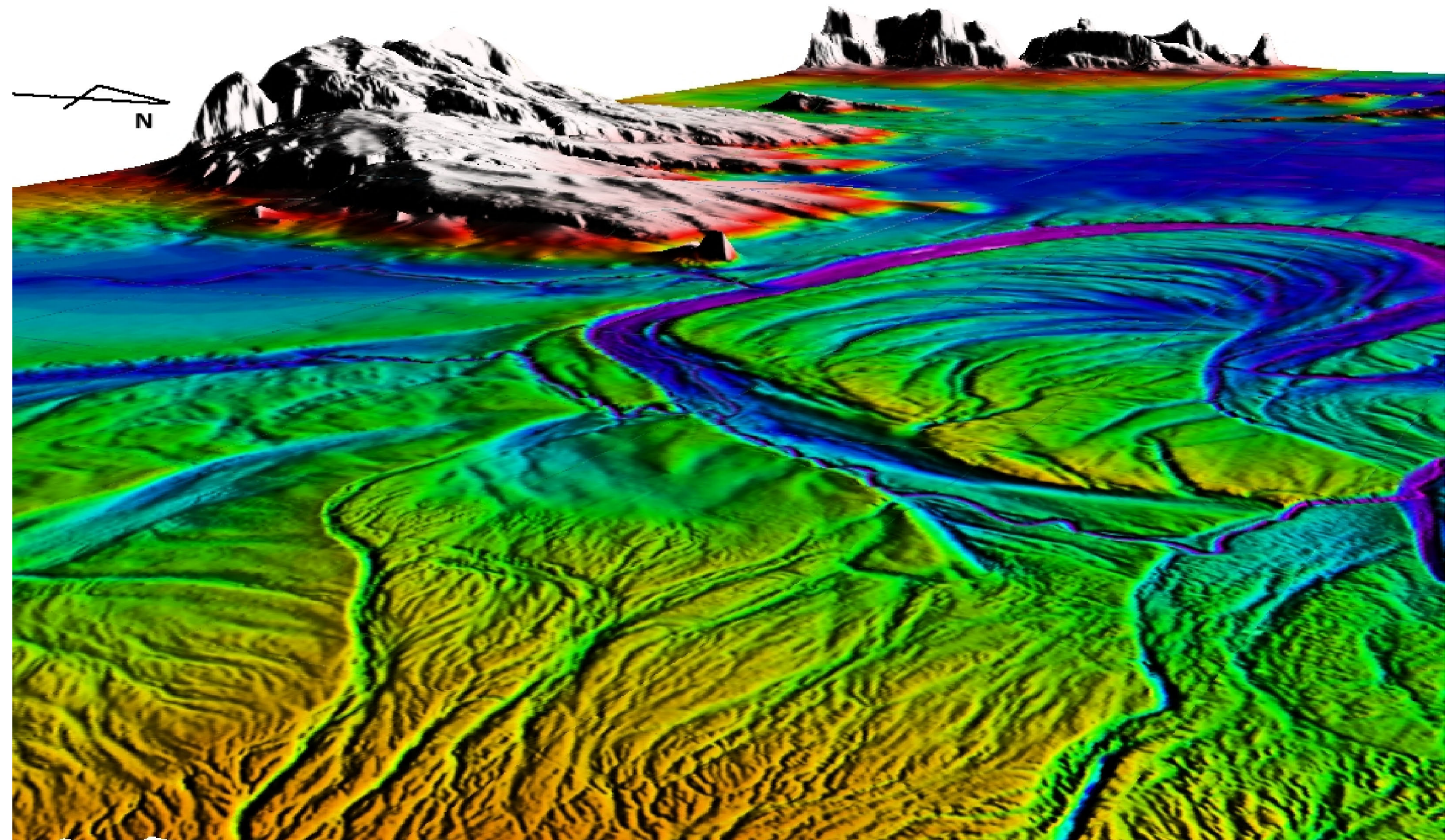
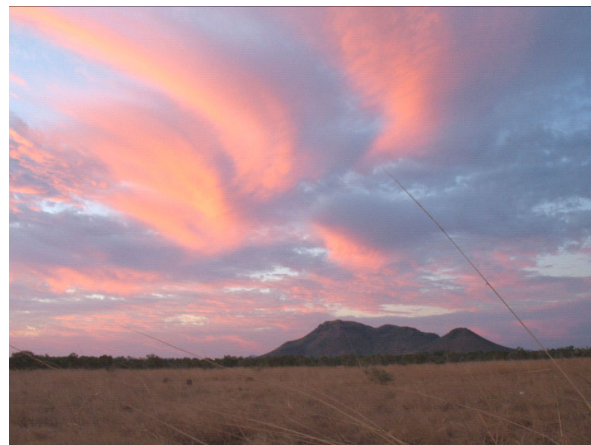


ATLAS - ORD VALLEY AEM INTERPRETATION PROJECT

MANTINEA PLAIN, CARLTON HILL & PARRY'S LAGOON



Maps produced by Heike Apps, Kristen Cullen, KP Tan, Larysa Halas, Jon Clarke, Ken Lawrie, Andrew Fitzpatrick and Tim Munday



Australian Government
Department of the Environment,
Water, Heritage and the Arts



Rangelands NRM
Western Australia



National Research
FLAGSHIPS
Water for a Healthy Country



Australian Government
Geoscience Australia

INTRODUCTION

This Atlas contains a suite of map products generated as part of the Ord Valley Airborne Electromagnetics (AEM) Interpretation Project. The project was co-funded by the Australian and Western Australian Governments to provide information in relation to salinity and groundwater management in the Ord Valley, Western Australia. The project involved the acquisition of airborne electromagnetic (AEM) and Light Ranging and Detection (LiDAR) surveys, and complementary drilling, borehole geophysics, laboratory analysis and interpretation services. The project was undertaken under the auspices of the National Action Plan for Salinity and Water Quality, and managed by Ord Irrigation Cooperative (OIC) for the WA Rangelands NRM Group. The Project was established in line with the scientific and technical standards established for salinity mapping in the Australian landscape context by the Joint Academies of Science (Spies and Woodgate, 2005).

A total of 5,936 line km of AEM data were acquired in July and August 2008, using the SkyTEM time domain AEM system operated by Geoforce Pty Ltd. The project area covered the existing Ord Irrigation Area (ORIA) Stage 1, and the Stage 2 areas earmarked for irrigation extension, including the Weaber, Keep River and Knox Creek Plains, and the Mantinea - Carlton Hill - Parry's Lagoon area. At the time of survey, existing boreholes were geophysical logged and water samples taken to assist with AEM data calibration. In addition to a program of surface geomorphic and salinity mapping and sampling, a limited program of new drilling was undertaken in May 2009 to obtain geological materials and samples for pore fluid analysis.

The Atlas products provide an overview of key elements of the hydrostratigraphy of the area including the distribution of sand and gravel aquifers, a regional water table map, groundwater quality (salinity), and salt stores. The geophysical datasets have been calibrated and validated using data from drilling and field sampling. The atlas products are complemented by release of a project GIS (Apps et al., 2009) containing all the AEM, LiDAR, drilling, field sampling and laboratory analytical data, as well as the interpretation products, and a final scientific report (Lawrie et al., 2009).

**Dr. Ken Lawrie
Project Leader
Ord Valley AEM Interpretation Project**

Contents

- | | | |
|----------------------------------|---|--|
| 1. Location of Project area | 12. Orthophoto | 23. Groundwater Salinity (TDS) |
| 2. Topographic Information | 13. Low Resolution DEM | 24. Surface Salinity (predictive classes) |
| 3. LANDSAT Imagery | 14. LiDAR | 25. Sub-surface Extent of Lithological Units |
| 4. Pre-existing Hydrogeology | 15. Potential Soil & Surface Permeability | 26. Clay Thickness |
| 5. Geology & Structure | 16. SkyTEM AEM Survey | 27. Gravel Thickness |
| 6. Geomorphology | 17. AEM Flight Survey Lines | 28. Sand Thickness |
| 7. Borehole Locations | 18. AEM Depth Slices | 29. Depth to Bedrock |
| 8. Vegetation - NDVI | 19. AEM Cross Sections (some examples) | 30. Flush Zones |
| 9. Regional Watertable | 20. Conductivity Above Watertable | 31. Flush Zone Thickness |
| 10. Gamma Ray Spectrometry | 21. Conductivity Below Watertable | 32. Salinity Hazard |
| 11. Low Resolution Aeromagnetics | 22. Salt Store | |

Ord Valley AEM Interpretation Project - Mantinea Plain, Carlton Hill & Parry's Lagoon Atlas; Apps, H.E¹.; Cullen, K¹; Tan, K.P¹; Halas, L¹.; Clarke, J.D.A¹.; Lawrie, K.C¹, Fitzpatrick, A².; Munday, T.J.², 2009.

¹ Geoscience Australia; ² CSIRO

Front cover image: 3D LiDAR image showing Parry's Lagoon looking from the Ord River to the South West (image - Heike Apps). Front cover photos from top to bottom: Elephant Rock and Lake Kununurra, Boab tree (photos - Ken Lawrie); centre - sunset at Carlton Plain (photo - Heike Apps).

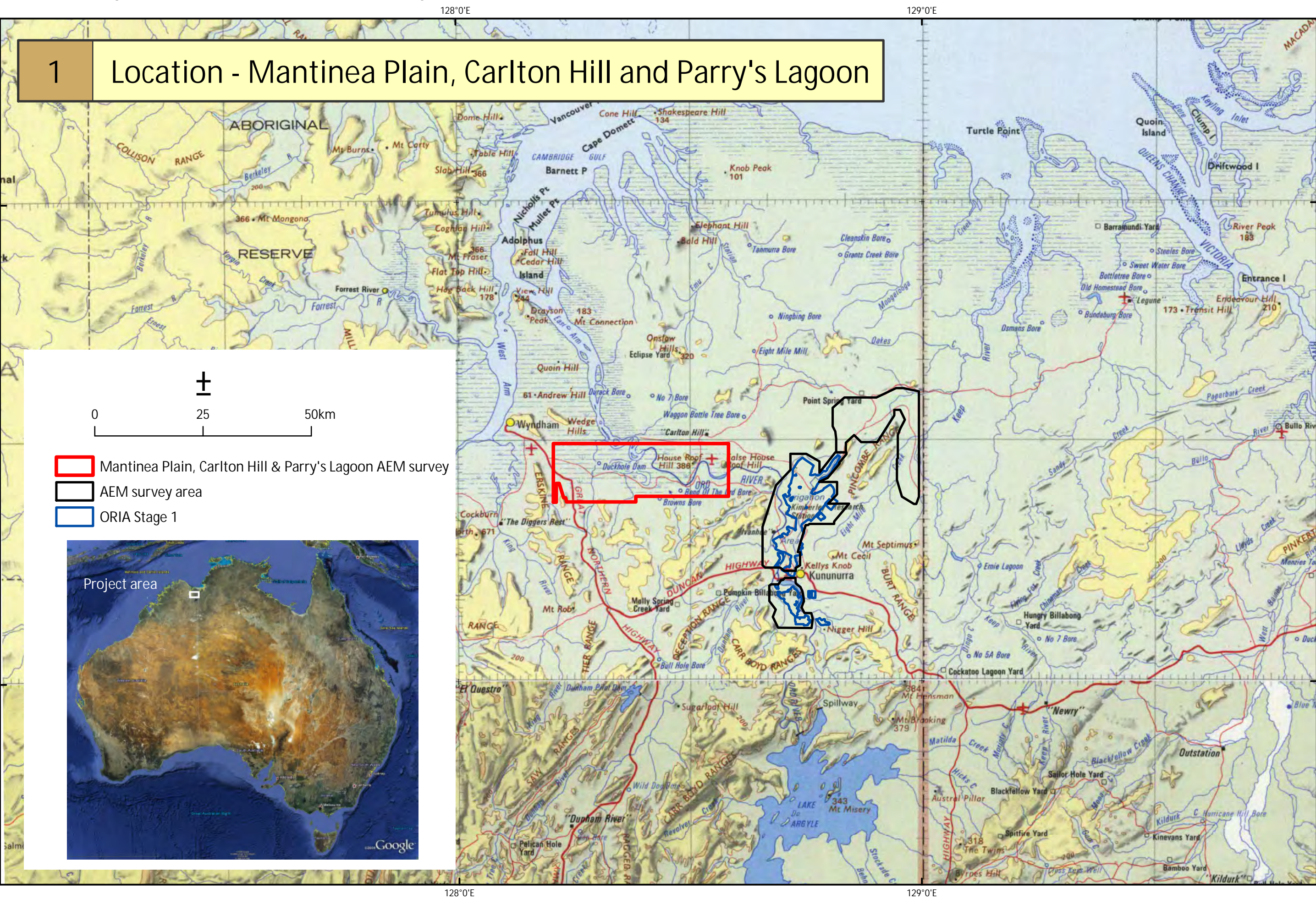
Copyright (c) Commonwealth of Australia 2009

This work is copyright. Apart from any fair dealings for the purposes of study, research, criticism or review, as permitted under the Copyright Act, no part may be reproduced by any process without written permission. Inquiries should be directed to the Communications Unit, Geoscience Australia, GPO Box 378, Canberra City, ACT, 2601.

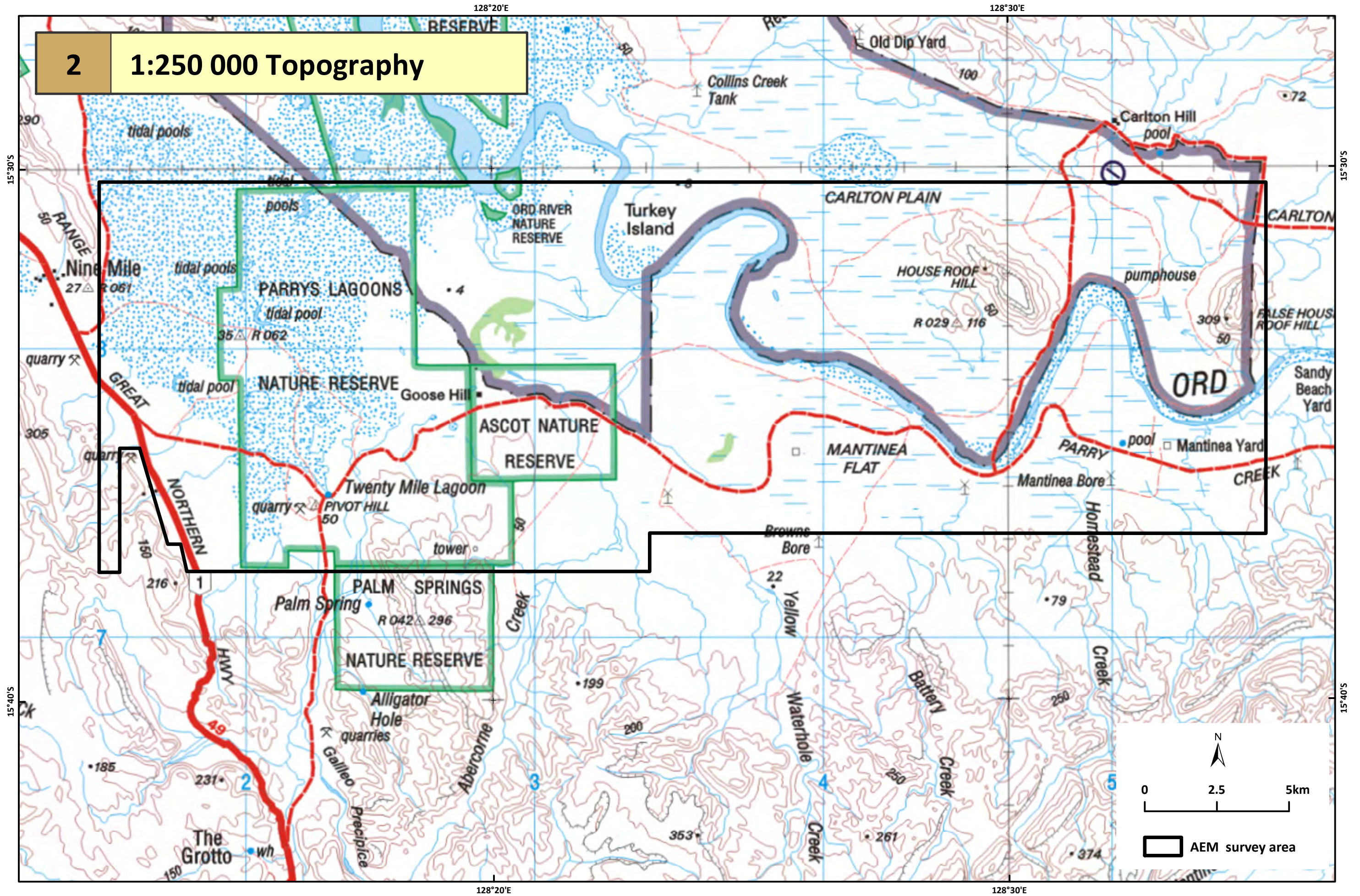
Geoscience Australia has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information is totally accurate or complete.

THEREFORE YOU SHOULD NOT RELY SOLELY ON THIS INFORMATION WHEN MAKING A COMMERCIAL DECISION.

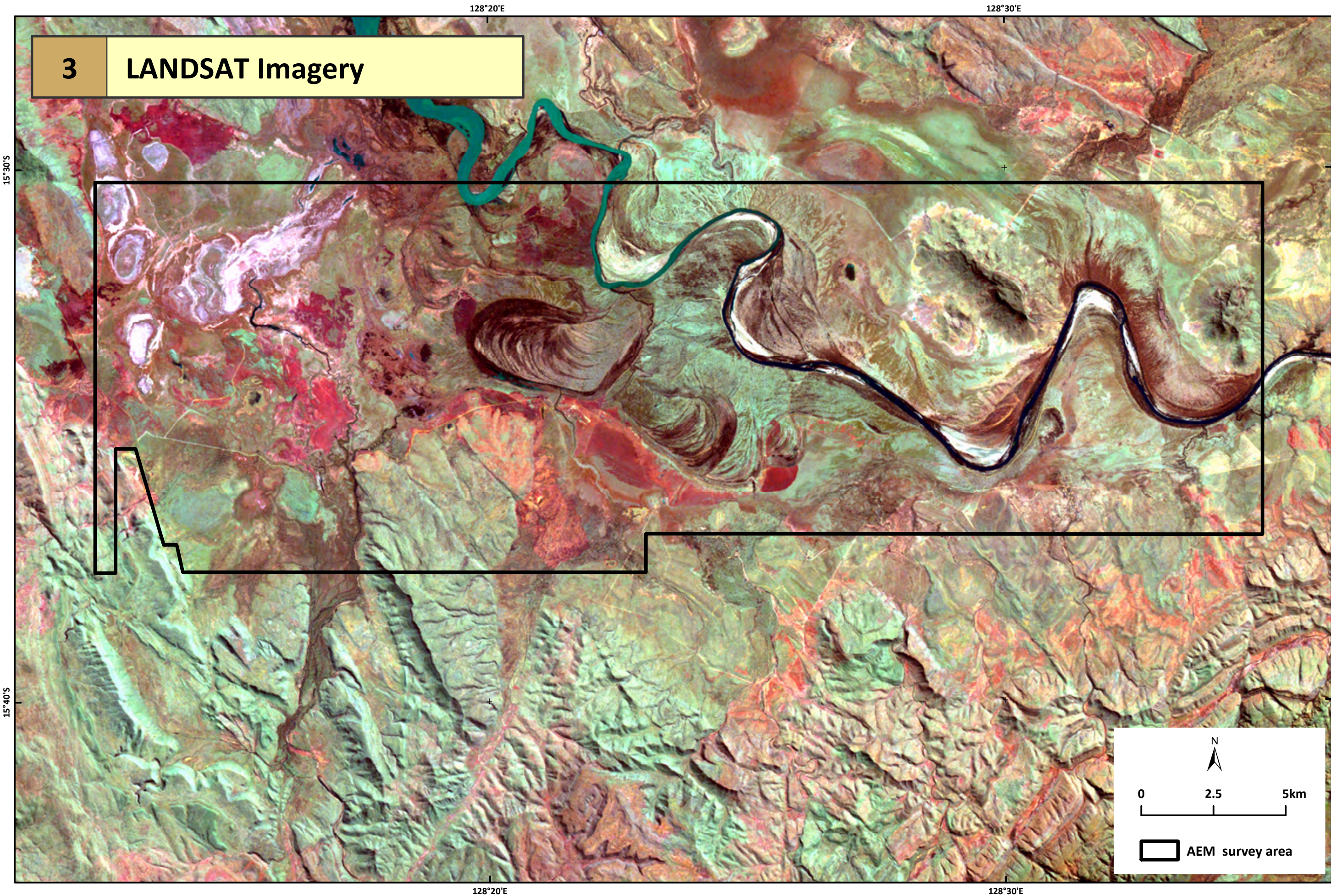
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



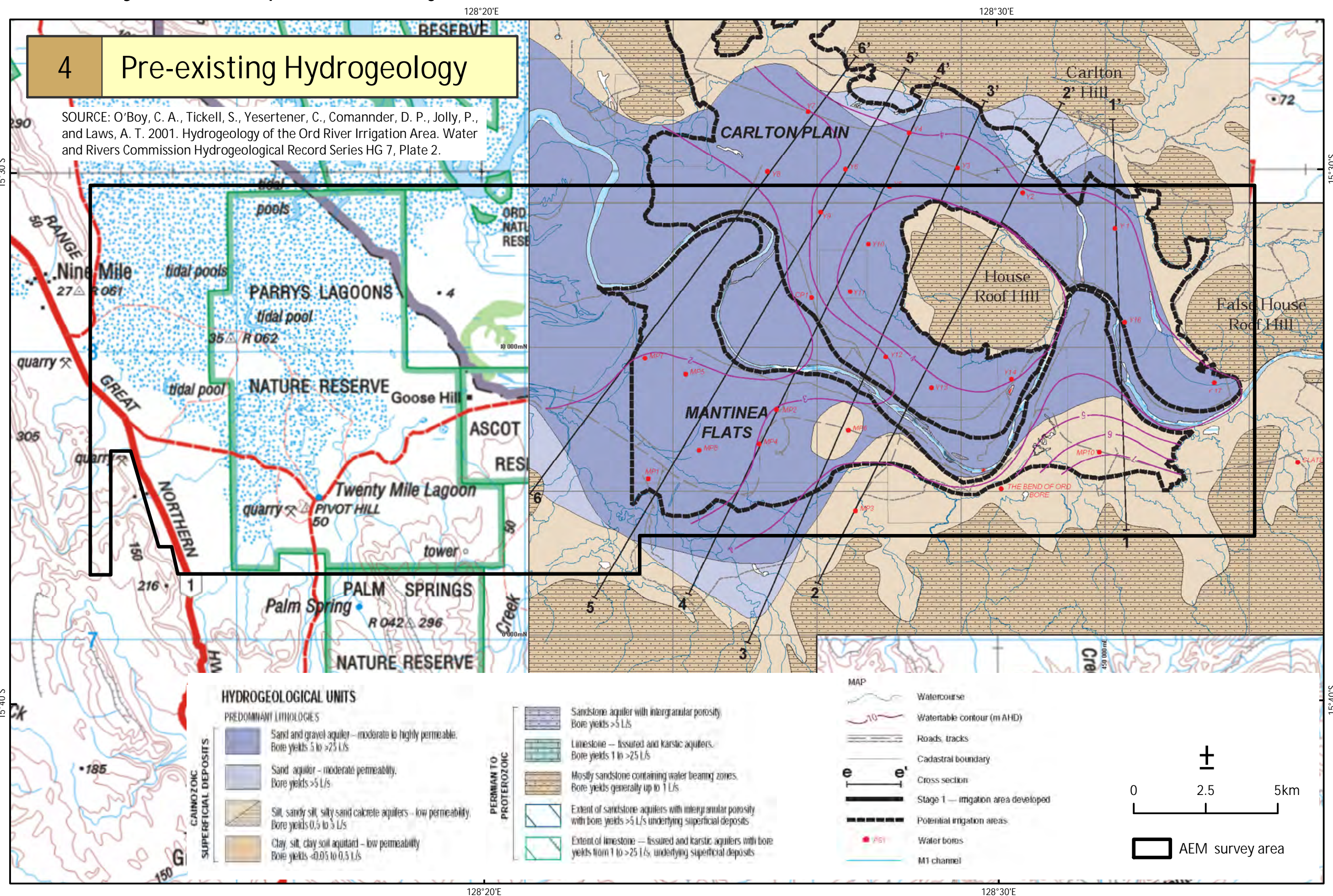
Ord Valley AEM Interpretation Project



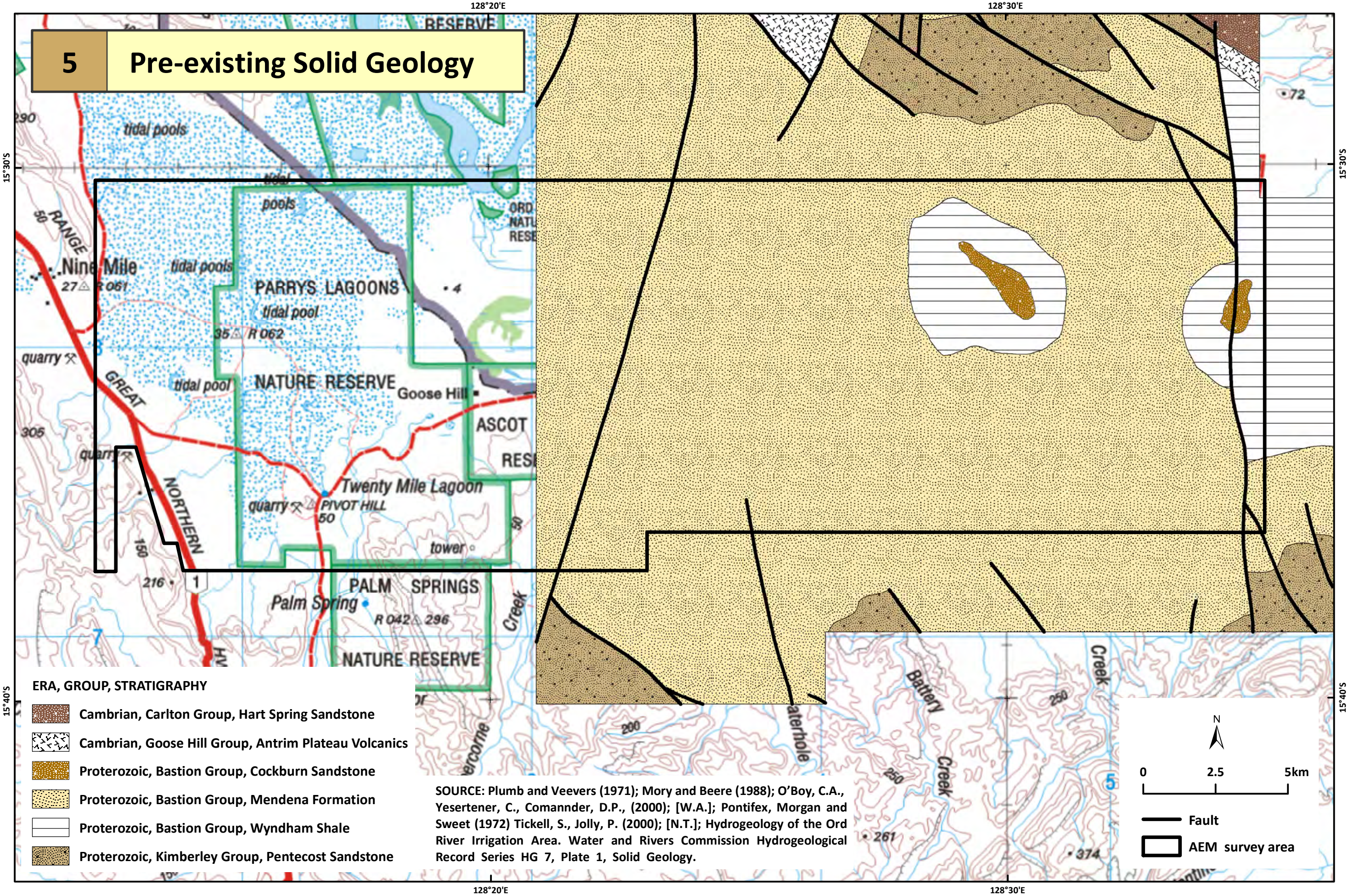
Ord Valley AEM Interpretation Project

4 Pre-existing Hydrogeology

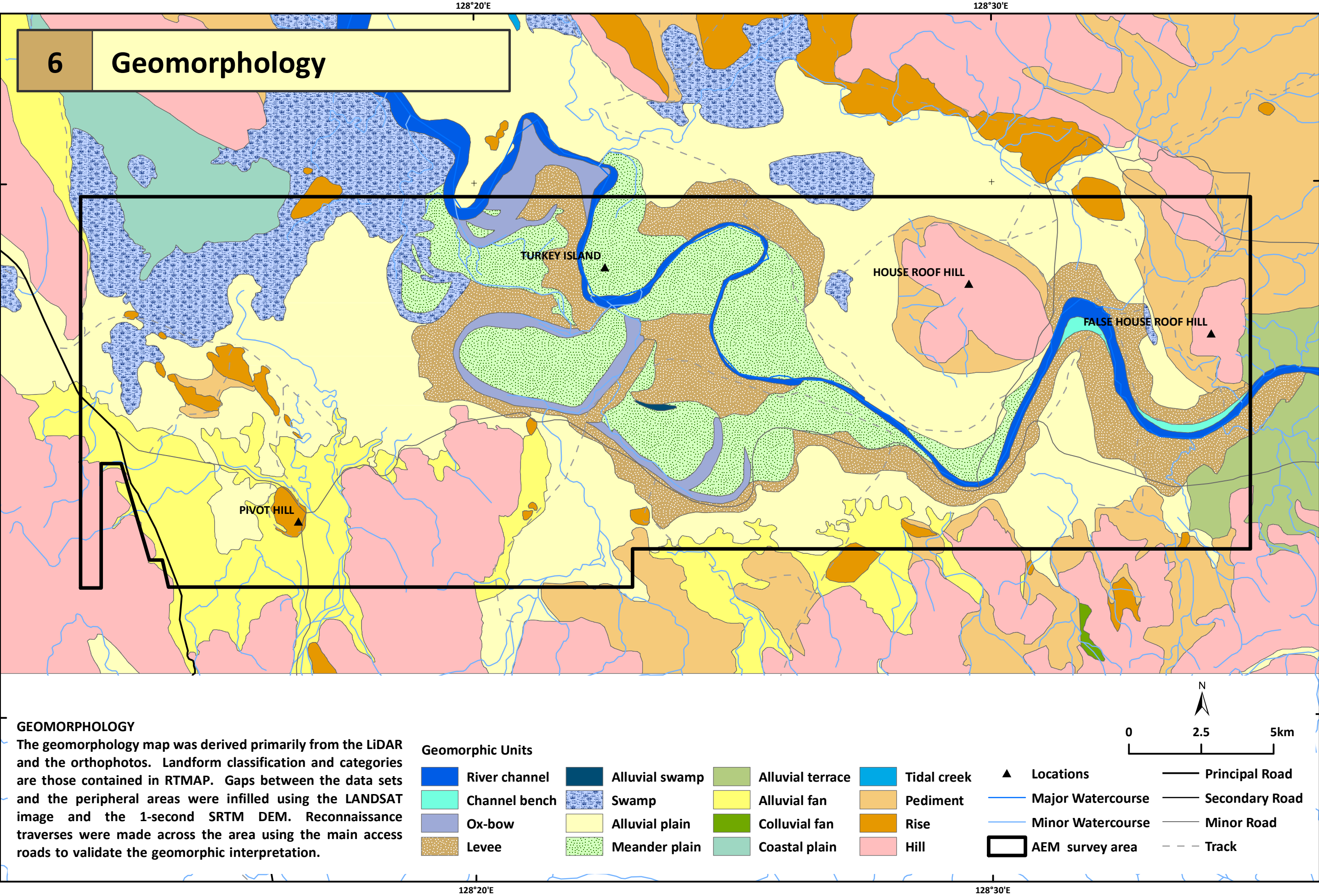
SOURCE: O'Boy, C. A., Tickell, S., Yesertener, C., Comander, D. P., Jolly, P., and Laws, A. T. 2001. Hydrogeology of the Ord River Irrigation Area. Water and Rivers Commission Hydrogeological Record Series HG 7, Plate 2.



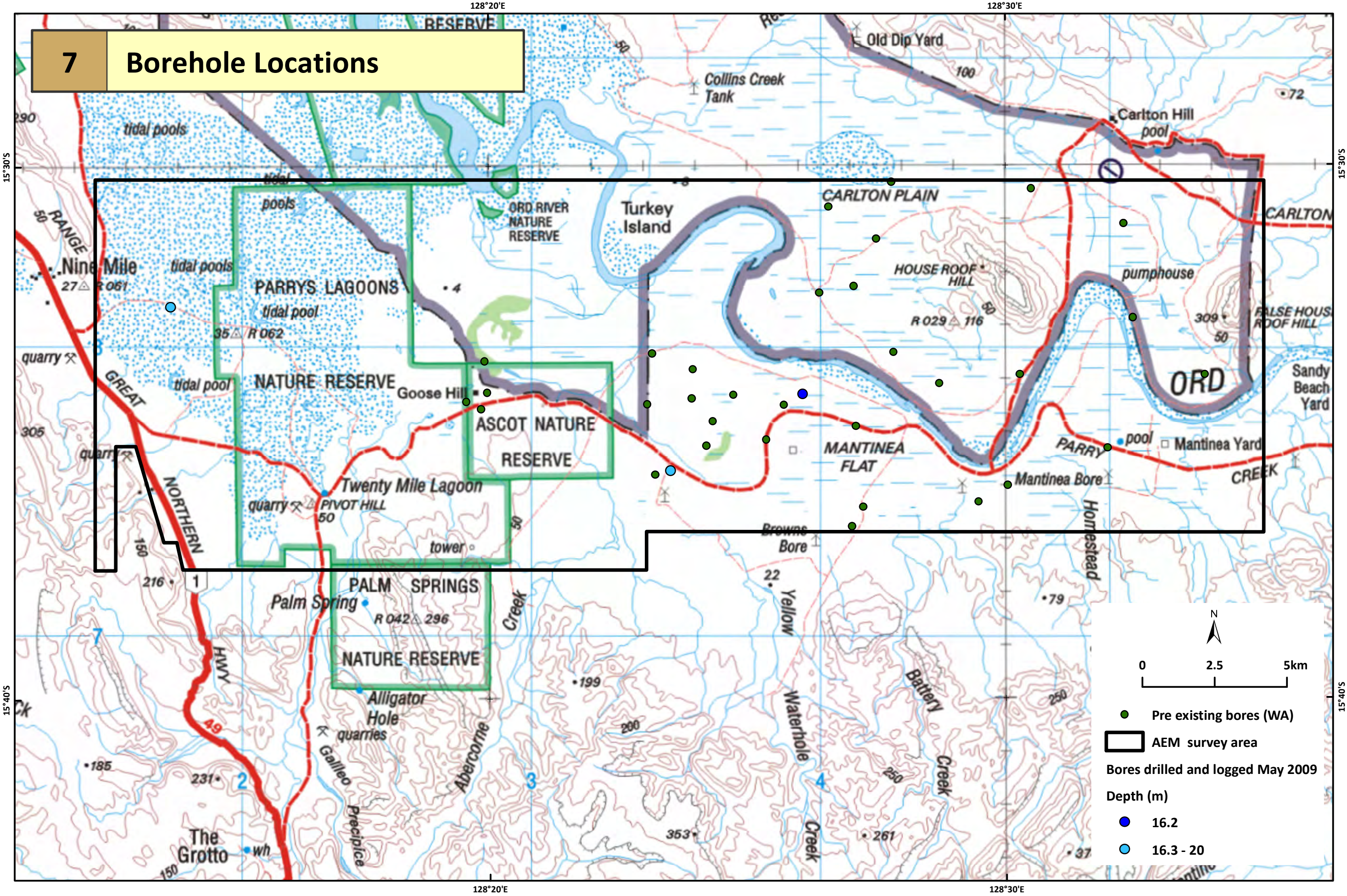
Ord Valley AEM Interpretation Project



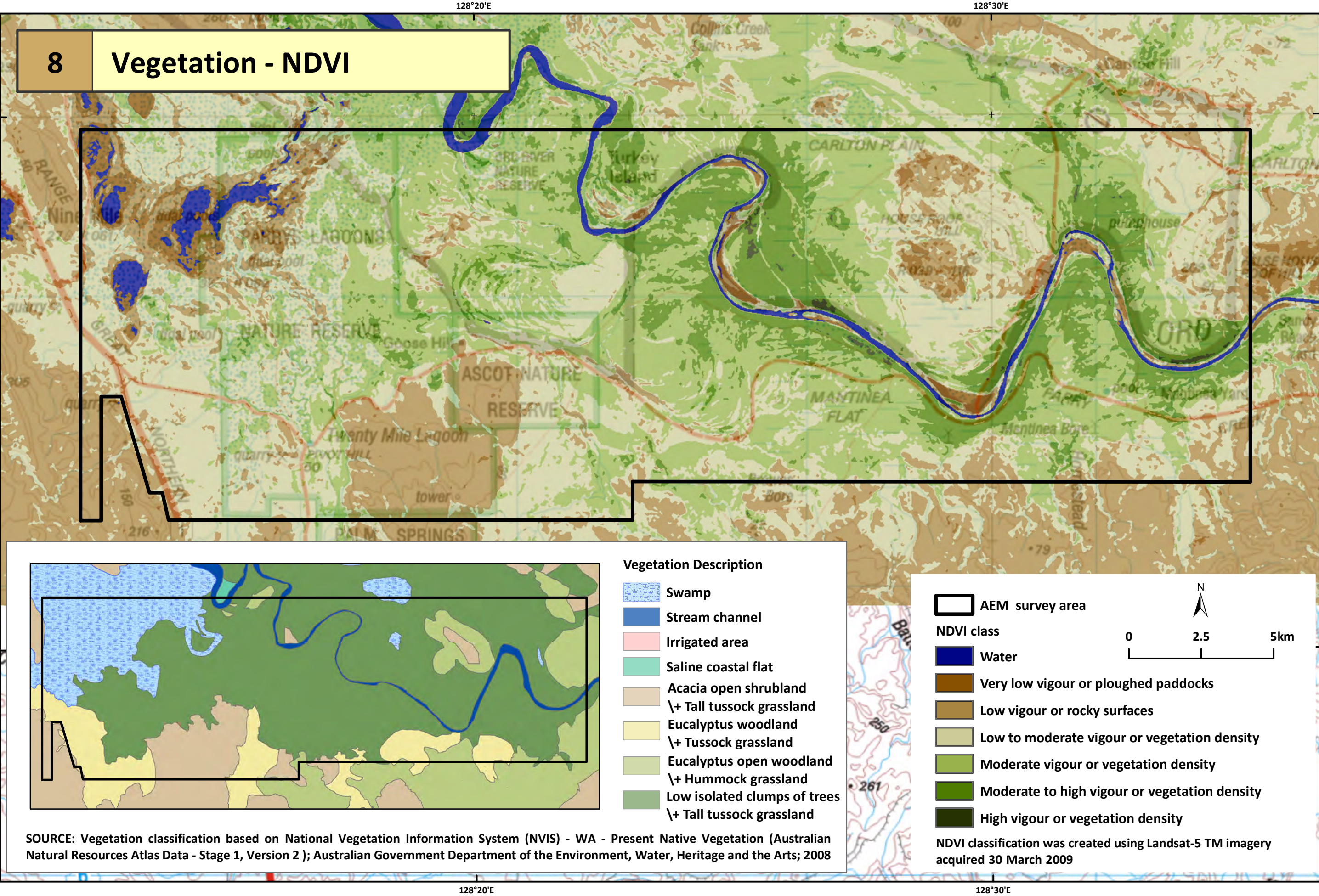
Ord Valley AEM Interpretation Project



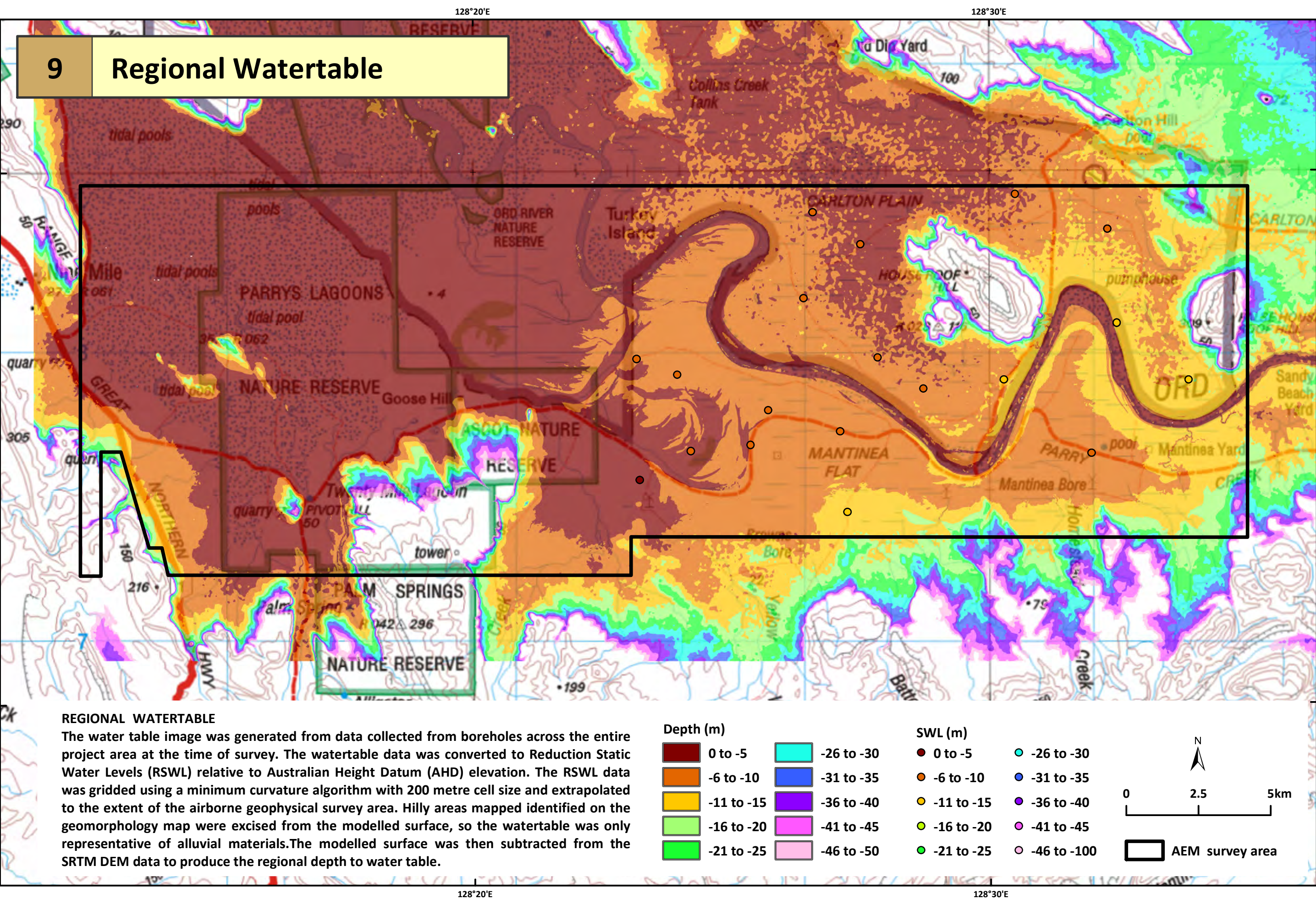
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



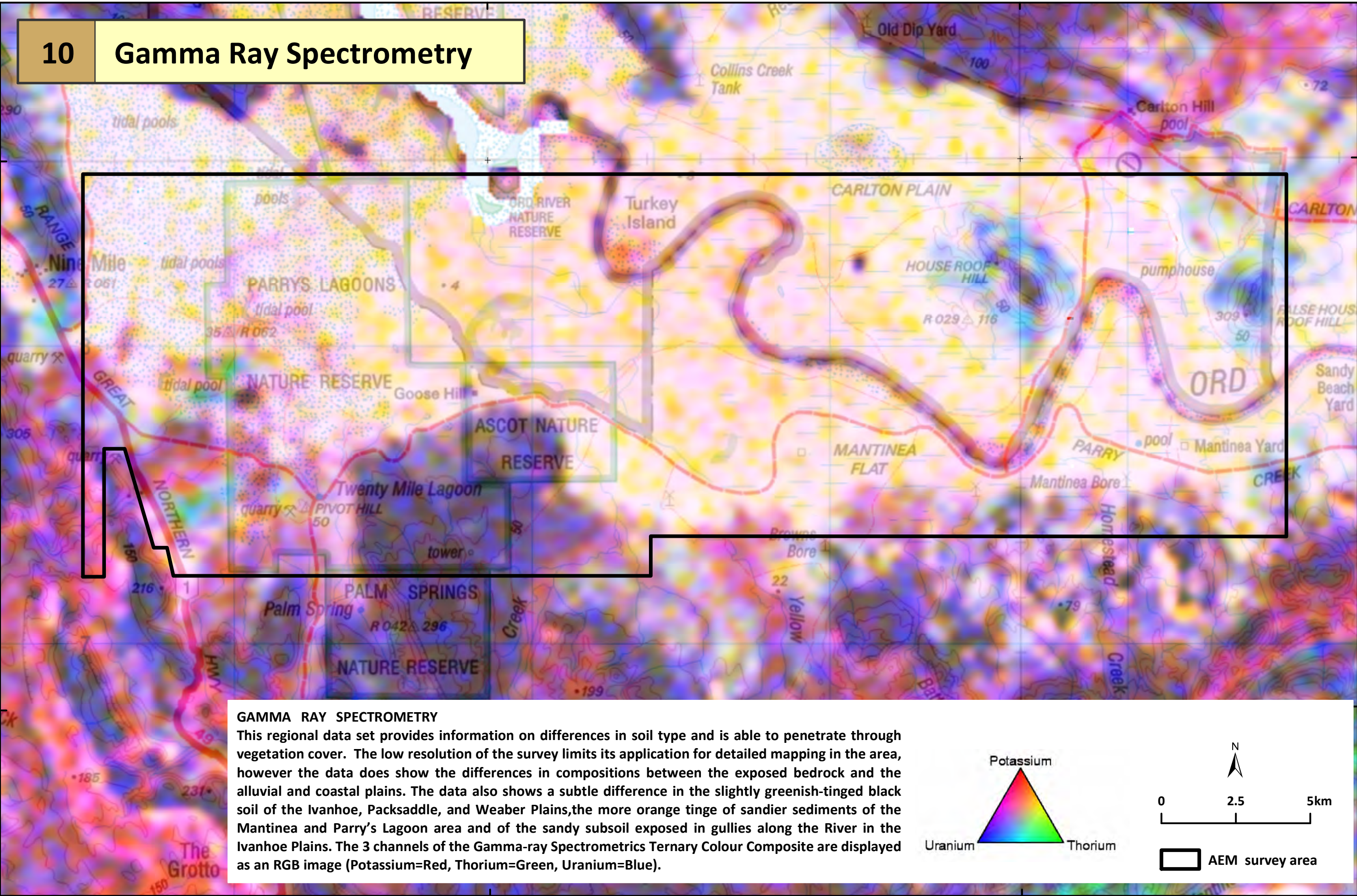
Ord Valley AEM Interpretation Project



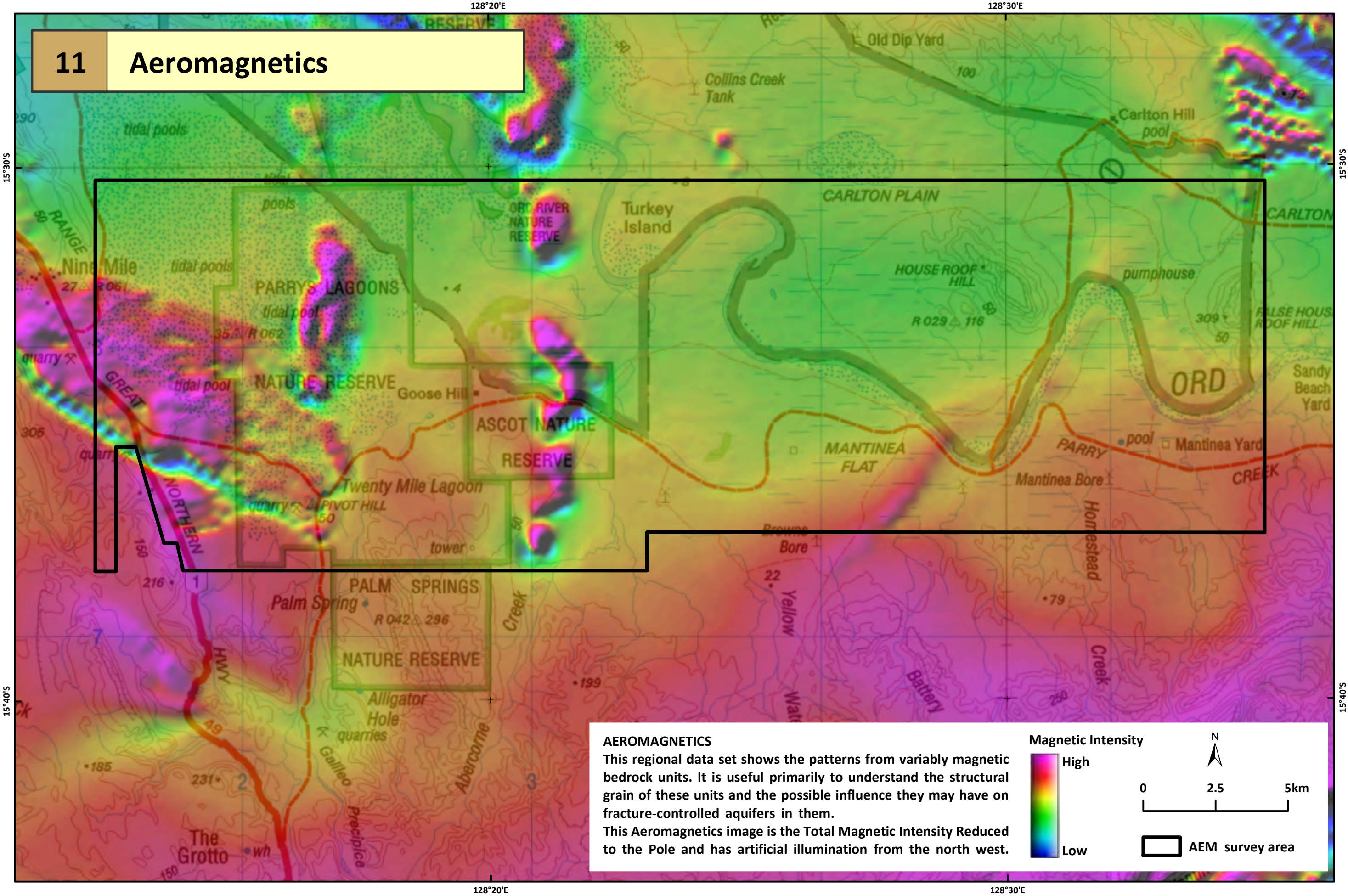
Ord Valley AEM Interpretation Project

10

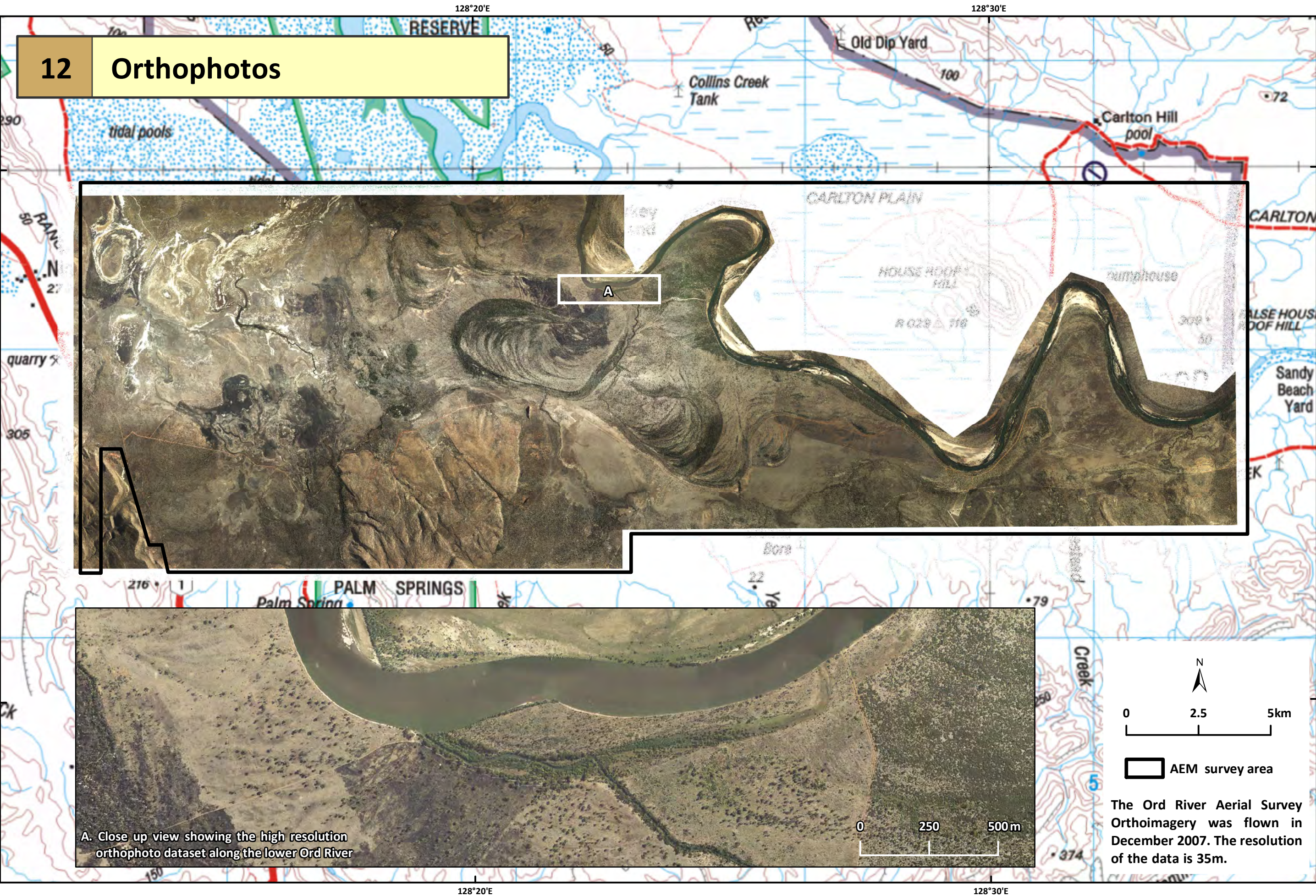
Gamma Ray Spectrometry



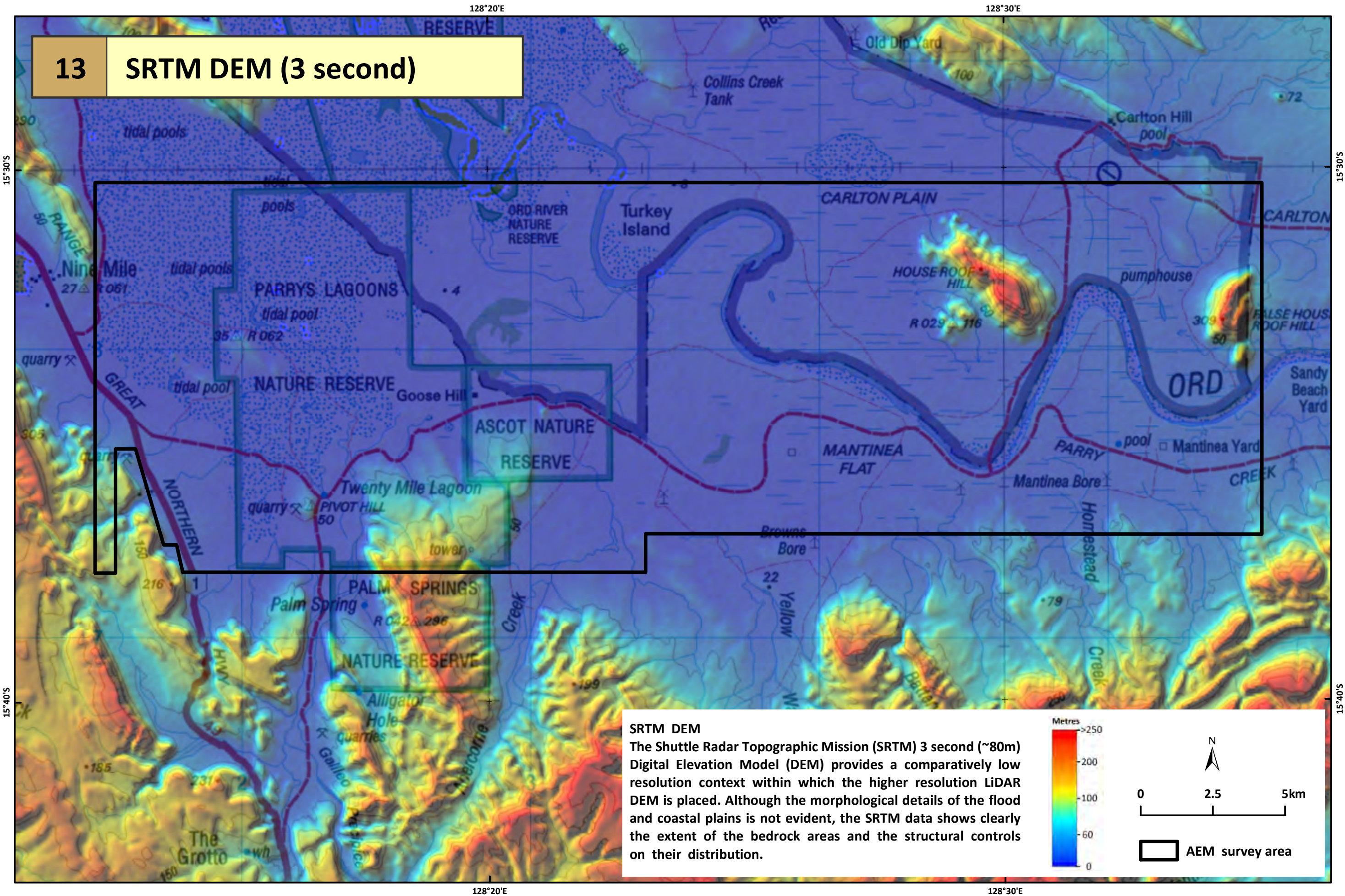
Ord Valley AEM Interpretation Project



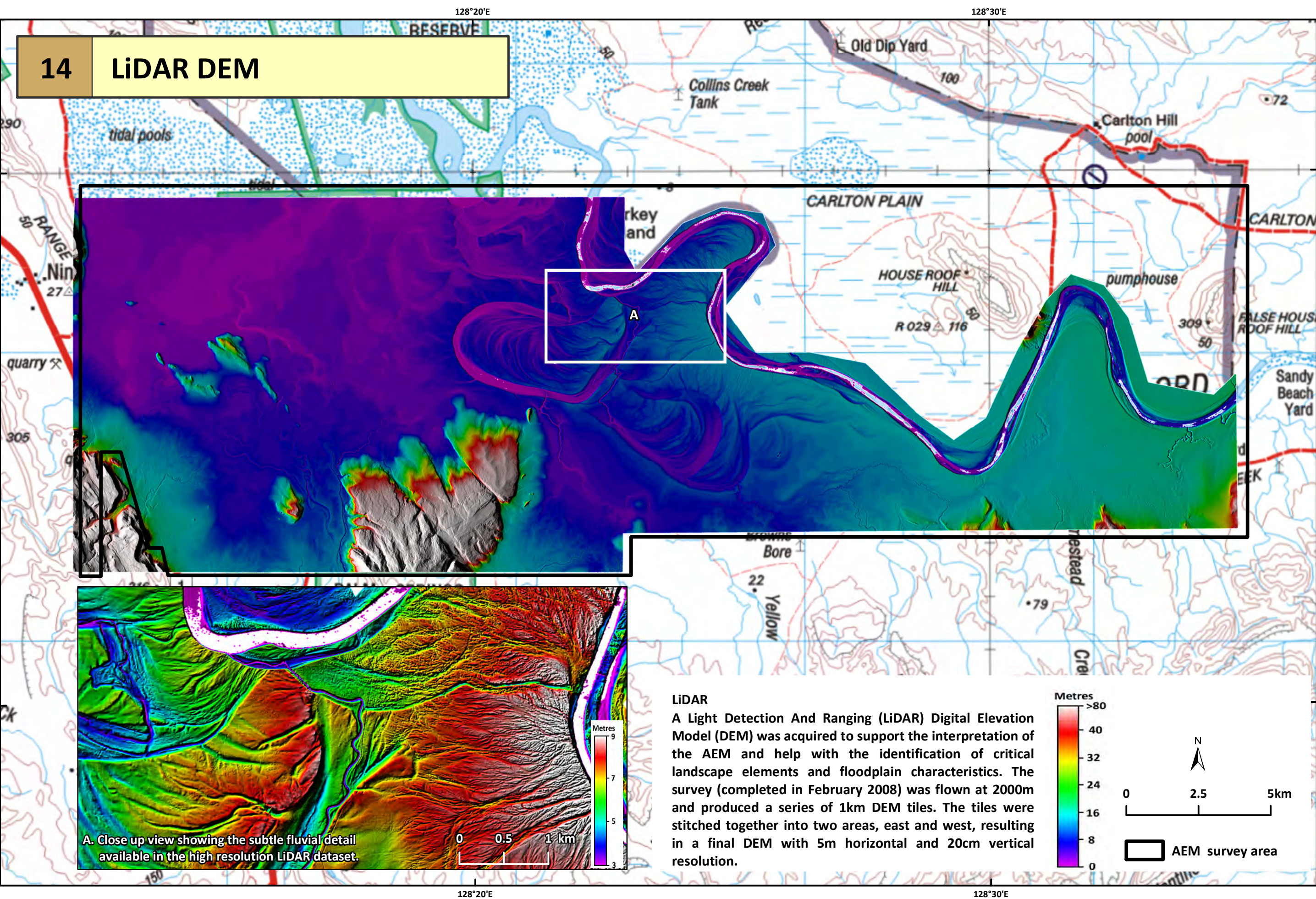
Ord Valley AEM Interpretation Project



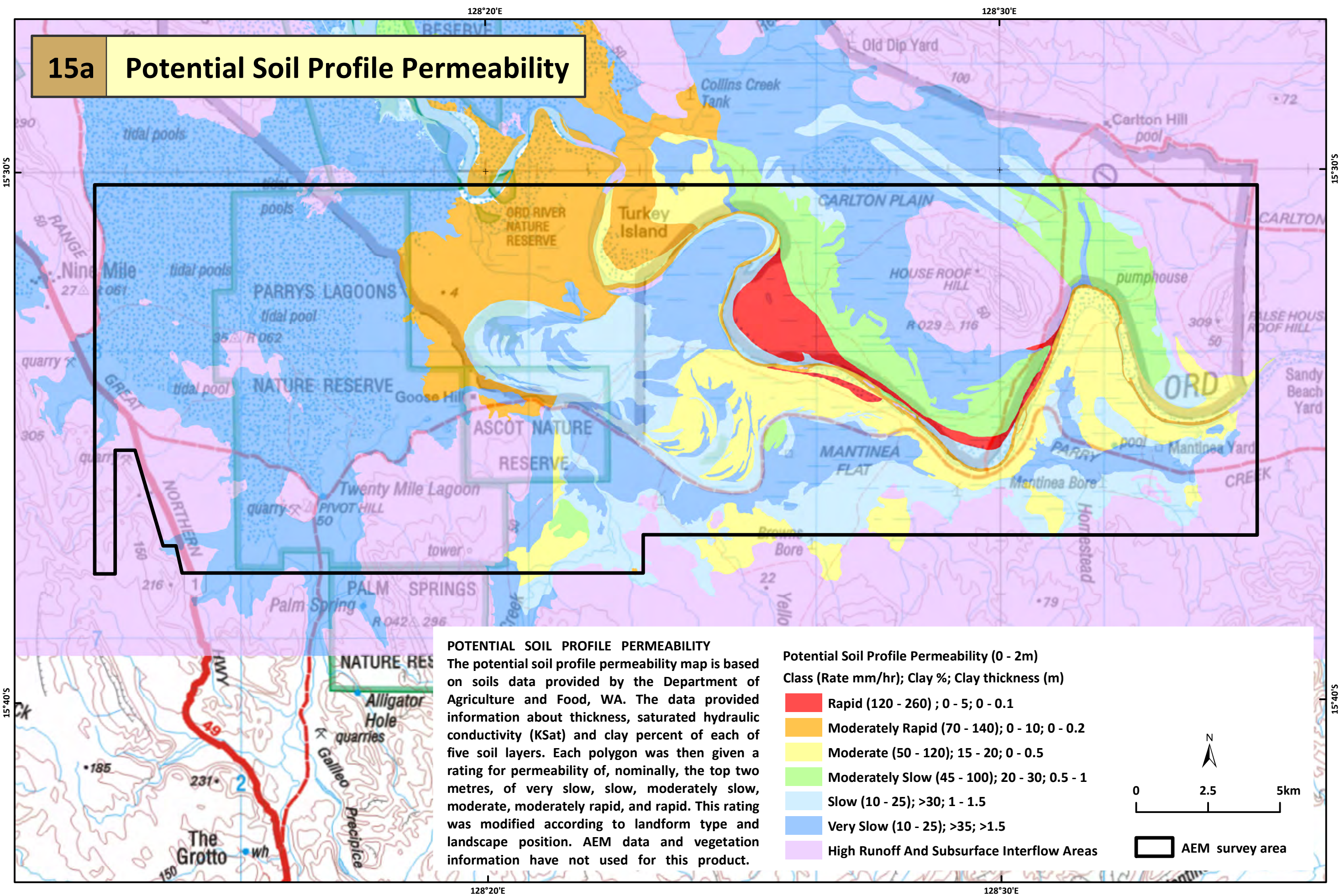
Ord Valley AEM Interpretation Project



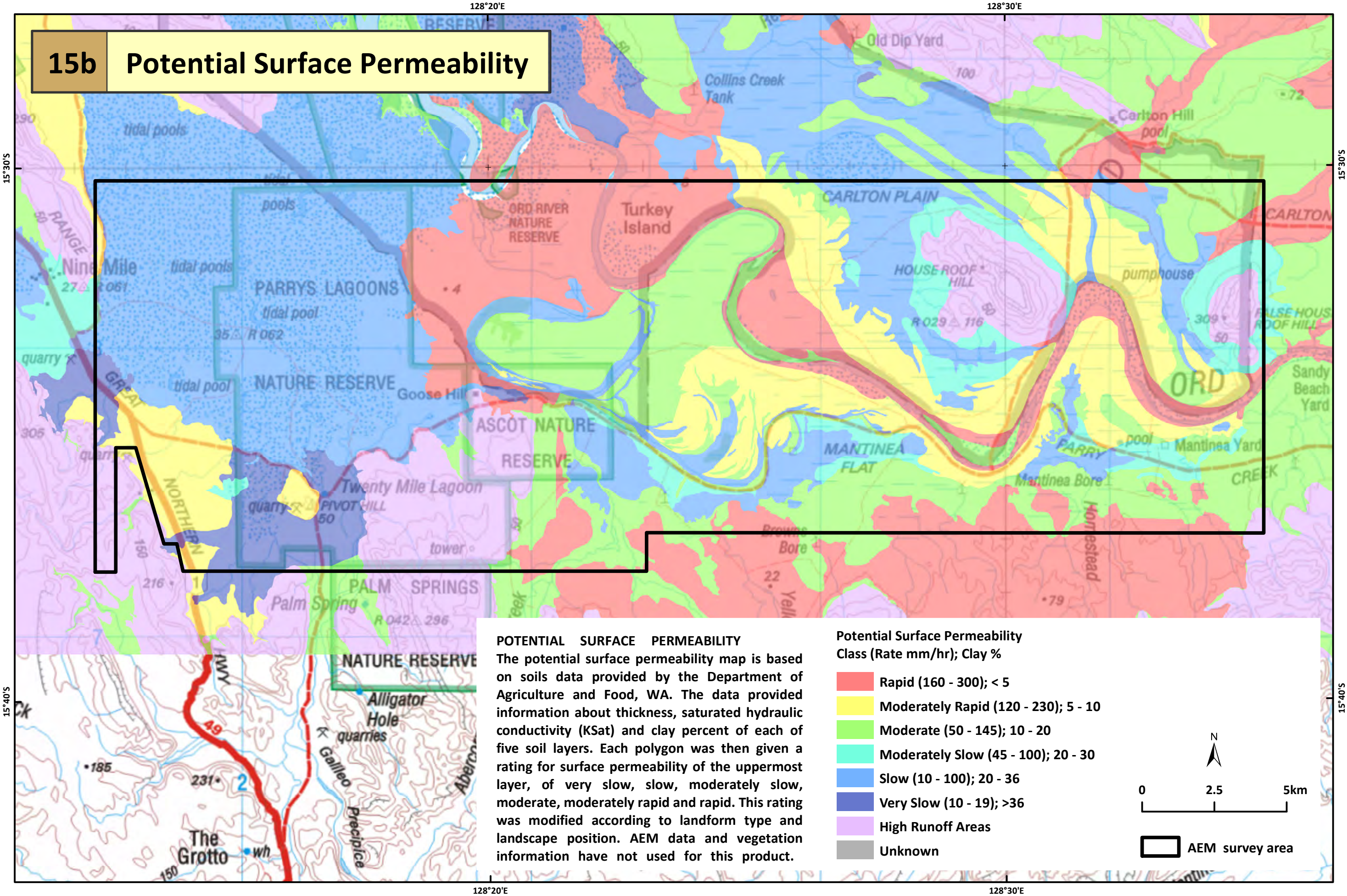
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



16

Ord Irrigation Area SkyTEM Helicopter EM Survey

This atlas contains conductivity models derived from the preliminary field-processed SkyTEM airborne electromagnetic (AEM) data collected over the Ord River area. The survey encompassed the ORIA1 irrigation area, proposed Area 2 extension (Keep River, Carlton Hill) and the Parry’s Lagoon Nature Reserve (Figure 1). The AEM data were collected during July-August 2008 by Geoforce Pty Ltd. This Atlas presents some of the images and interpretations derived from the processing of the SkyTEM data set.

The SkyTEM TDHEM System
The SkyTEM Time Domain EM system is carried as a sling-load towed beneath the helicopter (Figure 2) (Sørensen and Auken 2004). The nominal survey altitude of the transmitter in the Ord survey was ~30m, but this varied depending on the presence of trees or cultural features. The transmitter, mounted on a lightweight wooden lattice frame, is a four-turn, 16 x 16 m² eight sided loop divided into segments for transmitting a low moment in one turn and a high moment in all four turns. SkyTEM is capable of operating in a dual transmitter mode - in the Low Moment mode, a low. current, high base frequency and fast switch off provides early time data for shallow imaging under the landscape. In contrast when in High Moment mode, a higher current and a lower base frequency provide late time data for deeper imaging. The two modes can be run sequentially during a survey, as was done in the Ord survey. The receiver loop is rigidly mounted at the rear and slightly above the transmitter loop.

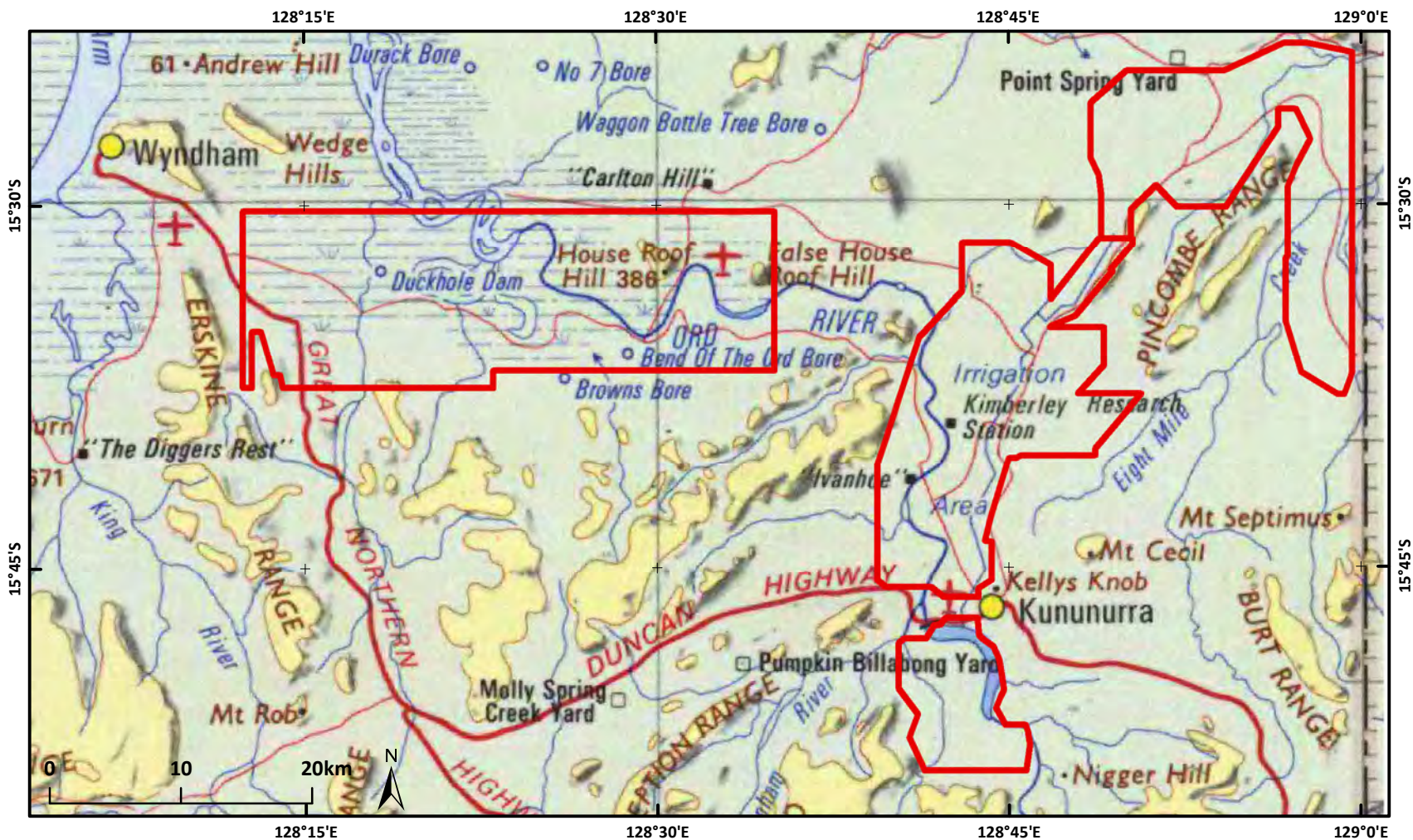


Figure 1: Map showing the location of the Ord SkyTEM survey in northern WA. The survey area is outlined in red

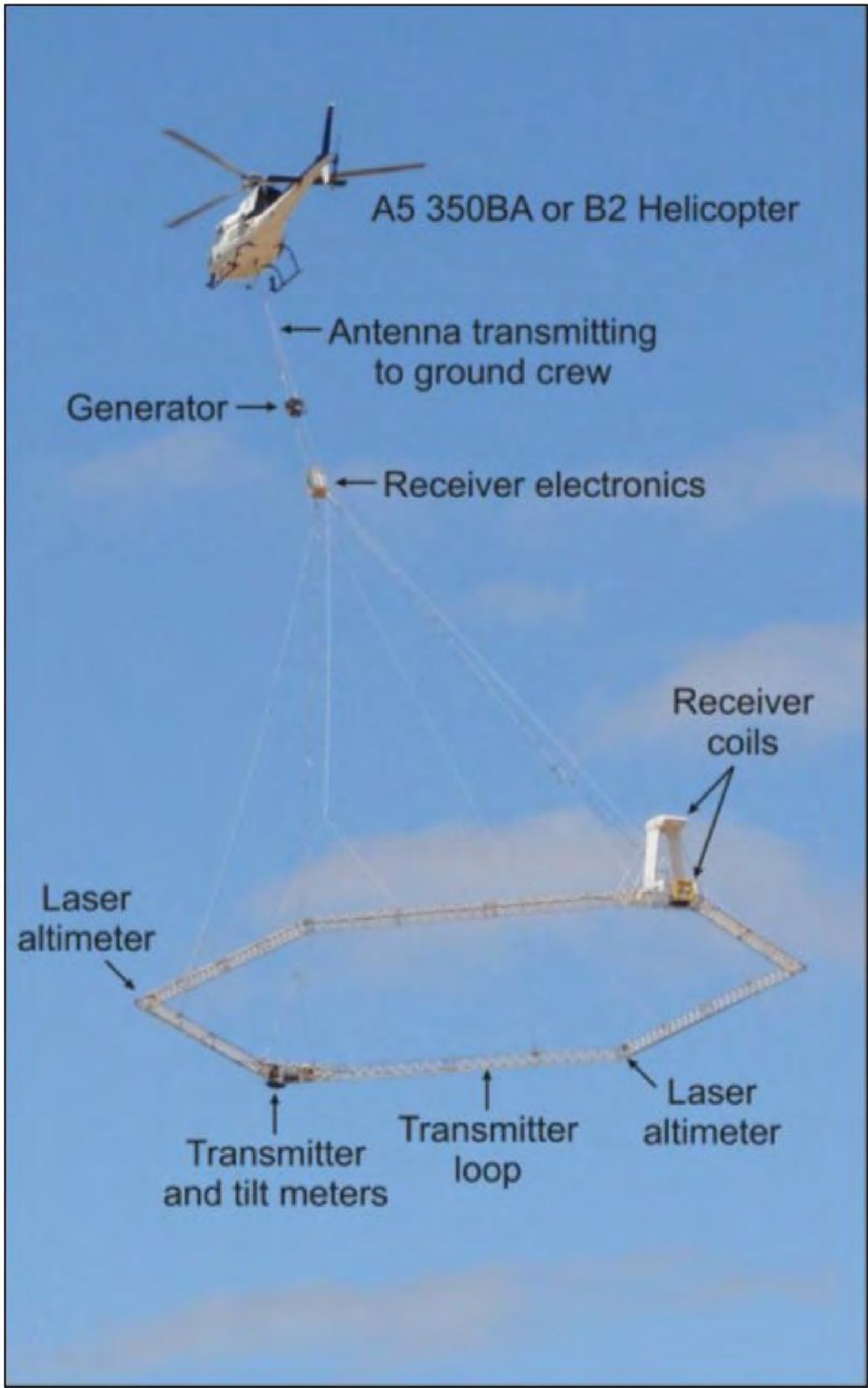


Figure 2: The SkyTEM helicopter electromagnetic system in survey mode

16

Ord Irrigation Area SkyTEM Helicopter EM Survey

Ord SkyTEM Survey Parameters
Details of the survey parameters for the Ord SkyTEM survey are summarised in Table 1:

Survey Area	Flight line spacing (metres)	Line direction - degrees azimuth (c/w from N.)
ORIA1	200	90
Keep River	200	0
Keep River/ORIA1 Subset	200	39
Carlton Hill	300	90
Parrys Lagoon	200	90

Table 1: Details of the Ord survey

Principles of AEM data acquisition
The basic principle of operation for a helicopter-borne Time Domain EM system is illustrated in Figure 3. Helicopter EM (HEM) systems such as SkyTEM have EM transmitters and receivers suspended below the helicopter and involve the measurement of the varying conductivity response of the ground due to the propagation of electromagnetic fields. Time domain systems such as SkyTEM, work on the principle of transmitting a current through the loop or coil of the transmitter. This in turn generates a magnetic field which induces a series of eddy currents in the earth below the coil. These eddy currents in turn generate a secondary magnetic field which is detected and measured by the receiver coil mounted at the rear of the transmitter loop. Variations in ground conductivity, caused by salt in the groundwater, or the presence of clays or other materials, will vary the magnitude of the induced or secondary magnetic field. By combining measurements of ground conductivity along each of the flights lines, we can generate a map of conductivity, as it varies with depth, across the landscape as seen in the maps displayed on the following pages.

AEM data processing and inversion
The data recorded by the SkyTEM system consists of a number of time channels which record the decay of the received secondary electromagnetic field as a series of voltages. These data are modelled through the process of inversion or by fast approximate techniques to provide a measurement of the ground conductivity both laterally and vertically (Figure 4). Typically 1-Dimensional (1D) inversion techniques are used due to their computational efficiency. 1D techniques treat each data point independently of one-another and model the ground conductivity vertically, assuming the earth comprises of a series of horizontal layers (commonly referred to as a layered earth model).

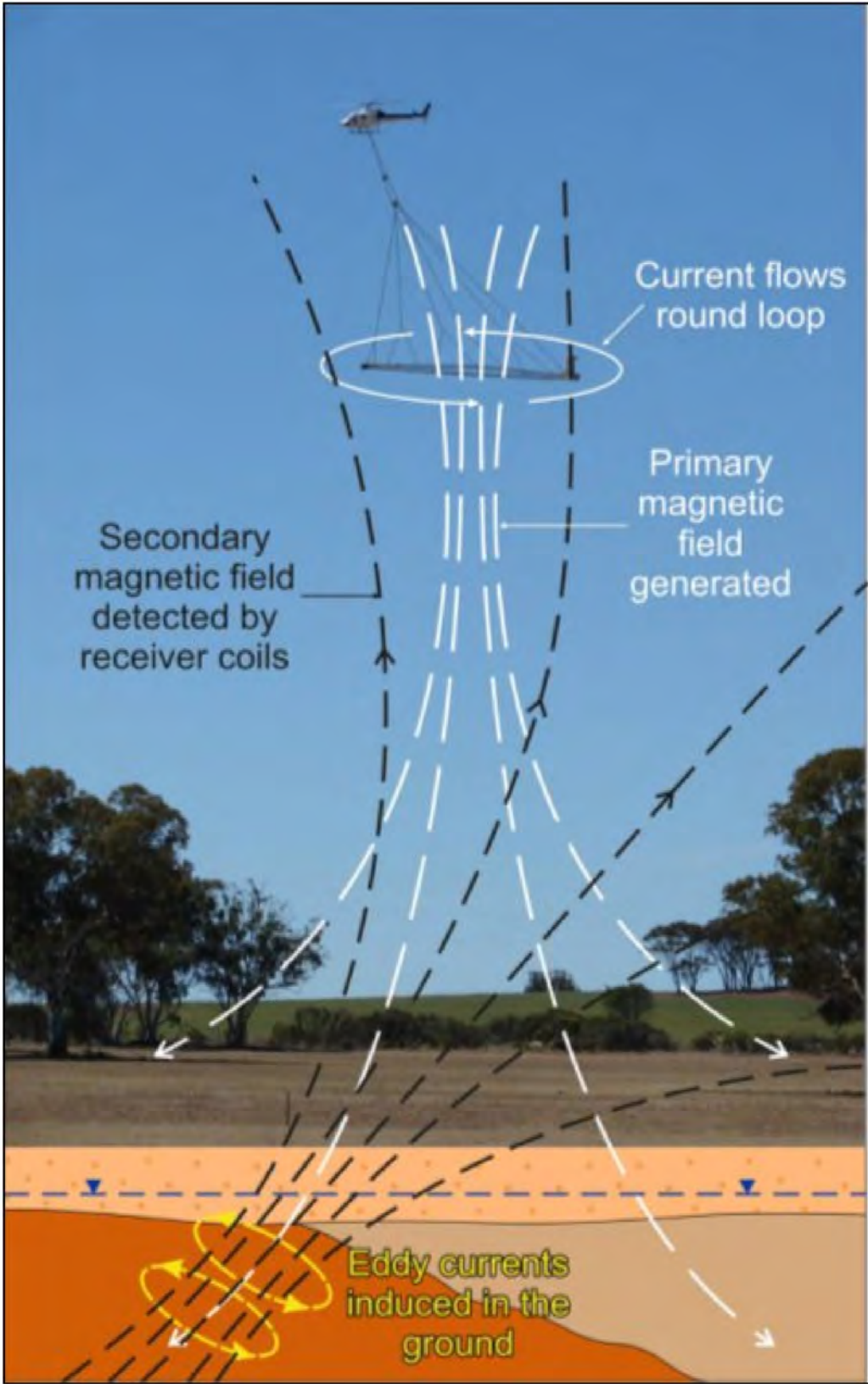


Figure 3: How the SkyTEM measures ground conductivity

16 Ord Irrigation Area SkyTEM Helicopter EM Survey

The resultant conductivity model can be presented as plan form, either as a map of conductivity at a particular depth below the ground surface or as maps showing conductivities at particular elevations in the landscape. Conductivity data can also be presented as vertical cross sections or stitched together to produce quasi-3D models.

The modelling presented in this report used the Aarhus Geophysics Workbench program. The SkyTEM data was processed in the Workbench program prior to inversion. Processing filters the electromagnetic sounding data along with the altitude and tilt data. The inversion was run with a laterally constrained inversion (LCI) algorithm (see Auken et.al, 2007) using the Aarhus Geophysics Workbench software. The algorithm utilises the low and high moment SkyTEM data separately and stitches the results together.

The inversion was run with an 18 layer smooth model down to a depth of 100 metres (Table 2). The conductivity data in this atlas have been presented as images showing the ground conductivity at particular depth intervals below the ground surface.

Layer	Thickness (m)	Depth from (m)	Depth to (m)
1	2	0	-2
2	2.01	-2	-4.2
3	2.02	-4.2	-6.7
4	2.05	-6.7	-9.5
5	2.08	-9.5	-12.7
6	2.11	-12.7	-16.3
7	2.16	-16.3	-20.3
8	2.21	-20.3	-24.8
9	2.28	-24.8	-29.8
10	2.35	-29.8	-35.4
11	2.43	-35.4	-41.7
12	2.52	-41.7	-48.8
13	2.62	-48.8	-56.8
14	2.72	-56.8	-65.8
15	2.84	-65.8	-75.8
16	2.97	-75.8	-87.1
17	3.11	-87.1	-99.8
18	¥	-99.8	¥

Table 2: Layer thickness and intervals for Full AEM Inversion.

References

Auken, E., Westergaard, J. A., Christiansen, A. V., and Sørensen, K. I., 2007, Processing and inversion of SkyTEM data for high resolution hydrogeophysical surveys: ASEG Conference 2007 , Perth, Western Australia

Sørensen, K. I. and Auken, E., 2004. SkyTEM - A new high resolution helicopter transient electromagnetic system: Exploration Geophysics, 35, 191-199.

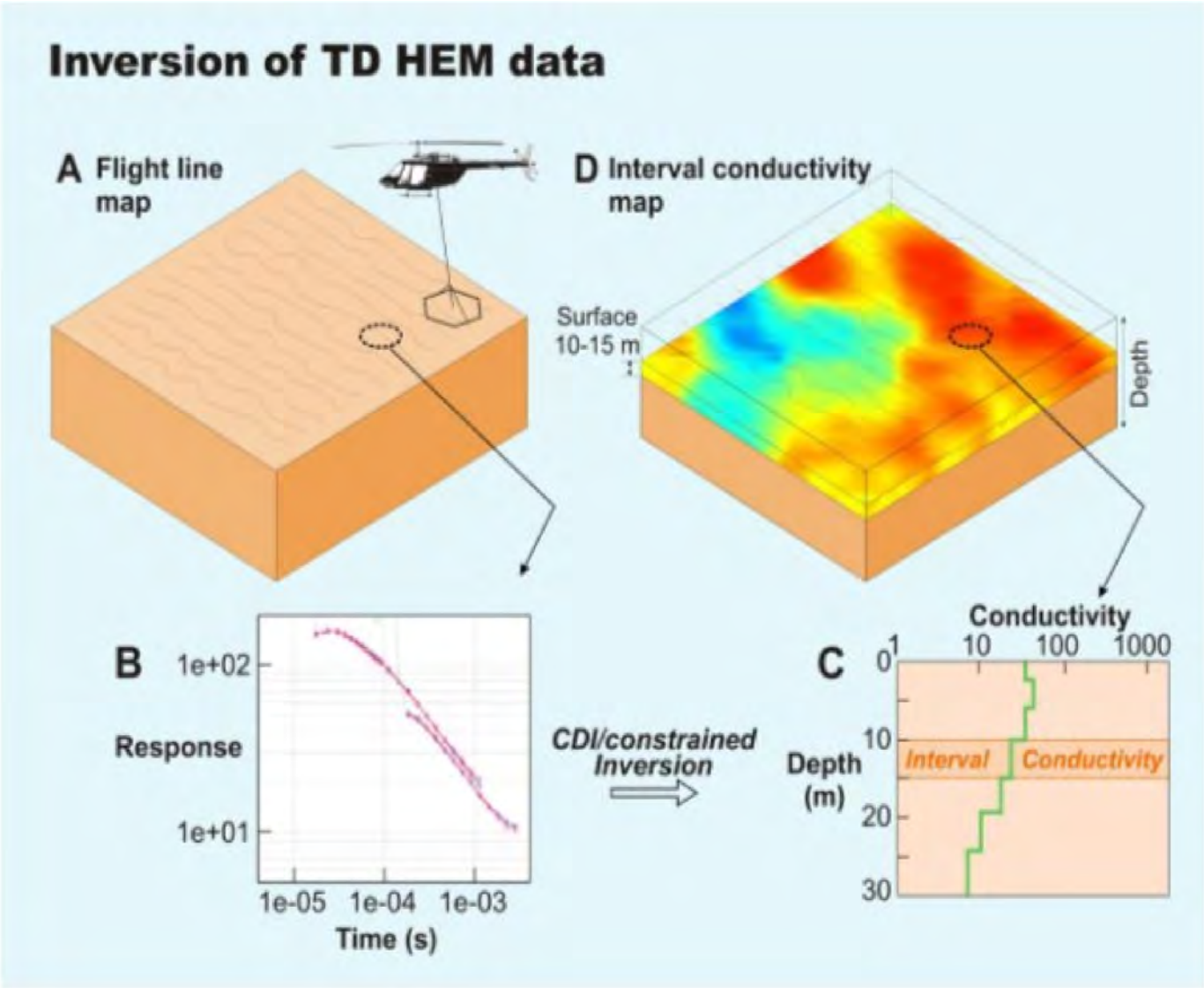
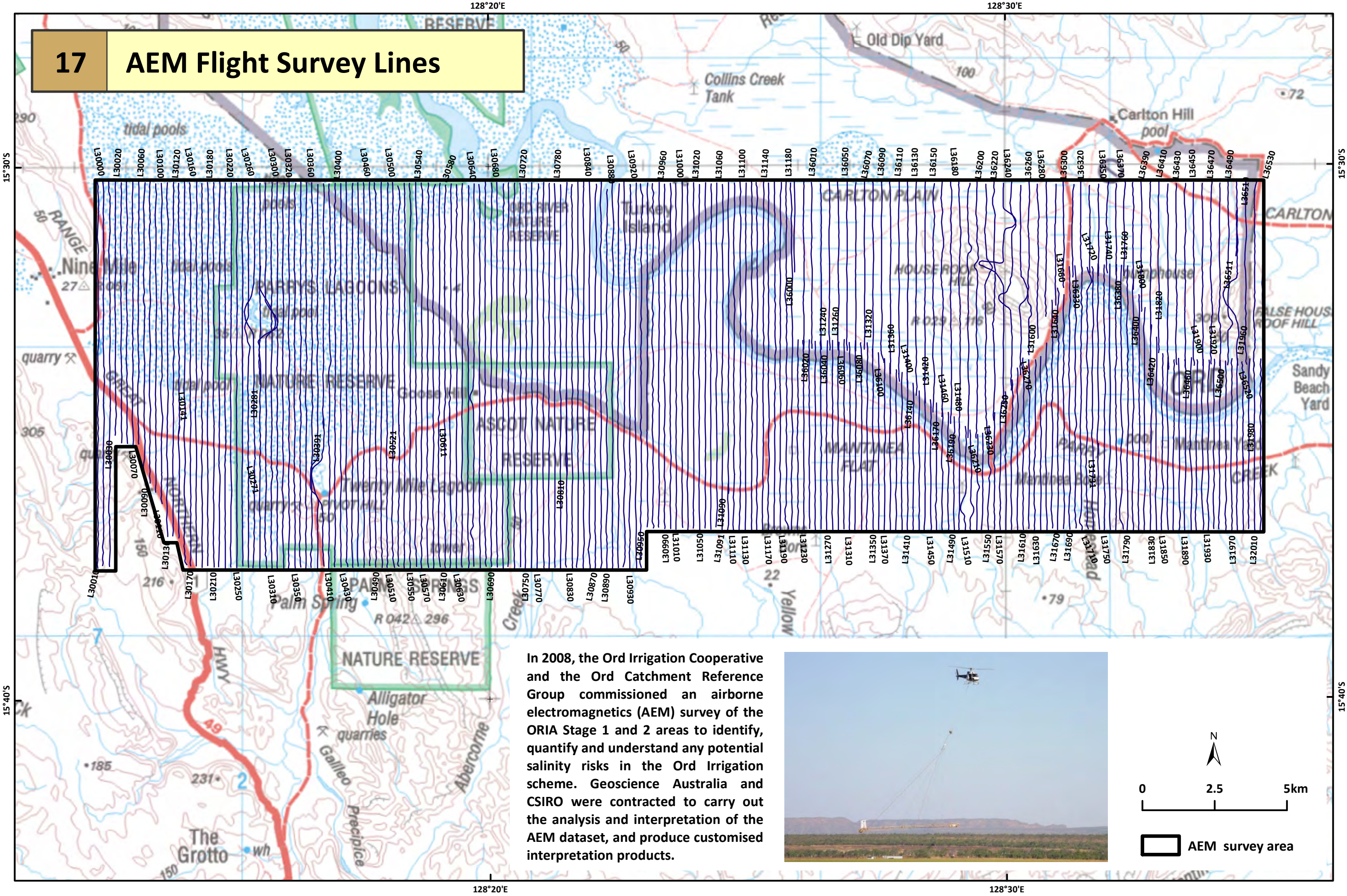
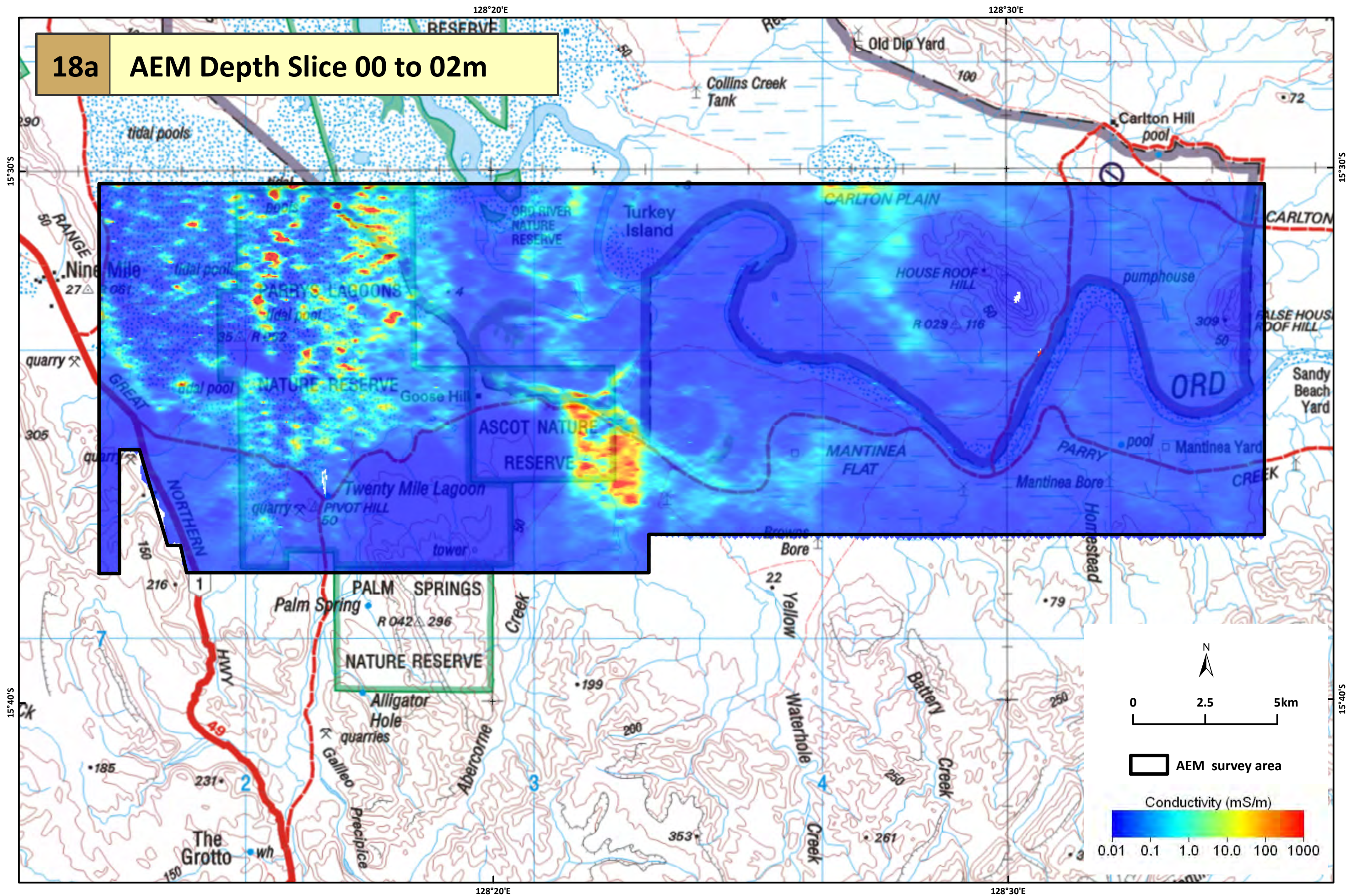


Figure 4: Schematic representation of how the SkyTEM measures a response from the ground, and how that data once collected is then converted through a process known as inversion to a model of ground conductivity. A) Data are acquired along parallel flight lines, with measurements made every 10-15m along each flight line; B) The EM receiver located on the loop towed beneath the helicopter measures the ground response; C) The measured response is used to determine the conductivity-depth function by transformation or inversion. D) Conductivity-depth values can be calculated for each observation and then stitched together into sections to provide a representation of the 2D variation of conductivity, sometimes referred to as a “parasection”. Conductivity-depth profiles can be combined into a 3D gridded volume from which arbitrary sections, horizontal depth slices (or interval conductivity images) and isosurfaces can be derived showing the spatial distribution of conductivity as it varies with depth.

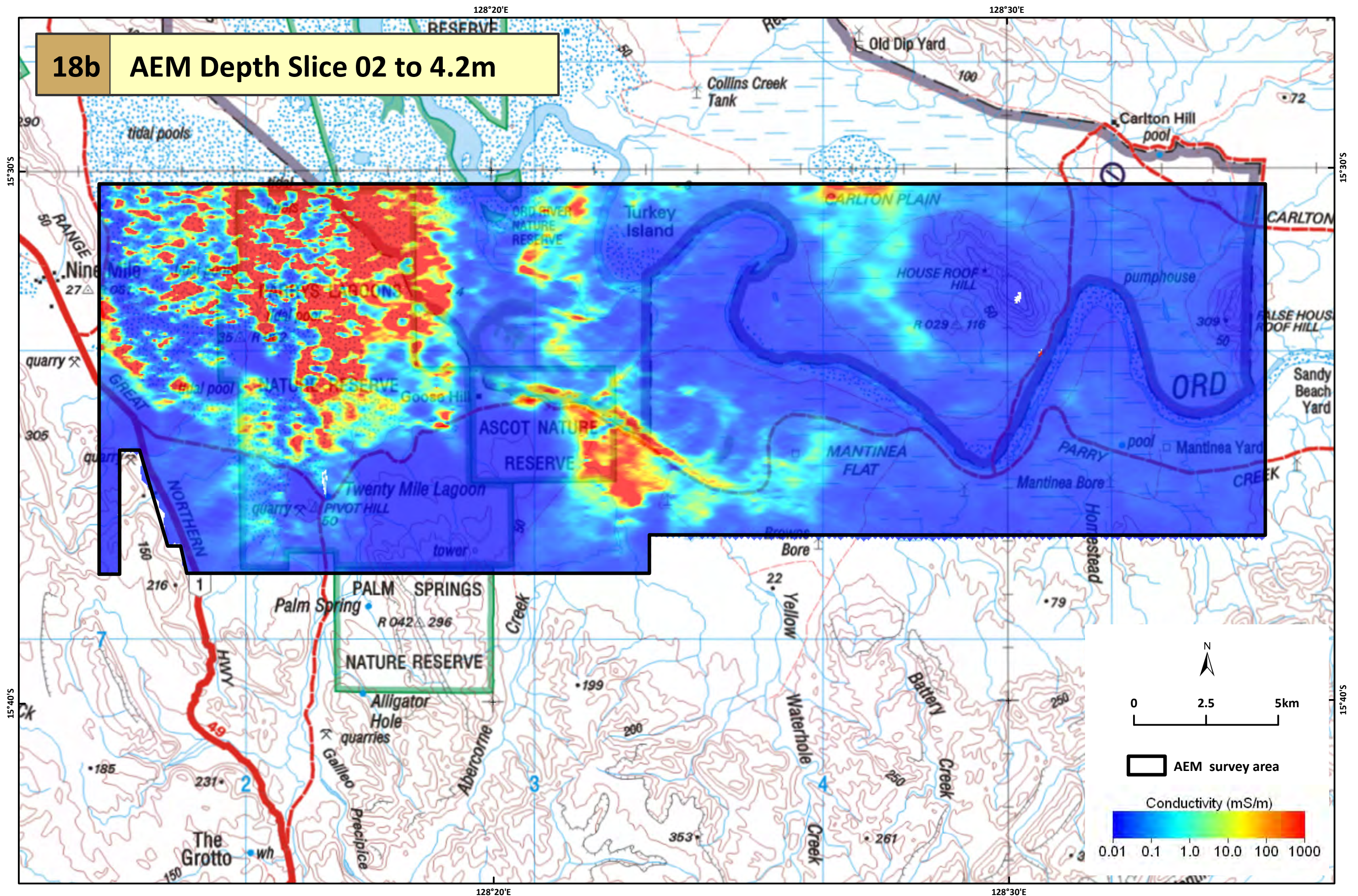
Ord Valley AEM Interpretation Project



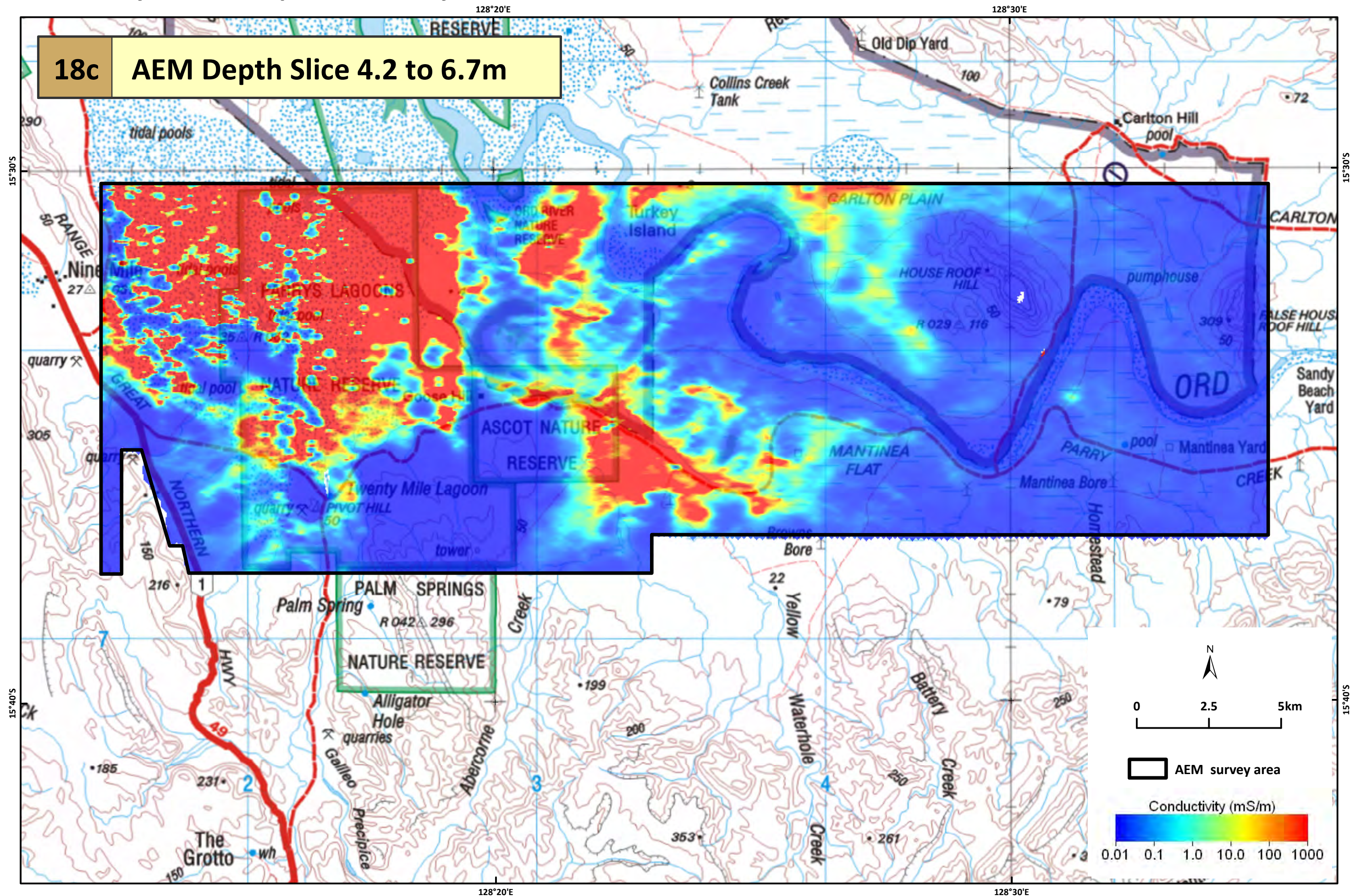
Ord Valley AEM Interpretation Project



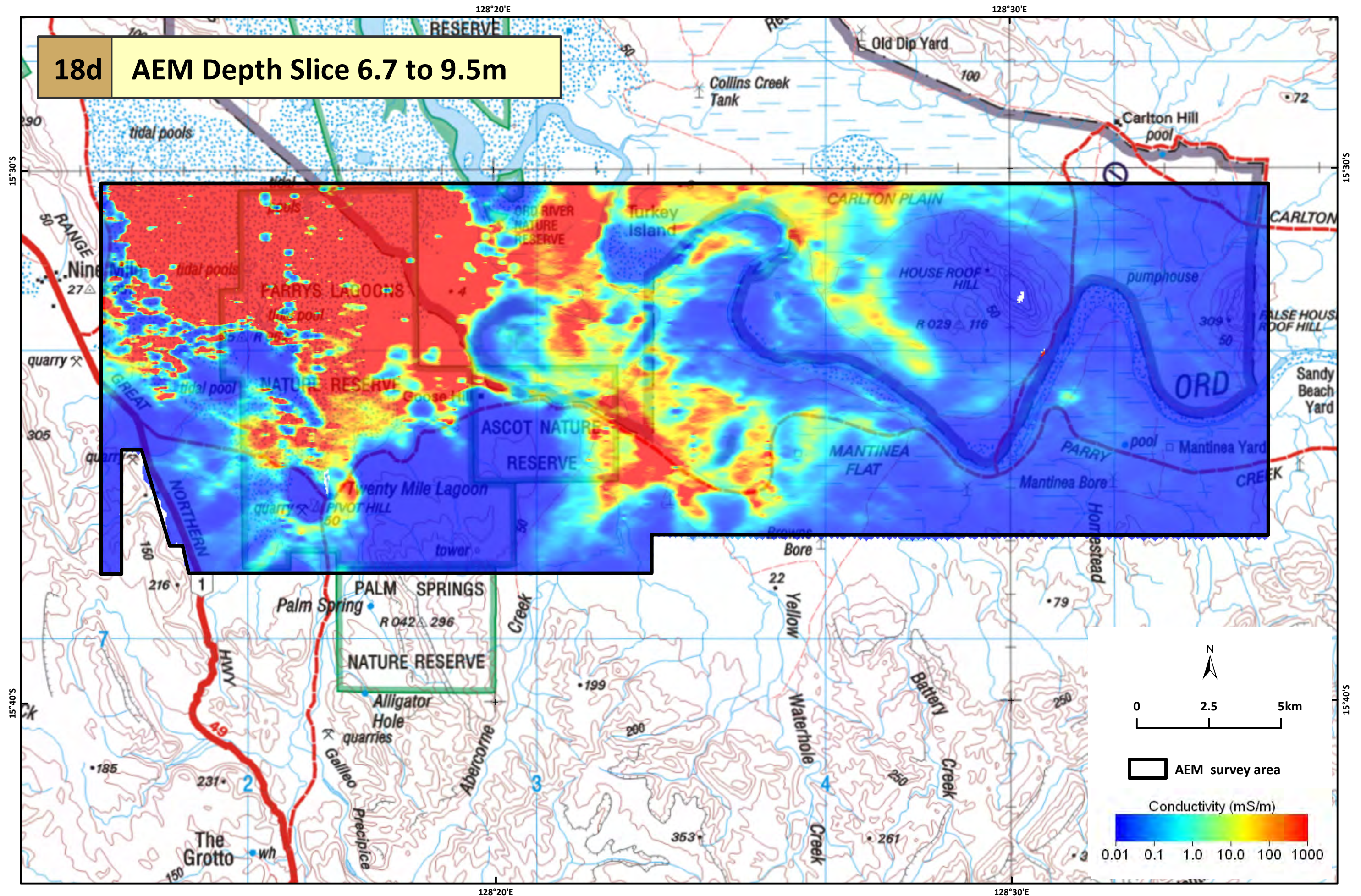
Ord Valley AEM Interpretation Project



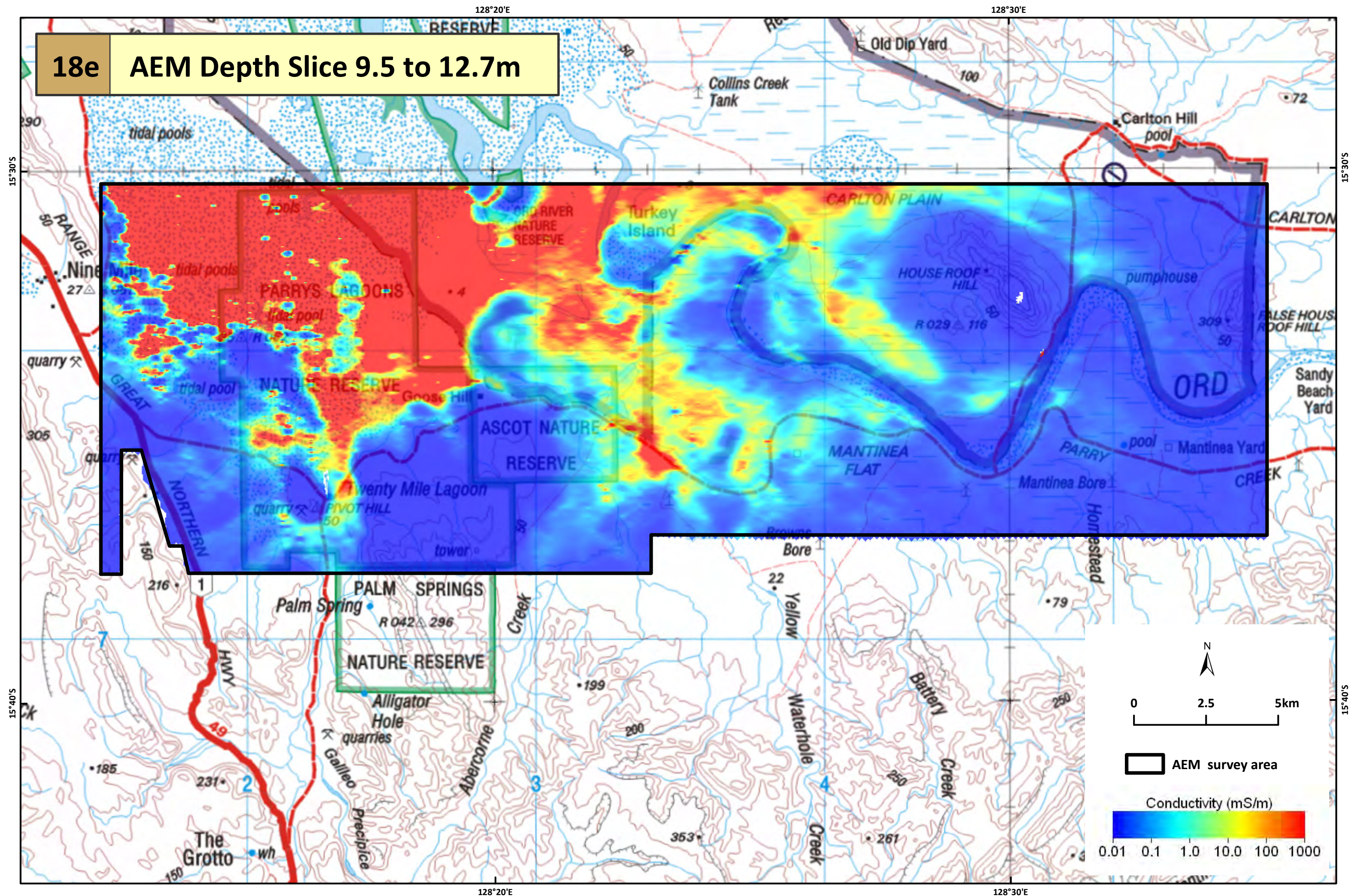
Ord Valley AEM Interpretation Project



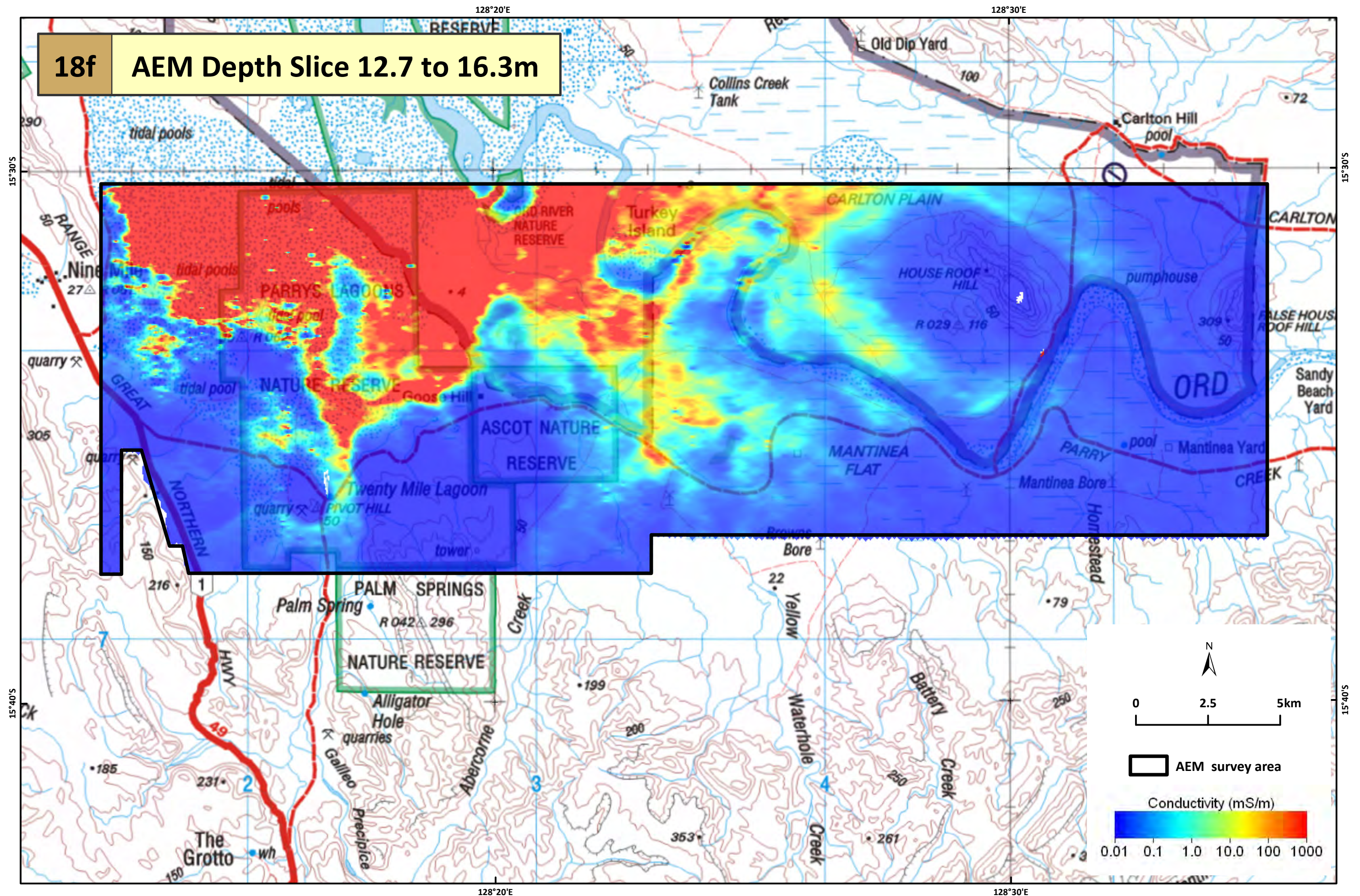
Ord Valley AEM Interpretation Project



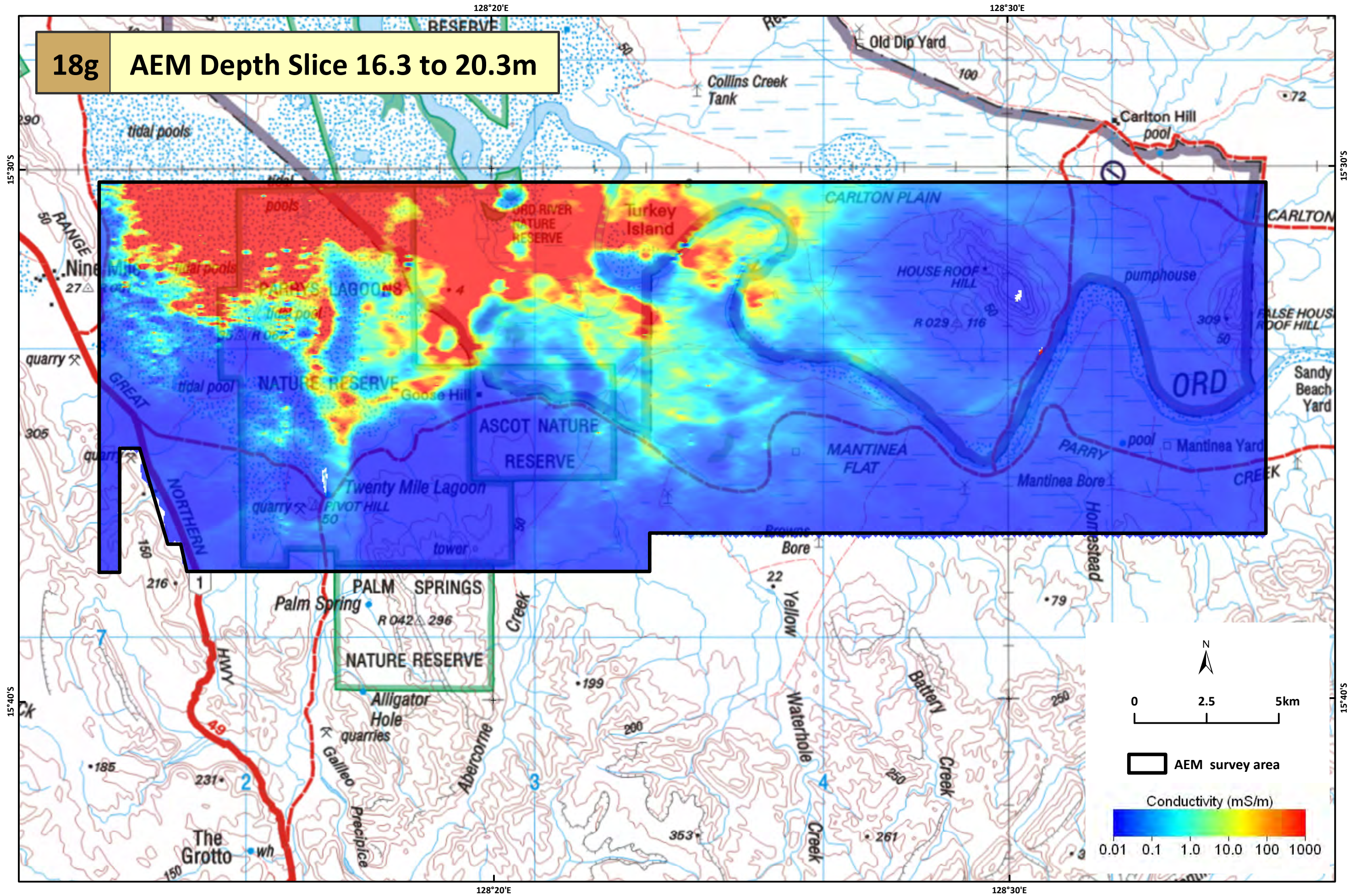
Ord Valley AEM Interpretation Project



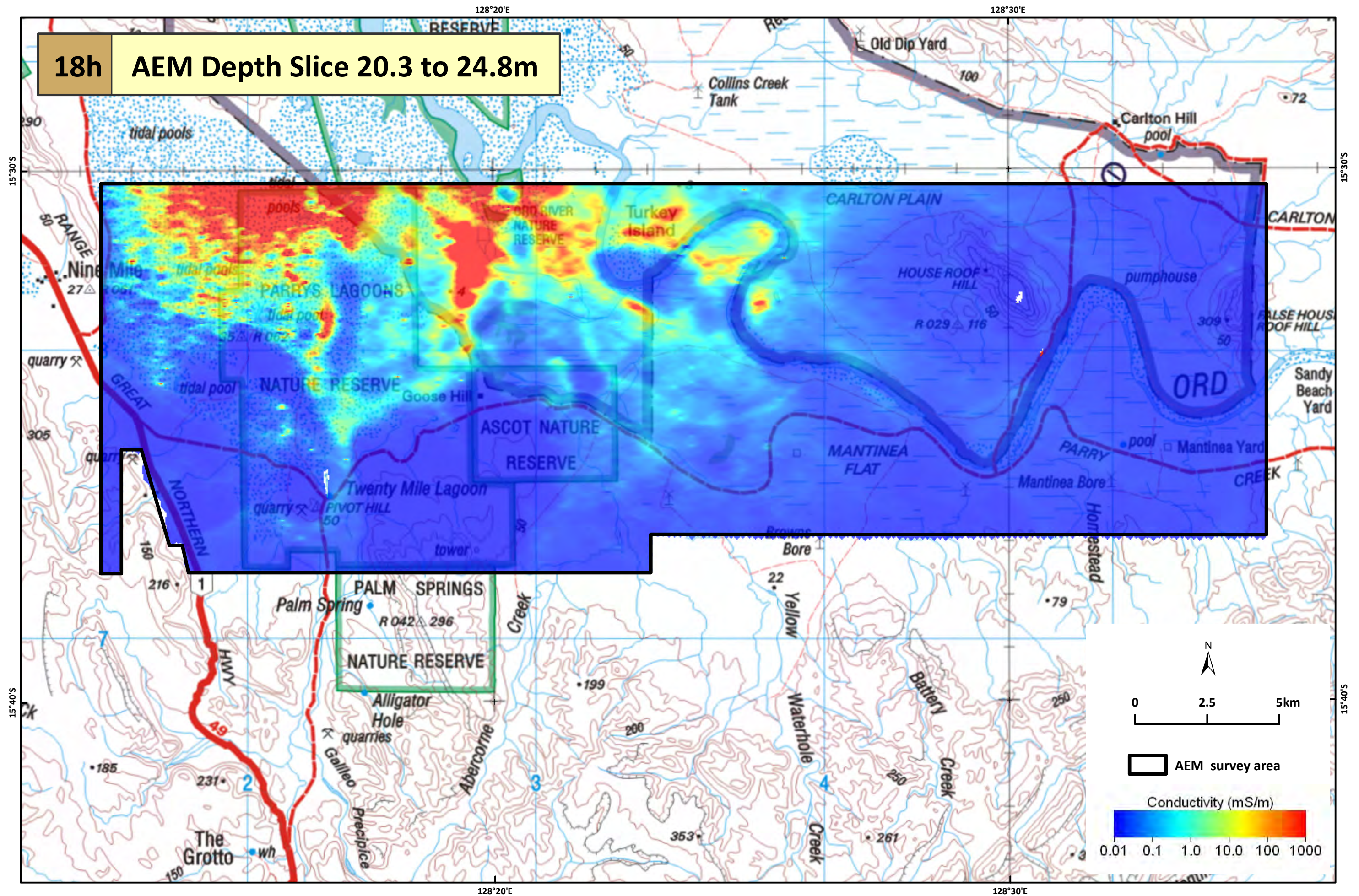
Ord Valley AEM Interpretation Project



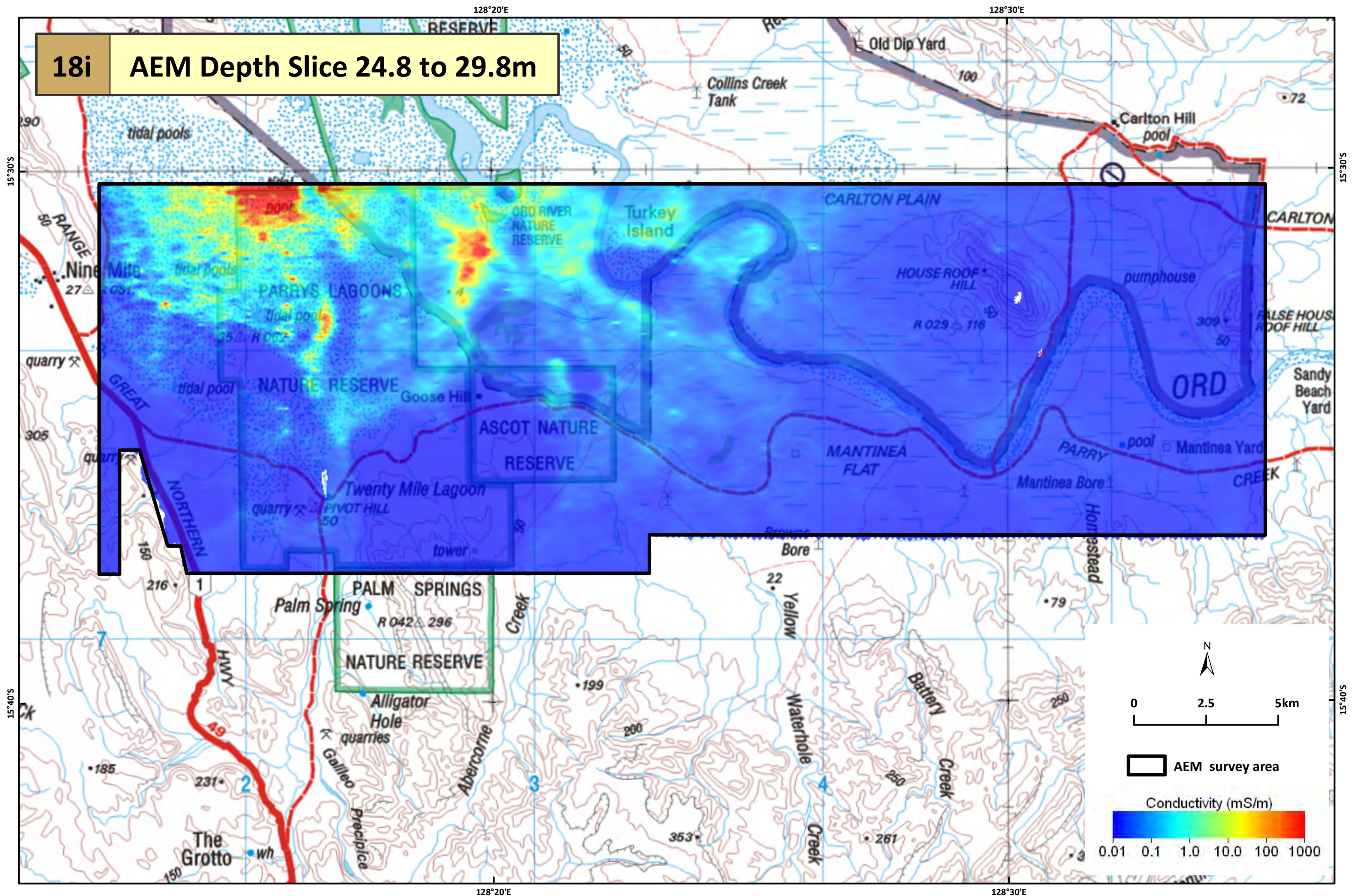
Ord Valley AEM Interpretation Project



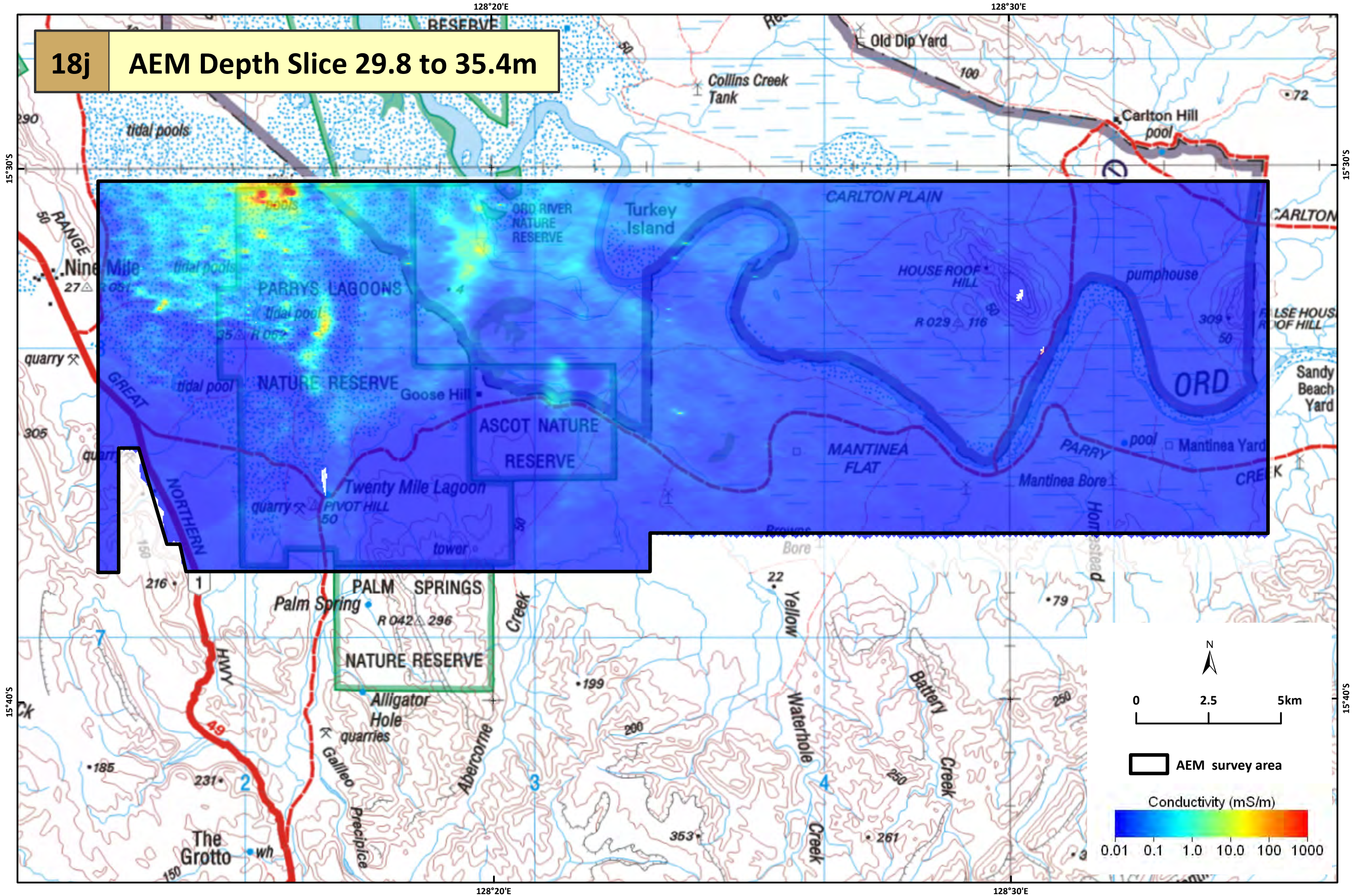
Ord Valley AEM Interpretation Project



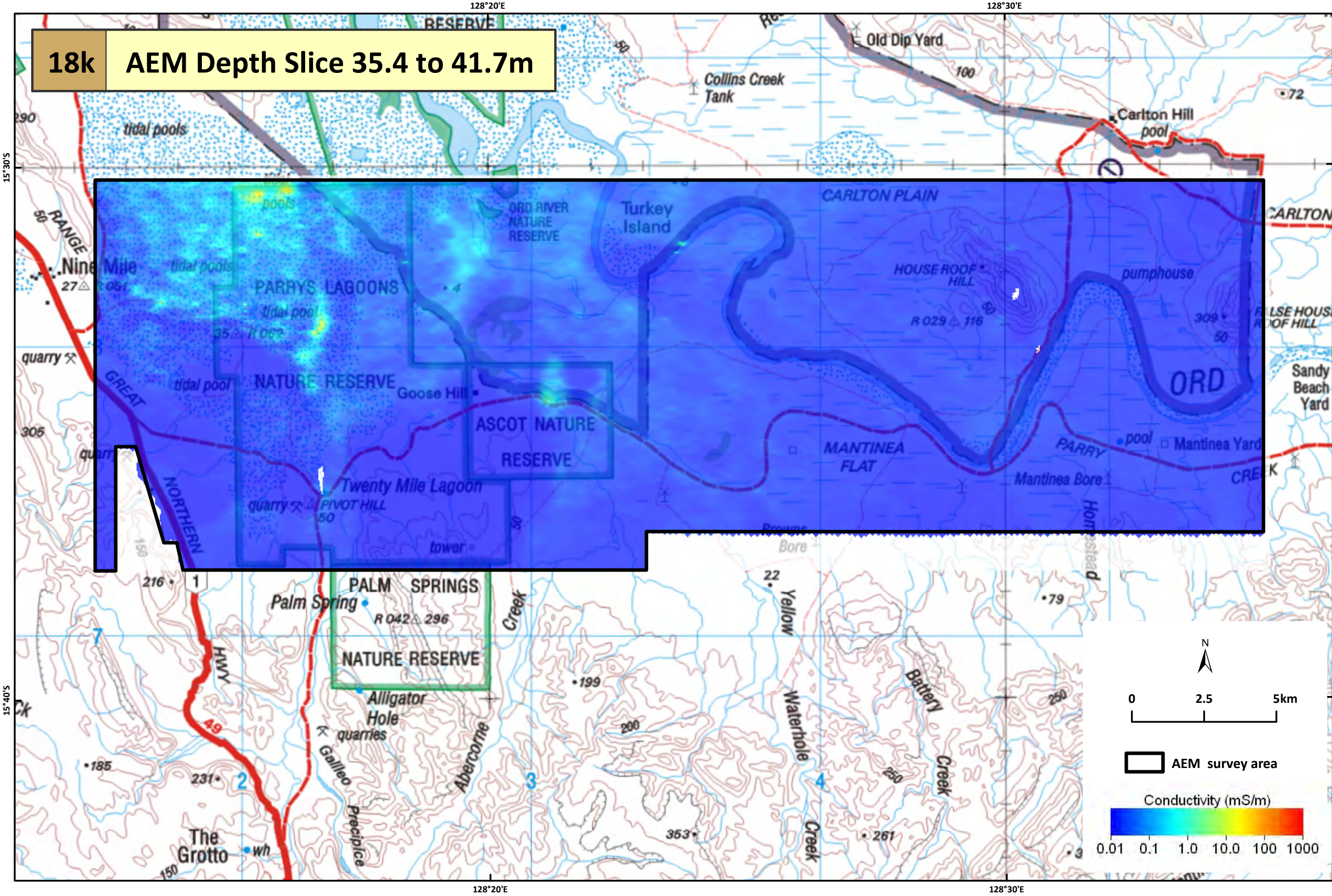
Ord Valley AEM Interpretation Project



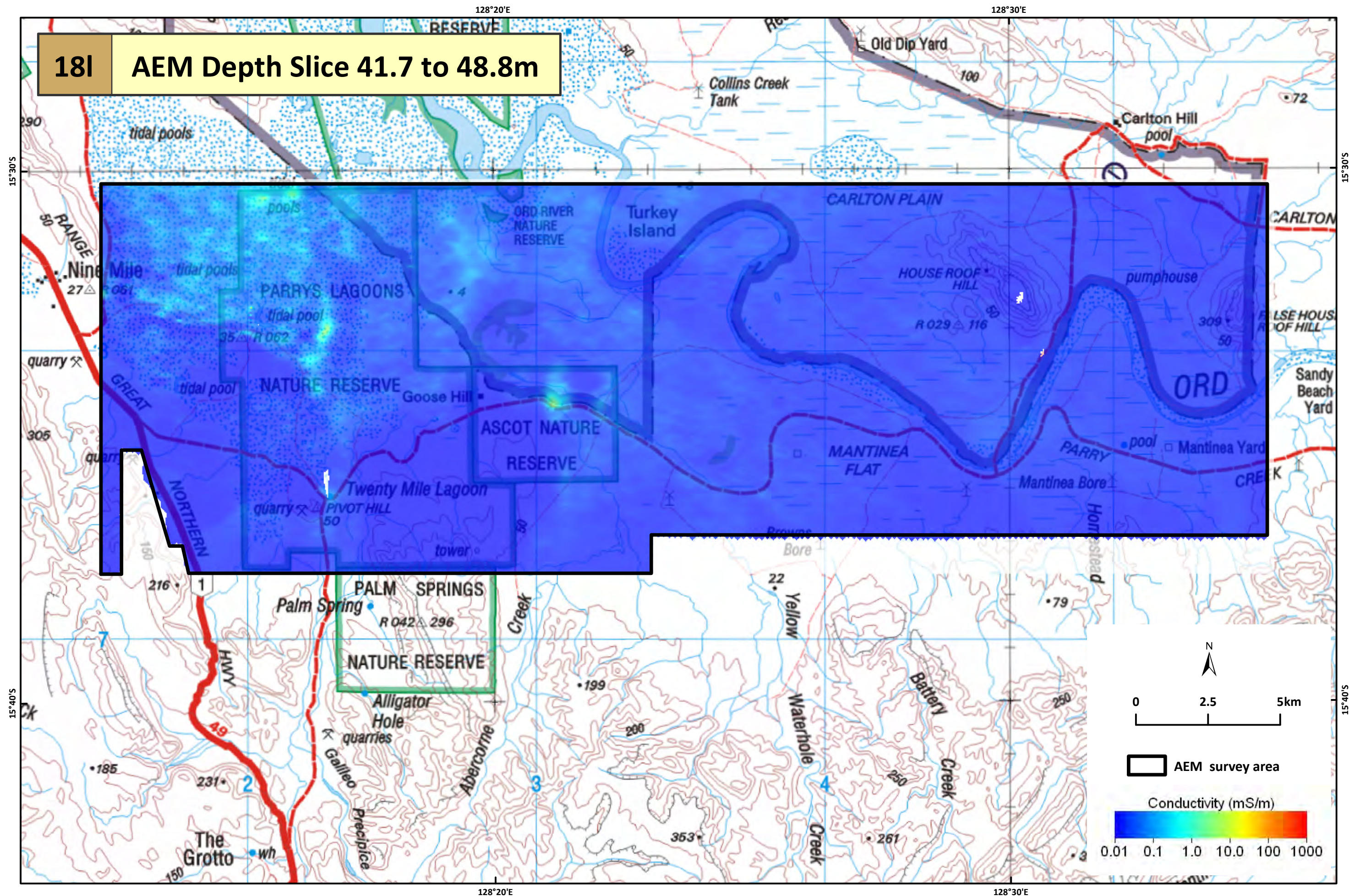
Ord Valley AEM Interpretation Project



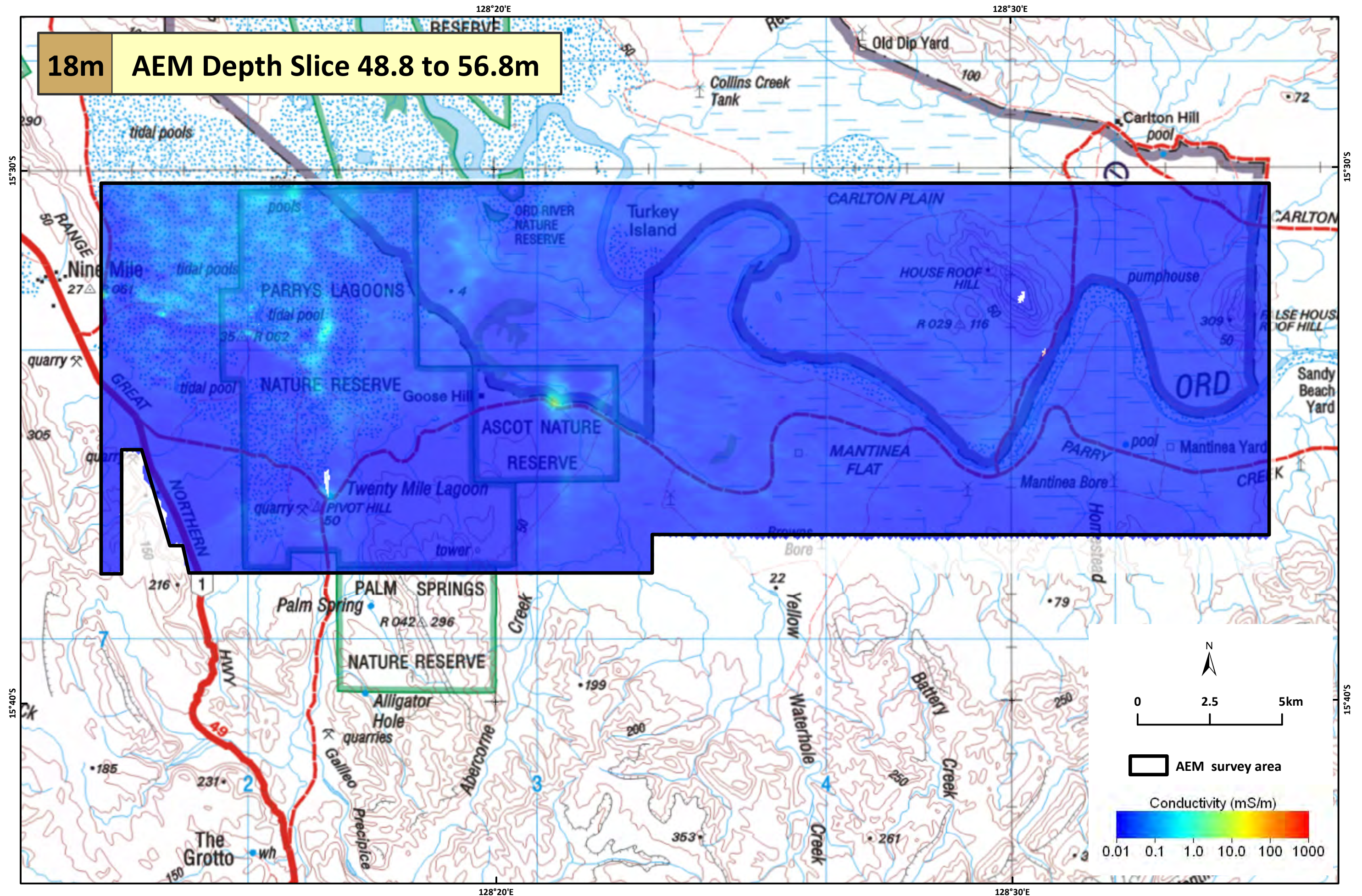
Ord Valley AEM Interpretation Project



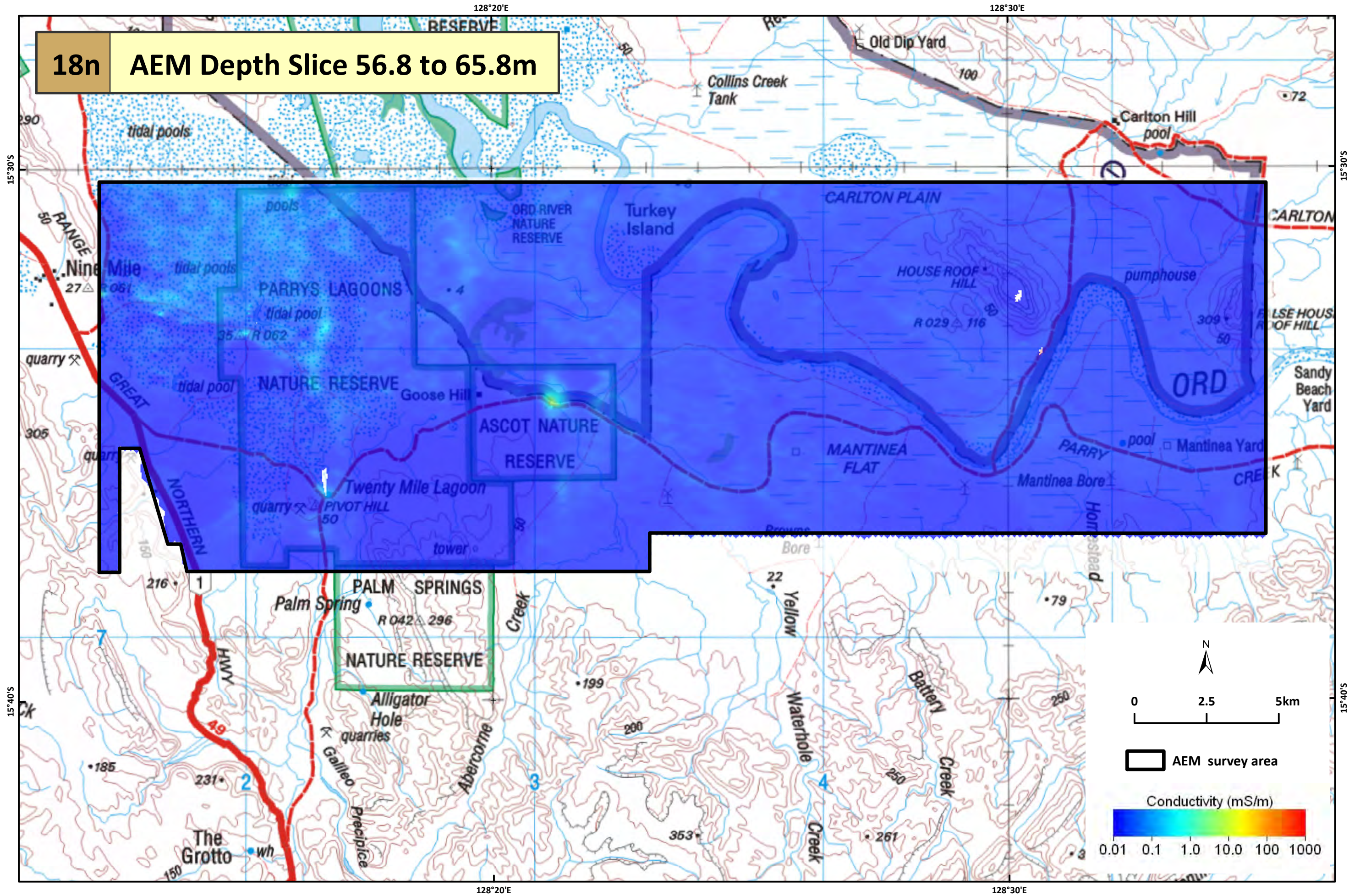
Ord Valley AEM Interpretation Project



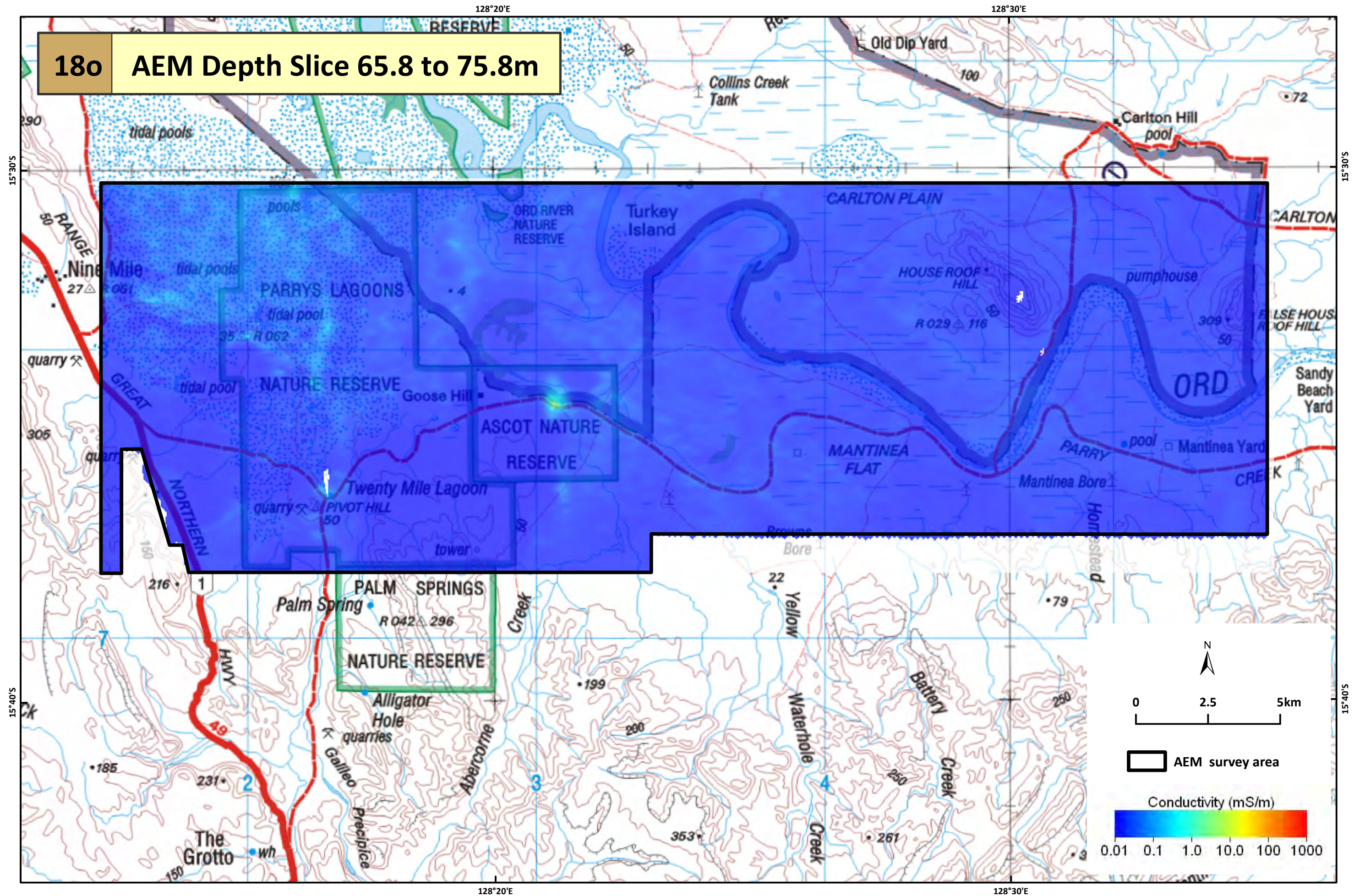
Ord Valley AEM Interpretation Project



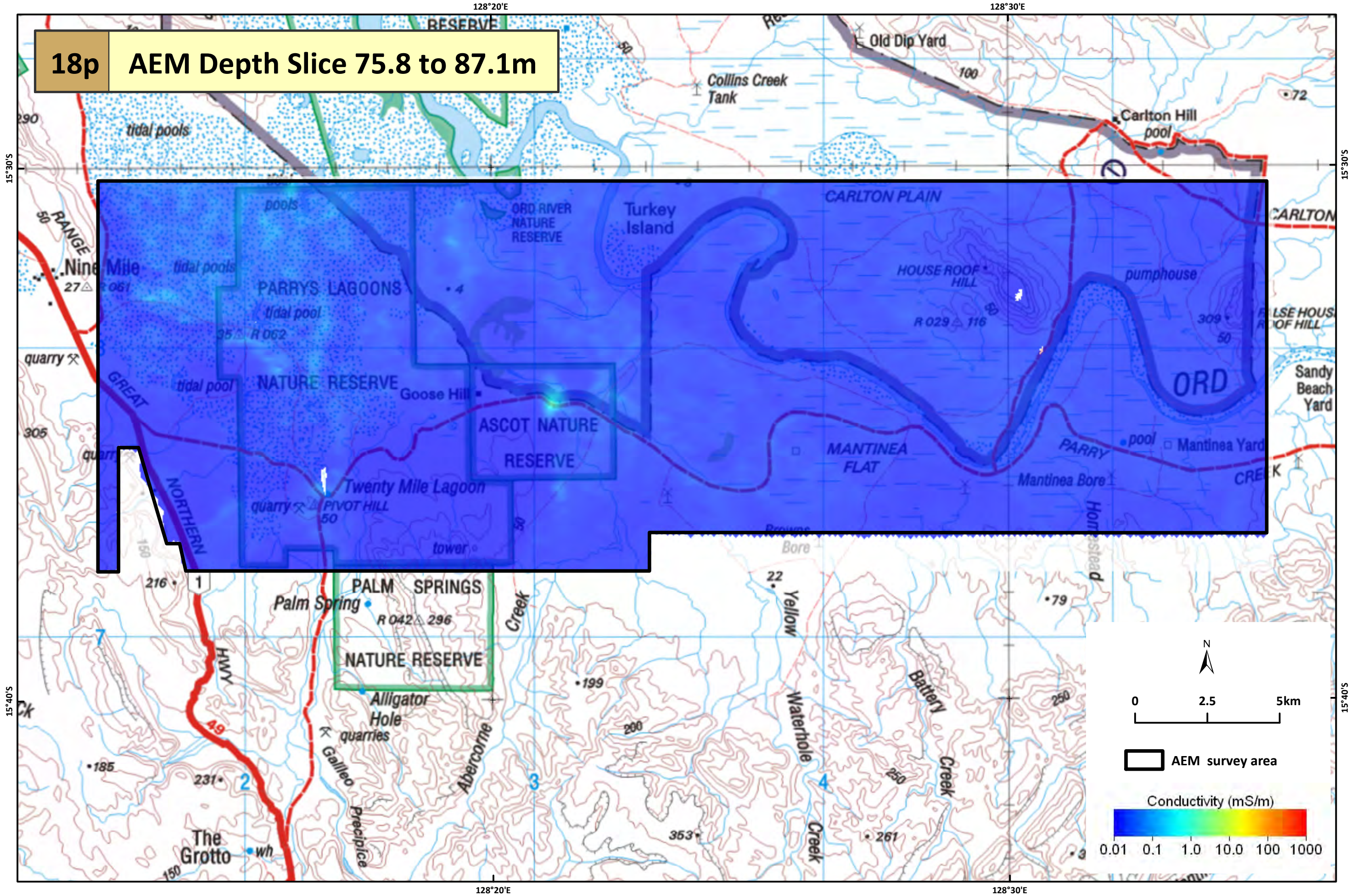
Ord Valley AEM Interpretation Project



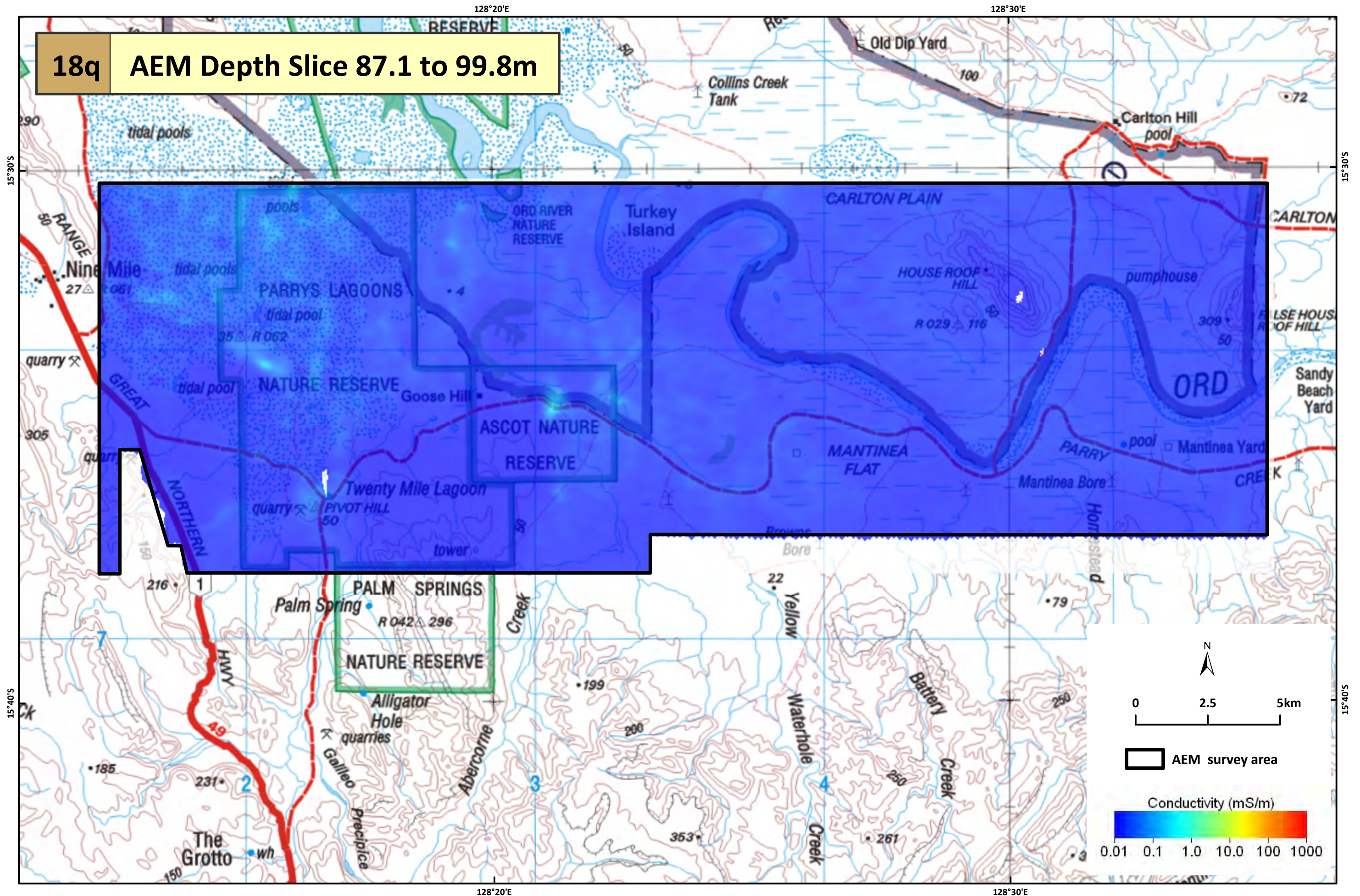
Ord Valley AEM Interpretation Project



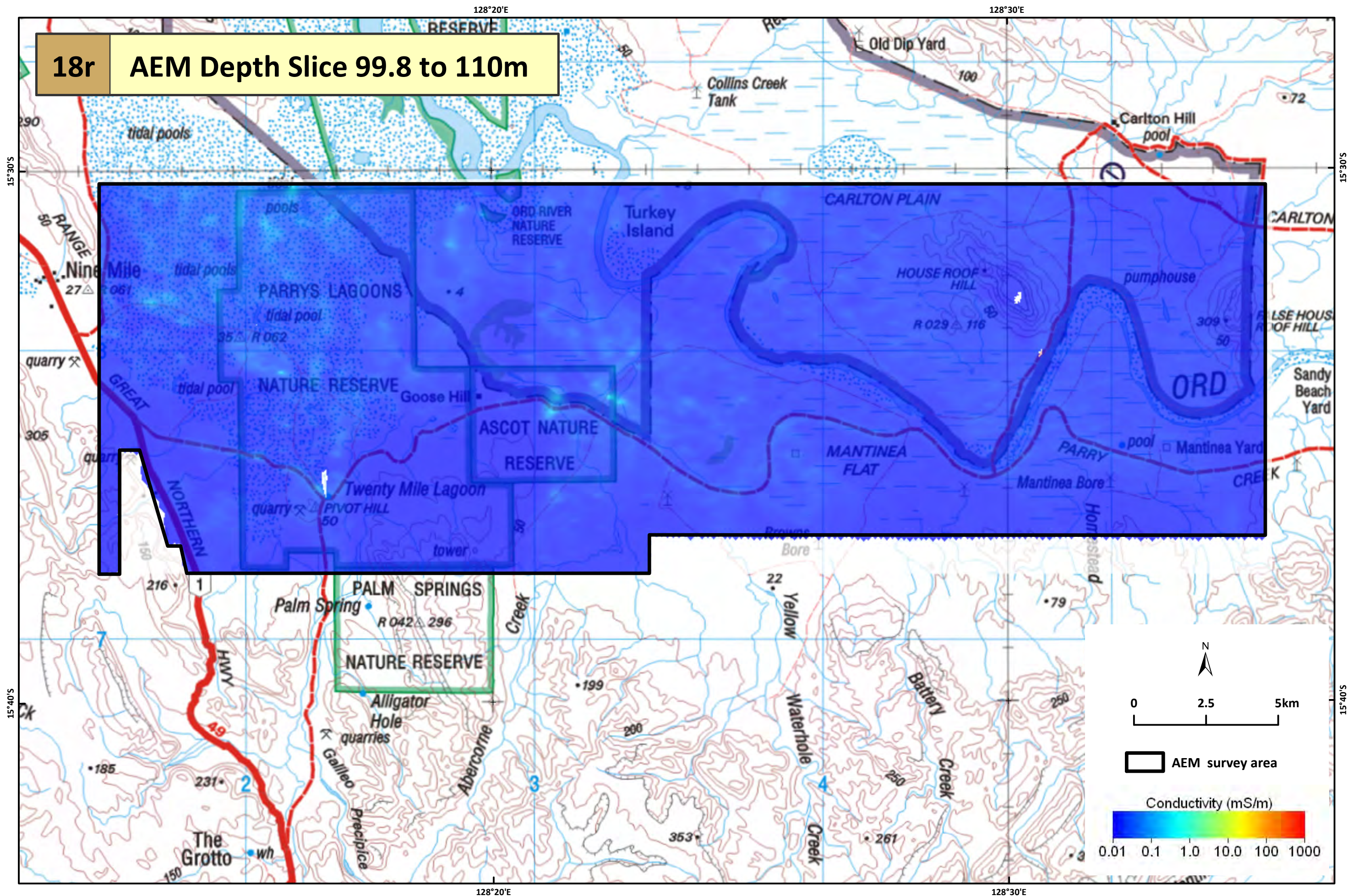
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

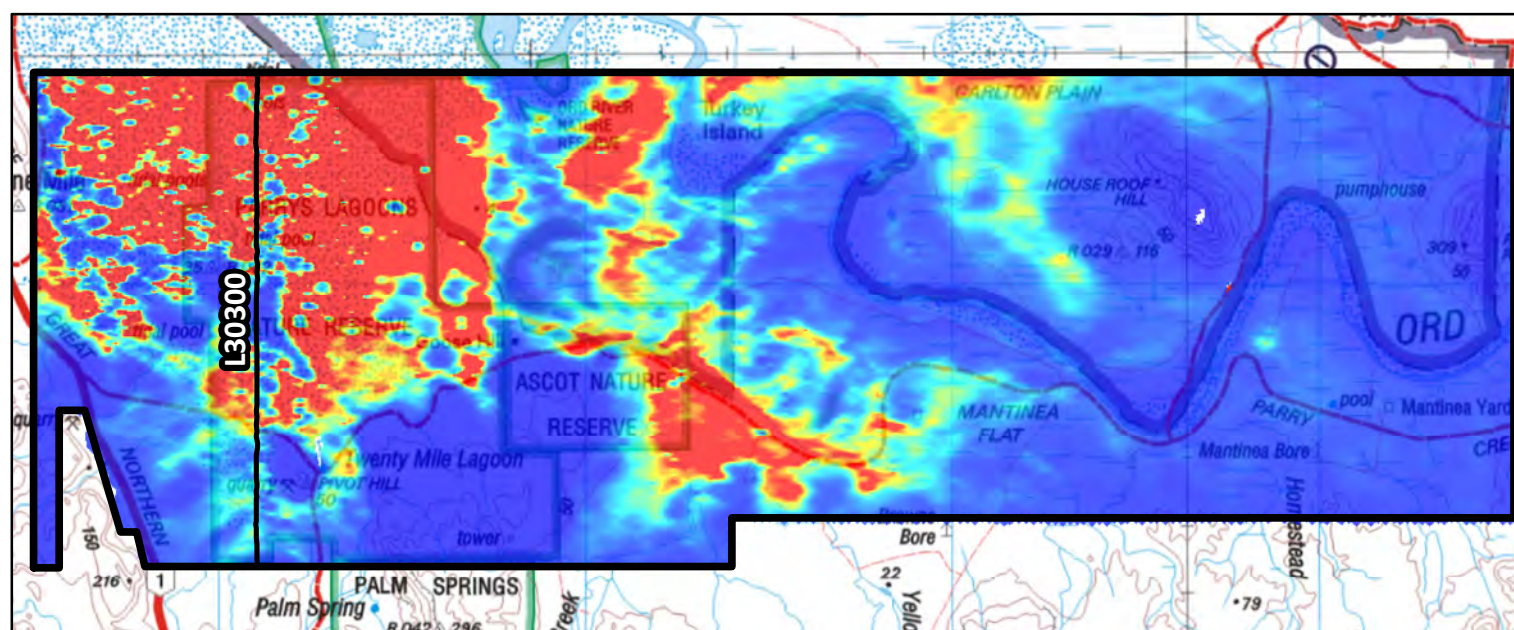


Ord Valley AEM Interpretation Project

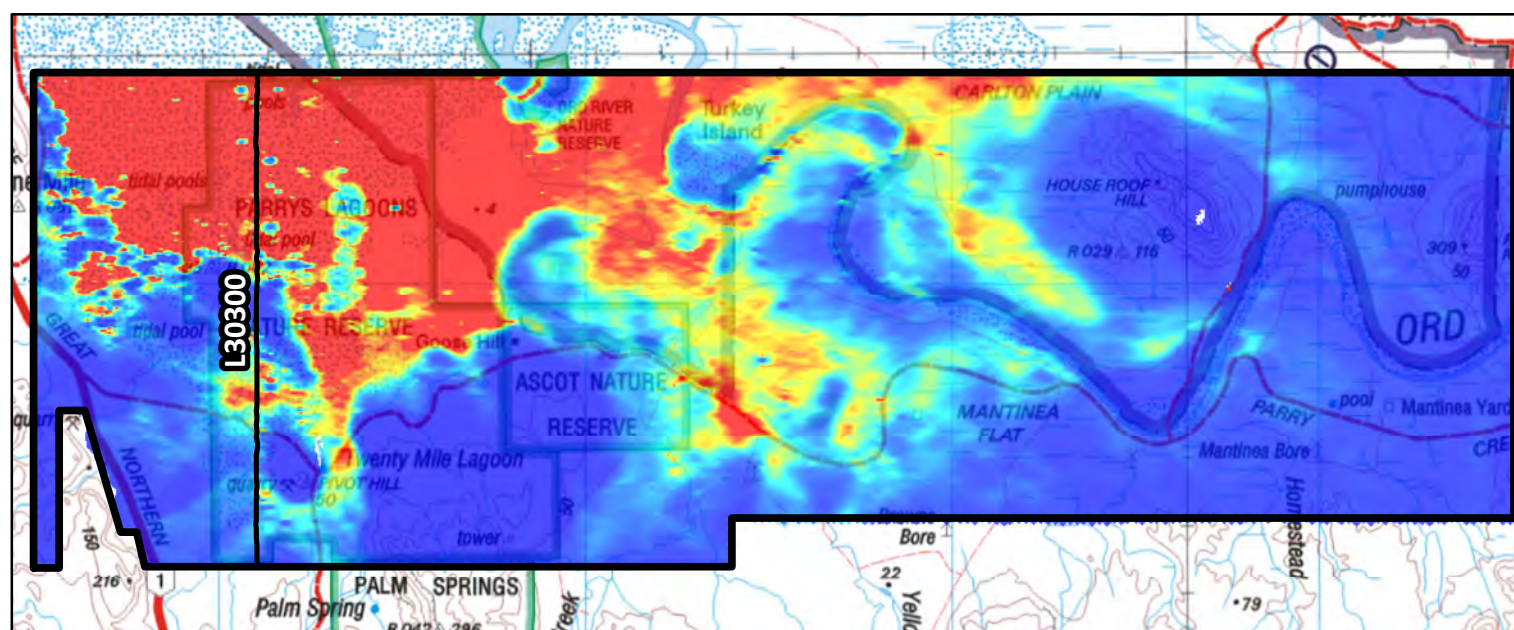


Ord Valley AEM Interpretation Project

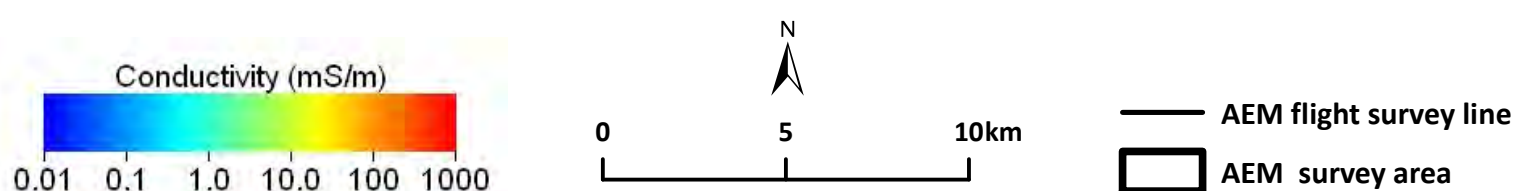
19a AEM Sections



AEM Depth slice 4.2 to 6.7m



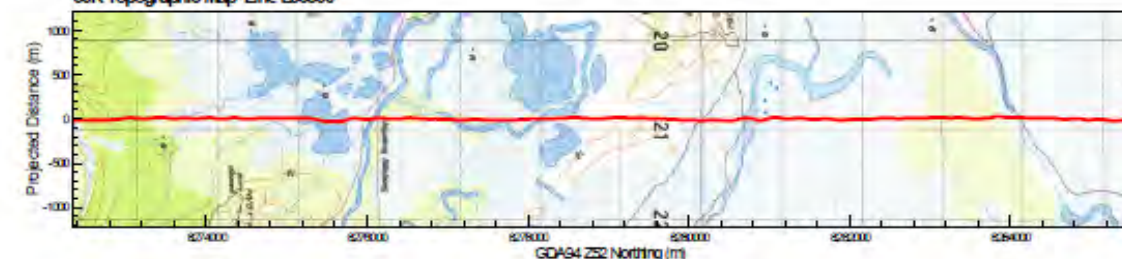
AEM Depth slice 9.5 to 12.7m



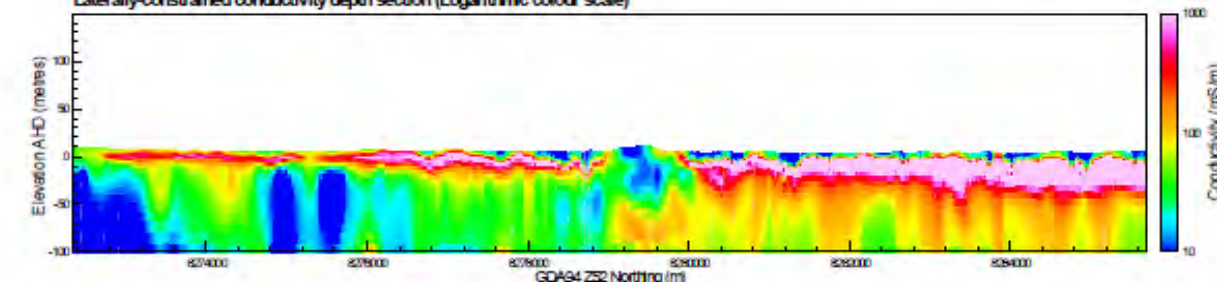
SkyTEM Ord Valley AEM Survey: Parrys Lagoon Laterally Constrained Inversion conductivity-depth sections

Flight Line Number
L30300

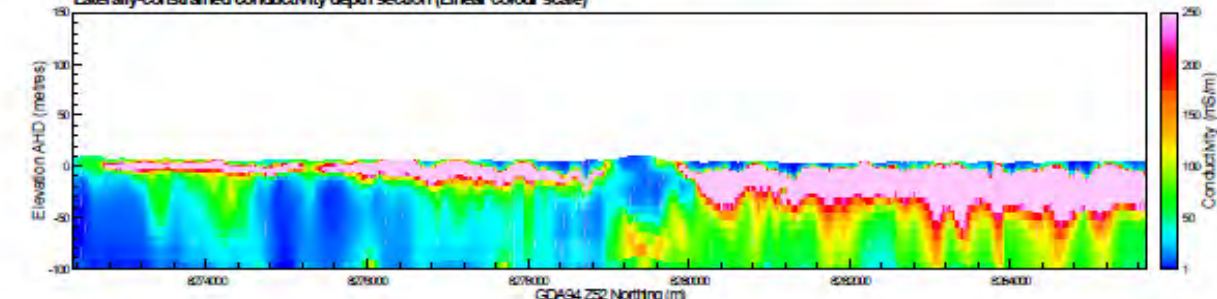
18 Layer Smooth model inversion of SkyTEM Binary survey data.
Processed and modelled using Aarhus Geophysics Workbench software
Model Version 1.0 Author: Andrew Fitzpatrick Date 26 May 2009 Projection GDA94 Zone 52
50K Topographic Map Line L30300



Laterally-constrained conductivity depth section (Logarithmic colour scale)



Laterally-constrained conductivity depth section (Linear colour scale)



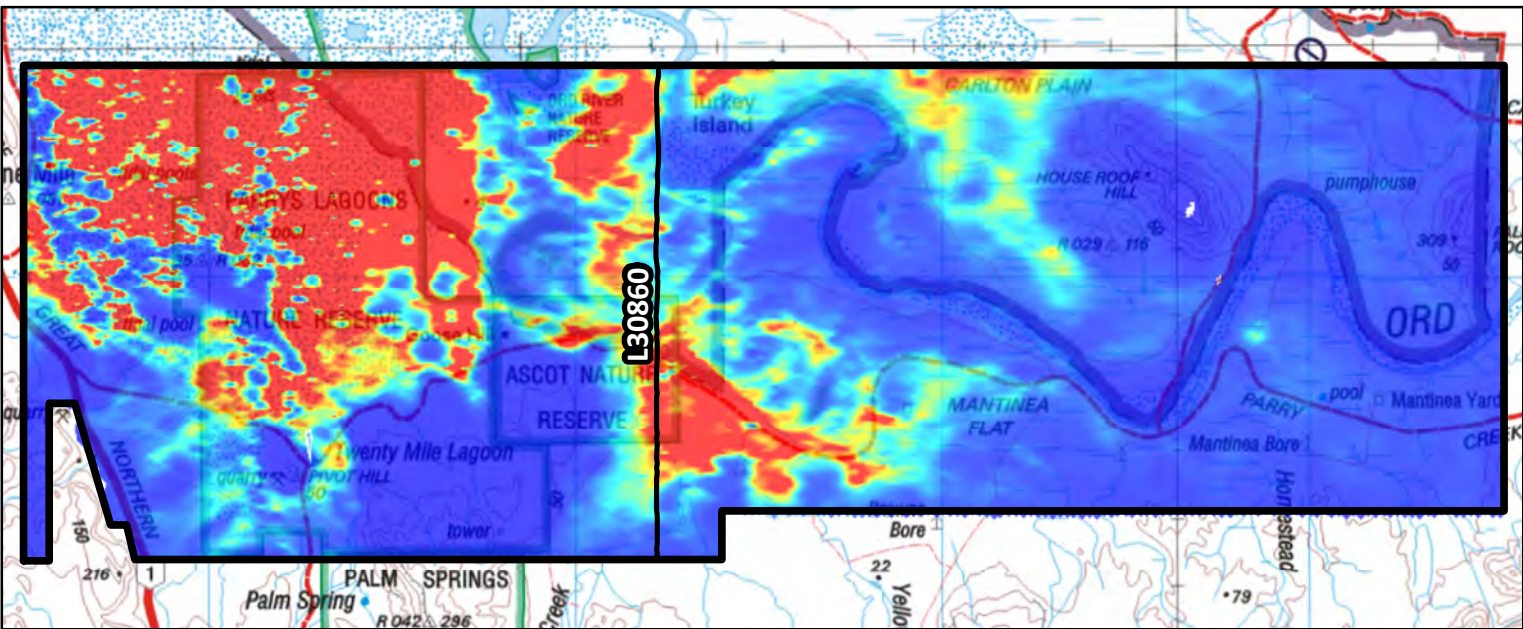
Data residual (below 0.5 is very good, below 1.0 is good, 1-2 moderate, above 3 is poor (generally related to resistive features))



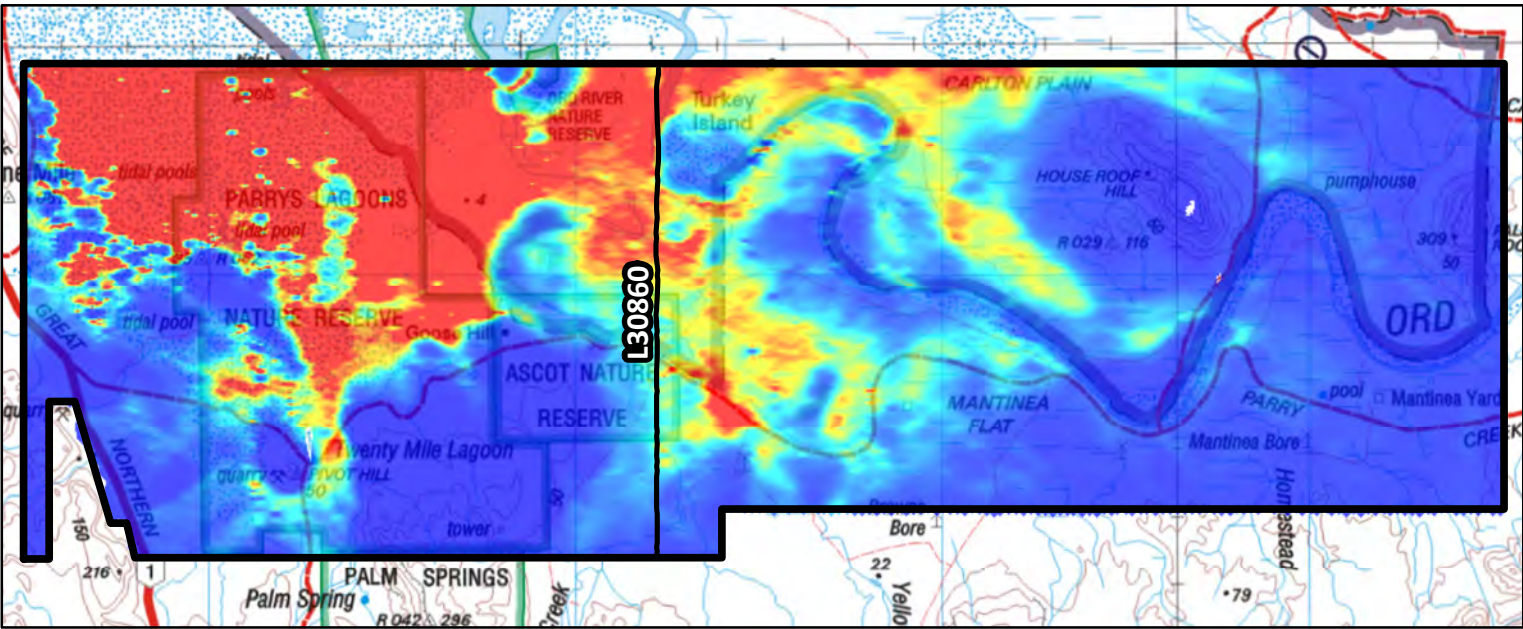
Ord Valley AEM Interpretation Project

19b

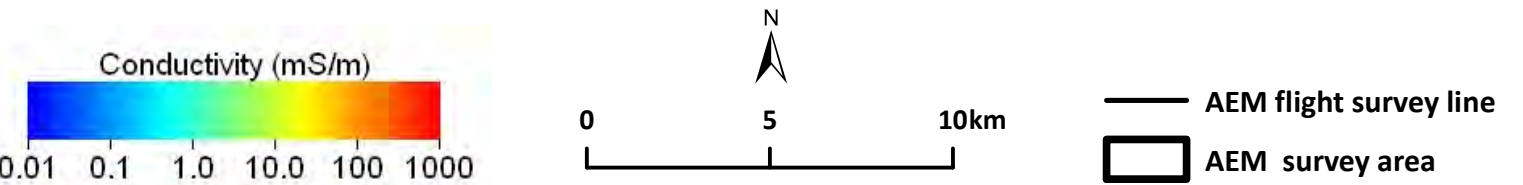
AEM Sections



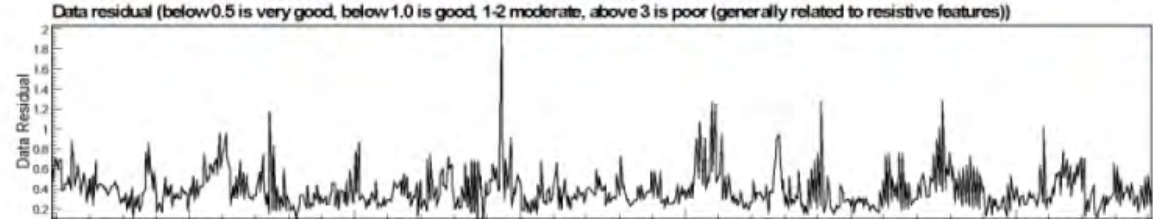
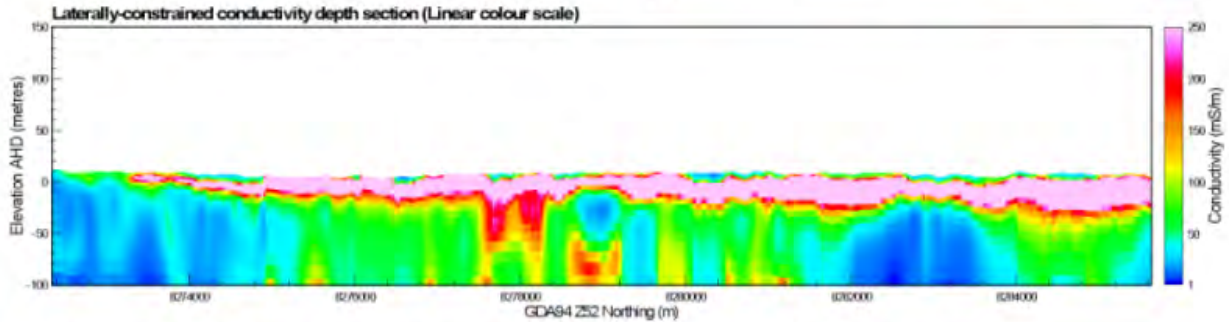
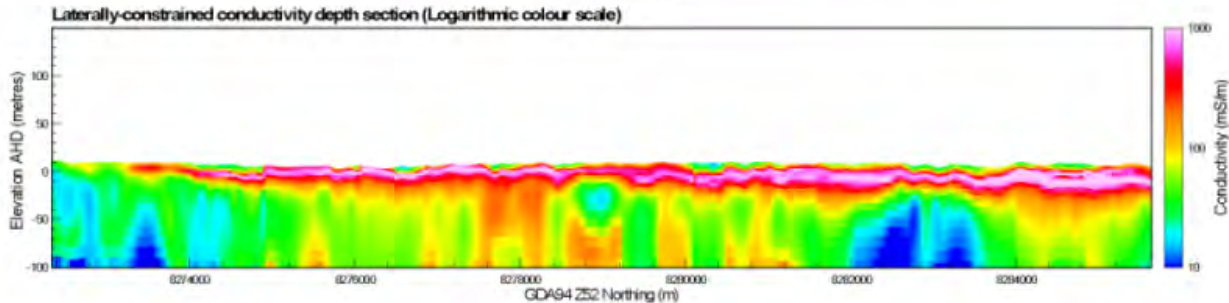
AEM Depth slice 4.2 to 6.7m



AEM Depth slice 9.5 to 12.7m

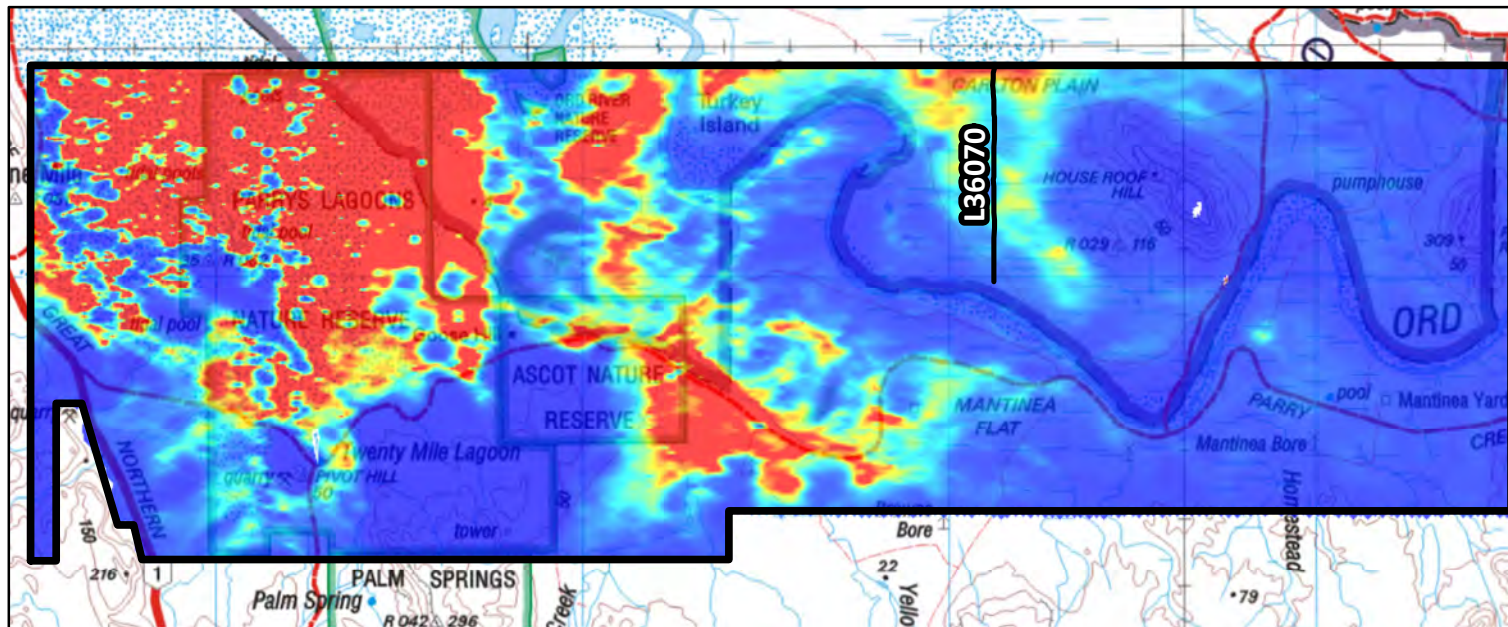


SkyTEM Ord Valley AEM Survey: Parrys Lagoon
Laterally Constrained Inversion conductivity-depth sections
Flight Line Number
L30860
18 Layer Smooth model inversion of SkyTEM Binary survey data.
Processed and modelled using Aarhus Geophysics Workbench software
Model Version 1.0 Author: Andrew Fitzpatrick Date 26 May 2009 Projection GDA94 Zone 52
50K Topographic Map Line L30860

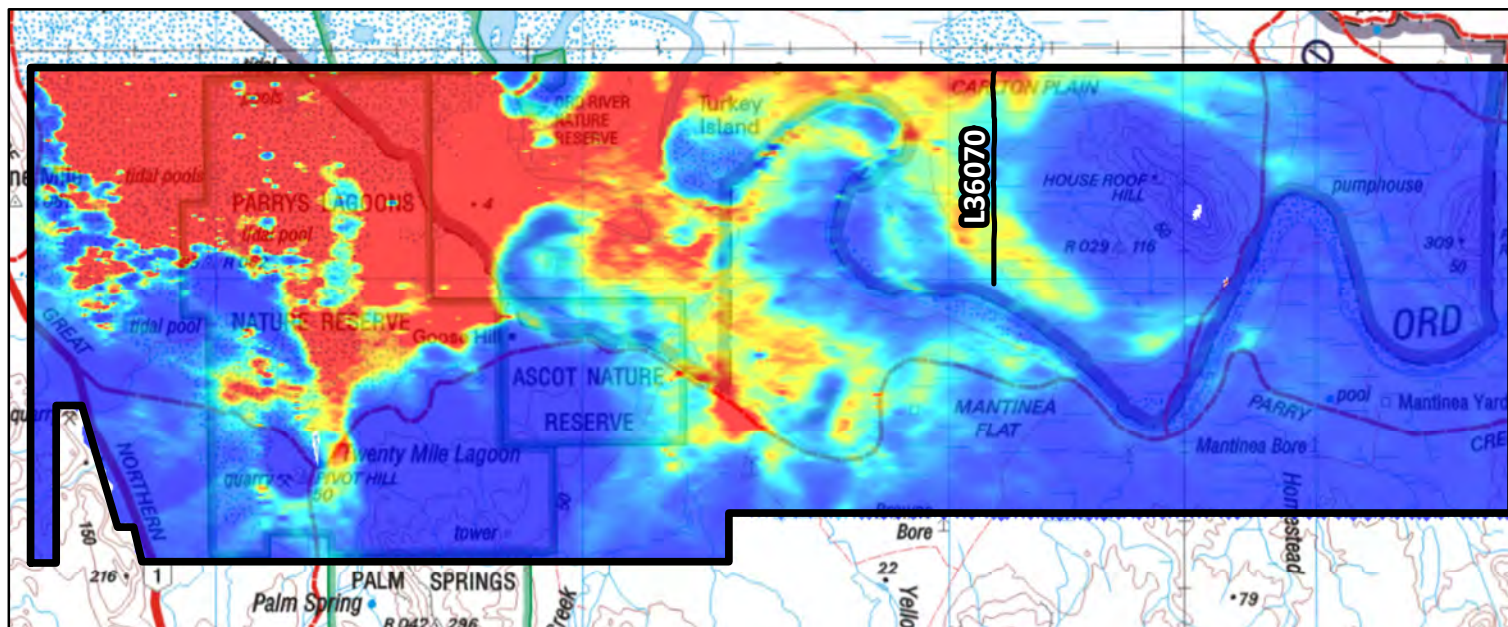


Ord Valley AEM Interpretation Project

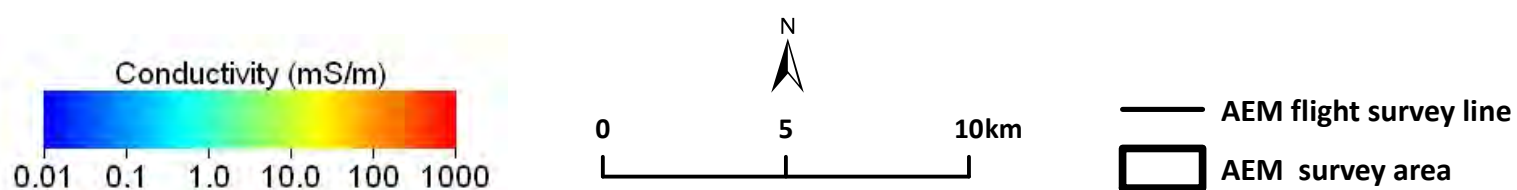
19c AEM Sections



AEM Depth slice 4.2 to 6.7m



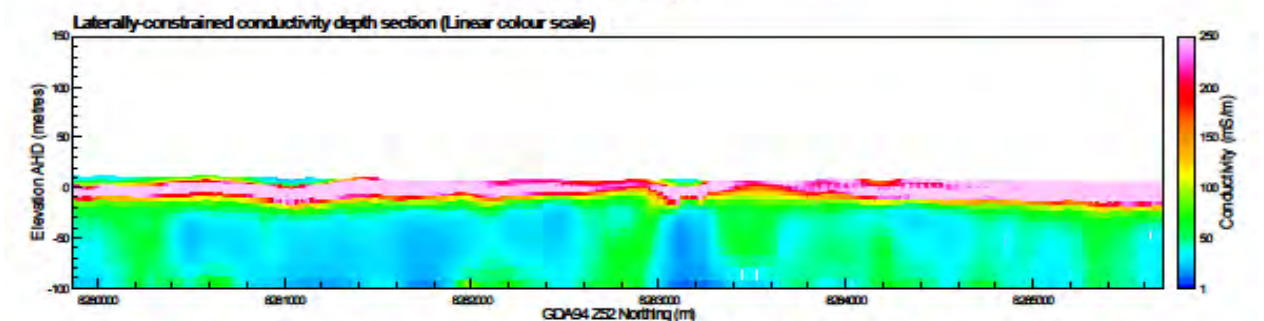
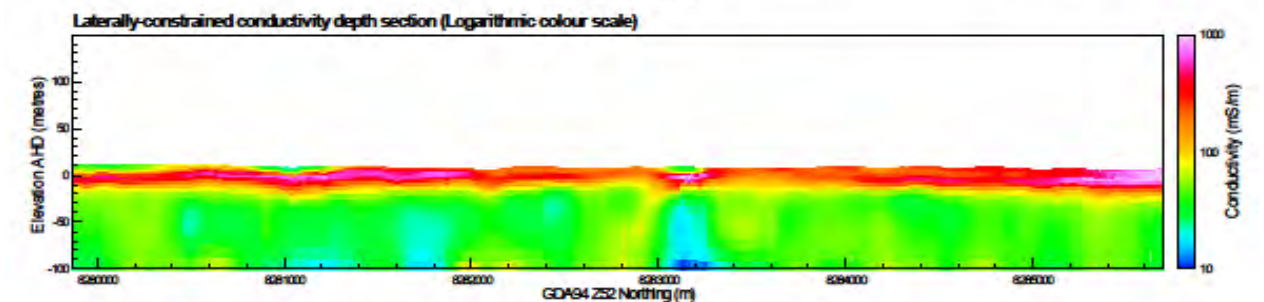
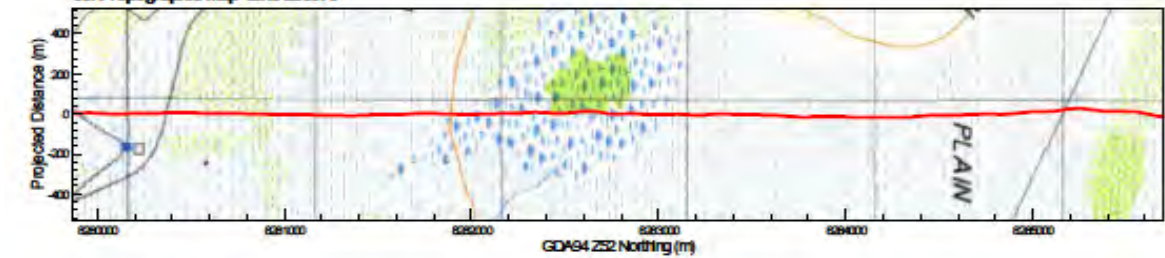
AEM Depth slice 9.5 to 12.7m



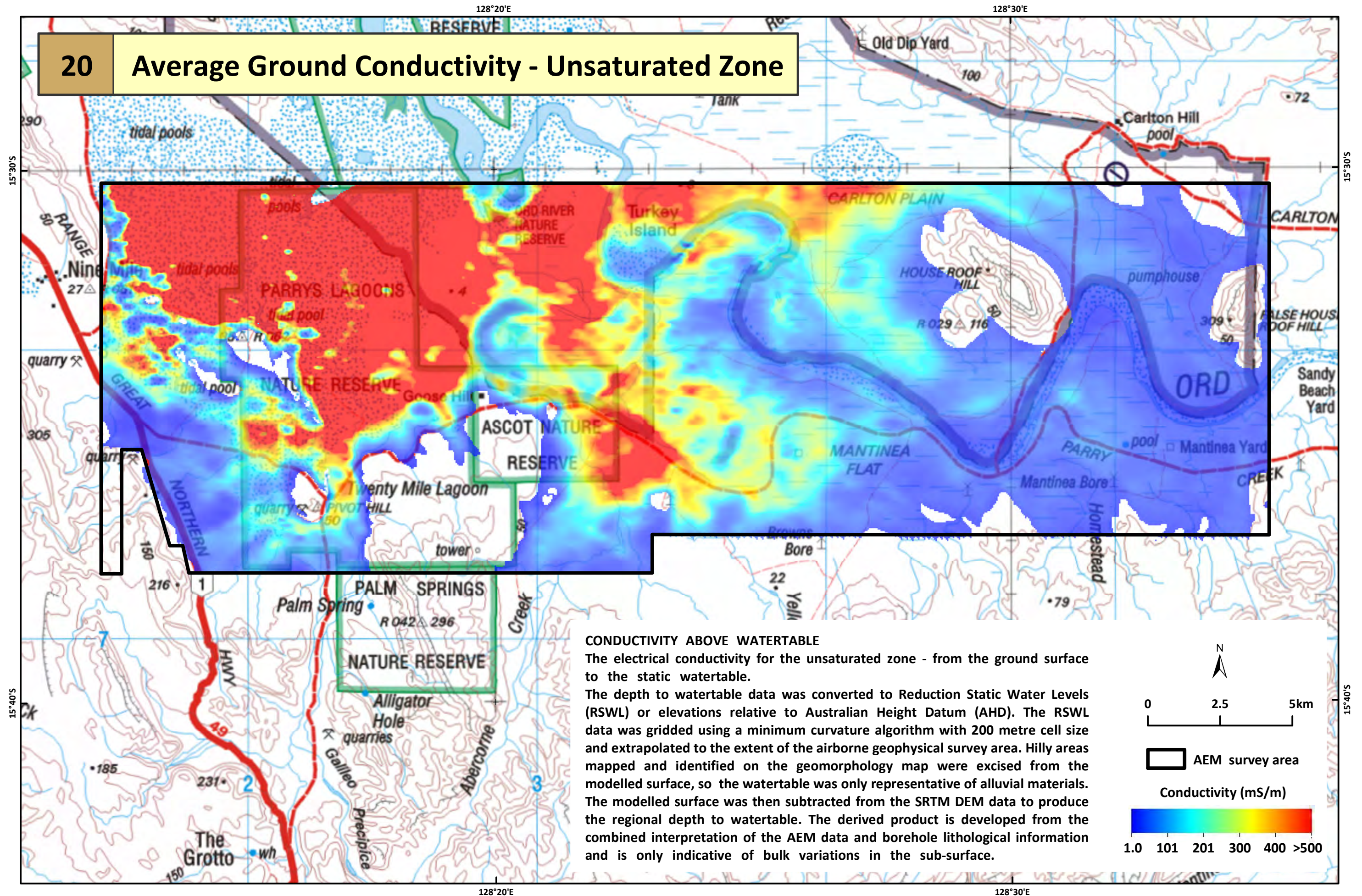
SkyTEM Ord Valley AEM Survey: Carlton Hill Laterally Constrained Inversion conductivity-depth sections

Flight Line Number
L36070

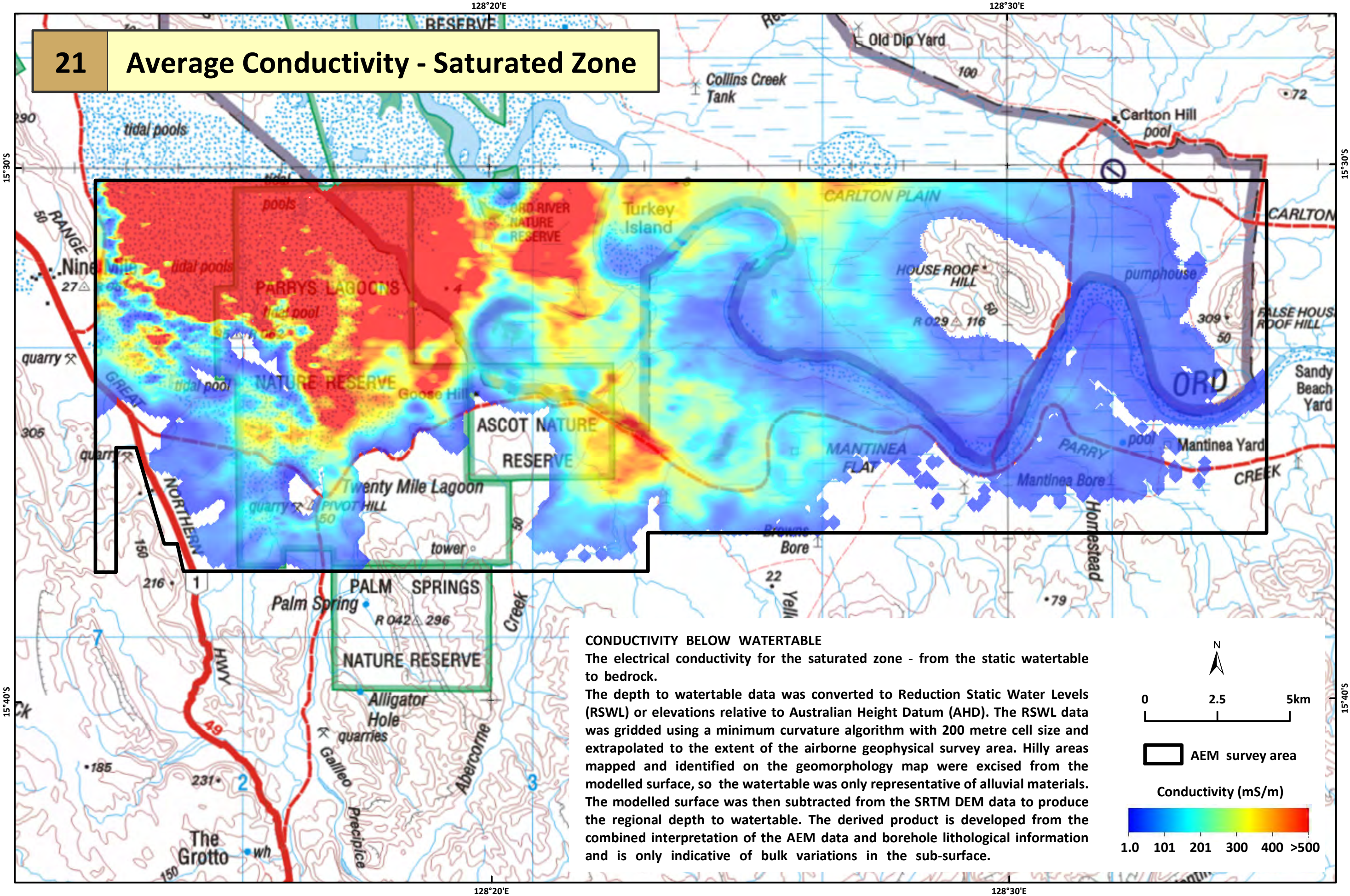
18 Layer Smooth model inversion of SkyTEM Binary survey data.
Processed and modelled using Aarhus Geophysics Workbench software
Model Version 1.0 Author: Andrew Fitzpatrick Date 26 May 2009 Projection GDA94 Zone 52
50K Topographic Map Line L36070



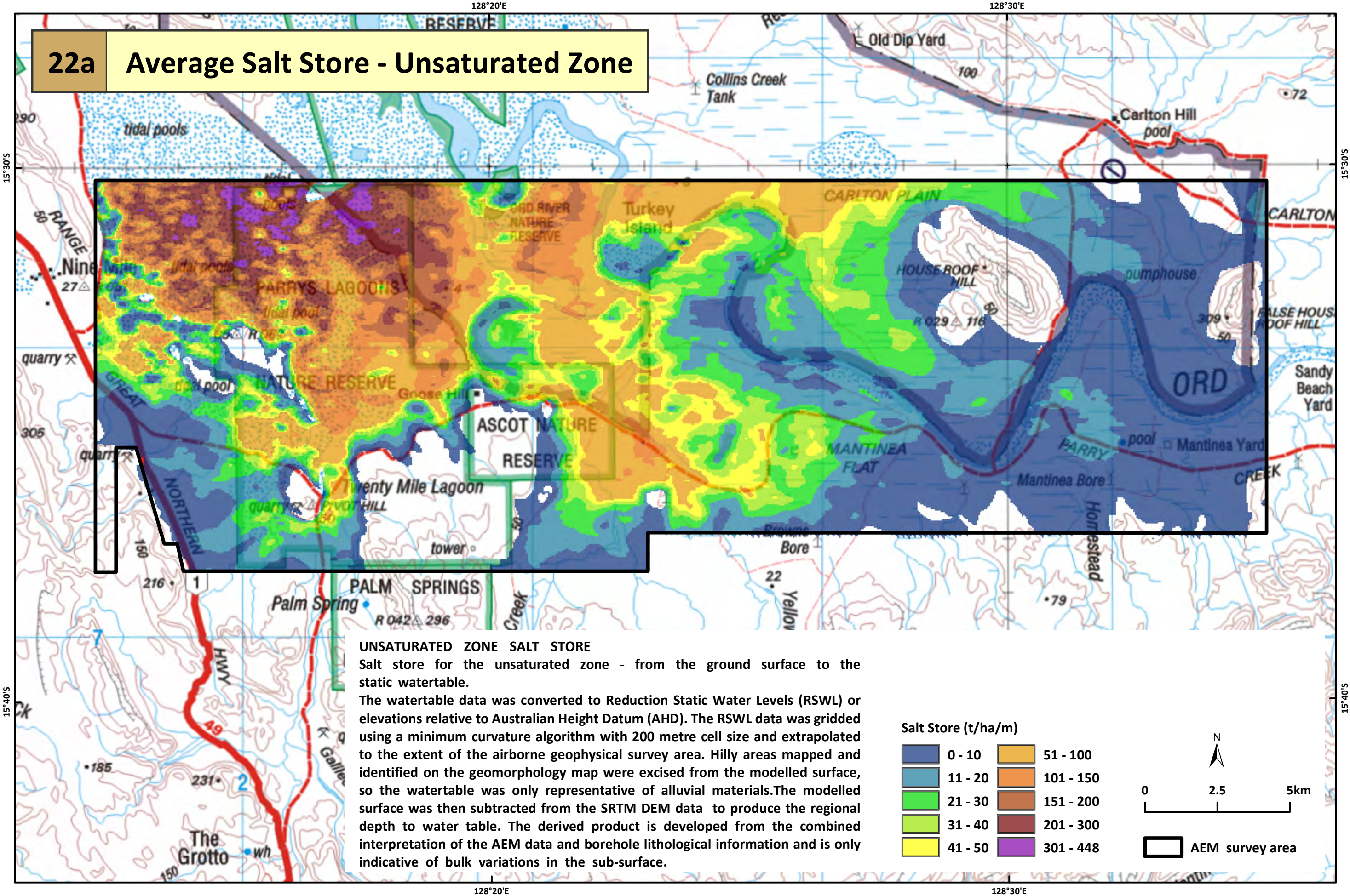
Ord Valley AEM Interpretation Project



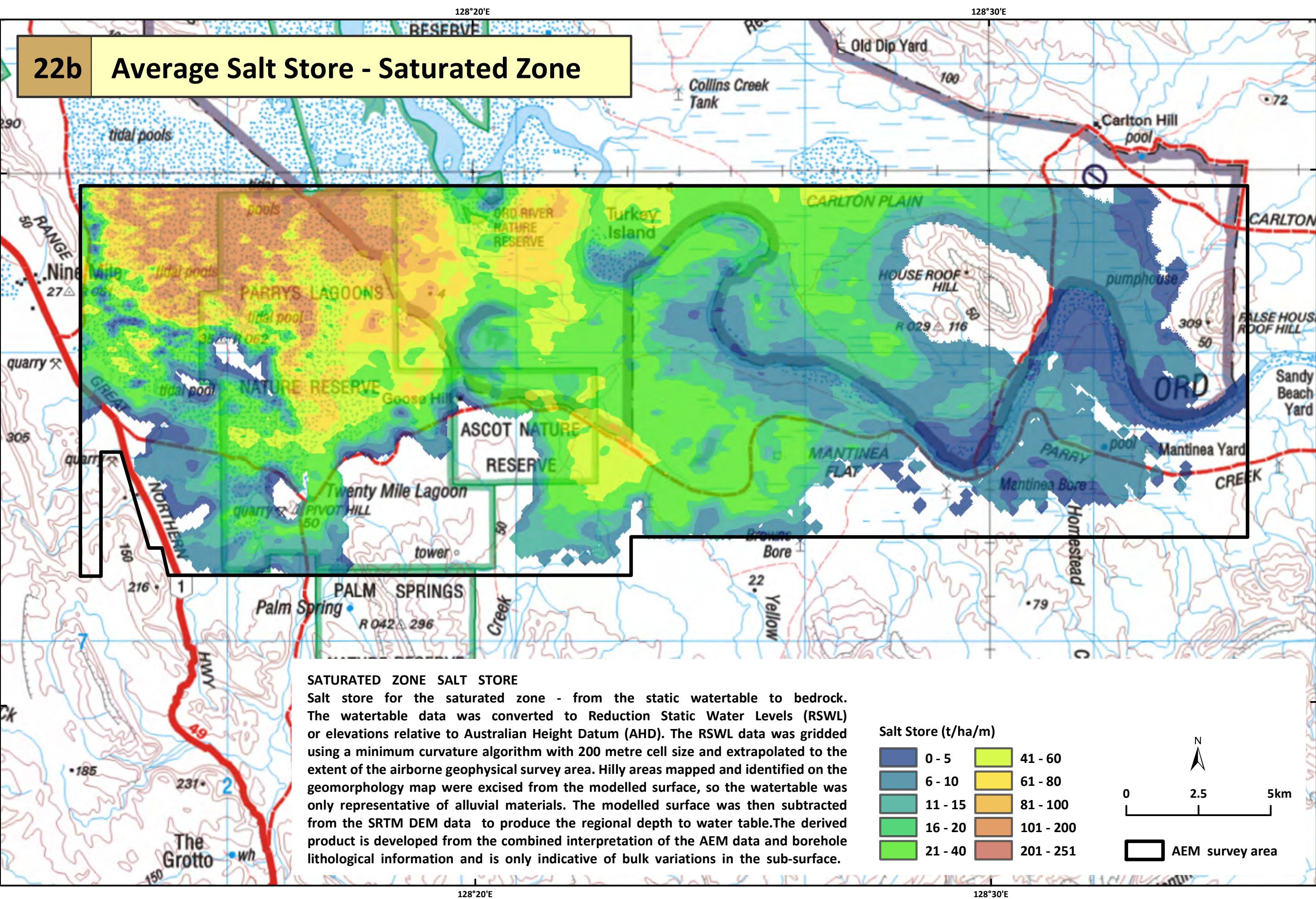
Ord Valley AEM Interpretation Project



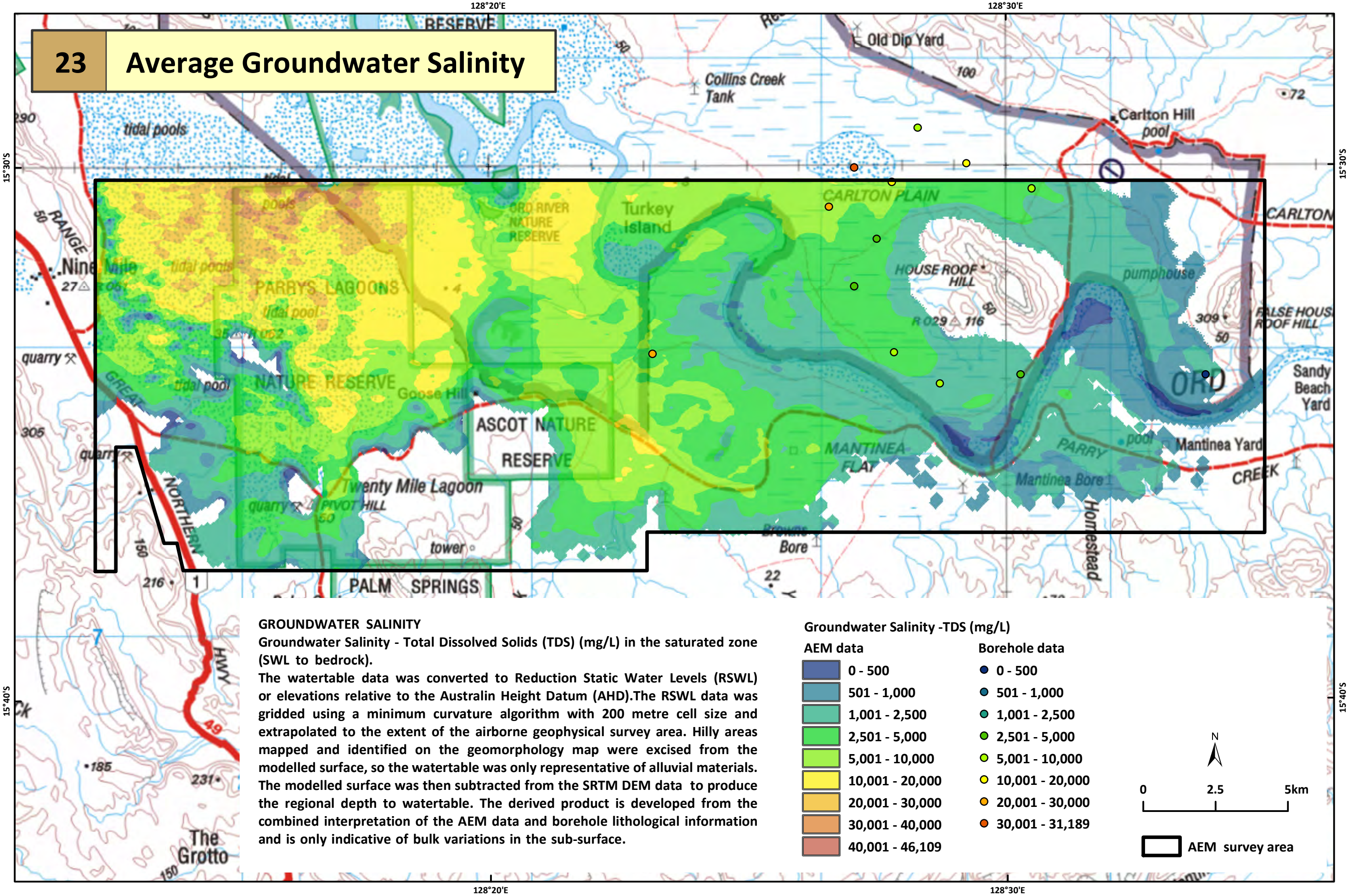
Ord Valley AEM Interpretation Project



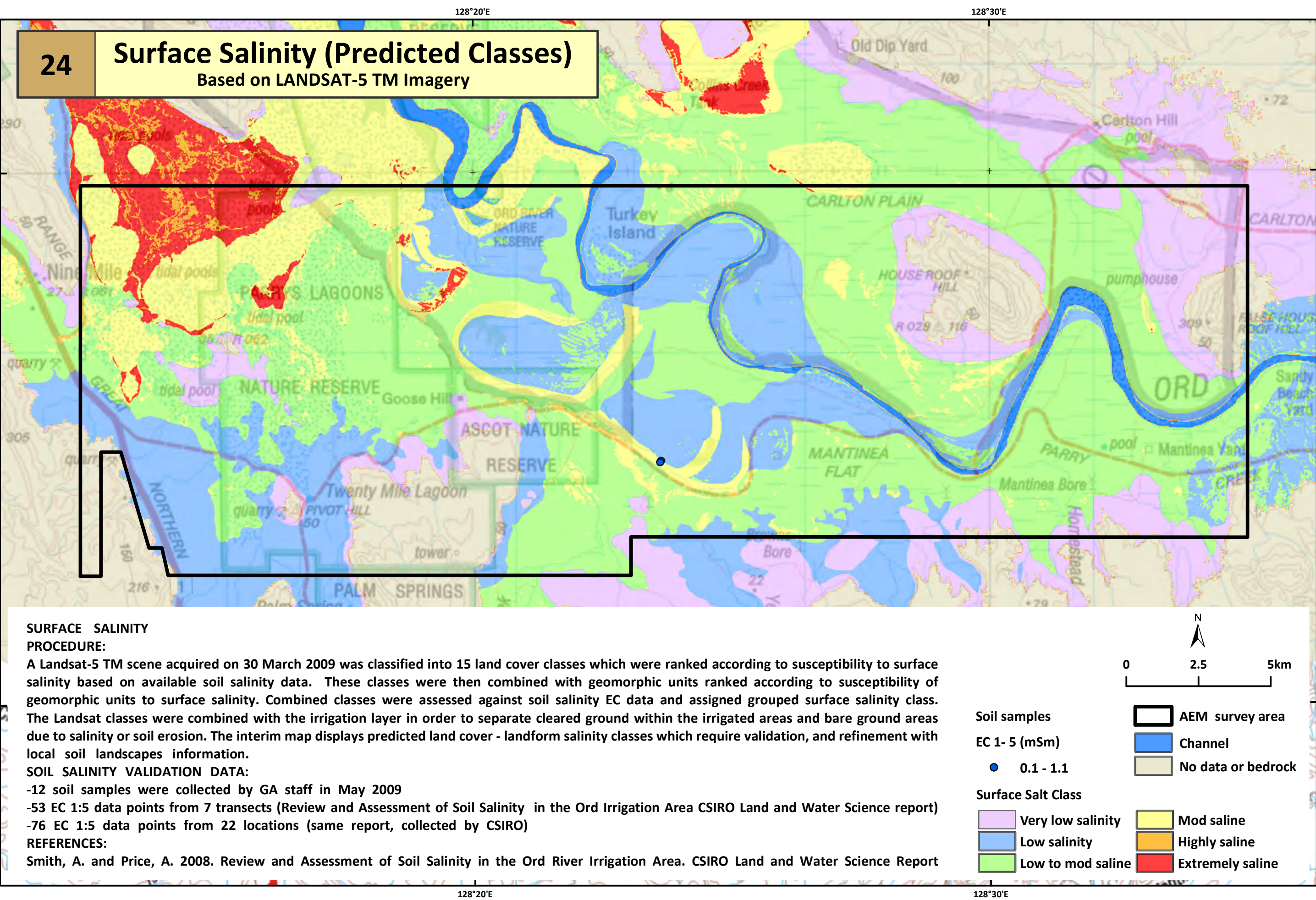
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

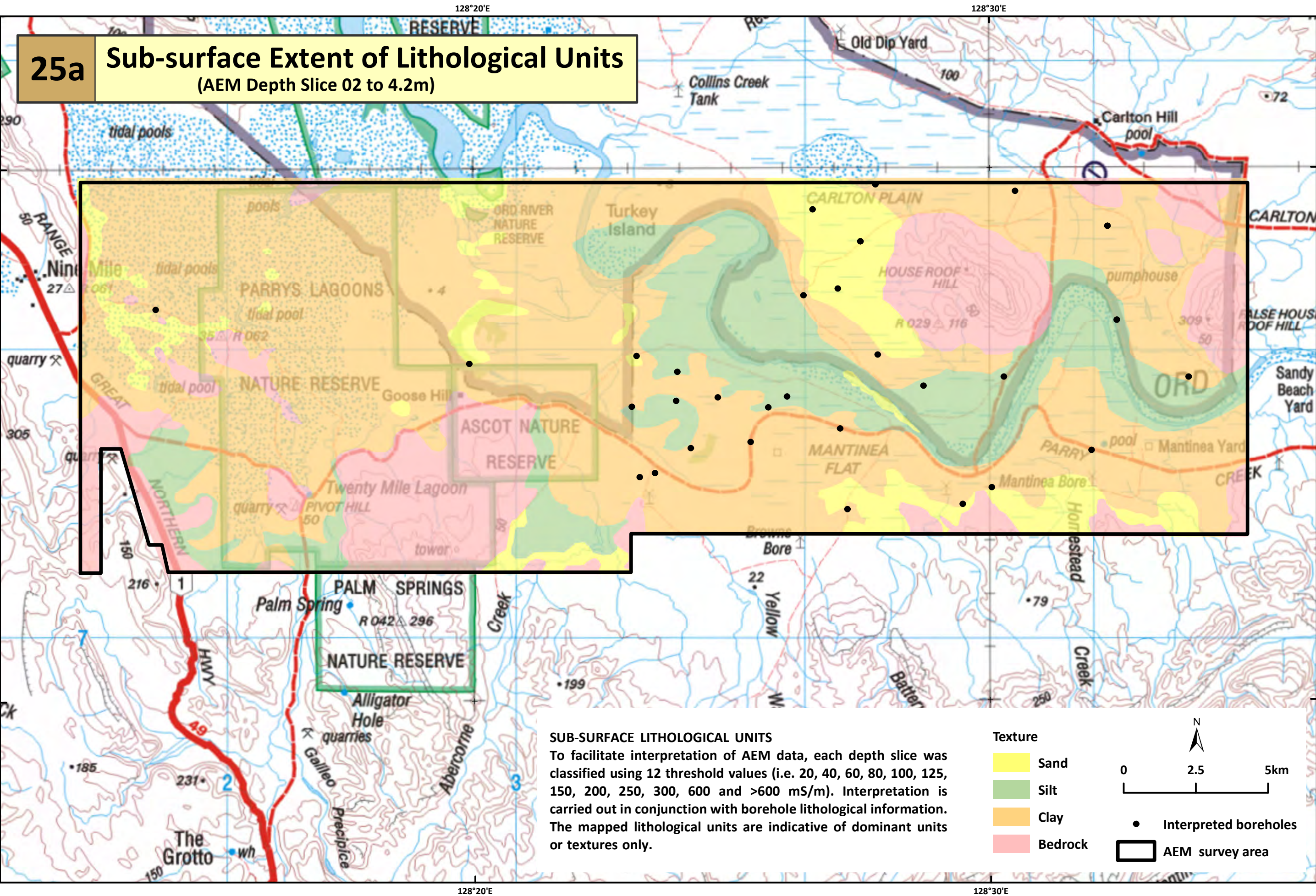


Ord Valley AEM Interpretation Project

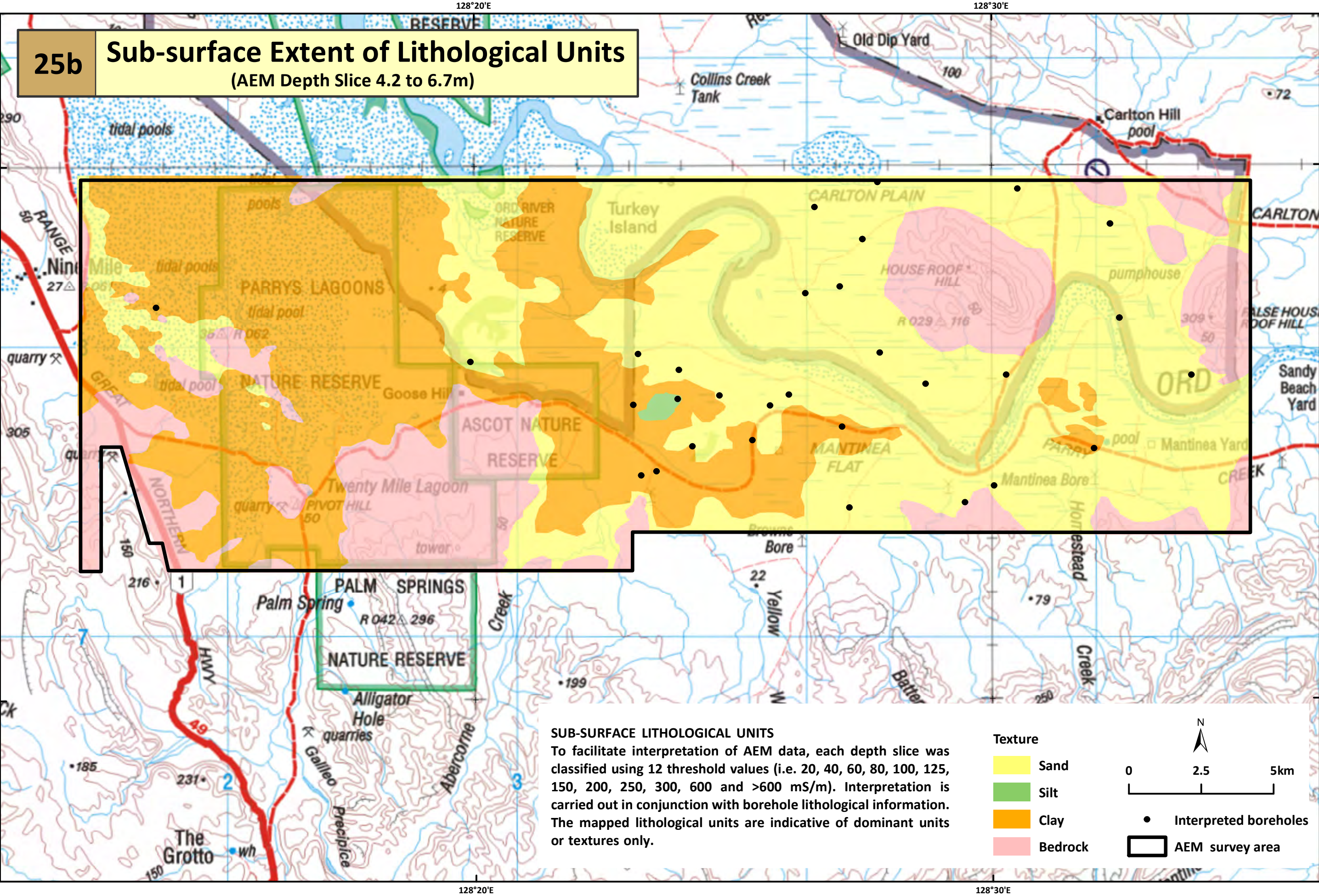


(c) Commonwealth of Australia (Geoscience Australia) 2009

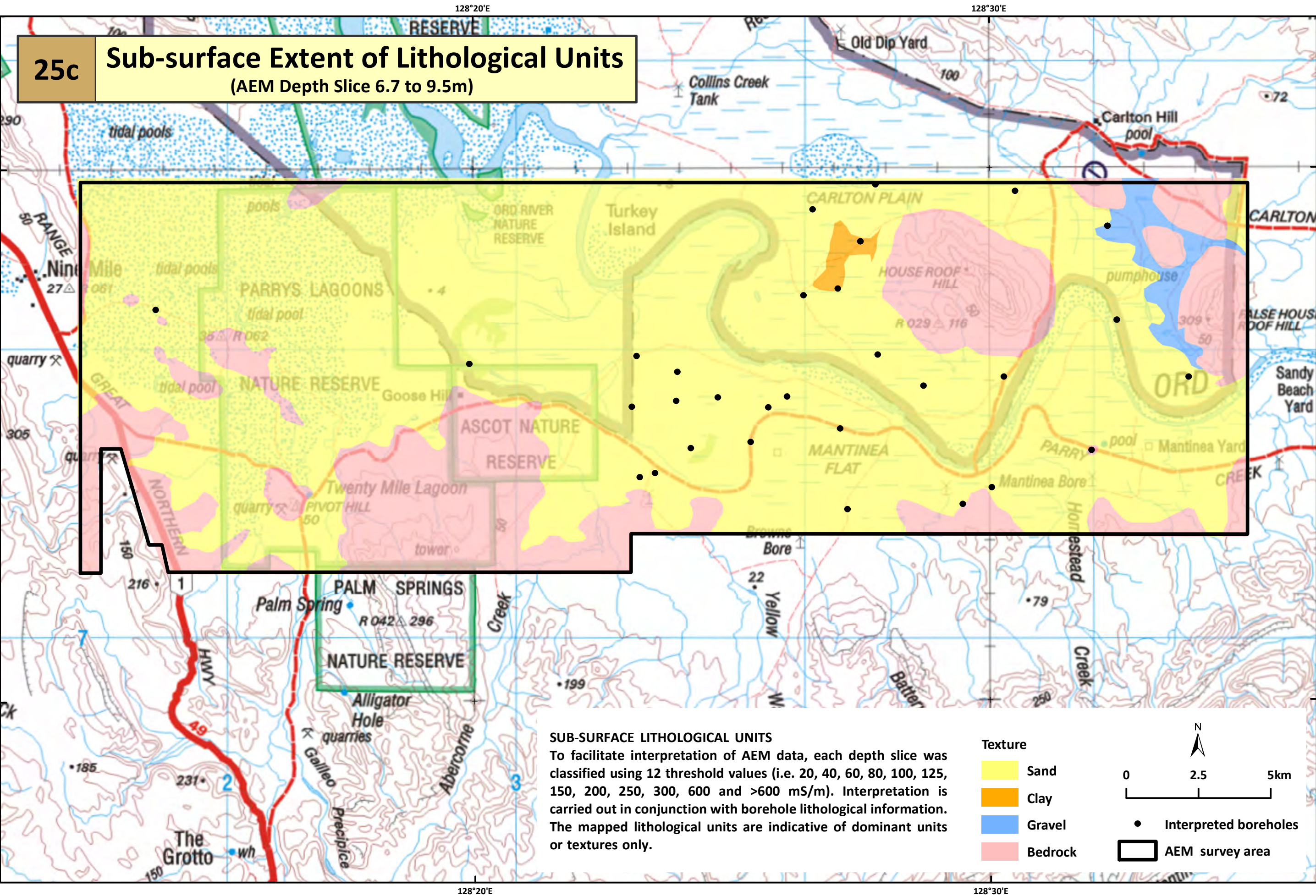
Ord Valley AEM Interpretation Project



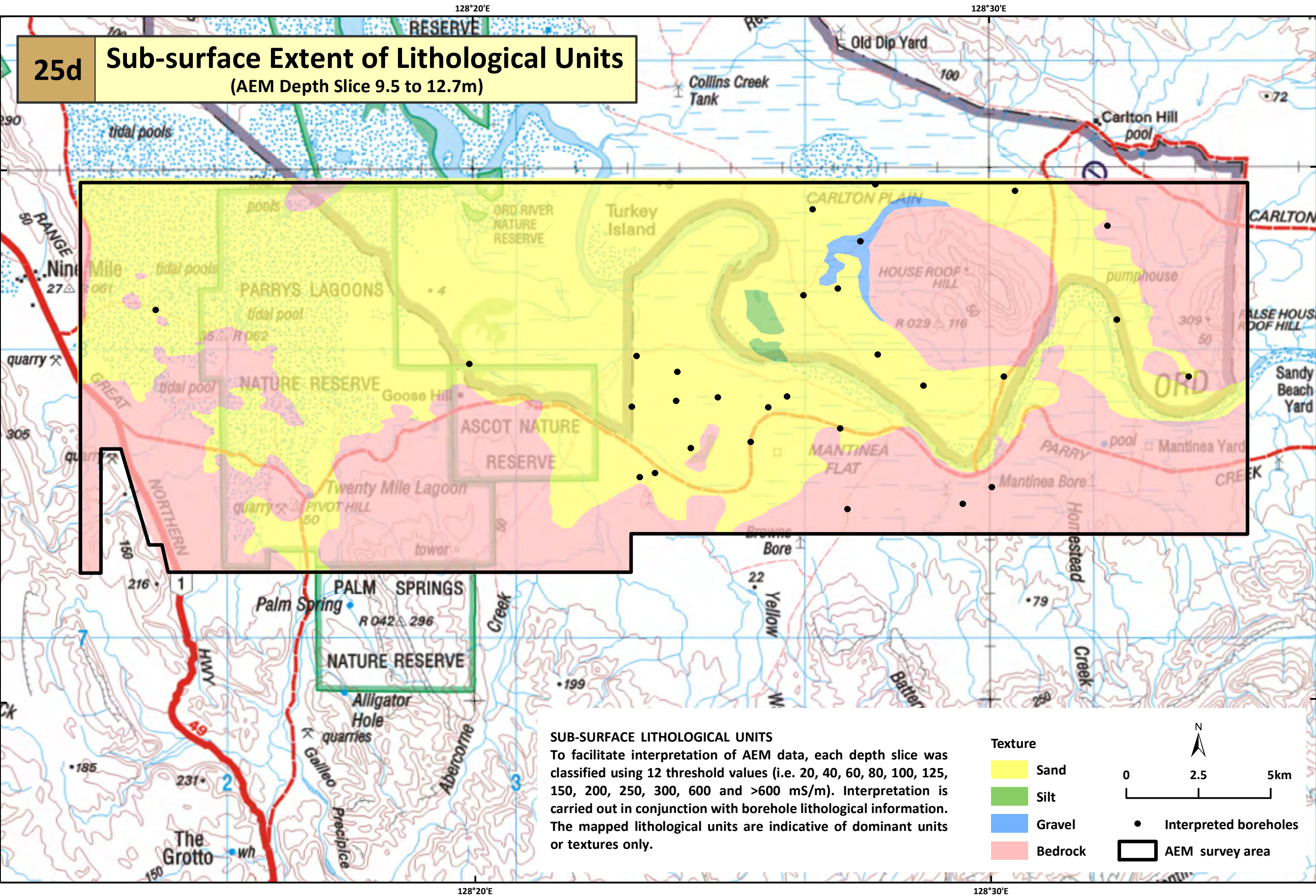
Ord Valley AEM Interpretation Project



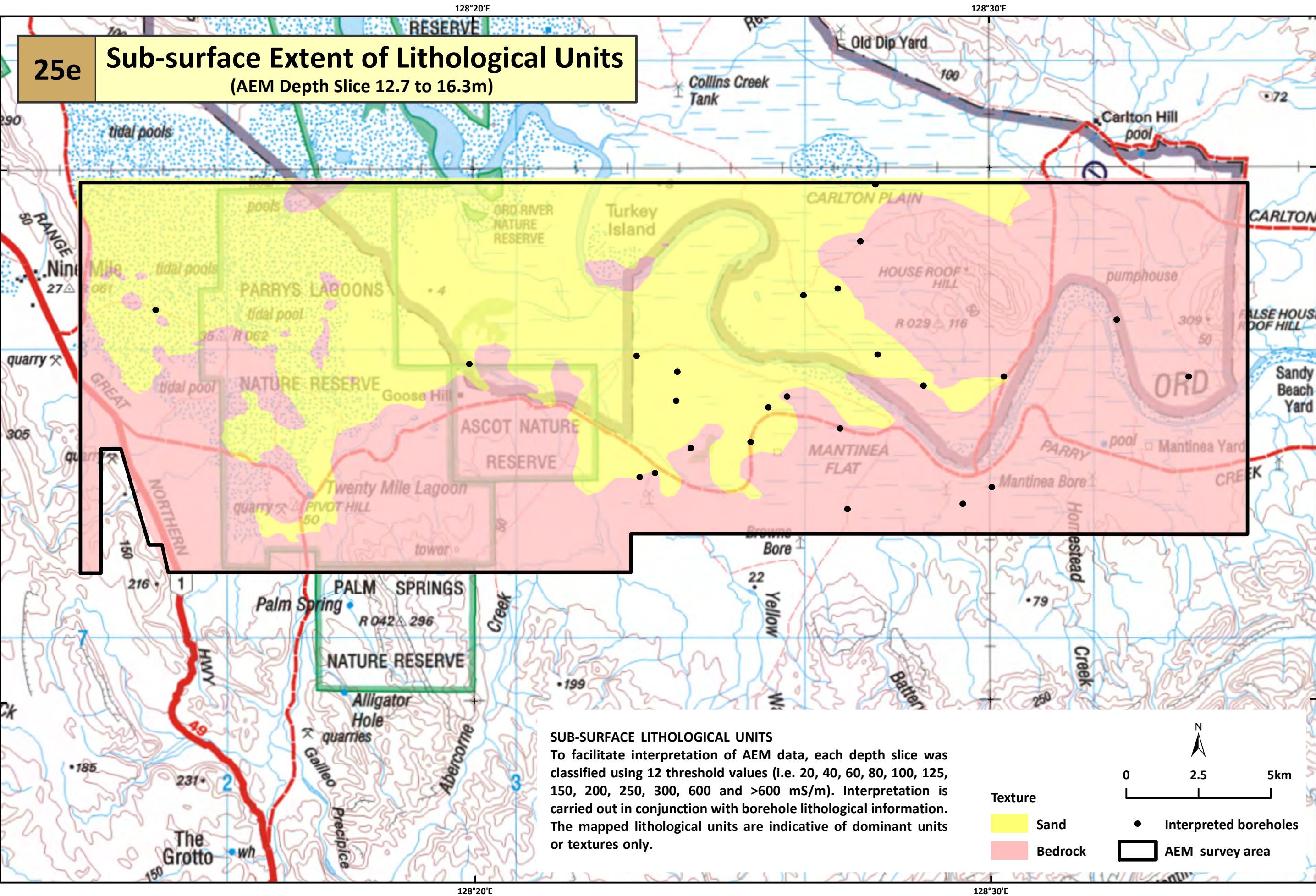
Ord Valley AEM Interpretation Project



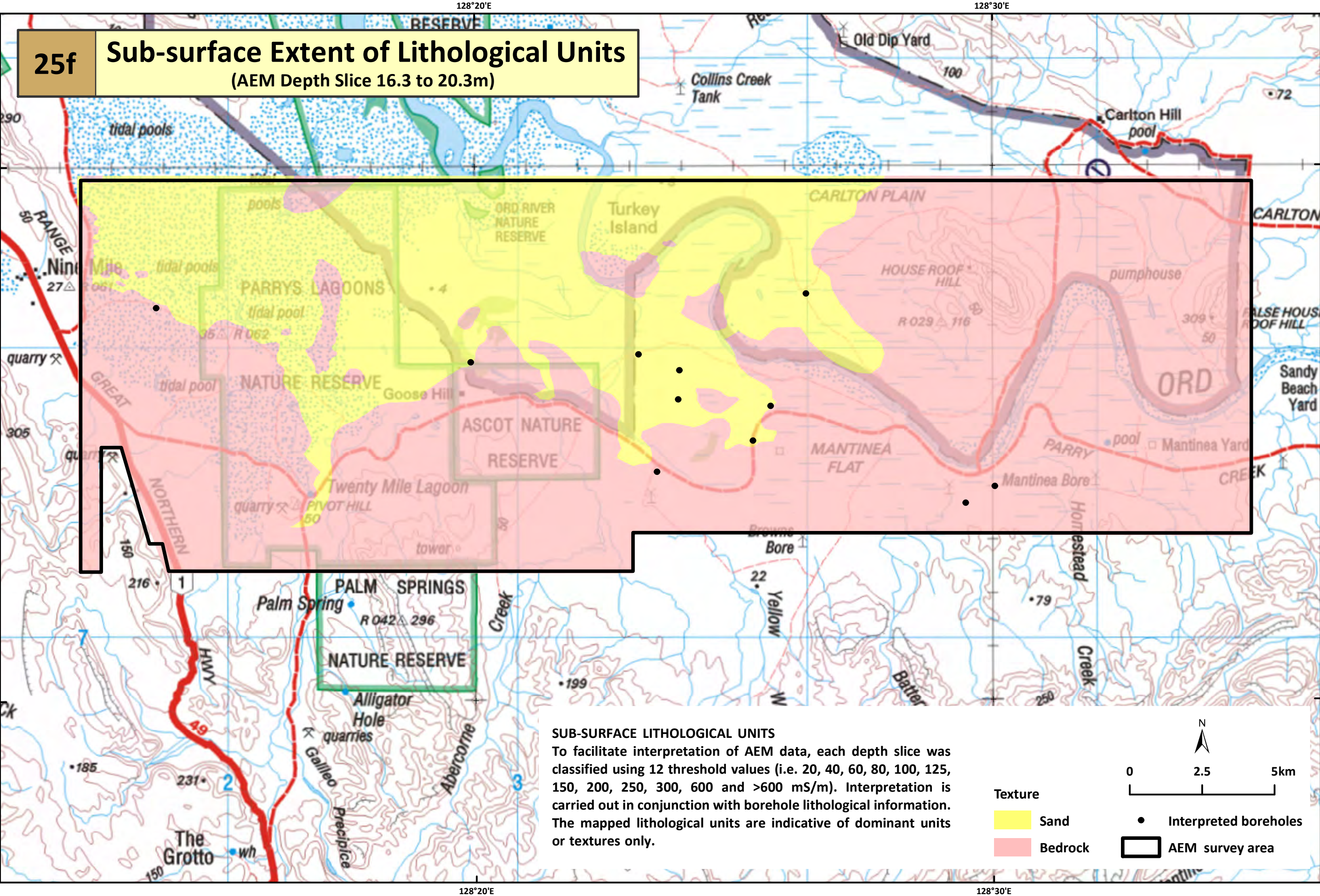
Ord Valley AEM Interpretation Project



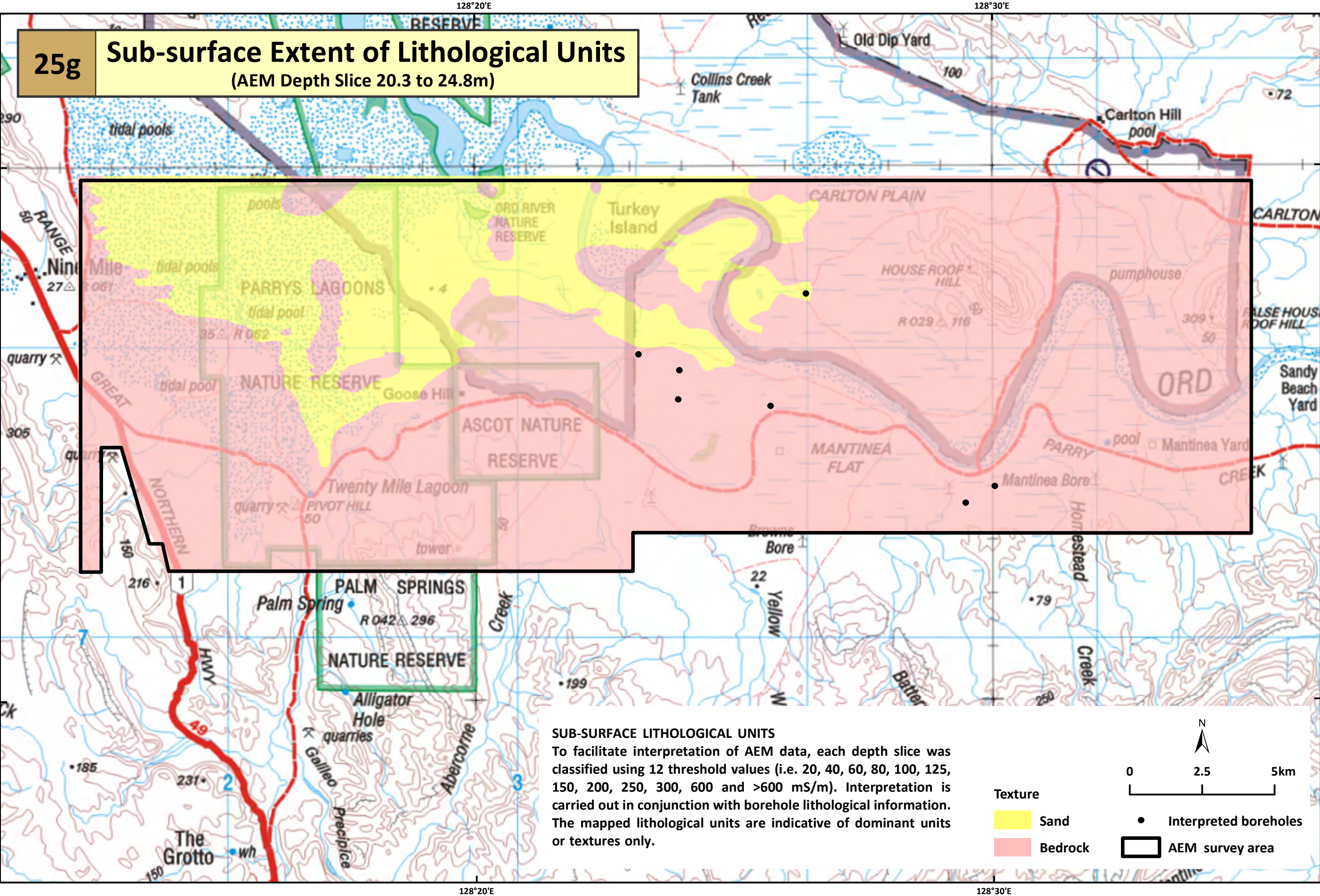
Ord Valley AEM Interpretation Project



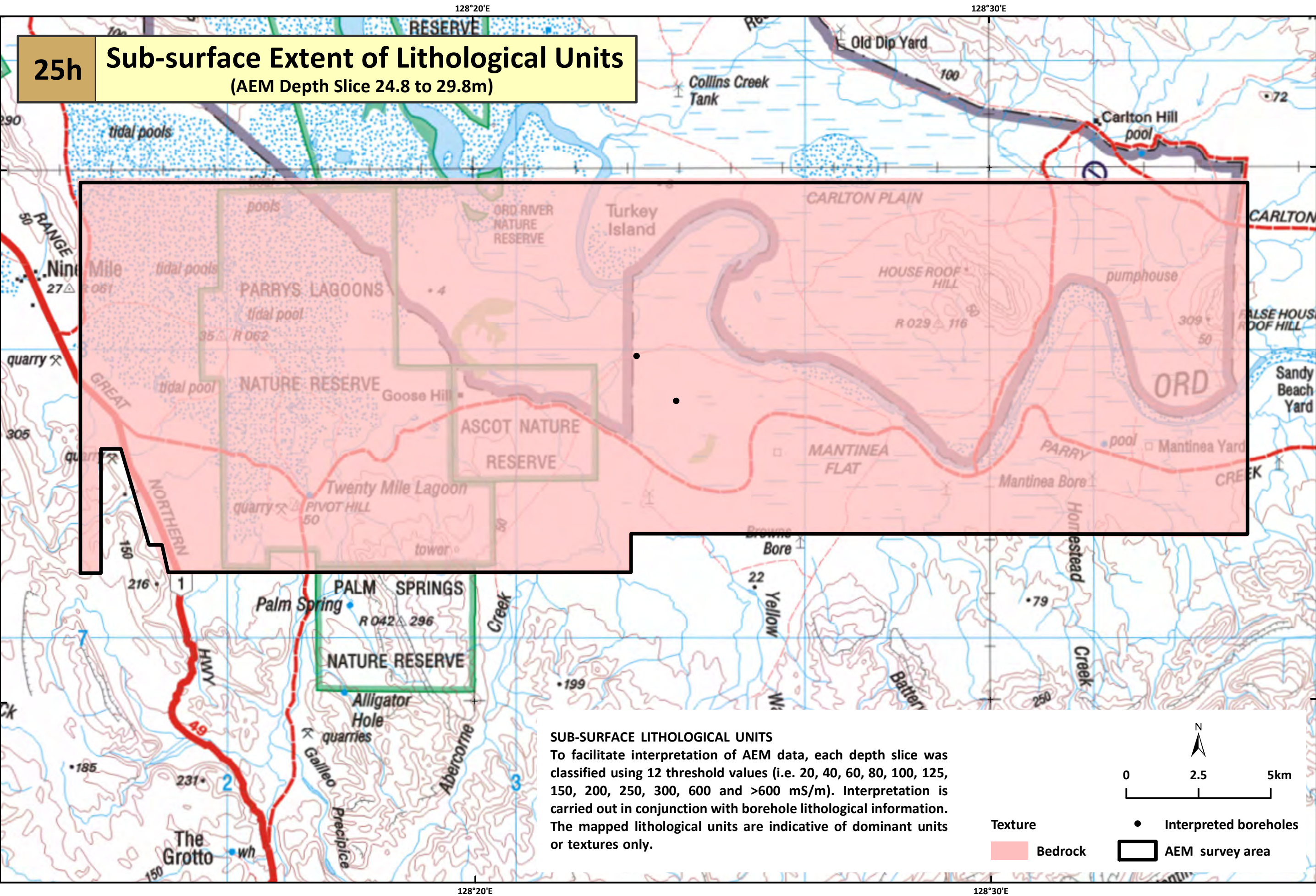
Ord Valley AEM Interpretation Project



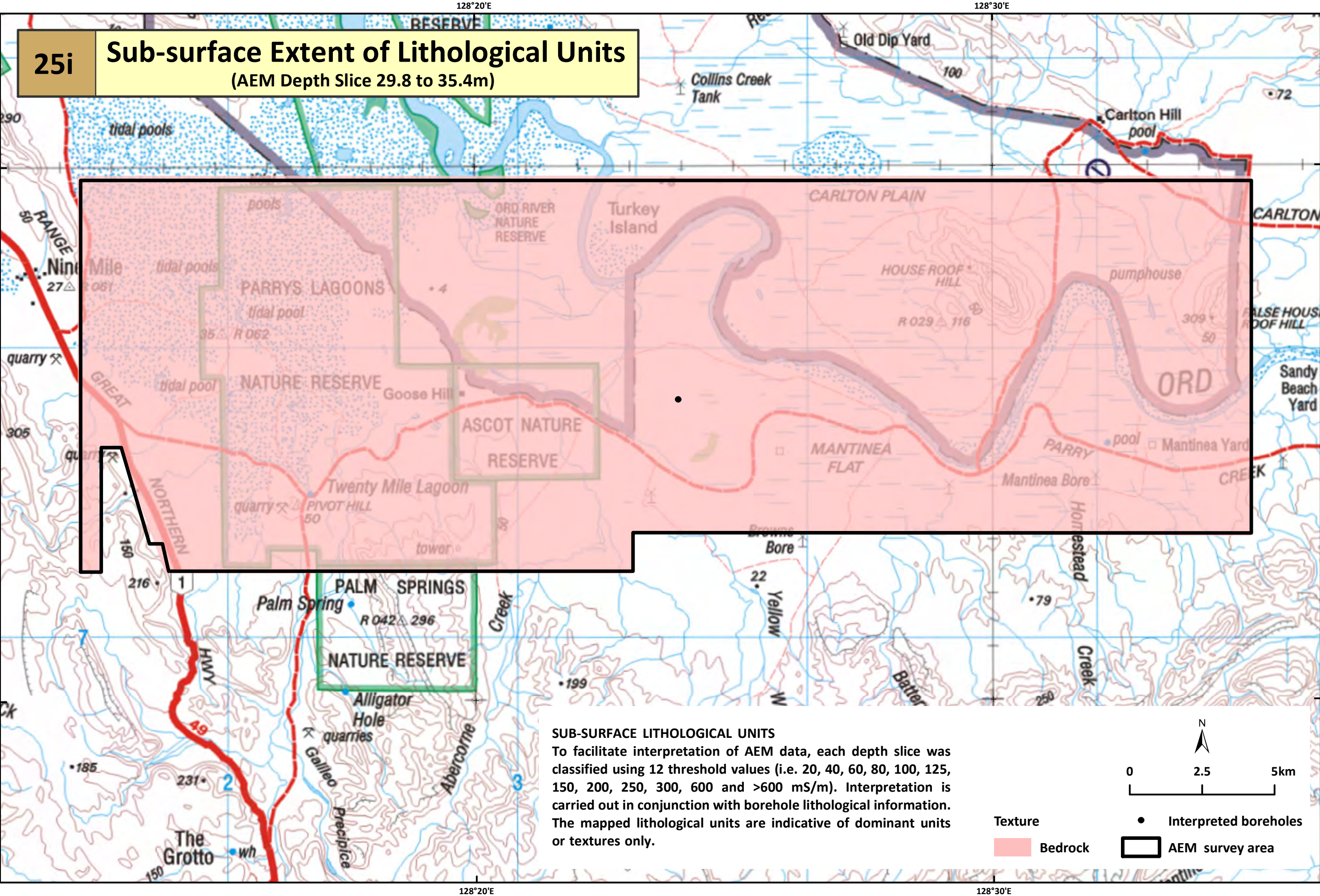
Ord Valley AEM Interpretation Project



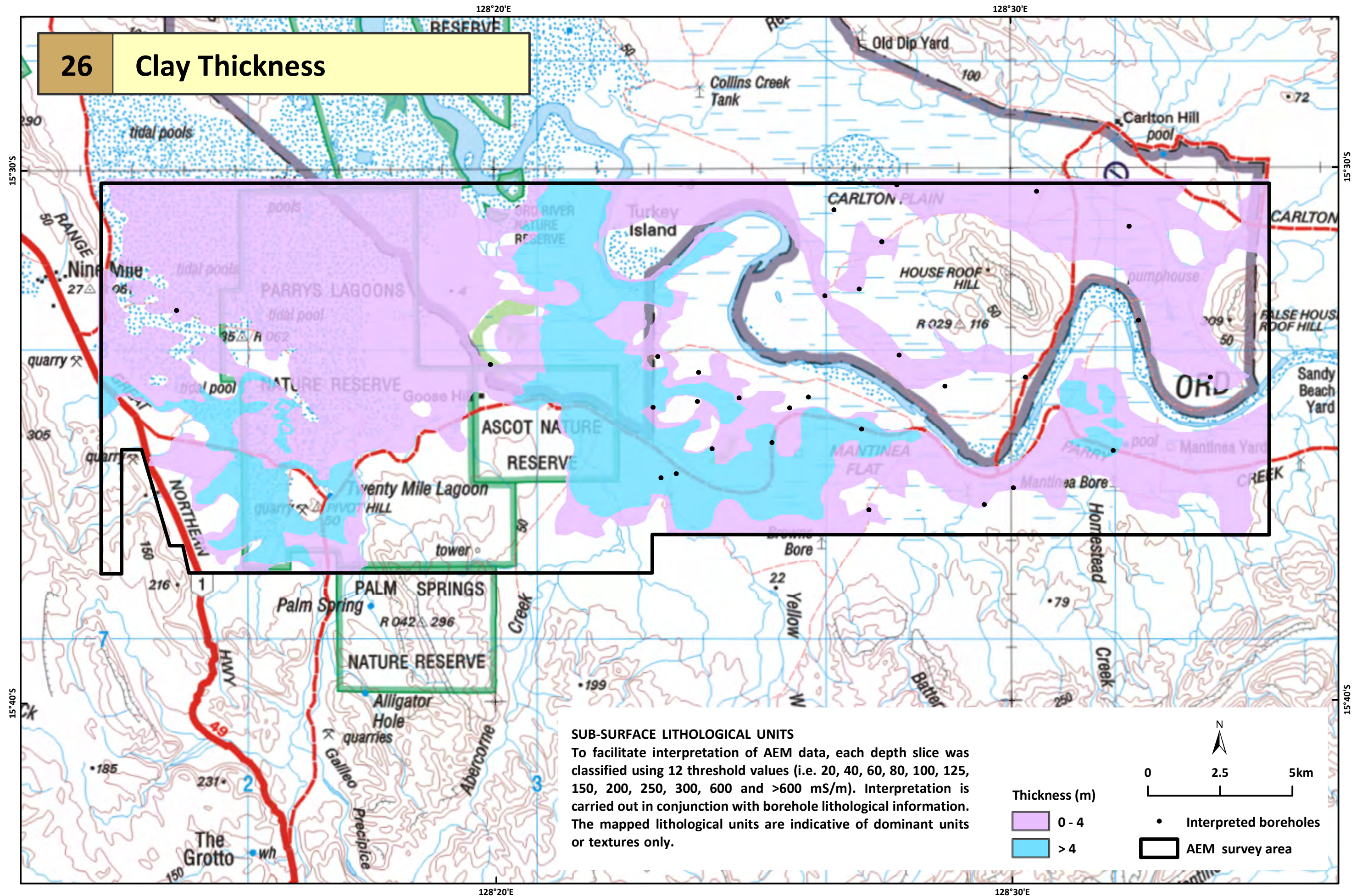
Ord Valley AEM Interpretation Project



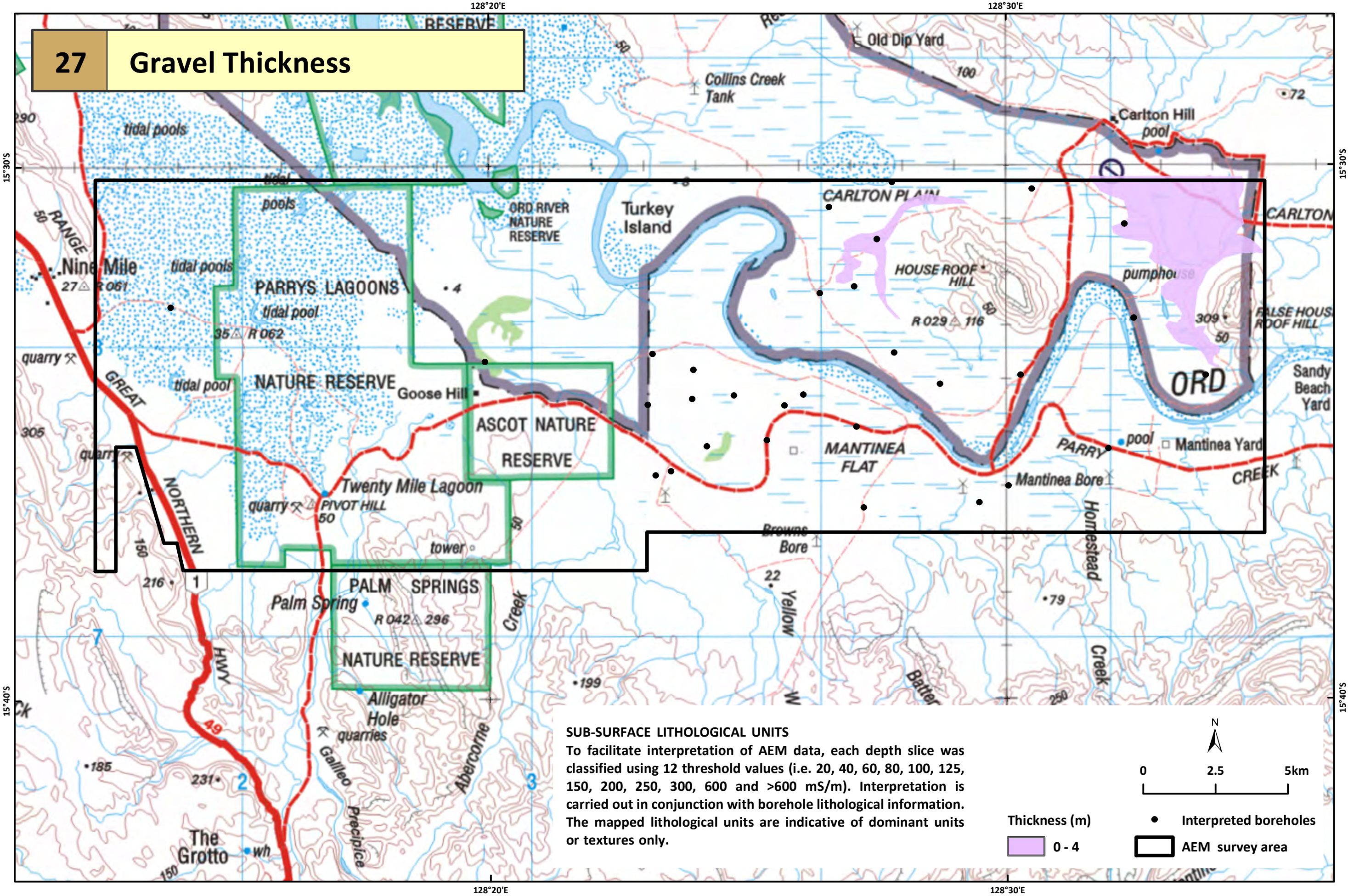
Ord Valley AEM Interpretation Project



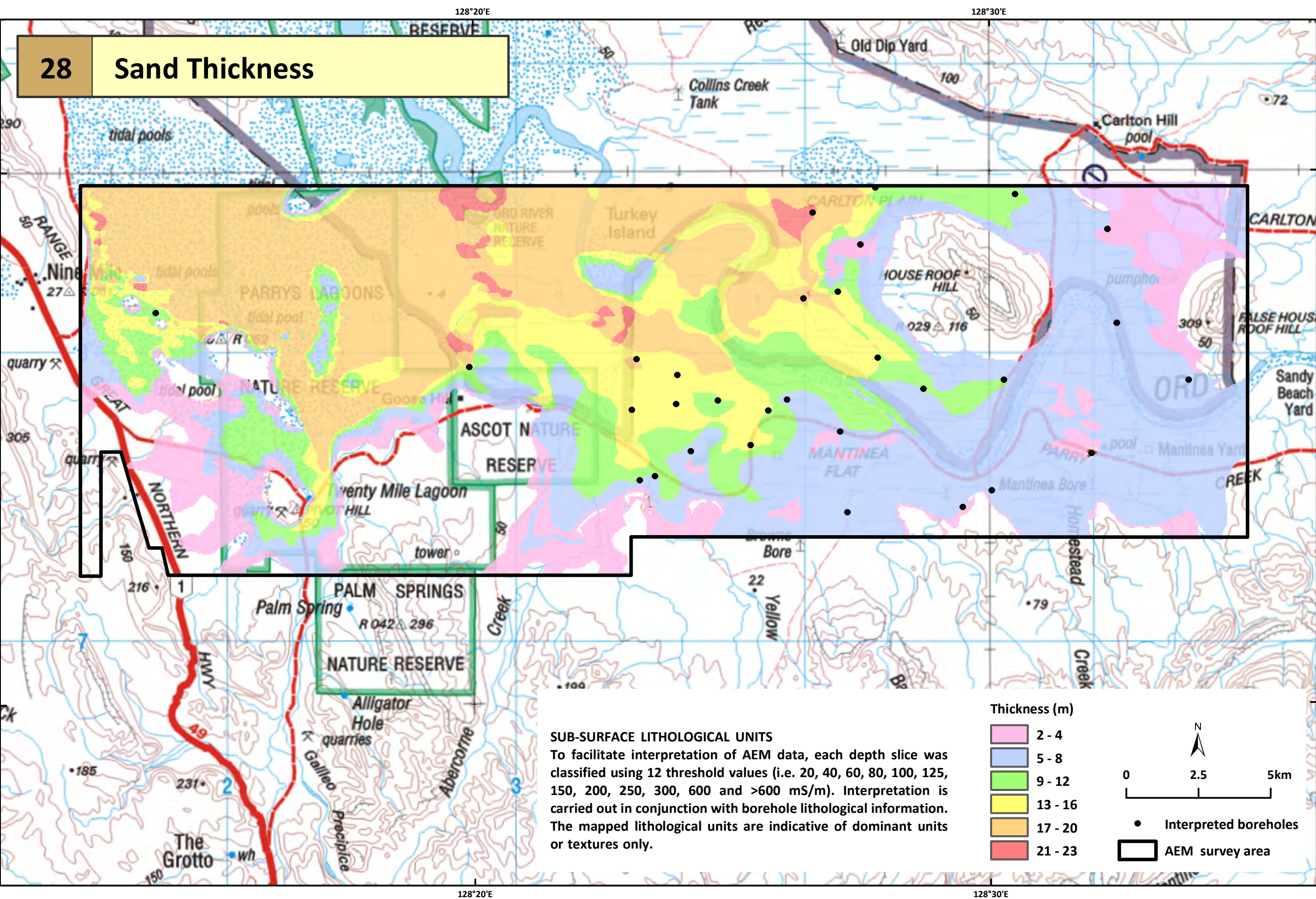
Ord Valley AEM Interpretation Project



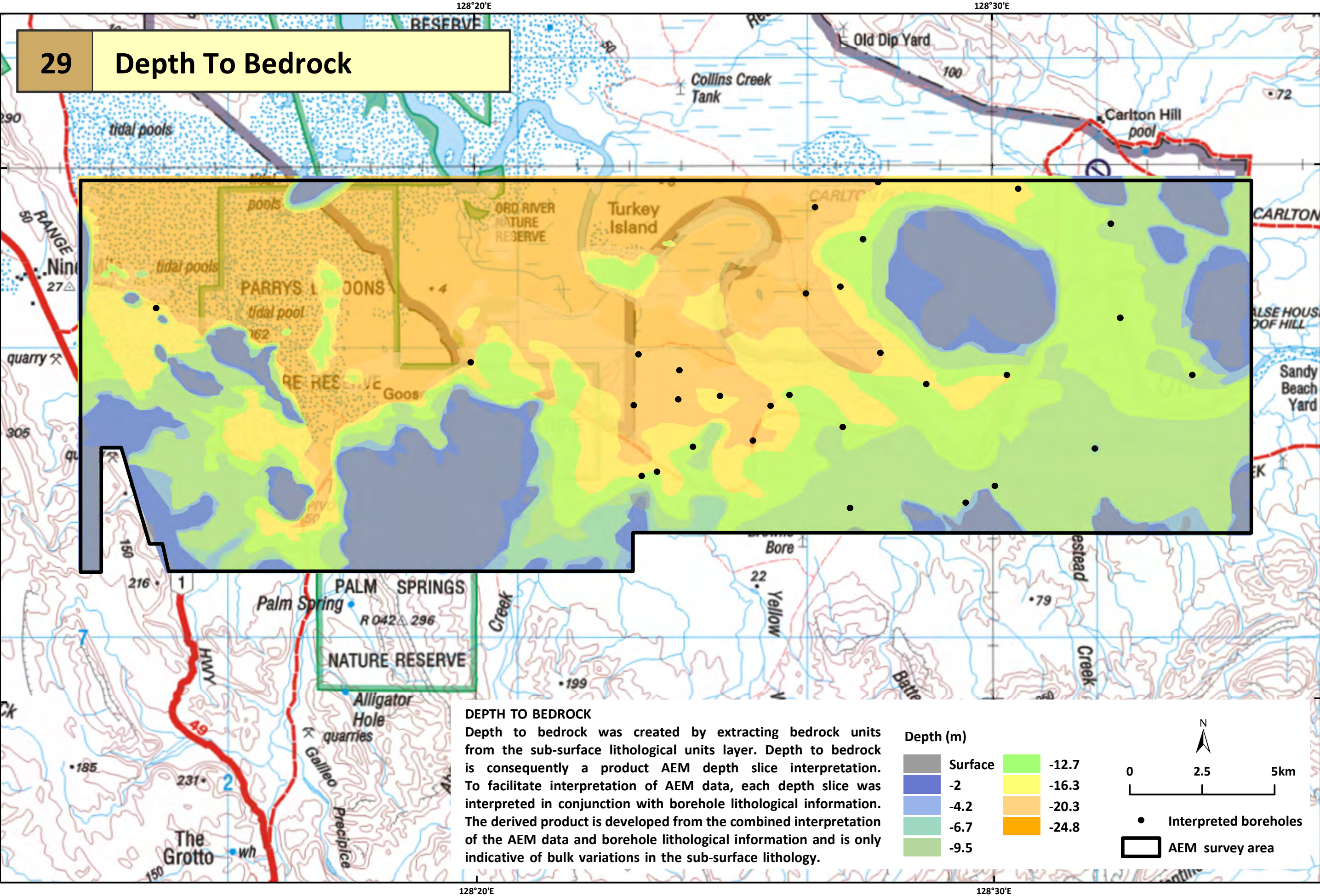
Ord Valley AEM Interpretation Project



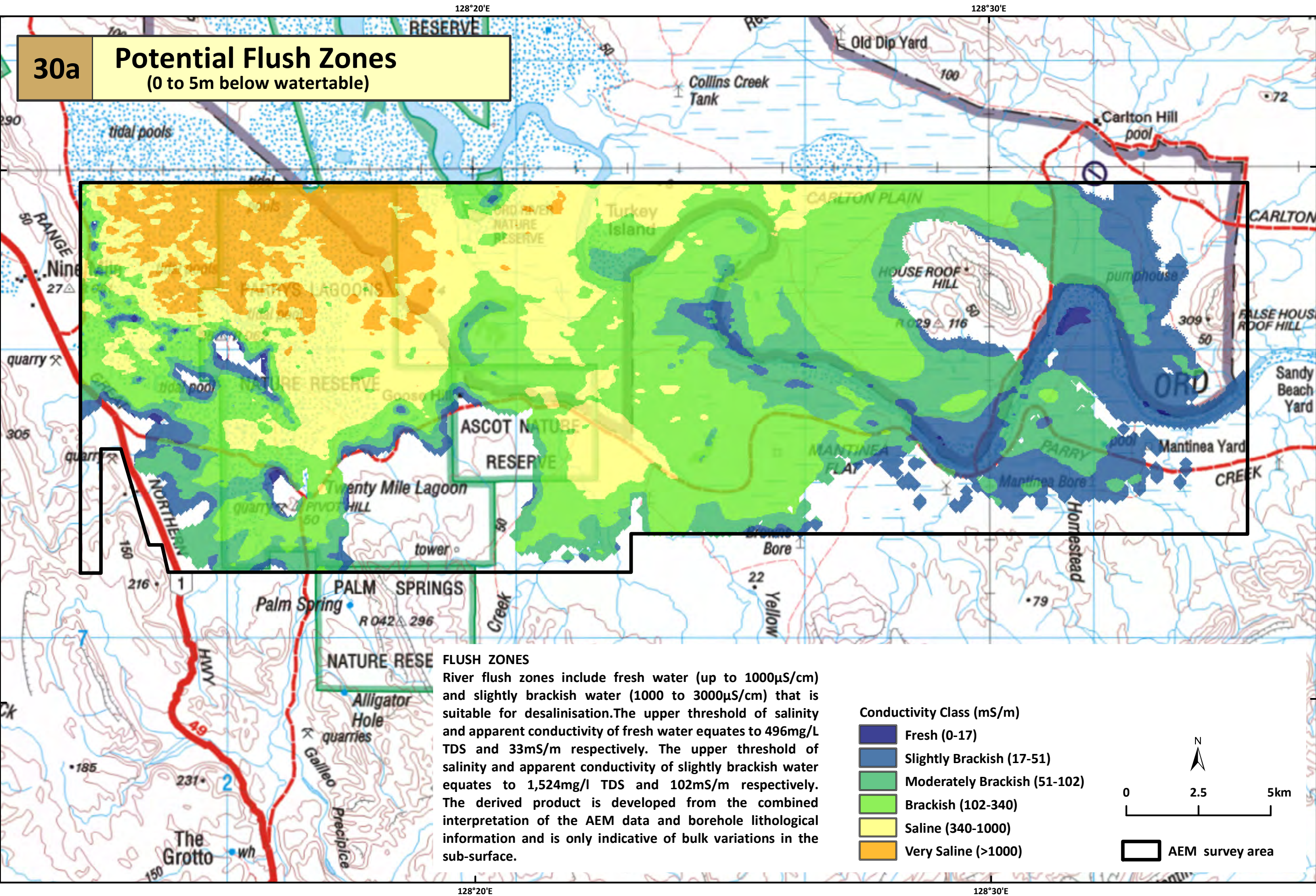
Ord Valley AEM Interpretation Project



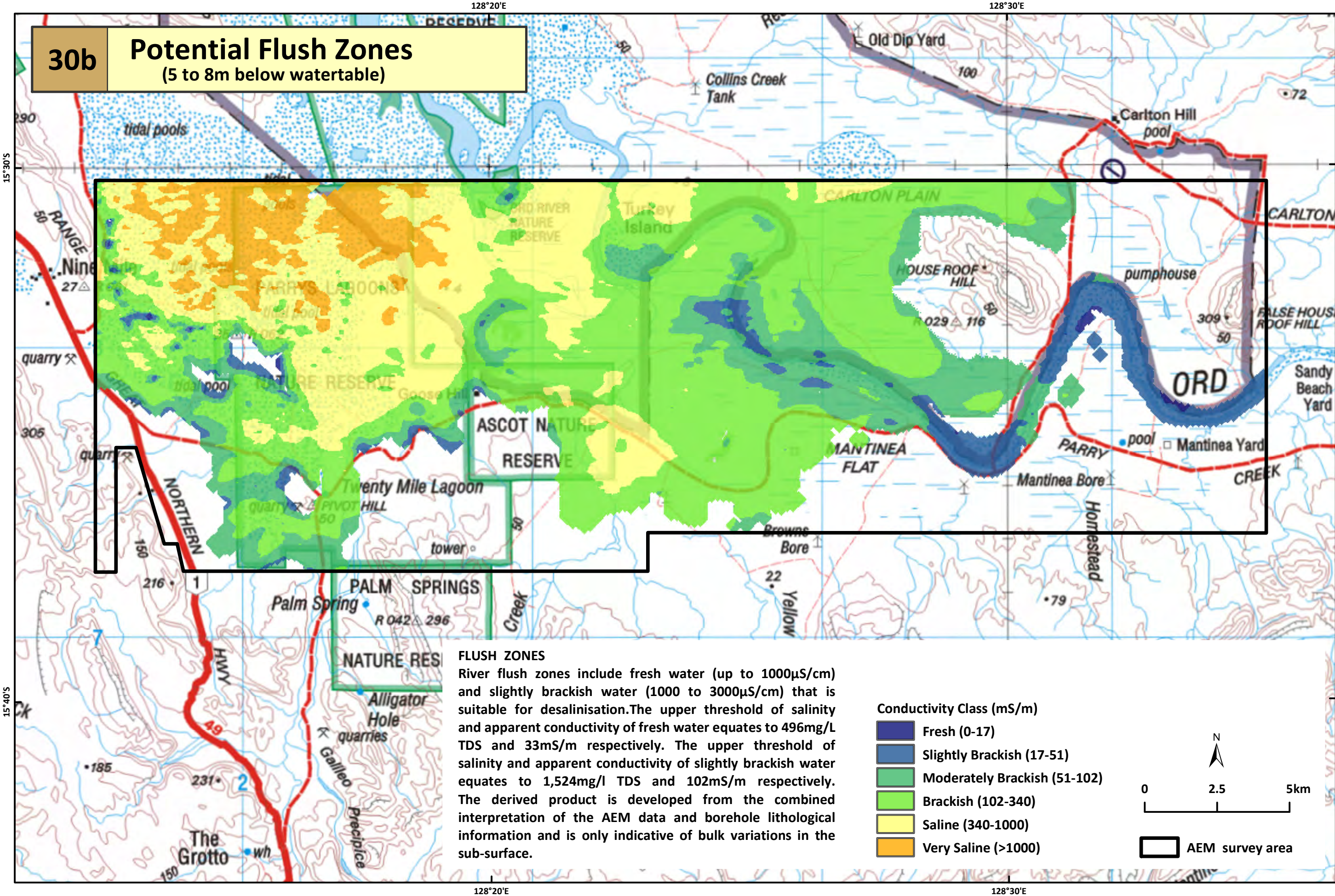
Ord Valley AEM Interpretation Project



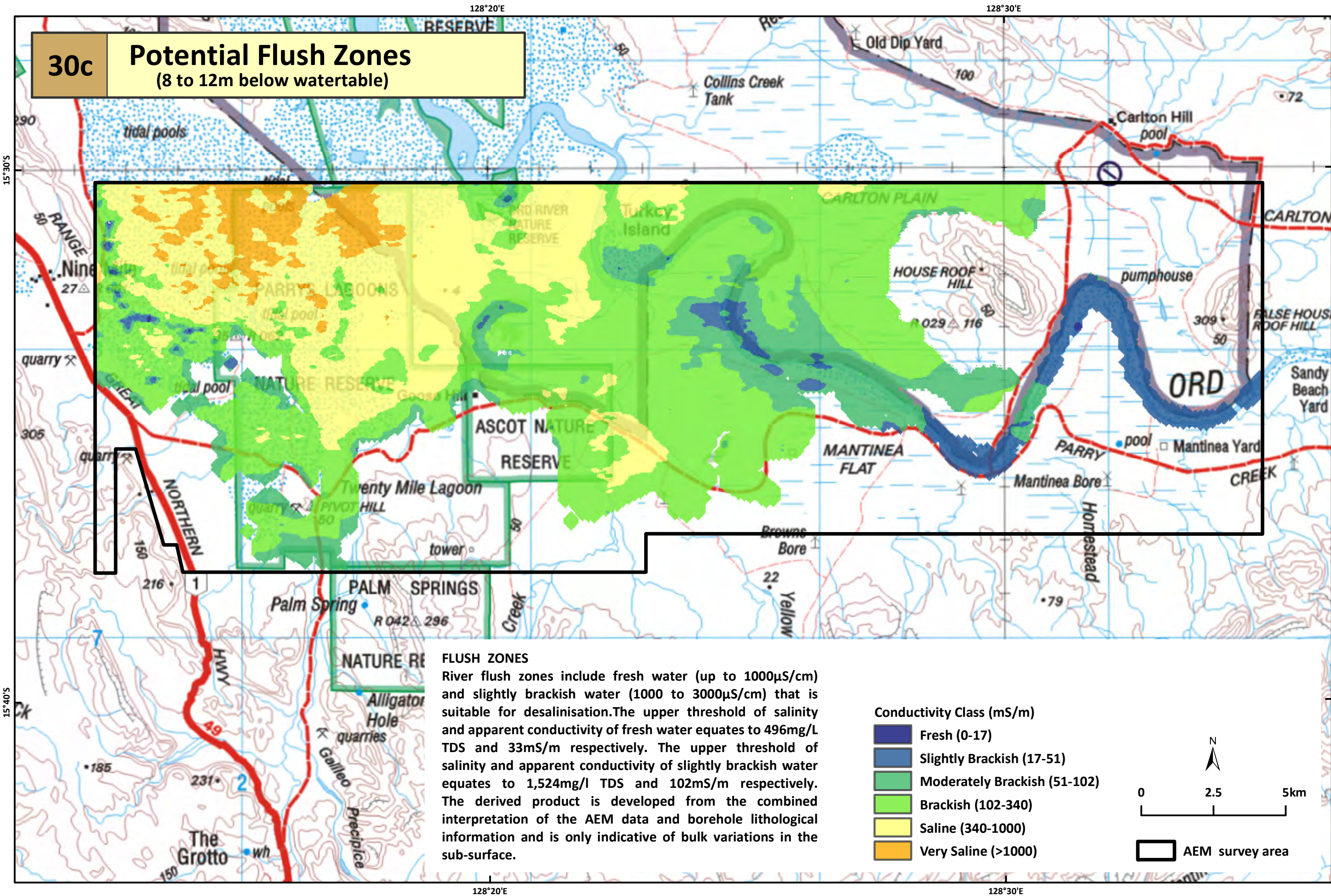
Ord Valley AEM Interpretation Project



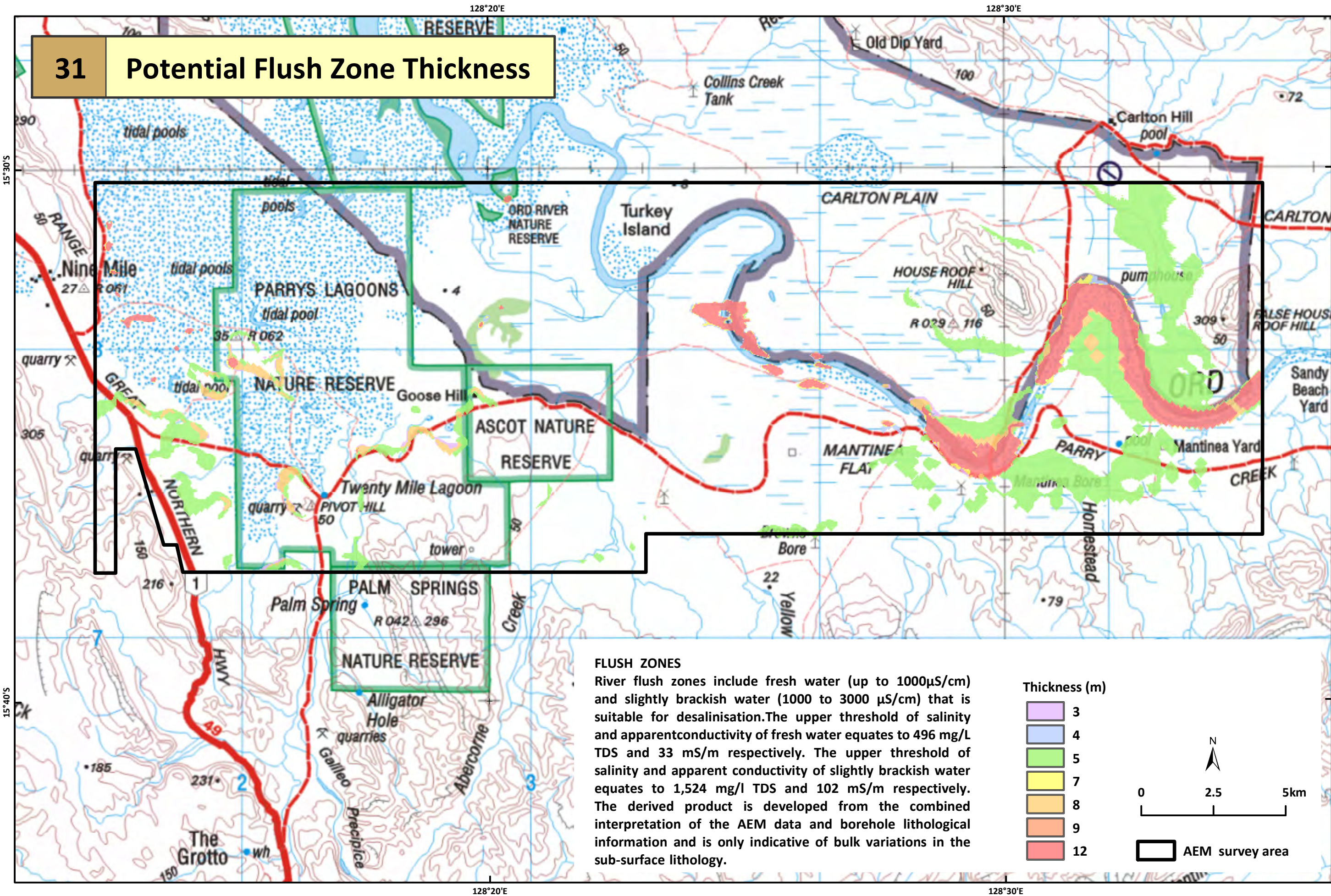
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

