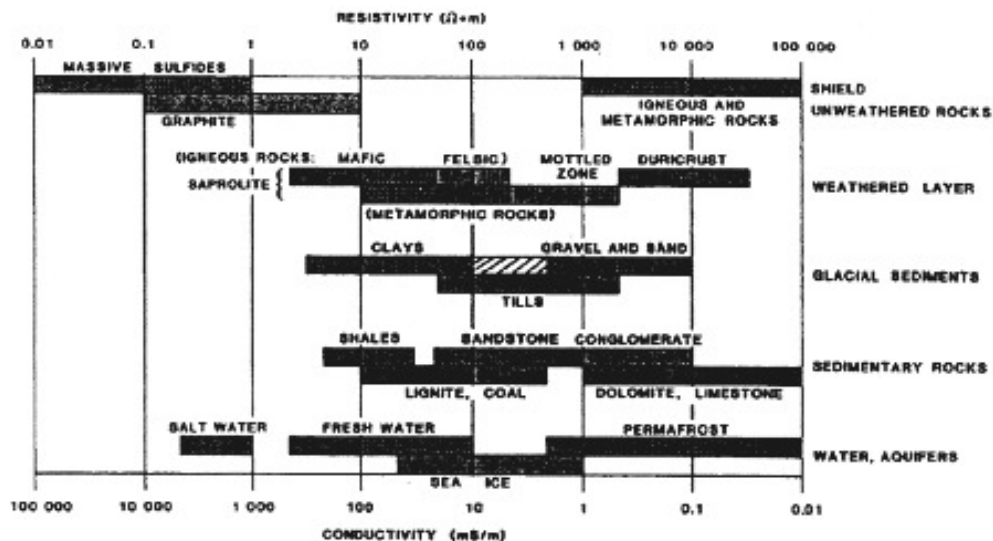


Figure 9-A: Typical ranges of electric resistivities of geological materials

The amount of water in a material depends on the porosity, which may be divided into primary and secondary porosity. Primary porosity consists of pore spaces between the mineral particles, and occurs in soils and sedimentary rocks. Secondary porosity consists of fractures and weathered zones, and this is the most important porosity in crystalline rock such as granite and gneiss. Secondary porosity may also be important in certain sedimentary rocks, such as limestone. Even

spaces may reduce the resistivity of the material drastically. The degree of water saturation will of course affect the resistivity, and the resistivity above the groundwater level will be higher than below if the material is the same. Consequently, the method can be used for finding the depth to groundwater in materials where a distinct groundwater table exists. However, if the content of fine grained material is significant the water content above the groundwater surface, held by

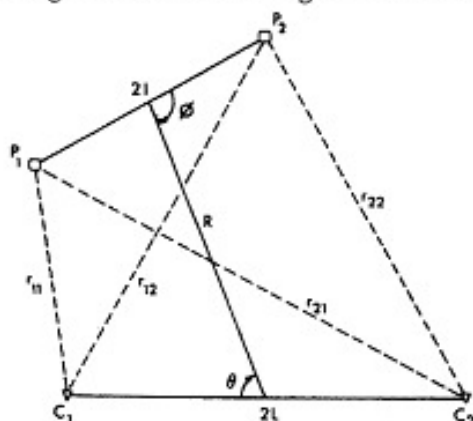


Figure 9-B: A generalized four-electrode array with potential electrodes P_1 , P_2 and current electrodes C_1 , C_2 ($0 < \theta$, $\phi < \pi$)

hygroscopic and capillary forces, may be large enough to dominate the electrical behavior of the material.

The resistivity of the pore water is determined by the concentration of ions in solution, the type of ions and the temperature. A range of resistivities for different types of water is given in table 9-1 below.

Type of water	Resistivity [Ωm]
Precipitation	30 - 1000
Surface water, in areas of igneous rock	30 - 500
Surface water, in areas of sedimentary rock	10 - 100
Groundwater, in areas of igneous rock	30 - 150
Groundwater, in areas of sedimentary rock	> 1
Sea water	≈ 0.2
Drinking water (max. salt content 0,25%)	> 1.8
Water for irrigation and stock watering (max. salt content 0,25%)	> 0.65

Table 9-1. Electric resistivity of some types of natural waters

The presence of clay minerals strongly affects the resistivity of sediments and weathered rock. The clay minerals may be regarded as electrically conductive particles, which can absorb and release ions and water molecules on its surface through an ion exchange process.

As the variation in temperature of the ground is generally small, the temperature influence is normally negligible. However, in e.g. geothermal applications the variation can be significant, as well as in permafrost regions. The mobility of ions increases with increasing temperature, as the viscosity of water is lowered. Hence a decrease in resistivity with increasing temperature can be observed for materials where electrolytic conduction dominate.

Measurement of the resistivity of the ground is carried out by transmitting a controlled current (I) between two electrodes pushed into the ground, while measuring the potential (U) between two other electrodes. Direct current (DC) or an alternating current (AC) of very low frequency is used, and the method is often called DC-resistivity. The resistance (R) is calculated using Ohm's law:

$$R = \frac{U}{I} \quad (9.1)$$

The material parameter resistivity (ρ), which is the inverse of electrical conductivity (σ), is related to the resistance via a geometrical factor. It is common, but not necessary, to place the potential electrodes symmetrically spaced on the line between the current electrodes. The resistivity of ground can be calculated using:

$$\rho = K \frac{U}{I}$$

where the geometrical factor is

$$K = 2\pi \left[\frac{1}{r_{11}} - \frac{1}{r_{12}} - \frac{1}{r_{21}} + \frac{1}{r_{22}} \right]^{-1} \quad (9.2)$$

for a generalized array, whose value depends on the positions of the electrodes as defined in figure 9-b.

In homogeneous ground the apparent resistivity will equal the true resistivity, but will normally be a combination of all contributing strata. Thus, the geometrically corrected quantity is called apparent resistivity (ρ_a).

figure 9-c shows examples of different collinear electrode configurations in use: Wenner (α , β and γ), Schlumberger, dipole-dipole, and pole-pole. It can be noted that the Wenner configuration is a special case where the four electrodes are equally spaced with a separation a . For the Schlumberger array the l/L -relation will vary during normal surveying, similarly the factor n will vary in a dipole-dipole survey. The different electrode configurations offers advantages and disadvantages compared to each other in terms of logistics and resolution, and the choice is usually a trade-off between these factors. Furthermore, the reciprocity principle states that the current and potential electrodes may change places without affecting the measured quantity. In some applications it may be an advantage to make use of the reciprocity principle for logistic reasons, or for estimating the measurement accuracy.

Preparations for Field Surveying

Look through archive material for the area (topographical maps, geological maps, aerial photographs, reports etc.), and consider whether resistivity surveying is a suitable method for the current problem. If so, select possible profile lines or sounding locations.

Walk around the area to be surveyed with maps and/or aerial photographs at hand (aerial photographs and a pocket stereoscope is often highly useful) to select the optimal line for the profile/sounding. Walk along the entire length of the planned line before putting out any equipment, to ensure that the selected lines are practical. This is of special importance in conducting LUND imaging surveys.

APPENDIX B:
SEISMIC EQUIPMENT AND INFORMATION SHEETS

TERRALOC MK6 FEATURES



Great features in a small seismograph

The Terraloc mark 6 is a high resolution multi-channel seismograph with an 18-bit A/D converter and 3-bit instantaneous floating point (IFP) amplifier. Overall resolution is thus 21 bits. Its dynamic range, 126 dB, eliminates all gain setting hassles and satisfies the most stringent shallow reflection requirements.

7,8" full colour daylight-visible backlit display with VGA resolution
 Armoured glass LCD protection
 Sealed, Rugged aluminium case protects against weather and rough handling
 sealed 1.44 MB 3.5" floppy drive
 Numeric keyboard
 Command keyboard

Added Terraloc advantages:

Great for tomography thanks to high sampling rates starting at 25 μ s.

Usable with various energy sources (even mini-vibrators) thanks to long record lengths, auxiliary source signature channel input and built-in correlation software.

provides sophisticated automation. Aversatile digital (TTL) interface (trigger IN/OUT,arming IN/OUT signals) makes it easy to connect several Terralocs and supports handshaking with vibrators and marine seismic energy sources.

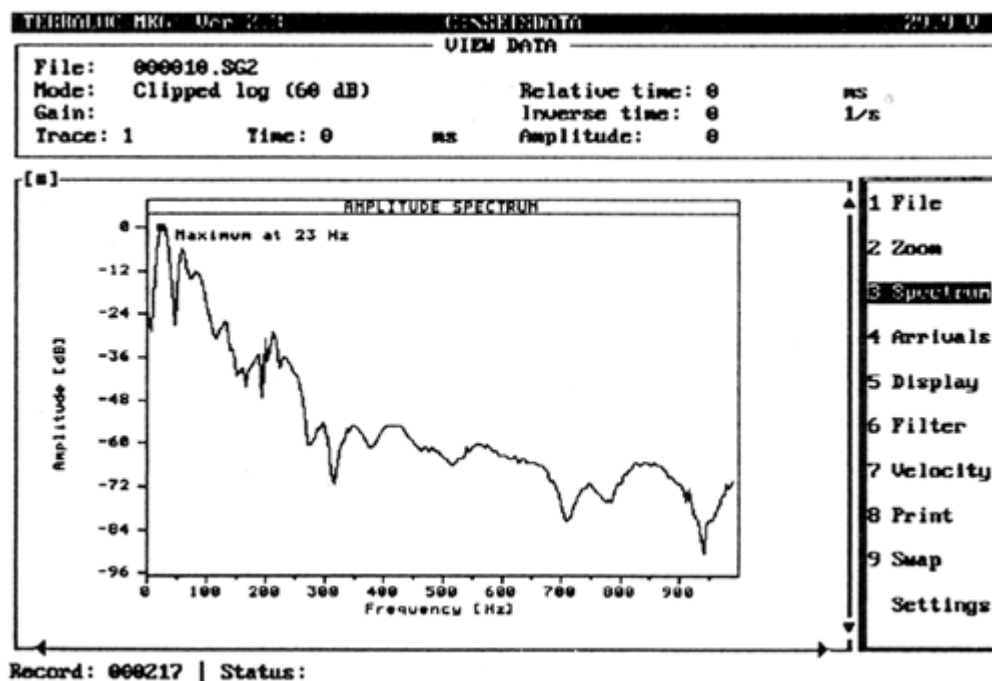
Ideal for refraction as well as shallow reflection seismics thanks to built-in roll-along function and a broad spectrum of analog and digital filters

In-field quality control. On-site geophone testing, cable testing and noise monitoring.
Wide choice of multi- or single-trace view modes and frequency spectrum analysis (FFT)

Powerful computer

Fully compatible with your office computer thanks to MS-DOS 6.0 or higher, an internal hard disk, a built-in 1.44mb floppy disk, and compliance with the international SEG-2 format for storing of seismic traces and header information.

Interpretation software can be installed and run right in your Terraloc field unit.



Spectrum analysis helps you select the right filter ,and it can also reveal soil properties

Lightweight and easy to use

The compact, lightweight Terraloc mark6 weighs only 16kg (24-channel version) and is less than half the size of its predecessor the popular Terraloc mark 3.

Carefully prepared, logically arranged documentation includes a copies of the operators manual (one for the field, and one to keep in the office), a user's manual for the computer , a complete description of the SEG-2 format and a service manual loaded with detailed technical information and schematics. Also included are a DOS manual and practice records to get you started.

Broad range of viewing provisions.

- Scroll through records
- Change display settings as desired
- Select different time-scales
- Select display mode
- Select trace mode
- Select AGC window length and set time and amplitude scale factors
- Analyse single-trace frequency content (FFT)
- Calculate refractor velocities
- Analyse ground noise
- Re-Scale traces individually
- Create a geophone test report
- Enlarge traces individually (Zoom)

Broad Printer support

The terraloc mark 6 supports a wide range of printers through dynamic link libraries (DLLs) via either the parallel or serial port and new printers can be added easily if required in the future.

Roll-along optimum offset

You can type in numerical values for roll-along start-trace, end-trace and step, you can roll along part of your receiver spread a step at a time . This feature is used in reflection surveys that include CDP stacking.

Expand your system

Two or more Mark 6's can easily be linked together to form a larger system. The print-out below is from a 96channel survey in which four 24-channel Terraloc's were connected

Technical Specifications for the Terraloc

- Number of channels (smaller unit)..... 4-24 in steps of 4
- Number of channels (larger unit)..... 4-48 in steps of 4
- Additional channels..... Easily obtained by linking two or more units together
- Up-hole channel..... Yes
- Sampling rate (selectable)..... 25, 50, 100, 200, 500,1000 and 2000 μ s
- Record length (selectable)..... 128, 256, 512, 1024, 2048,4096, 8192 or 16384 samples per trace equivalent to: 3.2 ms - 32.7 s
- Pre-trig record (selectable)..... 0-100 % of record length
- Pre stack correlation..... Yes, cross correlation with reference or any other channel
- Delay time Related to sampling rate May be set (for example) from: 0-0.8 s at 25 ps ,sampling rate 0-131 s at 2 ms sampling rate
- Stacking..... 32 bits, up to 999 impacts
- Unstack..... Remove last shot from stack
- First-arrivals picking..... Automatic or manual. Times can be saved with record
- Trigger inputs..... Trigger coil, make/brake, geophone, TTL
- A/D converter resolution..... 21 bits (18 bits plus 3-bit IFP)
- Dynamic range (theoretical/measured)..... 126 / 114 dB
- Max input signal..... 500 mV p-p
- Frequency range..... 1 - 4000 Hz (at 25 ps sampling rate)
- Total harmonic distortion..... - 80 dB
- Crosstalk..... - 86 dB
- Input impedance..... 3 k
- Noise monitor..... Amplitude or full waveform display available on-line

Analog filters

- Low cut (selectable)..... 12 or 24 dB/octave 16 steps from 12 to 240 Hz
- Notch..... 50 or 60 Hz specify when ordering
- Anti-aliasing..... set automatically based on sampling rate

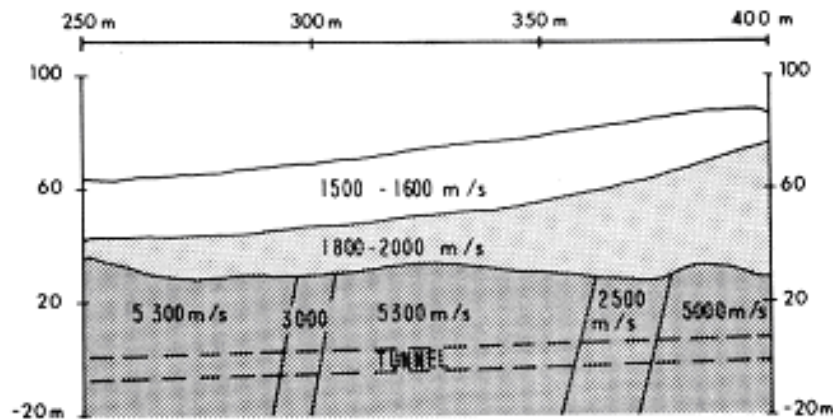
Digital filters

Bandpass, low-cut, high-cut, bandreject, alpha-beta and remove DC offset Spectrum analysis..... Any single trace

AREAS OF APPLICATION

Civil Engineering/Mining Exploration - Exploitation/Petroleum and Gas Sectors/ Geotechnology/Geology/ Hydrology.

- Identification of faults, fractures, shear zones.
- Detection of rock differences (veins, dykes, cavities, etc.).
- Determination of rock topography.
- Evaluation of volume of soil present or to be excavated.
- Excellent complement to geological mapping.
- Recognition of geophysical anomalies such as VLF, gravimetry, etc.
- Drill site selection, better target identification.
- Evaluation of the size, thickness and condition of surface shafts (mining exploitation).
- Mass Rock Quality Determination (MRQD).
- Detection of rock irregularities and breaks.
- Hydrogeology (detection of water tables, veins, reservoirs).
- Excellent complement to any geological analysis.



Interpretation results of a seismic profile

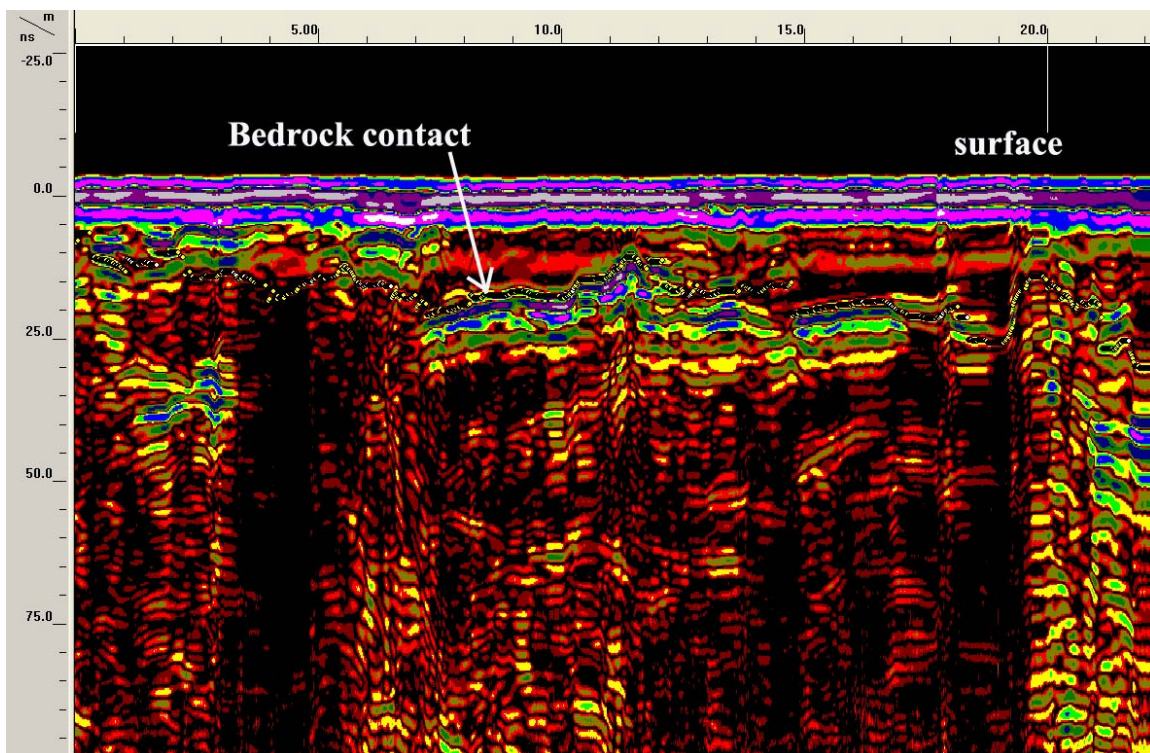
ADDITIONAL REMARKS

Geophysics GPR International Inc. has been recognized for the past fifteen years as a leader in both the application and the development of seismic methods. Seismic refraction is currently used in both civil and mining engineering; the use of lighter high-performance equipment and better tomographical interpretation of the results have contributed to its growing popularity.

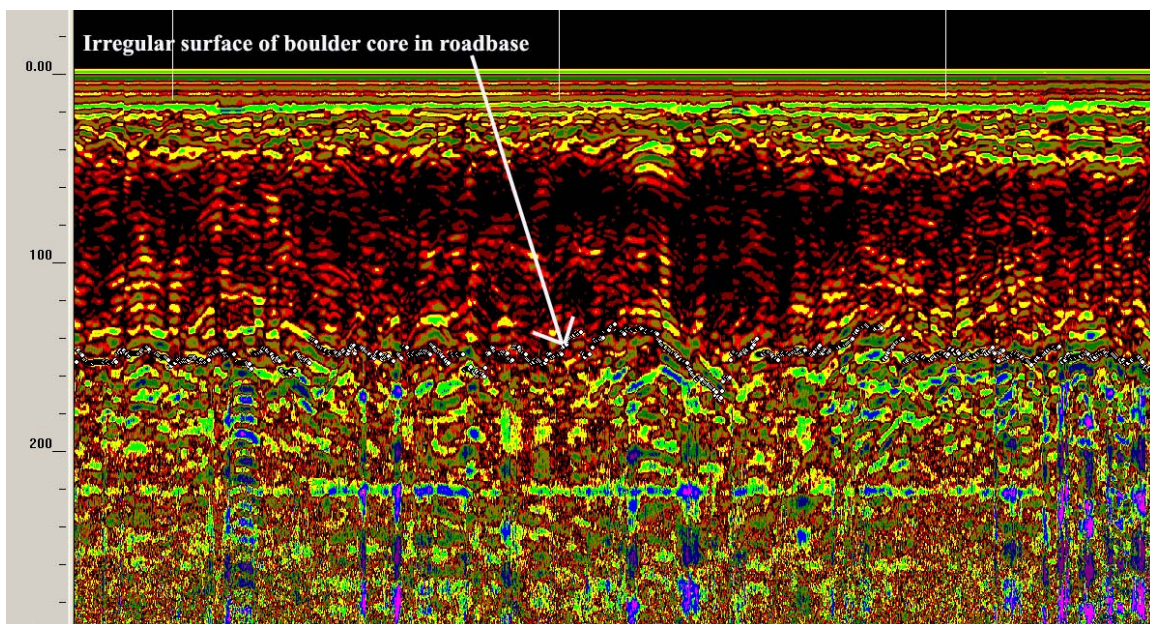


GEOPHYSICS G P R INTERNATIONAL INC.

**APPENDIX C:
GEORADAR EXAMPLE PROFILES AND EQUIPMENT AND
INFORMATION SHEETS**



EXAMPLE RADAR IMAGE OF SHALLOW BEDROCK CONTACT IN AREA 1



EXAMPLE RADAR IMAGE OF A PORTION OF PROFILE 4, AREA 1 WITH IRREGULAR CONTACT OF BOULDER ROAD BASE

SIR-3000 System by GSSI

Rugged, high-performance
GPR data acquisition system



Benefits

- Rugged, lightweight, hand-held and portable
- User-friendly
- High-resolution screen—easy to read in daylight
- Large data storage capacity
- Compatible with all GSSI ground-coupled antennas
- Built with pride in the U.S.A.

Applications

Concrete Inspection

Utility Mapping

Bridge Deck Inspection

Geological Investigation

Archaeology

Forensics/Law Enforcement

Snow/Ice Thickness Measurement

Research



The World Leader in
Subsurface Imaging™

Geophysical Survey Systems, Inc.
www.geophysical.com

SIR-3000 System Specifications

System

Antennas:

Compatible with all GSSI ground-coupled antennas

Number of Channels: 1 (one)

Data Storage:

Internal memory: 1 GB Flash memory card

Compact Flash port: Accepts industry standard CF memory up to 2 GB (user provided)

Processor: 32-bit Intel StrongArm™ RISC processor @ 206 MHz

Display: Enhanced 8.4" TFT, 800 x 600 resolution, 64K colors

Display Modes: Linescan, O-scope, 3D

Data Acquisition

Data Format: RADAN (dzt)

Scan Rate Examples:

220 scans/sec at 256 samples/scan, 16 bit

120 scans/sec at 512 samples/scan, 16 bit

Sample size: 8-bit or 16-bit, user-selectable

Scan Interval: User-selectable

Number of samples per scan:

256, 512, 1024, 2048, 4096, 8192

Operating Modes:

Free run, survey wheel, point mode

Time Range:

0-8,000 nanoseconds full scale, user-selectable

Gain: Manual or automatic, 1-5 gain points (-20 to +80 dB)

Filters:

Vertical: Low-Pass and High-Pass IIR and FIR

Horizontal: Stacking, Background Removal



Geophysical Survey Systems, Inc.
www.geophysical.com

Operating

Operating Temperature:

-10°C to 40°C ambient

Charging Power Requirements:

15 V DC, 4 amps

Battery: 10.8 V DC, internal

Transmit Rate: Up to 100 KHz

Input/Output

Available Ports:

Antenna input

DC power input

Serial RS232 (GPS port)

Compact Flash memory

USB master and slave

Mechanical

Dimensions:

31.5 (L) x 22 (W) x 10.5 (H) cm

12.4" x 8.7" x 4.1"

Weight: 4.1 kg, (9 lbs) including battery

Environmental: Water resistant

System Includes:

SIR-3000 data acquisition system

Transit case

2 batteries

Battery charger

AC adapter (also works as charger)

User manual

Sunshade

Carrying harness (optional)

Antennas and antenna control
cables sold separately

FCC Compliant

13 Klein Drive, PO Box 97
North Salem, NH 03073-0097
Tel: (603) 893-1109 Fax: (603) 889-3984
Sales@Geophysical.com

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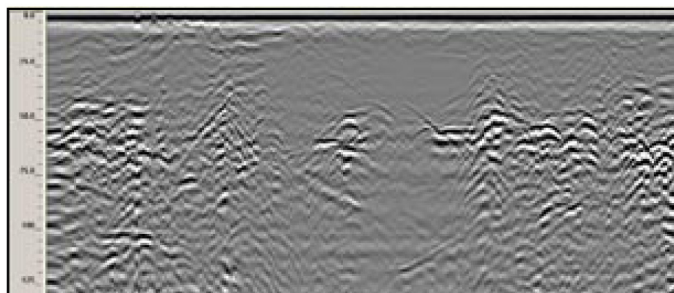
Antennas

Model 5104 - 270MHz

Utility Detection and Mapping
Engineering/Environmental
Geotechnical

The Model 5104 is suited for deeper utility, engineering and geotechnical applications.

Center Frequency:	270 MHz
Depth Range:	0- 6 m (0 - 18 ft)
Dimensions:	45 x 45 x 17 cm (18 x 18 x 6.5 in)
Weight:	8.6 kg (18.5 lbs)



GPR profile showing bedrock interface.

Model 3207 - 100MHz

Bistatic and Monostatic Operation

Geotechnical/Environmental
Mining

Center Frequency:	100 MHz
Depth Range:	2 - 15 m (5 - 50 ft) monostatic 0 - 30 m (0-100 ft) bistatic
Dimensions:	25 x 96 x 56 cm (10 x 38 x 22 in.) monostatic 25 x 96 x 200 cm (10 x 38 x 79 in.) bistatic
Weight:	13 kg (28 lbs) monostatic 28 kg (61 lbs) bistatic



The Model 3207 antenna is used for deep subsurface applications. The 3207AP (monostatic, left) combines the transmit and receive electronics in a single antenna housing. The 3207P (bistatic, right) is a versatile antenna pair that can operate in three different configurations to optimize performance.

Note: This antenna is currently for use outside the U.S.



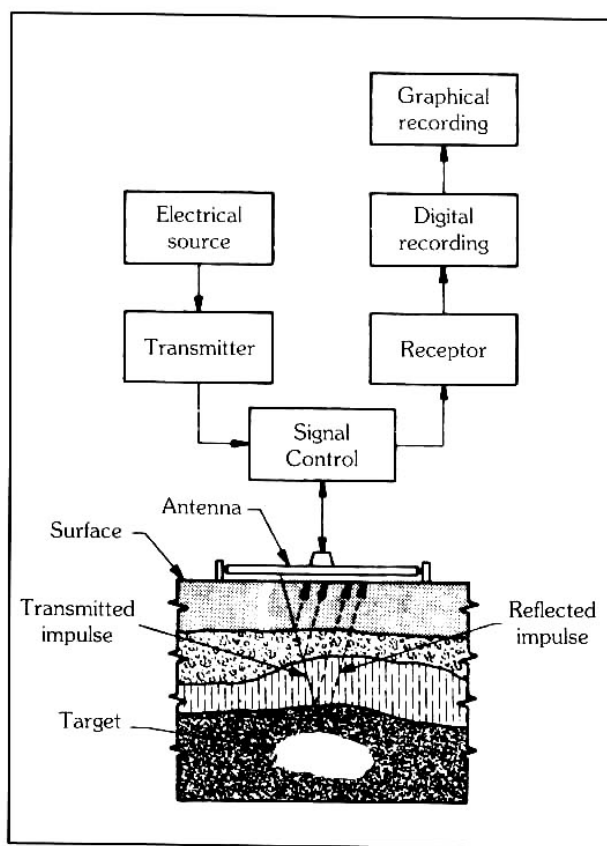
Geophysical Survey Systems, Inc.
12 Industrial Way, Salem, NH 03079-4843 USA
Tel: 603-893-1109 / Fax: 603-889-3984
www.geophysical.com / sales@geophysical.com

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March, 2006



GEORADAR

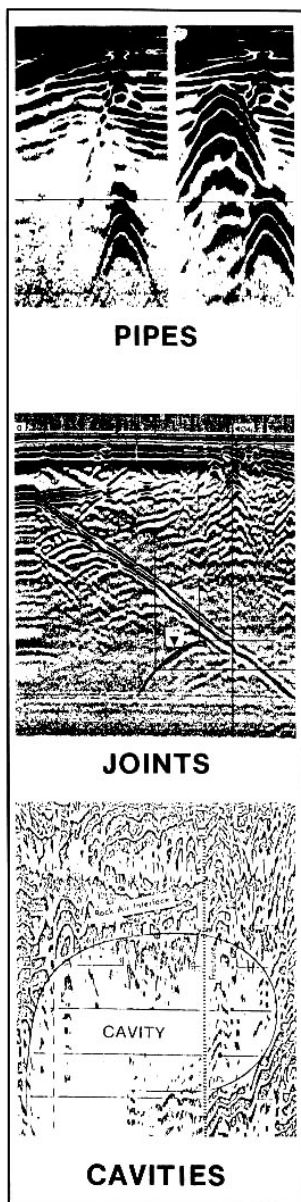
As indicated by its name, georadar combines high resolution radar with geology. The underlying principle is based on the propagation of electromagnetic wave impulses (VHF) that are reflected by anomalies in the terrain (joints, irregularities, interfaces, etc.) at different depths, and then captured by the antenna. The georadar records the time taken by each transmitted signal to complete the cycle in order to calculate the depth of the anomaly. The result is similar to a seismic reflection profile where all the reflections are displayed graphically. This technique is used to solve problems for which there had previously been no practical solution.



PRINCIPLES OF GEORADAR

FEATURES

- Penetration of more than 20 metres in certain materials (penetration being inversely proportional to conductivity).
- Surveying in continuous mode.
- Identification of objects measuring only a few centimeters.
- Light and manoeuvrable equipment.
- Detection of conductivity, open spaces and/or holes (cavities).
- Detection of breaks: faults, fractures, joints, cavities.
- Results similar to seismic reflection: continuous underground profile.
- Results available immediately.
- Can be used in land, sea or airborne surveys.



FIELDS OF APPLICATION

Civil Engineering / Mining Exploration-Exploitation / Research / Archaeology / Environment

- Geotechnology: investigation of soils and surface deposits.
- Optimal selection of anchor bolts in mines and quarries.
- Detection of buried pipes before beginning excavation.
- Detection of liquid or gas leakage in soils.
- Detection of cracks in concrete structures.
- Checking material homogeneity.
- Detection of cavities beneath road pavement.
- Determination of water saturation level.
- Detection of girders in reinforced concrete.
- Detection of pollutant leakage in water bodies.
- Inspection of buried disposal sites and or dangerous deposits.
- Continuous measurement of ice thickness.
- Archaeological research: ancient foundations, artifacts.
- Non-destructive method for measuring road pavement thickness.
- Localization and measurement of soil's thickness (swamps, peat bogs).
- Determination of rock beddings (location and thickness).
- Bathymetric studies (depth sounding).
- Calculation of the thickness of permafrost and ice.
- Geotechnical studies for the installation of aqueducts.

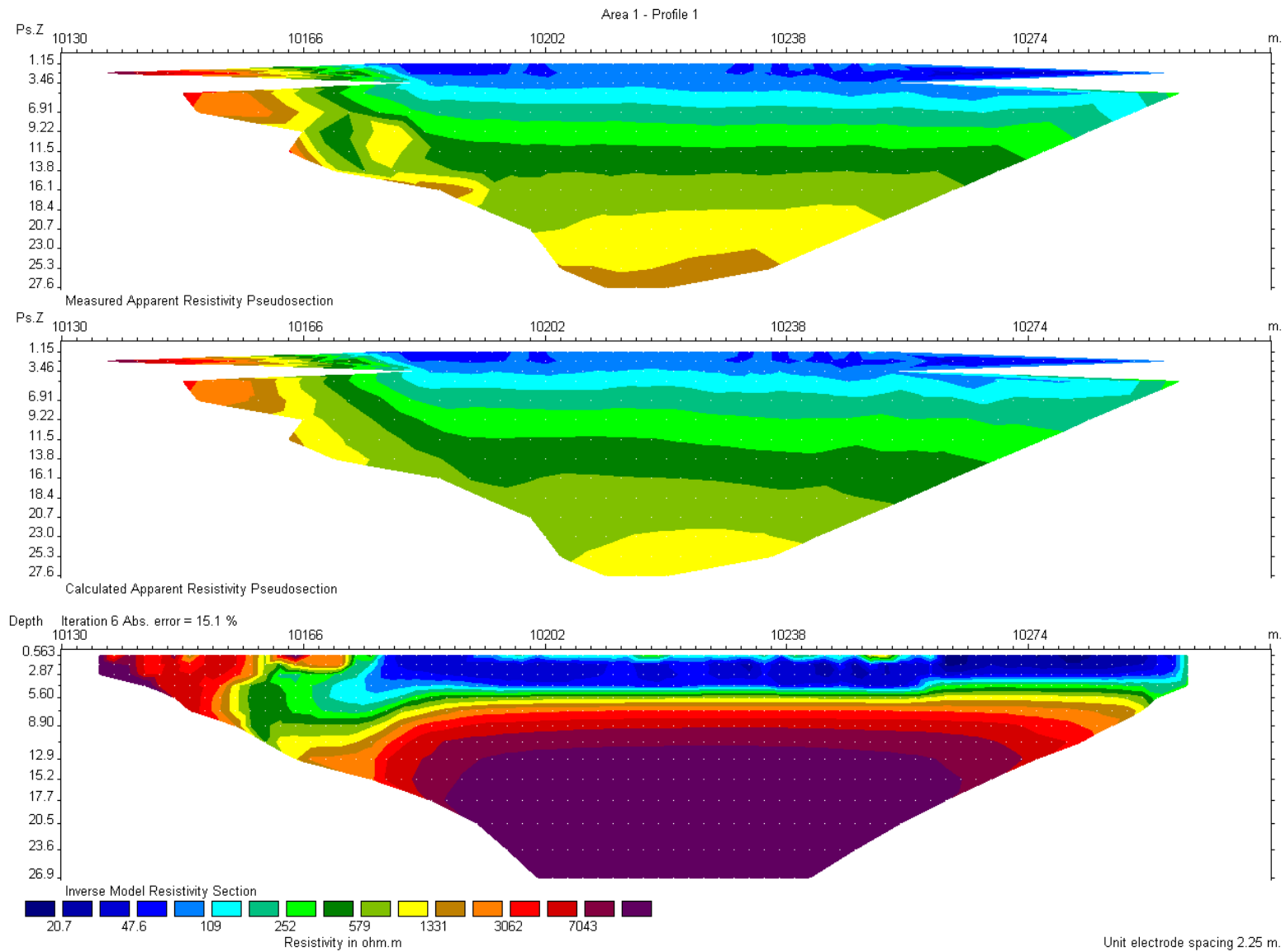
SPECIAL FEATURES

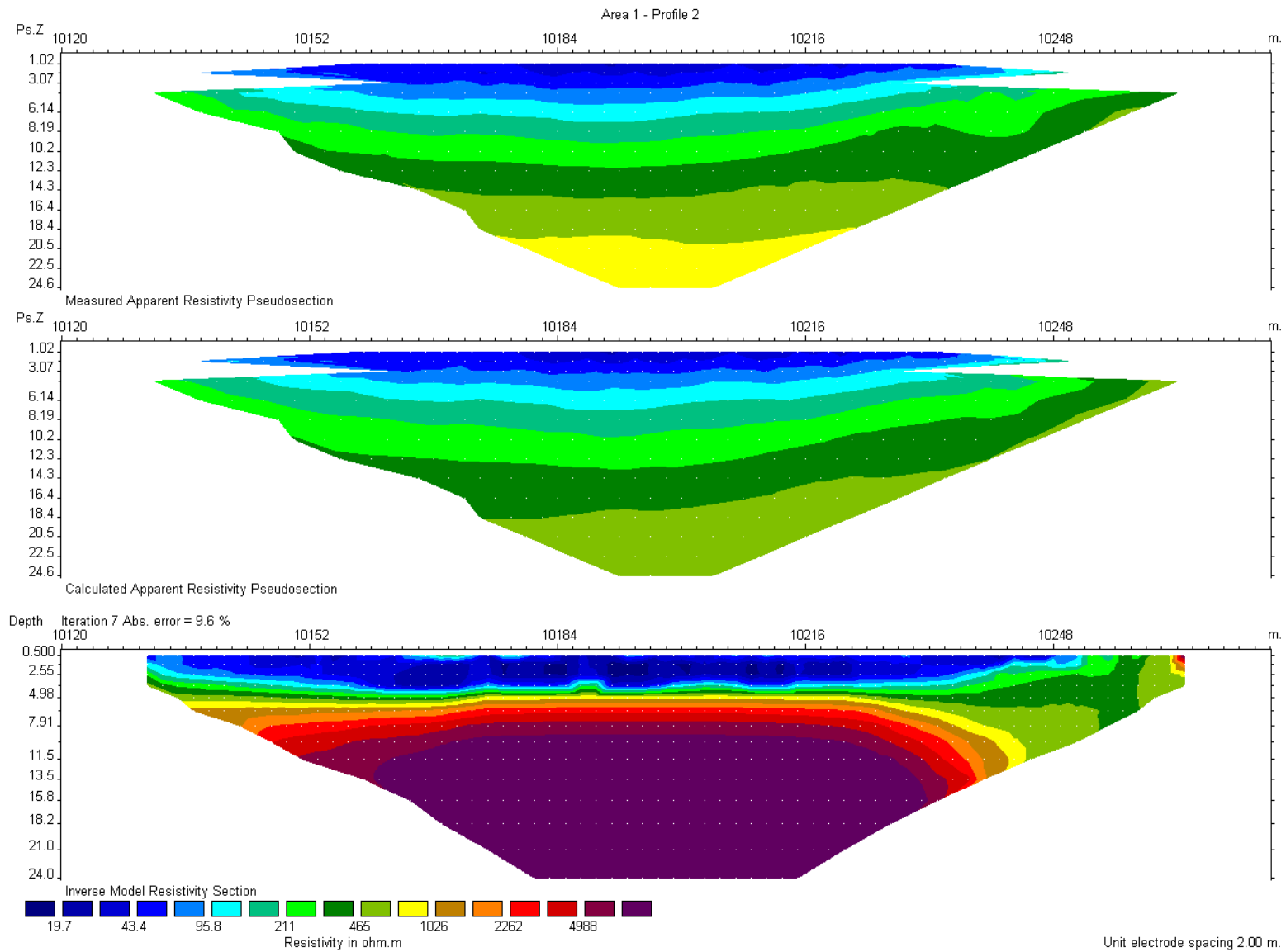
The equipment is practical, easy to manoeuvre, and multi-faceted. The field of application of georadar continues to expand in various sectors, particularly in geotechnology (aqueducts), civil engineering (excavation, structures) and mining (structures).

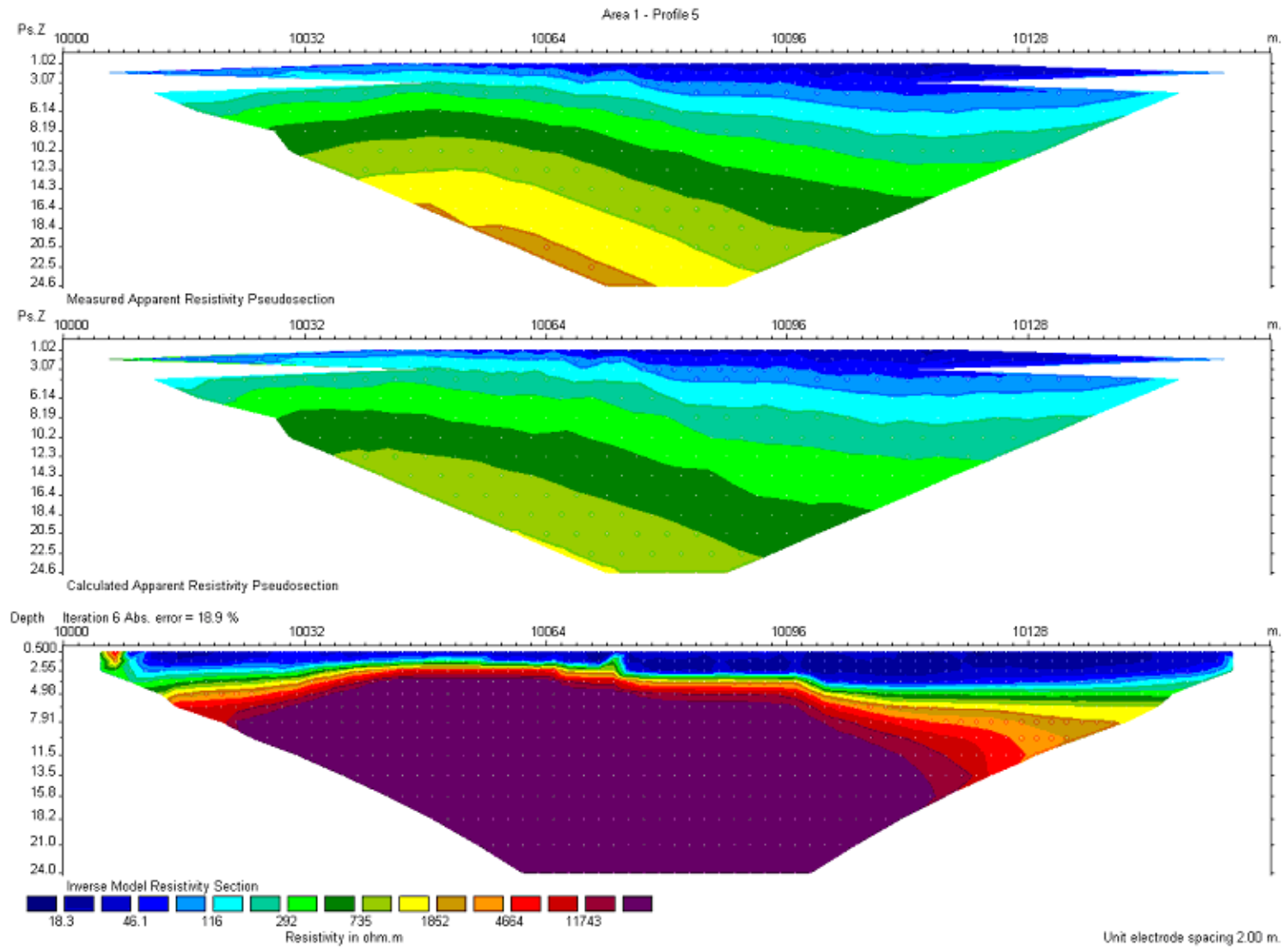


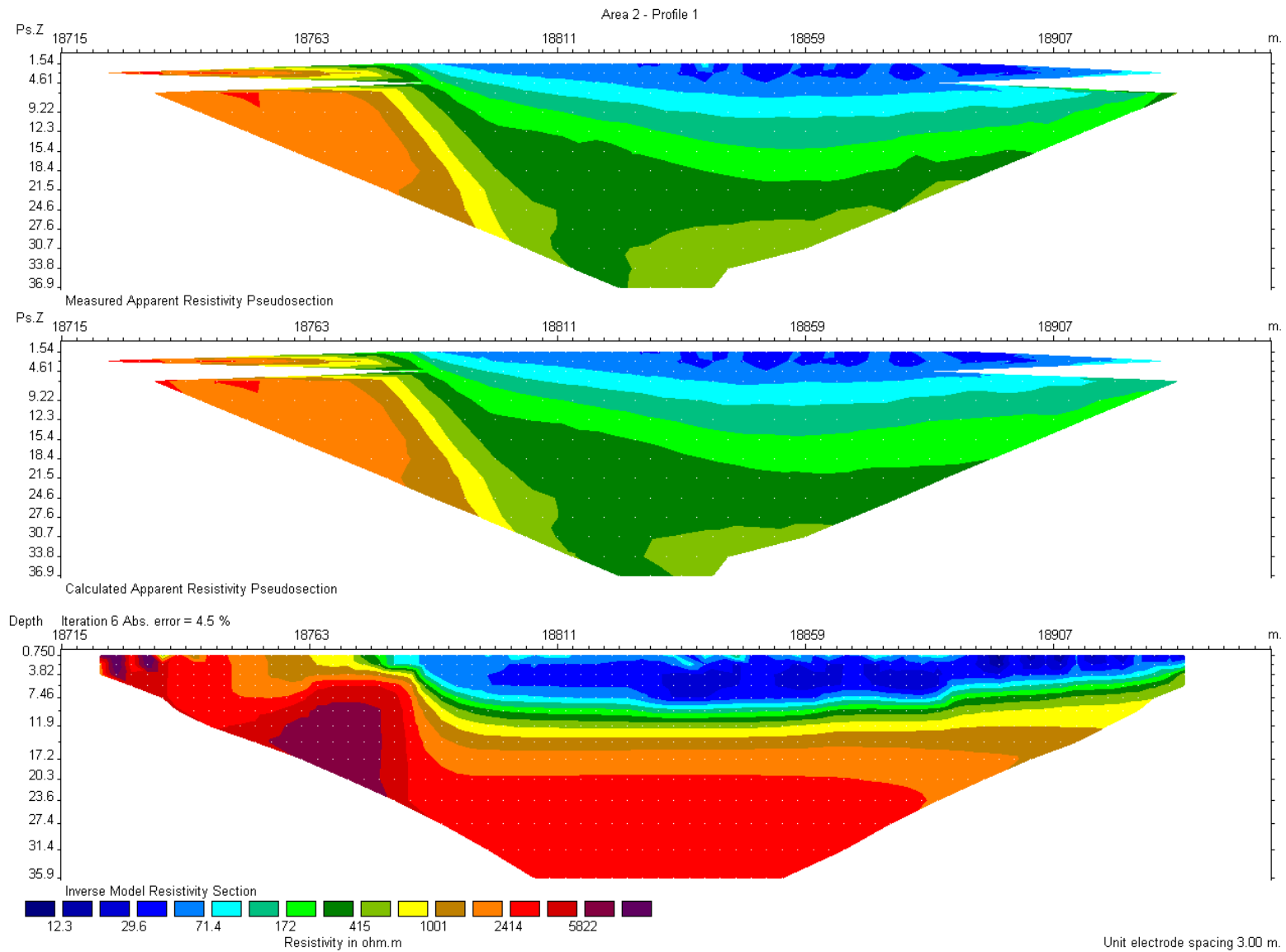
GEOPHYSICS G P R INTERNATIONAL INC.

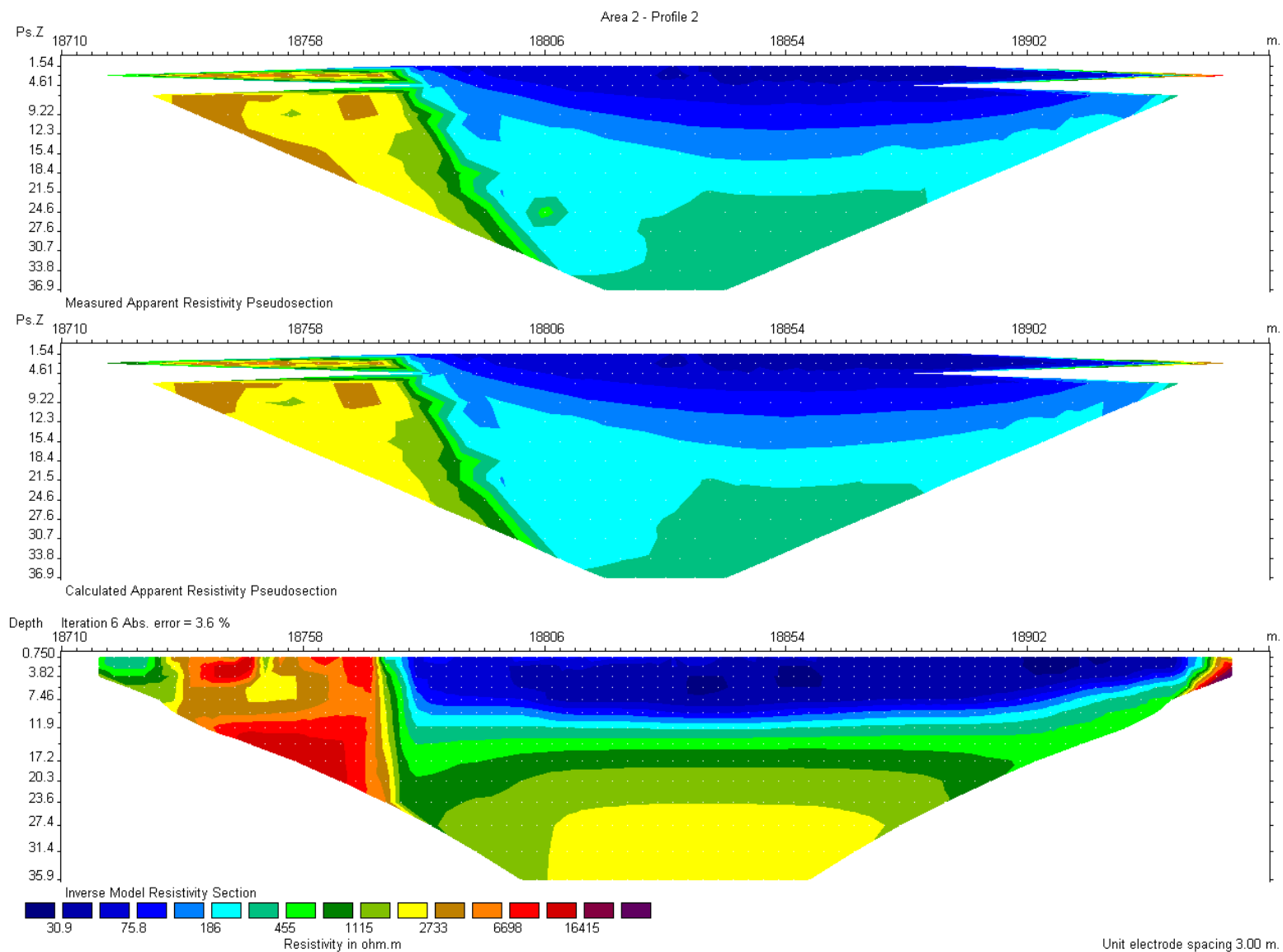
**APPENDIX D:
RESISTIVITY INVERSION PROFILES
FOR
AREA 1 AND AREA 2**

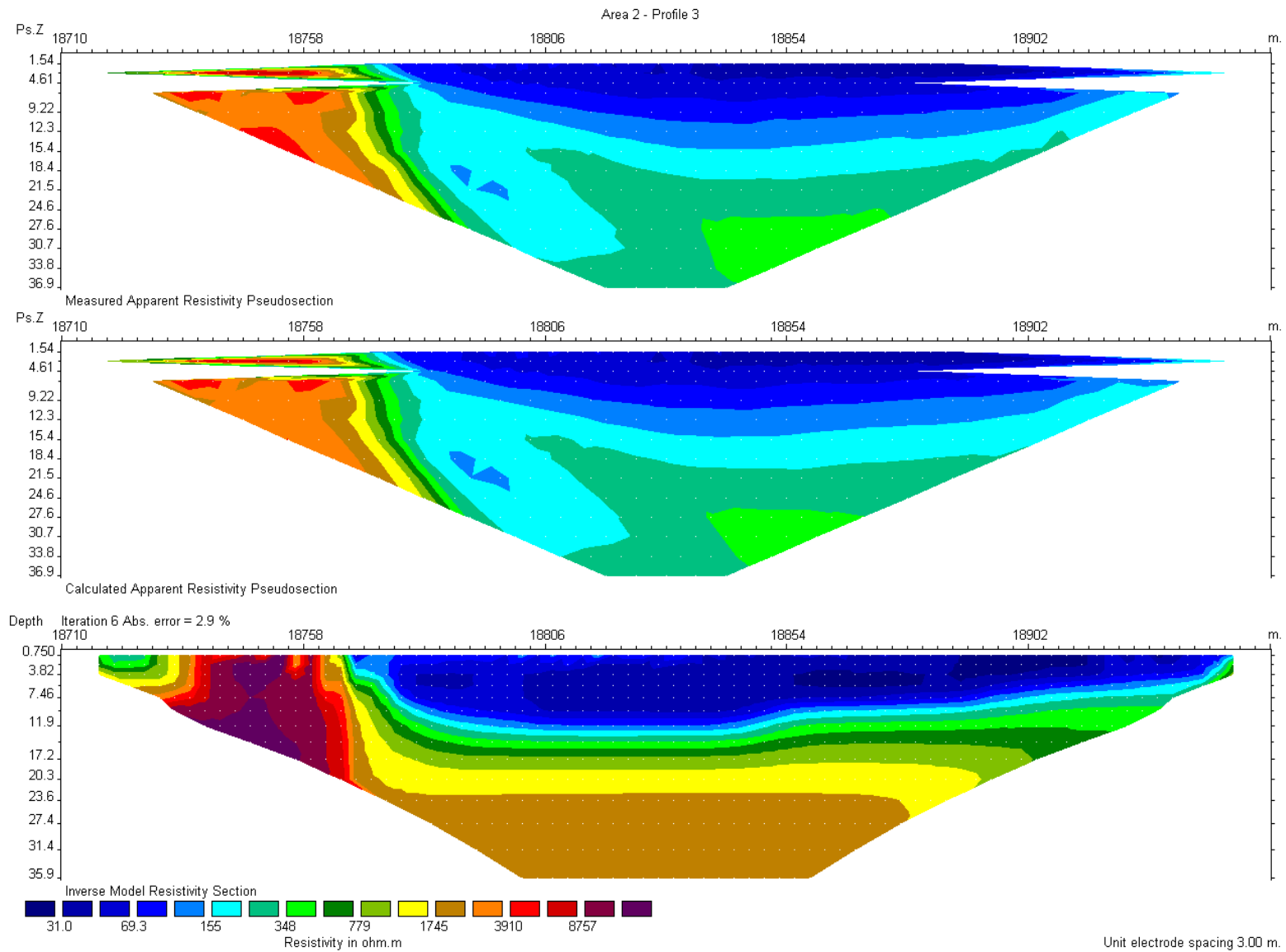


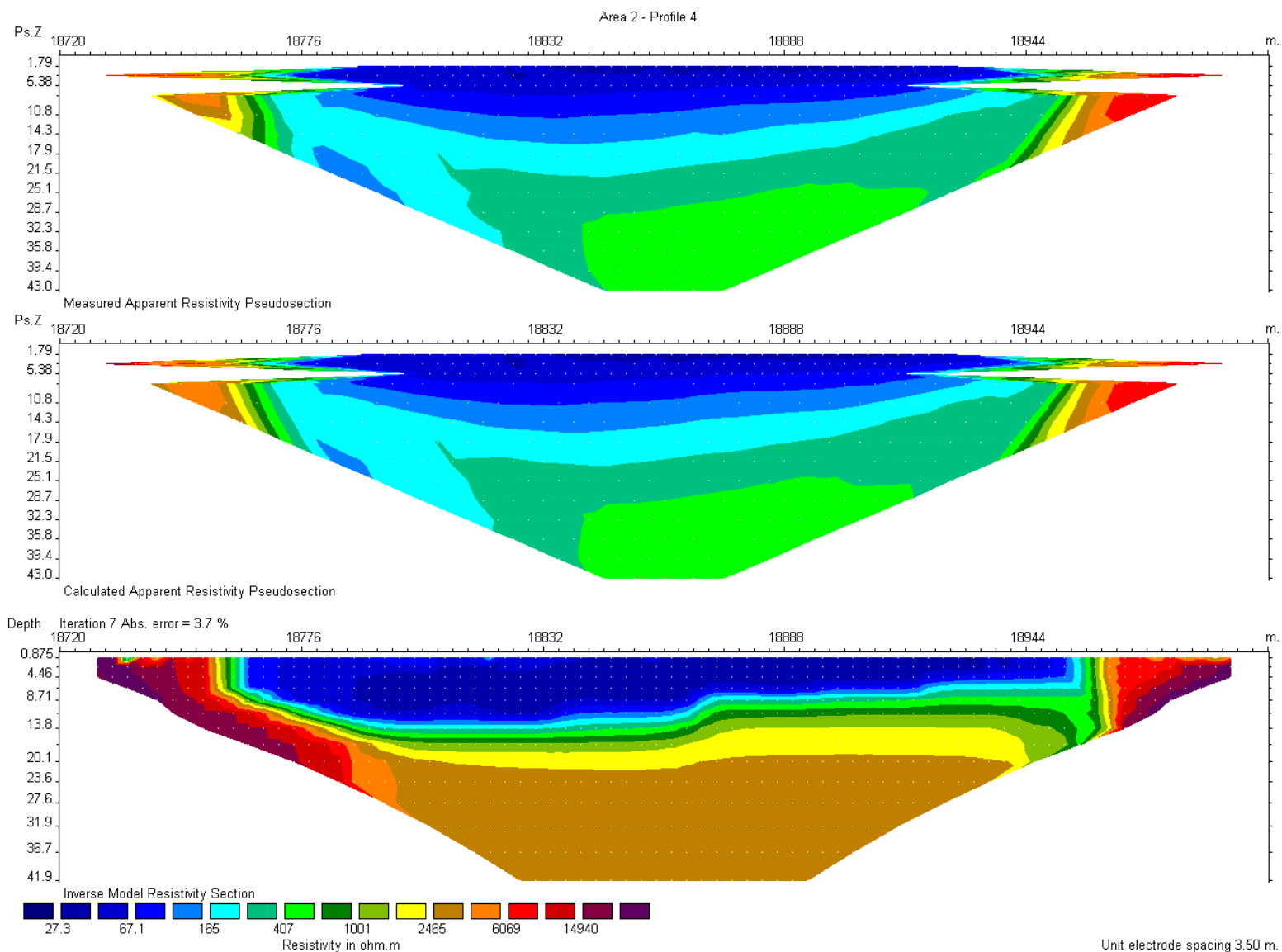


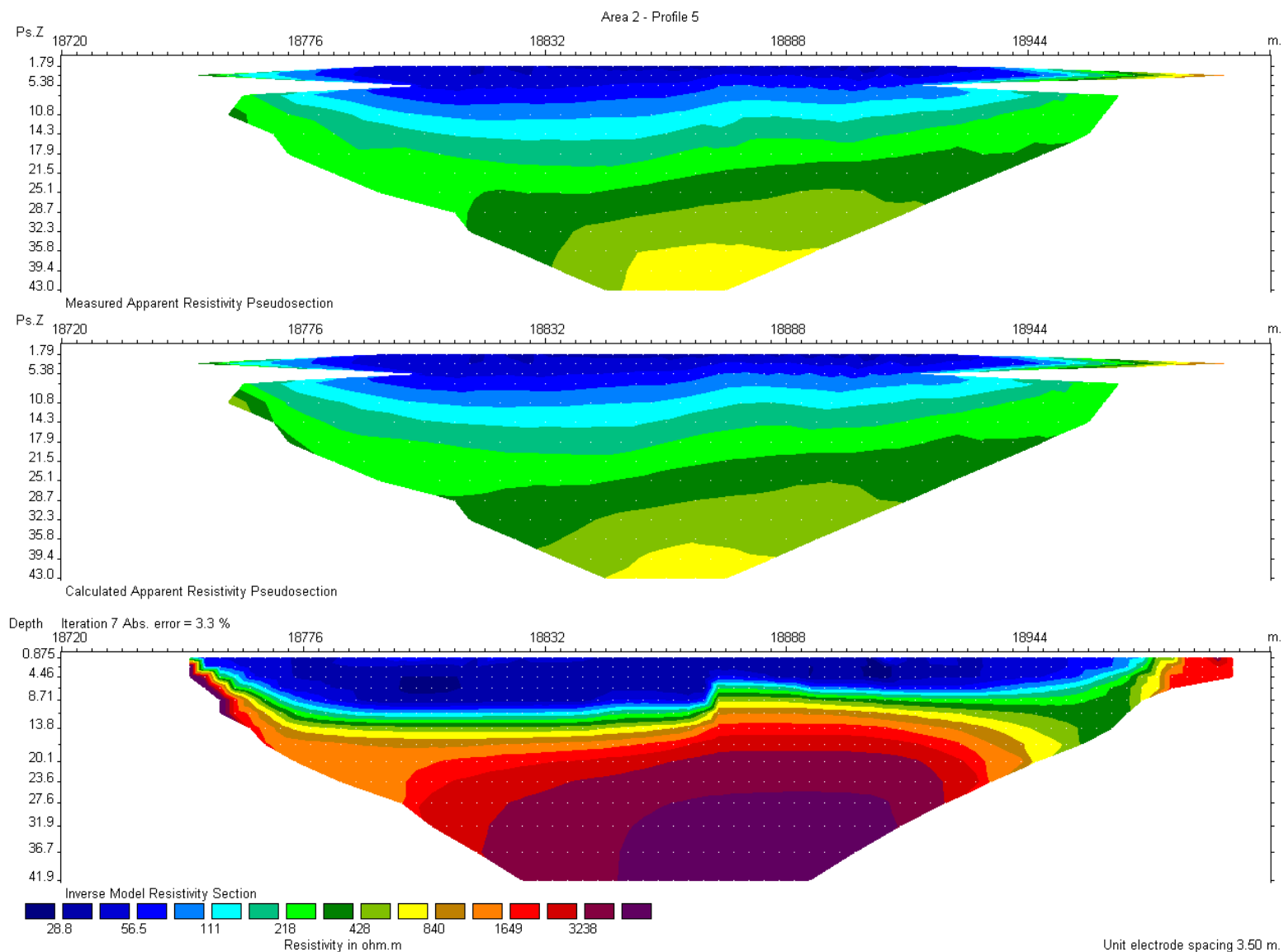


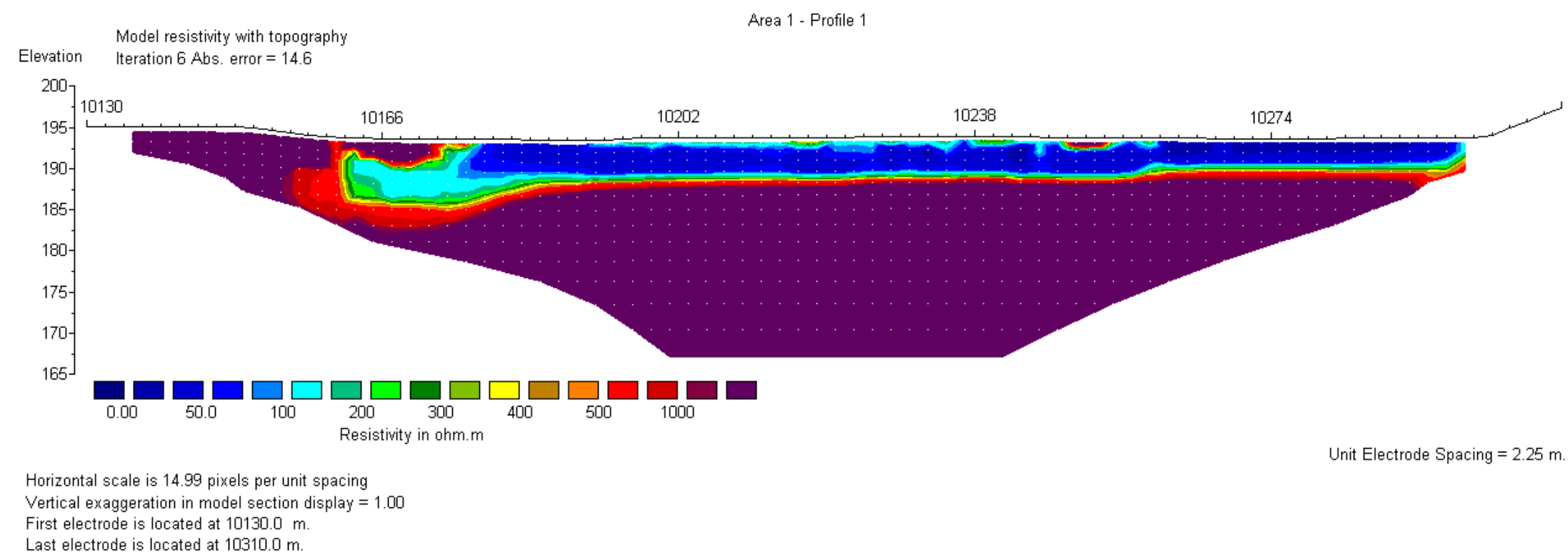


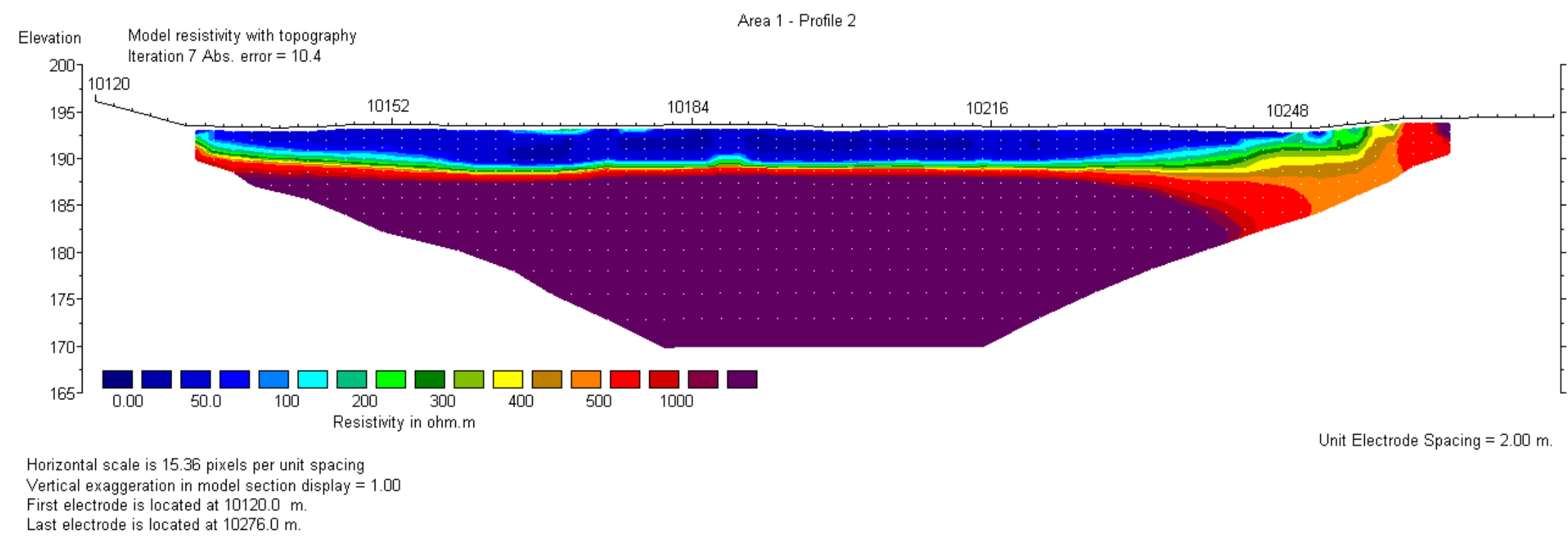


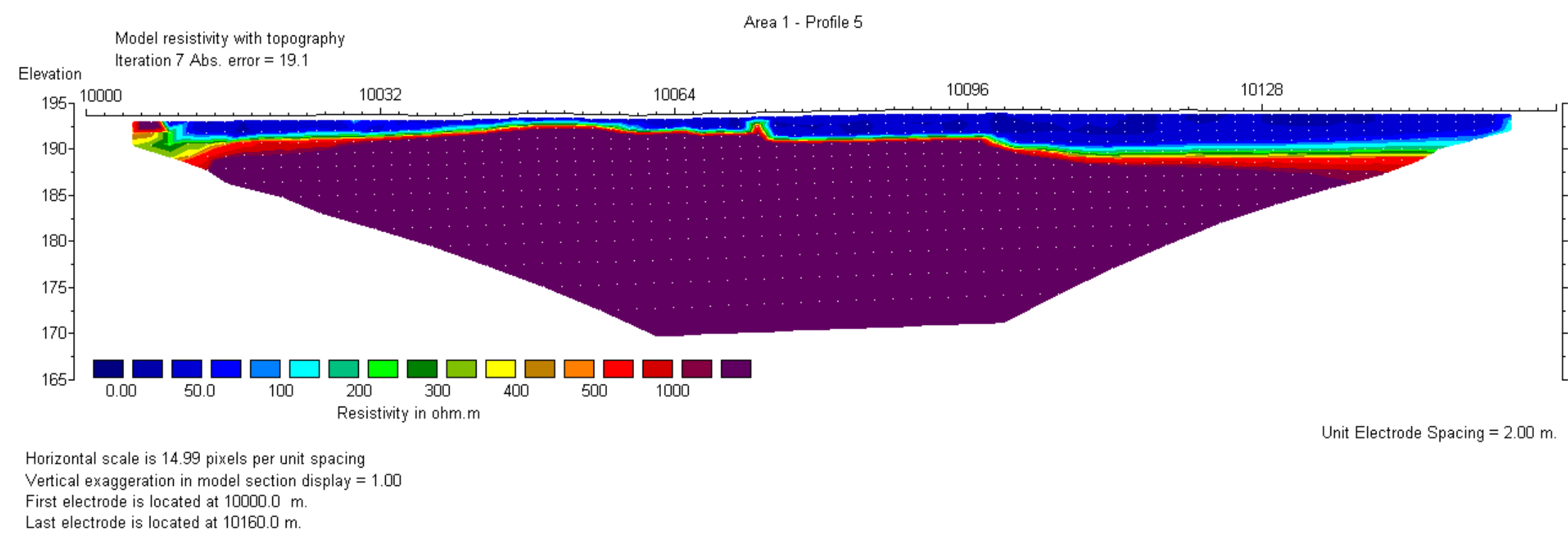


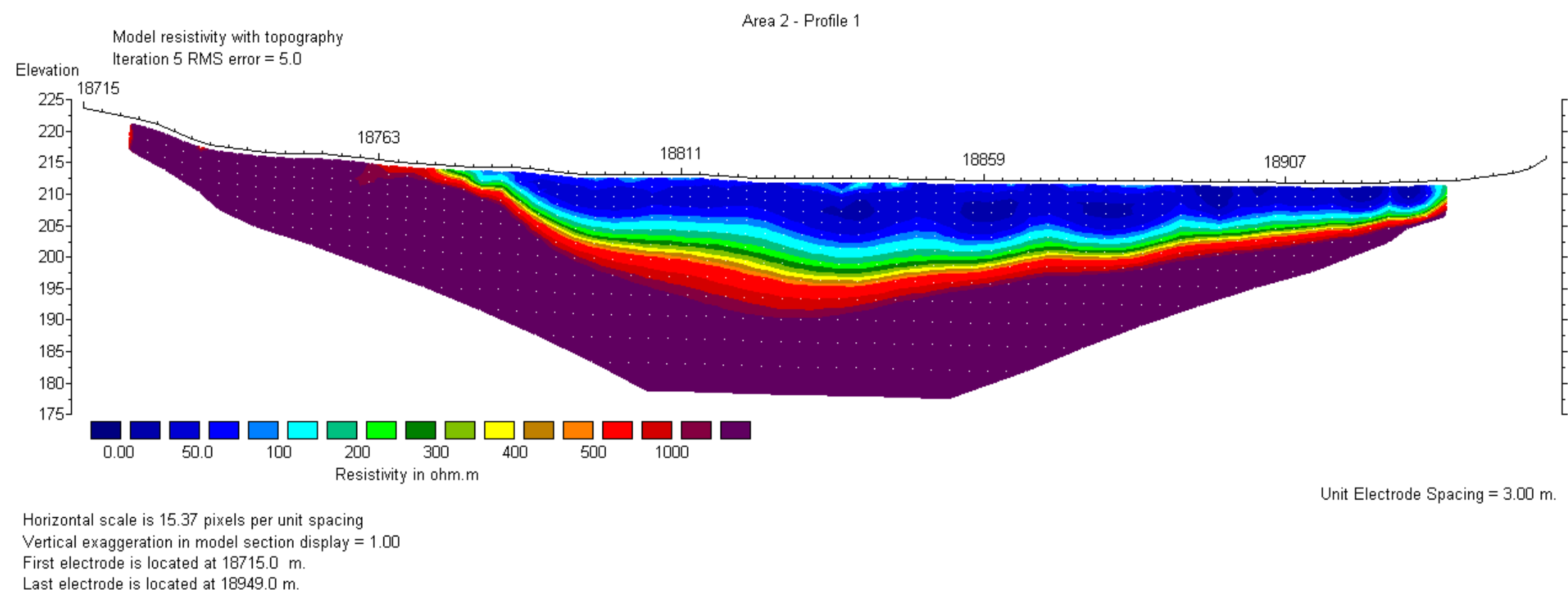


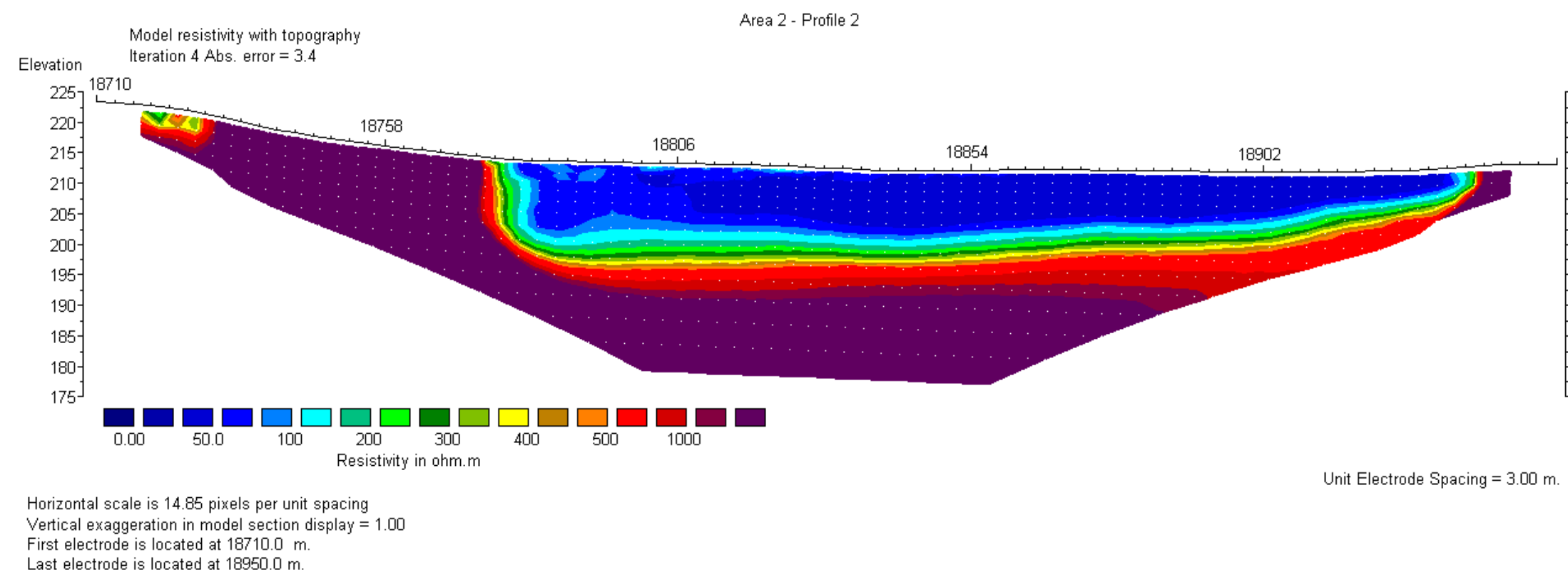


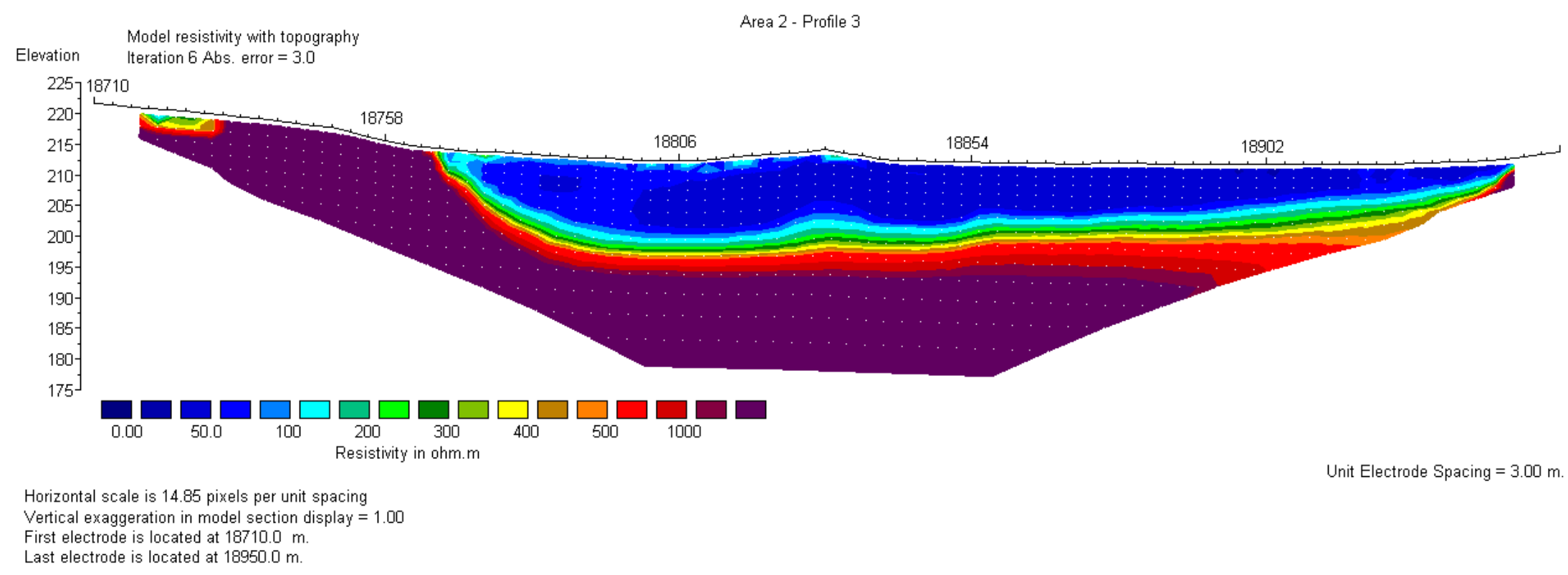


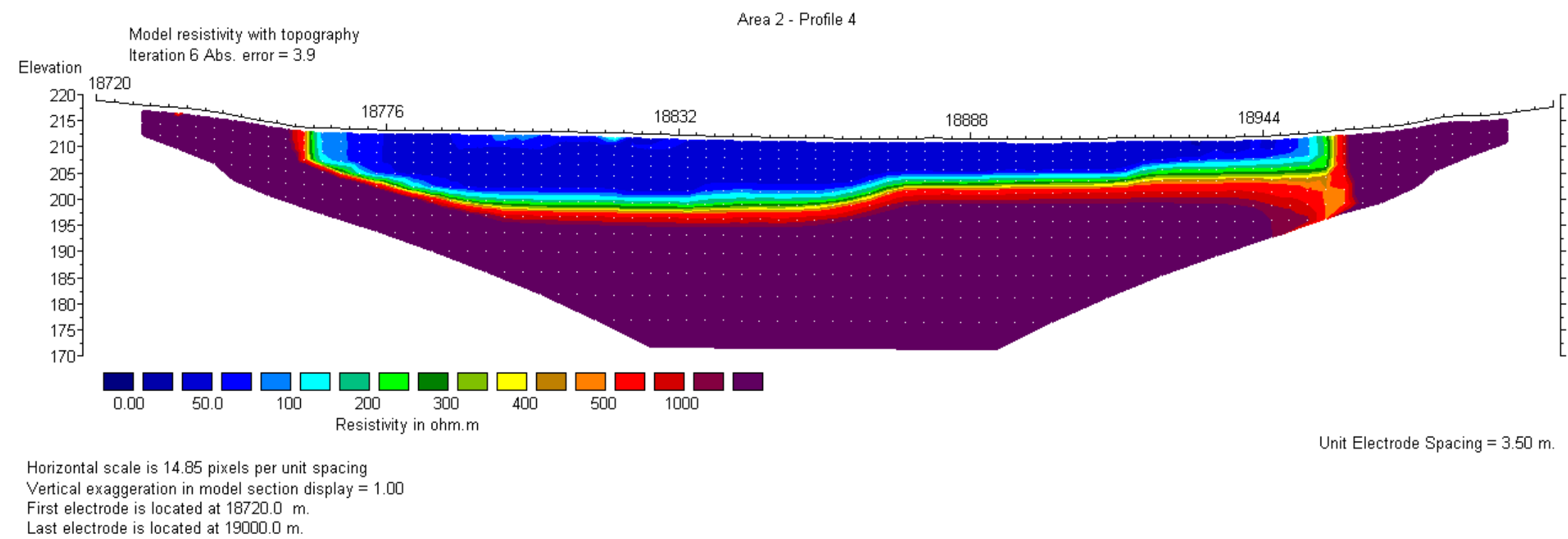


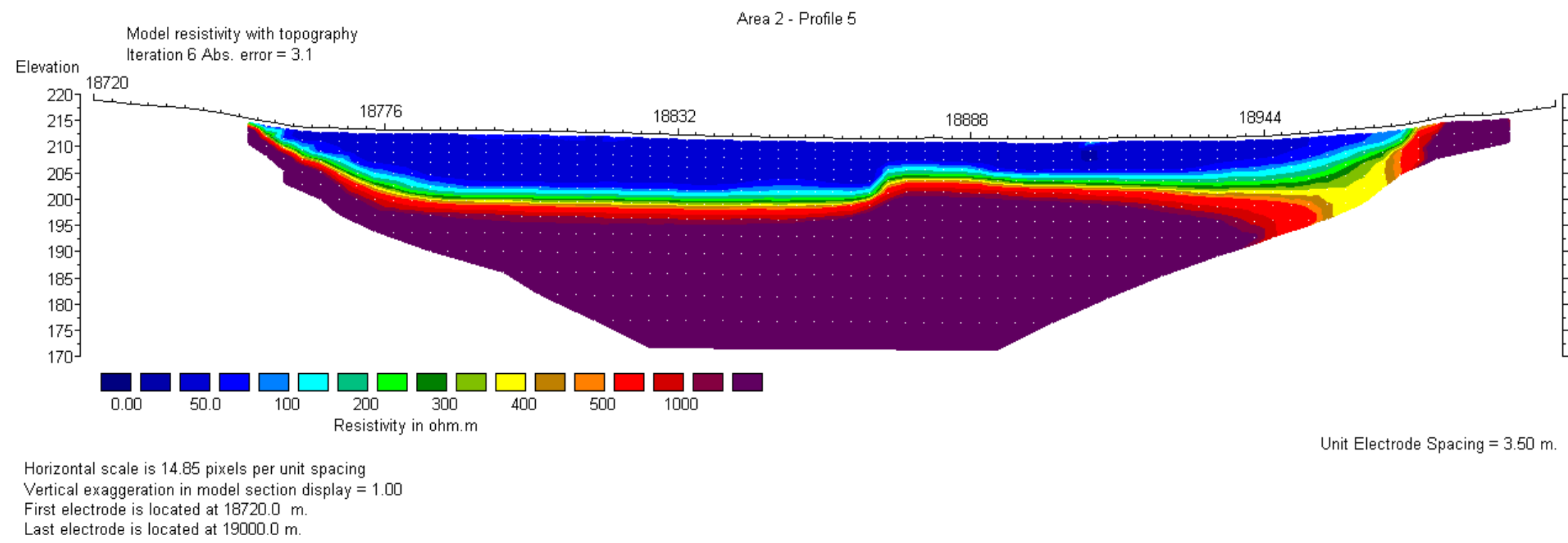












APPENDIX E

BOREHOLE LOGS N1-2, N17-2 AND DCPT N1-3



Peter MacCallum Ltd
Foundation Design

RECORD OF BOREHOLE No N17-2										1 of 2		METRIC			
G.W.P. 5379-02-00		LOCATION Hwy. 69 Sta. 25+370, C/L		Co-ords. S 123 108 N; 320 235 E		ORIGINATED BY FP									
DIST S4 HWY 69		BOREHOLE TYPE Continuous Flight Hollow Stem Augers				COMPILED BY FP									
DATUM Geodetic		DATE February 26, 2004				CHECKED BY									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT WATER CONTENT (%)		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT. LOT	NUMBER	TYPE	W VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60	20 40 60	KN/m ³	GR	SA	SI	CL
209.9	Ground Surface														
0.0	Peat, coarse fibrous		1	SS	13										
0.2	Dark brown Silty clay, trace sand clayey silt lenses		2	SS	13										
207.5	Stiff Brown Moist														
2.4	Clay, trace sand Firm Mottled Wet grey/brown		3	SS	5										
	Varved Grey		4	SS	NI**										
			5	SS	NI										
	silt lenses		6	SS	5										
201.7	Silt loose clay, trace sand Loose Grey Moist		7	SS	9										
8.2															
198.9	Sand, with gravel, with silt Loose Grey Wet		8	SS	6										
11.0			9	SS	7										
196.3	End of borehole Refusal on probable bedrock														
13.6															

ON_MOT_VERS 04TF030_N-FINAL.GPJ ON_MOT.GDT 5/26/04 12:24:35 PM

+7 .K⁻⁵ : Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE



Peto MacCallum Ltd.
Foundation Design

RECORD OF PENETRATION TEST No N1-3												1 of 1		METRIC		
G.W.P. 5379-02-00		LOCATION Hwy. 69 Sta. 10+350, o/s 50m Lt.		Co-ords. 5 111 332 N; 328 323 E		ORIGINATED BY RE										
DIST 54 HWY 69		BOREHOLE TYPE Dynamic Cone Penetration Test				COMPILED BY RE										
DATUM Geodetic		DATE March 27, 2004				CHECKED BY										
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT. LOC.	NUMBER	TYPE	W% VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100
194.0	Ground Surface															
0.0	Probable Peat															
	Probable Silty clay															
	Very soft															
	Probable Sand with silt															
	Compact															
186.0	End of dynamic cone penetration test															
7.1	Refusal on probable bedrock															
	Top 0.6 m frozen															
	"K" values shown were converted from 31.8 kg (70 lb) hammers															

MOT_DOPT R2304: D:\TF\906_H-FINAL\GPJ OK_MOT.DOT 5/28/04 11:29:34 AM
+7 .K⁻²: Numbers refer to Sensitivity 15 20 5 10 (%) STRAIN AT FAILURE



Peter MacCallum Ltd.
Foundation Design

RECORD OF BOREHOLE No N1-2 1 of 1 METRIC											
G.W.P. 5379-02-00		LOCATION Hwy. 69 Sta. 10+210, c/a 45m Rt.		ORIGINATED BY SM							
DIST S4 HWY 69		BOREHOLE TYPE Continuous Flight Hollow Stem Augers		COMPILED BY SM							
DATUM Geodetic		DATE February 28, 2004		CHECKED BY							
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	% VALU. BS	ELEVATION SCALE	20 40 60 80 100	20 40 60	W _p W L	UNIT WEIGHT	GR SA SI CL
194.6	Ground Surface										
0.0	Peat		1	SS	33						
	Dark brown Wet		2	SS	4						
192.3	Silty clay										
2.3	Soft Grey Wet		3	SS	2						
190.8	Sand, with silt, some gravel, trace clay										
3.8	Compact Brown Moist with gravel		4	SS	24						
			5	SS	15						
187.7	End of borehole										
6.9	Refusal on probable bedrock										
	* 2004 02 28										
	Water level measured after drilling										

ON_MOT_VERS 04TF030_N-FINAL.GPJ ON_MOT.GDT 50004 11:37:48 AM

+ .K⁻⁵ : Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

APPENDIX F

DRAWINGS T06902-A1-1, A1-2, A2-1 AND A2-2