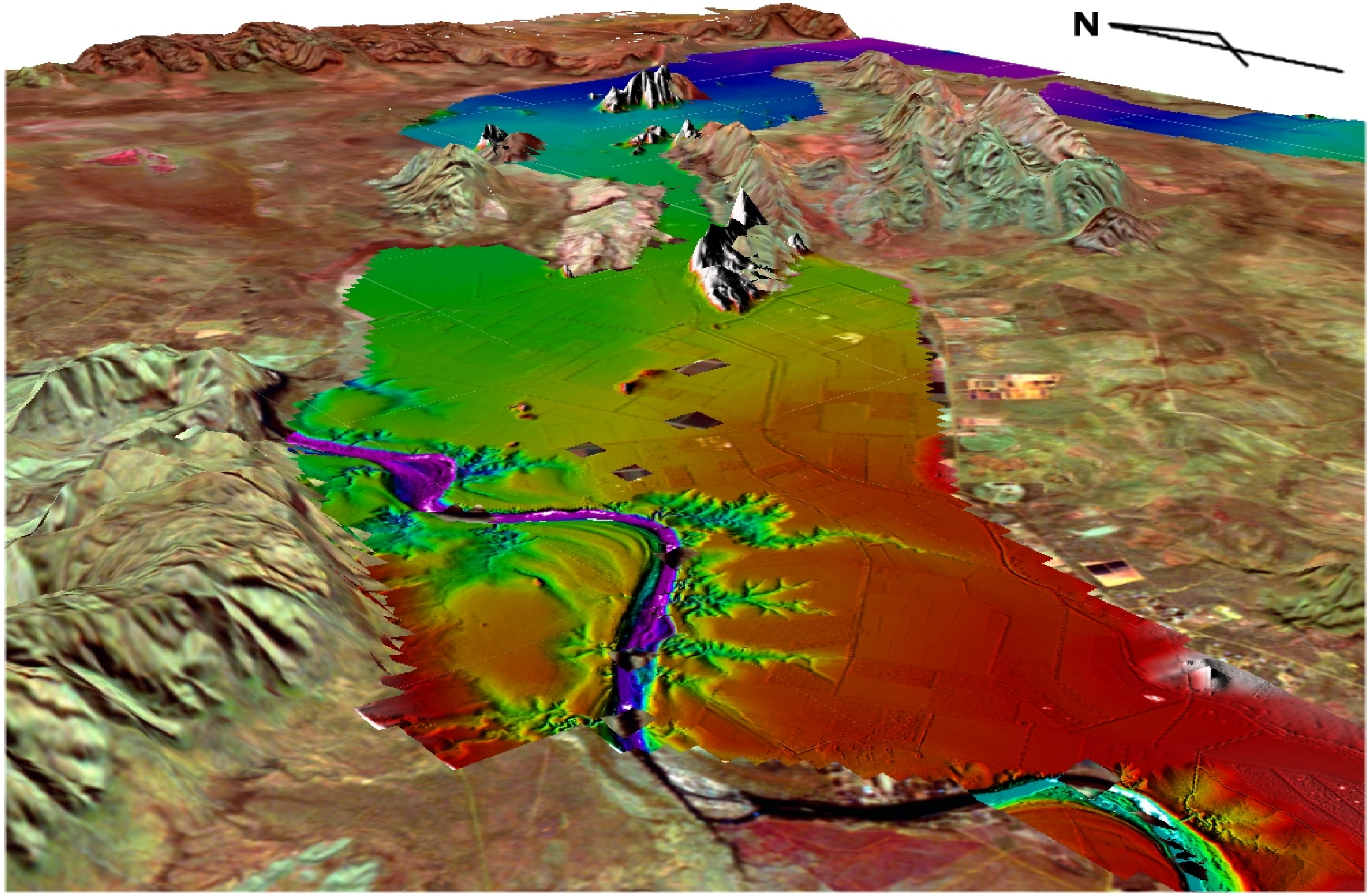
ATLAS - ORD VALLEY AEM INTERPRETATION PROJECT

OVERVIEW



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

GOVERNMENT OF WESTERN AUSTRALIA

Rangelands NRM Western Australia

Ord Irrigation Cooperative Ltd

National Research FLAGSHIPS Water for a Healthy Country

CSIRO

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).

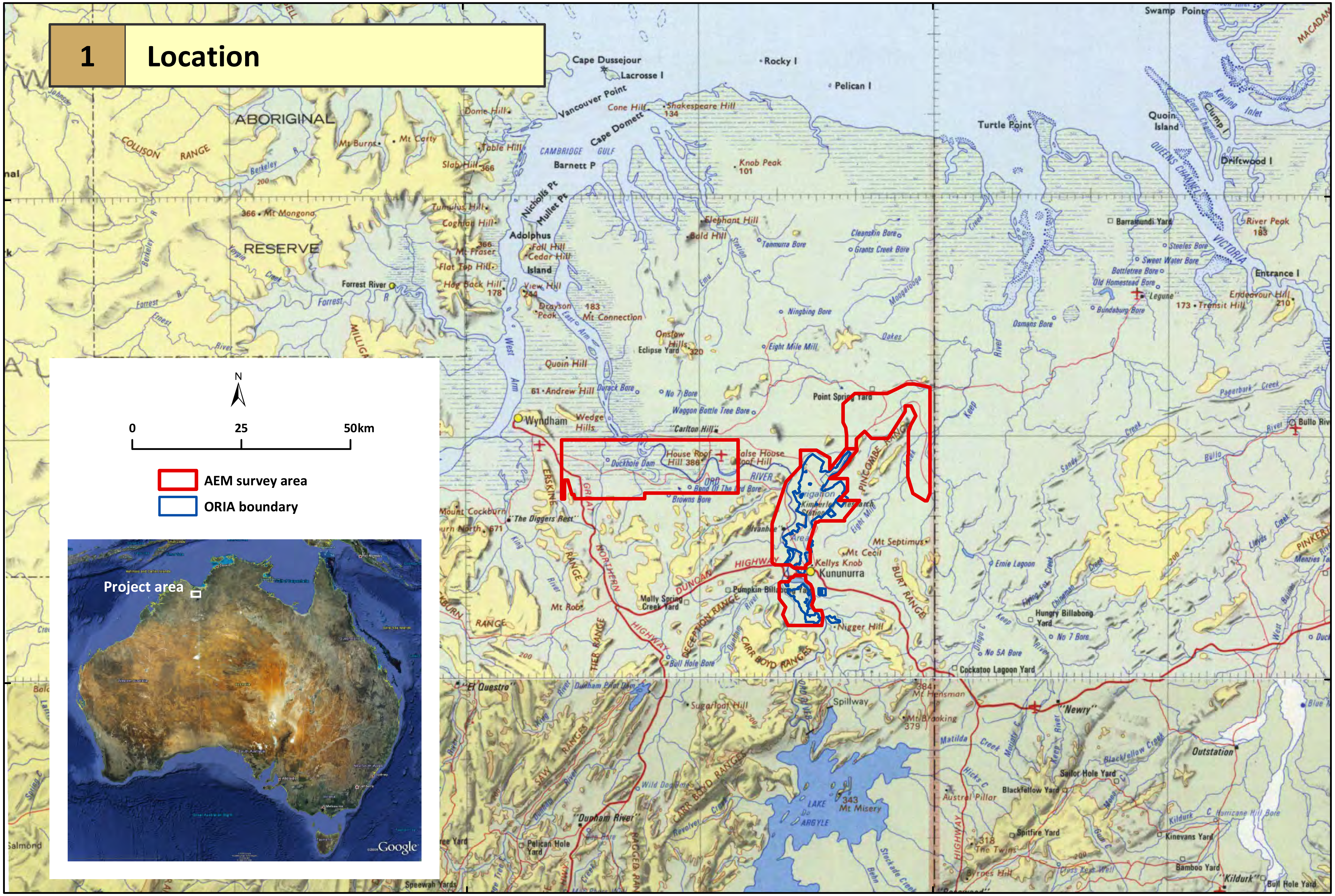
Dr. Ken Lawrie
Project Leader
Ord Valley AEM Interpretation Project

Contents

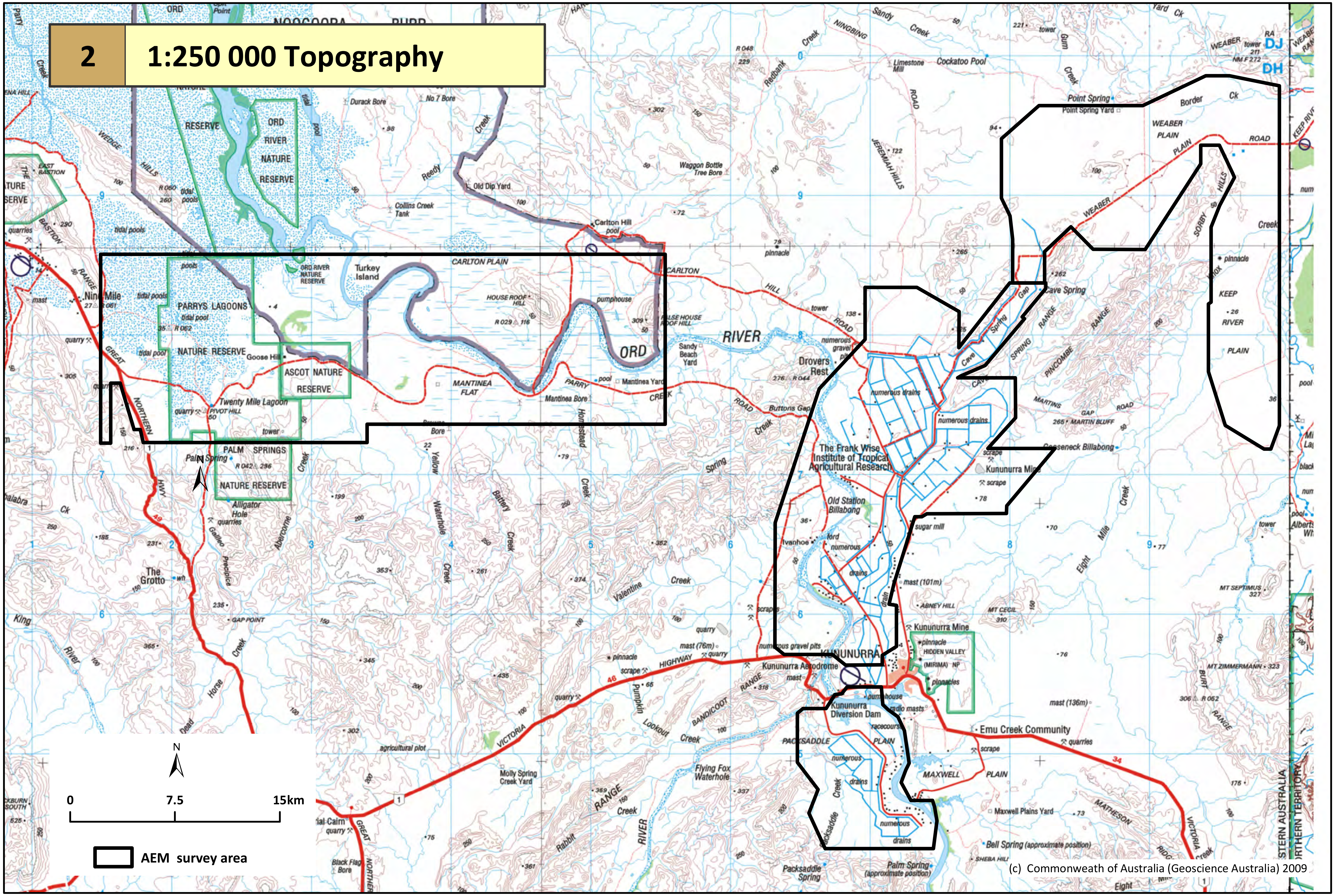
Ord Valley AEM Interpretation Project - Overview Atlas; Apps, H.E[1].; Cullen, K[1]; Tan, K.P[1]; Halas, L[1].; Clarke, J.D.A[1].; Lawrie, K.C[1], Fitzpatrick, A[2].; Munday, T.J.[2], 2009.
[1] Geoscience Australia; [2] CSIRO

Front cover image: 3D LiDAR image draped over LANDSAT showing the Ord Irrigation Area Stage 1. View looking NE towards Weaber Plains and Keep River (image - Heike Apps). Front cover photos from top to bottom: Elephant Rock and Lake Kununurra, M1 channel at Ivanhoe Plain, Boab tree (photos - Ken Lawrie).

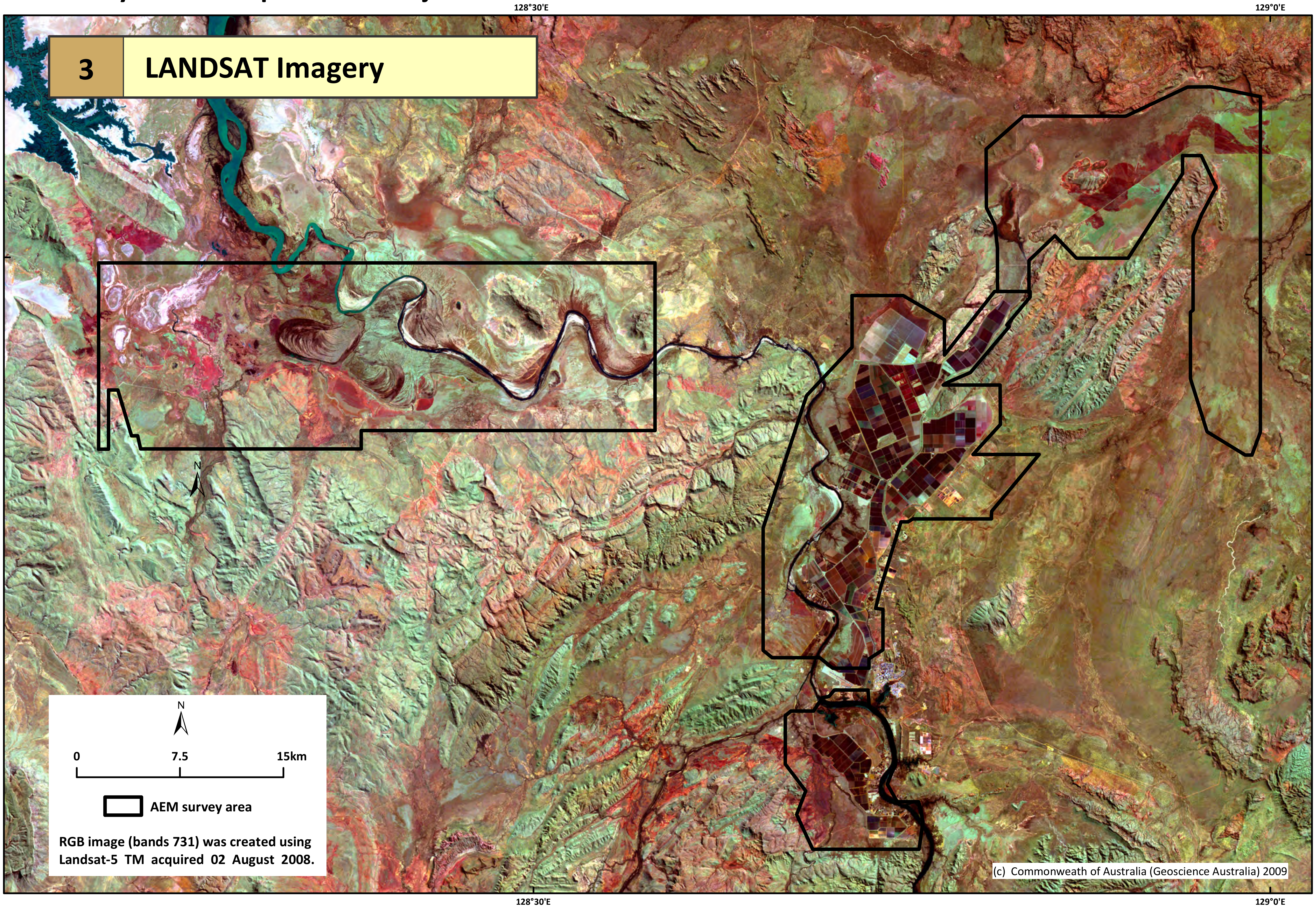
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

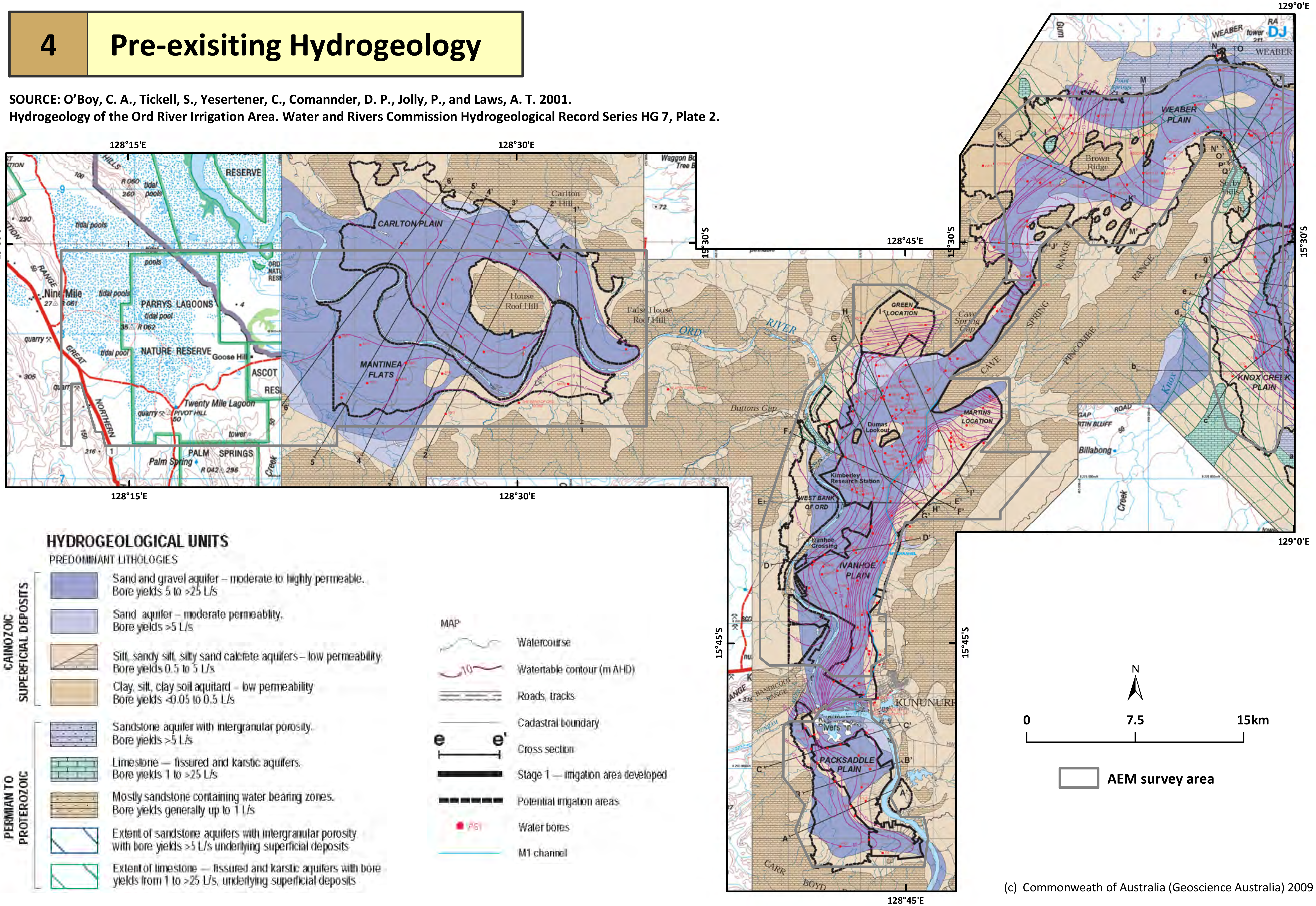


Ord Valley AEM Interpretation Project



4 Pre-exisiting Hydrogeology

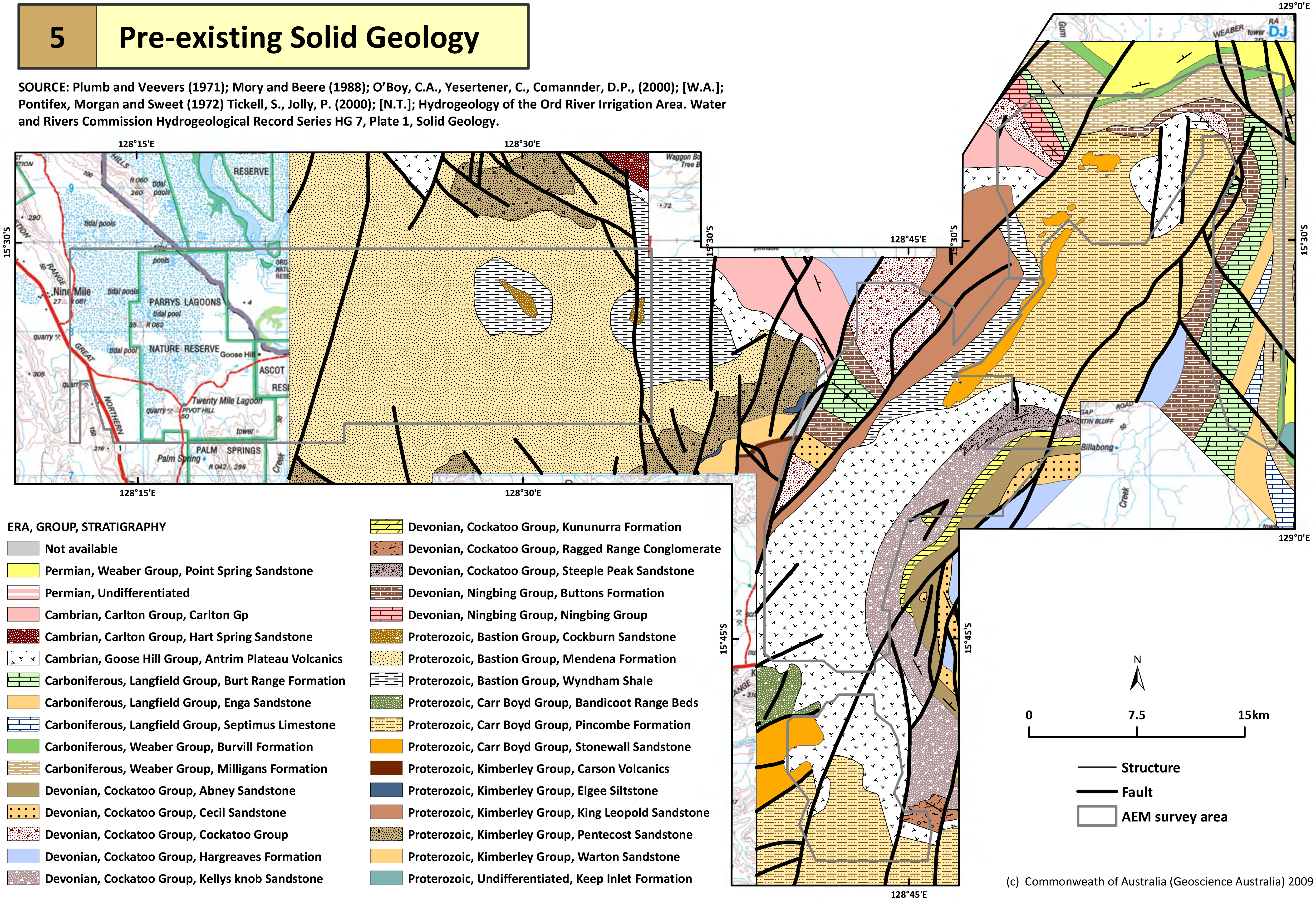
SOURCE: O'Boy, C. A., Tickell, S., Yesertener, C., Comannder, D. P., Jolly, P., and Laws, A. T. 2001. Hydrogeology of the Ord River Irrigation Area. Water and Rivers Commission Hydrogeological Record Series HG 7, Plate 2.



Ord Valley AEM Interpretation Project

5 Pre-existing Solid Geology

SOURCE: Plumb and Veevers (1971); Mory and Beere (1988); O'Boy, C.A., Yesertener, C., Comannder, D.P., (2000); [W.A.]; Pontifex, Morgan and Sweet (1972) Tickell, S., Jolly, P. (2000); [N.T.]; Hydrogeology of the Ord River Irrigation Area. Water and Rivers Commission Hydrogeological Record Series HG 7, Plate 1, Solid Geology.



ERA, GROUP, STRATIGRAPHY

- Not available
- Permian, Weaber Group, Point Spring Sandstone
- Permian, Undifferentiated
- Cambrian, Carlton Group, Carlton Gp
- Cambrian, Carlton Group, Hart Spring Sandstone
- Cambrian, Goose Hill Group, Antrim Plateau Volcanics
- Carboniferous, Langfield Group, Burt Range Formation
- Carboniferous, Langfield Group, Enga Sandstone
- Carboniferous, Langfield Group, Septimus Limestone
- Carboniferous, Weaber Group, Burvill Formation
- Carboniferous, Weaber Group, Milligans Formation
- Devonian, Cockatoo Group, Abney Sandstone
- Devonian, Cockatoo Group, Cecil Sandstone
- Devonian, Cockatoo Group, Cockatoo Group
- Devonian, Cockatoo Group, Hargreaves Formation
- Devonian, Cockatoo Group, Kellys knob Sandstone
- Devonian, Cockatoo Group, Kununurra Formation
- Devonian, Cockatoo Group, Ragged Range Conglomerate
- Devonian, Cockatoo Group, Steeple Peak Sandstone
- Devonian, Ningbing Group, Buttons Formation
- Devonian, Ningbing Group, Ningbing Group
- Proterozoic, Bastion Group, Cockburn Sandstone
- Proterozoic, Bastion Group, Mendena Formation
- Proterozoic, Bastion Group, Wyndham Shale
- Proterozoic, Carr Boyd Group, Bandicoot Range Beds
- Proterozoic, Carr Boyd Group, Pincombe Formation
- Proterozoic, Carr Boyd Group, Stonewall Sandstone
- Proterozoic, Kimberley Group, Carson Volcanics
- Proterozoic, Kimberley Group, Elgee Siltstone
- Proterozoic, Kimberley Group, King Leopold Sandstone
- Proterozoic, Kimberley Group, Pentecost Sandstone
- Proterozoic, Kimberley Group, Warton Sandstone
- Proterozoic, Undifferentiated, Keep Inlet Formation

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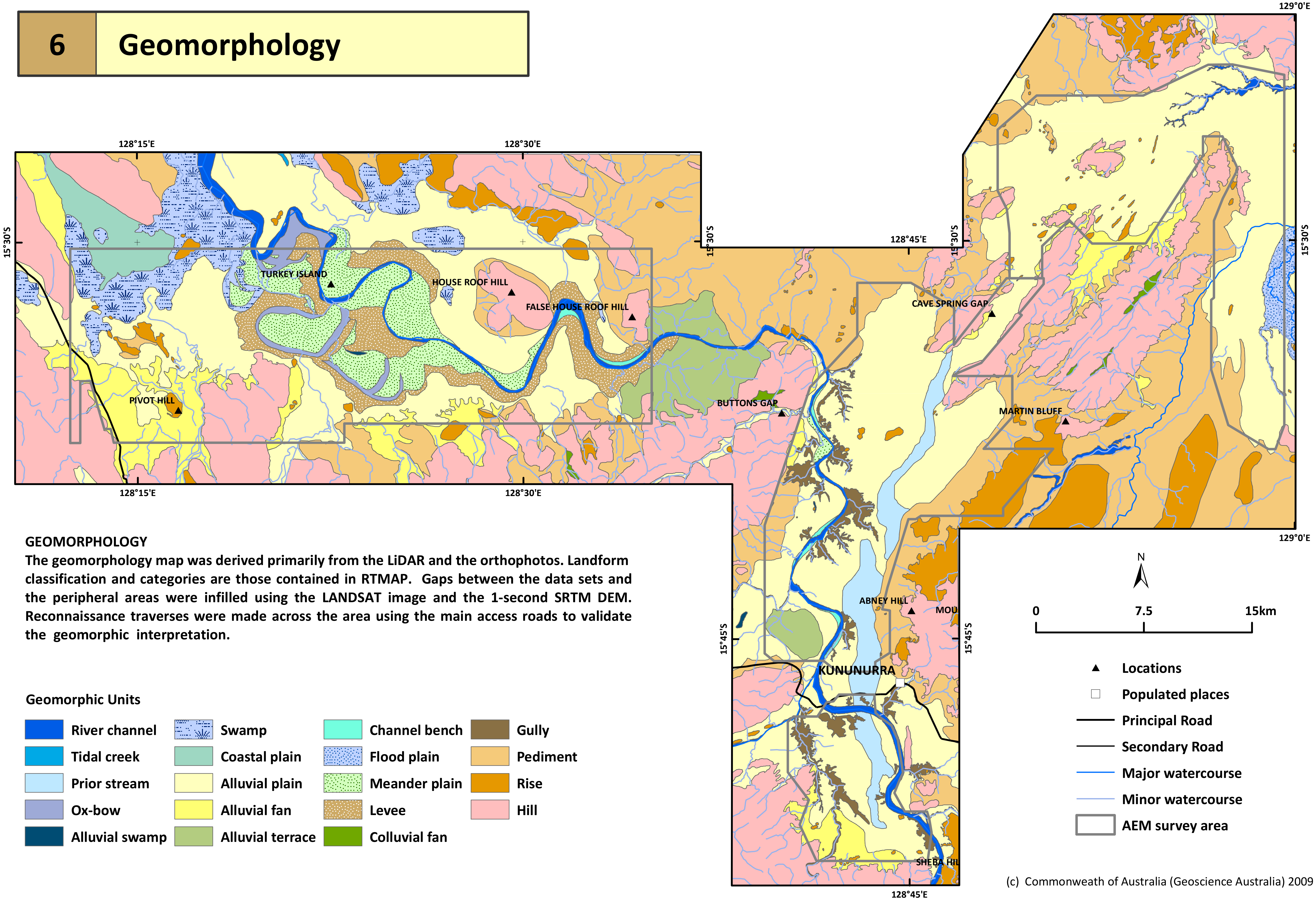
6 Geomorphology



GEOMORPHOLOGY

The geomorphology map was derived primarily from the LiDAR and the orthophotos. Landform classification and categories are those contained in RTMAP. Gaps between the data sets and the peripheral areas were infilled using the LANDSAT image and the 1-second SRTM DEM. Reconnaissance traverses were made across the area using the main access roads to validate the geomorphic interpretation.

Geomorphic Units

River channel	Swamp	Channel bench	Gully
Tidal creek	Coastal plain	Flood plain	Pediment
Prior stream	Alluvial plain	Meander plain	Rise
Ox-bow	Alluvial fan	Levee	Hill
Alluvial swamp	Alluvial terrace	Colluvial fan	

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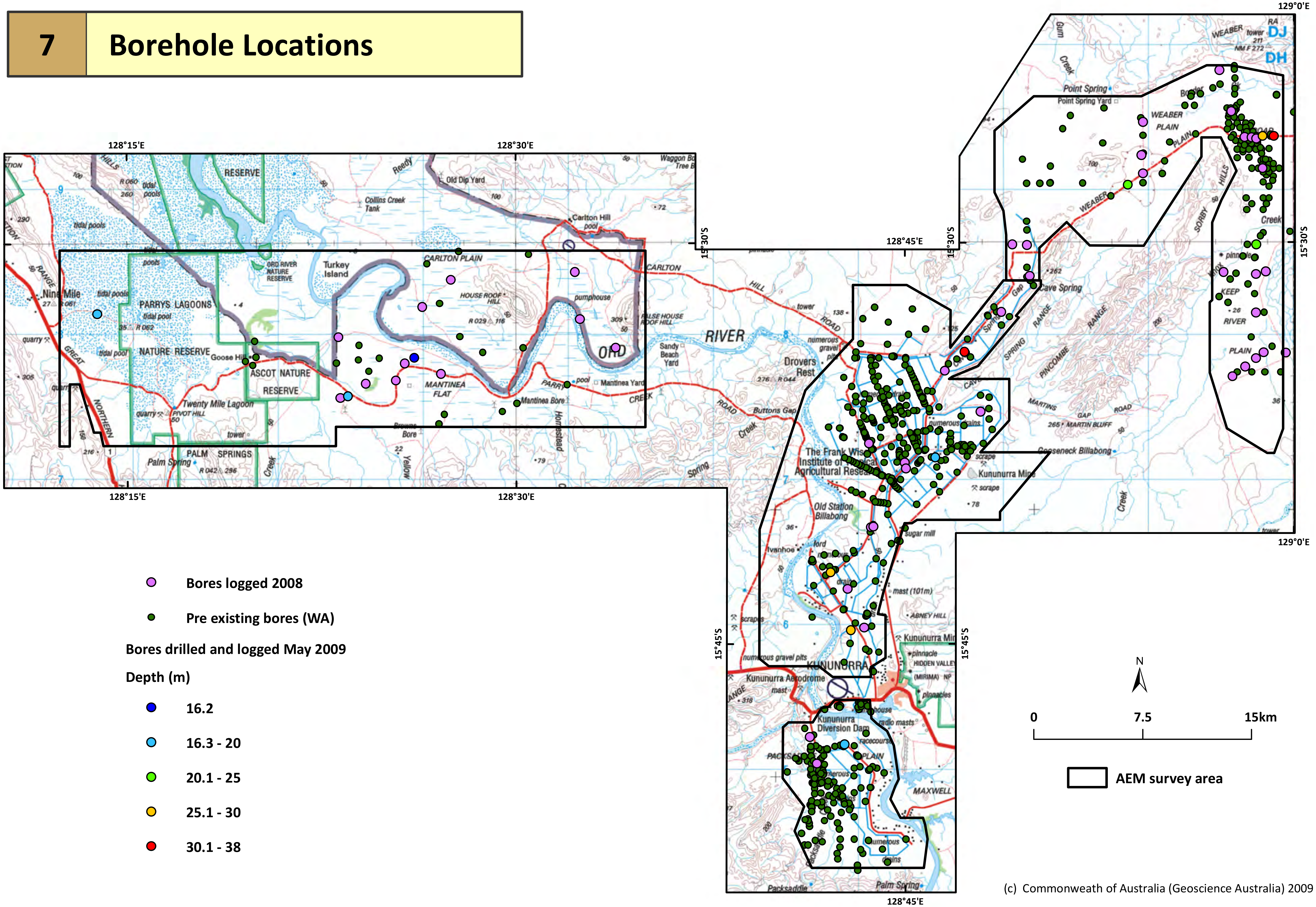
7 Borehole Locations



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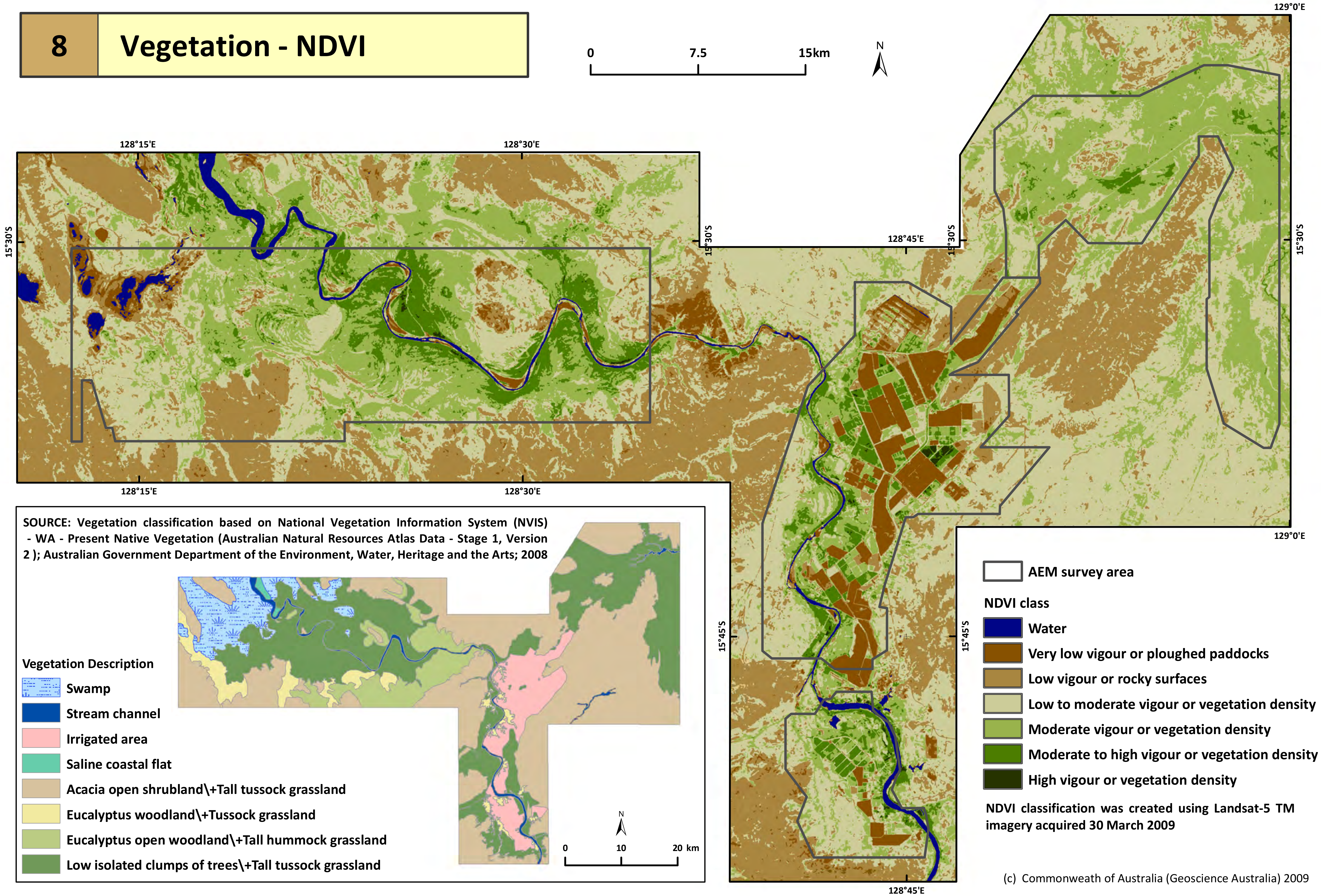
8 Vegetation - NDVI

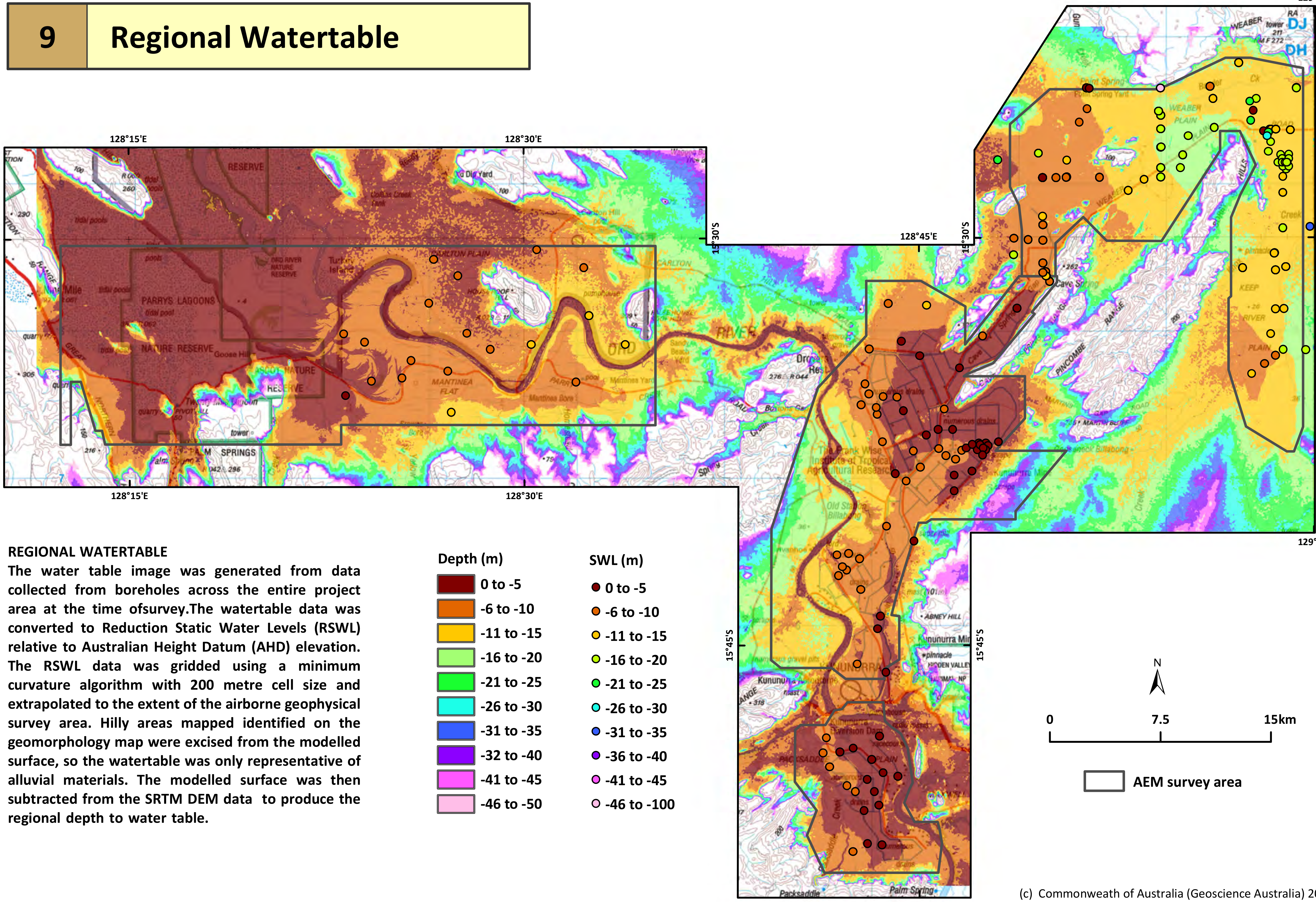


NDVI classification was created using Landsat-5 TM imagery acquired 30 March 2009

SOURCE: Vegetation classification based on National Vegetation Information System (NVIS) - WA - Present Native Vegetation (Australian Natural Resources Atlas Data - Stage 1, Version 2); Australian Government Department of the Environment, Water, Heritage and the Arts; 2008

Ord Valley AEM Interpretation Project

9 Regional Watertable



REGIONAL WATERTABLE

The water table image was generated from data collected from boreholes across the entire project area at the time ofsurvey.The watertable data was converted to Reduction Static Water Levels (RSWL) relative to Australian Height Datum (AHD) elevation. The RSWL data was gridded using a minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to water table.

Depth (m)	SWL (m)
0 to -5	0 to -5
-6 to -10	-6 to -10
-11 to -15	-11 to -15
-16 to -20	-16 to -20
-21 to -25	-21 to -25
-26 to -30	-26 to -30
-31 to -35	-31 to -35
-32 to -40	-36 to -40
-41 to -45	-41 to -45
-46 to -50	-46 to -100

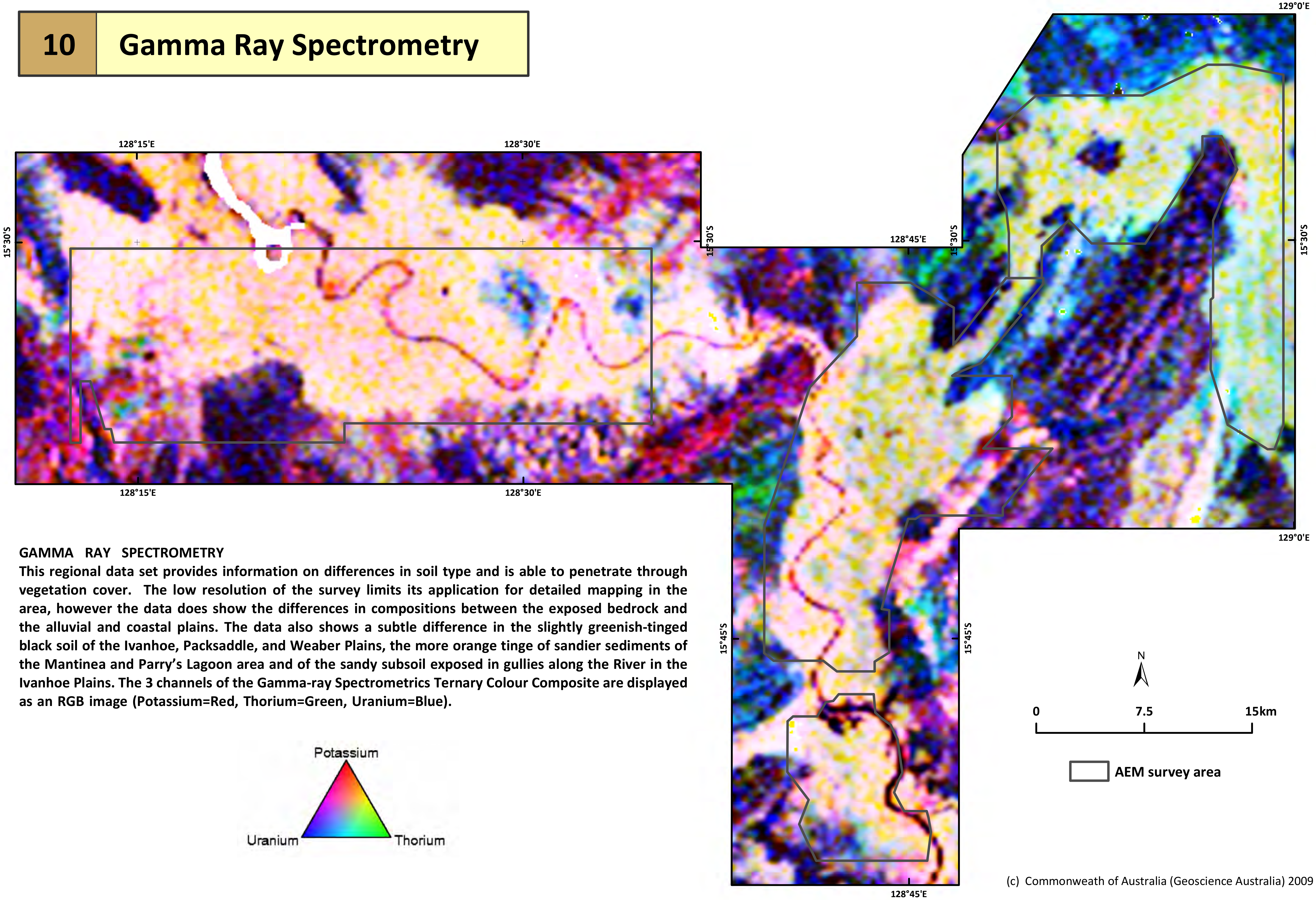
N

0 7.5 15km

AEM survey area

Ord Valley AEM Interpretation Project

10 Gamma Ray Spectrometry

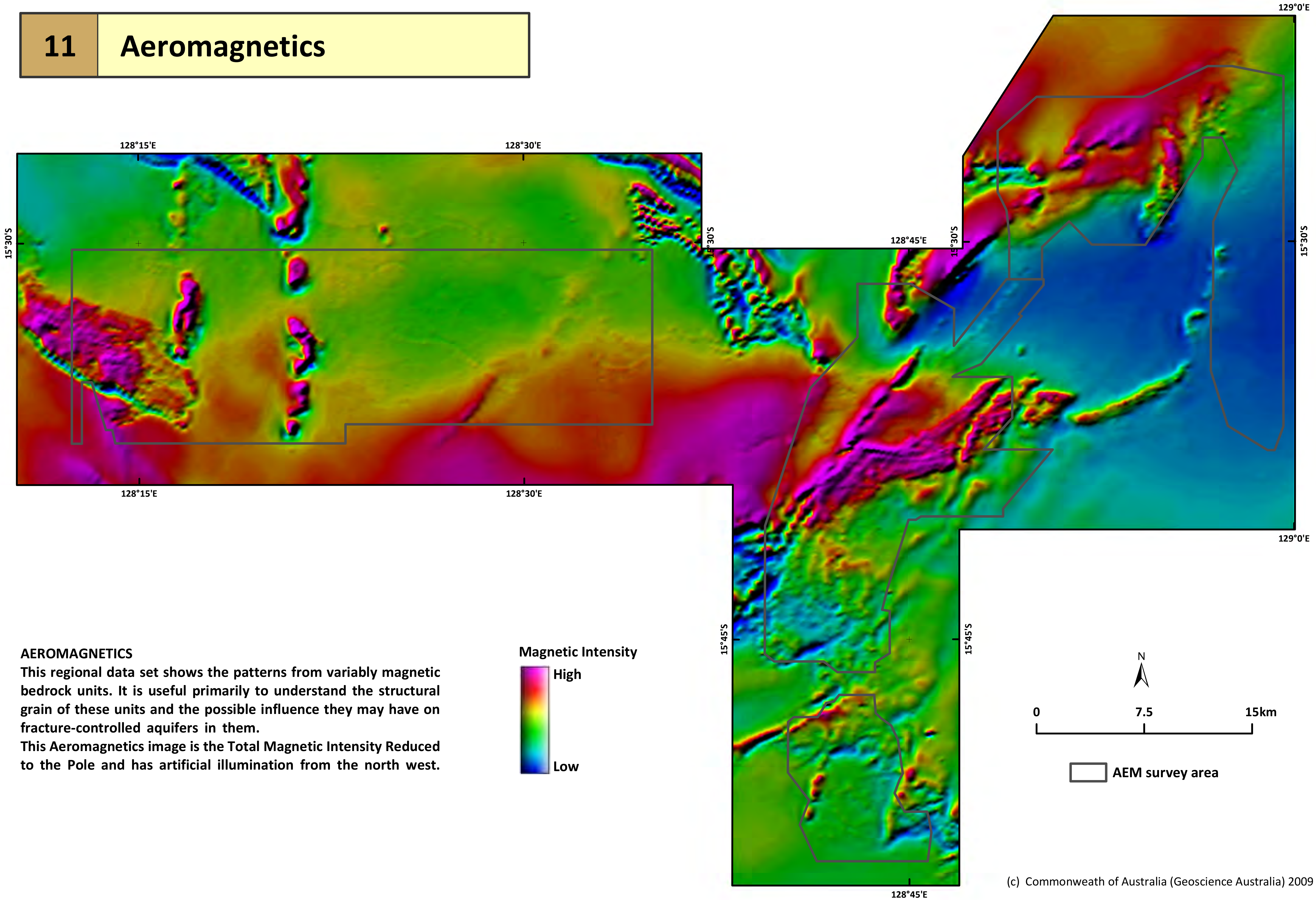


GAMMA RAY SPECTROMETRY

This regional data set provides information on differences in soil type and is able to penetrate through vegetation cover. The low resolution of the survey limits its application for detailed mapping in the area, however the data does show the differences in compositions between the exposed bedrock and the alluvial and coastal plains. The data also shows a subtle difference in the slightly greenish-tinged black soil of the Ivanhoe, Packsaddle, and Weaber Plains, the more orange tinge of sandier sediments of the Mantinea and Parry's Lagoon area and of the sandy subsoil exposed in gullies along the River in the Ivanhoe Plains. The 3 channels of the Gamma-ray Spectrometrics Ternary Colour Composite are displayed as an RGB image (Potassium=Red, Thorium=Green, Uranium=Blue).

Ord Valley AEM Interpretation Project

11 Aeromagnetics



AEROMAGNETICS
This regional data set shows the patterns from variably magnetic bedrock units. It is useful primarily to understand the structural grain of these units and the possible influence they may have on fracture-controlled aquifers in them.
This Aeromagnetics image is the Total Magnetic Intensity Reduced to the Pole and has artificial illumination from the north west.

Magnetic Intensity
High
Low

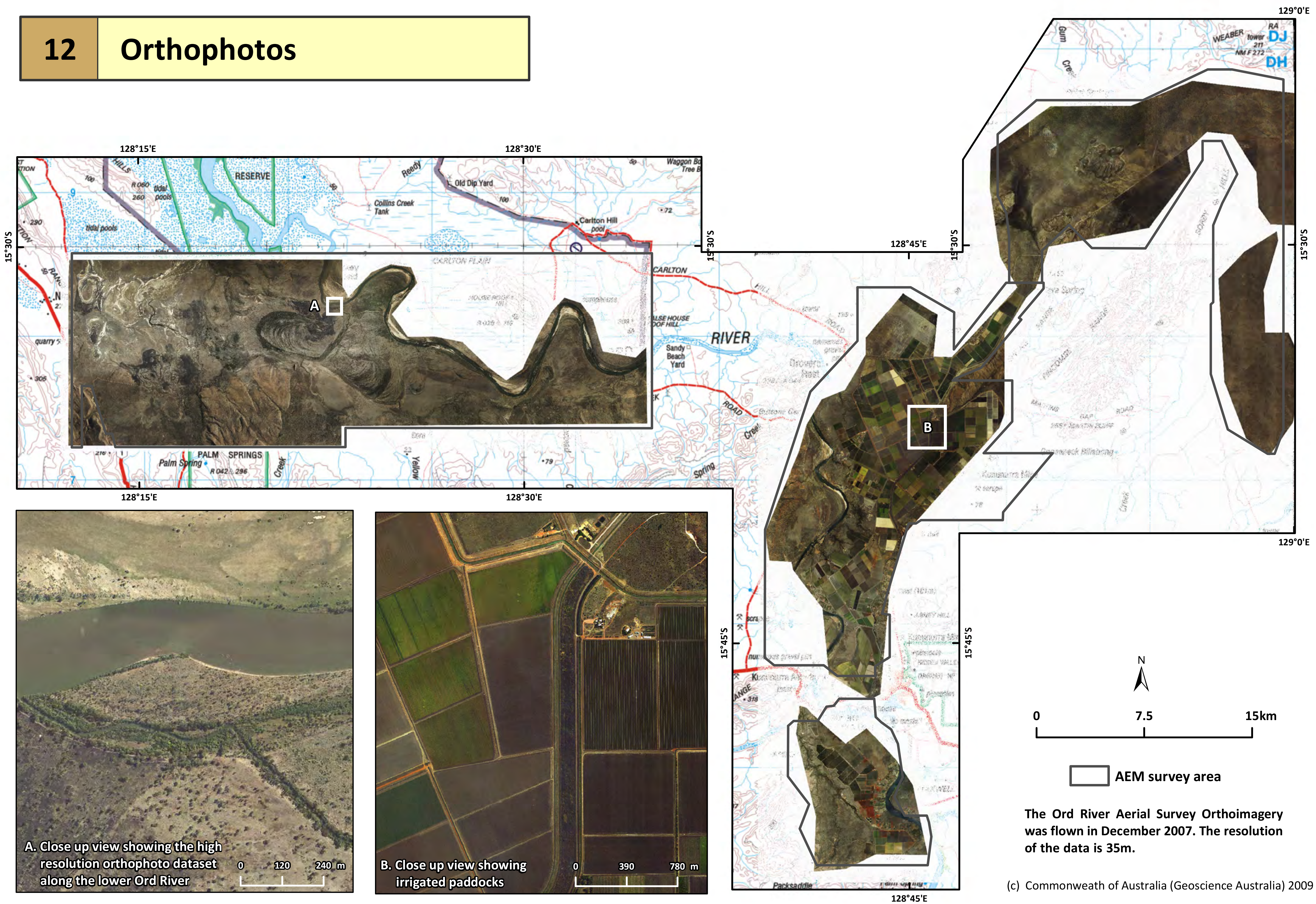
N

0 7.5 15km

AEM survey area

Ord Valley AEM Interpretation Project

12 Orthophotos



A. Close up view showing the high resolution orthophoto dataset along the lower Ord River

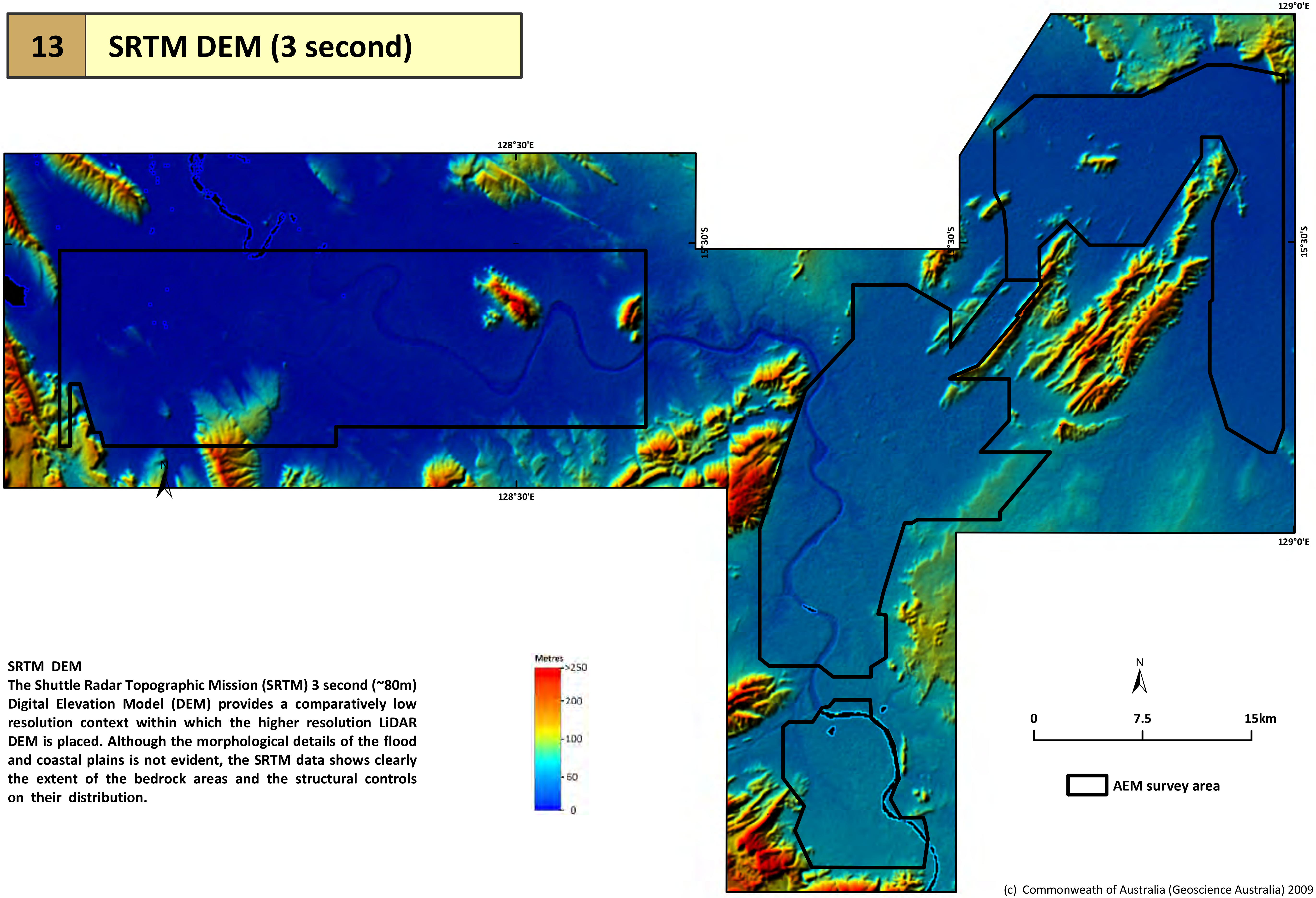
B. Close up view showing irrigated paddocks

AEM survey area

The Ord River Aerial Survey Orthoimagery was flown in December 2007. The resolution of the data is 35m.

Ord Valley AEM Interpretation Project

13 SRTM DEM (3 second)



SRTM DEM

The Shuttle Radar Topographic Mission (SRTM) 3 second (~80m) Digital Elevation Model (DEM) provides a comparatively low resolution context within which the higher resolution LiDAR DEM is placed. Although the morphological details of the flood and coastal plains is not evident, the SRTM data shows clearly the extent of the bedrock areas and the structural controls on their distribution.

Metres

>250

200

100

60

0

N

0 7.5 15km

AEM survey area

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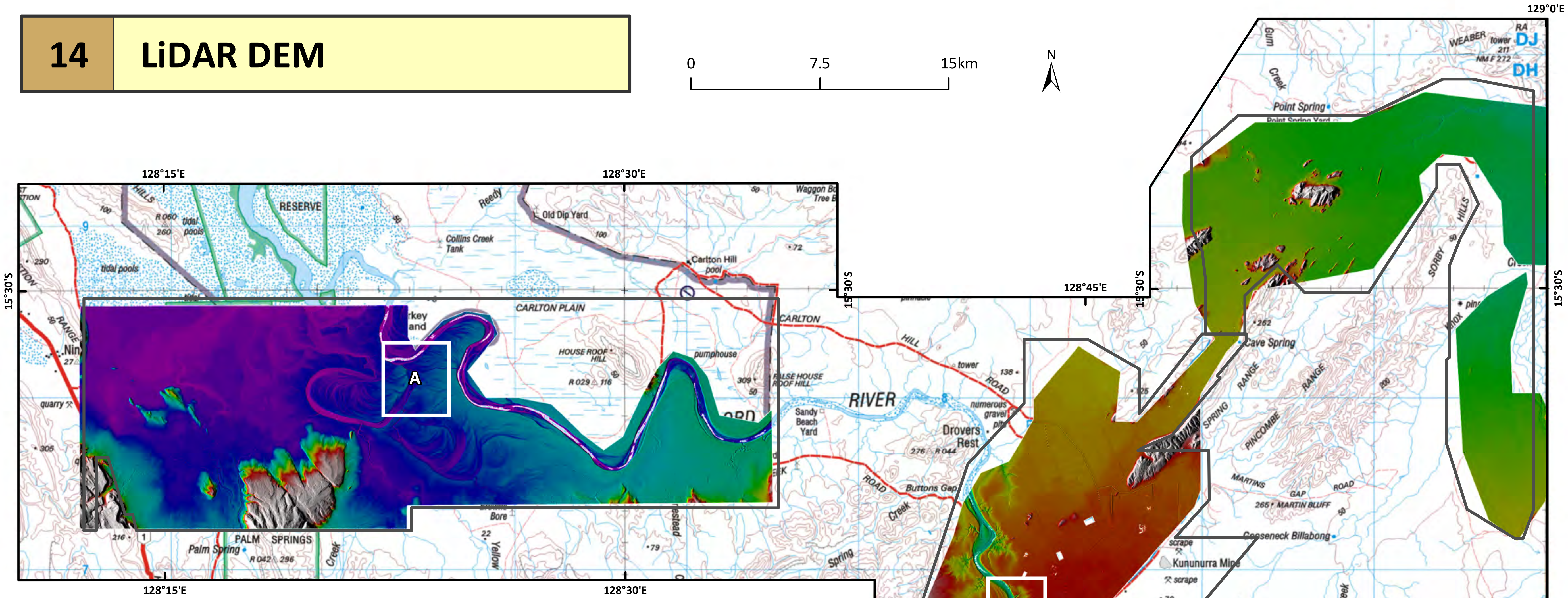
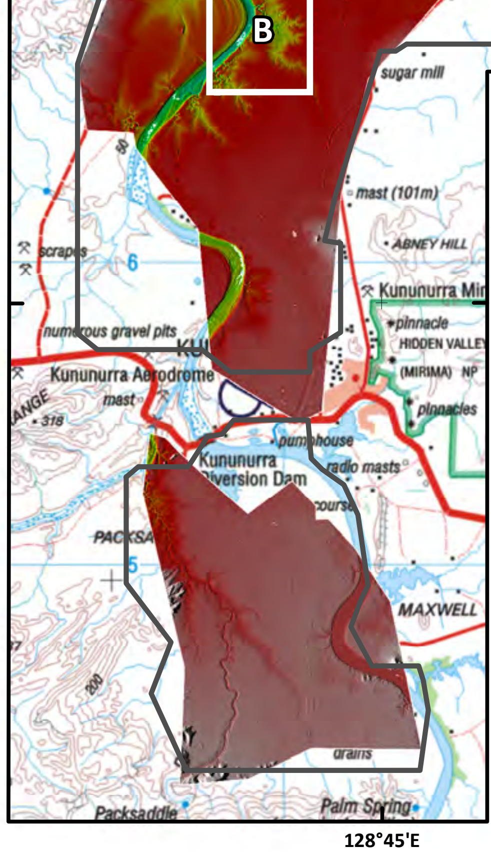
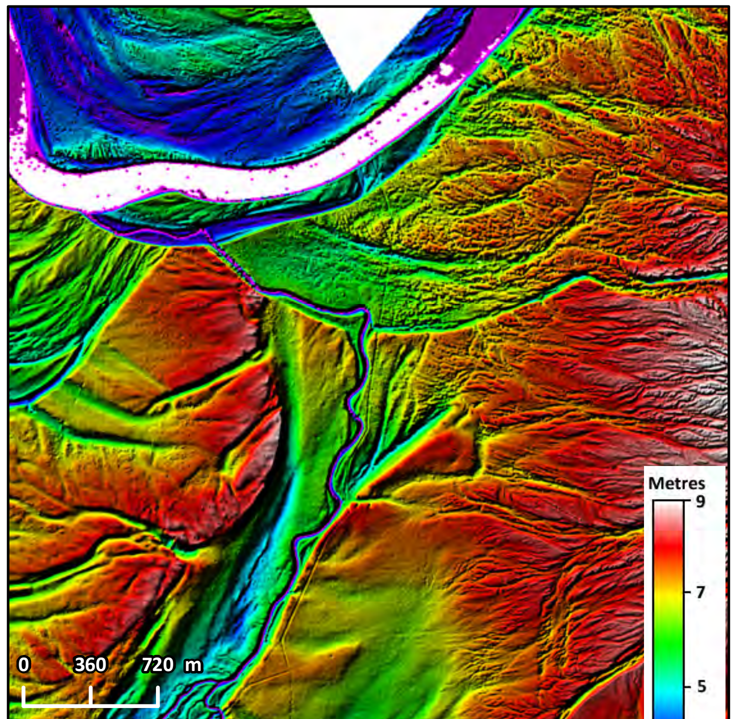
14 LiDAR DEM



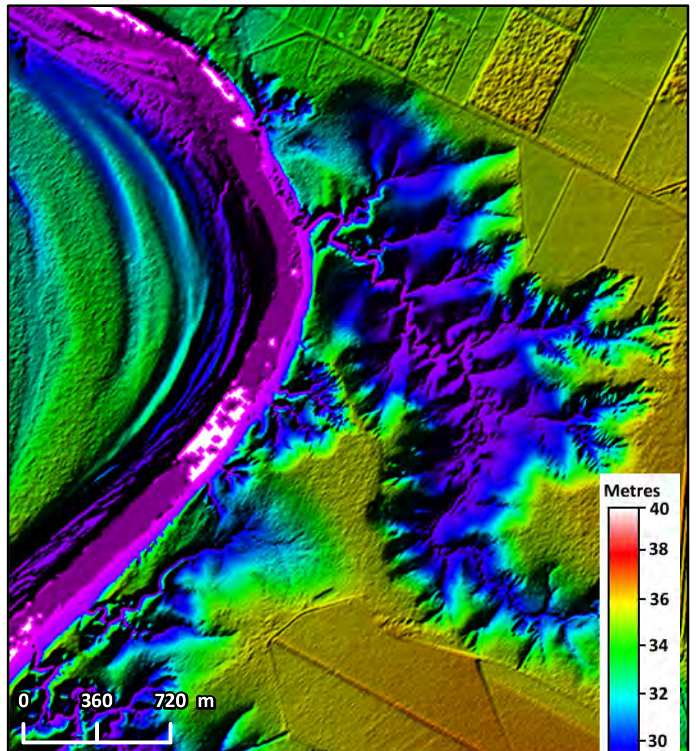


LiDAR

A Light Detection And Ranging (LiDAR) Digital Elevation Model (DEM) was acquired to support the interpretation of the AEM and help with the identification of critical landscape elements and floodplain characteristics. The survey (completed in February 2008) was flown at 2000m and produced a series of 1km DEM tiles. The tiles were stitched together into two areas, east and west, resulting in a final DEM with 5m horizontal and 20cm vertical resolution.



A. Close up view showing the subtle fluvial detail available in the high resolution LiDAR dataset.



B. River and gully features are clearly visible.

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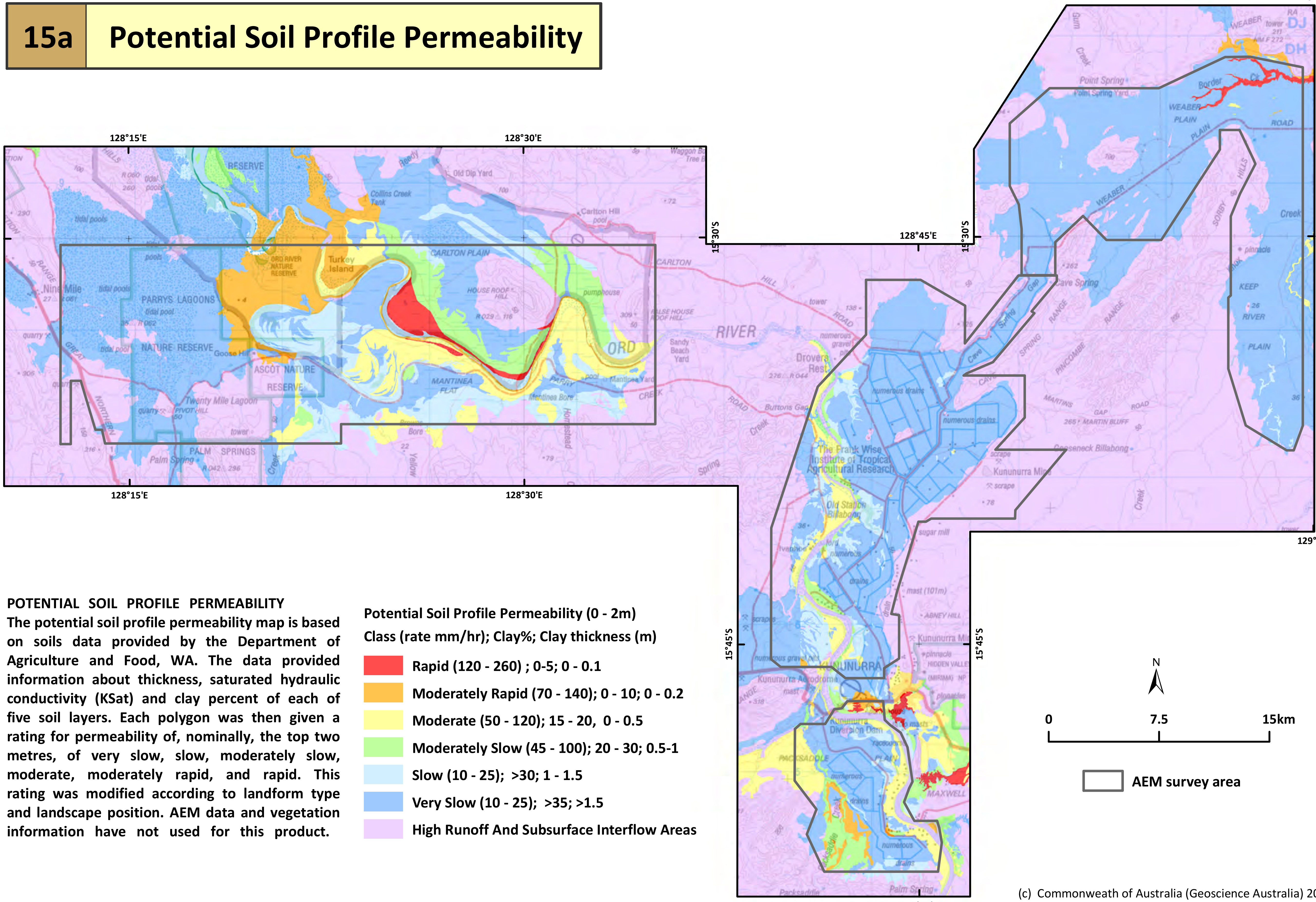
15a Potential Soil Profile Permeability



POTENTIAL SOIL PROFILE PERMEABILITY

The potential soil profile permeability map is based on soils data provided by the Department of Agriculture and Food, WA. The data provided information about thickness, saturated hydraulic conductivity (KSat) and clay percent of each of five soil layers. Each polygon was then given a rating for permeability of, nominally, the top two metres, of very slow, slow, moderately slow, moderate, moderately rapid, and rapid. This rating was modified according to landform type and landscape position. AEM data and vegetation information have not used for this product.

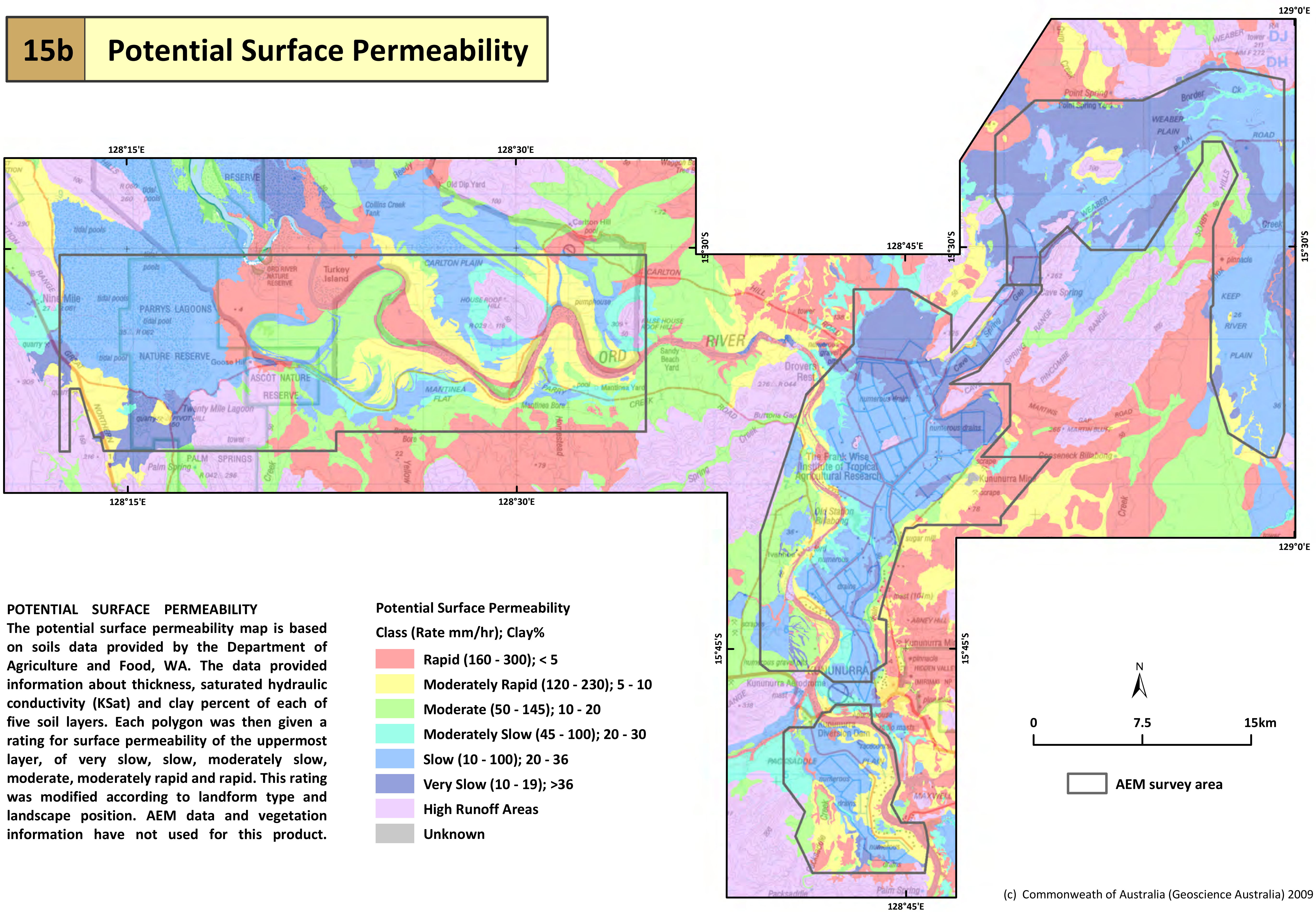
Potential Soil Profile Permeability (0 - 2m)

Class (rate mm/hr); Clay%; Clay thickness (m)

- Rapid (120 - 260) ; 0-5; 0 - 0.1
- Moderately Rapid (70 - 140); 0 - 10; 0 - 0.2
- Moderate (50 - 120); 15 - 20, 0 - 0.5
- Moderately Slow (45 - 100); 20 - 30; 0.5-1
- Slow (10 - 25); >30; 1 - 1.5
- Very Slow (10 - 25); >35; >1.5
- High Runoff And Subsurface Interflow Areas

Ord Valley AEM Interpretation Project

15b Potential Surface Permeability



POTENTIAL SURFACE PERMEABILITY
The potential surface permeability map is based on soils data provided by the Department of Agriculture and Food, WA. The data provided information about thickness, saturated hydraulic conductivity (KSat) and clay percent of each of five soil layers. Each polygon was then given a rating for surface permeability of the uppermost layer, of very slow, slow, moderately slow, moderate, moderately rapid and rapid. This rating was modified according to landform type and landscape position. AEM data and vegetation information have not used for this product.

Potential Surface Permeability

Class (Rate mm/hr); Clay%

- Rapid (160 - 300); < 5
- Moderately Rapid (120 - 230); 5 - 10
- Moderate (50 - 145); 10 - 20
- Moderately Slow (45 - 100); 20 - 30
- Slow (10 - 100); 20 - 36
- Very Slow (10 - 19); >36
- High Runoff Areas
- Unknown

N

0 7.5 15km

AEM survey area

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.

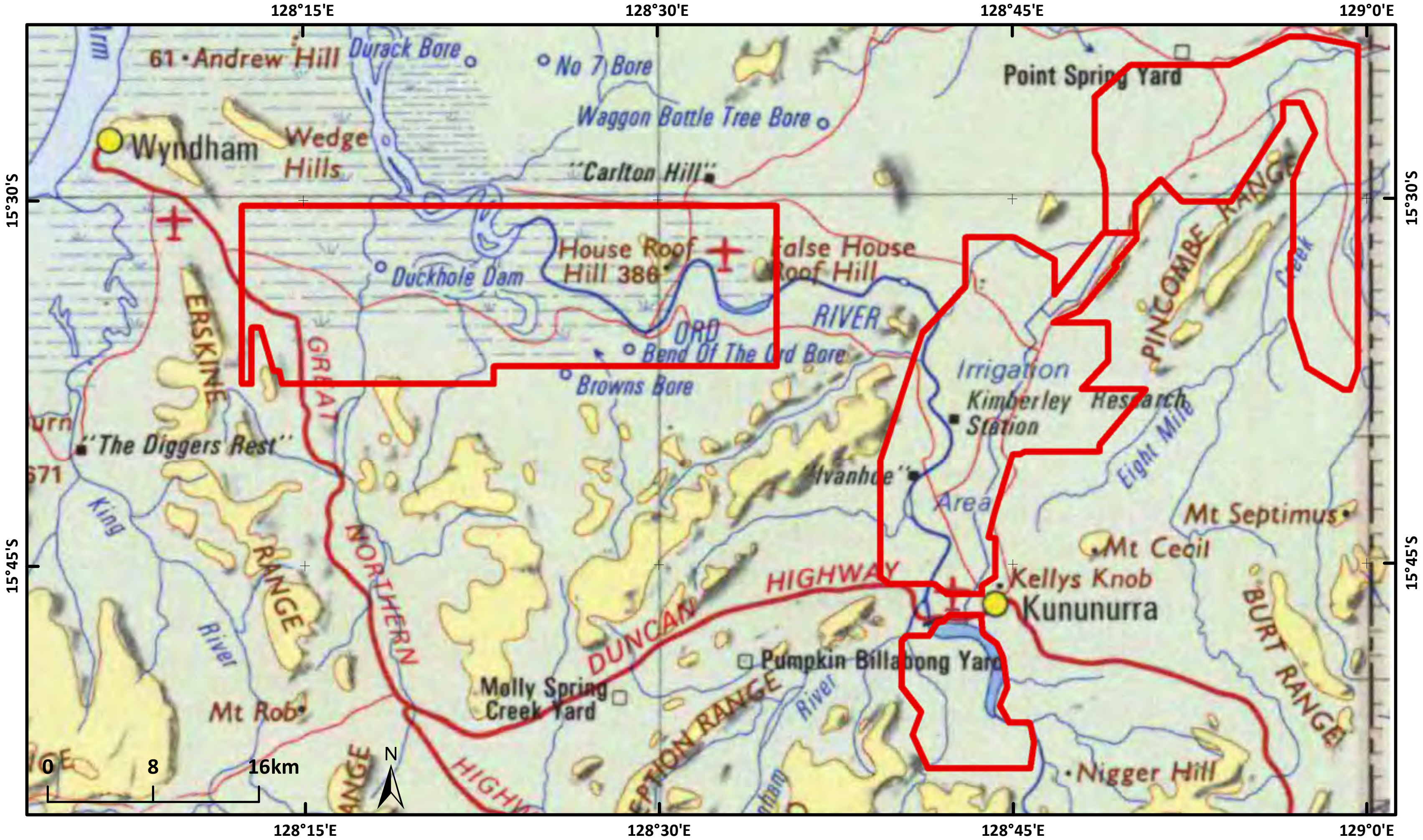


Figure 1: Map showing the location of the Ord SkyTEM survey in northern WA. The survey area is outlined in red

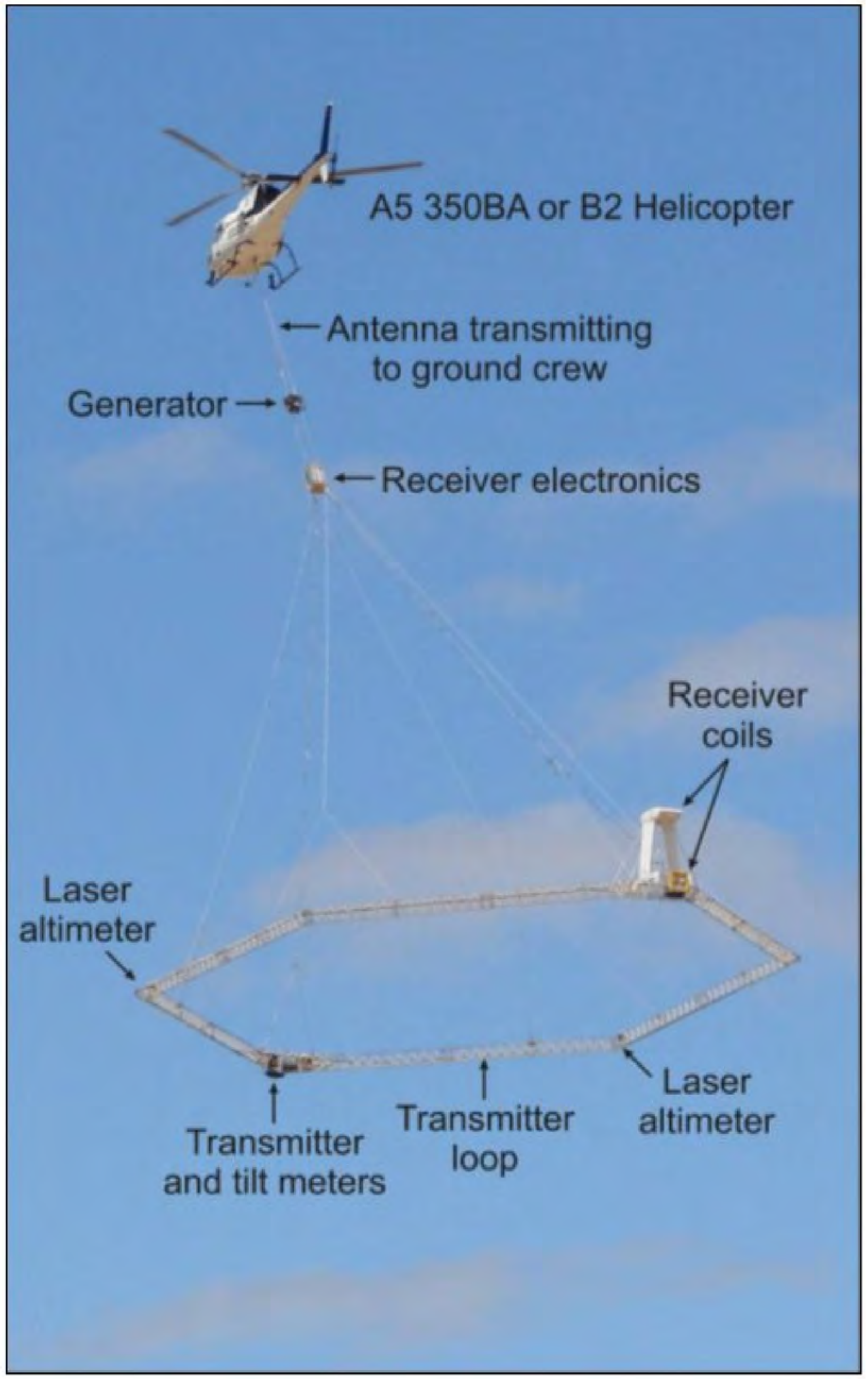


Figure 2: The SkyTEM helicopter electromagnetic system in survey mode

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).

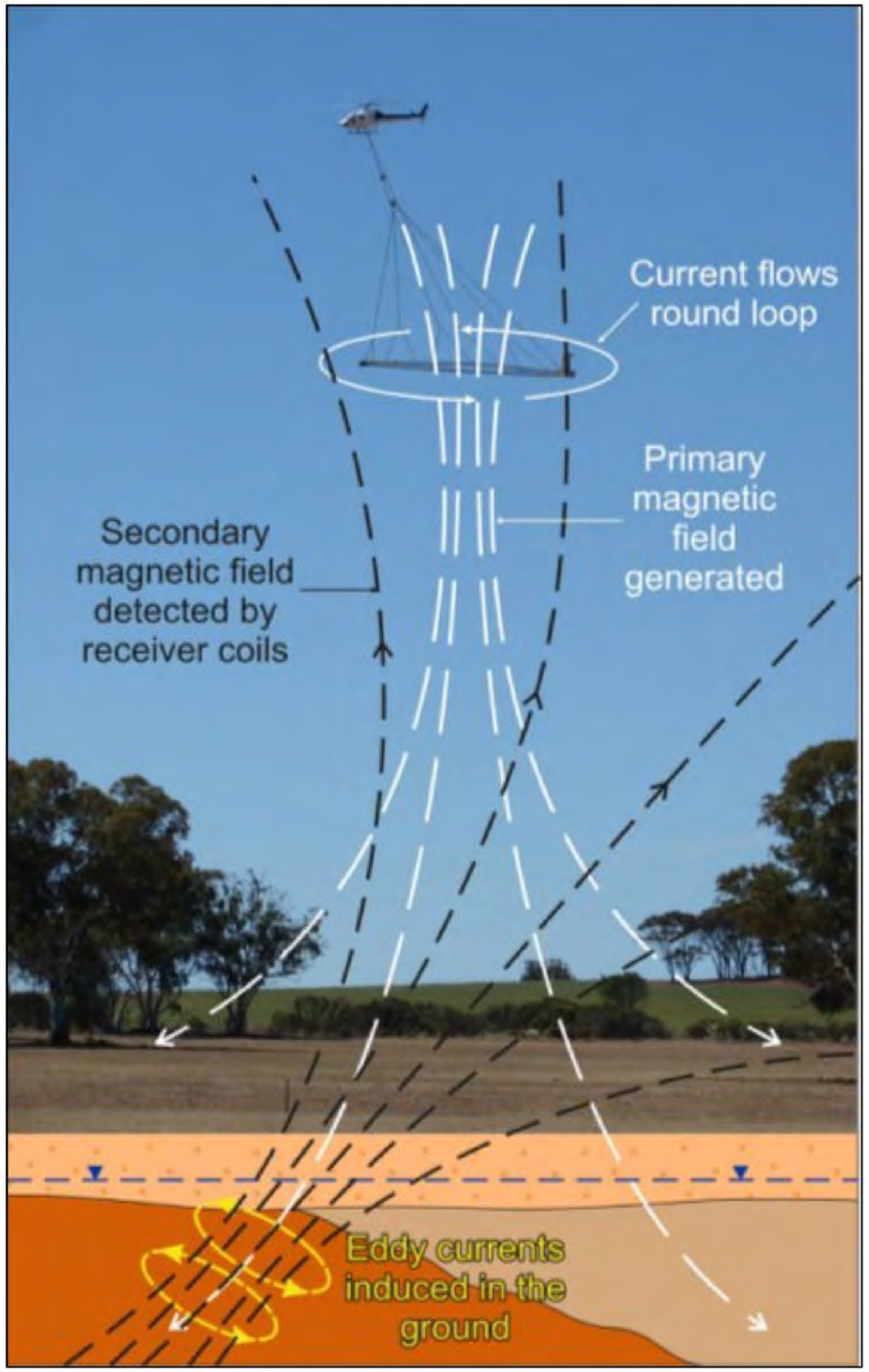


Figure 3: How the SkyTEM measures ground conductivity

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 a 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.

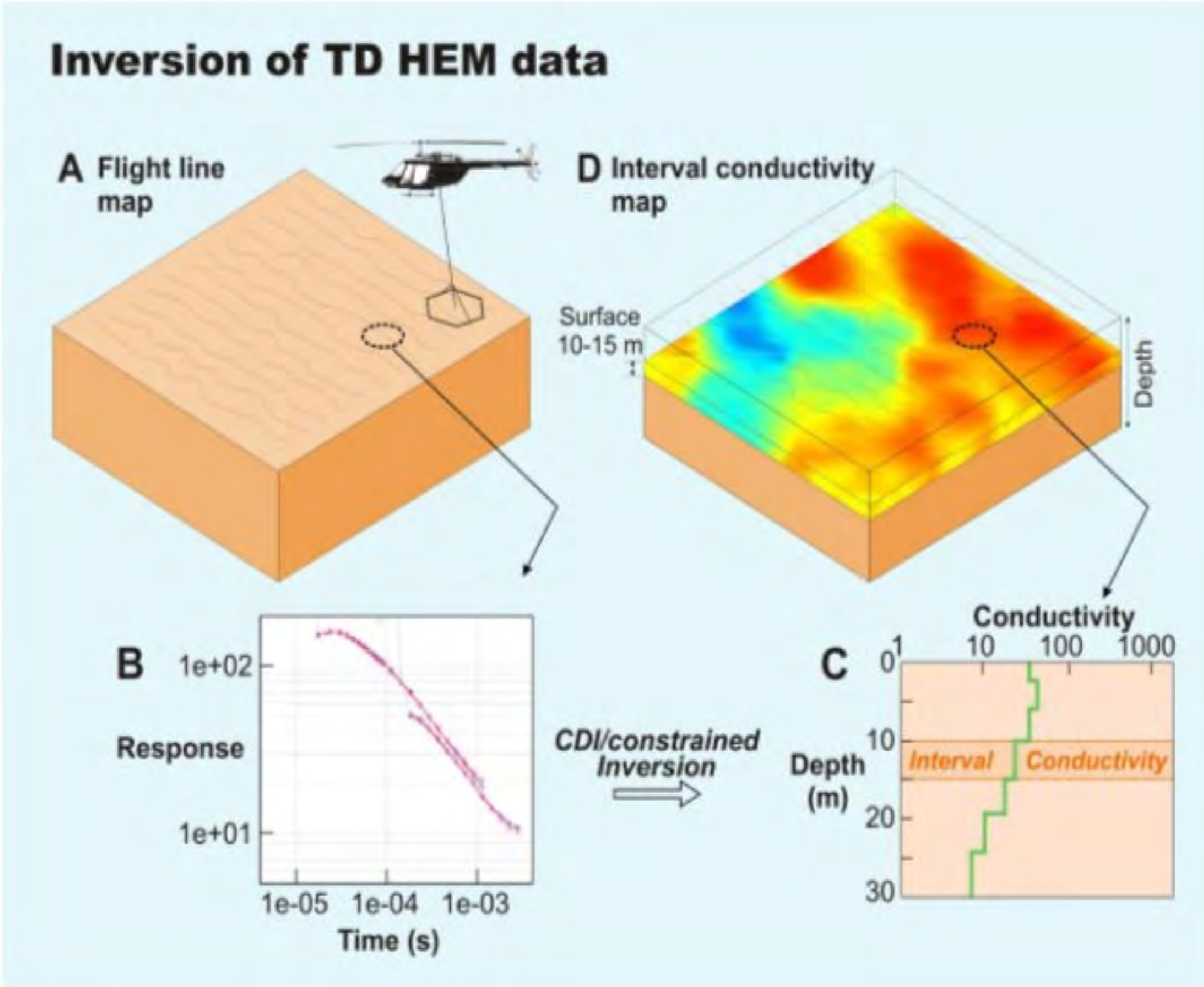
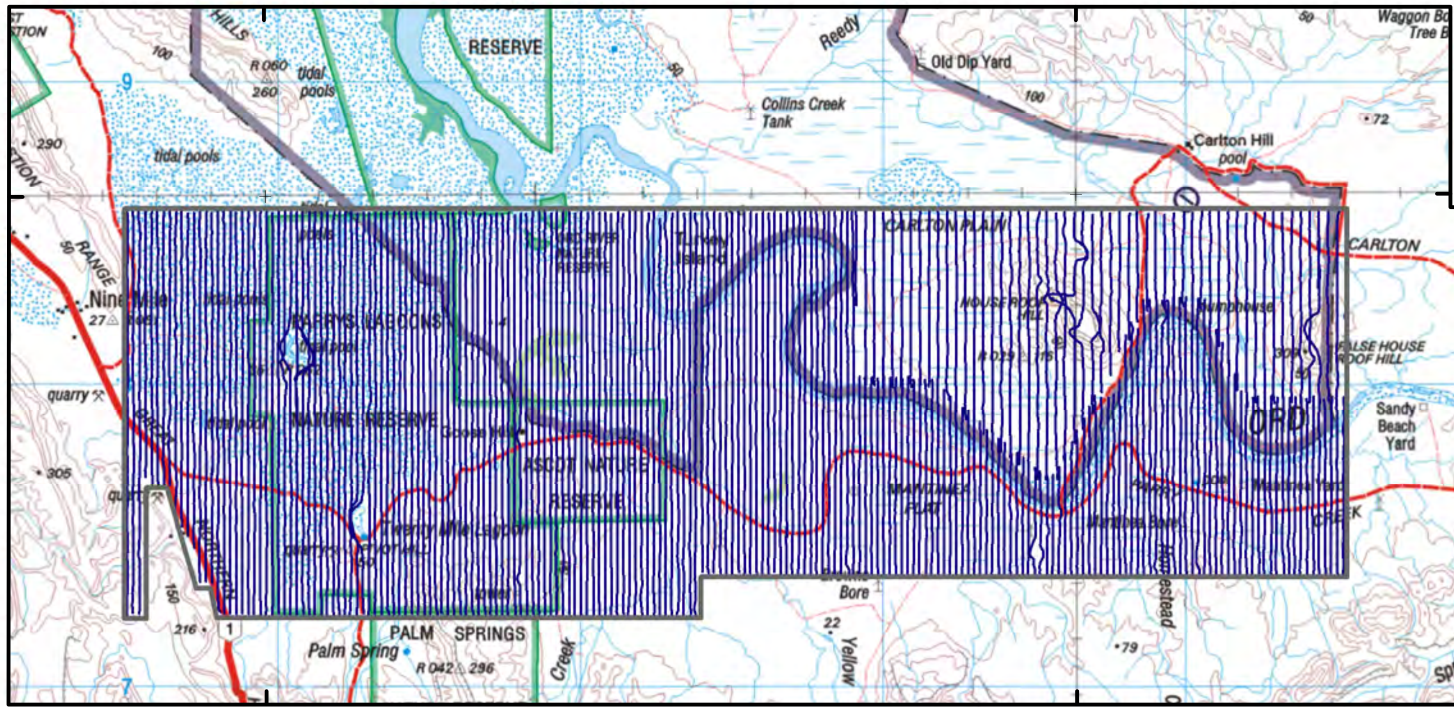
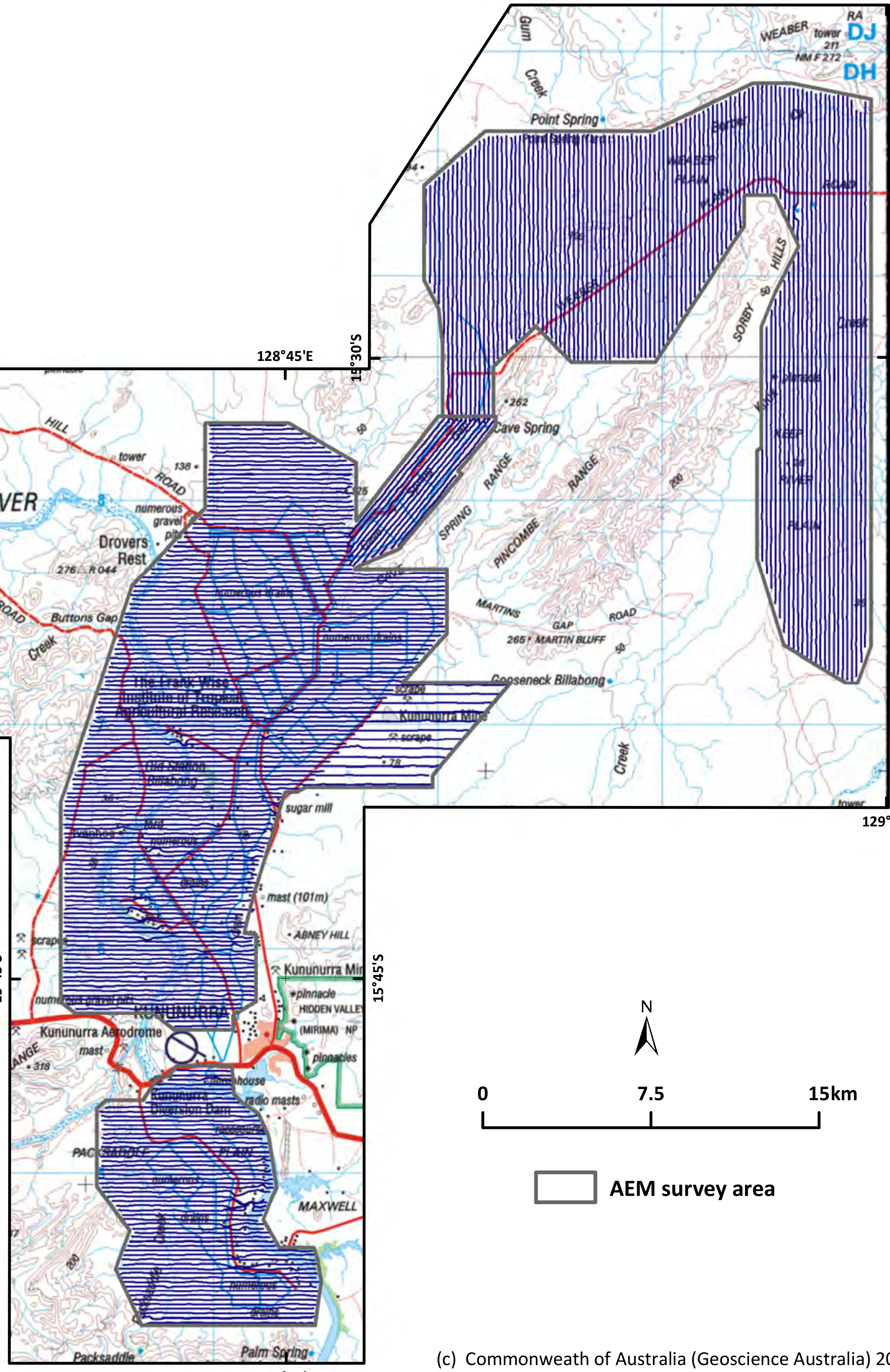


Figure 4: Schematic representation of how the SkyTEM measures a response from the ground, and how that data once collected is then converted through a process known as inversion to a model of ground conductivity. A) Data are acquired along parallel flight lines, with measurements made every 10-15m along 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

17 Flightlines





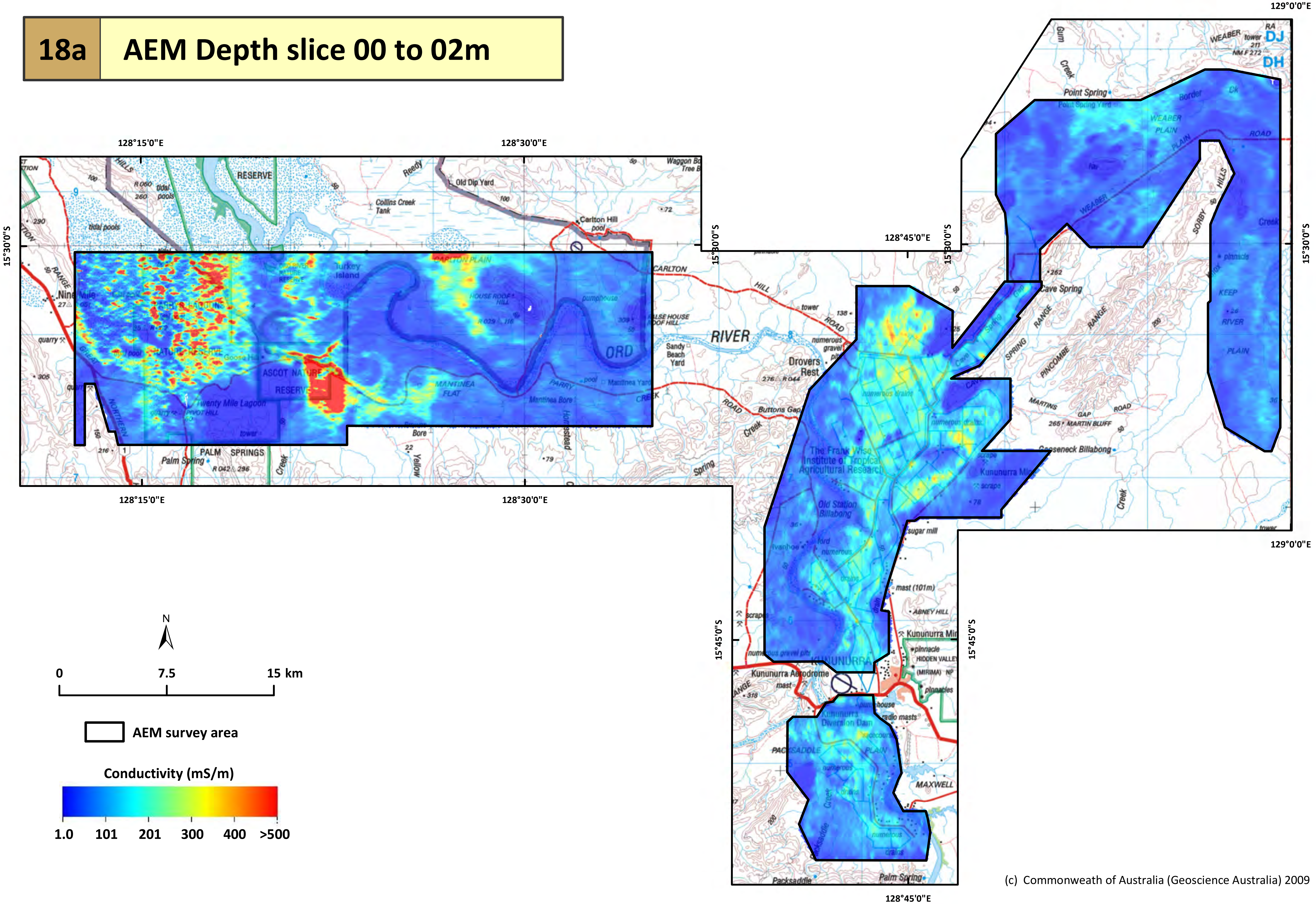
In 2008, the Ord Irrigation Cooperative and the Ord Catchment Reference Group commissioned an airborne electromagnetics (AEM) survey of the ORIA Stage 1 and 2 areas to identify, quantify and understand any potential salinity risks in the Ord Irrigation scheme. Geoscience Australia and CSIRO were contracted to carry out the analysis and interpretation of the AEM dataset, and produce customised interpretation products.

Flying over the irrigation area

The SkyTEM AEM survey was flown in August 2008. The system flew about 60m above the ground. The transmitter/receiver frame trailed about 30m above ground.

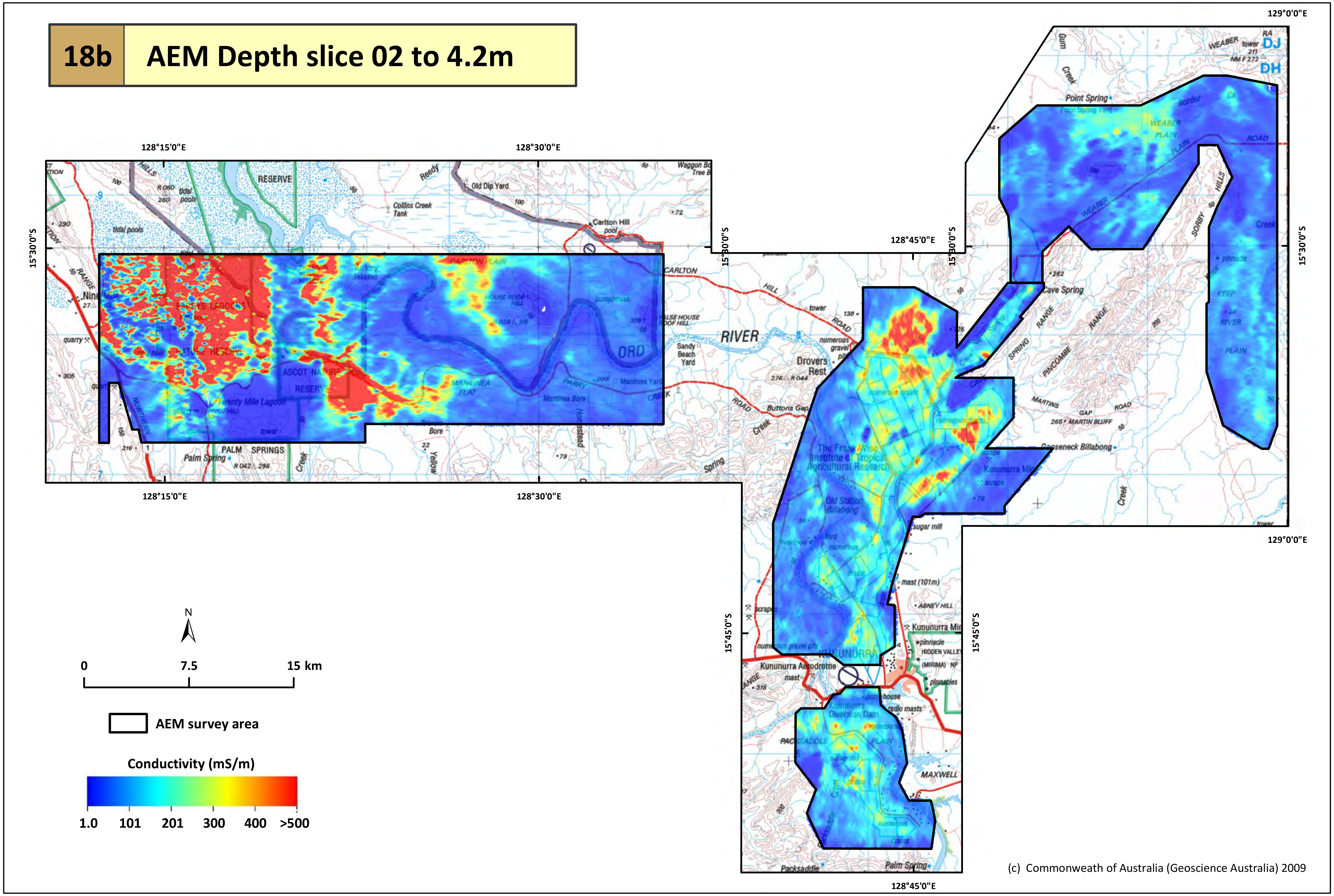
Ord Valley AEM Interpretation Project

18a AEM Depth slice 00 to 02m

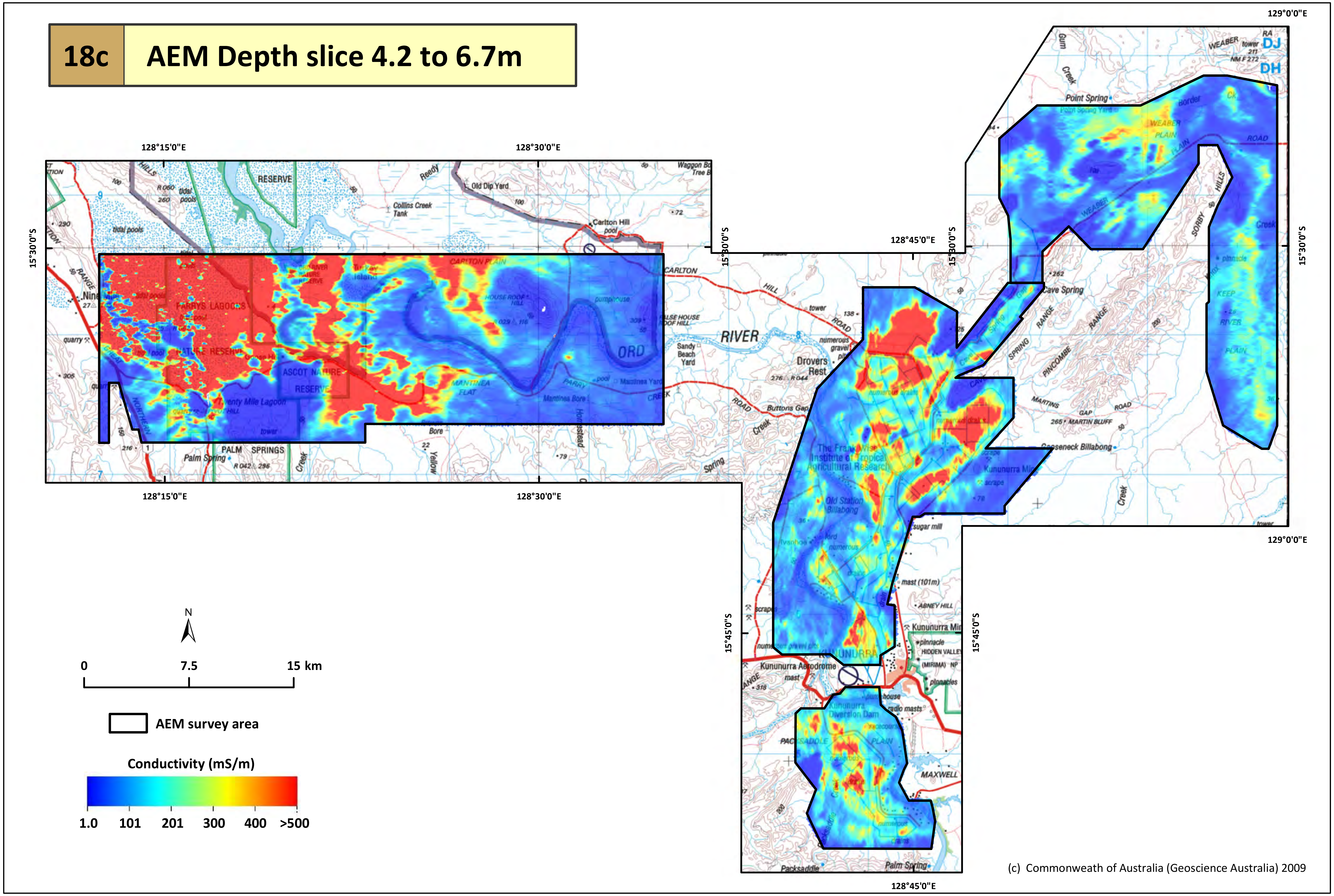


Ord Valley AEM Interpretation Project

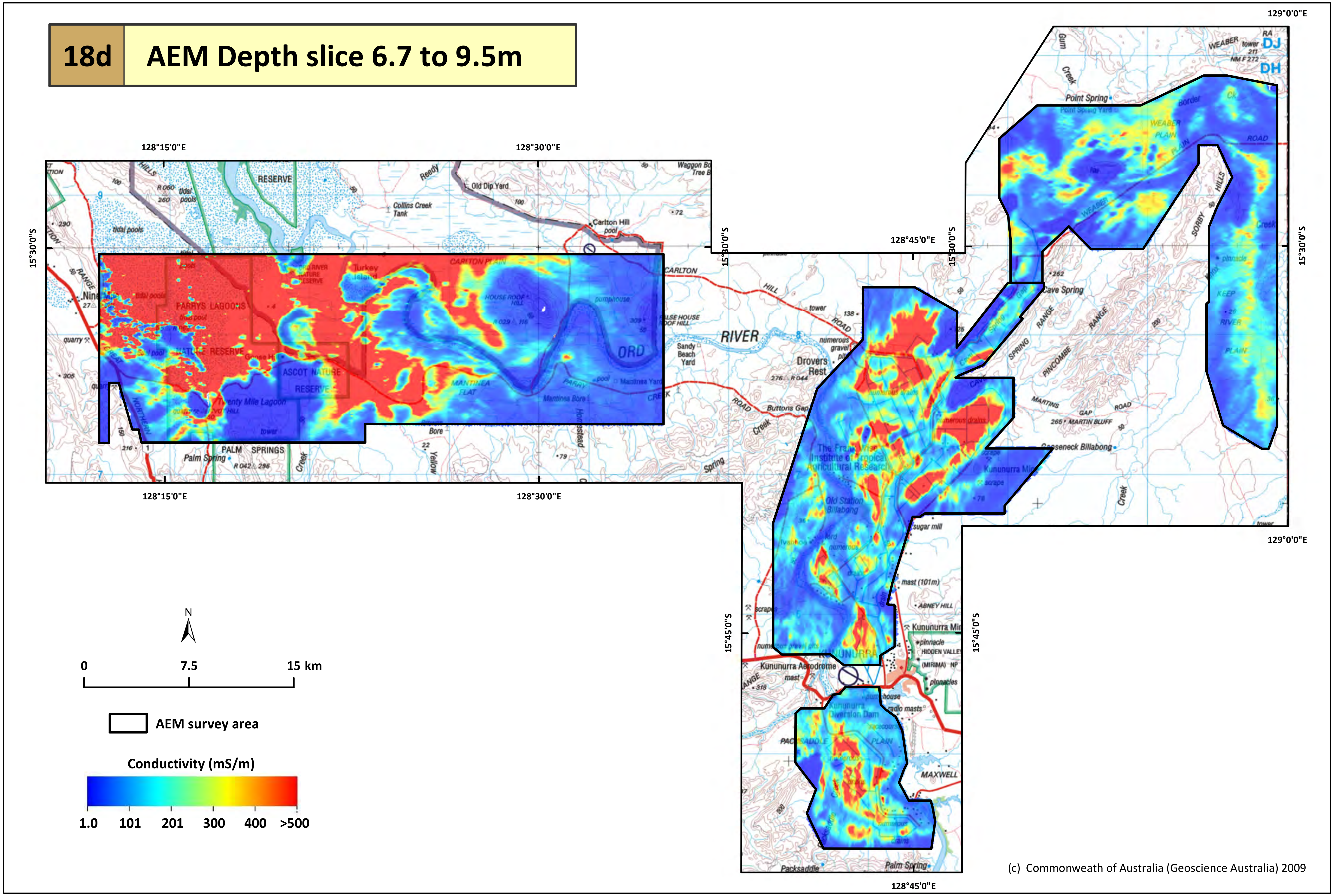
18b AEM Depth slice 02 to 4.2m



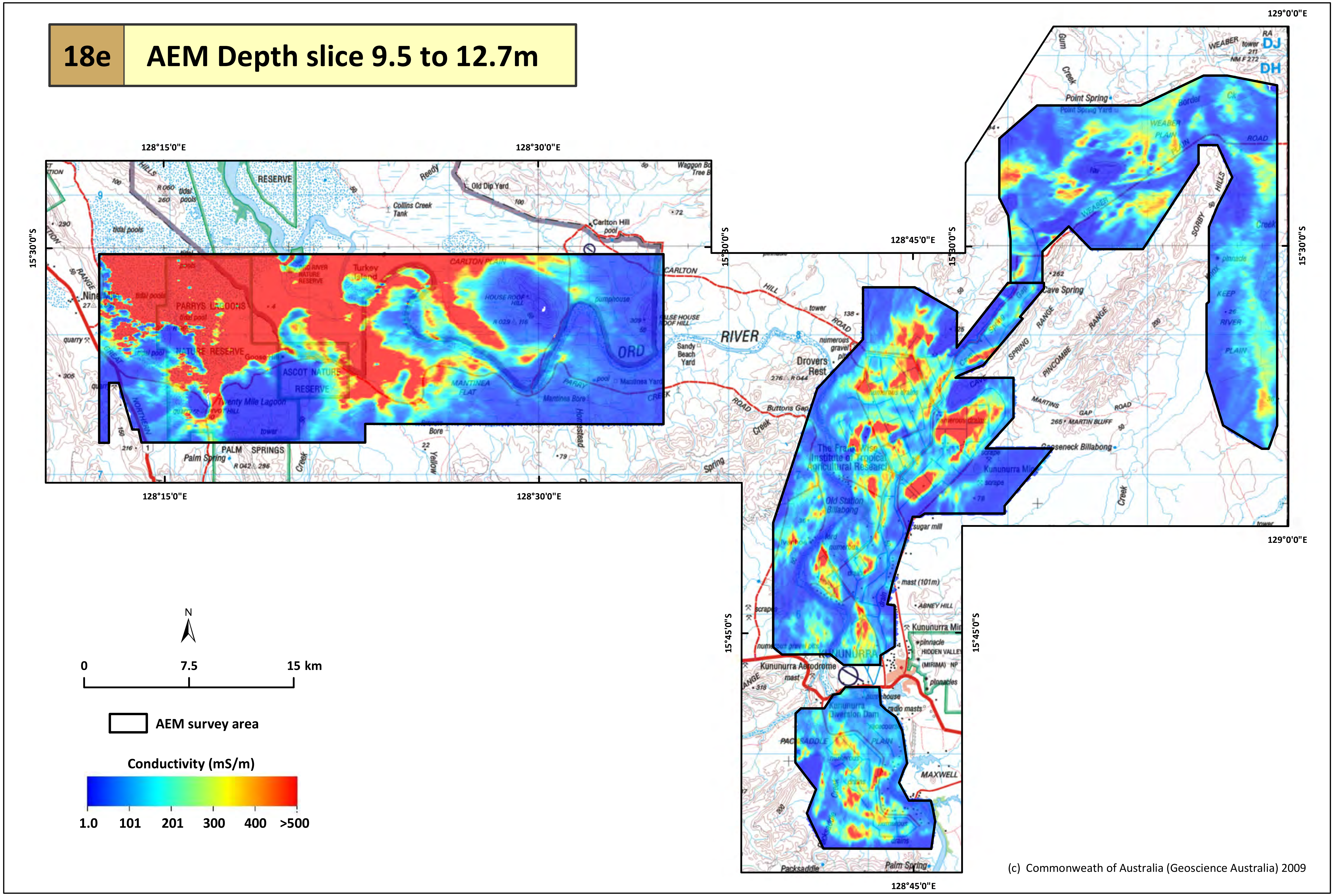
Ord Valley AEM Interpretation Project



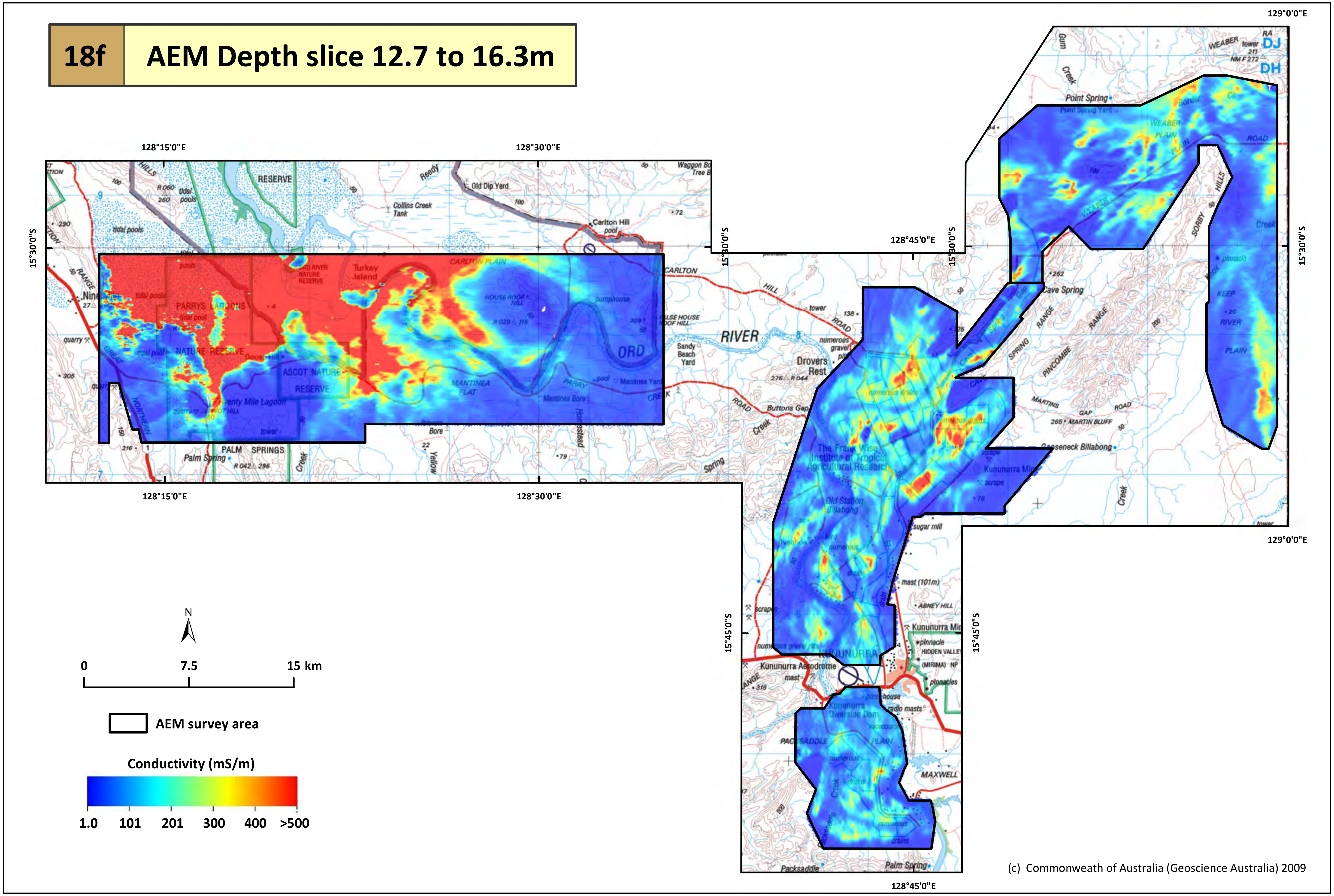
Ord Valley AEM Interpretation Project



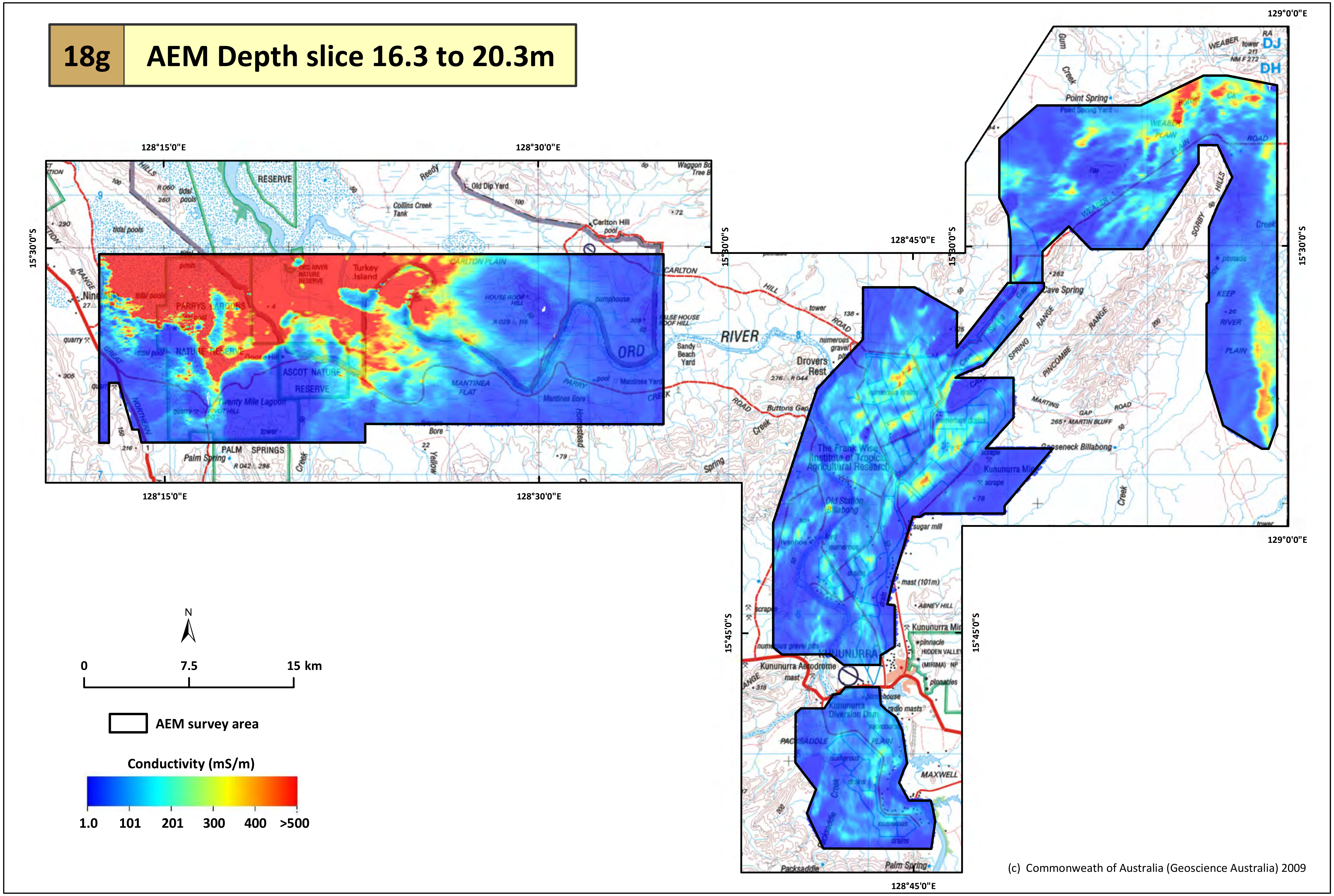
Ord Valley AEM Interpretation Project



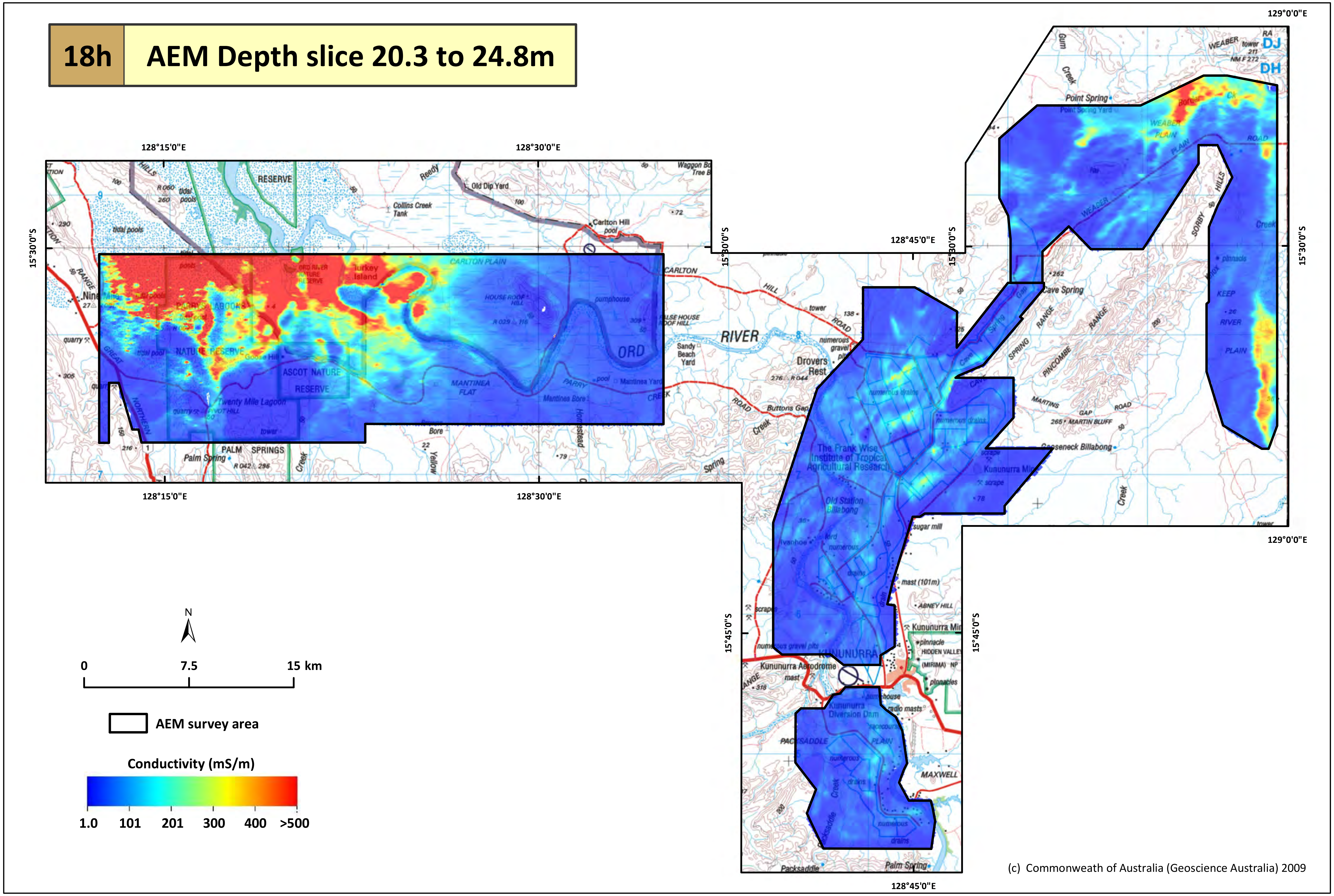
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

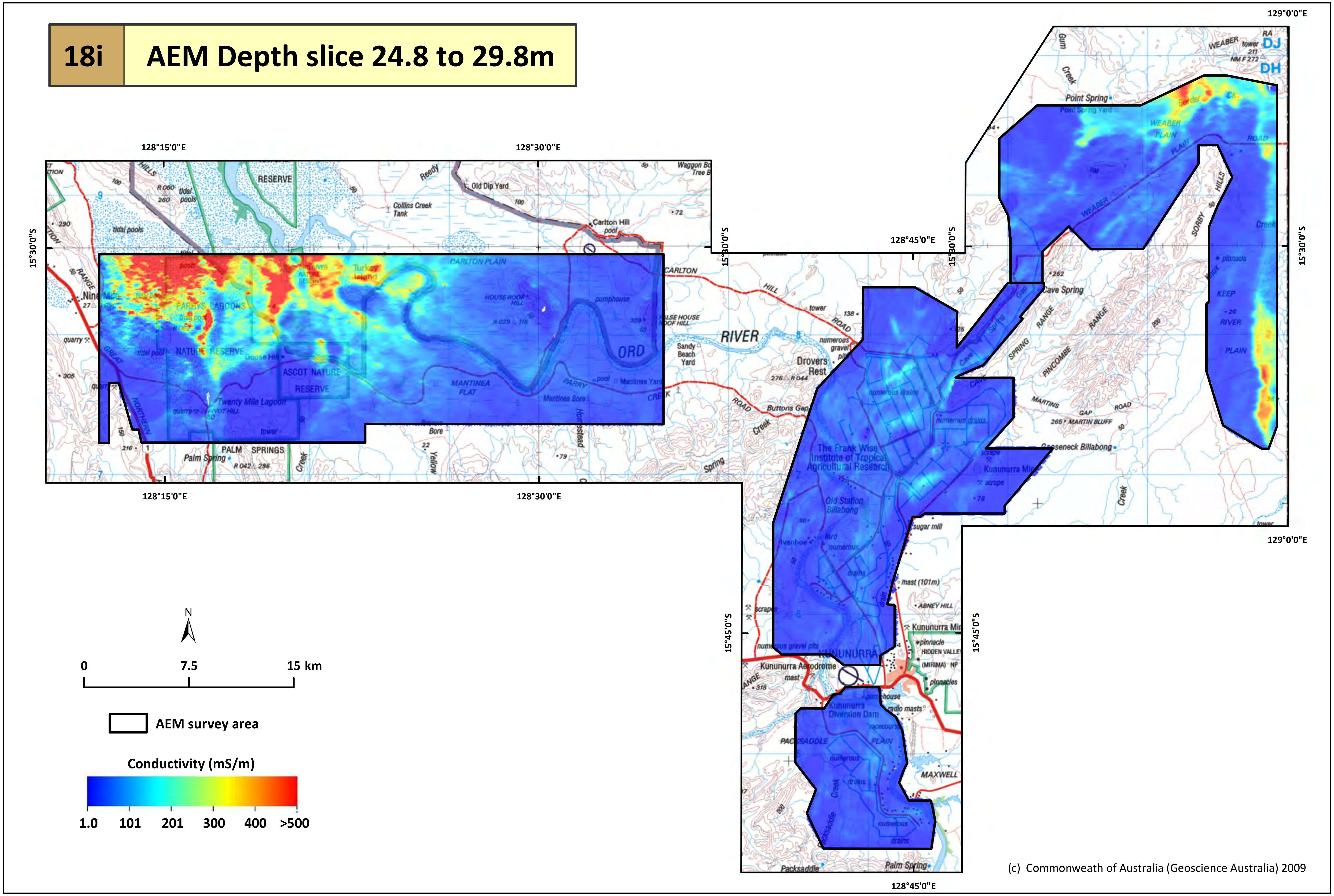


Ord Valley AEM Interpretation Project



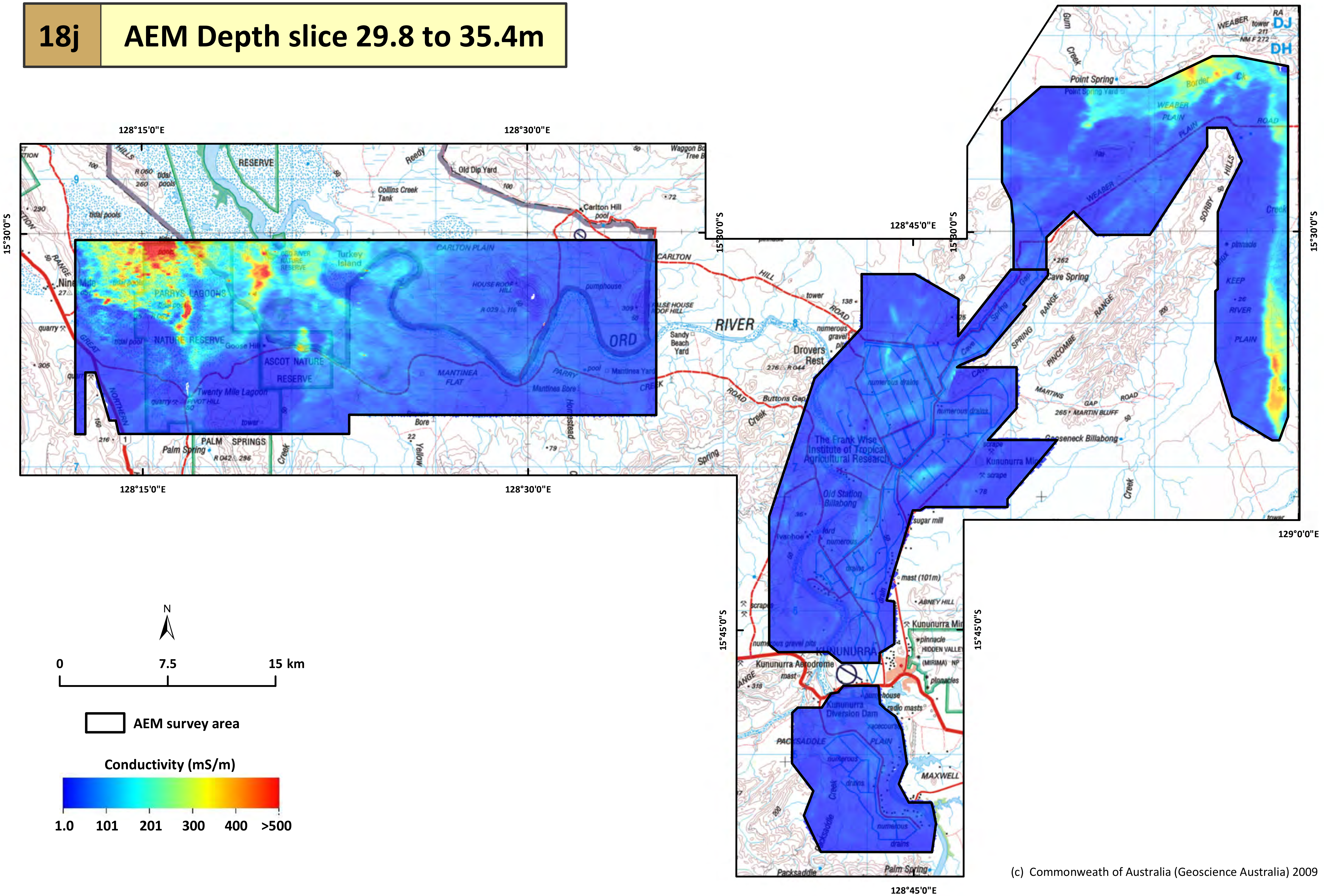
Ord Valley AEM Interpretation Project

18i AEM Depth slice 24.8 to 29.8m



Ord Valley AEM Interpretation Project

18j | AEM Depth slice 29.8 to 35.4m



N

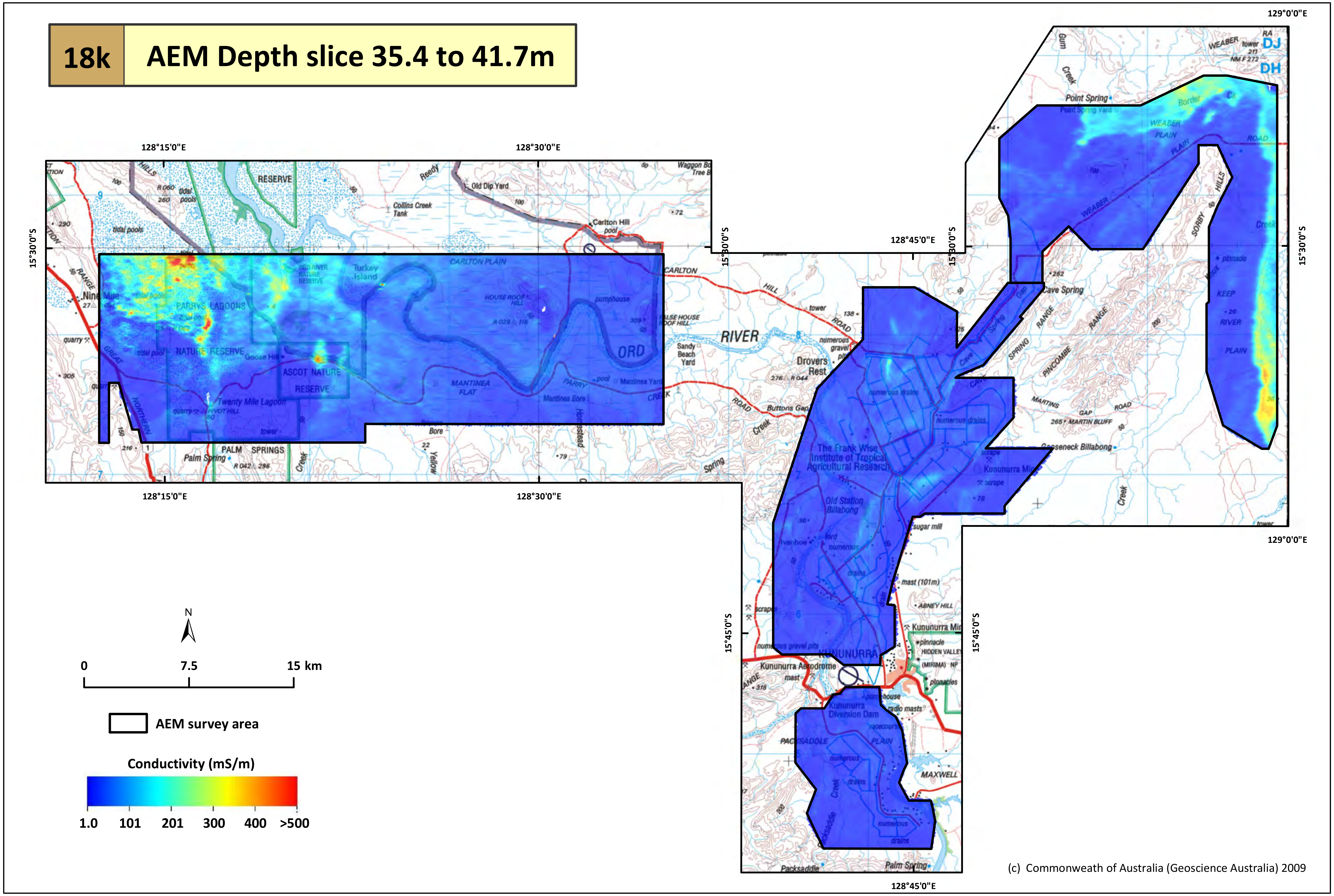
0 | 7.5 | 15 km

AEM survey area

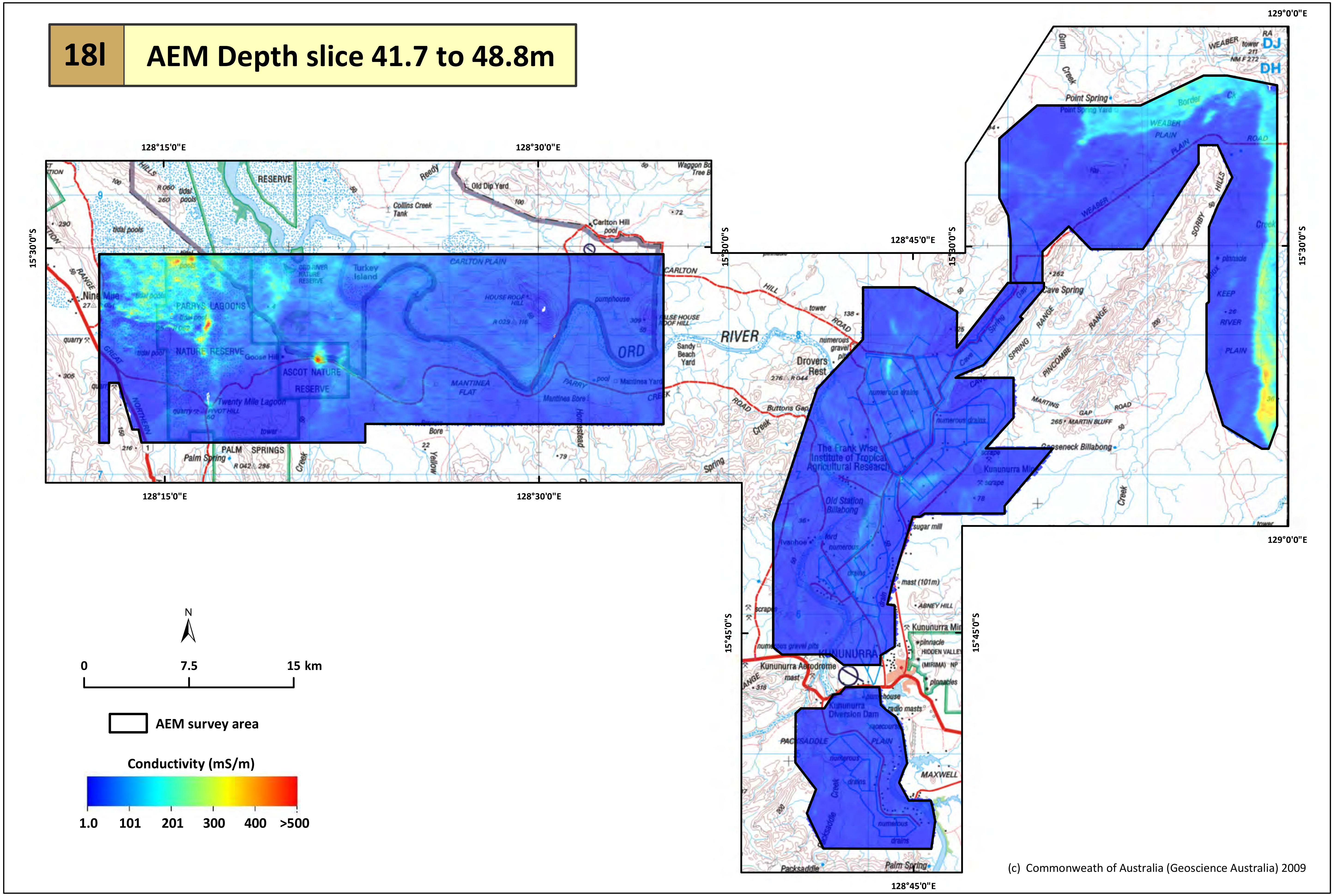
Conductivity (mS/m)

1.0 | 101 | 201 | 300 | 400 | >500

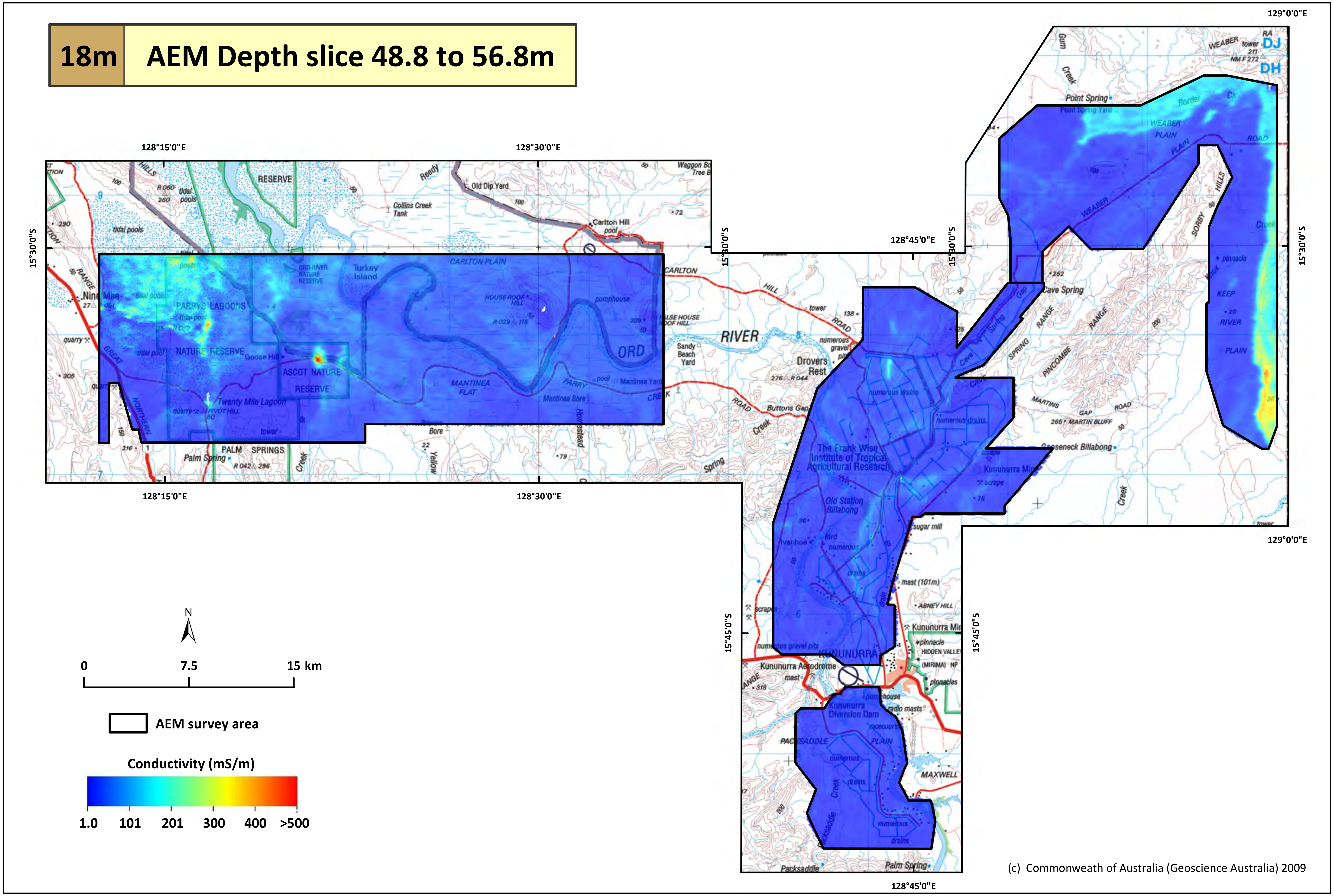
Ord Valley AEM Interpretation Project



Ord Valley AEM Interpretation Project

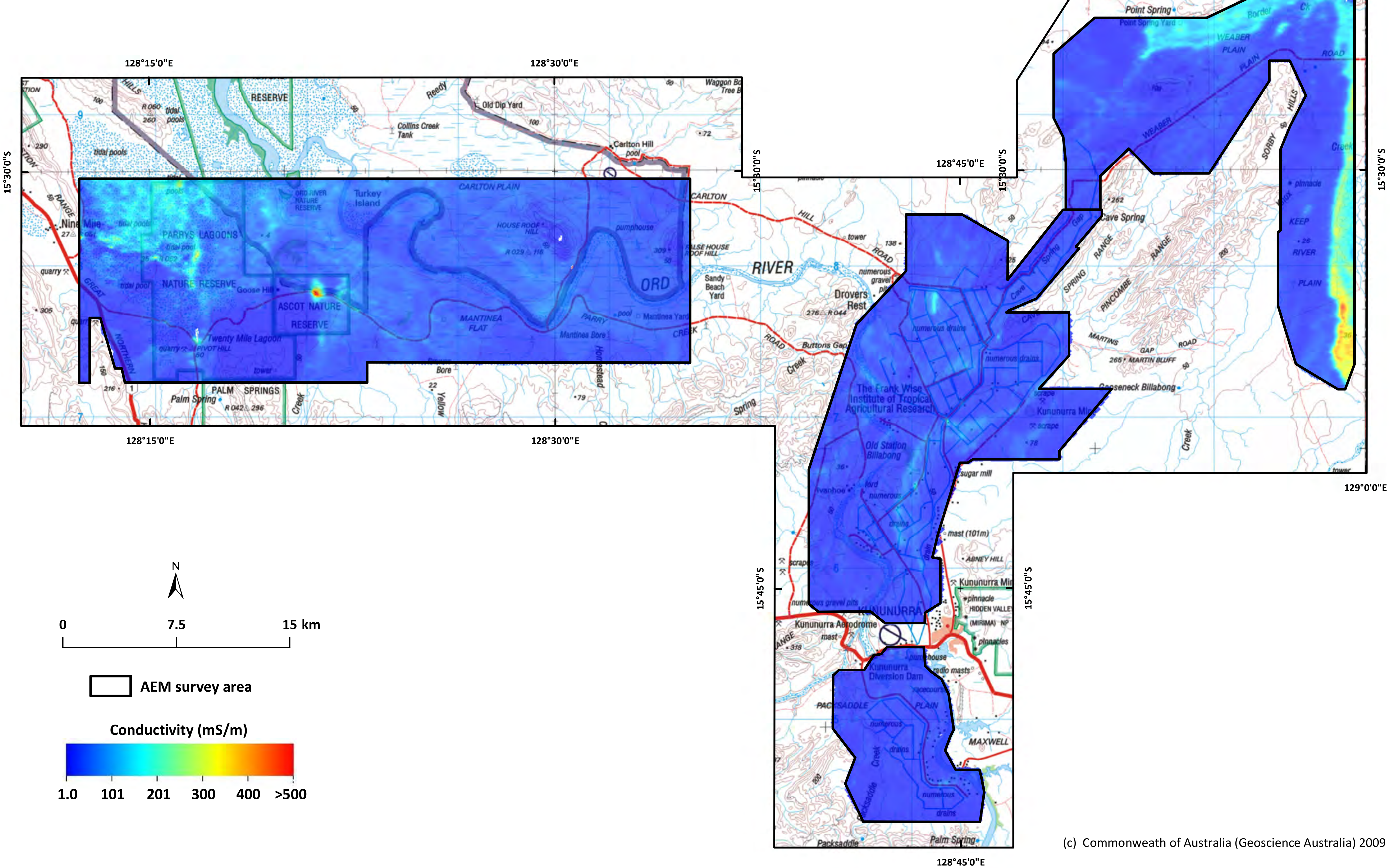


Ord Valley AEM Interpretation Project

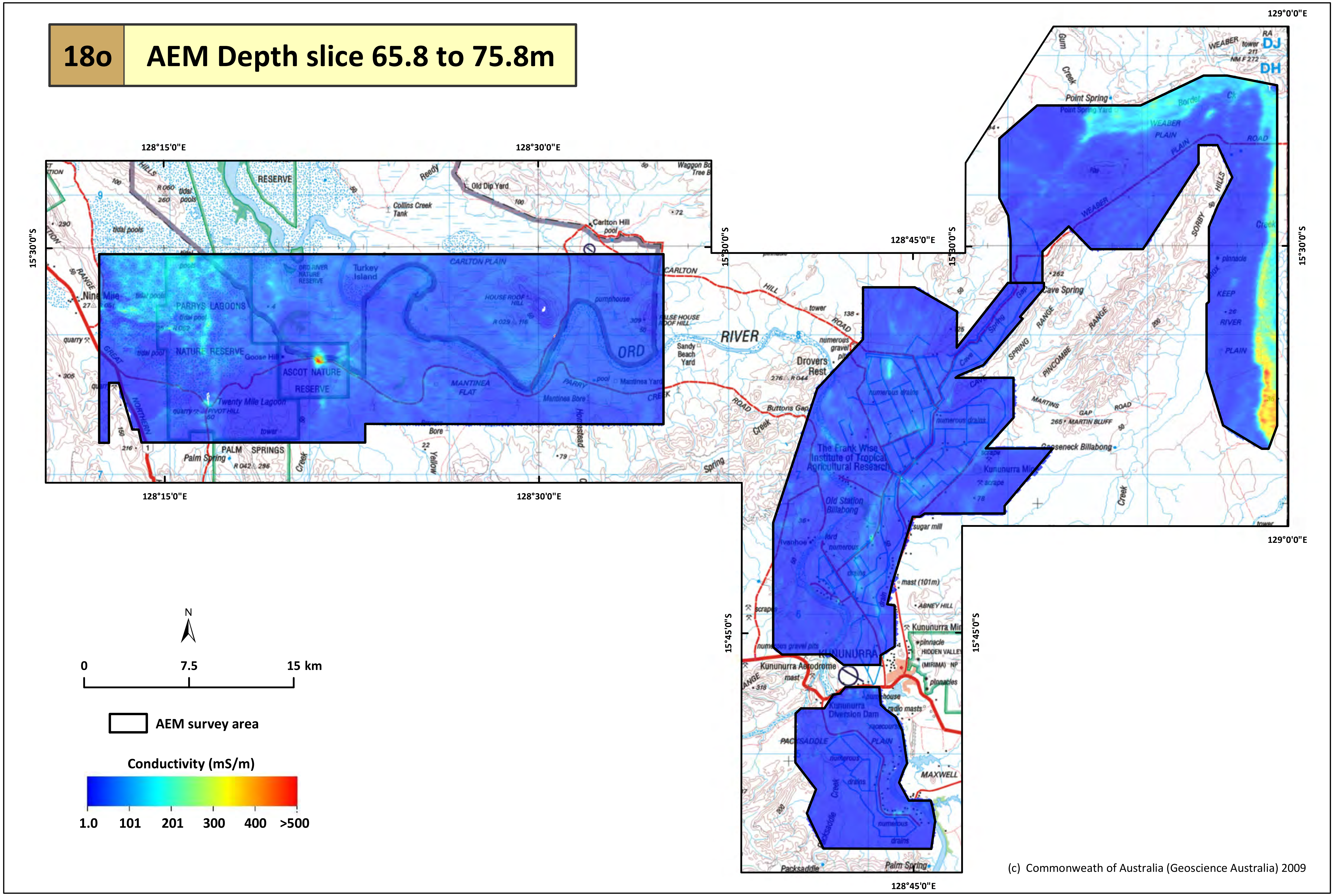


Ord Valley AEM Interpretation Project

18n AEM Depth slice 56.8 to 65.8m

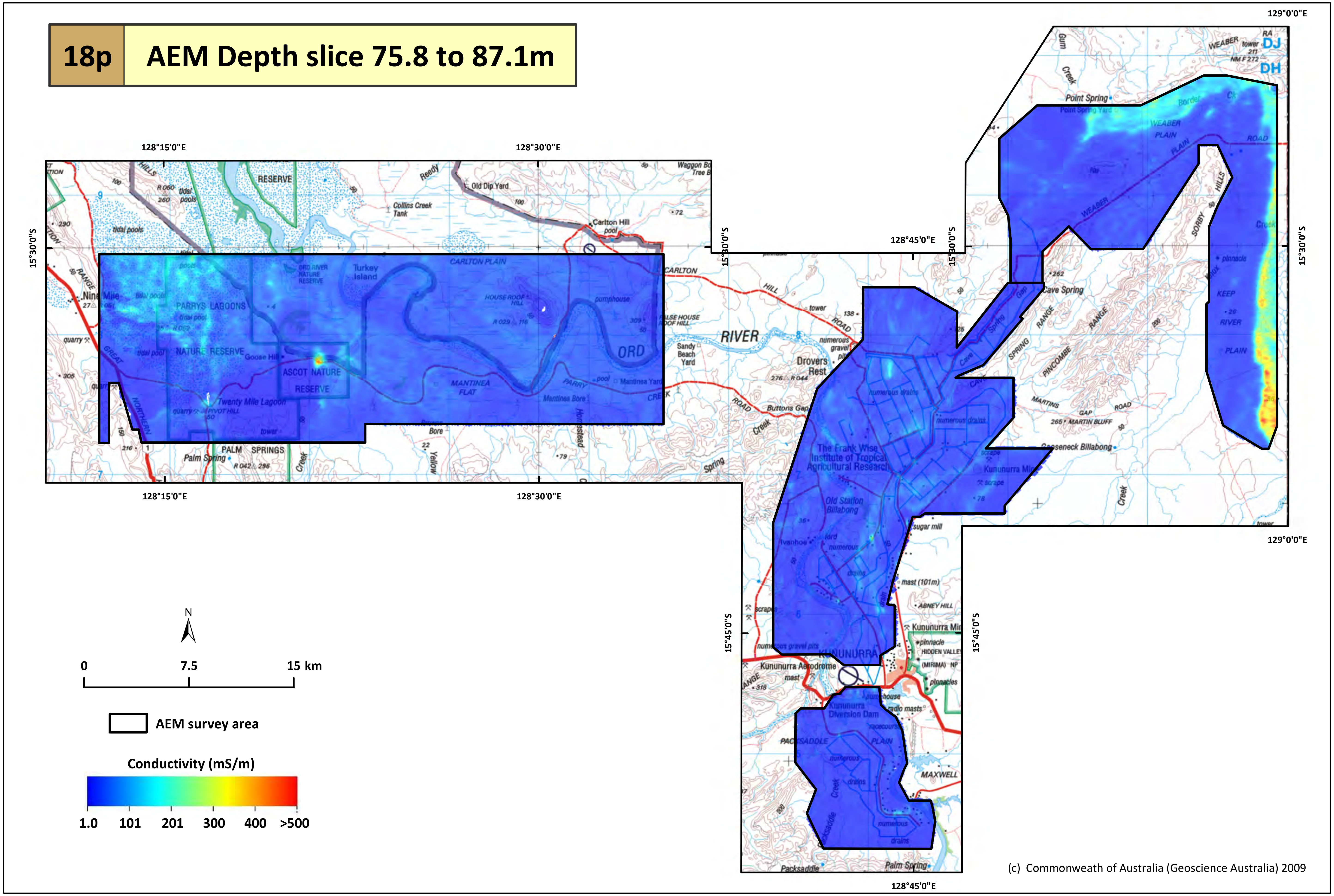


Ord Valley AEM Interpretation Project



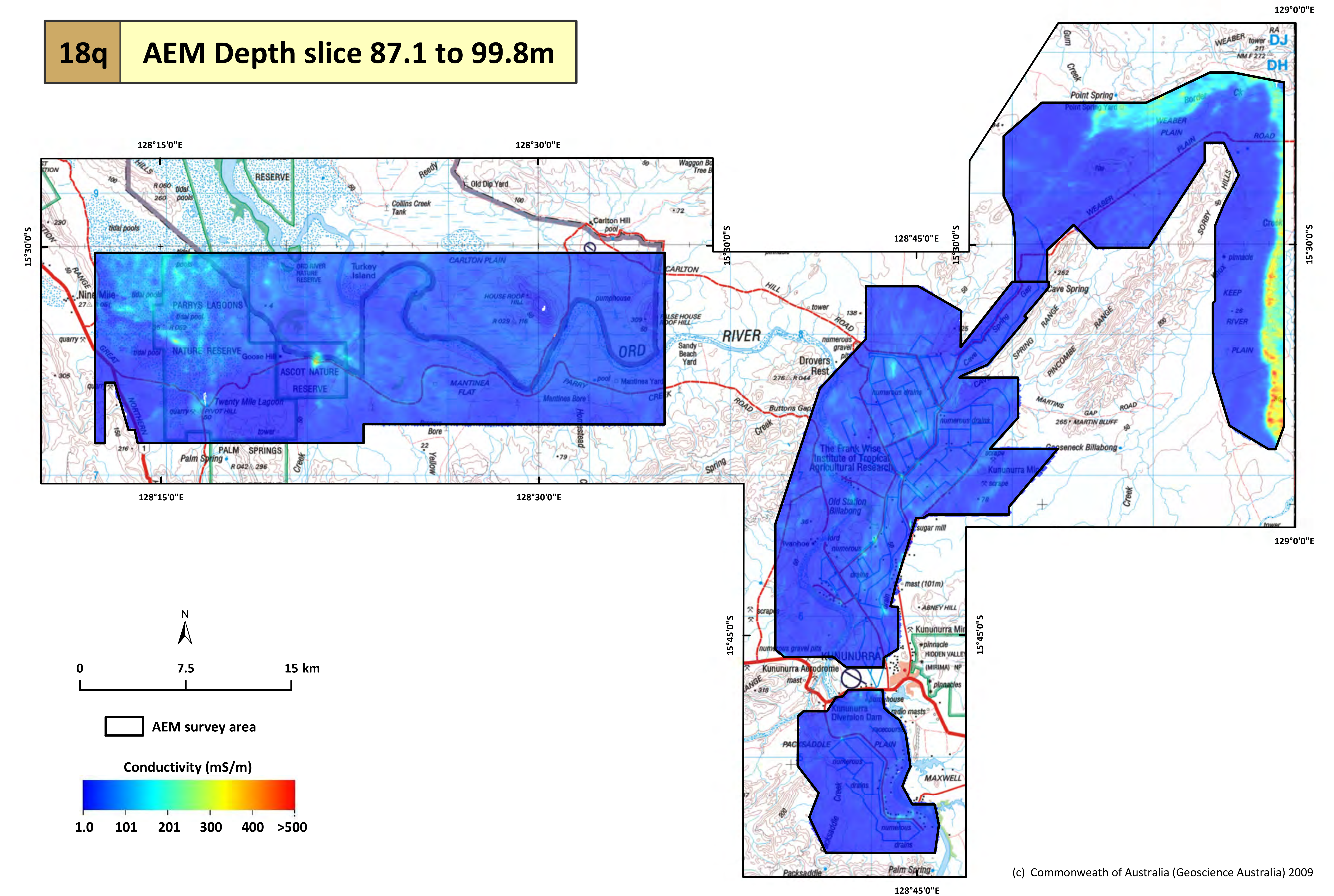
Ord Valley AEM Interpretation Project

18p AEM Depth slice 75.8 to 87.1m



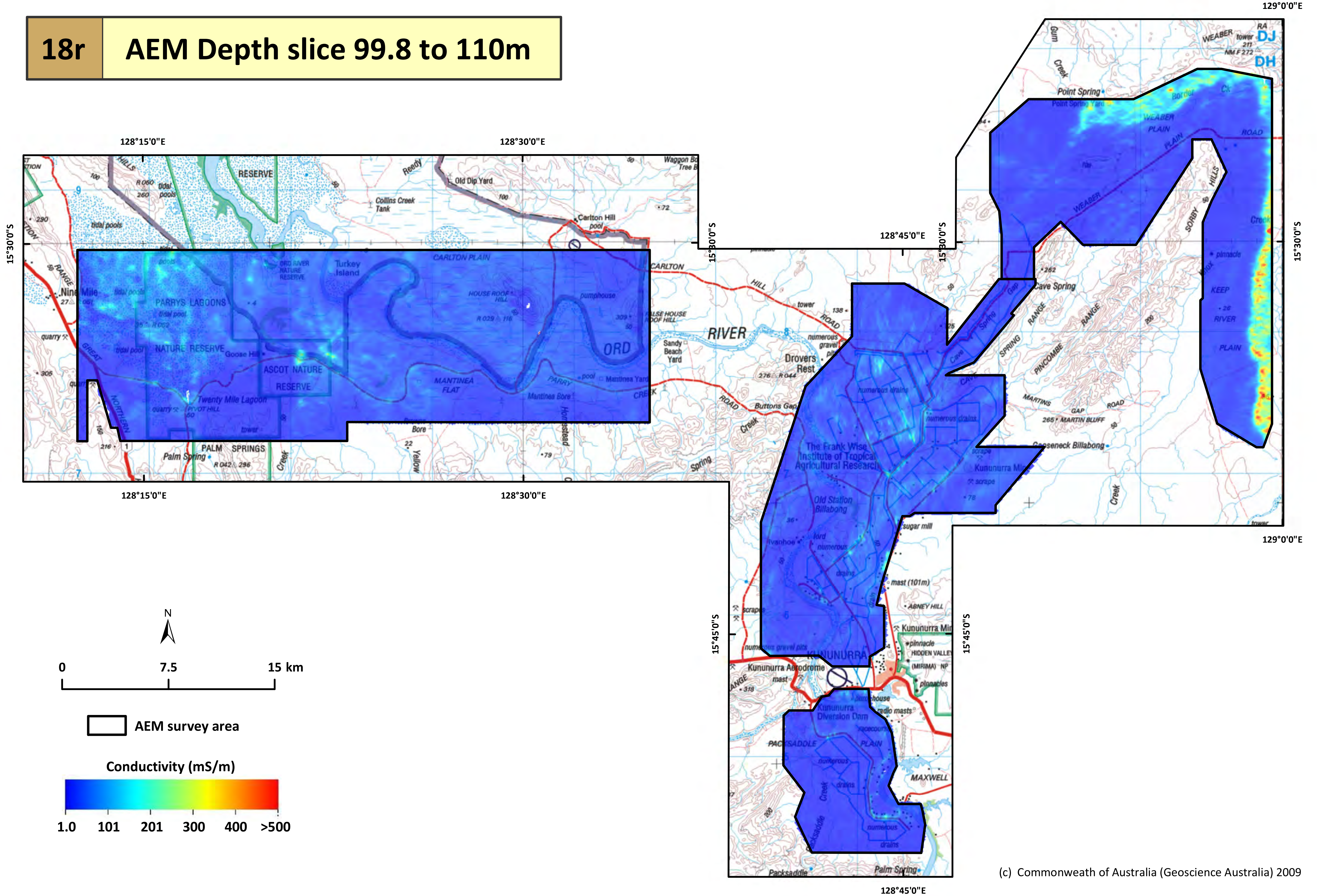
Ord Valley AEM Interpretation Project

18q AEM Depth slice 87.1 to 99.8m



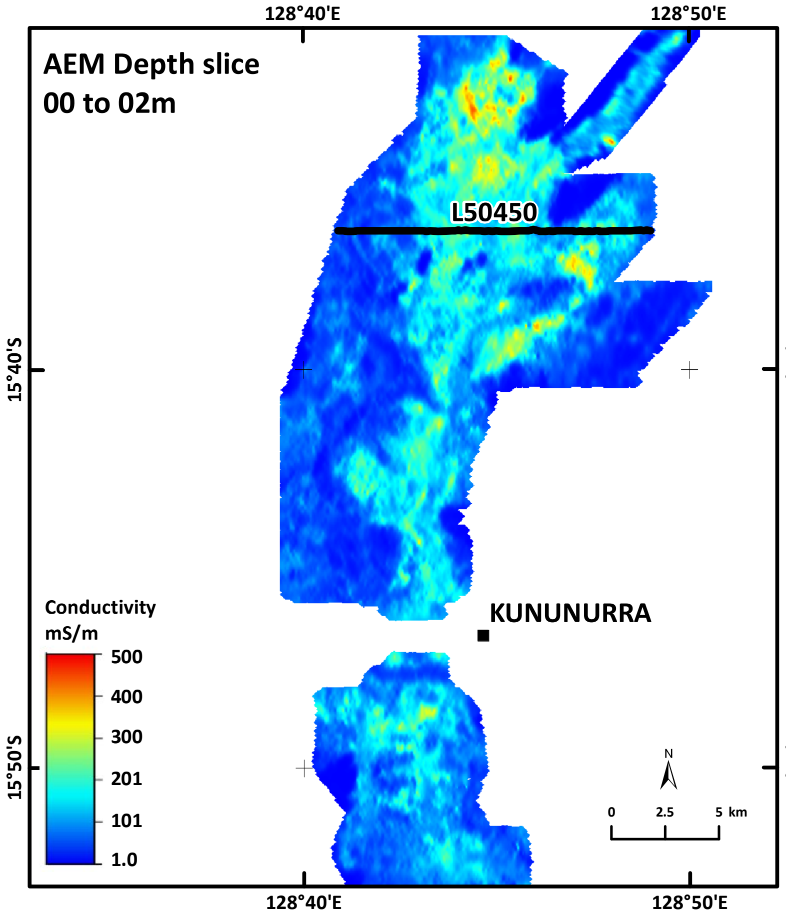
Ord Valley AEM Interpretation Project

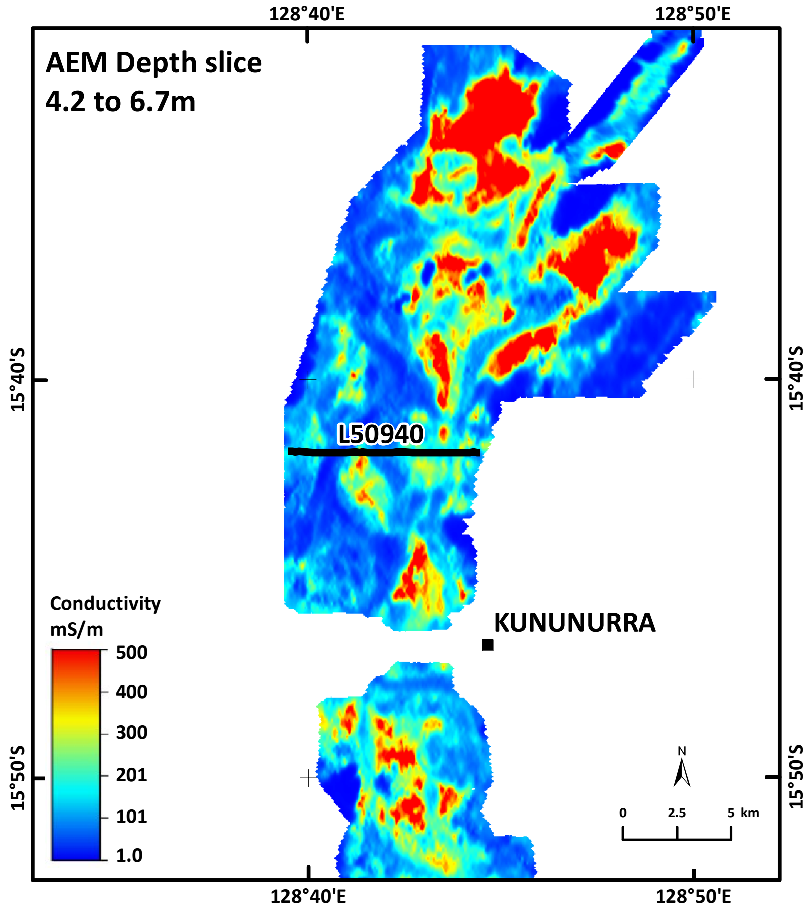
18r AEM Depth slice 99.8 to 110m

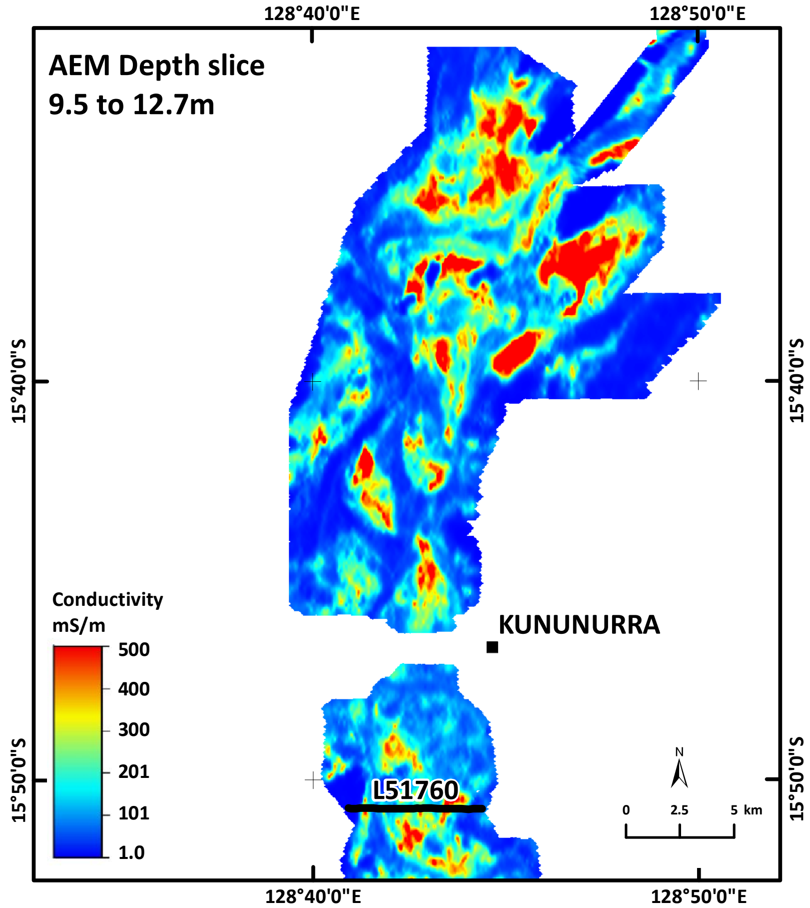


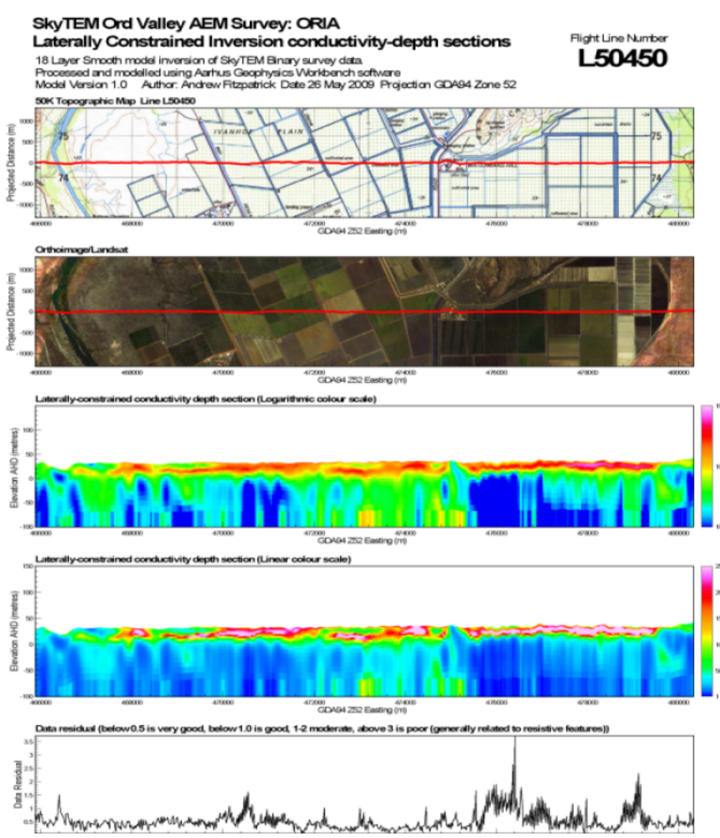
Ord Valley AEM Interpretation Project

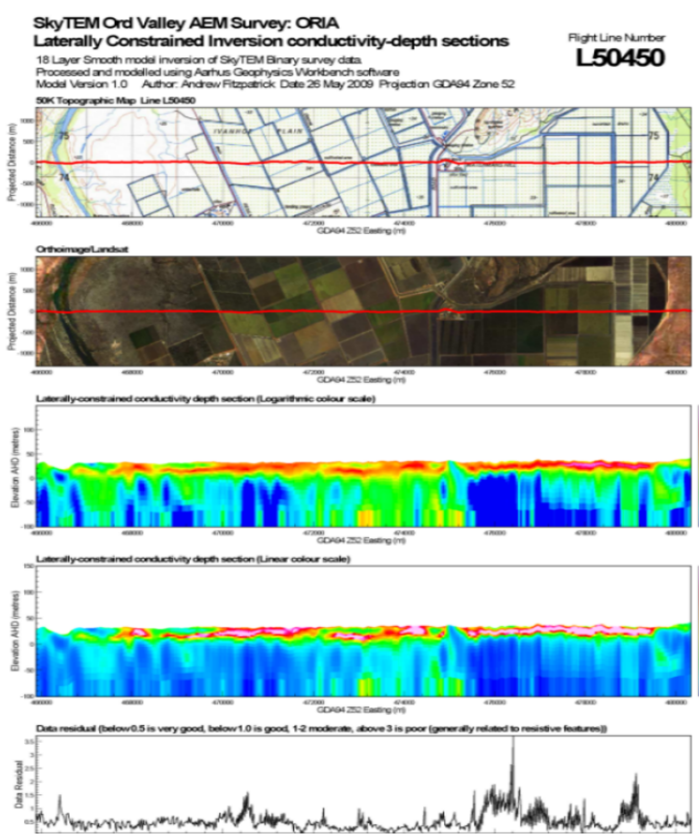
19 AEM Sections - ORIA Stage 1 & Ord West Bank

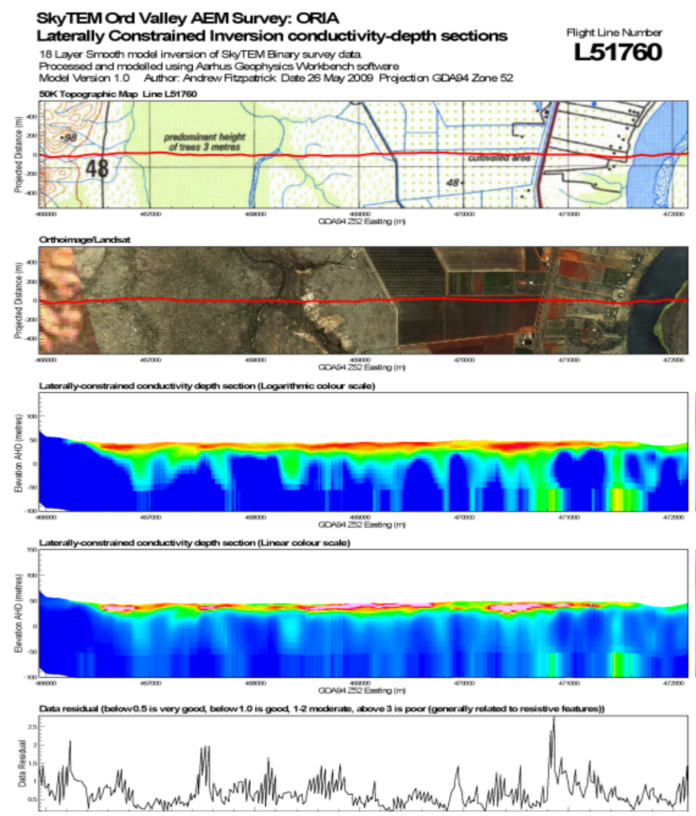






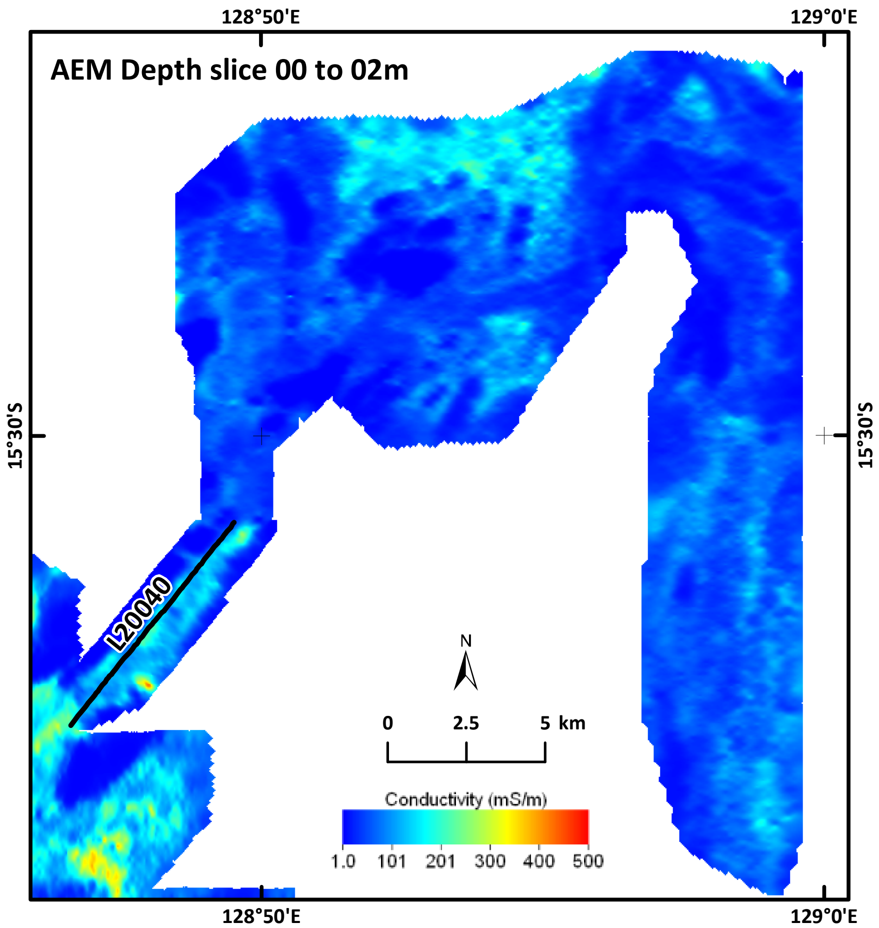


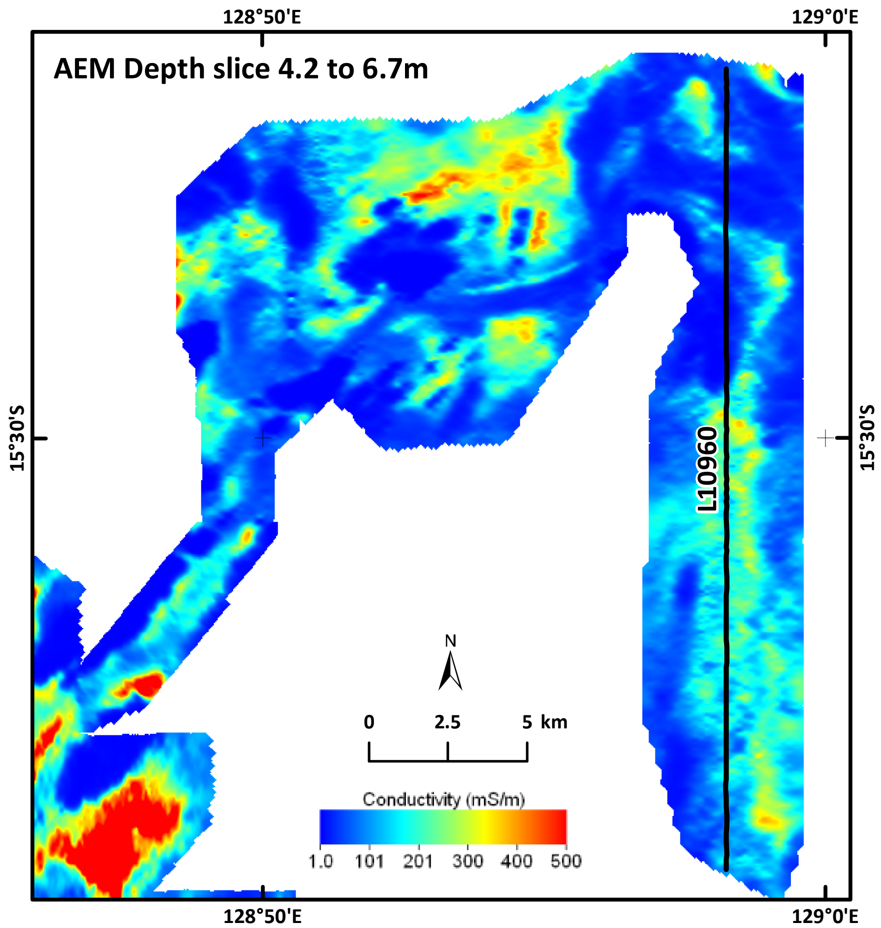


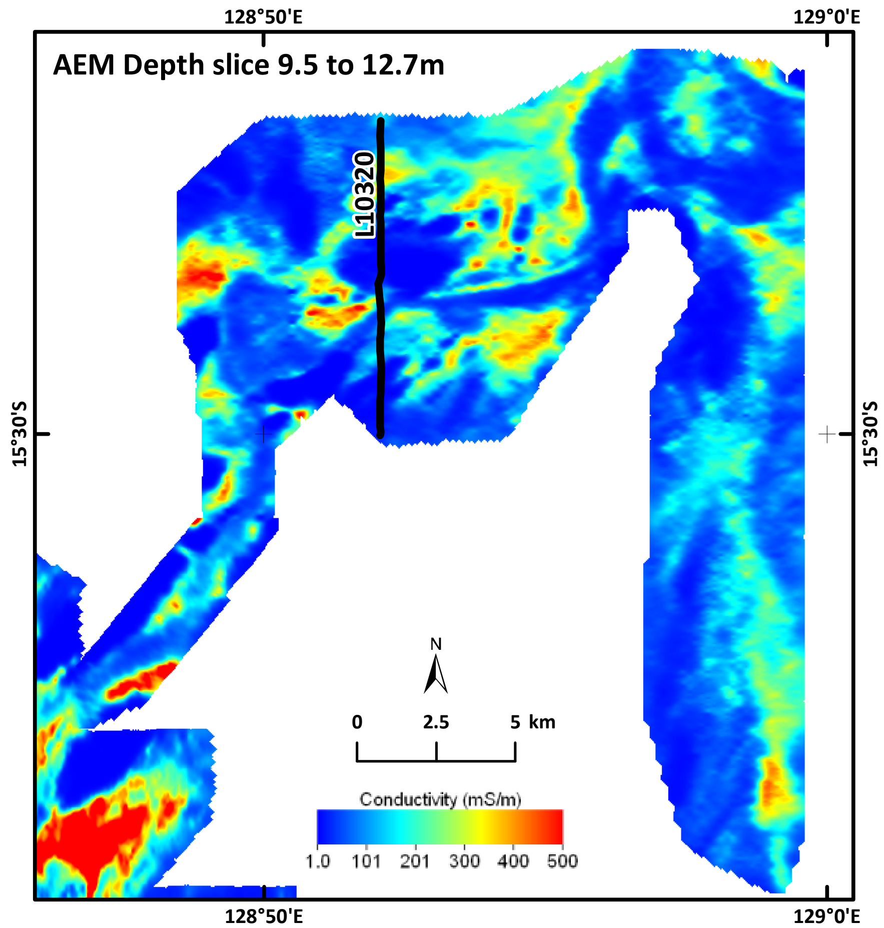


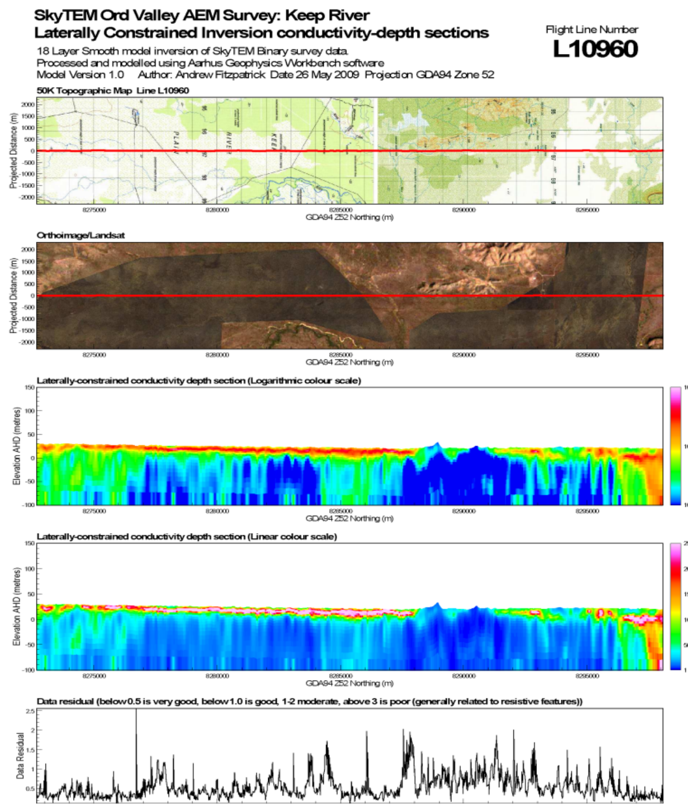
Ord Valley AEM Interpretation Project

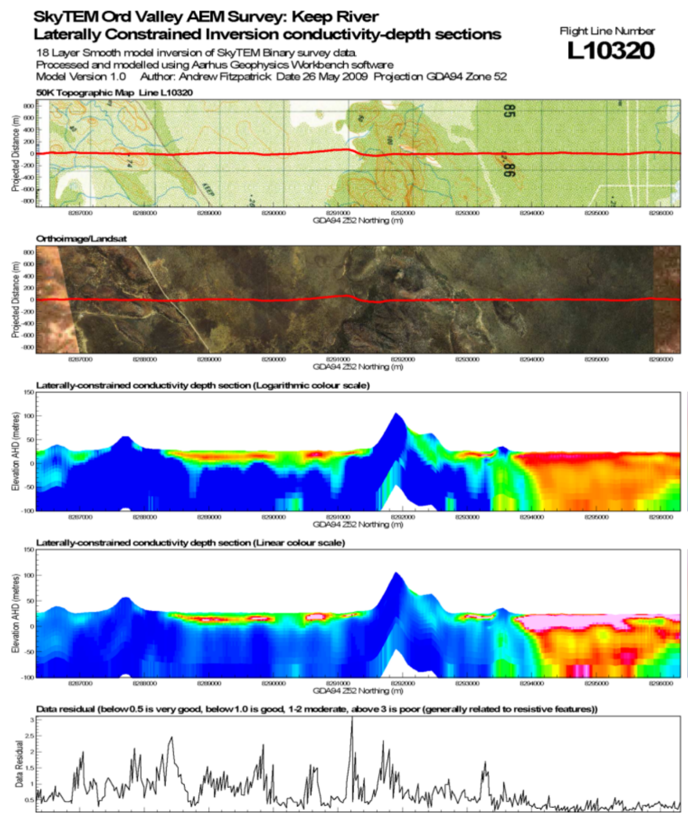
20 AEM Sections - Weaber, Knox & Keep River (WA) Plains

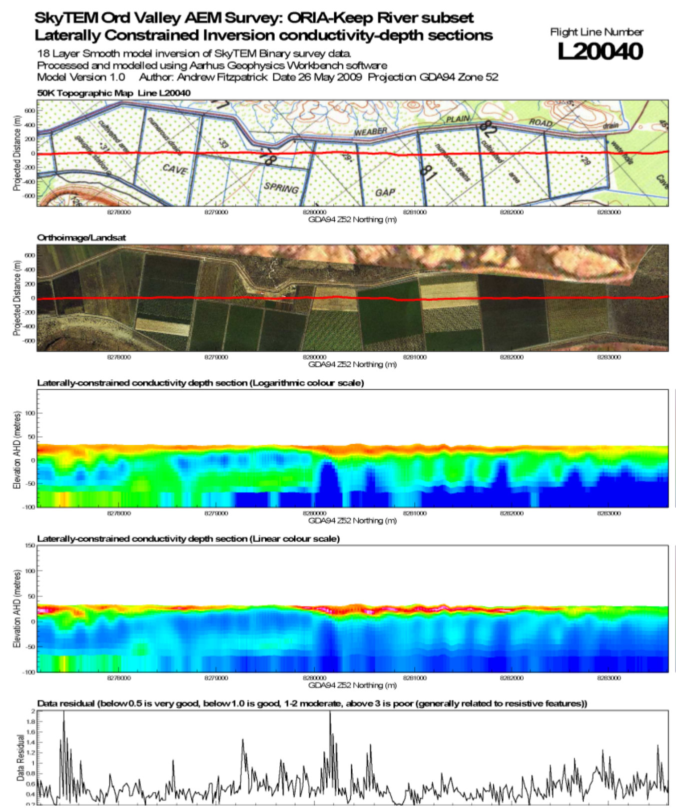






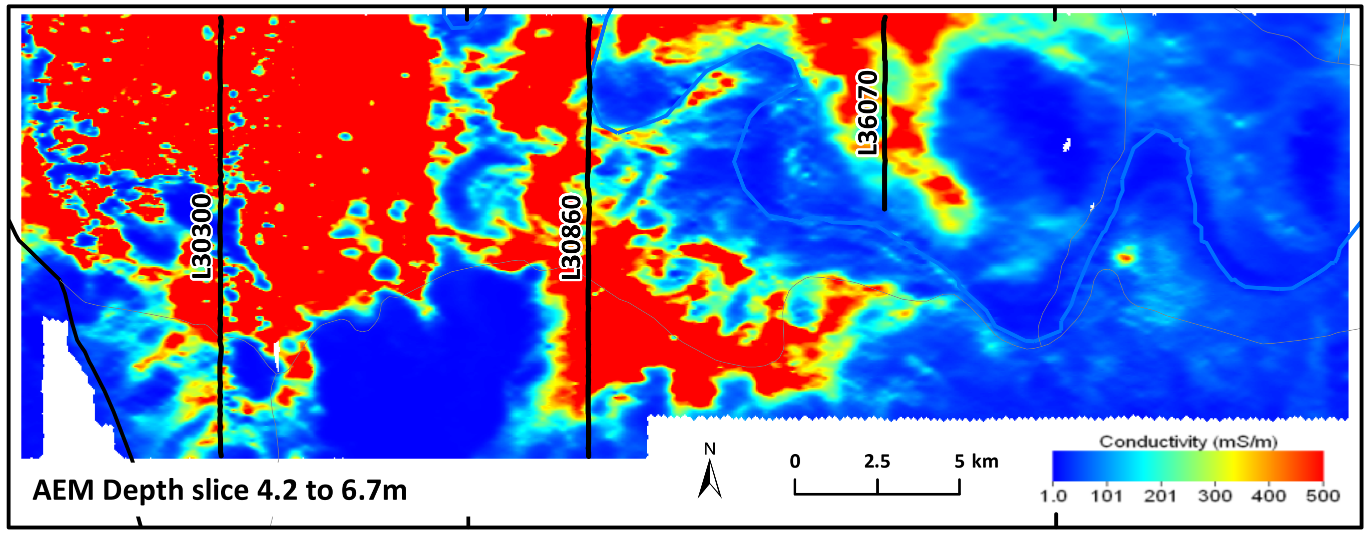


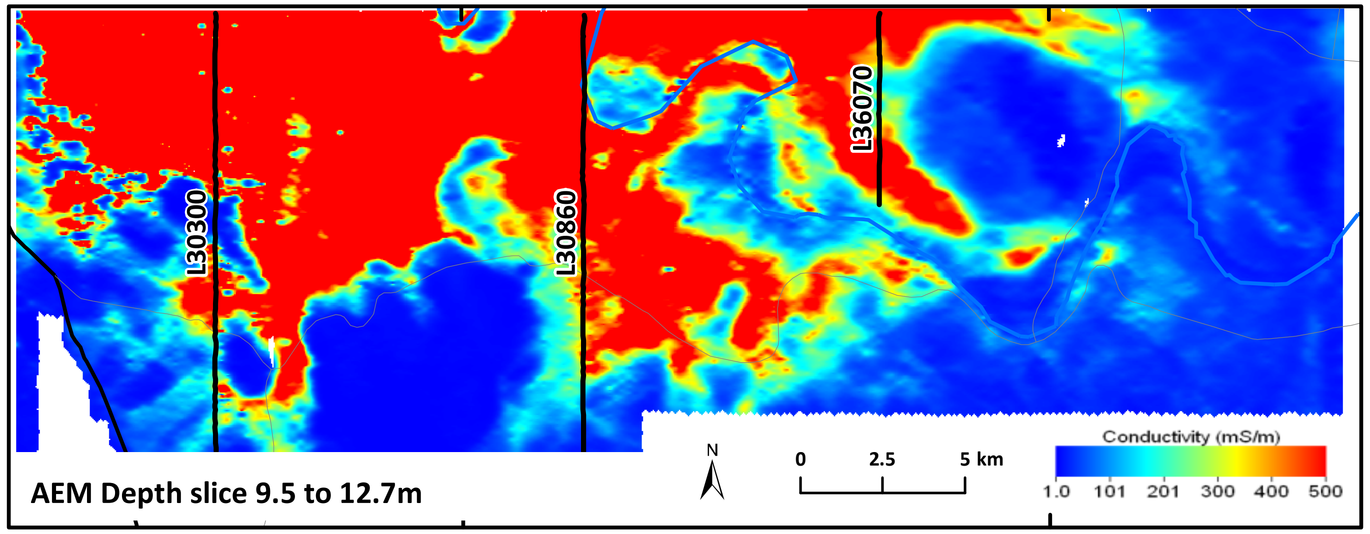


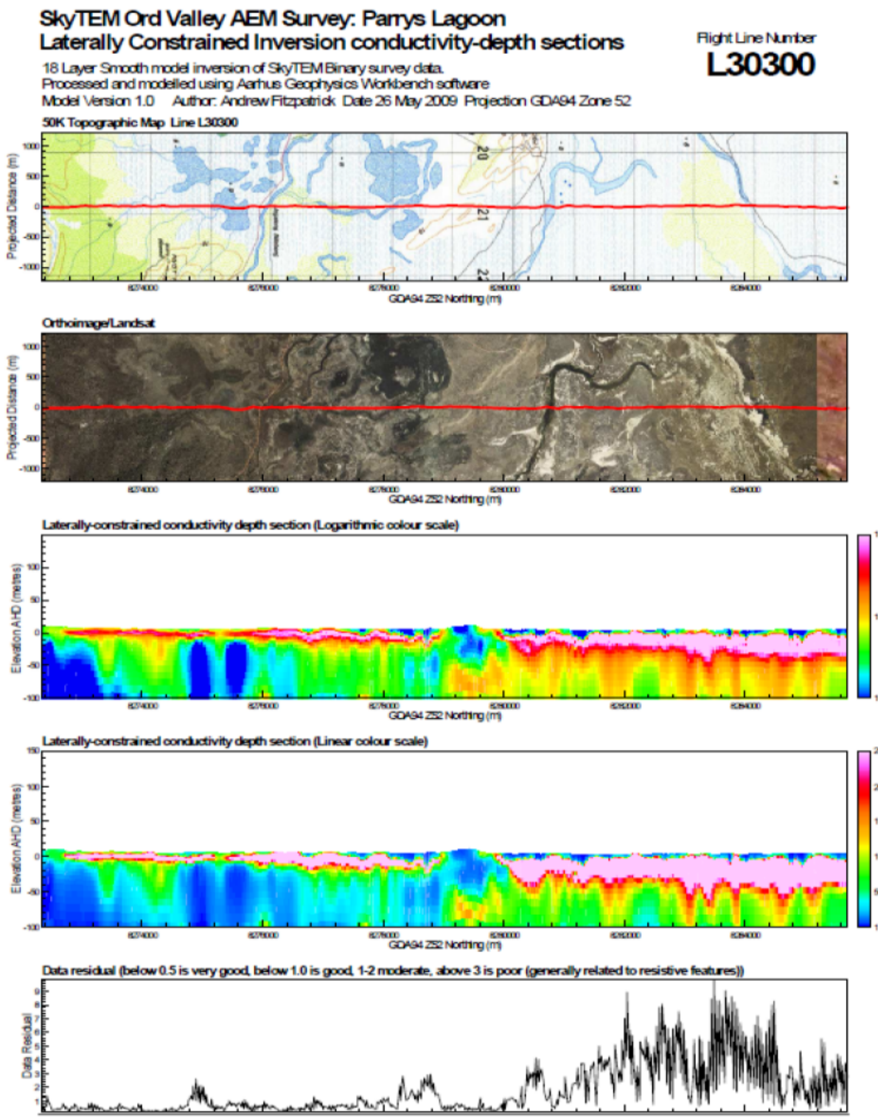


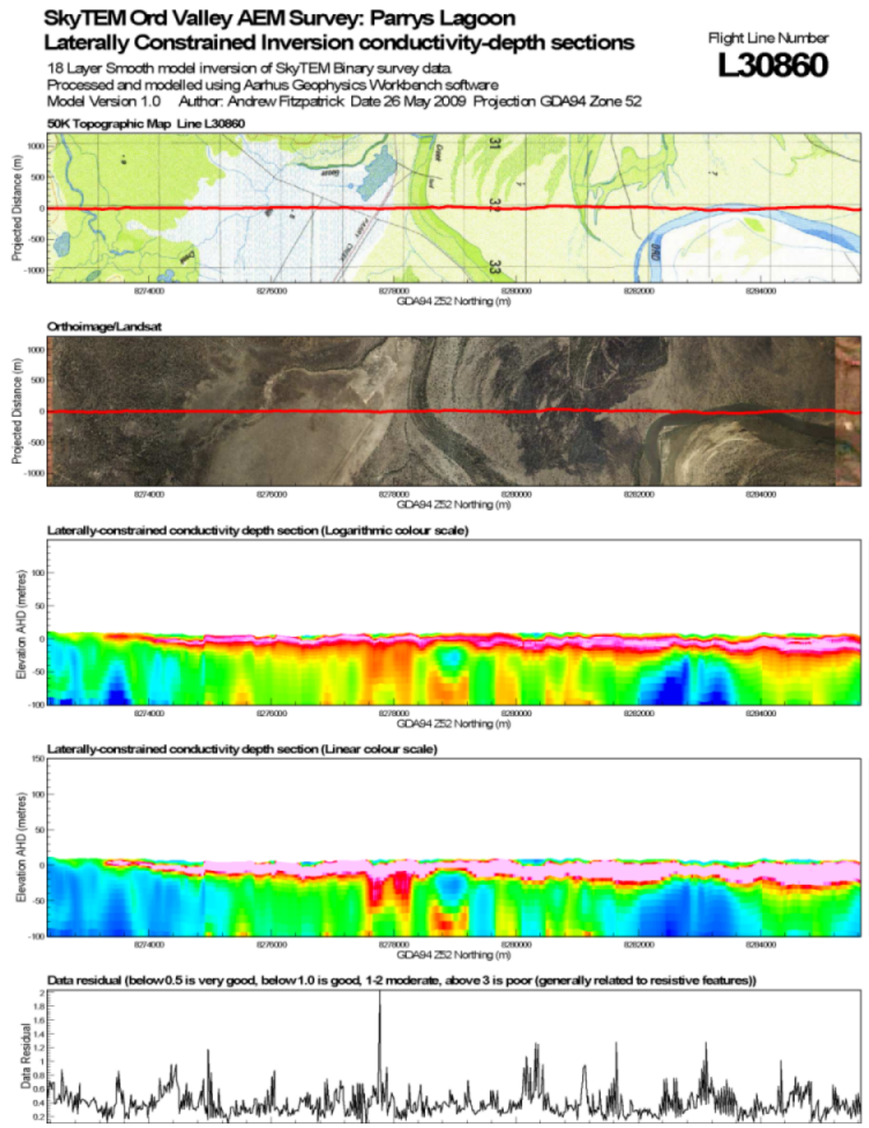
Ord Valley AEM Interpretation Project

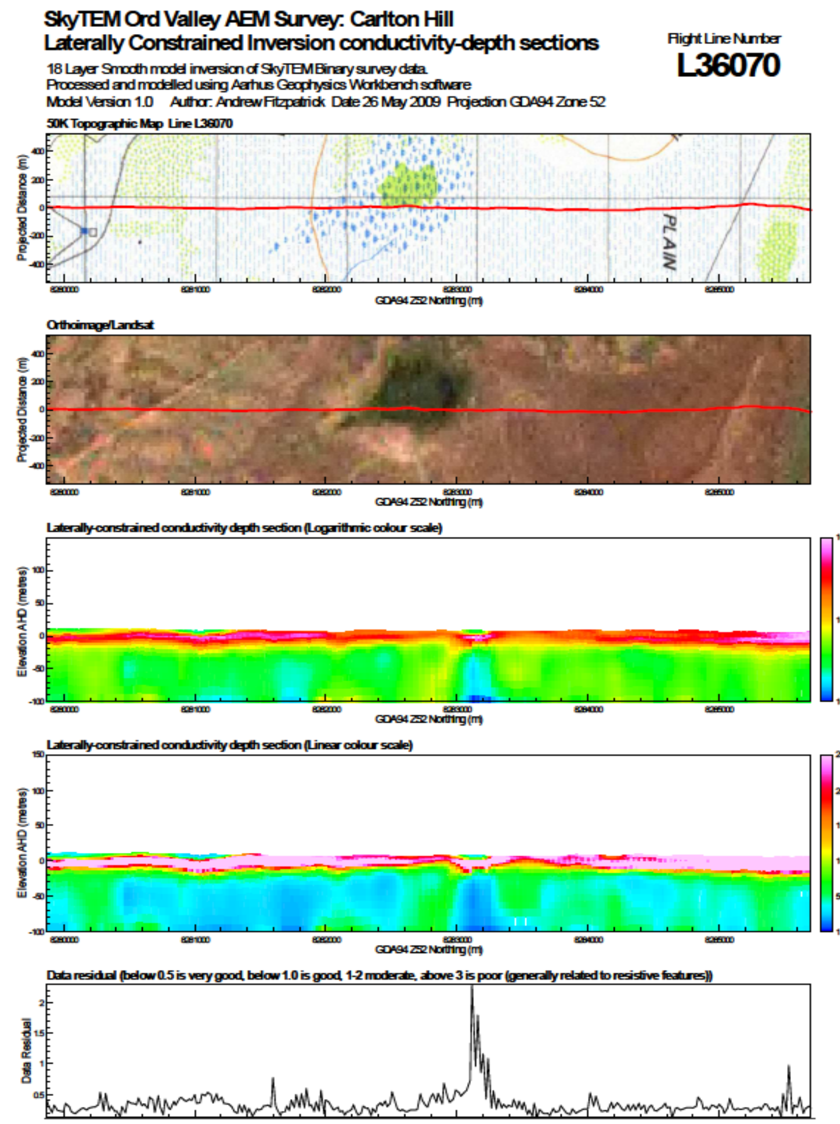
21 AEM Sections - Mantinea Plain, Carlton Hill & Parry's Lagoon



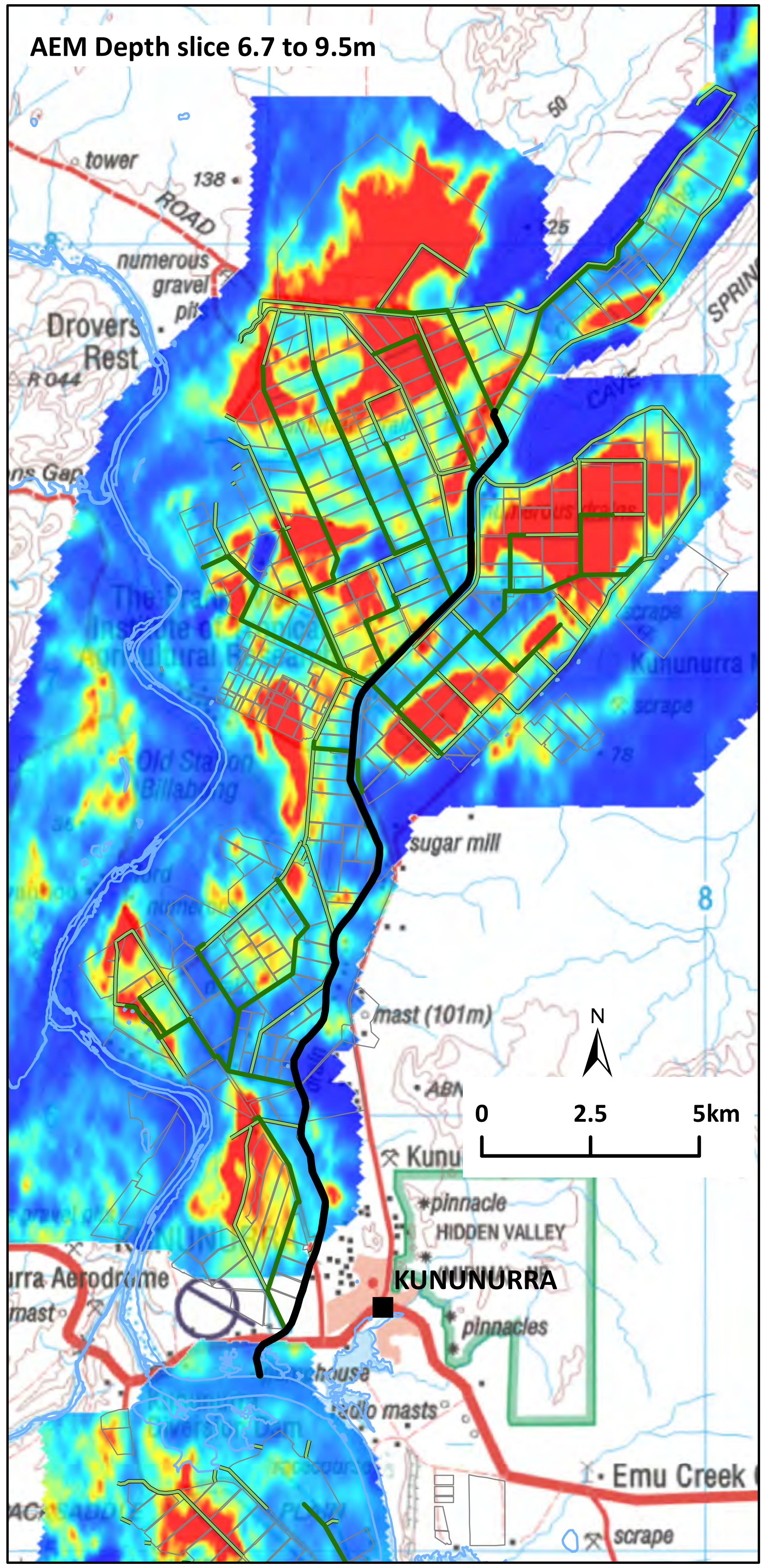


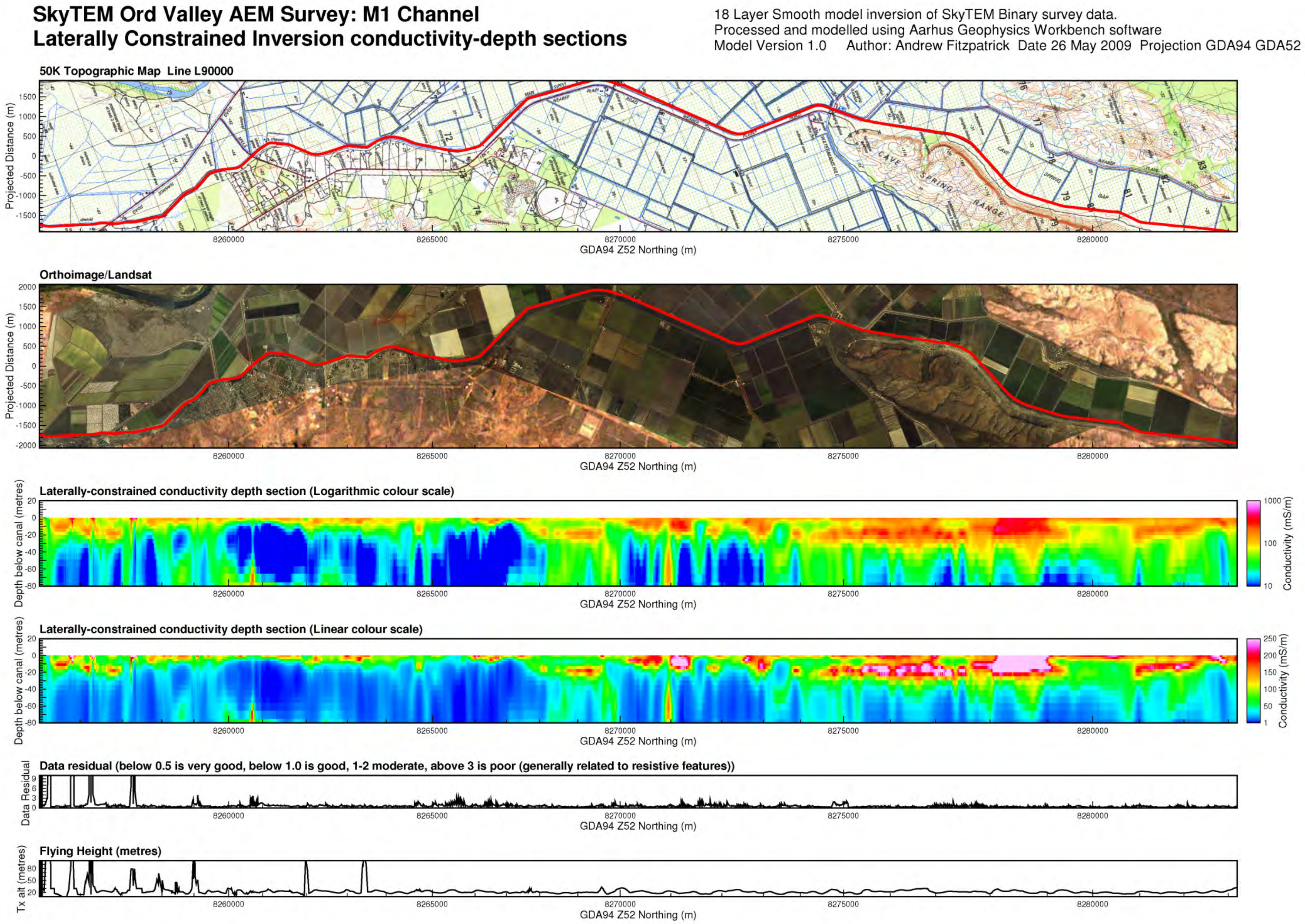






22 AEM Section - M1 Channel





Resistive (blue) zones are either due to near-surface bedrock or to loss of water from the M1 supply channel. These resistive zones are currently being assessed.

Conductivity (mS/m)

1.0 101 201 300 400 500

M1 Main Supply Channel

Supply Channels

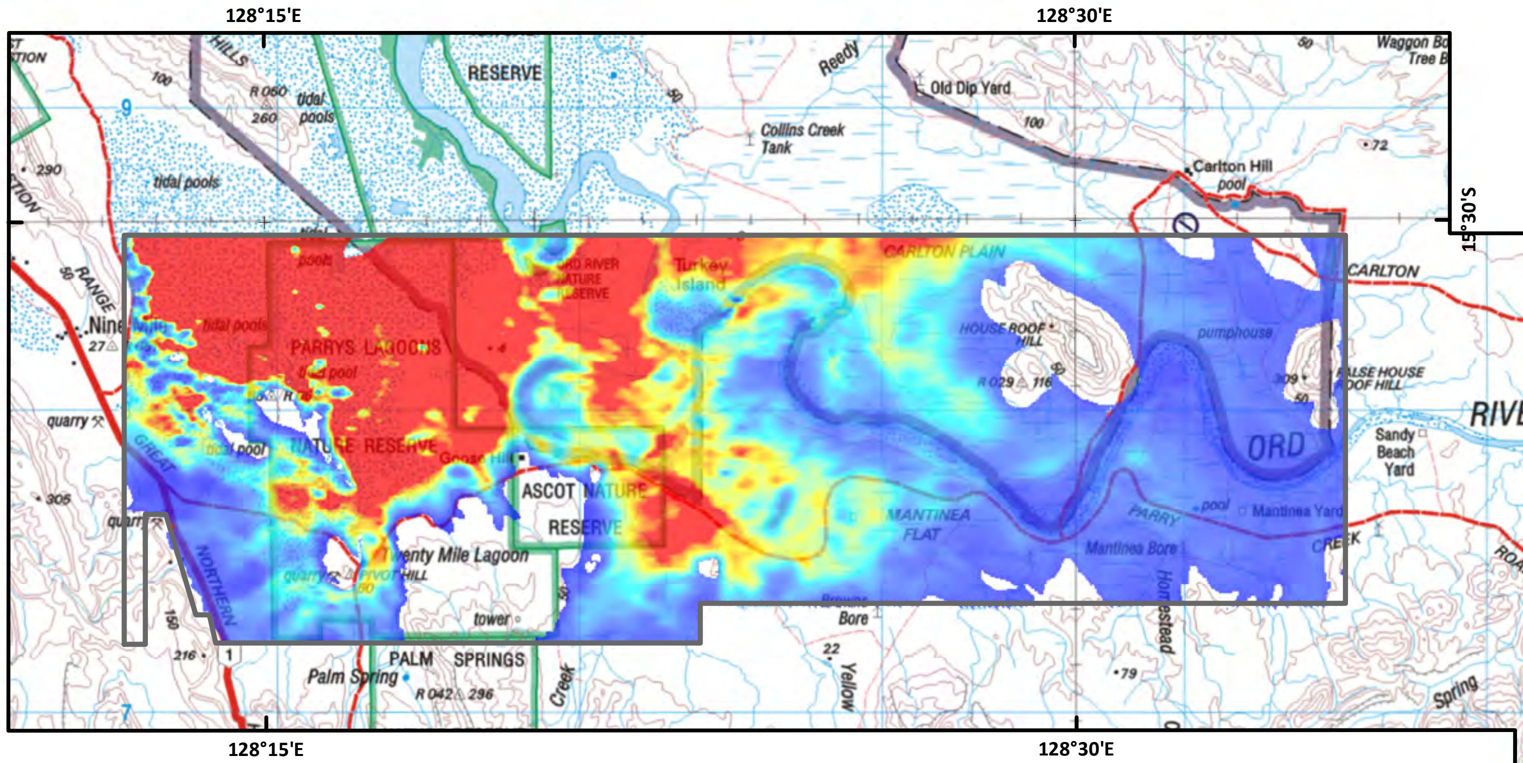
Surface Drains

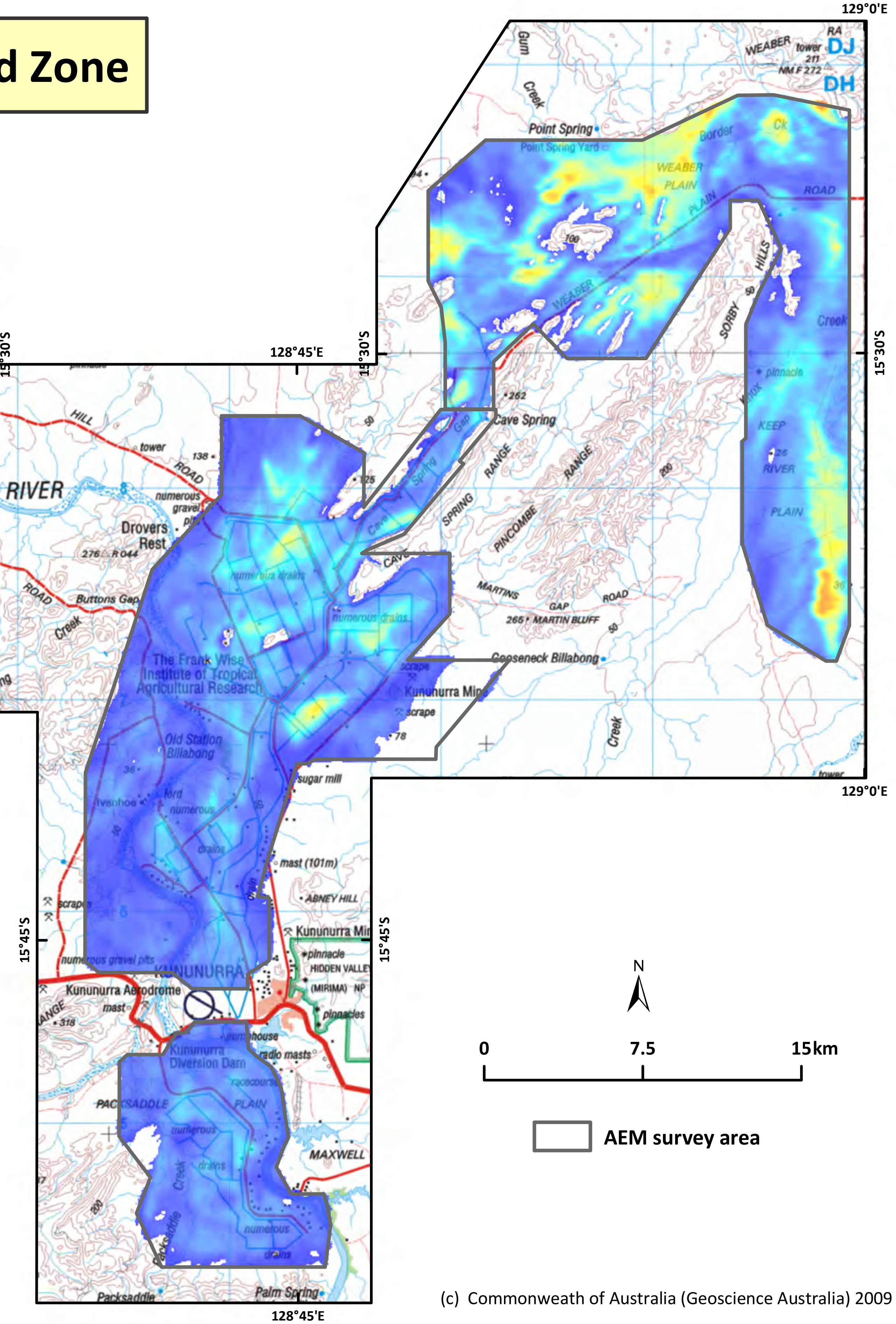
Ord River

Irrigated Areas

Ord Valley AEM Interpretation Project

23 Average Ground Conductivity - Unsaturated Zone





CONDUCTIVITY ABOVE WATERTABLE

The electrical conductivity for the unsaturated zone - from the ground surface to the static watertable.

The depth to watertable data was converted to Reduction Static Water Levels (RSWL) or elevations relative to Australian Height Datum (AHD). The RSWL data was gridded using a minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped and identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to watertable. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

Conductivity (mS/m)

>500
400
300
201
101
1.0

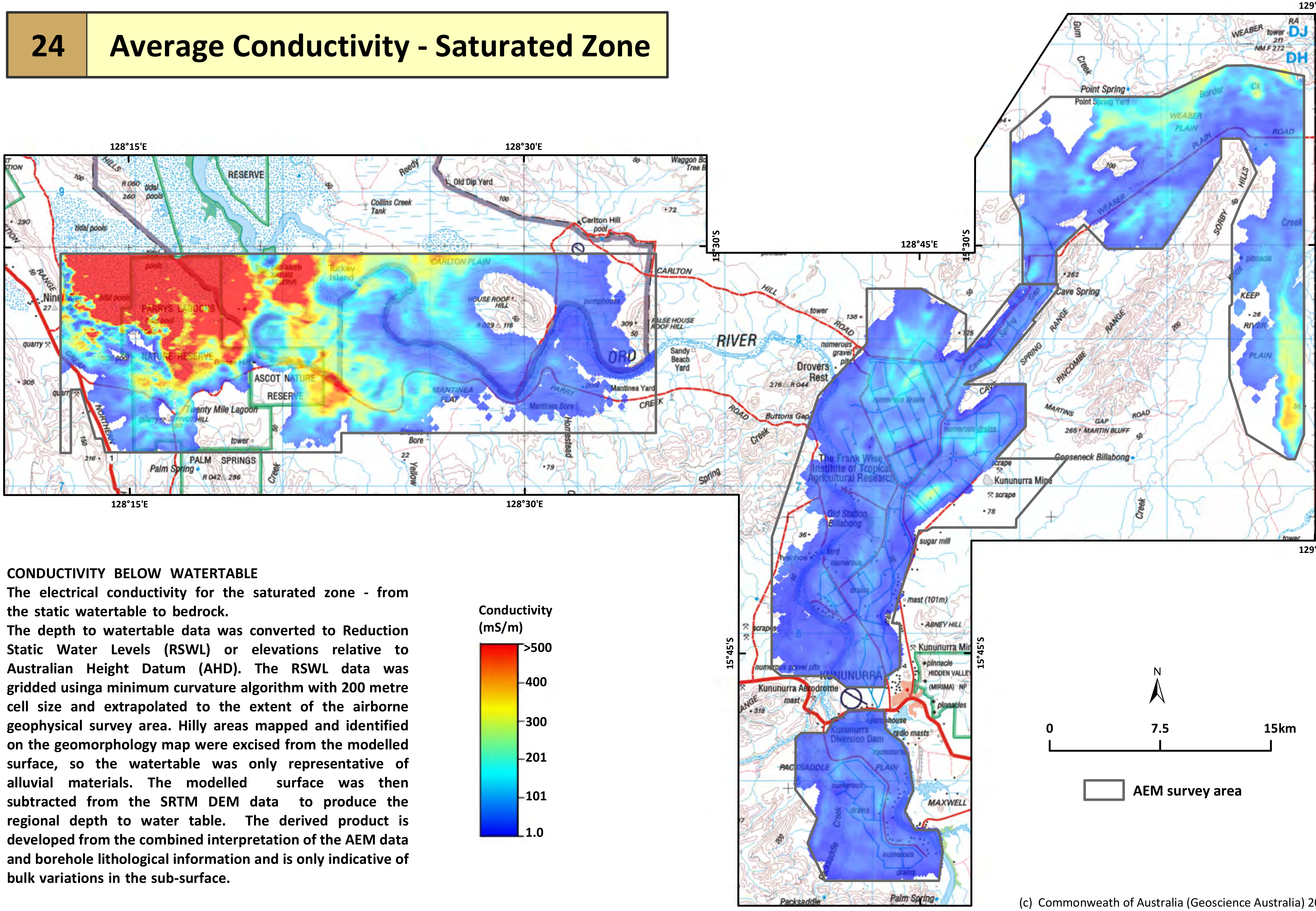
N

0 7.5 15km

AEM survey area

Ord Valley AEM Interpretation Project

24 Average Conductivity - Saturated Zone



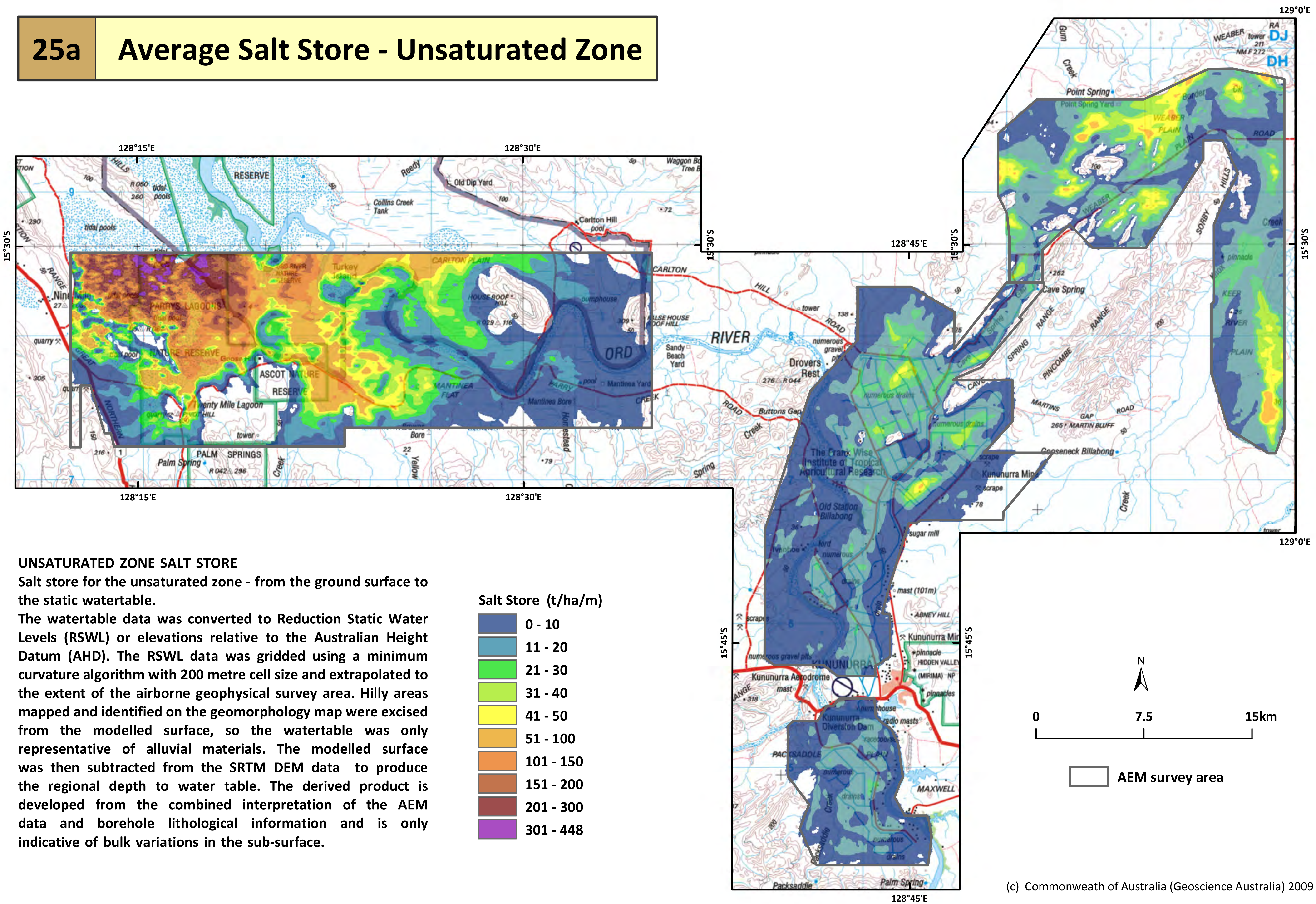
CONDUCTIVITY BELOW WATERTABLE

The electrical conductivity for the saturated zone - from the static watertable to bedrock.

The depth to watertable data was converted to Reduction Static Water Levels (RSWL) or elevations relative to Australian Height Datum (AHD). The RSWL data was gridded usinga minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped and identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to water table. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

Ord Valley AEM Interpretation Project

25a Average Salt Store - Unsaturated Zone

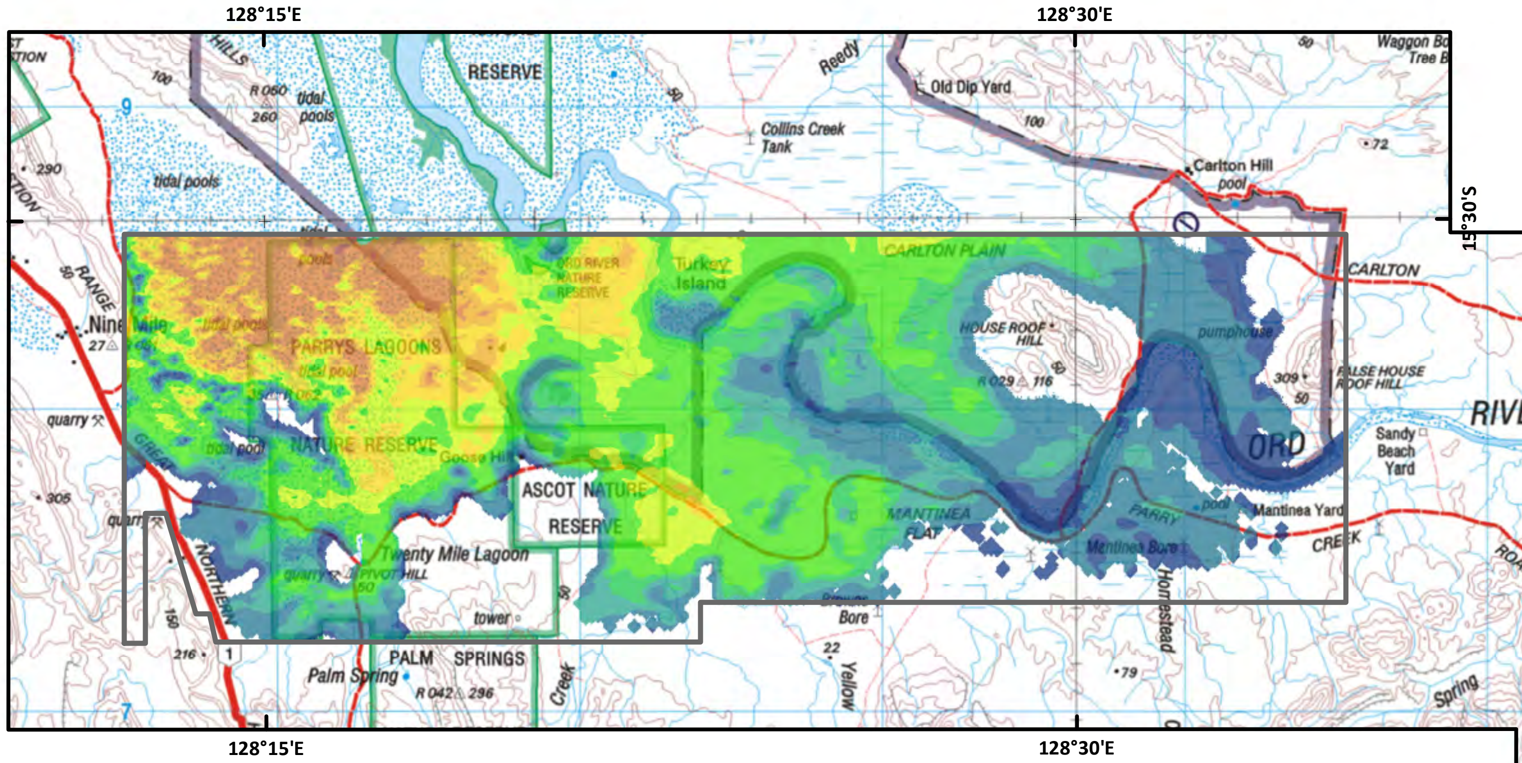


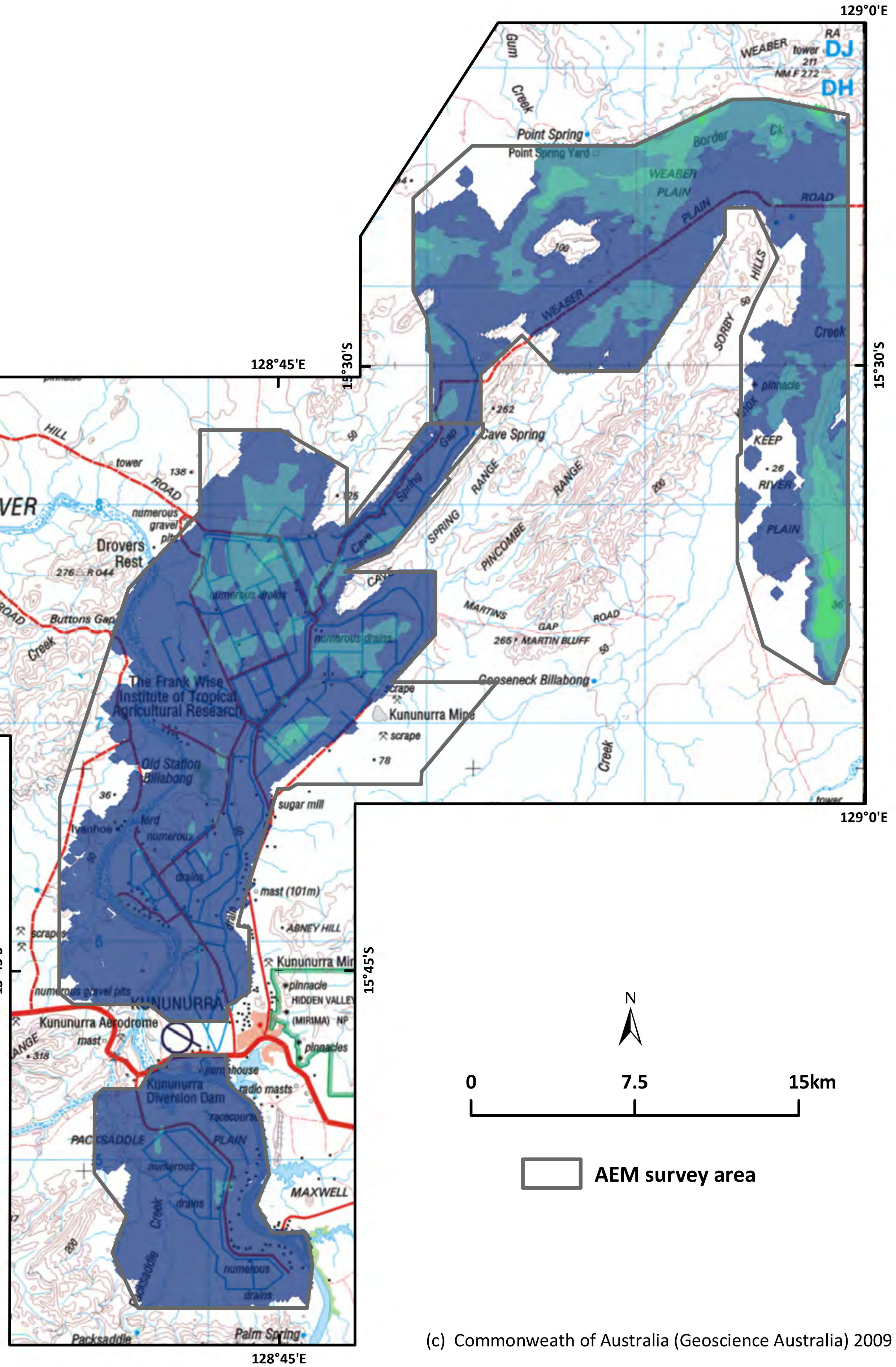
UNSATURATED ZONE SALT STORE

Salt store for the unsaturated zone - from the ground surface to the static watertable.

The watertable data was converted to Reduction Static Water Levels (RSWL) or elevations relative to the Australian Height Datum (AHD). The RSWL data was gridded using a minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped and identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to water table. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

25b Average Salt Store - Saturated Zone





SATURATED ZONE SALT STORE

Salt store for the saturated zone - from the static watertable to bedrock.

The watertable data was converted to Reduction Static Water Levels (RSWL) or elevations relative to Australian Height Datum (AHD). The RSWL data was gridded using a minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped and identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to water table. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

Salt Store (t/ha/m)

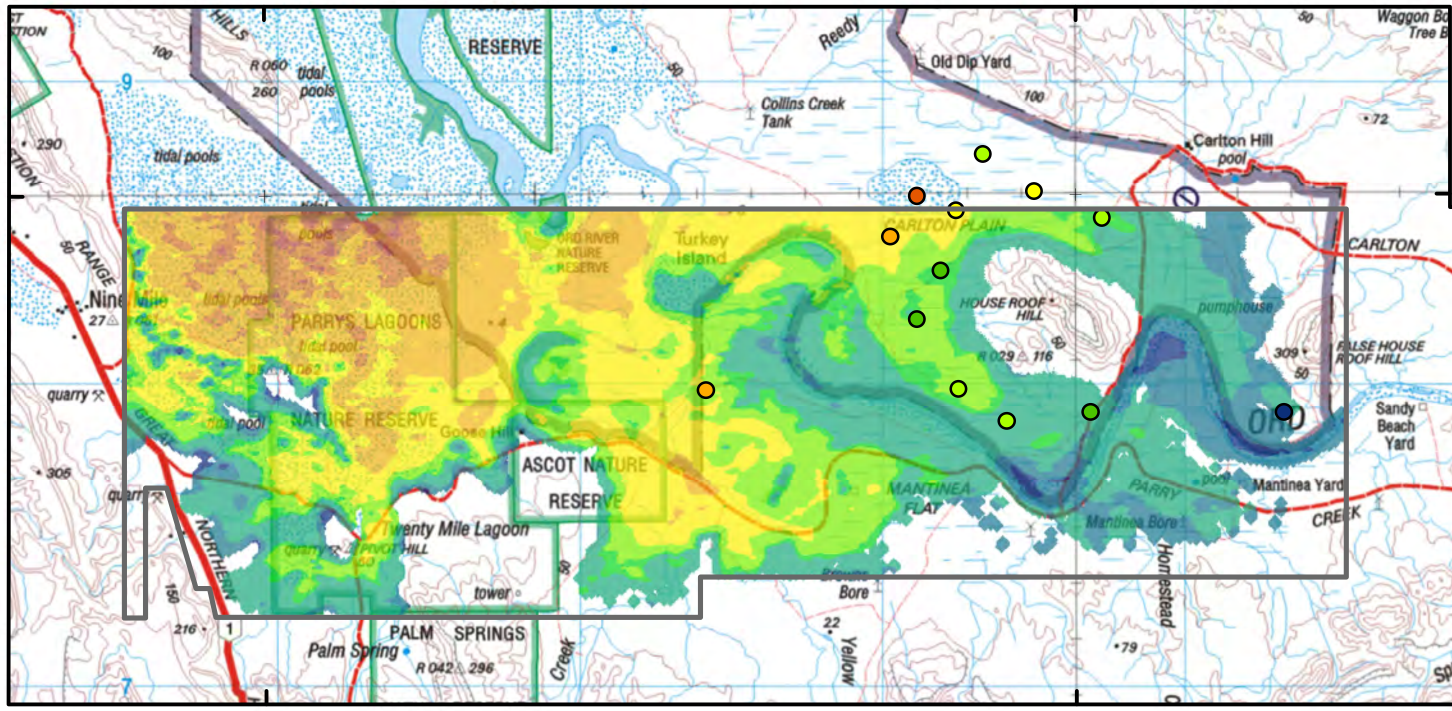
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 200
- 201 - 251

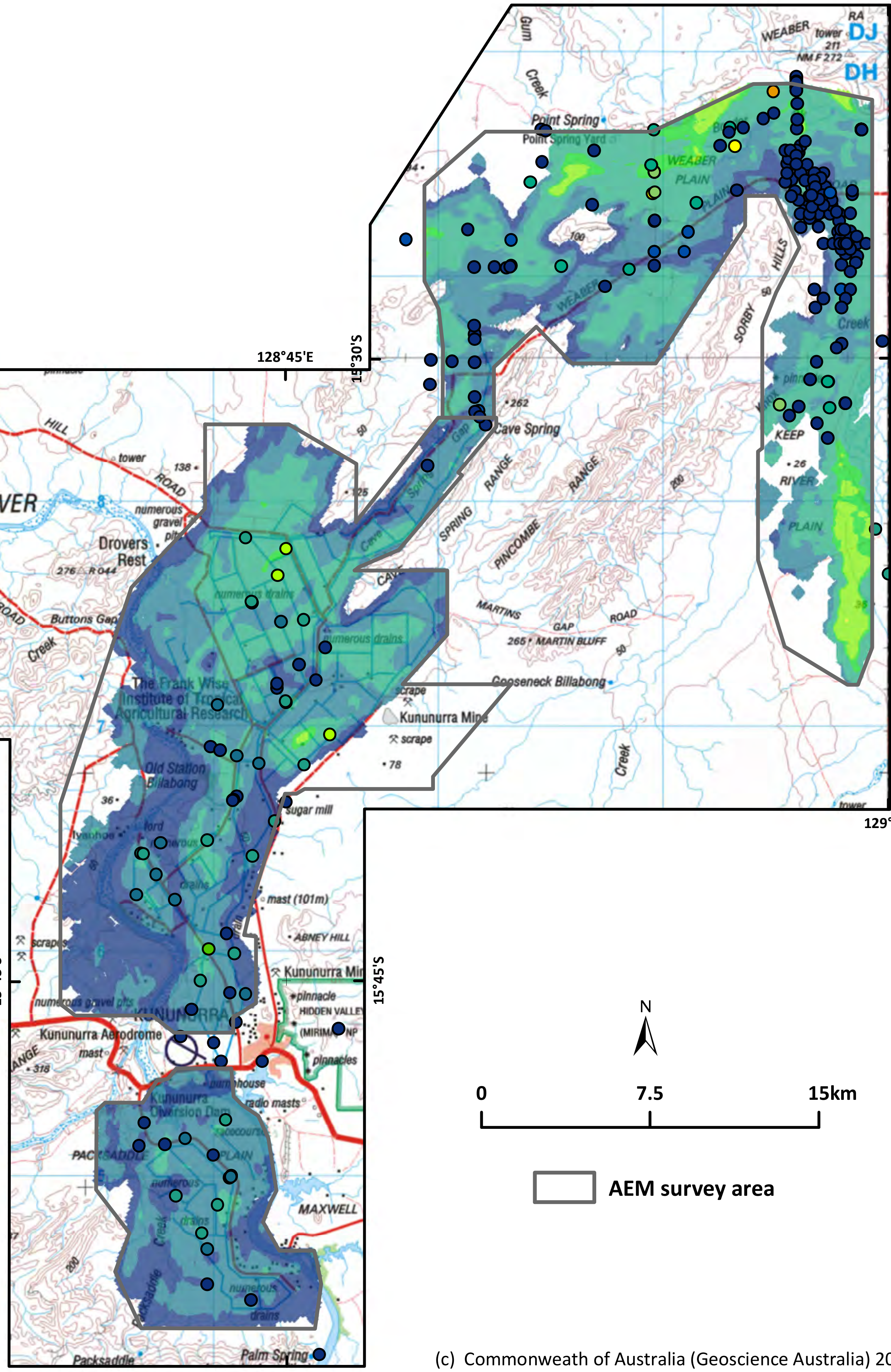
N

0 7.5 15km

AEM survey area

26 Average Groundwater Salinity





GROUNDWATER SALINITY

Groundwater Salinity - Total Dissolved Solids (TDS) (mg/l) in the saturated zone (SWL to bedrock). The watertable data was converted to Reduction Static Water Levels (RSWL) or elevations relative to Australian Height Datum (AHD). The RSWL data was gridded using a minimum curvature algorithm with 200 metre cell size and extrapolated to the extent of the airborne geophysical survey area. Hilly areas mapped and identified on the geomorphology map were excised from the modelled surface, so the watertable was only representative of alluvial materials. The modelled surface was then subtracted from the SRTM DEM data to produce the regional depth to watertable. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

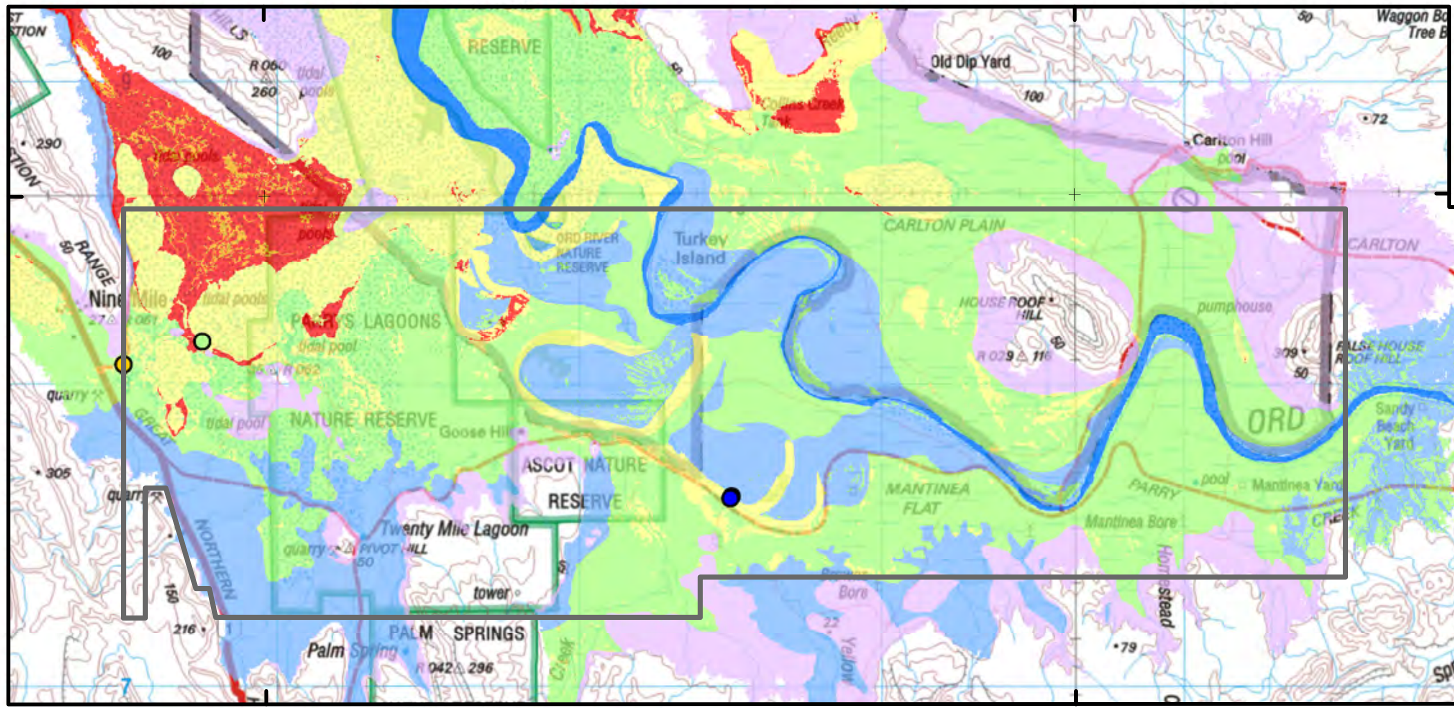
Groundwater Salinity -TDS (mg/L)

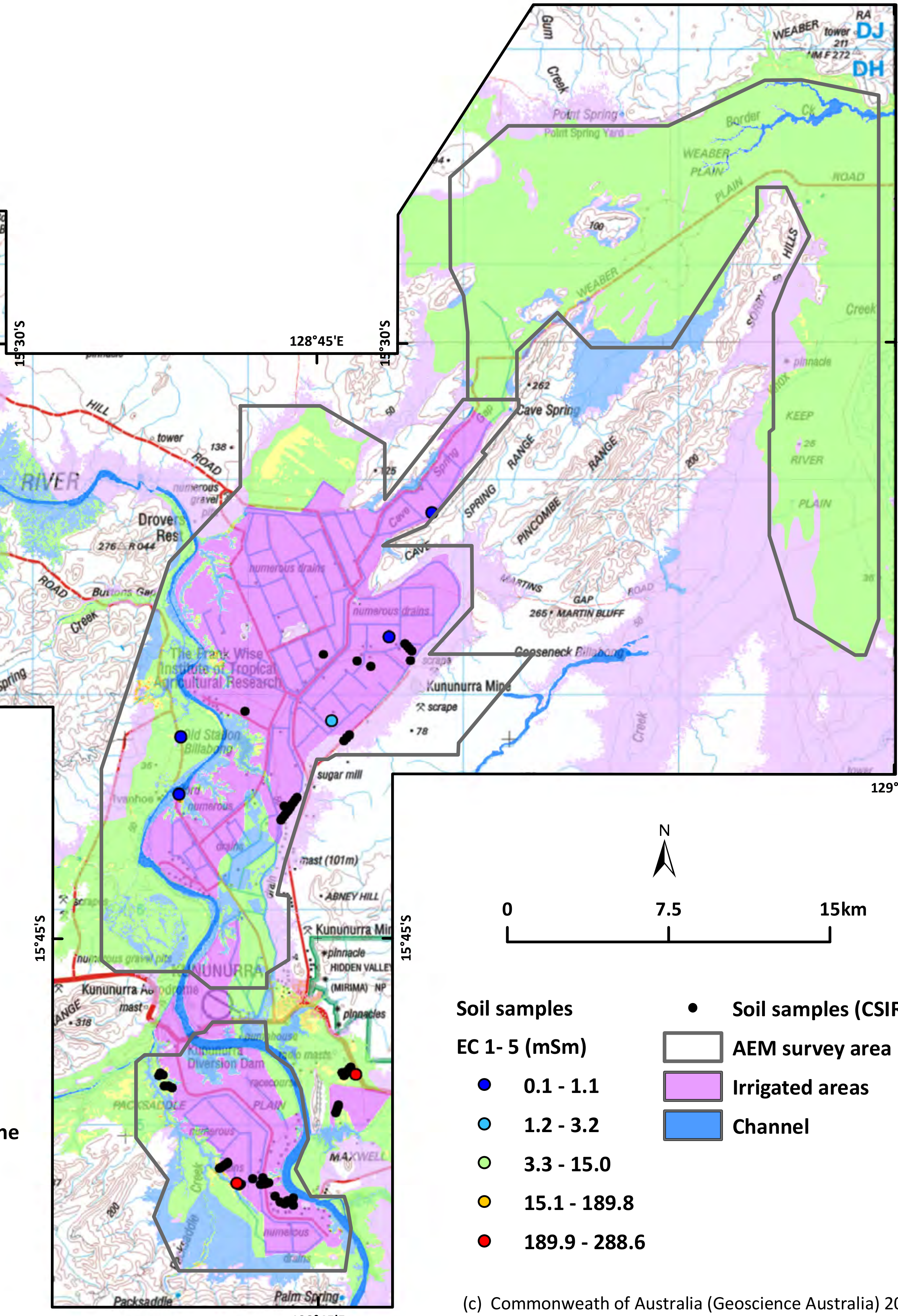
AEM data	Borehole data
0 - 500	0 - 500
501 - 1,000	501 - 1,000
1,001 - 2,500	1,001 - 2,500
2,501 - 3,000	2,501 - 5,000
3,001 - 5,000	5,001 - 10,000
5,001 - 10,000	10,001 - 20,000
10,001 - 20,000	20,001 - 30,000
20,001 - 30,000	30,001 - 31,189
30,001 - 46,109	

Ord Valley AEM Interpretation Project

27 Surface Salinity (Predicted Classes)

Based on LANDSAT-5 TM Imagery





N

0 7.5 15km

SURFACE SALINITY

PROCEDURE:

A Landsat-5 TM scene acquired on 30 March 2009 was classified into 15 land cover classes which were ranked according to susceptibility to surface salinity based on available soil salinity data. These classes were then combined with geomorphic units ranked according to susceptibility of geomorphic units to surface salinity. Combined classes were assessed against soil salinity EC data and assigned grouped surface salinity class.

The Landsat classes were combined with the irrigation layer in order to separate cleared ground within the irrigated areas and bare ground areas due to salinity or soil erosion. The interim map displays predicted land cover - landform salinity classes which require validation, and refinement with local soil landscapes information.

SOIL SALINITY VALIDATION DATA:

- 12 soil samples were collected by GA staff in May 2009
- 53 EC 1:5 data points from 7 transects (Review and Assessment of Soil Salinity in the Ord Irrigation Area CSIRO Land and Water Science report)
- 76 EC 1:5 data points from 22 locations (same report, collected by CSIRO)

REFERENCES:

Smith, A. and Price, A. 2008. Review and Assessment of Soil Salinity in the Ord River Irrigation Area.. CSIRO Land and Water Science Report

Surface Salt Class

- Very low salinity
- Low salinity
- Low to moderately saline
- Moderately saline
- Highly saline
- Extremely saline

Soil samples

EC 1- 5 (mSm)

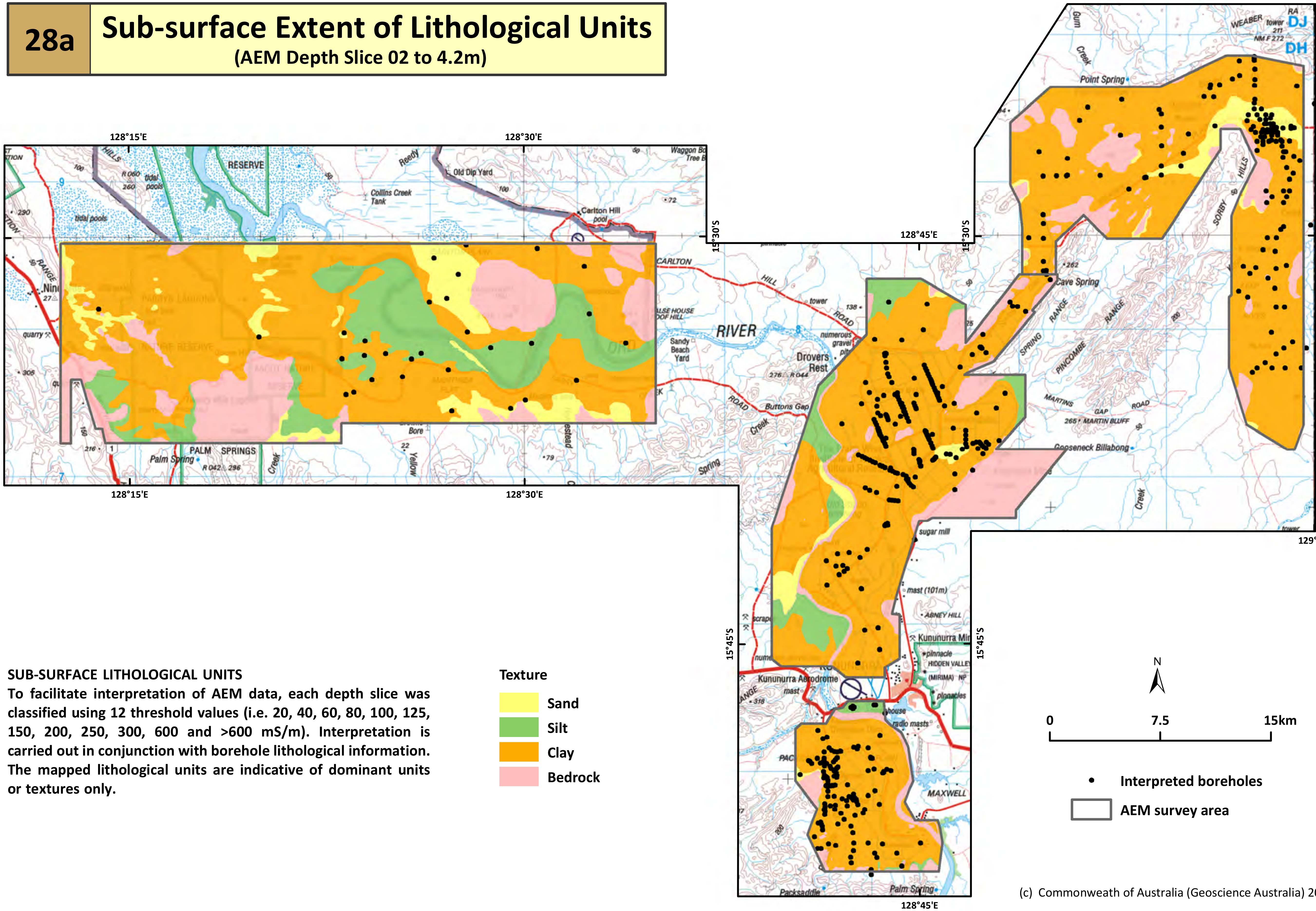
- 0.1 - 1.1
- 1.2 - 3.2
- 3.3 - 15.0
- 15.1 - 189.8
- 189.9 - 288.6

- Soil samples (CSIRO)
- AEM survey area
- Irrigated areas
- Channel

Ord Valley AEM Interpretation Project

28a Sub-surface Extent of Lithological Units

(AEM Depth Slice 02 to 4.2m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

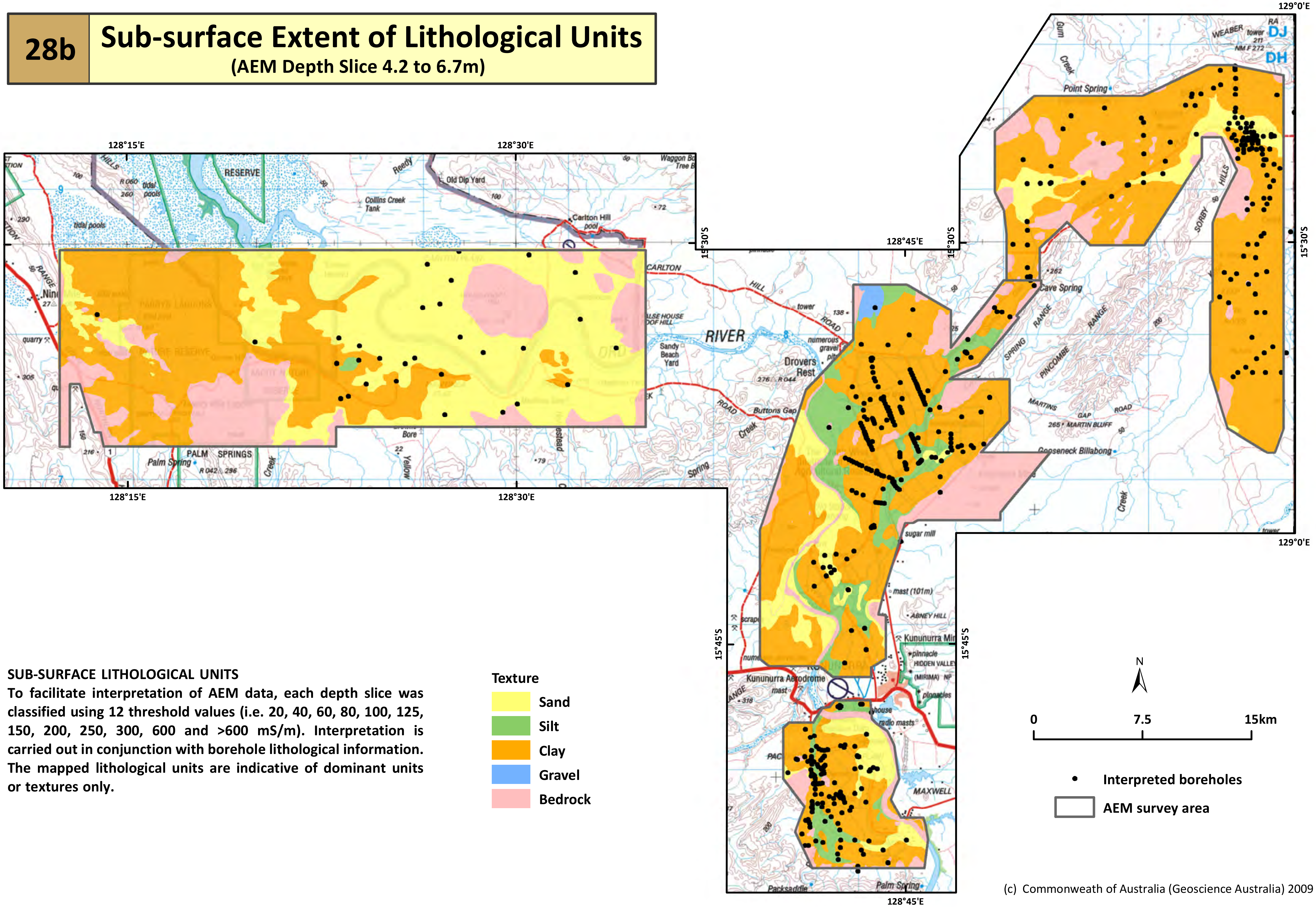
- Sand
- Silt
- Clay
- Bedrock

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

28b Sub-surface Extent of Lithological Units

(AEM Depth Slice 4.2 to 6.7m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

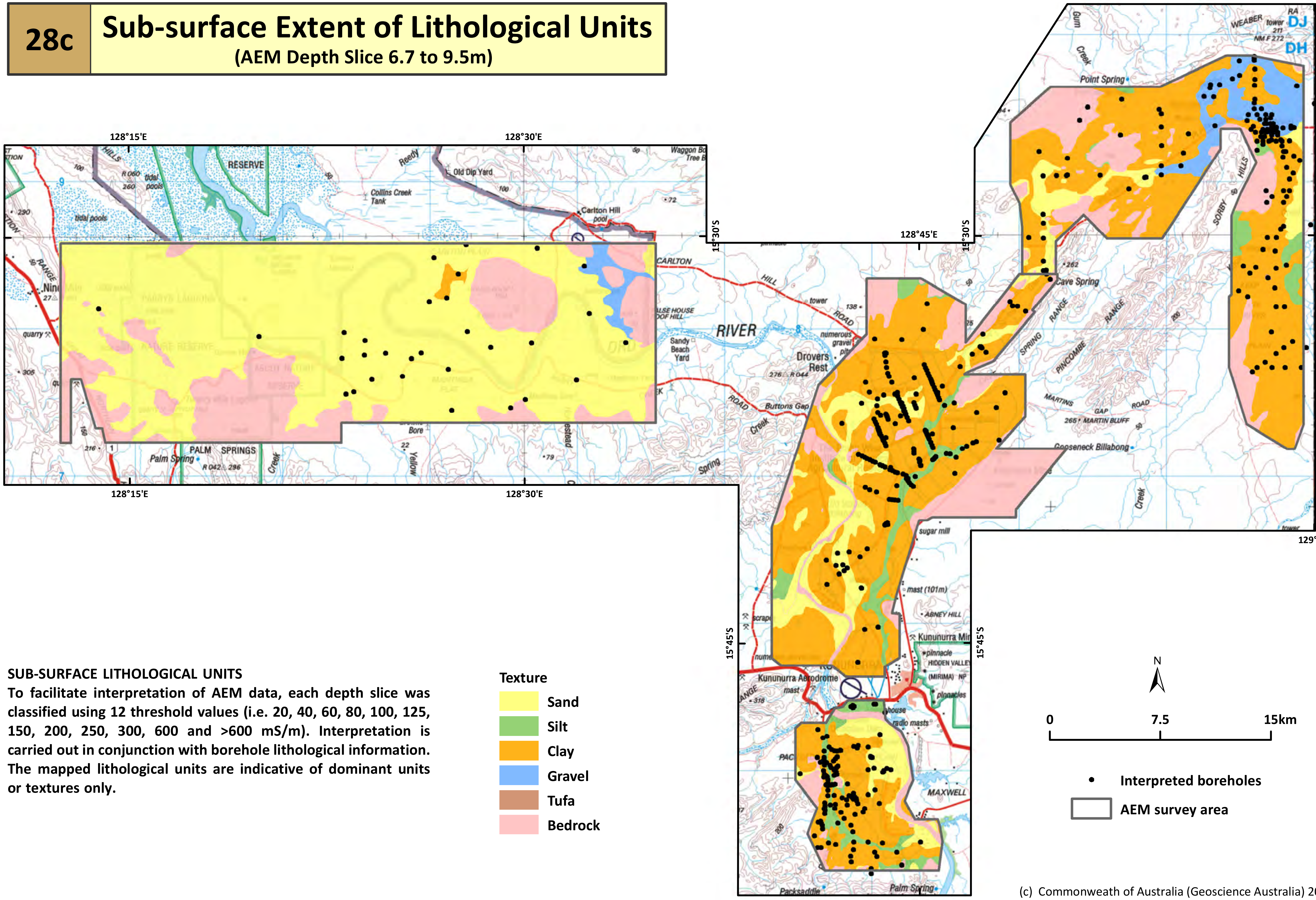
- Sand
- Silt
- Clay
- Gravel
- Bedrock

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

28c Sub-surface Extent of Lithological Units

(AEM Depth Slice 6.7 to 9.5m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

- Sand
- Silt
- Clay
- Gravel
- Tufa
- Bedrock

N

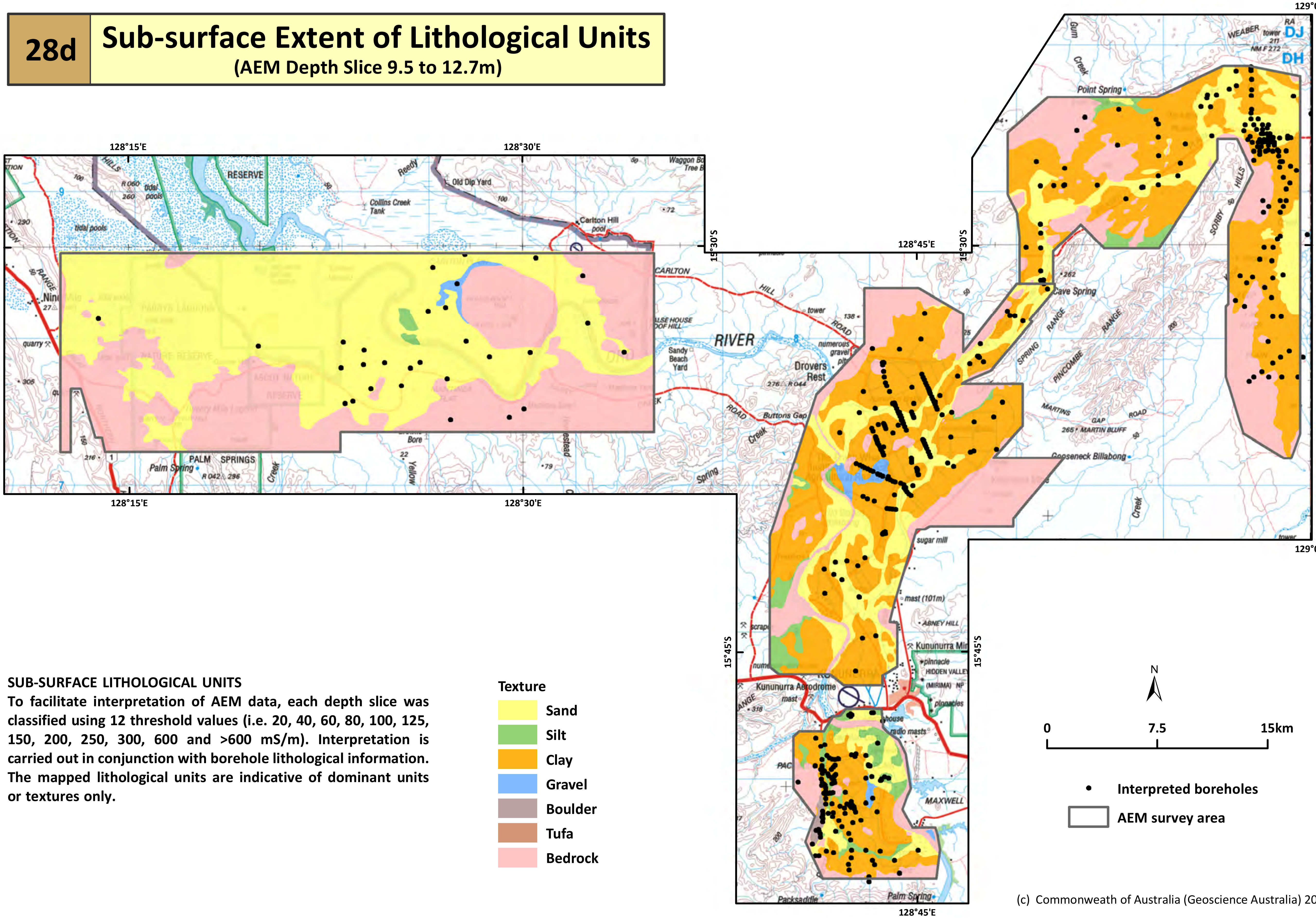
0 7.5 15km

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

28d Sub-surface Extent of Lithological Units

(AEM Depth Slice 9.5 to 12.7m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

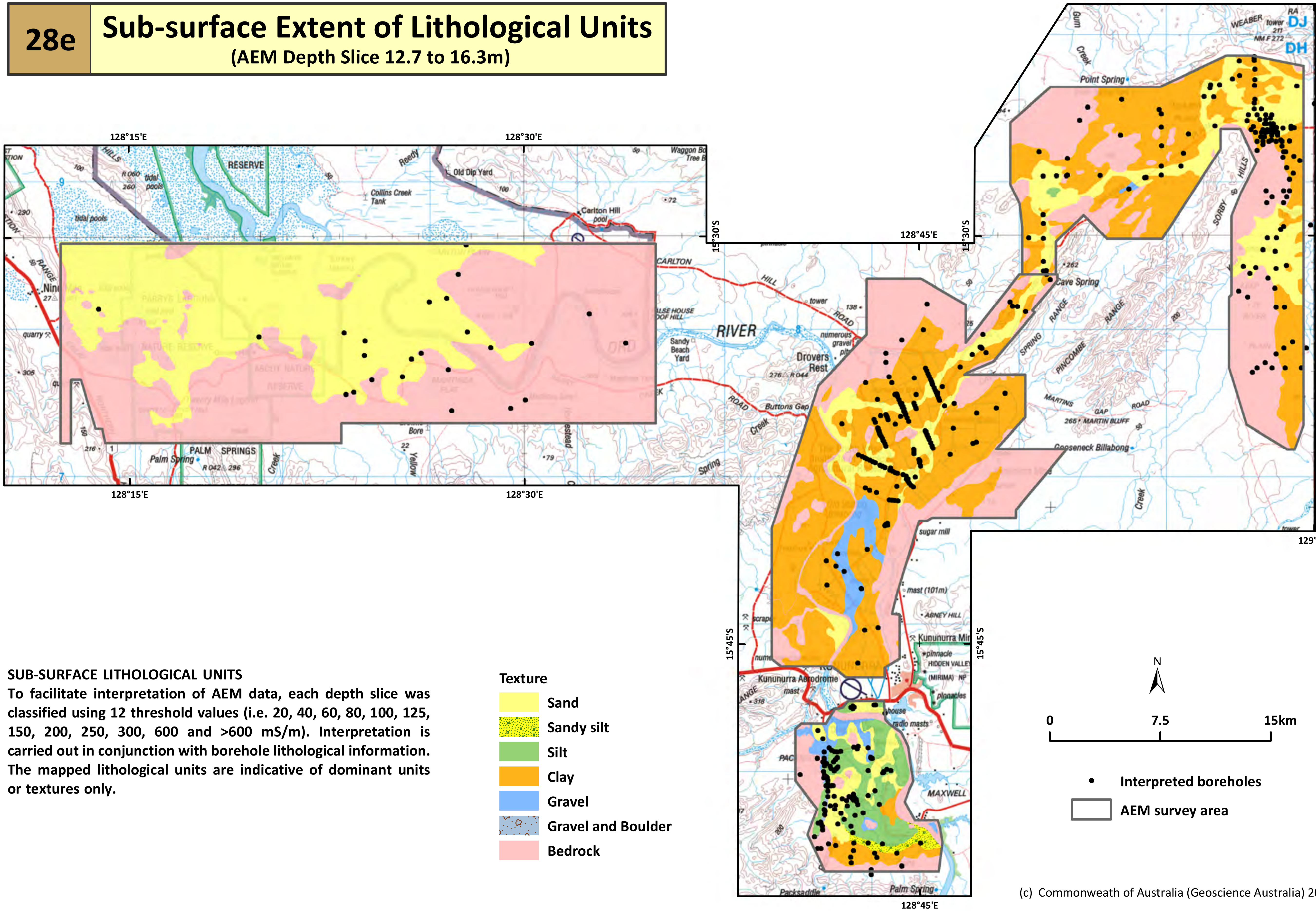
Texture

- Sand
- Silt
- Clay
- Gravel
- Boulder
- Tufa
- Bedrock

Ord Valley AEM Interpretation Project

28e Sub-surface Extent of Lithological Units

(AEM Depth Slice 12.7 to 16.3m)



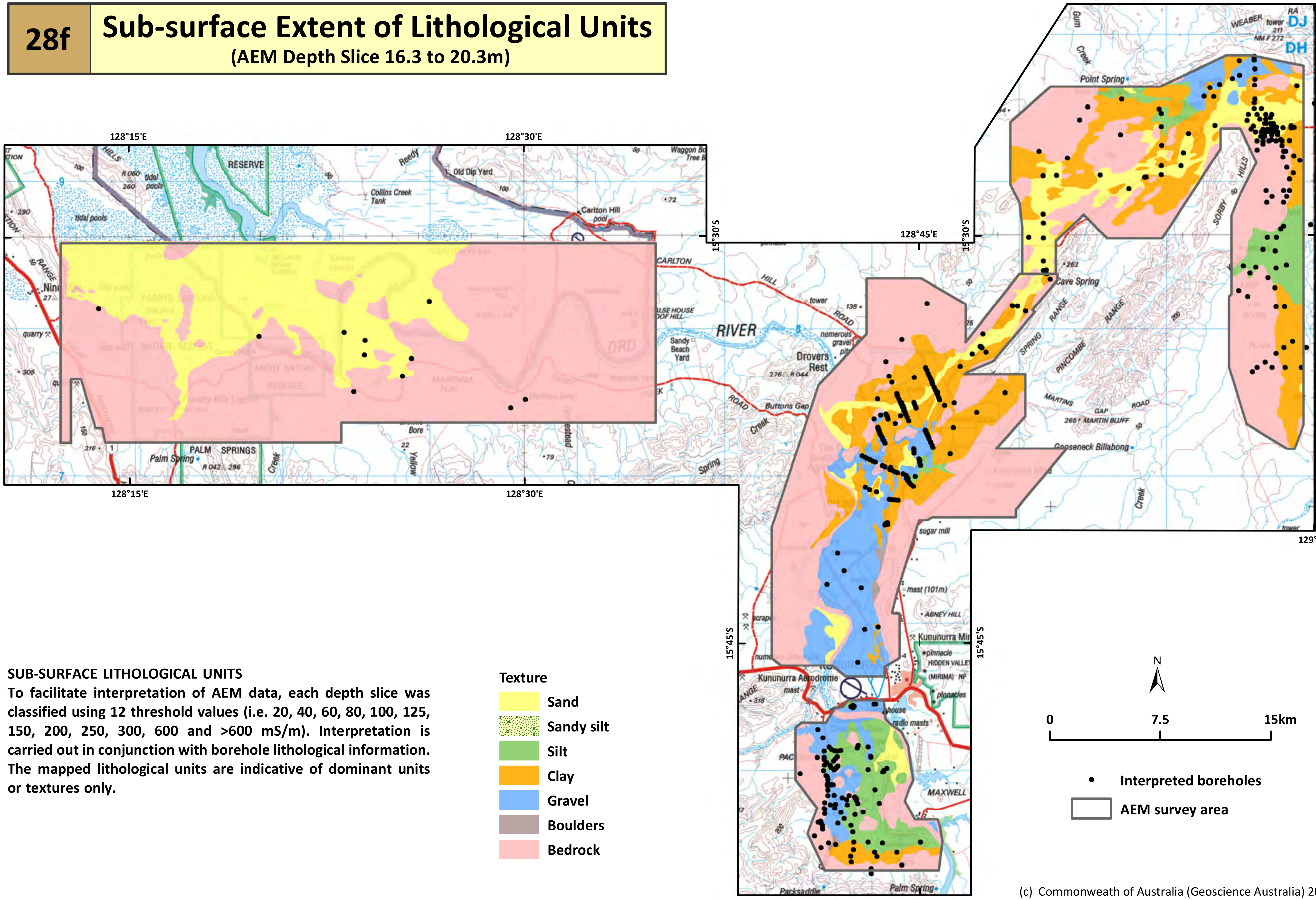
SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Ord Valley AEM Interpretation Project

28f Sub-surface Extent of Lithological Units

(AEM Depth Slice 16.3 to 20.3m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

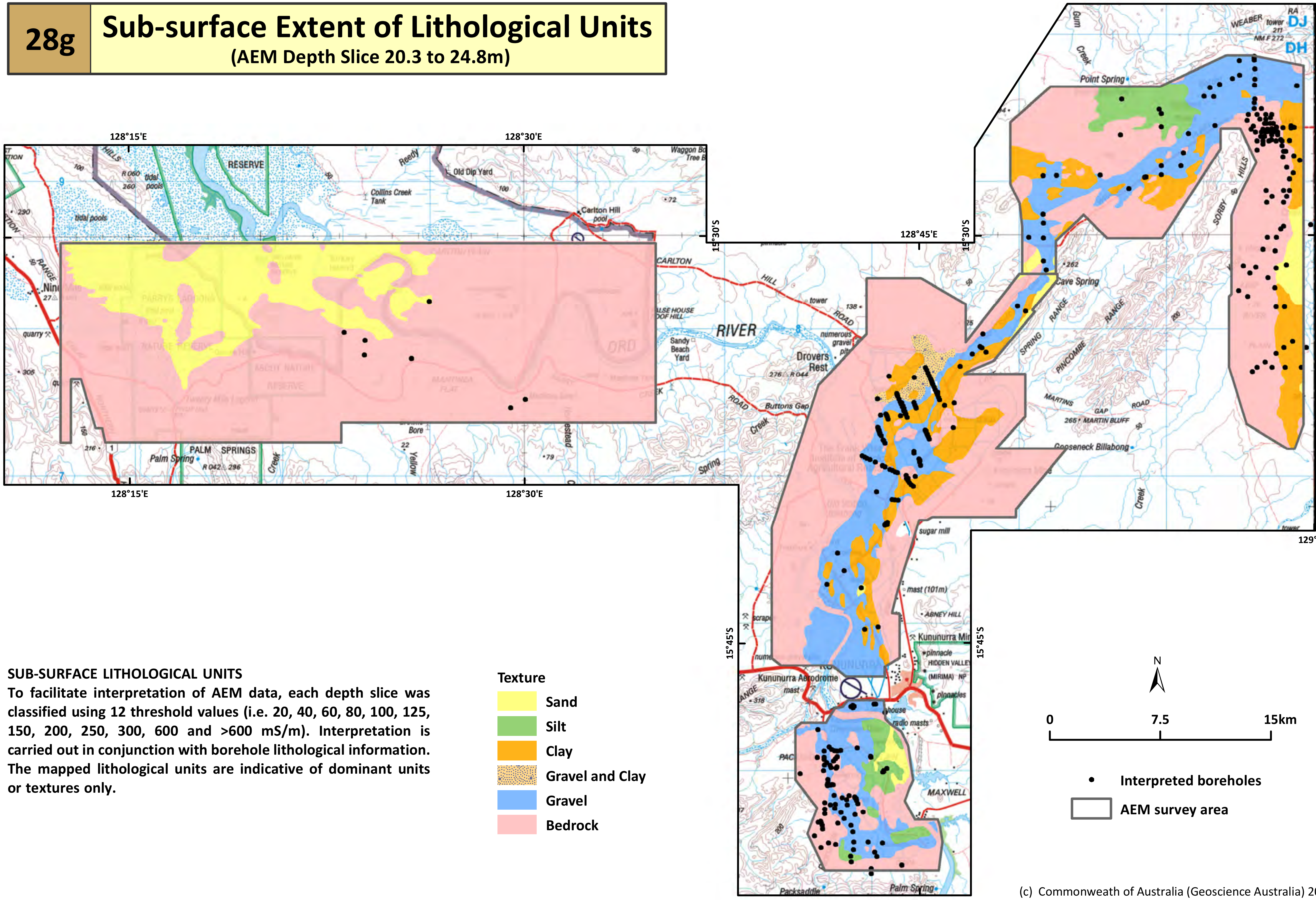
- Sand
- Sandy silt
- Silt
- Clay
- Gravel
- Boulders
- Bedrock

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

28g Sub-surface Extent of Lithological Units

(AEM Depth Slice 20.3 to 24.8m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

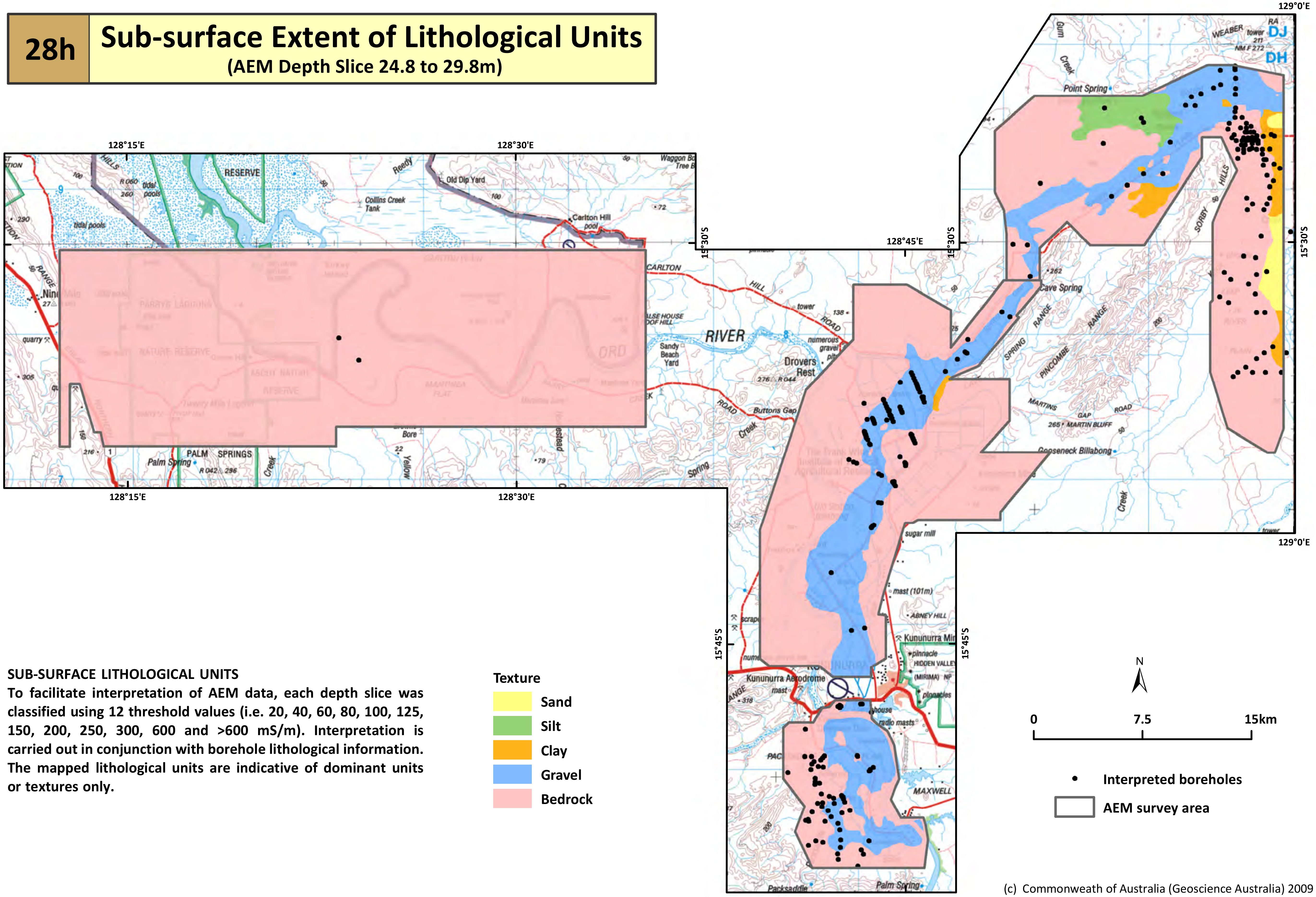
Texture

- Sand
- Silt
- Clay
- Gravel and Clay
- Gravel
- Bedrock

Ord Valley AEM Interpretation Project

28h Sub-surface Extent of Lithological Units

(AEM Depth Slice 24.8 to 29.8m)



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

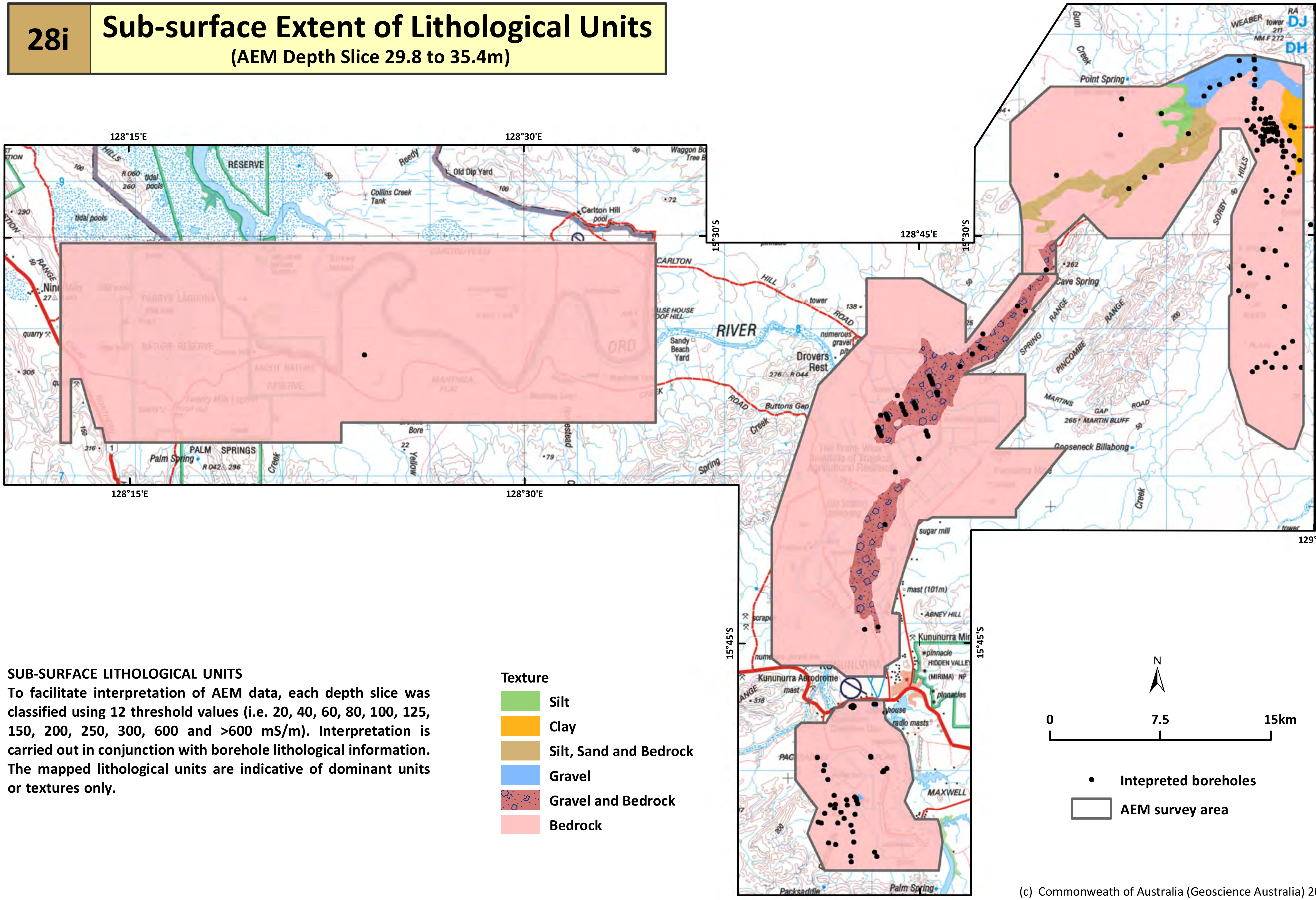
- Sand
- Silt
- Clay
- Gravel
- Bedrock

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

28i Sub-surface Extent of Lithological Units

(AEM Depth Slice 29.8 to 35.4m)



SUB-SURFACE LITHOLOGICAL UNITS

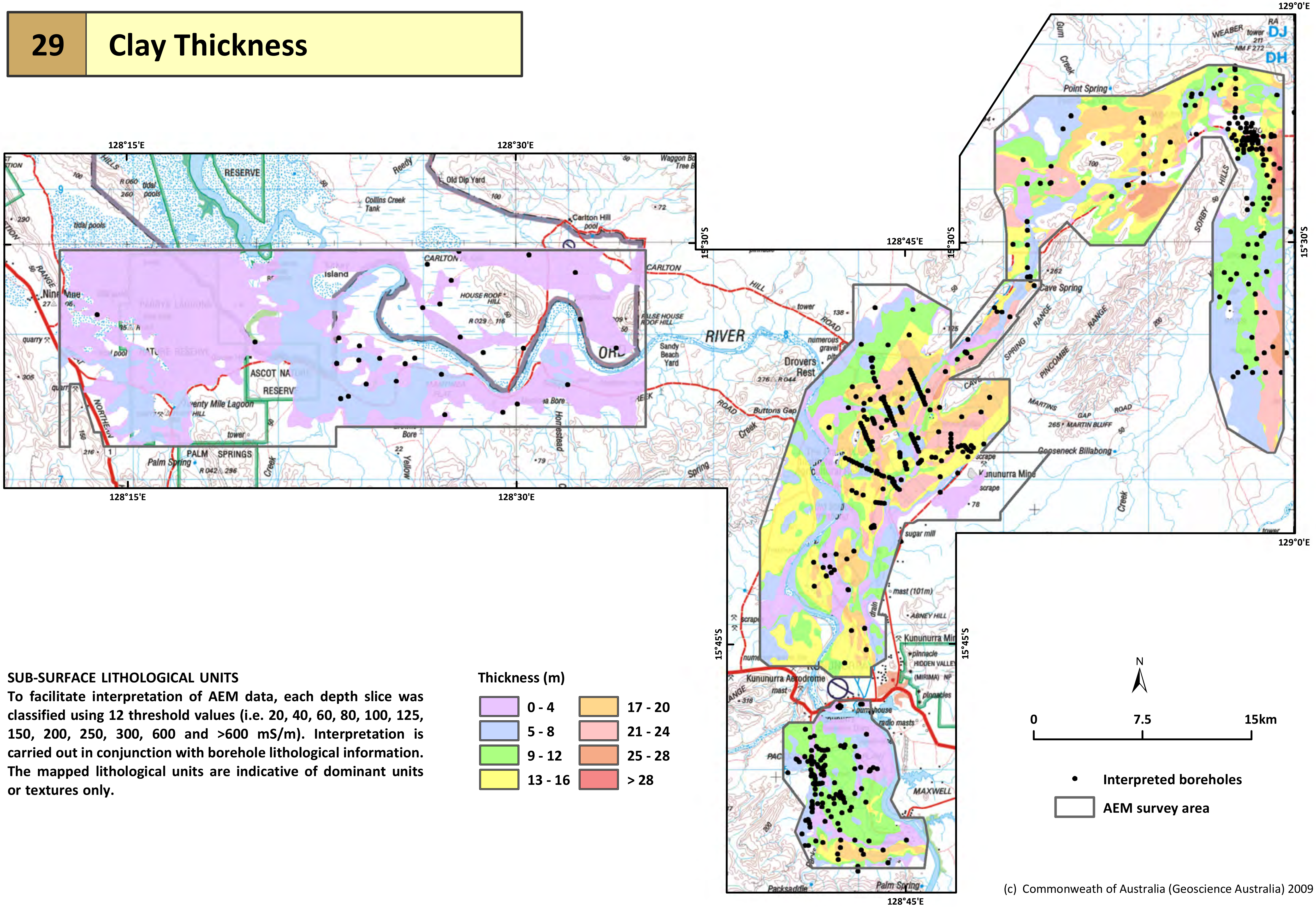
To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Texture

- Silt
- Clay
- Silt, Sand and Bedrock
- Gravel
- Gravel and Bedrock
- Bedrock

Ord Valley AEM Interpretation Project

29 Clay Thickness



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Thickness (m)

- 0 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 20
- 21 - 24
- 25 - 28
- > 28

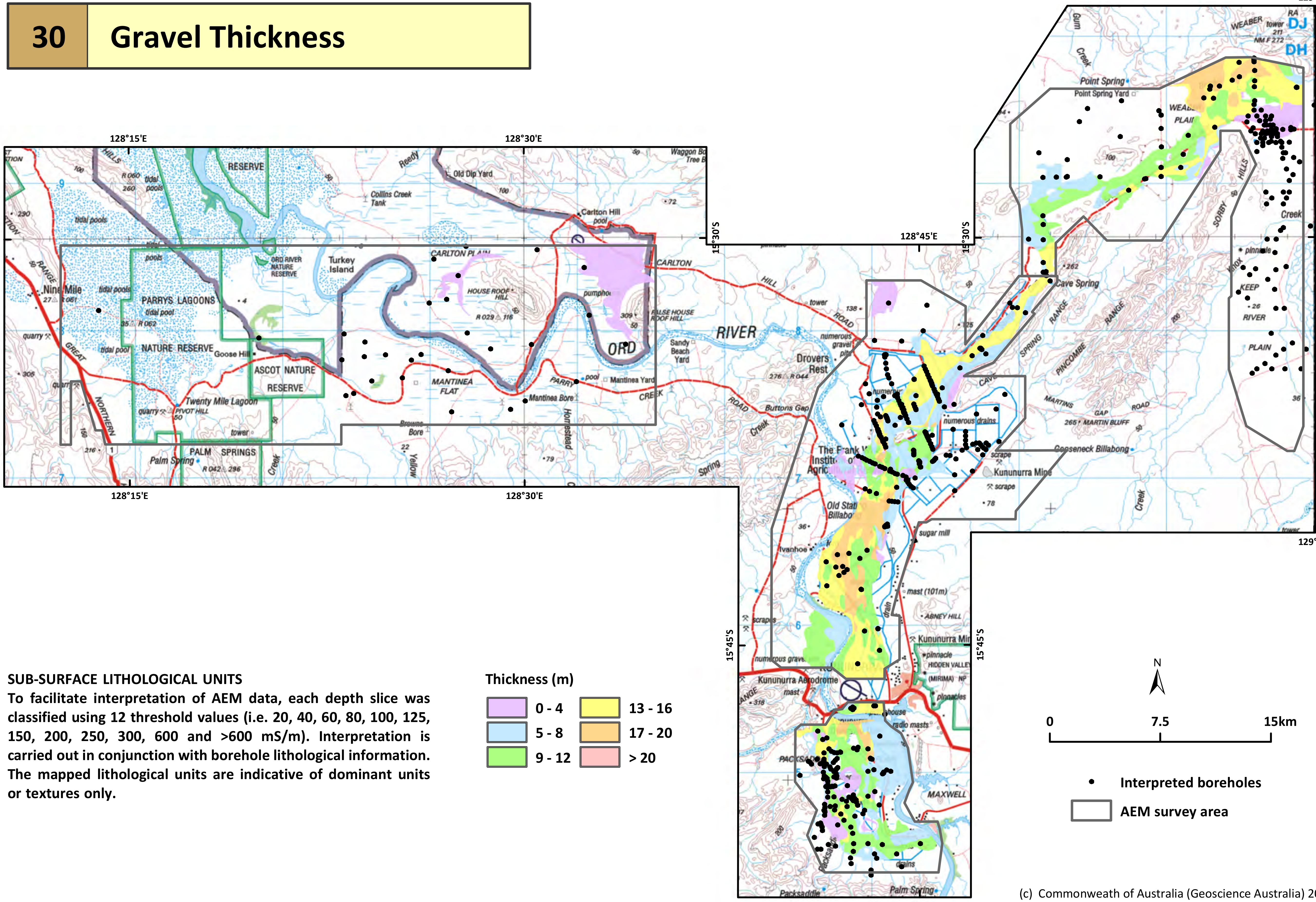
N

0 7.5 15km

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

30 Gravel Thickness



SUB-SURFACE LITHOLOGICAL UNITS

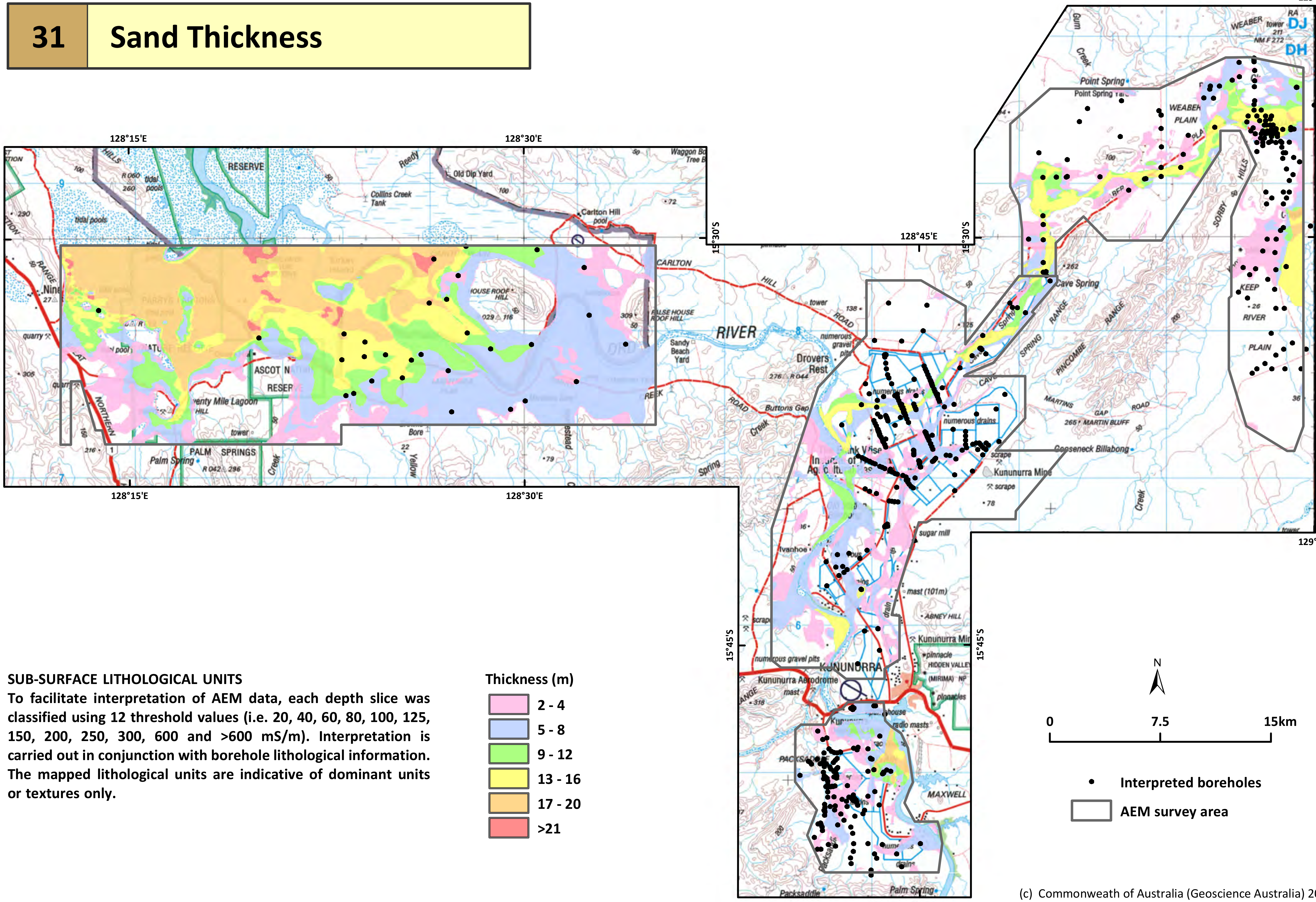
To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Thickness (m)

- 0 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 20
- > 20

Ord Valley AEM Interpretation Project

31 Sand Thickness



SUB-SURFACE LITHOLOGICAL UNITS

To facilitate interpretation of AEM data, each depth slice was classified using 12 threshold values (i.e. 20, 40, 60, 80, 100, 125, 150, 200, 250, 300, 600 and >600 mS/m). Interpretation is carried out in conjunction with borehole lithological information. The mapped lithological units are indicative of dominant units or textures only.

Thickness (m)

- 2 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 20
- >21

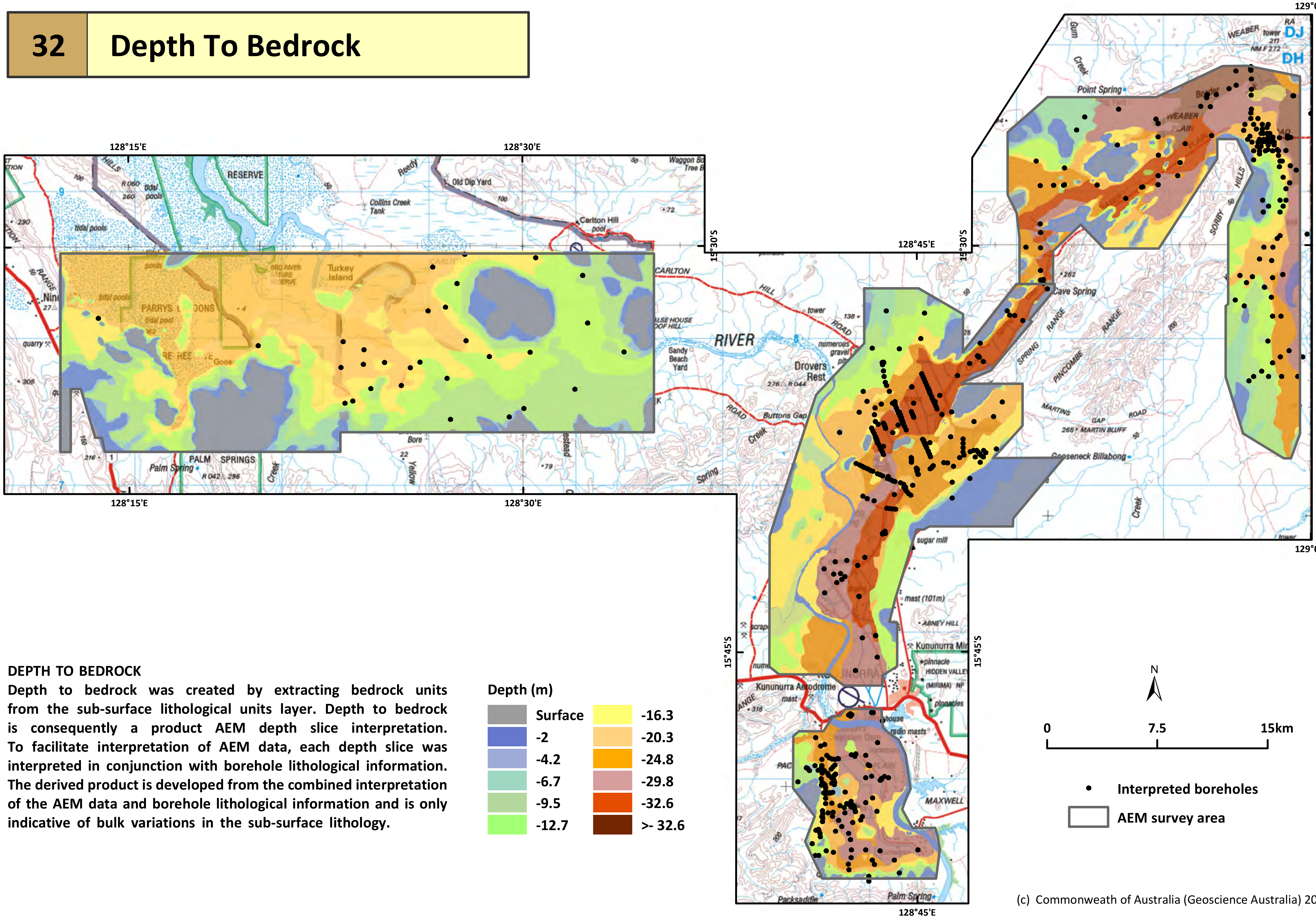
N

0 7.5 15km

- Interpreted boreholes
- AEM survey area

Ord Valley AEM Interpretation Project

32 Depth To Bedrock



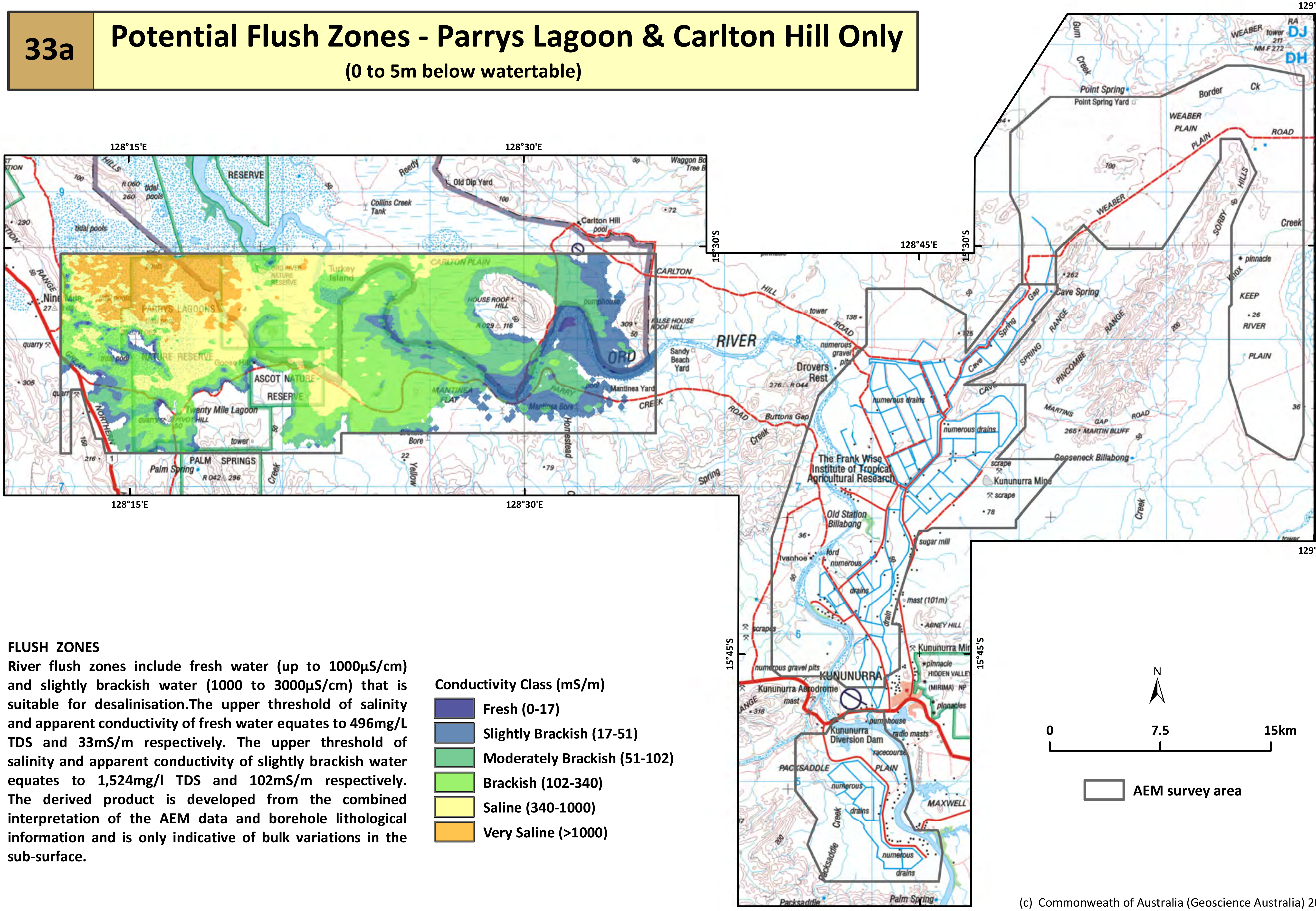
DEPTH TO BEDROCK

Depth to bedrock was created by extracting bedrock units from the sub-surface lithological units layer. Depth to bedrock is consequently a product AEM depth slice interpretation. To facilitate interpretation of AEM data, each depth slice was interpreted in conjunction with borehole lithological information. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface lithology.

Ord Valley AEM Interpretation Project

33a Potential Flush Zones - Parrys Lagoon & Carlton Hill Only

(0 to 5m below watertable)



FLUSH ZONES

River flush zones include fresh water (up to 1000µS/cm) and slightly brackish water (1000 to 3000µS/cm) that is suitable for desalinisation.The upper threshold of salinity and apparent conductivity of fresh water equates to 496mg/L TDS and 33mS/m respectively. The upper threshold of salinity and apparent conductivity of slightly brackish water equates to 1,524mg/l TDS and 102mS/m respectively. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

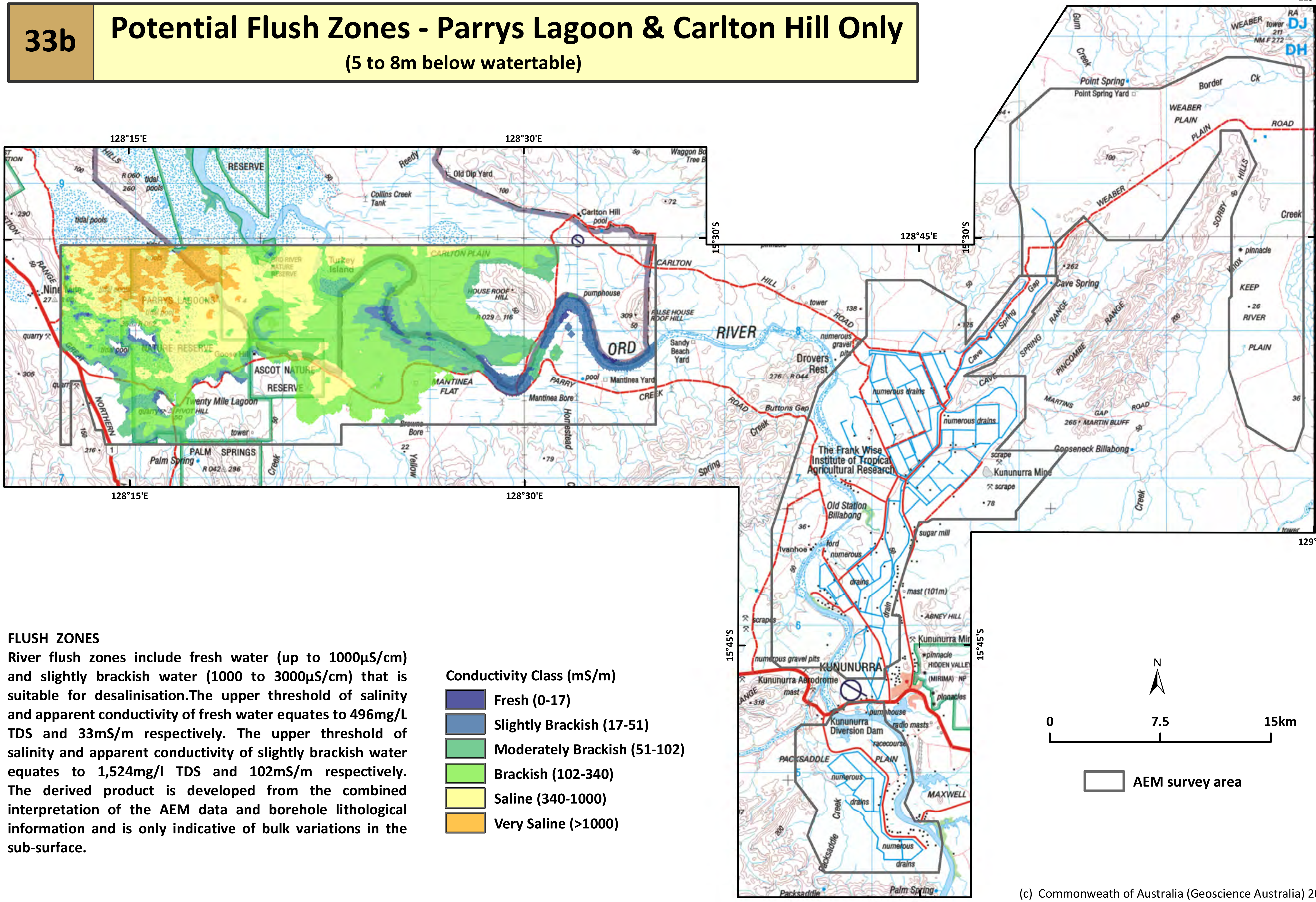
Conductivity Class (mS/m)

- Fresh (0-17)
- Slightly Brackish (17-51)
- Moderately Brackish (51-102)
- Brackish (102-340)
- Saline (340-1000)
- Very Saline (>1000)

Ord Valley AEM Interpretation Project

33b Potential Flush Zones - Parrys Lagoon & Carlton Hill Only

(5 to 8m below watertable)



FLUSH ZONES

River flush zones include fresh water (up to 1000µS/cm) and slightly brackish water (1000 to 3000µS/cm) that is suitable for desalinisation.The upper threshold of salinity and apparent conductivity of fresh water equates to 496mg/l TDS and 33mS/m respectively. The upper threshold of salinity and apparent conductivity of slightly brackish water equates to 1,524mg/l TDS and 102mS/m respectively. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

Conductivity Class (mS/m)

- Fresh (0-17)
- Slightly Brackish (17-51)
- Moderately Brackish (51-102)
- Brackish (102-340)
- Saline (340-1000)
- Very Saline (>1000)

N

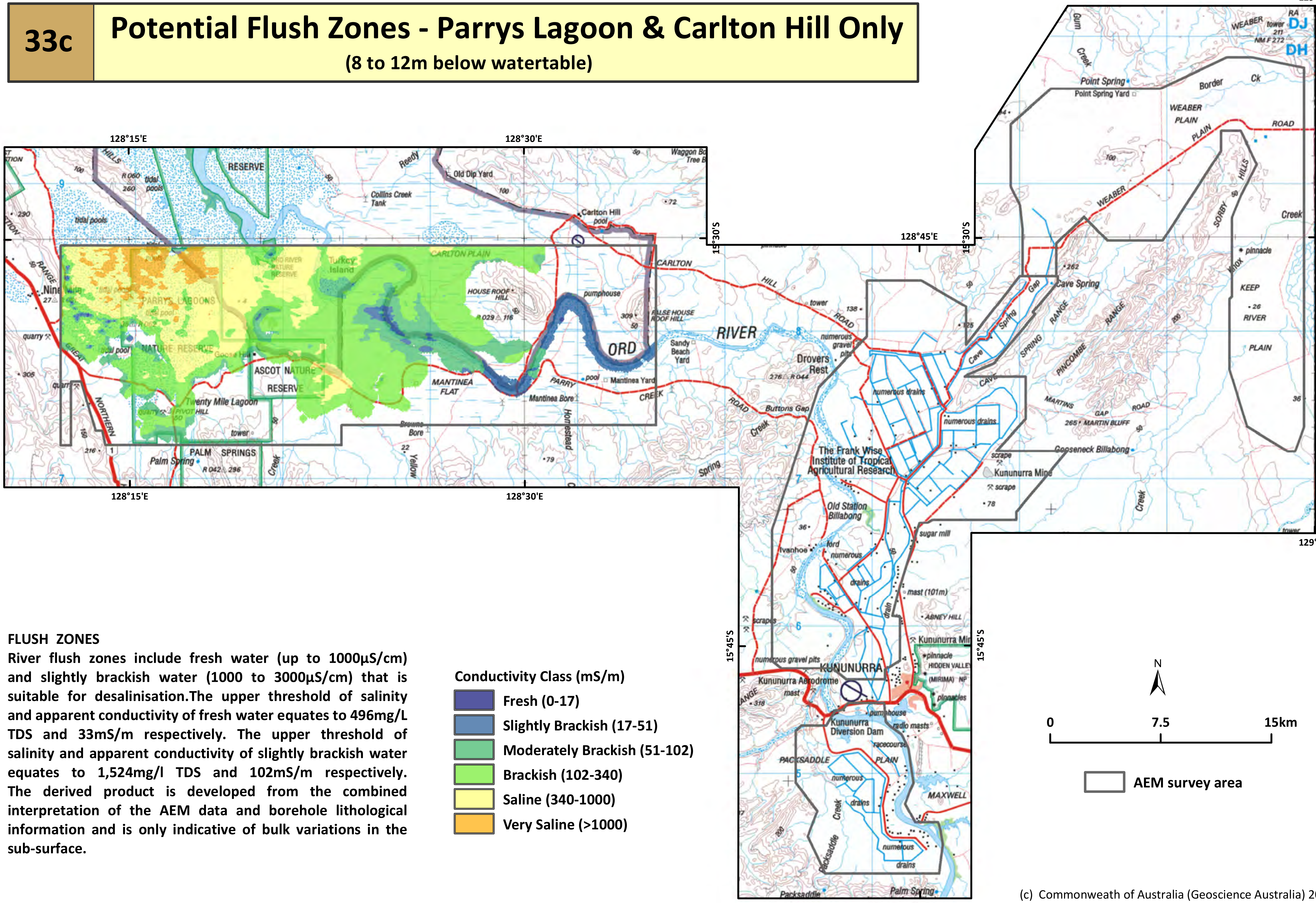
0 7.5 15km

AEM survey area

Ord Valley AEM Interpretation Project

33c Potential Flush Zones - Parrys Lagoon & Carlton Hill Only

(8 to 12m below watertable)



FLUSH ZONES

River flush zones include fresh water (up to 1000µS/cm) and slightly brackish water (1000 to 3000µS/cm) that is suitable for desalinisation.The upper threshold of salinity and apparent conductivity of fresh water equates to 496mg/L TDS and 33mS/m respectively. The upper threshold of salinity and apparent conductivity of slightly brackish water equates to 1,524mg/l TDS and 102mS/m respectively. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the sub-surface.

Conductivity Class (mS/m)

- Fresh (0-17)
- Slightly Brackish (17-51)
- Moderately Brackish (51-102)
- Brackish (102-340)
- Saline (340-1000)
- Very Saline (>1000)

N

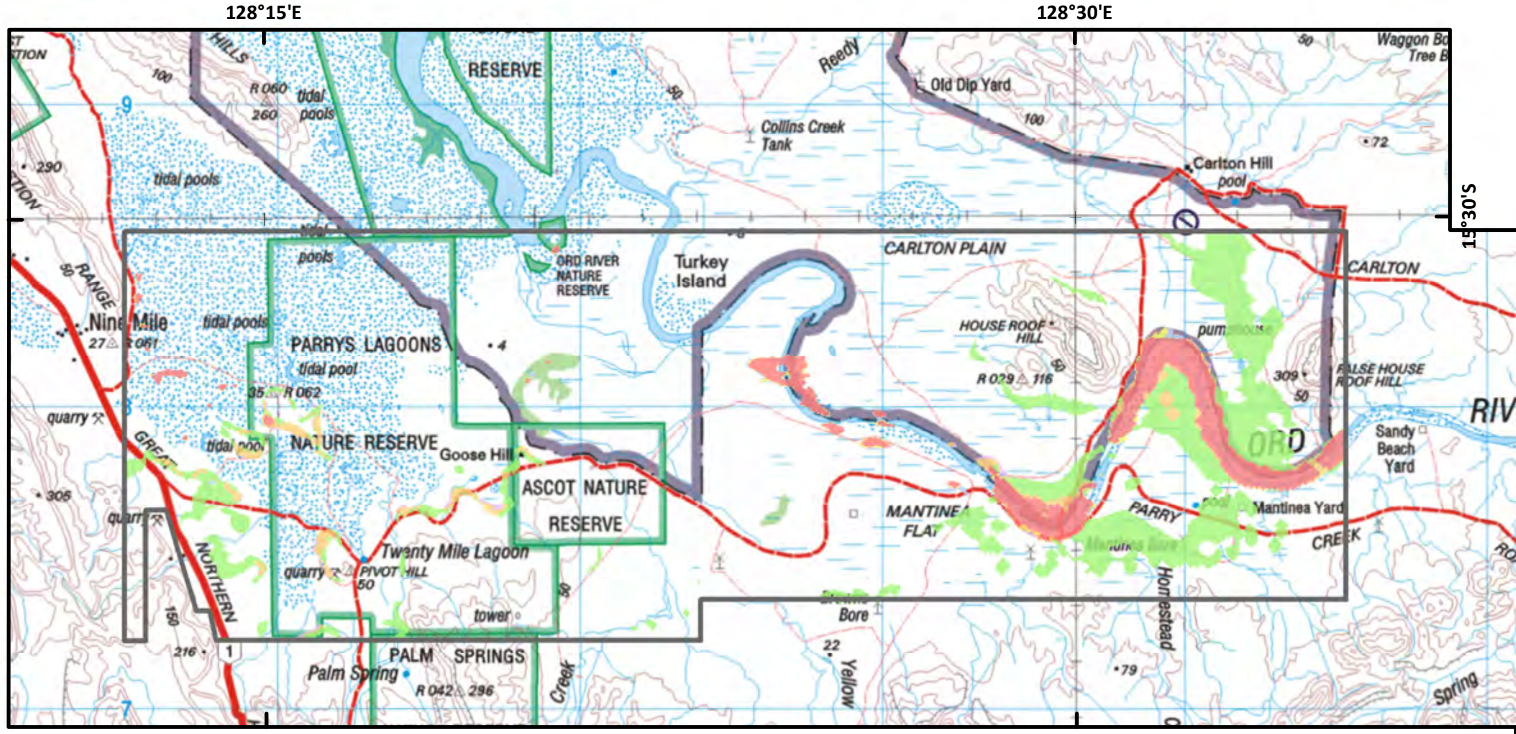
0 7.5 15km

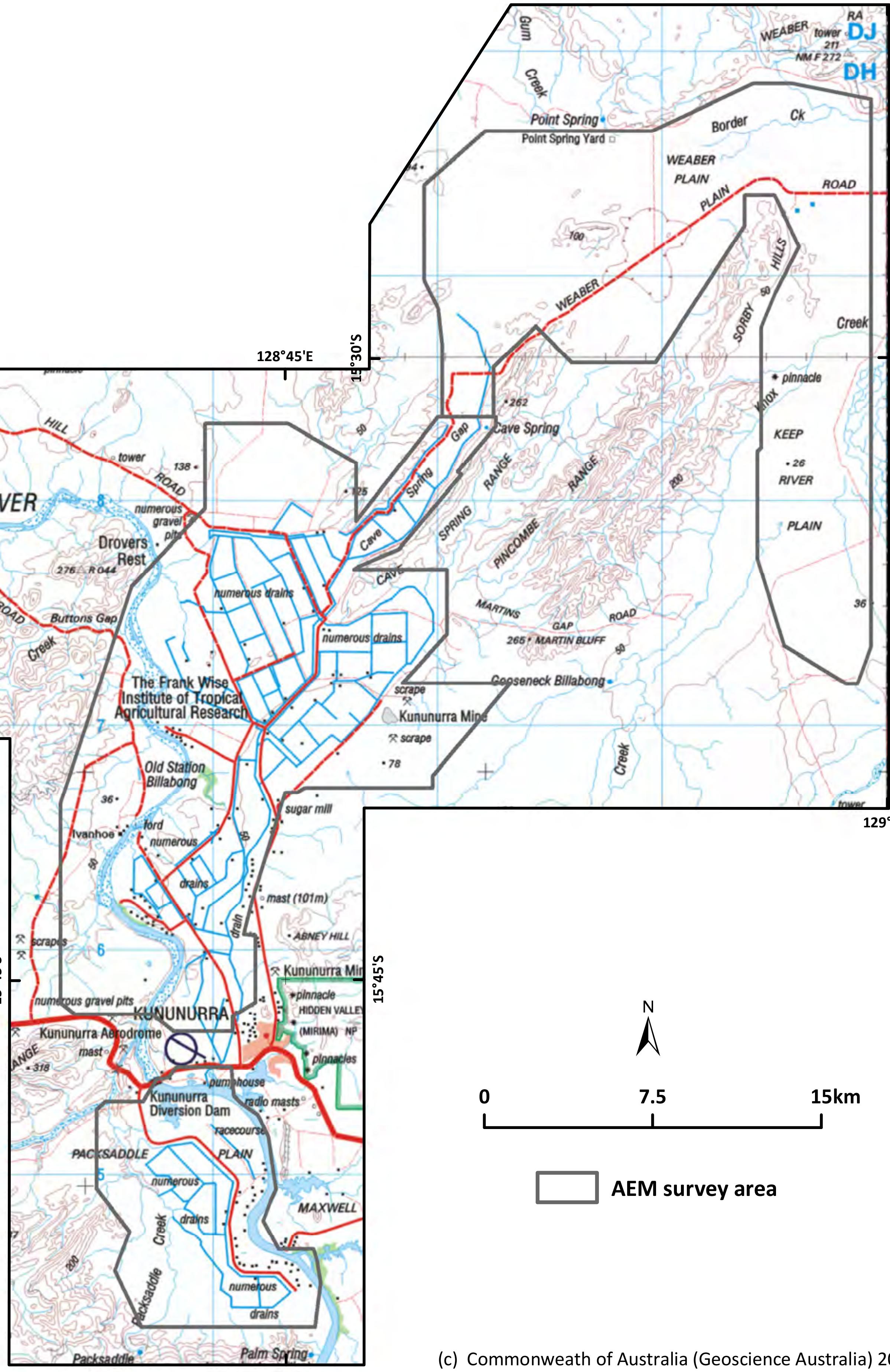
AEM survey area

Ord Valley AEM Interpretation Project

34 Potential Flush Zone Thickness

(Parrys Lagoon & Carlton Hill Only)





FLUSH ZONES

River flush zones include fresh water (up to 1000µS/cm) and slightly brackish water (1000 to 3000 µS/cm) that is suitable for desalinisation.The upper threshold of salinity and apparentconductivity of fresh water equates to 496 mg/L TDS and 33 mS/m respectively. The upper threshold of salinity and apparent conductivity of slightly brackish water equates to 1,524 mg/l TDS and 102 mS/m respectively. The derived product is developed from the combined interpretation of the AEM data and borehole lithological information and is only indicative of bulk variations in the subsurface lithology.

Thickness (m)

- 3
- 4
- 5
- 7
- 8
- 9
- 12

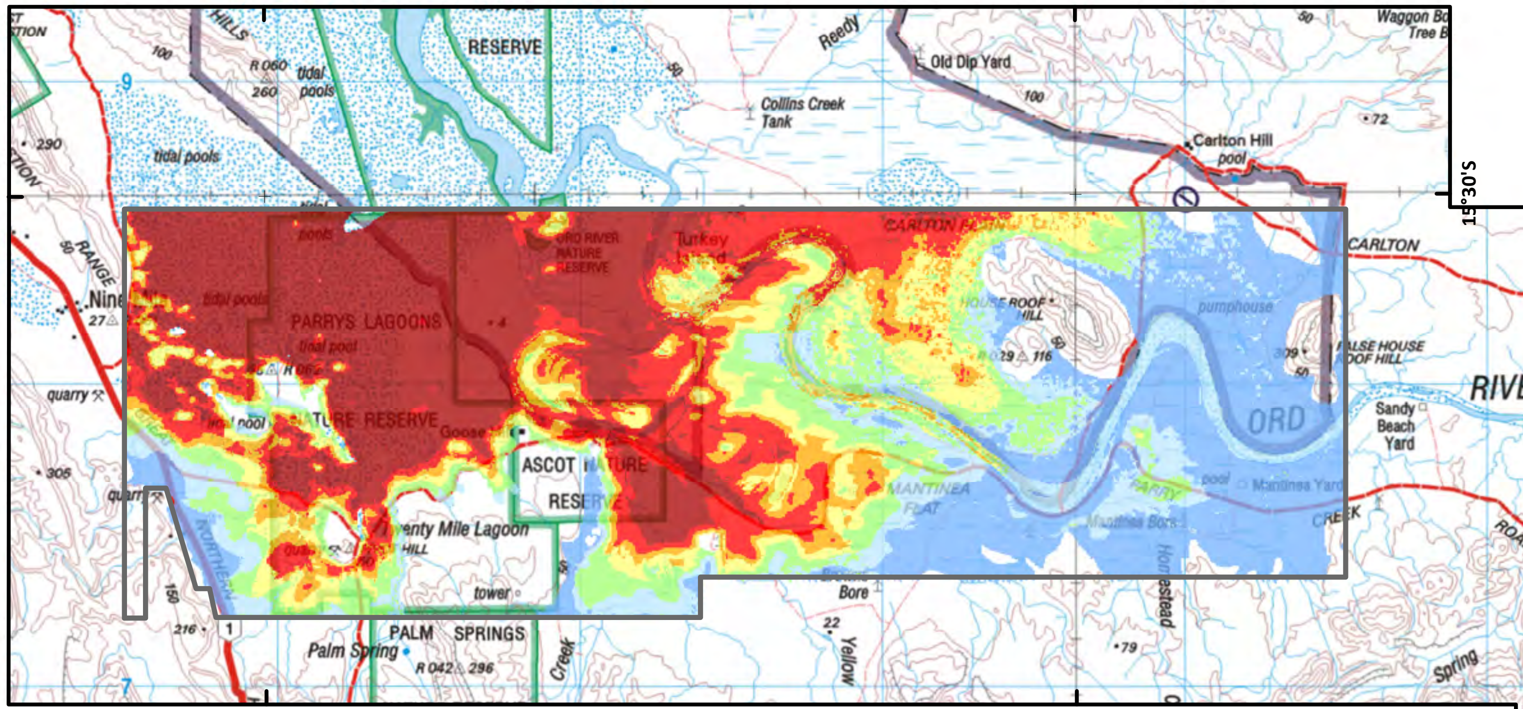
N

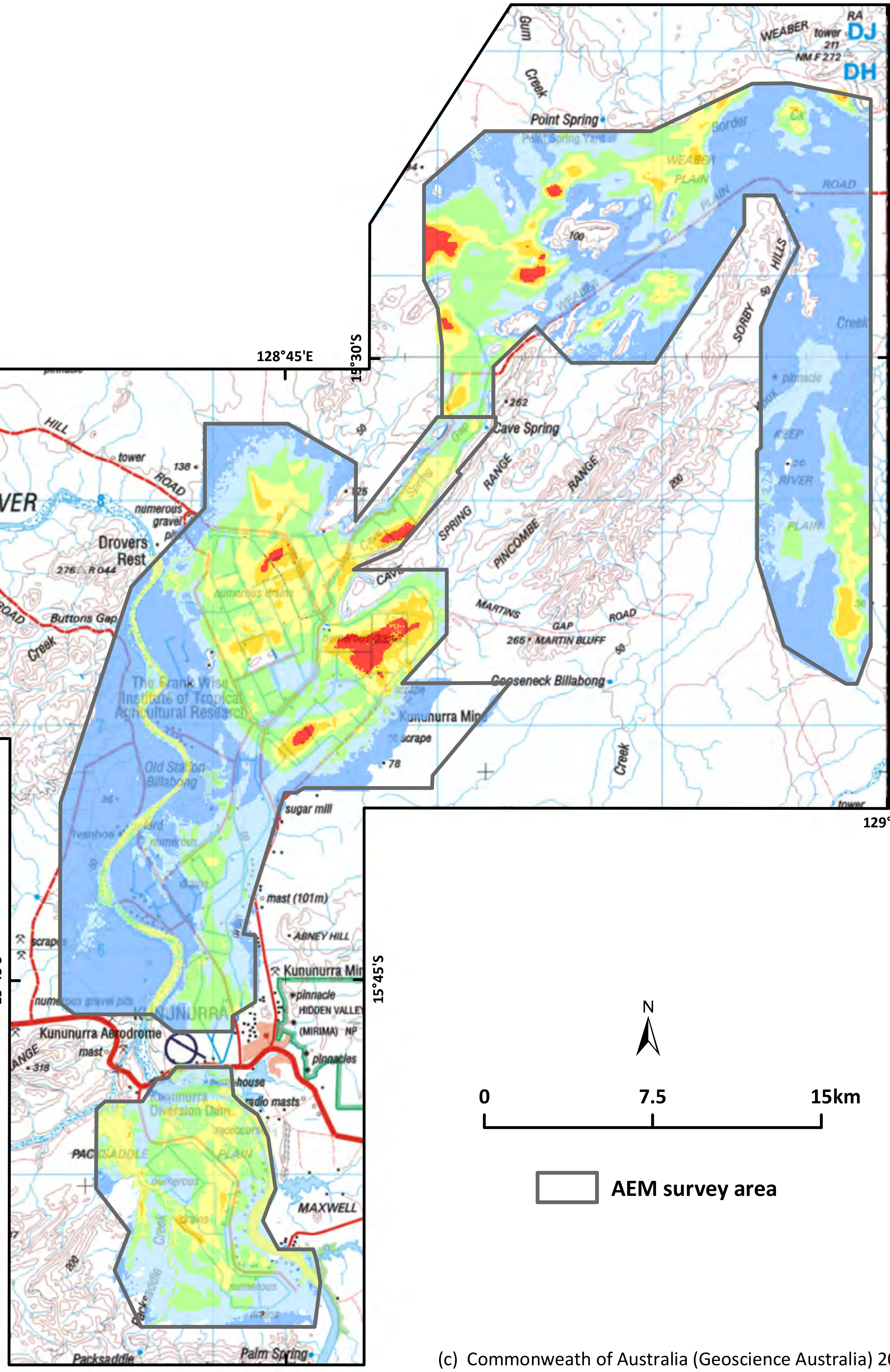
0 7.5 15km

AEM survey area

Ord Valley AEM Interpretation Project

35 Salinity Hazard - Unsaturated Zone





SALINITY HAZARD

Salinity hazard for the unsaturated zone - from the surface to the static watertable.

The main drivers for sub-surface salinity hazard are depth to watertable and salt store in the unsaturated zone. Of these, the depth to watertable has more influence than salt store, as evapo-transpiration will take place readily when the water table is within 2m from surface. The soil will become salinized through repeated cycle of wetting and drying even when the groundwater is fresh. Classes were assigned using a combination of depth to SWL and unsaturated zone salt stores. Extreme salt hazard class is only present in Parry's Lagoon – Carlton Plain due to the presence of very shallow and saline groundwater.

Hazard class

- Very Low
- Low
- Moderately Low
- Moderate
- High
- Very High
- Extremely High

N

0 7.5 15km

AEM survey area