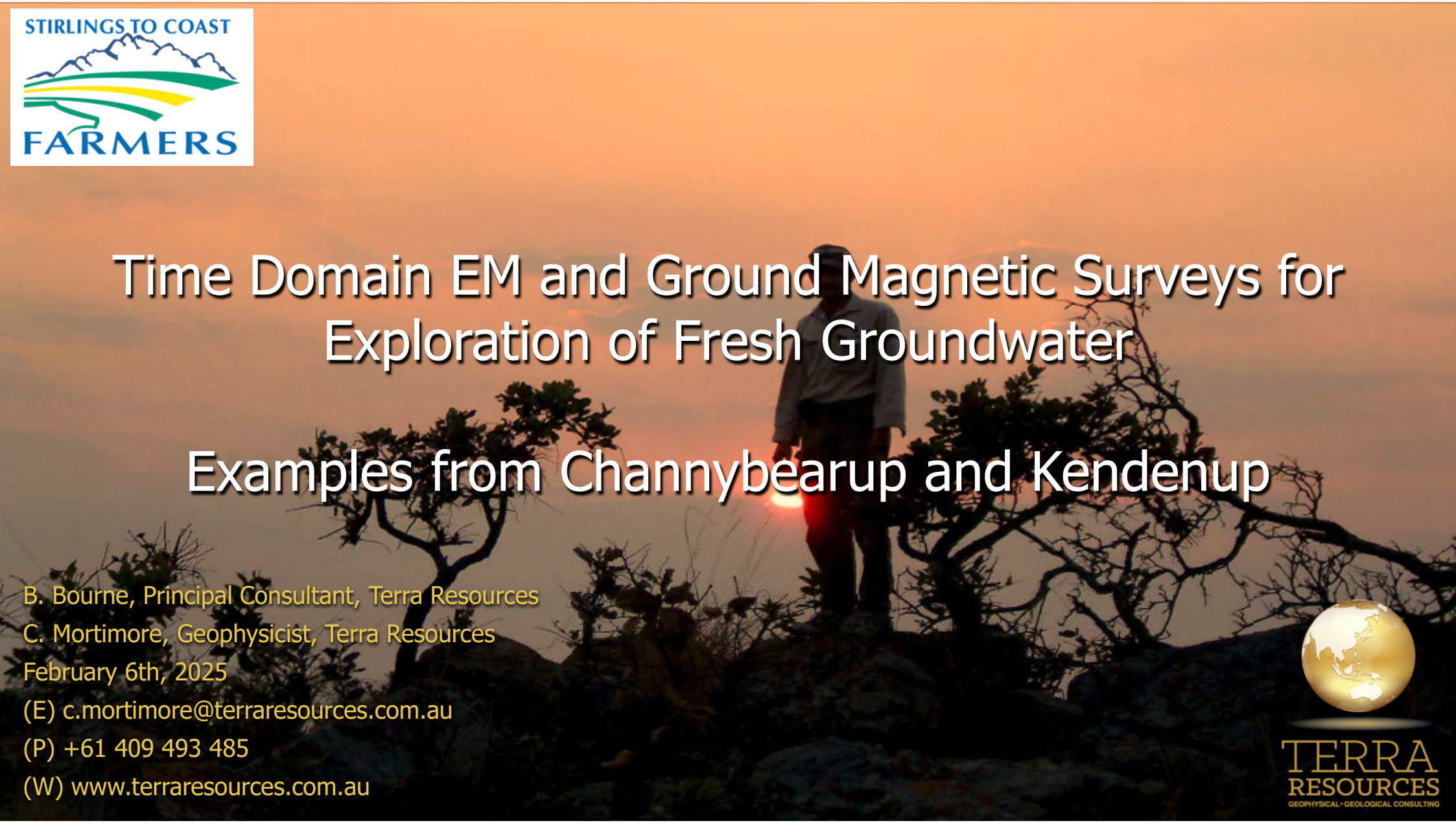

Time Domain EM and Ground Magnetic Surveys for Exploration of Fresh Groundwater

Examples from Channybearup and Kendenup

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TERRA RESOURCES
GEOPHYSICAL • GEOLOGICAL CONSULTING

Introduction

Loupe is a new portable TEM system developed in Western Australia for near-surface conductivity mapping.

This Presentation:

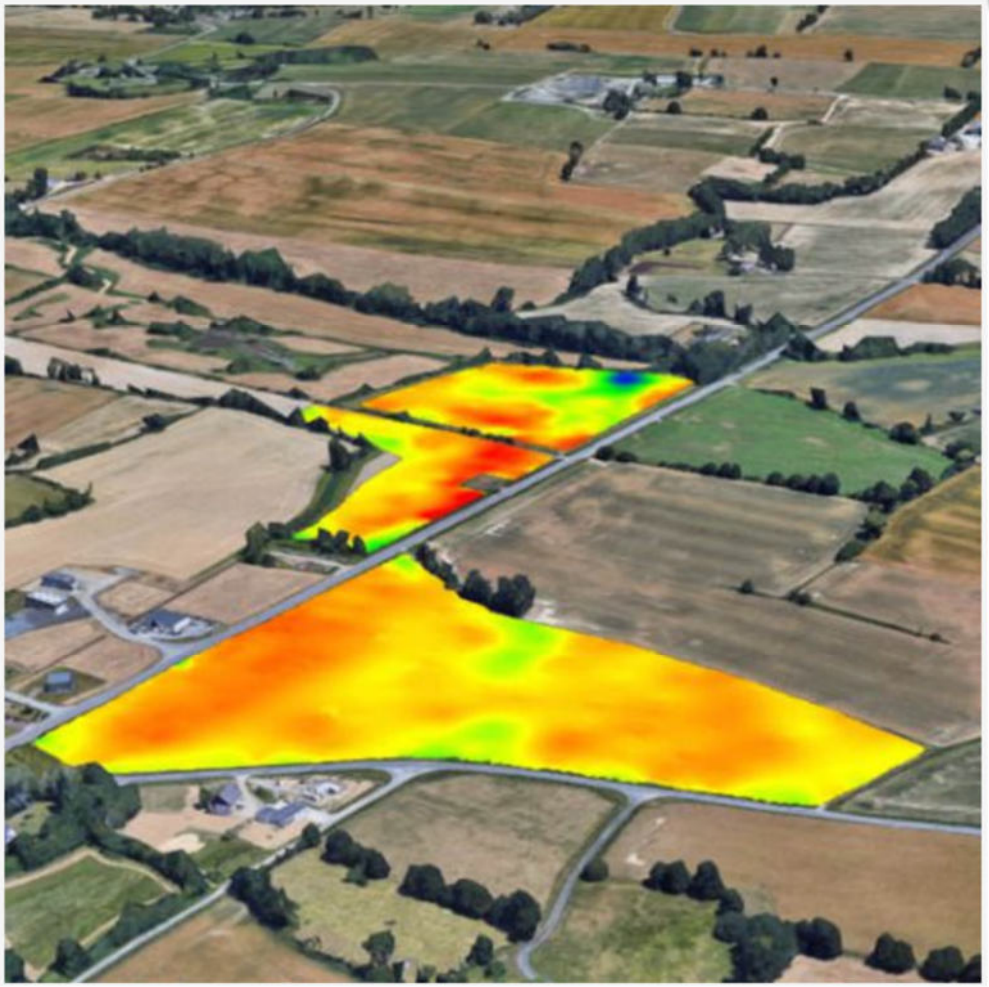
- Current Technology
- Design & Specifications of Loupe
- Ground Water Case Study
- Ground Water / Mapping Case Study

Existing Technology – EM38

EM38 frequency domain EM system for soil conductivity mapping

Specifications:

- Frequency ~145 000 Hz
- ~0.75m depth



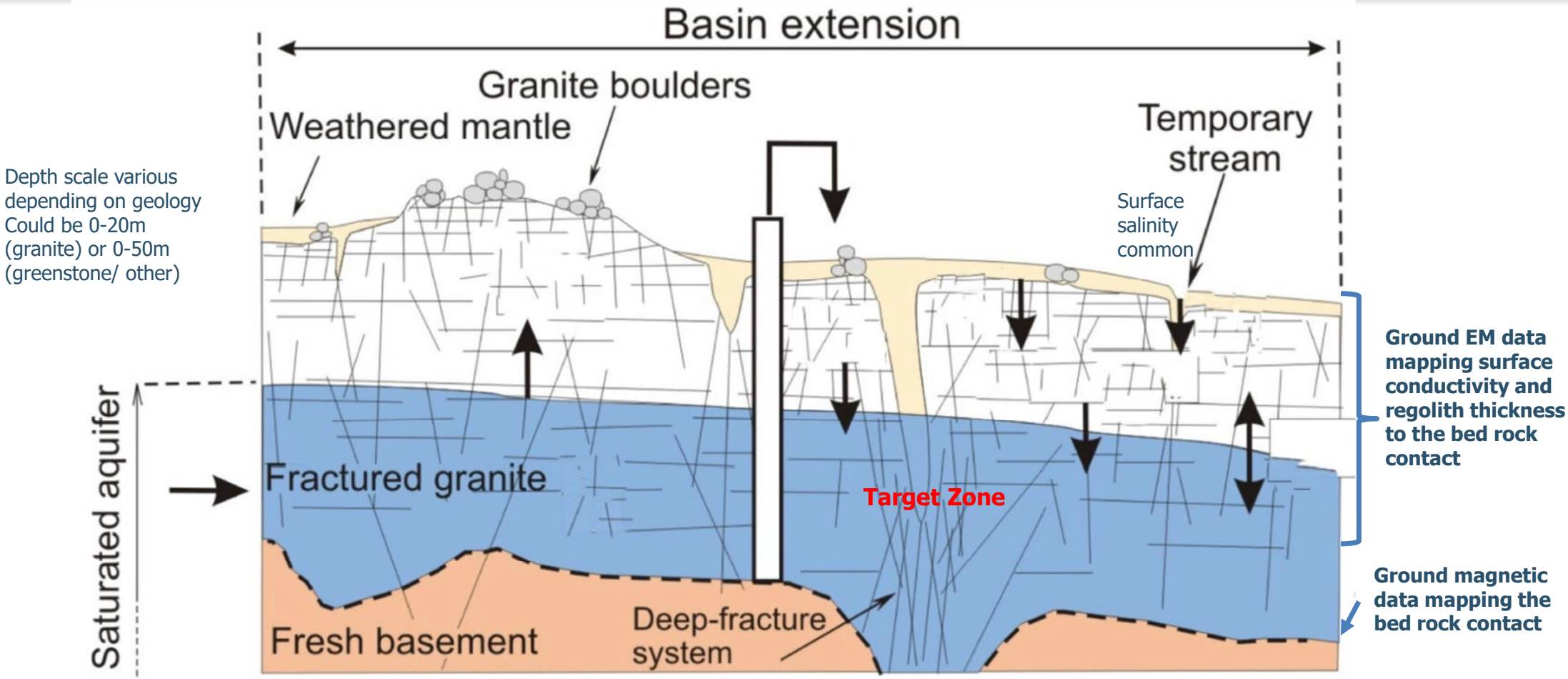
Design

- Backpacks light and comfortable so they can be worn for long periods
- Broad bandwidth measurements – low frequency (25 Hz) for good conductors, high frequency for near-surface mapping
- Full time-series collection, storage, and real-time processing / QC
- Accurate navigation and positioning
- Any kind of application where electrical conductivity is a useful physical parameter
- Terra Resources designed sled for agricultural and hydrogeological use

Specification

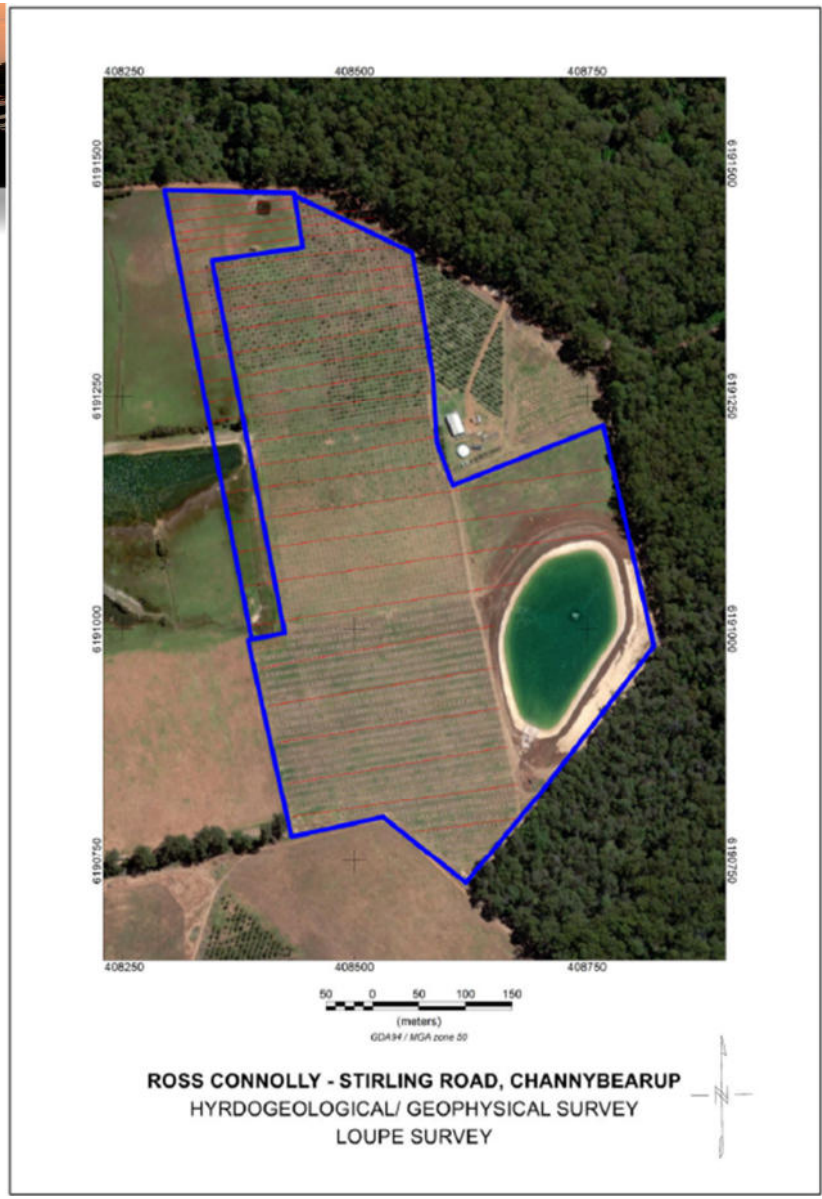
- 3-component receiver coil
- Receiver bandwidth 100 kHz
- Receiver sampling 500,000 cps
- Transmitter moment approximately 100 ATm^2
- Transmitter 50% duty cycle, switches off in 8 microseconds
- Typically, 10m tx-rx spacing
- Calibrated in approximately zero conductivity – system response well understood
- Magnetic field exposure levels to the transmitter operator are lab-tested to be below the most conservative international health guidelines

Granite Hosted Fracture Aquifers



Loupe EM Survey

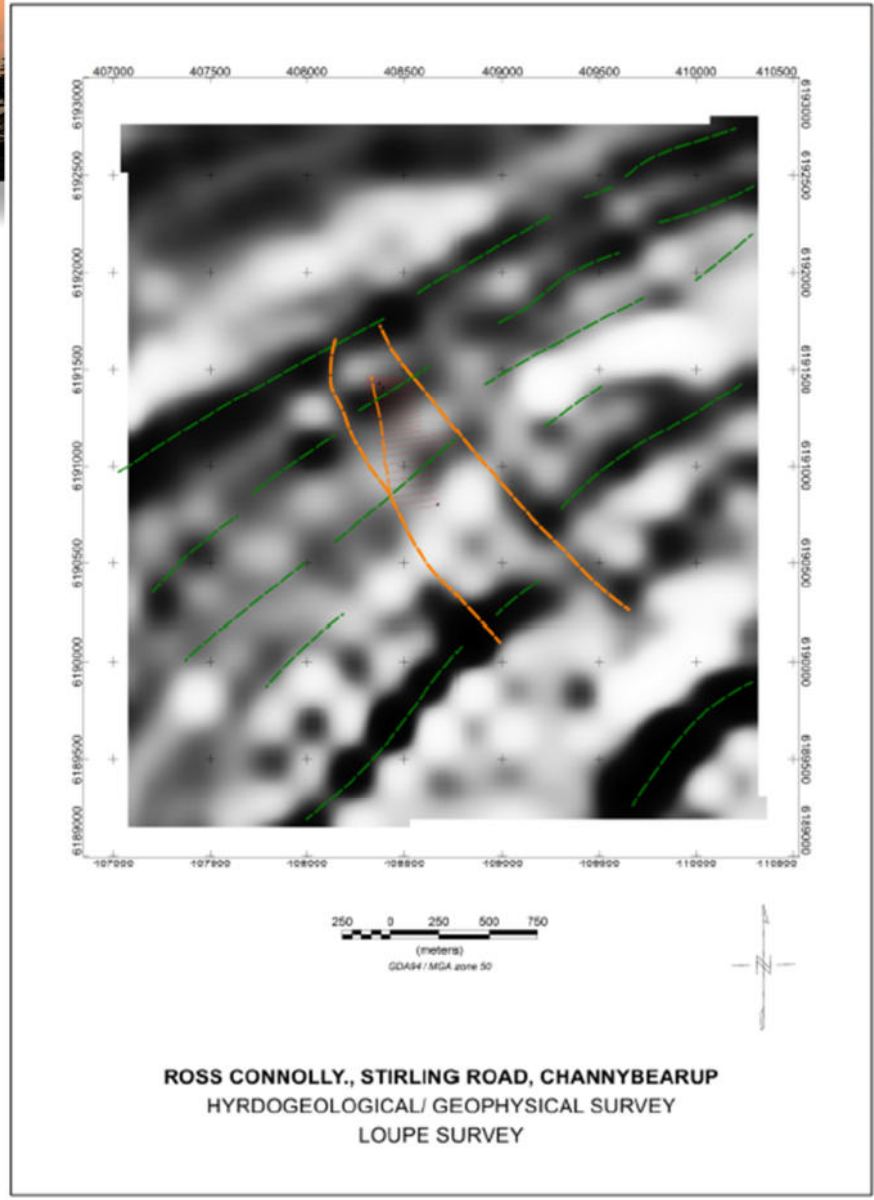
- A Loupe TEM (time-domain electromagnetic) survey was acquired over the Channybearup agricultural property (Truffles and Avocadoes) with the aim to detect additional bores to source fresh groundwater
- This involves;
  - TEM survey lines acquired perpendicular to freshwater sources
  - EMAX transform of the XZ component data to conductivity/ depth slices
  - Removal of excessive noise spikes
  - Interpretation/targeting made from resultant conductivity-depth slices and sections



Loupe EM survey- planned line paths. Blue lines are fence lines

Loupe EM Survey

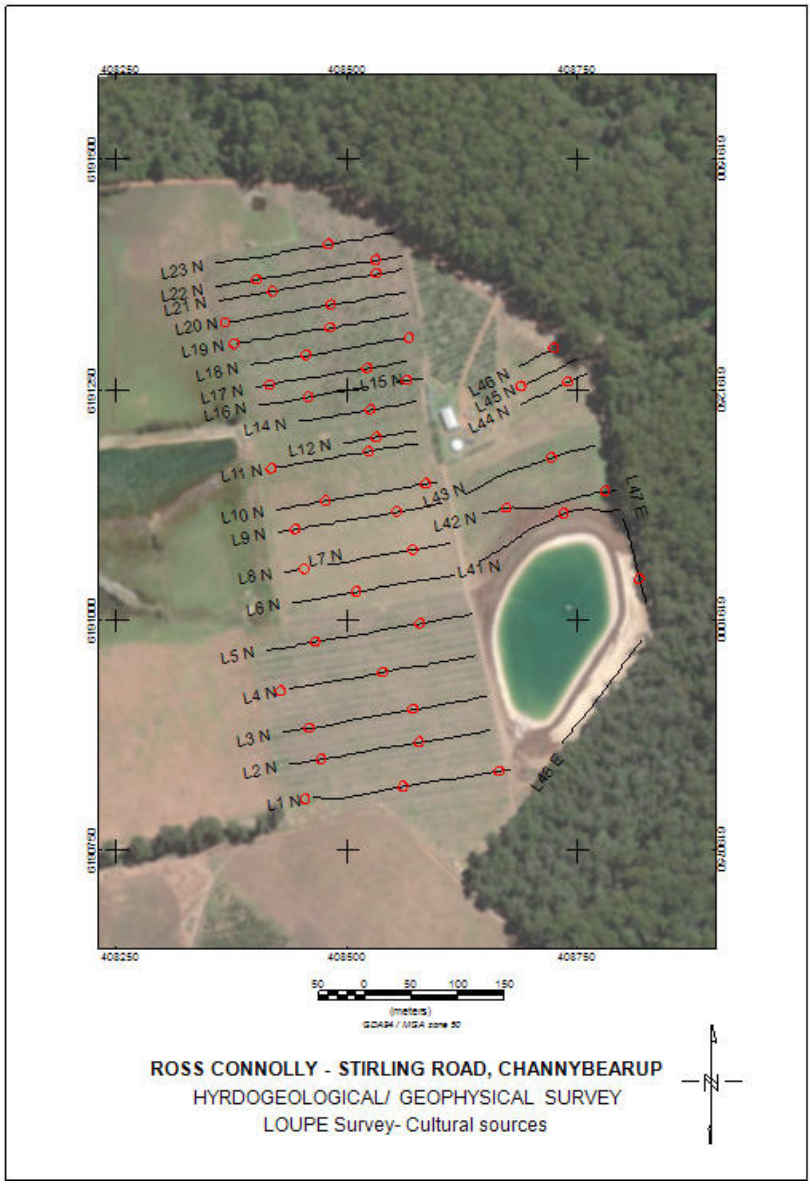
- Data collected 19/04/2024 by foot and at a base frequency of 75Hz
- Rolling hills with minimal vegetation over gneissic basement and clay bearing cover
- The regional magnetic data shows a NE-SW striking magnetic fabric (green) cross-cut by NW-SE trending faults



Regional Geology (1VD) with brief structural interpretation overlain.

Cultural Sources

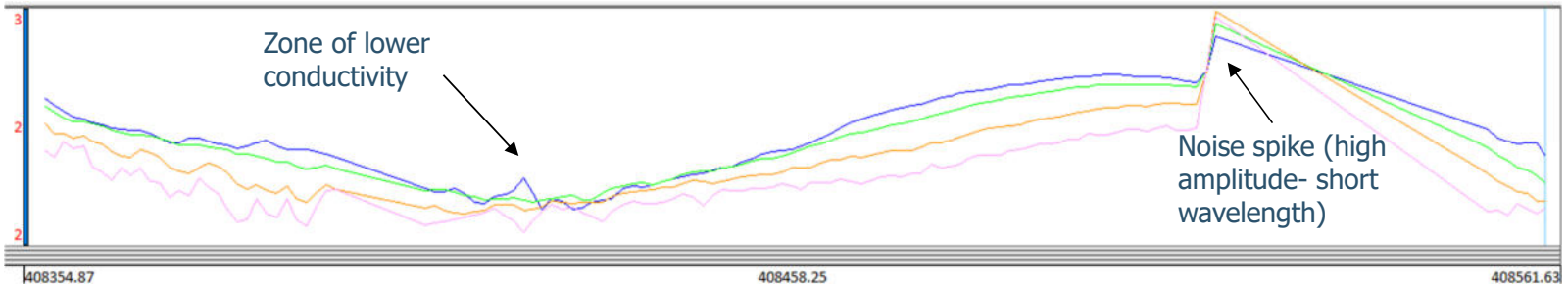
- Metal and electrical fences and metal bores
- Significant conductivity spikes are found throughout, including within fence boundaries and these are shown in the adjacent map
- Some lines were parallel to fence lines contained noise that misrepresented the landscape.
- Sections were made of all lines but noisy lines were omitted from the 3D model



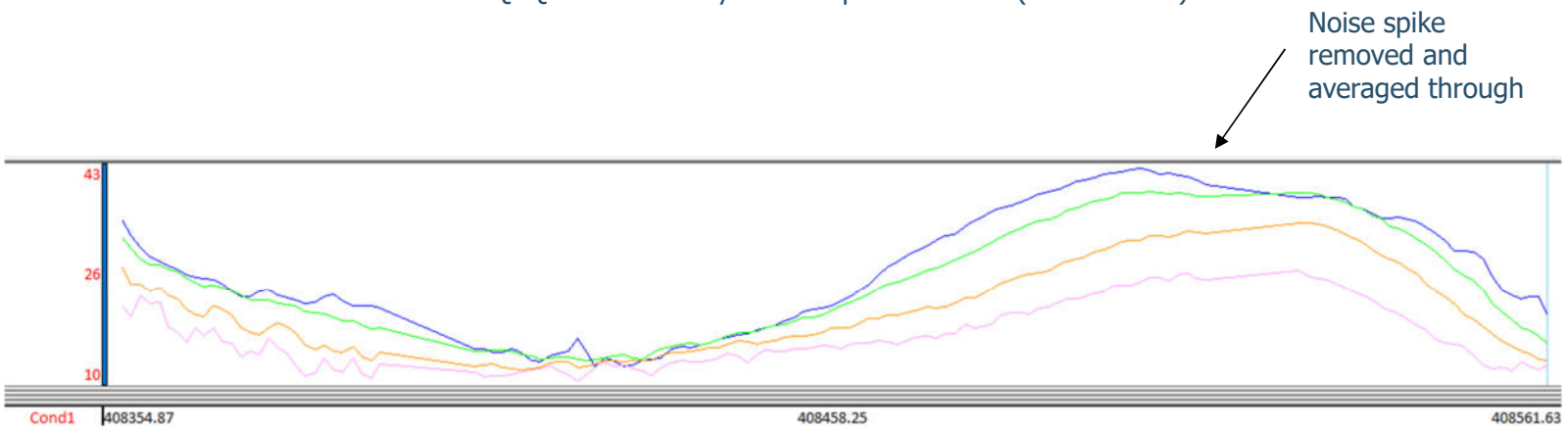
Loupe EM survey with red dots indicating noise spikes.

QA/QC Example

- Significant noise spikes were removed to improve the data quality



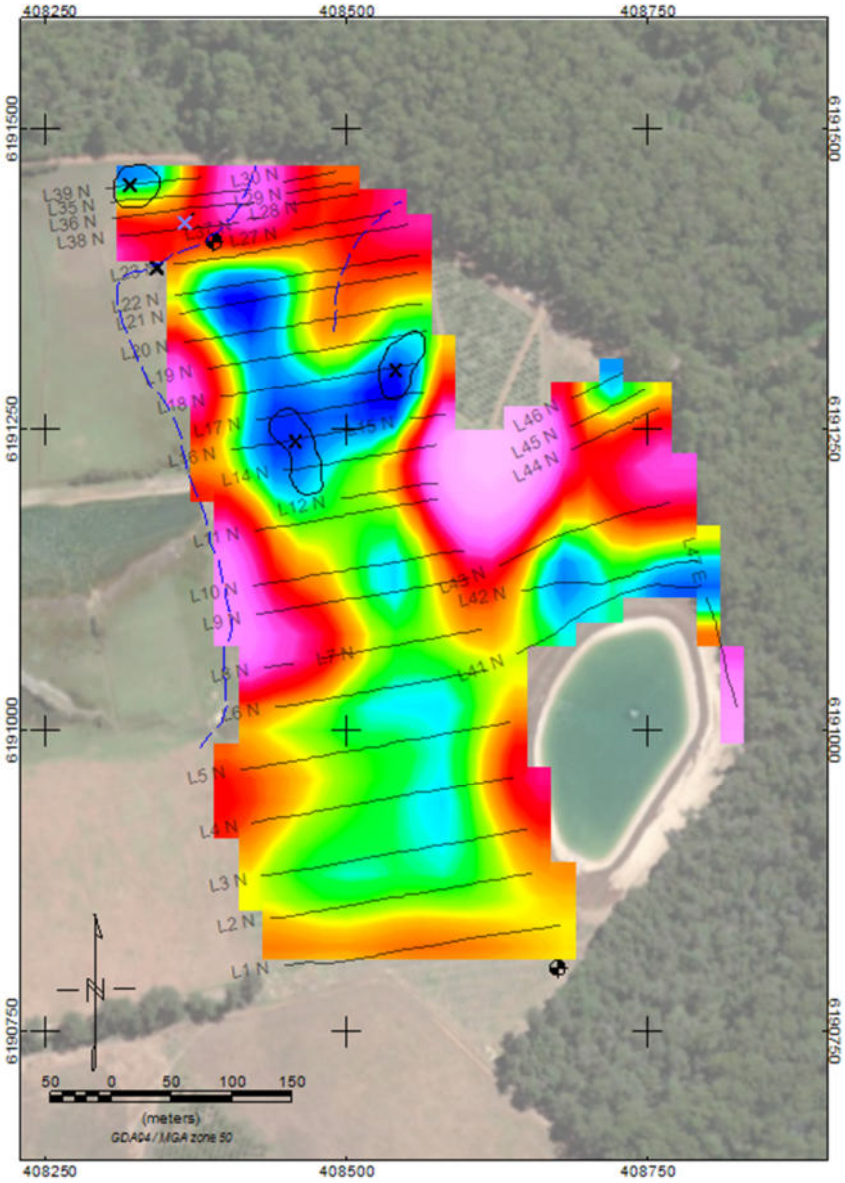
Before QAQC: Conductivity channel profile line 22 (XZ Ch 04-07)



After QAQC: Conductivity channel profile line 22 (XZ Ch 04-07)

Targeting (-20m)

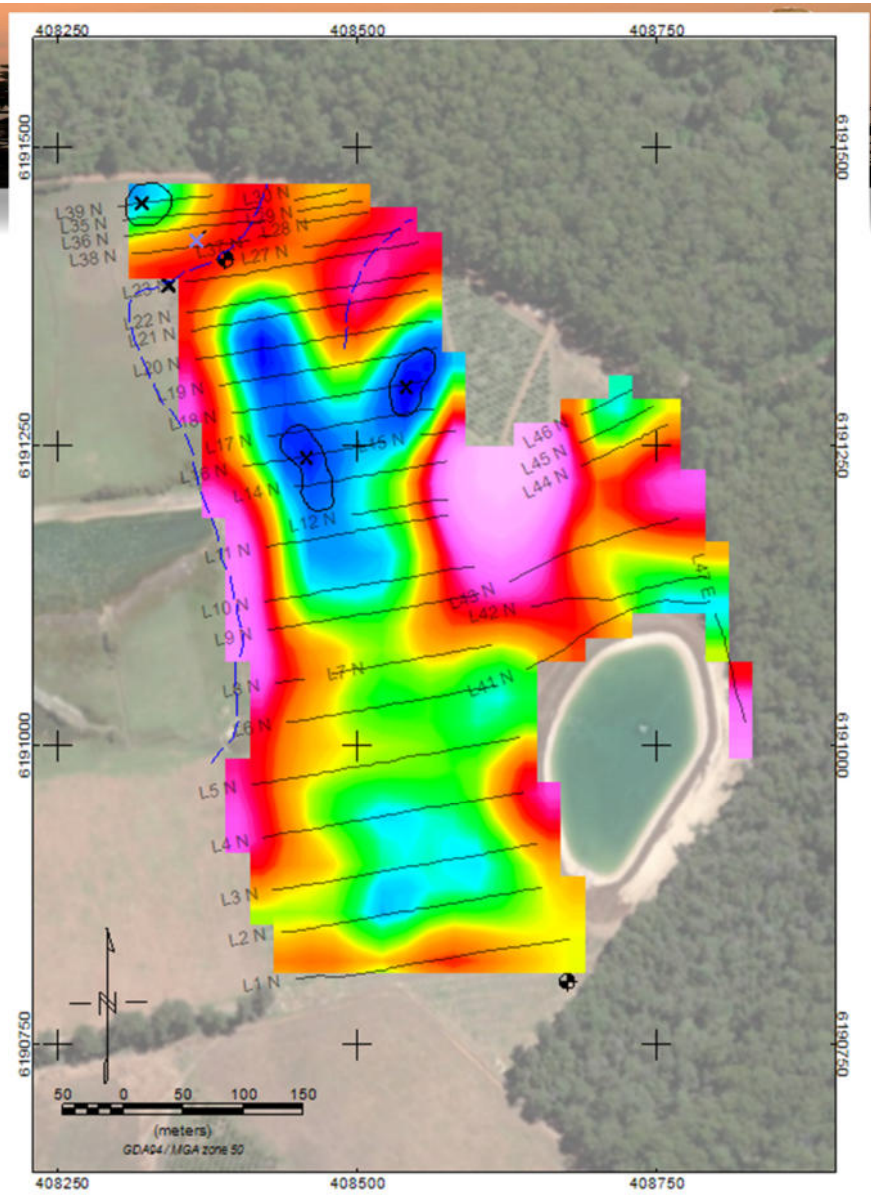
- Targets made with reference to channel amplitude maps and elevation slices derived from the EMAX transform of the XZ components
- Groundwater pathway (blue polyline) projected from conductivity highs and changes in magnetic intensity (representing faults or lithological contacts)
- North-south zone of high conductivity could reflect clay alteration along a fault zone



Conductivity-depth slice (-20m) derived from 3D modelling, with targets and projected groundwater pathways (blue)

Targeting (-30m)

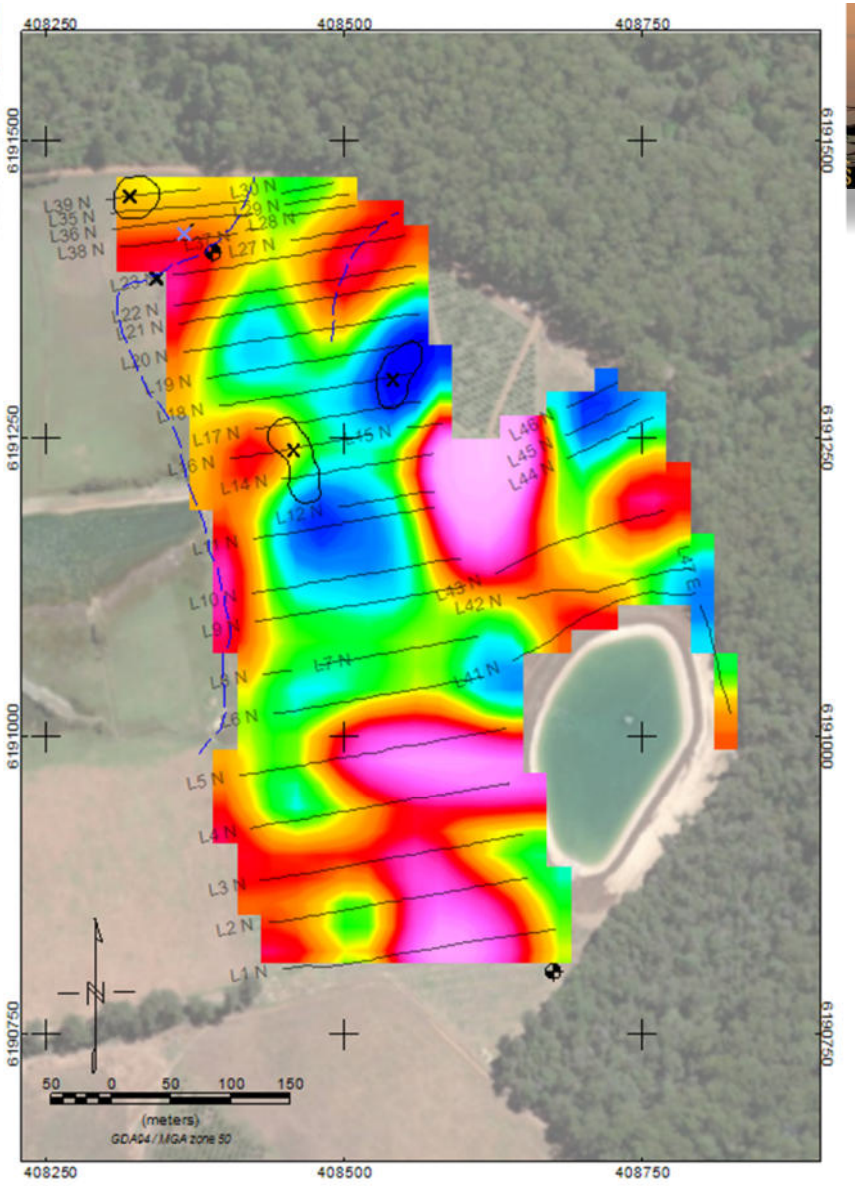
- Targets made with reference to channel amplitude maps and elevation slices derived from the EMAX transform of the XZ components
- Groundwater pathway (blue polyline) projected from conductivity highs and changes in magnetic intensity (representing faults or lithological contacts)
- North-south zone of high conductivity could reflect clay alteration along a fault zone



Conductivity-depth slice (-30m) derived from 3D modelling, with targets and projected groundwater pathways (blue)

Targeting (-40m)

- Targets made with reference to channel amplitude maps and elevation slices derived from the EMAX transform of the XZ components
- Groundwater pathway (blue polyline) projected from conductivity highs and changes in magnetic intensity (representing faults or lithological contacts)
- North-south zone of high conductivity could reflect clay alteration along a fault zone



Conductivity-depth slice (-40m) derived from 3D modelling, with targets and projected groundwater pathways (blue)

Magnetic Survey

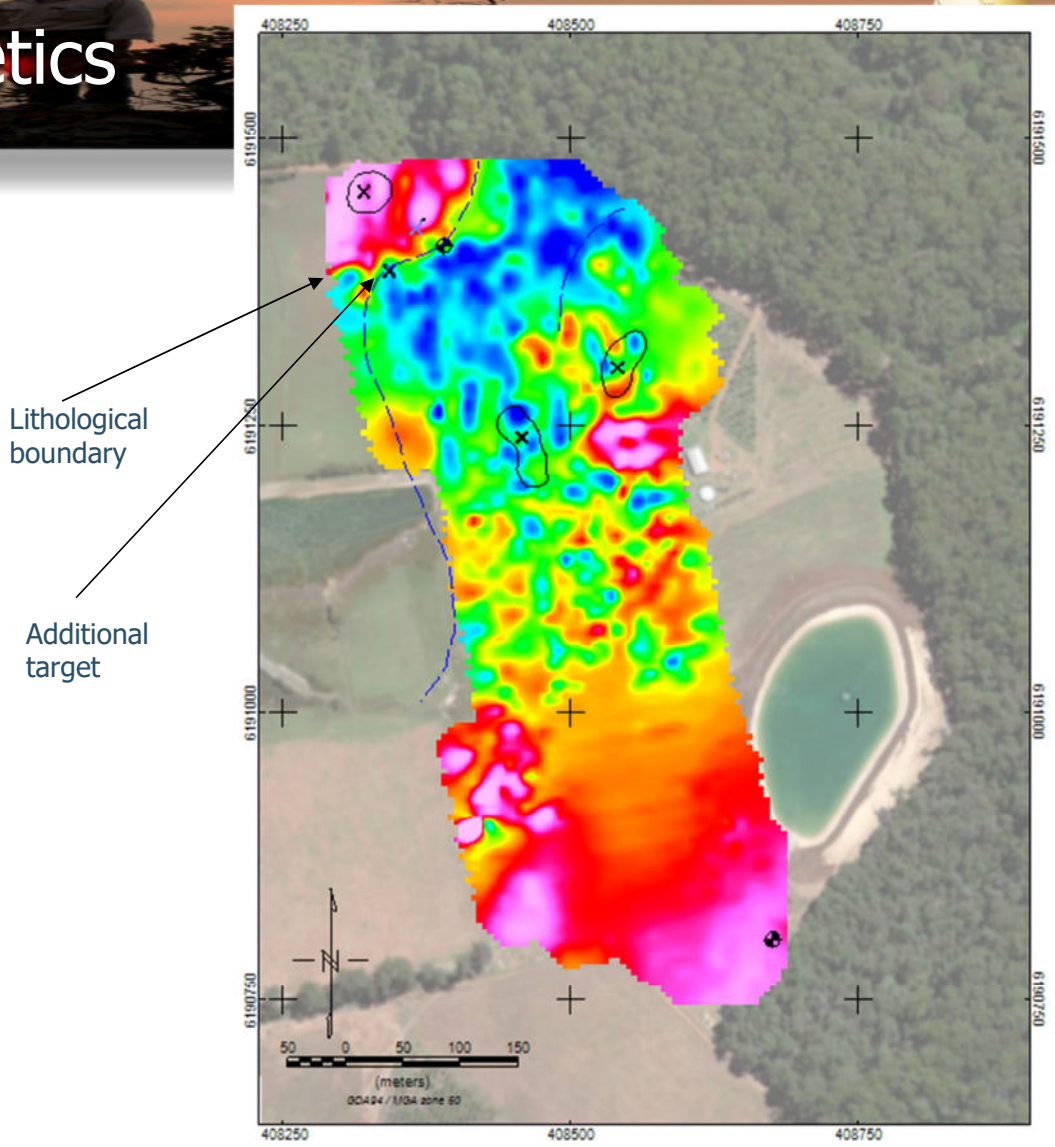
- Ground magnetic survey
- 21/05/2024
- ~EW lines with perpendicular tie lines
- ~16 line km

- Processing involves diurnal correction, QAQC and gridding of the corrected response (TMI nT)

Ground Magnetic Survey Line Paths over satellite

Additional Targeting from Magnetics

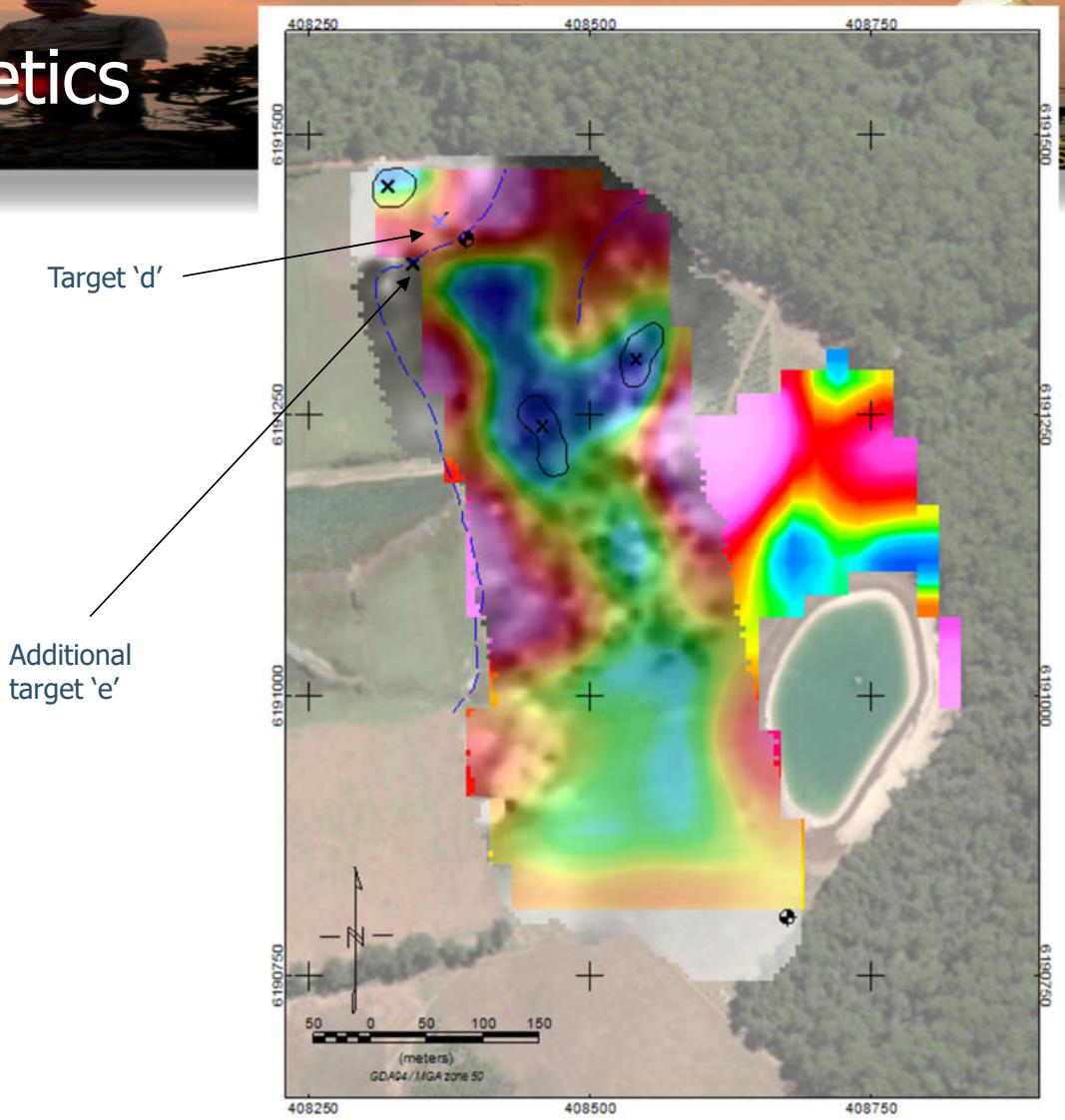
- Groundwater targeting made primarily on the EM response
- The ground magnetic data is used to supplement the interpretation
- High frequency magnetic response suggests shallow depth to bedrock
- A change in lithology is interpreted to where the magnetic response changes for high to low (gradient)
- Additional targeting along strike of a producing borehole on the granodirorite (high) contact. This zone is also coincident with a conductivity high in the EM



TMIRTP He with interpreted groundwater pathways (blue) and targets (black cross). The existing bore is shown as a circle.

Additional Targeting from Magnetics

- The additional target (target ‘e’) shows a similar EM response to the existing bore, is within a zone of similar magnetic intensity and appears to be along geological strike of the previous bore
- Another target (target ‘d’) is shown with a purple cross. This was the fourth proposed target from the EM survey



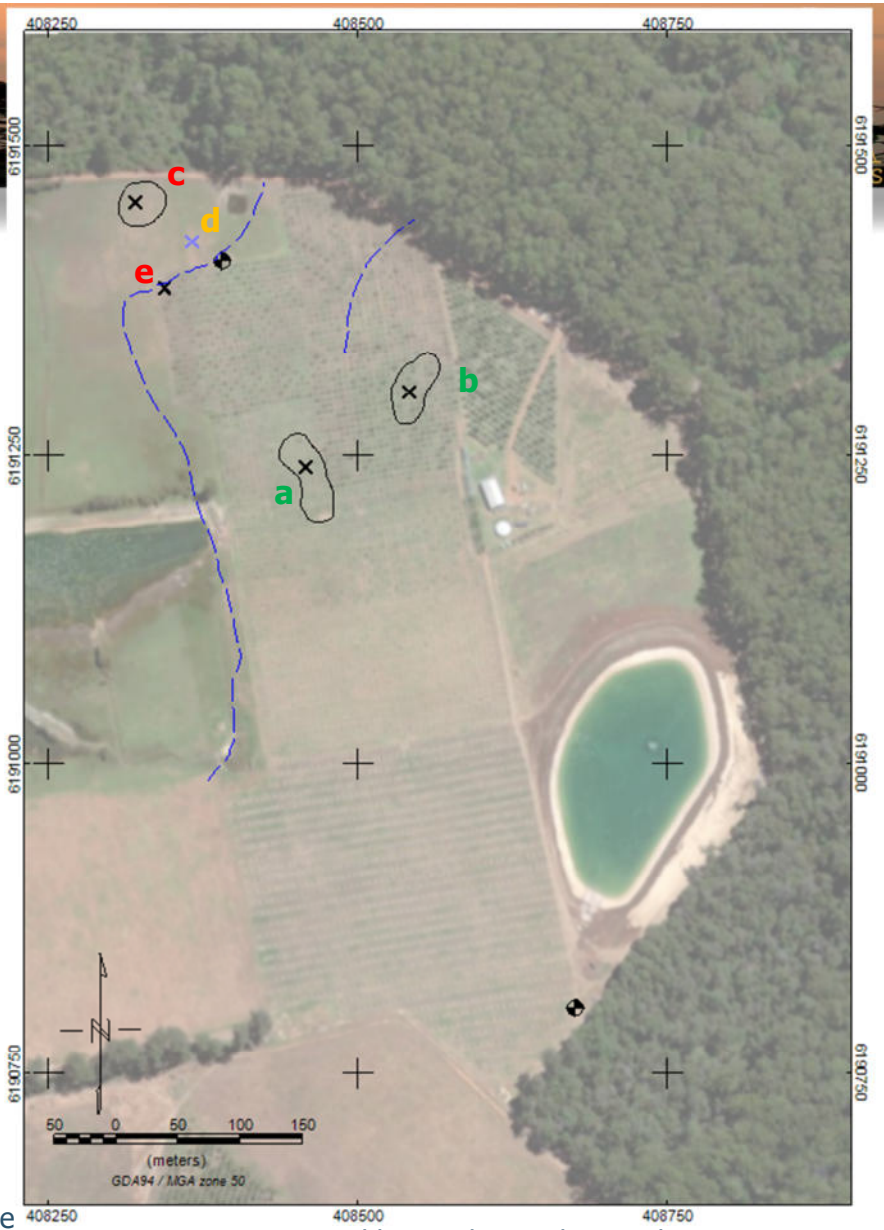
TMIRTP He (grey) overlain an EM depth slice (Z) at -20m. Interpreted groundwater pathways (blue) and targets (black cross) are shown and the existing bore is shown as a circle.

Summary of all Targets

- 3 broad zones of high resistivity at appropriate depths were targeted from the EM data alone
- An additional 2 targets were made from supplementing the existing EM data with interpretation of ground magnetics
- These targets are labelled a- e and given a priority ranking based on prospectivity potential (1 being highest/ most prospective)

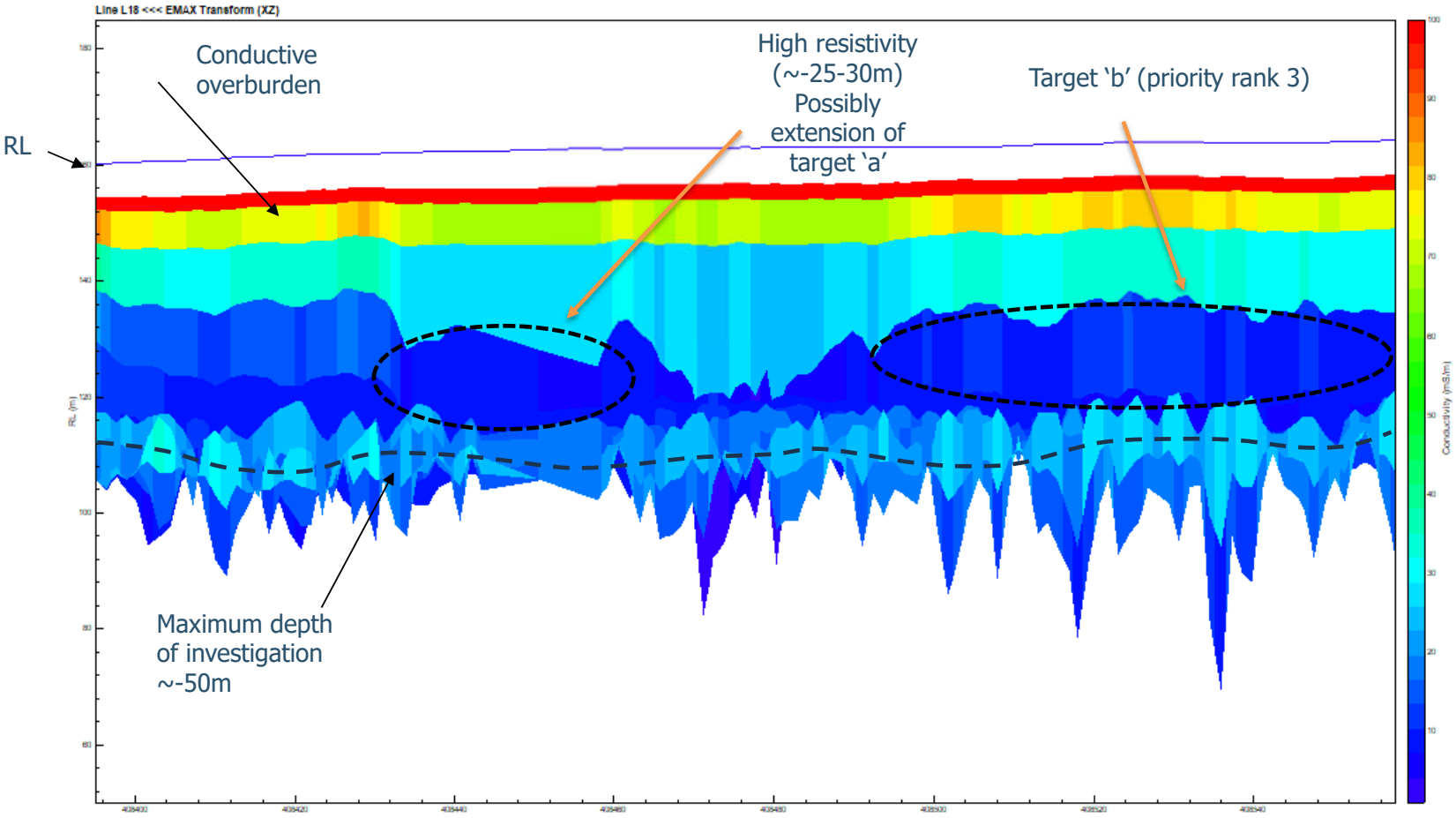
Target #	Priority Ranking	Drilling Status
a	3	No
b	3	No
c	1	Yes
d	**2**	**No**
e	**1**	**Yes**

Target number, priority and drilling status. New targets are shown in bold font.

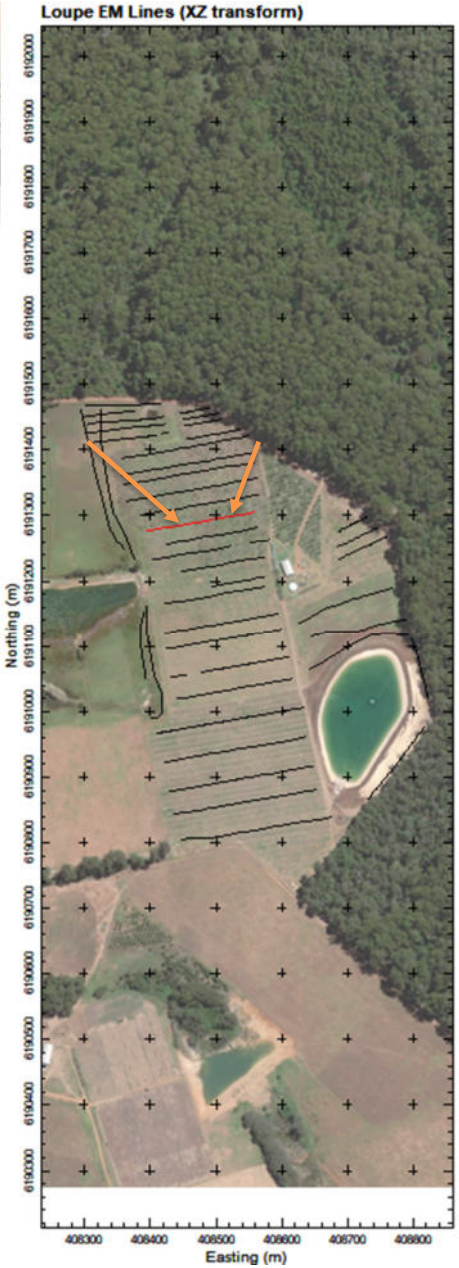


Interpretation and line paths overlain arial imagery

EM Interpretation Example: target 'b' (line 18)



Conductivity-depth section of line 18

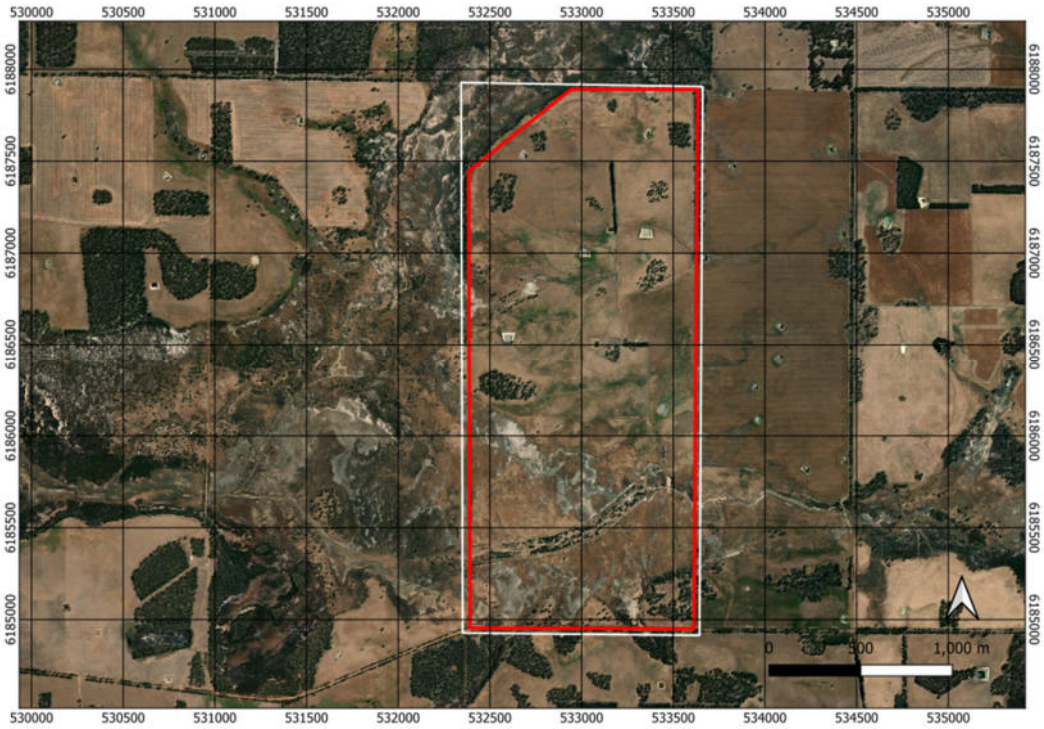


Conclusions/ Recommendations

- The maximum depth of investigation is ~-50m. Beyond this, signal becomes noisy.
- Zones of high resistivity (dark blue) may represent geological sources such as granitic bedrock but might alternatively represent fractures containing freshwater
- Increased conductivity, beyond the conductive cover, may be the result of weathering and increased clay content produced as a result of faulting and fracturing. These interconnected faults may act as groundwater pathways
- Targets from interpretation of ground magnetic data are in the form of faults, dykes and geological contacts. These appear linear/interconnected zones in magnetic gradients
- Target E was drill tested and now is a producing bore
- The recommendation is to drill target "b" for an additional bore in a different geological setting to the two know producing wells

Kendenup Overview

- Terra Resources have acquired remote sensing datasets over the Hall property near Kendenup in South West WA
- The survey boundary (red) was supplied by the client
- ASTER and Sentinel-2 datasets were processed and imaged over the extent of the white boundary which encompasses the property
- Magnetic imagery was processed using government data
- Magnetic and EM data were acquired during three days of field work on the property



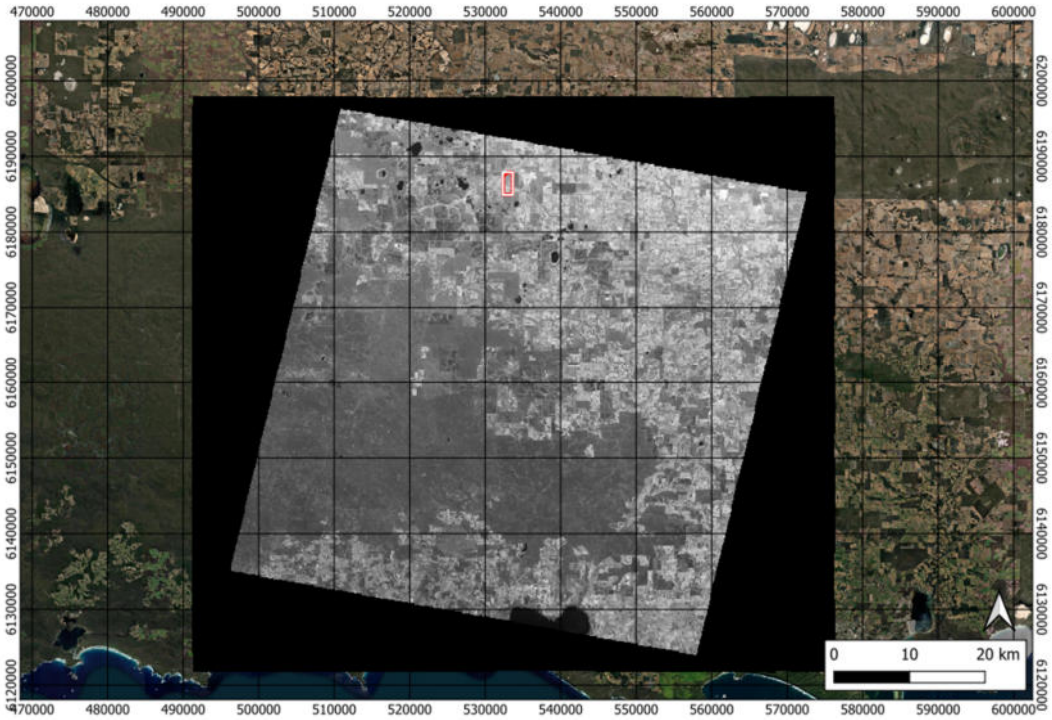
Hall property boundary (red) and the extent of ASTER and Sentinel-2 image processing (white) over satellite imagery.

Remote Sensing Processing

- ASTER
  - VNIR (15m): 3 bands
  - SWIR (30m): 6 bands
  - TIR (90m): 5 bands
- Sentinel-2
  - 10m: 4 bands
  - 20m: 6 bands
  - 60m: 2 bands

ASTER - Processing

- The following tile of ASTER data was used for processing, from 15/11/2004:
  - AST_L1T_00311152004021616_20150507013225_51763
- Workflow:
  - resampled each band to 15 m and clipped to the project area;
  - produced a series of band combinations based on recommendation by published papers

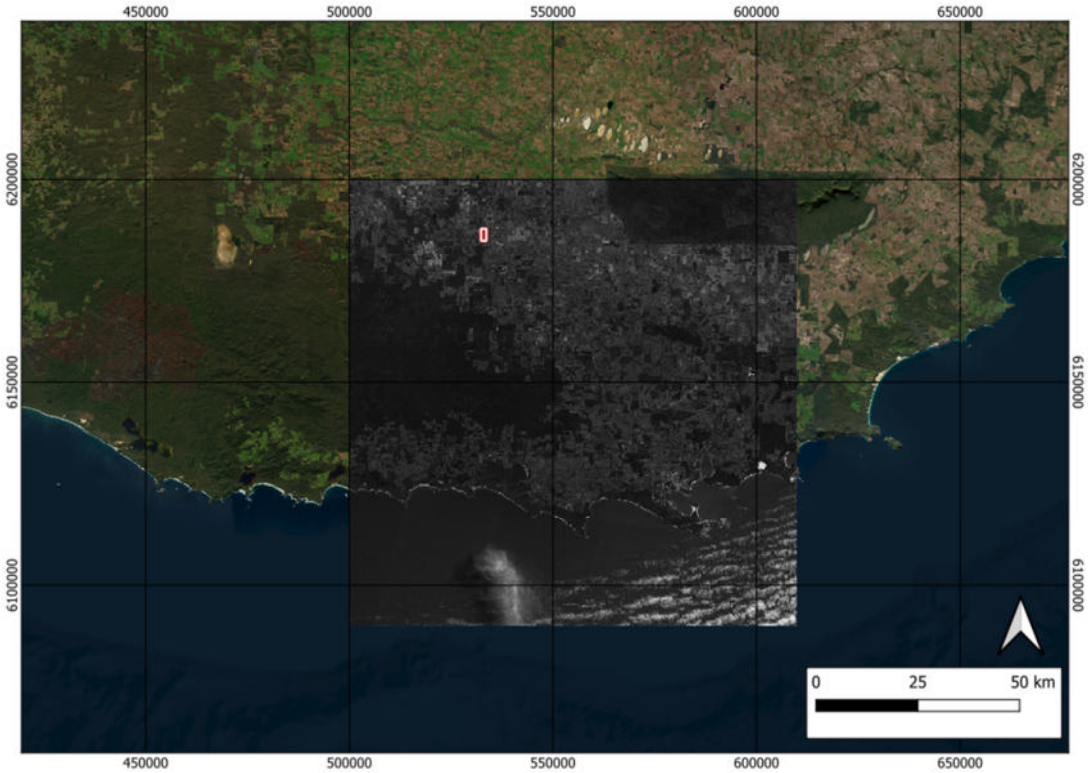


ASTER tile with property boundary(red) and processing boundary (white).

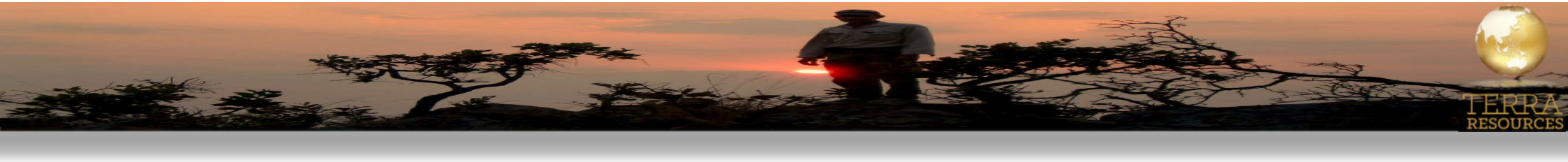
Sentinel-2 - Processing

- The following tile of Sentinel-2 data was used for processing, from 24/11/2023:
  - L1C_T50HNG_A035078_20231124T020855

- Workflow:
  - resampled each band to 10 m and clipped to the project area;
  - produced a series of band combinations based on Sentinel Hub's recommandation paper

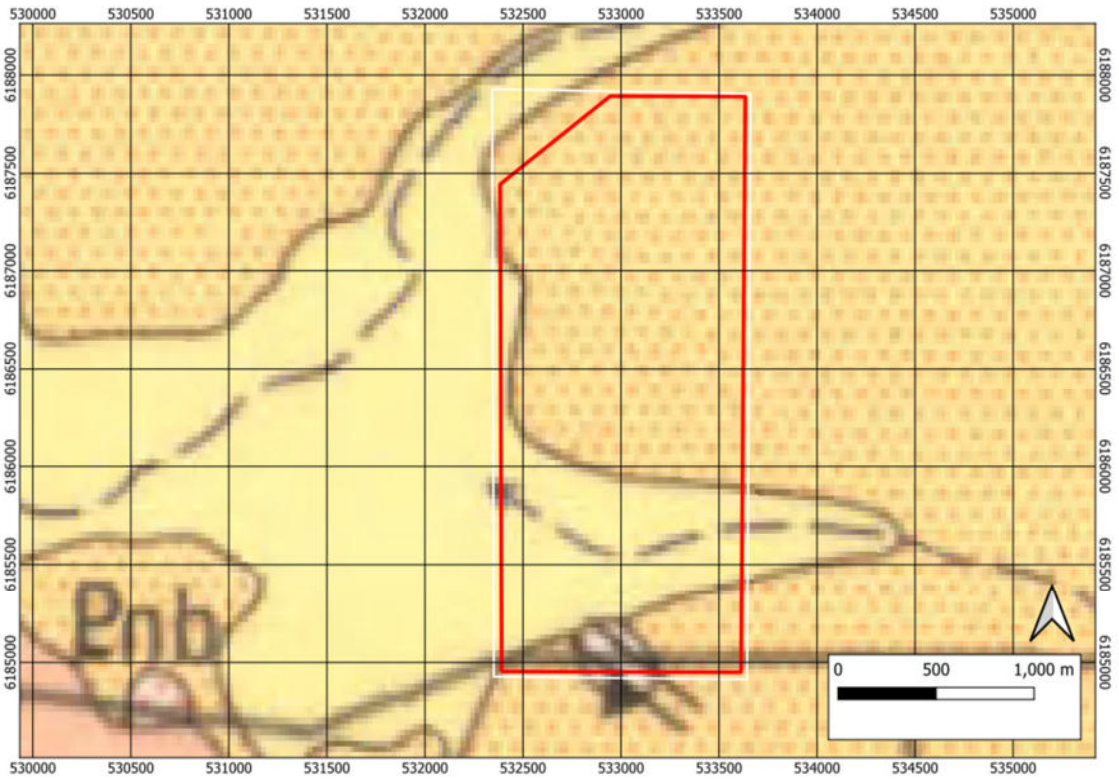


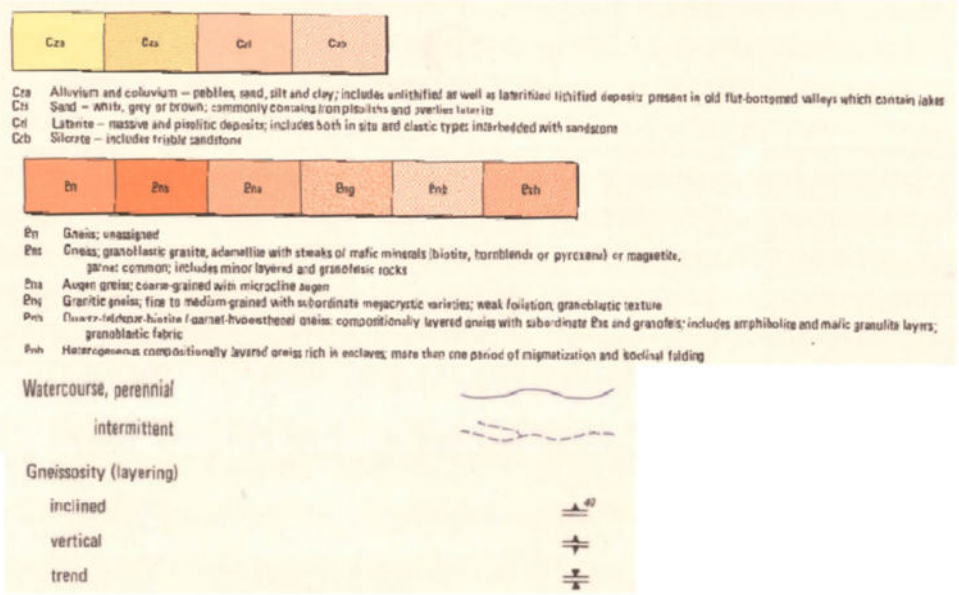
Sentinel-2 tile with property boundary(red) and processing boundary (white).



Analysis

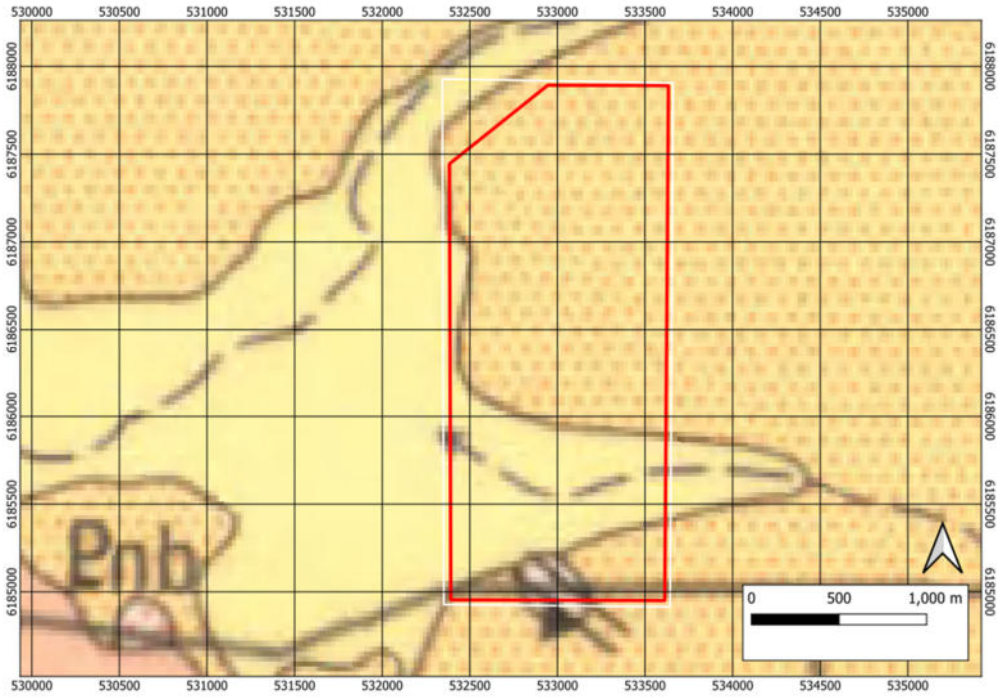
Geology



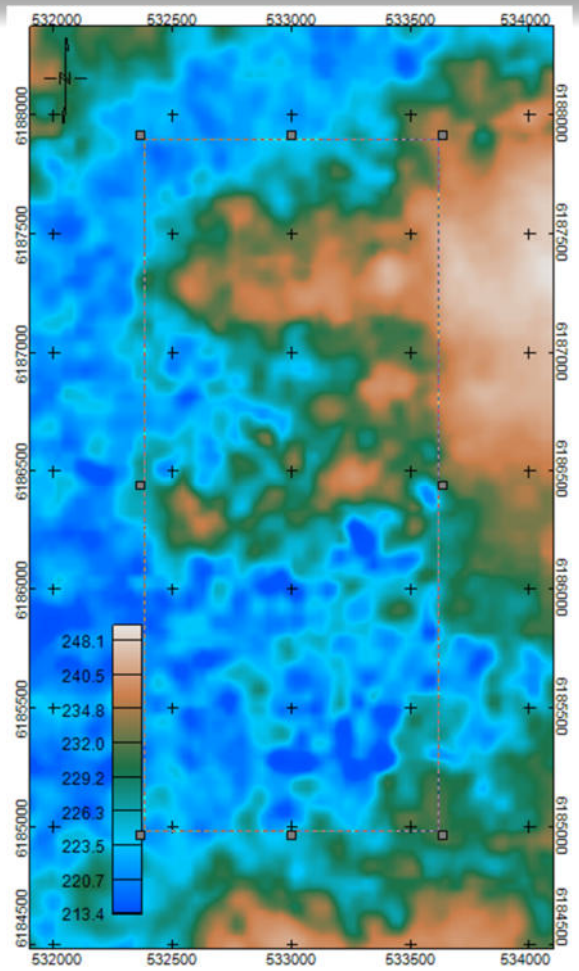


Property boundary (red) and processing boundary (white) overlaid on 250 K geological map (from GSWA).

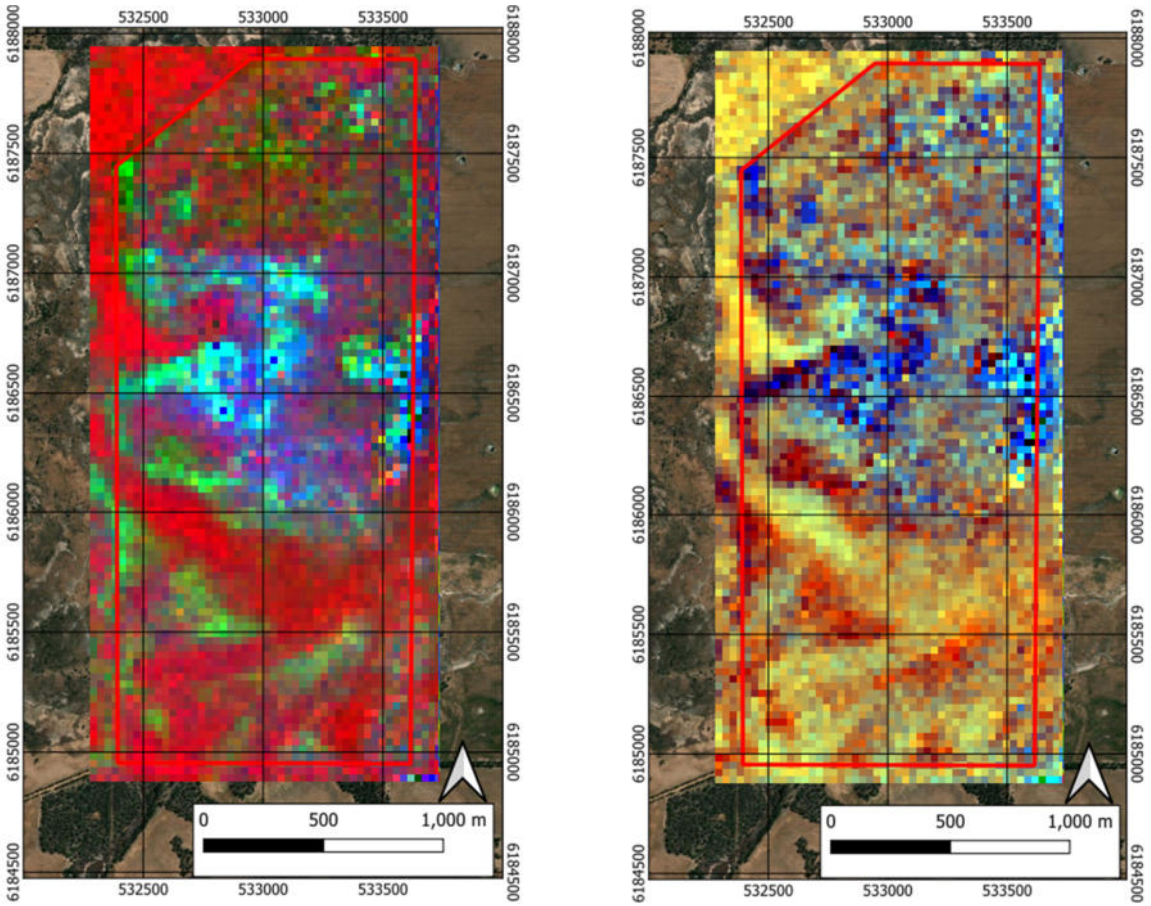
Geology and Satellite Topography (SRTM) Data



Property boundary (red) and processing boundary (white) overlaid on 250 K geological map (from GSWA).



ASTER Imagery



Left: clay-amphibole-laterite, right: AlOH minerals

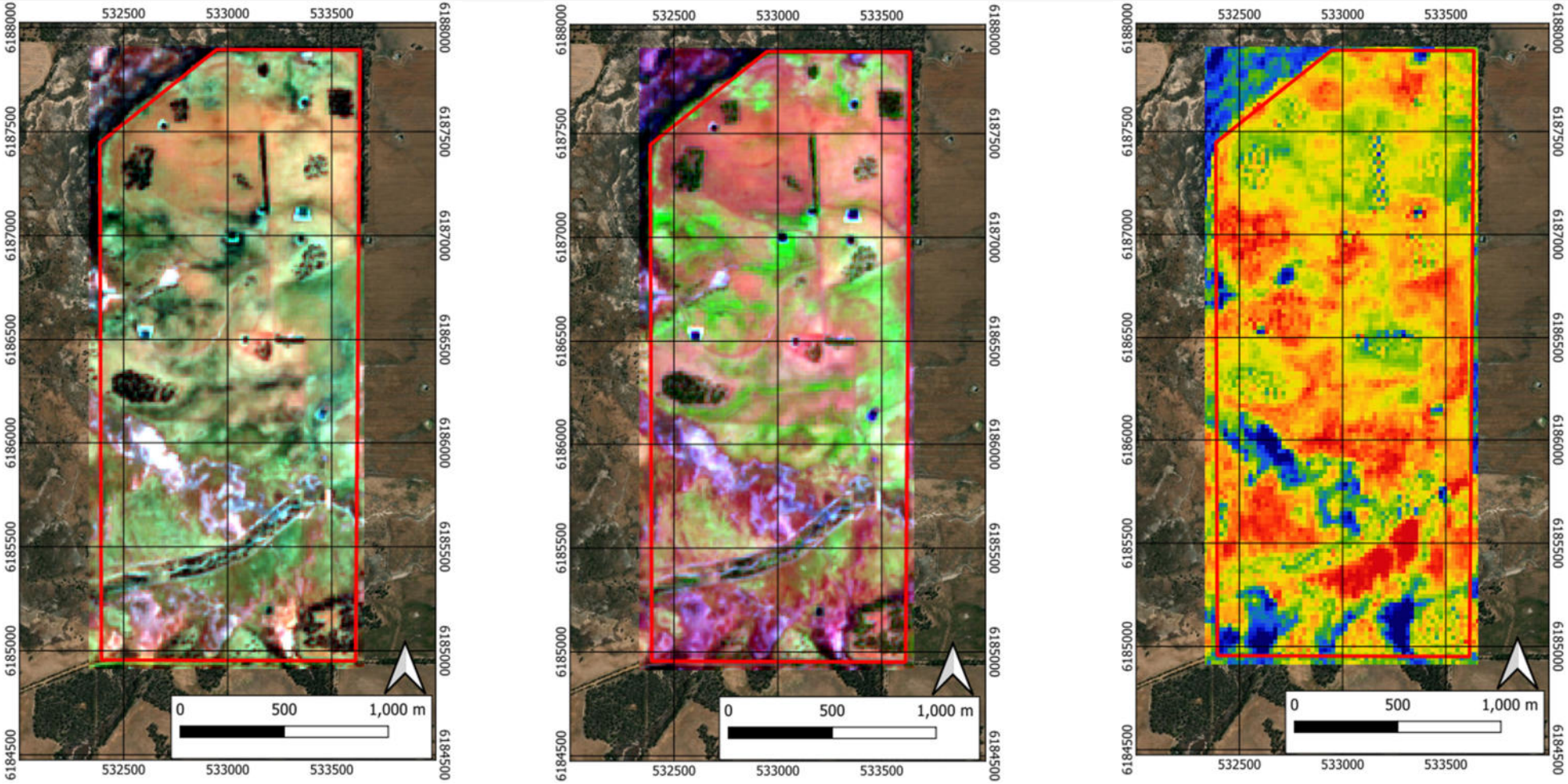
Clay-Amphibole-Laterite

- Red band = clay, green band = amphibole, blue band = laterite

AlOH Minerals

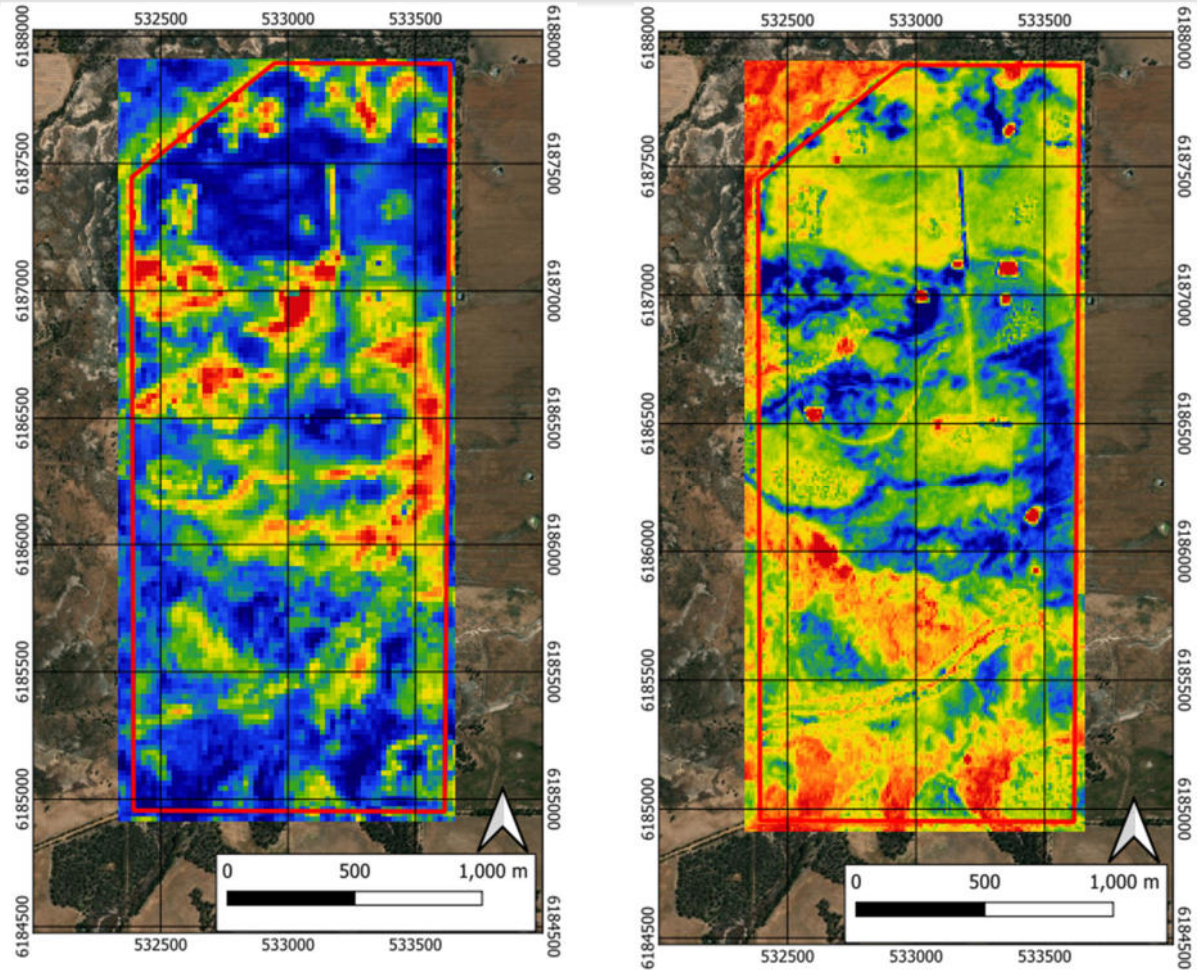
- Red band = phengite, green band = muscovite, blue band = kaolinite

Sentinel 2 Imagery



Left: geology; middle: agriculture; right: laterite alteration

Sentinel 2 Imagery



Left: moisture index, right: normalised difference water index (NDWI)

Moisture Index

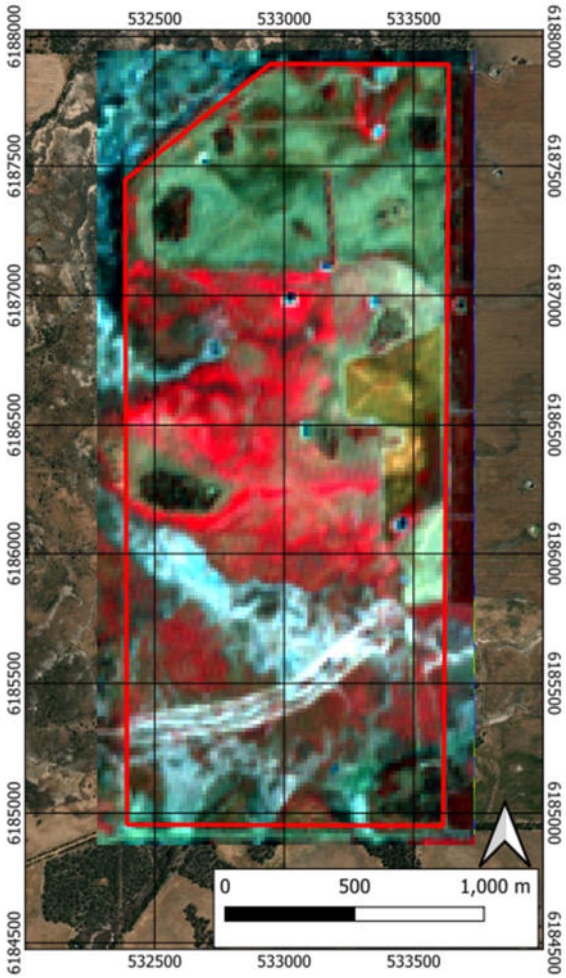
- Measures moisture content of vegetation
- High (red) values = no water stress

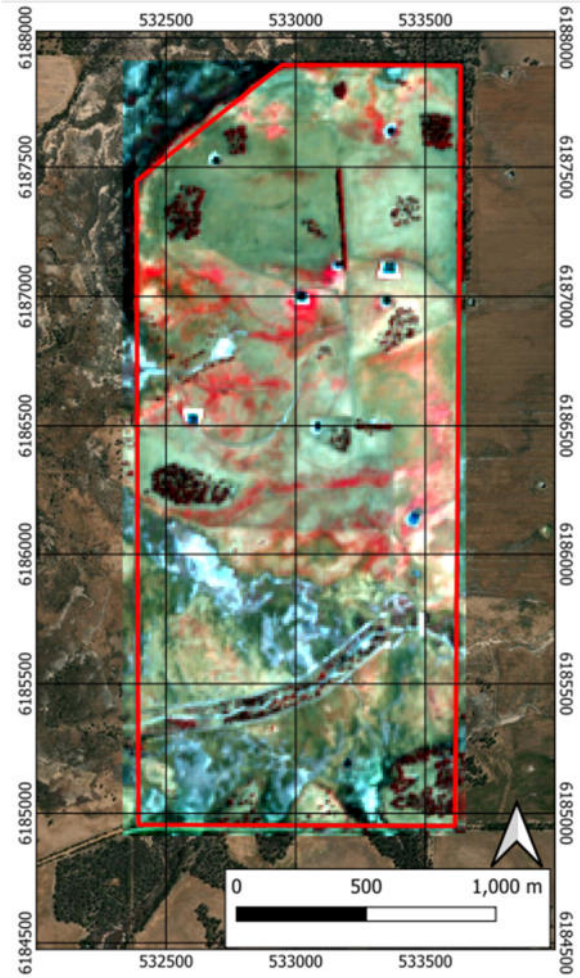
Normalised Difference Water Index

- Identifies water bodies

NDWI is used primarily to determine boundaries between land and water, whilst the moisture index indicates vegetation moisture content

Vegetation





ASTER (left) and Sentinel-2 (right) vegetation tiles side by side

Vegetation

- Helps interpret the amount of green vegetation cover
- Red = high content

Both tiles taken from November (ASTER in 2004 and Sentinel in 2023)

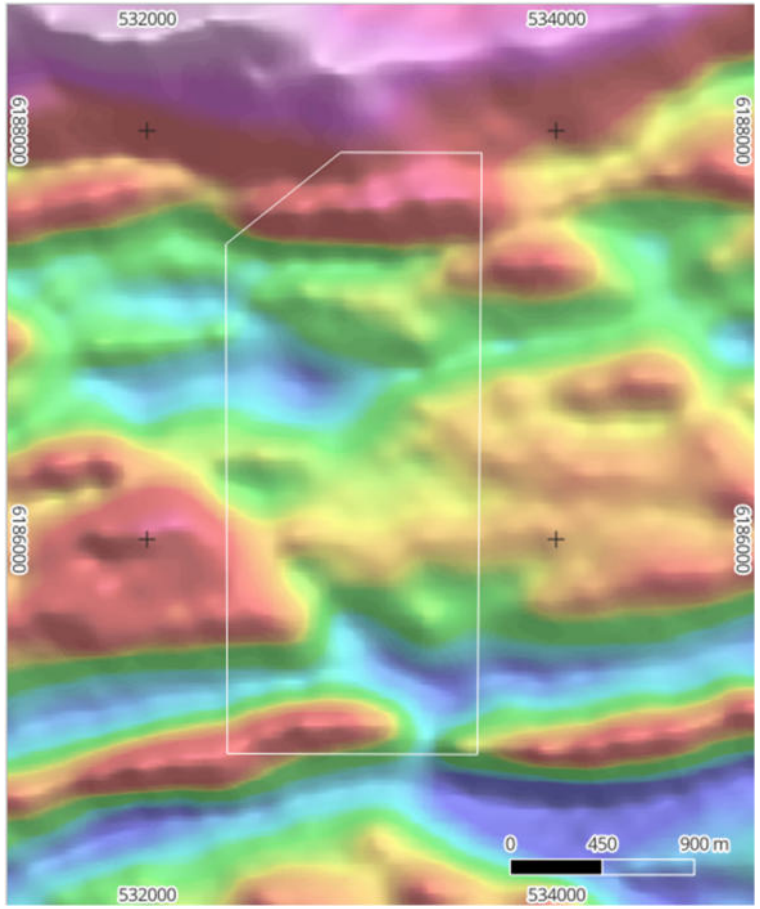
Seasonality has an effect on green vegetation content

Regional Airborne Magnetics and Ground Magnetics

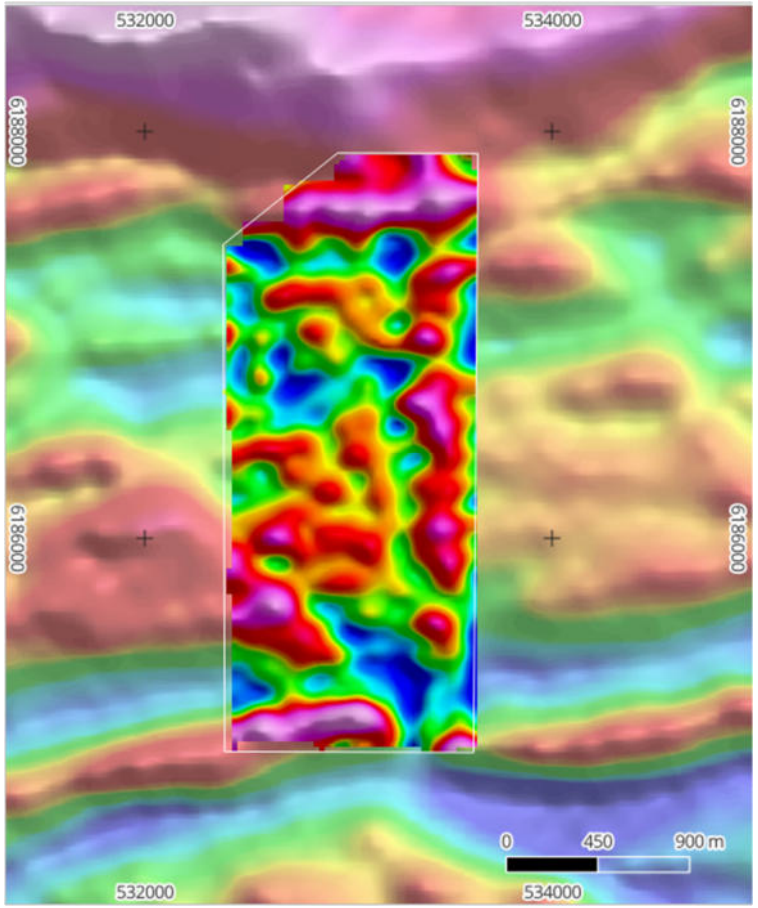
- Ground magnetic survey
- 2/02/2025
- ~NS lines with perpendicular tie lines
- ~19 line km

- Processing involves diurnal correction, QAQC and gridding of the corrected response (TMI nT)

Regional Mag



Detail mag over Regional Mag

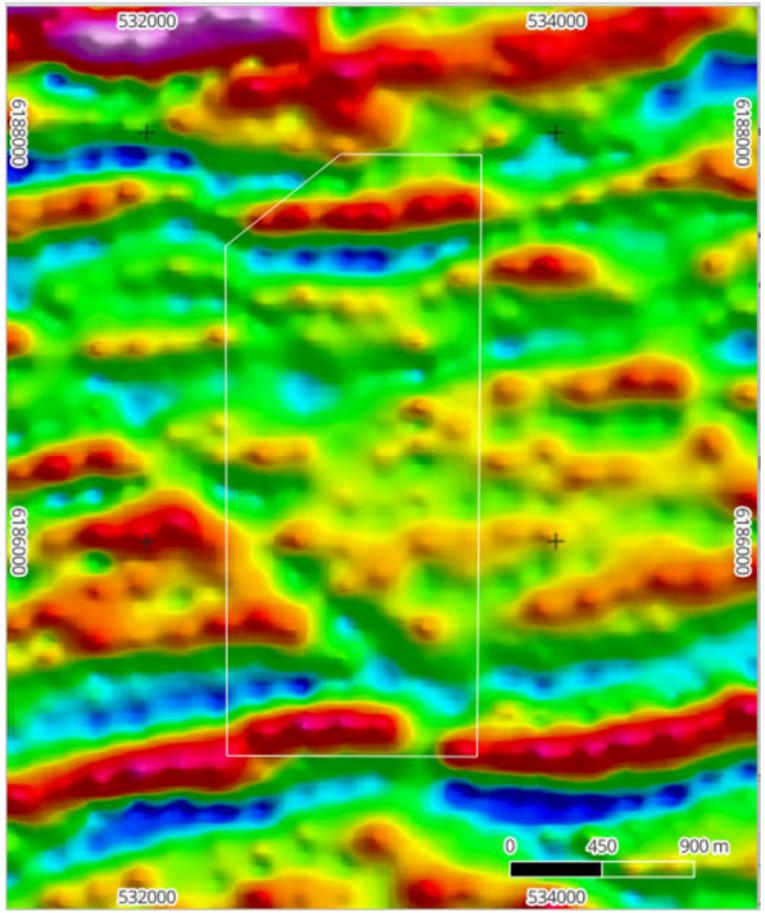


Regional Airborne Magnetics and Ground Magnetics

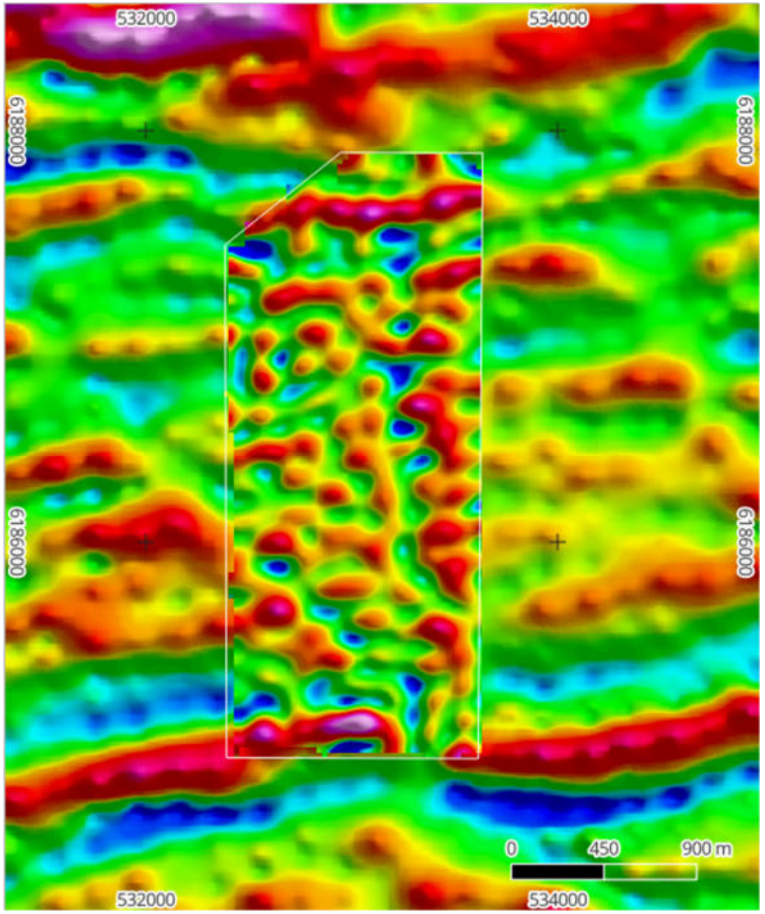
- Ground magnetic survey
- 2/02/2025
- ~NS lines with perpendicular tie lines
- ~19 line km

- Processing involves diurnal correction, QAQC and gridding of the corrected response (TMI nT)
- 1VD high frequency filter

Regional Mag 1VD



Detail mag 1VD over Regional Mag 1VD

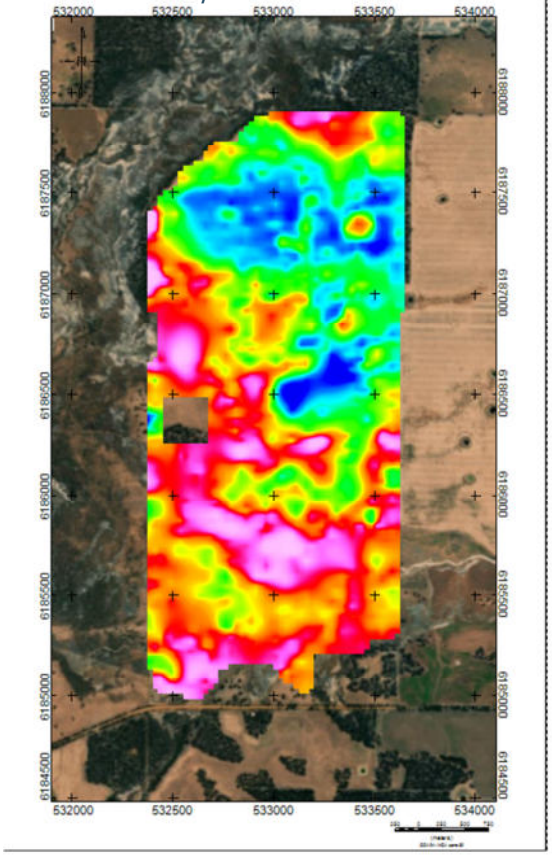


Loupe survey lines

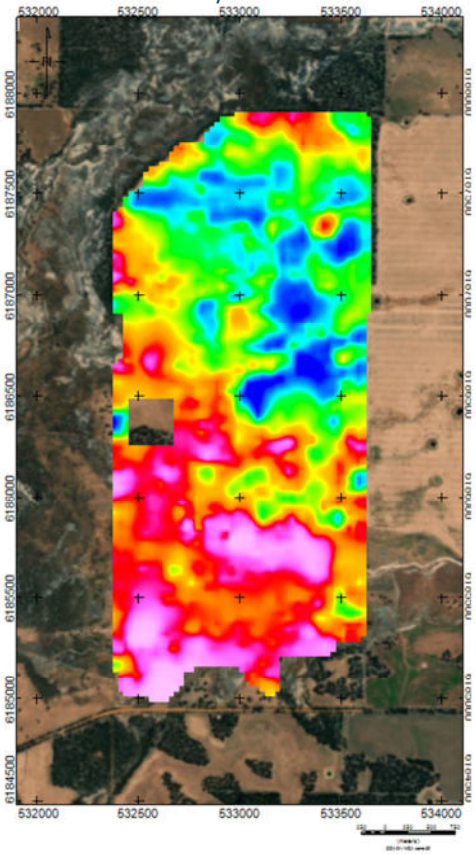
- A Loupe TEM (time-domain electromagnetic) survey was acquired over the Kendenup agricultural property with the aim to to source fresh groundwater
- This involves;
  - TEM survey lines acquired perpendicular to current drainage and best access to paddock
  - Removal of excessive noise spikes
  - Preliminary time channel and depth slices showing high amplitude (conductivity)

Loupe amplitude images

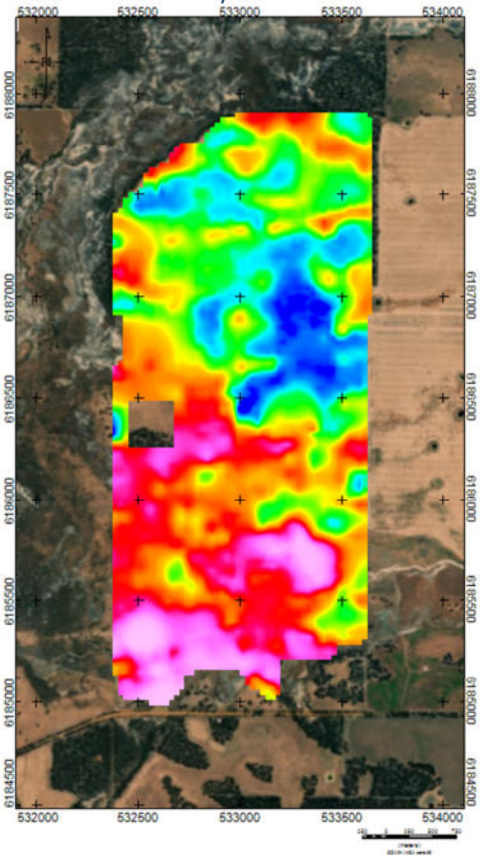
dB/dt Z CH5



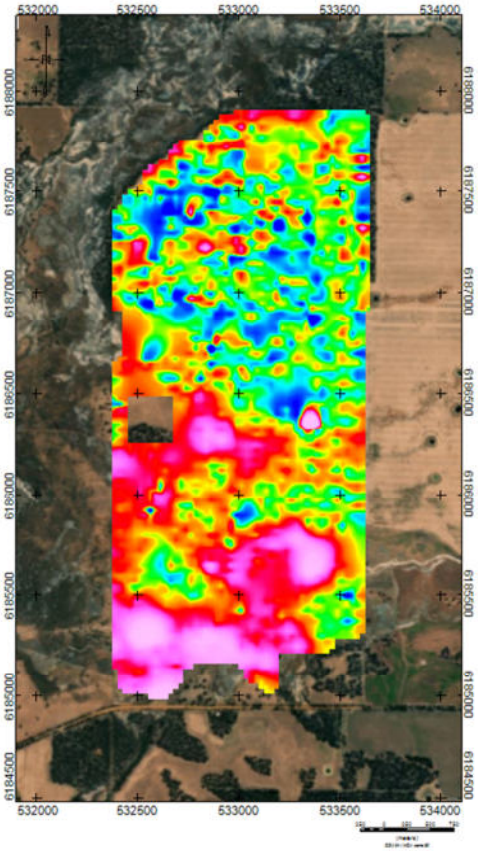
dB/dt Z CH10



dB/dt Z CH15

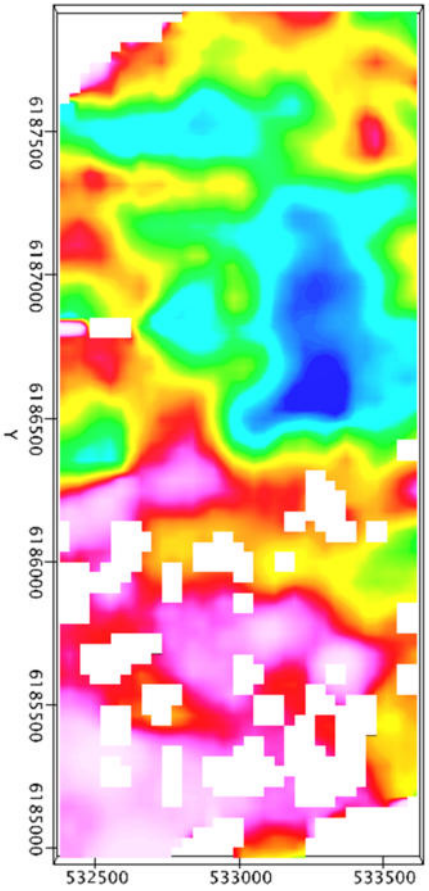


dB/dt Z CH20

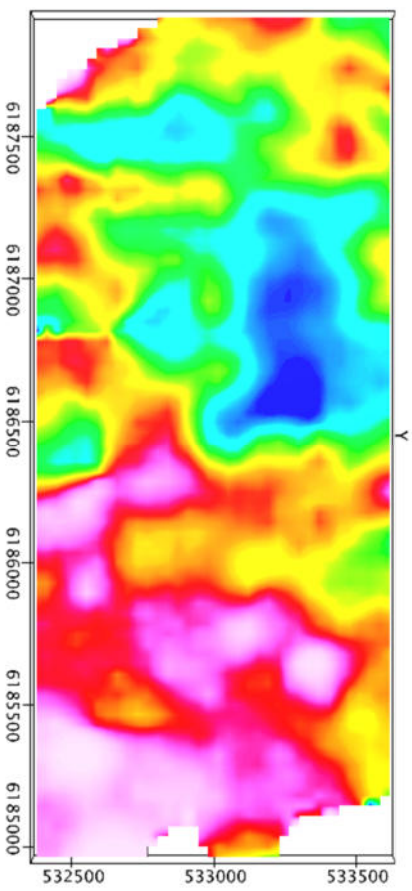


Loupe Emax CDI depth slices

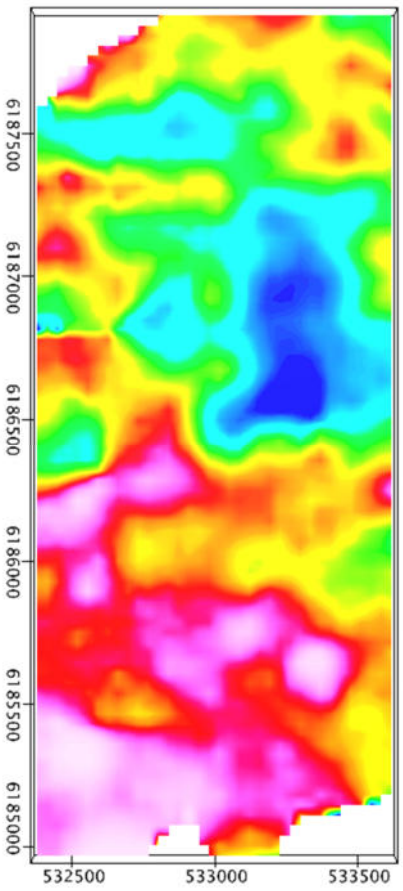
Depth slice at 220RL



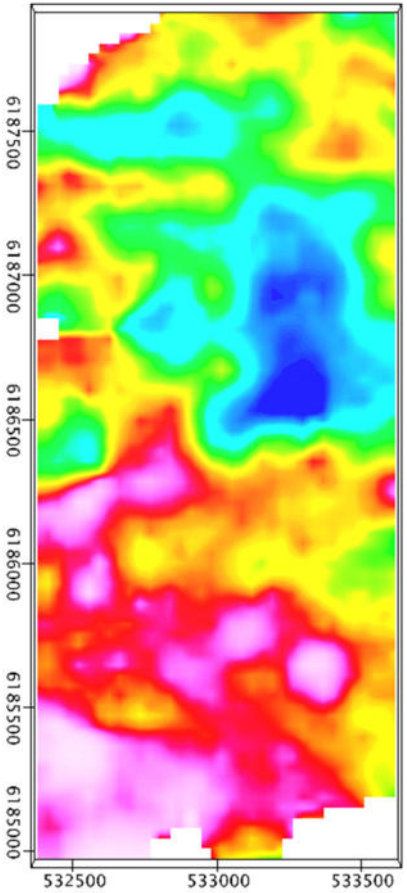
Depth slice at 210RL



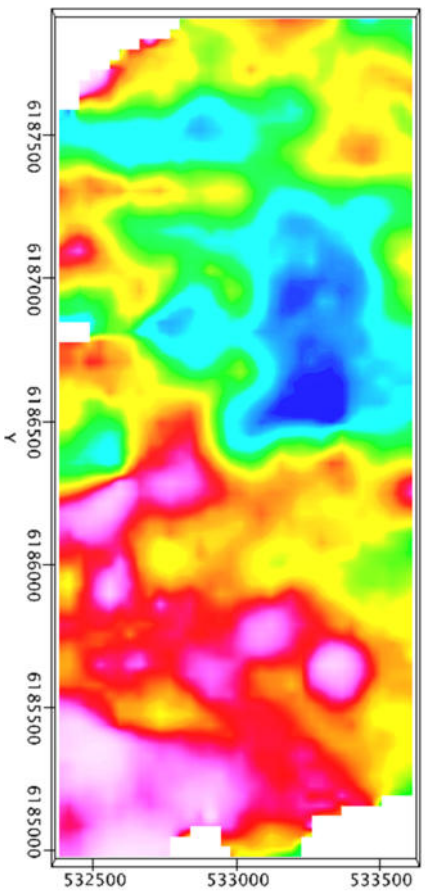
Depth slice at 200RL



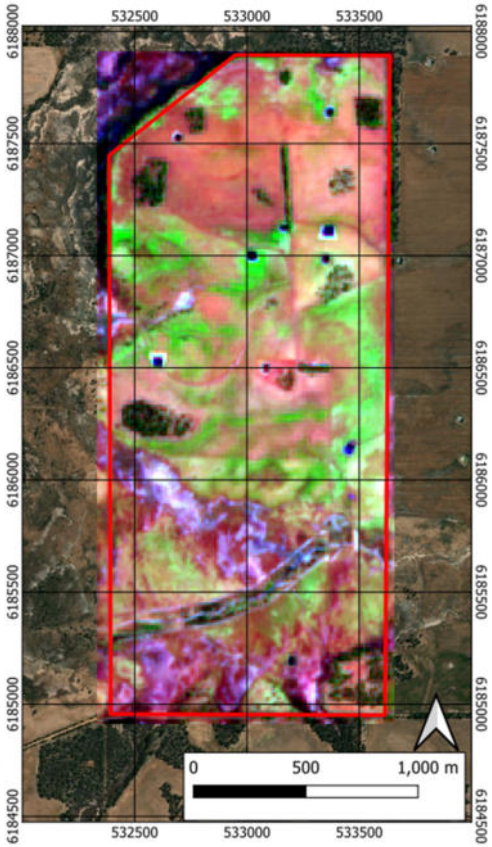
Depth slice at 175RL



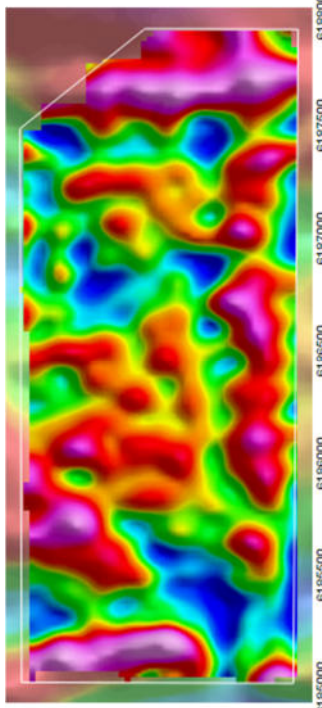
Depth slice at 150RL



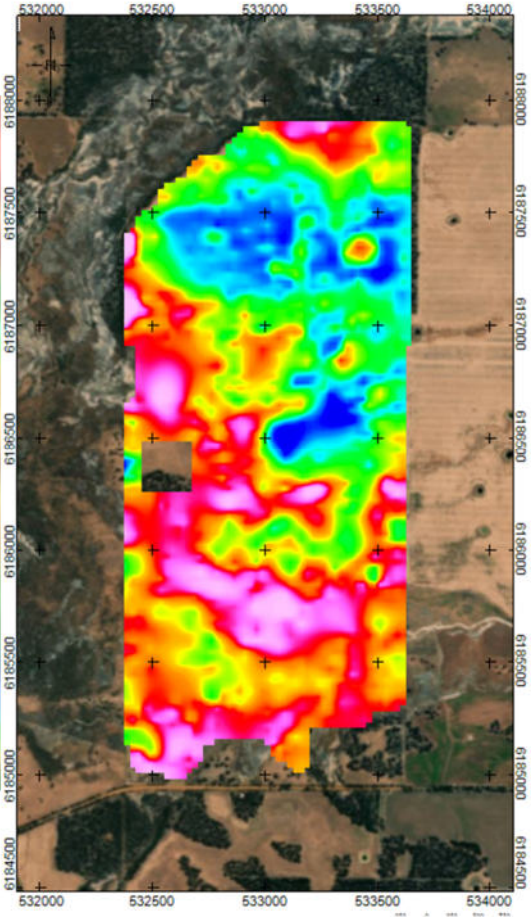
Loupe Emax CDI depth slices



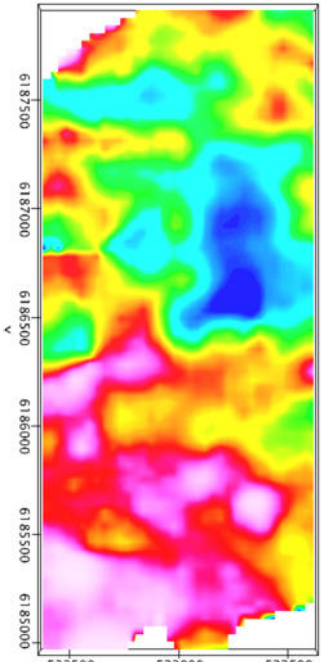
Sentinel 2 -Agricultural Image



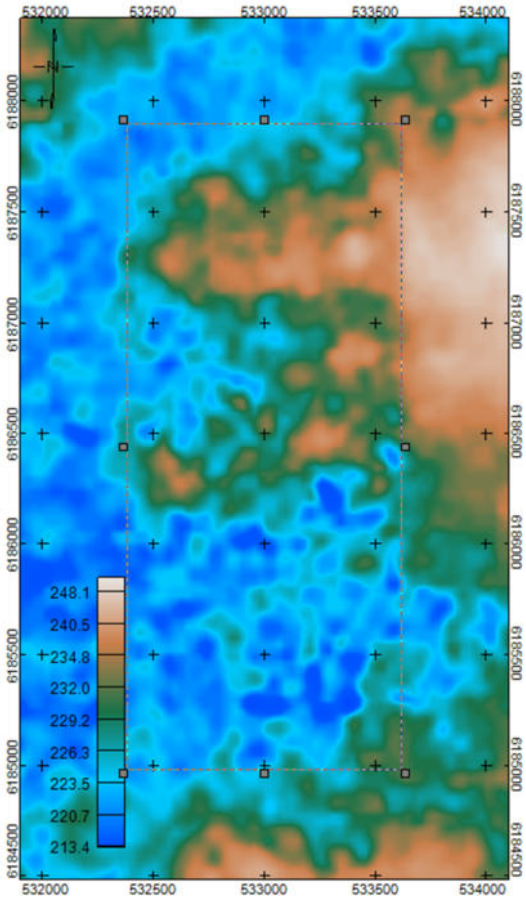
Magnetics



Early Time Channel (5)

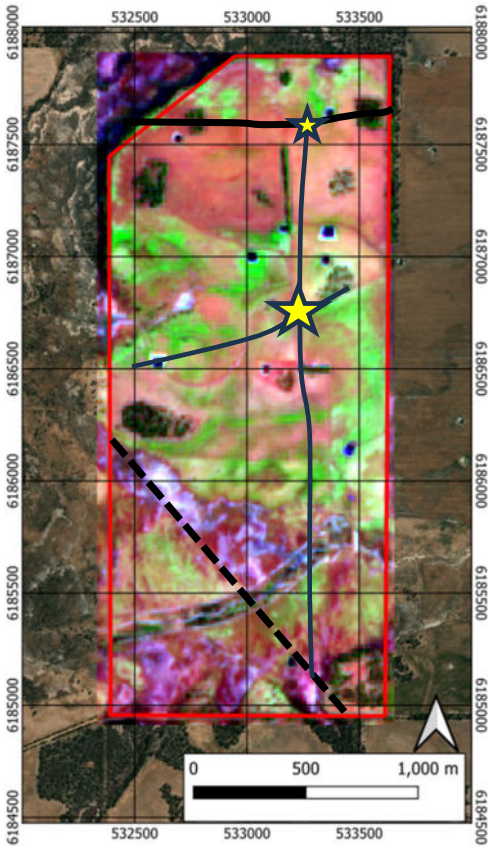


Depth slice at 200RL (-50m)

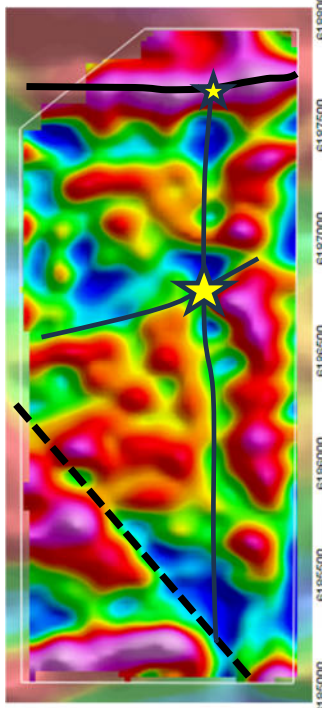


Topography

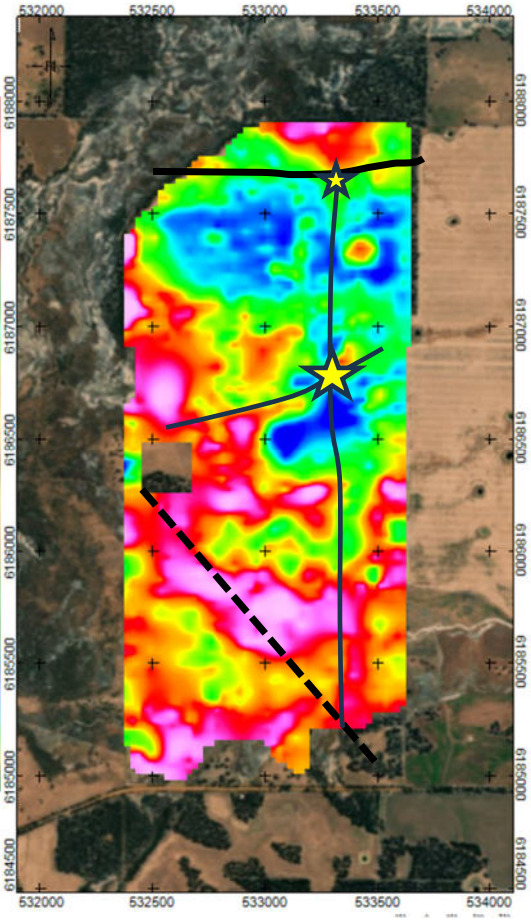
Loupe Emax CDI depth slices



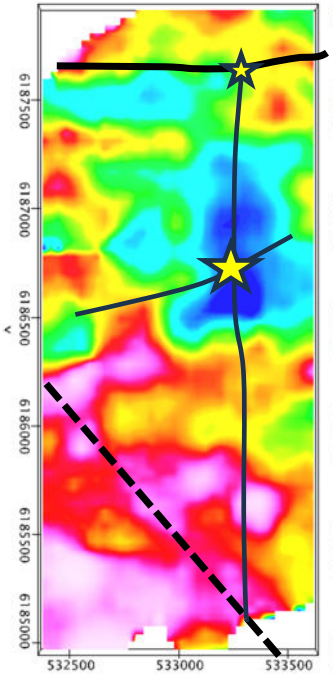
Sentinel 2 -Agricultural Image



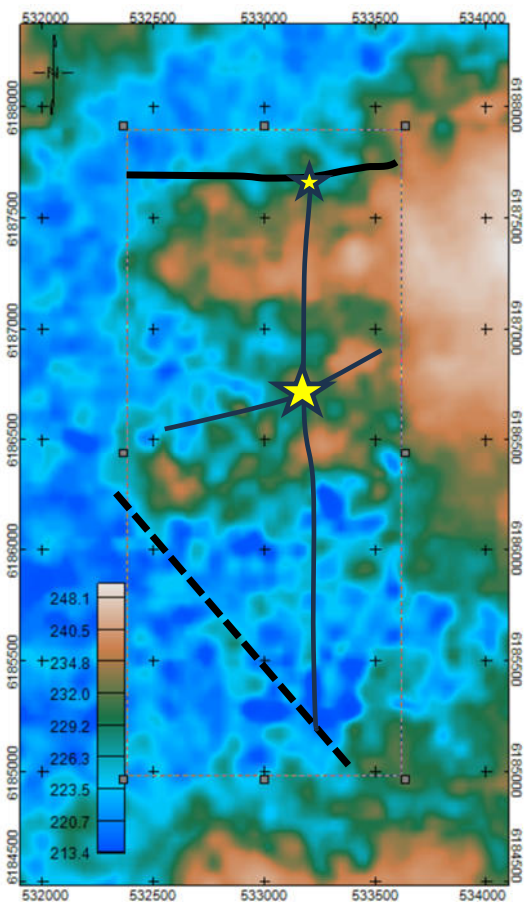
Magnetics



Early Time Channel (5)



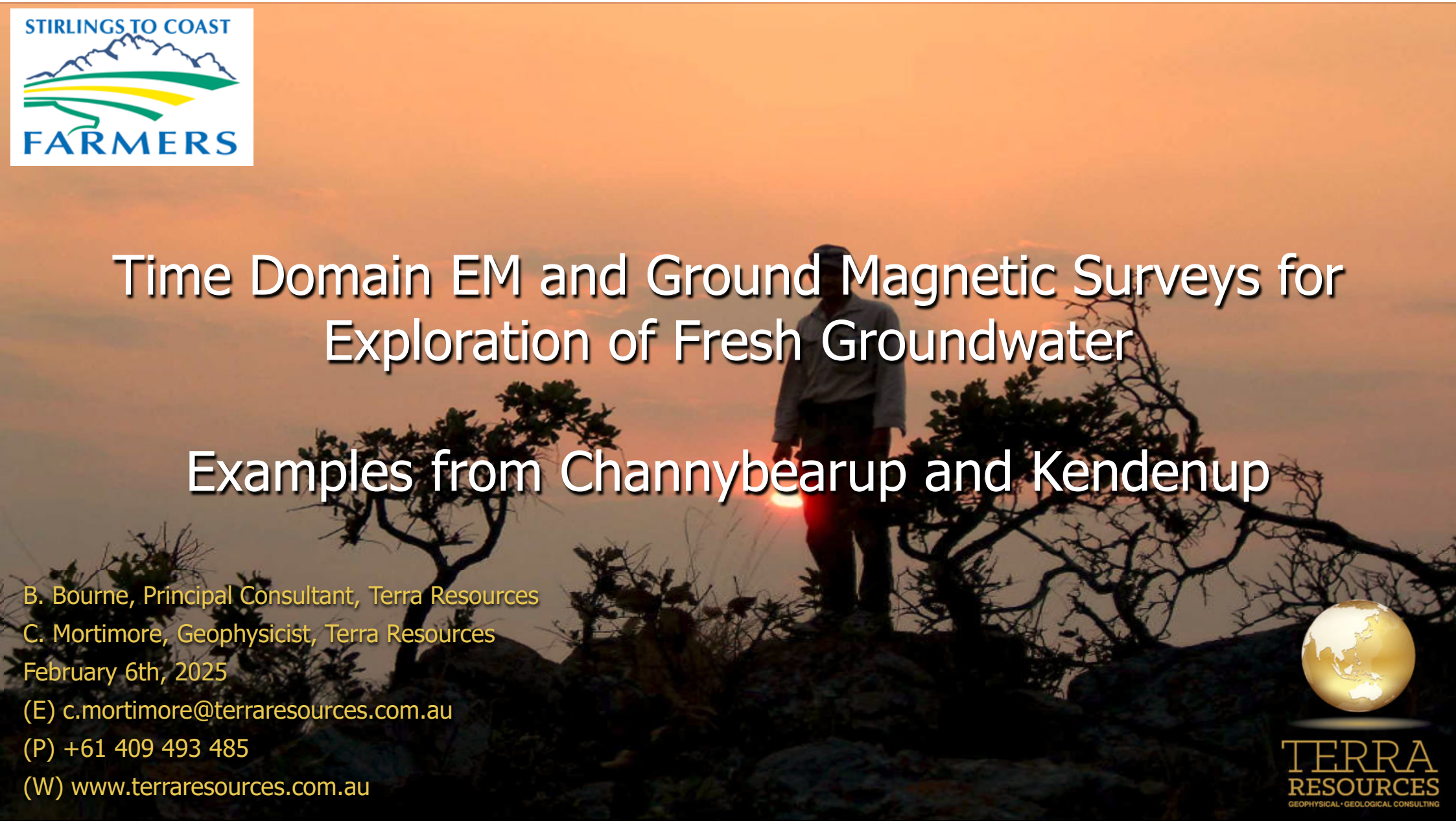
Depth slice at 200RL (-50m)



Topography

Summary

- Integration of remote sensing, magnetics and EM have increased the chances of finding areas prospective for ground water in unconventional settings
- Geological contacts and boundaries aligned with weak conductors may represent zones of increased fractionation
- Surface EM conductors that extend to depth in the Great Southern area are often associated with surface salt scalds and should be avoided when looking for ground water<50m in depth
- The ground water exploration target at Kendenup is yet to be drill tested



Time Domain EM and Ground Magnetic Surveys for Exploration of Fresh Groundwater

Examples from Channybearup and Kendenup

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