Appendix

G

TEM survey

Cobbora Proposed Coal Mine Transient Electromagnetic Groundwater Investigation

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phone 0418 964097

for Parsons Brinkerhoff, November 2011

GROUNDWATER IMAGING

Summary

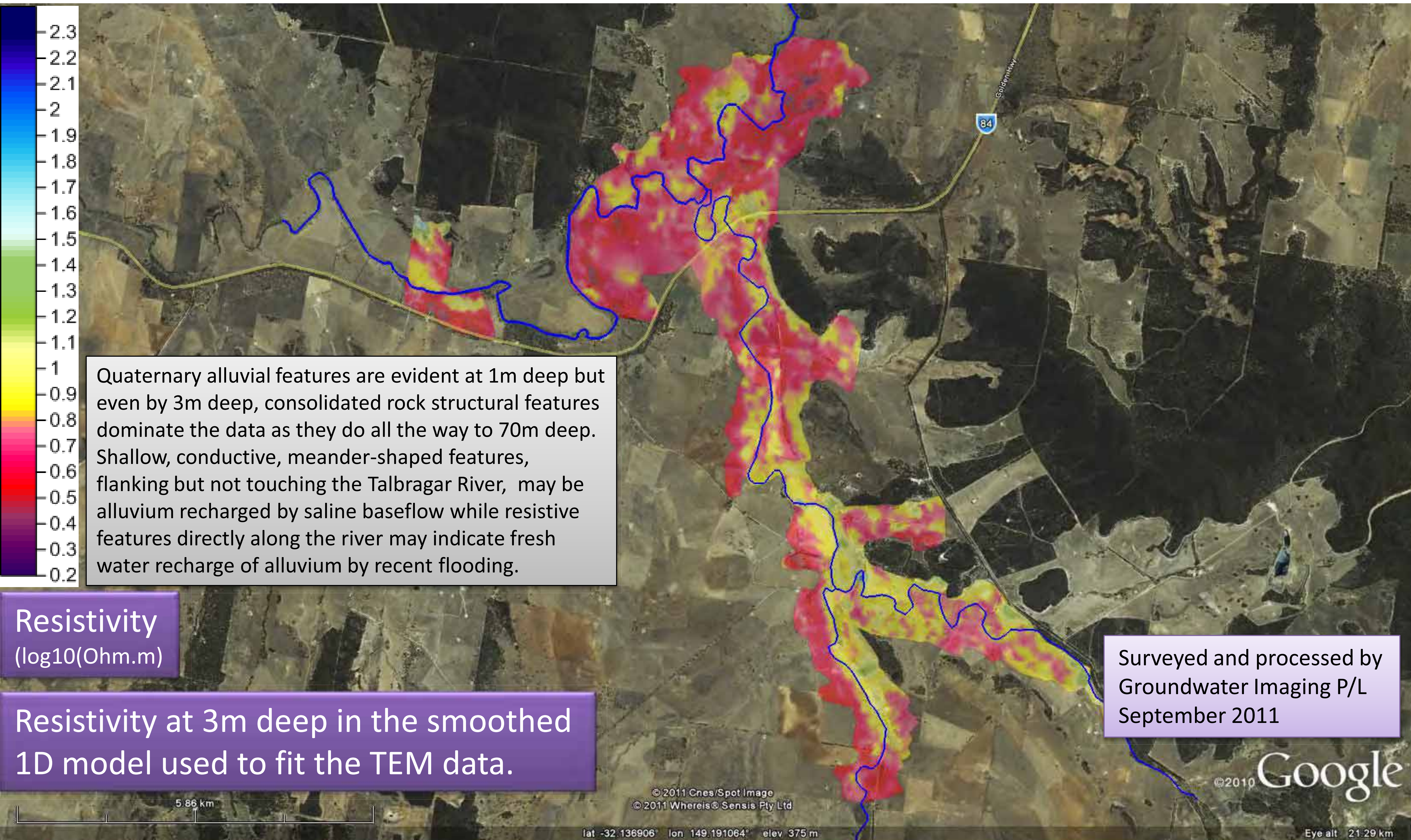
- 286 km of towed TEM was conducted in the Cobbora Holdings exploration area for the purpose of defining a groundwater conceptual model.
- Around the Talbragar River and the lowest part of Sandy Creek, there are numerous conductive, near- surface, roughly meander-shaped features and it is thought that these are saline baseflow saturated (or at least moistened) alluvium. Recent flooding has, it seems, created a zone of resistive alluvium along the river itself. Elsewhere there is little evidence to distinguish very scant alluvium from eluvium but there is considerable detail evident of structural and stratigraphic variation in the underlying consolidated rocks. By 12m deep the modeled resistivity predominantly indicates features that appear to be related to structure, weathering and erosion of pre-quaternary sediment.
- A dominant feature in the dataset is a lineament approximately along Sandy creek. East of this lineament, the deep substrate is resistive while to the west it is conductive.
- Modeled resistivity increases by orders of magnitude from less than 5 ohm.m at some locations near the surface, to more than 2000 ohm.m at some locations at depths more than 20m deep. Across the entire site, there is a marked increase in resistivity with depth suggesting that the TEM is detecting weathering of rock to clay at least. Within the shallow TEM data it is thought that much of the variation is attributable to variation in grain size and salinity of alluvium and eluvium.

Contents

Introduction

- METHOD : This survey, around the Talbragar River, Sandy Creek and Laheys Creek in the Cobbora Area, east of Dunedoo, NSW, was conducted using TerraTEM and a trailer mounted loop system in October 2011.
- AIM : The survey aimed to identify alluvial extent and any other potential groundwater flow paths in preparation for possible coal mining.
- SURVEY PARAMETERS : Where possible, a nominal line spacing of 100m was adopted. Data was provided at about 10m increments along line – enough to reveal the detail of faulted geology of the site. Survey depth of investigation was from 1m to 70m divided into 8 separate layers. Near the surface, the system footprint is small, so it can be used close to metal infrastructure, while at 70m 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.

An overview of the Cobbora towed Transient EM survey conducted in October 2011.



Quaternary alluvial features are evident at 1m deep but even by 3m deep, consolidated rock structural features dominate the data as they do all the way to 70m deep. Shallow, conductive, meander-shaped features, flanking but not touching the Talbragar River, may be alluvium recharged by saline baseflow while resistive features directly along the river may indicate fresh water recharge of alluvium by recent flooding.

Resistivity
(log10(Ohm.m)

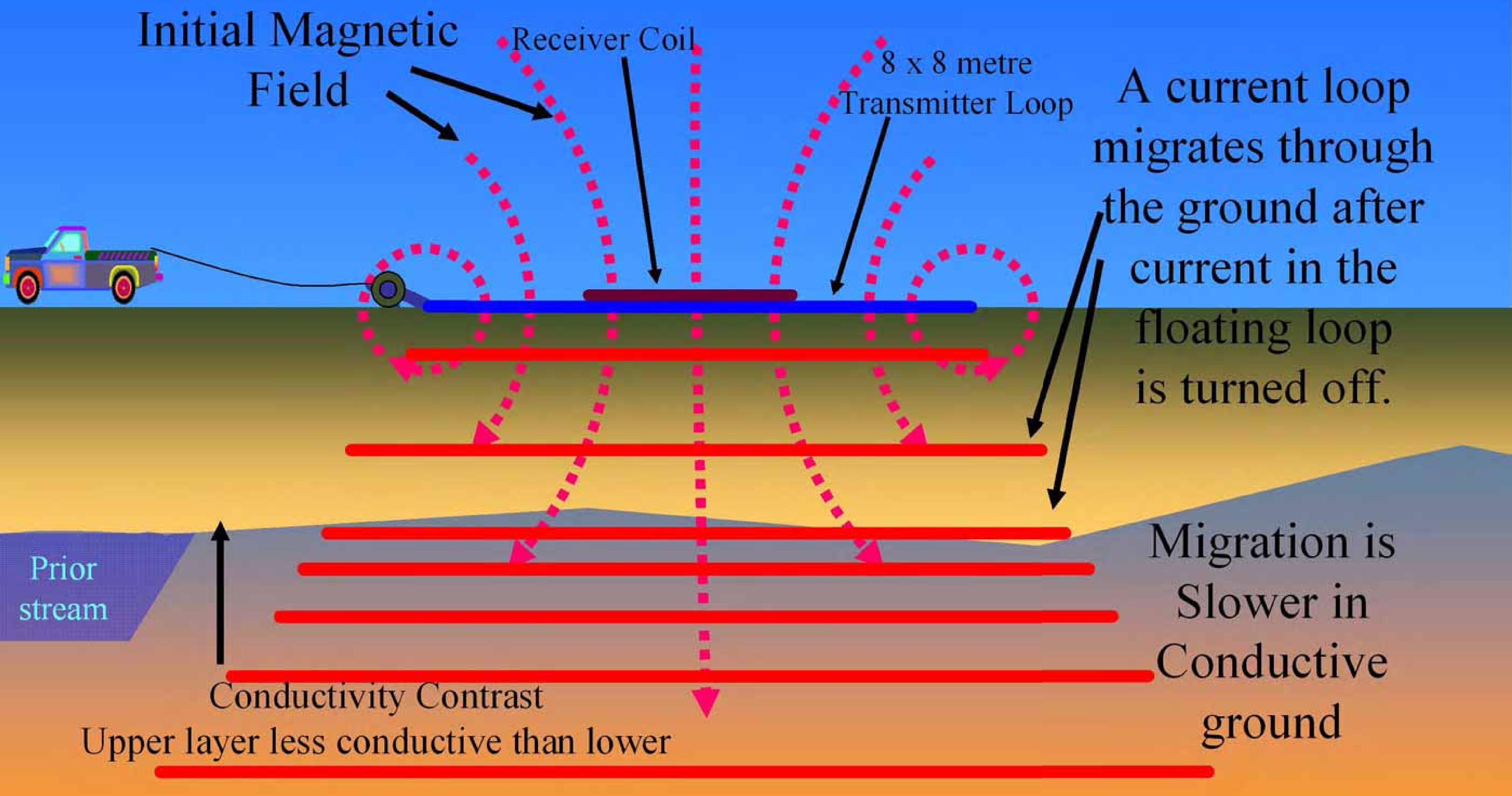
Resistivity at 3m deep in the smoothed 1D model used to fit the TEM data.

Surveyed and processed by Groundwater Imaging P/L September 2011

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 Conductivity for Investigation of Groundwater

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

LOW EC

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

HIGH EC

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

Overall Results & Interpretation

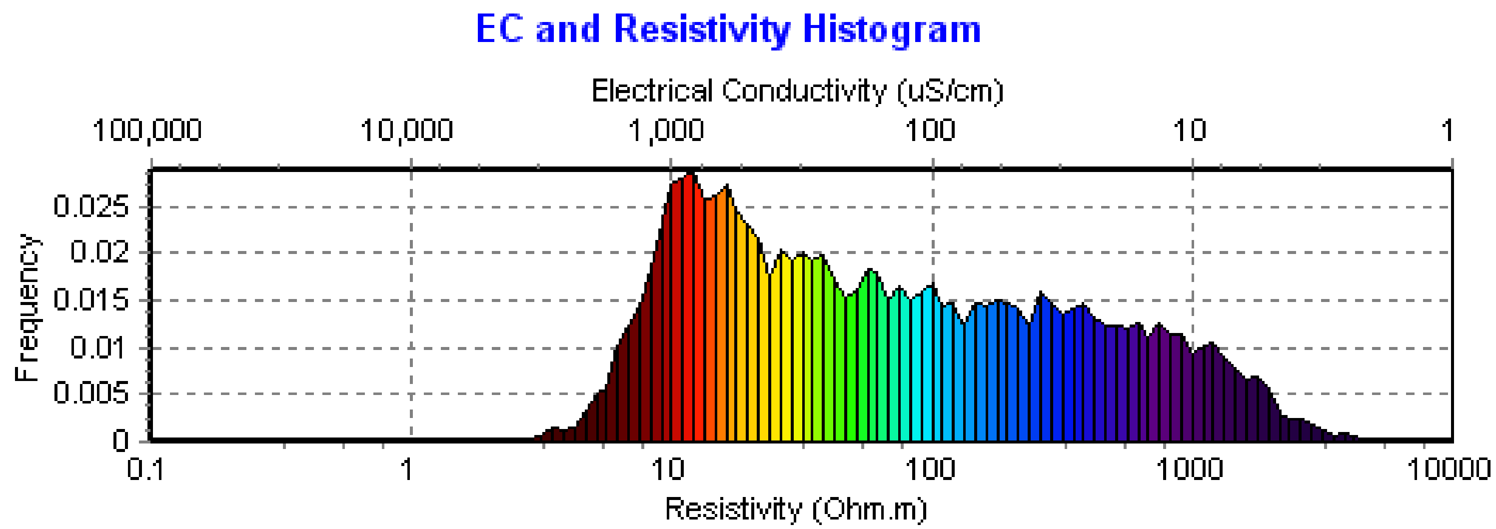
- There appears to be no simple correlation between alluvial thickness and resistivity at any depth sampled. The main reason appears to be that there is little alluvium in the area other than around the Talbragar River and what alluvium there is appears to be hydrogeologically and compositionally very similar to eluvium with which it is in contact. Further, there appears to be little resistivity contrast between some of the eluvium and some of the consolidated rock types.
- The dataset strongly depicts various lithologies with a clear boundary extending approximately along the line of Sandy Creek. It is clear that the lithologies are deformed in some places - numerous subtle fine details in the resistivity data are present in more than one line and are credible evidence of faulting, potentially hosting saline groundwater, and/or lithological variation.
- Some fences create bogus conductive anomalies however these are usually identified by approaching the fence repeatedly to identify its effect and then removing clearly affected data. Particularly in the deeper data, some fence effects remain and are evident as anomalies centered on fences. The worst is on the NE part of the O'Learys' property.
- In the very shallow modeled data, there exist meander shaped conductive anomalies around the Talbragar River and it is thought that these represent saline baseflow recharged quaternary alluvium. In contrast, along the river itself there is a slight resistive anomaly thought to represent alluvium recharged by fresh floodwater from recent floods.

Colour scales used in this presentation

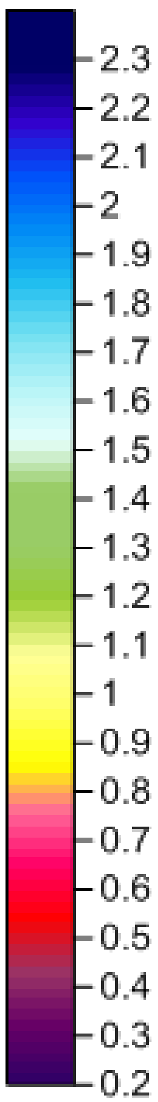
NSW Bores

Depth Slices

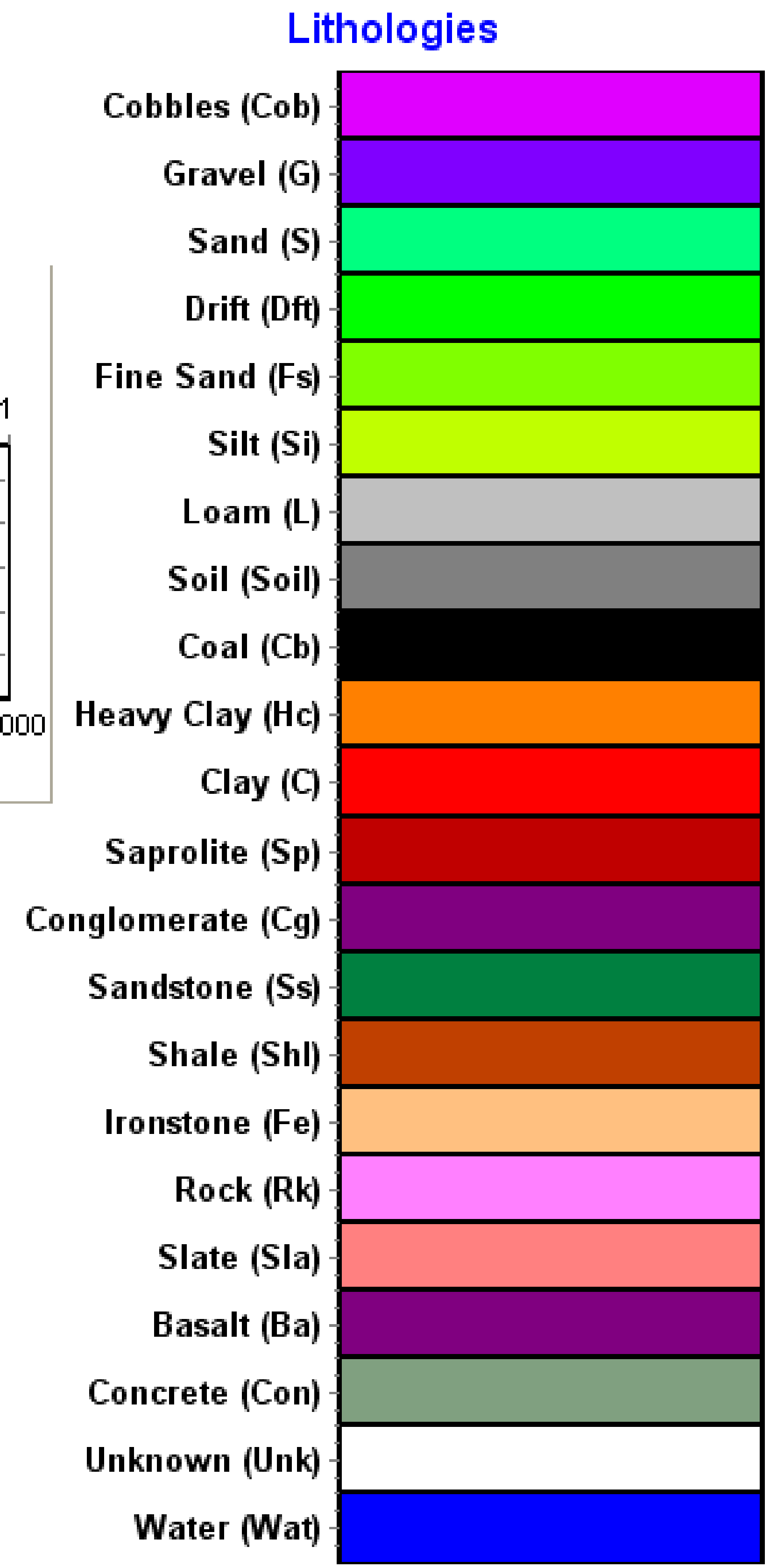
Resistivity Curtain Diagrams



Observe that resistivities encountered span three orders of magnitude. The very high resistivities are perhaps somewhat artificially high due to the limitations of system response removal that presently exist with the system used.



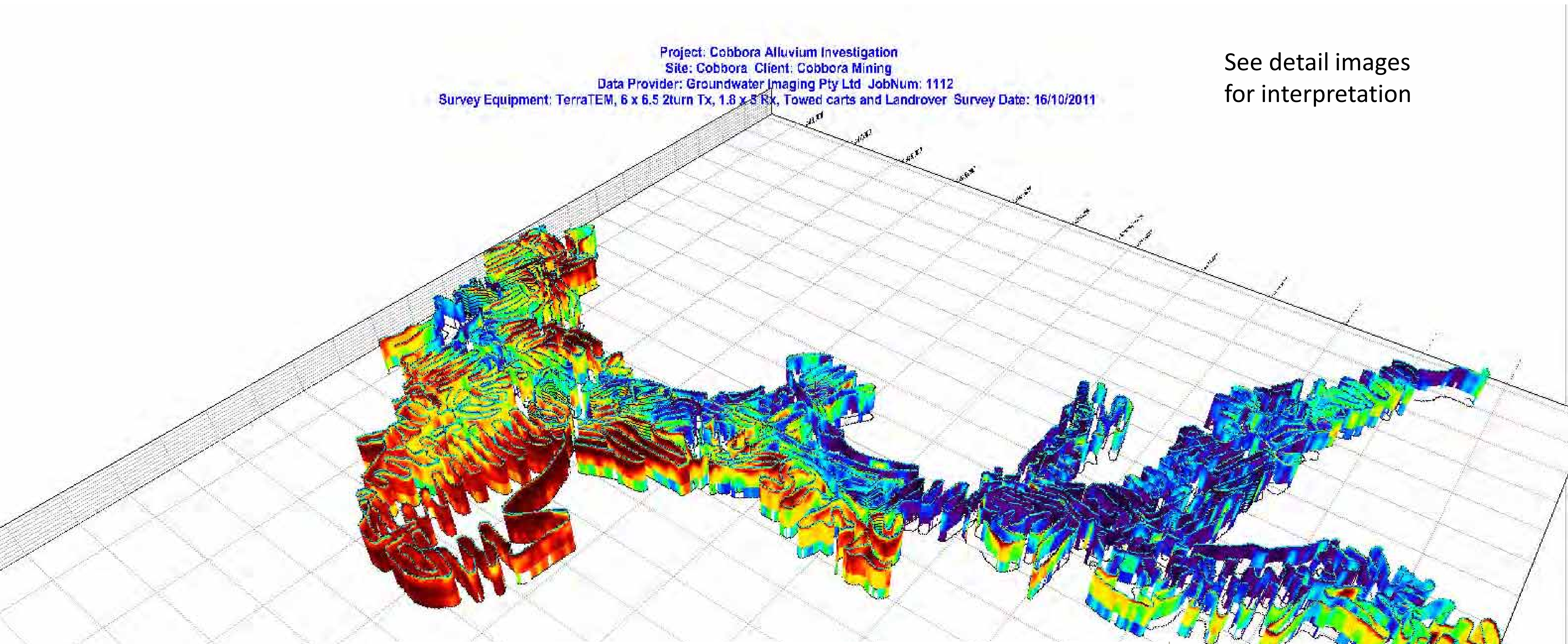
Resistivity (log10(Ohm.m)

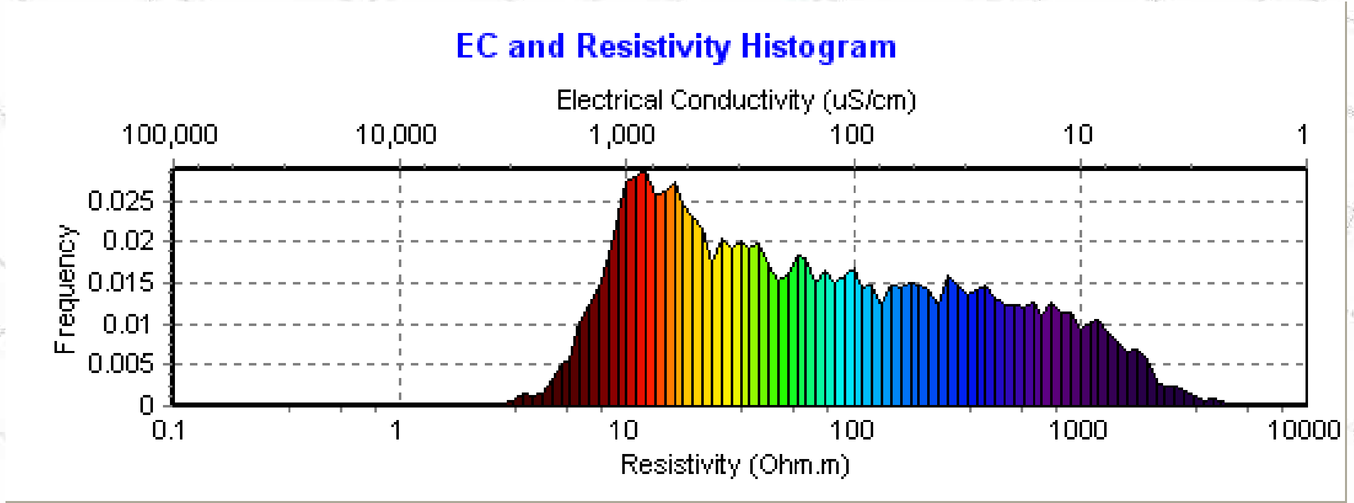


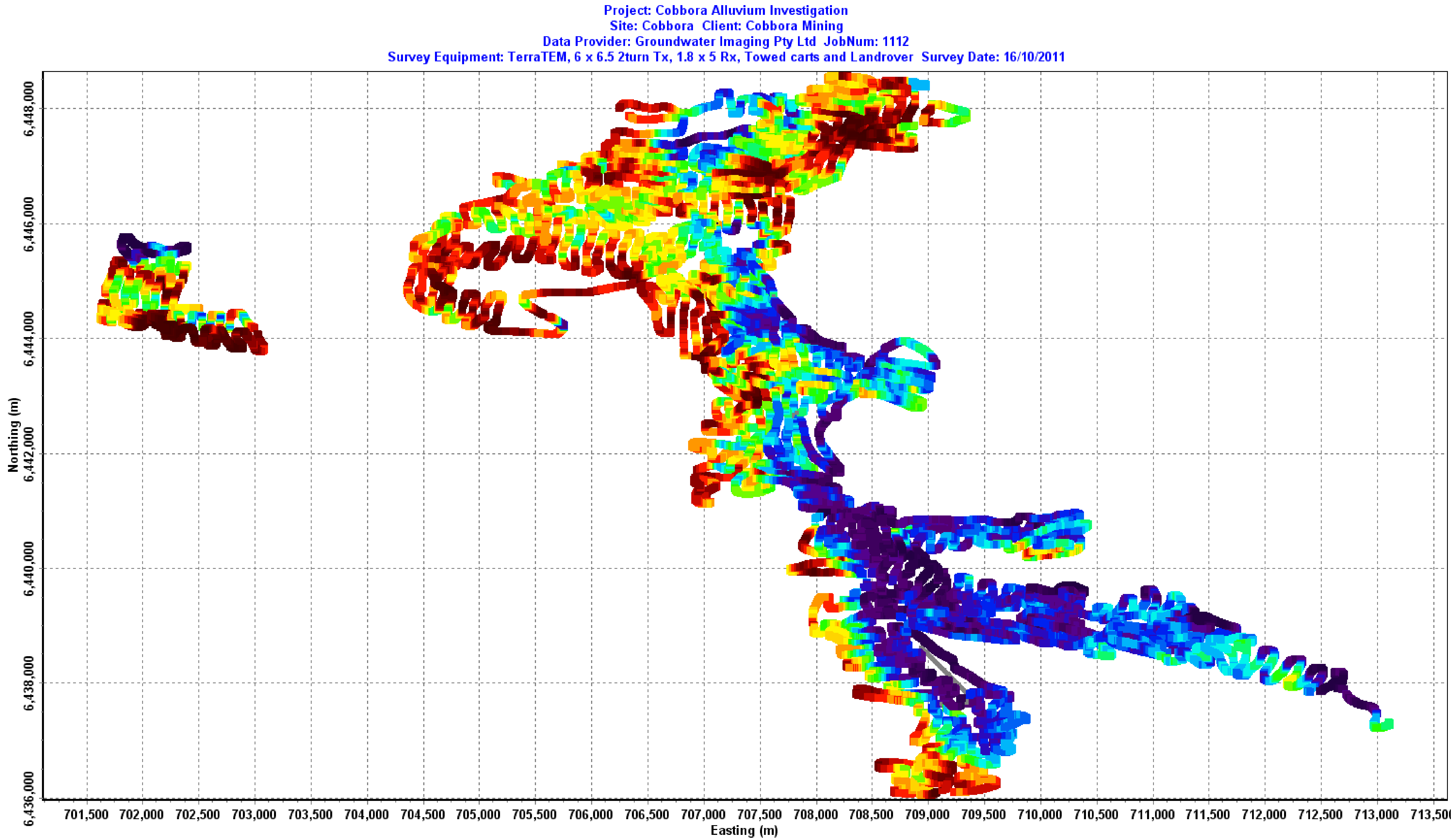
The entire Cobbora October 2011 TEM dataset viewed from the SW

Resistivity Curtain Diagram extending 100m into the substrate and looking from the south

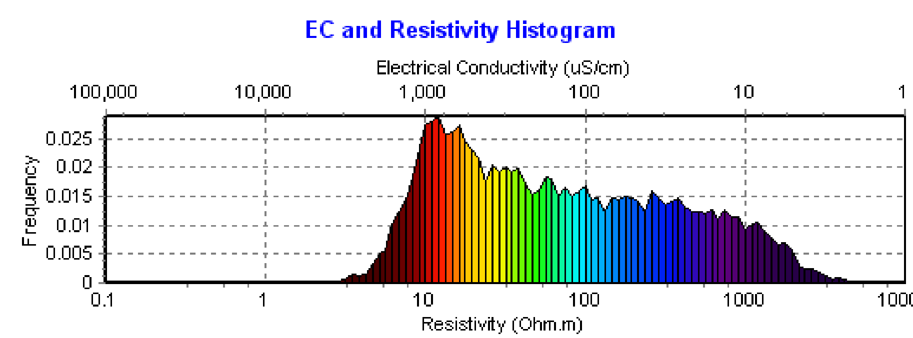
See detail images for interpretation

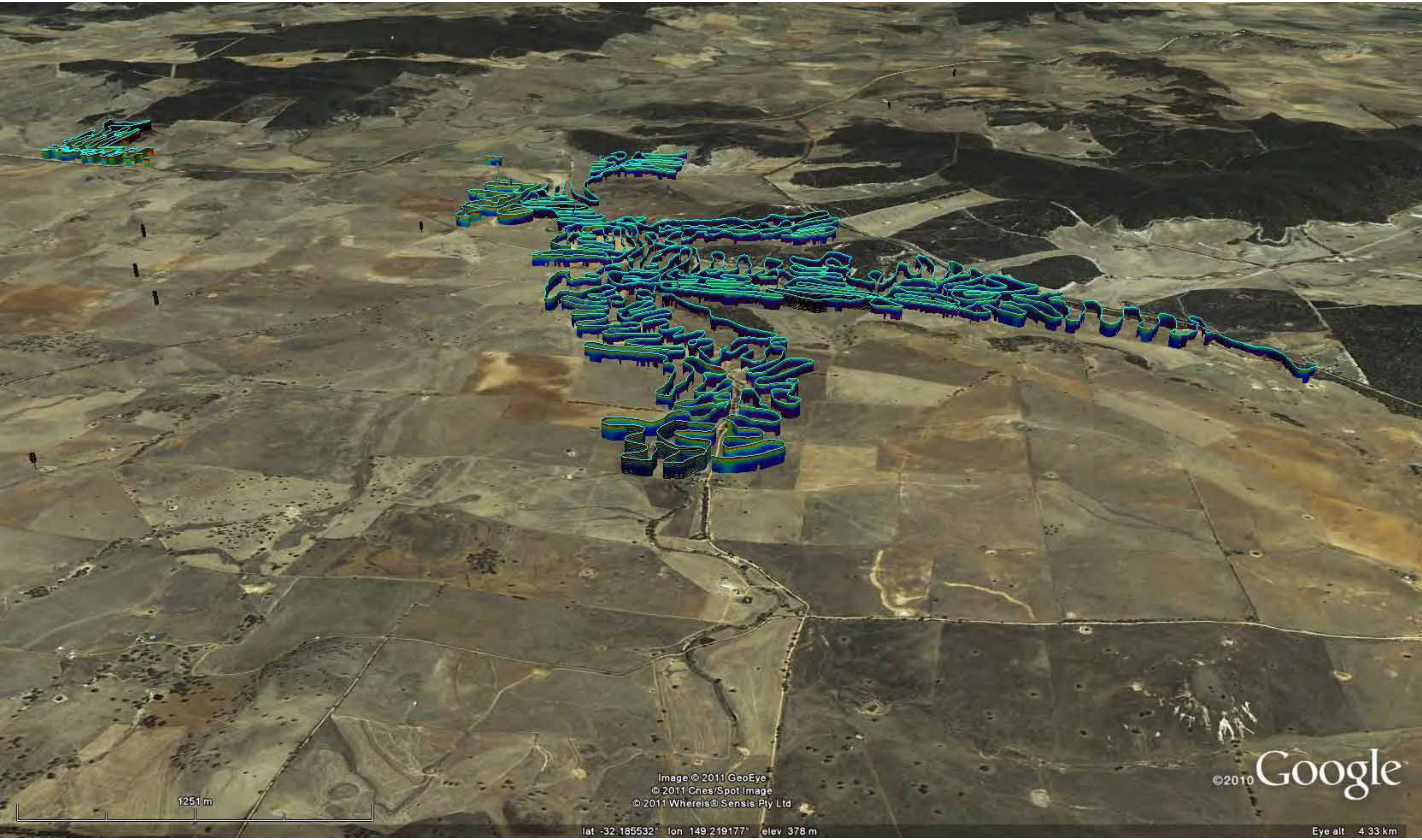




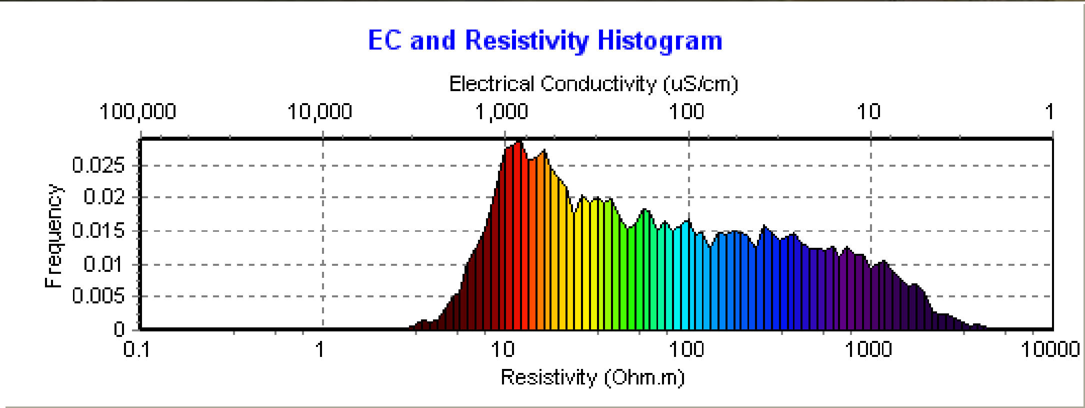


The entire Cobbora October 2011 TEM dataset – 7m depth slice.

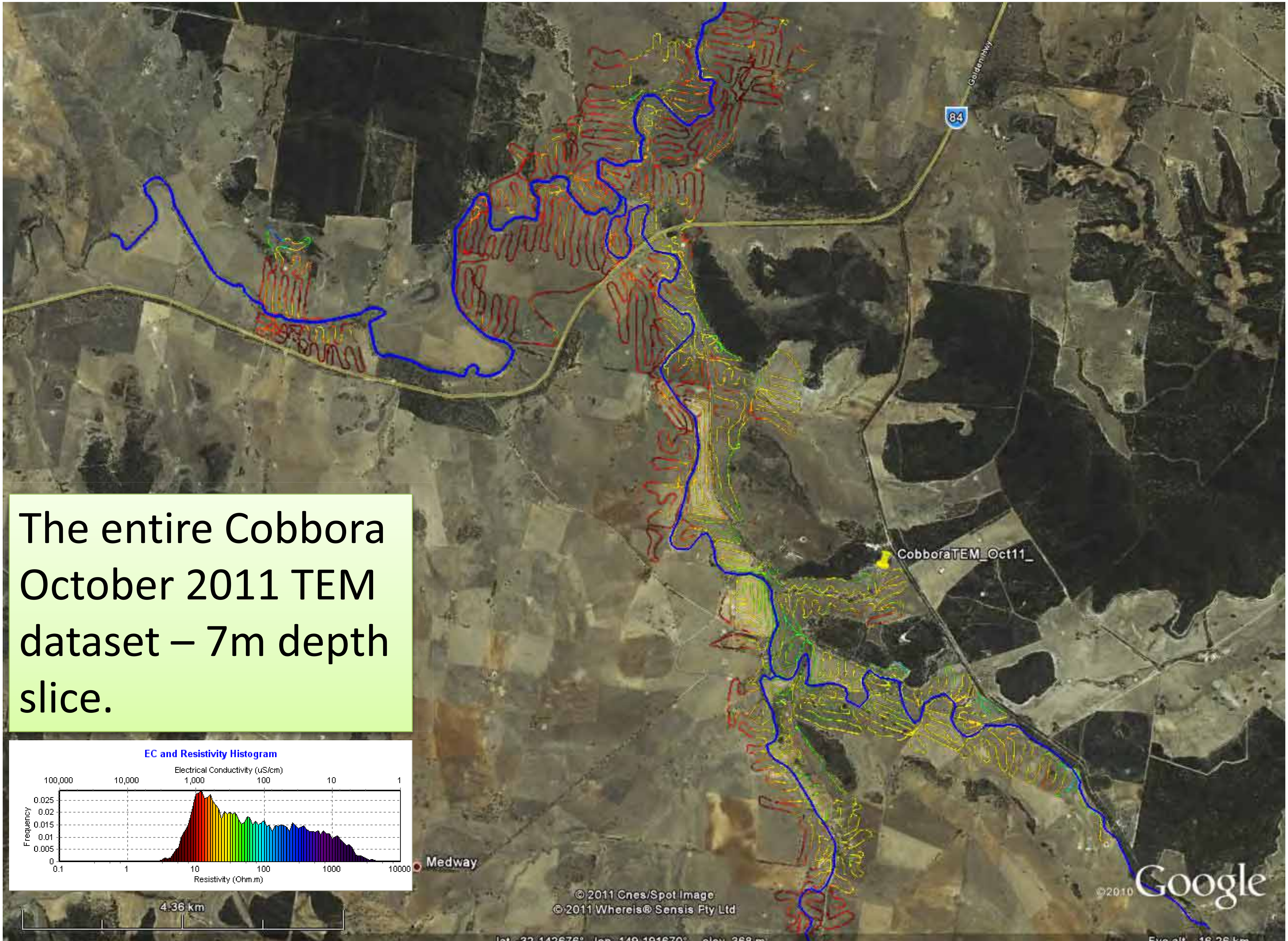


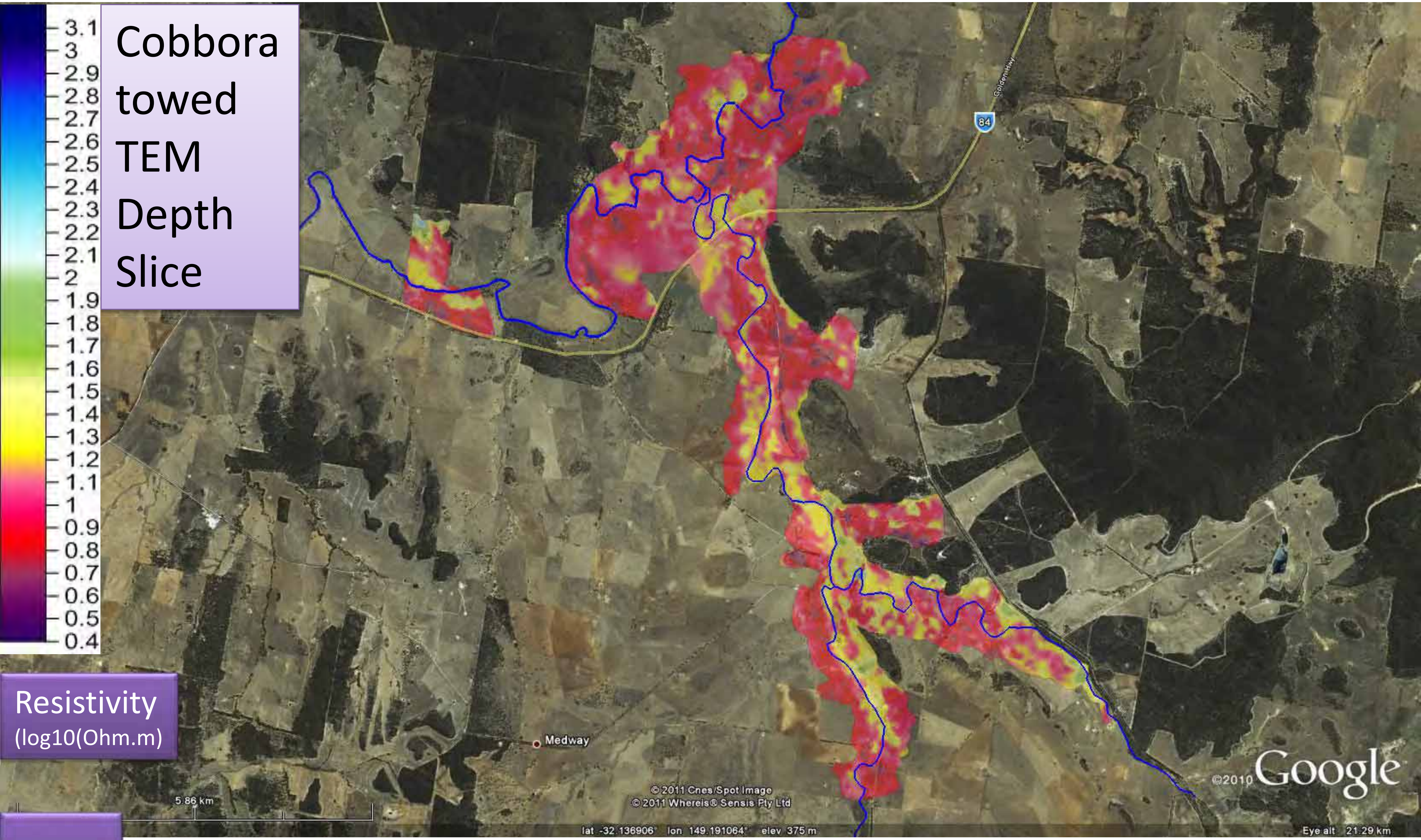


The entire Cobbora October 2011 TEM dataset viewed from the south



The entire Cobbora October 2011 TEM dataset – 7m depth slice.



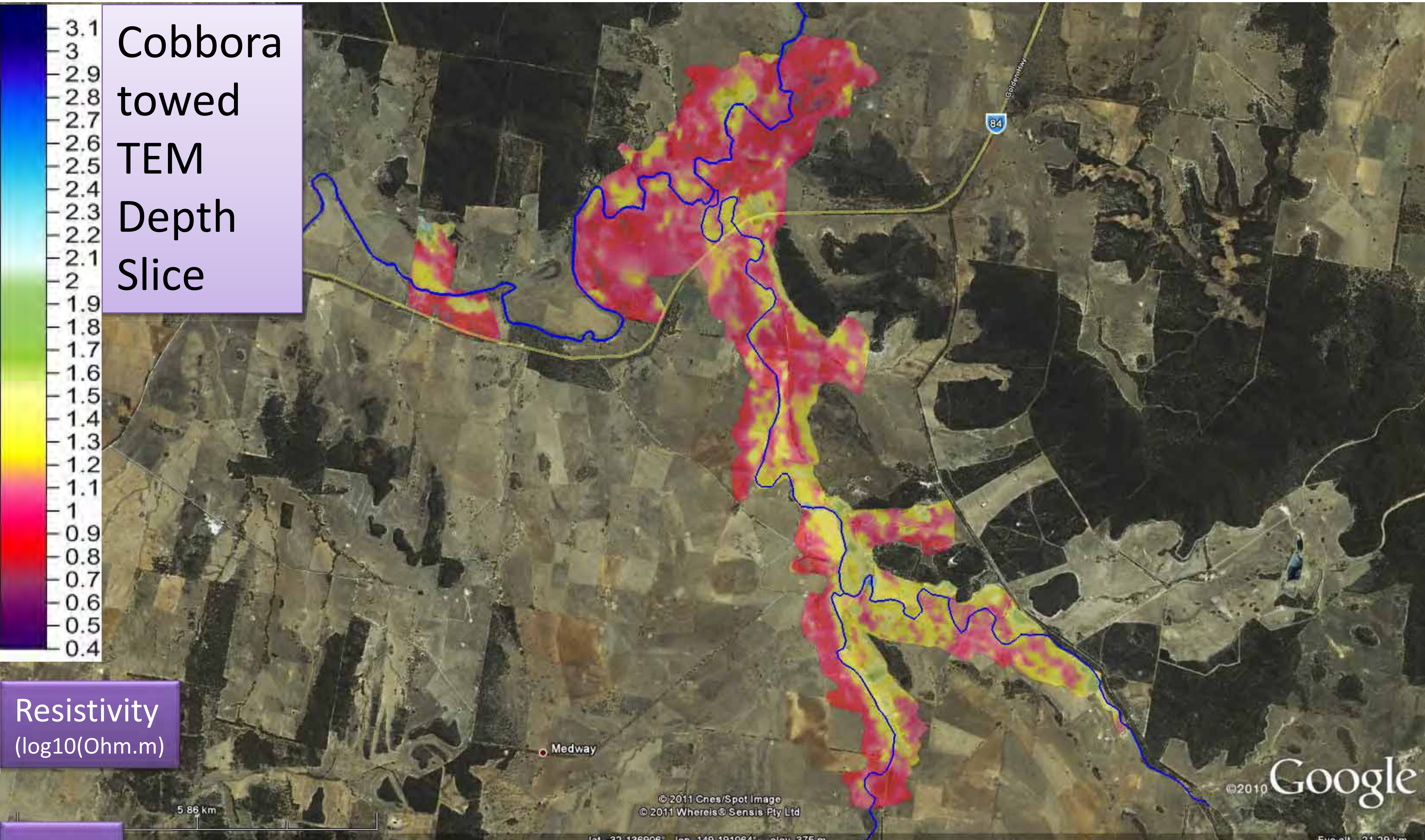


1m

Surveyed and processed by Groundwater Imaging P/L
October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice



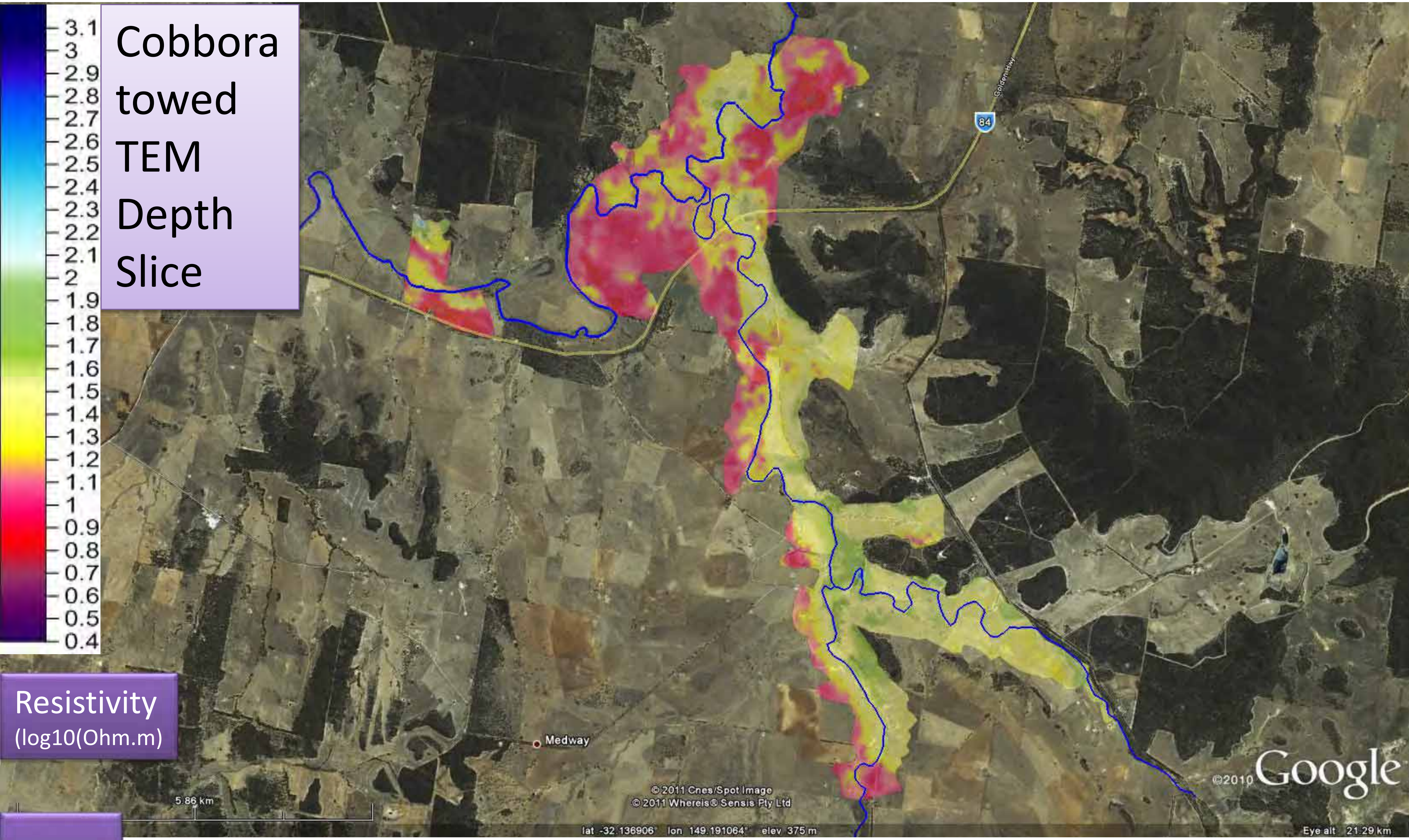
Resistivity
(log10(Ohm.m))

3m

Surveyed and processed by
Groundwater Imaging P/L
October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice



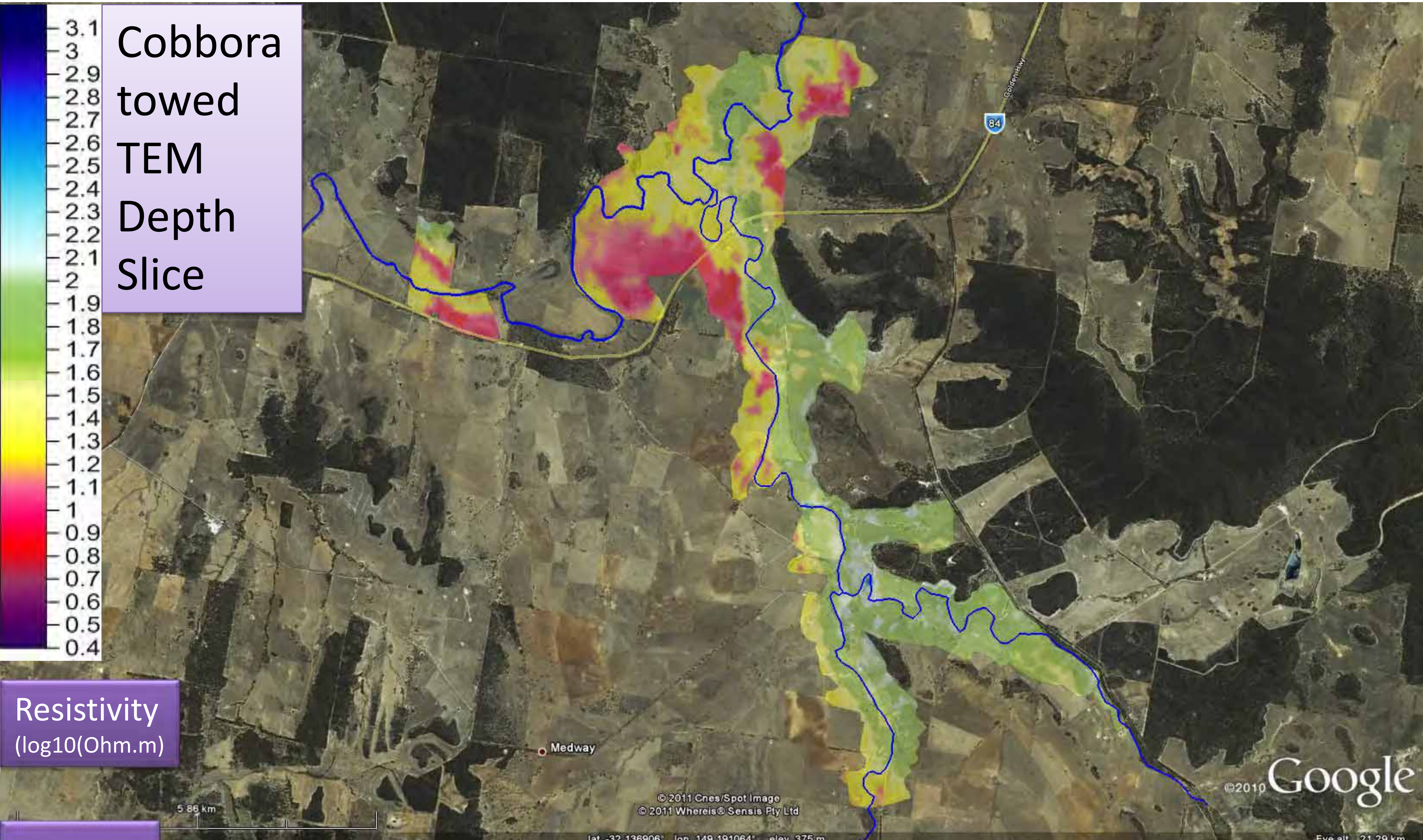
Resistivity
(log10(Ohm.m))

7m

Surveyed and processed by
Groundwater Imaging P/L
October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice



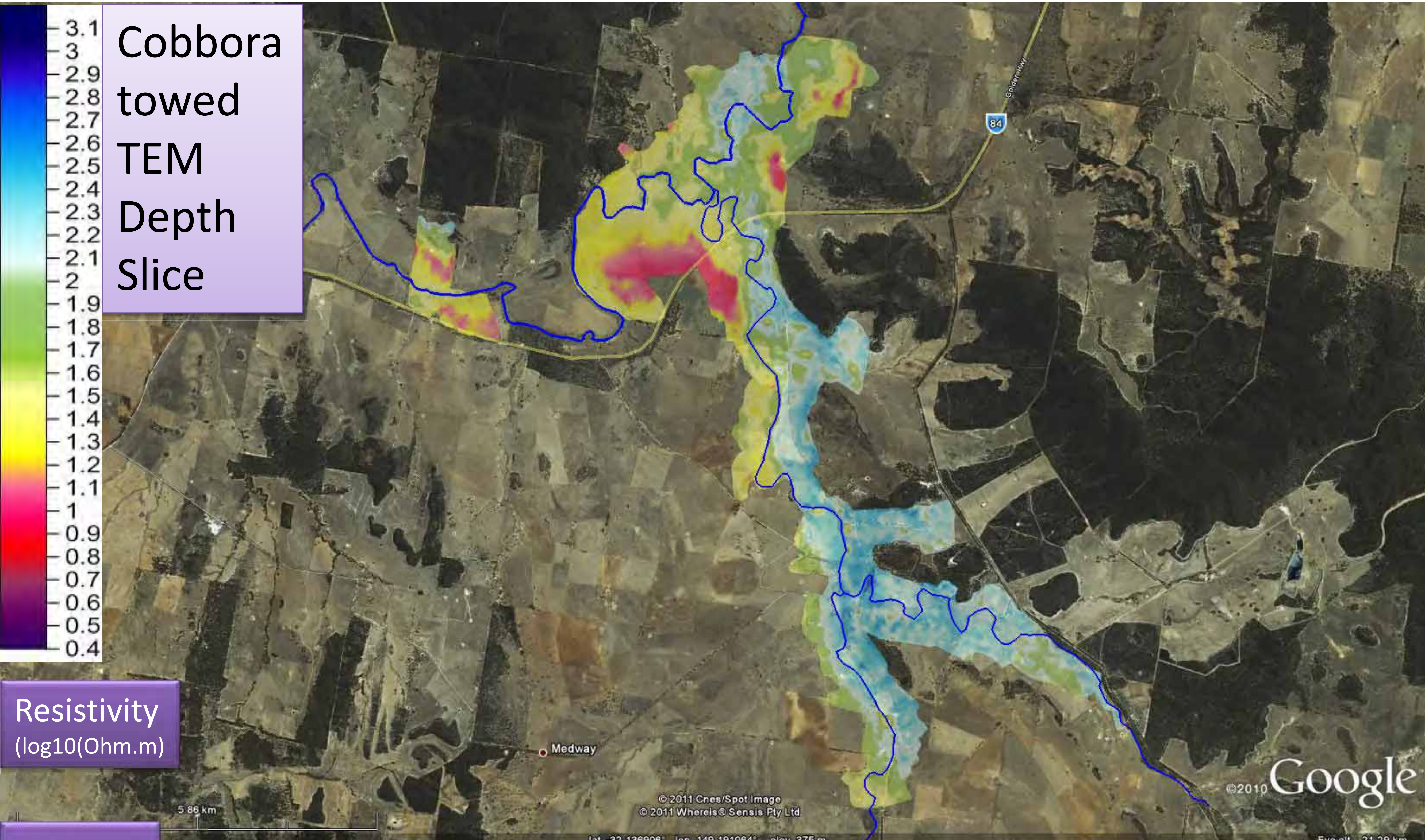
Resistivity (log10(Ohm.m)

12m

Surveyed and processed by Groundwater Imaging P/L October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice

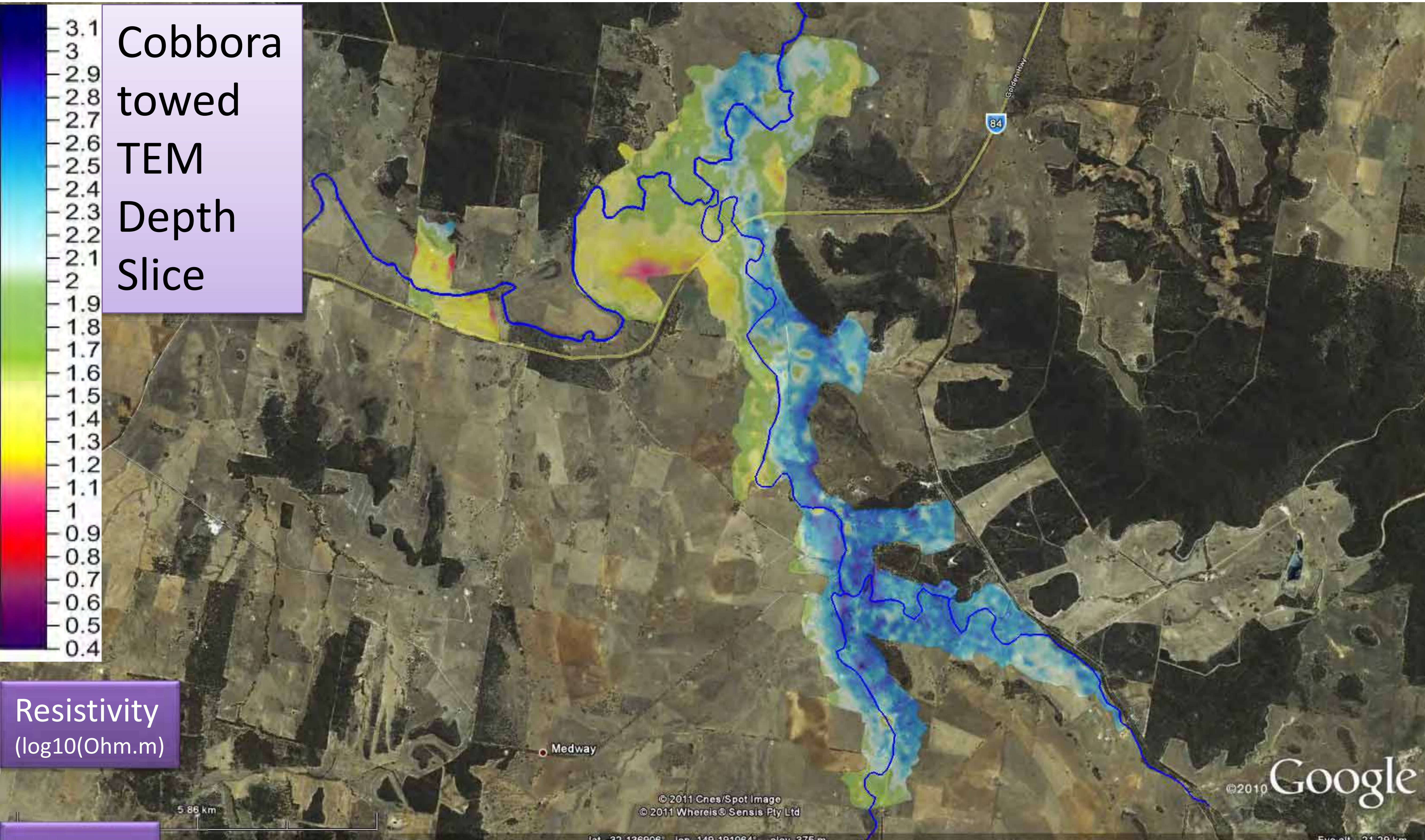


20m

Surveyed and processed by
Groundwater Imaging P/L
October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice



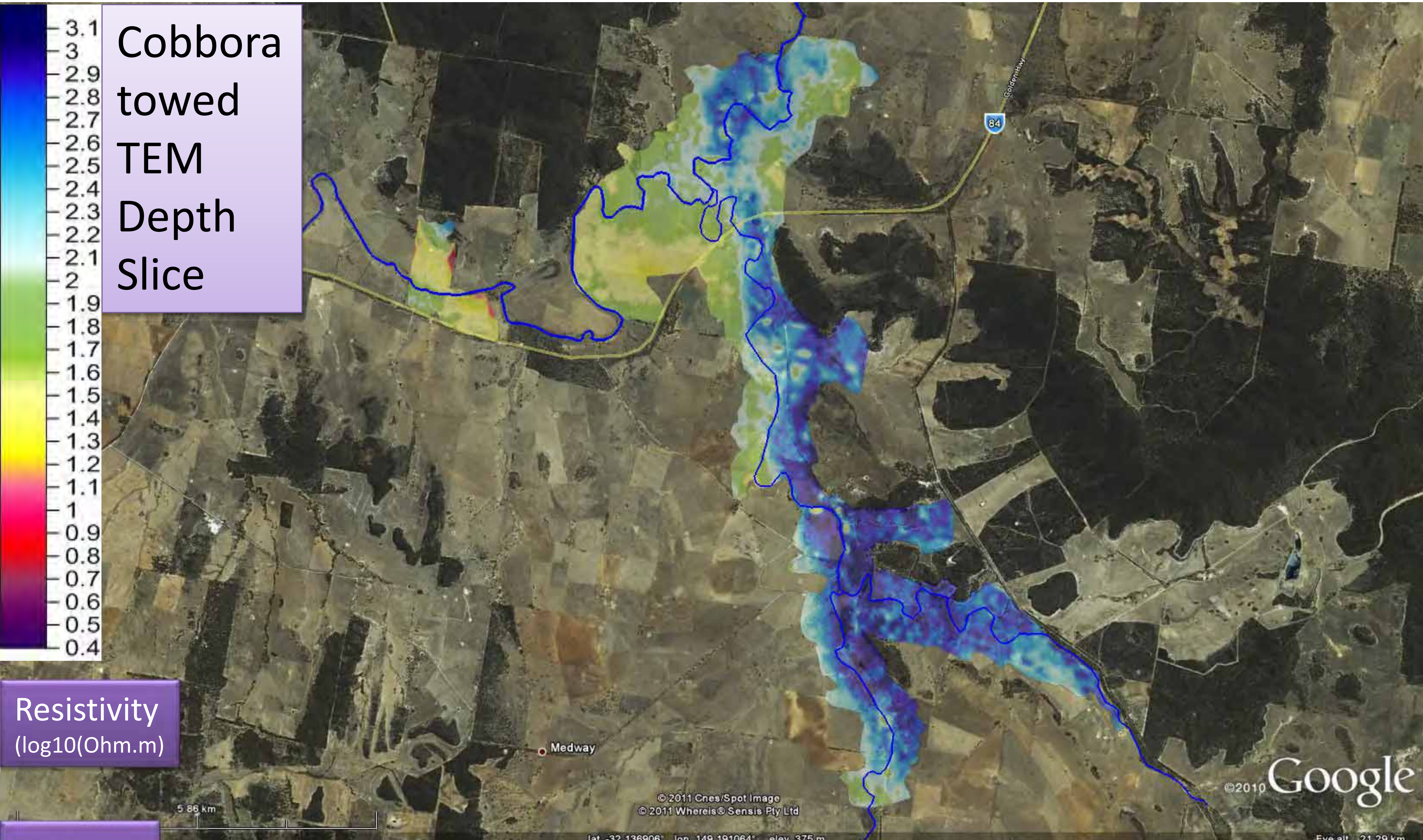
Resistivity
(log10(Ohm.m))

28m

Surveyed and processed by
Groundwater Imaging P/L
October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Cobbora towed TEM Depth Slice

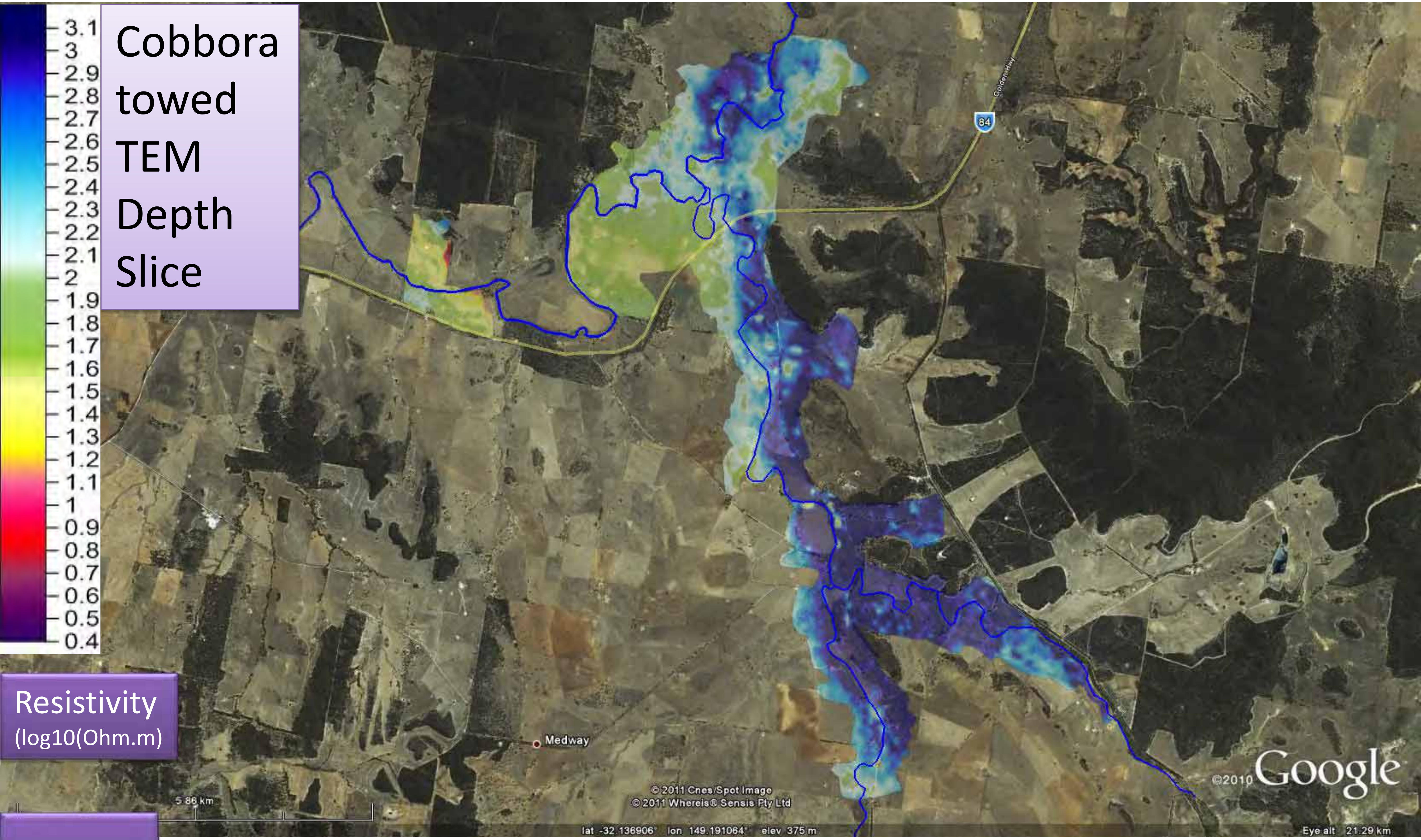


Resistivity (log10(Ohm.m)

36m

Surveyed and processed by Groundwater Imaging P/L October 2011

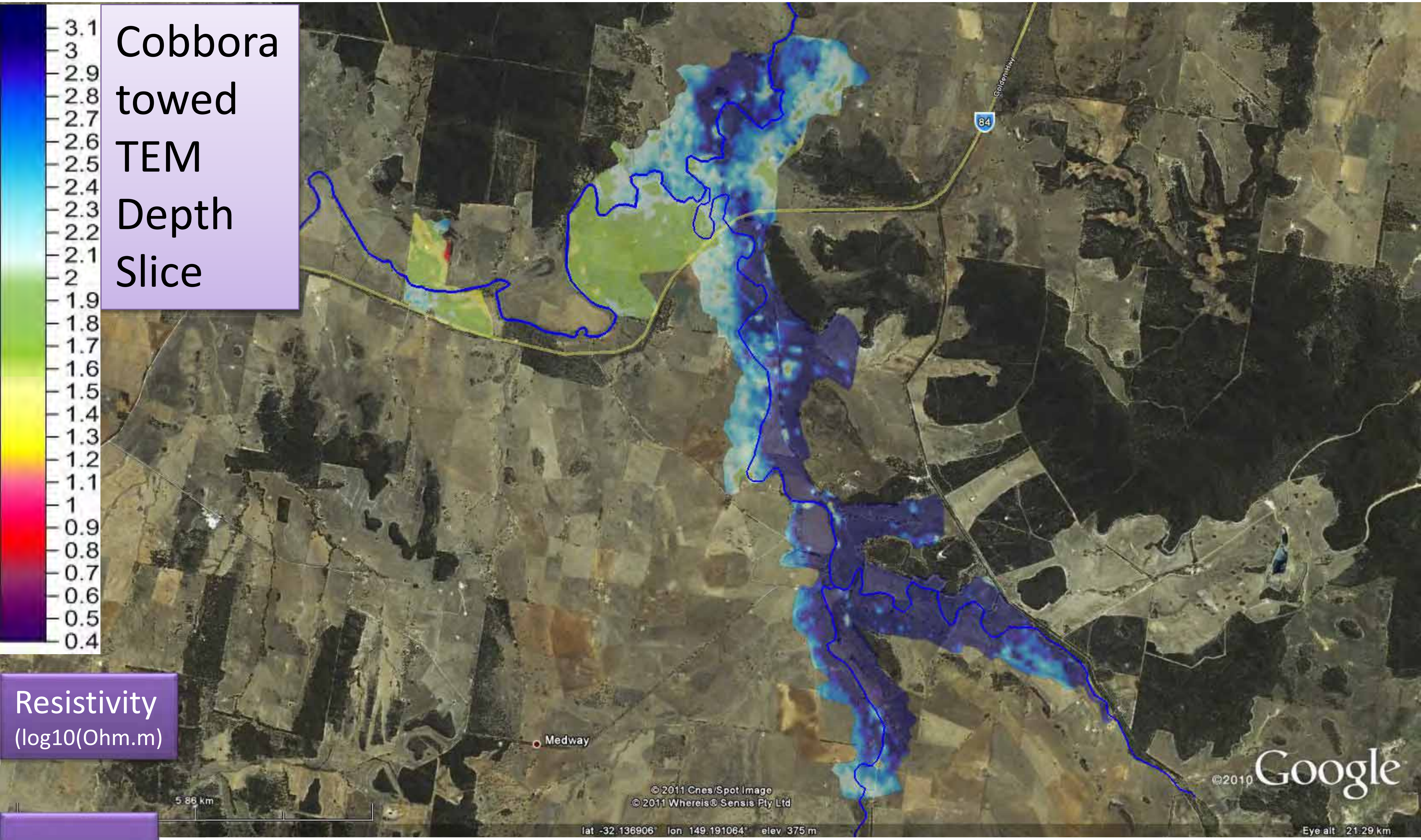
Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.



45m

Surveyed and processed by Groundwater Imaging P/L October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.



58m

Surveyed and processed by Groundwater Imaging P/L October 2011

Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.

Site specific 3D imagery and interpretation.

Inferred poorly sorted alluvial sands in the Talbragar River bank. These are only inferred because further comparison is needed to confirm that they are not simply weathered pre-Quaternary sedimentary strata. In this case it is thought that this is extremely unlikely.

Inferred saline eluvial plains on the west side of Sandy Creek. The towed TEM system is displayed with the large suspended transmitter loop in front of the trailing receiver loop.

Consolidated rock outcrop in Sandy Creek.
There is clearly no alluvium here.


Towed TEM in progress.

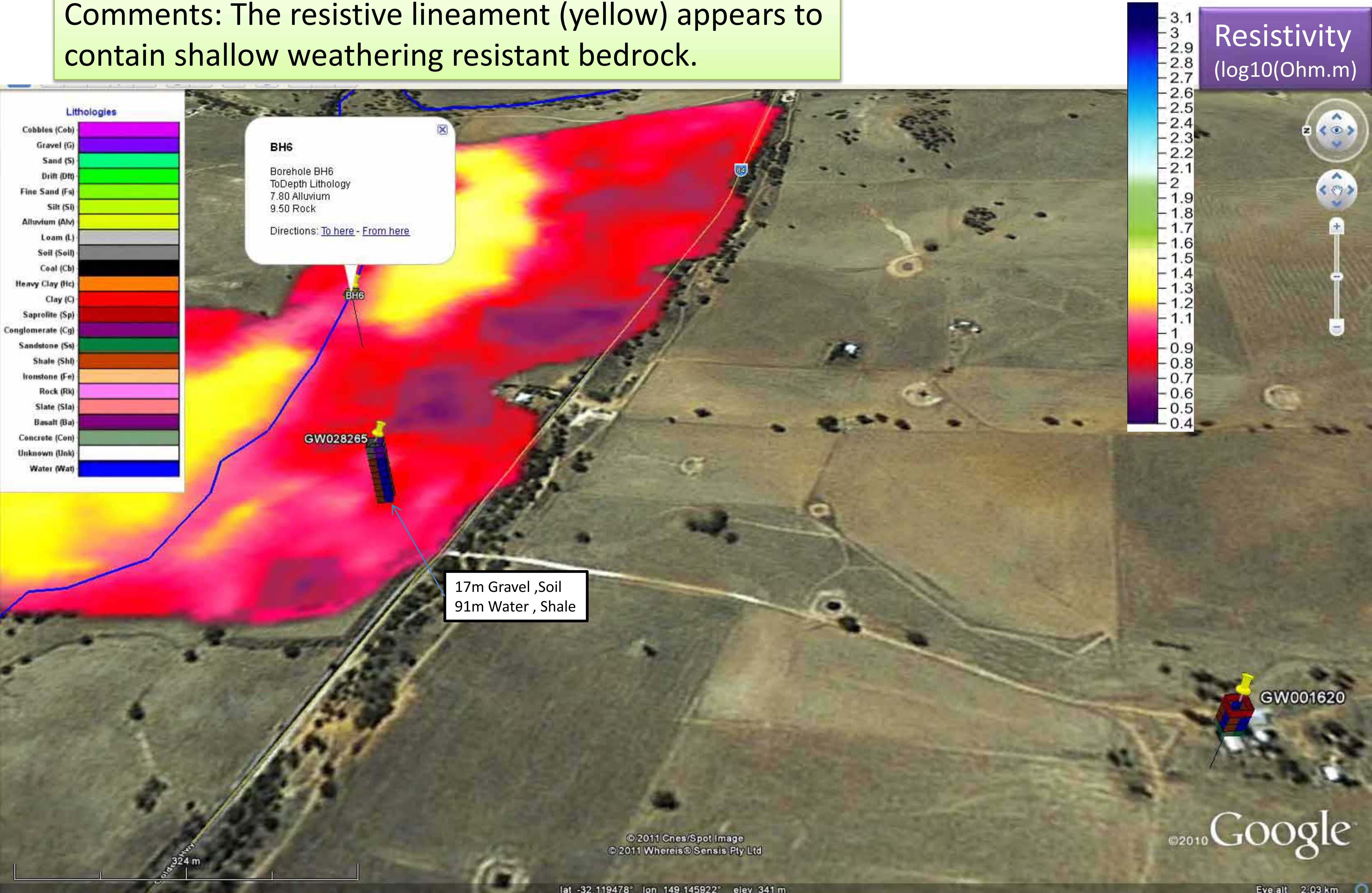

Rock outcrop in Sandy Creek at Sweeneys Road, viewed from the south-east.


Rock outcrop in Sandy Creek


Rock outcrop in Sandy Creek

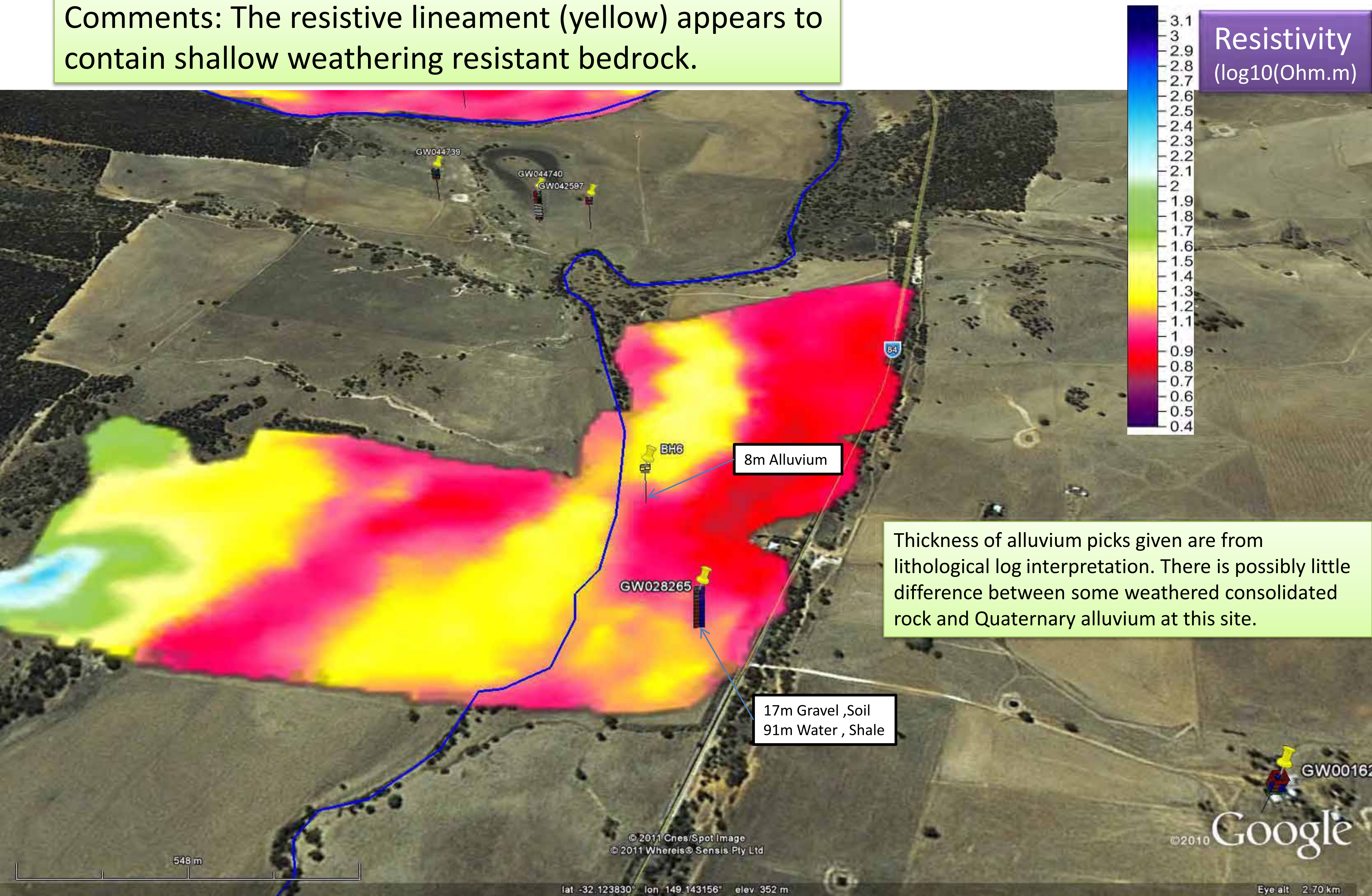
Bore details at O'Leary's viewed from the west over the 1m depth slice

Comments: The resistive lineament (yellow) appears to contain shallow weathering resistant bedrock.

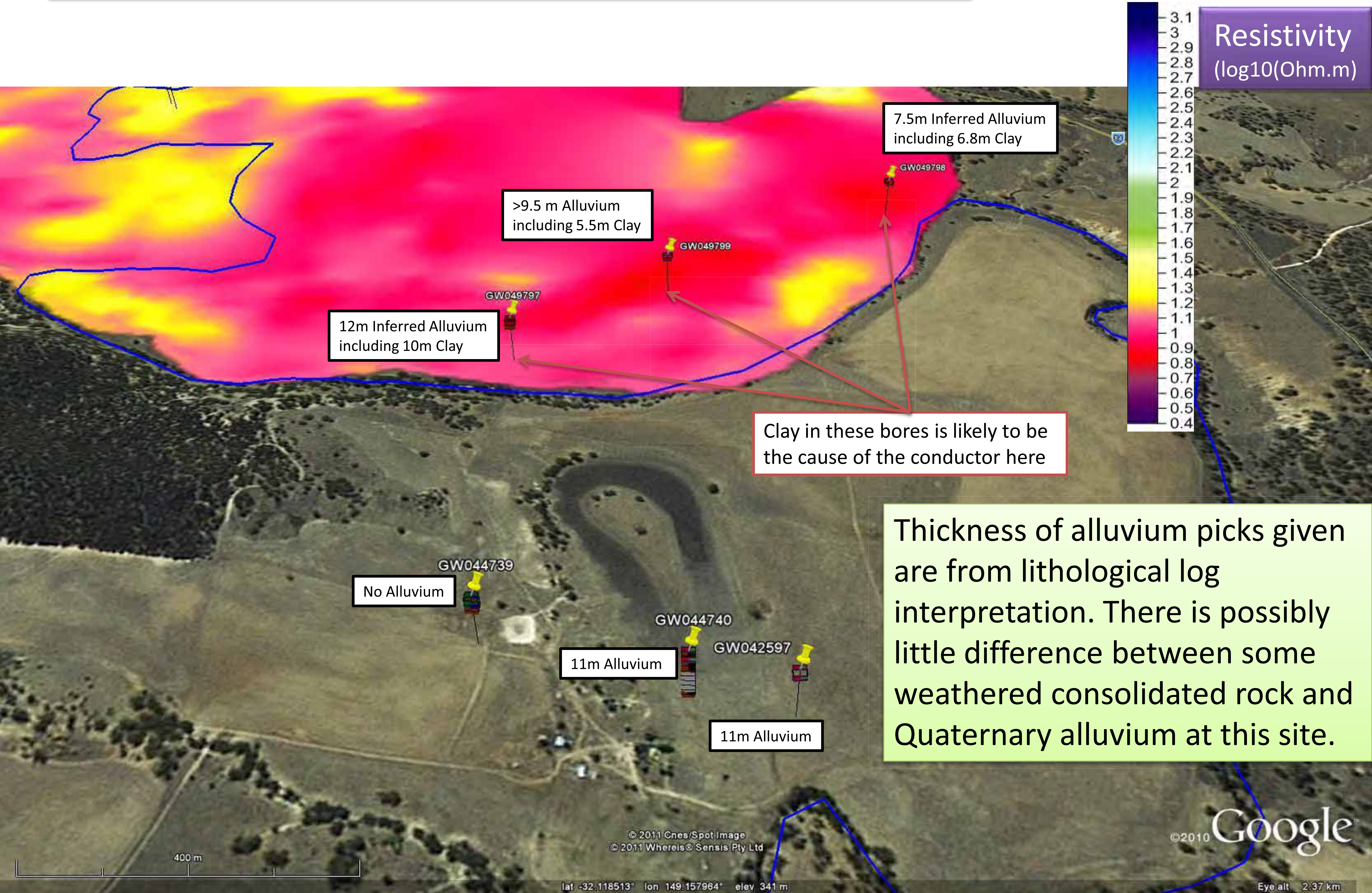


Bore details at O'Leary's viewed from the west over the 7m depth slice

Comments: The resistive lineament (yellow) appears to contain shallow weathering resistant bedrock.

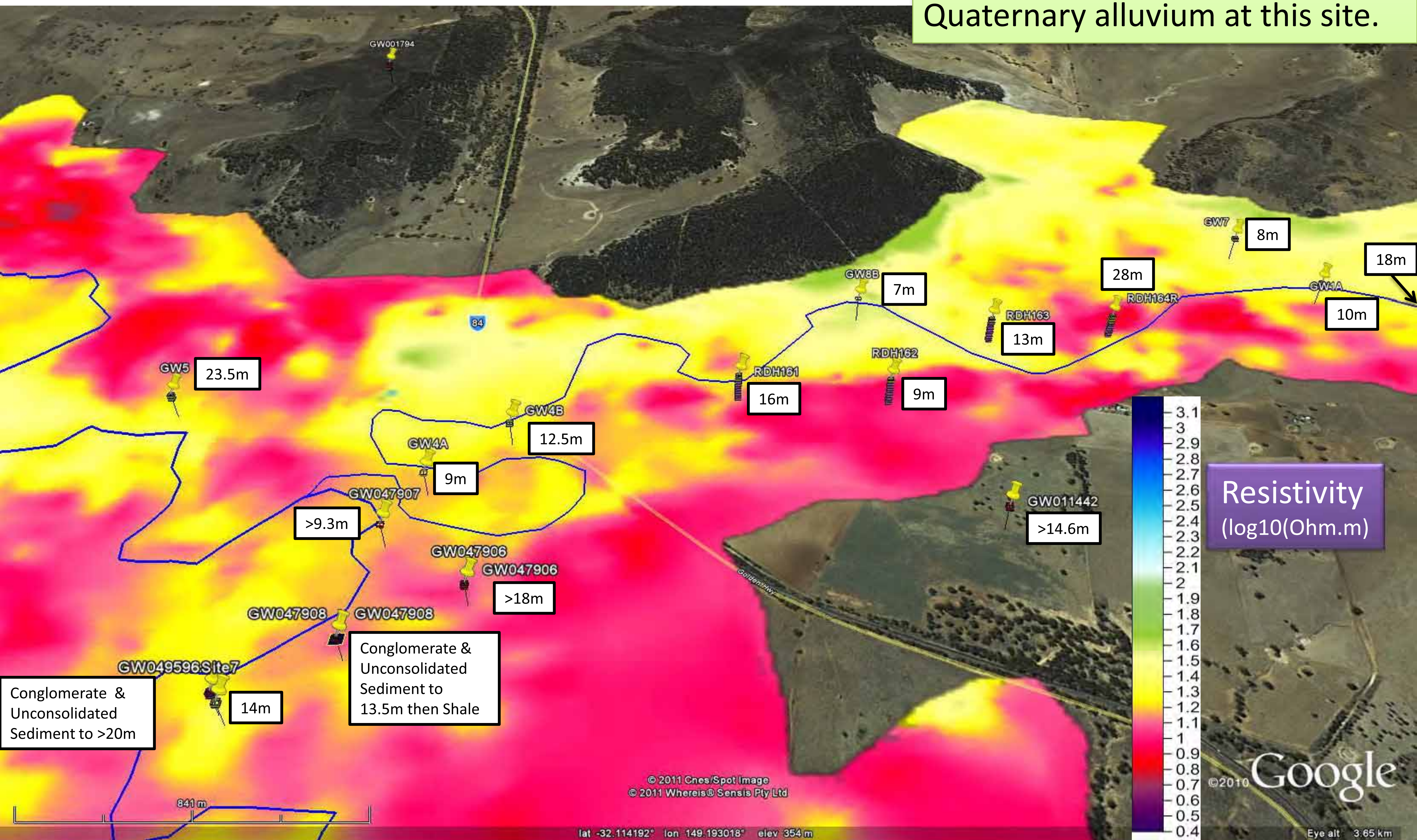


Bore details east of O'Leary's viewed from the west over the 7m depth slice.



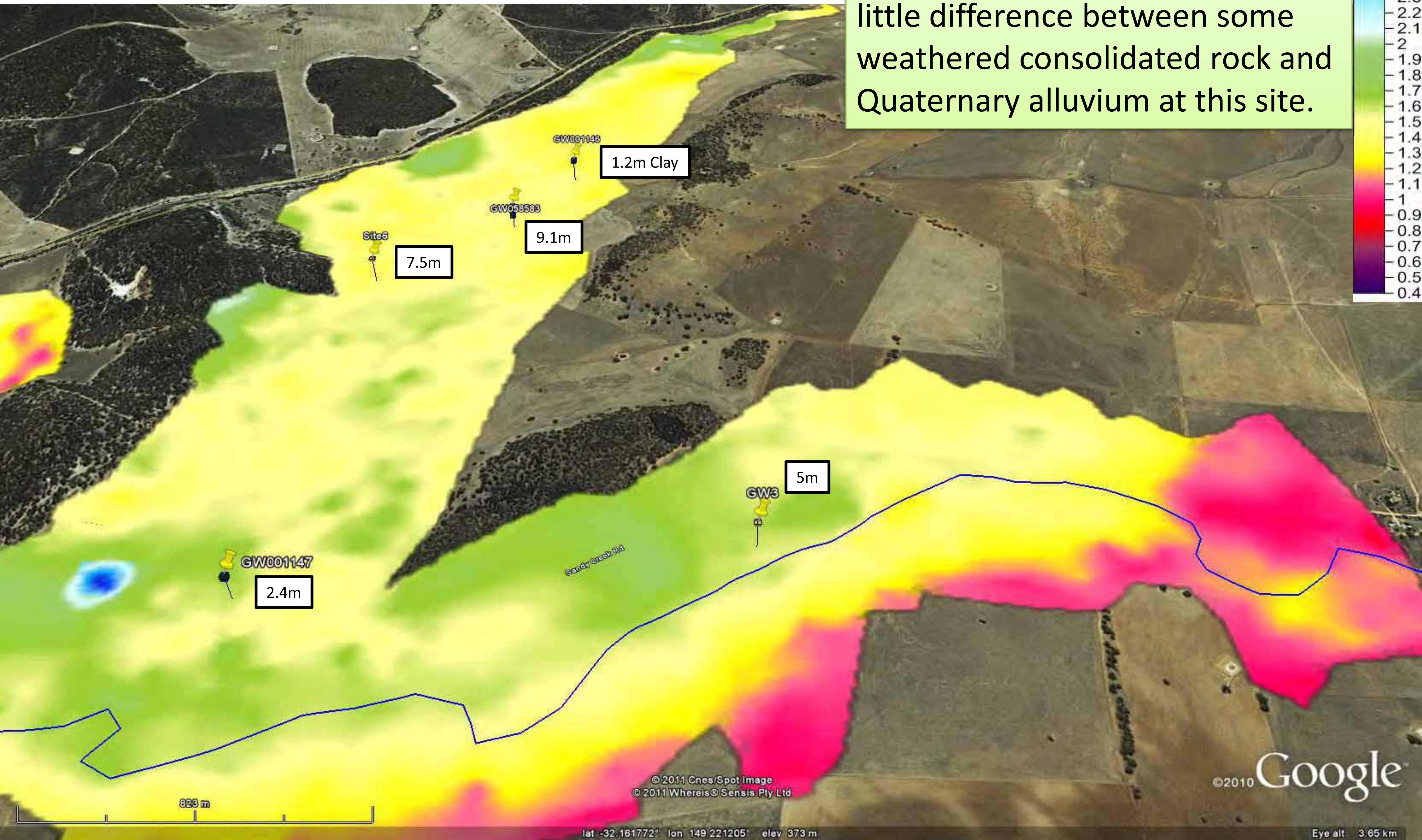
Bore details at the Talbragar River & Sandy Creek confluence viewed from the west over the 7m depth slice

Thickness of alluvium picks given are from lithological log interpretation. There is possibly little difference between some weathered consolidated rock and Quaternary alluvium at this site.

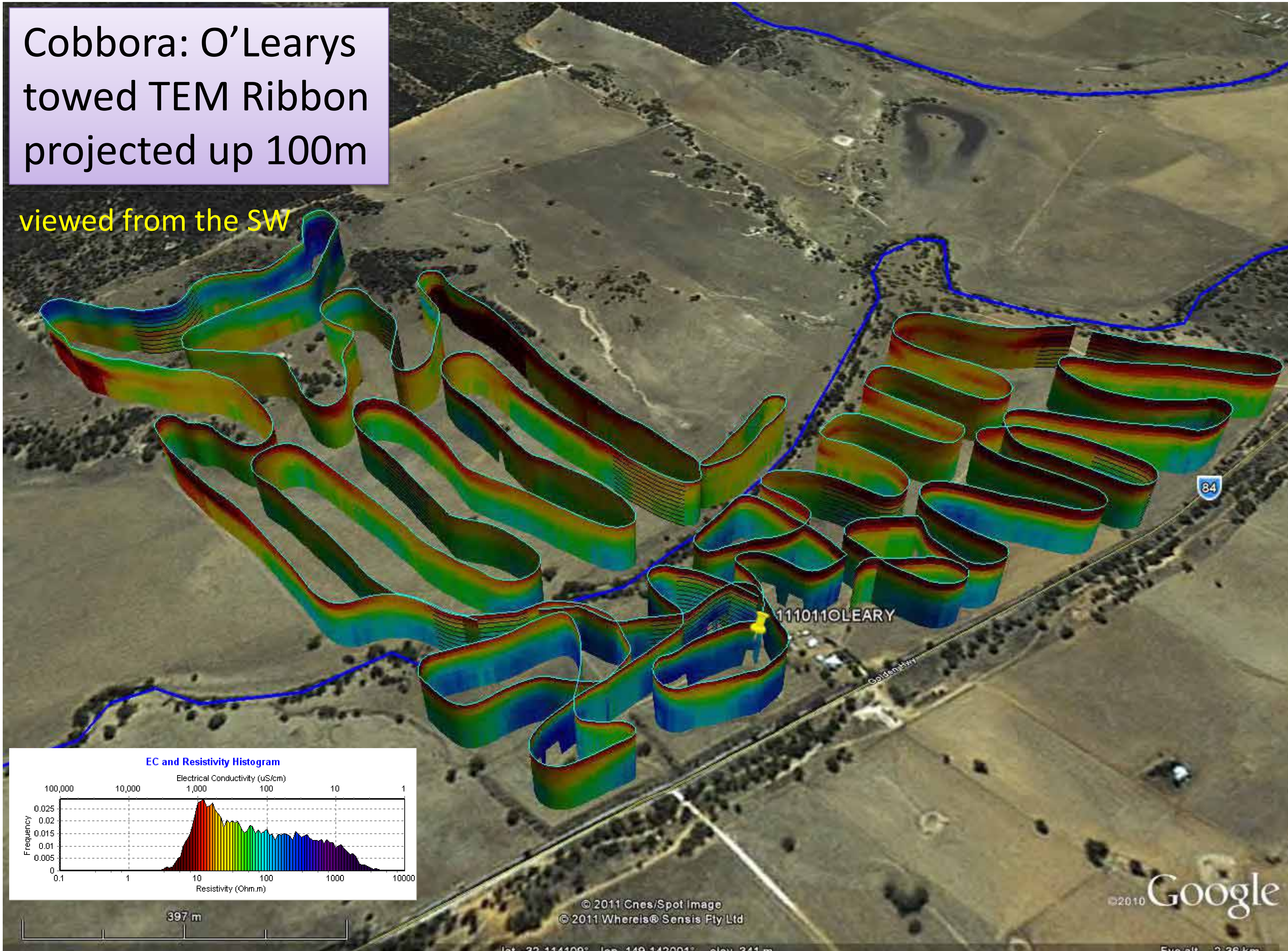


Bore details at Laheys Creek and Sandy Creek confluence viewed from the west over the 7m depth slice.

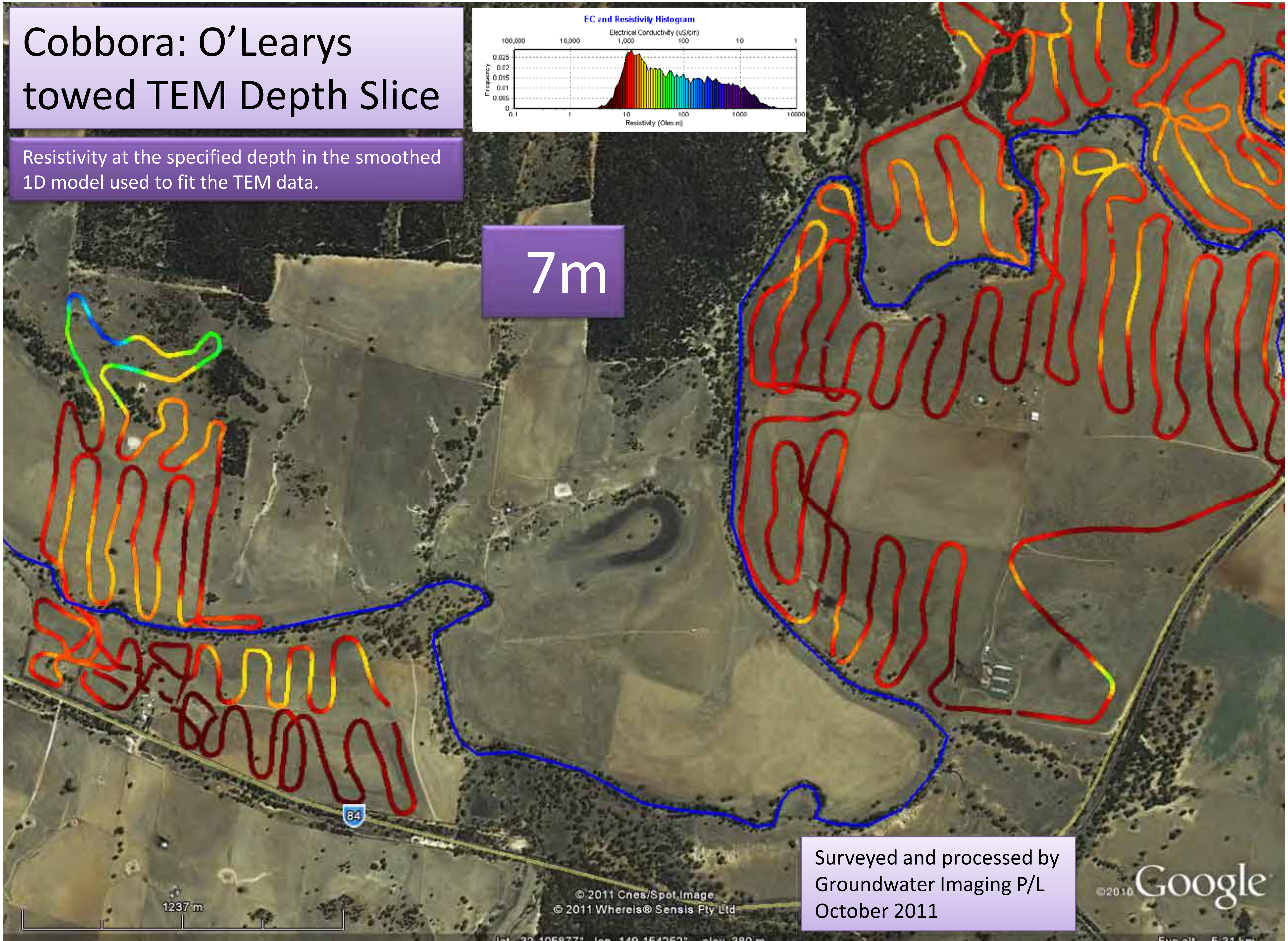
Thickness of alluvium picks given are from lithological log interpretation. There is possibly little difference between some weathered consolidated rock and Quaternary alluvium at this site.

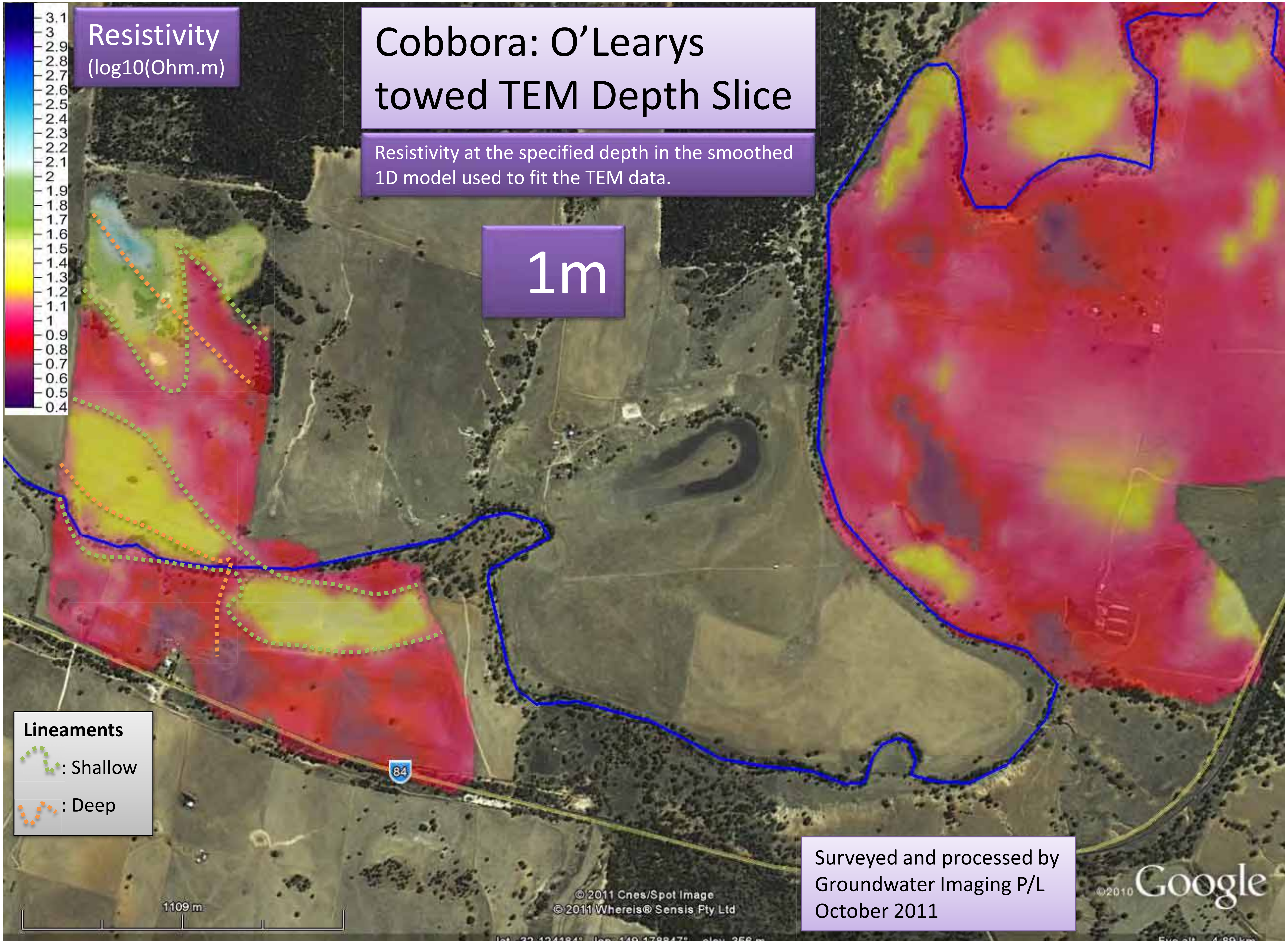


Cobbora: O'Learys towed TEM Ribbon projected up 100m



Cobbora: O'Learys towed TEM Depth Slice




Resistivity
(log10(Ohm.m)
3.1
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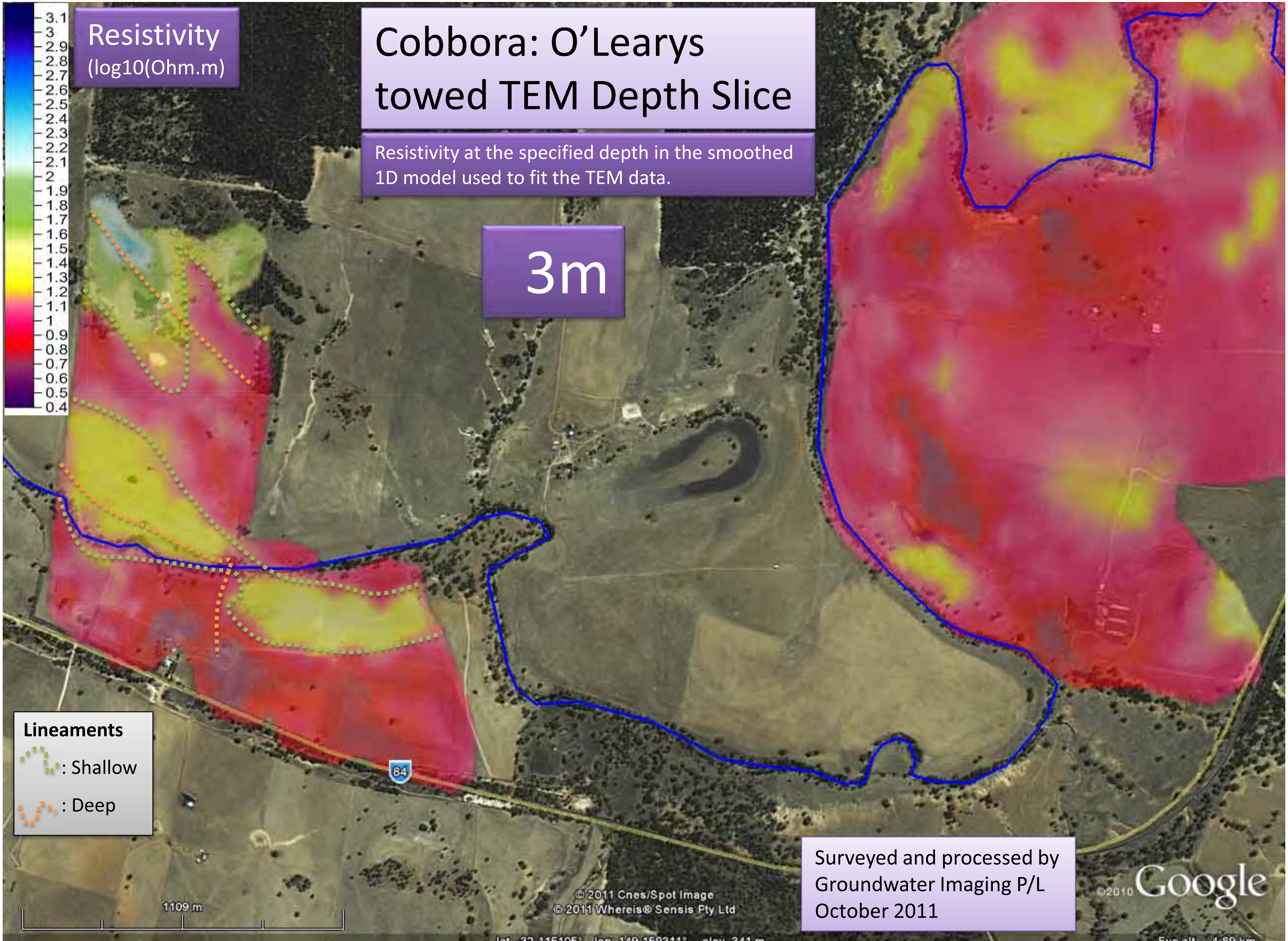
0.4
Cobbora: O'Learys
towed TEM Depth Slice
Resistivity at the specified depth in the smoothed 1D model used to fit the TEM data.
1m
Lineaments
: Shallow
: Deep
84
1109 m
© 2011 Cnes/Spot Image
© 2011 Whereis® Sensis Pty Ltd
lat -32.124184° lon 149.178847° elev 356 m
Surveyed and processed by
Groundwater Imaging P/L
October 2011
©2010 Google
Eye alt 4.89 km



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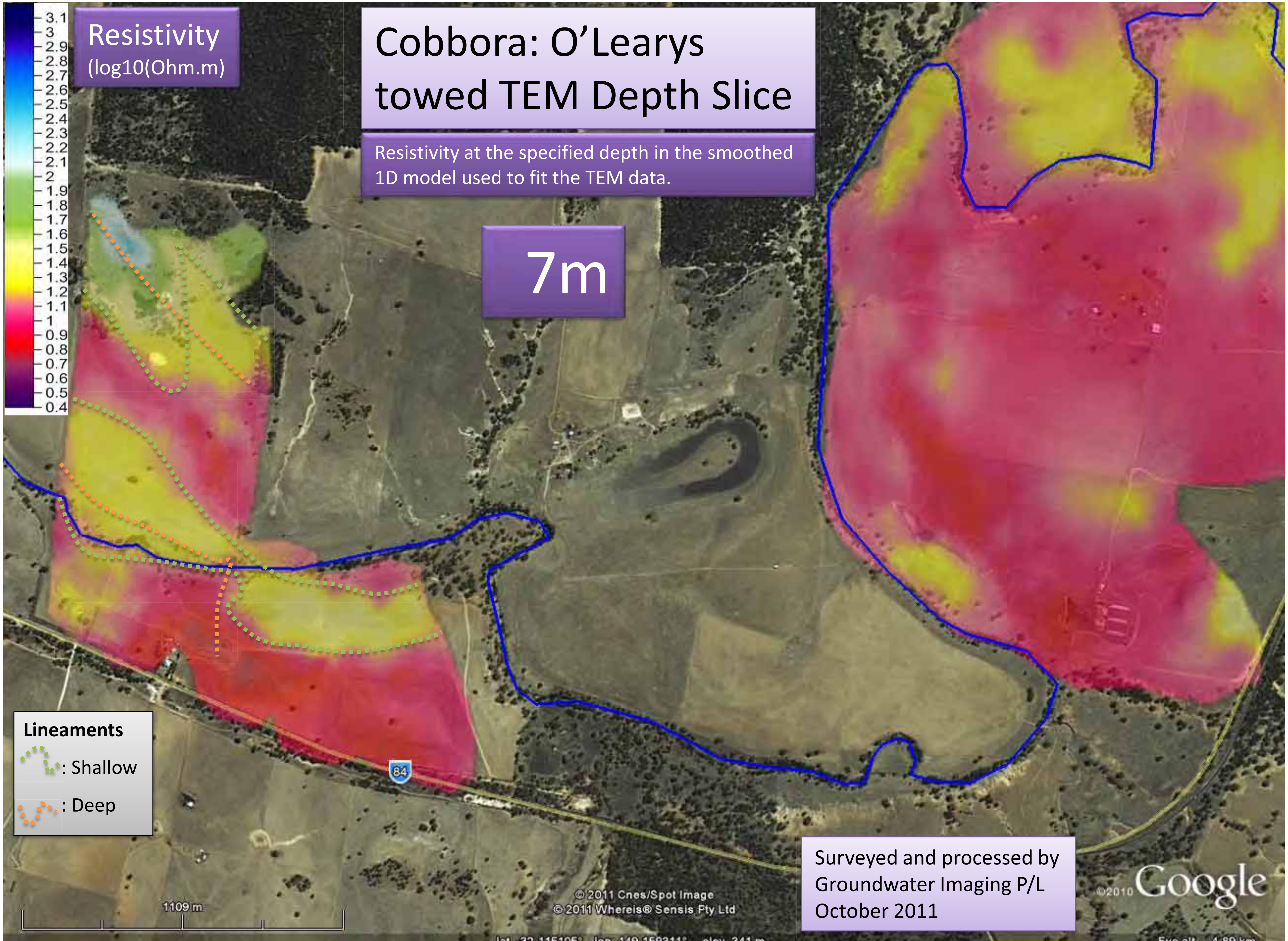
Lineaments
: Shallow
: Deep
84
1109 m
© 2011 Cnes/Spot Image
© 2011 Whereis® Sensis Pty Ltd
lat -32.115105° lon 149.159311° elev 341 m
Eye alt 4.89 km
©2010 Google
Surveyed and processed by Groundwater Imaging P/L October 2011



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© 2011 Cnes/Spot Image
© 2011 Whereis® Sensis Pty Ltd
lat -32.115105° lon 149.159311° elev 341 m
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©2010 Google
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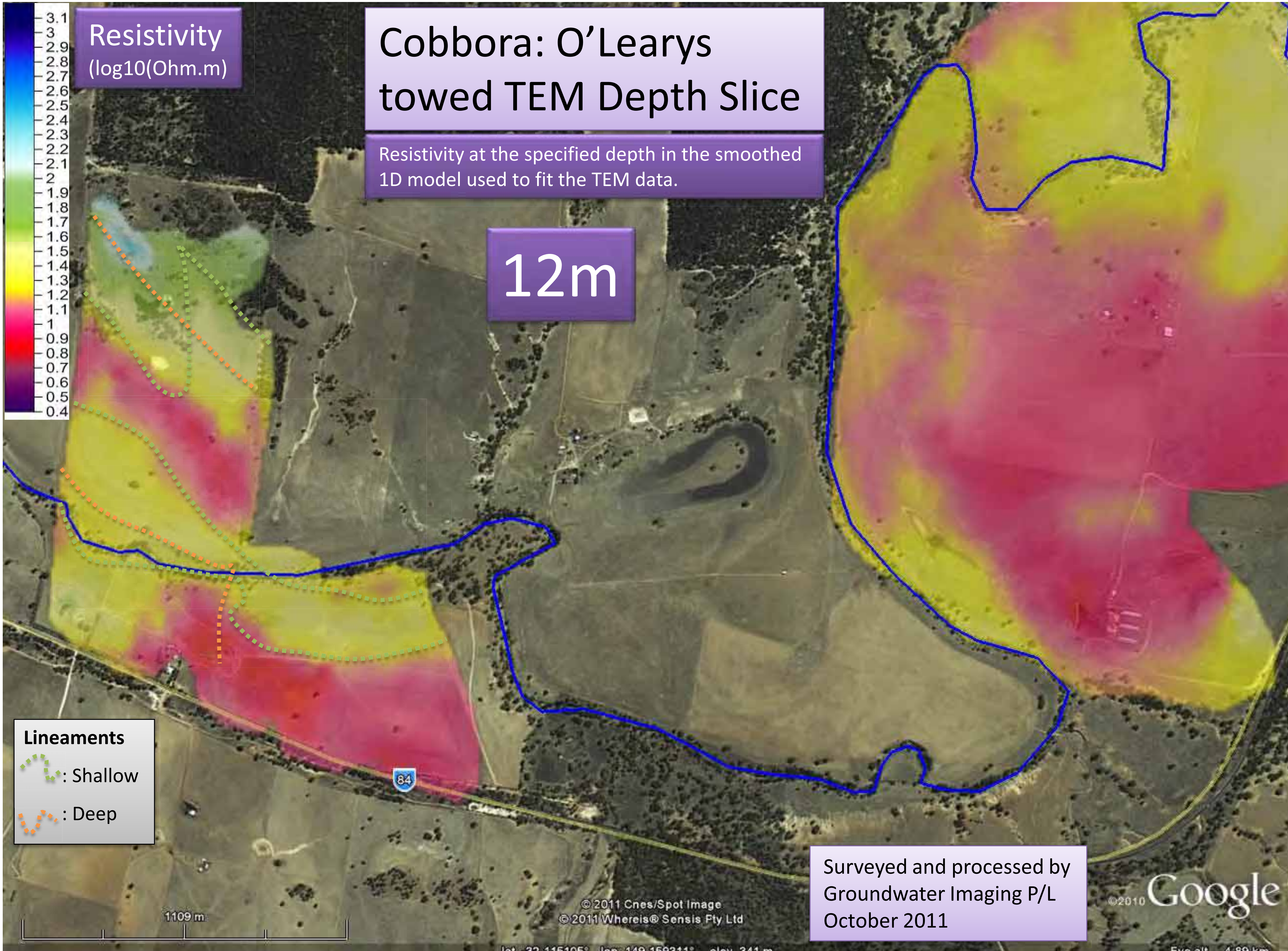
October 2011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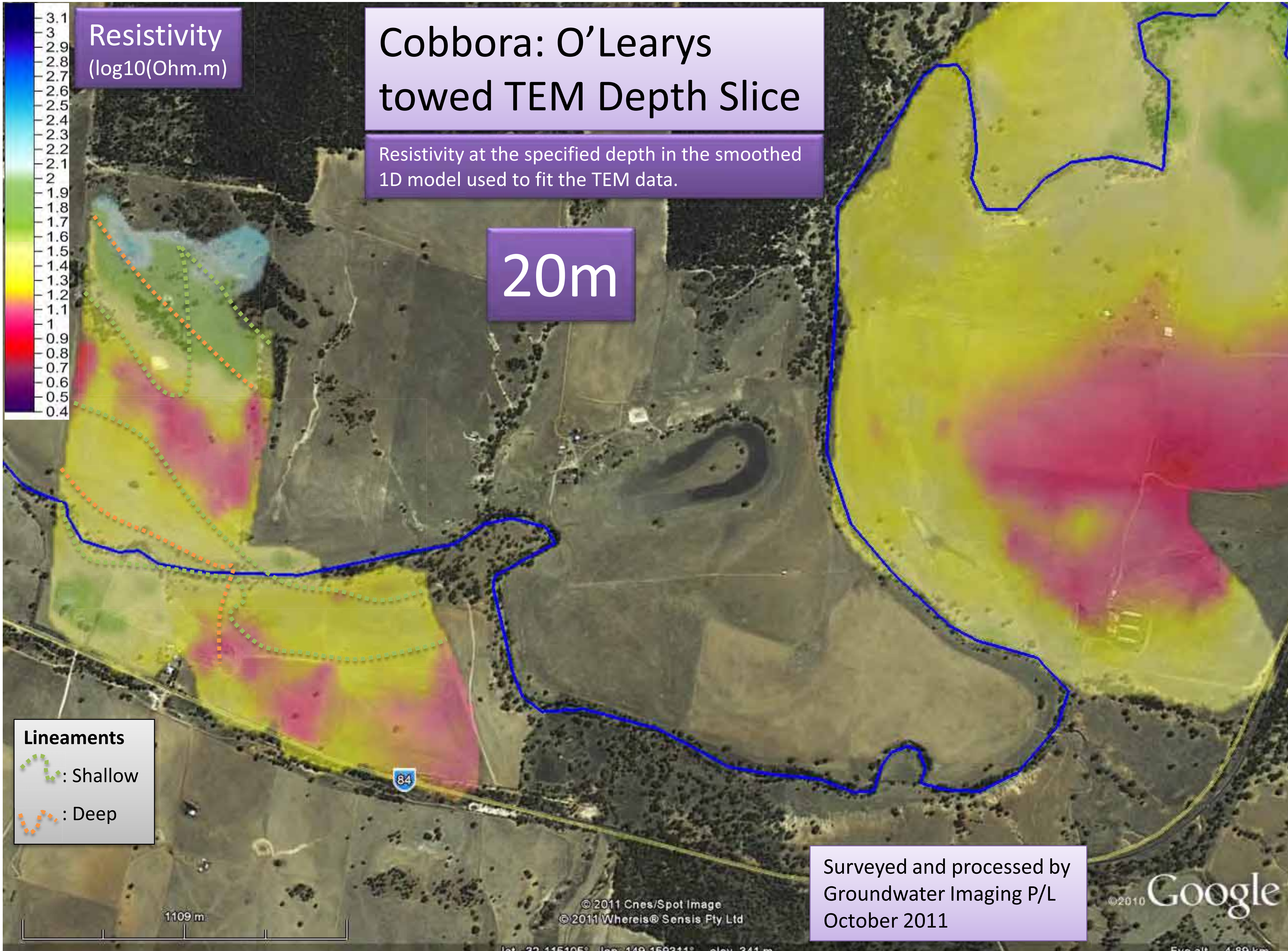

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lat -32.115105° lon 149.159311° elev 341 m
Surveyed and processed by Groundwater Imaging P/L October 2011
©2010 Google
Eye alt 4.89 km