A Transient Electromagnetic investigation of a North Victorian Farm

by Dr David Allen,
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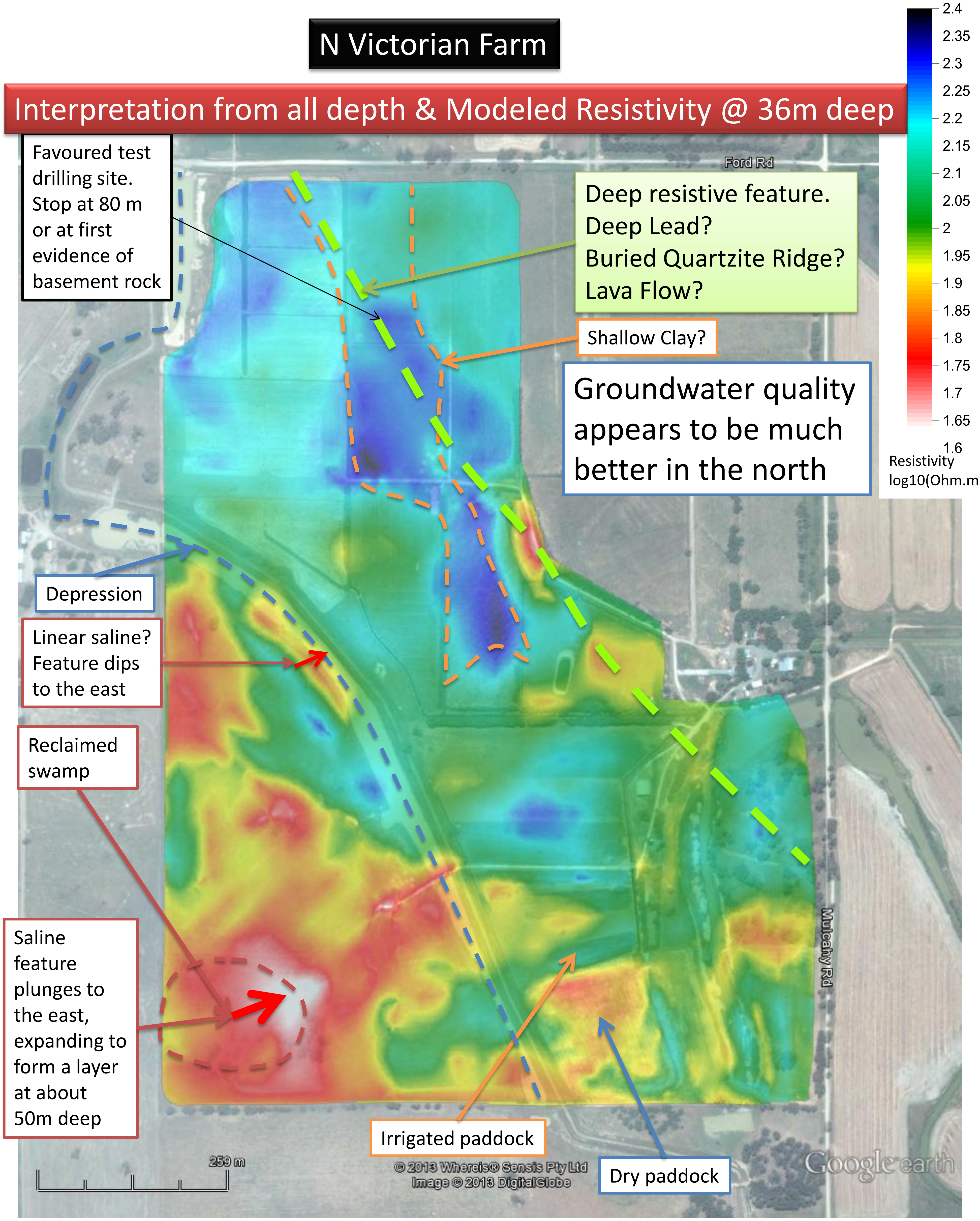
for public domain, August 2013

GROUNDWATER IMAGING

Survey Summary

- A north Victorian Farm, was surveyed using a mobile transient electromagnetic system installed on a trailer towed behind a quad bike and designed to image from the surface to 100m deep. The survey was a trial of the prototype equipment.
- As an initial trial, various teething problems existed and have since been identified, one involved damping of oscillations overprinting the useable signal. This resulted in less stable near surface data in this dataset and possible inconsistent calibration of model data with resect to depth. This problem is now fixed in the instrument but not in this dataset.
- Surface low resistivity (clayey and/or saline) features were identified extending to different depths and a long deep resistive linear feature was identified.
- A saline feature in the southwest extends downward and outward under the farm to extend into a low resistivity layer probably representing saline groundwater. It seems that this has historically been a saline groundwater discharge feature where evapotranspiration has resulted in subsoil salt concentration.
- A low resistivity feature in the centre-north has little depth (is entirely surficial).
- A resistive feature at depth is most prominently imaged at 80m and extends from the SE to NW of the property. It may be a basement rock ridge, a lava flow that is not weathered or a deep lead (preferred interp.).



N Victorian Farm
Interpretation from all depth & Modeled Resistivity @ 36m deep
Favoured test drilling site. Stop at 80 m or at first evidence of basement rock
Ford Rd
Deep resistive feature. Deep Lead? Buried Quartzite Ridge? Lava Flow?
Shallow Clay?
Groundwater quality appears to be much better in the north
Depression
Linear saline? Feature dips to the east
Reclaimed swamp
Saline feature plunges to the east, expanding to form a layer at about 50m deep
Mulcahy Rd
Irrigated paddock
Dry paddock
250 m
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Image © 2013 DigitalGlobe
Google earth
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity log10(Ohm.m)

Contents

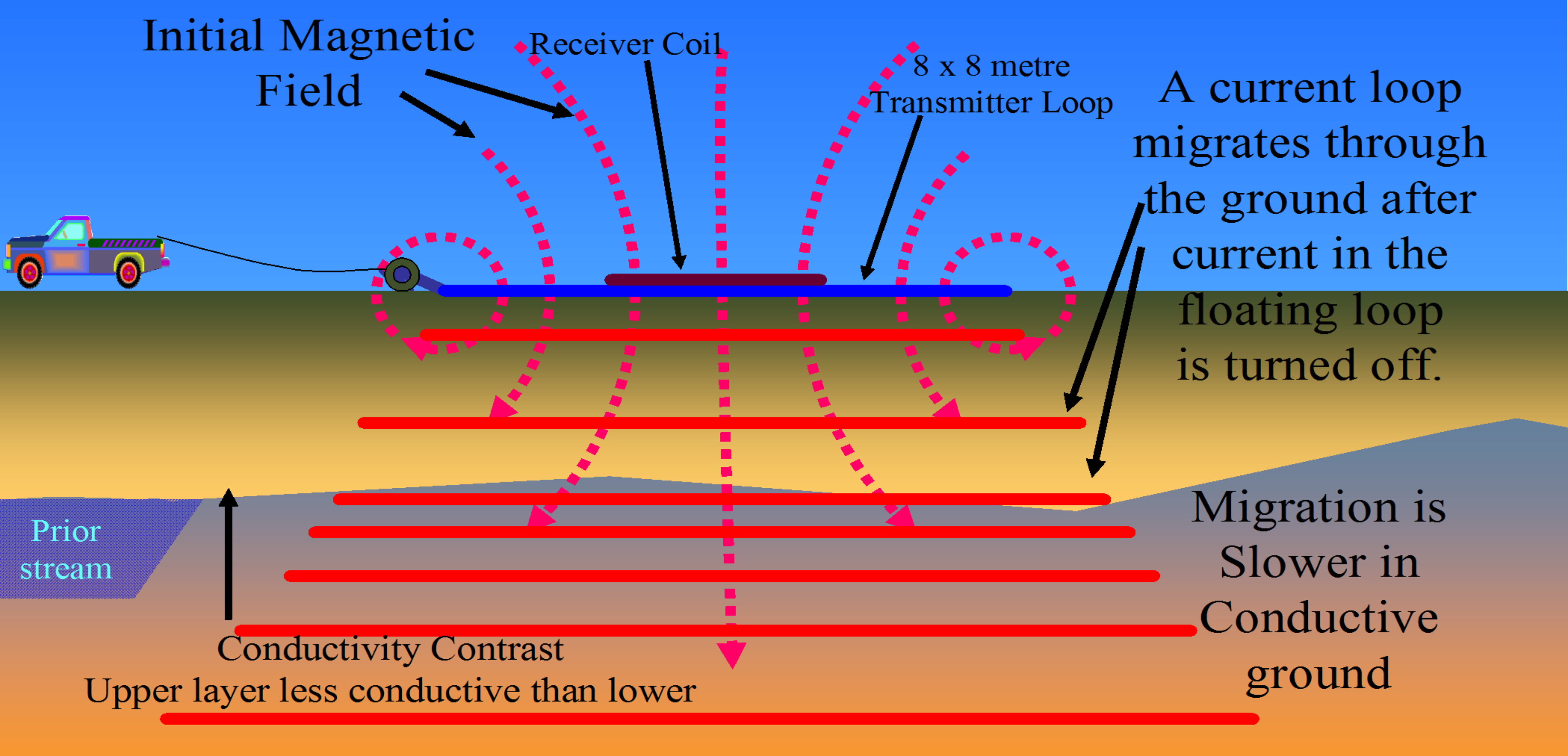
Introduction

- METHOD : Transient electromagnetic survey, on the property (Northern Victoria), was conducted using TerraTEM and a trailer mounted loop system in August 2013.
- AIM: To provide a demonstration dataset in this type of geology suitable for investigating groundwater and potential bore sites for irrigation.
- SURVEY PARAMETERS : Detailed mapping, was conducted at a nominal line spacing of 20m was adopted, while reconnaissance was conducted at 50m spacing or more depending on the scale of geological features under investigation. Data was provided at about 10m increments along line. Survey depth of investigation was from 1m to 80m divided into 10 separate layers. Near the surface, the system footprint is small, so it can be used close to metal infrastructure, while at 80m deep the footprint is thought to be over 80m across.
- DIGITAL DATA : For detailed understanding of the data, access all data and bore records from the supplied Google Earth files (_report/*.kmz on the report DVD) simply by opening the files in Google Earth or similar viewers. These are small files that are readily emailed. Positioning of potential new drill holes should involve location, within Google Earth, using the cursor co-ordinates displayed at the bottom of the screen. This method will be more accurate than measurement off the paper or raster maps supplied. Data may also be supplied in an ESRI ArcMap version 10 MXD file and component shapefiles and image files.
- DIGITAL BORE LITHOLOGIES : Lithologies and some water levels in existing bores are displayed in the Google Earth files – click on them to bring up particulars. Be aware that they are simply reproduction of government water bore drillers log records which contain positioning and other errors – treat them all with reservation. If better information is acquired they can be adjusted accordingly.
- GEOLOGY: The area is flat with alluvial cover consisting of clay flood deposits cut by sandy palaeochannel deposit.

Geophysical Methods Introduction

- A quick and comprehensive way of looking at a shallow (0 to 200m deep) groundwater resource is to image it with towed transient electromagnetic devices. The resultant EC image will reveal, in a blurred manner, the proportion of ions in solution in the groundwater and rock at various depth – usually this means that dry ground, good aquifers and fresh basement rock show as electrically resistive and contrast with clays and saline aquifers that show as electrically conductive. Determining exactly what each feature represents is then a matter of interpretation which is usually solved by comparison with borehole logs and a bit of logic (eg. basement rock will be at the base, an unsaturated zone will be at the top and prior river channels will be shaped concave-up).
- A schematic of a towed transient electromagnetic survey system is provided on the next slide. Electrical current is pulsed through a large transmitter loop and each pulse induces a 'smoke ring' of current in the ground below as it turns on and off. As the 'smoke ring' dissipates out into the ground its magnetic field decays and it is the decay of this magnetic field, along with the decay of the magnetic field resulting from the transmitter loop, that is detected by various receiver loops. The decay is abated by conductive layers and enhanced by resistive layers in the substrate.
- The system used on this job, photographed on the title page, had a 2 turn 6.5 x 5m transmitter loop with 3 receiver coils – one centrally located in the transmitter loop, one 12m behind the transmitter loop, and a small one mounted right on the transmitter loop wires. The system was operated using a Monash Geoscope TerraTEM with an accelerated transmitter (to see shallower features), the continuous acquisition option, a Trimble AgGPS114 receiving Omnistar DGPS corrections and several truck batteries for power supply. The system was towed by a Landrover Defender separated from the equipment by a 7m fibreglass boom and rope assembly.
- Processing of this data involves numerous steps presented in a separate text document. The main steps are removal of movement noise, primary field stripping, cleaning of the data (removal of data mainly affected by metallic objects etc.), spatial smoothing, modeling to transform the voltage versus time data to smoothness constrained layers of resistivity versus depth, more data cleaning, gridding and presentation. The principle step is the transformation (matrix inversion) which is carried out using the Aarhus Hydrogeophysics Group algorithm EM1DInv.

Towed Transient Electromagnetic System



Why use Electrical Resistivity for Investigation of Groundwater

- reveal spatial details not observable by any more economically viable means
- Resistivity responds clearly and conclusively to recharge pathways

RESISTIVITY is the INVERSE of ELECTRICAL CONDUCTIVITY commonly used as a measure of water salinity. This is not to be confused with HYDRAULIC CONDUCTIVITY.

HIGH RESISTIVITY

- Lack of Clays
- Low Saturation
- Fresh pore water
- Impervious fresh rock

LOW RESISTIVITY

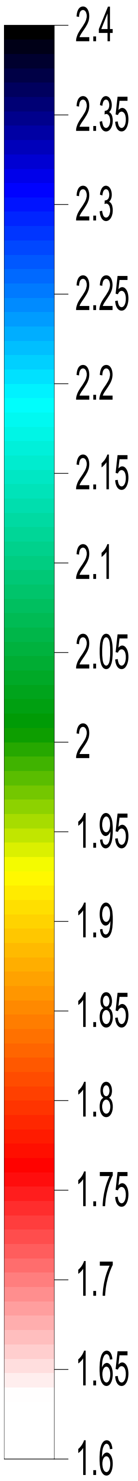
- Clays
- High Saturation
- Saline pore water
- Weathered rock

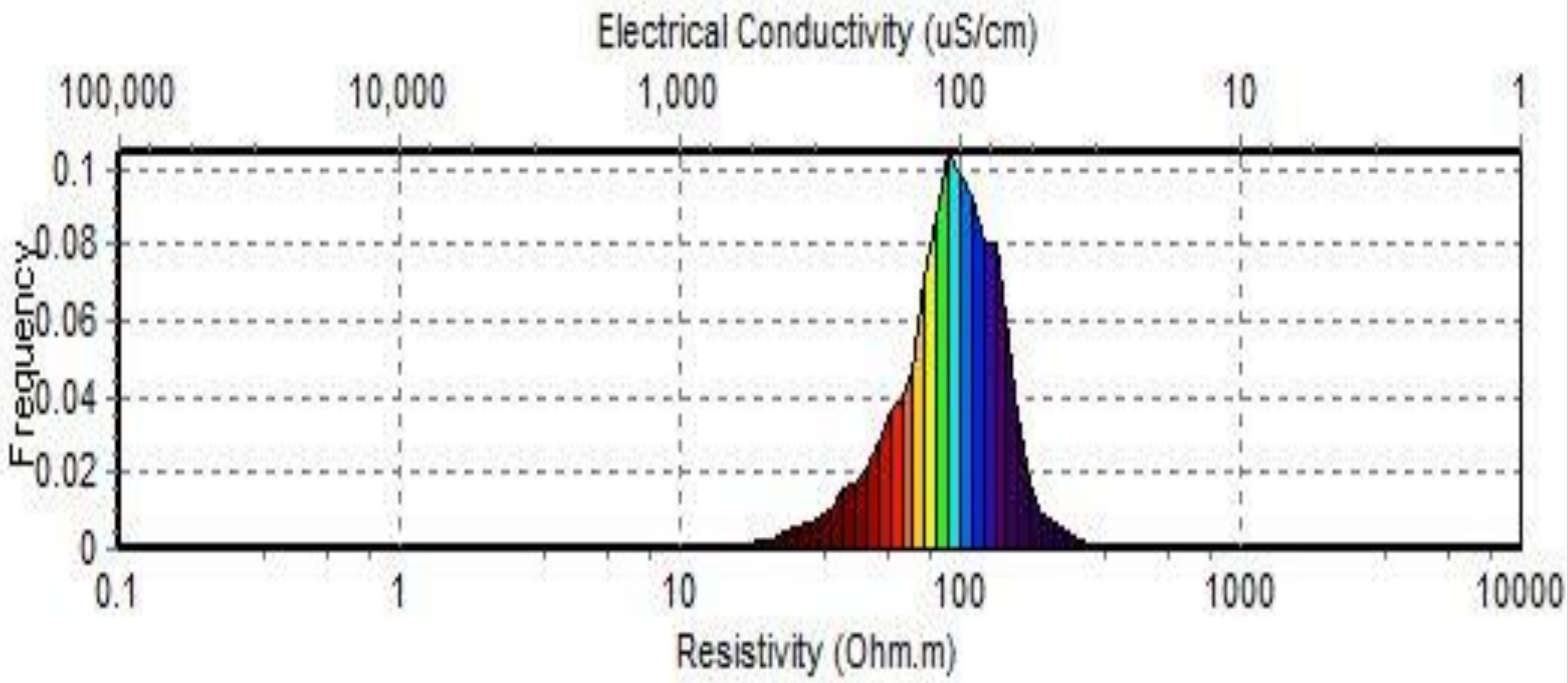
Results and Interpretation

Resistivity colour scales used in this presentation

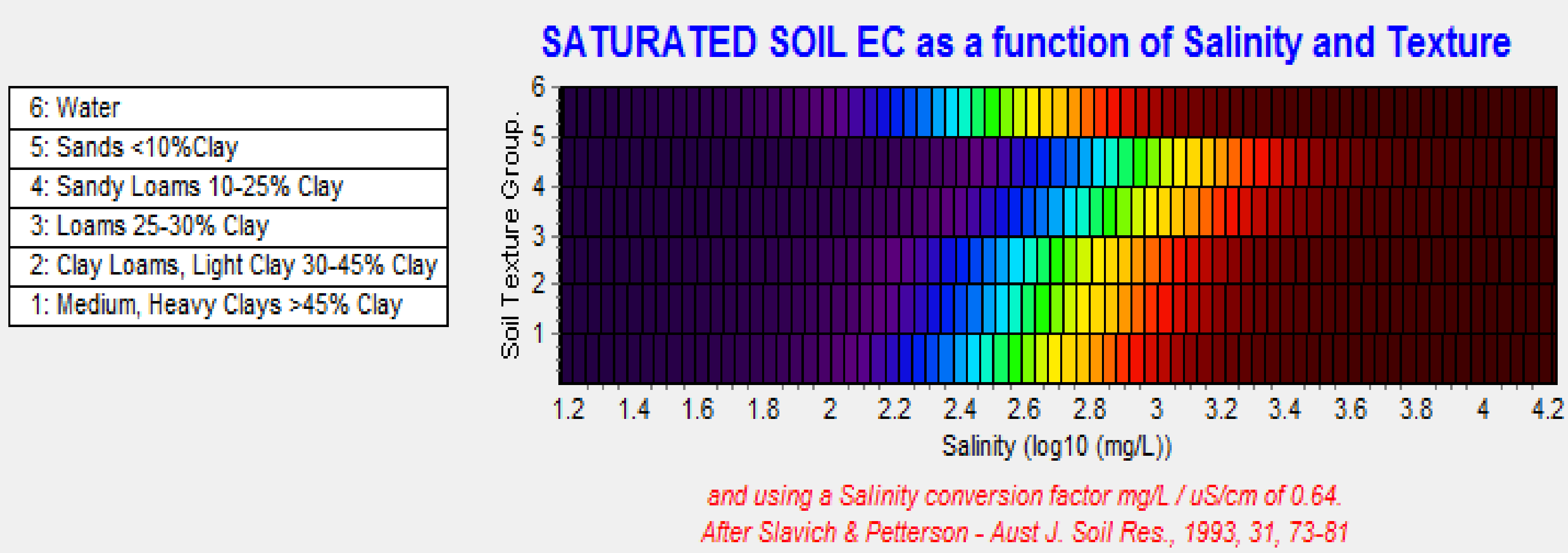
Depth Slices

Resistivity Curtain Diagrams





Using empirical conversion factors, the figure below indicates that, within saturated unconsolidated sediment, sediment type alone may account for about half an order of magnitude of change in resistivity, the remainder being due to groundwater salinity.



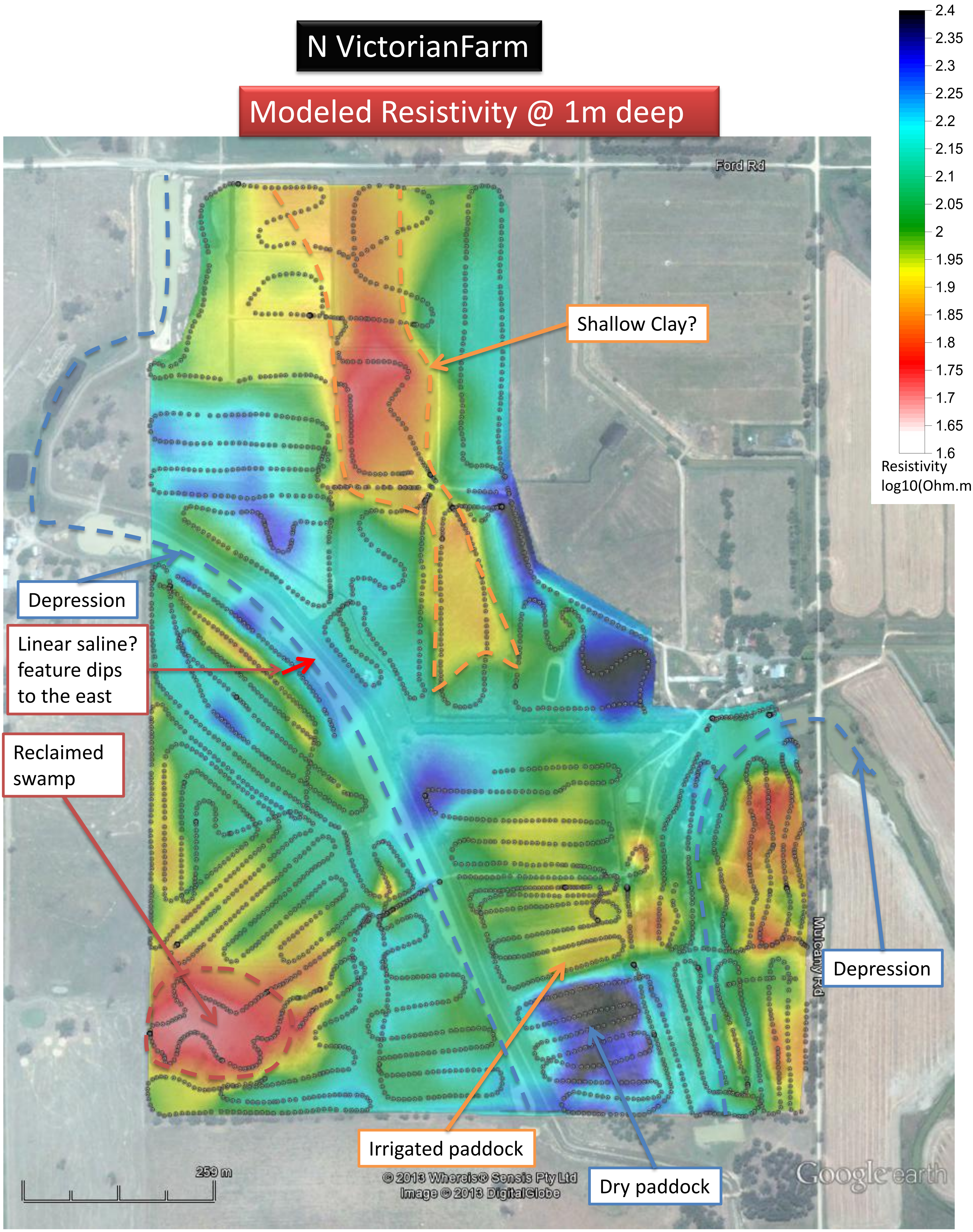
Resistivity (log10(Ohm.m))

N Victorian Farm

Background Image and Survey Path

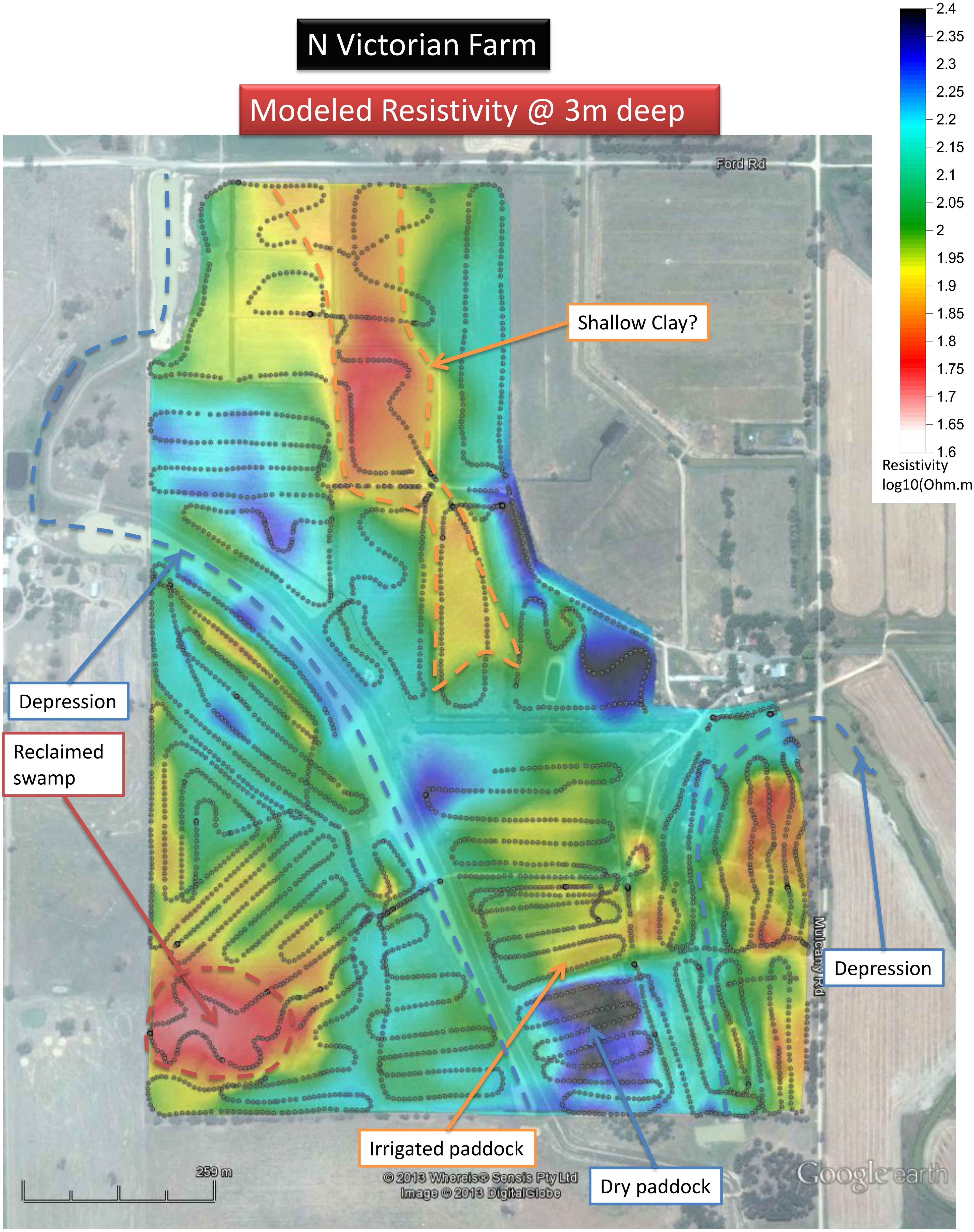
N VictorianFarm

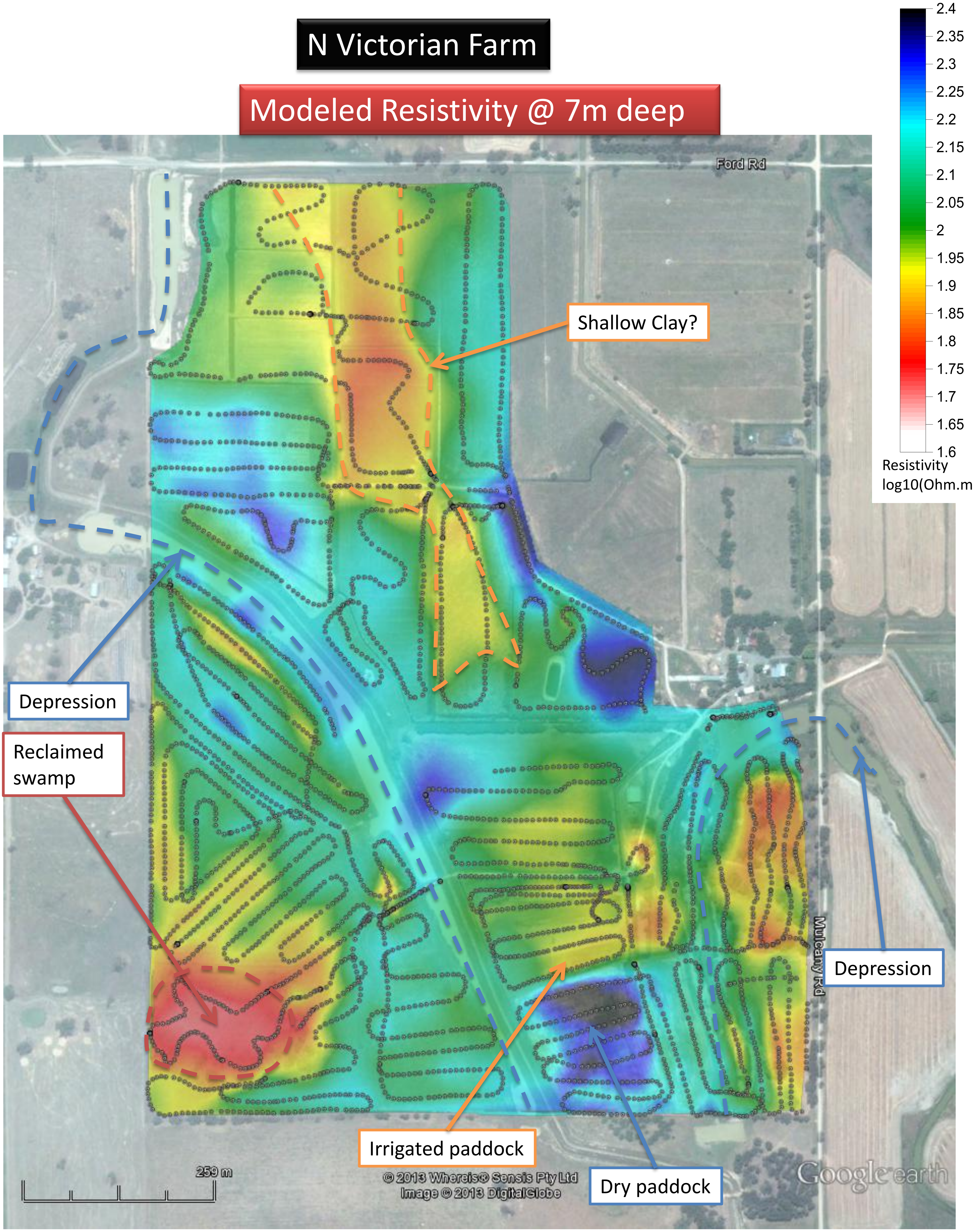
Modeled Resistivity @ 1m deep

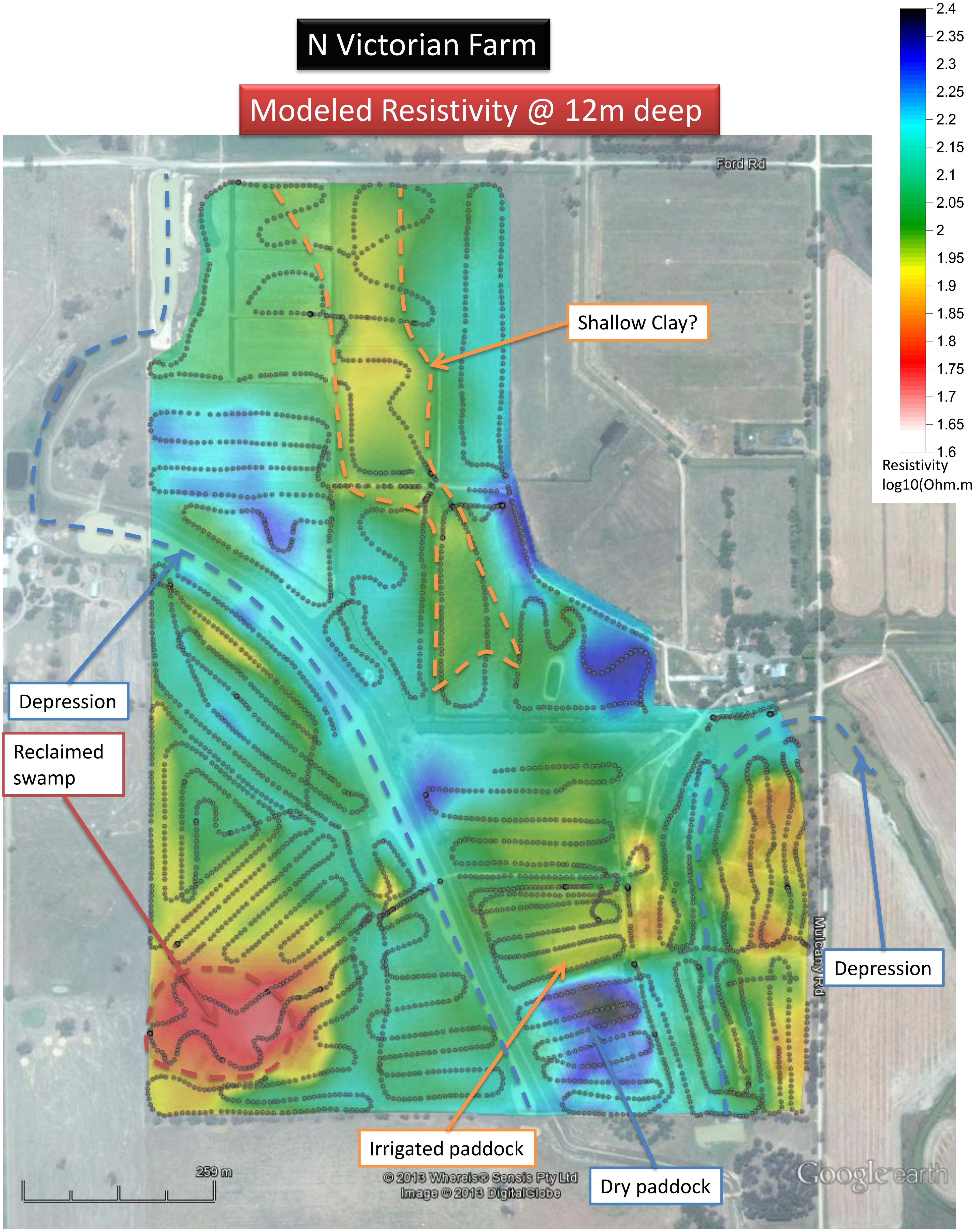


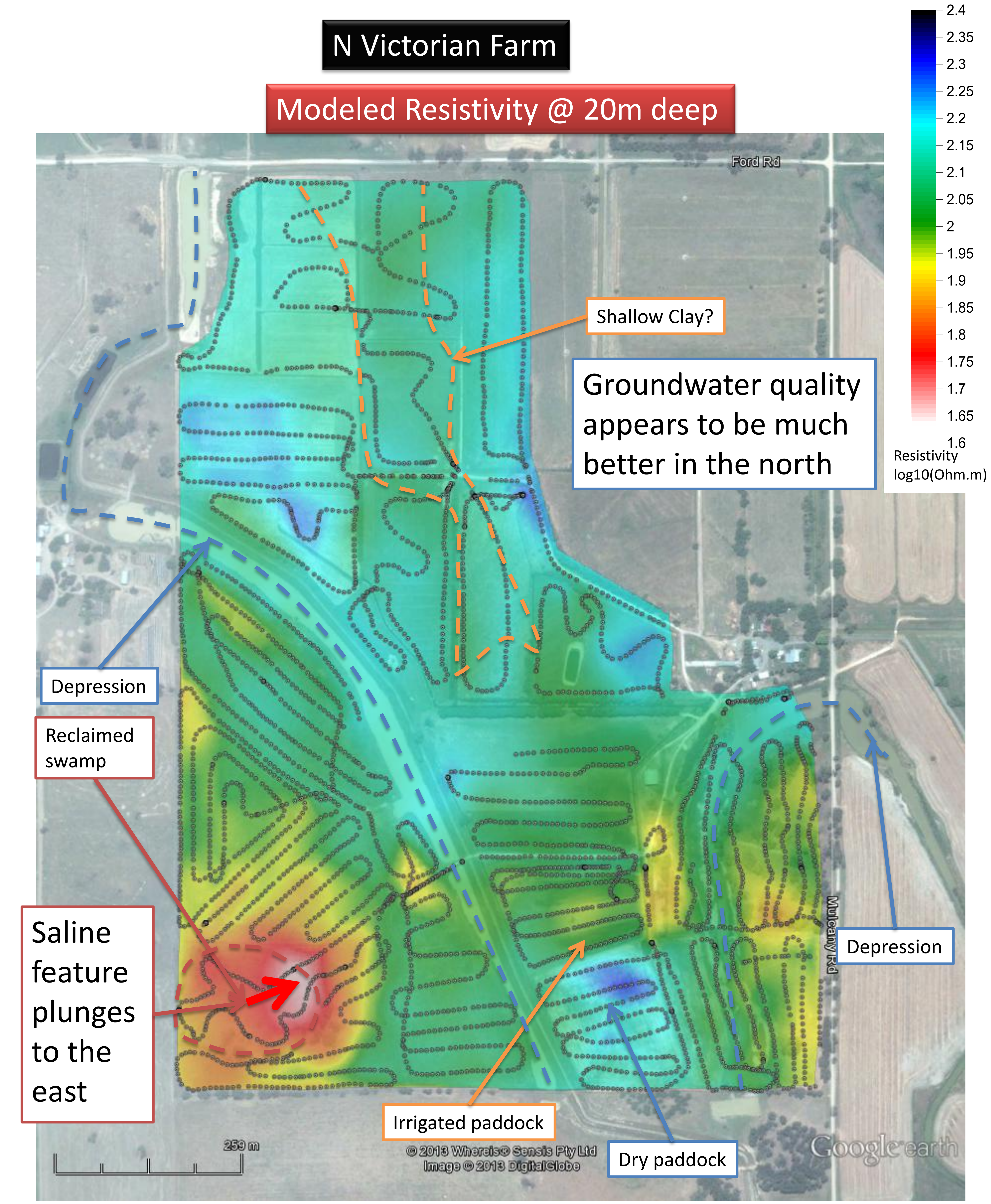
N Victorian Farm

Modeled Resistivity @ 3m deep




N Victorian Farm
Modeled Resistivity @ 7m deep
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity log10(Ohm.m)
Ford Rd
Shallow Clay?
Depression
Reclaimed swamp
Mulcahy Rd
Depression
Irrigated paddock
Dry paddock
259 m
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 DigitalGlobe
Google earth


N Victorian Farm
Modeled Resistivity @ 12m deep
Ford Rd
Shallow Clay?
Depression
Reclaimed swamp
Irrigated paddock
Dry paddock
Depression
Mulcahy Rd
259 m
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 DigitalGlobe
Google earth
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity
log10(Ohm.m)



N Victorian Farm
Modeled Resistivity @ 20m deep
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity
log10(Ohm.m)
Ford Rd
Shallow Clay?
Groundwater quality appears to be much better in the north
Depression
Reclaimed swamp
Saline feature plunges to the east
Irrigated paddock
Dry paddock
Depression
Mulcahy Rd
259 m
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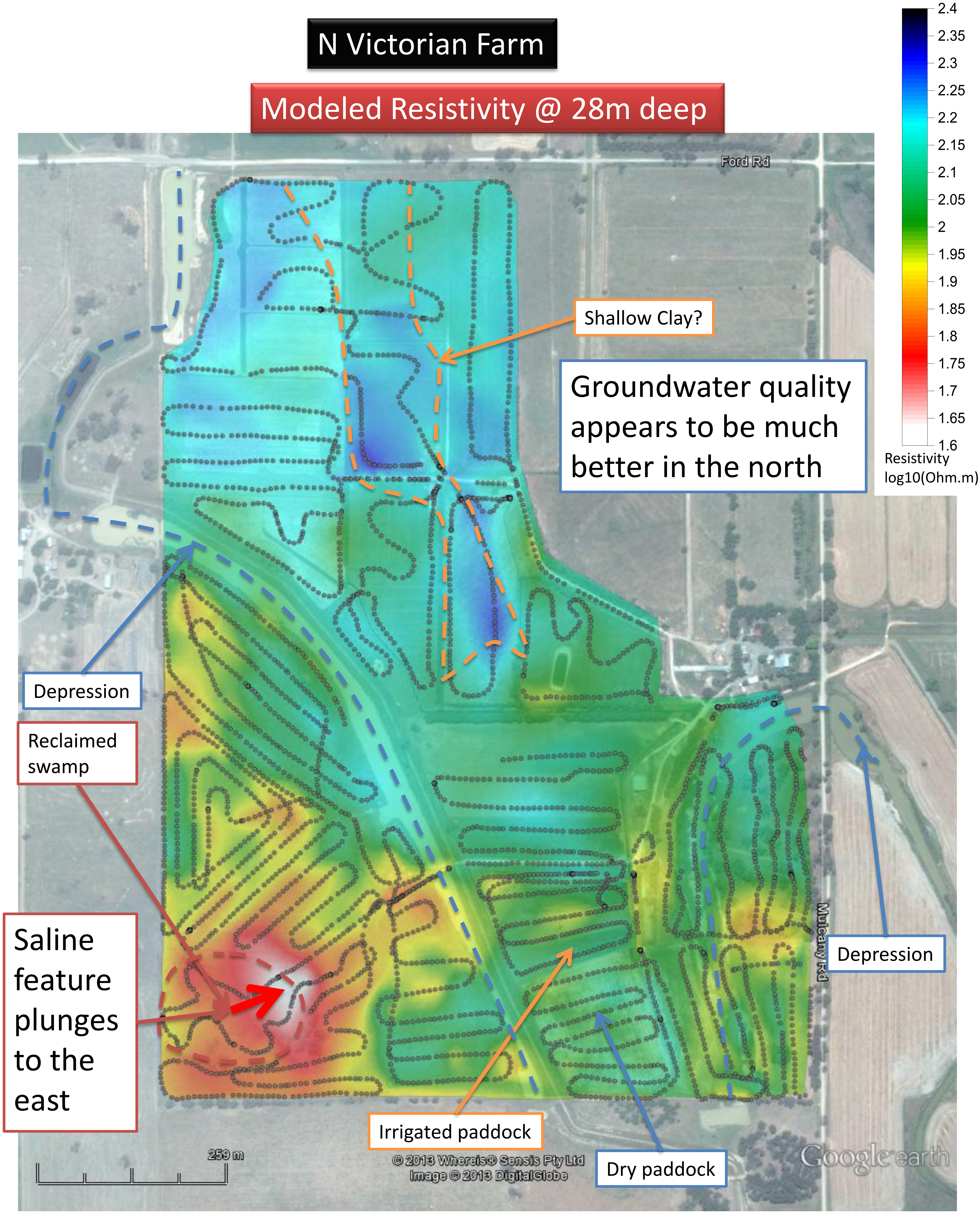
Image © 2013 DigitalGlobe
Google earth



N Victorian Farm
Modeled Resistivity @ 28m deep
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity
log10(Ohm.m)
Ford Rd
Shallow Clay?
Groundwater quality appears to be much better in the north
Depression
Reclaimed swamp
Saline feature plunges to the east
Depression
Mulcahy Rd
Irrigated paddock
Dry paddock
250 m
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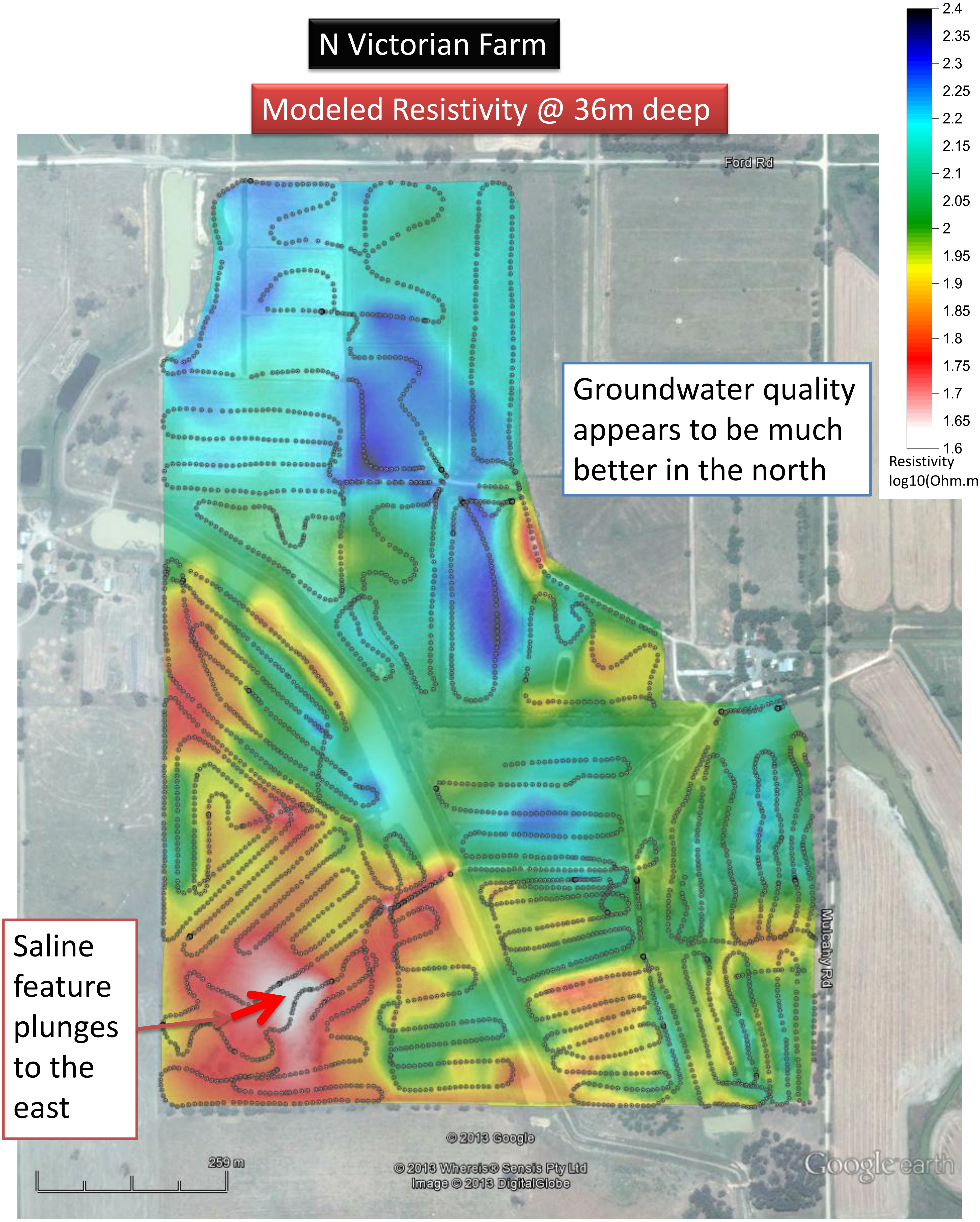
Image © 2013 DigitalGlobe
Google earth

N Victorian Farm

Modeled Resistivity @ 36m deep



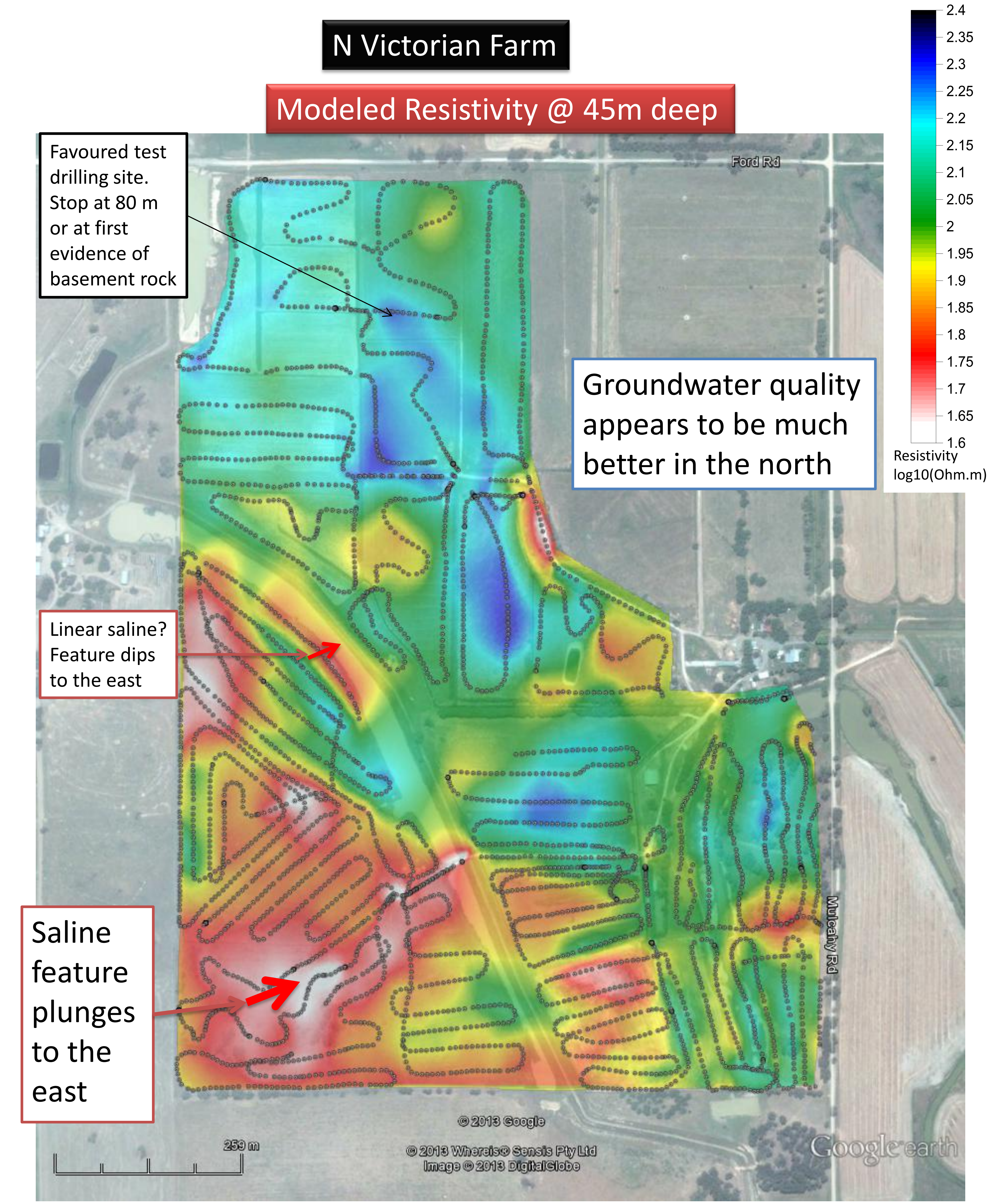

N Victorian Farm
Modeled Resistivity @ 45m deep
Favoured test drilling site. Stop at 80 m or at first evidence of basement rock
Groundwater quality appears to be much better in the north
Linear saline? Feature dips to the east
Saline feature plunges to the east
Ford Rd
Mulcahy Rd
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity log10(Ohm.m)
250 m
© 2013 Google
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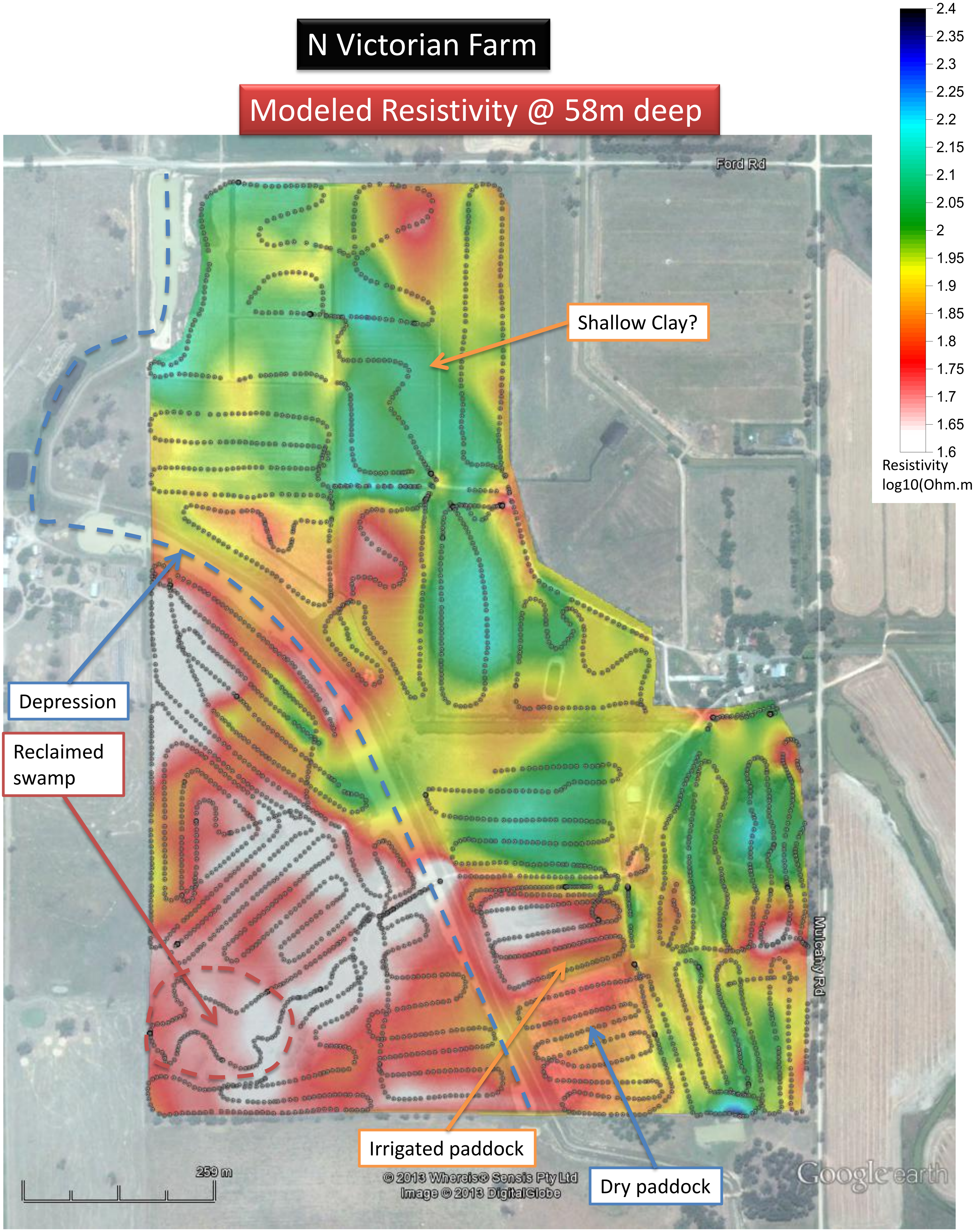
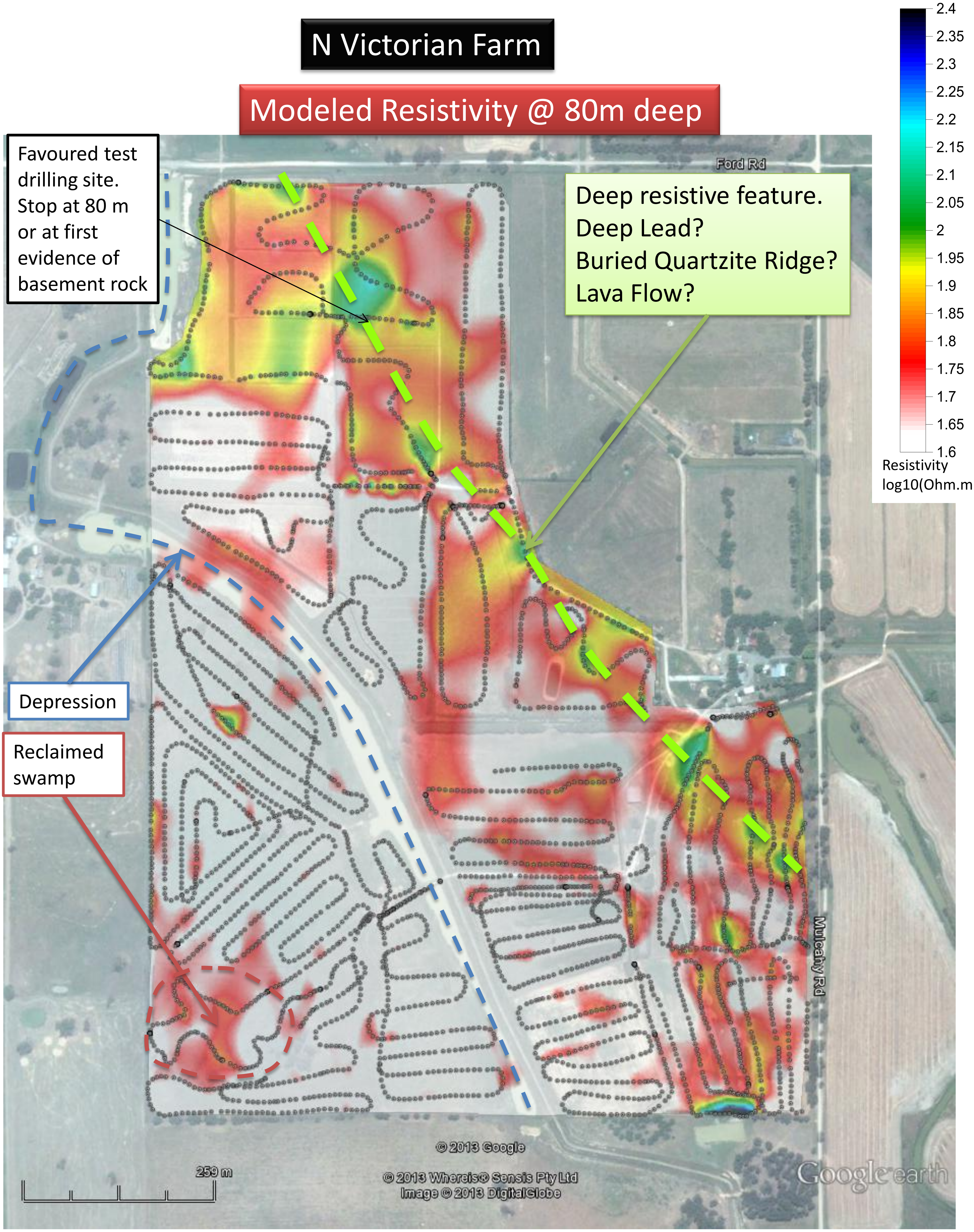
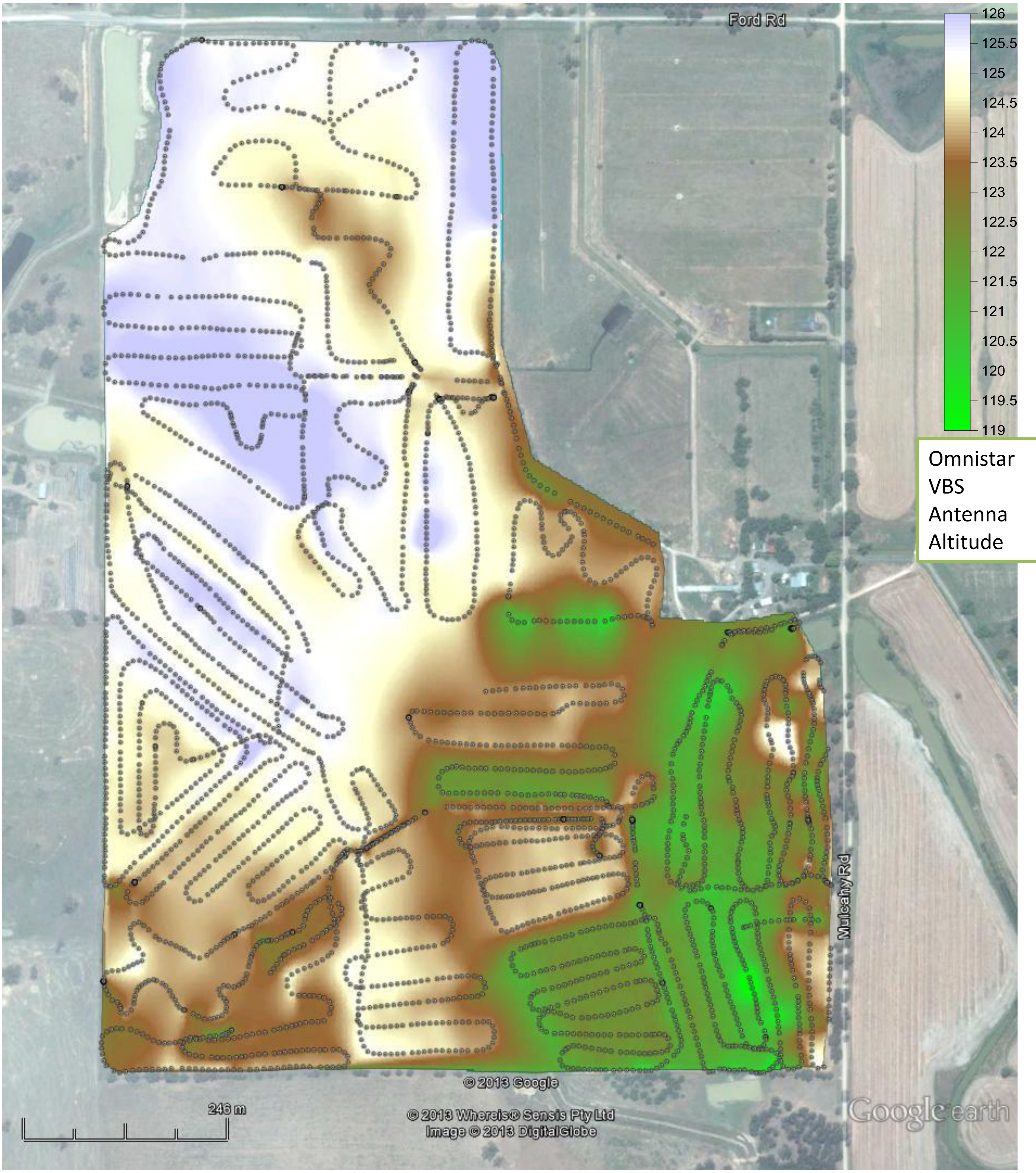
Image © 2013 DigitalGlobe
Google earth



N Victorian Farm
Modeled Resistivity @ 58m deep
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity
log10(Ohm.m)
Ford Rd
Shallow Clay?
Depression
Reclaimed
swamp
Irrigated paddock
Dry paddock
Mulcahy Rd
250 m
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 DigitalGlobe
Google earth


N Victorian Farm
Modeled Resistivity @ 80m deep
Favoured test drilling site. Stop at 80 m or at first evidence of basement rock
Deep resistive feature.
Deep Lead?
Buried Quartzite Ridge?
Lava Flow?
Depression
Reclaimed swamp
Ford Rd
Mulcahy Rd
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
Resistivity log10(Ohm.m)
250 m
© 2013 Google
© 2013 Whereis® Sensis Pty Ltd
Image © 2013 DigitalGlobe
Google earth

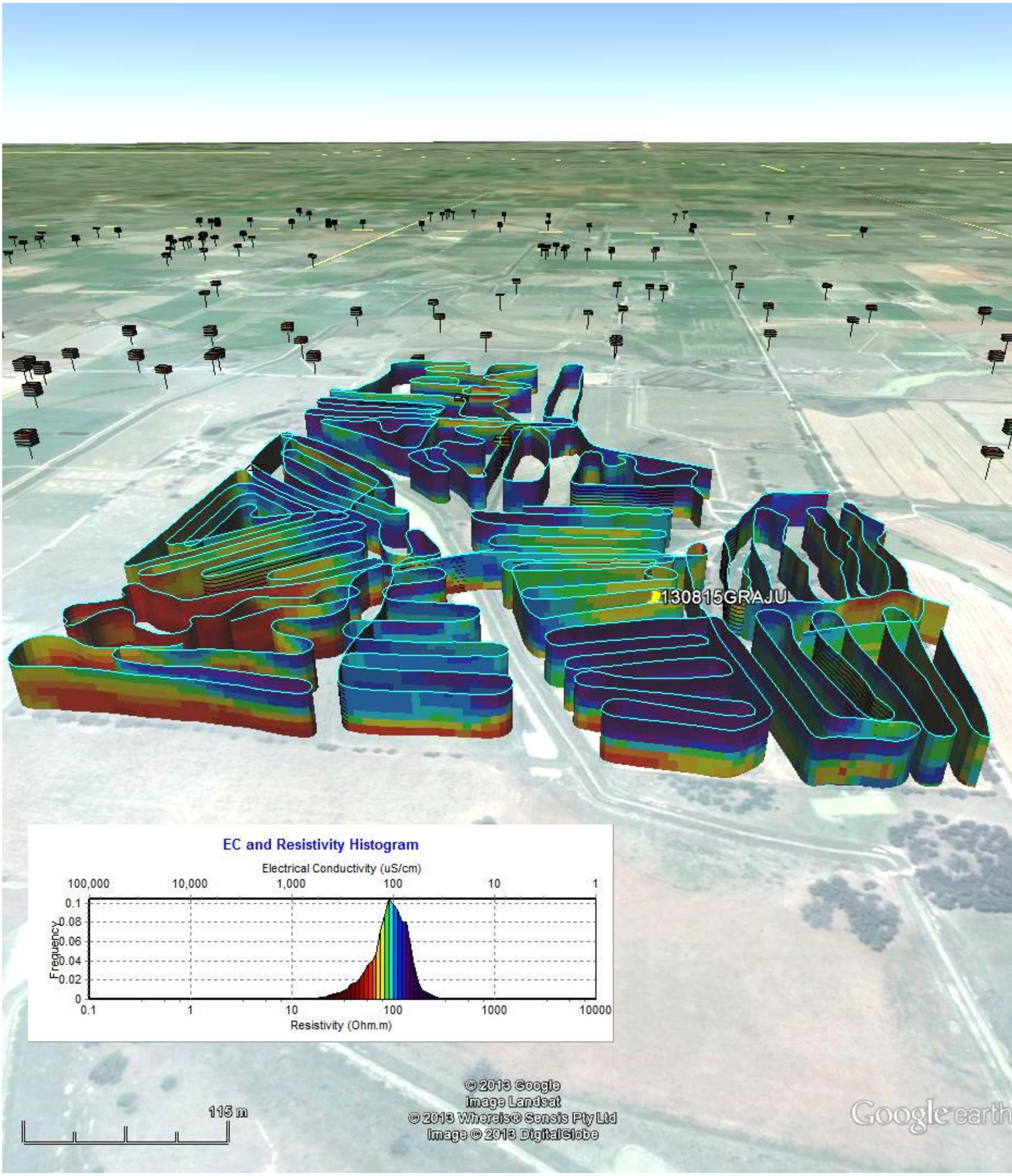
Farm Altitude (Omnistar VBS Antenna height) – this is subject to block shifts of up to about 3m – some of which are evident.



3D Curtain Diagrams projected up 50m above the ground

N Victorian Farm
View from South

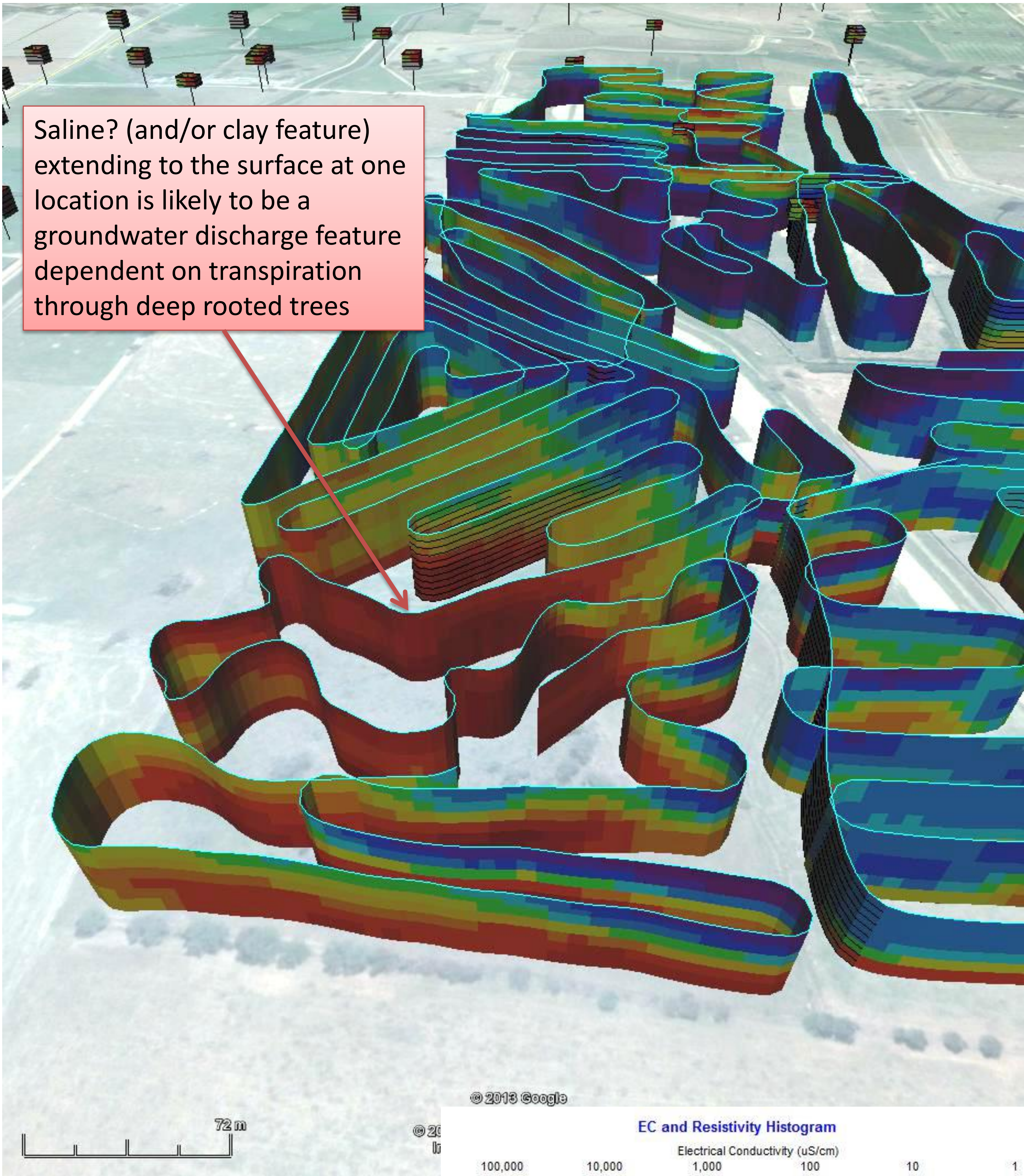
Resistivity Images projected 50m up

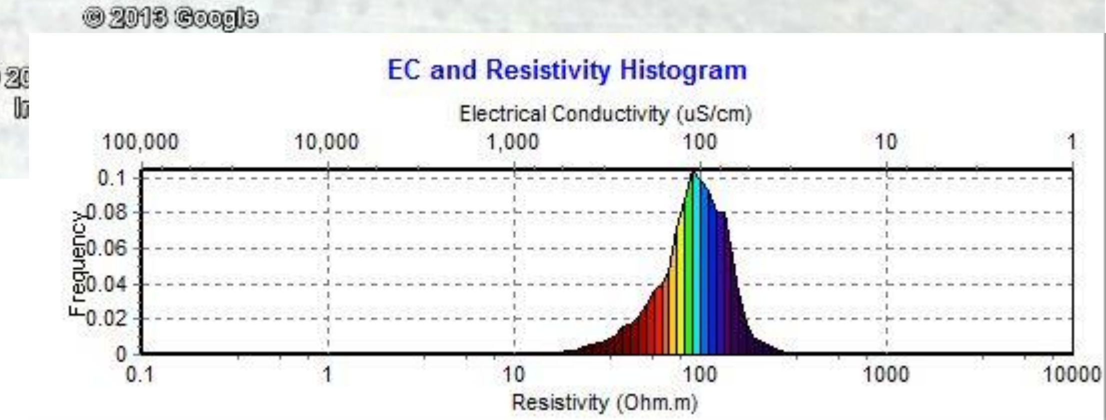


N Victorian Farm
SouthWest

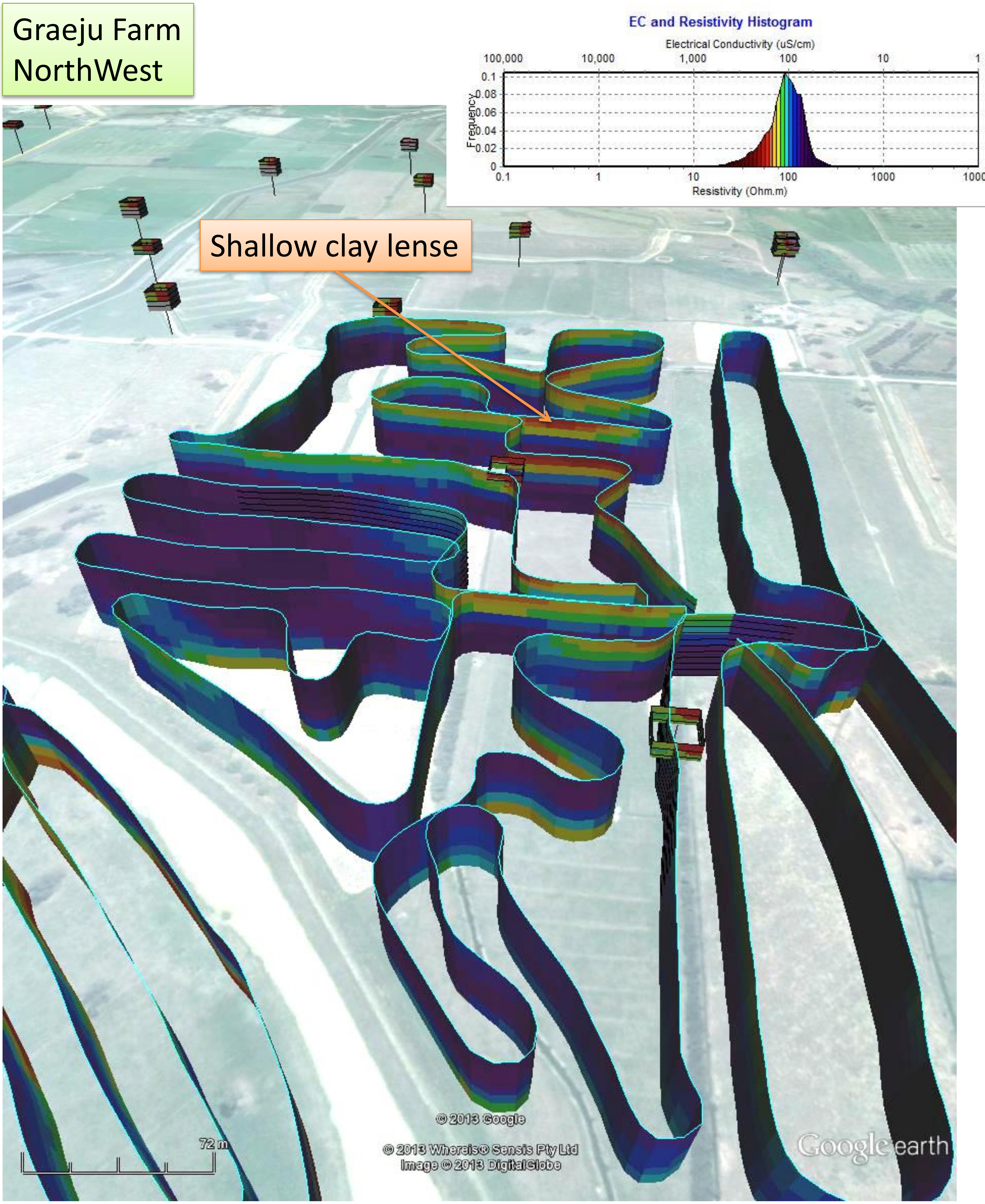
Resistivity Images projected 50m up

Saline? (and/or clay feature) extending to the surface at one location is likely to be a groundwater discharge feature dependent on transpiration through deep rooted trees





Graeju Farm
NorthWest



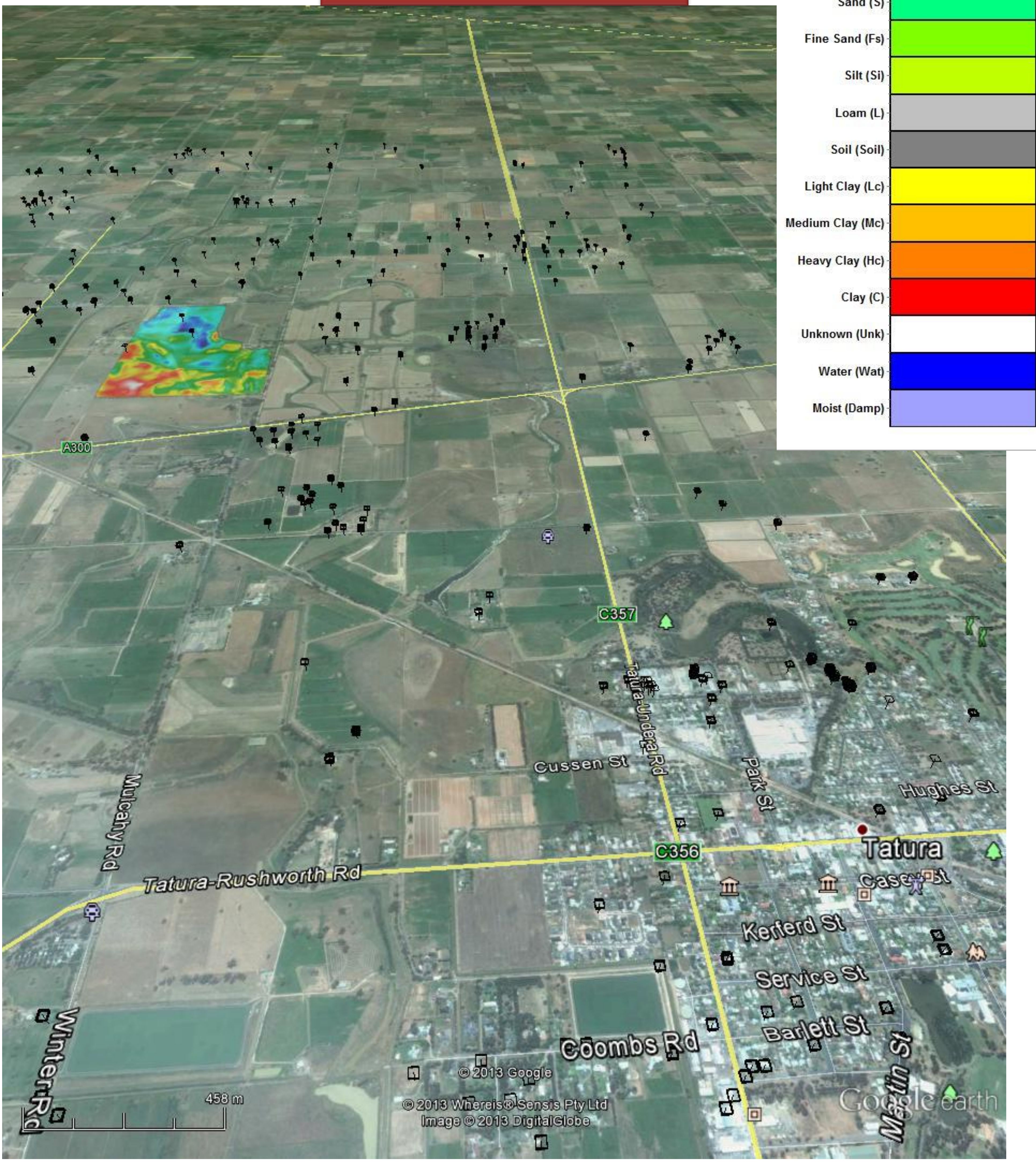
Resistivity Images projected 50m up

Bore locations and lithologies

- Bores are located from the state database and positions may be in error by up to 300m

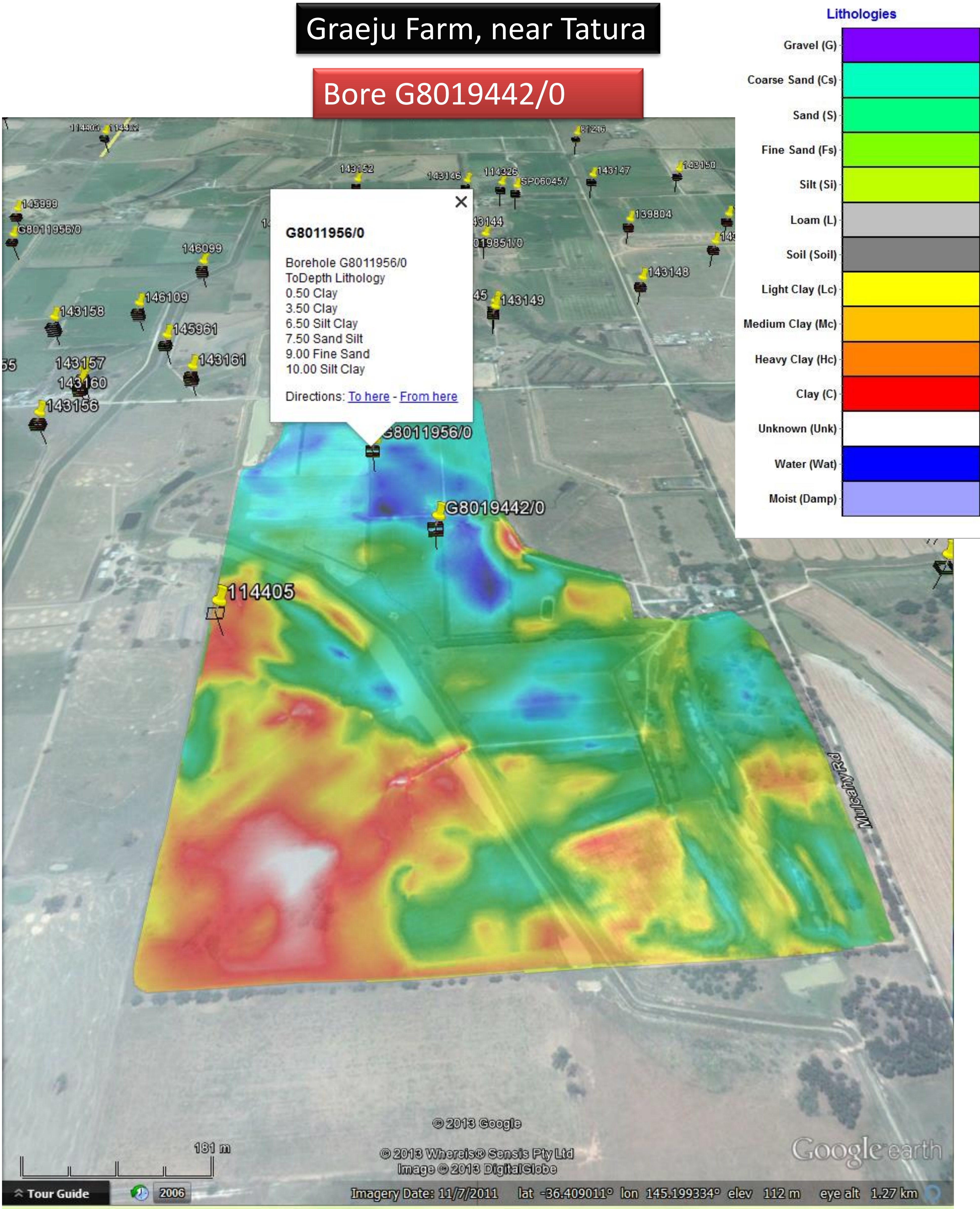
North Victorian Farm

Bores in State Database



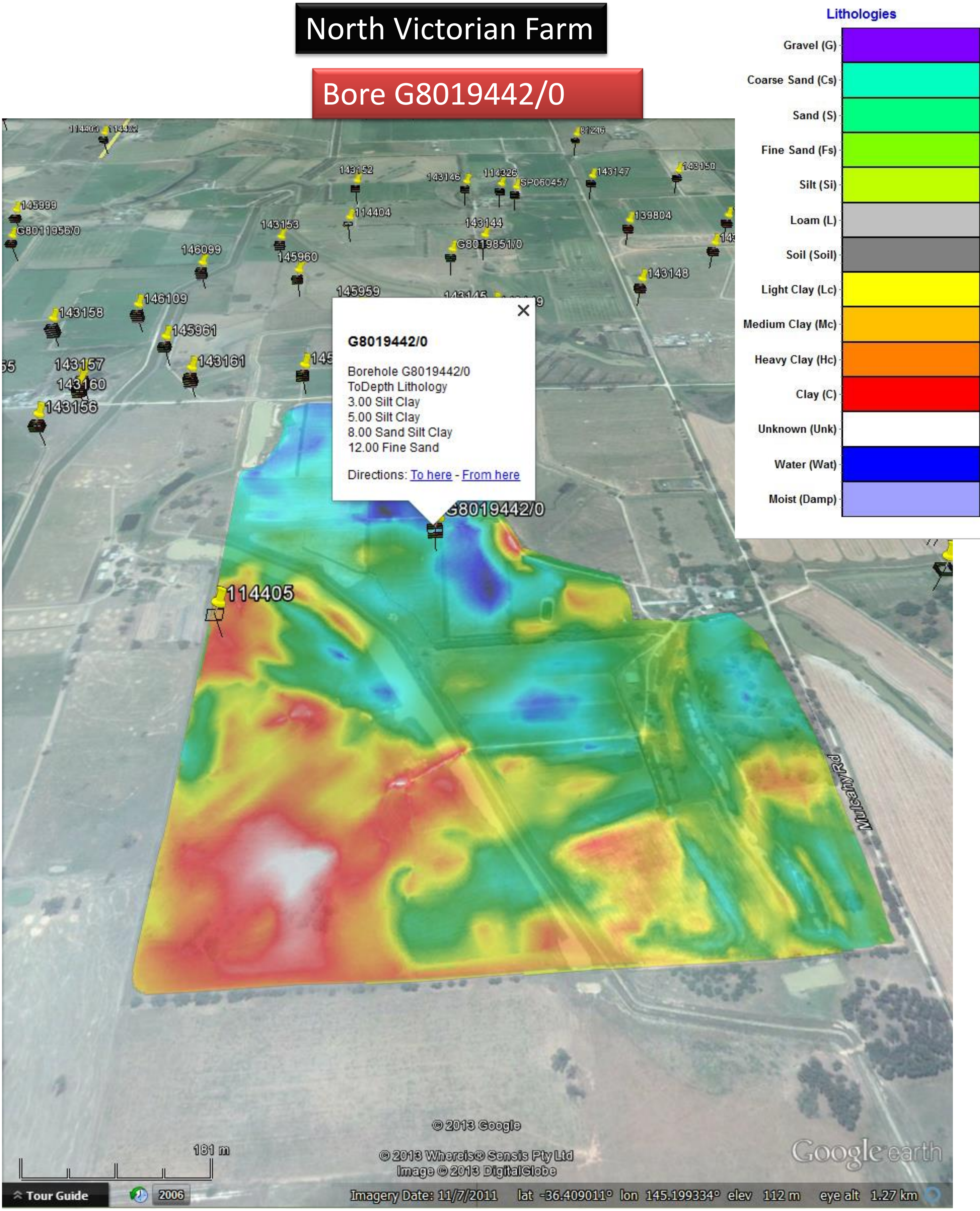
Graeju Farm, near Tatura

Bore G8019442/0



North Victorian Farm

Bore G8019442/0

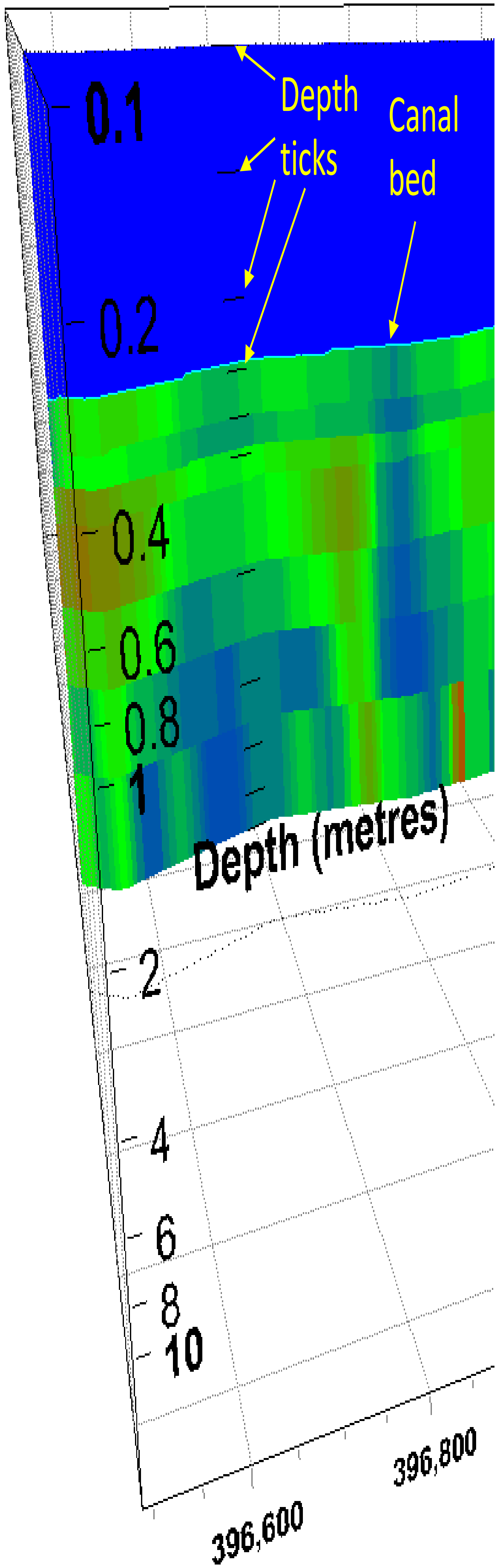


Conclusions

- A low resistivity (Saline?) mound exists in the SW part of North Victorian Farm. This extends into a layer about 50m under the SW of the property and deeper under the remainder.
- A low resistivity feature (Clay) in the centre north of the property is superficial, probably only extending 5m deep and is underlain by sandier sediment.
- The northern portion of the property is more prospective for groundwater (to a depth of around 40m)
- Prominent at around 80m is a linear resistive feature cutting across the NE corner of the property – this may be a deep lead, a buried quartzite ridge or a lava flow. Notice that it does seem to open out in the 58m depth slice suggesting that it is a deep lead recessed into low resistivity basement rock or sediment.
- As this was a prototype trial with circuitry not in its final form, system response and various system oscillations were not removed from the data prior to processing – the result is not necessarily correct. There is potential instability in the data as well as inconsistent calibration with respect to depth.

Appendices

- Identifying depths on ribbon images
- Towed Transient Electromagnetic schematic
- TEM platform configuration schematics
- TerraTEM specifications
- Processing sequence
- Results – Digital Products
- Production Report
- References



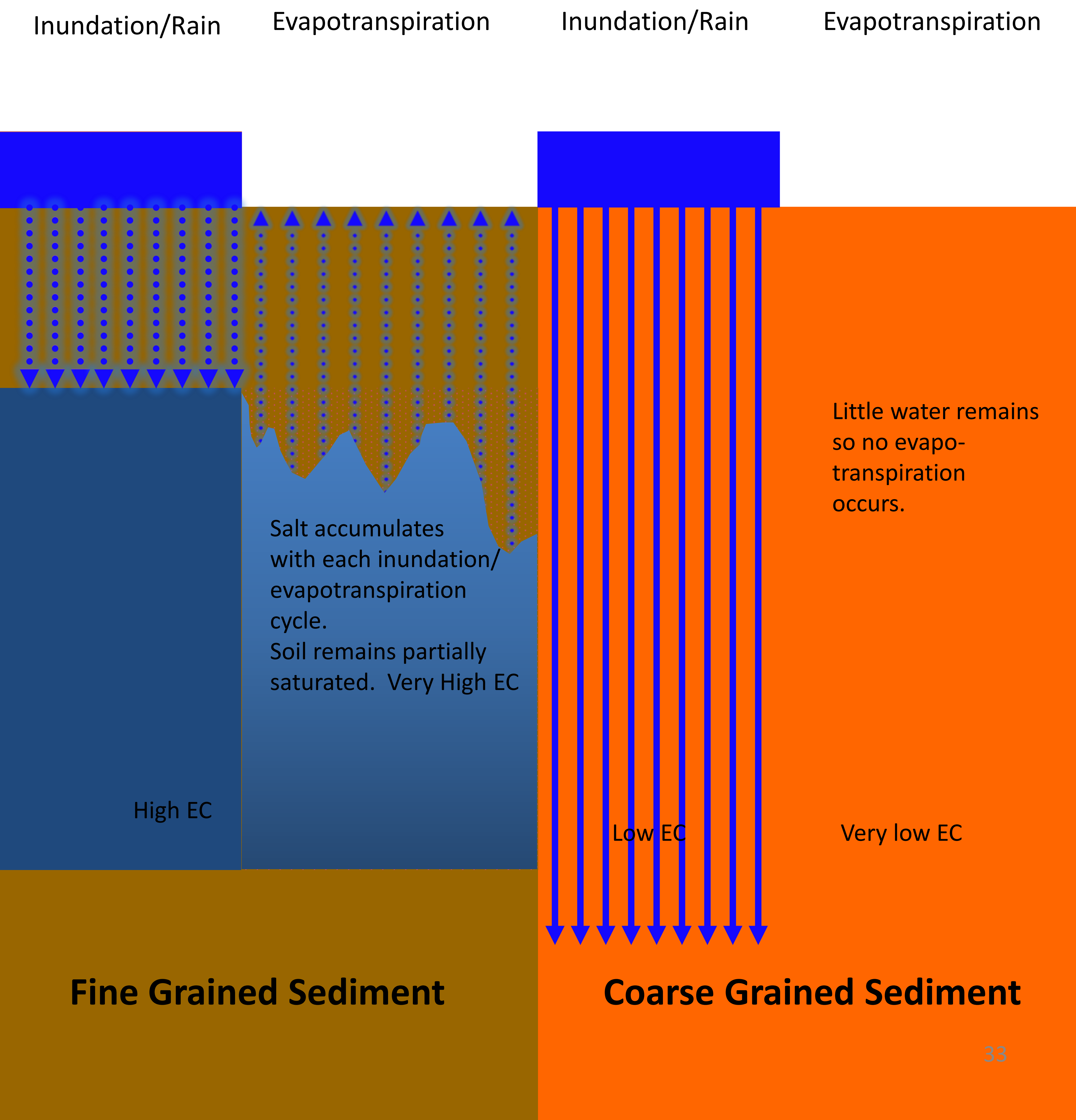
Identifying depths on ribbons

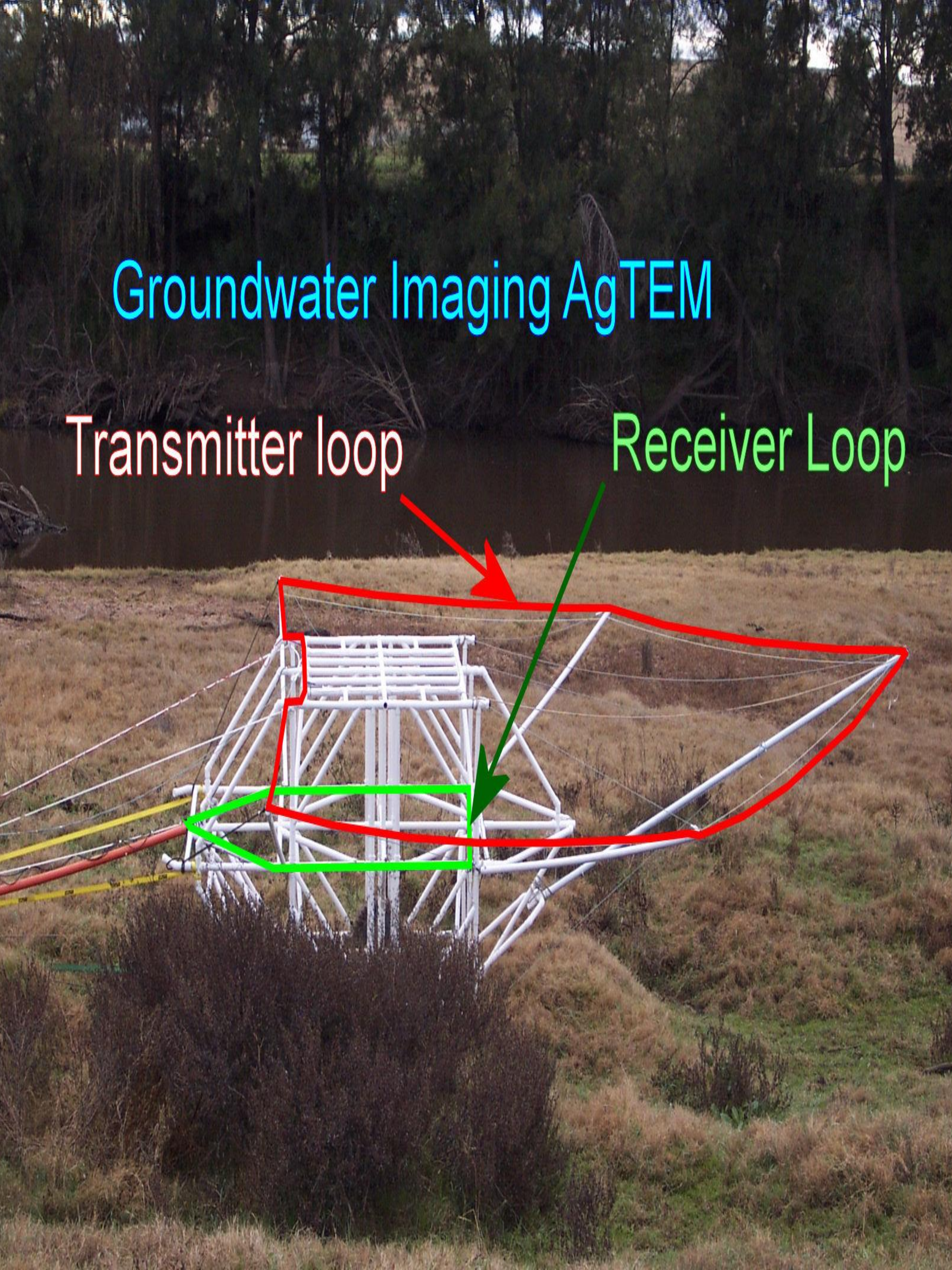
All the 3D imagery has the log or linear depth scales. It is labelled on the south-west corner of the 3D viewing space (as shown). Notice the increments are logarithmic. Logarithmic depth plotting is used so that deep data can be examined at the same time as detailed shallow (near canal bed) data. The geophysical data loses resolution with increasing depth and so this type of depth scale presents all the data in a way that is easy to see.

Look on the ribbon behind the depth scale and you will see a column of black ticks. These correspond to the ticks on the annotated depth scale. Notice that they bunch up at 1m. Black dots mark the projection of the ribbon onto the base plane of the viewing space which is 20 m below the surface.

The canal bed is marked with an aqua line.

Seepage, EC and soil texture in a recharge dominated environment.

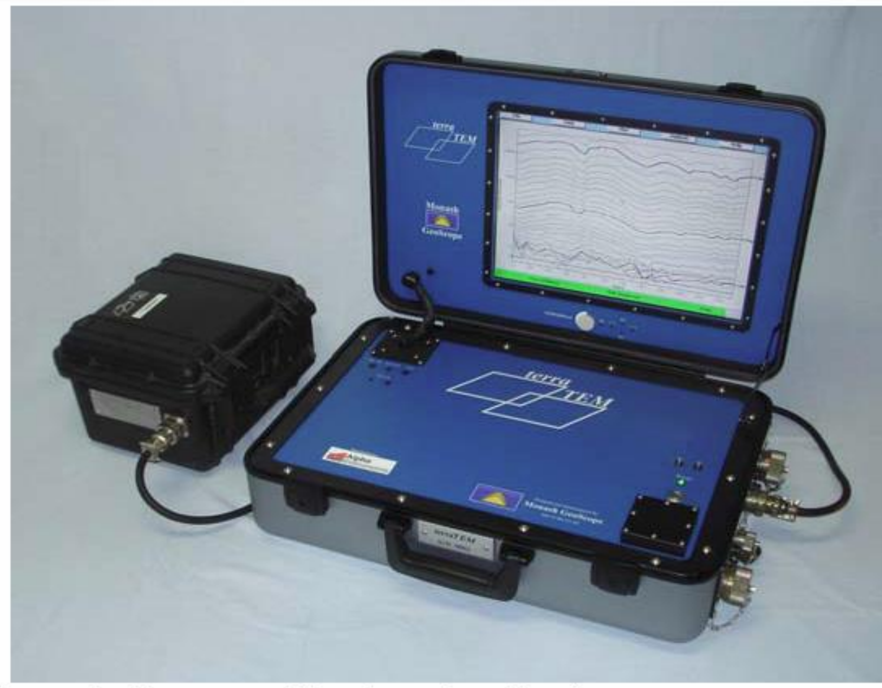



Groundwater Imaging AgTEM
Transmitter loop
Receiver Loop

Transient EM equipment specifications

terraTEM
Time-Domain EM Surveying System

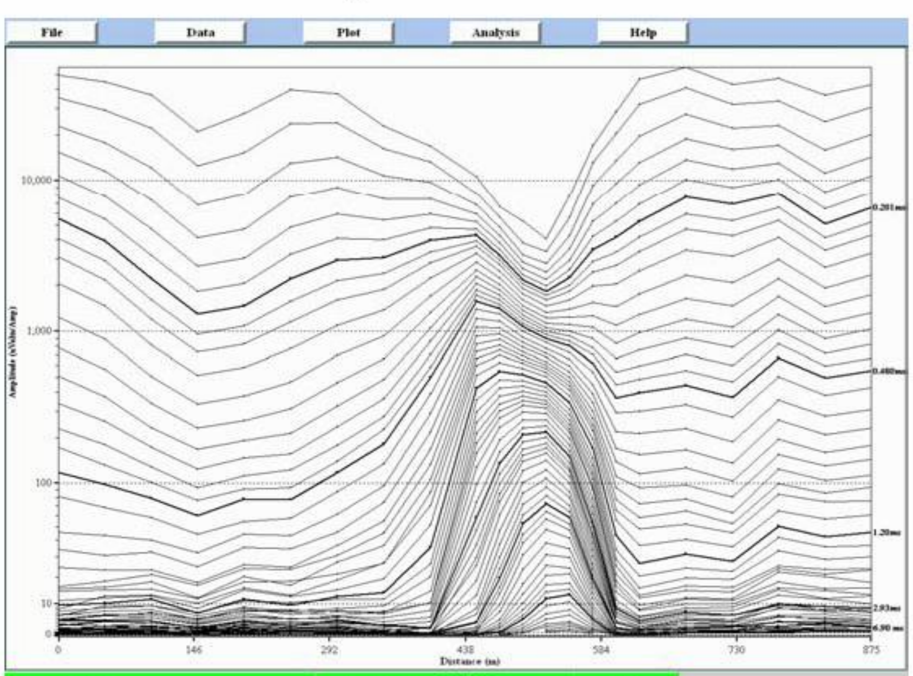
terraTEM Features



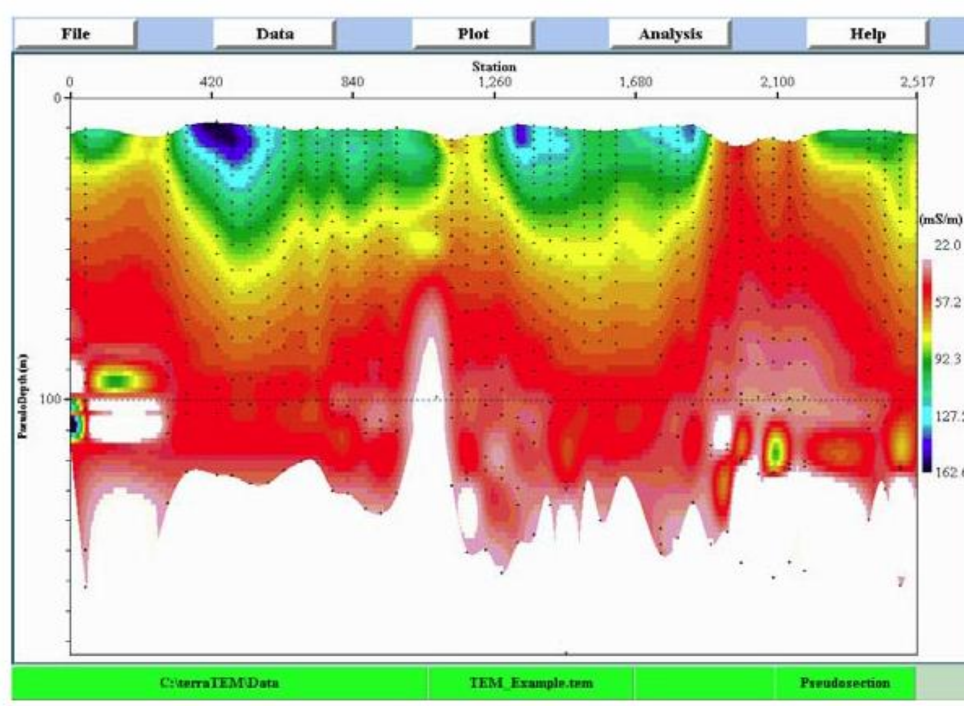
- Transmitter and receiver in one unit
- Single or 3 channel receiver with 10 amp. transmitter
- High speed sampling at 500 kHz for superior near surface resolution
- Easy to use touch screen with auto set-up and smart menus
- Large 15″ LCD display for data visualisation
- Fast and easy data transfer via USB port
- Integrated 12 channel GPS system for seamless station positioning (option)
- Integrated PC for data visualisation, data processing, and interpretation in field using built-in software
- Rugged construction with external 24 V battery power pack and charger
- Several optional extras to broaden capability
- Designed and built in Australia

Screen Dumps

The following are a number of screen views from the **terraTEM** system.



Full control of all aspects of data display, post-survey filtering, and decay curve analysis



Multiple display formats, including gridding and raster images (options)

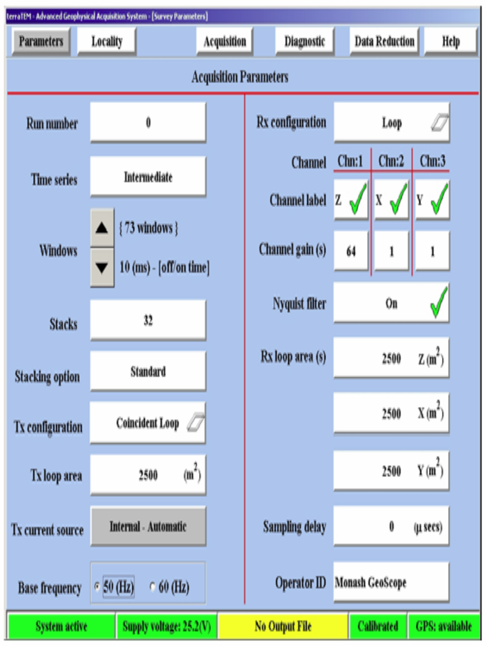
The **terraTEM** is designed, developed and manufactured by **Monash GeoScope**

Monash GeoScope

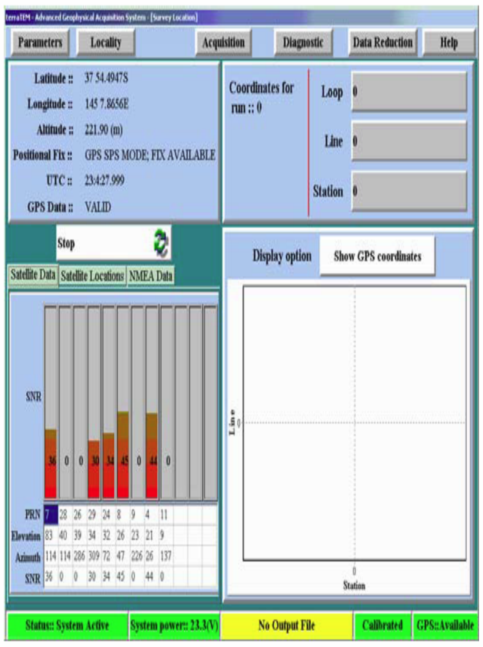
Applications

The **terraTEM** can be used for various applications including the following:

- Mineral exploration
- Near surface including geo-technical and engineering investigations
- Groundwater and salinity studies
- Environmental surveys



Easy access to all parameters, multiple binning and stacking options; smart menu system.



Internal GPS, for positional accuracy (option)

General Specifications

	terraTEM	Options
Transmitter Output	10 Amps. (max.)	**Enhanced Transmitter**
Receivers	1 Channel	**3 Channels (simultaneous)**
High Resolution Sampling Rates	500 kHz	-
User Selectable Multiple Time Gates	-	Option
Data Visualisation and Processing in field	Standard Software	**Enhanced Software**
Storage Device - 1 GB Flash Disk	Standard	-
GPS Receiver - 12 channel	-	Option
Communications - Port for Data Transfer	USB and RS-232 Standard	-
External Synchronisation	-	Option
Continuous Recording (with external GPS Interface)	-	Option
Extra Stacking Options and Gain Functions	10 Selectable Gain Settings from 1 to 8,000	Auto Gain
Vectem 3 Interface Module (for down-hole surveying)	-	Option
Interface Options (third party devices)	-	Option
Dimensions: Console: 530 x 350 x 160 mm. 13 kg. Battery Box: 280 x 250 x 180 mm. 12 kg.		
Operating Temperature: -10 to 40 degrees C.		

Further Information

For further information regarding this product, either technical or sales, please contact:

Alpha GeoInstruments

Unit 1, 43 Stanley Street, Peakhurst. N.S.W. 2210. Australia
Phone +61 (0) 2 9584 7555 **Fax** +61 (0) 2 9584 7599
e-mail info@alpha-geo.com **website** www.alpha-geo.com

Your Distributor:

terraTEM
Technical Specifications

Transmitter

Output	10 Amp. (max.)
On/Off Period	Adjustable 10 ms (50 Hz) or 8.33 ms (60 Hz) increments

Receiver

Sampling	500 kHz per channel, fixed
Inputs	+/- 40 V maximum continuous voltage.
Gain	User selectable fixed gains Other Gains Optional
Resolution	Maximum 28 bits, effective
Functions Measured	Tx/Rx loop resistance, Tx current, Tx turn-off time, battery voltage, automatic gain/offset calibration, transient response

Console

Display	LCD TFT, 15 inch
Touch Screen	Splashproof
Storage	1 GB flash RAM

External Interfaces

Communications	USB and Serial port for data transfer

Equipment Supplied

- Console
- Loop connectors
- Battery Pack (24 volts), complete with connector cable (overseas batteries not included)
- Battery charger
- USB flash disk (for data transfer)
- Operations manual

Sensor Attachments Available

Surface Receiver	RVR-1 or cable loop
Downhole	Vectem 3 or equivalent

Physical

Housing	Aluminium "Zero" case
Console: Weight	13 kgs.
Dimensions	530 x 350 x 160 mm.
Battery Pack: Weight	12 kgs.
Dimensions	280 x 250 x 180 mm.
Operating Temperature	-10 to 40 degrees C.

Options

GPS Receiver	12 channel receiver
Multi-channel Receiver	3 channel simultaneous A/D
External Transmitter Interface	External synchronisation option (for use with TEMTX-32, Zonge high powered transmitters)
Vectem 3 Interface	Internal interface module
Continuous Recording	Continuous recording of unit with external GPS interface using NMEA standard
Software Packages	Extra Stacking Options, Sferics Rejection and Gains, Spectral Analysis and Digital Signal Processing User-defined time series

Further Information

For further information regarding this product, either technical or sales, please contact:

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Your Distributor:

Towed platform TEM Method Description

- ***Towed platform TEM Method Description***
- Towed platform specifications are given on prior slides.
- Towed transient electromagnetic arrays have been applied by Sørensen, et. al.(2000), and the author (Allen, 2007) however the full potential of the technique is far from being realised. Other options for fast TEM data acquisition have been described by Harris et. al. (2006) and Hatch et. al. (2007).
-
- Key features of practical towed TEM devices are:
- They must facilitate towing of sufficiently large area transmitter loops and one or more receiver loops upon largely non-metallic structure;
- They must be robust enough to withstand field use;
- They must be capable of passing through farm gates and between other common obstructions without undue delay;
- They should be designed in such a way that they can isolate and minimise effects of incomplete transmitter turn off, loop self and mutual inductance, super-paramagnetic near-surface minerals and chargeable near-surface minerals;
- The transmitters need to be able to cleanly transmit high currents. Dual moment operation is beneficial;
- They must be readily road transportable and GPS equipped.
-
- Figure 4 presents a platform with the transmitter and receiver loops placed on dragged sheets, the sides of which can be raised when passing through gates. The main sheet is 2mm thick polyethylene which is heavy enough to prevent lifting by all but strong wind and rigid enough not to catch on stumps, barbed wire, and other obstacles. Practical size of the sheet is limited by the combination of the necessity of weight per unit area needed to prevent lifting by wind, and total weight which needs to be low enough to permit man-handling. The sheet is very useful for permitting precise layout of primary field nulling coils when using central loop receiver loops, and for spacing multi-turn transmitter loops so as to reduce self-capacitance and, to a lesser extent, self-inductance. It is difficult to increase the number of transmitter loop turns without compromising turn-off ramp integrity. This is a problem well understood by designers of airborne TEM systems.
-
- Receiver coil movement through the earth's magnetic field produces noise. When the coil is on a mat, it generally does not suffer from movement at frequencies above the sampling frequency as there are no taut elastic components that can resonate. Noise lower than the sampling frequency can be removed in post-processing of appropriately stacked data using techniques common to airborne TEM survey (eg. Noteboom, 2007).

Processing – introductory notes

One of the big advantages of a towed system is that it has a small near surface footprint that can isolate and avoid most problematic cultural effects. Further, it can be manoeuvred in order to test the effect of culture. In this way, processing, in effect, really starts during acquisition. Cultural effects need to be identified and this is done by repeatedly driving close to them and noting their response. Once problematic culture is identified, it is either avoided or its location is noted for later removal of affected data. The TerraTEM continuously displays decays of incoming data, and for quality control and verification of system response, these are continuously monitored while driving.

Data from all the relevant devices was merged together using interpolation and extrapolation where necessary. Position data was written in WGS84 UTM(MGA94 equivalent at the accuracy of the DGPS that will be used). Data is in tabular format in dBase files suitable for importing into ArcGIS and Google Earth products as specified in *Allen, D.A., 2005, Towards creation of a national multi-depth electrical conductivity database. Australian Society of Exploration Geophysicists, Preview, August, Issue No. 117.*

The Gridding was conducted as follows:

- Depth slice data was all log transformed;
- A proximity filter averaged points closer than 20m apart;
- An exclusion filter removed null records caused by depth slicing beneath cutoff depths;
- Natural neighbour gridding was performed with a cell size of 20m;
- The grid was blanked to remove most overshoots occurring around grid extremities in the absence of data;
- Gridding was imaged with valid and non-valid colour coded points registering data locations posted on the image so that viewers can determine what are real geological features and what are simply gridding artefacts. Non-valid points are important for showing where data cutoff above slicing depth as soundings penetrate much deeper depth when modelling resistive features – the result being that gridded data will be excessively resistive at depths below conductive feature cut out depths.

Data was then interpreted.

Processing Sequence

Define System Geometry

–

1. Quality control and data parsing during acquisition
    1. At the beginning of each day, select a reference sounding and plot it along with all incoming data.
    2. Watch all incoming data constantly making comparison with the reference sounding.
    3. Cancel acquisition or note problems as noise sources, metal artefacts, or equipment malfunctions are encountered. Alter course across ground to both more clearly define noise and artefacts and to subsequently avoid them.
    4. Each night, convert BIN file into TEM and TXT files and back them up.
    5. Each night, display selected channels of the data in plan view to appraise layout of geological features and any present geophysical artefacts.
2. Acquire system response from data obtained (stacked then averaged) in a very resistive area.
3. Determine EM1DInv inversion software initial model, constrains and control parameters.
4. –
5. Operations performed on TEM files
    1. Basetrend removal (optional – only possible on moderately to highly resistive areas). This removes movement noise from the receiver coil moving through the magnetic field of the earth slowly. Large mat receiver loops do not create much movement noise.
    2. Adjust magnitude according to primary field response (optional).
    3. Reject records with low primary field response as they are clearly suffering from equipment malfunction (eg. Receiver loop blown over by wind) (optional).
6. Convert TEM file into a relational voltage database (*Volt.DBF, *XVolt.DBF,*YVolt.DBF)
7. Normalize data using average magnitude of log10(data) from a small receiver placed directly on the transmitter loop wires (*YVolt.DBF) (This is optional as the data is already normalized according to current monitored (every 100 soundings in 2010)).
8. Remove system response, taking magnitude of transmitted data (proportional to *YVolts.DBF) into account for every sounding.
9. –
10. Display voltage data, in map view, coloured to represent magnitude of a particular channel. Simultaneously view decay plots of picked soundings, along with a reference sounding.
    1. Interactively remove geophysical artefacts by clicking on points or data segments.
    2. Alter the channel and repeat a.
    3. Repeat b. until satisfied that data is suitably cleaned.
    4. Interactively clip channel count on soundings with procedure as for a., b. and c. (optional).
11. Smooth voltage data horizontally. Trapezoidal filtering is ideal (optional). Note well that this step is conducted after removal of artefacts which would have spread their mess throughout the data if smoothed.
12. Calculate noise levels from sounding tails and specify ready for inversion. Should telecom cable or powerline noise be encountered, then this step will lead to recovery of shallow information without unduly corrupting deeper information!
13. Determine valid time range for inversion input from each sounding using noise levels specified in step 14.
14. Create EM1DInv inversion input files.
15. Run EM1DInv on each sounding, conjunctively inverting both in-loop and out-of-loop data. This scheduled using batch files and runs overnight, or even over several days or weeks.
16. Run EM1DInv again with lateral constraint (optional – also time consuming).
17. Read inversion output files to create relational *Ohmm.dbf files.
18. View *Ohmm.dbf files in plan view.
    1. Colour proportional to curve fitting RMS error and view to determine an appropriate cut-off RMS threshold. Exercise caution in determining the threshold as data in resistive areas will still be valid at much higher threshold than in conductive areas.
    2. Reject soundings with RMS error greater than the threshold level determined in a..
    3. Colour proportional to resistivity of successively deeper layers. Interactively remove or depth-limit soundings containing artefacts by clicking on points or data segments.
19. View *Ohmm.dbf in 3D – check data more, switching back and forth to 2D view to remove further artefacts.
20. Horizontally smooth the *Ohmm.dbf file to clean up erratic variation in inverted data.
21. Horizontally shift *Ohmm.dbf files to account for antenna offset.
22. –
23. Divide day *Ohmm.dbf files into logical segments (where appropriate) and recombine into *Ohmm.dbf files covering logical geographic extents.
24. Calculate resistivity distribution histograms and combine to make a master histogram for the area.
25. –
26. Re-load regional *Ohmm.dbf files and colour with master histogram equalization (quantization).
27. Query state bore databases and generate a subset of bore data for the area.
28. Interpret the drillers logs into lithological categories.
29. View bore log graphics with the resistivity data for each region.
30. Create graphics of histograms and lithological keys for posting externally.
31. Pack regional *ohm.dbf files and augment with shapefile indexes, projection files etc.
32. Create 3D polygon KML and shapefiles for each region (both resistivity and lithological files).
33. Slice each regional resistivity file into depths and output as *.csv with columns of logarithmically transformed resistivity for external gridding in packages such as Golden Software Surfer 9.
34. Create any other appropriate theme datasets (eg. Depth to maximum resistivity) and 3D graphics (eg. Voxler).
35. Grid and display depth slices, stacked if required in 3D space (Surfer).
36. Organize and refine KML files in Google Earth and select enhanced snapshot views. Combine into a folder and collectively output as a new KMZ file. The KMZ files are compact - Email to interested parties.
37. Collect all graphics in MS Powerpoint (A3 resolution!) and create a report. Make a summary report in MS Word (optional). Generate PDF report.
38. Package job DVD and printing, mailing etc.

Results – digital products

- EC datafiles in resistivity units - Ohm.metres accompany this presentation. There is one column for each layer sampled and one column for the depth to the bottom of each layer sampled. The datafiles are in dBase format and may be read using MS Excel, MS Access or ESRI software. ArcView contains a routine for expanding the dBase files into ESRI shapefiles but in most cases this is already done. Co-ordinates are all WGS84 (equivalent to MGA94 to the degree of accuracy of the survey) and are given as both UTM projection and latitude and longitude decimal degrees. Google Earth KML (or zipped = KMZ) format files are also provided for various 2D themes and in 3D. CSV ASCII files of depth slices also provided for generic loading into any spreadsheet or GIS software.
- **Results – Accompanying CD contents**
- The accompanying CD contains this document, digital data, the power point presentation, the A3Earth Plus. Further explanation is as follows:
- This report is stored as a *.doc (MS Word 2003 format) and *.pdf
- The powerpoint presentation is stored as *.ppt and *.pdf
- The Google Earth datasets are stored as *.KML and/or *.KMZ and are opened using File:Open in Google Earth.
- The A3 maps are stored, ready for viewing as *.pdf or *.jpg files
- Data files *Volt.dbf
- Transformed Data files *Ohmm.dbf.
- Depth slice files *DepthSlice.csv
- ESRI ArcMap file *.Mxd demonstrates access to transformed data files and can be used to locate them all.
- Golden Software Surfer *.srf displays and provides locations of all the gridded data files.
-
- All data is stored in GDA94/MGA94 UTM Zone 55 coordinates (Lat Long, E N, or both).

Production Report

Date	Charge	Details
15/08/13	Free Demonstation	Drive from Melbourne to Tatura – arrive 8.45am, conduct trial until 7.30pm – return to Melbourne
September 2013		Post Trial Testing, Processing and Presentation

Total production distance
excluding gaps >60m
= 28km

References

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- Allen, D.A., and Merrick, N.P., 2007, Robust 1D inversion of large towed geo-electric array datasets used for hydrogeological studies: Exploration Geophysics, Vol 38 No 1, ISSN0812-3985; Butsuri Tansa (Japanese) 60.1; and Mulli-Tamsa (Korean) 10.1. (http://www.publish.csiro.au/paper/EG07003.htm, Abstract 0.1 MB; Full Paper 1.7 MB).

- Smith, R.S, Edwards, R.N., & Busselli, G., 1994, An automatic technique for presentation of coincident-loop, impulse response, transient, electromagnetic data. Geophysics, Vol. 59, No. 10 pp. 1542-1550.

- Sørensen, K.I., Auken, E. and Thomsen, P., 2000, TDEM in Groundwater Mapping – A continuous approach: http://hgg.au.dk/media/soerensen2000cpresentation.pdf , Dept. of Earth Sci., Geoph. Lab. Univ. of Aarhus, Denmark.

- Spies, B.R., 1989, Depth of investigation in electromagnetic sounding methods. Geophysics, 54, 872-888