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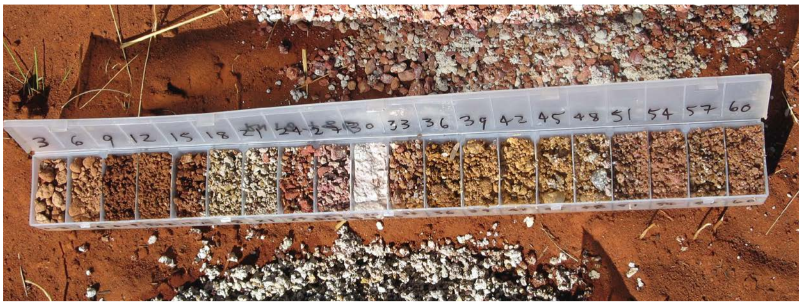

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FINAL TECHNICAL REPORT OF THE PALAEOVALLEY GROUNDWATER PROJECT FOR THE WILKINKARRA DEMONSTRATION SITE

GEOSCIENCE AUSTRALIA
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by

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Executive summary

Investigations in the Wilkinkarra region of central Australia focused on three locations: the Kintore Palaeovalley, Wilkinkarra Palaeovalley, and the Central Mount Wedge Basin. These were predominantly 'greenfield' sites, with the main study objective to obtain reconnaissance-scale data and information on key palaeovalley characteristics. No water bores had previously been drilled in the Wilkinkarra Palaeovalley (near Nyirripi community) so its depth, boundaries, stratigraphy and groundwater resources were essentially unknown. For the Kintore Palaeovalley (near Kintore community) minor information was available, such as 1990s-era bore data collected for the Western Water Study (Wischusen, 1998). The shallow parts of the Central Mount Wedge Basin (near Papunya community) had also been drilled and evaluated using ground geophysics (Lau et al., 1997), although the depth to basement, the nature of sediment infill, and the groundwater compositions for deeper sequences remained speculative.

FIELD INVESTIGATION PROGRAM

A range of ground-based geophysical techniques were trialled over areas where initial analysis of topographic and remote sensing datasets (e.g., NOAA-AVHRR night-time thermal imagery) indicated the potential for palaeovalley systems. These surveys included micro-gravity traverses (~140 km of survey data acquired), seismic reflection (11 km completed), and time-domain electromagnetic surveying (~40 km transect completed). Following-on from the geophysical study 26 investigation boreholes totalling 1,642 m were drilled using air and mud rotary methods. Data acquired were stratigraphic and downhole geophysical logs (gamma), water chemistry analyses including stable and radioisotopes, palynostratigraphic analyses, and time-series standing water levels.

WILKINKARRA AND KINTORE PALAEOVALLEYS

Field investigations significantly improved delineation of both the Wilkinkarra and Kintore Palaeovalleys, and generated new insights on hydrostratigraphy and groundwater resources. Interpretation of these datasets suggested that the Kintore and Wilkinkarra Palaeovalleys were formed by incision of major river systems in pre-Cenozoic times, when the landscape had considerably greater relief than the subdued present-day terrain. In contrast, the Central Mount Wedge Basin was created largely by tectonic activity. It occurs on the down-warped side of a major east-trending mountain-front fault zone, and is infilled by a thick package of lacustrine and fluvial sediments.

Drilling revealed that the Wilkinkarra and Kintore Palaeovalleys are broad and relatively shallow relict fluvial systems. The palaeovalley infill sediments were deposited on undulating and partly weathered basement rocks, deepening to approximately 130 m below ground level. The infill sediments are dominated by weathered and oxidised sandy alluvial facies, interbedded with fine-grained sediments such as clay and silt. Fining-upward sequences apparent in downhole gamma logs are typical of fluvial channel deposits. Black, silty clay containing organic matter was encountered at around 80 m depth below the surface in some bores in the Kintore Palaeovalley. Analysis of *in situ* fossil pollen spores indicated deposition likely occurred in the Middle to Late Eocene, suggesting restricted low-energy, swampy environments. Irregular calcrete deposits are widespread at or near the surface in both the Wilkinkarra and Kintore Palaeovalleys, and these commonly contain shallow potable groundwater resources.

Groundwater is abundant in both the Wilkinkarra and Kintore Palaeovalleys, with the watertables at relatively shallow depths below the surface (generally 3-5 m). Water quality is variably fresh to saline, with salinity generally increasing down-gradient along the groundwater flow-path. Modern recharge to these palaeovalley aquifers is episodic, as indicated by time-series data collected over the course of an unusually wet period (2010-2011) from two newly-established monitoring-bore sites.

The presence of fresh groundwater in this arid environment provides further evidence for modern recharge in these palaeovalleys.

An important outcome of project investigations was the discovery of previously unknown fresh groundwater resources in both the Wilkinkarra and Kintore Palaeovalleys. These discoveries are potentially a significant benefit to the nearby communities of Kintore and Nyirripi, e.g., the water resources could support horticultural activities (as occurs in the nearby Ti Tree Basin). The palaeovalley aquifer is a possible future freshwater supply option for the local people at Kintore (fresh water bores within 5 km of the community). Additional work undertaken by the project team led to the installation of a manually operated hand-pump (Winner's Bore) along a remote road that crosses the Wilkinkarra Palaeovalley, to be used for future emergency water supply situations, such as vehicle breakdowns (Wischusen and Lewis, 2010). The hand-pump represents an immediate and long-lasting benefit to the local community.

THE CENTRAL MOUNT WEDGE BASIN

Seismic reflection data across part of the Central Mount Wedge Basin revealed the previously unknown structure of the entire infill sequence. The deepest basin identified from the seismic data, just north of Papunya community, was drilled to basement at 474 metres below surface. This represents the thickest sequence of Cenozoic sediments discovered within any central Australian palaeovalley, and potentially the most significant accumulation of palaeovalley sediments within the entire Australian arid zone.

The stratigraphic composition of the basin comprises a thick (~350 m) and laterally extensive lacustrine sandy clay unit (the *Mount Wedge Clay*) overlain by coarser-grained, and strongly oxidised alluvial sediments (the *Currinya Clay*). The primary structures and sediment composition, as with those infilling the Kintore and Wilkinkarra Palaeovalley aquifers, are strongly overprinted by deep chemical weathering which hampers detailed facies analysis. Consequently, the stratigraphic profile of the Central Mount Wedge Basin is only correlated with sediments in the adjacent Lake Lewis Basin (to the east), although tenuous correlation with the Hale and overlying Waite Formation in other Cenozoic basins of central Australia may be possible with further work.

The water table in the Central Mount Wedge Basin is consistently ~30 metres depth below surface, although water quality varies spatially from fresh to moderately brackish. Groundwater is more saline in the deeper aquifer system, presumably due to longer residence times (confirmed by limited radiocarbon dating). This suggests that groundwater recharge to deeper parts of the Central Mount Wedge Basin is significantly retarded by the thick clay-rich sequence that dominates the lower part of the basin. Groundwater generally flows north, with recharge via relatively porous montane alluvial fans and creek systems draining from the nearby uplifted Belt Range. Discharge is in salt playas to the north-west of Central Mount Wedge, consequently the shallow aquifer salinity increases northwards.

SUMMARY AND CONCLUSIONS

Multi-component field investigations in the Wilkinkarra demonstration site have clearly illustrated the usefulness of gravity, seismic, electromagnetics and drilling for reconnaissance exploration and mapping of palaeovalley systems. The successful delineation of palaeovalleys using geophysical techniques relies on distinct contrasts in physical (e.g., density or porosity) or electrical (e.g., bulk resistivity) properties between the palaeovalley infill sediments and the bedrock. This work has also shown that, as for most geoscientific investigations, drilling remains one of the most useful methods for acquiring information on the composition and structure of the subsurface. Drilling is also crucial for obtaining groundwater samples to evaluate water compositions and other important hydrologic parameters.

These field investigations have highlighted the variability of palaeovalley aquifers, especially for water quality (salinity) and sediment composition. Considerable heterogeneity exists between drill sites across all demonstration areas. The complexity of the palaeovalley systems renders difficult:

- Stratigraphic correlation between sites;
- Reconstruction of depositional palaeo-environments; and
- Prediction of fresh water location.

Nonetheless, investigations have significantly advanced our understanding of the distribution and groundwater characteristics of these palaeovalleys and also provided important insights for the broader understanding of arid zone palaeovalleys in central Australia.

Due to the extensive and inaccessible nature of palaeovalley systems in the Wilkinkarra region field investigations were restricted to localised areas. The most readily accessible areas have now been surveyed and drilled. Further exploration and assessment of palaeovalleys on the ground would be very difficult because of problems with access. A regional and spatially based investigative approach (using remotely sensed data) is now required to further map the distribution of palaeovalleys. An airborne electromagnetic (AEM) survey would help address many of the questions raised by this study, and provide the regional investigative approach required in this vast and inaccessible landscape.

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Abbreviations and acronyms

ADWG	Australian Drinking Water Guidelines
AEM	Airborne Electromagnetics
APY	Anangu Pitjantjatjara Yankunytjatjara
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Czk	Cenozoic calcrete
DEM	Digital Elevation Model
GA	Geoscience Australia
Ga	Billions of years ago
GIS	Geographic Information System
GL	Gigalitre: one billion litres (equivalent to 1000 megalitres, ML)
GMWL	Global Meteoric Water Line
kL	kilolitre: 1000 litres (cubic litre: m^3)
LMWL	Local Meteoric Water Line
Ma	Millions of years ago
ML	Megalitre: one million (1,000,000) litres
MODIS	Moderate Resolution Imaging Spectroradiometer
MrVBF	Multi-resolution Valley Bottom Flatness Index
NCGRT	National Centre for Groundwater Research and Training
NOAA-AVHRR	National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer
NRETAS	Northern Territory Department of Natural Resources, Environment, the Arts and Sport
NT	Northern Territory
NTGS	Northern Territory Geological Survey
NTIR	Night Time Infra-Red
NWC	National Water Commission
NWI	National Water Initiative 2004
OESP	Onshore Energy Security Program
pMC	percent Modern Carbon
Qa	Quaternary alluvium
RAB	Rotary Air Blast

RN	Registered Number (in the NT government borehole database)
RNWS	Raising National Water Standards
SA	South Australia
SIROTEM	CSIRO Transient Electromagnetic system
SMOW	Standard Mean Ocean Water
SRTM	Shuttle Radar Topographic Mission
SWL	Standing Water Level
TAG	Technical Advisory Group
TDS	Total Dissolved Solids
TMI	Total Magnetic Intensity
WA	Western Australia
WASANT	WA – SA – NT

Units

cm	centimetres
m	metres
km	kilometres
m/s	metres per second
L/s	litres per second
mg/L	milligrams per litre
mS/m	milli-Siemens per metre
S/m	Siemens per metre
µS/cm	micro-Siemens per centimetre
kL	kilolitre: 1,000 litres (cubic litre: m^3)
ML	Megalitre: one million (1,000,000) litres
GL	Gigalitre: one billion litres (equivalent to 1,000 megalitres, ML)
mGal	milliGals (unit of gravity measurement)

1. Introduction

Palaeovalleys host significant groundwater resources in the arid southern region of the Northern Territory. They are important water supplies for many remote communities, mineral exploration and mining operations, horticultural regions and tourist enterprises. The Tanami Goldmine, Yulara Tourist Resort and the Ti-Tree table grape and mango orchards are examples of activities that currently depend on palaeovalley aquifers. However, despite their importance to the economic, social and environmental well-being of the Northern Territory, the location, characteristics and hydrogeologic processes of palaeovalley groundwater systems remain poorly understood and have only been locally investigated in the past.

In many ways, the evolution of outback palaeovalleys is the story of the Late Cretaceous to Cenozoic geological history of central Australia. It begins with the widespread humid landscapes of perennial rivers surrounded by vast temperate rainforests (White, 1994). As Gondwana drifted northward during the Cenozoic, climatic conditions fluctuated and the region overall became increasingly hotter and drier. The major inland river systems began to receive less rainfall, eventually leaving only widespread dry river valleys infilled with sedimentary material eroded from surrounding ranges. In the modern-day arid environment of central Australia the remnants of many palaeovalleys form disconnected chains of salt lakes and playas.

Episodes of Cenozoic tectonic activity also initiated the development of deep sedimentary basins which accumulated hundreds of metres of lacustrine and alluvial sediments sourced from nearby mountain ranges (Senior et al., 1995).

In the modern environment, the palaeovalleys of central Australia are buried geologic features, commonly obscured by Quaternary sand sheets and linear dunes. Scarce clues now exist at the surface to indicate their existence, although the occurrence of calcrete or subtle topographic variations in the landscape can assist in defining their course. Consequently, combined with the vast and remote expanse of arid central Australia, the full extent and nature of the palaeovalley network in the NT has remained largely unknown.

The importance of palaeovalley aquifers in the arid and semi-arid zone, and the need to better understand their groundwater resources, was recognised by the National Water Commission and led to funding for the joint commonwealth, state and territory government project known as the *Palaeovalley Groundwater Project*[1]. This work was directed at improving the knowledge base of the extent, quality and sustainability of groundwater resources in palaeovalleys across arid Australia. The investigative approach involved targeted studies at multiple demonstration sites in the arid regions of Western Australia (WA), South Australia (SA) and the Northern Territory (NT).

A major focus of the NT work program for the *Palaeovalley Groundwater Project* targeted the Lake Mackay (Wilkinkarra) region (Figure 1.1). This is a large and remote area several hundred kilometres west of Alice Springs, and includes the communities of Kintore, Nyirripi and Papunya. The region is mostly owned and inhabited by Aboriginal people who live in small settlements which provide basic services. A few unsealed and poorly maintained roads provide access to some parts of the region, but much of this vast area remains largely inaccessible. The remarkable desert ecology is largely intact and, apart from feral animals and fire-related impacts, remains relatively undisturbed.

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[1] This project is also known as ‘Water for Australia’s Arid Zone – Identifying and Assessing Australia’s Palaeovalley Groundwater Resources’.

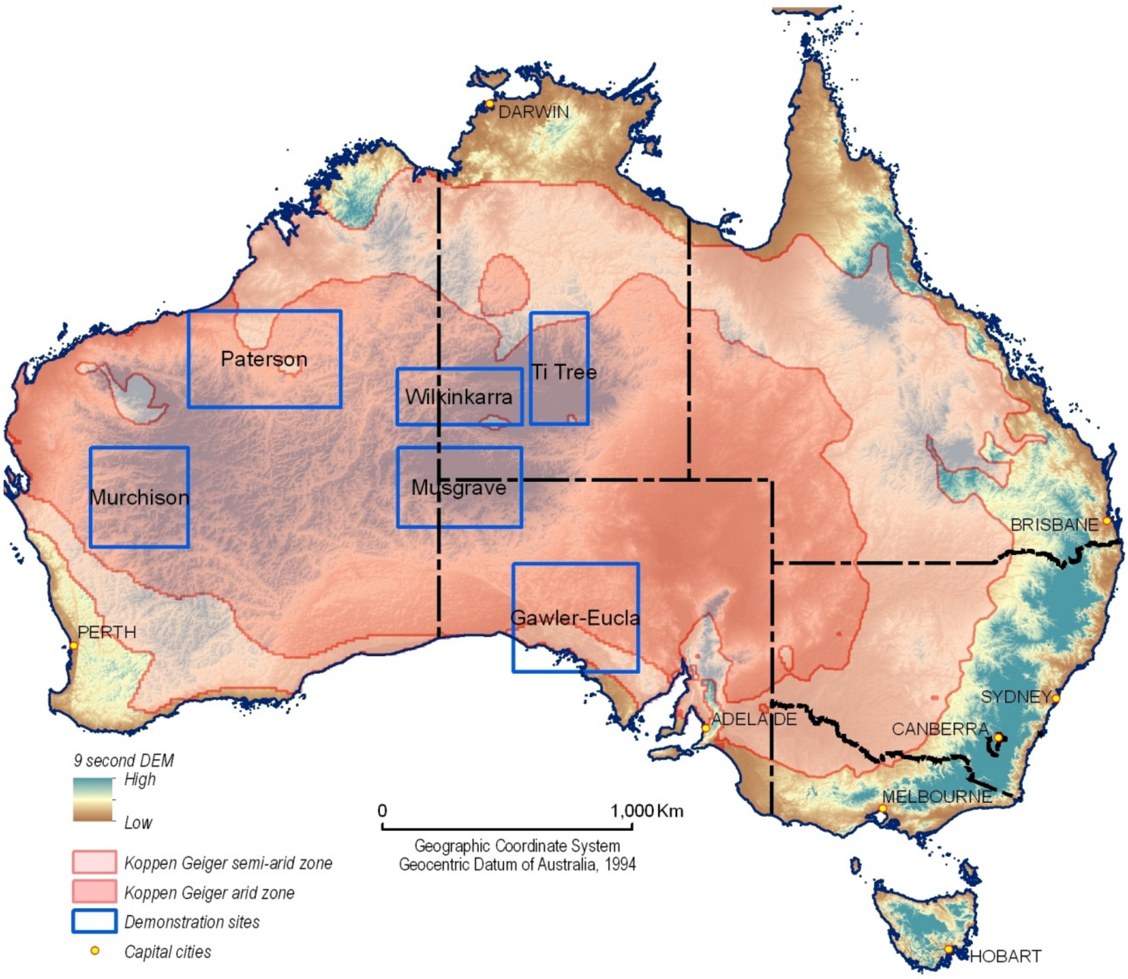

Figure 1.1: *Demonstration sites for the Palaeovalley Groundwater Project.*

Field data collection, analysis and interpretation were undertaken for this project at a number of Wilkinkarra sites between 2009 and 2011. The choice of study areas was mainly dictated by accessibility and the availability of existing data, and included:

- Nyirripi (Wilkinkarra Palaeovalley);
- Kintore (Kintore Palaeovalley); and
- Central Mount Wedge (Central Mount Wedge Basin).

A range of exploration and assessment methods were applied at these sites to improve understanding of the palaeovalley characteristics and to identify technologies and investigative approaches which are most effective for palaeovalley groundwater exploration.

This report presents final details of hydrogeological investigations at the three study sites in the Wilkinkarra demonstration area. This includes detailed discussion of the methods, results and interpretation of the data. The last section of the report draws comparisons between the field investigation areas and provides a national and regional overview of palaeovalley features in the Wilkinkarra region.

This report is part of a suite of final outputs from the *Palaeovalley Groundwater Project,* including the project summary report (http://www.nwc.gov.au/__data/assets/pdf_file/0017/23165/Waterlines-86-Water-for-Australias-arid-zone.pdf), the WASANT Palaeovalley Map (http://www.ga.gov.au/cedda/maps/347), and the palaeovalley methodology toolbox (Gow et al., 2012) which provides information on the various methods used for delineating, assessing and characterising palaeovalley systems and their groundwater resources.

2. Regional spatial data analysis

Palaeovalleys in Australia's arid zone are difficult to detect at the surface as they have only limited (or no) surface expression. Consequently, the use of enhanced remote sensing data has many potential applications for mapping and interpreting palaeovalley networks. Initial exploration for palaeovalleys is best achieved through the integration of multiple remote sensing datasets including those derived from digital elevation models (DEMs), satellite imagery and geophysical surveys. The theory and operation of these remote sensing systems is further discussed in the Palaeovalley Investigative Toolbox report (Gow et al., 2012).

For the purpose of this study in the Wilkinkarra demonstration area, the following methods were used to help delineate the distribution and extent of regional palaeovalley systems:

1. Multi-resolution valley bottom flatness index (MrVBF);
2. Advanced very high resolution radiometer (AVHRR); and
3. Landsat Thematic Mapper.

2.1 MULTI-RESOLUTION VALLEY BOTTOM FLATNESS (Mr VBF)

The MrVBF dataset is a derived product from the 1-arc second Shuttle Radar Topographic Mission (SRTM) digital elevation model (~30 metre resolution)[2]. The MrVBF algorithm is used to identify flat and low-lying areas in the landscape and has proven successful in highlighting arid zone geomorphic features related to palaeovalleys. The MrVBF image for the Wilkinkarra area (Figure 2.1) illustrates that the main palaeovalleys that link with Lake Mackay (Australia's fourth largest salt lake) on the NT-WA border underlie relatively low and flat-lying terrain.

2.2 ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR)

The AVHRR sensor is hosted onboard the polar-orbiting satellites of the National Oceanic and Atmospheric Administration (NOAA). The NOAA-AVHRR sensor measures between four and six spectral bands, including those of the visible, near-infrared and thermal infrared spectrum. This system is mainly used to study clouds, ice, snow and land-water boundaries, and is also capable of measuring temperatures produced by different radiating surfaces. The sensor has a spatial resolution of ~1.1 km which makes the dataset relatively coarse, and best-suited for national- to regional-scale studies.

Data acquired by the NOAA-AVHRR sensor may be useful for delineating arid zone palaeovalleys due to variations that can occur in the thermal response of porous, water-bearing sediments (e.g., infilling palaeovalleys) and surrounding areas of near-surface bedrock. The thermal data is generally acquired pre-dawn to provide the maximum contrast in thermal inertia between these different geological materials (which reflects variations in their relative degree of near-surface water saturation), e.g., Hou et al., 2000; Hou and Mauger, 2005.

In the Wilkinkarra region NOAA-AVHRR data was obtained pre-dawn following a significant period of rainfall (to allow for enhanced saturation of aquifer sediments). However, analysis of the NOAA-AVHRR data (Figure 2.2) did not greatly assist in identifying the location of any trunk or tributary palaeovalleys. Consequently, this remote sensing technique proved relatively ineffective for this study site, possibly because prior widespread rainfall had led to similar levels of near-surface saturation in the different types of geological materials.

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[2] Other types of digital elevation model data (e.g., data derived from LIDAR surveys) could also have the MrVBF algorithm applied for similar analysis.

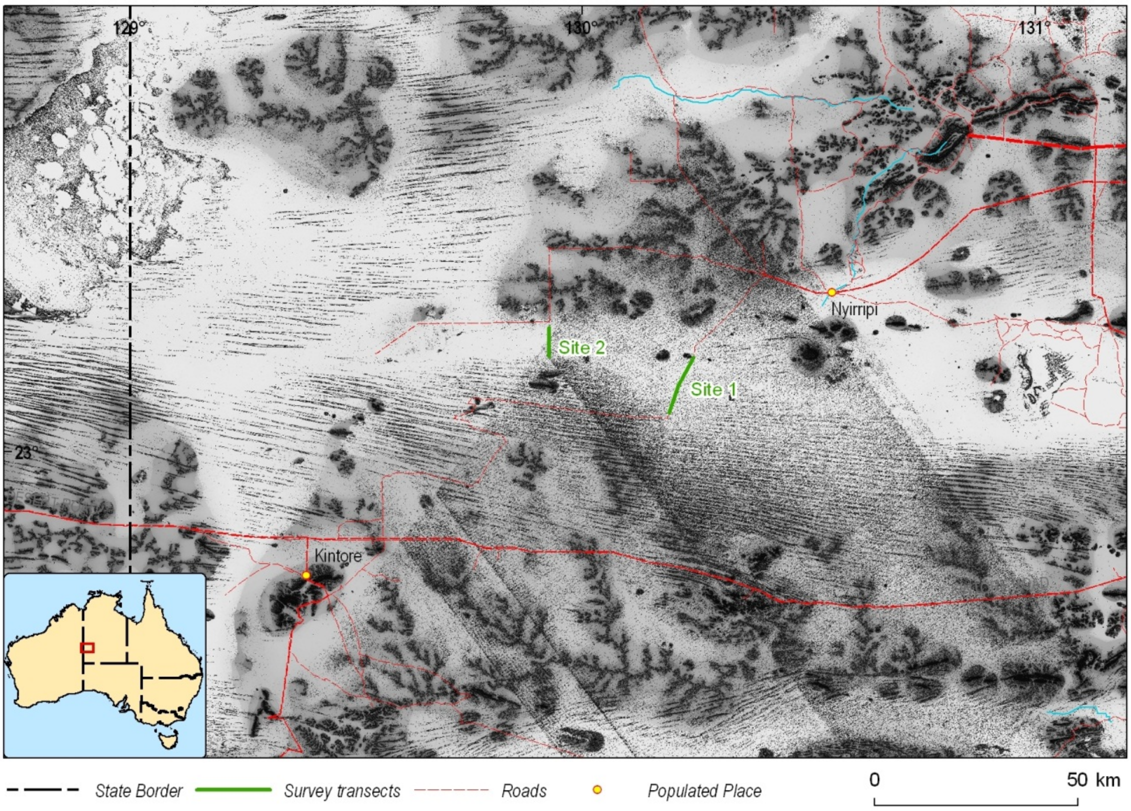

Figure 2.1: *MrVBF image of the Wilkinkarra demonstration site in central Australia. The flat, low-lying areas shown in white and paler grey tones indicate a much broader palaeovalley system than that originally mapped by Tickell (2008). The location of ground geophysical and rotary drilling transects conducted for this project are shown as Site 1 and Site 2.*

2.3 LANDSAT 5 THEMATIC MAPPER (TM)

Landsat TM imagery was used by Woodcock et al. (1997) in an integrated remote sensing study of the Papunya–Kintore region for the Western Water Study[3]. A method known as 'spectral unmixing' of the Landsat TM data produced the best results for delineating the local palaeodrainage system. The method matches multispectral data to end-member material reflectance spectra. These end-members (such as clay, iron oxide and quartz) are then resolved mathematically to determine their relative contribution to the overall reflectance value (Bierwirth, 1990).

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[3] The Western Water Study is discussed further in Section 3.4 (Previous Studies).

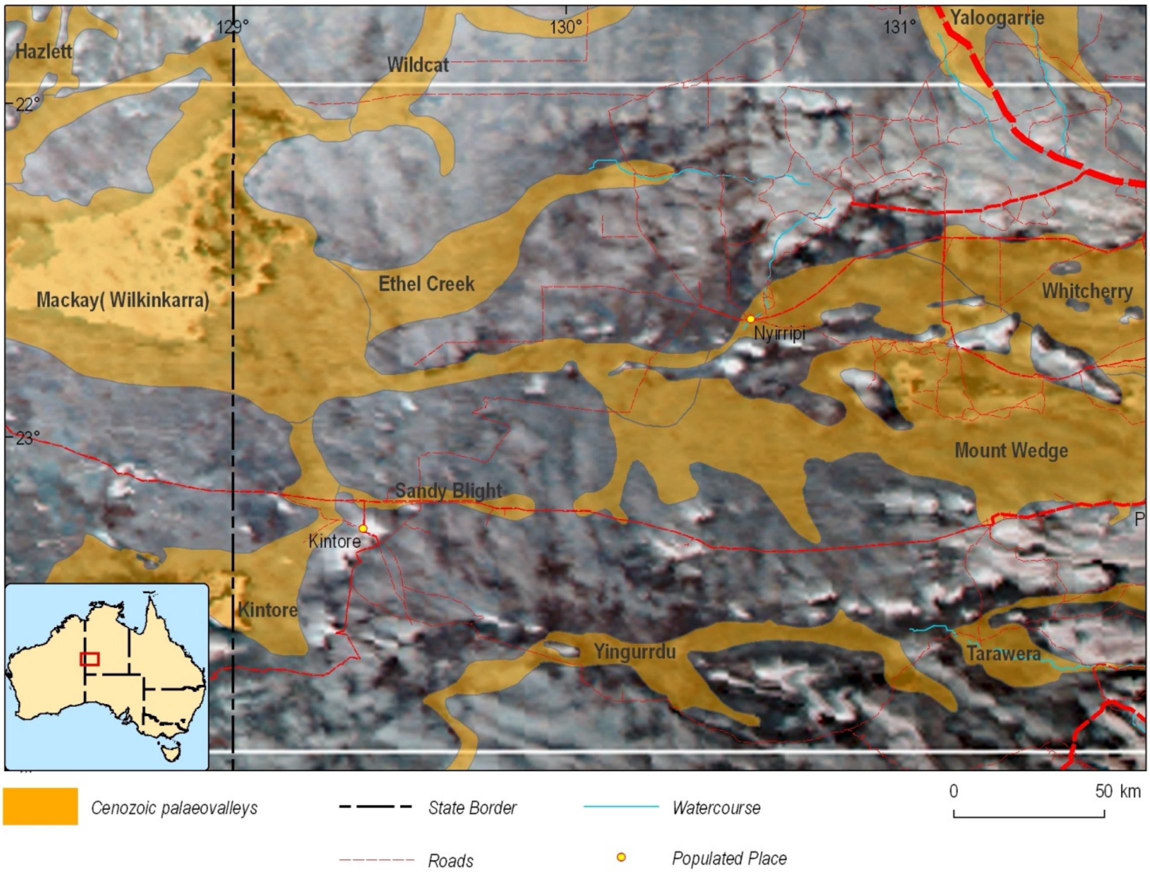

Figure 2.2: *A National Oceanic and Atmospheric Administration (NOAA) – Advanced Very High Resolution Radiometer (AVHRR) image of the Wilkinkarra demonstration site acquired pre-dawn on 6 March 2009. The darker areas are relatively cooler compared to the lighter areas, and in some cases correspond with the location of near-surface saturated sediments infilling palaeovalleys. The Cenozoic palaeovalley boundaries shown here are derived from Bell et al., 2012.*

3. Wilkinkarra Palaeovalley

3.1 INTRODUCTION

The Wilkinkarra Palaeovalley was selected as a study site for the *Palaeovalley Groundwater Project* based on the findings of previous work which indicated the presence of significant palaeovalley systems in the Lake Mackay and Nyirripi region, e.g., Tickell (2008). Most of these palaeovalleys had not been drilled prior to this investigation and very little information was known about their shape, size, stratigraphy or groundwater resources. The Wilkinkarra region presented an opportunity for investigating largely unexplored palaeovalleys and testing a range of field and analytical methods to improve overall knowledge about these remote aquifer systems.

This chapter focuses on the hydrogeological investigations of the Wilkinkarra Palaeovalley conducted for this project between 2008 and 2011. It provides a comprehensive account of the research program, key findings and results obtained from work within the Nyirripi area of central Australia.

3.2 CHARACTERISTICS OF THE WILKINKARRA REGION

3.2.1 Location and site access

The Wilkinkarra Palaeovalley is approximately 550 km north-west of Alice Springs and occurs within the Lake Mackay Aboriginal Land Trust (Figure 3.1). The palaeovalley was assigned the local name *Wilkinkarra* during discussions with the Geoscience Australia project team in 2011. *Wilkinkarra* is the local name for Lake Mackay, a large salt lake in the Western Desert region of central Australia. Lake Mackay features extensively in the tjukurrpa ('Dreaming') narratives of the Pintupi and Kukatja people (Graham, 2003).

The region is largely uninhabited apart from the community of Nyirripi, with a population of approximately 300 residents. An approved permit is required for non-residents to visit and work in the region. The land is used for traditional purposes such as hunting and cultural activities. Some previous mineral exploration activity (e.g., for gold) has occurred in the area on designated exploration tenements, but these have not focused on the palaeovalleys.

Field sites in the area were limited due to access problems caused by extensive linear sand dunes. The main study sites were south-west of the Nyirripi community (Figure 3.1), centred around two transects (Sites 1 and 2) approximately perpendicular to the palaeovalley axis. Site 1 was an 18 km-long section along the Nyirripi to Kintore road, about 40 km south-west of Nyirripi township and also south-west of Emu Bore (RN7042), known locally as *Pirdi.*

Site 2 was around 40 km down-gradient of Site 1 and nearer to Lake Mackay, further along the presumed flow path of the Wilkinkarra Palaeovalley. One other site near Kalimpimpa Soak (south of the Wilkinkarra Palaeovalley) on the Nyirripi to Kintore road was also drilled for this investigation. This bore aimed to determine the nature of the stratigraphic profile and the depth to the watertable, as well as obtaining a water sample for analysis.

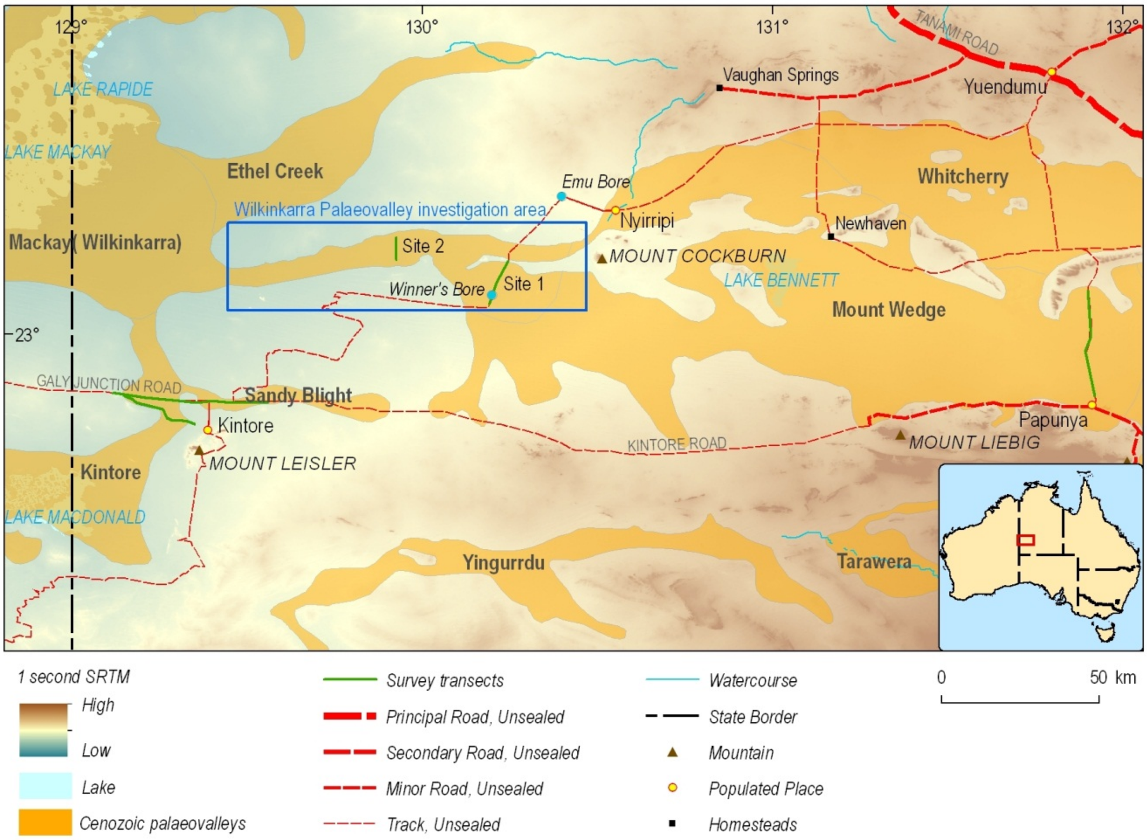

Figure 3.1: *The Wilkinkarra Palaeovalley in central Australia. Cenozoic palaeovalleys (after Bell et al., 2012) superimposed on the national-scale 1-second digital elevation model derived from the SRTM dataset.*

3.2.2 Climate

The area has a hot and arid climate. The nearest rainfall station to the Wilkinkarra site is approximately 100 km to the north-east at Vaughan Springs. Mean annual rainfall is 200–300 mm/year, and has high variability (as defined by the Bureau of Meteorology rainfall variability index: http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall-variability/index.jsp , whereby rainfall occurs on very few days of the year). Rainfall levels are higher in the summer months, influenced by the northern monsoon system (Figure 3.2).

The long-term average annual pan evaporation rate in the study area is 2,800–3,200 mm, based on data from 1975 to 2005 *(*www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp*)*. This is approximately 8–10 times the annual rainfall.

3.2.3 Topography

The Wilkinkarra Palaeovalley is evident from satellite imagery (such as Landsat) due to extensive near-surface calcrete and the chain of playas formed within the margins. From its surface expression the palaeovalley appears to extend from the Central Mount Wedge Basin in the east, to Lake Mackay in the west. The surface trace of the palaeovalley also marks the lowest point in the landscape. Although this evidence suggests that the Central Mount Wedge Basin is directly linked to Lake Mackay, the continuity of groundwater flow between these systems is unknown.

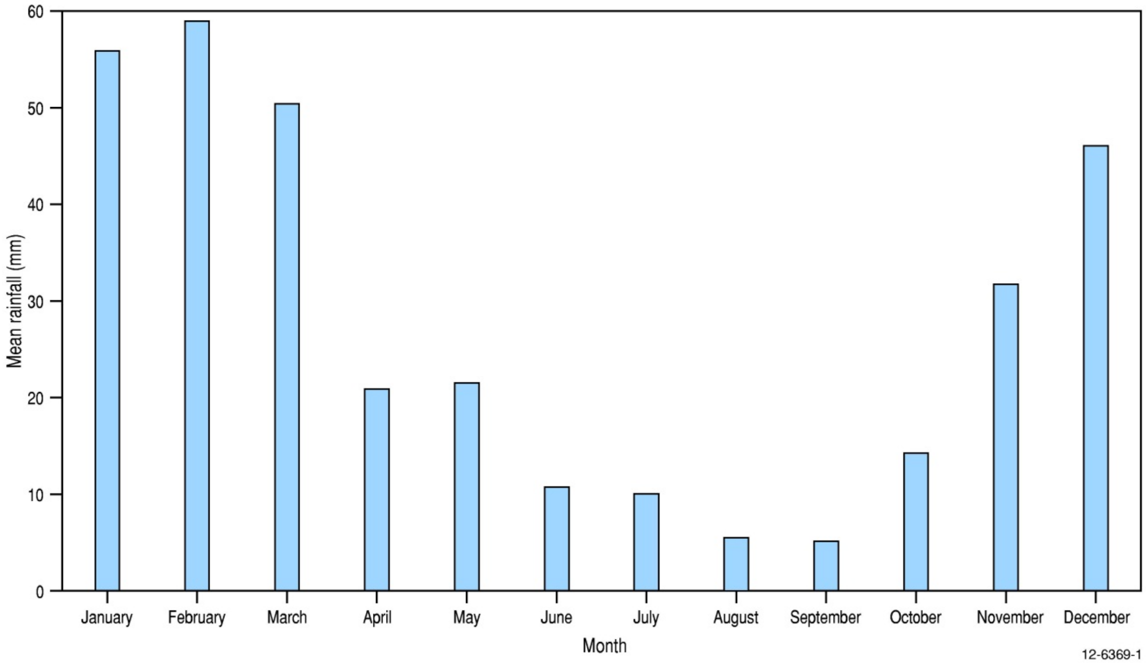

Figure 3.2: *Mean monthly rainfall recorded at Vaughan Springs (1960 to 2011 data).*

The terrain of the Wilkinkarra demonstration site is predominantly flat to slightly undulating. Isolated inselbergs such as Mount Carey and Mount Redvers and the Campbell Range (further east) provide dramatic relief from the otherwise flat landscape. Locally, the terrain across the survey transects is hummocky due to sporadic exposures of hard 'ribbon-like' calcrete and some longitudinal aeolian dunes which stand ~5 metres high and trend east to west.

A subtle regional topographic gradient extends from east to west, with Lake Mackay the lowest landscape feature at approximately 365 metres Australian Height Datum (AHD). The elevation of the field investigation sites to the east of Lake Mackay are around 100 m higher.

3.2.4 Geology

The Wilkinkarra demonstration site is within the Aileron Province of the Western Arunta Region (Figure 3.3). This geological domain has a complex stratigraphic, structural and metamorphic history and is dominated by amphibolite-grade metamorphic rocks of the Paleoproterozoic Lander Rock Formation. These have been intruded by Paleoproterozoic and Mesoproterozoic granitoids and are overlain in part by the Vaughan Springs Quartzite of the Ngalia Basin.

The regional 1:250,000 geological mapsheet (Lake Mackay, SF52-11) is dominated by Quaternary cover sediments and has only ~1% outcropping basement rocks (Figure 3.4). Extensive aeolian and sheetwash sandplains, longitudinal dunes, and minor lacustrine deposits (clay, calcrete and silcrete) cover the bedrock units. The sand plain is broken in places by low quartzite rises, cuestas and mesas such as Mount Redvers. Saprolitic outcrops also occur, mainly consisting of pisolitic ferricrete. The relatively thick sequences of Cenozoic sediments infilling palaeovalleys across the region were poorly known prior to this study.

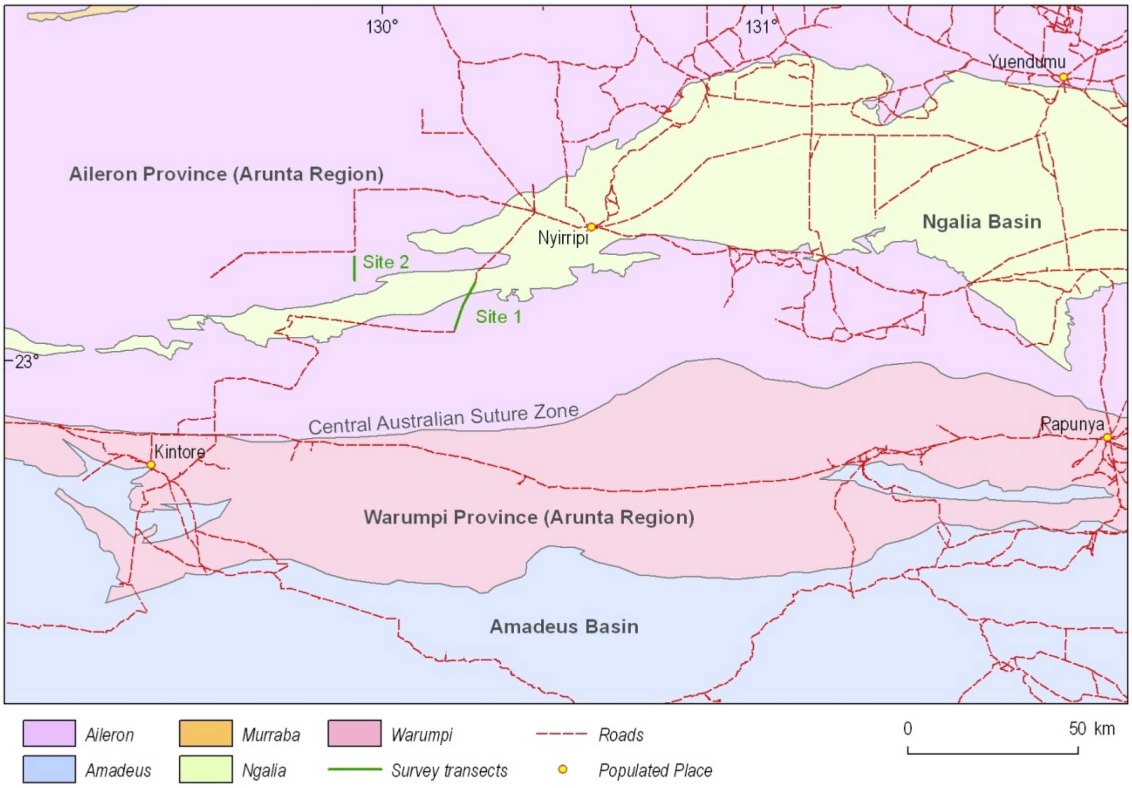

Figure 3.3: *Regional geology of the Wilkinkarra region.*

3.2.5 Groundwater resources and use

There are very few existing bores within 20–30 km of the study sites investigated for the Wilkinkarra Palaeovalley (Figure 3.5). The only production bore in the area is Emu Bore, which was established as a water supply for an outstation near Nyirripi (although it is currently uninhabited).

Further to the south several unproductive bores were drilled along the Nyirripi to Kintore road near Kalimpimpa soak, a traditional local water supply. There is also a shallow bore at an abandoned Newmont mineral exploration camp about 50 km west of Emu Bore, which was visited during fieldwork for this project.

Groundwater from the Nyirripi town borefield, located between Waite Creek and the local airstrip, is the sole water supply for this community. Apart from remote area travellers accessing traditional water supplies such as soaks, there are no other known groundwater users in the region. Water use is not currently regulated.

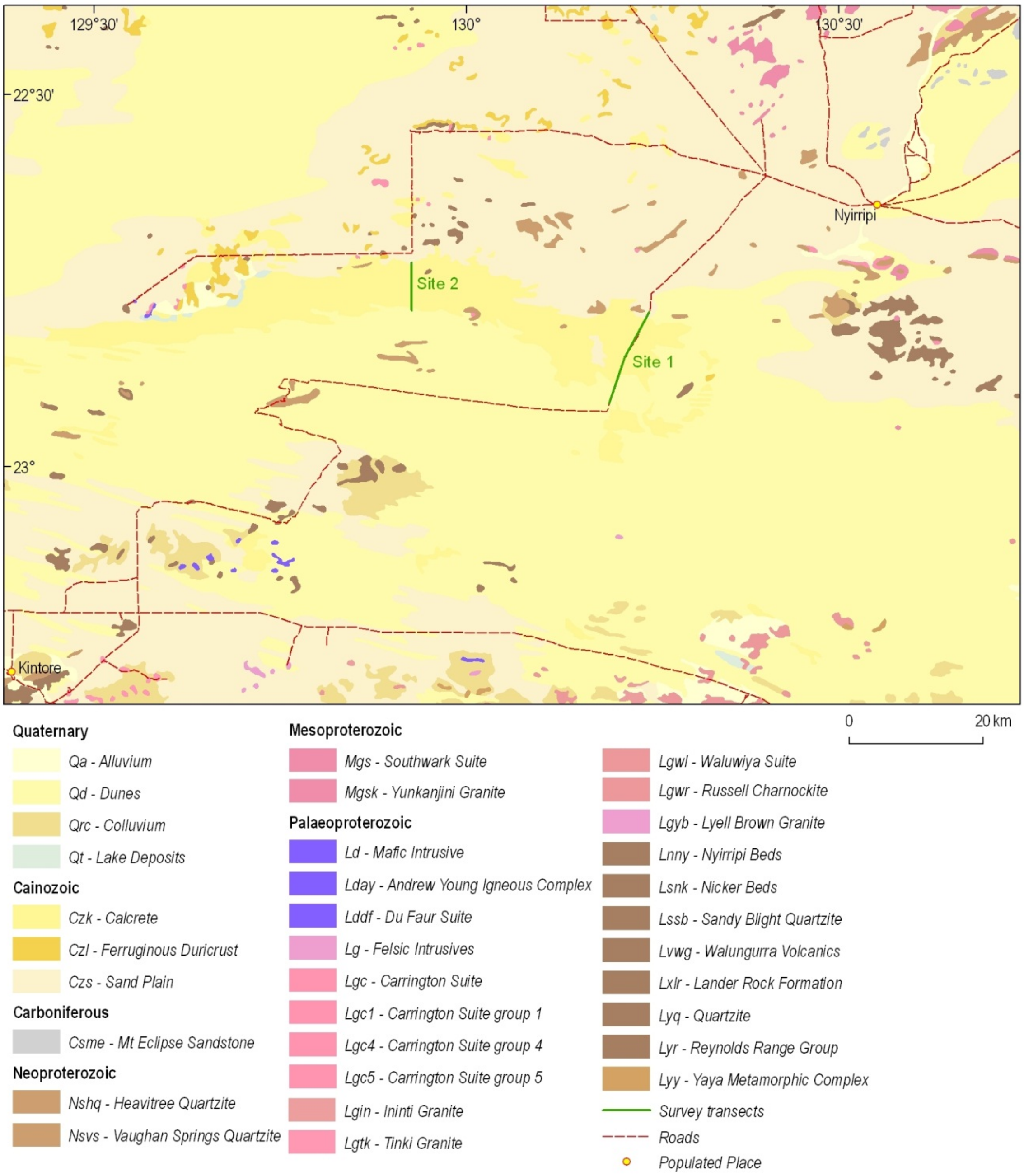

Figure 3.4: *Portion of the Lake Mackay 1:250,000 surface geology map, focused on the region around the Wilkinkarra Palaeovalley.*

3.2.6 Vegetation

The investigation site is within the Great Sandy Desert Bioregion (Thackway and Cresswell, 1995). Vegetation in this bioregion mainly consists of desert grassland, low woodland and shrubs, although some southern areas have tree and shrub steppe with spinifex grasslands.

The vegetation in the vicinity of the Wilkinkarra Palaeovalley consists largely of open woodland (with sparse, low-lying Bloodwood trees, *Corymbia opaca*, at the southern end of Site 1), open country spinifex (*Triodia basedowii*) grassland, and shrubland with various acacia, ptilotus, grevillea, and cassia and hakea species.

The vegetation is mostly typical of sandplains in central Australia, although there are some notable exceptions:

- In low-lying areas salt tolerant vegetation occurs including *Frankenia cordata*. This reflects areas of saline soil where the capillary zone is near-surface. In regions of mounded sand, *Triodia basedowii* are dominant species;
- Two species of *Melaleuca* (*glomerata* and *lasiandra*) are not typical of sand plains. A similar melaleuca–spinifex association occurs in areas of shallow saline water and calcrete on Newhaven and Mount Wedge stations;
- Two *Corymbia* species have a relatively restricted distribution. *Corymbia opaca* is uncommon, and generally occurs on higher dunes, possibly because of the greater depth of soil above the water table; and
- *Corymbia aperrinja* was not seen in the area, although it commonly grows on calcrete with shallow watertables in parts of Newhaven station. Possibly, the groundwater in this area may be too saline to support this species (?).

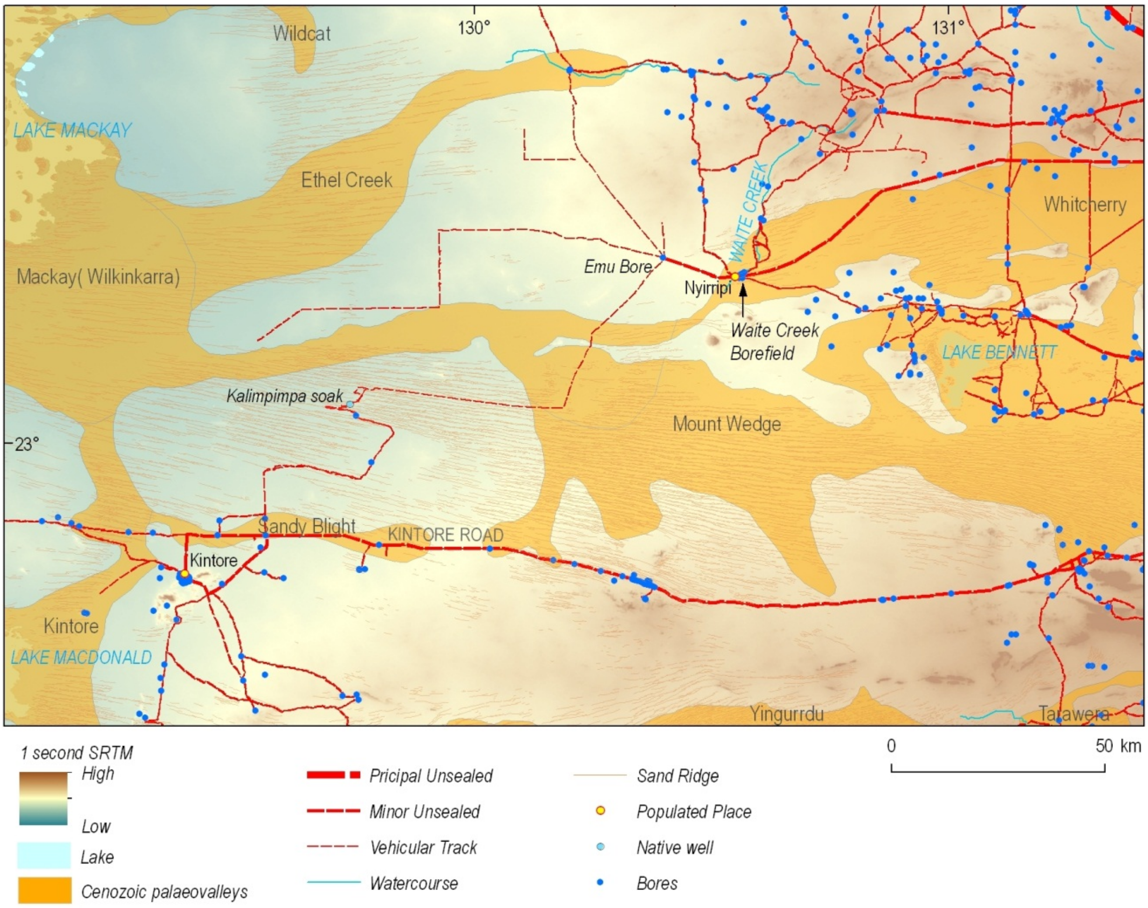

Figure 3.5: *Groundwater bores in the Wilkinkarra Palaeovalley region (prior to work conducted for this project). Cenozoic palaeovalleys after Bell et al., 2012.*

3.2.7 Surface hydrology

There are no permanent surface water bodies in the area, apart from the Pirdi sinkhole south of Emu Bore which provides access to the watertable but is off-limits to visitors for indigenous cultural reasons. Other isolated locations may have small permanent water supplies but that type of information is generally kept guarded because of its cultural significance to the local Aboriginal people. Minor drainage lines in the area may flow following significant rainfall events, and some small claypans may also pond surface water after downpours, but such features are generally dry.

3.2.8 Lake Mackay

Wilkinkarra, known to non-indigenous Australians as Lake Mackay, is approximately 550 km west-northwest of Alice Springs, straddling the WA-NT border (Figure 3.1). The lake bed covers roughly 4,000 square kilometres and is bounded on all sides by desert terrain. The lake is mostly dry but can hold surface water after heavy rains in unusually wet years, as occurred in both 2001 and 2010.

The water immediately beneath the surface of Lake Mackay is highly saline, and was measured at ~110,000 µS/cm during a field visit in November 2009 (Figure 3.6). The lake is a regional groundwater discharge site.

Figure 3.6: *View across Lake Mackay from the southern shoreline showing Dr Steven Lewis of Geoscience Australia studying the typical chocolate coloured hypersaline sediments which occur immediately below the salt encrusted surface.*

3.3 PREVIOUS GEOSCIENTIFIC STUDIES

3.3.1 Regional mapping

This section summarises previous geoscientific studies conducted (either wholly or partly) within the region of the Lake Mackay 1:250,000 mapsheet, within which the Wilkinkarra Palaeovalley occurs.

The Bureau of Mineral Resources (BMR) first mapped the geology of the Lake Mackay region in 1968 (Nicholas, 1972). A second edition of the Lake Mackay 1:250,000 surface geology map was released by the Northern Territory Geological Survey (NTGS) in 2008 (Edgoose et al., 2008), along with an interpreted basement geology map. Several other geological mapping studies have also covered portions of the region, such as Wells et al. (1970, 1983) and Blake et al. (1979).

The Wilkinkarra Palaeovalley that traverses the Lake Mackay mapsheet from east to west was first delineated and mapped by Langford et al. (1995) as part of continental-scale mapping undertaken during development of the *Palaeogeographic Atlas of Australia*. This work mapped Late Oligocene to Middle Miocene fluvio-lacustrine sediments within the palaeovalley system. The palaeovalley tract, now marked by a chain of playas, was assumed by Senior et al. (1995) to drain westward into Lake Mackay due to its seemingly contiguous link with the Central Mount Wedge Basin (to the east).

3.3.2 The Western Water Study (WWS)

In the late 1990's, a regional hydrogeological investigation called the Western Water Study (also known as *Wiluraratja Kapi* or WWS) was undertaken as a joint project by agencies from the Australian and NT governments, as well as the Aboriginal and Torres Strait Islander Commission (ATSIC). The WWS area encompassed the Lake Mackay, Mt Doreen, Mt Liebig and Mt Rennie 1:250,000 mapsheets in central Australia. The objective of the WWS was to assess and map the hydrogeology of the region, using a geographic information system (GIS) database as the primary analysis tool. One of the main outcomes of this work was the production of a 1:500,000 map of major aquifer systems in the Papunya–Yuendumu–Kintore region (Wischusen, 1998).

As part of the WWS, Lau et al. (1997) also focused on the Cenozoic geology of the Papunya–Yuendumu–Kintore region. This work developed an isopach map of Cenozoic sediment thickness based on interpretation of drilling and seismic records, and incorporated the previous Cenozoic mapping work of Langford et al. (1995) and Senior et al. (1995).

The WWS divided the study region into six aquifer classes, including fractured rock aquifers and primary porosity aquifers. In many cases, these aquifer systems (especially in the Lake Mackay region) were extrapolated across the vast region on the basis of sparse bore data. The aquifer system which is essentially analogous to palaeovalleys was described as the 'Cainozoic System'[4]. The 'Cainozoic System' aquifer contained variably thick alluvial and lacustrine sediments and associated chemically precipitated sediments such as calcrete, silcrete and ferricrete. Groundwater quality in these systems was mainly classed as 'brackish' (with mean total dissolved solids, TDS, of ~3,200 mg/L). Modest groundwater yields were obtained from relatively shallow depths, e.g., 2-5 L/s (Wischusen, 1998).

As well as interpreting and mapping the hydrogeology of the region, the WWS also involved:

- An integrated remote sensing study for the region from Papunya to Kintore (Woodcock et al., 1997). This work refined the mapped extent of the Wilkinkarra Palaeovalley on the Lake Mackay mapsheet, and identified a tributary branch of the palaeovalley (known as the Mount Russell Palaeovalley);
- A ground geophysical study to investigate palaeovalley infill sediments near Kintore and in the Central Mount Wedge Basin (Anning et al., 1996); and
- Analysis of groundwater quality in the Papunya–Kintore Region by Hostetler et al. (1998).

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[4] Note that Cainozoic was the accepted spelling used for this geological era at the time of the WWS, although it is no longer in official use on the International Chronostratigraphic Chart and has been replaced by Cenozoic.

3.3.3 Recent work

Ten years after the WWS, Tickell (2008) interpreted and mapped the occurrence of palaeovalleys across the NT based on geological mapping data and surface features evident in Landsat and Shuttle Radar Terrain Model (SRTM) imagery. This work provided a sound basis for the new investigative program conducted for the *Palaeovalley Groundwater Project*.

In summary, the investigation of Cenozoic geology and hydrogeology in the Lake Mackay area has been primarily based on sparse drilling data and interpretation of satellite imagery, which has assumed that palaeovalleys can be identified from surface features in the landscape and reflectance from calcrete deposits. Apart from the lithologic log for Emu Bore, there was no detailed stratigraphic data available (prior to this study) to constrain the stratigraphy and sedimentology of palaeovalleys in this vast region.

3.4 PROJECT RESEARCH QUESTIONS

The key research questions which formed the basis of *Palaeovalley Groundwater Project* investigative efforts in the Lake Mackay area were:

1. What is the spatial extent and morphologic nature of regional palaeovalley systems?
2. How and when did these palaeovalley systems evolve?
3. What is the sedimentologic and stratigraphic nature of the palaeovalley infill sediments?
4. What is the quantity and quality of the groundwater resources contained in palaeovalley aquifers?
5. What are the dominant recharge mechanisms that affect the palaeovalley groundwater systems?

3.5 FIELD PROGRAM OBJECTIVES

Field investigations in the Wilkinkarra Palaeovalley demonstration site were designed to improve understanding of the systems morphology, sedimentology and hydrogeology, primarily through a targeted drilling program. This ‘greenfield’ study site also presented an opportunity to test and evaluate the usefulness of various spatial analytical methods and geophysical techniques for identifying and delineating palaeovalleys.

The main objectives of the field investigation program were to:

A. Test the efficacy and usefulness of geophysical survey methods for:

1. Resolving palaeovalley morphology and locating the thalweg zone,
2. Defining the stratigraphic profile of palaeovalley infill sediments, and
3. Delineating groundwater resources in palaeovalley aquifers.

B. Conduct an investigative drilling program across the Wilkinkarra Palaeovalley to:

1. Acquire detailed lithologic data on the nature of palaeovalley infill sediments to help interpret geological characteristics and landscape evolution;
2. Collect suitable sample material for palynological analysis and dating;
3. Test and characterise groundwater resources in palaeovalley aquifers, including aquifer hydraulic parameters and groundwater chemistry; and
4. Ascertain recharge and discharge characteristics.

3.6 FIELD INVESTIGATIONS IN THE WILKINKARRA PALAEOVALLEY

Field investigations in the Wilkinkarra Palaeovalley were undertaken in the Nyirripi region between 2009 and 2011. This work involved ground geophysical surveying, drilling of investigation bores and groundwater sampling and analysis.

3.6.1 Clearances and consultation

Sacred site clearances were required prior to undertaking geophysical and drilling work. A clearance application was submitted to the Central Land Council in Alice Springs in February 2009, and the appropriate certificate was issued in August 2009. A second application was made in March 2010 for further field work later in 2010. Due to wet conditions restricting access to the field site, the required clearance work by the CLC could not be undertaken until April 2011. Consequently, this delay meant that no field work was possible during 2010.

Outside of the official clearance process, community consultation was also an important consideration. Ongoing communication with the Central Desert Shire office at Nyirripi ensured that the local community was fully informed of the proposed work program. The community was further notified of impending work via a notice in the community store and during various opportunistic consultations.

3.6.2 Geophysics

Two geophysical techniques were used to explore and define the Wilkinkarra Palaeovalley:

- Ground-based gravity surveying, and
- Time domain (transient) electromagnetic surveying (TEM).

Ground-based gravity surveying has previously been used in studies of buried valleys as a rapid and inexpensive method for mapping bedrock topography and valley depth (Magee, 2009). The application of this method to help define palaeovalleys relies on the significant density contrast between Cenozoic infill sediments and surrounding older basement rocks. Poorly consolidated alluvial sediments typically have densities of ~1.8–2.0 g/cm^3 whereas the density of indurated basement rocks of granitic composition typically varies from 2.4–3.0 g/cm^3. The density contrast, and thus the effectiveness of the method, is reduced in areas where the basement rocks are deeply weathered, or where the composition of the basement rock types varies across the survey area.

TEM was chosen as a further cost-effective survey method to measure the electrical conductance of the subsurface geologic materials. This method operates by sending an electronic pulse into the earth and measuring the intensity of the response. The EM response is partly influenced by variations in groundwater salinity, and partly by the inherent conductivity of the formation rocks or sediments. This method can provide information on groundwater salinity and can be used to help define palaeovalleys in places where the saturated granular infill sediments occur within a relatively non-porous buried channel.

3.6.2.1 Gravity survey methods

Two traverses were surveyed (Site 1 and Site 2), orientated perpendicular to the axial trend of the palaeovalley (Figure 3.7). The specific aim of the gravity survey was to site drill targets into the palaeovalley sediments, and to assist with the interpretation of the basement morphology and stratigraphic infill package.

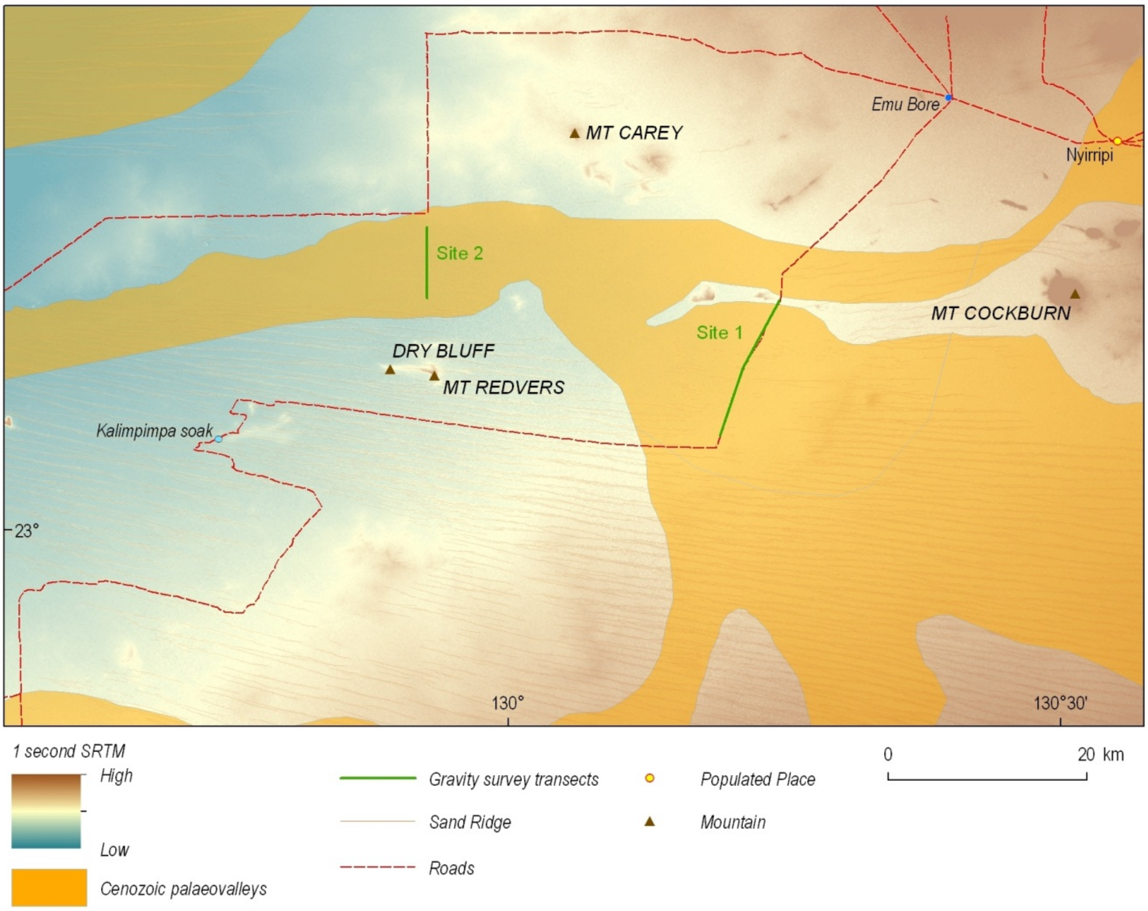

Figure 3.7: *Gravity survey transects at Site 1 and Site 2 across the Wilkinkarra Palaeovalley. Cenozoic palaeovalleys after Bell et al., 2012.*

The initial ground gravity survey (Site 1) was an 18.4 km-long transect consisting of 46 stations spaced 400 m apart along the Kintore to Nyirripi road. This work was completed in July 2009 using a LaCoste and Romberg Model G gravity meter (accurate to 0.01 milliGals, mGal) provided by the Continental Geophysics Section of Geoscience Australia. Given the interpreted width of the Wilkinkarra Palaeovalley in this region (>20 km wide based on analysis of remotely sensed data), the 400 m station spacing was considered the optimal distance for defining the size and shape of the gravity anomaly associated with the palaeovalley, while also providing suitable survey coverage (distance) across the entire width of the buried valley system.

In October 2009, further gravity measurements were taken at 57 infill gravity stations spaced 100 m apart[5] to evaluate the effectiveness of more detailed infill data to improve definition of the palaeovalley gravity anomaly.

In June 2011, a 10 km-long gravity traverse (200 m station spacing) was completed at Site 2, approximately 37 km west of Site 1 on the Wilkinkarra Palaeovalley (Figure 3.7). This work was undertaken by the Northern Territory Geological Survey (NTGS) using a Scintrex CG-5 “Autograv” gravity meter.

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[5] The 100 m spaced infill gravity data were acquired between original survey stations 2000 and 7600 along the Nyirripi to Kintore road.

3.6.2.2 *Gravity data processing*

One of the critical data corrections required for gravity surveying relates to variations in the elevation of each survey station (Griffiths and King, 1981). In July 2009 detailed elevation data for each station along the Site 1 survey line was captured using a Real Time Kinematic (RTK) Global Positioning System (GPS).

For the microgravity survey traverse at Site 2, elevation data for each station was obtained by the NT Department of Lands and Planning. A RTK GPS similar to that used at Site 1 was also used to obtain the Site 2 elevation data.

Processing of the gravity data was undertaken to derive the Bouguer 2.67 gravity anomaly[6] for the survey transect, following the processing methods described in Blakely (1996) and Telford et al. (1990). Additionally, the regional gravity trend was removed from the dataset by subtracting a linear computer-generated trend-line (using Grapher™ software).

Further processing of the gravity data for Site 1 was undertaken using Fourier processing to enhance features within the dataset. A gravity model was also constructed to simulate the Bouguer gravity response for both survey sites.

3.6.2.3 *Gravity survey results and discussion*

Processing of the gravity data for Site 1 shows a broad gravity low coincident with most of the Wilkinkarra Palaeovalley (with up to 5 mGal variation from background), and several lower frequency gravity anomalies (Figure 3.8). The measured gravity data are elevated near to the location of outcropping basement rocks at the northern end of the palaeovalley survey line (~2,000 metre survey station). This relative gravity high clearly demarcates the northern boundary of the incised palaeovalley system.

The Site 2 gravity profile also shows a broad basement high at the northern end of the palaeovalley (Figure 3.8).

Fourier analysis of Site 1 gravity data was used to further enhance the density anomaly associated with the incised palaeovalley. This method transforms data from the spatial domain into the frequency domain, thus enhancing the dominant data frequencies. A first vertical derivative (FVD) algorithm was also applied to these data (Figure 3.9), showing a number of significant gravity low anomalies (interpreted as inset channels) along the length of the survey.

A 2D gravity model was constructed to simulate the 400 m Bouguer gravity response and help predict depth to basement (Figure 3.9). The model used geological data obtained from drilling and assumed a basement density of 2.6 x 10^3 kg/m^3 and a channel fill density of 1.9x10^3 kg/m^3. The model ignored possible density variations that may exist between the granitic basement rocks of the Arunta Region (central and southern-end of the survey) and the Neoproterozoic sandstone of the Ngalia Basin which underlies palaeovalley sediments at the northern end.

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[6] The Bouguer 2.67 gravity anomaly assumes a rock density of 2.67 g/cm^3.

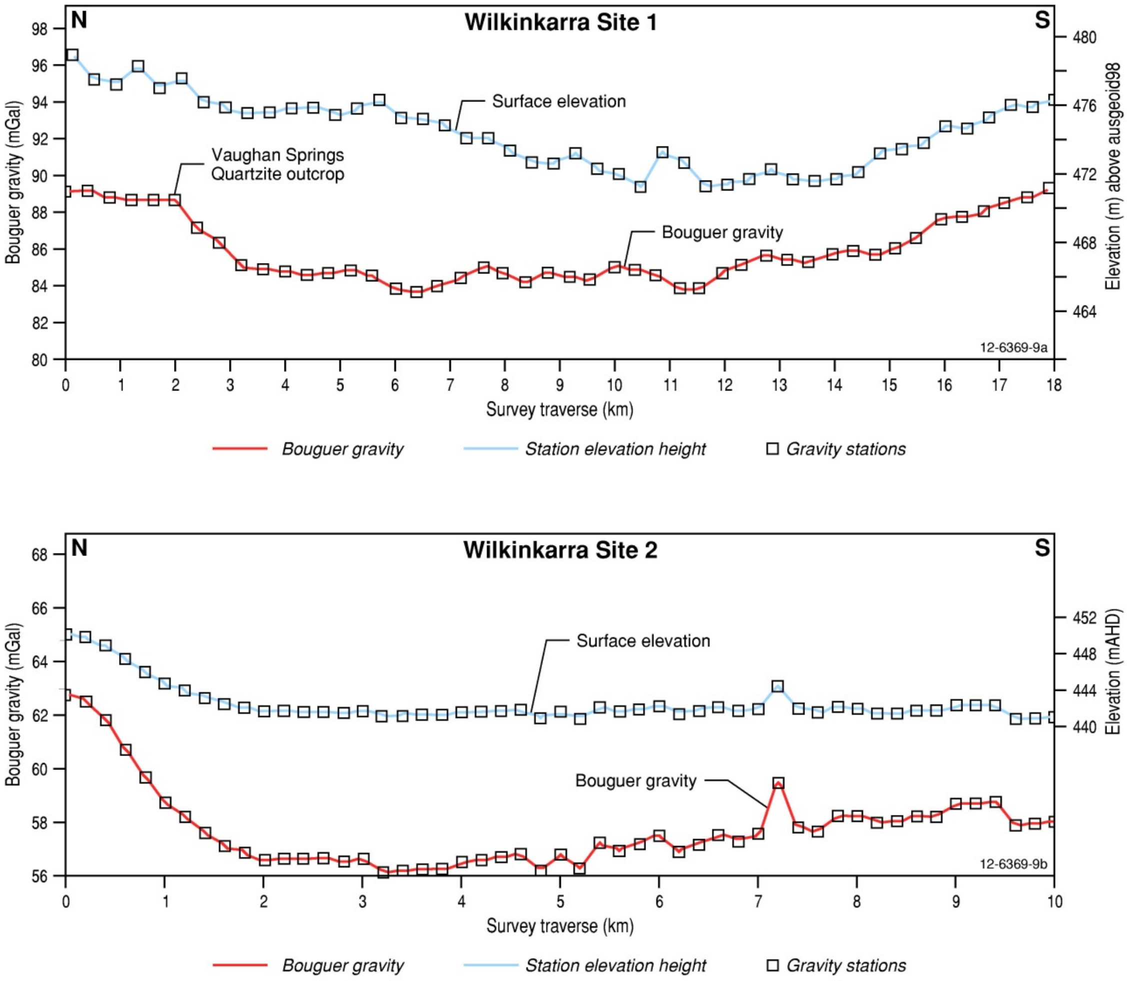

Figure 3.8: *Bouguer gravity and surface elevation data for survey transects at Site 1 and Site 2 across the Wilkinkarra Palaeovalley. Station spacing for Site 1 is 400 m, and for Site 2 is 200 m.*

The gravity model underestimated basement depth in some places and overestimated it in others, but overall provided a reasonable representation (Figure 3.9). The inability of the model to accurately simulate the depth of the contact zone between palaeovalley sediments and the underlying basement rocks is probably due to variations in the composition of the basement rocks and the degree of weathering. In particular, the degree of metamorphism and composition of the Arunta Region rocks is complex and highly variable (e.g., phyllite was encountered at the base of one drillhole, whereas granitic material was encountered in another), and hence the density of the basement rocks is likely to vary along the transect. These factors limited the ability of gravity data to accurately define basement contours and the depth of sedimentary infill within the palaeovalley.

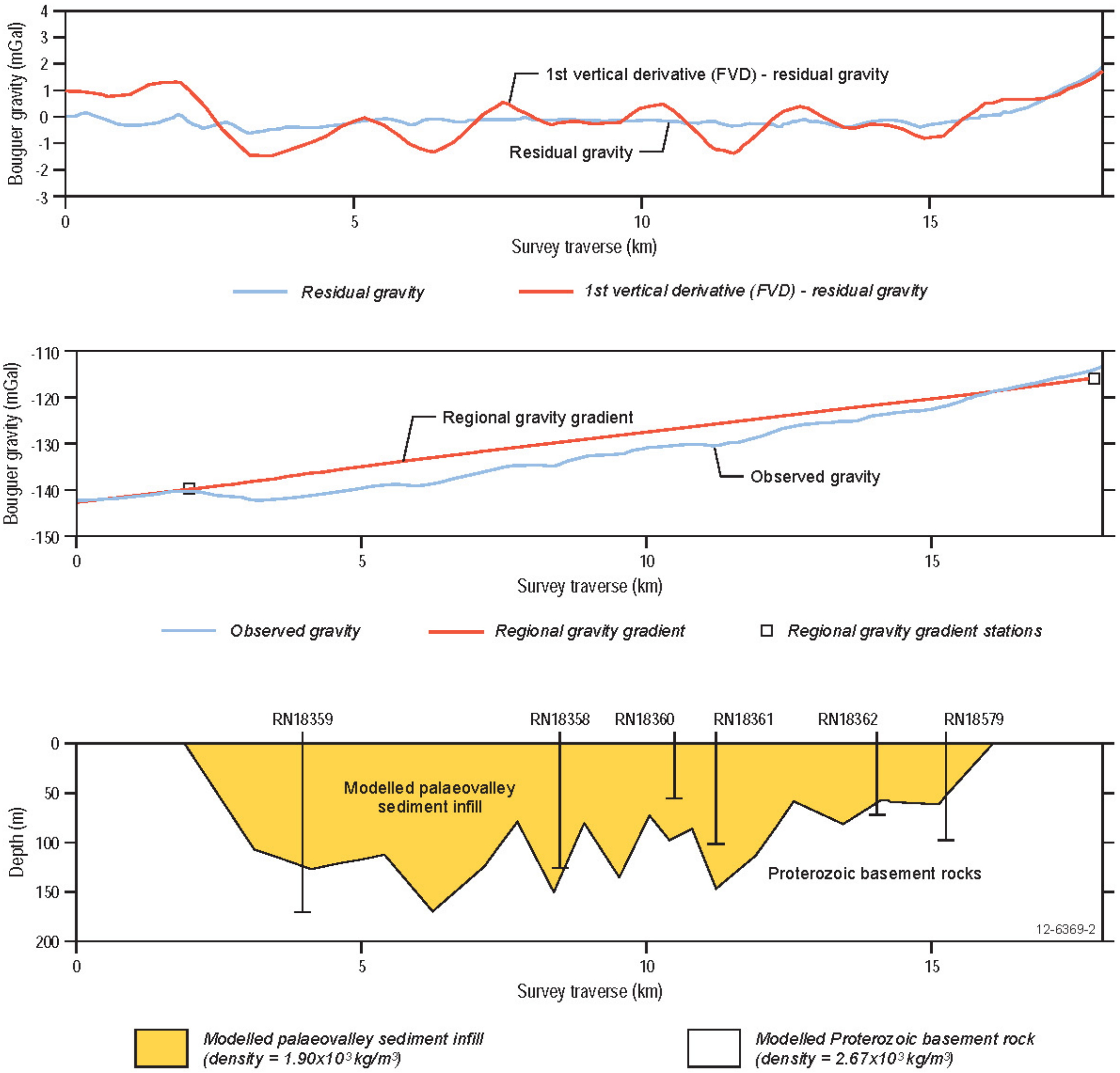

Figure 3.9: *2D gravity model using data from the Site 1 survey transect across the Wilkinkarra Palaeovalley.*

3.6.2.4 Time-domain electromagnetic (EM) survey

The time-domain EM survey was undertaken at Site 1 with SiroTEM Mark III coincident 100 m x 100 m sounding loops, using early time series and 0.3 mS initial delay. Data for 130 stations were obtained at 100 m spacing in August 2009 by NRETAS staff. The EM system generated a 2D profile (pseudo-section) of the subsurface conductivity distribution.

Groundwater Imaging Pty Ltd (GWI) was engaged to further process the SiroTEM data to determine its suitability for deriving accurate information on the basement depth and sedimentary layering. GWI used *EM1DInv,* a software application from the Aarhus Hydrogeophysics Group, to invert the raw data and generate a vertical resistivity section (VRS). Work undertaken by GWI showed that the SiroTEM data collected in the Nyirripi region was of good quality (Allen, 2010).

The GWI conductivity section shows a distinct conductive response associated with depth in the northern 5 km-long segment of the transect (Figure 3.10). A less-pronounced conductive response is evident for the central to southern end of the survey line. The higher conductivity zone is interpreted as saline groundwater within the palaeovalley sediments in the northern transect. Several moderately conductive features occur within the southern half of the transect (Figure 3.10), but the overall conductivity response is lower in this segment of the survey. This implies that fresher groundwater occurs within the sediments of the southern half of the palaeovalley (probably reflecting that this area is nearer to the main groundwater recharge zone of the palaeovalley).

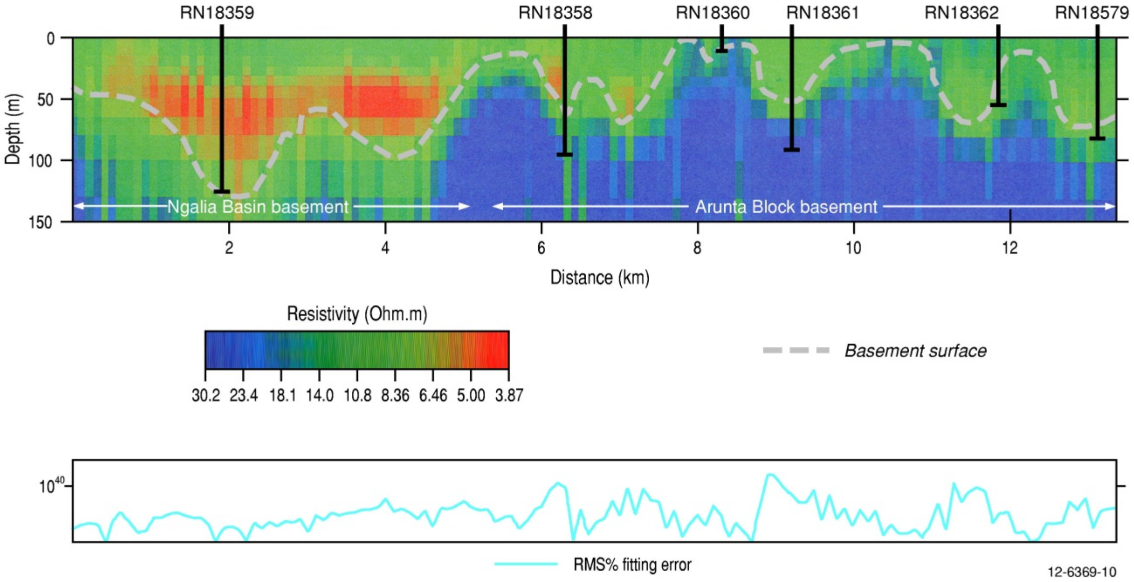

Figure 3.10: *Transient Electromagnetic Survey (SiroTEM) data for the Site 1 transect at the Wilkinkarra Palaeovalley.*

The basement contact interpreted by GWI is represented by the dashed line on the VRS and the drilled bores are shown to approximate basement depth (Figure 3.10). According to the drilling data the basement depth for the Wilkinkarra Palaeovalley was overstated for the northern third of the line (left hand end of transect in Figure 3.10). This may be due to variations in the composition of the basement rocks for this region, compared to the central and southern segments. The basement rocks underlying the northern part of the Site 1 transect are mostly sandstones of the Ngalia Basin. These are lithologically similar to the overlying Cenozoic palaeovalley infill and probably have comparable hydrogeological properties. However, there is significantly greater contrast in the physical properties of the Arunta Region basement rocks (consisting of more indurated metamorphic and igneous rocks) and the overlying palaeovalley sediments at the southern end of the survey line. Consequently, the electromagnetic data have probably underestimated the basement depth for the central and southern segments of the transect.

In addition to changes in the composition of the basement rocks the TEM data in Figure 3.10 are also influenced by variations in groundwater salinity within the palaeovalley aquifer. The highest conductivity response in the VRS coincides with the highest salinity groundwater obtained during the drilling program (with TDS ranging from ~4,000 to 6,000 mg/L). In contrast, groundwater salinity in the central and southern parts is considerably fresher (600 to 800 mg/L), coinciding with the lower conductivity response evident on the VRS (Figure 3.10).

3.6.3 Drilling

3.6.3.1 Drilling methods

Six investigation bores were drilled along the Nyirripi to Kintore road in October and November of 2009. Follow-up drilling was undertaken in July 2011 with a further six bores drilled at four sites (Figure 3.11).

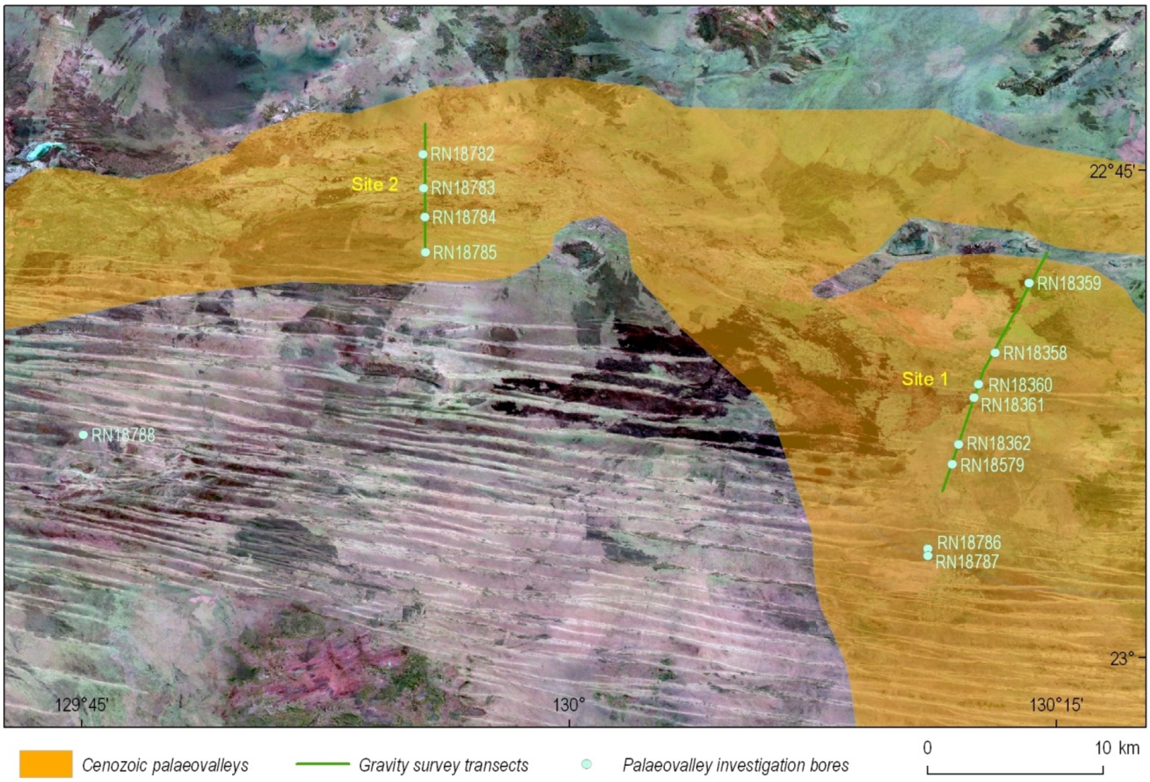

Figure 3.11: *Investigative bore sites drilled in the Wilkinkarra Palaeovalley for the Palaeovalley Groundwater Project. The Cenozoic palaeovalley extent shown here is derived from Bell et al., 2012.*

Bore sites were based on interpreted geophysical data and specifically targeted the deeper parts of the palaeovalley to intersect the maximum thickness of Cenozoic sedimentary infill. Some bores also targeted the buried side slopes of the palaeovalley. Drilling was conducted by the Northern Territory government drilling crew using an Ingersoll Rand 1500 drilling rig.

Air-rotary drilling was mainly used as it allows for collection of both lithologic and groundwater data during drilling. Most of the bores intersected the entire thickness of alluvial Cenozoic sediments in the palaeovalley and penetrated to the underlying weathered bedrocks. Basement rock intersections were not always easy to identify due to intense weathering. During drilling operations, composite drill chip samples were collected, logged and bagged for every 3 m interval.

Downhole gamma logging was also conducted for each hole at the completion of drilling. In unstable bores (e.g., due to caving), the gamma log was run through the drill pipe. This was taken into account when interpreting logs as the drilling rods attenuate the gamma response.

Airlifted water samples were collected during drilling operations. Field measurements of groundwater electrical conductivity (EC) and pH were recorded at regular intervals, and airlift yields were also regularly estimated. The interpretation of these data accounted for increasing submergence with depth and the effect of overlying aquifers. The sampling program aimed to collect shallow and deeper groundwater samples from each hole (especially where water quality variations were noted from the downhole field measurements). Standard groundwater sampling QA/QC procedures (Sundaram et al., 2009) were used to ensure the integrity of samples collected for routine analysis. The final sample collected from each bore (for isotopic analysis) was taken with the aid of a submersible downhole pump.

Twenty samples were dispatched to Northern Territory Environmental Laboratories (NTEL) for hydrochemical analysis. Samples were tested in the laboratory for pH, conductivity, alkalinity, major/minor cations and anions, nitrates, metals and trace metals. Additional samples were also submitted to the CSIRO Laboratory in Adelaide and the Rafter Laboratory (operated by GNS) in New Zealand for analysis of stable oxygen and hydrogen isotopes to assist with the interpretation of groundwater processes, such as recharge rates. Several samples were also submitted to the Australian National University SSAMS Radiocarbon Dating Centre for analysis of radiogenic carbon (^{14}C) to estimate groundwater residence times.

Most bores were completed as permanent monitoring bores with installation of 6 metre 203 mm cemented steel surface collars, and 100 millimetre PVC casing (Figure 3.12). The hand-slotted section of PVC casing was positioned in the highest yielding part of the water-bearing formation. The completed surface installation consists of a lockable steel standpipe surrounding the stickup casing, with a nearby marker pole.

A pressure transducer logger (a *Minitroll*™) was installed in bore RN18359[7] in May 2010 to record daily water level changes over time. Standing water levels were also measured for the accessible monitoring bores.

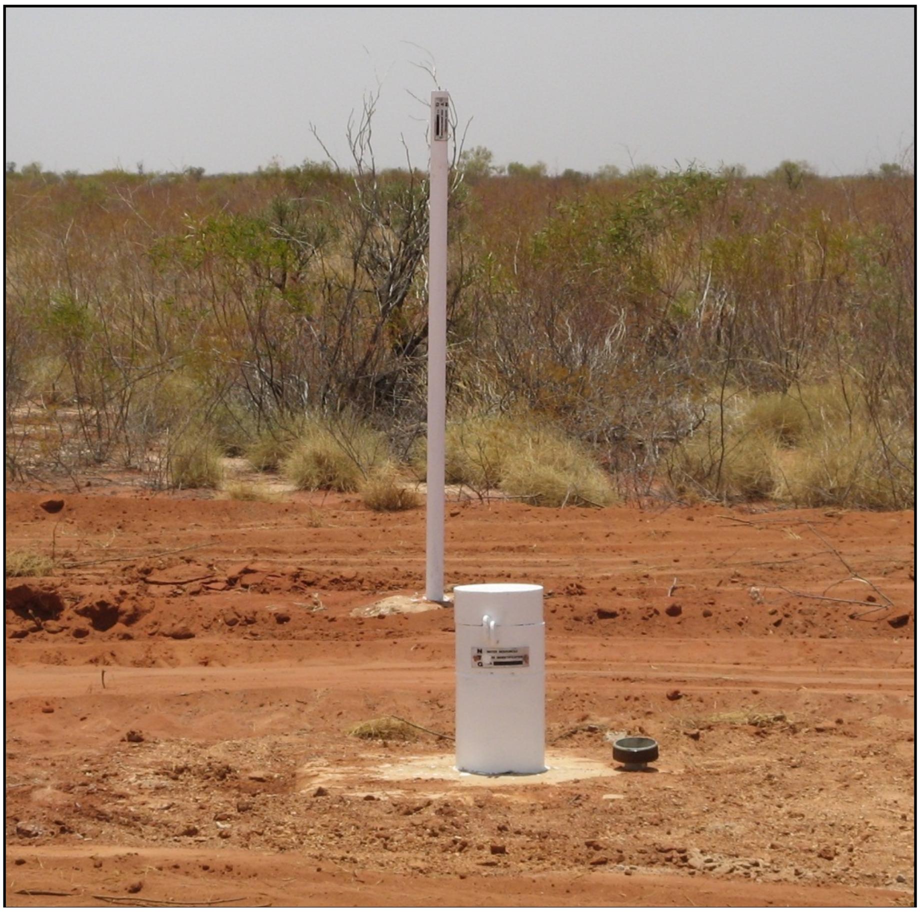

Figure 3.12: *Typical surface installation for investigation bores drilled in the Wilkinkarra Palaeovalley.*

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[7] Bore RN18359 was selected for the downhole logger because it was the deepest bore drilled into the Wilkinkarra Palaeovalley.

3.6.3.2 Drilling results

Drilling in the Wilkinkarra Palaeovalley and surrounding Nyirripi region involved installation of 13 bores totalling nearly 950 m (Figure 3.11). Cenozoic sediments infilling the main trunk palaeovalley were intersected in most bores, and stratigraphic thickness ranged from 9 to 127 m. This reflects the variable nature of the pre-Cenozoic erosional surface of the basement Ngalia Basin and Arunta Block (Tables 3.1–3.2). Summary drilling logs for all bores, including downhole gamma logs which indicate generally fining-upward sedimentary sequences, are provided in Appendix 1.

This drilling program confirmed the presence of a major sediment-filled palaeovalley system, and revealed broad (~20 km wide) valley morphology with multiple channel networks inset within the wider primary valley. Drilling also confirmed that the elevation of the palaeovalley floor rises towards the west, although the surface elevation declines westward (Figure 3.13). Thus, the thickness of the palaeovalley infill sequence decreases from over 100 m depth (Site 1) to less than 40 m depth at Site 2 (Figure 3.14). These data suggest that the drainage flow directions of the past may have been different to modern drainage directions, and Lake Mackay may not have always been the major depocentre of the regional drainage network.

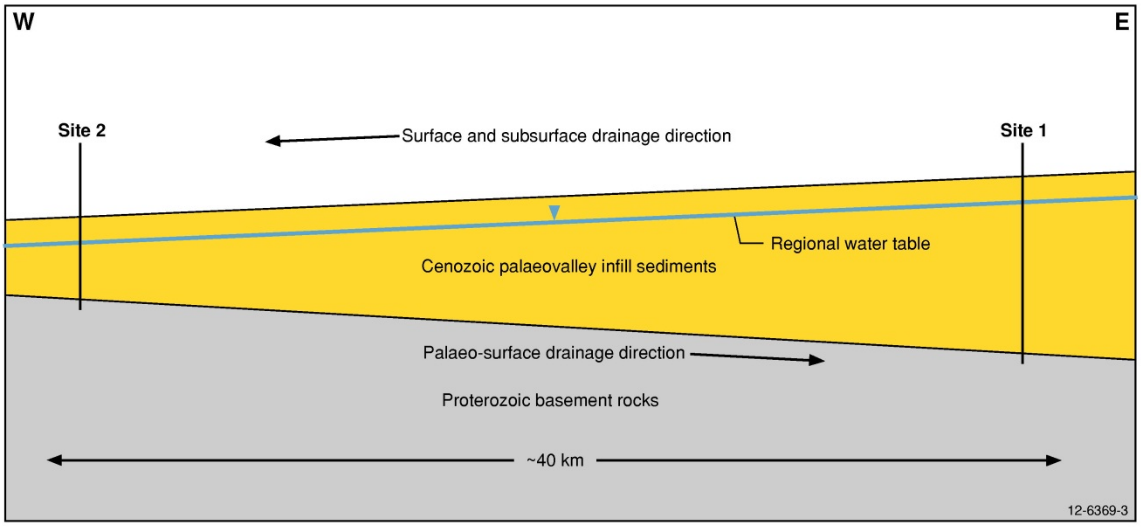

Figure 3.13: *Schematic diagram of the axial geometry of the Wilkinkarra Palaeovalley identified during the project drilling program.*

Table 3.1: Summary of boreholes drilled into the Wilkinkarra Palaeovalley in 2009.

BORE ID	EASTING	NORTHING	SURFACE ELEVATION (mad)	TOTAL BORE DEPTH (mbgl)	DEPTH OF CASING (mbgl)	BASEMENT DEPTH (mbgl)	HIGHEST YIELD (L/s)	SWL (mbgl)	FIELD EC (µS/cm)	BORE CASING DETAILS
RN18359	626869	7477232	475.8	174.0	73.0	127	18	5.14	7,900	50 mm Cl12 PVC, 6m, 152mm steel collar
RN18358	625036	7473278	472.6	126.0	72.3	116	10	2.77	7,220	50 mm Cl12 PVC, 6m, 152mm steel collar
RN18360	624143	7471502	471.2	54.5	backfilled	9	seepage	5.80	7,360	n/a
RN18361	623909	7470744	472.6	103.6	70.6	75	2.5	4.97	6,310	50 mm Cl12 PVC, 6m, 152mm steel collar
RN18362	623075	7468092	471.6	79.2	35.5	72	8	3.90	1,200	152 mm steel, 8-inch steel collar. Equipped with handpump – 'Winners Bore'
RN18579	622720	7466954	473.4	96.0	backfilled	84	7	4.05	1,009	n/a

Note:

1. The coordinate system and datum for the easting and northing is UTM Zone 52 – WGS84.
2. The highest yield data were estimated during drilling operations.
3. The field measured electrical conductivity is the maximum value measured from each bore.
4. Abbreviations used above are:

mad = metres above datum - AUSGEOID98
mbgl = metres below ground level
SWL = standing water level
EC = electrical conductivity

Table 3.2: Summary of boreholes drilled in the Wilkinkarra Palaeovalley in 2011.

BORE	EASTING	NORTHING	SURFACE ELEVATION (mad)	TOTAL BORE DEPTH (mbgl)	DEPTH OF CASING (mbgl)	BASEMENT INTERSECT (mbgl)	HIGHEST YIELD (L/s)	SWL (mbgl)	FIELD EC (µS/cm)	BORE CASING DETAILS
RN18782	594987	7484792	441.08	78.5	40.0	39	5	2.70	18,500	50 mm Cl12 PVC, twin piezometers installed (shallow & deep), 152 mm steel collar
RN18783	595029	7482853	440.86	43	12.7	33	11.5	3.92	12,000	100 mm Cl12 PVC, 152 mm steel collar
RN18784	595067	7481206	441.70	36	18.9	Not intersected	17	3.52	8,900	100 mm Cl12 PVC, 152 mm steel collar
RN18785	595090	7479192	441.71	48.3	31.2	39	15	3.86	11,700	100 mm Cl12 PVC, 152 mm steel collar
RN18786	621410	7462159	unknown	61.5	31.7	30.0	2.6	3.52	1,380	100 mm Cl12 PVC, 152 mm steel collar
RN18787	621418	7461759	unknown	18	18.5	13	0.3	3.82	1,260	100 mm Cl12 PVC, 152 mm steel collar
RN18788	577019	7468935	unknown	31	30.5	15	0.2	4.5	4,660	100 mm Cl12 PVC, 152 mm steel collar

Note:

1. The coordinate system and datum for the easting and northing is UTM Zone 52 – WGS84.
2. The highest yield data were estimated during drilling operations.
3. The field measured electrical conductivity is the maximum value measured from each bore.
4. The SWL measurement in bore RN18782 (with twin piezometers) is for the shallow piezometers.
4. Abbreviations used above are:

mad = metres above datum - AUSGEOID98
mbgl = metres below ground level
SWL = standing water level
EC = electrical conductivity

Overall, the Cenozoic sediments are dominated by quartz sand with variable sorting and weathering characteristics. These are interbedded with subordinate layers of thin clay or silt. The sand-rich sediments are commonly micaceous, reflecting the dominantly granitic and gneissic provenance. The generalised sediment profile encountered during drilling in the Wilkinkarra Palaeovalley can be summarised as:

- Thin to negligible red Quaternary aeolian sand widespread at surface, generally <0.1 m thick;
- Extensive calcrete 6–12 m in the shallow subsurface; and
- Underlying the calcrete the palaeovalley sediments are dominated by poorly cemented, fine- to coarse-grained sands (some partially lithified) which are moderately sorted, and mainly consist of subrounded to subangular quartz grains. Minor subangular quartz gravel also occurs throughout the sequence. No fine-grained carbonaceous material (e.g., clay or lignite) was encountered within any bores. In borehole RN18359, ~20 m of fine- to medium-grained, well rounded quartz sand was intersected immediately above the basement rocks. This basal sand unit, which may represent a palaeovalley thalweg deposit, was not recovered in other bores.

From a hydrogeological perspective the entire palaeovalley sediment sequence forms a moderate to good quality aquifer, with no obvious aquitard or aquiclude layers. Average yields are~5–10 L/s.

Basement rocks encountered during drilling vary considerably across the width of the palaeovalley. In general, the regional 1:250,000 geological mapping (Edgoose et al., 2008) was validated along the Site 1 transect. In particular, the drilling program delineated the boundary between the Neoproterozoic Vaughan Springs Quartzite of the Ngalia Basin at the northern end of the transect and the granitic and gneissic Lander Rock Formation at the southern end (Figure 3.14).

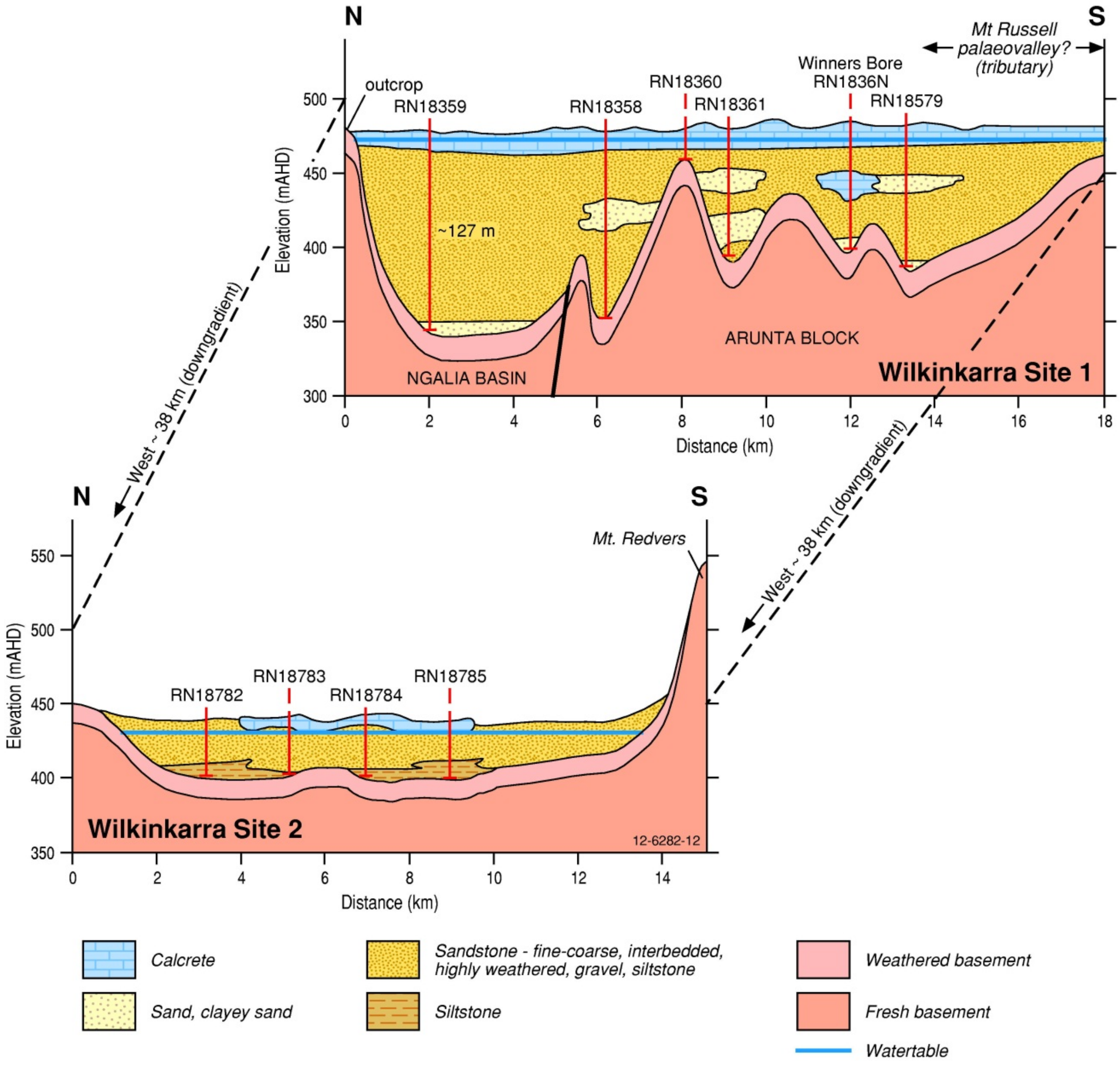

Figure 3.14: *Cross-section of the Wilkinkarra Palaeovalley at Sites 1 and 2 based on integrated drilling and geophysical studies. RN numbers shown are bores drilled through the palaeovalley infill sequence to bedrock for this project.*

3.6.4 Hydrogeology

Abundant groundwater resources occur in calcrete and underlying alluvial sediments at shallow depths (~3 m below surface) within the Wilkinkarra Palaeovalley. Measured airlift yields vary from seepage to 18 litres-per-second (L/s). Based on the observed lithological variation and water quality data the entire palaeovalley alluvial sequence is interpreted to be a vertically interconnected hydrogeological system. In particular, aquifer porosity is similar throughout the downhole profile, and there are no significant confining layers. This indicates that the aquifer can largely be considered as an unconfined system. It is likely that some of the clay- and silt-rich beds of the alluvial sequence may impede groundwater flow (at least to some degree), and areas of relatively elevated basement rocks may act as groundwater divides, which could compartmentalise zones of the aquifer.

3.6.4.1 Groundwater recharge

Recharge volumes and rates are difficult to estimate given the lack of prior groundwater level time-series data. The proportion of recharge is assumed to be very small relative to rainfall (<1%), as most surface water (following rainfall) is likely to be lost by evapotranspiration before it can infiltrate to the groundwater system. Recharge probably occurs only when a certain rainfall intensity and duration threshold is exceeded and is thus extremely sporadic in this arid zone setting. The dominant mechanism of groundwater recharge to the palaeovalley has not been established but may be a combination of diffuse and direct recharge. The karst-like nature of near-surface calcrete in the Wilkinkarra Palaeovalley may provide pathways for direct recharge.

Since May 2010 time series data has been collected from the downhole pressure transducer logger in RN18359 (installed in the middle of an unusually wet year in 2010). Manual measurements of water levels were also collected on four occasions. The bore hydrograph (Figure 3.15) shows that water levels rose by around 1.4 m between September 2009 and September 2010 in response to high rainfall (rainfall records are those from nearby weather stations). Thus, the Wilkinkarra Palaeovalley aquifer receives modern recharge, although the recharge response at this location is not immediate. The several months lag between rainfall and the rise in the groundwater level indicates the amount of time that it takes for water to percolate through the ~5 m thick unsaturated zone, or via other unknown routes (either via direct or diffuse recharge processes). Further, the plot indicates that recharge probably occurs only when individual rainfall events exceed ~30 mm.

Interpretation of hydrogeochemistry data can also provide information on groundwater recharge processes (Section 3.6.5). The interpretation of water quality data for the Wilkinkarra Palaeovalley suggests that recent recharge to the system has occurred at the southern end of the palaeovalley at Site 1 due to the presence of lower salinity water compared to the northern end. However, the radiocarbon data for groundwater from Winner's Bore (RN18362), at the southern end of the palaeovalley, indicates uncorrected groundwater residence time of ~13,830 years (17.85 pMC). In contrast, groundwater at the northern end of Site 1 is considerably younger at 2,705 years (71.39 pMC).

One explanation for the discrepancy in the salinity and age data is that recharge has occurred under different climatic regimes. Palaeoclimatic reconstructions in the nearby Great Artesian Basin indicate that much wetter conditions existed in the past, compared with the present-day arid setting. Distinct humid periods occurred between 3,000–6,000 and 11,000–13,000 years ago, respectively (Ullman and Collerson, 1994; De Deckker et al., 2009; S. Fulton, 2011, pers. comm.). The 'older' water in the Wilkinkarra Palaeovalley may have been recharged during wetter times, and consequently been subjected to much lower rates of evapotranspiration (ET). Thus, this older water now has much lower salinity. Conversely, the 'younger' water at the northern end of Site 1 may have been recharged in more arid conditions when the prevailing ET rates were significantly higher, resulting in the more saline compositions that now occur.

The salinity/age discrepancy may also be the result of different recharge and flow paths. The younger and more saline groundwater may have recharged through clay or sandy clay sediments, and spent more time in the zone where salts are concentrated by ET. Conversely, the fresher water may have been more rapidly recharged along a different flow path. Further and more detailed studies (beyond the reconnaissance level scope of this investigation) are now required to better understand the recharge mechanisms in this arid zone setting.

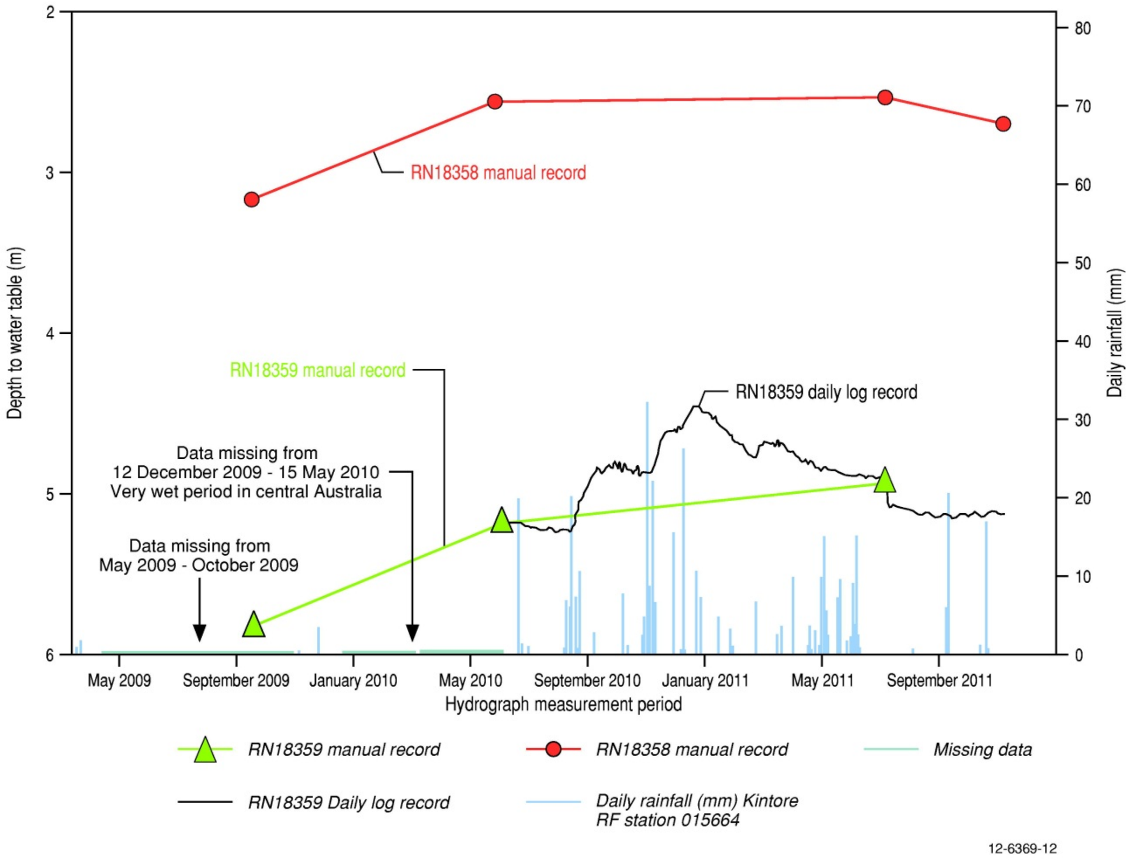

Figure 3.15: *Bore hydrographs for the Wilkinkarra Palaeovalley (2009 to 2011) and rainfall records for Kintore weather station.*

3.6.4.2 Groundwater flow direction

Comparison of standing water levels between bores at Site 1 and those down-gradient at Site 2 confirms that groundwater flow is westward and towards Lake Mackay. The approximate groundwater gradient is 0.001.

3.6.4.3 Groundwater discharge

The elevation of the palaeovalley basement rises westward between Site 1 and Site 2, bringing groundwater closer to the evaporative zone as it nears Lake Mackay (Figure 3.13). A number of small playas (groundwater discharge sites) occur near Site 2 (Figure 3.16). Some groundwater is probably also lost via evapotranspiration before it reaches Lake Mackay, the terminal discharge zone of the Wilkinkarra Palaeovalley aquifer.

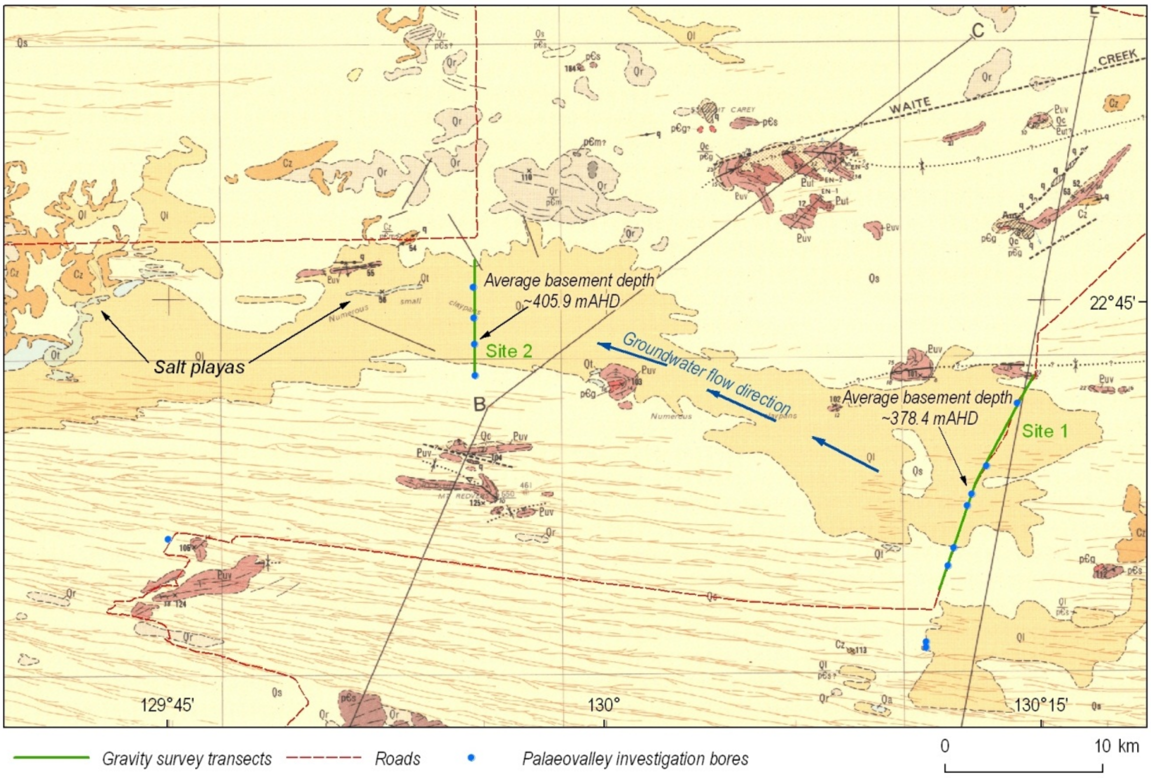

Figure 3.16: *Basement topography and discharge features in the Wilkinkarra Palaeovalley. Note the increase in size and number of saline playas closer to Lake Mackay (situated just off the western edge of this map).*

3.6.5 Hydrogeochemistry

A total of 20 groundwater samples were collected from the newly drilled and constructed bores in the Wilkinkarra Palaeovalley (Appendix 2). The groundwater ionic chemistry is characterised as:

- Groundwater salinity is relatively high in bores from the central and northern part of Site 1 (RN18358 to RN18361), with total dissolved solids (TDS) ~3,300–5,700 mg/L (mean of 4,700 mg/L). In contrast, groundwater is considerably fresher in the southern bores[8] which have mean TDS of 675 mg/L (Figure 3.17).
- Groundwater salinity at Site 2 (down-gradient of Site 1) is much higher, with an average TDS of nearly 8,000 mg/L. Increased salinity here is probably due to the shallower basement (thinner Cenozoic sediment profile), causing groundwater to occur nearer to the surface. Thus, it is more strongly affected by evaporative concentration of salts. This is supported by the presence of several saline playas near Site 2 (Figure 3.16). Similarly, groundwater salinity is consistently higher in the shallow calcrete aquifers, again due to evaporative concentration of salts. Below the calcrete zone only relatively minor variation occurs in groundwater salinity down-profile. This implies that the aquifer system is strongly interconnected.

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[8] The four southern bores along Site 1 transect in the Wilkinkarra Palaeovalley are RN18362, RN18579, RN18786, and RN18787.

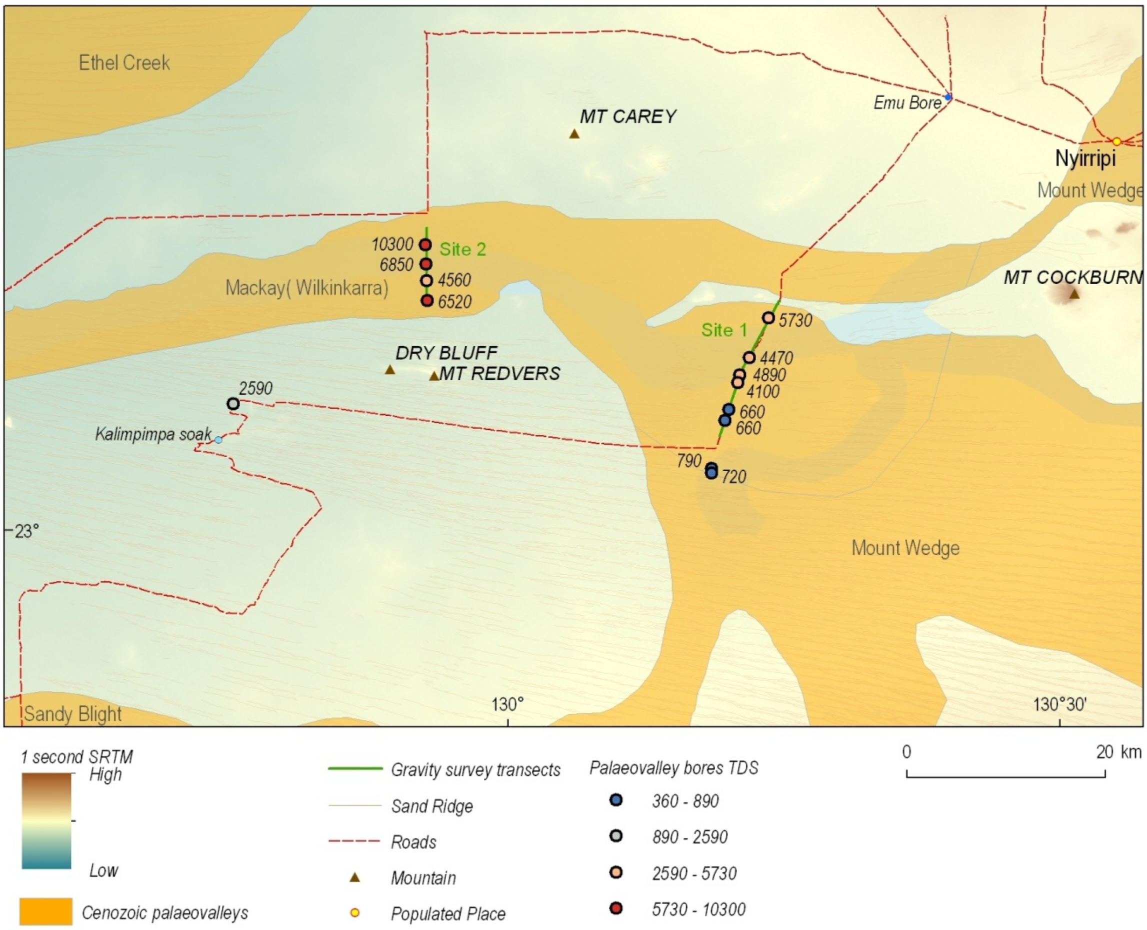

Figure 3.17: *Distribution of groundwater salinity in bores in the Wilkinkarra Palaeovalley. Data shown for total dissolved solids (TDS) in mg/L. Cenozoic palaeovalleys shown here after Bell et al., 2012.*

- Groundwater chemistry falls into two main hydrochemical facies, or water types (Figure 3.18), these being: 1. Na-Cl dominated at the northern end of Site 1, and for all of Site 2; and 2. Na-HCO_3-Cl and Na-Ca-HCO_3-Cl at the southern end of Site 1. HCO_3-dominated waters are broadly indicative of recharge zones. In terms of the dominant anions, the groundwater types correspond respectively with the upper and lower zone of the Chebotarev sequence of chemical evolution of natural groundwater for sedimentary basins (Freeze and Cherry, 1979).
- With the exception of bores RN18782 and RN18788, nitrate levels consistently exceed drinking water guidelines (50 mg/L) and in some cases are more than double the recommended maximum concentration. Elevated nitrate levels can cause health problems for babies and small children. Nitrate concentrations above the drinking water limit are common in groundwater from Australia's arid zone, particularly in shallow unconfined aquifers (Murray and Siebert, 1962). Natural processes of near-surface biological fixation are the cause of such elevated nitrate levels (Barnes et al., 1992).
- Other ions occur in some samples at levels above the recommended potability limits, such as fluorine, iodine, molybdenum, and uranium. However, there are no consistent spatial patterns or trends evident in the distribution of these elevated ionic species.

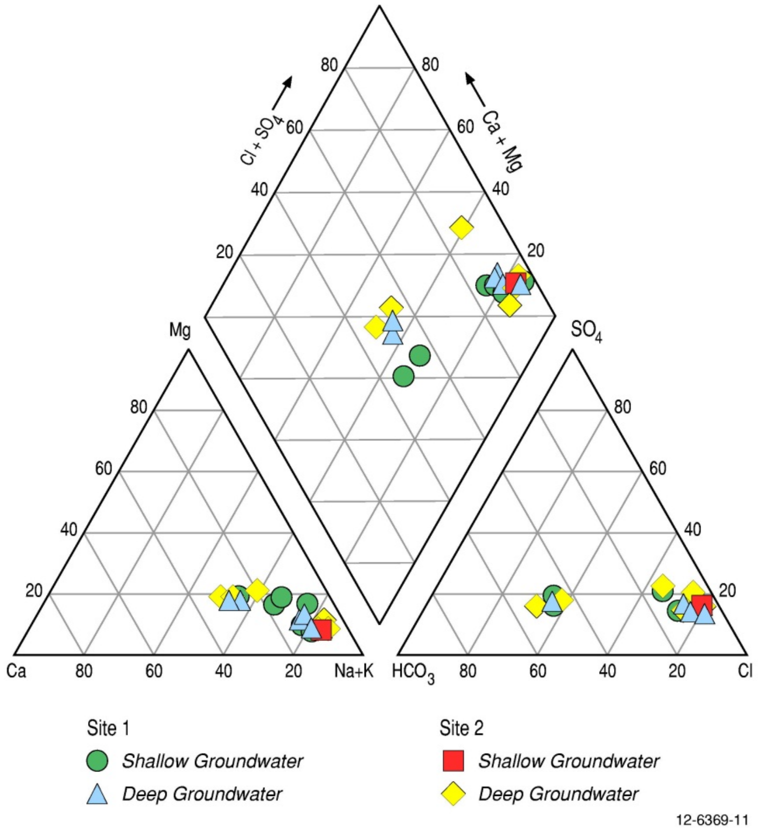

Figure 3.18: *Piper diagram for groundwater samples from the Wilkinkarra Palaeovalley, showing two main hydrochemical groups. These are interpreted as groundwater end-members, with more saline water from the northern part of Site 1 and Site 2, and fresher water from southern Site 1.*

3.6.5.1 Stable isotopes

The isotopic (deuterium and oxygen-18) composition of groundwater relative to rainfall provides a useful method of estimating recharge mechanisms. The results of stable isotope analysis from the Wilkinkarra Palaeovalley were plotted against the local meteoric water line (LMWL) for Alice Springs (Figure 3.19).

Groundwater in the Wilkinkarra Palaeovalley is relatively enriched in the heavier isotope $\delta^{18}O$ compared to the Alice Springs LMWL, indicating that considerable evaporation has occurred during recharge. Thus, diffuse recharge is considered the most likely recharge mechanism to this groundwater system, with evaporative losses occurring from the soil water zone. However, the stable isotope signature of the saline water is similar to that of the fresher water (RN18359 vs. RN18362), which indicates that higher salt concentrations are not entirely the result of evaporative losses causing differential fractionation of isotopes. Transpiration (by vegetation), which does not fractionate isotopes as evaporation does, may also play an important role in controlling groundwater salinity within the Wilkinkarra Palaeovalley.

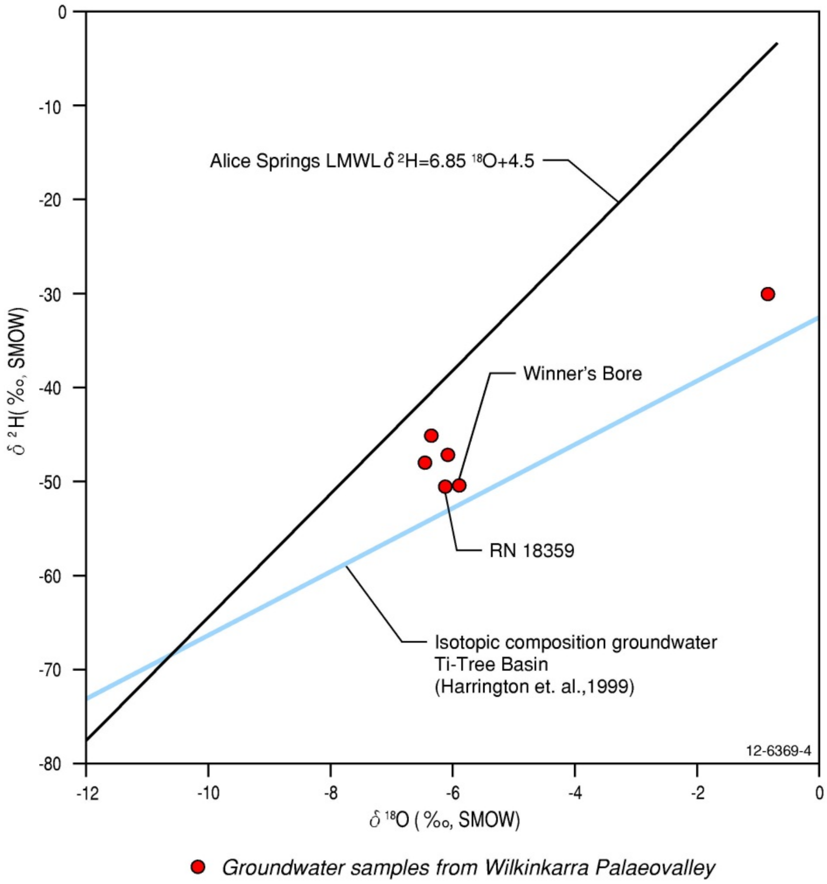

Figure 3.19: *δ^2 H vs. δ^{18}O plot showing the local meteoric water line (LMWL) for Alice Springs, groundwater from the Ti-Tree Basin (blue line, for comparison, data from Harrington et. al., 1999), and the composition of groundwater for bores from the Wilkinkarra Palaeovalley.*

3.6.5.2 Carbon-14

A groundwater sample from bore RN18362 (Winner's Bore) was analysed for carbon-14 at the Australian National University's SSAMS Radiocarbon Dating Centre. The sample contained 17.87 pMC (percent Modern Carbon), with an uncorrected mean residence time of 13,830 yrs (using the Libby half-life of 5,568 years and following the conventions of Stuiver and Polach, 1997). This groundwater age assumes no water-rock interaction and, as such, indicates the maximum possible age for the sample.

Carbon-14 analysis of palaeovalley groundwater from bores at the northern end of Site 1 yielded 81.15 pMC (uncorrected age of 1,680 yrs) and 71.39 pMC (2,705 yrs) for RN18359 and RN18358 respectively, indicating much younger water. These results were unexpected given that these bores contain more saline groundwater. The radiocarbon data from the Wilkinkarra Palaeovalley indicates that there is not a simple linear relationship between groundwater residence time and salinity. Rather, groundwater processes such as evapotranspiration provide important controls on the composition of groundwater in this arid zone palaeovalley.

3.6.6 Winner's Bore

Bore RN18362 drilled at Site 1 on the Nyirripi to Kintore road intersected good quality potable water, with TDS of 660–760 mg/L. This road has a long and unfortunate history of vehicular break downs, which have led in several cases to stranded travellers perishing on the remote roadside due to lack of water. Consequently, following consultation with the local communities, this investigation bore was further constructed as a roadside water supply using a hand-pump mechanism designed by the Centre for Appropriate Technology (CAT) in Alice Springs (Figure 3.20). This bore will make travelling the back road safer and is thus of enduring value to travellers and the local communities. The full story of Winner's Bore was published as an AusGeo News article in September 2010 (Wischusen and Lewis, 2010).

Figure 3.20: *The handpump mechanism installed at Winner's Bore on the Nyirripi to Kintore road as an emergency water supply.*

3.7 KEY RESEARCH FINDINGS

The Wilkinkarra Palaeovalley was incised as a broad (10–20 km wide), undulating river system during previous wetter climates of the Early to Middle Cenozoic. This ancient landscape had considerably greater topographic variation (relief) than that of the present-day desert environment.

The modern palaeovalley system is defined at the surface by extensive calcrete deposits. Incised into the broad valley (in some places) are a number of 'inset' valleys, possibly representing multiple phases of fluvial incision[9]. The deepest and broadest inset valley occurs at the northern end of Site 1, bounded by outcropping Vaughan Springs Quartzite to the north and an abrupt southern boundary which coincides with the structural contact zone between the Ngalia Basin and the Arunta Region (Figure 3.14). In the southern part of the palaeovalley at Site 1 are several narrow and deeply incised (some >100 m deep) valleys, compartmentalised by basement rock highs. Thus, palaeovalley geometry is strongly influenced by the underlying bedrock geology and regional structure.

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[9] Although these multiple valley incision events are not necessarily analogous to the evolution of the Yilgarn (WA) palaeovalleys as described by de Broekert and Sandiford (2009).

The Cenozoic valley-infill sediments are characterised by semi-consolidated to consolidated alluvial sands, silts and clays which range from highly oxidised to fresh. The degree of weathering and the drilling method precluded detailed facies analysis. The palaeovalley sediments form a porous and unconfined aquifer system containing significant groundwater resources accessible at relatively shallow depths.

The palaeovalley aquifer contains groundwater ranging from fresh (southern end of Site 1) to highly brackish, with overall increasing salinity westward towards Lake Mackay. According to Magee (2009), a common characteristic of arid zone palaeovalley systems is the occurrence of lower salinity groundwater in tributary palaeovalleys and calcrete aquifers. The source of freshwater hosted in the Wilkinkarra Palaeovalley at Site 1 may be a palaeotributary joining the main trunk system from the south. This inferred tributary (the Mount Russell Palaeovalley) was first detected on Landsat imagery as part of the WWS (Section 3.3). However, the Mount Russell Palaeovalley has yet to be confirmed or evaluated by drilling.

Carbon-14 analysis provided an uncorrected groundwater residence time of 13,830 years at the southern end of Site 1 and a much younger 1,680 years at the northern end. These data contrast with expected age relationships based on ionic compositions, as the younger waters are more saline (Na-Cl type) whereas the older water is fresher (Na-Ca-HCO_3-Cl type). Further work is required to improve understanding of the salinity – age relationships.

The Wilkinkarra Palaeovalley aquifer receives modern recharge, mostly via diffuse infiltration (as indicated by stable isotope data). However, the karstic nature of the near-surface calcrete zones may also provide preferential pathways for groundwater recharge.

The timing of initial incision and fluvial development of the Wilkinkarra Palaeovalley is unknown, although it probably formed during the Late Cretaceous or Early Cenozoic. The earliest recognised period of widespread deep weathering in central Australia was during the Late Cretaceous (Senior et al., 1995). No material suitable for dating was encountered in the Cenozoic infill and thus the timing of deposition of the sediments remains unknown, although it can be broadly inferred from other palaeovalleys in central Australia. In particular, Senior et al. (1995) noted that rapid subsidence and sedimentation during the Eocene infilled the larger palaeovalleys and basins of central Australia.

The modern surface water flow (active only after heavy rains) and groundwater flow direction in the Wilkinkarra Palaeovalley is westward towards Lake Mackay (similar to the topographic gradient). However, drilling has revealed that the basement (palaeosurface) gradient is eastwards. This implies that the direction of surface flow, and possibly groundwater flow, has varied in the past and that Lake Mackay has not always acted as a regional depocentre. Upward-doming of the MacDonnell Ranges in the Late Pliocene may have reversed drainage directions and shifted the depocentre westwards to Lake Mackay. The Late Pliocene was also a time of warmer and wetter climatic conditions, which likely caused regional rejuvenation of drainage systems (Senior et al, 1995).

3.8 CONCLUSIONS

Data collected during field investigations in 2009 and 2011 at Sites 1 and 2 in the Wilkinkarra Palaeovalley have significantly expanded previous knowledge of the sedimentology and groundwater resources of this aquifer. However, the regional reconnaissance-scale nature of the work program meant that more detailed studies were beyond scope, and many new research questions now need to be addressed to better understand the key processes that affect this palaeovalley groundwater system.

The installation of a hand-pump at Winner's Bore is a lasting and durable legacy of the *Palaeovalley Groundwater Project* in this remote part of central Australia. Although the discovery of fresh groundwater in this part of the country is of potential future benefit to the local people (e.g., providing water resources to support horticulture projects), the tangible outcome of an operating hand-pump on the Kintore to Nyirripi back-road provides an immediate community benefit. Further, the installation of the hand-pump led to considerable support and goodwill for the project from the local communities, which greatly assisted the project team, e.g., with consultation for access to the drilling sites.

Due to the extensive and inaccessible nature of palaeovalley systems in the Wilkinkarra area, the investigation sites for this project were restricted to areas that could be accessed relatively easily (e.g., without needing to establish new tracks for drill rig access). Further investigative drilling would likely prove difficult as the most accessible sites have already been drilled.

The field investigation program has shown that ground-based geophysics can provide a useful tool for reconnaissance-scale exploration of palaeovalley morphology. However, the success of geophysical methods for palaeovalley exploration relies on distinct contrasts in parameters such as density, porosity, and electrical conductivity between the basement rocks and the overlying infill sediments (Gow et al., 2012). In cases where such physical or electrical contrasts are subdued or non-existent, geophysics will likely prove less successful.

As a next step in better understanding the regional spatial network of palaeovalleys in the Wilkinkarra area, it would be useful to implement a broader scale mapping approach, using a combination of satellite imagery and airborne geophysical techniques (particularly airborne electromagnetics, AEM). This would significantly improve targeting of future ground-based drilling investigations, and could also provide an initial dataset to assess groundwater salinity distribution across the region.

4. Kintore Palaeovalley

4.1 INTRODUCTION

The Kintore community (also known as *Walungurru*) is at the foot of the Kintore Range approximately 530 km west of Alice Springs, close to the border between the Northern Territory and Western Australia (Figure 4.1). The nearest permanent settlement is Mount Liebig, 100 km to the east. The Kintore region is covered by the Mount Rennie 1:250,000 mapsheet.

Kintore is home to around 450 Pintubi people who returned to their homelands from Papunya after the installation of a water bore in the Kintore Range in 1981. The land is used almost exclusively for traditional indigenous activities and is located entirely on Aboriginal freehold land within the Haasts Bluff Aboriginal Land Trust.

Previous work for the Western Water Study in the Kintore region identified significant Cenozoic deposits to the north and west of the ranges, forming the Kintore Palaeovalley (e.g., Lau et al., 1997; Wischusen, 1998). The Kintore Palaeovalley was chosen as a demonstration site for the *Palaeovalley Groundwater Project* to build upon the previous knowledge of the aquifer system and address key research questions that arose from past work, e.g., during the Western Water Study. In addition, the proximity of this palaeovalley to Kintore means that an improved understanding of its groundwater resources is important for any potential future use in the community.

This chapter provides a final record of investigations undertaken for the Kintore Palaeovalley between 2009 and 2011, including detailed analysis and interpretation of the hydrogeological data and results.

4.2 CHARACTERISTICS OF THE KINTORE REGION

4.2.1 Climate

The area has a hot arid climate. A rainfall recording station was established at Kintore in 1993 (station 15664), although the monthly rainfall record is incomplete due to intermittent readings. Mean annual rainfall is 200–300 mm/year and highly variable (BOM Rainfall variability index: *http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall-variability/index.jsp),* with rainfall generally occurring only on a few days of the year. As at Vaughan Springs (Figure 3.2) rainfall tends to be higher in the summer months, due to the influence of the northern monsoonal system.

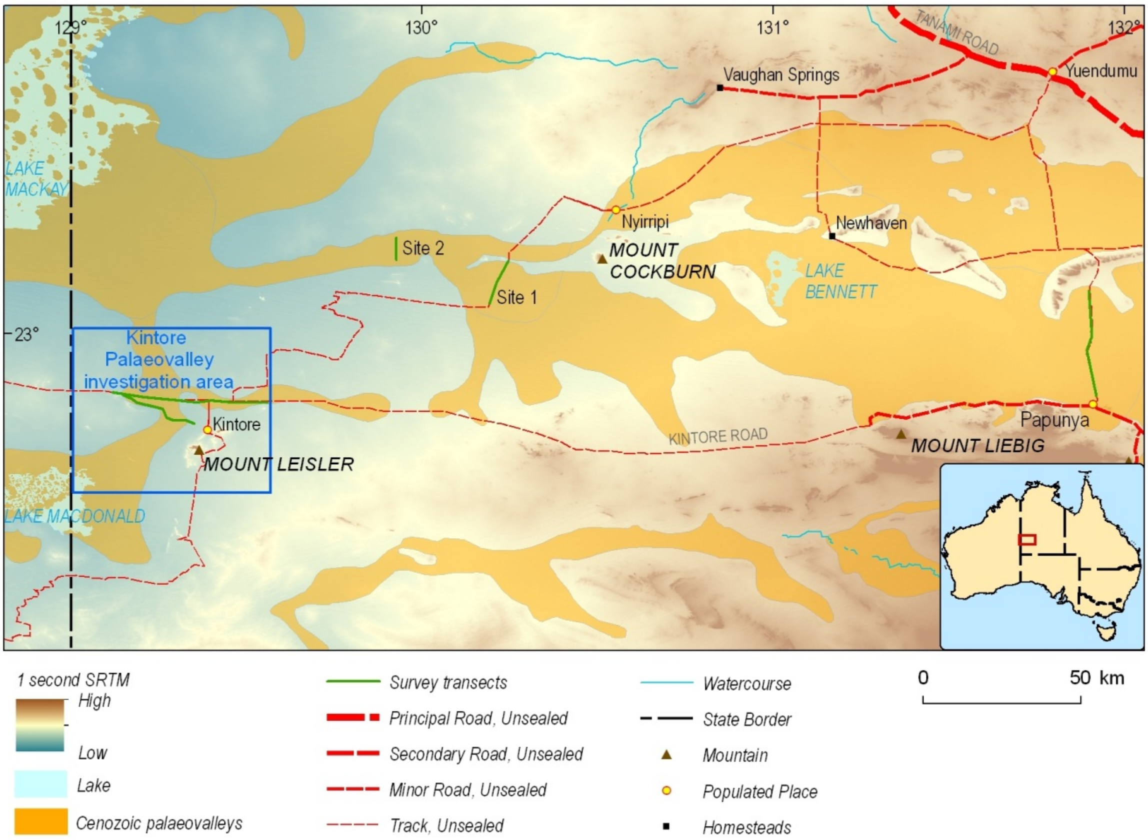

Figure 4.1: *Topography and infrastructure in the region of the Kintore Palaeovalley. Cenozoic palaeovalleys (after Bell et al., 2012) superimposed on the national-scale 1 second digital elevation model based on the SRTM dataset.*

The long-term annual average pan evaporation rate in the study area is 2,800–3,200 mm, based on records for 1975 to 2005 *(http://www.bom.gov.au/jsp/ncc/climate_averages/evaporation/index.jsp)*. This is approximately 8–10 times the annual rainfall, highlighting the extreme aridity of the area.

4.2.2 Topography

The Kintore study area encompasses the broad, gently sloping plains to the north and north-west of the Kintore Range. The palaeovalley is infilled and now buried beneath the flat alluvial floodplains of the modern landscape. The Kintore Ranges are 15 km long and consist of peaks of Proterozoic quartzite that rise to over 350 m above the surrounding plains (Figure 4.2). The two largest peaks are Mount Leisler and Mount Strickland.

4.2.3 Geology

The Kintore Palaeovalley is within the Warumpi Province of the Western Arunta Region (Figure 4.3). The Arunta Region has a complex stratigraphic, structural and metamorphic history extending from the Palaeoproterozoic to the Palaeozoic. Many different rock types comprise the bedrock geology in this region, including granite, gneiss, quartzite and the Late Proterozoic limestone of the Bitter Springs Formation.

Figure 4.2: *View looking south-east towards the Kintore Range, across the alluvial plain that covers the Kintore Palaeovalley.*

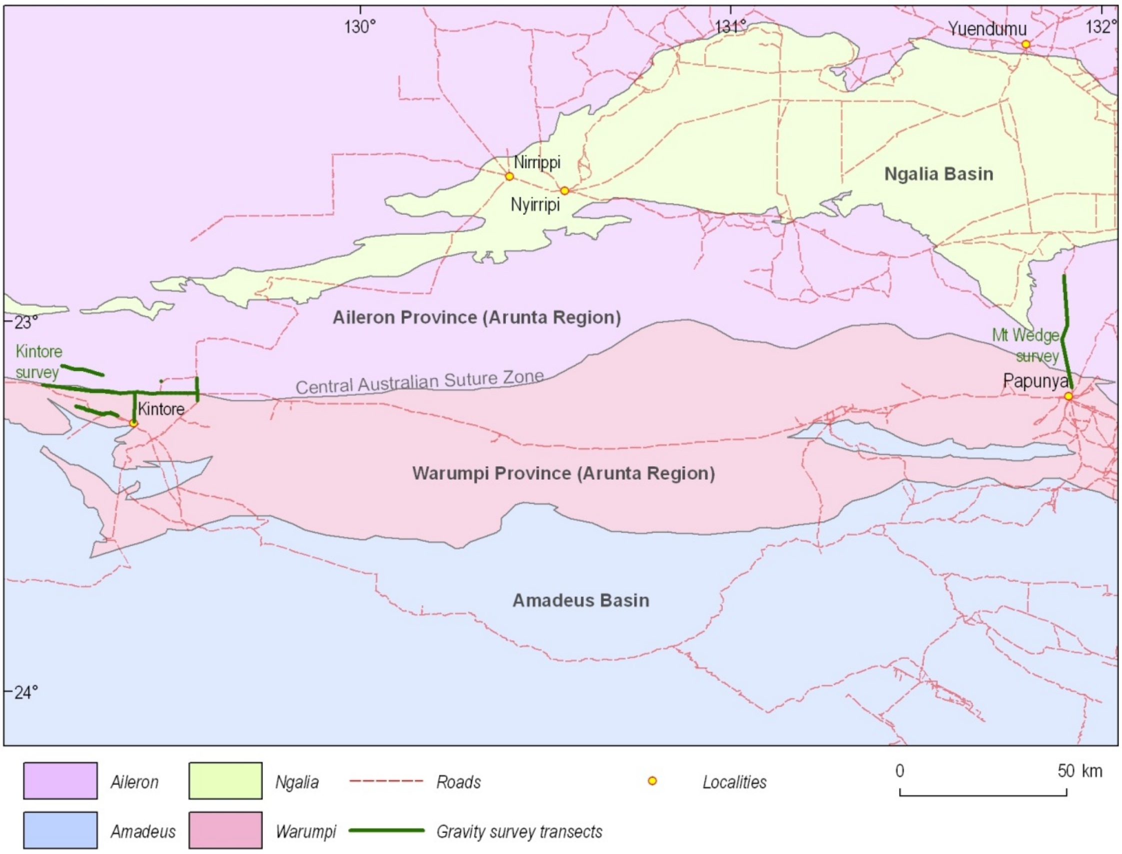

Figure 4.3: *Major geological provinces in the central western part of the Northern Territory.*

The major tectonic boundary that separates the Aileron Province (previously the Northern Arunta) and the Warumpi Province (previously the Southern Arunta) is known as the Central Australian Suture (CAS) (Scrimgeour et al., 2005). This sublinear structure is >800 km long and forms a major zone of crustal weakness which has experienced a long and complex tectonic history, including multiple episodes of reactivation, such as during the Alice Springs Orogeny (approximately 300 to 400 million years ago). A smaller tectonic zone, the Desert Bore Shear, forms part of the CAS and extends roughly from Papunya to Kintore. The Kintore Palaeovalley cuts across the Desert Bore Shear just north of the Gary Junction Road.

The Kintore Palaeovalley is on the Mount Rennie 1:250,000 geological mapsheet (Close et al., 2004). Surface geology mapping indicates that most of the region is covered by Quaternary to Recent sediments, mostly aeolian sands (Figure 4.4). Proterozoic basement rocks form about 20% of the geological exposure at the surface, reflecting the ancient and subdued nature of the landscape.

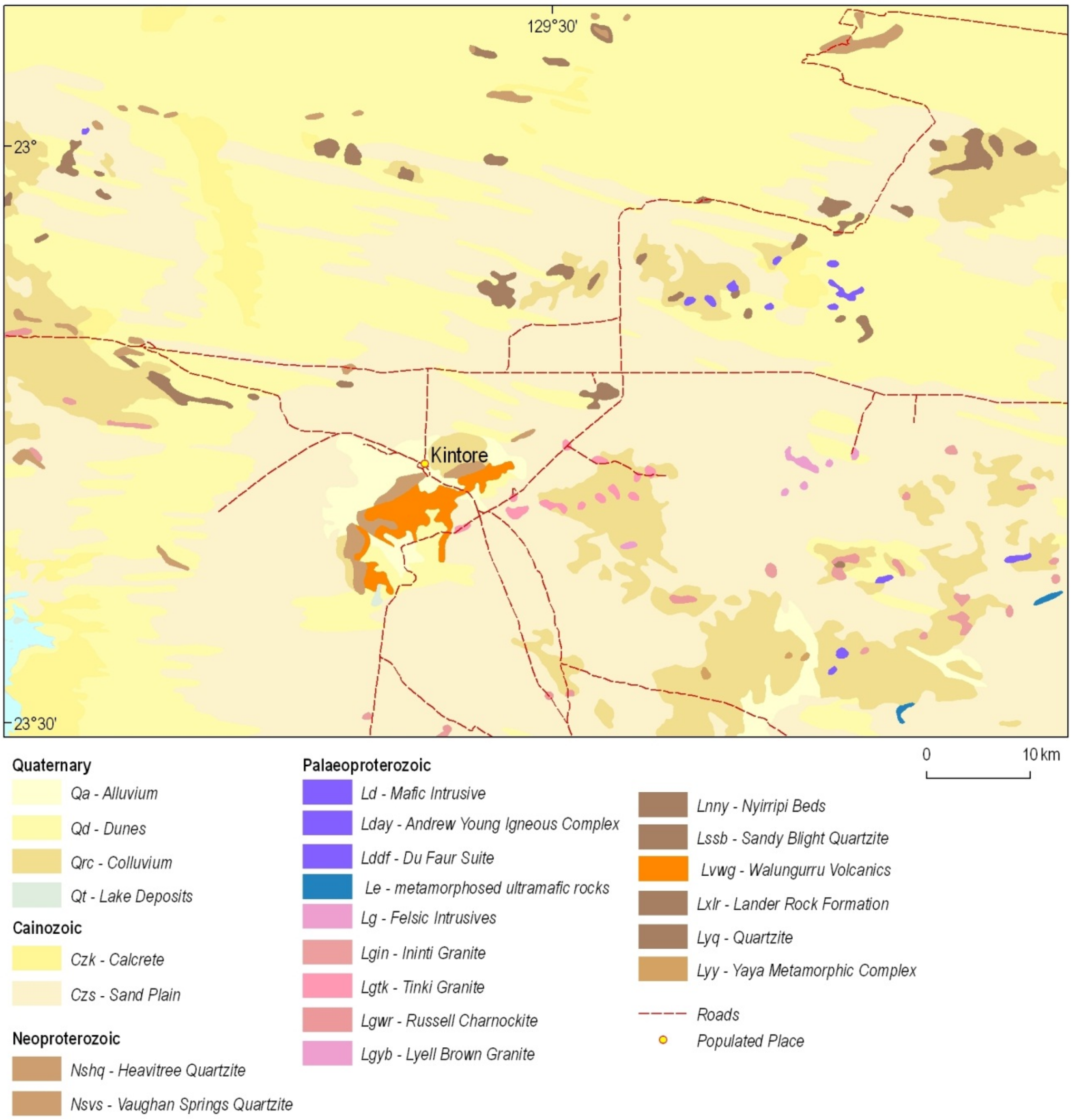

Figure 4.4: *Surface geology of the region around the Kintore Palaeovalley.*

4.2.4 Groundwater resources and use

The Kintore community relies entirely on groundwater extracted from a fractured rock aquifer in the Kintore Range. The hydrogeology of this aquifer was described by Wischusen (1995).

On the plains to the north and west of the Kintore Range, around 18 bores were drilled during the period 1980–2000 for use in road construction and for water supply at outstations. These bores intersected groundwater hosted in Cenozoic sediments (in places up to 90 m thick), with salinity mainly in the range of 1,500–2,500 mg/L (TDS). There are no regulations on the use of groundwater within the area.

4.2.5 Vegetation

The Kintore region is within the Great Sandy Desert Bioregion and is mostly desert grassland, low woodland and shrubs (Thackway and Cresswell, 1995). Southern areas of the bioregion consist of tree and shrub steppe with spinifex grasslands. Vegetation is dominated by open spinifex (*Triodia* sp.) grassland with scattered shrubs and trees including Ghost gum (*Corymbia aperrarinja).*

4.2.6 Surface hydrology

There is no permanent surface water in the Kintore area although the Pintubi people traditionally obtained shallow soak water in the Kintore Ranges (Myers, 1986). In years of very high rainfall (such as 2001) surface water may sometimes pond on the plains west of Kintore. The intermittent Kintore Creek flows westward from the base of the Kintore Range and onto the nearby alluvial plains, providing a possible (sporadic) mechanism for direct recharge of groundwater to the Kintore Palaeovalley. Stream gauge data for Kintore Creek illustrate that rainfall events in excess of ~40 mm are required for surface water to flow (Figure 4.5).

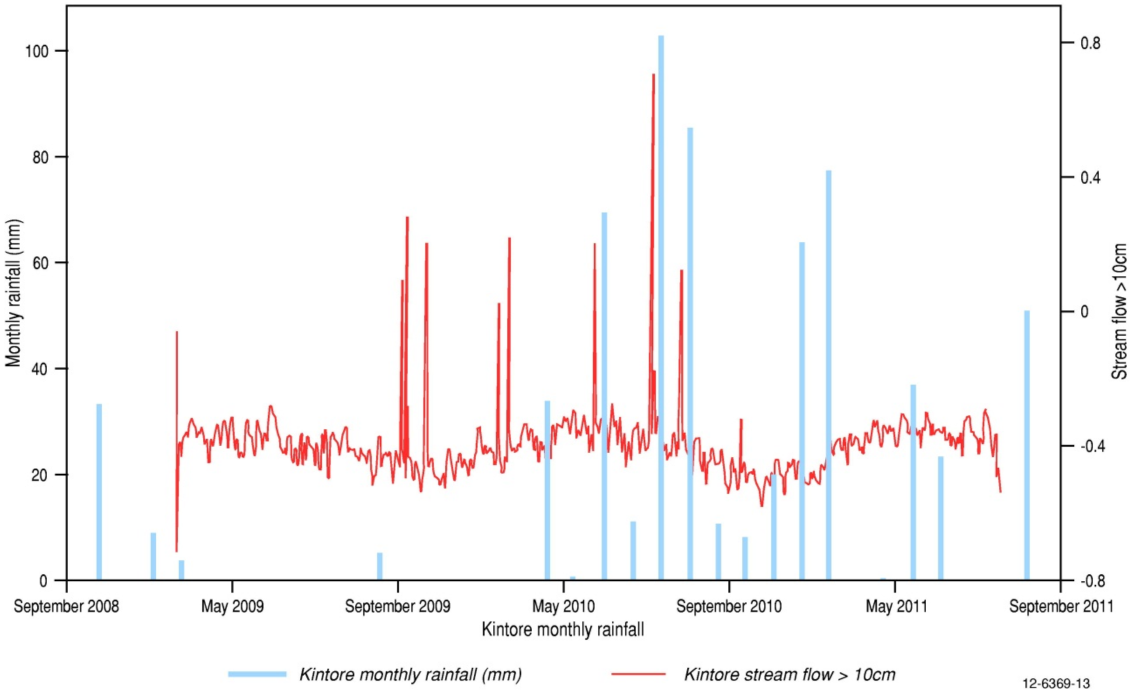

Figure 4.5: *Stream gauge data and monthly rainfall for Kintore from September 2008 to September 2011.*

4.2.7 Lake Macdonald (Karkaratintja)

A large saline playa known as Lake Macdonald (*Karkaratintja*) occurs approximately 30 km south-west of the study area (Figure 4.6). Lake Macdonald is intermittently inundated and is presumed to act as a regional groundwater discharge zone.

Figure 4.6: *Lake Macdonald viewed from the western shoreline (looking eastwards) in October 2009 (photograph by Maria Woodgate).*

4.3 PREVIOUS GEOSCIENTIFIC STUDIES

Previous geoscientific and groundwater studies in the Kintore region are similar to those previously outlined for the Wilkinkarra Palaeovalley. Refer to Section 3.3 for further information.

4.4 PROJECT RESEARCH QUESTIONS

The main focus for the *Palaeovalley Groundwater Project* in the Kintore region was to improve understanding of the sedimentology, stratigraphy and groundwater resources of the Cenozoic aquifer sequences to the west, north and north-east of the community. These investigations built upon existing knowledge acquired from previous studies, such as the Western Water Study (Section 3.3) and the hydrogeological work of Wischusen (1995). Particular effort was invested in acquiring new field data around the north-trending Kintore Palaeovalley, in an area 10–20 km north-west of Kintore community.

The specific questions addressed for this project included:

- What direction does groundwater flow in the Kintore Palaeovalley? In particular, does it flow north towards Lake Mackay, or south-west towards Lake Macdonald? Is there evidence for a groundwater divide in the Kintore palaeovalley?
- What is the basement depth near existing bore RN16852? This bore was originally completed at ~92 m below surface but did not intersect basement. Previous electrical soundings predicted basement to occur ~150 m below ground level (Anning et al. 1996).

- What are the main processes that control the groundwater system in the Kintore Palaeovalley? What is the recharge and discharge regime?
- What influence does nearby bedrock outcrop have on groundwater processes?
- What are the hydrogeochemical characteristics of groundwater in the Cenozoic aquifers? Is there evidence for fresh groundwater resources?
- What is the depositional history of the sedimentary infill of the Kintore Palaeovalley and the surrounding area?
- How does this palaeovalley compare to others in the NT and other states? Are there features that correlate with palaeovalleys in other regions?

4.5 FIELD PROGRAM OBJECTIVES

The 2009 and 2011 field investigation program consisted of two main activities, geophysical surveying followed by investigative drilling. This work program was designed to:

A. Test the efficacy of ground-based geophysical survey methods (gravity and electromagnetics) for:

1. Resolving the morphology of the contact between the palaeovalley infill sediments and underlying weathered basement rocks and, in particular, locating the thalweg sediments (best aquifer zone);
2. Resolving the stratigraphic profile of palaeovalley infill sediments; and
3. Siting drilling targets.

B. Conduct investigative drilling to:

1. Acquire detailed lithologic data on palaeovalley infill sediments to inform interpretation of the geology and geomorphology of the system;
2. Determine depth to basement rocks across the palaeovalley infill sequence;
3. Locate groundwater resources and obtain preliminary information on water yield and quality;
4. Collect downhole sediment samples containing carbonaceous material for stratigraphic dating via analysis of palynomorphs (spores and pollen); and
5. Improve characterisation of groundwater resources in palaeovalley aquifers, primarily the hydrogeochemical composition but also groundwater gradients and other hydraulic parameters.

4.6 FIELD INVESTIGATIONS IN THE KINTORE PALAEOVALLEY

4.6.1 Clearances and consultation

Similar to work in the Nyirripi area, a sacred site clearance was required prior to the geophysical survey and drilling work near Kintore. The initial clearance certificate was issued by the Central Land Council in August 2009, with an additional certificate issued in 2011 for the second phase of fieldwork. Consultation with the local Aboriginal community was also undertaken prior to fieldwork to provide information on the type of work to be conducted, and the objectives of the program. Outside of the official clearance process, ongoing consultation involved liaising with the West MacDonnell Shire office at Kintore.

4.6.2 Geophysics

4.6.2.1 *Geophysical methods*

Two geophysical survey methods were trialled across the target palaeovalley system in the Kintore region: 1. ground-based gravity, and 2. time-domain (transient) electromagnetic (TEM) surveying. Three ground geophysical survey transects oriented perpendicular to the trend of the Kintore Palaeovalley were completed (roughly west to east transects). Additional gravity surveying was undertaken on several other local roads to provide a more comprehensive understanding of regional gravity variations (Figure 4.7).

The locations of the gravity traverse lines were selected on the basis of:

- Site accessibility, with most transects located along existing roads or tracks;
- Orientation of the survey, such that the transects were oblique or perpendicular to the interpreted flow axis of the palaeovalley;
- Maximising exploration efforts over areas of significantly thick Cenozoic alluvial sequences (as defined by previous interpretations);
- Attempting to define the shape and topography of the underlying basement rocks; and
- Building on previous geophysical surveys in the area undertaken by Anning et al. (1996).

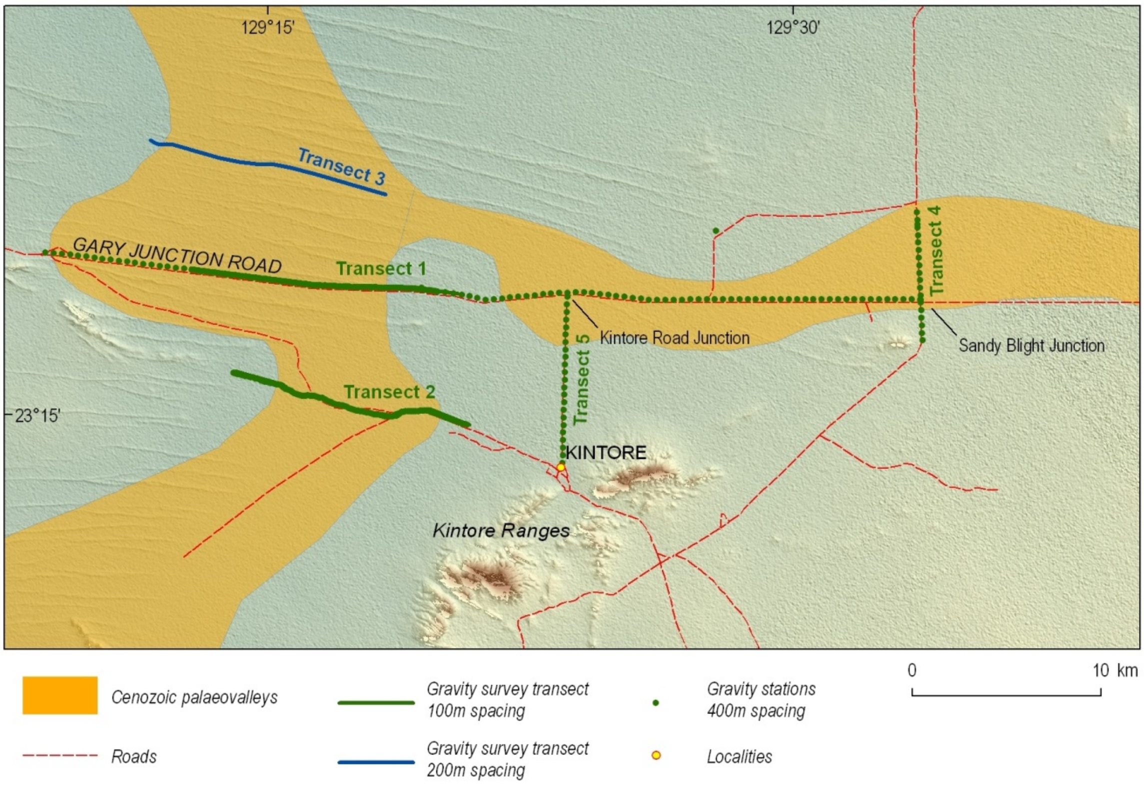

Figure 4.7: *Gravity survey transects for the Kintore Palaeovalley. Cenozoic palaeovalleys after Bell et al., 2012.*

For most transects, the distance between each gravity station was 400 m. This was based on the estimated width of the main palaeovalley and the narrower thalweg. The survey spacing was subsequently tested at several finer scales (100 m and 200 m station spacing) to provide enhanced definition for locating the deepest part of the palaeovalley. The entire gravity survey program involved acquisition of almost 70 km of line data at 400 m spacing, 24 km of infill gravity data at 100 m spacing, and 12 km at 200 m spacing.

The elevation of the Kintore gravity stations was determined by a levelling survey undertaken by senior surveyors from the NT Government. The 2009 survey used optical levelling, whereas the 2011 elevation survey used a Real-Time Kinetic Differential GPS system. The elevation data were tied to four existing 3rd order bench marks from the National Mapping program (conducted in the 1960s and 1970s). This enabled the elevation data to be adjusted to the Australian Height Datum.

All gravity stations were levelled to 3rd order accuracy with the levelling runs connected to the existing bench marks. Typically, 3rd order levelling accuracy is defined as the 12 mm square root (km). Thus, for 4 km of surveying the accuracy would be better than 12 x 2 = 24 mm. For 36 km of surveying the accuracy would be better than 12 x 6 = 72 mm. There was excellent agreement in the station elevations compared with the existing bench marks. As a further check of accuracy the levelling run end-points were compared with static differential GPS data and also showed very close agreement.

A time-domain electromagnetic survey was undertaken coinciding with two of the gravity transects, using the SiroTEM system (Figure 4.8). Coincident loops spaced at 100 m were surveyed (matching the position of gravity stations).

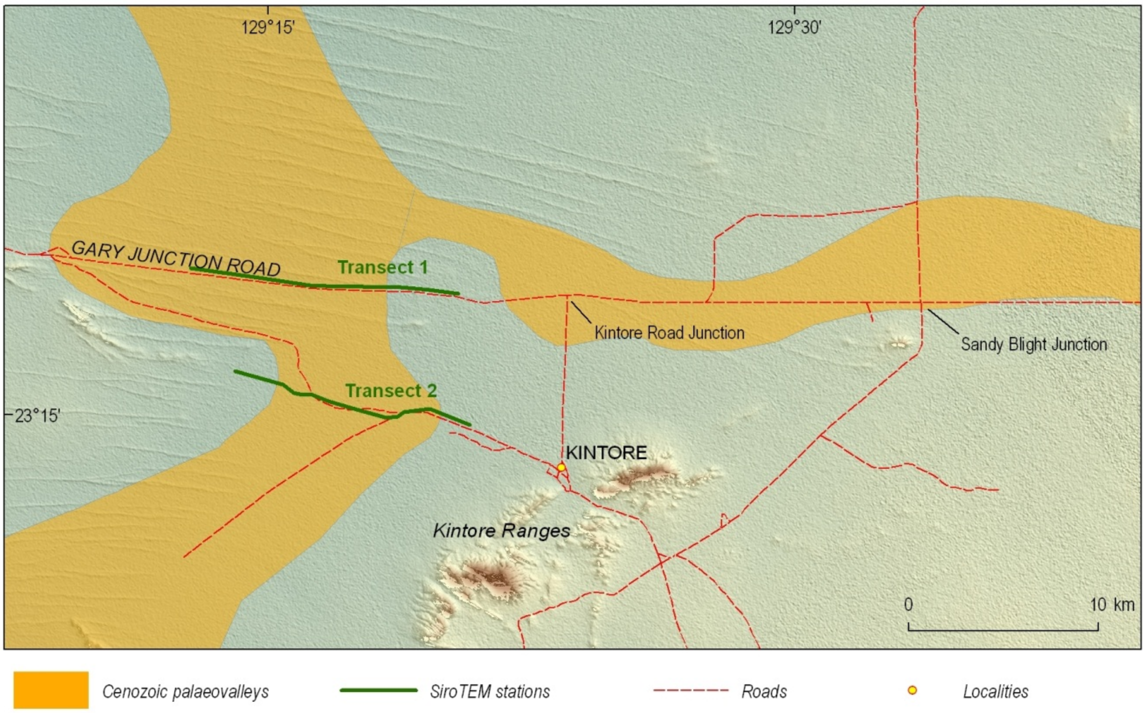

Figure 4.8: *Time-domain electromagnetic (TEM) surveys for the Kintore Palaeovalley. Cenozoic palaeovalleys after Bell et al., 2012.*

4.6.2.2 Gravity Survey Results

The processed ground gravity data acquired for each survey transect across the Kintore Palaeovalley are presented in Figure 4.9 to Figure 4.13. A gravity model was constructed to simulate the 400 m Bouguer gravity response along the Gary Junction Road (Figure 4.14). Based on previous drilling data from Wilkinkarra, a basement rock density of 2.7 x 10^3 kg/m^3 and a palaeovalley sediment infill density of 1.7 x 10^3 kg/m^3 were used to derive this model. Both the raw and modelled gravity data indicated two significant channel segments within the broader palaeovalley, with the western-most palaeochannel being the deepest.

The 100 m spaced gravity station data acquired for the Gary Junction Road Transect (Transect 1) and the Western Track Transect (Transect 2) were also modelled to derive the Bouguer gravity response (Figures 4.15–4.16). The model for the 100 m spaced Transect 1 segment used a basement density of 2.3 x 10^3 kg/m^3 to represent the interpreted limestone basement rocks. Decreasing the density contrast between the palaeovalley infill sediments and the basement rocks (i.e., by making the basement rocks less dense) effectively increased the depth of the modelled valley. Increasing the slope of the regional gravity trend also increased the estimated depth of the valley.

Basement rock intersections (from drilling) were plotted against the Bouguer gravity response for Transect 2 to evaluate the correlation between the modelled gravity profile and the actual palaeovalley morphology (Figure 4.17). The actual depth to basement below the palaeovalley infill sediments closely matches the modelled response for 75% of the data points. The main discrepancy is for bore RN18581, which may be explained by deeper weathering of the granitoid basement rocks in this vicinity.

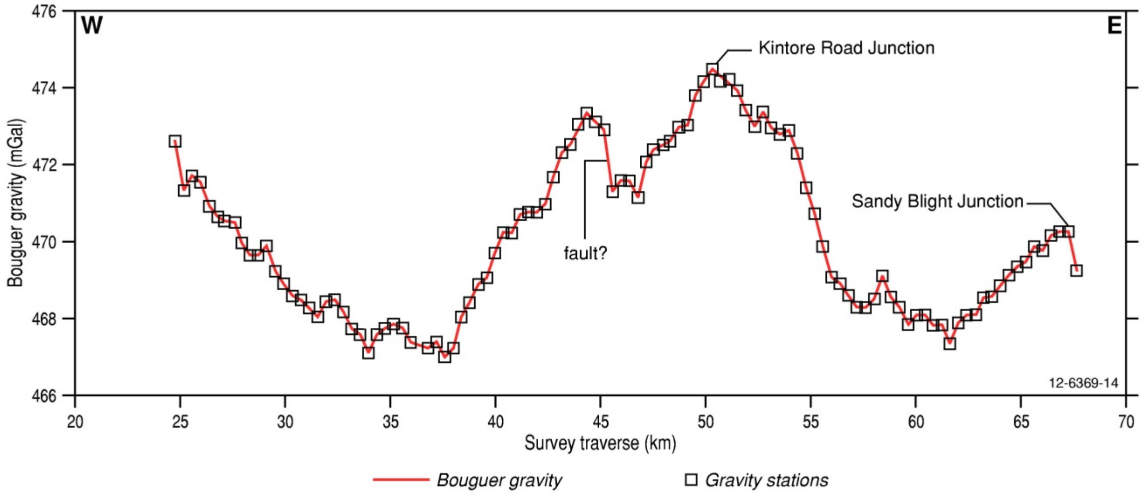

Figure 4.9: *Bouguer gravity data for Transect 1 across the Kintore Palaeovalley.*

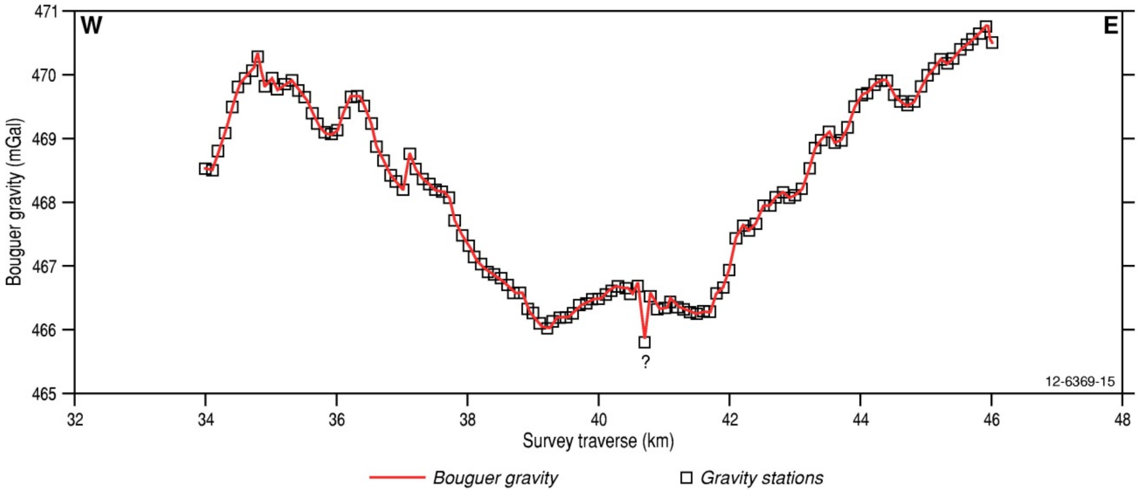

Figure 4.10: *Bouguer gravity data for Transect 2 across the Kintore Palaeovalley.*

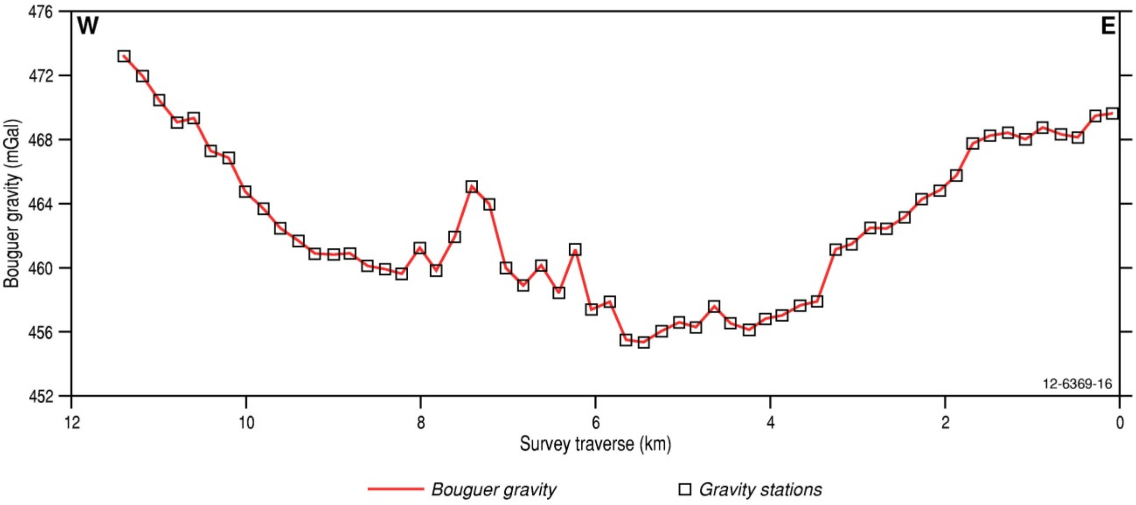

Figure 4.11: Bouguer gravity data for Transect 3 across the Kintore Palaeovalley.

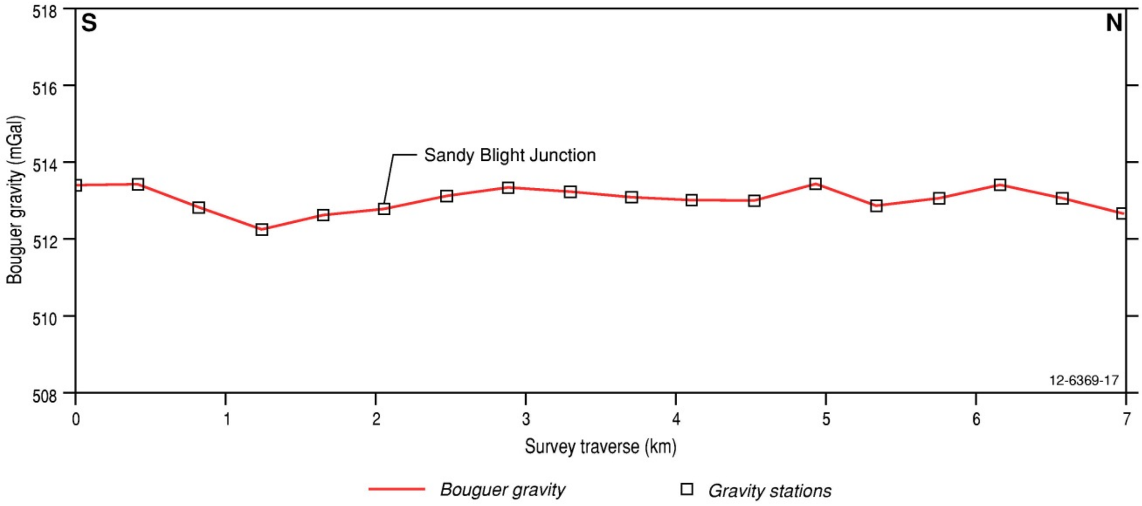

Figure 4.12: Bouguer gravity data for Transect 4 across the Kintore Palaeovalley.

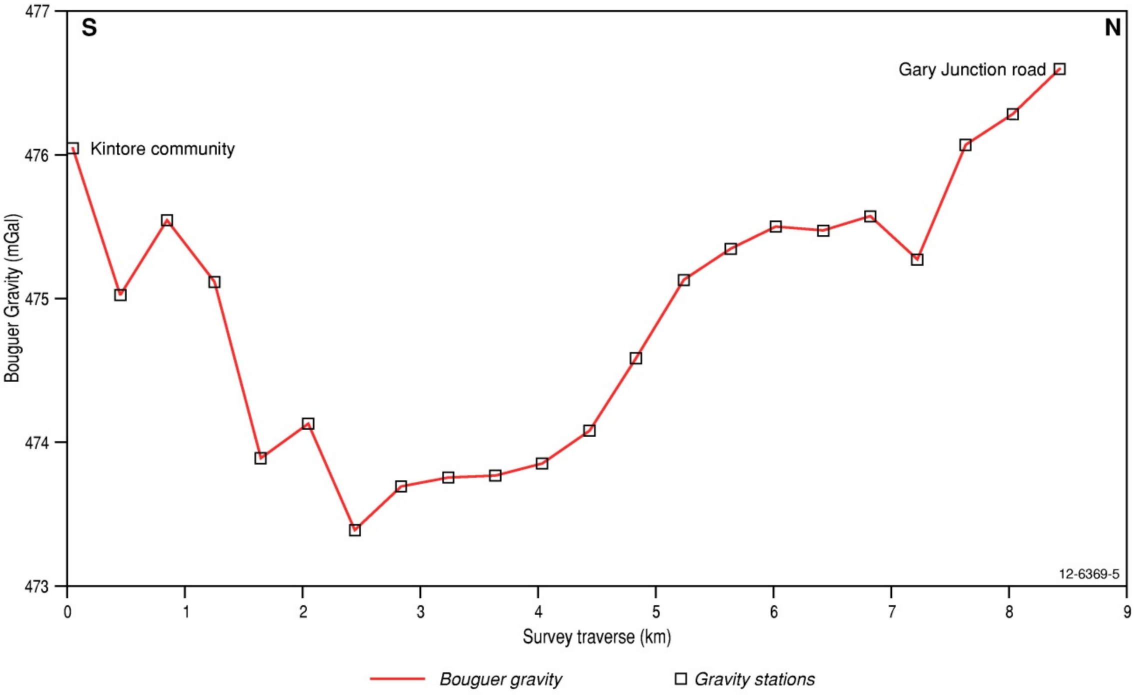

Figure 4.13: *Bouguer gravity plot for Transect 5 across the Kintore Palaeovalley.*

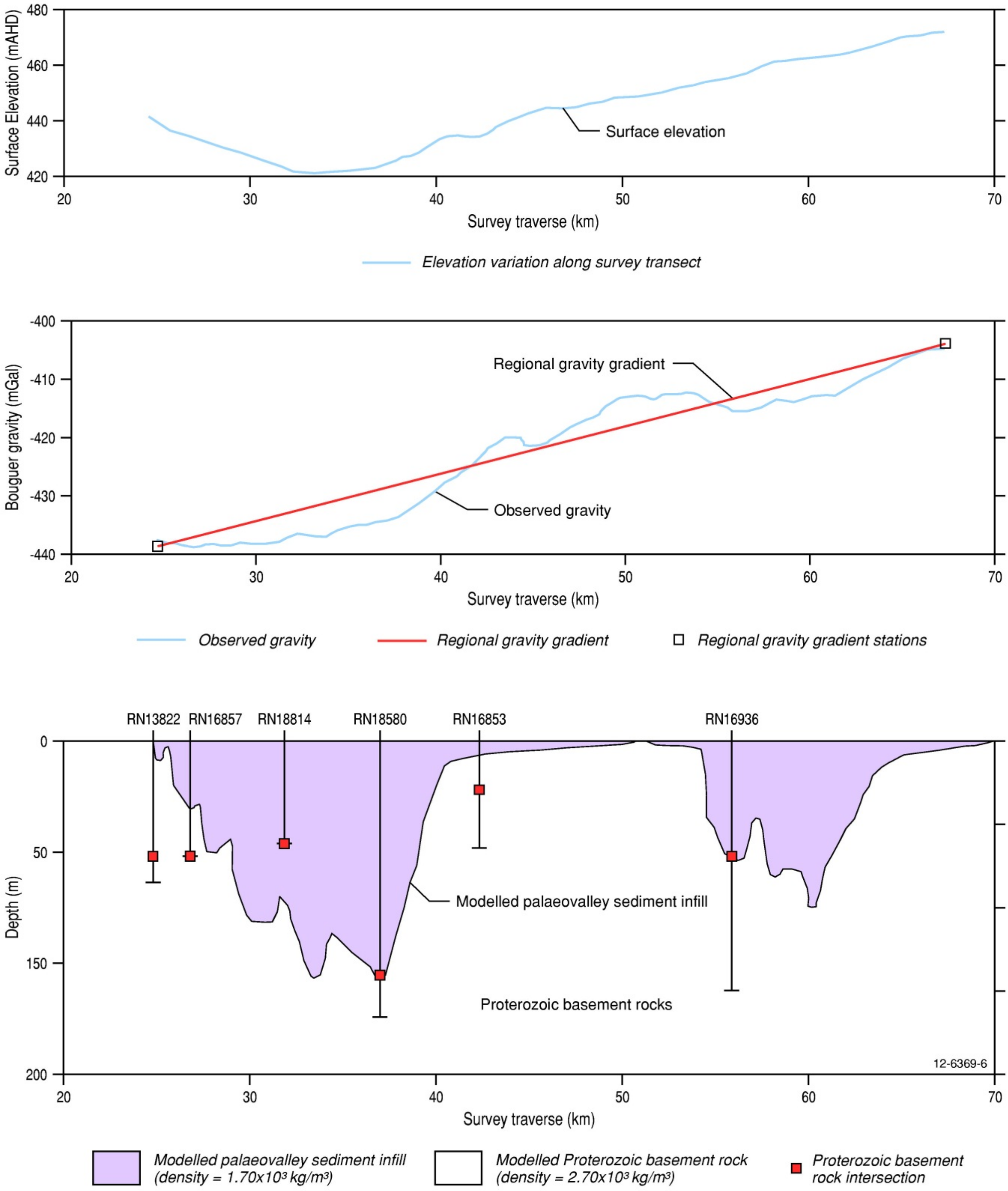

Figure 4.14: *Bouguer gravity model for the Gary Junction Road Transect 1.*

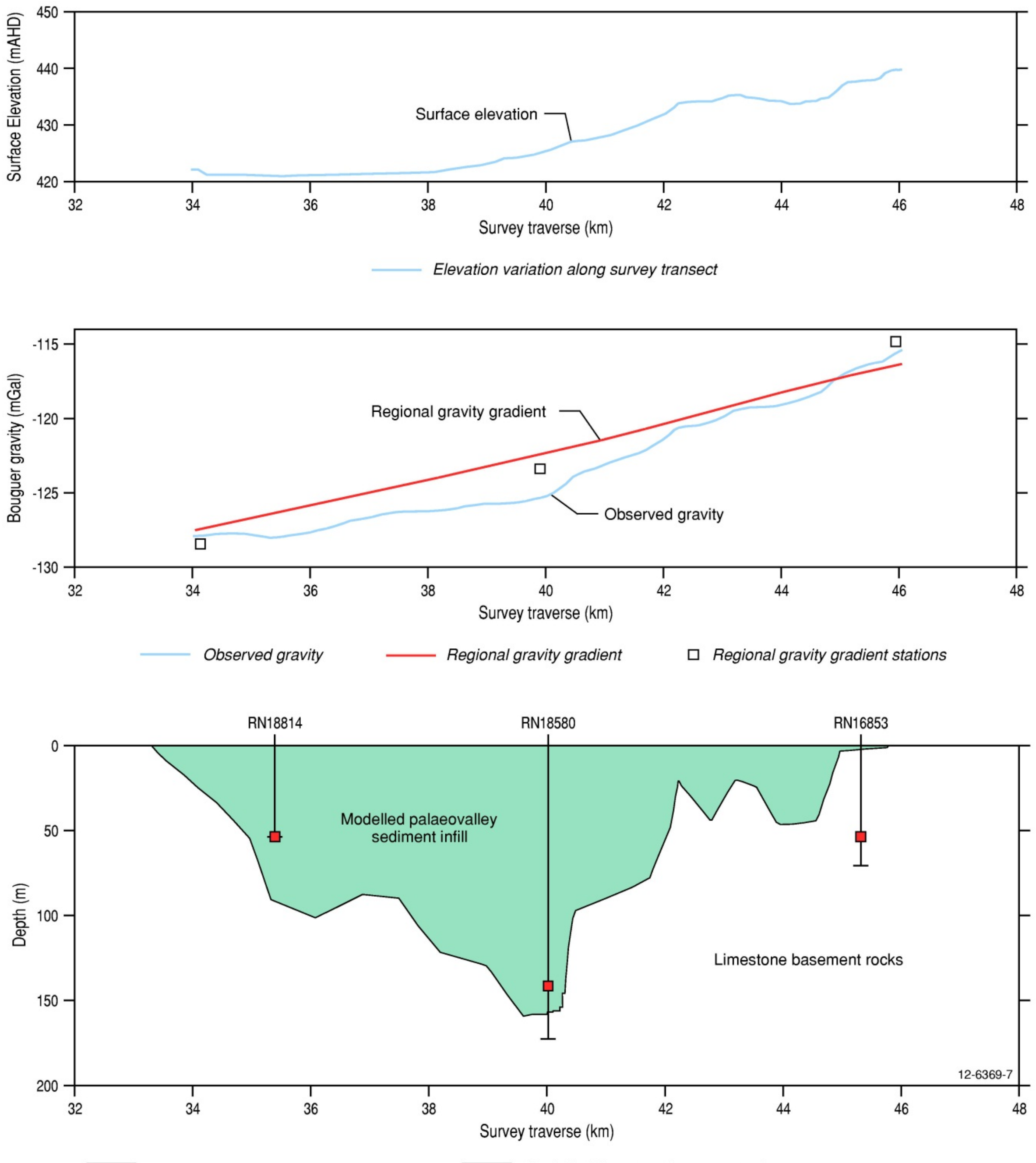

Figure 4.15: *Modelled Bouguer gravity response for 100 m spaced gravity stations for Transect 1 across the Kintore Palaeovalley.*

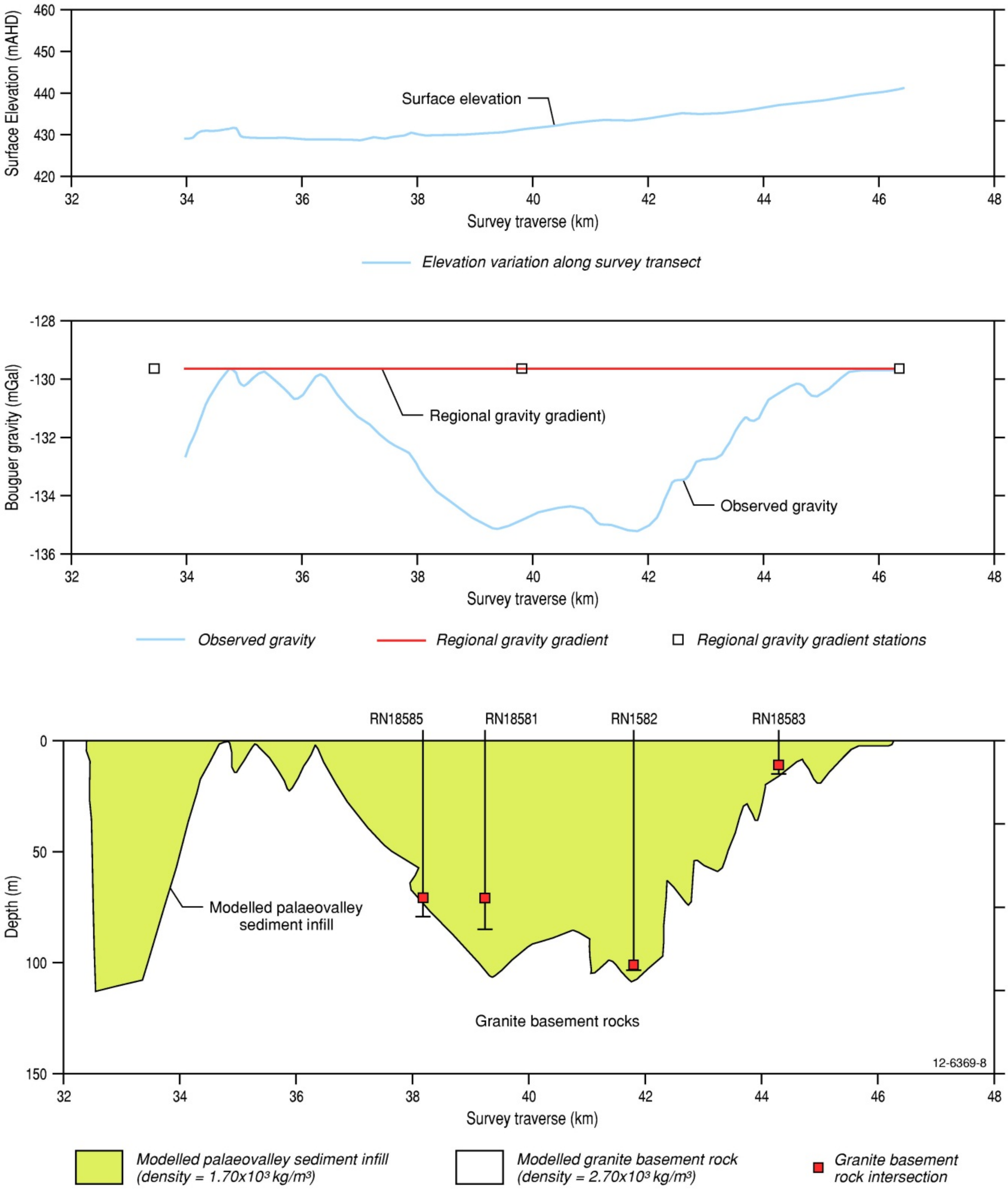

***Figure 4.16:** Modelled Bouguer gravity response for 100 m spaced gravity stations for Transect 2 across the Kintore Palaeovalley.*

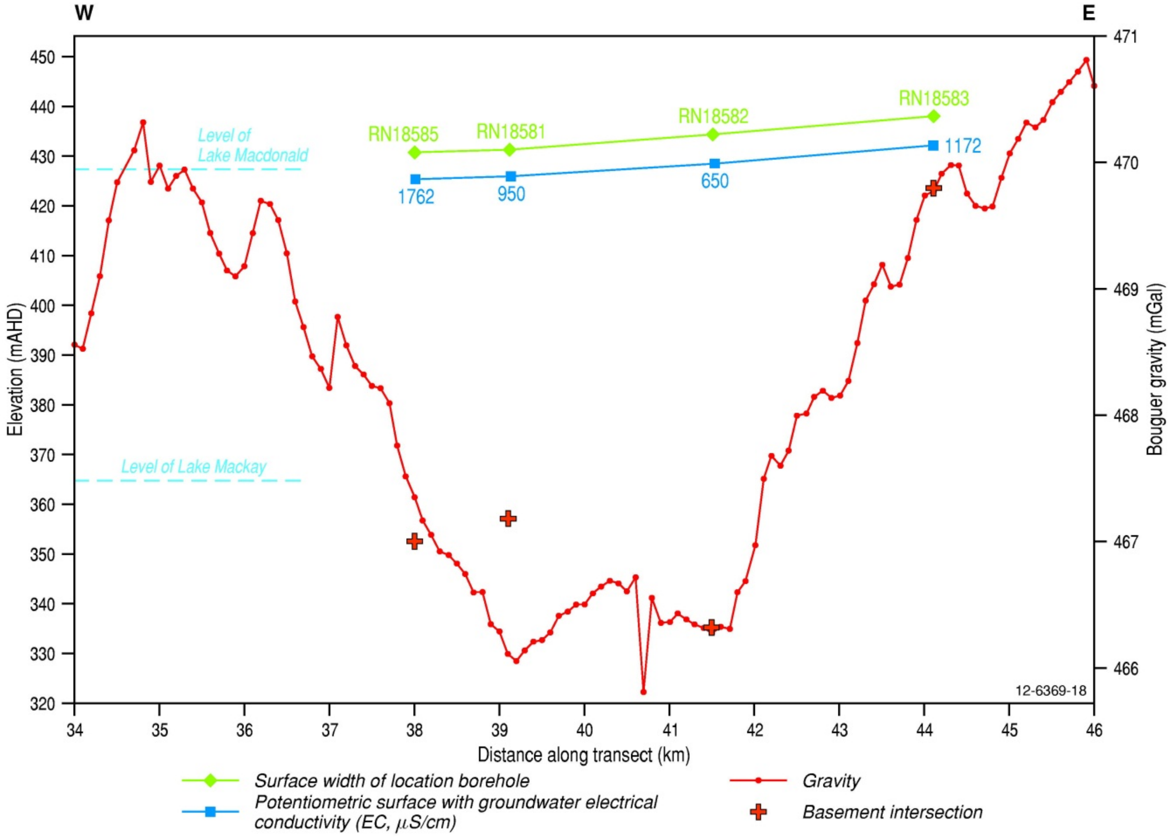

Figure 4.17: *Comparison of modelled gravity profile and actual drilling data for Transect 2 across the Kintore Palaeovalley.*

4.6.2.3 Time-domain electromagnetic survey results

The SiroTEM raw conductance data for the Gary Junction Road (Transect 1) and the western track (Transect 2) was processed to produce apparent conductivity pseudo-sections (Figures 4.18–4.19). The electromagnetic response in these images is a function of formation porosity, interstitial water conductivity, and the formation (rock and sediment) conductivity. In this case, the high conductivity zones (red) are caused by brackish water contained in the palaeovalley sediments. The zones of lower conductivity (blue) are interpreted as underlying resistive basement rocks.[10]

High conductivity zones in Transect 2 data are interpreted to coincide with the deeper and more porous section of the palaeovalley infill sediments. These host a greater volume of electrically conductive groundwater (saline) than the surrounding bedrock. The resistive response near bore RN18583 is related to shallow bedrock.

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[10] Note that subsequent work with this SiroTEM system discovered that several of the mid-range channels were not functioning correctly at the time of the Kintore survey. An attempt to improve the processing of these data was undertaken by Ground Water Imaging Pty Ltd, including data review and inversion. A summary of this work is presented and discussed in the next section.

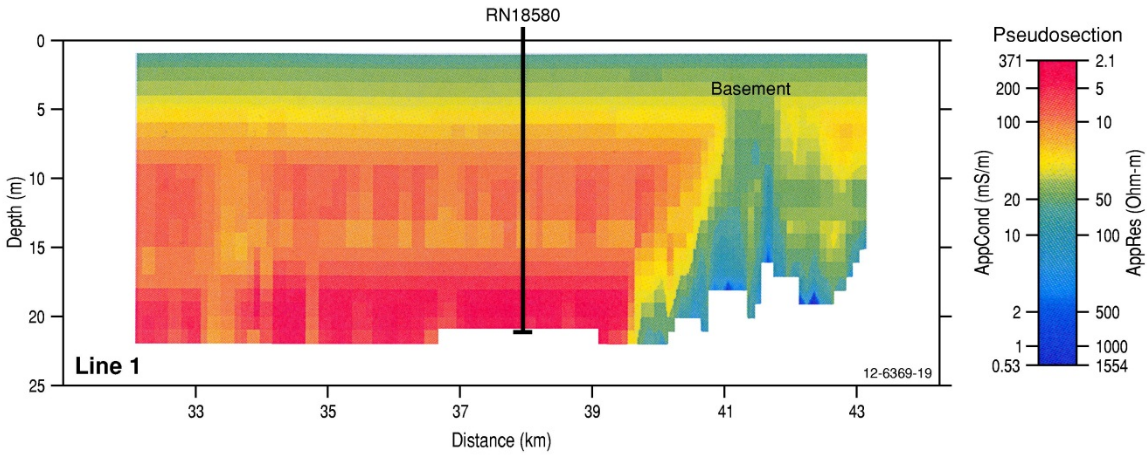

Figure 4.18: *Apparent conductivity pseudo-section from SiroTEM survey on the Gary Junction Road (Transect 1). The y-axis shows depth below surface (metres) and the x-axis shows metres along the transect.*

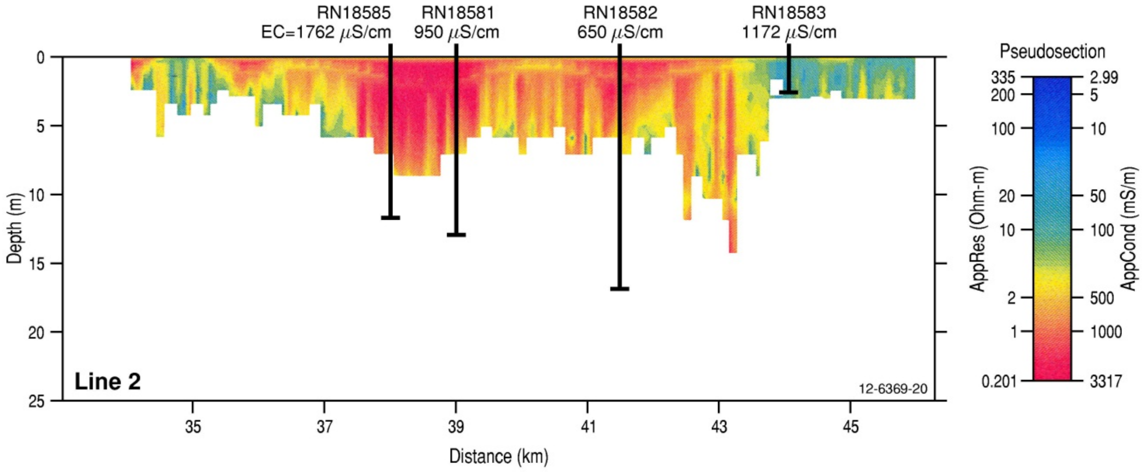

Figure 4.19: *Apparent conductivity pseudo-section for Transect 2 showing the location of new investigation bores, with groundwater electrical conductivity data (µS/cm) for each bore.*

4.6.2.4 Review of SiroTEM inversion

Groundwater Imaging Pty Ltd (GWI) re-processed the SiroTEM data from Kintore to establish whether basement depth and layering could be determined (Figure 4.20). GWI used EM1DInv software from the Aarhus Hydrogeophysics Group for data inversion, which produced superior results to the EMVision V4 software used in initial processing. Problems with the data due to instrument malfunction at Kintore could not be resolved so the resistivity data are unreliable below 60 m depth.

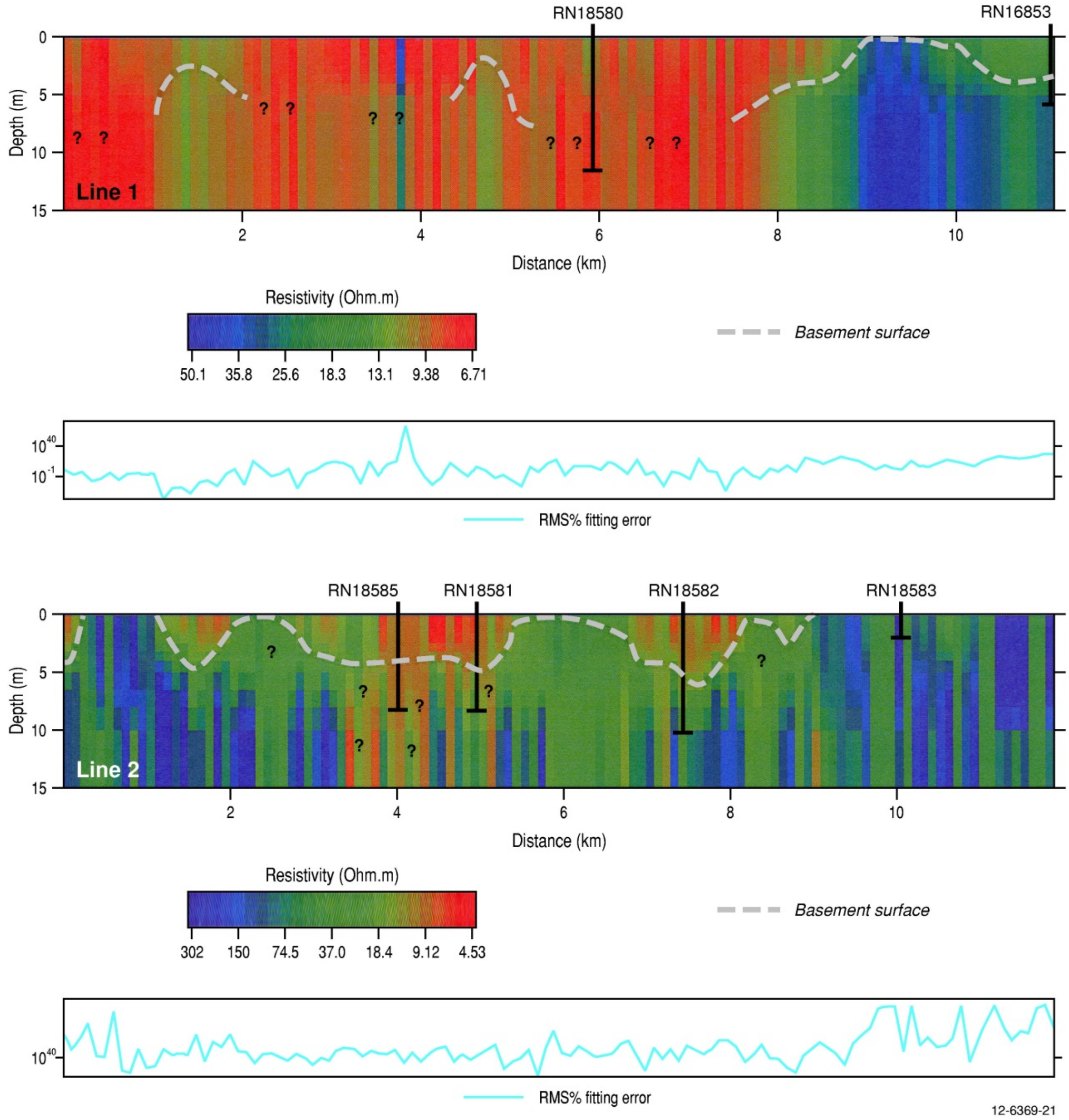

Figure 4.20: *Vertical Resistivity Sections from the Kintore SiroTEM survey with estimated basement depth marked by the dashed line. The upper section is Transect 1 and the lower section is Transect 2. Areas of uncertainty in the data are shown by the question marks.*

Specific observations from the SiroTEM data are:

- The interpreted basement high at the eastern end of the Gary Junction Road (Transect 1) correlates with the ground gravity data and observations from geological mapping of outcrop.
- The interpreted basement depth for Transect 2 shows a basement high between boreholes RN18581 and RN18582 which is not confirmed by drilling, and only partially indicated by the ground gravity data (Figure 4.17). This may be caused by variation in the composition of the infill sediments (such as a greater proportion of clay-rich sediments) or it may reflect a zone of more saline groundwater, i.e., with higher electrical conductivity. Further drilling is required to resolve this uncertainty.

In conclusion, the SiroTEM method was not particularly useful for mapping the depth and extent of Kintore Palaeovalley. This is because of the combination of poor instrument performance (partial malfunction) and the nature of the substrate itself, i.e., there is insufficient contrast in the conductivity signature of the palaeovalley sediments and the surrounding bedrock.

4.6.3 Drilling

Thirteen new bores, totalling about 824 m, were drilled in the Kintore Palaeovalley using the air rotary method, initially during November 2009 and then later in September 2011 (Figure 4.21). Drilling was conducted by the Northern Territory Government drilling crew, using an Ingersoll Rand 1500 drilling rig. The investigation bores were targeted to intersect the deepest parts of the palaeovalley based on anomalies in the gravity survey data. The bores were distributed regularly across the palaeovalley to develop a detailed cross-section.

Drilling focused on an unexplored area west of Kintore. The first bore drilled was on the Gary Junction Road near existing bore RN16852. The main aim of this hole was to evaluate depth to basement (RN16852 did not intersect basement), and test the effectiveness of the existing geophysical data. For example, the gravity data indicated that this was the deepest part of the palaeovalley (thalweg). Previous geophysical data from this site (an electrical sounding by Anning et al., 1996) indicated that the palaeovalley sediments were approximately 150 m thick.

Composite drill chip samples were collected, logged and bagged for every 3 metre interval, i.e., half rod length.

Water samples were collected during drilling operations by airlifting. Field measurements of groundwater electrical conductivity (EC) and pH were recorded at regular intervals during drilling. Aquifer yields were also regularly estimated. The sampling program aimed to collect shallow and deeper samples from each hole (if warranted on the basis of field measured water quality data downhole). The final sample (for isotope analysis) was acquired using a submersible down-hole pump. Eleven samples were dispatched for hydrochemical analysis to Northern Territory Environmental Laboratories (NTEL). All samples were laboratory tested for pH, conductivity, alkalinity, major/minor cations and anions, nitrates, metals and trace metals. Additional samples were submitted to the CSIRO laboratory in Adelaide and the Rafter Laboratory in New Zealand for analysis of stable oxygen and hydrogen isotopes to assist with the interpretation of groundwater processes, such as estimating recharge rates. Several samples were also submitted for analysis of radiogenic carbon (^{14}C) for groundwater dating.

Most bores were completed as permanent monitoring bores with installation of 6 metre long steel collars (150 mm diameter) and 100 millimetre diameter PVC casing. The slotted section of PVC casing was positioned in the highest yielding part of the water-bearing sediments. The completed surface installation consists of a lockable steel standpipe surrounding the stickup casing with a nearby marker pole, similar to those previously described for the Wilkinkarra Palaeovalley (Figure 3.12).

A pressure transducer logger (*Minitroll*™) was installed in bore RN18582 in May 2010 to record daily water level changes over time. Standing water levels were also measured for the more readily accessible monitoring bores.

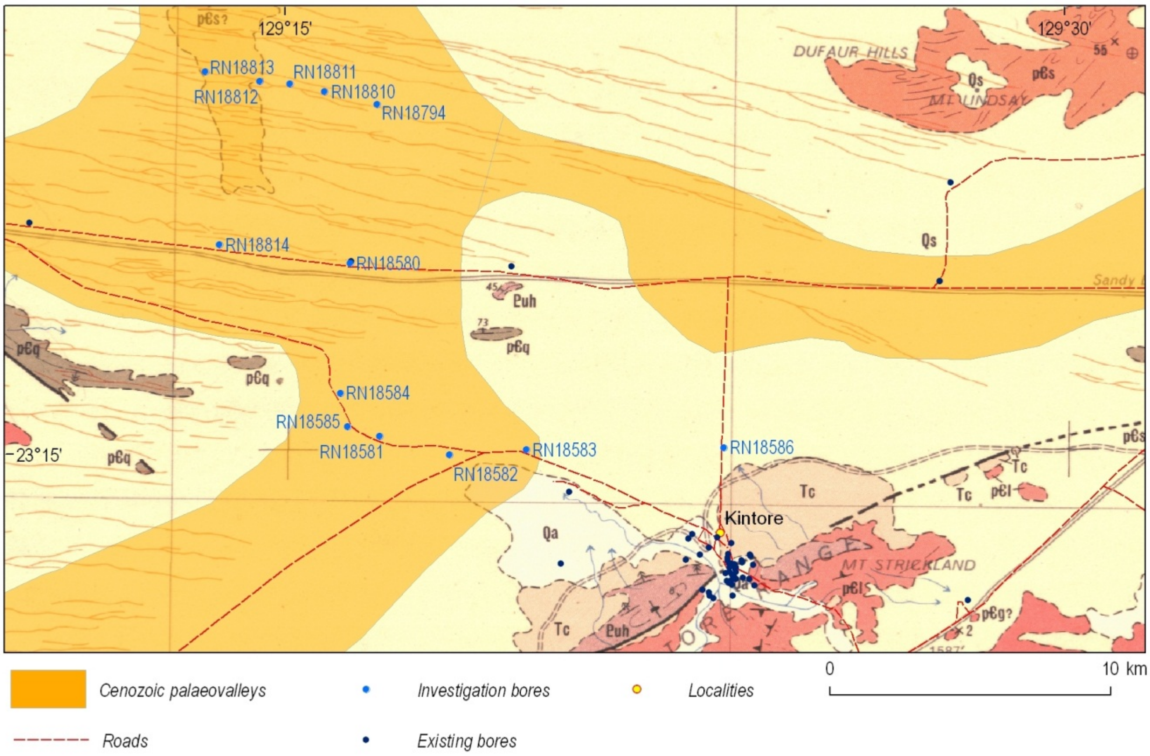

__Figure 4.21:__ Investigation bores drilled in the Kintore Palaeovalley in 2009 and 2011. Cenozoic palaeovalleys (after Bell et al., 2012) superimposed on regional geology from the Mount Rennie 1:250,000 mapsheet.

4.6.3.1 Drilling results

Drilling of 13 new bores in the Kintore region confirmed the existence of a significant north-trending palaeovalley system 10–15 km west of Kintore (Figure 4.21). Up to ~100 m of alluvial Cenozoic sediments were intersected above weathered basement rocks in the central part of the palaeovalley, with significantly thinner sediment sequences near to the valley margins (Table 4.1–4.2). Three geological cross-sections based on the drilling transects and interpreted geophysical data for the Kintore Palaeovalley (transect locations shown in Figure 4.7) are presented as Figures 4.22–4.24. Summary geological logs for Kintore Palaeovalley bores, including down-hole gamma logs, are presented in Appendix 3.

Table 4.1: Summary of investigation bores drilled in the Kintore Palaeovalley in 2009.

BORE ID	EASTING	NORTHING	SURFACE ELEVATION (mAHD)	TOTAL BORE DEPTH (mbgl)	DEPTH OF CASING (mbgl)	BASEMENT DEPTH (mbgl)	HIGHEST YIELD (L/s)	SWL (mbtoc)	FIELD EC (µS/cm)	BORE CASING DETAILS
RN18580 (adjacent to RN16852)	527735	7435542	425.37	125.9	83.4	105	20	6.69	3,459	150 mm steel casing
RN18581	528681	7429403	431.32	84.7	51.5	74	10	5.81	950	100 mm Cl12 PVC casing
RN18582	530967	7428756	434.44	102.0	97.0	99	10	6.23	650	100 mm Cl12 PVC casing. Logger installed May 2010
RN18583	533503	7428917	438.04	17.0	16.5	14.5	0.1	6.28	1,172	50 mm Cl12 PVC casing
RN18584	527407	7430943	447.51	28.0	28.0	24	10	4.55	1,298	100 mm Cl12 PVC casing
RN18585	527646	7429762	430.74	82.4	57.1	78	10-12	5.72	1,762	100 mm Cl12 PVC casing
RN18586	539982	7428983	451.18	41.9	37.1	12	seepage	28.16	1,120	50 mm Cl12 PVC casing

Note:

1. The coordinate system and datum for the easting and northing is UTM Zone 52 – WGS84.
2. The highest yield data were estimated during drilling operations.
3. The field measured electrical conductivity is the maximum value measured from each bore.
4. Abbreviations used above are:

mAHD = metres Australian Height Datum
mbgl = metres below ground level
SWL = standing water level (measured after bore completion)
EC = electrical conductivity

Table 4.2: Summary of investigation bores drilled in the Kintore Palaeovalley in 2011.

BORE ID	EASTING	NORTHING	SURFACE ELEVATION (mAHD)	TOTAL BORE DEPTH (mbgl)	DEPTH OF CASING ((mbgl)	BASEMENT DEPTH (mbgl)	HIGHEST YIELD (L/s)	SWL (mbtoc)	FIELD EC (µS/cm)	BORE CASING DETAILS
RN18794	528626	7441184	424.60	36.0	26.5	17.5	0.8	5.05	2,780	100 mm PVC, 8 m 158 mm surface steel collar cemented in
RN18810	526910	7441651	421.70	34	26.00	22.2	5	6.10	2,730	100 mm PVC, 8 m 158 mm surface steel collar cemented in
RN18811	525774	7441917	420.47	72.8	Twin piezo's 28, 52	44.5	12	5.47, 5.21	7,020	50 mm PVC twin piezometers, 158 mm sfc steel
RN18812	524773	7442017	420.46	82	28	33?	15	5.15	6,330	50 mm PVC suspended with 1 m sump
RN18813	522983	7442363	419.18	76.2	48	67	9	4.05	4,000	100 mm PVC with 1m sump
RN18814	523453	7436218	422.96	48	24	24	4	14.53	1,830	100 mm PVC with 1m sump

Note:

1. The coordinate system and datum for the easting and northing is UTM Zone 52 – WGS84.
2. The highest yield data were estimated during drilling operations.
3. The field measured electrical conductivity is the maximum value measured from each bore.
4. Abbreviations used above are:

mAHD = metres Australian Height Datum
mbgl = metres below ground level
SWL = standing water level (measured after bore completion)
EC = electrical conductivity

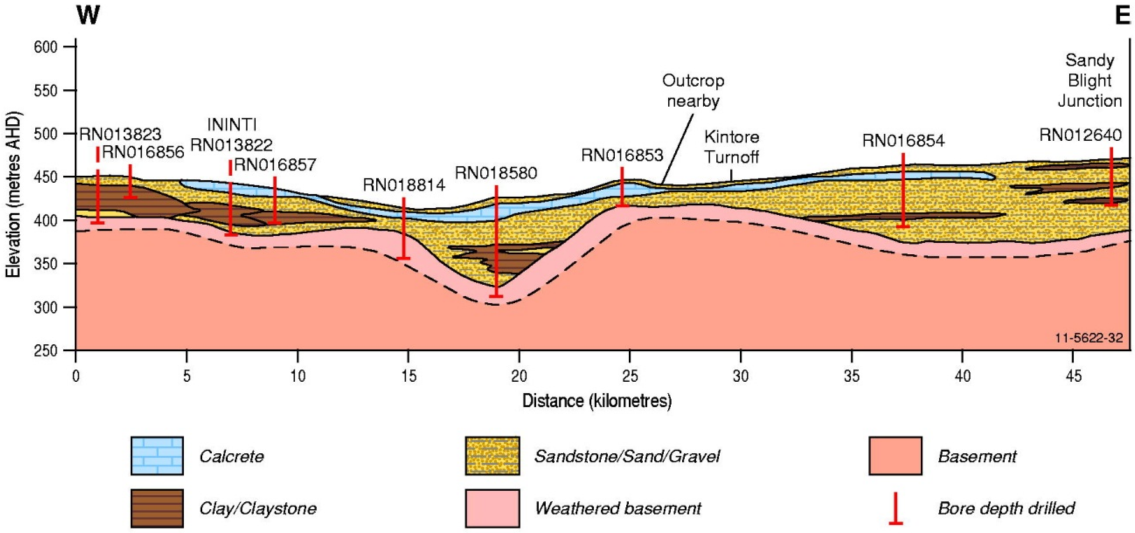

Figure 4.22: *Geological cross-section of the Kintore Palaeovalley for Transect 1.*

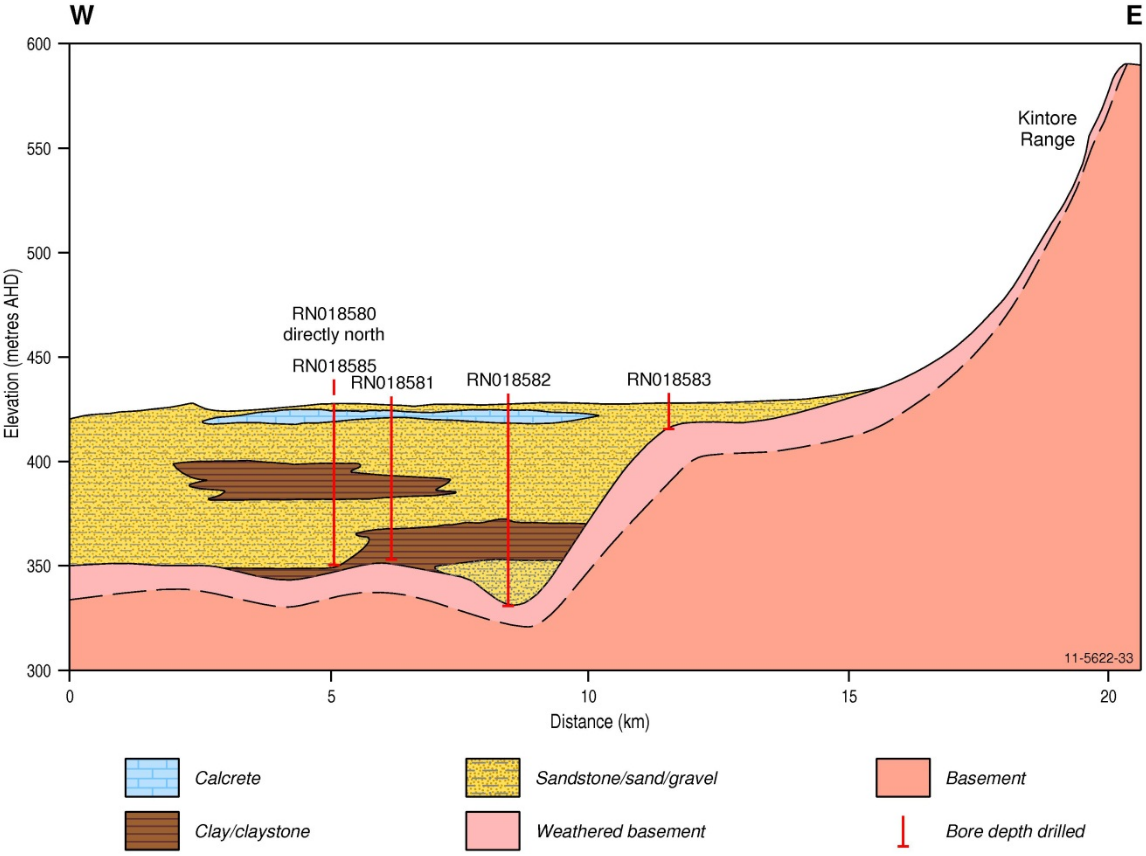

Figure 4.23: *Geological cross-section of the Kintore Palaeovalley for Transect 2.*

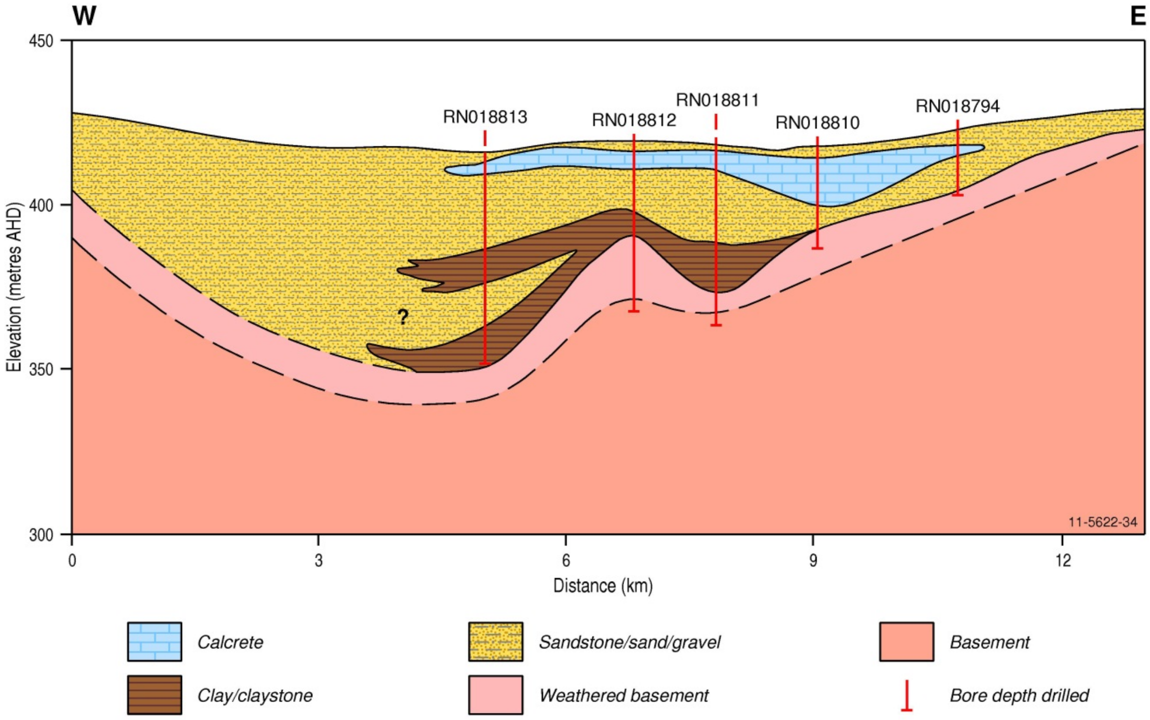

Figure 4.24: *Geological cross-section of the Kintore Palaeovalley for Transect 3.*

4.6.3.2 Infill stratigraphy

Based on the results of the drilling program the main characteristics of the Cenozoic geology of the Kintore Palaeovalley are:

- Quaternary aeolian sands form a widespread cover sequence across the palaeovalley to a depth of 1–2 m;
- Palaeovalley infill sediments are dominated by fine- to coarse-grained sand. The sediments are variably lithified and weathered and contain abundant quartz. Clay and silt layers are subordinate. As in other central Australian palaeovalleys the Cenozoic infill has been strongly overprinted by chemical weathering which has altered much of the original (non-quartz) composition and obscured most primary sedimentary structures;
- The infill Cenozoic stratigraphy is very heterogeneous and most sedimentary units are discontinuous across the palaeovalley (Figure 4.25);
- Near-surface calcrete bodies are the most laterally continuous units in the Kintore Palaeovalley, although only minor calcrete is developed in the central parts of the palaeovalley (which contain the lowest salinity groundwater);
- Some clay-rich zones in the lower parts of the infill sequence may be saprolitic (weathering-related), rather than formed by depositional processes; and
- In many bores the contact between the Cenozoic infill sediments and the weathered bedrock is difficult to accurately determine.

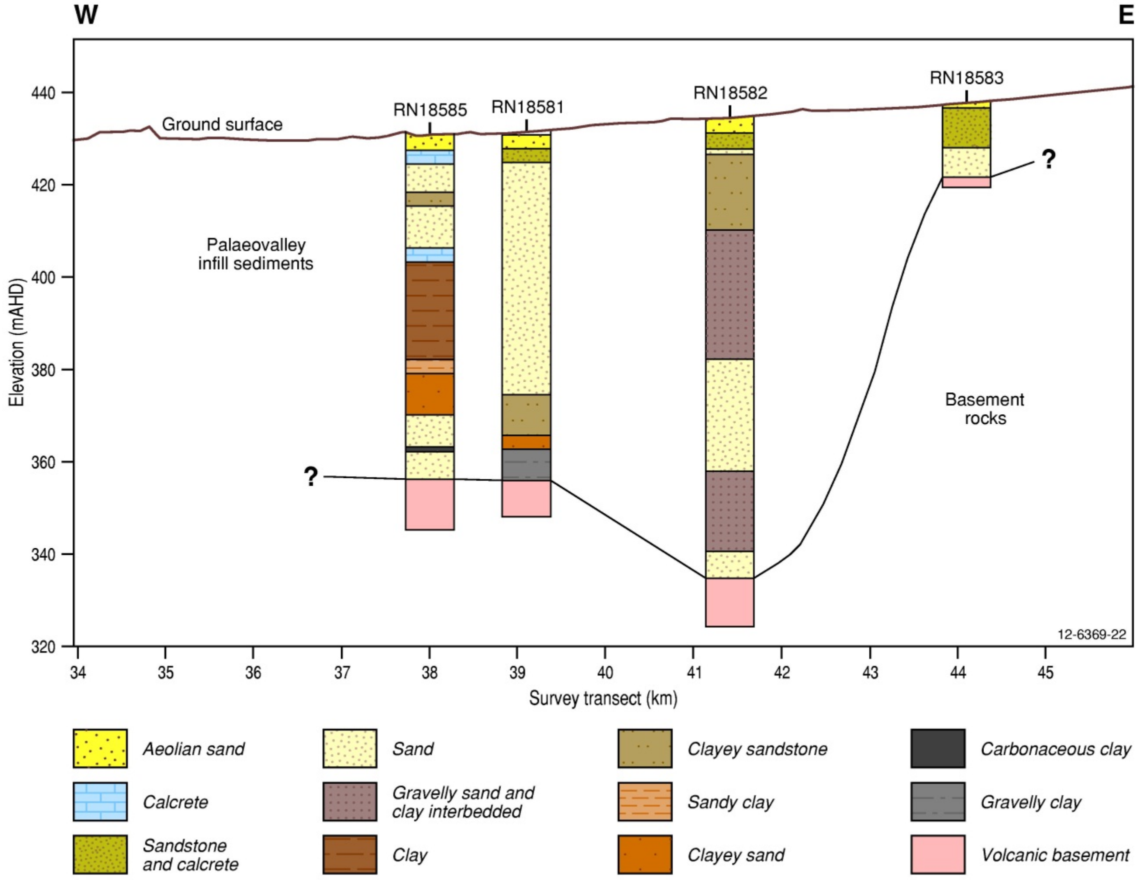

Figure 4.25: *Composite lithologic profiles of four bores drilled in the Kintore Palaeovalley along Transect 2, highlighting significant lateral facies variability.*

Carbonaceous clay was collected from the basal sand-rich section of RN18585 (Figure 4.26). This material yielded Cenozoic spore-pollen (*Nothofagidites* spp.) interpreted to have been deposited during the Middle to Late Eocene (M. MacPhail, 2010, pers. comm.). The isolated carbonaceous sediment recovered from this bore suggests a restricted swamp-like depositional setting.

4.6.3.3 Basement morphology

Depth to basement is an important parameter to resolve as it assists with reconstructing the palaeodrainage network history and understanding landscape evolution. The deepest bore drilled for this project in the Kintore Palaeovalley (RN18580) intersected basement at 105 m below surface (on the Gary Junction Road). A previous electrical sounding near this site (Anning et al., 1996) predicted basement depth of ~150 m. The gravity data acquired along Transect 1 also indicated that this location is the deepest part of the palaeovalley.

The five holes drilled on the plain to the west of Kintore intersected basement at depths <99 m below surface. Bores drilled along Transect 3 north of the Gary Junction Road intersected basement at depths of <67 m. Borehole basement intersections below Cenozoic sediments from the Kintore area indicate that the main palaeovalley axis (flow direction) is towards the northwest, i.e., towards Lake Mackay. This is slightly offset to the west from the palaeovalley mapped by Tickell (2008) which was based on mapping outcrops of calcrete. The deepest bore drilled along Transect 3 was the western-most bore on the edge of the calcrete mound, suggesting that the palaeovalley thalweg is offset from the surface calcrete zone.

Figure 4.26: *Carbonaceous silty clay from bore RN18585, which yielded Cenozoic spores and pollen which suggests that deposition occurred during the Mid to Late Eocene.*

4.6.4 Hydrogeology

Drilling of the palaeovalley system to the west and north-west of Kintore encountered significant groundwater in the saturated Cenozoic sediment infill, with the watertable typically at 4–7 m below surface. In the thickest part of the infill sequence groundwater yields commonly range from 8–20 L/s (Tables 4.1–4.2). The two eastern-most bores on Transect 2 (RN18583 and RN18586) and the eastern bore on Transect 3 (RN18794) intersected only thin Cenozoic sediment sequences (i.e., elevated basement rock) and consequently produced only groundwater seepage.

Water quality is relatively homogenous down-hole (as measured from field parameters such as electrical conductivity), indicating that the palaeovalley sediments form a porous, interconnected and unconfined aquifer system. Confining layers or aquitards do not form part of the sedimentary package. The standing water level measured in twin piezometers installed at RN18812 showed negligible vertical variation in groundwater head.

Standing water levels measured following drilling and the construction of bores were used to generate a local piezometric surface. These data indicated that the hydraulic gradient extends towards the north-west from the basement high at RN18583, suggesting that groundwater flow mirrors the present surface topography (which slopes west-north-west at a gradient of about 1:500). Thus, within the main boundaries of the palaeovalley, groundwater flows in a northerly direction and eventually discharges at Lake Mackay.

4.6.4.1 Groundwater recharge

Recharge rates are difficult to estimate given the lack of groundwater level time-series data. The arid conditions of the region imply that the proportion of recharge relative to actual rainfall is very low, as most rainfall is either directly evaporated or transpired by the native vegetation. Recharge only occurs following significant rainfall events, which may be spread over several days or weeks.

A pressure transducer data logger was installed in monitoring bore RN18582 (along the West Track) in May 2010. The bore hydrograph data shows that the aquifer responds to at least annual/seasonal rainfall variation and probably even specific rainfall events (Figure 4.27). There is an obvious time lag in the groundwater level response associated with specific rain periods, particularly during the period from late 2010 to early 2011. However, rainfall events in February and March 2011 do not seem to have resulted in recharge. Declining water levels over 2011 indicate there is active throughflow in the system. Water levels in the palaeovalley aquifer rose in response to wet conditions in 2010, and are subsequently declining during drier times in 2011-2012.

Groundwater hydrochemistry can also be used to assess recharge, and this is further discussed in Section 4.6.5.

The dominant mechanism of groundwater recharge to the palaeovalley has not been established but may be via a combination of diffuse and direct recharge mechanisms. Various intermittent creeks drain north-westward from the Kintore Range, providing potential zones for direct recharge.

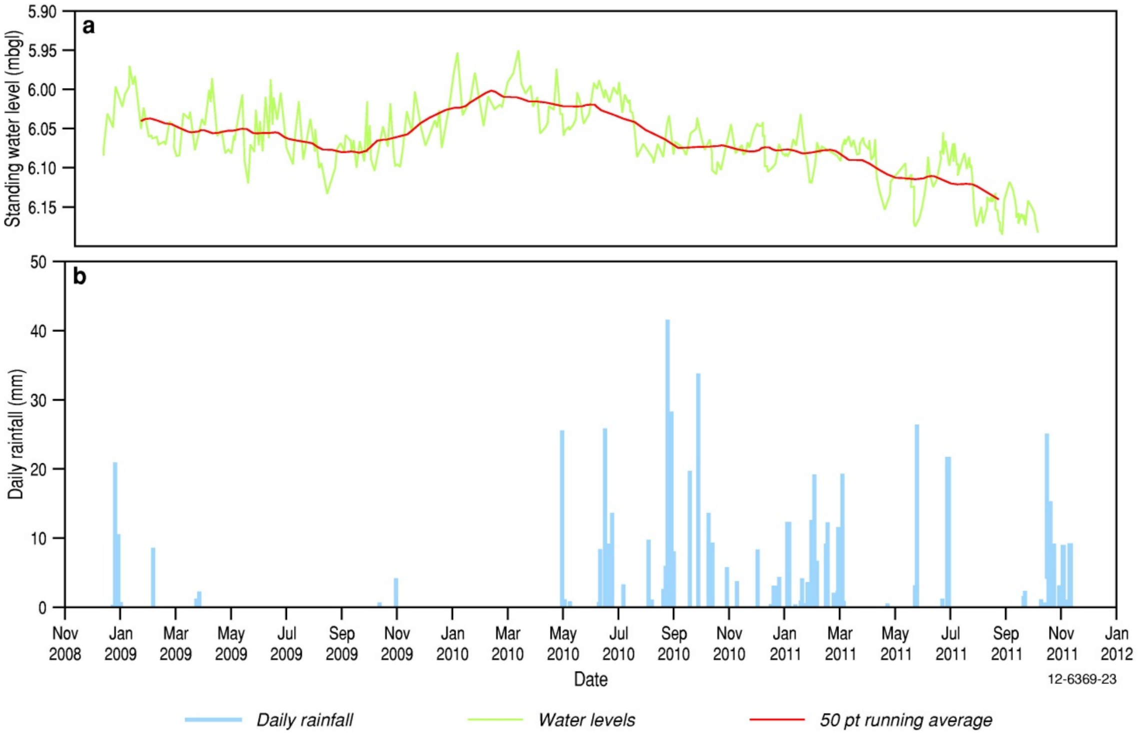

Figure 4.27: *Bore hydrograph for RN18582 (uncorrected for barometric pressure) plotted with rainfall recorded at Kintore for November 2008 to January 2012.*

4.6.5 Hydrogeochemistry

Groundwater quality varies considerably between bores in the Kintore Palaeovalley, although the compositions are typical of arid zone aquifers in central Australia (Figure 4.28–4.29). Overall, salinity increases with distance away from the Kintore Range (Figure 4.28). This supports the theory that most recharge enters the palaeovalley aquifer near the local topographic high point and then flows along a north-directed path towards Lake Mackay. The variable water quality also partially reflects the geological heterogeneity of the alluvial aquifer sediments. Results of ionic chemical analysis of groundwater samples from Kintore Palaeovalley bores are shown in Appendix 4.

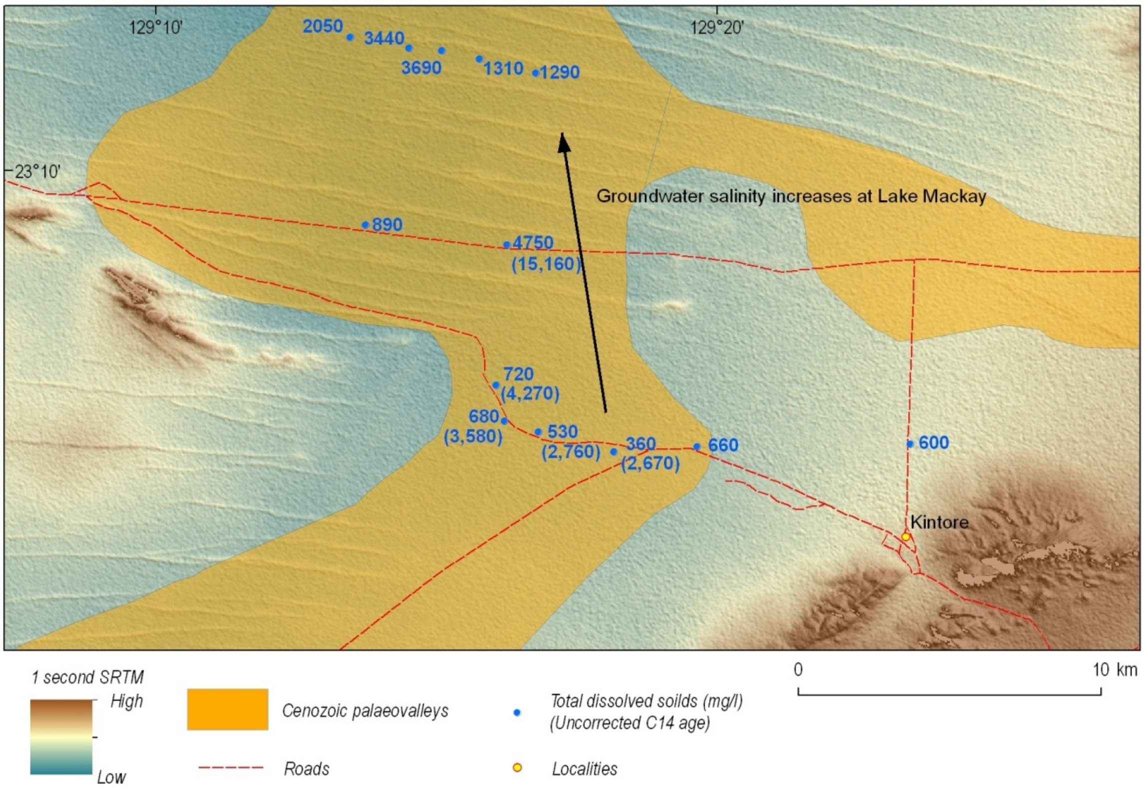

Figure 4.28: *Groundwater salinity (total dissolved solids) and uncorrected ^{14}C age (in years before present) for bores in the Kintore Palaeovalley. The arrow signifies the trend of increasing salinity along the groundwater flow-path towards Lake Mackay (to the north).*

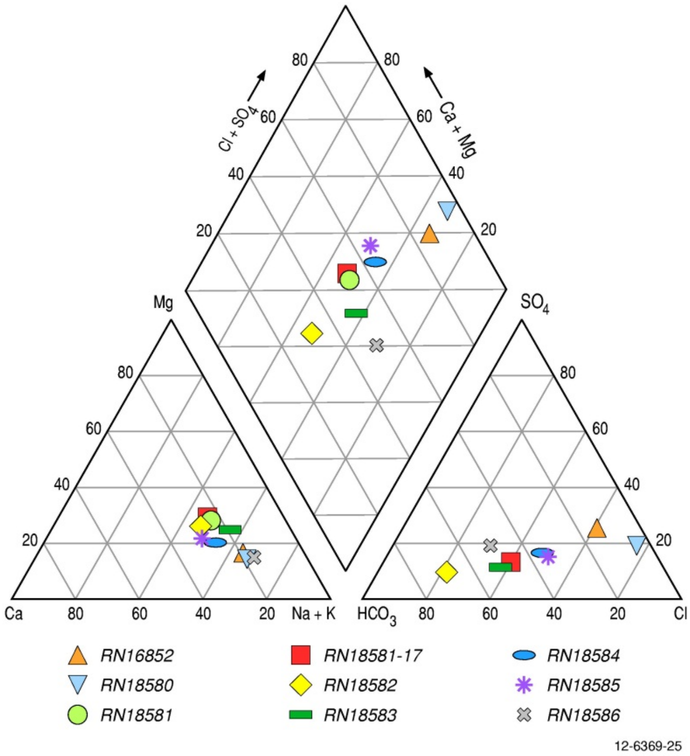

Figure 4.29: *Piper diagram for groundwater from the Kintore Palaeovalley.*

The groundwater in the Kintore Palaeovalley can be classified into two main hydrochemical facies: Na–Cl, and Na–HCO_3. The Na–Cl facies is most common at the western edge of the palaeovalley system and may be due to concentration by evapotranspiration, or addition of saline recharge. In contrast, the Na–HCO_3 assemblage occurs in the central part of the palaeovalley where groundwater is relatively fresh. This facies is indicative of more recent recharge.

Analysis of the hydrochemical data (Appendix 4) further indicates that:

- Groundwater is mostly fresh in the deeper part of the palaeovalley, with total dissolved solids (TDS) ranging from 360–720 mg/L;
- Groundwater salinity increases with distance away from the Kintore Range, with TDS up to 4,7500 mg/L (Figure 4.28);
- Nitrate levels are consistently above drinking water guideline limits; and
- Some samples also contain elevated levels of boron, iodine, and some metals.

The groundwater compositions for the Kintore and Wilkinkarra Palaeovalleys were compared with data for the Cenozoic and mountain-front aquifers from the Western Water Study (Figure 4.30).

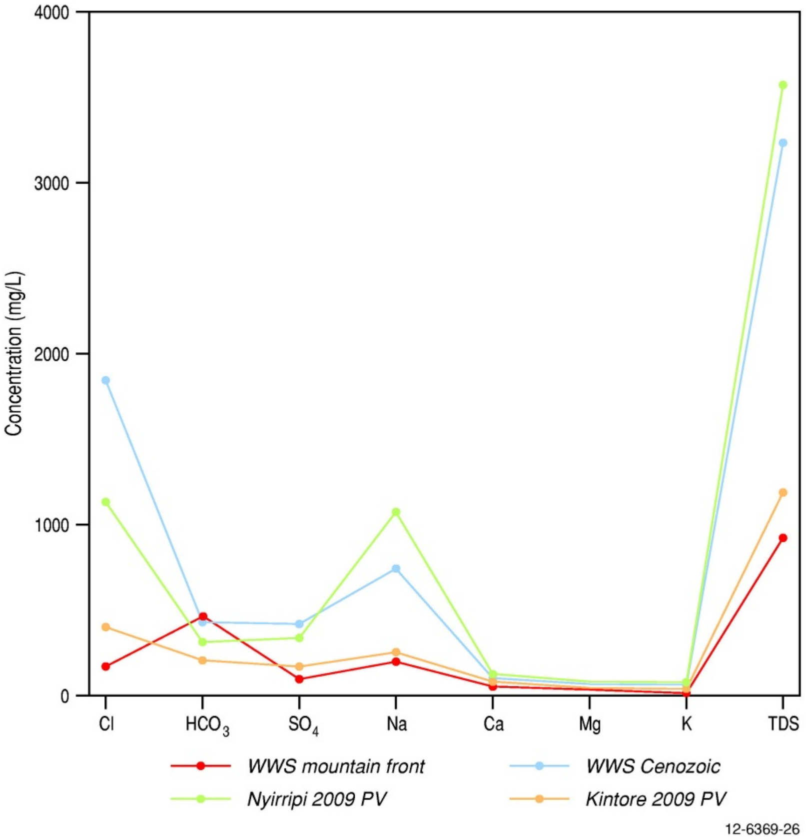

Figure 4.30: *Water chemistry fingerprint plot comparing mean water composition for the mountain-front and Cenozoic aquifers of the Western Water Study (Wischusen, 1998) with mean palaeovalley groundwater compositions from Kintore and Wilkinkarra.*

The Wilkinkarra Palaeovalley near Nyirripi has similar groundwater chemistry to the WWS Cenozoic aquifer type, whereas the Kintore Palaeovalley is aligned more closely with groundwater from the mountain-front systems (Hostetler et al., 1998). Regionally, the mountain-front systems are known to host potable water as runoff occurs from the upland regions and infiltrates through the connected alluvial fan deposits, which improves recharge rates and water quality (Wischusen, 1998). Indeed, the Kintore Palaeovalley is adjacent to the Kintore Range, as opposed to the Wilkinkarra Palaeovalley which is in a predominantly flat landscape. However, the discovery of potable groundwater in the Wilkinkarra Palaeovalley, well away from any upland sediment outcrops, shows that fresh water is not necessarily confined to mountain-front settings in this arid environment.

4.6.6 Stable isotopes

The stable isotope (deuterium and oxygen-18) composition of groundwater relative to rainfall provides a method of estimating recharge mechanisms. The stable isotope data for groundwater from six bores in the Kintore Palaeovalley are relatively enriched in the heavier isotope $\delta^{18}O$ when compared to the Alice Springs local meteoric water line (LMWL) (Figure 4.31). This indicates that considerable evaporation of the rainfall occurred during recharge to the palaeovalley groundwater system. This suggests that diffuse recharge mechanisms provide the main recharge pathway for the palaeovalley aquifer, with considerable evaporative losses occurring from soil water during infiltration.

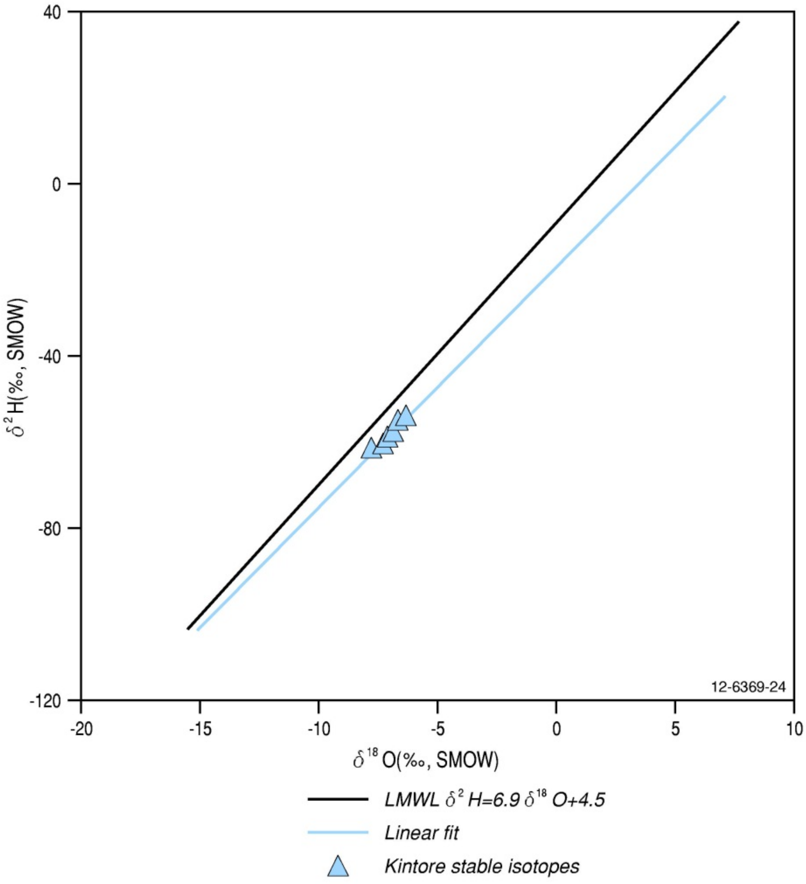

Figure 4.31: *δ^2H vs. $\delta^{18}O$ plot of groundwater from the Kintore Palaeovalley compared with the Alice Springs local meteoric water line (LMWL).*

4.6.7 Carbon-14

Groundwater residence times were estimated for several bores in the Kintore Palaeovalley using radiocarbon dating. The estimated groundwater residence time for four bores containing relatively fresh groundwater (TDS of 360–720 mg/L) varies from 2,670 to 4,270 years before present, BP (Figure 4.28). These bores are located on Transect 2, about 5–7 km north-west of Kintore. Bore RN18580 on the Gary Junction Road contains more saline groundwater (TDS of 4,750 mg/L) and also has a significantly older radiocarbon signature, with an uncorrected age of 15,160 years BP. These data indicate that the interpreted age of groundwater in the Kintore Palaeovalley increases with distance away from the Kintore Range, providing further evidence that most recharge occurs either within, or very close to, the range.

4.7 INTERPRETATION AND KEY FINDINGS

Field investigations in the Kintore Palaeovalley confirmed that significant groundwater resources are hosted by palaeovalley infill sediments underlying the plains north-west and west of Kintore. The north-west trending palaeovalley contains up to 105 m of Cenozoic sediments within an approximately 4–8 km wide ancient valley. Apart from scattered calcrete outcrops north of the Gary Junction Road, the Kintore Palaeovalley is completely obscured at surface by thin Quaternary aeolian sands and modern sheetwash deposits.

The palaeovalley is infilled with alluvial sediments that are strongly overprinted by weathering. This has altered much of the sediment composition (apart from quartz) and probably obscured many primary structures, making facies analysis difficult. The sediments are predominantly sand (some are partially lithified and form sandstone) containing abundant quartz. Clay- and silt-rich layers are subordinate. The infill stratigraphy is typically heterogeneous and correlation between bores is difficult. Only minor calcrete occurs in the central parts of the palaeovalley near Kintore, where groundwater is fresher. Further north towards Lake Mackay groundwater increases in salinity.

Carbonaceous sediments from a basal clay-rich zone in RN18585 yielded spore-pollen considered to be Middle to Late Eocene (MacPhail, 2010). Previous palynology from the Kintore Palaeovalley (RN16852) indicated deposition also occurred in the Oligocene to Miocene. The occurrence of minor carbonaceous sediments implies swampy depositional settings, although they were probably not widespread.

The palaeovalley aquifer contains abundant fresh water, with TDS ranging from 360–720 mg/L and yields of up to 20 L/s. These are several kilometres west-north-west of the Kintore Range and are presumably fed by recharge received from creeks that flow off the nearby Kintore Range (following significant rainfall events). Groundwater flows to the north-west through the palaeovalley sediments, becoming increasingly saline northwards (with TDS up to ~5,500 mg/L). Groundwater salinity varies with distance away from the Kintore Range, possibly due to the heterogeneity of the aquifer. It is likely (but not confirmed by this study), that groundwater continues northwards and eventually discharges at Lake Mackay.

The freshwater resource discovered west of Kintore is potable apart from elevated nitrate concentrations, which are common in arid zone groundwater systems.

4.8 CONCLUSIONS

Data collected during 2009 to 2011 field investigations for the Kintore Palaeovalley have significantly expanded knowledge of this groundwater system, and highlighted areas where further work is needed. The key conclusions from this study are:

- The Kintore Palaeovalley occurs in a mountain-front geological setting, adjacent to the Kintore Range. The influence of this setting on the hydrogeology is apparent in the groundwater composition, with the freshest water nearest to the range and increased salinity away from the range along the flowpath. The groundwater is akin to that of other mountain-front settings in this arid region, most notably from Papunya and Mt Liebig (Wischusen, 1998).
- The Kintore Palaeovalley was incised as a major river system into underlying bedrocks of the Arunta region in the Late Mesozoic or Early Cenozoic. At this time the climate was significantly different to the present arid setting, with much higher rainfall and humidity (Langford et al., 1995). The landscape was also different, as the topographic relief was much higher than the modern flat terrain and vegetation was more extensive.
- A previously unknown fresh groundwater resource was discovered near the Kintore community. As well as being a potential future benefit to the local community, the presence of fresh groundwater indicates that this palaeovalley is actively receiving recharge.
- The palaeovalley field investigation program has shown that geophysics can provide a useful tool for reconnaissance-scale exploration of palaeovalleys. However, the success of geophysics to detect and map palaeovalleys relies on there being a measurable contrast in physical or electrical properties (such as density, porosity and electrical conductivity) between the underlying basement rocks and the palaeovalley infill sediments. In this field program, microgravity surveying proved reasonably accurate in defining the Kintore Palaeovalley due to the density contrast between the Proterozoic metavolcanic, granitic and limestone basement rocks and the quartz-dominated sediment infill.
- Many aspects of this palaeovalley system remain unknown, such as the northern and southern extents, and the nature and degree of connection between the aquifers drilled on the northern (Gary Junction Road) and southern (West Kintore Track) transects. More effective regional-scale mapping could be undertaken using a remote approach, based on analysis of certain satellite imagery or airborne geophysical data. This would allow wider coverage of the investigation area and thus more effective targeting of ground-based efforts. In particular, an airborne electromagnetic (AEM) survey, which has proven successful in mapping palaeovalleys in other arid zone areas such as the Paterson Province in Western Australia (English et al., 2012a), could provide a suitable technology for this purpose.

5. Central Mount Wedge Basin

5.1 INTRODUCTION

The Central Mount Wedge Basin is approximately 300 km north-west of Alice Springs, and immediately north of the Aboriginal community of Papunya. Central Mount Wedge is one of several Cenozoic intermontane basins occupying depressions between bedrock mountain ranges in the central Australian uplands. The Central Mount Wedge Basin was initially mapped by Senior et al. (1995) during their study of the Cenozoic geology of central Australia, which focused on the Eastern Arunta Block (Figure 5.1). However, the basin outlines of Senior et al. (1995) are poorly defined due to lack of detailed information.

Figure 5.1: *Cenozoic Basins in central Australia (after Senior et al. 1995).*

Although the Central Mount Wedge Basin has been subjected to previous hydrogeological research, prior to this study the deeper basin sedimentary sequences had been largely unexplored. Consequently, information on the depth, basement topography and infill stratigraphy of the entire basin were unknown. The nature of the Cenozoic infill at depth was of particular interest, specifically for the potential existence of deep Eocene sand aquifers, known from palaeovalleys elsewhere in Australia. It was also important to assess the extent and characteristics of the water resources contained at depth (e.g., inter-aquifer connectivity), especially considering that potable water occurs in the shallower basin aquifer.

The *Palaeovalley Groundwater Project* endeavoured to address these questions by undertaking field investigations between 2008 and 2011 in the Central Mount Wedge Basin. This chapter presents the key data and findings of those investigations.

5.2 CHARACTERISTICS OF THE CENTRAL MOUNT WEDGE REGION

Investigations in the Central Mount Wedge region focused on a readily accessible track which runs northwards from Papunya towards Central Mount Wedge (Figure 5.2). This transect was the site of previous hydrogeological surveys and drilling work, e.g., Anning et al., 1996, Lau et al., 1997. The study area occurs on the Mount Liebig and Mount Doreen 1:250,000 series mapsheets, and covers both pastoral property (Derwent Station) and Aboriginal Land Trust, ALT, tenure (the Ngalurrtju ALT and Haasts Bluff ALT).

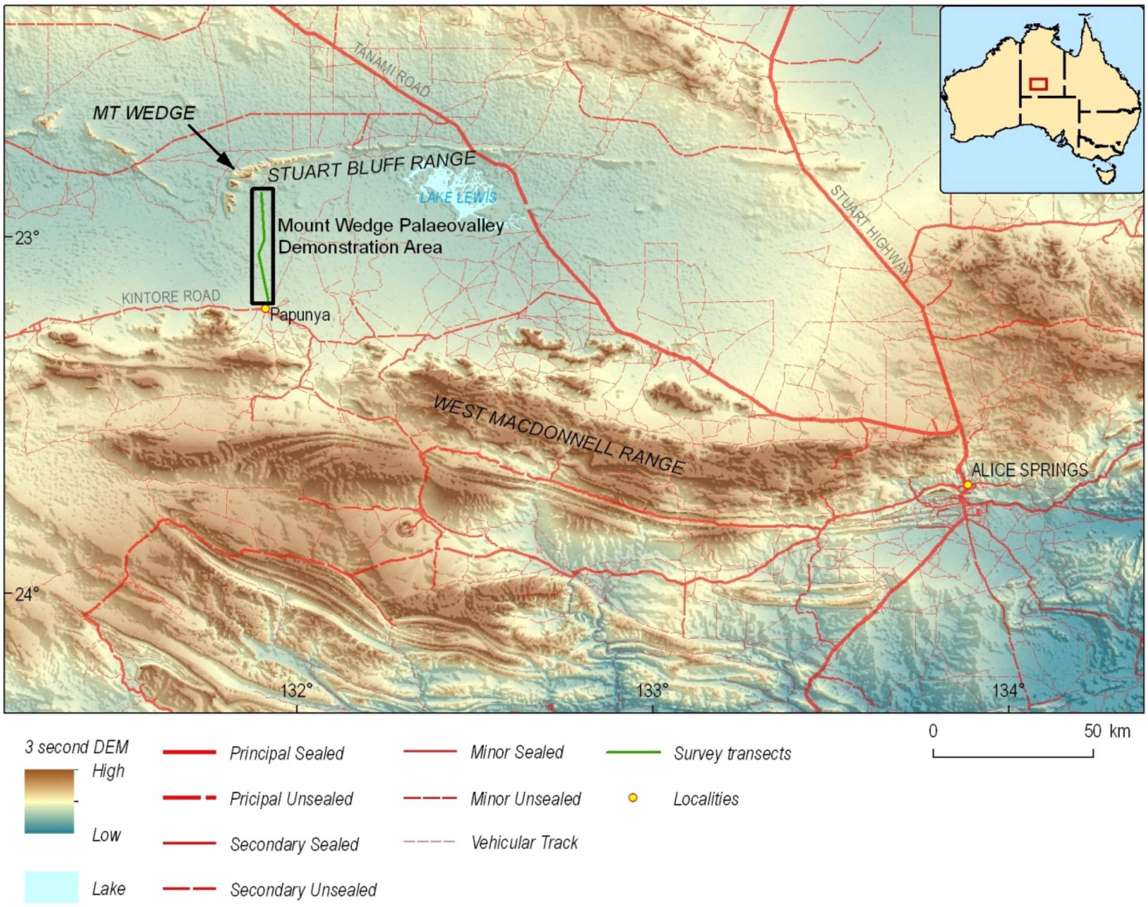

Figure 5.2: *Topographic features of the main investigation area for the Central Mount Wedge Basin.*

5.2.1 Climate

The climate of the area is semi-arid to arid with highly variable rainfall averaging 200–300 mm per year. The variability is highlighted by recent annual rainfall totals for the Papunya weather station

(015612), with 91.4 mm of rain (2009) and 505.8 mm of rain (2010). The evaporation rate is extremely high and is approximately 10 times that of the annual rainfall.

5.2.2 Topography

The study region is set in a basin-and-range province with extensive fluvial-lacustrine plains abutting the Proterozoic West MacDonnell Ranges (Figure 5.2). The Belt Range, just south of the Papunya community, marks the southern boundary of the Central Mount Wedge Basin. The Stuart Bluff Range, a quartzite cuesta (formed of Vaughan Springs Quartzite, the basal unit of the Ngalia Basin), bisects the basin and forms the southern boundary of the Neoproterozoic Ngalia Basin.

The Central Mount Wedge peak (*Karrinyarra*) is a prominent topographic feature in the basin. It stands at 1,095 mAHD and is the highest point on the Stuart Bluff Range (Figure 5.3). The basin is bounded at the northern end by the Walpiri Range near the community of Yuendumu.

Figure 5.3: *The Central Mount Wedge peak in the Stuart Bluff Range.*

5.2.3 Geology

The Cenozoic Central Mount Wedge Basin overlies (and is surrounded by) the fault-bounded blocks of the Proterozoic Arunta Region and the Neoproterozoic to Paleozoic Ngalia Basin (Figure 4.3). The basement rock types are dominated by granite and metamorphic pellites and psammites of the Lander Rock Formation. The major structural trend of the basement rocks is sub-parallel to the east-trending Central Australian Suture (CAS) Zone (Figure 5.4). The CAS was initially recognised by the Bureau of Mineral Resources 1985 Arunta Seismic traverse. It is a major northward dipping basement structure that extends to >20km depth (Goleby et al., 1989; Wright et al., 1991).

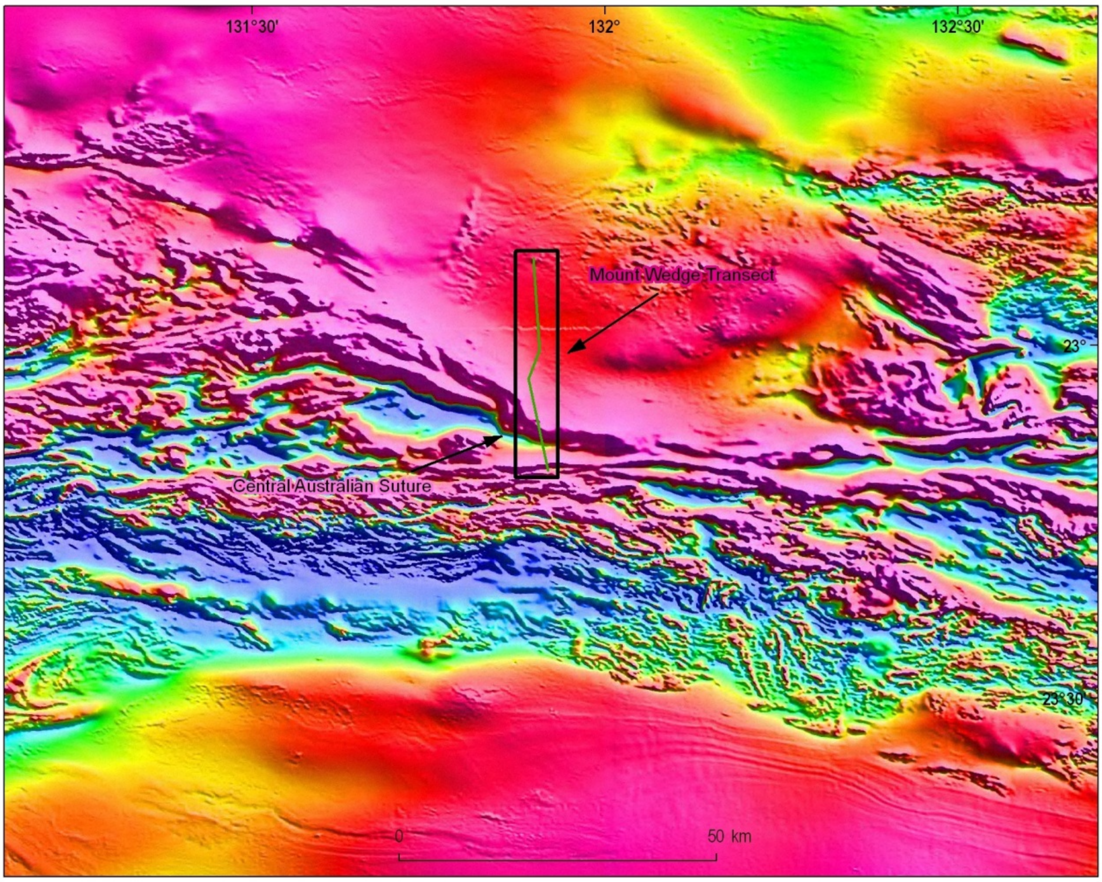

Figure 5.4: *Total magnetic intensity (TMI) image of the region around the Central Mount Wedge Basin.*

Tectonism during the Alice Springs Orogeny (approximately 300 to 400 million years ago) led to extensive thrusting and folding of the basement rocks. This orogenic activity produced the central Australian uplands, now characterised by rugged, east-trending mountain ranges and broad, flat valleys. The intermontane plains are depocentres infilled with sediments, although with little indication of the overall depth or configuration of the basins. Subsidence north of the Central Australian Suture (Redbank Thrust Zone) likely initiated development of the Cenozoic basins (Beekman et al. 1997). Palaeobotanical evidence indicates that tectonic development of these basins within the Arunta Region occurred during the Paleocene or earliest Eocene (MacPhail, 2007; 2010).

The surface geology of the region consists of extensive aeolian sand cover, including some linear dune systems (Figure 5.5). Modern alluvium occurs along drainage lines.

5.2.4 Groundwater resources and use

Previous exploration for groundwater resources in the Central Mount Wedge Basin (to depths of ~150 m below surface) has shown that the infill sediments form a watertable aquifer (Lau et al., 1997). This aquifer hosts fresh water resources close to the southern basin margin, with the watertable around 30 to 40 metres below surface. Most recharge occurs via the porous sedimentary sequences at the base of the Belt Range. Groundwater salinity generally increases northwards away from this recharge zone in the direction of groundwater flow. North of the Stuart Bluff Range a system of saline playas form a zone of groundwater discharge. Hydraulic parameters are known for the aquifer at the Papunya borefield but not elsewhere. The Papunya community relies on the potable resources of this aquifer. Some stock bores on pastoral properties such as Derwent Station also tap the Central Mount Wedge Basin aquifer.

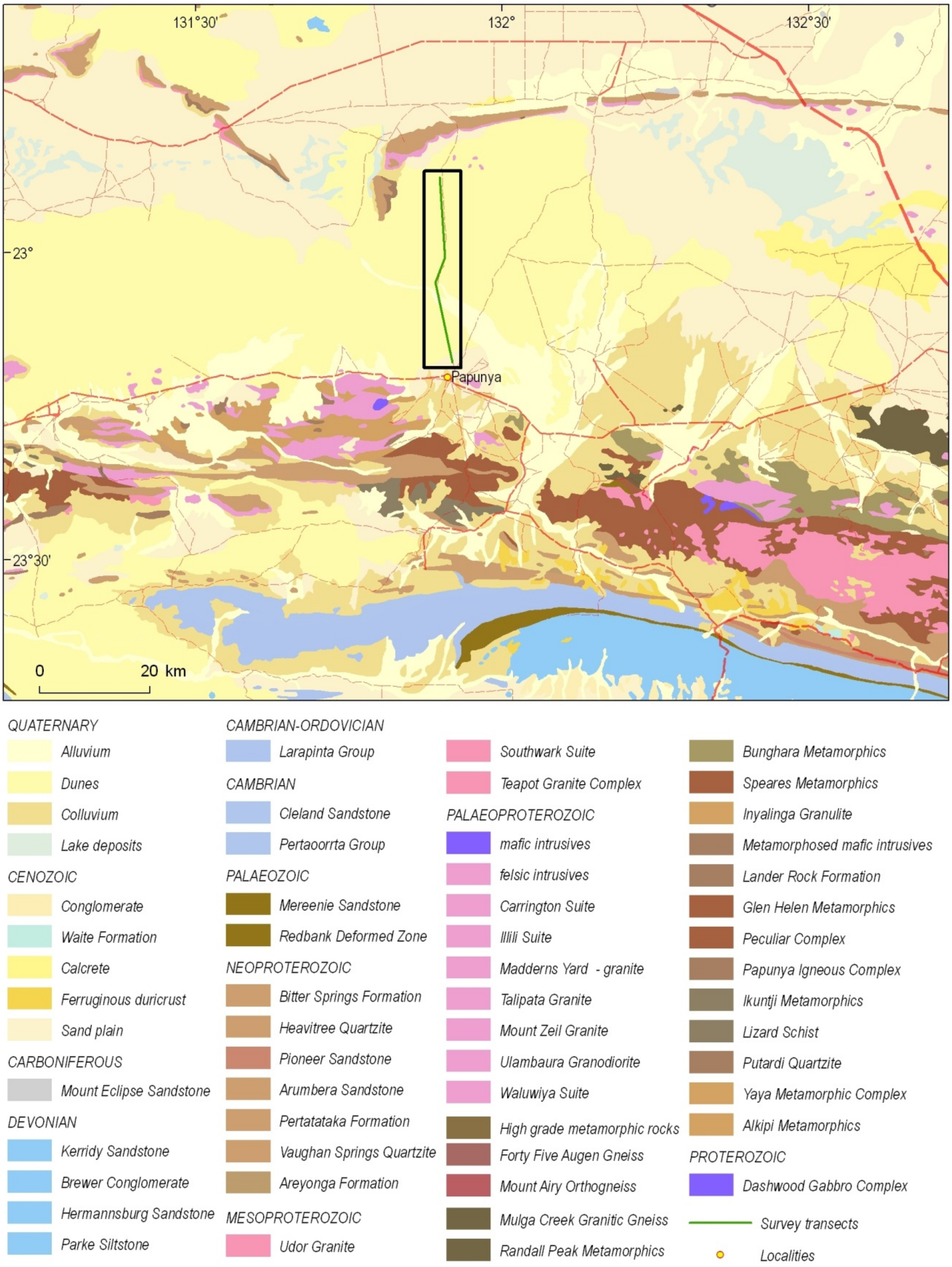

***Figure 5.5:** Surface geology of the Central Mount Wedge Basin and adjacent upland region.*

5.2.5 Vegetation

The site is flat to gently sloping and dominated by open sandy terrain with spinifex and Desert Oaks (*Allocasuarina dicaisneana*). Other vegetation assemblages include Mulga (*Acacia aneura*) woodlands and shrublands.

5.2.6 Surface hydrology

Apart from minor spring-fed rockholes in the Stuart Bluff Range (generally off-limits due to cultural reasons), there are no permanent surface water resources in the area. An unnamed ephemeral creek crosses the survey area roughly midway between Papunya and the Stuart Bluff Range. Minor surface water flow was observed in this creek following heavy rainfall events in 2010.

5.3 PREVIOUS STUDIES

The Central Mount Wedge Basin was first mapped by Senior et al. (1995) in a study on the Cenozoic sedimentary basins of the Alice Springs region. This study was based on stratigraphic drillcore obtained by the Bureau of Mineral Resources during 1:250,000 scale geological mapping. The preliminary basin map showed the Central Mount Wedge Basin extending eastward to encompass the Lake Lewis catchment. However, subsequent research by English (2002) on the evolution of Cenozoic basins in inland Australia delineated two discrete systems, the Central Mount Wedge Basin and the Lake Lewis Basin (Figure 5.6). The basins are separated by a basement high of crystalline bedrock (English, 2002) which acts as a groundwater divide.

The Cenozoic sediment sequences and groundwater resources of the Central Mount Wedge Basin were first investigated in detail as part of the Western Water Study, *Wilurartja Kapi* (Anning et al. 1996; Lau et al., 1997). The aim of this work was to investigate regional Cenozoic geology and groundwater resources, and evaluate the use of various geophysical survey methods. As part of this study geophysical surveys were performed along a 100 km-long transect between Papunya and Yuendumu. The techniques used included vertical electrical soundings and time-domain electromagnetic soundings. In 1995, 31 joint soundings were performed along the survey transect (Figure 5.7). Interpretation of the geophysical data was aided by a number of existing and new bores drilled along the Papunya to Yuendumu Road (Figure 5.7). The resistivity-depth sections indicated an electrically conductive basin overlying resistive basement rocks (gneiss and granite) of the Arunta Region.

In 1995, six new investigation bores were drilled along the road between Papunya and Central Mount Wedge. The maximum bore depth was 197 metres below surface (Figure 5.8). Interpretation of the drilling data defined discrete sedimentary units in the basin, which had been deposited onto the basement rocks of the Arunta Region. These were:

- An upper unit (the *Currinya Clay*, Tpy) of alluvial fan sediments; and
- A lower unit (Tmkw) of lacustrine (littoral carbonate) clay, termed the *Mount Wedge Clay* by Lau et al. (1997) (100 to 150 m thick).

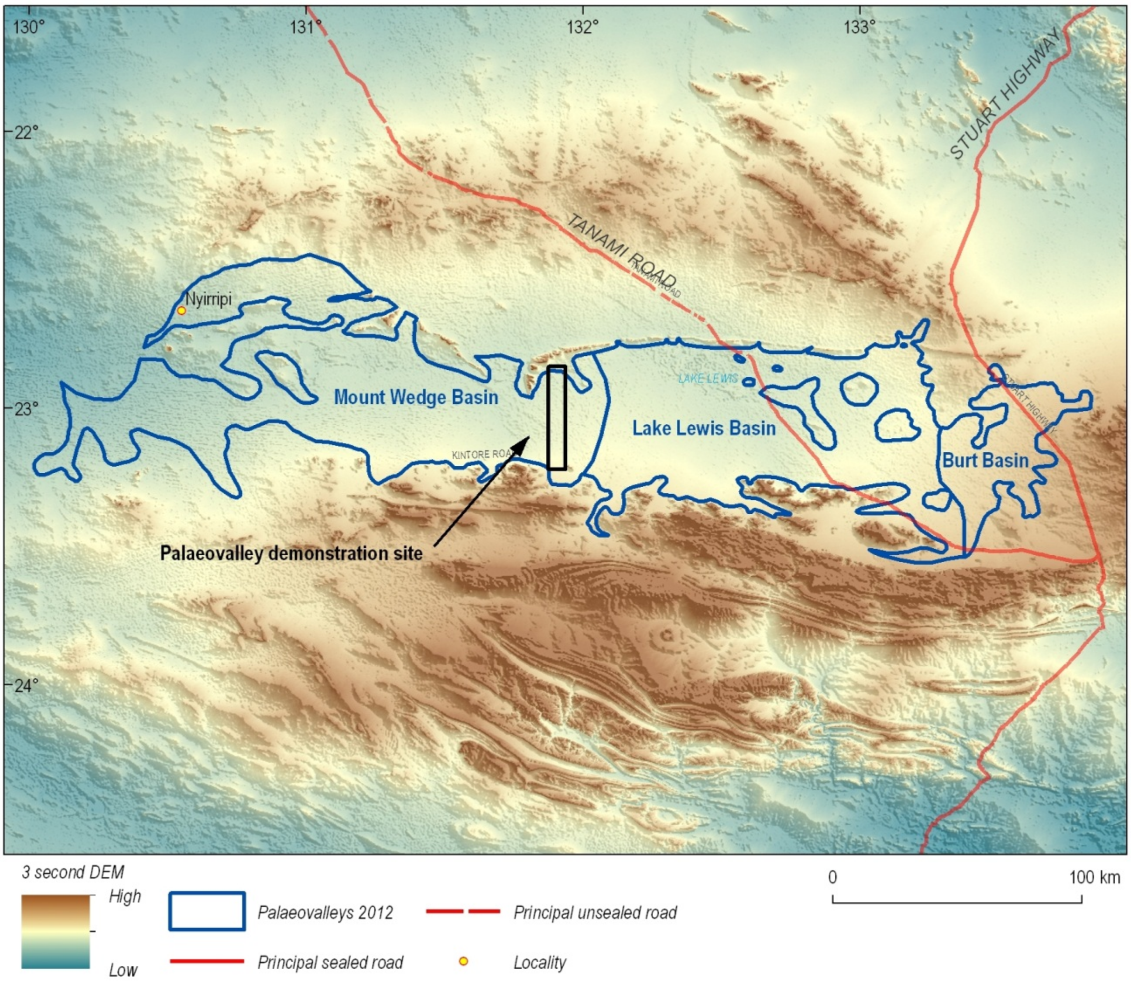

Figure 5.6: *The Central Mount Wedge, Lake Lewis and Burt Basins.*

The basal clay unit was characterised as a dark, pyrite bearing, shelly lacustrine clay, with minor lignite. The clay is overlain by approximately 100 m of heterogenous alluvial fan deposits comprising of sand, gravel and clay. Of the bores drilled along the survey transect, only one bore intersected basement rocks at the southern end of the basin (RN5376 at 120 metres below surface at the southern end of the basin just north of Papunya). Three bores intersected basement rocks at 60 metres depth (or less) near the northern end of the basin, close to the Stuart Bluff Range. The deeper part of the basin was not explored in this study.

Lau et al. (1997) generated a stylised cross-section of the basin based on integrated drilling and geophysics data (Figure 5.8). A map and cross-section were produced but there were no accompanying reports or explanations published.

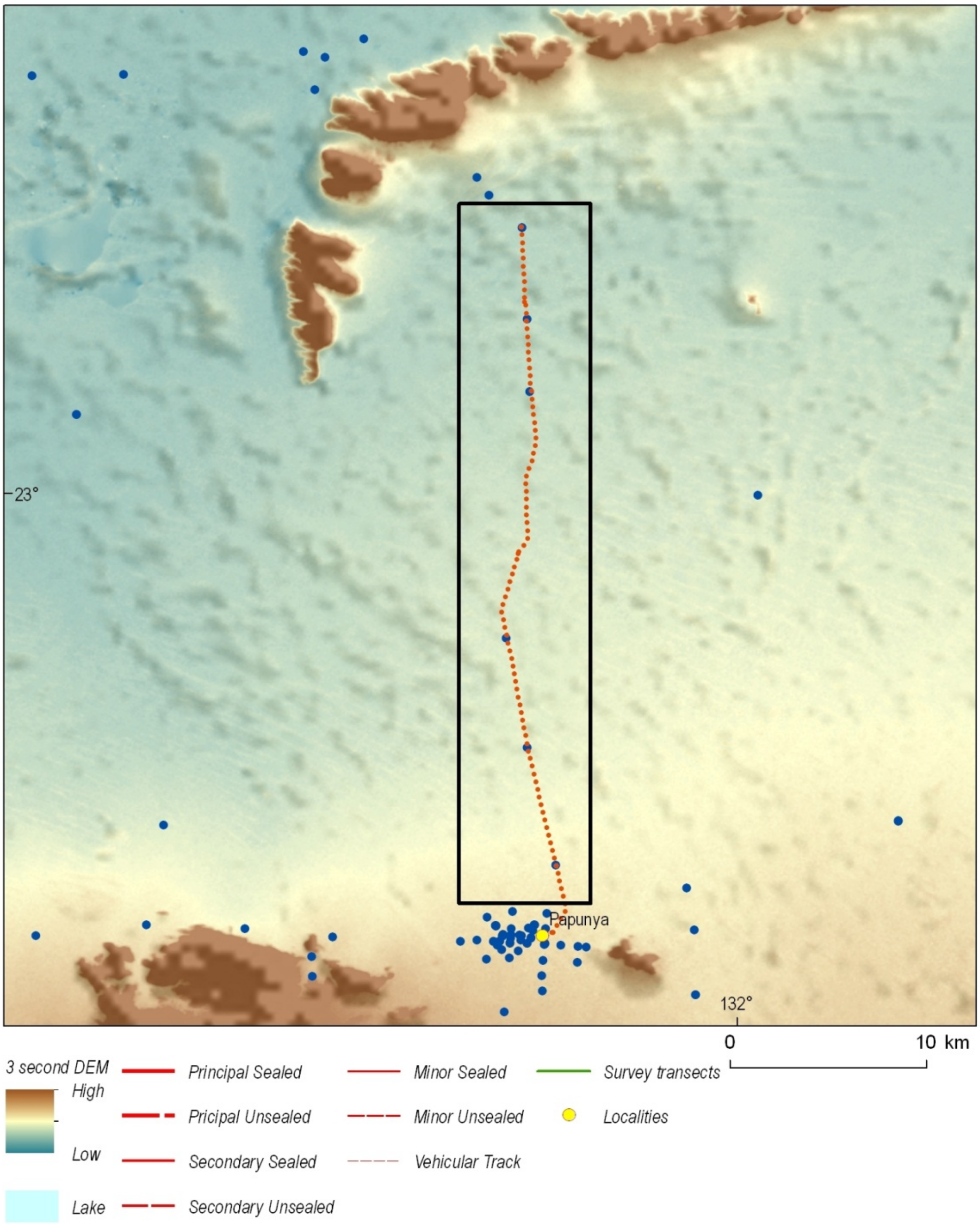

Figure 5.7: *Central Mount Wedge transect showing location of existing bores (blue dots), and gravity stations (red dots along transect).*

No further work was published on the Cenozoic basins in this area until the 2002 PhD thesis of Pauline English, which provided detailed characterisation of the geology, hydrogeology, geomorphology, hydrology and palaeoenvironment of the Lake Lewis Basin. This work is relevant to the palaeovalley investigations at the Central Mount Wedge Basin because: *'the Mount Wedge and Lake Lewis Basin share a common Tertiary evolution and a parallel Quaternary evolution* (English, 2002)'.

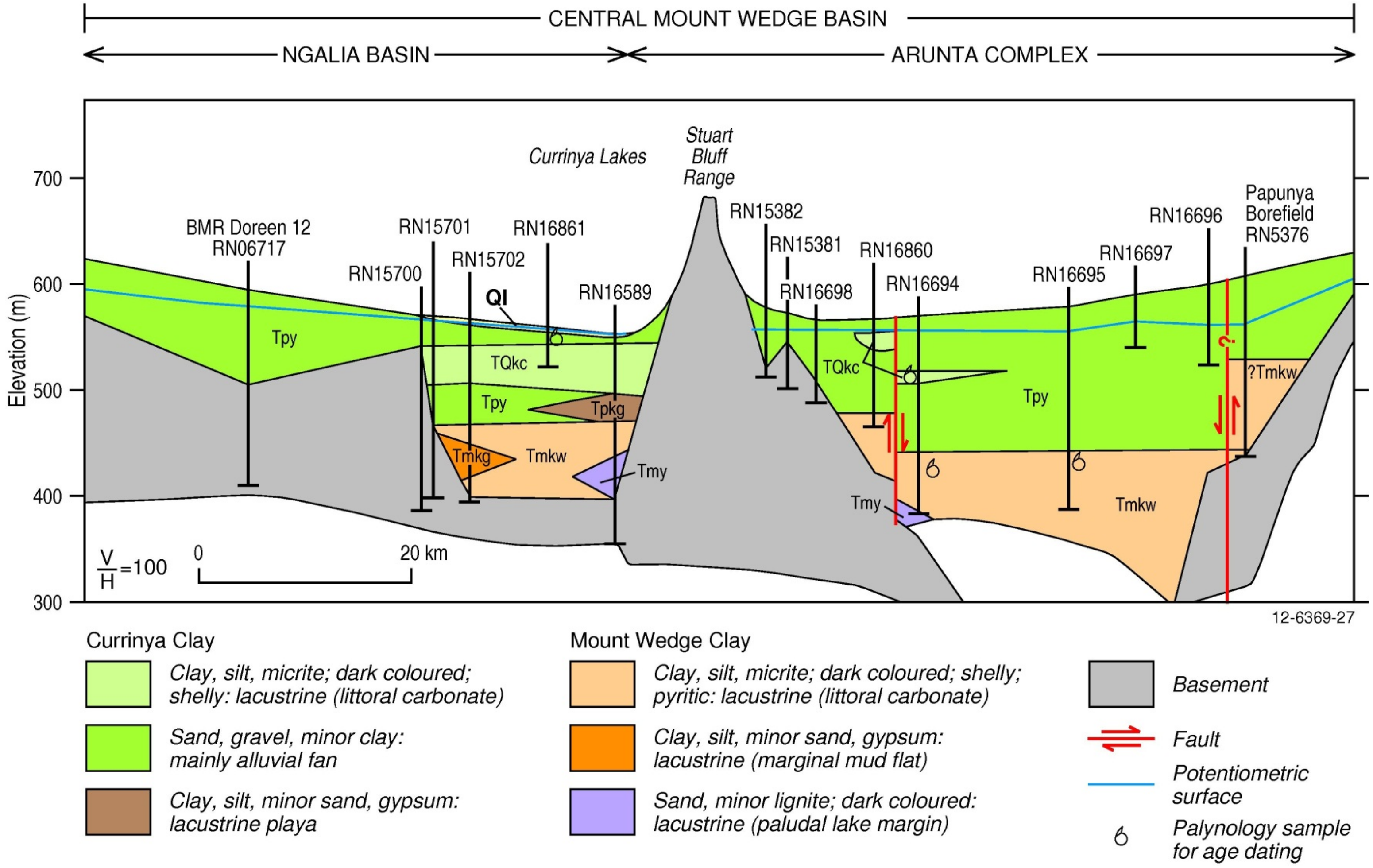

Figure 5.8: *Interpretive cross-section of the Central Mount Wedge Basin based on investigations for the Western Water Study (after Lau et al., 1997). Vertical lines are boreholes.*

5.4 FIELD PROGRAM OBJECTIVES

The Central Mount Wedge Basin was selected for further investigation as part of the *Palaeovalley Groundwater Project* to address critical knowledge gaps relating to the Cenozoic mountain-front basins of central Australia. The focus of the investigation was the stratigraphy and hydrogeology of the poorly known deeper sedimentary sequences (>250–300 m below ground level). Prior to this study there were no bores that penetrated to basement rocks in the central part of the basin.

The 2009 to 2011 field investigation program in the Central Mount Wedge Basin area was designed to:

A. Test the efficacy and usefulness of ground-based geophysical survey methods such as gravity, electromagnetics, and seismic reflection for:

1. Resolving the morphology and nature of the contact between the palaeovalley infill sediments and underlying weathered basement rocks,
2. Defining the stratigraphic profile of palaeovalley infill sediments, and
3. Assessing the groundwater resources of the palaeovalley aquifers.

B. Drill an investigation bore in the inferred deepest part of the basin to intersect the entire stratigraphic infill sequence down to the underlying basement rocks, to:

1. Collect sediment samples containing carbonaceous matter for palynostratigraphic dating (analysis of spores and pollen); and
2. Test and characterise groundwater resources in the deep palaeovalley aquifer, primarily hydrogeochemical compositions but also groundwater gradients and hydraulic parameters.

5.5 FIELD INVESTIGATIONS IN THE CENTRAL MOUNT WEDGE BASIN

5.5.1 Sacred site clearance

A sacred site clearance application to undertake field work along the Papunya to Central Mount Wedge Road was submitted in May 2009 and issued by the Central Land Council in November 2009[11]. The clearance certificate identified several areas along the road where field activities were excluded due to cultural reasons.

5.5.2 Geophysics

5.5.2.1 Gravity survey method

Work undertaken in the Central Mount Wedge study area in 2009 was based along the Papunya to Central Mount Wedge Road. This was the same transect drilled and surveyed for the Western Water Study in the mid-1990s (Figure 5.7).

Ground gravity readings were undertaken by Geoscience Australia using the same LaCoste & Romberg Model G gravity meter that had been used for the Nyirripi and Kintore surveys. Work was completed in two phases (21–22 August and 15–16 September 2009) and resulted in 37 km of gravity data collected at 400 metre station spacing. An additional 6 km of infill gravity data was acquired at 100 m spacing along the southern section of the road. The infill station data were obtained to evaluate the usefulness of closely spaced data to improve definition of the contact between the underlying basement rocks and the basin infill sediments.

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[11] The time it takes to obtain a sacred site clearance demands that planning be undertaken well in advance of field investigations. This proved problematic in the context of the *Palaeovalley Groundwater Project* as the field investigations were planned on a semi-yearly cycle (according to the findings of the previous years work).

The gravity station elevation survey was undertaken by NT government surveyors on 21–23 August 2009. The survey used real-time, dual frequency differential GPS (similar to that used at Nyirripi), with a receiver transmitter base station established at a static location and a roving differential GPS used to record location and elevation data for each gravity station. The estimated elevation accuracy is ~1 cm. The final calculated heights for the survey are expressed as pseudo-Australian Height Datum (AHD), which is similar to actual AHD but derived from the Ausgeoid98 model (Featherstone et al., 2001).

At the conclusion of the gravity and elevation survey the data were processed for standard gravity corrections (e.g., height variations, instrument drift, tidal effects etc.), as outlined previously in this report.

5.5.2.2 Gravity survey results

The results of the gravity survey show an undulating profile with significant gravity trough near the southern end of the transect (Figure 5.9). This relative gravity low is evident in surveys acquired at both 400 m and 100 m spacing, with minor offset in these datasets probably due to slightly different trend-lines used in processing to remove regional gravity effects. The deepest part of the gravity trough (zone of lowest relative density) was identified as a potential drill target to penetrate the entire Cenozoic sediment package and intersect the underlying bedrock. The subsequent acquisition of seismic reflection data improved definition of the drill target.

Comparison of the 100 m-spaced gravity survey data with the 400 m-spaced data indicates that higher resolution surveying recorded micro-variations in the gravity field that were not detected by the wider spaced dataset. However, such anomalies are relatively minor, indicating that the 400 m spacing is adequate for identifying the broad-scale nature of this palaeovalley system.

5.5.2.3 SiroTEM survey method

A SiroTEM time-domain electromagnetic survey was undertaken in June 2010 along the survey transect (between northing coordinates of 7,447,788 and 7,436,615). Early time series readings were taken using 200 x 200 m coincident loops of 2.5 mm wire with 3.5 Amps of transmitter current and an initial delay of 500 microseconds. The data were subsequently processed to show a pseudo-section of subsurface resistivity variations with depth (Figure 5.10). The SiroTEM method was used to investigate the Central Mount Wedge Basin as it proved successful in resolving the palaeovalley morphology in the nearby Wilkinkarra Palaeovalley (at Nyirripi).

5.5.2.4 SiroTEM survey results

The conductivity depth image (CDI) generated from the SiroTEM survey shows a resistive layer to approximately 150 m below the surface at the northern end of the line, below which is a conductive layer (Figure 5.10). This conductive zone is most likely a response to the Mount Wedge Clay, which consists of several hundred metres of clay and sandy clay sediments. The upper surface of the Mount Wedge Clay occurs at between 100–150 m below surface. The lowermost resistive layer (crystalline basement rocks) is masked in some places by zones of higher conductivity, probably caused by saline groundwater and/or clay-rich sediments. In some places along the traverse line there are areas of increased noise which has degraded the signal response. These are attributed to abandoned car bodies left along the roadside.

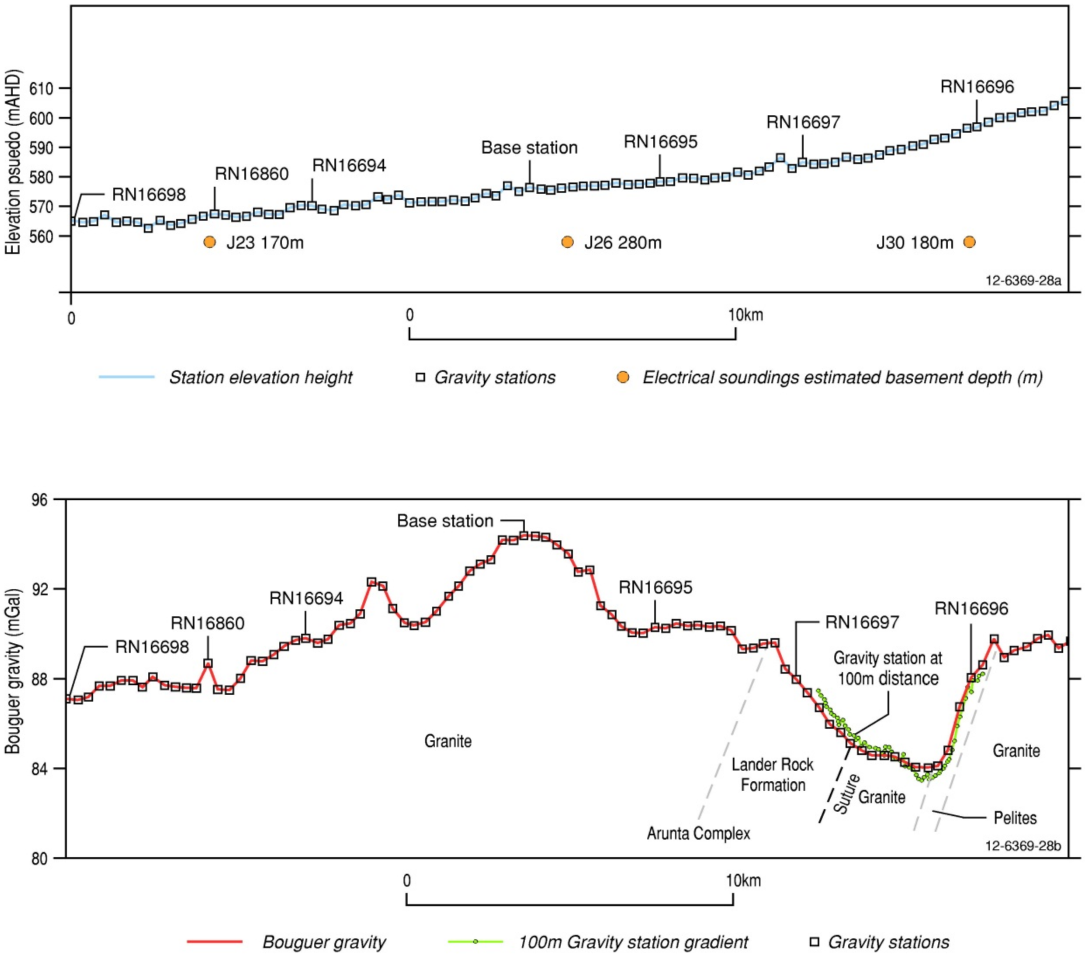

Figure 5.9: *Elevation (upper figure) and gravity profile (lower) data from the Central Mount Wedge Basin. The zone with the Bouguer gravity low is the likely deepest part of the basin infill sequence (near the southern end of the survey). The depth of bores into the Cenozoic sediments (prior to this study) is indicated, along with the location of the previous joint geophysical soundings by Anning et al. (1995).*

Rhoades et al. (1976) demonstrated that the apparent conductivity of material is the weighted sum of the electrical conductivity of liquid and solid phases as per Equation 1:

Equation 1: $$EC_a = EC_w \theta \tau + EC_s$$

Where: EC_a = apparent conductivity (mS/m), EC_w = pore water conductivity, θ is the volumetric water content, τ is the tortuosity and EC_s is the solid phase conductivity.

In the absence of massive sulfide minerals the conductivity response is mainly attributed to the liquid phase, which is in turn attributed to the volumetric water content and electrolytic (predominantly Na and Cl) ion concentrations in the pore water (Tan et al., 2005). Based on this assumption, apparent conductivities for Central Mount Wedge bores were calculated using known water conductivity data and an estimated porosity of 0.25 for comparison with the SiroTEM results (Figure 5.10). The apparent conductivities measured downhole and using the SiroTEM system are well correlated.

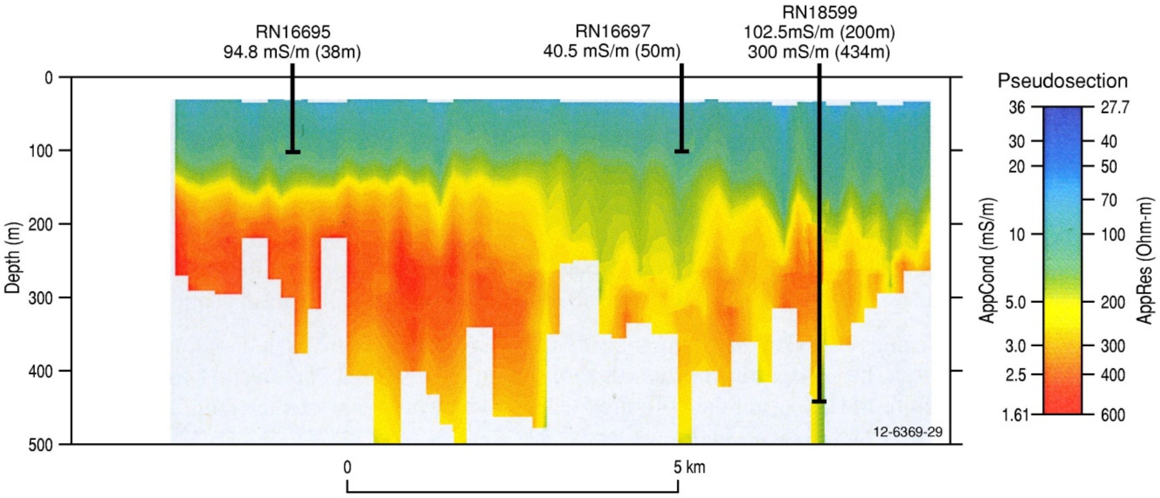

Figure 5.10: *SiroTEM Conductivity–Depth Section for the Central Mount Wedge transect showing bores and apparent conductivity variations.*

5.5.3 Seismic reflection survey

5.5.3.1 Seismic data acquisition

The opportunity arose in September 2010 to undertake high-resolution seismic reflection surveying in part of the Central Mount Wedge Basin[12]. The seismic reflection method has rarely been used in arid zone palaeovalley studies in Australia previously, so the project team grasped the chance to:

- Demonstrate and evaluate the application of the seismic method for exploring and better understanding arid zone palaeovalley systems;
- Determine the location of the deepest sedimentary infill sequence of the Central Mount Wedge palaeovalley to guide future drilling to basement; and
- Improve the understanding of the Cenozoic stratigraphic profile through the Central Mount Wedge Basin, particularly targeting potential basal sand-bearing aquifers, depth and profile of the contact between the basement Proterozoic rocks and the overlying Cenozoic sediments, and the style and depth of other prominent reflectors in the palaeovalley infill sequence.

The acquisition of seismic reflection data commenced on 27 September 2010 and began about 4 km north of Papunya community. The survey traversed northwards along the unsealed Papunya to Central Mount Wedge Road and acquired 11.52 km of seismic reflection data (Figure 5.11). The length of the survey line was restricted by cultural heritage exclusion zones (previously identified at both ends of the survey line on the heritage clearance certificate).

The survey acquisition parameters are shown in Table 5.1. The seismic source was supplied by a mini vibroseis truck which had low environmental impact and provided rapid data acquisition (Figure 5.12). The geophone array for each seismic shot was spaced at 1.3 metre-intervals along the seismic line (Figure 5.13).

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[12] This occurred due to the fortuitous availability in the local area of a seismic reflection survey crew from Terrex Seismic Pty Ltd.

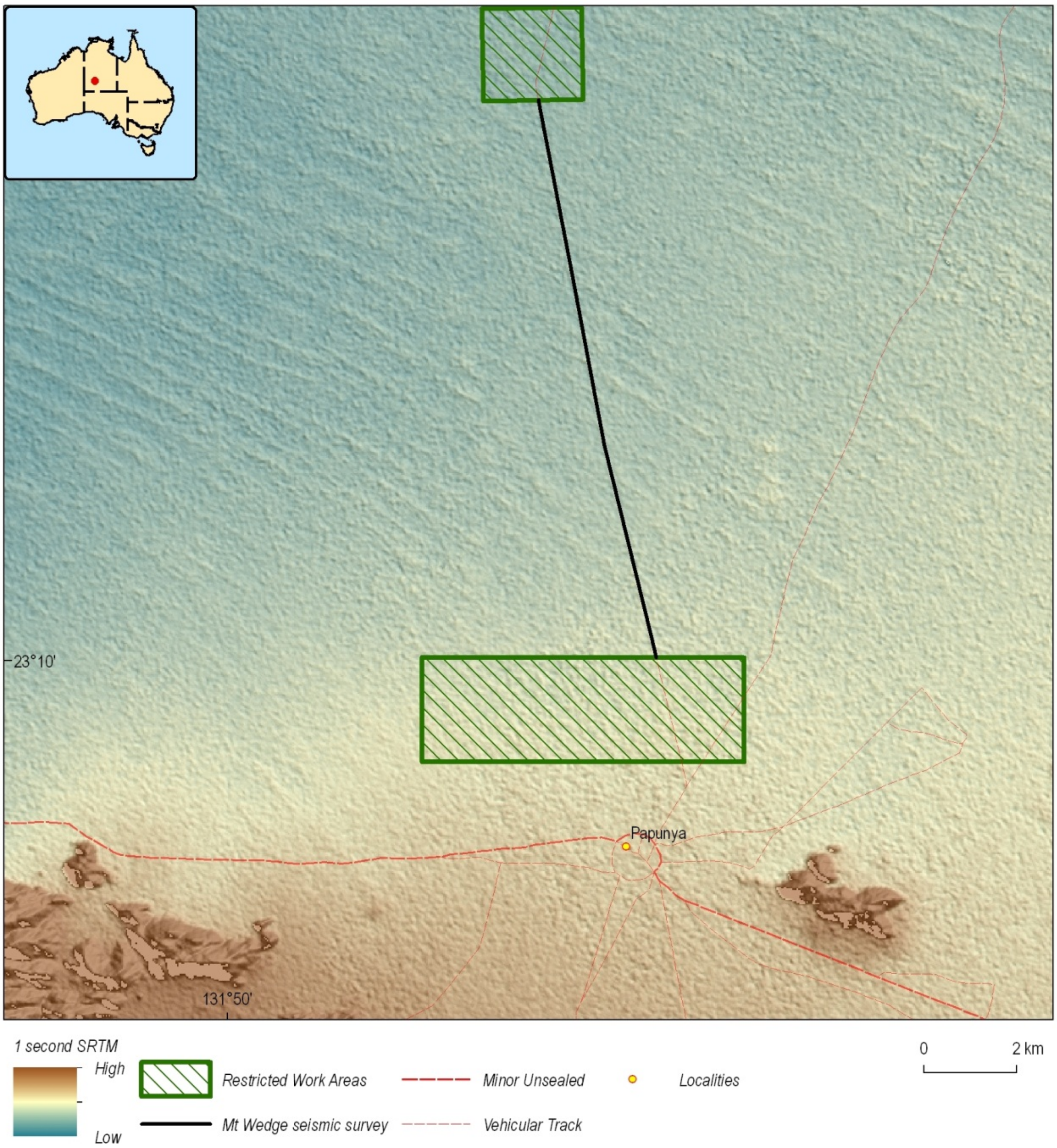

Figure 5.11: *Seismic reflection survey in Central Mount Wedge Basin showing the location of the restricted work areas due to cultural heritage values.*

The data acquisition rate was restricted by the time taken to move geophones and cables along the seismic line, and for this reason efforts were made to obtain as much data as possible with the source and recording parameters extended. The 8 second recording sweeps provided more energy for less time. As the target of interest was expected to be at depth of around 0.5 second (two-way time), a 2 second recording time was considered appropriate to image the dipping features to be migrated. The 8 second recording time was chosen to investigate the maximum time of signal achievable with the seismic source, and to provide an image of any bedrock structures as deeply as possible. These parameters did not slow down the data acquisition rate (different parameters could have been used if required).

5.5.3.2 Seismic reflection processing

The seismic reflection data for the Central Mount Wedge survey were processed by the Seismic Acquisition and Processing Section in the Minerals and Natural Hazards Division of Geoscience Australia. Details of the processing methodology are provided in Appendix 5.

Table 5.1: Seismic acquisition parameters for the Central Mount Wedge survey.

LINE	10GA-PA1
SOURCE TYPE	1 x IVI Minivibe EV; theoretical peak force of 66,000 N, 85 % force used
SOURCE ARRAY	1 x Minivibe centred on half station
SWEEP LENGTH	1 x 8 s
SWEEP FREQUENCY	15-200 Hz
VIBRATION POINT (VP) INTERVAL	8 m
TOTAL VPS	1,441 over 11.52 km
SHOT RECORD SWEEP CORRELATION	The recording system cross-correlated the sweep for each VP with its respective reference sweep and stacked the cross-correlated sweeps, creating a single 8 s record for each VP.
RECEIVER GROUP 6	geophones centred on station at 1.3 m spacing
GROUP INTERVAL	8 m
NUMBER OF RECORDED CHANNELS	160 spread over 1,272 m
MAXIMUM OFFSET	644 m
FOLD (NOMINAL)	80
RECORD LENGTH	8 s
SAMPLING RATE	1 ms
SEISMIC DATA RECORDING	SEG-D demultiplexed format using a Sercel SN428 recording system

5.5.3.3 Conclusions on processed seismic reflection data

The processed seismic reflection image (Figure 5.14) clearly resolves the broad and undulating contact surface between the Proterozoic basement rocks and the Cenozoic infill sediments. It also shows significant basement faulting. Many depth variations at the basement–sediment interface (peaks and troughs) are probably associated with block faulting of the crystalline basement rocks of the Arunta Region.

Strong seismic reflections across the Central Mount Wedge Basin form sub-horizontal layers which are distinct from the basement surface. These responses are typical of sediments formed within a continental fluvial environment. The basement reflectors are predominantly non-horizontal, typical of steeply dipping structural zones in the crystalline basement rocks. Based on correlation with drilling data the upper part of the Mount Wedge Clay is a well defined reflector horizon about 100 to 150 metres below surface.

The ground gravity survey data correspond closely with the observed basement surface variation. However, the discrepancy between the gravity and seismic reflection data suggests that the main structural features (Central Australian Suture) and the likely variation in basement rock types across the survey may significantly affect the gravity response.

__Figure 5.12:__ The IVI Minivibe EV in action.

__Figure 5.13:__ Groups of six geophones with 1.3 metre spacing placed along the seismic line.

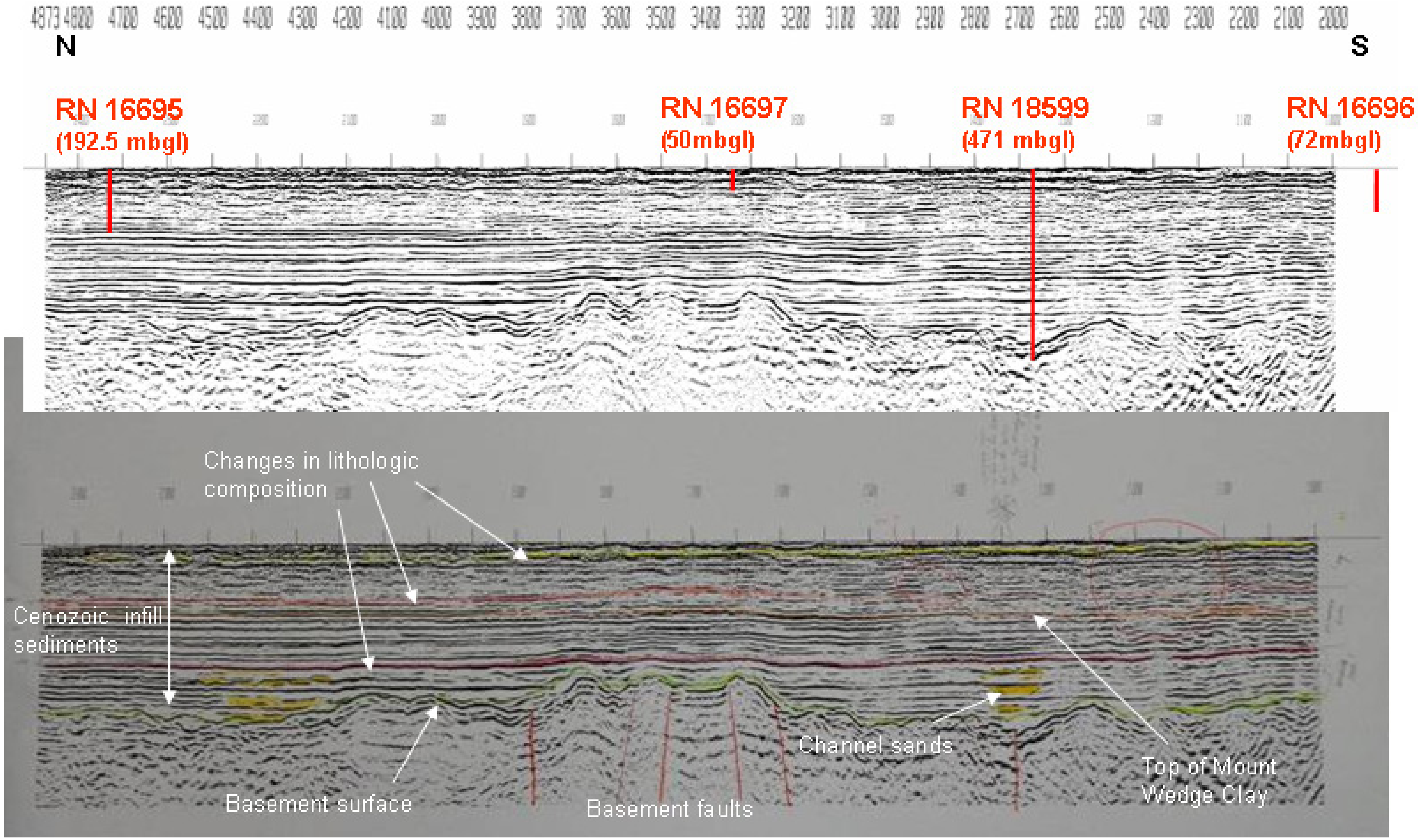

Figure 5.14: *Processed seismic reflection data for the Central Mount Wedge Basin (facies interpretations by John Wischusen).*

5.5.4 Investigation bore drilling

The NT Government Ingersoll Rand drilling rig was used to drill the deep Central Mount Wedge investigation bore (RN18599) in late November 2010. The drilling construction method used was based on the successful approach from the Ti-Tree Basin (Wischusen et al., 2012).

The rotary mud drilling method was used to ensure the bore remained open for the duration of drilling. This approach precluded the acquisition of detailed downhole groundwater data, although it was essential to successfully reach basement. An 8-inch steel collar was installed against the top 6 m of the bore, and drilling proceeded to 200 m depth using bentonite mud. The top 200 m was subsequently cased with 6-inch steel casing. The bore was airlifted at this point to estimate the groundwater yield and collect a groundwater sample.

The mud was then changed to a polymer mud (Pac L and Pac R) and drilling proceeded through the 6-inch steel casing until the basement rocks were intersected at ~474 m. This was determined from the bore cuttings and the change in drilling penetration rate. Lithologic samples were collected at 3 m intervals.

Following completion of the bore a downhole gamma log was run through the drill pipe. Based on data from the gamma log and the drilling samples, a section of coarse sand and gravel was selected (at depth of 438 to 442 metres below surface) to set the bore inlet screens for acquiring groundwater samples from the deep Cenozoic aquifer. The hole was then backfilled to this level, and 4-inch API pipe (4 m lengths of 4 inch stainless steel screens) was telescoped through the 6-inch steel casing in the upper section. A flange was placed above the screen to isolate the targeted aquifer from the annulus. The bore was completed at the surface with a concrete slab and marker pole. Following construction the bore was developed for some time and an airlift sample acquired.

In March 2011 the bore was sampled using a submersible pump and the collected groundwater was subsequently sent for chemical analysis to Northern Territory Environmental Laboratories (NTEL). Samples were also submitted to the GNS laboratory in New Zealand for analysis of stable and radiocarbon isotopes.

5.5.5 Drilling results

The geological log for RN18599, including gamma log and construction details is included in Appendix 6.

5.5.5.1 Basement depth and morphology

The depth to basement along the Central Mount Wedge transect was estimated at around 400 to 500 metres below surface based on the seismic reflection data. Drilling confirmed that fresh basement rocks occur at 474 metres depth, coincident with the deepest trough evident on the seismic data. This also coincides with the interpreted location of the Central Australian Suture Zone, a major east-trending structural feature and faulted zone of preferential weathering and erosion. The depth to basement at the bore site is significantly greater than the estimated depth of the nearby Lake Lewis Basin, ~160 metres below surface (English, 2002).

The uppermost basement surface beneath the Central Mount Wedge Basin is similar to that delineated via a seismic profile for the adjacent Lake Lewis Basin (English, 2002). By contrast, it is markedly different from the relatively well defined and channel-like palaeovalleys further west around Kintore and Nyirripi.

5.5.5.2 Lithology

The Cenozoic infill sediments are dominated by sandy clays with minor gravel beds. Semi-consolidated sandstones occur at shallower depths. The upper 120 m of the infill sequence is coarser grained, oxidised, and more poorly sorted than the underlying sediments (Figure 5.15). The colour and consistency of sediments changes consistently at depths ~120 m to sandy clay with light olive green clay-rich matrix. The sandy fraction ranges from 10–60% of the total sediment material and consists of fine- to medium-grained, angular to subrounded quartz with minor biotite and muscovite (reflecting granitic source). Mottled zones in the middle to lower parts of the sequence suggest former weathering surfaces. Pallid zones in the lower half of the bore indicate kaolinisation of feldspars and thus overprinting of the original sedimentary material by deep chemical weathering (Figure 5.15).

No carbonaceous material was encountered for palynostratigraphic analysis.

Figure 5.15: Sampled sedimentary material (3 metre intervals) from bore RN18599 in the Central Mount Wedge Basin.

The thick pale olive green basal clay is interpreted as the Mount Wedge Clay formation, based on comparison of bore logs from the same transect by Lau et al. (1997).

Cross-sections through the adjacent Lake Lewis Basin (English, 2002) show a widespread basal unit of dominantly unoxidised grey-green clay over the crystalline basement. This unit is, in turn, overlain by a series of reddish sandy clay and sand-rich deposits, commonly >100 m thick. The basal clay unit contains pyrite, is variably mottled and has been strongly overprinted by weathering. It is similar to the Mount Wedge Clay.

5.5.5.3 Interpreted depositional environment

The upper 120 m thick sedimentary sequence in RN18599 is similar to the Lau et al. (1997) upper unit (Currinya Clay, Tpy) interpreted to have formed in an alluvial fan setting. Given the paucity of coarse-grained sediments typical of most alluvial fan deposits (e.g., debris flow type) the sequence intersected in RN18599 probably represents a distal alluvial fan facies dominated by sheetwash or alluvial plain sediments. These alluvial fan sediments are thus distal from their source (mountain range) and were transported by a major river system (parallel to the axis of the range) to the central part of the basin, where deposition probably occurred within a series of small ephemeral lakes. This scenario accounts for the presence of littoral carbonate ±swamp and wetland deposits of the lower

Mount Wedge Clay Unit (Tmky). Lake-level changes and the resulting shifting shorelines would have resulted in the accumulation of coarser grained material intercalated between lake muds (Carmen Krapf, pers comm. 2010).

The accommodation space which caused the formation of the Central Mount Wedge Basin was tectonically induced by fault displacement at the basin margins. The extensive thickness of Cenozoic sediments deposited in the deepest part of the basin (approximately 474 m) indicates that significant accommodation space was created during tectonism. A revised cross-section for the Central Mount Wedge Basin based on the new investigation program, and updated from the work of Lau et al. (1997), is shown in Figure 5.16.

5.5.6 Hydrogeology

At the completion of bore RN18599 the standing water level was measured as 30.2 metres below ground level (mbgl), representing the hydraulic head of the aquifer at around 440 mbgl. Nearby bore RN16696 recorded a standing water level (measured in November 2010) of 38.5 mbgl, representing the head at 65 mbgl. A density correction (Equation 2, after Lusczynski, 1961) was applied to the head measurement from RN18599 because of the increased groundwater salinity. This resulted in an equivalent freshwater head of 30.708 mbgl. Thus, there is upward head gradient down the profile, indicating that the deeper aquifer is confined.

Equation 2:

$$H_f = (\rho_s / \rho_f)\, H_p$$

Where: H_p = point water pressure head, H_f = equivalent freshwater head, ρ_s = density saline water, and ρ_f = density fresh water.

5.5.7 Hydrogeochemistry

During drilling of bore RN18599 groundwater was sampled from ~200 m depth (after the initial bore segment was cased). The field-measured electrical conductivity (EC) of this sample, representative of the shallow aquifer system, was 1,415 µS/cm. In comparison, groundwater airlifted from the deeper aquifer after the bore was completed and developed (with a yield of ~12 L/s) was saline (EC of 12,380 µS/cm). The increase in salinity downhole suggests that there is negligible connection between the upper (fresh to brackish) aquifer and the deeper (saline aquifer).

Additional to the groundwater collected for analysis from RN18599, a sample was also collected from an existing bore approximately 20 km north (RN16694). This bore is screened in the shallow aquifer of the Central Mount Wedge Basin. Summary compositional data are presented in Table 5.3, and comprehensive laboratory data are in Appendix 7. Compositional differences in groundwater from the Central Mount Wedge Basin are shown in the Piper diagram (Figure 5.17).

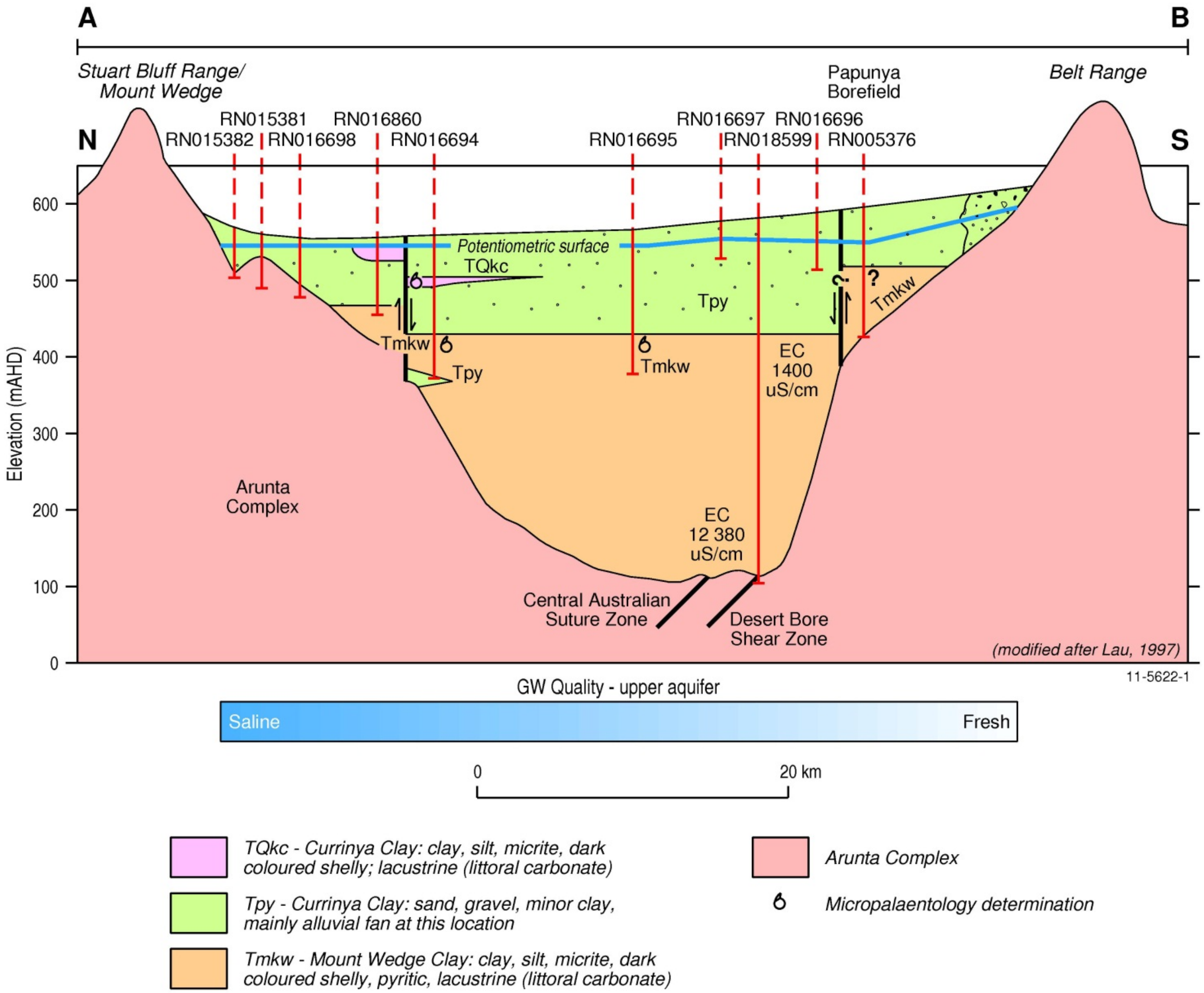

Figure 5.16: *Interpretive cross-section for the Central Mount Wedge Basin.*

Table 5.3: Summary groundwater chemistry data for bores in the Central Mount Wedge Basin.

BORE	pH	EC	TDS	Cl	HCO_3	NO_3	Na	I	U	Mn	Pb
	units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L
RN18599 (deep)	8.2	8,800	6,260	2,640	216	12.1	1,080	150	27.4	585	18
RN16694 (shallow)	8.5	2,520	1,530	497	262	24.5	349	260	9.17	<5	<1
Drinking water guidelines*						50		100	20	500	10

**Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004*

The laboratory data were used to calculate the chloride/bromide ratio to help interpret the source of the deep groundwater. These anions normally behave conservatively, but can be affected by dissolution or precipitation of halite, anion absorption and exchange or biological activity in the subsurface root zone. The Cl^-/Br^- ratio for groundwater from the deep aquifer is 1,078, whereas the ratio for the shallow aquifer at RN16694 is 362. The mass ratios for groundwater from the Central Mount Wedge Basin mostly indicate that these waters have been affected by dissolution of halite (Davis et al. 1998).

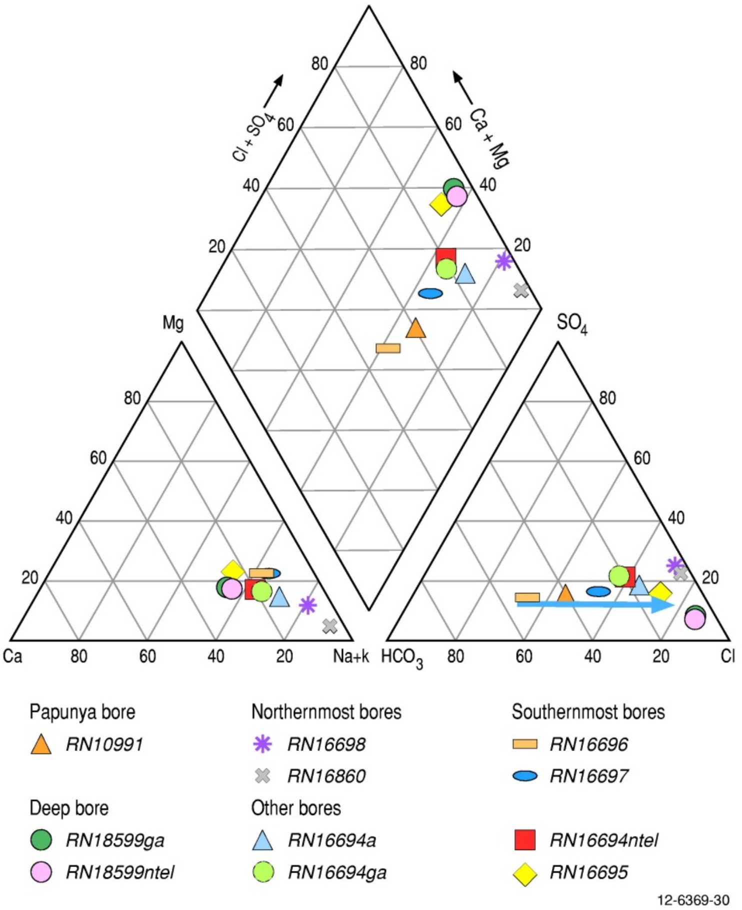

***Figure 5.17:** Piper diagram of groundwater chemistry for the Central Mount Wedge Basin.*

The composition of groundwater from the deep aquifer is broadly similar to that of the shallow aquifer, particularly the high chloride and sodium levels (consistent with halite dissolution). However, the deep groundwater system has some distinct variations, such as higher calcium concentrations and elevated levels of some metals (Table 5.3). This may be explained by input of groundwater derived from the underlying fractured rock aquifer in the meta-volcanic basement formation, implying that the deeper aquifer system in the Central Mount Wedge Basin is hydraulically connected with the basement rock aquifer. However, the extent and flux of this connection is presently unknown.

5.5.8 Stable isotopes

The isotopic (deuterium and oxygen-18) composition of groundwater relative to rainfall provides a method of estimating recharge mechanisms. The stable isotope data for groundwater from the deep bore (RN18599) and one of the shallow bores (RN16694) indicates that the groundwater from the deep Central Mount Wedge Basin is relatively enriched in the heavier isotope $\delta^{18}O$ when compared to the local meteoric water line (LMWL) for Alice Springs (which is the nearest LMWL available). These data imply that significant evaporation has affected groundwater in both aquifers during recharge, indicating that recharge likely occurs by a diffuse mechanism, with evaporative losses occurring from soil water.

5.5.9 Carbon-14

Groundwater collected from bore RN18599 following well completion and development was submitted for radiocarbon analysis at the Rafter Radiocarbon Laboratory in New Zealand. The analysis yielded a percent modern carbon (pMC) value of 2.86 ±0.06. The Stuiver and Polach method (1977) was used to estimate an uncorrected radiocarbon age of 28,490 ±160 years BP (before present). In contrast, the pMC value for groundwater from bore RN16694 (20 km to the north and screened in the shallow basin aquifer) is 9, which equates to an uncorrected radiocarbon age of ~20,000 years BP. This comparison indicates that groundwater in the shallower aquifer is relatively younger than groundwater in the deeper aquifer. In contrast to these ‘older’ groundwater systems, the pMC value of groundwater from a bore closer to the mountain front recharge zone at Papunya (RN5754) was previously measured at 80 (with a residence time of ~1,750 years BP). This indicates that groundwater tapped by this bore is younger and closer to the main recharge zone.

5.6 INTERPRETATION AND KEY FINDINGS

The deepest bore drilled in the Central Mount Wedge Basin to date has revealed that the sedimentary infill sequence has a maximum thickness of approximately 474 m. This makes it one of the deepest Cenozoic basins known from the central Australian region. The basin is broad and has an irregular and weathered basement palaeotopographic surface, which rises steeply to the north abutting the granite slopes of the Stuart Bluff Range and to the south against the quartzite-rich slopes of the Belt Range.

The basin is infilled with laterally extensive layers of fluvio-lacustrine sediments, mainly sandy clay and clay. Two stratigraphic formations occur within the basin:

- An uppermost coarser-grained formation known as the Currinya Clay (Tpy). This oxidised and heterogeneous unit, with a maximum thickness of ~120 metres, was probably deposited in a distal alluvial fan setting (sheetwash deposits) or upon an alluvial plain.
- Underlying the upper unit is a thicker sequence (~350 metres thick) of light olive green to grey sandy clay, known as the Mount Wedge Clay (Tmkw). Relatively thin beds of sandy gravel occur close to the base of this clay-rich unit but porosity is relatively poor because of extensive secondary clay minerals (e.g., alteration products of feldspar) in the gravel matrix. The proportion of fine-grained quartz sand varies with depth, implying that coarser grained sediments were intercalated with lake-bed muds as levels in the lake changed (i.e., rose and fell over-time) and shorelines shifted. The basal clay-rich formation is very similar to, and contiguous with, the Mount Wedge Clay sequences known at depth in the adjacent Lake Lewis Basin.

A detailed facies analysis was not possible during this preliminary investigation because of the strong weathering overprint and lack of carbonaceous horizons. The highly weathered nature of the Cenozoic sedimentary infill is a common feature of other palaeovalleys in central Australia.

Groundwater is abundant in the Central Mount Wedge Basin with the water table at around 30 mbgl, although the quality varies considerably. Groundwater in the deeper aquifer is more saline than the overlying shallower aquifer, with halite dissolution likely to be an important process causing increased salinity. Radiocarbon data indicates that the oldest water in the basin occurs at considerable depth. This is presumably due to the long timeframe required for recharge to infiltrate to the deeper aquifer system, as it is significantly retarded by the thick clay-rich sequences in the lower half of the basin sequence.

Groundwater flows from south to north in the basin, recharging via the porous montane fans and creeks draining from the Belt Range. The eventual discharge points are salt playas north-west of Central Mount Wedge. Accordingly, the salinity of the shallow sedimentary aquifer increases significantly northwards.

5.6.1 Comparison of methods

A range of exploration methods were evaluated across the Central Mount Wedge Basin between Papunya and the Stuart Bluff Range. Geophysical techniques included vertical electrical soundings (VES), time-domain electromagnetic soundings (TEM), microgravity surveying and seismic reflection surveying. A number of shallow bores (up to 192 mbgl) were previously drilled in a south to north transect across the basin (for the Western Water Study).

During the new fieldwork program for this present study the first deep investigation bore in the Central Mount Wedge Basin intersected the Proterozoic basement rocks at 474 mbgl. Downhole gamma and inductive conductivity logging were also acquired. The relative merits and cost effectiveness of these techniques (and a host of others) are outlined in the Palaeovalley Methodology Toolbox Report (Gow et al., 2012).

Of the various surface geophysical techniques, the seismic reflection survey provided the useful and detailed information on the underlying basement morphology. It also helped to understand the major facies variations across the basin, most notably the change from the upper oxidised alluvial sequence to the underlying Mount Wedge Clay. The seismic reflection data provided useful information on the laterally extensive sedimentary layering typical of lacustrine environments. In some places, the typical horizontal layering is disrupted by distinct channel-like features (possibly sand-rich), and there are also possible evaporite sequences in the profile, such as gypsum- and halite-bearing zones. Although drilling confirmed the presence of 3–4 m thick sandy layers at depth, the scale of these features is inconsistent with the resolution of the seismic data. Further investigation, possibly using core drilling, could provide greater information about such features.

Despite the undoubted effectiveness of seismic reflection surveying in characterising palaeovalley infill stratigraphy and the depth and shape of the underlying basement rocks, it is rarely used in groundwater investigations because of its relative expense.

Gravity surveying is significantly cheaper and easier to initiate and implement compared to seismic reflection. The gravity survey over the Central Mount Wedge Basin showed that it is a reasonably useful tool for identifying the deeper parts of the basin infill sequence, although it does not afford the same high-degree of resolution as seismic. However, gravity is certainly a relatively inexpensive and reliable reconnaissance tool to apply during initial delineation of palaeovalley systems.

The TEM method was not successful in delineating the basement depth or profile at the Central Mount Wedge site. However, the TEM survey did assist in resolving the shape of the uppermost resistive layer (alluvium containing fresher water), as well as the lower part of the thick conductive clay sequence. Saline groundwater occurring in the deeper part of the basin may have hampered the effectiveness of the TEM signal in penetrating to the deeper parts of the basin and the underlying basement rocks. From experience of the technique in the Wilkinkarra region, TEM surveying is more suited to shallower palaeovalley systems further west near Lake Mackay. It is not useful for delineating high salinity groundwater at depth.

The VES method, used by Anning (1996), underestimated the depth to basement in the current survey area.

Downhole gamma logging is useful for assisting in sedimentary facies analysis, especially when used in conjunction with rotary drilling techniques.

5.7 CONCLUSIONS

The results of field investigations at Central Mount Wedge in 2010 enabled refinement of the Lau et al. (1997) conceptual model, particularly in relation to the depth and morphology of the basement, and groundwater quality. The Central Mount Wedge Basin is around 474 m deep, making it one of the deepest known Cenozoic basins in central Australia. The investigation borehole has been constructed as a monitoring bore and further groundwater sampling for isotope analysis may occur in the future.

In terms of palaeovalley types, the Lake Mackay to Lake Lewis palaeodrainage system (Woodcock et al., 1997) is a broader feature than many of the West and South Australian palaeodrainage systems, mainly because tectonic activity has played a more significant role (compared to fluvial incision) in its evolution and development.

The seismic reflection survey method proved to be highly successful at this location, providing unambiguous imagery of the basement morphology and accurate prediction of depth to basement. It also provided detailed resolution of major facies variations in the basin sedimentary infill sequence. Some of the finer-scale features observed in the seismic reflection data are likely depositional features (although further analysis of these would require core drilling to resolve).

The inferred depositional environment of the Central Mount Wedge Basin has implications for the exploration methodology for groundwater in palaeovalleys. The methods that worked effectively for shallower palaeovalley systems in the Kintore and Nyirripi regions (such as TEM) did not work as well in the deeper Cenozoic basin at Central Mount Wedge. Consequently, the experience gained from the reconnaissance-level studies for this project can be used to help guide the most effective application of different survey methods, depending on the type of palaeovalley system to be assessed.

6. Conceptual models of central Australian palaeovalleys

6.1 REGIONAL CONTEXT

The palaeovalleys investigated in the Wilkinkarra region fall broadly into two main categories:

- Deep Cenozoic basins formed by epeirogenic tectonic activity; and
- Shallow broad palaeovalleys created mainly by fluvial erosion.

6.1.1 Deep Cenozoic basins

The deep Cenozoic basins of central Australia include the Central Mount Wedge, Lake Lewis, Burt, Ti-Tree and Hale Basins (Figure 5.1). These occur in a basin-and-range tectonic setting characterised by distinct contrasts in topographic relief with easterly-striking ridges and broad, flat valleys. Subsidence north of the major regional fault system (the Central Australian Suture zone) probably initiated development of these Cenozoic basins. Significant accommodation space was created and large lake systems formed in the topographically depressed areas near the active fault zone, resulting in deposition of extensive fluvial and lacustrine sediments. In places, these Cenozoic basins accumulated sediments nearly 500 m thick, e.g., in the Central Mount Wedge Basin.

As the basins subsided and were gradually infilled the overall thickness of the sediment packages increased near to the adjacent mountain ranges (the sediment source area), and the main depocentre shifted northwards. This led to accumulation of alluvial fan and fluvial plain sediments above the lacustrine sequences. Increasing aridity in the Late Pliocene and Quaternary has resulted in the near demise of surface water as a primary agent in the evolution of the landscape. However, groundwater processes have become increasingly important in shaping the geomorphology of the basins, such as in the development of extensive playas. Strong weathering and oxidation during this time has also overprinted the infill sediments and destroyed much of the primary sedimentary fabric and structure, rendering facies analysis very difficult.

The basin-and-range model is not unique to central Australia, and was initially described from the Cenozoic basins of Arizona (Figure 6.1). The Arizona model shows similar features to the central Australian basins, although the local systems have flatter basinal shapes and steeper bounding ranges compared to those from the continental USA.

The Cenozoic basins now host abundant groundwater resources which vary in quality from fresh to hypersaline. Freshwater is found near to the recharge zones in the porous sediments of the mountain-front system. In these areas the watertable is 30 to 40 metres below the surface. Thick lacustrine clays in the lower part of the infill sequence retard or confine groundwater flow, resulting in distinct salinity variations at different depths. Saline groundwater typically occurs in the deeper parts of the basin, whereas potable water may occur in the shallower aquifer.

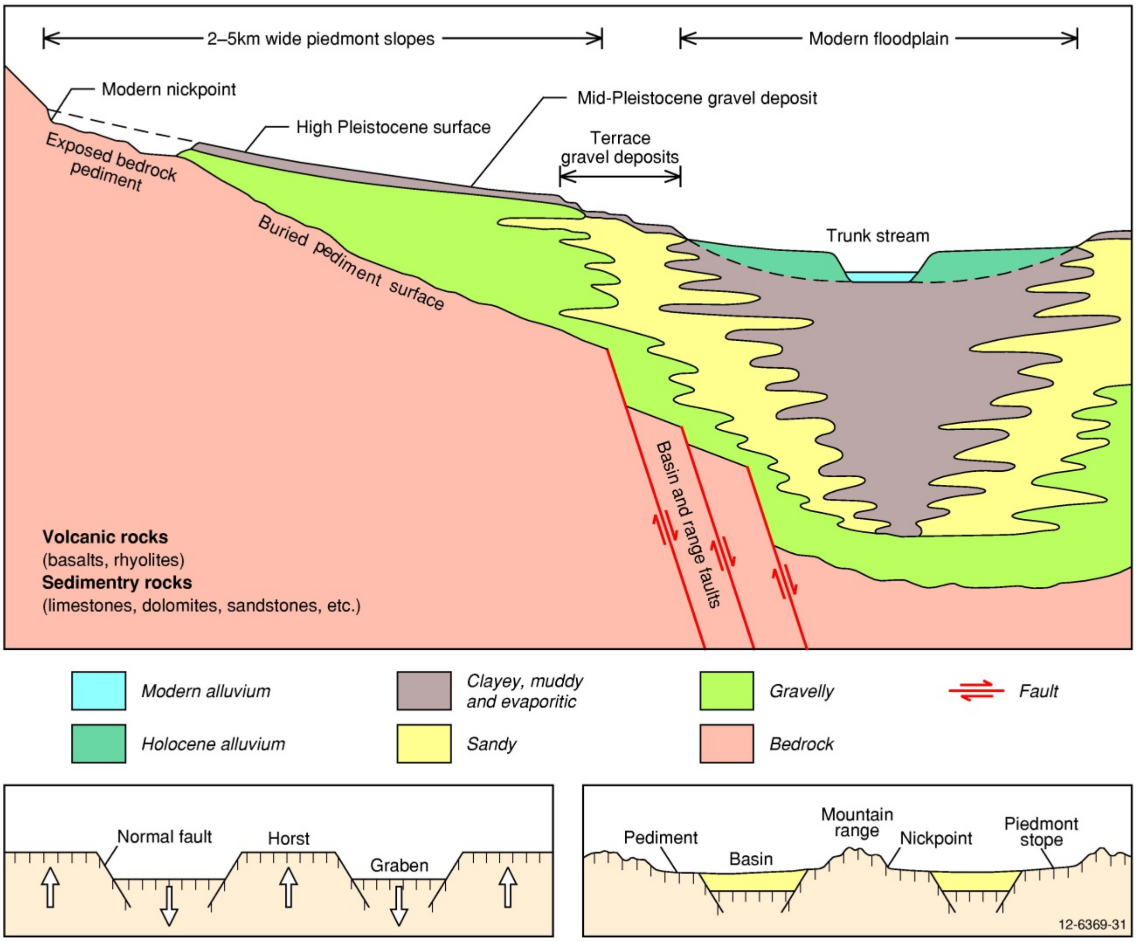

***Figure 6.1:** Cross-section of a typical basin and range province valley. Inset: schematic diagram depicting the role of block faulting in development of basin-and-range structural features (main figure modified after Scarborough and Pierce, 1978; inset modified after Rahn, 1966).*

6.1.2 Shallow broad palaeovalleys

The major structural zone (the Central Australian Suture) that formed the deep Cenozoic basins of central Australia extends to the NT–WA border. However, the extensive mountain-front uplift and subsidence in the area from Papunya to Alice Springs did not occur locally around Kintore. Consequently, neotectonism has had a less significant role in palaeovalley development in the region of Nyrripi, Kintore and Lake Mackay.

The local palaeovalleys in this region were initially incised into the basement rock units of the Arunta Complex by ancient rivers which most likely developed during the Late Mesozoic. The inset valleys set in the broader pre-Cenozoic primary valleys were probably incised due to sporadic periods of epeirogenic uplift in the Palaeocene and Eocene, which initiated incision of the smaller inset valley systems. However, rather than deep mountain-front basins, the palaeovalleys in the Kintore and Nyirripi area are much shallower (maximum sediment thickness of 130 m, with an average thickness of 55 m). They also formed relatively broad valley features, e.g., at least 20 km wide in the case of the Wilkinkarra Palaeovalley.

The sediments infilling the shallow palaeovalleys near the NT–WA border region are dominantly sand-rich with subordinate amounts of interbedded clays. Extensive outcrops of calcrete have developed during more recent times in the shallow sediment infill sequences. Similar to the deep

Cenozoic basins, the infill sediments have been strongly overprinted by weathering which obscures the original fabric and nature of the sediments.

The shallow incised palaeovalleys in the western part of the Wilkinkarra demonstration area differ from the deeper basin systems in many significant ways, particularly:

- Calcrete is more common and extensive in the shallower incised systems, due to thinner sediment sequences and the proximity of groundwater to the evaporative zone[13].
- The sediment infill of the 'western' palaeovalleys is generally more sand-rich and coarser than the basin systems, which contain a greater amount of alluvial fan material. Swamp or lacustrine deposits are much less common, and where they occur, are generally laterally discontinuous.
- Groundwater yields in the shallow palaeovalleys are higher than in the deeper basins (based on the results of drilling RN18599) reflecting the greater overall abundance of coarse-grained and hydraulically conductive sediments.
- The groundwater quality of the shallow palaeovalleys is similar to that of the deep basins, ranging from fresh to saline and with elevated nitrate levels common.

This study has demonstrated that both the Wilkinkarra and Kintore Palaeovalleys receive modern recharge to their groundwater systems. This is despite slightly different geological settings, with the Wilkinkarra Palaeovalley set in a mostly flat landscape, and the Kintore Palaeovalley adjacent to the Kintore Range, in a mountain-front setting.

The discovery of potable groundwater at Kintore is not surprising given the mountain front geological setting. This groundwater is hydrogeochemically akin to groundwater from other mountain-front settings in the region, most notably from Papunya and Mount Liebig (Wischusen, 1998). However, the discovery of potable groundwater in the Wilkinkarra Palaeovalley, distant from outcropping bedrock zones of recharge, shows that fresh water is not solely confined to mountain-front settings in the modern desert environment. In this case modern recharge may be fed into the main trunk of the Wilkinkarra Palaeovalley via the Mount Russell tributary system. Fresher groundwater has also been noted within palaeotributaries in the Yilgarn region of Western Australia, suggesting that connected palaeodrainage networks are capable of transmitting fresher groundwater a significant distance away from primary recharge zones.

6.1.2.1 Stratigraphic correlation

Stratigraphic correlations were tenuously made between sediments in the Kintore Palaeovalley and those of the Central Mount Wedge Basin. The major formations of the Central Mount Wedge Basin could in turn be considered equivalents of the Hale and Waite Formations found in palaeovalleys in the eastern Arunta Region (Figure 6.2).

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[13] Minor amounts of calcrete occur in the deeper basinal systems but it is much less common.

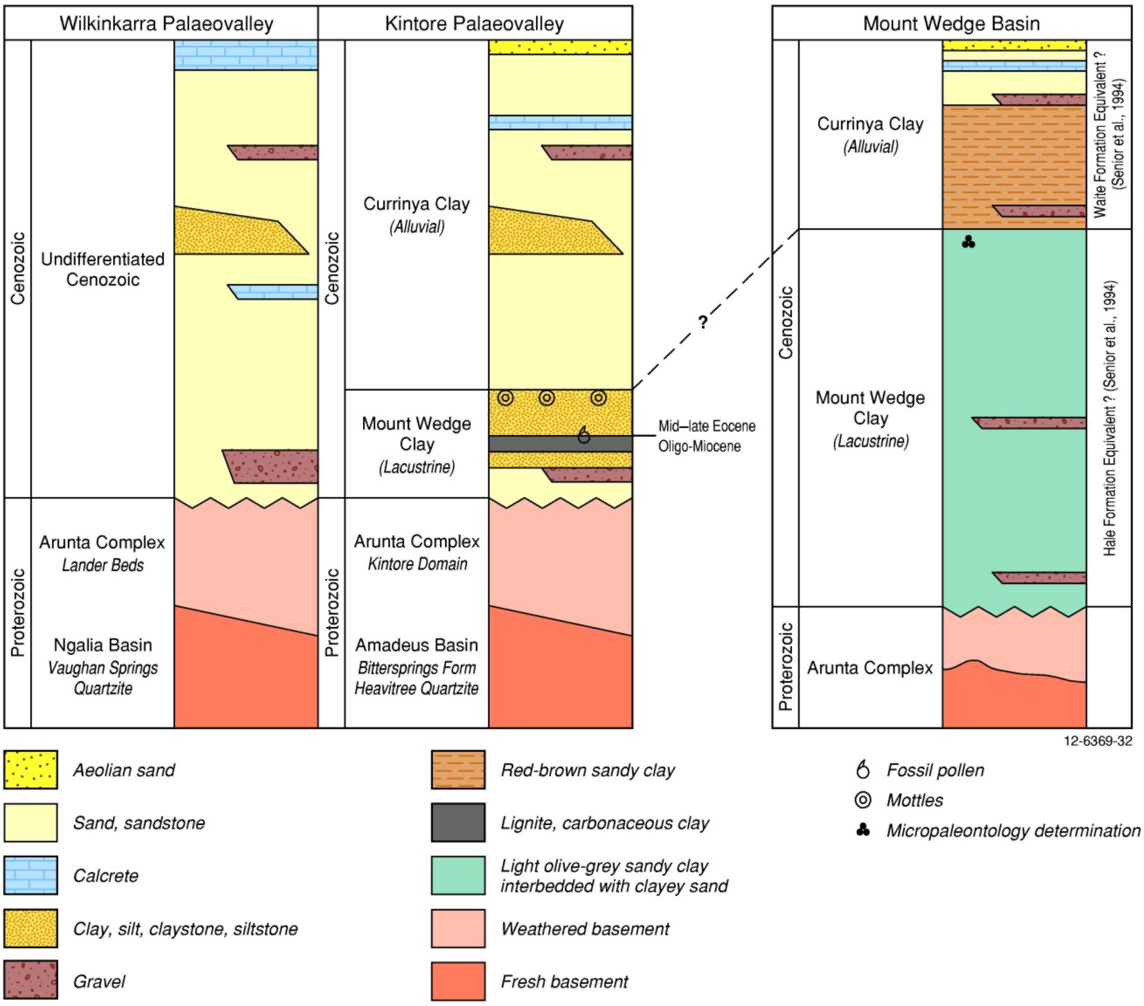

Figure 6.2: Stratigraphic correlation chart for central Australian palaeovalleys assessed for the Palaeovalley Groundwater Project.

6.2 NATIONAL CONTEXT

Palaeovalley networks are widely preserved over much of arid Australia, due to the continent's long-term tectonic stability, generally low relief and geologically slow rates of erosion. Although perennial surface fluvial processes have long since ceased, palaeovalleys remain active in the contemporary landscape as dynamic groundwater systems. Past and present work on Australian palaeovalleys has shown significant local- to regional-scale variability in their scale, morphology, sedimentology, and their relative position in the contemporary landscape. This has significant implications for hydrogeology and groundwater exploration as palaeovalley depth, storage volume, and water quality are all influenced by these variables. This section provides a brief comparison between the palaeovalley systems in the Wilkinkarra demonstration area and those in other regions of arid Australia.

In terms of scale and morphology, the Kintore and Wilkinkarra Palaeovalleys are broadly similar to the palaeovalleys of the Gawler–Eucla region (SA) (Hou et al., 2001; Hou, 2004), slightly shallower overall than the Murchison (WA) palaeovalleys (English et al., 2012b), and much deeper than palaeovalleys in the Yilgarn region of WA (Commander et al., 1992). The Wilkinkarra Palaeovalley, with multiple 'inset' channels, is similar in structure to the Murchison River Palaeovalley near Beringarra homestead (English et al., 2012b). The Central Mount Wedge and Ti-Tree Basin palaeovalleys are of much larger scale, and differ significantly overall to the incised palaeovalleys of the Wilkinkarra region (Wischusen et al., 2012). These deeper basins (tectonically influenced in their development) are unique to the central Australian region of the Northern Territory.

The sedimentology of palaeovalleys is similarly variable across the continent. Eocene basal sand and gravel units confined by thick clay sequences are a common feature in the Yilgarn as well as the Gawler, and have also been found in the Ti-Tree Basin (Magee, 2009). The Murchison palaeovalleys are dominated by sands throughout, with subordinate clay (English et al., 2012b).

Investigations in the Wilkinkarra and Kintore Palaeovalleys indicated that although basal sands and gravels appear in some of the inset channels, they are not widespread. Thick sequences of Oligo-Miocene clay- and silt-rich sedimentary units (potential aquitards) are also uncommon. Rather, the sedimentology of these systems is heterogenous, with predominantly fining-upward sequences and laterally discontinuous and interbedded units sporadically developed throughout the infill successions.

Palaeovalley groundwater quality also varies considerably across Australia’s arid and semi-arid zones. Water quality is generally brackish to saline, and fresher palaeovalley groundwater resources, at least on the continental scale, are the exception rather than the rule. However, relatively fresh to slightly brackish groundwater occurs in the upper-reaches of some Yilgarn palaeovalleys (P. Commander, 2010, pers. comm.), mountain-front palaeovalleys near Kintore, and are interpreted to occur in palaeotributaries of the Wilkinkarra Palaeovalley. Abundant fresh water resources are also present in the upper aquifers of the Central Mount Wedge Basin and the Ti-Tree Basin in central Australia. In the palaeovalleys of the Murchison region in WA, shallow calcrete aquifers contain fresh water resources (English et al., 2012b). However, in the shallow palaeovalley systems of central Australia groundwater in the shallow calcrete zones is slightly more saline than groundwater in the underlying alluvial aquifers, presumably due to enhanced evaporative concentration of salts in near-surface aquifers.

In common with palaeovalleys in other regions, palaeovalleys in the Wilkinkarra demonstration site have a higher storage capacity and transmissivity than the surrounding weathered and fractured basement rocks of the Arunta Region. An exception to this generalisation is where the Wilkinkarra Palaeovalley overlies friable Neoproterozoic sedimentary rocks of the Ngalia Basin, which have similar porosity to the overlying Cenozoic alluvium.

7. Conclusions

Investigations for the *Palaeovalley Groundwater Project* in the Wilkinkarra region between 2009 and 2011 have successfully defined two major palaeovalley systems (Wilkinkarra and Kintore Palaeovalleys) and the larger and deeper Central Mount Wedge Basin. This work has addressed major hydrogeological questions relating to these systems and significantly advanced our understanding of local groundwater resources and processes, particularly in the previously unknown areas around Kintore and Lake Mackay. However, the localised field investigation approach across the extensive landscape, combined with the regional remoteness and inaccessibility, has meant that the project investigations have raised many more questions than have been answered. Nonetheless, a valuable contribution to the body of work on palaeovalleys in central Australia has been achieved from this demonstration study.

The work program has shown that ground geophysical methods are a useful tool for the exploration and delineation of palaeovalleys. The success of geophysical methods relies on distinct contrasts in parameters such as density, porosity and conductivity between the basement rocks and the overlying palaeovalley infill sediments. The more rapid and lower cost methods used were ground gravity and electromagnetic surveying, with the latter proving more useful in shallow palaeovalley environments than in deeper basins. The more expensive (but also more effective) method was seismic reflection.

Due to the extensive and inaccessible nature of the palaeovalley systems in the Wilkinkarra region, the field investigations were restricted to localised areas. Consequently, the easiest areas to access have now been drilled, and any further exploration of the area would be considerably more difficult because of restricted access. It would be useful to further develop a regional and spatially based approach to provide rapid, effective mapping of the palaeovalleys on a broader scale. Given the geologic composition of the region, an airborne electromagnetic (AEM) survey would likely be the best method to map these regional palaeovalley systems. This approach would resolve many of the outstanding questions raised by this study and provide the regional mapping approach required for this vast landscape.

Finally, the installation of a hand-pump at Winner’s Bore is a lasting and durable legacy of the *Palaeovalley Groundwater Project* in this remote part of central Australia. Although the discovery of fresh groundwater in this part of the country is of potential future benefit to the local people (e.g., providing water resources to support future horticulture development) the immediate and tangible outcome of an operating hand-pump on the Kintore to Nyirripi road is a significant benefit from this National Water Commission project.

8. Acknowledgements

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9. Glossary

ADWG: Australian Drinking Water Guidelines, developed by the National Health and Medical Research Council (NHMRC) and the Natural Resource Management Ministerial Council (NRMMC) to provide an authoritative reference to the Australian community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured.

Aeolian: Pertains to wind; especially said of dune sand and finer sediments such as dust transported (blown) and laid down by the wind.

Aeromagnetic: Applying to airborne surveys that measure the total magnetic intensity of rock below a flown grid, interpreted in terms of changes in the properties of rocks and magnetic patterns.

Airborne Electromagnetic (AEM) survey: A geophysical survey method that maps the subsurface conductivity structure of the survey area using a loop mounted on a fixed-wing aircraft or carried beneath a helicopter. Many such systems exist with different performances, allowing the survey to be tailored to the needs of the end users. The method is sometimes referred to as airborne EM.

Alluvial/alluvium: Sediments deposited by the action of rivers in low-lying areas and flood plains.

Anastomosing: Refers to an interlacing network of branching and reuniting channels.

Aquifer: A geological horizon that holds and conducts water, the water is contained within the porosity of the aquifer. Aquifers may be unconfined, meaning they are open to the atmosphere, or confined, meaning they are capped by a relatively impermeable unit, or aquitard.

Aquiclude: A rock or sediment whose very low hydraulic conductivity makes it almost impermeable to groundwater flow (even though it may be saturated with groundwater). It limits an aquifer, and may form confining strata.

Aquitard: A relatively impermeable geological layer that caps a confined aquifer. Its low hydraulic conductivity allows some movement of water through it, but at a slower rate than that of the adjacent aquifer.

Archean: Rocks older than 2.5 billion years (2500 Million years); spelled Archaean in older literature.

Architecture: The relationship of different geological units to each other in space. For example, regolith architecture, sedimentary architecture etc.

Basement: The crust below the rocks of interest; in hydrogeology it means non-prospective rocks below accessible groundwater. Commonly refers to igneous and metamorphic rocks which are unconformably overlain by sedimentary beds or cover material, and sometimes used to indicate ‘bedrock’, i.e., underlying or encasing palaeovalley sediments.

Basin: Subsided part of the Earth’s crust in which sediments accumulates from surrounding higher areas.

Bed/bedding: Layers/layering of sediments or sedimentary rocks that reflect differences in grainsize, composition or colour of constituent grains.

Bedrock: Loose term given to any geological material that underlies the stratum of interest. Bedrock commonly consists of crystalline rocks such as granite or metasedimentary rocks.

Braid Plain (braided river, braided channel): A river course that consists of a number of small channels separated by bars of sediment. A braid plain may be laterally broad, have no confining banks, or lack stabilizing vegetation.

Brine: A concentrated solution of salts formed by the partial evaporation of saline water. A 'brine pool' typically underlies salt lakes, infusing pore spaces in palaeovalley or palaeolacustrine sediments.

Calcrete: Calcium carbonate ($CaCO_3$) formed in soil or sediments in a semi-arid region under conditions of sparse rainfall and warm temperatures, normally by precipitation of calcium. Calcrete is common in low-lying areas in arid to semi-arid regions, particularly palaeovalleys ('valley calcrete'), and may form aureoles around salt lakes. It is commonly a significant near-surface aquifer in the arid zone.

Capillary fringe: Zone above the saturated zone – neither saturated nor unsaturated but between the two.

Carbonate: Carried in solution in surface water or groundwater. The two main types are: pedogenic (or vadose) calcretes that form in the soil profile and groundwater (non-pedogenic or phreatic) calcretes which tends to precipitate at the watertable in the overlying capillary fringe.

Catchment: The area of land from which rainwater drains into a river, stream or lake. Catchments are separated from each other by divides or water sheds.

Cenozoic: Geologic era for the last 65.5 Ma (Million years) that encompasses three periods: Paleogene, Neogene and Quaternary. It is also sob-divided into the epochs: Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene (the latter two making up the Quaternary, see below). The Cenozoic was formerly referred to as the *Tertiary* and until recently the term *Cainozoic* was used.

Chalcedony: variety of very fine grained quartz (SiO_2); sometimes occurs in silicified calcrete that may be a significant near-surface aquifer.

Clay: Refers to either grainsize or mineralogy: (a) an earthy sediment composed of rock or mineral fragments or detrital particles smaller than a very fine silt grain; (b) clay minerals are hydrous aluminium silicates derived largely from feldspars, micas and carbonate by weathering.

Colluvium: Rock debris that has moved down a hillslope either by gravity or surface wash.

Confined aquifer: An aquifer that is sealed above and below by impermeable material.

Conglomerate: A sedimentary deposit formed by cementing gravels and cobbles together with minerals precipitated from groundwater.

Consolidated: See *cemented.*

Craton: Part of the Earth's crust which is no longer affected by tectonic activity and has been stable for about a billion years (1,000 Million years)

Deflation: Removal of material from a land surface by aeolian processes. It is most effective where extensive unconsolidated sediments are exposed, as on dry lake or river beds.

Diagenesis: The changes that occur to sediments after they are deposited, including cementation and weathering.

DEM: See *Digital Elevation Models.*

Depocentre: A site of maximum deposition, where the thickest accumulation of sediment is found, within a sedimentary basin or valley.

Desiccation: Drying out.

Detrital: Material derived from the mechanical breakdown of rock by the processes of weathering and erosion.

Digital Elevation Models (DEM): Digital representations of the topography of the earth that are important components of geographic information systems (GIS). DEM are obtained by many systems, including ground surveying, airborne radar and laser surveys, or from satellite radar.

Discharge: The flow of groundwater to surface water, bores, from one aquifer to the other or the sea. Also includes evapotranspiration from shallow aquifers.

Discharge zone: An area in which subsurface water is discharged to the land surface; in the arid zone it is where evaporite minerals (salts) precipitate as the water evaporates to the atmosphere.

Dissected: A term applied to landscapes which have been extensively eroded by valleys and gullies.

Down-hole logging: A method of measuring the geophysical properties of the rocks, soils, or sediments penetrated by a drillhole. A tool that measures properties such as conductivity and natural gamma radioactivity is lowered down the borehole; data is recorded during both descent and ascent of the tool. Down-hole logging is a vital technique to calibrate conductivity and surveys and interpret geological logs.

Drawdown: The lowering of the watertable or potentiometric surface, normally as a result of the deliberate (or excessive) extraction of groundwater.

Duricrust: A hardened layer formed in the regolith by cementation of soil or sediment, generally by minerals rich in iron, sulfate, silica, or carbonate.

EC: Electrical Conductivity, a measure of conductivity and a proxy for salinity, typically measured in micro Siemens per cm (µS/cm). Fresh drinking water is, ideally, less than 100 µS/cm while seawater has a conductivity of 54,000 µS/cm.

Erosion: Part of the process of denudation that includes the physical breaking down, chemical solution, and transportation of material. Movement of soil or rock material is by the agents of running water, wind and gravity. Differential erosion pertains to adjacent or subjacent materials that have eroded differentially; the more reactive material is rapidly weathered and more easily transported, and tends to leave more recessive landforms relative to more resistant material which forms upstanding landforms.

Evaporative concentration: Concentration of solutes in groundwater owing to evaporation down-gradient in the flow path or at near-surface levels. The concentration of chemical constituents may remain fairly constant although the volume of water in which they are dissolved decreases owing to evaporation.

Evapotranspiration: Combined term for water lost as vapour from a soil or open water surface (evaporation) and from the surface of a plant (transpiration).

Fault: Fracture in a rock body along which displacement (movement) has occurred.

Feldspar: A common rock-forming mineral consisting of aluminium, silicon, oxygen and varying amounts of calcium, sodium, and potassium.

Ferricrete: A hardened iron-rich duricrust/weathering profile. Many Australian duricrusts formed during the Late Cretaceous and early Cenozoic when the climate was warm and humid. The term ‘ferricrete’ is preferred over the more obsolete term ‘laterite’ which has ambiguous definitions.

Fluvial: Pertaining to a river, Fluvial processes relate to water flow (within and beyond a stream channel) bringing about erosion, transfer and deposition of sediment. ‘Fluviatile’ relates to sediments of fluvial origin.

Fracture: Cracks in indurated rocks formed by stress and strain. Fractures along which significant movement has occurred are called faults.

Gamma ray logging: Down-hole geophysical logging technique that maps the gamma radiation released by naturally occurring uranium, thorium and radioactive potassium within rocks and regolith.

Geomorphology: The study of landforms.

Geophysics: The study of the physical properties of the earth, in particular magnetic, conductivity, and radiometric properties, or variations in the earth’s gravity. Geophysical techniques are widely used in mineral exploration and can help to understand the subsurface structure of the earth, locate groundwater, and map salinity (as well as many other applications).

Geographical Information Systems (GIS): GIS are computer-based systems for creating, storing, analysing and managing multiple layers of spatial data. These datasets include maps of geology, topography, infrastructure, soils, vegetation, and land use. GIS allow users to create interactive queries to analyse trends and patterns in spatial information.

Gigalitre (GL): one billion litres (equivalent to 1000 megalitres, ML).

Gneiss: Coarse-grained banded crystalline rocks that formed from regional metamorphism; the banding reflects the separation of constituent mafic (iron and magnesium-rich) and felsic (feldspar and silica/quartz-rich) minerals.

GOCAD: 3D modelling software for building subsurface geologic models.

Goethite: A yellowish-brown iron hydroxide mineral that is common in soils and regolith.

Granite: A light-coloured, coarse-grained crystalline igneous rock consisting mainly of quartz and feldspar, plus mica and accessory minerals.

Granules: Gravel-sized sediment between 2-4 mm in diameter.

Gravel: All loose, coarse-grained sediments with grains greater than 2 mm diameter.

Gypsum: Calcium sulphate ($CaSO_4.2H_2O$). ‘Gypcrete’ refers to indurated secondary precipitates of gypsum deposits which are common around salt lakes. ‘Gypsiferous’ refers to gypsum-rich material. Gypsiferous dunes, which commonly make islands and skirt the margins of salt lakes, have formed from gypsum crusts deflated from the lakebed and redeposited by aeolian action.

Haematite: A reddish-brown iron oxide mineral that is common in soils and regolith.

Hydraulic conductivity (permeability): The ability of a rock, unconsolidated sediment or soil to permit water flow through its pores.

Hydraulic gradient: A measure of the change in groundwater head over a given distance. Maximum flow will normally be in the direction of the maximum fall in the head.

Hydrogeology: The study of geological properties of rocks, soils, and sediments as they relate to groundwater movement and storage.

Hypersaline: More saline than seawater, which has TDS of approximately 35,000 ppm (mg/L).

Igneous: Applied to one of three main groups of rock types (igneous, metamorphic and sedimentary), to describe those rocks that have crystallized from magma.

Incised channel: A river channel that has cut down below its original flood plain. This commonly occurs in response to changes in river flow conditions or geological uplift.

Indurated: The process of hardening, such as occurs when sediments are turned into rock by various cementing agents, or surface hardening of some exposed rock surfaces that can occur during weathering.

Kilolitre (kL): 1000 litres (cubic litre: m^3)

Lacustrine: Pertaining to, produced by, or formed in a lake.

LANDSAT: A polar-orbit satellite launched by NASA to collect *multispectral* images of the Earth surface. Seven satellites have been launched in the series. Commonly written as “Landsat”.

Lignite: Peat or brown coal. Carbon-rich material formed from the remains of fossil plants that were deposited in lakes or swamps and subsequently buried, dehydrated and compressed.

Limestone: Sedimentary rock composed of calcium carbonate ($CaCO_3$) of organic, chemical or detrital origin.

Lithic: A term applied to sand or gravel where the particles are made up of rock fragments.

Mafic: Describes dark-coloured igneous rocks with a high proportion of iron- and magnesium-rich minerals.

Magnetic survey: A geophysical survey method that maps the distribution of magnetic materials in the earth. Magnetic surveys can be carried out on the ground or from aircraft, the latter terms ‘aeromagnetic surveys’.

Megalitre (ML): one million (1,000,000) litres

Metadata: Information about the source and accuracy of information used in a *GIS.*

Metamorphics: General term for rocks that have been recrystallised as a result of heat and pressure.

Milligal (mGal): A unit of acceleration used in the gravitational method of geophysical prospecting. It is about one millionth of the average value of the acceleration due to gravity at the Earth's surface; i.e., 1 milligal = 1 cm/s^2.

Mineralogy: Mineral composition of a rock or sediment.

Multispectral imagery: Images acquired by satellites or aircraft that capture more than the three colour bands visible to the human eye. Multispectral images can be manipulated and combined in a *GIS* to emphasise subtle features such as variations in soil composition or vegetation.

Palaeochannel: Refers to the main channel of ancient rivers, sometimes called the ‘thalweg’, the lowest point of incision along the river bed where coarser sediments are commonly deposited. Former river channels that are recognised in the surface (from aerial or satellite images) or subsurface (typically in *AEM* surveys or drilling).

Palaeogeography: The reconstruction of physical geography of past geologic ages in an attempt to restore areas to their depositional condition.

Palaeovalley: Ancient valleys infilled with sediments that were incised by past river systems. Palaeovalley sediments include (but are not restricted to) those of *palaeochannels*. Typically palaeovalley sediments are not associated with currently active river (fluvial) processes, although they are commonly significant aquifers.

Paleozoic: Geologic Era spanning approximately 542 Ma (million years ago) to 251 Ma. Australia was part of the Gondwana supercontinent during this time.

Palynology: The study of microscopic particles of organic composition, such as pollen and spores, found in sediments, than enables stratigraphic dating (palynostratigraphy) and interpretation of depositional environments of the sediments in which they are found.

Pediment: A gently-sloping apron of exposed or shallowly buried bedrock surrounding hills and rises.

Pedogenic: Processes or features pertaining to soil formation.

Peneplain: An area of low relief mantled by continuous regolith and by wide shallow river valleys, a peneplain – the end-product of a cycle of erosion – is produced by denudation over a long period of time.

Permeability: See *Hydraulic conductivity*.

Phreatic: Refers to the zone of saturation, the soil or rock below the level of the watertable where all voids are saturated.

Porosity: Open spaces in rocks and sediments that can hold water. *Primary porosity* formed when the sediments were laid down; these spaces may be variably infilled by *cement*, leaving remnant primary porosity. *Secondary porosity* forms through modification of rocks, such as by dissolution of soluble grains, formation of *fractures*, or solution-forming *karst.*

Potable: Described fresh water that is safe to drink and palatable for human consumption – water in which the concentration of salts and other constituents are low or have been lowered sufficiently by treatment, for consumption.

Potentiometry/potentiometric: Representation of the level to which groundwater in a confined aquifer rises in boreholes. The potentiometric surface is mapped by interpolation between borehole measurements. The slope of the potentiometric surface defines the direction of groundwater flow.

Progradation: The seaward movement of the coastal zone caused by infilling of coastal environments by sediments derived from the land after a *transgression.*

Proterozoic: A geological era that encompasses the time between 2,500 and 545 million years ago. The Proterozoic is formally divided into the Paleoproterozoic (2,500 and 1,600 million years), Mesoproterozoic (1,600-1,000 million years), and Neoproterozoic (1,000-545 million years).

Provenance: The source or origin of detrital sediments**.**

Quartz: A very common mineral consisting of silicon dioxide that commonly occurs in river sands and as the main mineral in sandstones.

Quartzite: *Sandstone* consisting largely of quartz that has been recrystallised (metamorphosed) by exposure to geological heat and pressure.

Quaternary: Geological Period spanning approximately the most recent 2.5 Ma (Million years). The Quaternary is sub-divided into two epochs, the Pleistocene (2.5 Ma to approximately 11,000 years ago) and the Holocene (11,000 years to the present). The Quaternary is characterised by extreme climate fluctuations, alternating glacial and interglacial periods, with aridification of the Australian inland being a legacy of the last glacial.

Radiometric: Also known as (airborne) gamma-ray spectrometry (AGS) or gamma-radiometic measurement. A spectrometer measures gamma-radiation from isotopes of potassium, thorium and uranium emitted from rocks and sediment to record the distribution of these elements in the landscape.

Recharge: The process by which water is added to an aquifer; the downward movement of water from the soil to the watertable. Also, the total volume of water added to the total amount of groundwater in storage within a given period of time. A 'recharge area' acts as a catchment for a particular aquifer.

Regolith: The earth materials that occur between fresh rock and fresh air, including *weathered* rocks, soils, shallow groundwater and sediments.

Relict: A term applied to landscape features that are no longer being actively formed. For example, the floodplain of the Ord River is regarded as relict because, prior to dam construction, it was not being inundated during seasonal floods.

Rotary mud drilling: A relatively cheap drilling method that uses a rotating cutting bit to drill a hole. Samples are brought to the surface as cuttings supported by a circulated drilling fluid containing mud, and this also keeps the hole open. Samples are contaminated by the drilling fluid, and these are averaged over the sample interval (typically 1-5 m). Material from shallower depths can also contaminate samples drilled further down-hole. Also known as mud drilling, mud rotary or rotary drilling.

Salinity: Areas where salt is being deposited in the near-surface environment. Salinity is a natural phenomenon but can be increased through land use practices involving inappropriate types of soil management, vegetation clearing, cropping, and irrigation. Within the arid zone, salinity is largely 'Primary' or 'Natural' salinity, brought about steadily through aridification during the Quaternary. In disturbed agricultural lands, salinisation is commonly regarded as 'Secondary' or 'Anthropogenic' salinity.

Salinity ranges: For the purpose of the *Palaeovalley Groundwater Project* the following ranges have been used when discussing groundwater salinity: <1,000 mg/L TDS = fresh water, 1,001 to 10,000 mg/L = brackish water, 10,001 to 35,000 mg/L = saline water, >35,000 mg/L = hypersaline water.

Sandstone: A *sedimentary* rock composed of sand-sized particles.

Saprock: Compact, slightly weathered rock with low porosity; defined as having less than 20% of weatherable minerals altered but generally requiring a hammer blow to break. It may still contain rock structure.

Saprolite: Saprolite is weathered rock in which more than 20% of the weatherable minerals in the original rock have been altered *in situ*, with interstitial grain relationships being undisturbed. Saprolite is altered from the original rock by mainly chemical alteration and loss without any change in volume. This is sometimes referred to as constant volume alteration. Saprolite can be highly porous and permeable and may be an important aquifer.

Saprolith: Saprolith is all those parts of a weathering profile that have been formed strictly *in situ*, with interstitial grain relationships being undisturbed. This contrasts with residual material or pedolith, which has been disturbed. Saprolith is altered from the original rock by mainly chemical alteration and loss without any change in volume. It is subdivided into *saprock* and *saprolite*.

Schist: A regional metamorphic rock composed of mica, quartz, and mafic minerals that have a preferred orientation.

Sedimentary: Pertaining to deposition of sediments and sedimentary process, for example, a sedimentary rock is a rock once composed of sediments such as sand, gravel, silt, etc.

Shale: A *sedimentary* rock composed of clay particles.

Sheetwash: A geomorphological process by which a thin layer of water flow over the surface of a hillslope and may transport surface regolith material downslope. It is important process in semi-arid regions, especially in mulga country.

Silica: Term applied to fine-grained *quartz* (SiO_2) cement in sediments and soils. 'Silcrete' is silica rich duricrust that functions as a cement.

Silicification: Process by which silica is deposited.

Siltstone: A *sedimentary* rock composed of silt-sized particles.

Succession: Term applied to a series of sedimentary or volcanic deposits.

Stratigraphy: The study of how different layers of sediments can be related to each other.

SRTM: *Digital Elevation Model* data collected during the 2000 STS-99 **S**huttle **R**adar **T**opography **M**ission by the Space Shuttle Endeavour. SRTM data is widely available at 3-arc second (~90 m) horizontal resolution and on a restricted basis at 1-arc second (~30 m) horizontal resolution.

Terrane: Used in geology to distinguish a fragment of crustal material of a particular rock type from an adjacent rock type (abbreviated from 'tectonostratigraphic terrane').

TDS: Total Dissolved Solids, measured in parts per million (ppm), equivalent to milligrams per litre (mg/L). Drinking water has a TDS of 100 to 1,000 ppm (mg/L); seawater has a TDS of approximately 35,000 ppm (mg/L).

Thalweg: The deepest continuous channel within a river valley, typically marking the course of the most active and fastest part of the main river channel. In palaeovalleys the thalweg usually contains the most coarse-grained and well sorted sediments, making it the most conductive aquifer zone in the buried valley sedimentary sequence, and a common borehole target.

Transgression: A long-term rise in relative sea-level causing flooding of the coastal zone, for example, after the end of the last ice age, or in the Cenozoic when palaeovalleys in the southern part of Australia because inundated by seawater and accumulated marine sediments, as in the Eucla Basin/Nullarbor Plain.

Transgressive: Pertaining to processes or sediments resulting from a (marine) *Transgression.*

Transmissivity: A measure of the ability of groundwater to pass through soil, sediment or rock making up an aquifer. The rate at which groundwater, under the hydraulic gradient, is transmitted.

Transpiration: Water given off by plants via pores in the surface tissues.

Unconfined: See *aquifer.*

Unconformity: A *bounding surface* where the rocks below rest at a different angle to those above, for example, where alluvial gravels rest on bedrock.

Unconsolidated: See *uncemented.*

Unsaturated zone: Occurs above the watertable and above the capillary fringe**.**

Vadose zone: Soil-water, unsaturated, aeration zone. The zone between the ground surface and the watertable.

Watertable: The surface below which an *unconfined aquifer* is saturated with water. See also *potentiometric surface.*

Weathered/weathering: The physical and chemical changes that a rock undergoes when it is exposed to the atmosphere and shallow groundwater.

Wetlands: Low-lying areas subject to partial or continuous inundation. Also called swamps.

XRD: X-ray diffraction. An analytical method used to determine the mineral composition of soil, sediment, and rock samples.

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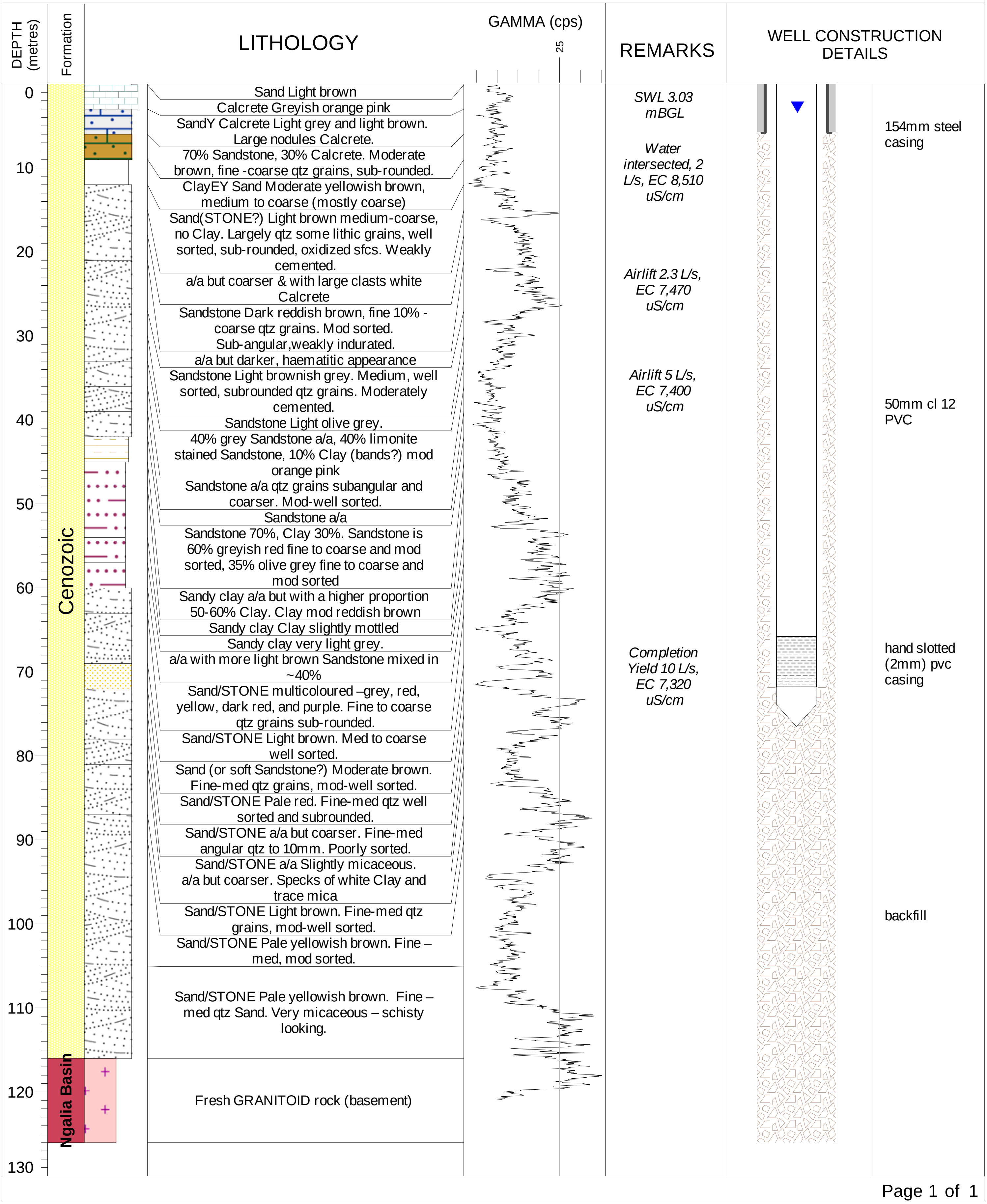
Appendix 1 – Bore logs for the Wilkinkarra Palaeovalley

This appendix contains copies of completed bore logs drilled as part of investigations for the *Palaeovalley Groundwater Project* in the Wilkinkarra Palaeovalley. These include the following bores:

1. RN18358
2. RN18359
3. RN18360
4. RN18361
5. RN18362
6. RN18579
7. RN18782
8. RN18783
9. RN18784
10. RN18785
11. RN18786
12. RN18787
13. RN18788

Palaeovalley Groundwater Project RN018358

LOCATION: *Nyirripi*
TOTAL DEPTH (m): *126*
AIRLIFT SALINITY (µS/cm): *7220*
DATE STARTED: *23.09.2009*
CONSTRUCTED DEPTH (mBGL): *72.3*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7473278*
DATE COMPLETED: *25.09.2009*
CASING HEIGHT (m): *0.4*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *625036*
ELEVATION: *472.6*
STANDING WATER LEVEL (mbgl): *2.77*
LOGGED BY: *M Woodgate*



LITHOLOGY

- Sand Light brown
- Calcrete Greyish orange pink
- SandY Calcrete Light grey and light brown. Large nodules Calcrete.
- 70% Sandstone, 30% Calcrete. Moderate brown, fine -coarse qtz grains, sub-rounded.
- ClayEY Sand Moderate yellowish brown, medium to coarse (mostly coarse)
- Sand(STONE?) Light brown medium-coarse, no Clay. Largely qtz some lithic grains, well sorted, sub-rounded, oxidized sfcs. Weakly cemented.
- a/a but coarser & with large clasts white Calcrete
- Sandstone Dark reddish brown, fine 10% - coarse qtz grains. Mod sorted. Sub-angular,weakly indurated.
- a/a but darker, haematitic appearance
- Sandstone Light brownish grey. Medium, well sorted, subrounded qtz grains. Moderately cemented.
- Sandstone Light olive grey.
- 40% grey Sandstone a/a, 40% limonite stained Sandstone, 10% Clay (bands?) mod orange pink
- Sandstone a/a qtz grains subangular and coarser. Mod-well sorted.
- Sandstone a/a
- Sandstone 70%, Clay 30%. Sandstone is 60% greyish red fine to coarse and mod sorted, 35% olive grey fine to coarse and mod sorted
- Sandy clay a/a but with a higher proportion 50-60% Clay. Clay mod reddish brown
- Sandy clay Clay slightly mottled
- Sandy clay very light grey.
- a/a with more light brown Sandstone mixed in ~40%
- Sand/STONE multicoloured –grey, red, yellow, dark red, and purple. Fine to coarse qtz grains sub-rounded.
- Sand/STONE Light brown. Med to coarse well sorted.
- Sand (or soft Sandstone?) Moderate brown. Fine-med qtz grains, mod-well sorted.
- Sand/STONE Pale red. Fine-med qtz well sorted and subrounded.
- Sand/STONE a/a but coarser. Fine-med angular qtz to 10mm. Poorly sorted.
- Sand/STONE a/a Slightly micaceous.
- a/a but coarser. Specks of white Clay and trace mica
- Sand/STONE Light brown. Fine-med qtz grains, mod-well sorted.
- Sand/STONE Pale yellowish brown. Fine – med, mod sorted.
- Sand/STONE Pale yellowish brown. Fine – med qtz Sand. Very micaceous – schisty looking.
- Fresh GRANITOID rock (basement)

REMARKS

SWL 3.03 mBGL

Water intersected, 2 L/s, EC 8,510 uS/cm

Airlift 2.3 L/s, EC 7,470 uS/cm

Airlift 5 L/s, EC 7,400 uS/cm

Completion Yield 10 L/s, EC 7,320 uS/cm

WELL CONSTRUCTION DETAILS

154mm steel casing

50mm cl 12 PVC

hand slotted (2mm) pvc casing

backfill

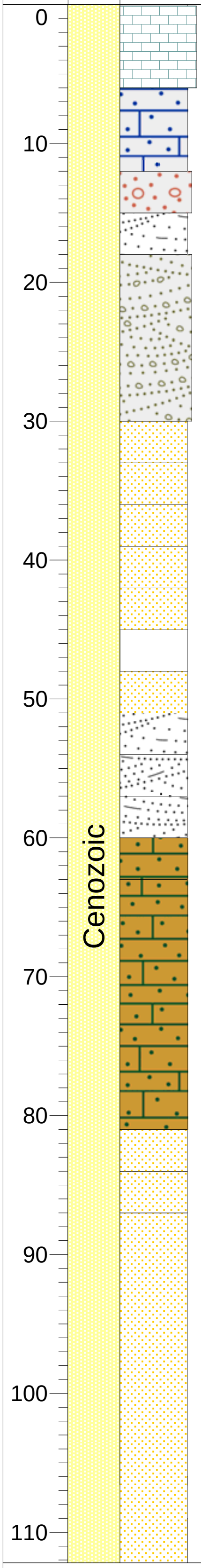
Palaeovalley Groundwater Project

RN018359

Northern Territory Government

LOCATION: *Nyirripi*
TOTAL DEPTH (m): *174*
AIRLIFT SALINITY (μS/cm): *7900*
DATE STARTED: *26.09.2009*
CONSTRUCTED DEPTH (mBGL): *78*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7477232*
DATE COMPLETED: *28.09.2009*
CASING HEIGHT (m): *0.8*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *626869*
ELEVATION: *475.8*
STANDING WATER LEVEL (mbgl): *5.14*
LOGGED BY: *M Woodgate*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



LITHOLOGY

Sand Light brown, fine, well sorted and rounded.

Calcrete Greyish orange pink

SandY Calcrete (about 50/50) Light brown . Sand: med- coarse qtz grains, sub-angular, mod sorted. Calcrete dull, nodular.

SandY Gravel Light brown. Coarse qtz grains & Gravel to 10mm. Sub-angular to angular.Moderately sorted.

Sandstone Light brown. Weathered and weakly indurated. Qtz grains fine-coarse, angular-sub-angular, mod sorted. Ironstone nodules scattered throughout.

Sand/STONE and Gravel Light brown. Fine-coarse qtz grains, angular-sub-angular.

Sand Light brown. Coarse – 50% subrounded qtz, 10% Calcrete with scattered qtz grains – predominantly oxidized sfcs.

a/a with qtz Gravel ~15% - sub-rounded, yellow skins, mod sorted.

a/a but moderate brown colour

a/a with Calcrete bands around 42m

a/a with small proportion of highly weathered oxidized Sandstone, fine-med grained.

Sand and Sandstone Moderate brown. Fine-medium, subrounded to angular, highly oxidized and hard in places. Mod sorting. Trace ironstone.

Sand Moderate brown. Fine to coarse, (predom coarse), subangular -angular, poorly sorted qtz grains.

Sandstone Moderate brown. Fine-med well sorted qtz, subrounded. Qtz Gravel ~10%.

a/a but less qtz Gravel. More indurated.

Same as 48-51 but Light brown

Sandstone ~40% - Light brown med grained, poorly sorted, weathered Sandstone , ClaySTONE ~40% - Light brownish grey, fine grained stone with trace coarse, rounded, qtz grains throughout, QTZ Gravel ~20% -angular-subangular.

a/a but more grey ClaySTONE.

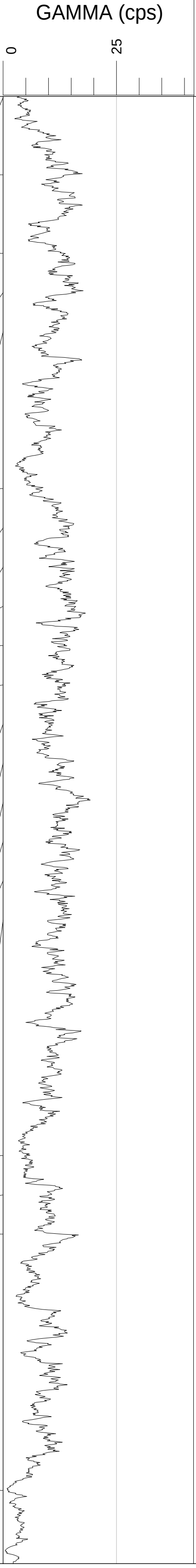
Sand greyish orange. Fine-med qtz grains, subrounded-rounded, well sorted

As per 60-63

As per 60-63 – mixture weathered brown Sandstone and grey ClaySTONE (banded ?) with lots of small angular quartz Gravel throughout. Overall poorly to moderately sorted – texturally immature.

Sand Pinkish grey – light grey fine-medium ,free flowing Sand. 'soft drilling' qtz grains sub rounded-subangular mod-well sorted

GAMMA (cps)



REMARKS

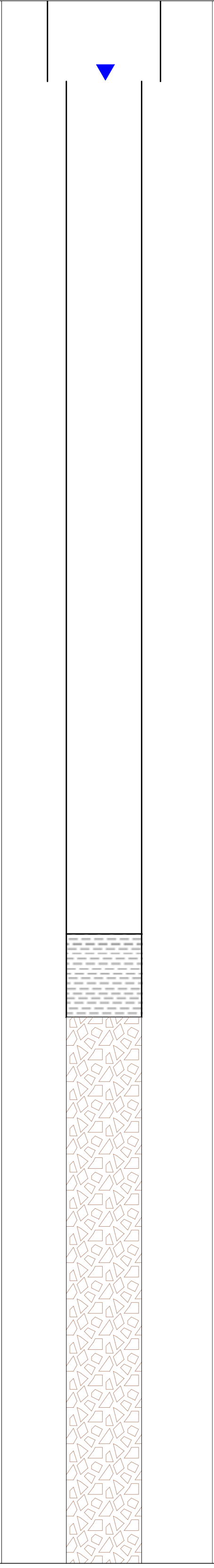
SWL 5.14 mBGL

Water intersection, 2 L/s, 9,150 uS/cm

Airlift 5 L/s, EC 8,000 uS/cm

Airlift 8 L/s, EC 7,610 uS/cm

WELL CONSTRUCTION DETAILS



158mm steel casing, standpipe 0.15m stickup

50mm cl 12 PVC

hand slotted (2mm) pvc casing

Northern Territory Government

Palaeovalley Groundwater Project RN018359

LOCATION: *Nyirripi*

TOTAL DEPTH (m): *174*

AIRLIFT SALINITY (µS/cm): *7900*

DATE STARTED: *26.09.2009*

CONSTRUCTED DEPTH (mBGL): *78*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7477232*
WGS 84 Zone 53

DATE COMPLETED: *28.09.2009*

CASING HEIGHT (m): *0.8*

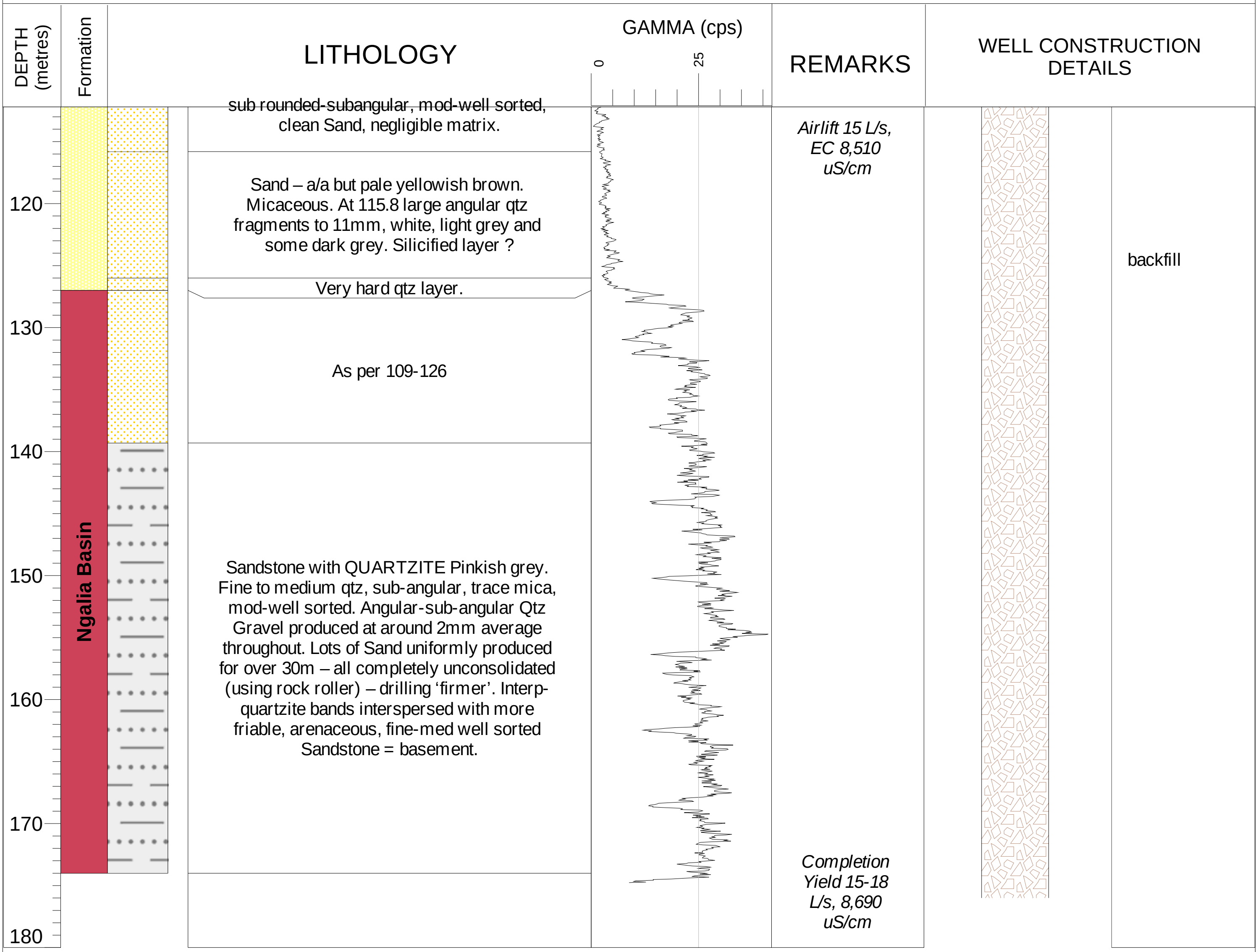
DRILLER: *I Mcmasters*

EASTING: *626869*
WGS 84 Zone 53

ELEVATION: *475.8*

STANDING WATER LEVEL (mbgl): *5.14*

LOGGED BY: *M Woodgate*



sub rounded-subangular, mod-well sorted, clean Sand, negligible matrix.

Sand – a/a but pale yellowish brown. Micaceous. At 115.8 large angular qtz fragments to 11mm, white, light grey and some dark grey. Silicified layer ?

Very hard qtz layer.

As per 109-126

Sandstone with QUARTZITE Pinkish grey. Fine to medium qtz, sub-angular, trace mica, mod-well sorted. Angular-sub-angular Qtz Gravel produced at around 2mm average throughout. Lots of Sand uniformly produced for over 30m – all completely unconsolidated (using rock roller) – drilling ‘firmer’. Interp- quartzite bands interspersed with more friable, arenaceous, fine-med well sorted Sandstone = basement.

Airlift 15 L/s, EC 8,510 uS/cm

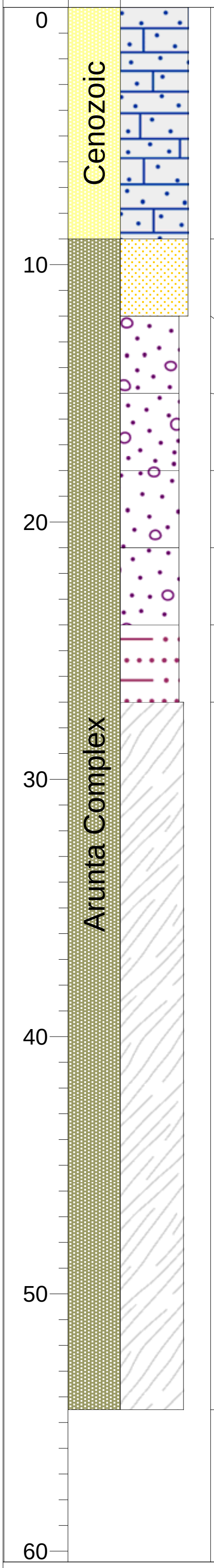
Completion Yield 15-18 L/s, 8,690 uS/cm

Northern Territory Government

Palaeovalley Groundwater Project RN018360

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*54.5*	**AIRLIFT SALINITY (μS/cm):**	*7360*
DATE STARTED:	*30.09.2009*	**CONSTRUCTED DEPTH (mBGL):**		**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7471502*	**DATE COMPLETED:**	*30.09.2009*	**CASING HEIGHT (m):**	**DRILLER:**	*I Mcmasters*
EASTING: WGS 84 Zone 53 *624143*	**ELEVATION:** *471.2*	**STANDING WATER LEVEL (mbgl):**	*5.8*	**LOGGED BY:**	*M Woodgate*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



SandY Calcrete Pale reddish brown.

ClayEY SILTY Sand. Moderate reddish brown, fine Sand. Lots mica Sand is qtz and subangular looks like weathered metamorphics.

SandY SILTY Clay. Greyish red, chocolatey colour. 5%, sheeny Clay, feels talcy – micaceous.

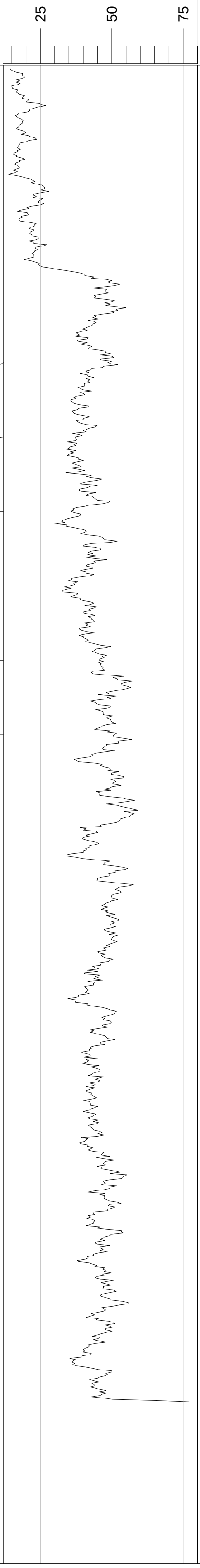
a/a

a/a but dark yellowish brown and damp.

a/a

Sandy clay – Light olive grey . Abundant qtz, mica, biotite. Weathered schist.

Weathered schist as above.

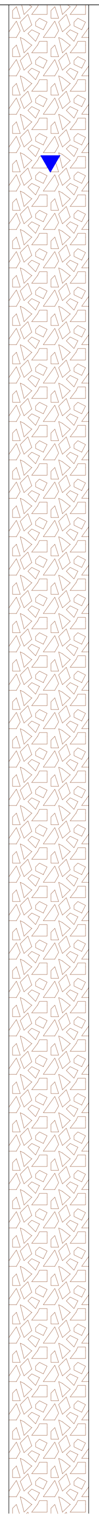


SWL 5.80 mBGL

Water intersected, 1 L/s, EC 9,980 uS/cm

Seepage, EC 7,360 uS/cm

Completion yield 0.5 L/s, EC 7,880 uS/cm



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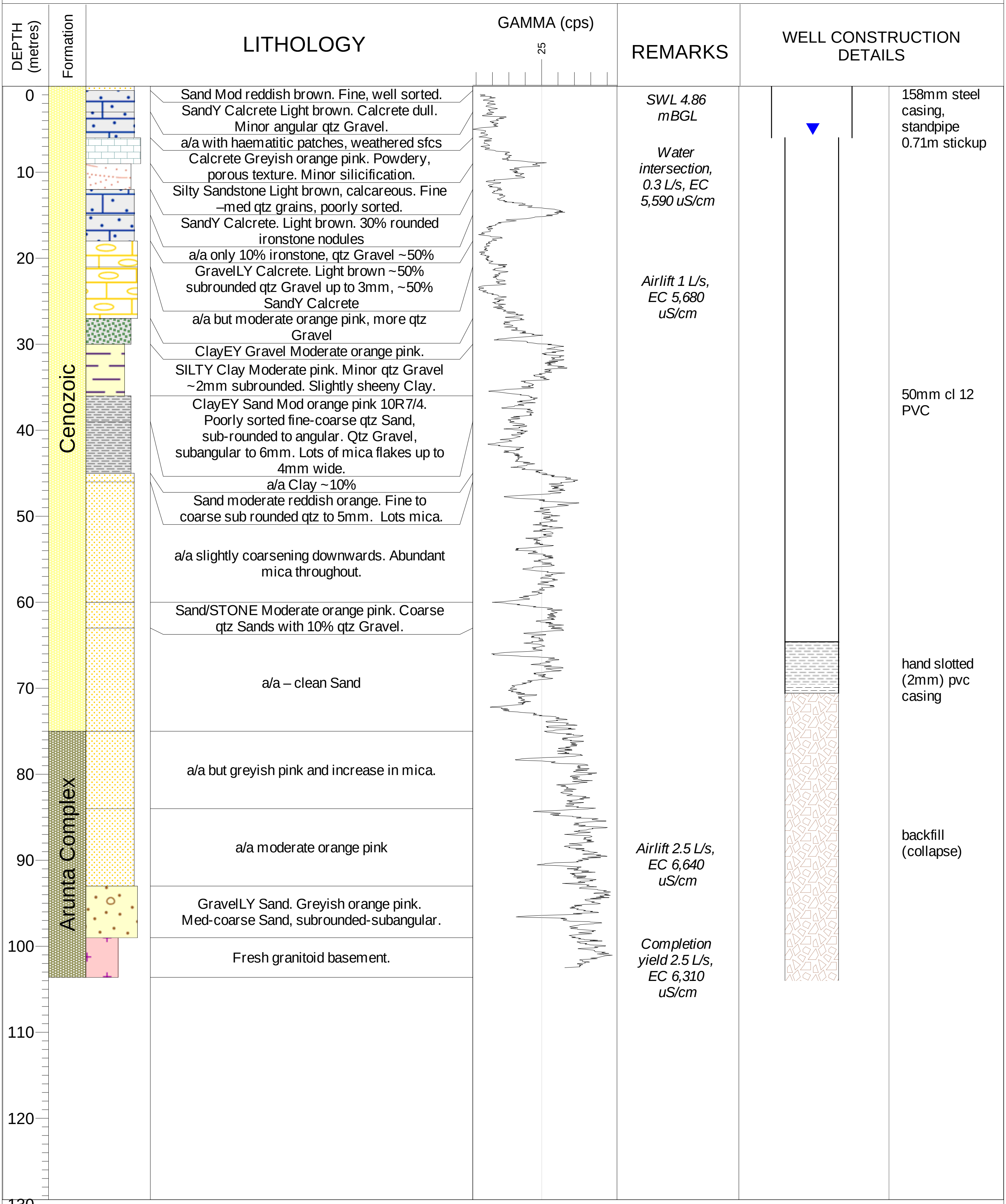
Palaeovalley Groundwater Project RN018361

Northern Territory Government

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*103.6*	**AIRLIFT SALINITY (µS/cm):**	*6310*
DATE STARTED:	*2.10.2009*	**CONSTRUCTED DEPTH (mBGL):**	*70.6*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7470744*	**DATE COMPLETED:**	*3.10.2009*	**CASING HEIGHT (m):**	*0.59*
DRILLER:	*I Mcmasters*	**EASTING:** WGS 84 Zone 53	*623909*	**ELEVATION:**	*472.6*
STANDING WATER LEVEL (mbgl):	*4.97*	**LOGGED BY:**	*M Woodgate*		



LITHOLOGY

Sand Mod reddish brown. Fine, well sorted.

SandY Calcrete Light brown. Calcrete dull. Minor angular qtz Gravel.

a/a with haematitic patches, weathered sfcs

Calcrete Greyish orange pink. Powdery, porous texture. Minor silicification.

Silty Sandstone Light brown, calcareous. Fine –med qtz grains, poorly sorted.

SandY Calcrete. Light brown. 30% rounded ironstone nodules

a/a only 10% ironstone, qtz Gravel ~50%

GravelLY Calcrete. Light brown ~50% subrounded qtz Gravel up to 3mm, ~50% SandY Calcrete

a/a but moderate orange pink, more qtz Gravel

ClayEY Gravel Moderate orange pink.

SILTY Clay Moderate pink. Minor qtz Gravel ~2mm subrounded. Slightly sheeny Clay.

ClayEY Sand Mod orange pink 10R7/4. Poorly sorted fine-coarse qtz Sand, sub-rounded to angular. Qtz Gravel, subangular to 6mm. Lots of mica flakes up to 4mm wide.

a/a Clay ~10%

Sand moderate reddish orange. Fine to coarse sub rounded qtz to 5mm. Lots mica.

a/a slightly coarsening downwards. Abundant mica throughout.

Sand/STONE Moderate orange pink. Coarse qtz Sands with 10% qtz Gravel.

a/a – clean Sand

a/a but greyish pink and increase in mica.

a/a moderate orange pink

GravelLY Sand. Greyish orange pink. Med-coarse Sand, subrounded-subangular.

Fresh granitoid basement.

REMARKS

SWL 4.86 mBGL

Water intersection, 0.3 L/s, EC 5,590 uS/cm

Airlift 1 L/s, EC 5,680 uS/cm

Airlift 2.5 L/s, EC 6,640 uS/cm

Completion yield 2.5 L/s, EC 6,310 uS/cm

WELL CONSTRUCTION DETAILS

158mm steel casing, standpipe 0.71m stickup

50mm cl 12 PVC

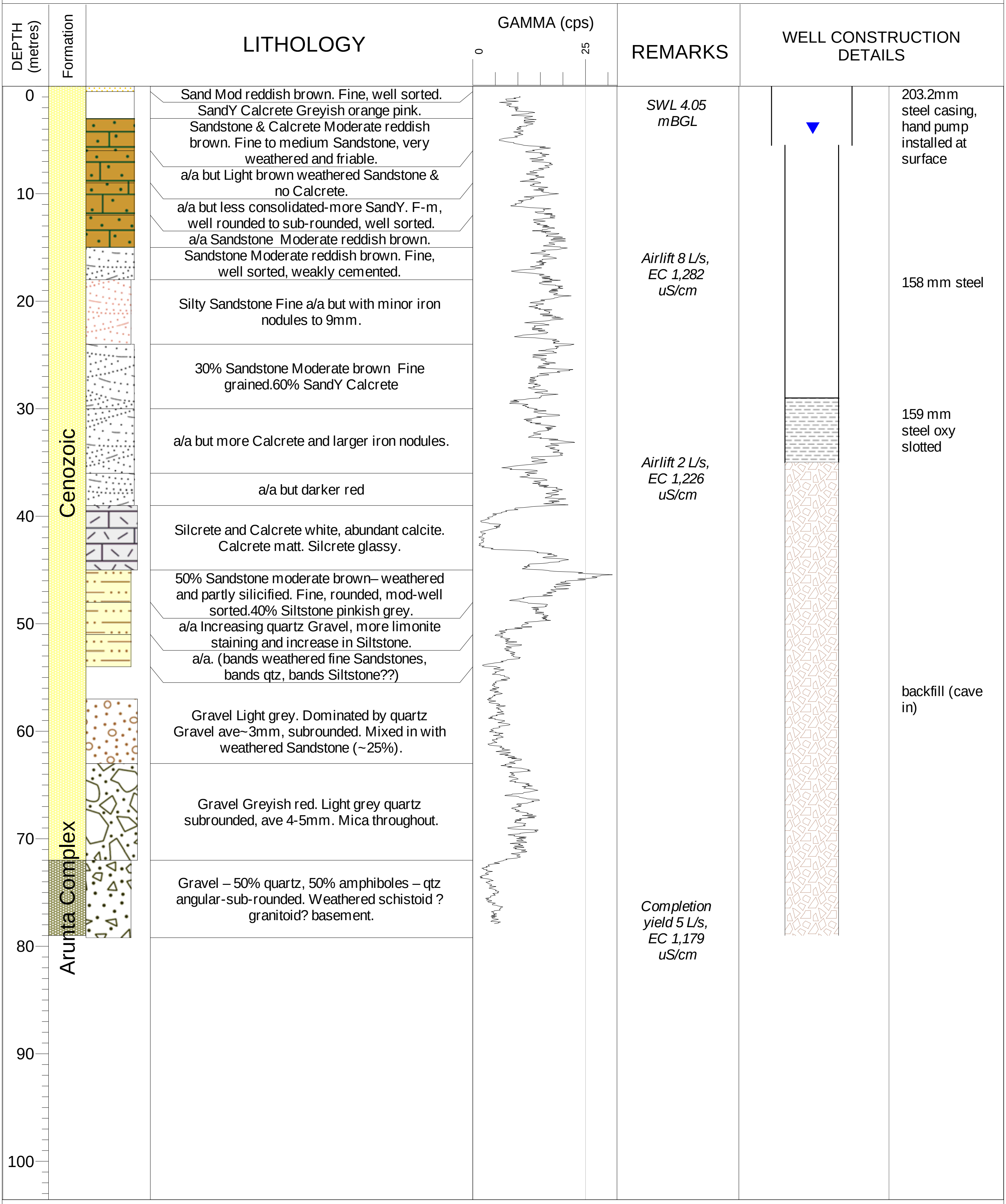
hand slotted (2mm) pvc casing

backfill (collapse)

Northern Territory Government

Palaeovalley Groundwater Project RN018362

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*79.2*	**AIRLIFT SALINITY (μS/cm):**	*1200*
DATE STARTED:	*3.10.2009*	**CONSTRUCTED DEPTH (mBGL):**	*35.5*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7468092*	**DATE COMPLETED:** *5.10.2009*	**CASING HEIGHT (m):**		**DRILLER:**	*I Mcmasters*
EASTING: WGS 84 Zone 53 *623075*	**ELEVATION:** *471.6*	**STANDING WATER LEVEL (mbgl):**	*3.9*	**LOGGED BY:**	*M Woodgate*



LITHOLOGY

Sand Mod reddish brown. Fine, well sorted.

SandY Calcrete Greyish orange pink.

Sandstone & Calcrete Moderate reddish brown. Fine to medium Sandstone, very weathered and friable.

a/a but Light brown weathered Sandstone & no Calcrete.

a/a but less consolidated-more SandY. F-m, well rounded to sub-rounded, well sorted.

a/a Sandstone Moderate reddish brown.

Sandstone Moderate reddish brown. Fine, well sorted, weakly cemented.

Silty Sandstone Fine a/a but with minor iron nodules to 9mm.

30% Sandstone Moderate brown Fine grained.60% SandY Calcrete

a/a but more Calcrete and larger iron nodules.

a/a but darker red

Silcrete and Calcrete white, abundant calcite. Calcrete matt. Silcrete glassy.

50% Sandstone moderate brown– weathered and partly silicified. Fine, rounded, mod-well sorted.40% Siltstone pinkish grey.

a/a Increasing quartz Gravel, more limonite staining and increase in Siltstone.

a/a. (bands weathered fine Sandstones, bands qtz, bands Siltstone??)

Gravel Light grey. Dominated by quartz Gravel ave~3mm, subrounded. Mixed in with weathered Sandstone (~25%).

Gravel Greyish red. Light grey quartz subrounded, ave 4-5mm. Mica throughout.

Gravel – 50% quartz, 50% amphiboles – qtz angular-sub-rounded. Weathered schistoid ? granitoid? basement.

REMARKS

SWL 4.05 mBGL

Airlift 8 L/s, EC 1,282 uS/cm

Airlift 2 L/s, EC 1,226 uS/cm

Completion yield 5 L/s, EC 1,179 uS/cm

WELL CONSTRUCTION DETAILS

203.2mm steel casing, hand pump installed at surface

158 mm steel

159 mm steel oxy slotted

backfill (cave in)

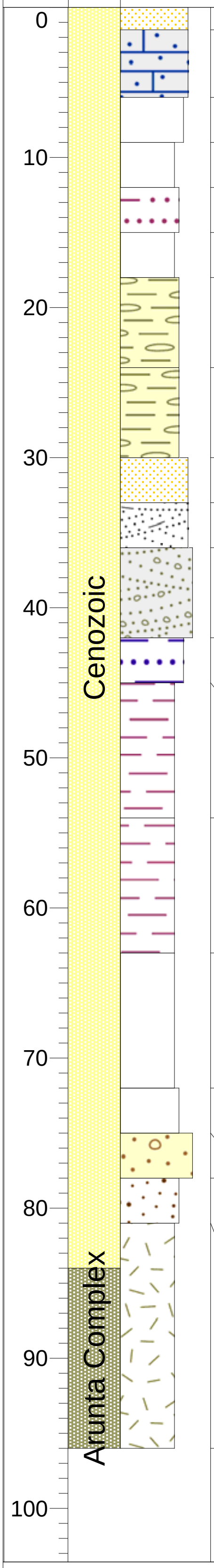
Northern Territory Government

Palaeovalley Groundwater Project RN018579

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*96*	**AIRLIFT SALINITY (µS/cm):**	*1009*
DATE STARTED:	*6.10.2009*	**CONSTRUCTED DEPTH (mBGL):**		**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7466954*	**DATE COMPLETED:**	*6.10.2009*	**CASING HEIGHT (m):**	
DRILLER:	*I Mcmasters*				
EASTING: WGS 84 Zone 53	*622720*	**ELEVATION:**	*473.4*	**STANDING WATER LEVEL (mbgl):**	*4.05*
LOGGED BY:	*M Woodgate*				

DEPTH (metres)

Formation



LITHOLOGY

Sand Mod reddish brown. Fine, well sorted.

SandY Calcrete Greyish orange pink. Partly silicified.

SandY SILT. Pale yellowish brown

ClayEY SILT. Moderate brown.

Sandy clay. Moderate brown Calcareous with Calcrete bands.

As per 9-12.

GravelLY Clay. Moderate brown. Gravel (~25%) includes iron nodules to 4mm & quartz Gravel.

a/a subrounded-rounded lithic pebbles & iron nodules to 20mm

Sand. Moderate reddish brown. Fine-medium, qtz & lithic, moderately sorted, subangular.

Sandstone Moderate reddish brown.

GravelLY Sandstone. a/a but with rounded iron nodules to 20mm.

SandY Siltstone Moderate yellowish brown. Limonite stained SandY Siltstone. Sand (~10%) fine-med qtz, subrounded.

ClaySTONE Light olive grey.

a/a but with increasing weathered Siltstone/Sandstone. About 50% fresh ClaySTONE, 50% weathered Siltstone.

Clay & ClaySTONE a/a with light grey ClaySTONE and weathered Siltstone, but with lots of Clay – moderate orange pink.

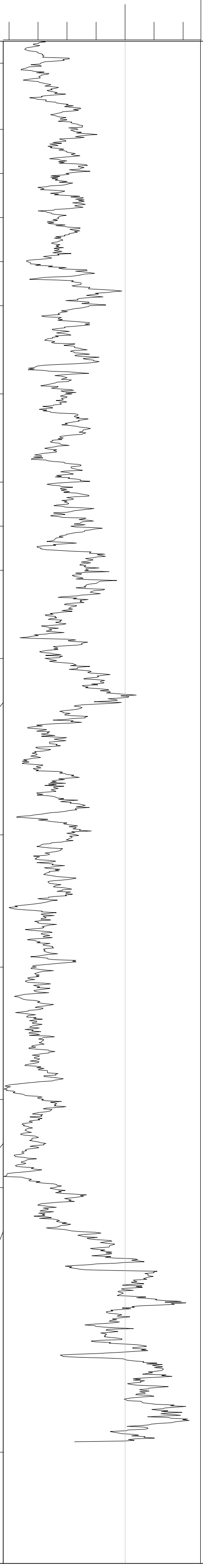
Clay ~ 30% mottled greyish yellow/ pale grey-white , fine Sand throughout.Sand ~60% med-coarse qtz.

GravelLY Sand Dusky yellow.

GravelLY Siltstone. Dark yellowish orange. ‘platey’ looking, sheeny, soft and flaky ‘Phyllite’. Muscovite very fine- sericite. 20% angular qtz.

a/a mustard yellow phyllite - basement

GAMMA (cps)



REMARKS

handpump installed - 'Winners Bore'

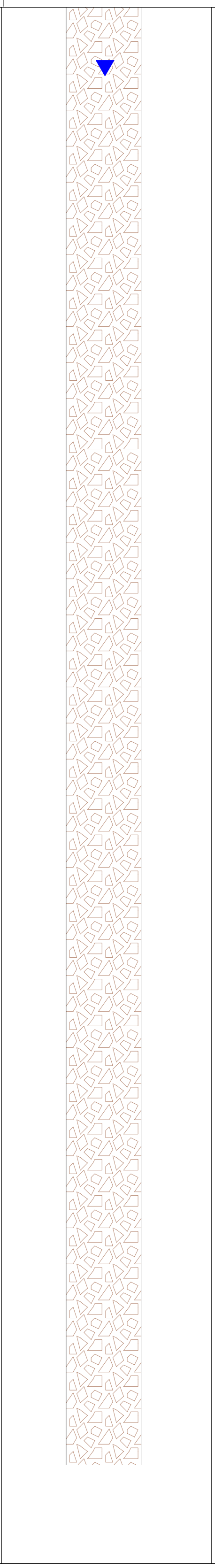
SWL 4.05 mBGL

Water intersection 0.2 L/s, EC 1,114 uS/cm

Airlift 4 L/s, EC 1,034 uS/cm

Completion yield 7 L/s, EC 1,009 uS/cm

WELL CONSTRUCTION DETAILS



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Northern Territory Government

Palaeovalley Groundwater Project

RN018782

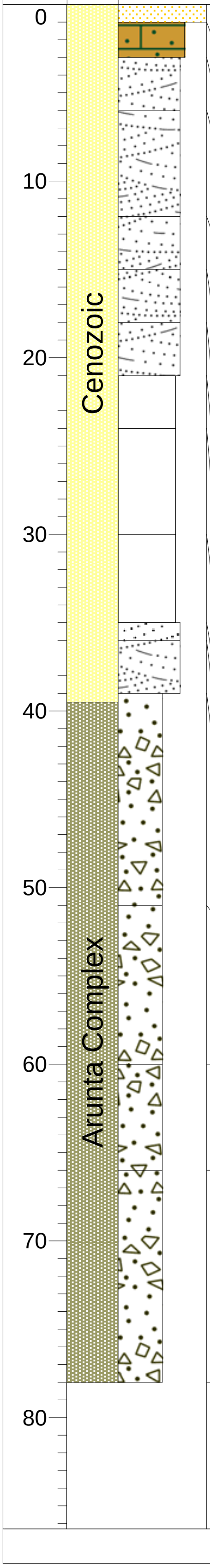
LOCATION: *Nyirripi*
TOTAL DEPTH (m): *78.5*
AIRLIFT SALINITY (µS/cm): *18500*

DATE STARTED: *15.7.2011*
CONSTRUCTED DEPTH (mBGL): *40*
DRILLING RIG: *Ingersol Rand*

NORTHING: WGS 84 Zone 53 *7484792*
DATE COMPLETED: *19.07.2011*
CASING HEIGHT (m): *0.52*
DRILLER: *I Mcmasters*

EASTING: WGS 84 Zone 53 *594987*
ELEVATION: *441.08*
STANDING WATER LEVEL (mbgl): *2.7*
LOGGED BY: *R Read*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



Sand. Very coarse to fine grained moderate red brown (10R5/6) weakly cemented Silty Sandstone.

Sandstone. Light brown and white fine to coarse Sandstone, ranging from soft Calcrete cemented to hard Silcrete cemented.

Sandstone. Moderate orange pink coarse to fine grained Calcrete cemented Sandstone.

Sandstone. Very coarse (dominantly about 1 mm, ranging from 0.5 up to 5 mm pebbles) very weakly cemented rounded to sub-angular light brown (5YR6/2) Sandstone.

Sandstone. Sample mostly disaggregated Sand as above, some chips pale reddish brown (10R5/4) friable moderately well cemented Silty Sandstone. Dominantly medium grained (0.5 mm), ranging fine to very coarse.

Sandstone. Large chips light brown well cemented Sandstone, fall back. Soft pale yellow brown fine to medium grained Sandstone plus pale red brown fine grained Silty Sandstone.

Siltstone. Pale yellow brown mostly fine grained ranging to coarse moderately well cemented quartz Sandstone.

Siltstone. Very light grey weakly silica cemented Siltstone with 10% Sand size quartz.

Siltstone. White silicified Siltstone, about 10% ferruginised to greyish red.

Siltstone. White silicified Siltstone with 5% Sand size quartz grains.

Sandstone. Greyish orange (10YR7/4) very coarse grained (1 to 2 mm) sub-angular quartz Sand.

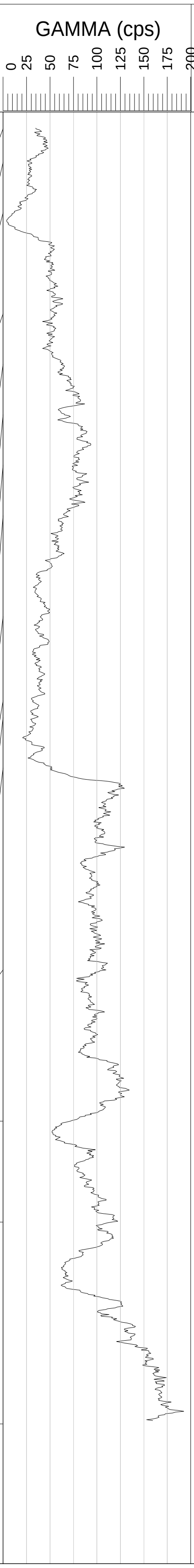
Sand. 50% very coarse disaggregated quartz Sand, 50% white silicified Siltstone.

WEATHERED GRANITE. Greyish orange (colour difficult because of fall back) sub-angular quartz Sand, ~ 2 mm, up to 10 mm.

WEATHERED GRANITE. Similar to above, plus white Clay.

WEATHERED GRANITE. Similar to above, small chips white Siltstone .

WEATHERED GRANITE. Quartz grains, 2 to 10 mm, pink felspar, some mica.



EC 18,980, 5 L/s

EC 16,100, ~4 L/s. Lower EC probably due to foam

EC 18400, airlift 2.1 L/s

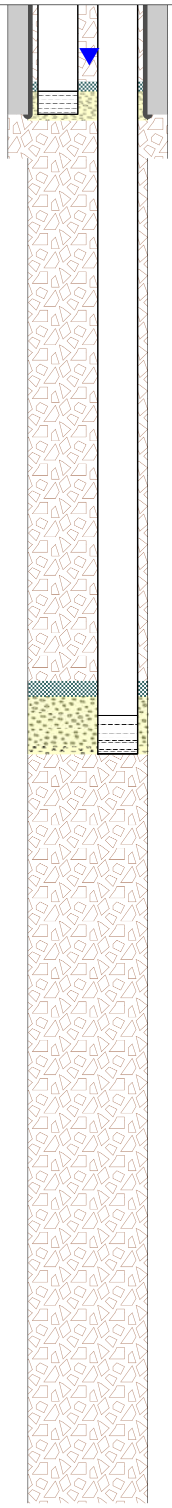
EC 18500, airlift 4 L/s

EC 19300, airlift 3 L/s

EC 22200, airlift 3 L/s

EC 31000, airlift 3 L/s

EC 33200, airlift 3 L/s



158 mm steel collar cemented
50 mm cl 12 PVC slotted
bentonite & gravel pack

50 mm cl 12 PVC

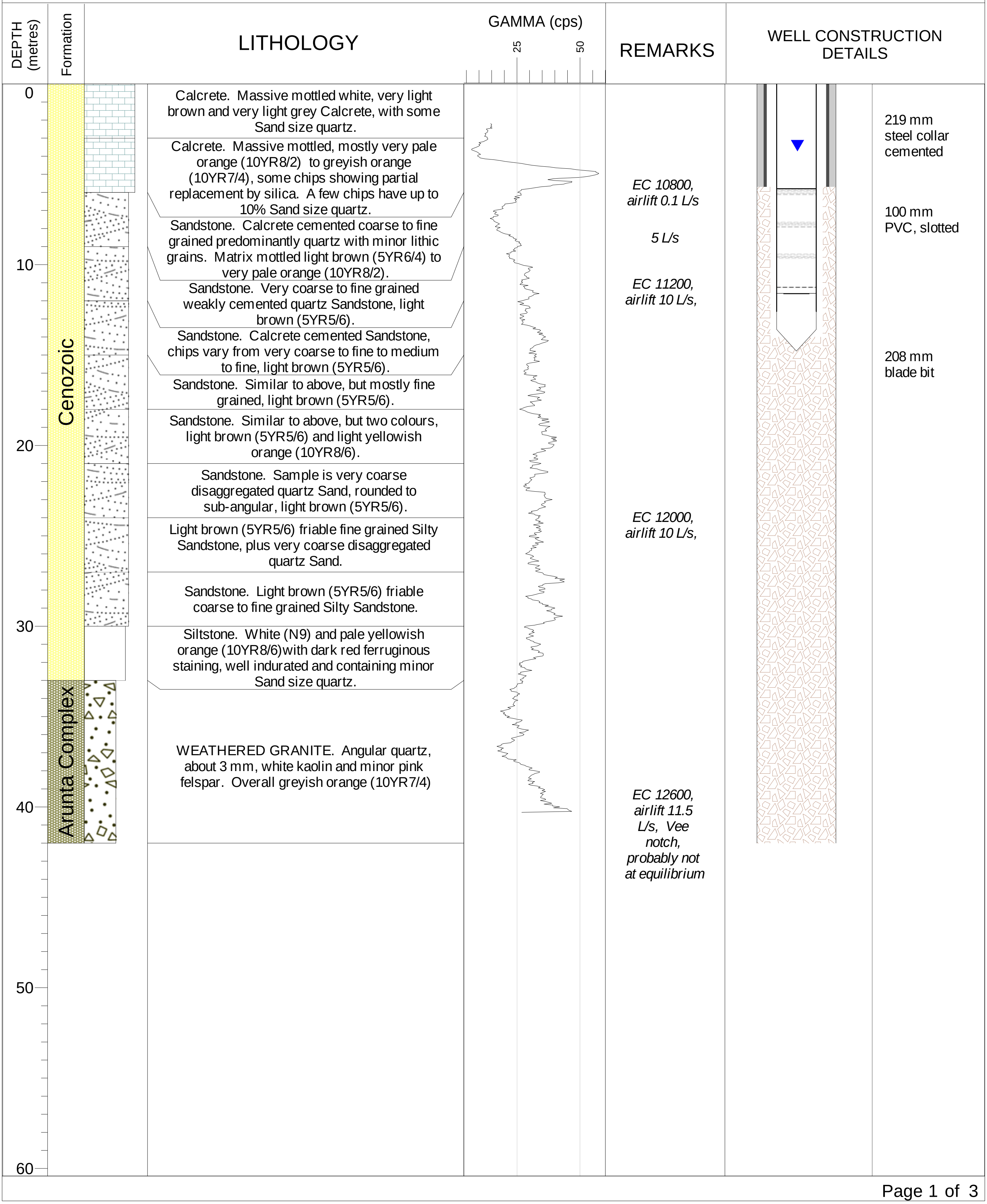
slots, gravel pack & bentonite

Northern Territory Government

Palaeovalley Groundwater Project

RN018783

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*43*	**AIRLIFT SALINITY (μS/cm):**	*12000*
DATE STARTED:	*19.07.2011*	**CONSTRUCTED DEPTH (mBGL):**	*12.7*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7482853*		**DATE COMPLETED:** *20.07.2011*		**CASING HEIGHT (m):** *0.62*	**DRILLER:** *I Mcmasters*
EASTING: WGS 84 Zone 53 *595029*		**ELEVATION:** *440.86*		**STANDING WATER LEVEL (mbgl):** *3.92*	**LOGGED BY:** *R Read*



Calcrete. Massive mottled white, very light brown and very light grey Calcrete, with some Sand size quartz.

Calcrete. Massive mottled, mostly very pale orange (10YR8/2) to greyish orange (10YR7/4), some chips showing partial replacement by silica. A few chips have up to 10% Sand size quartz.

Sandstone. Calcrete cemented coarse to fine grained predominantly quartz with minor lithic grains. Matrix mottled light brown (5YR6/4) to very pale orange (10YR8/2).

Sandstone. Very coarse to fine grained weakly cemented quartz Sandstone, light brown (5YR5/6).

Sandstone. Calcrete cemented Sandstone, chips vary from very coarse to fine to medium to fine, light brown (5YR5/6).

Sandstone. Similar to above, but mostly fine grained, light brown (5YR5/6).

Sandstone. Similar to above, but two colours, light brown (5YR5/6) and light yellowish orange (10YR8/6).

Sandstone. Sample is very coarse disaggregated quartz Sand, rounded to sub-angular, light brown (5YR5/6).

Light brown (5YR5/6) friable fine grained Silty Sandstone, plus very coarse disaggregated quartz Sand.

Sandstone. Light brown (5YR5/6) friable coarse to fine grained Silty Sandstone.

Siltstone. White (N9) and pale yellowish orange (10YR8/6)with dark red ferruginous staining, well indurated and containing minor Sand size quartz.

WEATHERED GRANITE. Angular quartz, about 3 mm, white kaolin and minor pink felspar. Overall greyish orange (10YR7/4)

EC 10800, airlift 0.1 L/s

5 L/s

EC 11200, airlift 10 L/s,

EC 12000, airlift 10 L/s,

EC 12600, airlift 11.5 L/s, Vee notch, probably not at equilibrium

219 mm steel collar cemented

100 mm PVC, slotted

208 mm blade bit

Palaeovalley Groundwater Project

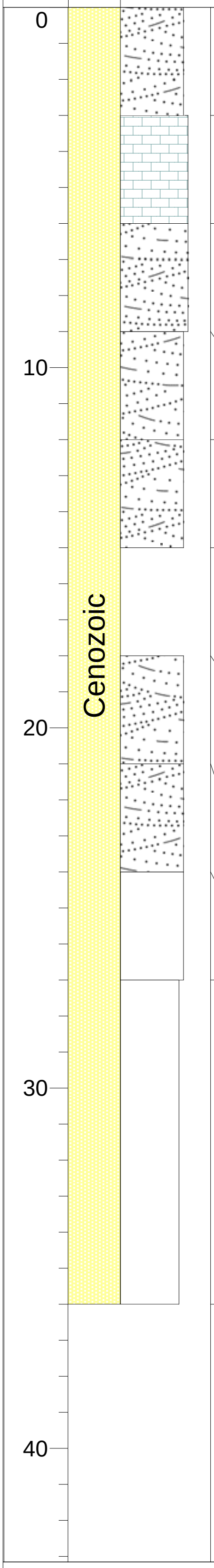
RN018784

Northern Territory Government

LOCATION:	*Nyirripi*	**TOTAL DEPTH (m):**	*36*	**AIRLIFT SALINITY (μS/cm):**	*8900*
DATE STARTED:	*20.07.2011*	**CONSTRUCTED DEPTH (mBGL):**	*18.9*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7481206*	**DATE COMPLETED:** *21.07.2011*		**CASING HEIGHT (m):** *0.42*	
DRILLER:	*I Mcmasters*				
EASTING: WGS 84 Zone 53	*595067*	**ELEVATION:** *441.7*		**STANDING WATER LEVEL (mbgl):** *3.52*	
LOGGED BY:	*R Read*				

DEPTH (metres)

Formation



LITHOLOGY

Sandstone. Soft coarse to fine grained poorly sorted Silty Sandstone, moderate reddish brown (10R4/6).

Calcrete. Massive, moderate orange pink (10R7/4) to greyish orange (10YR7/4).

Calcrete. Massive Calcrete, reddish brown (10R5/4), passing down to Calcrete cemented Sandstone, coarse to fine grained, poorly sorted, greyish orange (10YR7/4), with well rounded quartz pebbles to 5 mm. Also greyish yellow (5YR8/4) Siltstone.

Sandstone. Light brown (5YR5/6) very coarse to fine grained moderately indurated Sandstone.

Sandstone. Coarse disaggregated quartz Sand (driller reports Sand 15 to 16.8), plus Sandstone as above.

Sandstone. Sample mostly disaggregated Sand as above, some chips pale reddish brown (10R5/4) friable moderately well cemented Silty Sandstone. Dominantly medium grained (0.5 mm), ranging fine to very coarse.

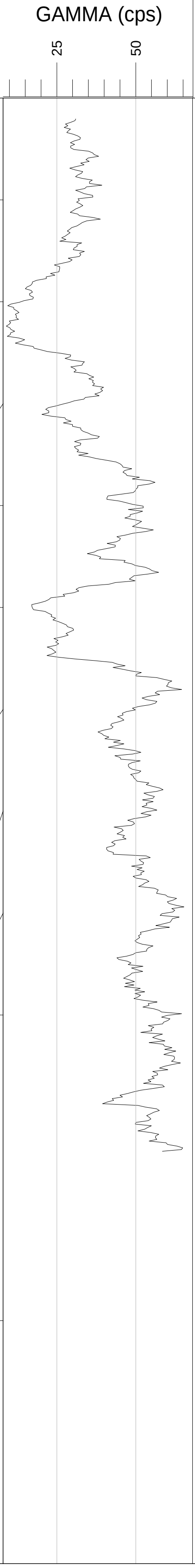
Sandstone. Sample mostly disaggregated Sand as above, some chips moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) friable to well indurated Silty Sandstone. Medium to fine grained, mostly rounded to sub-rounded grains.

Sandstone. Sample mostly disaggregated quartz Sand, plus chips mostly fine grained ranging to coarse friable Silty Sandstone, moderate reddish orange (10R6/6).

Sample mostly as above, plus chips white Siltstone with some Sand size quartz, partly silica cemented.

Siltstone. Sample mixture as large water flow eroding the hole. Disaggregated quartz, reddish orange Sandstone as above, and some chips white Siltstone with fine quartz Sand, grains light grey or light brown and white Silty Sandstone.

GAMMA (cps)



REMARKS

~ 0.1 L/s

1 L/s

EC 8590,
airlift 2 L/s,
bucket

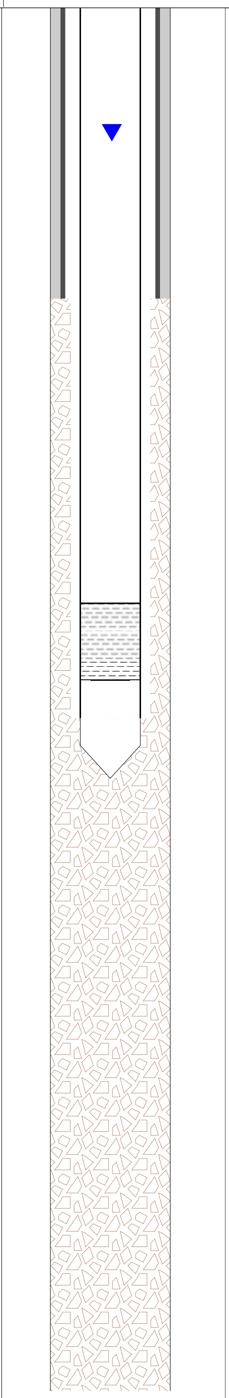
EC 8900,
airlift 5 L/s,
Vee notch

EC 8900,
airlift 10 L/s,
Vee notch

EC 8900,
airlift 17 L/s,
Vee notch

EC 8900,
airlift 17 L/s,
Vee notch

WELL CONSTRUCTION DETAILS



219 mm
steel collar
cemented

100 mm PVC

slots
208 mm drill
bit

Northern Territory Government

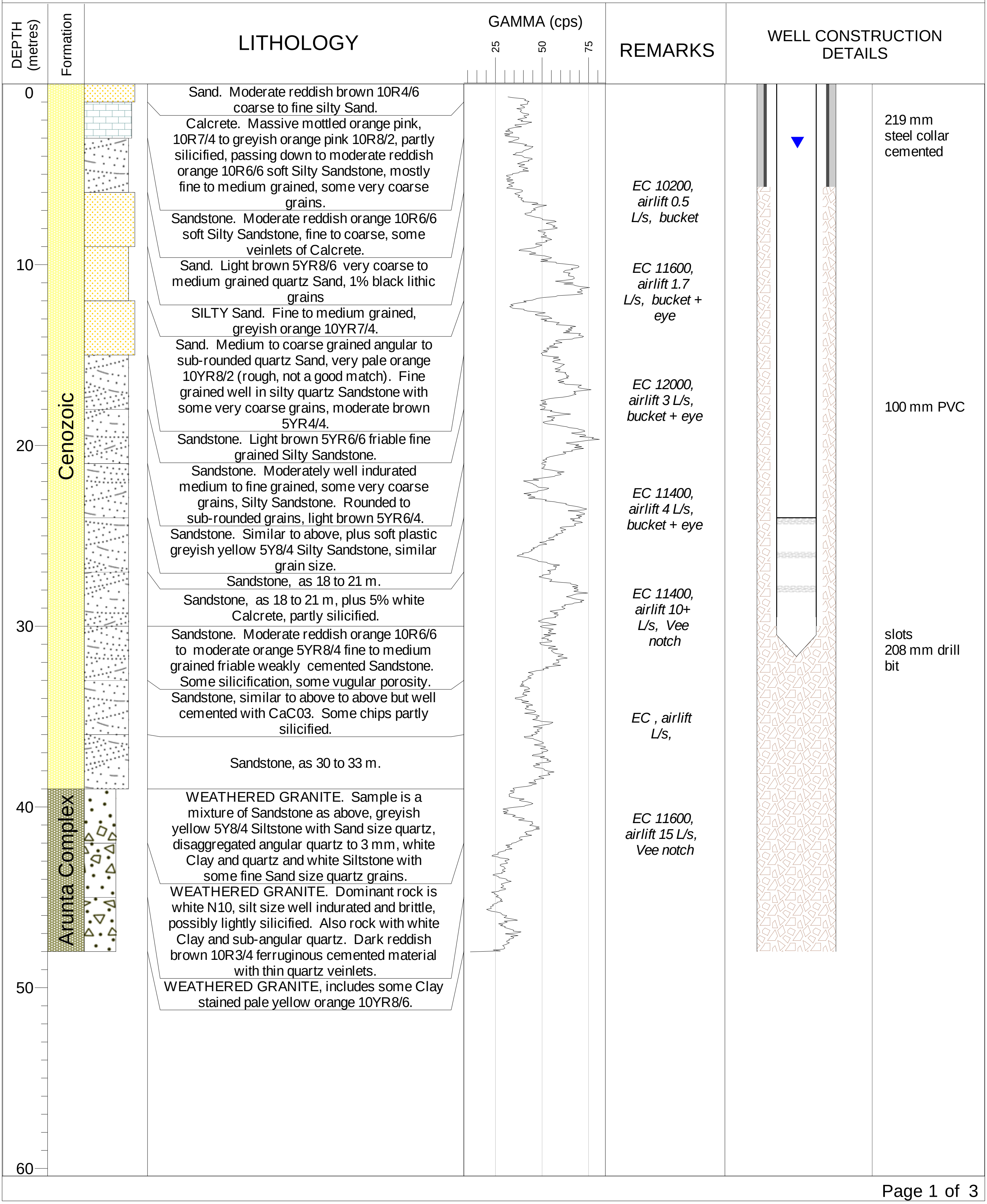
Palaeovalley Groundwater Project RN018785

LOCATION: *Nyirripi*
TOTAL DEPTH (m): *48.3*
AIRLIFT SALINITY (µS/cm): *11700*

DATE STARTED: *21.07.2011*
CONSTRUCTED DEPTH (mBGL): *31.2*
DRILLING RIG: *Ingersol Rand*

NORTHING: *7479192*
WGS 84 Zone 53
DATE COMPLETED: *22.07.2011*
CASING HEIGHT (m): *0.52*
DRILLER: *I Mcmasters*

EASTING: *595090*
WGS 84 Zone 53
ELEVATION: *441.71*
STANDING WATER LEVEL (mbgl): *3.86*
LOGGED BY: *R Read*



LITHOLOGY

Sand. Moderate reddish brown 10R4/6 coarse to fine silty Sand.

Calcrete. Massive mottled orange pink, 10R7/4 to greyish orange pink 10R8/2, partly silicified, passing down to moderate reddish orange 10R6/6 soft Silty Sandstone, mostly fine to medium grained, some very coarse grains.

Sandstone. Moderate reddish orange 10R6/6 soft Silty Sandstone, fine to coarse, some veinlets of Calcrete.

Sand. Light brown 5YR8/6 very coarse to medium grained quartz Sand, 1% black lithic grains

SILTY Sand. Fine to medium grained, greyish orange 10YR7/4.

Sand. Medium to coarse grained angular to sub-rounded quartz Sand, very pale orange 10YR8/2 (rough, not a good match). Fine grained well in silty quartz Sandstone with some very coarse grains, moderate brown 5YR4/4.

Sandstone. Light brown 5YR6/6 friable fine grained Silty Sandstone.

Sandstone. Moderately well indurated medium to fine grained, some very coarse grains, Silty Sandstone. Rounded to sub-rounded grains, light brown 5YR6/4.

Sandstone. Similar to above, plus soft plastic greyish yellow 5Y8/4 Silty Sandstone, similar grain size.

Sandstone, as 18 to 21 m.

Sandstone, as 18 to 21 m, plus 5% white Calcrete, partly silicified.

Sandstone. Moderate reddish orange 10R6/6 to moderate orange 5YR8/4 fine to medium grained friable weakly cemented Sandstone. Some silicification, some vugular porosity.

Sandstone, similar to above but well cemented with CaC03. Some chips partly silicified.

Sandstone, as 30 to 33 m.

WEATHERED GRANITE. Sample is a mixture of Sandstone as above, greyish yellow 5Y8/4 Siltstone with Sand size quartz, disaggregated angular quartz to 3 mm, white Clay and quartz and white Siltstone with some fine Sand size quartz grains.

WEATHERED GRANITE. Dominant rock is white N10, silt size well indurated and brittle, possibly lightly silicified. Also rock with white Clay and sub-angular quartz. Dark reddish brown 10R3/4 ferruginous cemented material with thin quartz veinlets.

WEATHERED GRANITE, includes some Clay stained pale yellow orange 10YR8/6.

REMARKS

EC 10200, airlift 0.5 L/s, bucket

EC 11600, airlift 1.7 L/s, bucket + eye

EC 12000, airlift 3 L/s, bucket + eye

EC 11400, airlift 4 L/s, bucket + eye

EC 11400, airlift 10+ L/s, Vee notch

EC , airlift L/s,

EC 11600, airlift 15 L/s, Vee notch

WELL CONSTRUCTION DETAILS

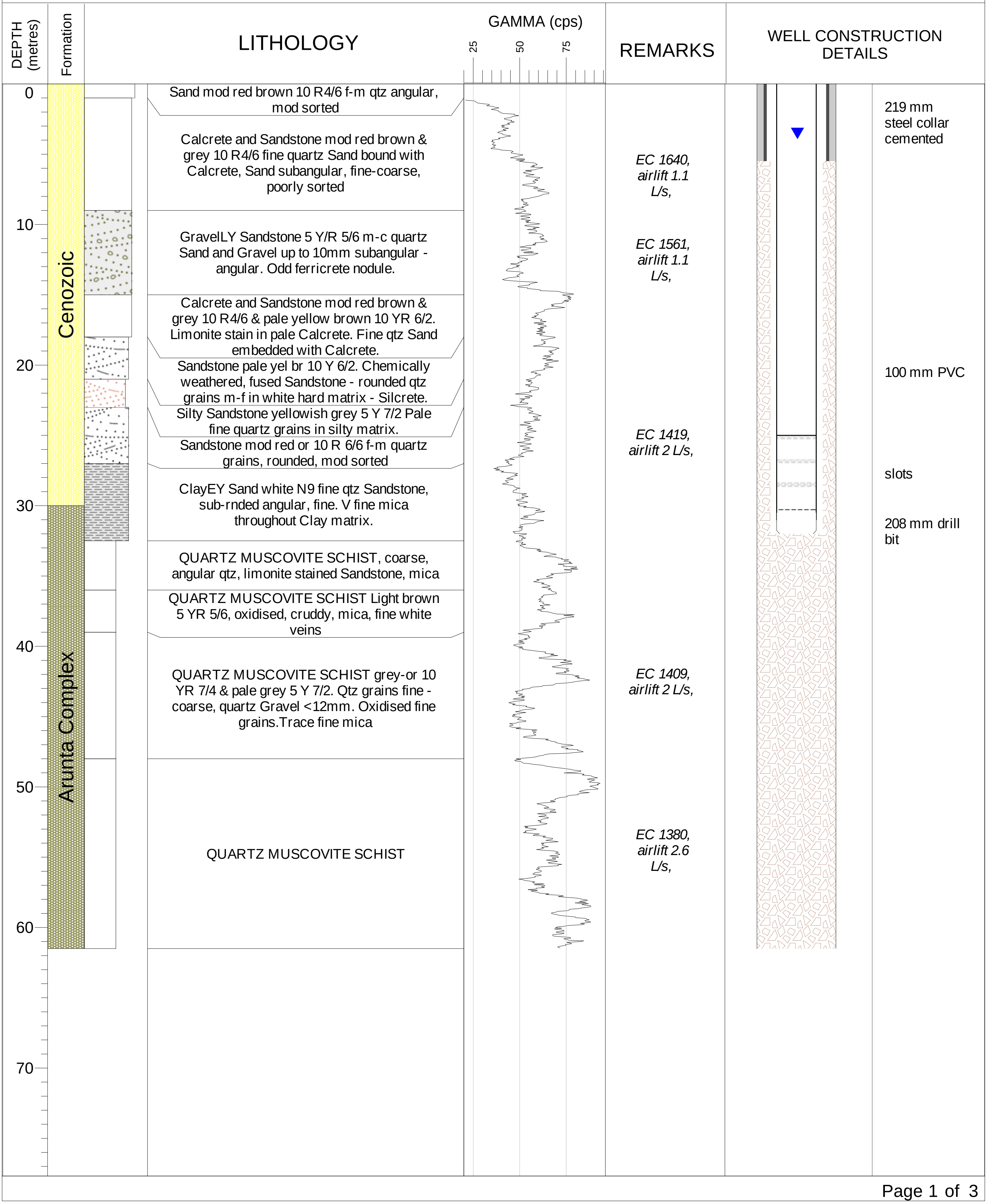
219 mm steel collar cemented

100 mm PVC

slots
208 mm drill bit

Palaeovalley Groundwater Project RN018786

LOCATION: *Nyirripi*
TOTAL DEPTH (m): *61.5*
AIRLIFT SALINITY (µS/cm): *1380*
DATE STARTED: *25.07.2011*
CONSTRUCTED DEPTH (mBGL): *31.7*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7462159*
DATE COMPLETED: *26.07.2011*
CASING HEIGHT (m): *0.41*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *621410*
ELEVATION: *0*
STANDING WATER LEVEL (mbgl): *3.52*
LOGGED BY: *M Woodgate*



Sand mod red brown 10 R4/6 f-m qtz angular, mod sorted

Calcrete and Sandstone mod red brown & grey 10 R4/6 fine quartz Sand bound with Calcrete, Sand subangular, fine-coarse, poorly sorted

GravelLY Sandstone 5 Y/R 5/6 m-c quartz Sand and Gravel up to 10mm subangular - angular. Odd ferricrete nodule.

Calcrete and Sandstone mod red brown & grey 10 R4/6 & pale yellow brown 10 YR 6/2. Limonite stain in pale Calcrete. Fine qtz Sand embedded with Calcrete.

Sandstone pale yel br 10 Y 6/2. Chemically weathered, fused Sandstone - rounded qtz grains m-f in white hard matrix - Silcrete.

Silty Sandstone yellowish grey 5 Y 7/2 Pale fine quartz grains in silty matrix.

Sandstone mod red or 10 R 6/6 f-m quartz grains, rounded, mod sorted

ClayEY Sand white N9 fine qtz Sandstone, sub-rnded angular, fine. V fine mica throughout Clay matrix.

QUARTZ MUSCOVITE SCHIST, coarse, angular qtz, limonite stained Sandstone, mica

QUARTZ MUSCOVITE SCHIST Light brown 5 YR 5/6, oxidised, cruddy, mica, fine white veins

QUARTZ MUSCOVITE SCHIST grey-or 10 YR 7/4 & pale grey 5 Y 7/2. Qtz grains fine - coarse, quartz Gravel <12mm. Oxidised fine grains.Trace fine mica

QUARTZ MUSCOVITE SCHIST

EC 1640, airlift 1.1 L/s,

EC 1561, airlift 1.1 L/s,

EC 1419, airlift 2 L/s,

EC 1409, airlift 2 L/s,

EC 1380, airlift 2.6 L/s,

219 mm steel collar cemented

100 mm PVC

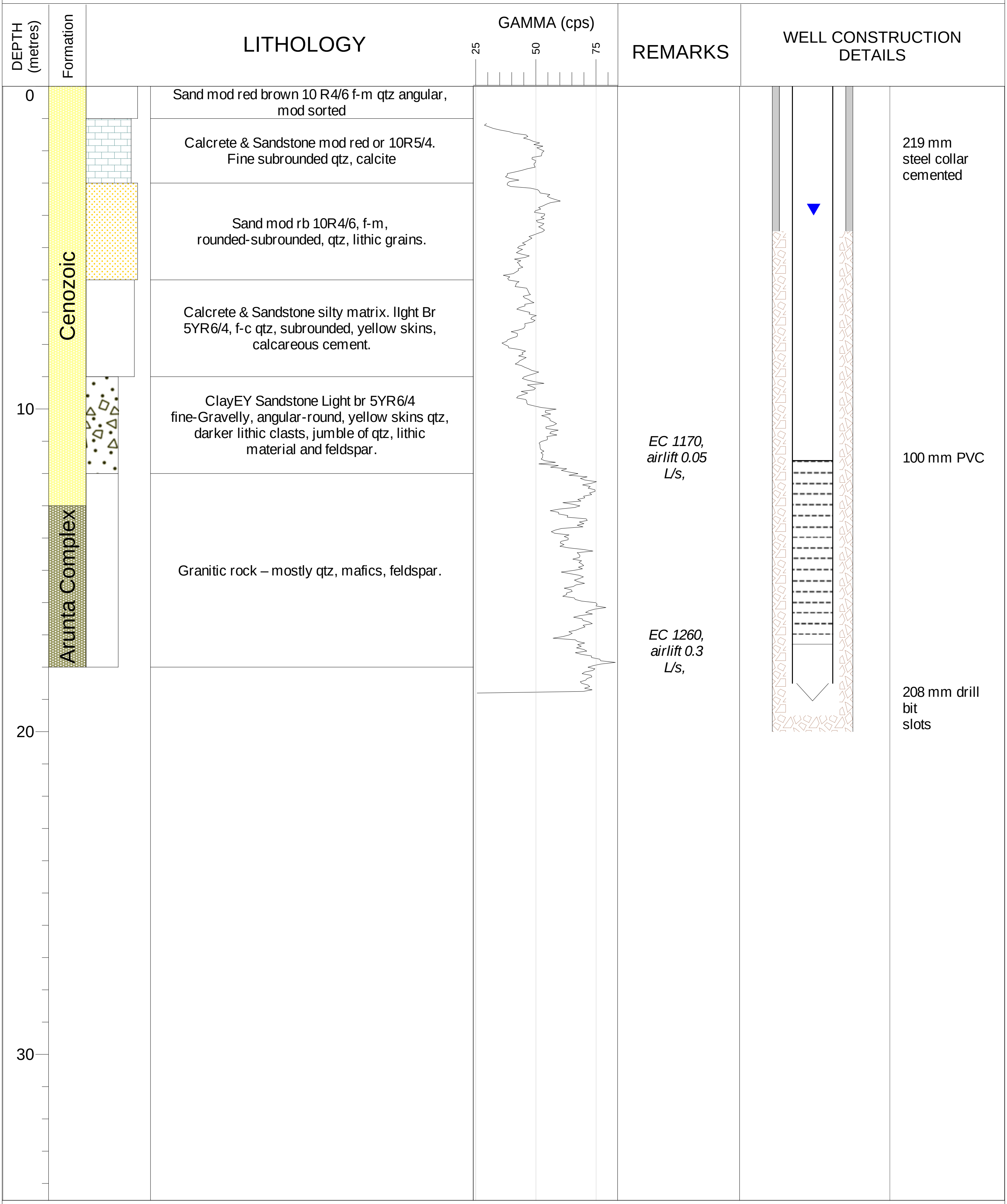
slots

208 mm drill bit

Palaeovalley Groundwater Project

RN018787

LOCATION: *Nyirripi*
TOTAL DEPTH (m): *18*
AIRLIFT SALINITY (μS/cm): *1260*
DATE STARTED: *26.07.2011*
CONSTRUCTED DEPTH (mBGL): *18.52*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7461759*
DATE COMPLETED: *27.07.2011*
CASING HEIGHT (m): *0.41*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *621418*
ELEVATION: *0*
STANDING WATER LEVEL (mbgl): *3.82*
LOGGED BY: *M Woodgate*



Sand mod red brown 10 R4/6 f-m qtz angular, mod sorted

Calcrete & Sandstone mod red or 10R5/4. Fine subrounded qtz, calcite

Sand mod rb 10R4/6, f-m, rounded-subrounded, qtz, lithic grains.

Calcrete & Sandstone silty matrix. lIght Br 5YR6/4, f-c qtz, subrounded, yellow skins, calcareous cement.

ClayEY Sandstone Light br 5YR6/4 fine-Gravelly, angular-round, yellow skins qtz, darker lithic clasts, jumble of qtz, lithic material and feldspar.

Granitic rock – mostly qtz, mafics, feldspar.

EC 1170, airlift 0.05 L/s,

EC 1260, airlift 0.3 L/s,

219 mm steel collar cemented

100 mm PVC

208 mm drill bit slots

Northern Territory Government

Palaeovalley Groundwater Project RN018788

LOCATION: *Nyirripi*

TOTAL DEPTH (m): *31*

AIRLIFT SALINITY (μS/cm): *4660*

DATE STARTED: *28.07.2011*

CONSTRUCTED DEPTH (mBGL): *30.5*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7468935*
WGS 84 Zone 53

DATE COMPLETED: *28.07.2011*

CASING HEIGHT (m): *0.4*

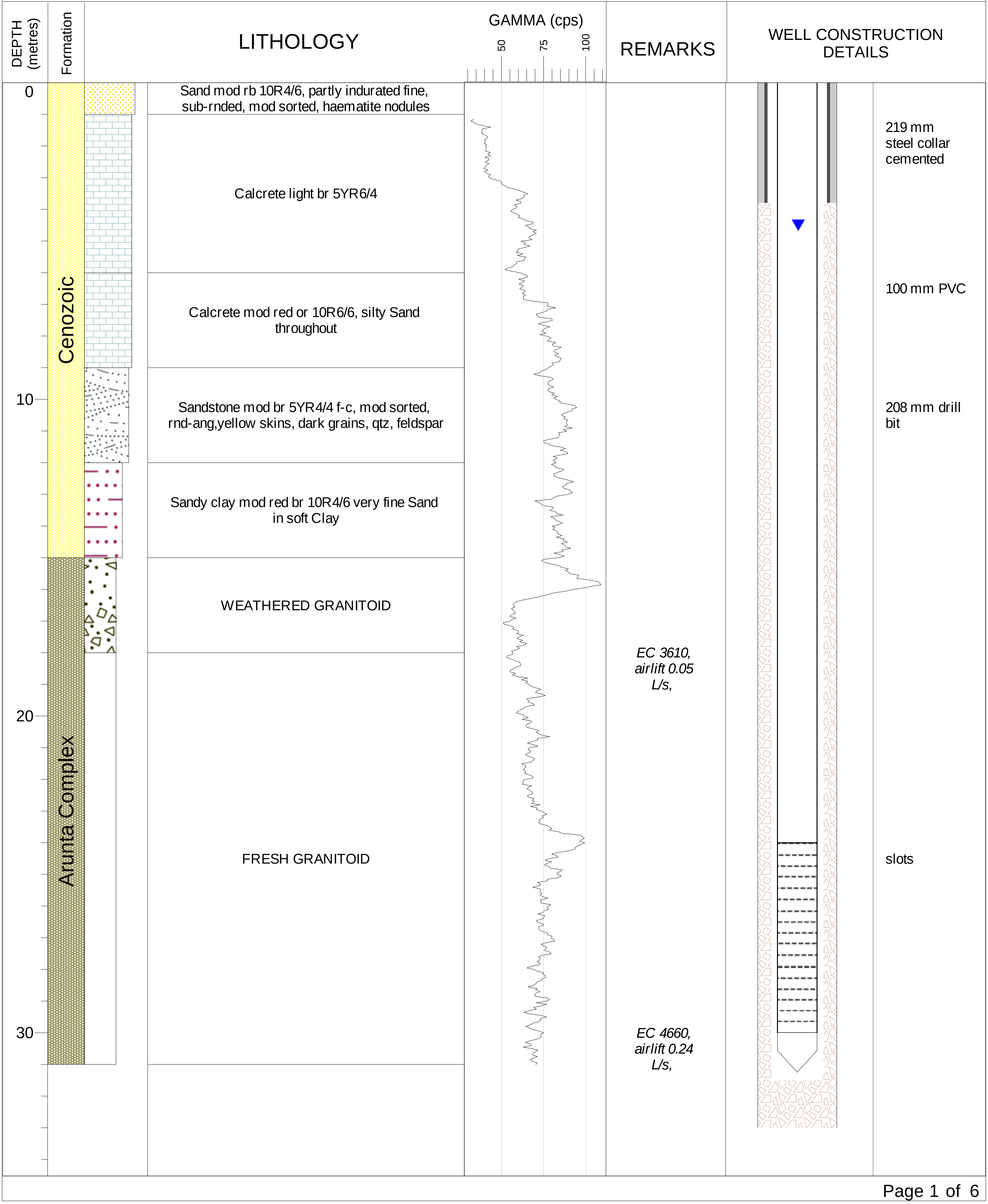
DRILLER: *I Mcmasters*

EASTING: *577019*
WGS 84 Zone 53

ELEVATION: *0*

STANDING WATER LEVEL (mbgl): *4.5*

LOGGED BY: *M Woodgate*



LITHOLOGY

Sand mod rb 10R4/6, partly indurated fine, sub-rnded, mod sorted, haematite nodules

Calcrete light br 5YR6/4

Calcrete mod red or 10R6/6, silty Sand throughout

Sandstone mod br 5YR4/4 f-c, mod sorted, rnd-ang,yellow skins, dark grains, qtz, feldspar

Sandy clay mod red br 10R4/6 very fine Sand in soft Clay

WEATHERED GRANITOID

FRESH GRANITOID

REMARKS

EC 3610, airlift 0.05 L/s,

EC 4660, airlift 0.24 L/s,

WELL CONSTRUCTION DETAILS

219 mm steel collar cemented

100 mm PVC

208 mm drill bit

slots

Appendix 2 – Hydrogeochemical data for the Wilkinkarra Palaeovalley

This appendix contains the laboratory analytical data for groundwater samples collected from the Wilkinkarra Palaeovalley. Chemical constituents that exceed Australian Drinking Water Quality Guideline limits (shown in blue in the lower-most row of each table) are highlighted in red.

Table A2.1: Hydrogeochemical data for bores in the Wilkinkarra Palaeovalley.

Bore & sample depth	Sampling date	pH	EC	Alk.	CO_3	HCO_3	OH	TSS	TDS	NO_2_N	NO_2	NO_3	Cl	PO_4	NH_3
		units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
RN18358_6	24/09/2009	7.4	8,110	560	<1	560	<1	240	4970	0.01	0.04	79.1	2,340	0.02	0.05
RN18358_126	24/09/2009	7.6	7,340	402	<1	402	<1	60	4510	0.04	0.14	82.8	2,160	0.015	0.43
RN18359_6	28/09/2009	7.5	8,660	589	<1	589	<1	600	5410	0.285	0.94	81.3	2,540	0.015	0.085
RN18359_170	29/09/2009	7.6	9,220	438	<1	438	<1	220	5730	<0.005	<0.02	74.7	2,800	0.015	0.855
RN18360_54	3/10/2009	8.1	7,900	444	<1	444	<1	130	4890	0.015	0.04	79.6	2,350	0.01	0.165
RN18361_7.4	3/10/2009	7.9	5,320	491	<1	491	<1	270	3340	0.095	0.3	127	1,350	0.015	0.06
RN18361_103	3/10/2009	7.9	6,660	376	<1	376	<1	320	4100	0.04	0.12	96.7	1,920	0.01	0.18
RN18362_18.2	5/10/2009	7.9	1,170	342	<1	342	<1	330	760	0.03	0.1	67.8	122	0.015	0.065
RN18362_79.2	5/10/2009	7.8	1,050	279	<1	279	<1	50	660	0.015	0.04	70.4	114	0.015	0.06
RN18579_12.2	6/10/2009	7.4	1,010	246	<1	246	<1	30	660	0.035	0.12	76.4	117	0.015	0.055
RN18579_85.4	6/10/2009	7.5	922	222	<1	222	<1	110	620	0.01	0.02	72.3	103	0.015	0.34
RN18782SHALLOW	16/07/2011	7.7	19,900	549	<1	549	<1	690	11600	0.01	0.02	39.5	5,580	0.055	0.06
RN18782DEEP	18/08/2011	8.1	18,400	495	<1	495	<1	340	10300	0.015	0.04	44.4	5,050	0.055	0.005
RN18783	20/07/2011	8.1	12,500	484	<1	484	<1	190	6850	0.01	0.04	57	3,380	0.055	<0.005
RN18784	22/07/2011	8.3	8,610	572	<1	572	<1	720	4560	0.03	0.1	75.4	2,350	0.055	0.01
RN18785	23/07/2011	8.4	11,900	407	9	398	<1	120	6520	0.01	0.04	89	2,980	0.055	<0.005
RN18786	26/07/2011	8.3	1,300	288	<1	287	<1	130	790	0.01	0.04	71.3	148	0.045	<0.005
RN18787	27/07/2011	8.4	1,180	320	2	318	<1	100	720	0.005	<0.02	62.6	114	0.04	<0.005
RN18788	28/07/2011	8.3	4,850	302	2	301	<1	160	2590	<0.005	<0.02	39.5	1,060	0.03	<0.005
Drinking water guidelines*										0.9		50			

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Table A2.1 (cont…): Hydrogeochemical data for bores in the Wilkinkarra Palaeovalley.

Bore ID & sample depth	F	Hardness	Ca	K	Mg	Na	SiO_2	SO_4	Ag	Al	As	B	Ba	Be	Br	Cd
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN18358_6	1.8	856	176	89.8	101	1,470	86.4	612	<10	4,920	1.5	880	50	<1	4,020	<0.2
RN18358_126	1.5	751	154	79.2	88.9	1,350	73.2	543	<10	260	<0.5	780	<50	<1	3,720	<0.2
RN18359_6	1.5	802	176	85.4	87.7	1,650	79	667	<10	640	1	900	<50	<1	4,360	<0.2
RN18359_170	1.3	886	190	86	100	1,740	66	675	<10	2,140	1.5	840	<50	<1	4,660	<0.2
RN18360_54	1.8	913	172	93.3	118	1,400	51.6	594	<10	40	<0.5	860	50	<1	4,560	<0.2
RN18361_7.4	2.3	669	83.1	135	112	890	83.2	571	<10	6,520	1.5	1,320	200	<1	5,080	<0.2
RN18361_103	1.9	753	120	115	110	1,160	56	571	<10	40	<0.5	1,060	<50	<1	4,740	<0.2
RN18362_18.2	2.2	200	38	36.9	25.4	164	90.6	82.8	<10	>LWR	1.5	500	100	<1	982	<0.2
RN18362_79.2	0.9	234	55.2	26.8	23.3	126	81	72.6	<10	140	0.5	340	<50	<1	824	<0.2
RN18579_12.2	1.3	222	49	28.6	24.3	116	80	72.7	<10	1,060	0.5	360	<50	<1	808	<0.2
RN18579_85.4	1.1	210	51.8	23.6	19.7	105	73.8	68.9	<10	60	0.5	320	<50	<1	688	<0.2
RN18782_SHALLOW	3.1	1,610	280	169	220	3,840	90.4	1590	<10	9,100	2	1,540	100	<2	10,700	<0.8
RN18782_DEEP	3.8	1,400	256	146	184	3,440	85.4	1360	<10	9,700	<2	1,520	<50	<2	9,710	<0.8
RN18783	3.1	969	180	109	126	2,300	89.6	920	<10	7,000	2.5	1,240	<50	<2	6,860	<0.8
RN18784	2.9	559	83.7	91.4	85.1	1,540	96.6	635	<10	>LWR	3	1,020	50	<1	4,990	<0.2
RN18785	1.6	945	140	158	145	2,060	77	1,130	<10	4,080	<2	1,860	<50	<2	9,370	<0.8
RN18786	1.3	296	70.5	34	29.1	130	86	90.3	<10	8,120	<0.5	420	50	<1	1,040	<0.2
RN18787	1.3	287	70.6	32.5	26.9	115	85.6	78.5	<10	4,180	<0.5	400	100	<1	774	<0.2
RN18788	1.3	896	166	77.6	117	581	54.6	496	<10	5,940	0.5	1,180	100	<1	4,860	<0.2
Drinking water guidelines	1.5								100		7.0	4,000	700			

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Table A2.1 (cont…): Hydrogeochemical data for bores in the Wilkinkarra Palaeovalley.

Bore ID & sample depth	**Cr**	**Cu**	**Fe**	**Hg**	**I**	**Mn**	**Mo**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**U**	**Zn**
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN18358_6	10	<10	5,180	<0.8	490	120	10	12	2	<2	<8	<10	44.9	<10
RN18358_126	5	<10	5,340	<0.8	580	45	<5	2	8	<2	14	<10	44	<10
RN18359_6	<5	<10	920	<0.8	550	15	<5	<2	15	<2	17	<10	41.1	<10
RN18359_170	15	<10	7,380	<0.1	460	190	<5	6	4	0.6	20	<10	32.5	10
RN18360_54	<5	<10	2,640	<0.8	920	35	<5	<2	<1	<2	18	<10	28.5	<10
RN18361_7.4	<5	<10	2,160	<0.1	140	10	<5	2	4	<0.2	4	<10	5.54	<10
RN18361_103	<5	<10	2,840	<0.1	110	110	5	4	1	<0.2	4	<10	6.13	10
RN18362_18.2	<5	<10	2,820	<0.1	430	145	15	6	1	<0.2	2	<10	43.7	10
RN18362_79.2	10	<10	5,180	<0.8	490	120	10	12	2	<2	<8	<10	44.9	<10
RN18579_12.2	5	<10	5,340	<0.8	580	45	<5	2	8	<2	14	<10	44	<10
RN18579_85.4	<5	<10	920	<0.8	550	15	<5	<2	15	<2	17	<10	41.1	<10
Drinking water guidelines	50	2,000		1	100	500	50	20	10		10		20	-

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Appendix 3 – Bore logs for the Kintore Palaeovalley

This appendix contains copies of completed bore logs drilled as part of investigations for the *Palaeovalley Groundwater Project* in the Kintore Palaeovalley. These include the following bores:

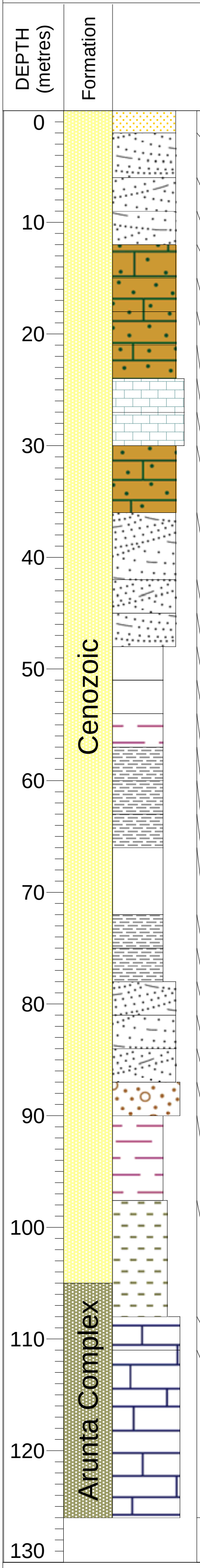
1. RN18580
2. RN18581
3. RN18582
4. RN18583
5. RN18584
6. RN18585
7. RN18586
8. RN18794
9. RN18810
10. RN18811
11. RN18812
12. RN18813
13. RN18814

Palaeovalley Groundwater Project

RN018580

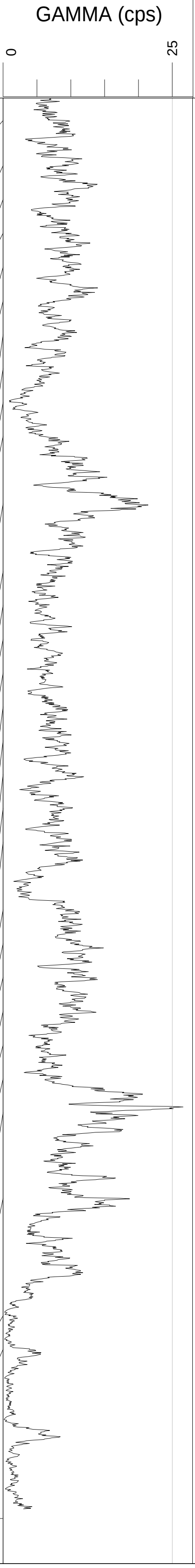
Northern Territory Government

LOCATION: *Kintore*
TOTAL DEPTH (m): *125.9*
AIRLIFT SALINITY (µS/cm): *3459*
DATE STARTED: *21.10.2009*
CONSTRUCTED DEPTH (mBGL): *83.4*
DRILLING RIG: *Ingersol Rand*
NORTHING: *7435542* WGS 84 Zone 53
DATE COMPLETED: *29.10.2009*
CASING HEIGHT (m): *0.55*
DRILLER: *I Mcmasters*
EASTING: *527735* WGS 84 Zone 53
ELEVATION: *425.4*
STANDING WATER LEVEL (mbgl): *6.14*
LOGGED BY: *M Woodgate*



LITHOLOGY

- Sand moderate reddish brown. Fine-coarse, sub angular-subrounded
- Sandstone greyish orange, Fine-coarse, sub-rndd – rndd, friable, iron stained, mod sorted.
- Sandstone Light brown, fine, friable, sub-angular-subrnded. 10% Clay
- a/a with qtz Gravel ~5%.
- Sandstone Light brown, Calcrete ~50%, massive with some minor clasts of white xstalline Calcrete/Silcrete.
- a/a w. less Clay and more Calcrete. Calcrete and Sandstone appear indurated.
- Sandstone & Calcrete Light brown, weathered, oxidized. Fine-coarse quartz Sandstone, poorly sorted, subrnded to subang.
- Sandstone & Calcrete ~50/50.
- Calcrete Pale olive
- Calcrete Very light grey, partly silicified.
- Sandy claySTONE and Sandstone interbedded. ClaySTONE yellowish grey . Sandstone dark yellowish orange Fine qtz Sandstone, subrndded, well sorted. Friable.
- Sandstone – yellowish grey, Clay matrix (greywacke?). Fine to medium qtz grains subrndded. Purple ClaySTONE fragments.
- a/a Purple ClaySTONE component increasing downhole.
- a/a 20% purple ClaySTONE, crumbly
- ClaySTONE very dusky red purple, some colour variation. Microfractured.
- 60% ClaySTONE Light grey 40% ClaySTONE multicoloured, predom purple, some light brown.
- 30% ClaySTONE light grey 70% ClaySTONE purple. Penetration slow.
- Clay dark purple mottled slightly with dark grey. Soft. Poor sample return.
- a/a Poor sample return
- Clay pale red . Bands of ClaySTONE – medium grey
- a/a Clay, ClaySTONE 50/50.
- Clay very light grey.
- a/a Clay very sticky
- Sandstone very light grey, Fine qtz Sand, 30% Clay a/a. very friable Sandstone
- a/a less Clay
- Sandstone yellowish grey, med qtz, subrounded, well sorted.
- Gravel Light - med grey. Qtz, subangular-subrounded. Poorly sorted up to 15mm rounded pebbles.
- Sandy claySTONE. White, cemented, dull and powdery, ~30% subrounded fine qtz grains in white Clay matrix.
- SHALE & QUARTZ Light to dark grey. Finely laminated in places. Trace pyrite. Microcrystalline/ siliceous in places.
- LIMESTONE medium – dark grey, microcrystalline, fine veins filled with white qtz.
- LIMESTONE Medium dark grey – crystalline with some dark grey 'bands'. Some finer lamination – light grey to medium grey. Hard drilling with some fractured sections (drillers). Pyrite (gold), calcite & qtz vein infill.



REMARKS

SWL 6.09 mBGL Damp

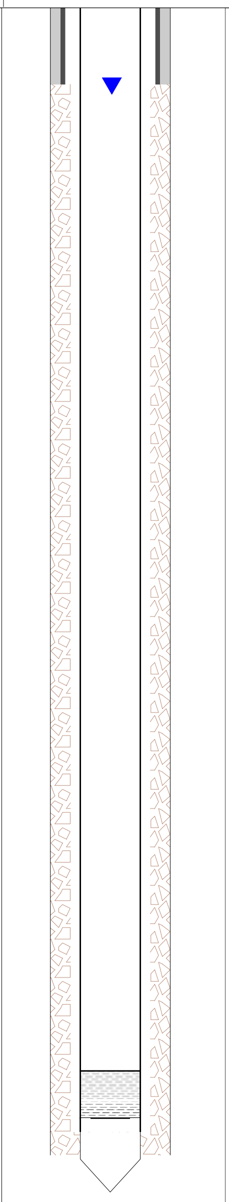
Water intersection, 0.1 L/s, EC 1859 uS/cm

EC 2,790 uS/cm

Airlift 8 L/s, EC 6,330 uS/cm

Completion yield 2.5 L/s

WELL CONSTRUCTION DETAILS



203.2mm steel casing

158mm steel casing

114mm 0.5mm steel screen

backfill

end of hole

Northern Territory Government

Palaeovalley Groundwater Project

RN018581

LOCATION: *Kintore*

TOTAL DEPTH (m): *84.7*

AIRLIFT SALINITY (µS/cm): *950*

DATE STARTED: *30.10.2009*

CONSTRUCTED DEPTH (mBGL): *51.5*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7429403*
WGS 84 Zone 53

DATE COMPLETED: *3.11.2009*

CASING HEIGHT (m): *0.53*

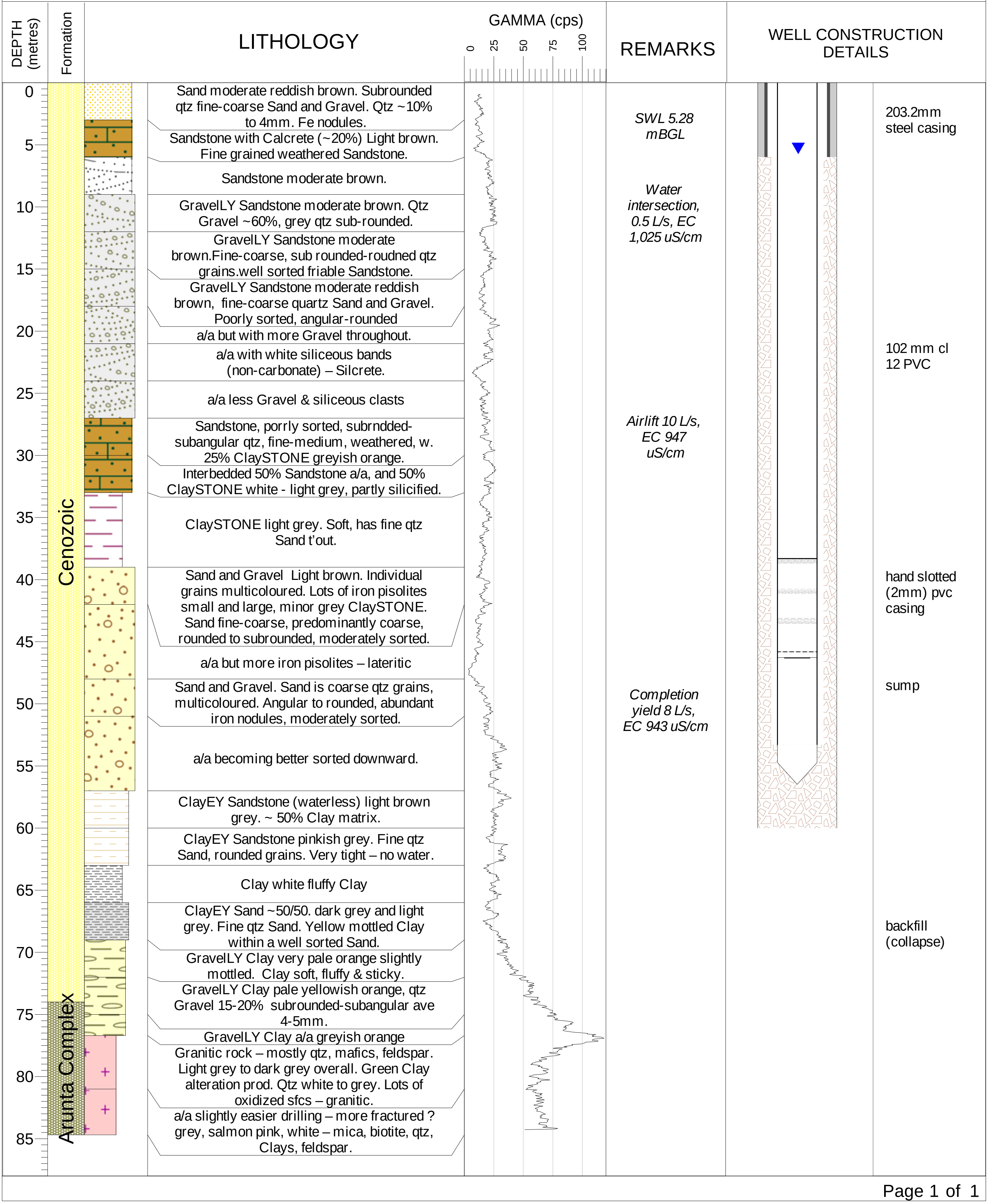
DRILLER: *I Mcmasters*

EASTING: *528681*
WGS 84 Zone 53

ELEVATION: *431.3*

STANDING WATER LEVEL (mbgl): *5.28*

LOGGED BY: *M Woodgate*



LITHOLOGY

Sand moderate reddish brown. Subrounded qtz fine-coarse Sand and Gravel. Qtz ~10% to 4mm. Fe nodules.

Sandstone with Calcrete (~20%) Light brown. Fine grained weathered Sandstone.

Sandstone moderate brown.

GravelLY Sandstone moderate brown. Qtz Gravel ~60%, grey qtz sub-rounded.

GravelLY Sandstone moderate brown.Fine-coarse, sub rounded-roudned qtz grains.well sorted friable Sandstone.

GravelLY Sandstone moderate reddish brown, fine-coarse quartz Sand and Gravel. Poorly sorted, angular-rounded

a/a but with more Gravel throughout.

a/a with white siliceous bands (non-carbonate) – Silcrete.

a/a less Gravel & siliceous clasts

Sandstone, porrly sorted, subrndded-subangular qtz, fine-medium, weathered, w. 25% ClaySTONE greyish orange.

Interbedded 50% Sandstone a/a, and 50% ClaySTONE white - light grey, partly silicified.

ClaySTONE light grey. Soft, has fine qtz Sand t'out.

Sand and Gravel Light brown. Individual grains multicoloured. Lots of iron pisolites small and large, minor grey ClaySTONE. Sand fine-coarse, predominantly coarse, rounded to subrounded, moderately sorted.

a/a but more iron pisolites – lateritic

Sand and Gravel. Sand is coarse qtz grains, multicoloured. Angular to rounded, abundant iron nodules, moderately sorted.

a/a becoming better sorted downward.

ClayEY Sandstone (waterless) light brown grey. ~ 50% Clay matrix.

ClayEY Sandstone pinkish grey. Fine qtz Sand, rounded grains. Very tight – no water.

Clay white fluffy Clay

ClayEY Sand ~50/50. dark grey and light grey. Fine qtz Sand. Yellow mottled Clay within a well sorted Sand.

GravelLY Clay very pale orange slightly mottled. Clay soft, fluffy & sticky.

GravelLY Clay pale yellowish orange, qtz Gravel 15-20% subrounded-subangular ave 4-5mm.

GravelLY Clay a/a greyish orange

Granitic rock – mostly qtz, mafics, feldspar. Light grey to dark grey overall. Green Clay alteration prod. Qtz white to grey. Lots of oxidized sfcs – granitic.

a/a slightly easier drilling – more fractured ? grey, salmon pink, white – mica, biotite, qtz, Clays, feldspar.

REMARKS

SWL 5.28 mBGL

Water intersection, 0.5 L/s, EC 1,025 uS/cm

Airlift 10 L/s, EC 947 uS/cm

Completion yield 8 L/s, EC 943 uS/cm

WELL CONSTRUCTION DETAILS

203.2mm steel casing

102 mm cl 12 PVC

hand slotted (2mm) pvc casing

sump

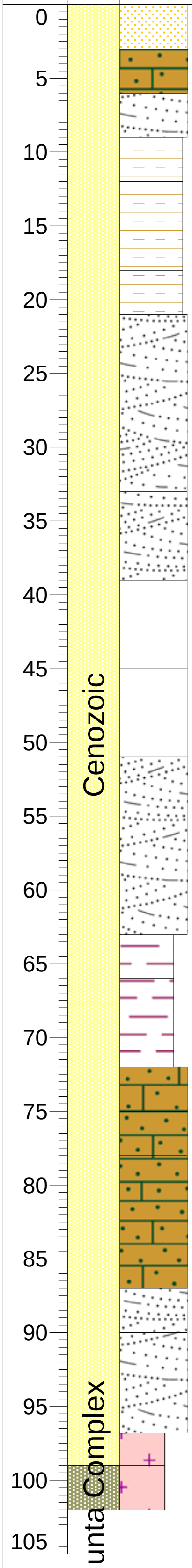
backfill (collapse)

Palaeovalley Groundwater Project

RN018582

LOCATION: Kintore	**TOTAL DEPTH (m):** 102	**AIRLIFT SALINITY (µS/cm):** 650	
DATE STARTED: 4.11.2009	**CONSTRUCTED DEPTH (mBGL):** 97	**DRILLING RIG:** Ingersol Rand	
NORTHING: WGS 84 Zone 53 7428756	**DATE COMPLETED:** 5.11.2009	**CASING HEIGHT (m):** 0.41	**DRILLER:** I Mcmasters
EASTING: WGS 84 Zone 53 530967	**ELEVATION:** 434.4	**STANDING WATER LEVEL (mbgl):** 5.82	**LOGGED BY:** M Woodgate

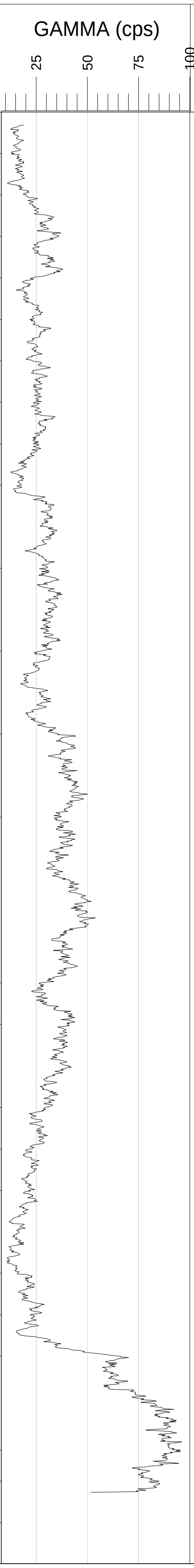
DEPTH (metres) | Formation



LITHOLOGY

Sand moderate reddish brown . Fine-medium quartz.
Sandstone & Calcrete Light brown, fine grained, very weathered.
Sandstone moderate red brown, trace qtz Gravel, fine well sorted, weathered..
ClayEY Sandstone light brown Sand grains fine, abundant mica.
a/a but medium – coarse.
ClayEY Sandstone moderate reddish brown
a/a less Clay, ironstone chips
Sandstone moderate reddish brown fine-med, moderately sorted, subrounded
a/a lots dark grey patches - haematite
a/a coarser grains
a/a dark reddish brown
GravelLY Sandstone (50%) & ClaySTONE (50%). Moderate yellowish brown.
a/a Sandstone – fine, mod sorted, moderate reddish brown, ClaySTONE light grey. 10% quartz Gravel.
Sandstone moderate reddish brown
ClaySTONE very light grey
ClaySTONE light grey ~30% oxidized sfcs, yellow, red, purple stains. Microfracturing – no qtz.
ClaySTONE 50%, interbedded with Sandstone, moderate red brown
a/a with more Gravel beds within the Sandstone
a/a interbedded red brown Sandstone and light grey ClaySTONE.
a/a with qtz Gravel subangular, less ClaySTONE
Sandstone greyish orange, fine-med qtz grains, subrounded, moderately sorted.
a/a increasing qtz Gravel to 5mm diameter. Also 20% light grey brown Clay.
Weathered xstalline basement. Fractured, lots quartz, lots oxidized sfcs, minor mafics.
Fresh granitoid basement, quartz, biotite, muscovite.

GAMMA (cps)



REMARKS

SWL 5.49 mBGL

Seepage

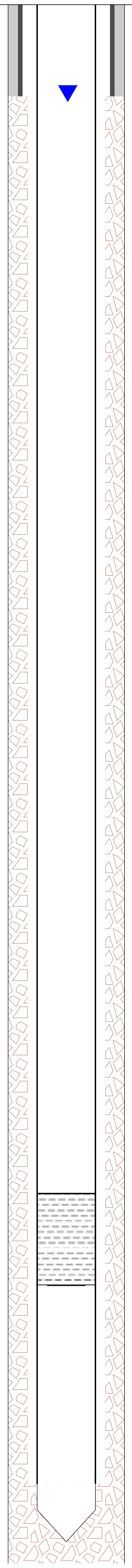
Water intersection, 0.1 L/s, EC 647 uS/cm

Airlift 0.5 L/s, EC 640 uS/cm

Completion yield 10 L/s, 690 uS/cm

Airlift 9.5 L/s, EC 687 uS/cm

WELL CONSTRUCTION DETAILS



203.2mm steel casing

102 mm cl 12 PVC

hand slotted (2mm) pvc casing

sump

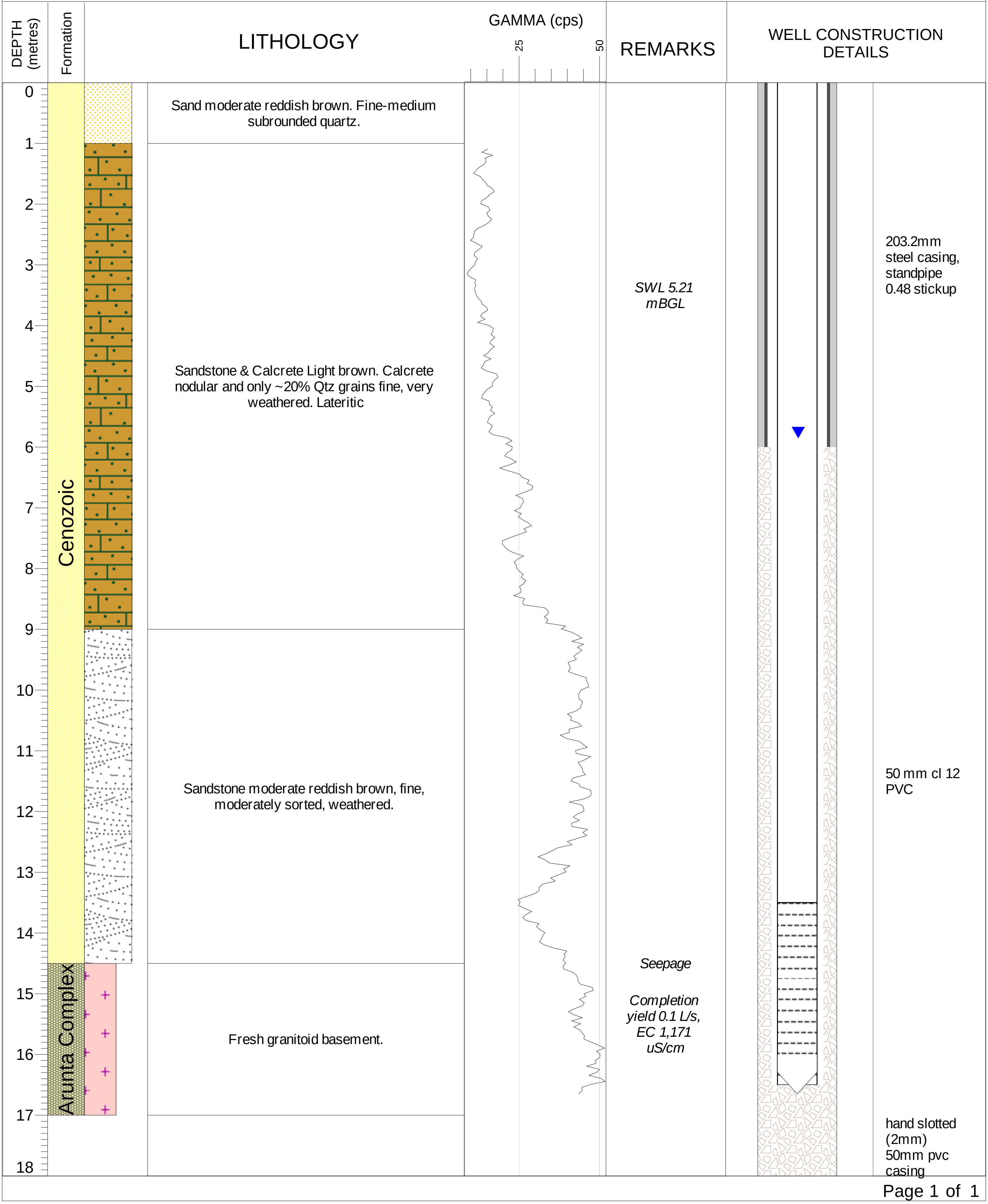
backfill

Northern Territory Government

Palaeovalley Groundwater Project

RN018583

LOCATION:	*Kintore*	**TOTAL DEPTH (m):**	*17*	**AIRLIFT SALINITY (μS/cm):**	*1172*
DATE STARTED:	*5.11.2009*	**CONSTRUCTED DEPTH (mBGL):**	*16.5*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7428917*	**DATE COMPLETED:**	*6.11.2009*	**CASING HEIGHT (m):**	*0.52*
DRILLER:	*I Mcmasters*				
EASTING: WGS 84 Zone 53	*533503*	**ELEVATION:**	*438*	**STANDING WATER LEVEL (mbgl):**	*5.76*
LOGGED BY:	*M Woodgate*				



Sand moderate reddish brown. Fine-medium subrounded quartz.

Sandstone & Calcrete Light brown. Calcrete nodular and only ~20% Qtz grains fine, very weathered. Lateritic

Sandstone moderate reddish brown, fine, moderately sorted, weathered.

Fresh granitoid basement.

SWL 5.21 mBGL

Seepage

Completion yield 0.1 L/s, EC 1,171 uS/cm

203.2mm steel casing, standpipe 0.48 stickup

50 mm cl 12 PVC

hand slotted (2mm) 50mm pvc casing

Northern Territory Government

Palaeovalley Groundwater Project

RN018584

LOCATION: *Kintore*

TOTAL DEPTH (m): *28*

AIRLIFT SALINITY (µS/cm): *1298*

DATE STARTED: *6.11.2009*

CONSTRUCTED DEPTH (mBGL): *28*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7430943*
WGS 84 Zone 53

DATE COMPLETED: *8.11.2009*

CASING HEIGHT (m): *0.41*

DRILLER: *I Mcmasters*

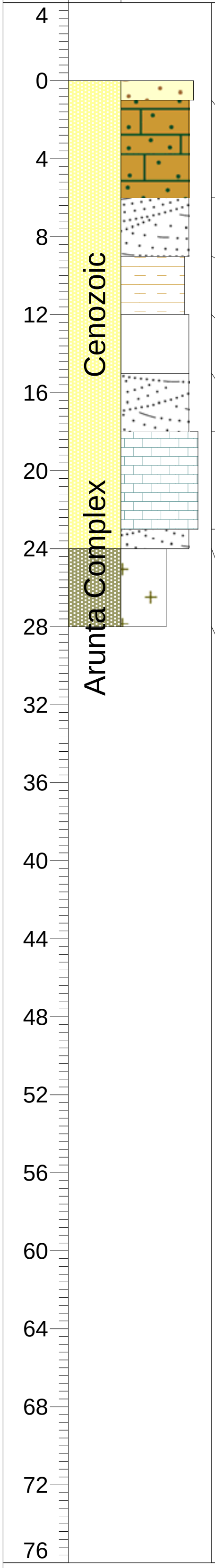
EASTING: *527407*
WGS 84 Zone 53

ELEVATION: *447.5*

STANDING WATER LEVEL (mbgl): *4.14*

LOGGED BY: *M Woodgate*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



GravelLY Sand moderate reddish brown. Abundant iron pisolites. Fine-medium subrounded quartz Sand.

Sandstone (20%) & Calcrete (80%) Light brown. Calcrete nodular. Fine grained weathered Sandstone.

Sandstone moderate brown. Fine – med quartz grained, subrounded and moderately sorted, slightly ClayEY.

ClayEY Sandstone moderate brown. Fine-med weathered Sandstone, qtz grains round-subrounded, moderately sorted.

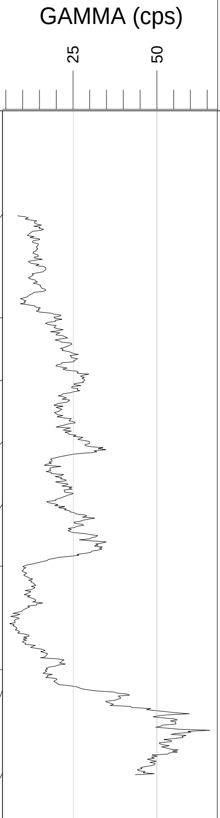
Sandstone & Gravel ~50/50 moderate yellowish brown - angular to subangular, fine Sandstone.

Sandstone a/a

Calcrete

Sandstone moderate reddish brown fine-med moderately sorted a/a small iron pisolites t'out ~5%.

Very hard igneous rock – olive grey. Microcrystalline, foliated/flow banding, minor fracturing, dull sheen on surface.

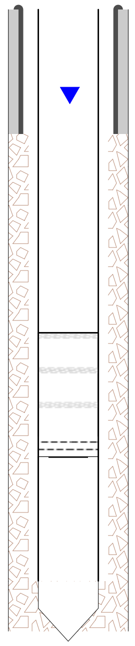


SWL 4.14 mBGL

Water intersected, 0.5 L/s, EC 1,298 uS/cm

Airlift 10 L/s, EC 1,298 uS/cm

Completion yield 10 L/s, EC 1,313 uS/cm



203.2mm steel casing

102 mm cl 12 PVC

hand slotted (2mm) pvc casing

sump

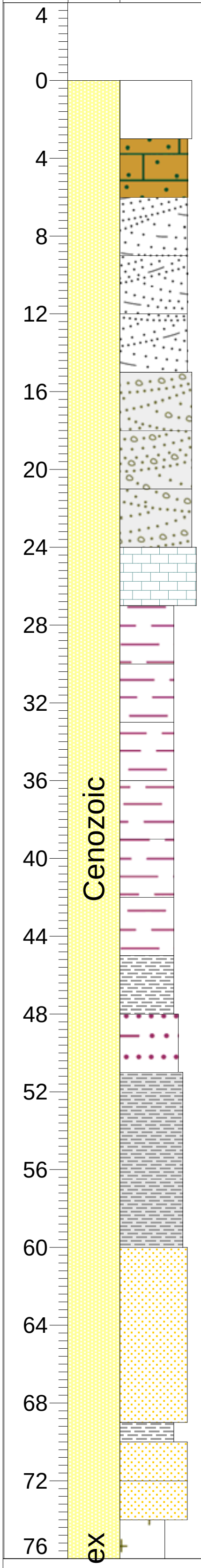
EOH

Palaeovalley Groundwater Project

RN018585

LOCATION:	*Kintore*	**TOTAL DEPTH (m):**	*82.4*	**AIRLIFT SALINITY (μS/cm):**	*1762*
DATE STARTED:	*8.11.2009*	**CONSTRUCTED DEPTH (mBGL):**	*57.1*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7429762*	**DATE COMPLETED:**	*9.11.2009*	**CASING HEIGHT (m):**	*0.41*
DRILLER:	*I Mcmasters*				
EASTING: WGS 84 Zone 53	*527646*	**ELEVATION:**	*430.7*	**STANDING WATER LEVEL (mbgl):**	*5.31*
LOGGED BY:	*M Woodgate*				

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



LITHOLOGY

GravelLY Sand moderate reddish brown. Quartz Gravel to 12mm and iron pisolites t'out. Poorly sorted.

Sandstone & Calcrete (~50/50) Light brown. Fine red brown Sandstone, haematite patches.

Sandstone moderate brown, fine, moderately sorted, weathered.

Sandstone moderate brown, fine-coarse, poorly sorted, qtz grains subrounded to angular.

a/a but ClayEY

Sandstone & Gravel moderate reddish brown. Multicoloured subangular –subrounded qtz in a fine- medium Sandstone. Gravel ~30%

a/a with more Gravel

Sandstone & Gravel (~50/50) light brown, qtz grains subangular-subrounded.

Calcrete white, hard.

ClaySTONE pale greenish yellow, half oxidized, half fresh.

ClaySTONE Light green a/a & fine moderate red brown Sandstone interbedded.

ClaySTONE light green a/a. Large weathered ClaySTONE & Sandstone Gravel up to 15mm. Dark purple, brown, red surfaces

ClaySTONE and weathered Gravel. ClaySTONE pinkish grey. Gravel dark purple, brown, orange ~40%

a/a lots of weathered purple ClaySTONE

a/a less Gravel

Clay mottled, moderate red & some grey.

Sandy clay ~50/50 Dark yellowish orange with some grey mottling. Sand fine-med rounded qtz.

ClayEY Sand Greyish orange mottled with light grey. Fine-coarse Sand, moderately sorted, subrounded-subangular.

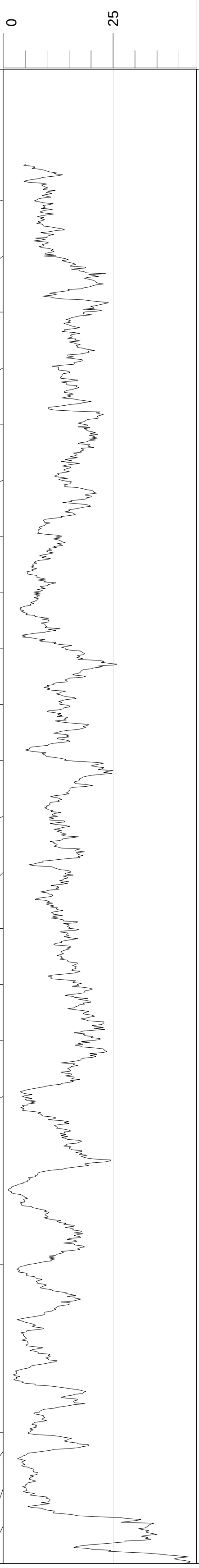
Sand greyish orange. Fairly clean, fine-medium qtz Sand subrounded-subangular, well sorted.

Clay dark grey - black, carbonaceous appearance. Sample for palynology.

Sand yellowish grey. Clean fine-med quartz Sand, well sorted, rounded-subrounded, qtz Gravel ~5%.

a/a qtz Gravel ~20%

GAMMA (cps)



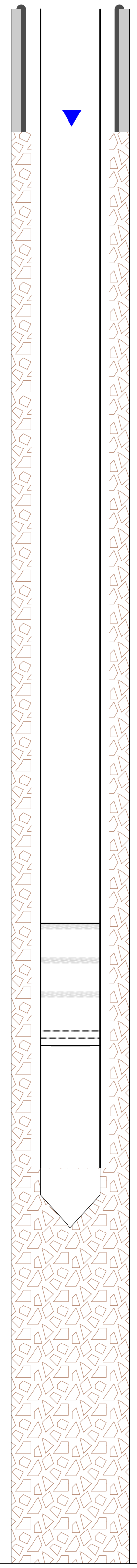
REMARKS

SWL 5.87 mBTOC

Water intersected, 0.1 L/s, EC 1,221 uS/cm

Airlift 2 L/s, EC 1,258 uS/cm

WELL CONSTRUCTION DETAILS



203.2mm steel casing

102 mm cl 12 PVC

hand slotted (2mm) pvc casing

sump

backfill (collapse)

Northern Territory Government

Palaeovalley Groundwater Project RN018586

LOCATION: *Kintore*

TOTAL DEPTH (m): *41.9*

AIRLIFT SALINITY (µS/cm): *1120*

DATE STARTED: *11.11.2009*

CONSTRUCTED DEPTH (mBGL): *37.1*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7428983*
WGS 84 Zone 53

DATE COMPLETED: *11.11.2009*

CASING HEIGHT (m): *0.5*

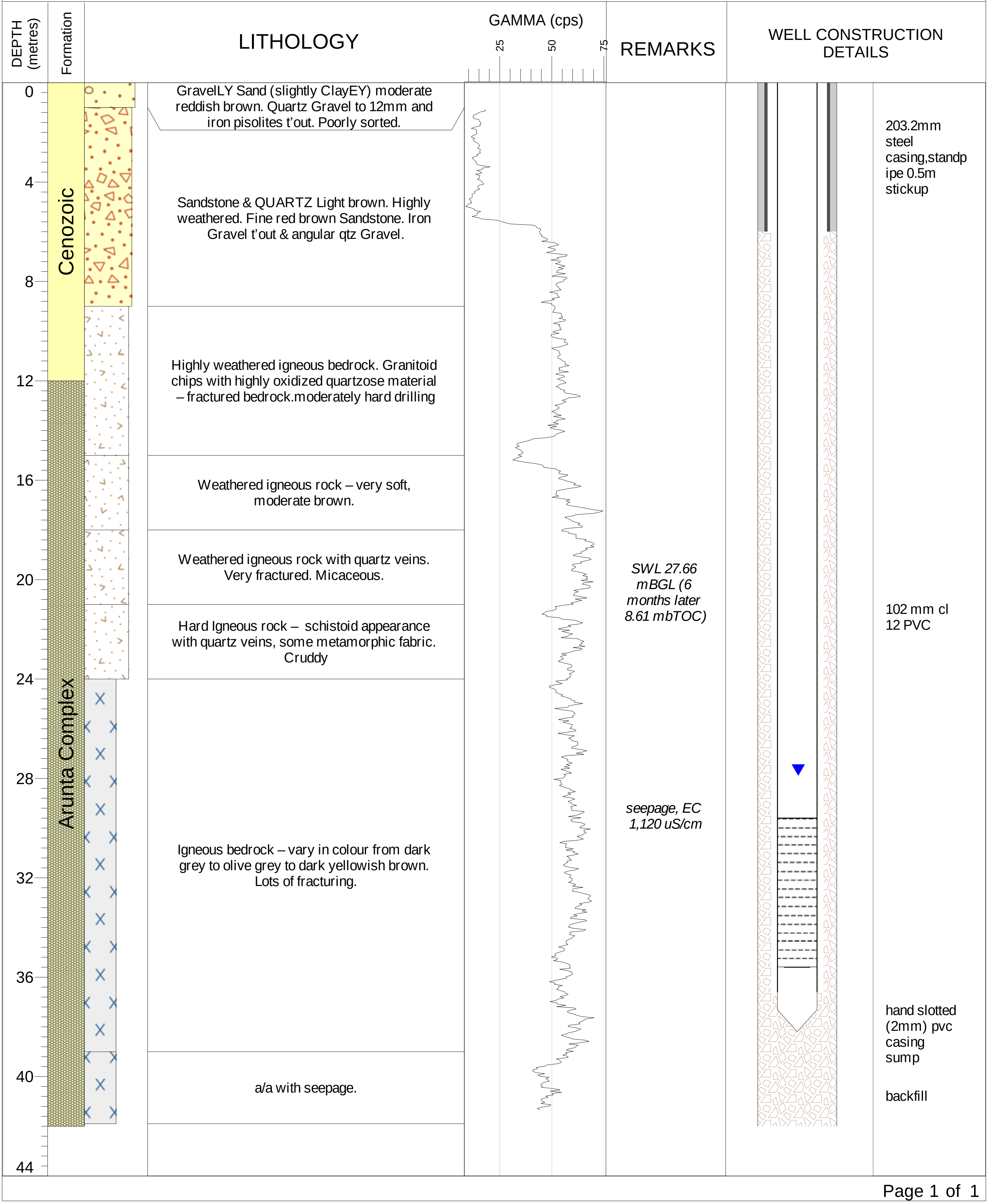
DRILLER: *I Mcmasters*

EASTING: *539982*
WGS 84 Zone 53

ELEVATION: *451.2*

STANDING WATER LEVEL (mbgl): *27.66*

LOGGED BY: *M Woodgate*



GravelLY Sand (slightly ClayEY) moderate reddish brown. Quartz Gravel to 12mm and iron pisolites t'out. Poorly sorted.

Sandstone & QUARTZ Light brown. Highly weathered. Fine red brown Sandstone. Iron Gravel t'out & angular qtz Gravel.

Highly weathered igneous bedrock. Granitoid chips with highly oxidized quartzose material – fractured bedrock.moderately hard drilling

Weathered igneous rock – very soft, moderate brown.

Weathered igneous rock with quartz veins. Very fractured. Micaceous.

Hard Igneous rock – schistoid appearance with quartz veins, some metamorphic fabric. Cruddy

Igneous bedrock – vary in colour from dark grey to olive grey to dark yellowish brown. Lots of fracturing.

a/a with seepage.

SWL 27.66 mBGL (6 months later 8.61 mbTOC)

seepage, EC 1,120 uS/cm

203.2mm steel casing,standpipe 0.5m stickup

102 mm cl 12 PVC

hand slotted (2mm) pvc casing sump

backfill

Northern Territory Government

Palaeovalley Groundwater Project

RN018794

LOCATION: *Kintore*

TOTAL DEPTH (m): *27*

AIRLIFT SALINITY (µS/cm): *2789*

DATE STARTED: *9.10.2011*

CONSTRUCTED DEPTH (mBGL): *26.6*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7441184*
WGS 84 Zone 53

DATE COMPLETED: *10.09.2011*

CASING HEIGHT (m): *0.4*

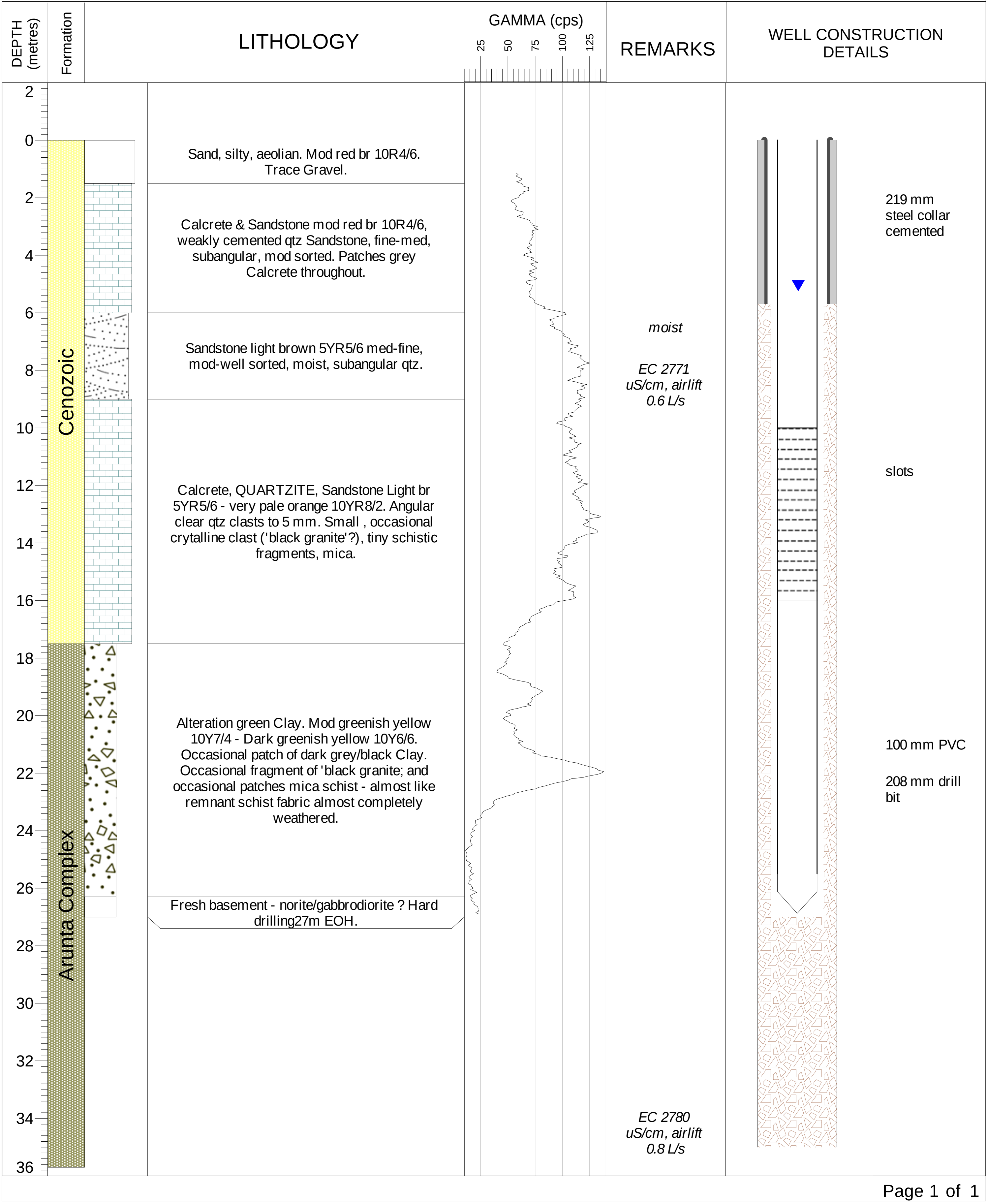
DRILLER: *I Mcmasters*

EASTING: *528626*
WGS 84 Zone 53

ELEVATION: *424.6*

STANDING WATER LEVEL (mbgl): *5.05*

LOGGED BY: *M Woodgate*



Sand, silty, aeolian. Mod red br 10R4/6. Trace Gravel.

Calcrete & Sandstone mod red br 10R4/6, weakly cemented qtz Sandstone, fine-med, subangular, mod sorted. Patches grey Calcrete throughout.

Sandstone light brown 5YR5/6 med-fine, mod-well sorted, moist, subangular qtz.

Calcrete, QUARTZITE, Sandstone Light br 5YR5/6 - very pale orange 10YR8/2. Angular clear qtz clasts to 5 mm. Small , occasional crytalline clast ('black granite'?), tiny schistic fragments, mica.

Alteration green Clay. Mod greenish yellow 10Y7/4 - Dark greenish yellow 10Y6/6. Occasional patch of dark grey/black Clay. Occasional fragment of 'black granite; and occasional patches mica schist - almost like remnant schist fabric almost completely weathered.

Fresh basement - norite/gabbrodiorite ? Hard drilling27m EOH.

moist

EC 2771 uS/cm, airlift 0.6 L/s

EC 2780 uS/cm, airlift 0.8 L/s

219 mm steel collar cemented

slots

100 mm PVC

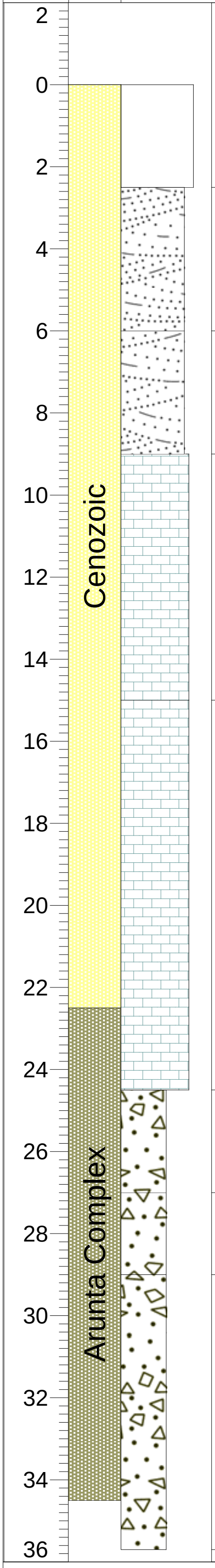
208 mm drill bit

Palaeovalley Groundwater Project RN018810

Northern Territory Government

LOCATION: *Kintore*
TOTAL DEPTH (m): *35.7*
AIRLIFT SALINITY (µS/cm): *2730*
DATE STARTED: *10.9.2011*
CONSTRUCTED DEPTH (mBGL): *26*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7441651*
DATE COMPLETED: *12.9.2011*
CASING HEIGHT (m): *0.4*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *526910*
ELEVATION: *421.7*
STANDING WATER LEVEL (mbgl): *6.1*
LOGGED BY: *M Woodgate*

DEPTH (metres)	Formation	LITHOLOGY	GAMMA (cps)	REMARKS	WELL CONSTRUCTION DETAILS



Sand (aeolian) f-c, poorly sorted, mod red br 10YR4/6. Subangular. Silty.

Sandstone, calcareous light brown 5YR5/6 cemented weakly into nodules in places, trace angular quartz Gravel, trace mica flakes.

Sandstone, Calcrete light brown 5YR5/6 - 5YR6/4.f-c qtz, angular, occ feldspar, mica. Soft, weakly cemented, subangular-subrounded .

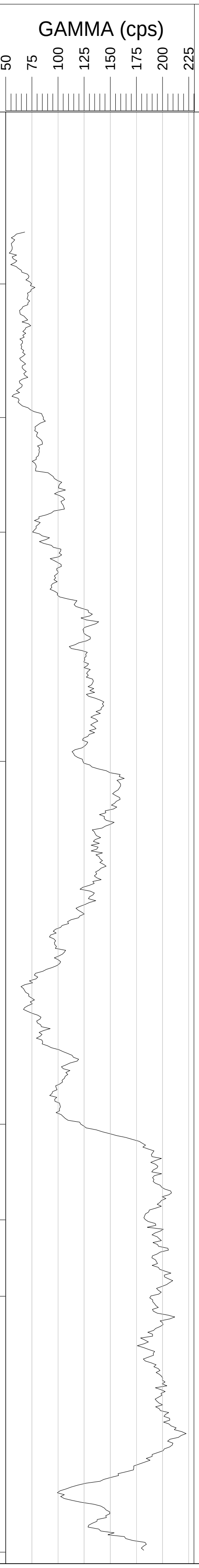
Calcrete, Sandstone, QUARTZ. Light brown 5YR5/6. Sandstone f-c - more coarse fraction, white-grey Calcrete.

Calcrete, Sandstone, QUARTZ. Light brown 5YR5/6. Sandstone f-c - more coarse fraction, white-grey Calcrete.

Weathered basement. Granitic (Black Granite/schistic). Lots mica, quartz, mafics, small portion qtz yellow skins.Still drillable by blade bit.

Weathered basement. Predominantly oxidised surfaces - fracture zone. Granitic (Black Granite/schistic).

Weathered basement. Granitic (Black Granite/schistic). Lots mafics,mica, quartz, rose quartz, lesser feldspar.Still drillable by blade bit.EOH



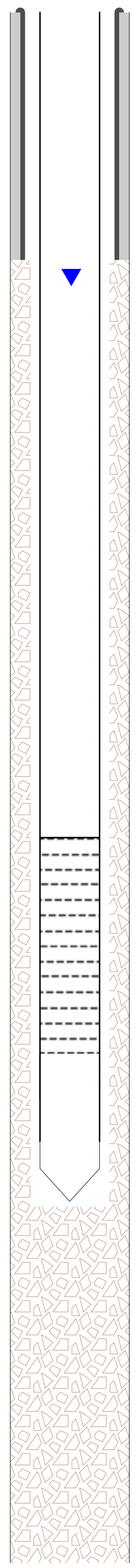
moist

EC 2448 uS/cm, airlift 0.5 L/s

EC 2760 uS/cm, airlift 2 L/s

EC 2730 uS/cm, airlift 5 L/s

EC 2740 uS/cm, airlift 4 L/s



219 mm steel collar cemented

100 mm PVC

208 mm drill bit

slots

Northern Territory Government

Palaeovalley Groundwater Project

RN018811

LOCATION: *Kintore*
TOTAL DEPTH (m): *72.8*
AIRLIFT SALINITY (μS/cm): *7020*

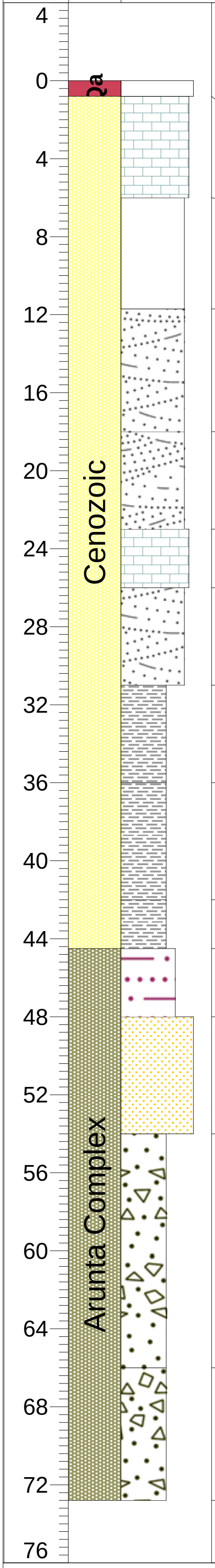
DATE STARTED: *12.9.2011*
CONSTRUCTED DEPTH (mBGL): *52*
DRILLING RIG: *Ingersol Rand*

NORTHING: *7441917*
WGS 84 Zone 53
DATE COMPLETED: *13.9.2011*
CASING HEIGHT (m): *0.4*
DRILLER: *I Mcmasters*

EASTING: *525774*
WGS 84 Zone 53
ELEVATION: *420.47*
STANDING WATER LEVEL (mbgl): *5.47*
LOGGED BY: *M Woodgate*

DEPTH (metres)

Formation



LITHOLOGY

Sand, silty, aeolian. Mod red br 10R4/6. Trace Gravel.

Calcrete and Silcrete, pinkish grey 5YR8/1."cavernous'. Trace mica flakes in disorganised qtz. Sandstone - calcareous. Hammer drill.

Silcrete. Some opaque, some clear, white, very pale orange (10 YR8/2)

Gravelly Sandstone, moderate brown 5YR4/4 f-c, subrounded, yellow skins on some qtz grains.

Gravelly Sandstone, Calcrete, Silcrete mod brown 5YR4/4, subrounded qtz grains up to ~4mm. Yellowish grey 5Y7/2 Calcrete.

Calcrete, Silcrete. Milky white Silcrete.

Gravelly Sandstone, mod red brown 10YR6/4, f-c, grey Calcrete. Qtz subrounded up to ~5mm.

Clay, dark yellowish orange 10YR6/6-pale yellowish brown 10YR6/2. Sticky. Slightly mottled in places. Change to blade bit.

Clay, yellowisg grey 5Y7/2, sticky. F-med Sand ~20% at 39-42

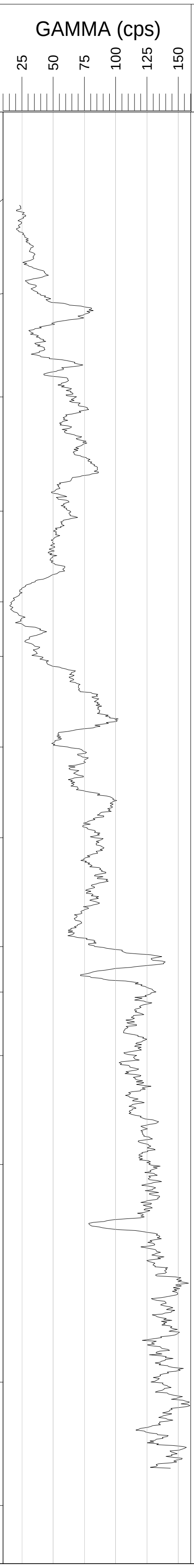
Clay as per above with thin lateritic layer, nodules etc at ~43m.Base of Cz.

Sandy clay white N9. Qtz grains in white Clay

Clean Coarse Quartz Sand- Gravel weathered granitic basement.

Weathered granite (?) - quartz, mafics, mica.

Weathered amphibolite schist - dark, flaky, highly micaceous volcanic.Some yellow surfaces.Soft drilling - highly weathered.



REMARKS

EC 6500 uS/cm, airlift 0.6 L/s

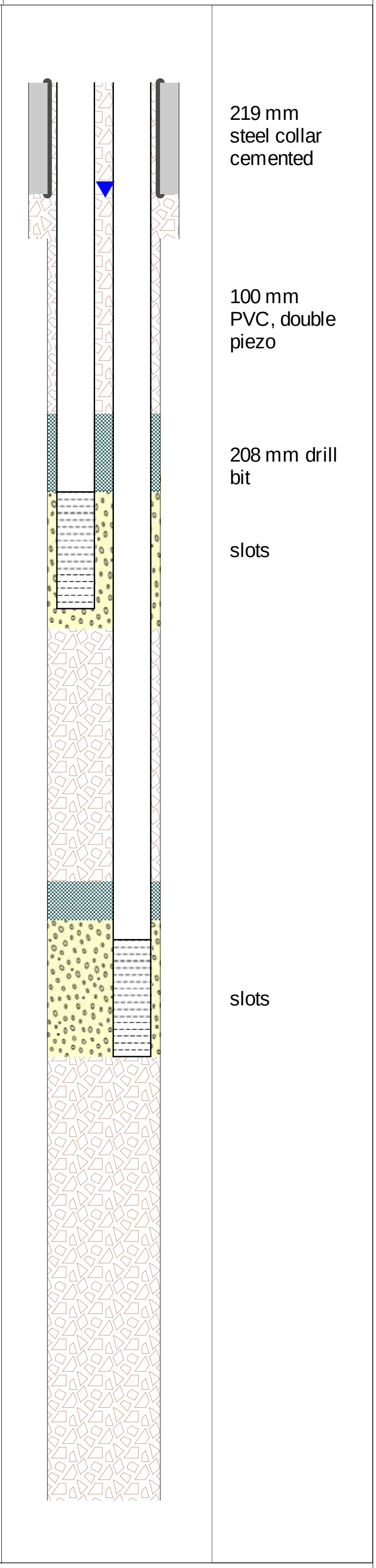
EC 7220 uS/cm, airlift 5 L/s

EC 6910 uS/cm, airlift 6 L/s

EC 7030 uS/cm, airlift 10 L/s

EC 7020 uS/cm, airlift 12 L/s

WELL CONSTRUCTION DETAILS



Northern Territory Government

Palaeovalley Groundwater Project

RN018812

LOCATION: *Kintore*

TOTAL DEPTH (m): *82*

AIRLIFT SALINITY (μS/cm): *6339*

DATE STARTED: *14.9.2011*

CONSTRUCTED DEPTH (mBGL): *28*

DRILLING RIG: *Ingersol Rand*

NORTHING: WGS 84 Zone 53 *7442017*

DATE COMPLETED: *15.9.2011*

CASING HEIGHT (m): *0.4*

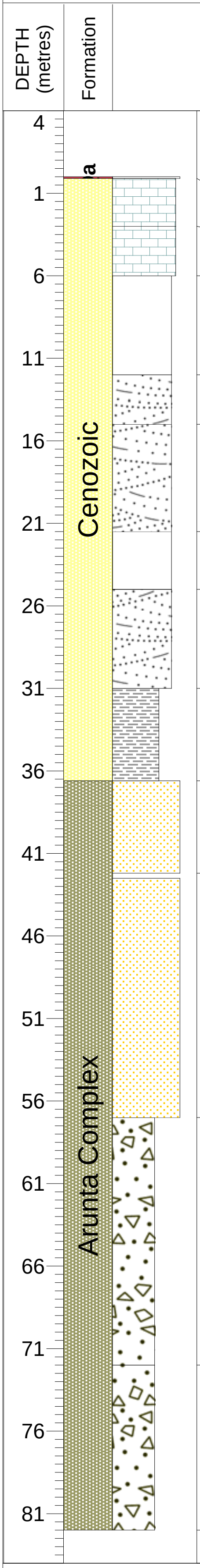
DRILLER: *I Mcmasters*

EASTING: WGS 84 Zone 53 *524773*

ELEVATION: *420.46*

STANDING WATER LEVEL (mbgl): *5.15*

LOGGED BY: *M Woodgate*



LITHOLOGY

Silty Sand, Mod red brown 10YR4/6, aeolian

Calcrete, Sandstone, cavernous, Sandstone f-c Light Brown 5YR2/2

Calcrete, Silcrete. Milky white Silcrete.

Silcrete/Calcrete, greyish orange pink 5YR7/2. Sandy in places, f-c subrounded, chalcedonic in patches

Sandstone (Calcareous). Light Brown 5YR6/4, f-c, modsorted, subangular

Sandstone (Calcareous) & Qtz Gravel. Mod red brown 10YR4/6, highly weathered, oxidised, f-c, poorly sorted, subangular

Silcrete white, Sandstone Light Brown 5YR6/4

Sandstone & QUARTZ. Mod brown 5YR4/4. Qtz Gravel, f-c Sandstone, disorganised quartz, slightly 'lateritic'

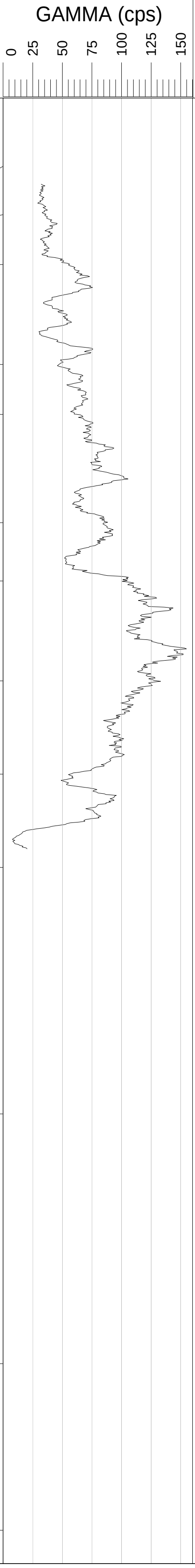
Clay, Sandy clay yellowish grey 5Y7/2 - pale yellowish brown 10YR6/2. Slightly mottled yellow. Sticky Clay with fine Sand in some layers.

Sand, predom coarse, mod sorted, angular-subrounded Sand with ~50% yellow skins - caving in 'free flowing' - use foam to maintain hole.(Weathered basement)

Sand, coarse, interbedded with Sandy clay, odd mafic flake, angular grains, mod well sorted.Light Brown 5YR6/4

Sand, coarse, interbedded with Sandy clay, odd mafic flake, becoming micaceous downhole, angular grains, mod well sorted.Light Brown 5YR6/4

Sand, increasingly schistic- Weathered basement.



REMARKS

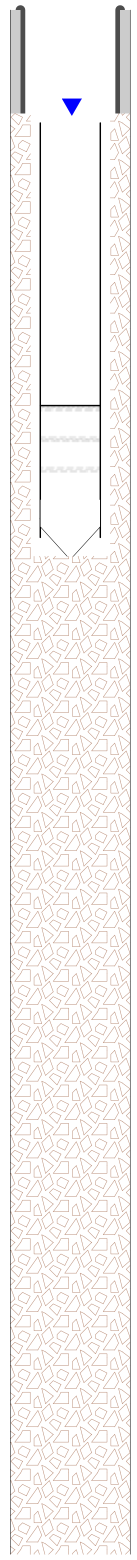
EC 3520 uS/cm, airlift 0.1 L/s

EC 5610 uS/cm, airlift 4 L/s

EC 5780 uS/cm, airlift 8 L/s

EC 6330 uS/cm, airlift 10 L/s

WELL CONSTRUCTION DETAILS



219 mm steel collar cemented

100 mm PVC

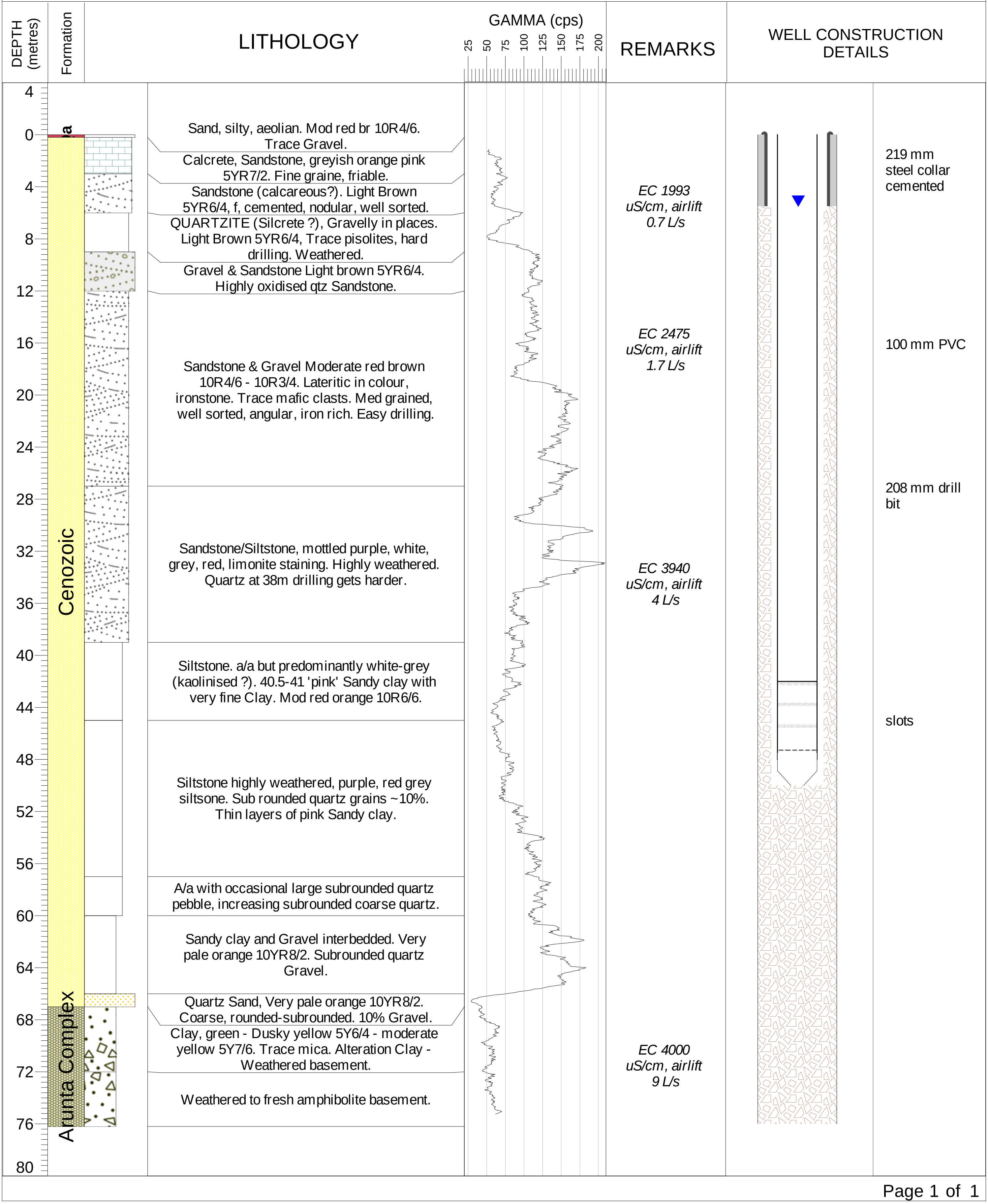
208 mm drill bit

slots

Palaeovalley Groundwater Project

RN018813

LOCATION:	*Kintore*	**TOTAL DEPTH (m):**	*76.2*	**AIRLIFT SALINITY (µS/cm):**	*4000*
DATE STARTED:	*16.9.2011*	**CONSTRUCTED DEPTH (mBGL):**	*49*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53	*7442363*	**DATE COMPLETED:**	*17.9.2011*	**CASING HEIGHT (m):**	*0.4*
DRILLER:	*I Mcmasters*				
EASTING: WGS 84 Zone 53	*522983*	**ELEVATION:**	*419.18*	**STANDING WATER LEVEL (mbgl):**	
LOGGED BY:	*M Woodgate*				



Sand, silty, aeolian. Mod red br 10R4/6. Trace Gravel.

Calcrete, Sandstone, greyish orange pink 5YR7/2. Fine graine, friable.

Sandstone (calcareous?). Light Brown 5YR6/4, f, cemented, nodular, well sorted.

QUARTZITE (Silcrete ?), Gravelly in places. Light Brown 5YR6/4, Trace pisolites, hard drilling. Weathered.

Gravel & Sandstone Light brown 5YR6/4. Highly oxidised qtz Sandstone.

Sandstone & Gravel Moderate red brown 10R4/6 - 10R3/4. Lateritic in colour, ironstone. Trace mafic clasts. Med grained, well sorted, angular, iron rich. Easy drilling.

Sandstone/Siltstone, mottled purple, white, grey, red, limonite staining. Highly weathered. Quartz at 38m drilling gets harder.

Siltstone. a/a but predominantly white-grey (kaolinised ?). 40.5-41 'pink' Sandy clay with very fine Clay. Mod red orange 10R6/6.

Siltstone highly weathered, purple, red grey siltsone. Sub rounded quartz grains ~10%. Thin layers of pink Sandy clay.

A/a with occasional large subrounded quartz pebble, increasing subrounded coarse quartz.

Sandy clay and Gravel interbedded. Very pale orange 10YR8/2. Subrounded quartz Gravel.

Quartz Sand, Very pale orange 10YR8/2. Coarse, rounded-subrounded. 10% Gravel.

Clay, green - Dusky yellow 5Y6/4 - moderate yellow 5Y7/6. Trace mica. Alteration Clay - Weathered basement.

Weathered to fresh amphibolite basement.

EC 1993 uS/cm, airlift 0.7 L/s

EC 2475 uS/cm, airlift 1.7 L/s

EC 3940 uS/cm, airlift 4 L/s

EC 4000 uS/cm, airlift 9 L/s

Northern Territory Government

Palaeovalley Groundwater Project

RN018814

LOCATION: *Kintore*
TOTAL DEPTH (m): *48*
AIRLIFT SALINITY (µS/cm): *1870*

DATE STARTED: *19.9.2011*
CONSTRUCTED DEPTH (mBGL): *25*
DRILLING RIG: *Ingersol Rand*

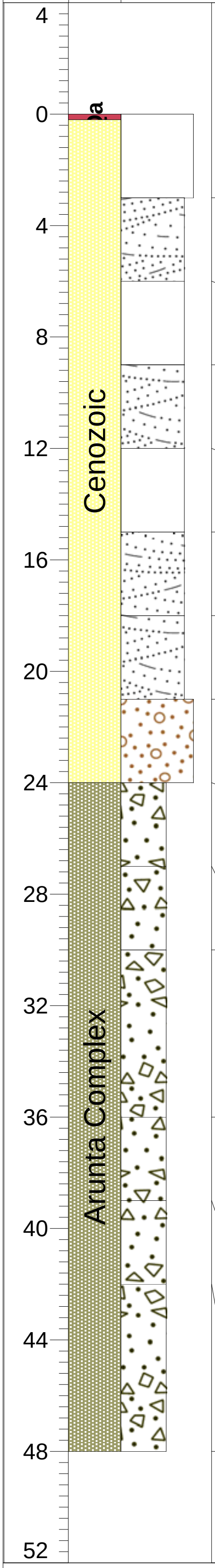
NORTHING: *7436218*
WGS 84 Zone 53
DATE COMPLETED: *20.9.2011*
CASING HEIGHT (m): *0.4*
DRILLER: *I Mcmasters*

EASTING: *523453*
WGS 84 Zone 53
ELEVATION: *422.96*
STANDING WATER LEVEL (mbgl): *14.53*
LOGGED BY: *R Read*

DEPTH (metres)

Formation

LITHOLOGY



Sand, moderate red brown poorly std coarse to fine silty Sand.

Sandstone, moderate reddish brown 10R4/6 and light brown 5YR5/6 well indurated Silty Sandstone with Calcrete veinlets. Some greyish orange 10YR7/4 Calcrete.

Silcrete, white, massive, some stained pale yellowish orange.

Sandstone, soft plastic fine grained very silty, greyish yellow 5Y8/4. As coarse to fine grainde moderately indurated friable Silty Sandstone, light brown 5YR5/6.

Silcrete, massive, white and with yellow brown (no match on chart) iron-oxide staining.

Y/R5/6 fine to coarse grained Sandstone, plus some Silcrete as above.

Sandstone, dark reddish brown 10R3/4 fine grained, friable and silty.

Gravel, rounded quartz pebble to 25 mm. Brown lithix well rounded pebbles to 5 mm. Some angular vein quartz. 30% Sandstone as above.

Clay & QUARTZ. 80% soft plastic yellowish gy 5Y7/2 Clay with quartz ranging from apparently rounded Sand size up to 5 mm and angular. 20% moderate red brown 10R4/6 with fine to coarse Sand size quartz.

Yellowish gy 5Y7/2 Siltstone, well indurated and lightly silicified with Sand size quartz.

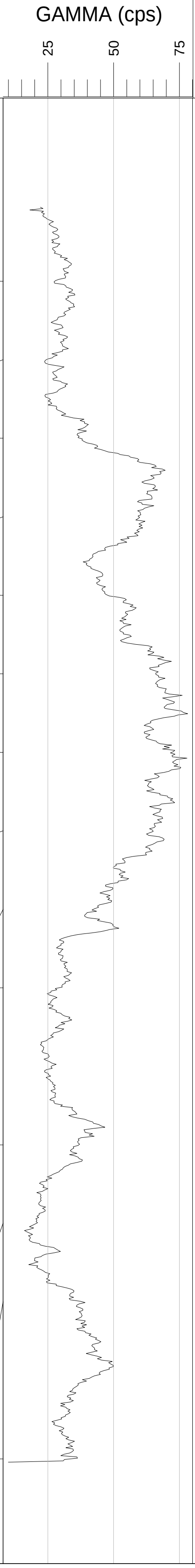
Clay & QUARTZ, very light grey N8 part stained pale yellow orange 10YR8/6 with Sand size quartz.

Clay & QUARTZ. Soft plastic yellowish grey 5Y7/2 Clay with some quartz. Dusky red 5R3/4 well indurated (ferruginized and silicified) rock with Sand size quartz. Well indurated rock stained greyish yellow 5Y8/4 to light brown 5YR8/6 with Sand size quartz.

Clay & QUARTZ. Very light grey N8 soft plastic Clay with about 20% coarse Sand size quartz. Greyish red 10R4/2 will indurated rock with medium to coarse Sand sized quartz. Single fragment of fresh quartz with included biotite.

As above, with rare very soft greenish fragments.

GAMMA (cps)

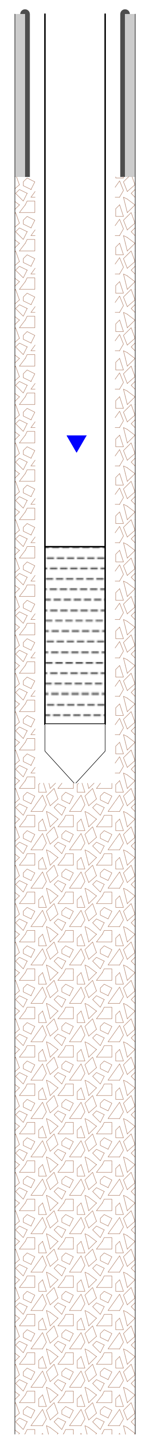


REMARKS

EC 1780 uS/cm, airlift 2.5 L/s

EC 1830 uS/cm, airlift 4 L/s

WELL CONSTRUCTION DETAILS



219 mm steel collar cemented

100 mm PVC

208 mm drill bit

slots

Appendix 4 – Hydrogeochemical data for the Kintore Palaeovalley

This appendix contains the laboratory analytical data for groundwater samples collected from the Kintore Palaeovalley. Chemical constituents that exceed Australian Drinking Water Quality Guideline limits (shown in blue in the lower-most row of each table) are highlighted in red.

Table A4.1: Hydrogeochemistry data for the Kintore Palaeovalley.

Bore & sample depth	**Sampling date**	**pH**	**EC**	**Alkalinity**	**CO_3**	**HCO_3**	**OH**	**TSS**	**TDS**	**NO_2**	**NO_2**	**NO_3**	**Cl**	**PO_4**	**NH_3**
		units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
RN16852	26/10/09	7.5	3,070	264	<1	264	<1	<10	1990	0.015	0.04	66.4	668	0.03	0.025
RN18580	27/10/09	7.7	7,380	189	<1	189	<1	<10	4750	0.015	0.06	0.16	2220	0.01	0.115
RN18581	31/10/09	7.6	825	183	<1	183	<1	<10	530	0.025	0.08	83.6	90	0.035	0.075
RN18581-17	31/10/09	7.7	839	187	<1	187	<1	30	530	0.045	0.14	86.6	93.5	0.025	0.05
RN18582	5/11/09	7.6	581	179	<1	179	<1	<10	360	0.015	0.04	57.8	32.3	0.035	0.05
RN18583	6/11/09	7.9	993	251	<1	251	<1	100	660	0.02	0.06	89.2	104	0.03	0.12
RN18584	9/11/09	7.7	1,130	195	<1	195	<1	<10	720	<0.005	<0.02	108	155	0.03	<0.005
RN18585	9/11/09	7.7	1,090	182	<1	182	<1	<10	680	0.005	<0.02	103	156	0.03	<0.005
RN18586	11/11/09	7.9	988	248	<1	248	<1	450	600	0.66	2.18	68.6	87.5	0.01	0.175
RN18794	12/09/11	7.9	2,200	286	<1	286	<1	100	1290	0.015	0.06	96	417	0.035	<0.005
RN18810	13/09/11	8.2	2,210	237	<1	237	<1	100	1310	0.025	0.08	107	420	0.03	<0.005
RN18811	14/09/11	7.9	5,770	345	<1	345	<1	190	3690	0.015	0.06	112	1320	0.03	0.145
RN18812	15/09/11	7.9	5,320	198	<1	198	<1	110	3440	0.015	0.04	53.1	1420	0.02	0.115
RN18813	16/09/11	8.1	3170	258	<1	258	<1	1040	2050	<0.005	<0.02	51.2	624	0.035	<0.005
RN18814	20/09/11	8.3	1560	178	<1	178	<1	90	890	0.005	<0.02	59.5	287	0.03	0.225
Drinking water guidelines										0.9		50			

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Table A4.1 (cont…): Hydrogeochemistry data for the Kintore Palaeovalley.

Bore ID & sample depth	F	Hardness	Ca	K	Mg	Na	SiO_2	SO_4	Ag	Al	As	B	Ba	Be	Br	Cd
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN16852	1.3	551	117	54.5	62.9	438	82.8	378	<10	<20	0.5	980	<50	<1	3,460	<0.2
RN18580	1.2	1310	284	74.9	145	1,130	17.6	802	<10	80	<0.5	820	<50	<1	8,350	<0.2
RN18581	1.3	219	39.7	24.3	29.2	80	80.4	40.7	<10	140	1	440	100	<1	724	<0.2
RN18581-17	1.1	231	41.4	25.7	31.1	80.3	81.4	42.4	<10	>LWR	1.5	440	100	<1	760	<0.2
RN18582	0.9	165	33.4	15.4	19.8	55.6	76.4	20.3	<10	40	1	320	100	<1	346	<0.2
RN18583	1.7	229	40.4	40.9	31.2	110	88	44.5	<10	9,360	3.5	680	400	13	724	<0.2
RN18584	1	262	58.8	38.2	28.1	118	78.4	71.2	<10	<20	1	480	50	<1	926	<0.2
RN18585	1	285	65.2	36	29.7	105	80	65	<10	<20	1	440	50	<1	994	<0.2
RN18586	2	160	33.5	32.1	18.5	142	34.2	74.5	<10	>LWR	4.5	740	100	<1	758	<0.2
RN18794	0.9	379	81.3	43.3	42.8	311	90.8	215	<10	4,380	1.5	720	<50	1	2,040	<0.2
RN18810	0.8	395	86.9	41.8	43.3	301	84	232	<10	4,720	2	700	<50	1	2,040	<0.2
RN18811	1.2	1120	217	81.9	141	799	81.8	827	<10	>LWR	1	1,220	<50	1	6,460	<0.2
RN18812	1	1290	296	56.3	134	622	53.2	572	<10	7,220	1.5	620	<50	1	3,940	<0.2
RN18813	1	733	153	53.8	85.1	402	87.8	610	<10	>LWR	3.5	660	150	2	2,350	0.2
RN18814	1.1	310	67.6	30.7	34.4	177	88.8	155	<10	>LWR	1.5	360	<50	1	1,130	<0.2
Drinking water guidelines	1.5								100		7	4,000	700			

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Table A4.1 (cont…): Hydrogeochemistry data for the Kintore Palaeovalley.

Bore ID & sample depth	Cr	Cu	Fe	Hg	I	Mn	Mo	Ni	Pb	Sb	Se	Sn	U	Zn
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN16852	<5	<10	<20	<0.1	750	<5	<5	<2	<1	<0.2	6	<10	11.8	<10
RN18580	<5	<10	>LWR	<0.1	710	40	<5	2	<1	<0.2	3	<10	21.6	<10
RN18581	<5	<10	220	<0.1	170	10	<5	<2	<1	<0.2	3	<10	1.63	50
RN18581-17	<5	20	>LWR	<0.1	170	45	<5	2	<1	<0.2	3	<10	1.61	<10
RN18582	<5	<10	40	<0.1	120	<5	<5	<2	<1	<0.2	2	<10	1.26	<10
RN18583	105	670	>LWR	<0.1	540	365	90	98	32	<0.2	4	<10	3.77	40
RN18584	<5	<10	<20	<0.1	250	<5	<5	<2	<1	<0.2	3	<10	3.09	<10
RN18585	<5	<10	20	<0.1	260	<5	<5	<2	<1	<0.2	3	<10	3.18	<10
RN18586	30	30	>LWR	<0.1	420	565	35	26	5	<0.2	10	<10	8.57	40
RN18794	25	20	4,980	<0.2	290	95	<5	10	2	<0.5	5	<10	12.2	40
RN18810	5	<10	4,580	<0.2	280	60	<5	4	1	<0.5	4	<10	13.8	10
RN18811	20	20	4,060	<0.2	610	55	<5	4	4	<0.5	7	<10	27.6	<10
RN18812	10	10	5,840	<0.2	280	85	<5	4	1	<0.5	4	<10	13.2	<10
RN18813	35	<10	>LWR	<0.2	390	30	<5	6	5	<0.5	3	<10	15.8	<10
RN18814	5	<10	1,720	<0.2	140	5	<5	<2	1	<0.5	3	<10	5.3	<10
Drinking water guidelines	50	2,000		1	100	500	50	20	10		10		20	-

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004

Appendix 5 – Central Mount Wedge seismic reflection processing methodology

By Josef Holzschuh

The seismic reflection data for the Central Mount Wedge seismic survey were processed by Josef Holzschuh, a member of the Seismic Acquisition and Processing project in the Onshore Energy and Minerals Division of Geoscience Australia. Processing used Disco/Focus processing software on a Red Hat Enterprise Linux Sun Fire X4600 M2 server. The processing sequence applied to the data is shown in Table A5.1 and described further in the section below. The migrated seismic section with initial geologic interpretation is shown as Figure 5.14.

Table A5.1: Seismic reflection processing sequence for line 10GA-PA1.

SEISMIC PROCESSING STEP	PROCESSING SPECIFICATIONS
1	Data quality assurance / quality control (QA/QC)
2	Geometry definition (CDP interval 4 metres)
3	SEG-D to Disco format conversion
4	First breaks picked to create refractor model for refraction statics
5	Inner trace edits to remove noisy traces next to the source
6	Band pass filter: 0-180 ms: 5-200Hz, slope 36 db/octave
6a	Band-pass filter: 00-8000 ms; 15-200Hz, slope 36 db/octave
7	Spectral equalisation over 25-205 Hz (300 ms AGC gate)
8	Common midpoint sort
10	Application of floating datum residual refraction statics
11	Velocity analysis
12	Application of automatic residual statics
13	Velocity analysis
14	Normal moveout correction with 15 % stretch mute
15	Offset regularisation
16	Dip moveout (DMO) correction
17	1Common midpoint stack
18	Omega-X migration
19	Signal coherency enhancement
20	Application of mean datum statics, datum 600 m (AHD), replacement velocity 2,050 metres-per-second
21	Trace amplitude scaling for display

CDP LINE GEOMETRY DEFINITION

The common depth point (CDP) is the common reflecting point at depth on a reflector, whereas the common midpoint (CMP) is the midpoint between each geophone station (receiver) and the source. The final CDPs are defined along the CDP line, which is a curve of best-fit through the source–receiver midpoints which reduces the effects of variations along the seismic line, e.g., slight bends in the road and source moving away from the geophones due to obstacles along the seismic line. Each trace (i.e., source–receiver pair) midpoint is allocated to the nearest CDP bin (group). The CDP line was processed as a straight line after stacking.

REFRACTION STATICS

Variations in surface elevation, weathering layer depth and weathering layer velocity can produce significant time delays in land seismic data. Static corrections are applied in the processing stream to remove these effects. The refraction statics were applied in two stages using a floating datum. An intermediate step of automatic residual statics produced fine-tuning of the corrections. The final statics were calculated relative to a datum of 600 metres (AHD) using a replacement velocity of 2,050 m/s determined as an average from the first arrivals.

BAND PASS FILTER AND SPECTRAL EQUALISATION

A typical shot record from the Papunya survey (shot 850) is shown in Figure A5.1. The two-way time (TWT) indicates the time required for the seismic wave to travel from the vibrator source to some point below the surface and back up to a receiver. The refracted first arrivals, groundroll, reflection hyperbolae and air wave are identified (Figure A5.1). The effects of bandpass filtering and spectral equalisation are shown on the bottom right image, enhancing reflection hyperbolae and reducing groundroll noise. The air wave is the sound wave generated by the vibrator source and travels at 330 m/s, e.g., Figure A5.1 where the airwave has an offset of 330 metres at 1 second TWT.

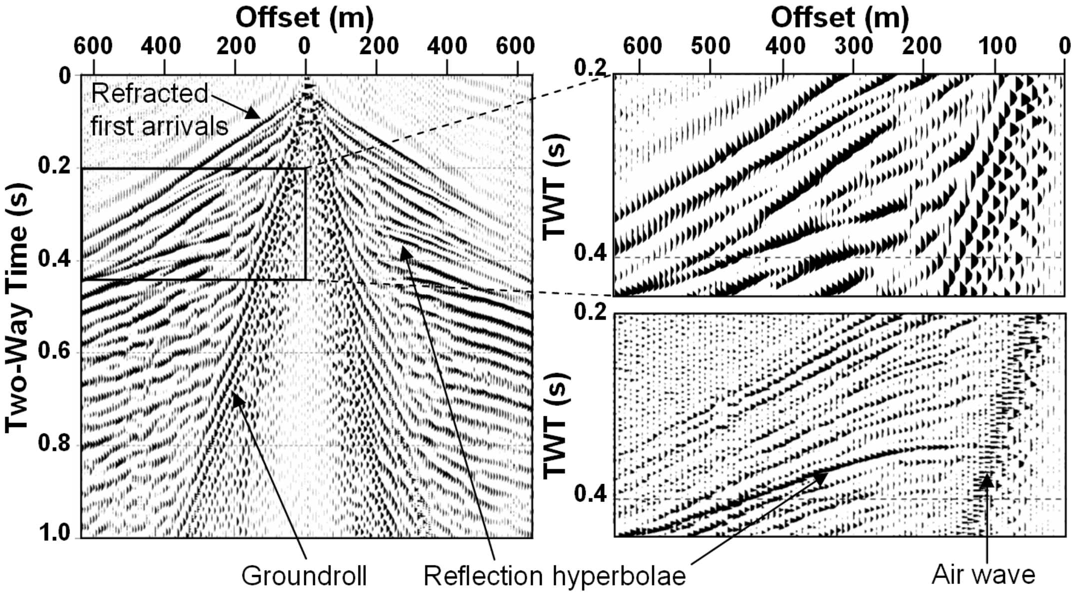


Figure A5.1: *Left, a typical shot record limited to 1 second two-way time (TWT) with different energy components identified. On the right top an enlarged section and below, the same section after bandpass filter and spectral equalization applied to enhance reflections and reduce groundroll noise.*

CDP SORTING

Seismic data acquisition is achieved in shot–receiver coordinates however seismic data processing is commonly in midpoint-offset coordinates. Hence, the required coordinate transformation is achieved by CMP sorting, which requires field geometry information. Each individual trace is assigned to the midpoint between the shot and the receiver locations associated with that trace. Those traces with the same midpoint location are grouped together, making up a CMP gather (Yilmaz, 1987). The CMP gathers are then sorted by offset.

Common depth point (CDP) gather is equivalent to the common midpoint (CMP) only when the reflectors are horizontal and velocities do not vary horizontally. However, when there are dipping reflectors in the subsurface, these two gathers are not equivalent and only the term CMP gather should be used. Disco/Focus software uses the term CDP so this term is herein used in reference to data processing.

Figure A5.2 shows typical CDP gather with traces from shots 813 to 892, including shot 850 in Figure A5.1.

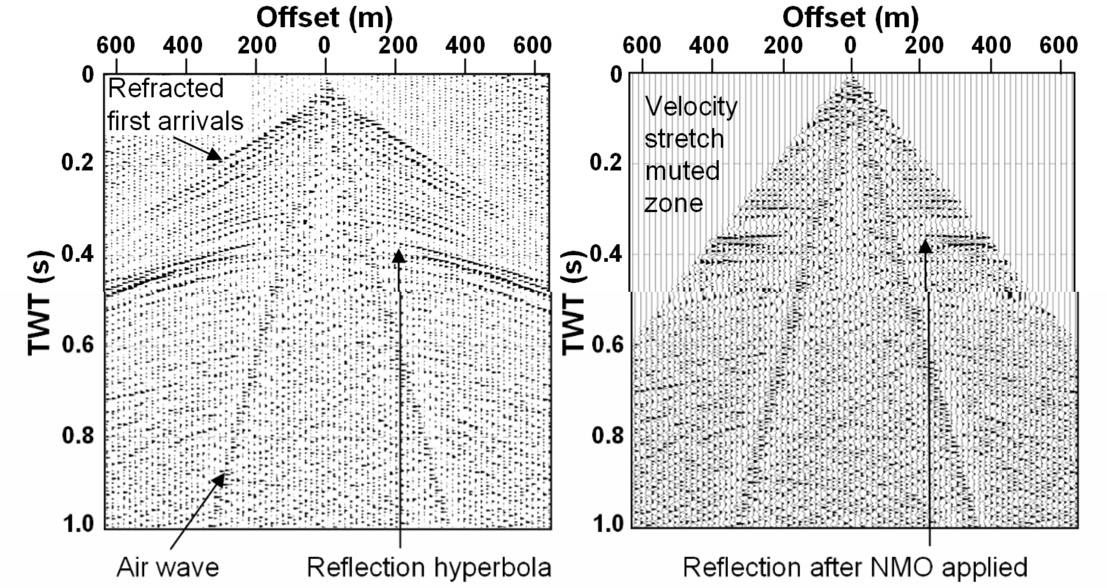


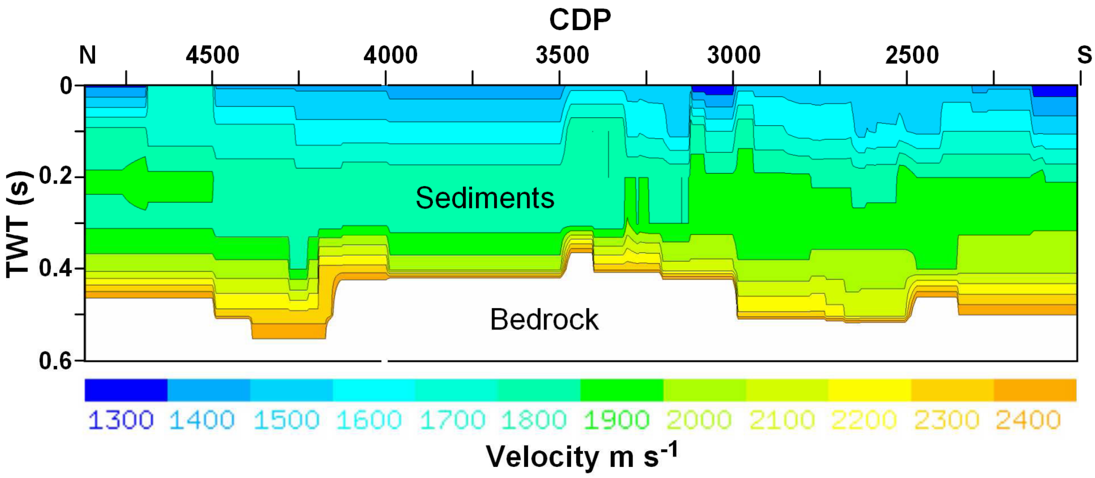
***Figure A5.2:** Shot records are sorted into CDP gathers as seen on the left. On the right normal moveout (NMO) stacking velocities and statics are applied, with a stretch mute that mutes all signals stretched beyond a preset percentage (15% in this example).*

NORMAL MOVEOUT CORRECTION AND STRETCH MUTING

After the shot records are sorted into CPD gathers, normal moveout (NMO) correction removes time variations across CDP gathers by adjusting for the time delays caused by increasing offset between source and receivers across the gather. The time variations can be seen as the hyperbolic shape of the reflected arrivals and the linear refracted arrivals on the left image of Figure A5.2.

The NMO correction is applied as a stacking velocity which best aligns the reflections in the CDP gather, as seen on the right side of Figure. All the traces in the CDP gather are later summed (stacked) to produce one trace on the final stack, enhancing the aligned reflected signal and suppressing random noise.

Correct velocity correction ensures all the signals align and produce the strongest and best resolved signal. Velocities for horizontal, or near-horizontal, layers are picked for NMO correction. However, dipping structures will align at incorrect velocities at this stage, and velocities for dipping structures can only be determined after dip moveout (DMO) correction. The velocities which provided the strongest reflections after stacking were chosen as the correct stacking velocities. The final velocities were picked from data with all corrections applied except the mean refraction static, i.e., velocities were applied prior to moving the data to its final datum. The final NMO velocities picked to create the best stacked image can be visualised as gridded data (Figure A5.3). This shows the general shape of the bedrock and is vertically stretched by approximately V/H=5, assuming an average sedimentary velocity of 2,000 m/s. This shows that the velocity spectrum across the seismic line is fairly uniform with a slight decrease after CDP 3100 from 0.2 to 0.4 seconds. These velocity variations can indicate minor changes in the sedimentary composition, compaction or porosity. The bedrock stacking velocities increase from 4,500 metres-per-second just below the sediments to 5,500 metres-per-second at 1 second TWT. With the 644 metre maximum offset acquisition parameters, changes in these high velocities below 1 second have no significant effect on the data as there are no major hyperbolic shapes for reflections at these depths and offsets.



FigureA5.3: *The NMO stacking velocity spectrum for the seismic line. The bedrock velocities increase from 4,500 m/s just below the sediments to 5,500 m/s at 1 second TWT.*

An undesirable side effect of NMO correction is the deformation of the wavelet caused by NMO stretch. The NMO correction can cause traces to be stretched in a time-varying manner and this distortion increases at shallow times and large offsets. To prevent the degradation of especially shallow events, the distorted zone is deleted (muted) before stacking by applying stretch muting (Yilmaz, 1986). Figure A5.2, right-side, shows the CDP gather after NMO correction and mute stretch applied.

DIP MOVEOUT CORRECTION

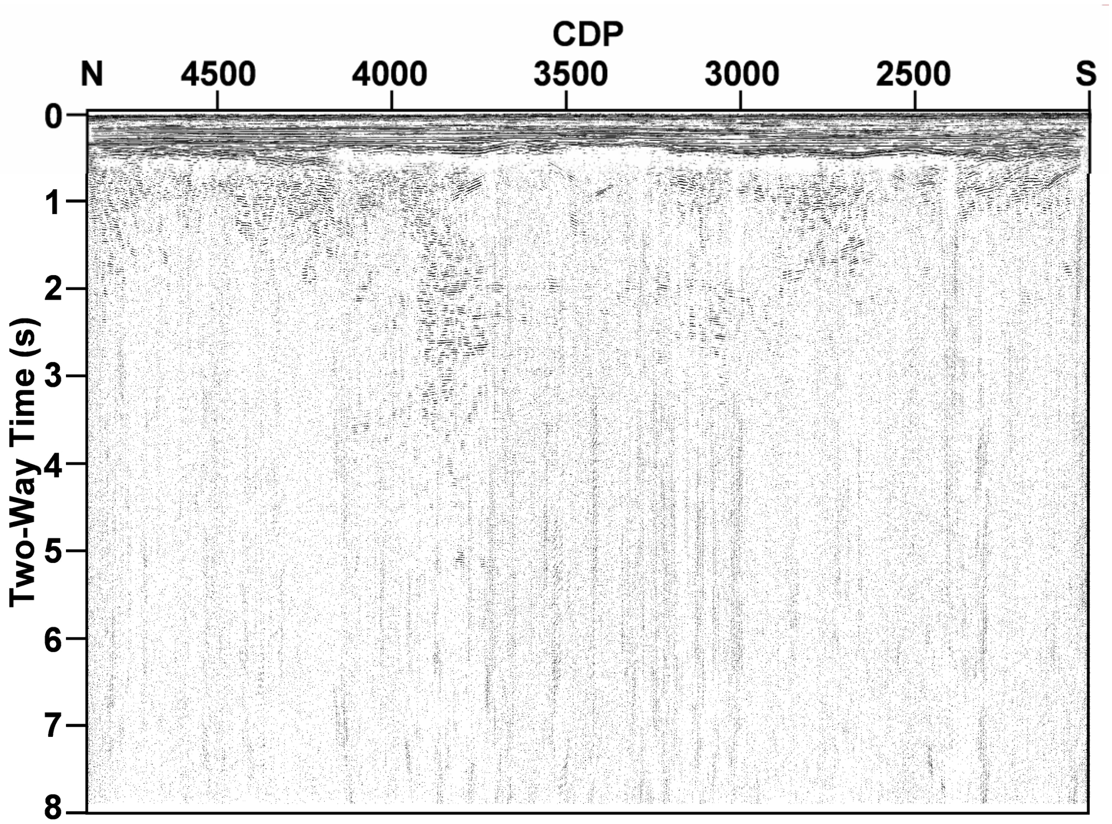
Dip moveout (DMO) correction, also known as partial prestack migration, adjusts the NMO correction for the increase in stacking velocity as structural dip increases, and has the effect of correcting the NMO to account for different dips along the line. After DMO, intersecting dipping and flat reflections will correctly stack with the same stacking velocity. With this data no significant dips were encountered at this step, and no further velocities were selected after DMO was applied.

COMMON DEPTH POINT STACK

Common-depth-point stacking is the summing of traces in a CDP gather to produce a single trace at the CDP location. The traces in the gather are aligned by the NMO and DMO processes to achieve optimal summation (Figure A5.2).

The CDP technique uses redundant recording to improve signal to noise (S/N) ratio. To achieve redundancy, the same subsurface points are recorded in the field with multiple shots and varying offsets. The improvement of S/N is based on the assumptions that the reflection signal on a trace (Yilmaz, 1987). Stacking the data improves the signal to noise ratio of the data by _n, where n is the number of traces summed (the fold). A nominal fold of 80 resulted from the acquisition geometry for the Papunya seismic survey. As the source was always in the midpoint of active geophones the fold tapered off at both ends of the line as fewer geophones were active when the source approached the line end-points.

The final DMO stack of all 8 seconds of recorded data is shown in Figure A5.4. Some variation in bedrock structure is evident. The acquisition parameters used in the survey provided reflected signals at CDP 3900 down to about 3.5 seconds two-way travel time. This converts to about 10 km (V/H=1/3) assuming an average crustal velocity of 6,000 m/s for bedrock and average sediment velocity of 2,000 m/s for the sedimentary section (V/H=1). Static corrections have been applied to remove the upper weathering layer and topography.

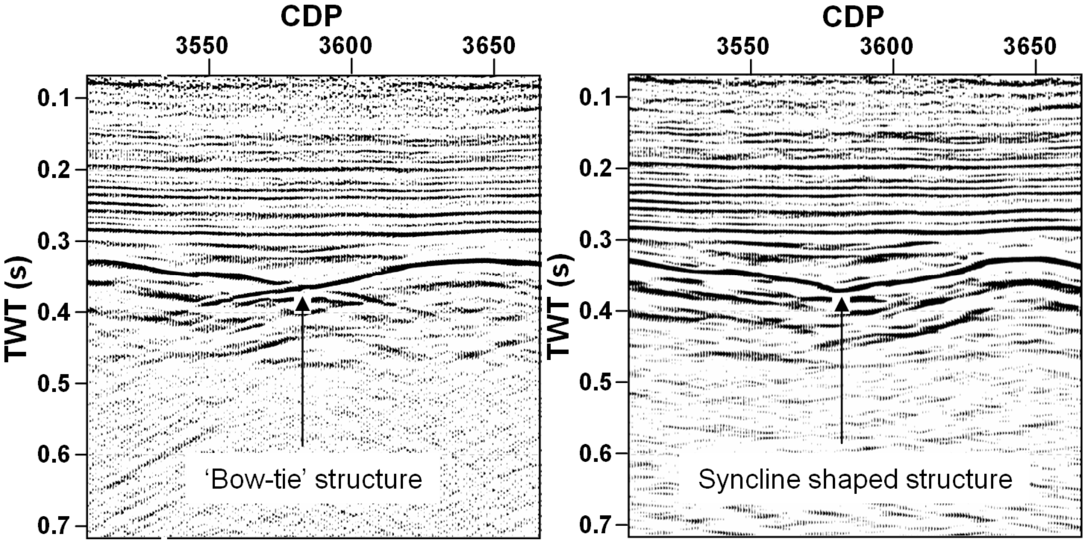


FigureA5.4: *DMO stack to 8 seconds showing that some bedrock structures can be imaged to about 4 seconds two-way time. The sedimentary section to 0.5 seconds is 0.5 km deep with V/H=1 assuming an average sedimentary velocity of 2,000 m/s. The bedrock has V/H=1/3 assuming an average crustal velocity of 6,000 m/s and 1 second equals 3 km for the bedrock. The data have been corrected to a datum of 600 m AHD at time 0 seconds.*

POSTSTACK TIME MIGRATION AND DISPLAY

Migration is the final processing step, moving dipping reflections to their most likely positions and improving horizontal resolution. Reflections that appear as dipping on the stack section will be moved up-dip and are shortened after migration. Diffraction hyperbolas resulting from discontinuities, such as terminations of reflectors at faults, should collapse to a small region at the apex of the hyperbola after migration. However, areas of poor signal-to-noise ratio in the line can produce artefacts in the data which will not migrate successfully. Some diffraction hyperbolas in the stacked section that diminish after migration may also suggest fractures or faulting.

For unmigrated data, the total area contributing to the observed reflection amplitude is approximated by the **Fresnel Zone**. The Fresnel Zone defines the lateral resolution of the data. After 2D migration the Fresnel Zone will collapse along the seismic line to a spatial resolution equivalent to the temporal resolution on the seismic trace (Bancroft, 2009). A syncline-shaped structure may appear as a ‘bow-tie’ on a stacked section and can be corrected by proper migration of seismic data, thereby improving the lateral resolution (Figure A7.5).



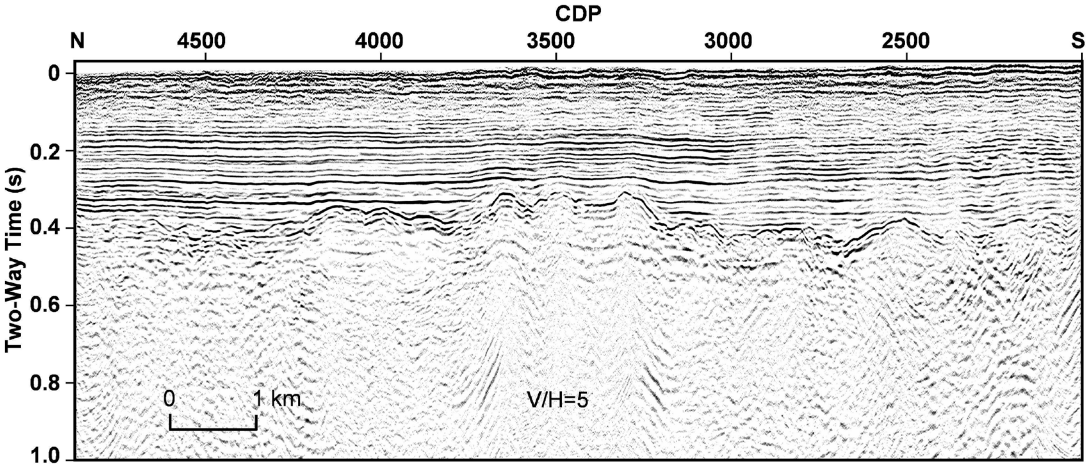
FigureA5.5: *DMO stack on the left shows a 'bow-tie' structure. On the right, migration has moved all events to their correct locations reconstructing a syncline shaped structure.*

The final migrated time section should have dipping reflections in the correct spatial location. Dipping structures and diffraction hyperbolas collapse to their smallest size at the correct migration velocity and will start to stretch at higher migration velocities. During migration testing the velocity just before the signal stretches is chosen as the best migration velocity for each section of the data. The Omega-X (frequency-space) migration algorithm used to process the data is described in Yilmaz (2001).

Coherency filters were applied to the data to enhance reflections for final display images, i.e. coherent reflections are enhanced and random events diminished. The final migrated image is shown as Figure A5.6, with V/H=5 used due to the small size of this image. Between CDP 3250–3750 the horizontal reflections do not contact the strong bedrock reflections. This may indicate significant bedrock weathering zone.

DEPTH CONVERSION

Depth conversion is performed using the stacking velocities. The software calculates the interval velocity between each of the stacking velocities using the Dix equation as described in Yilmaz (2001). Stacking velocities that decrease with time will produce errors with the Dix equation so the stacking velocities were adjusted to remove velocity decreases with time, using the faster upper velocity to replace a slower velocity directly below (if encountered). Significant lateral variation in velocities can also produce jagged edges or steps in the depth-converted image, so the stacking velocities were also smoothed using a 3-point running average.



FigureA5.6: *Migrated seismic line 10GA-PA1. Static corrections have been applied to remove the upper weathering layer and topography variations with the data corrected to a datum of 600 m AHD at time 0.0 s. V/H=5 is used to enhance the small image size.*

The final depth converted image provided useful insight for planning the deep Central Mount Wedge drilling program by identifying the location and depth of the thickest sediment section, i.e., greatest depth to bedrock. Subsequent drilling (details this chapter) showed the depth conversion to be accurate with <10 % error for the seismic-interpreted bedrock depth. The seismic depth estimate is about 500 metres to bedrock at the drillhole site; drilling penetrated bedrock at 471 metres depth below surface (Figure A5.7). The minor difference in depth is probably due to removal of velocities decreasing with time, and also smoothing of the velocities prior to depth conversion, as well as using preliminary processing results.

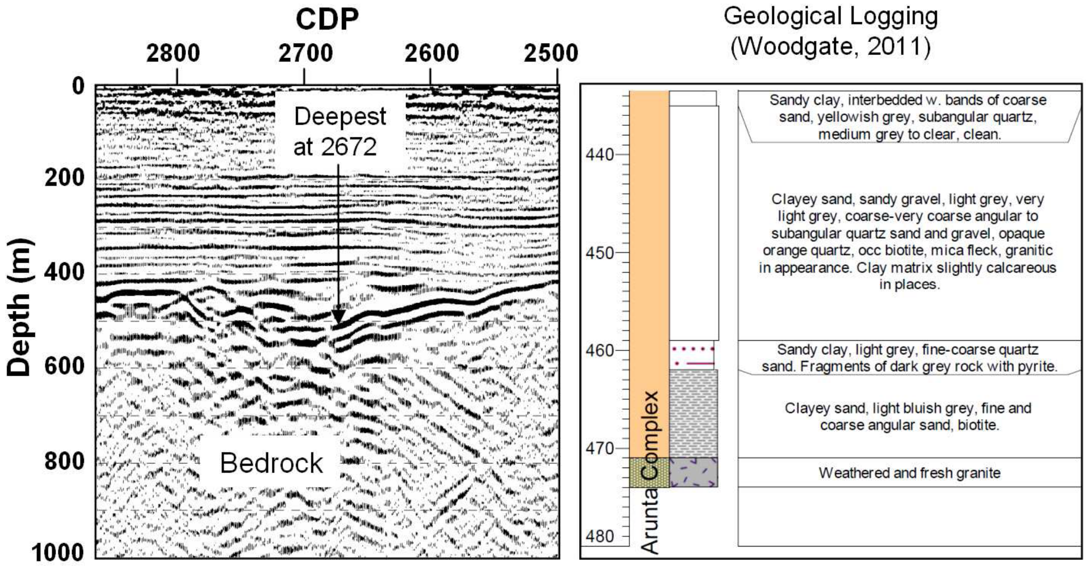


Figure A5.7: *Part of the depth-converted migrated image showing the drillhole location at the deepest part of the Central Mount Wedge Basin. The results from later bore drilling showed the seismic depth conversion to be a good approximation.*

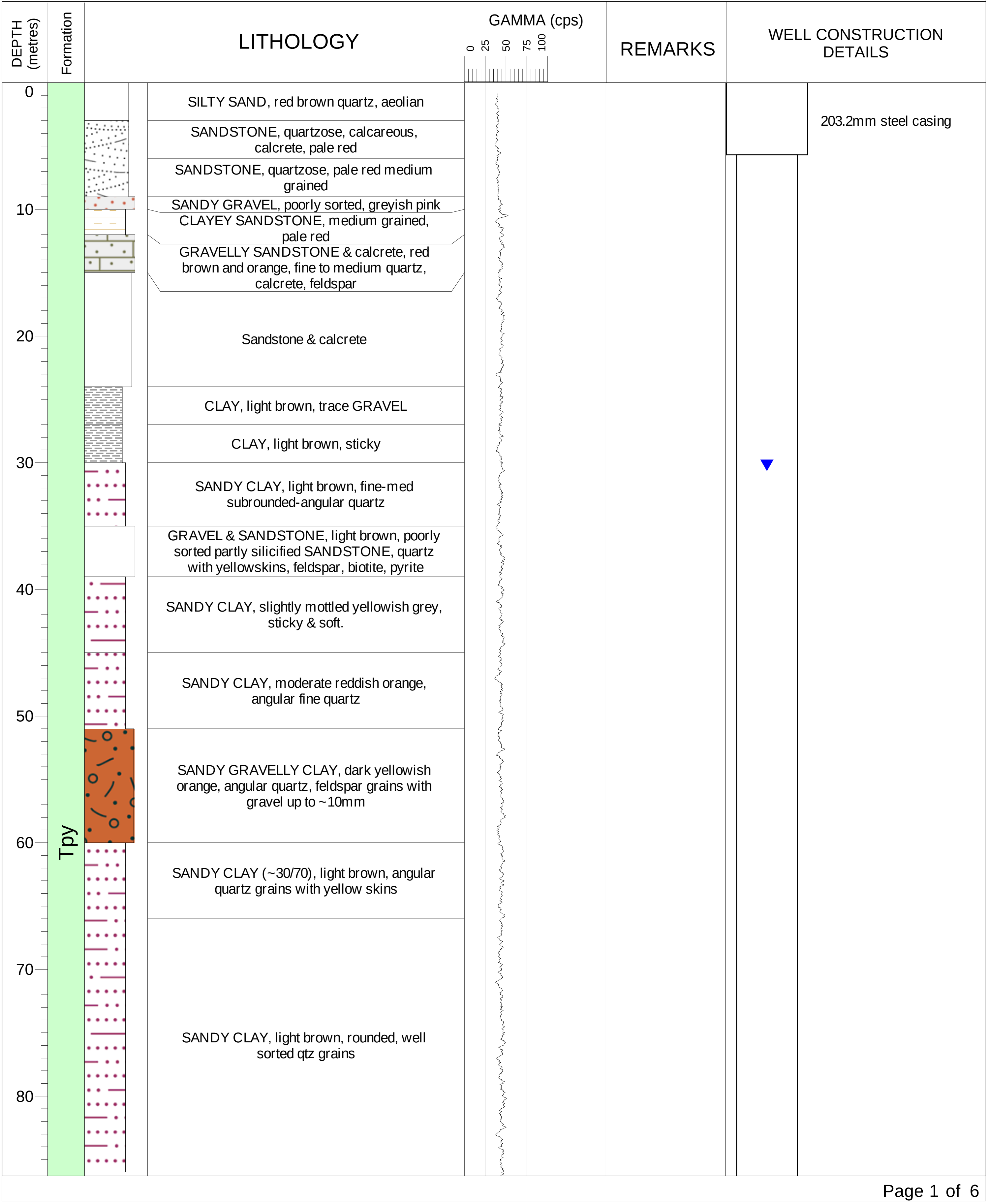
Appendix 6 – Bore log for Central Mount Wedge Basin

This appendix contains a copy of the completed stratigraphic log for the deep bore (RN18599) drilled in the Central Mount Wedge Basin as part of investigations for the *Palaeovalley Groundwater Project*.

Northern Territory Government

Palaeovalley Groundwater Project RN018599

LOCATION:	*Mt Wedge*	**TOTAL DEPTH (m):**	*473.9*	**AIRLIFT SALINITY (µS/cm):**	*12000*
DATE STARTED:	*23.11.2010*	**CONSTRUCTED DEPTH (mBGL):**	*443*	**DRILLING RIG:**	*Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7428756*	**DATE COMPLETED:** *10.12.2010*	**CASING HEIGHT (m):**	*0.5*	**DRILLER:**	*I Mcmasters*
EASTING: WGS 84 Zone 53 *530967*	**ELEVATION:**	**STANDING WATER LEVEL (mbgl):**	*30.2*	**LOGGED BY:**	*M Woodgate*



SILTY SAND, red brown quartz, aeolian

SANDSTONE, quartzose, calcareous, calcrete, pale red

SANDSTONE, quartzose, pale red medium grained

SANDY GRAVEL, poorly sorted, greyish pink

CLAYEY SANDSTONE, medium grained, pale red

GRAVELLY SANDSTONE & calcrete, red brown and orange, fine to medium quartz, calcrete, feldspar

Sandstone & calcrete

CLAY, light brown, trace GRAVEL

CLAY, light brown, sticky

SANDY CLAY, light brown, fine-med subrounded-angular quartz

GRAVEL & SANDSTONE, light brown, poorly sorted partly silicified SANDSTONE, quartz with yellowskins, feldspar, biotite, pyrite

SANDY CLAY, slightly mottled yellowish grey, sticky & soft.

SANDY CLAY, moderate reddish orange, angular fine quartz

SANDY GRAVELLY CLAY, dark yellowish orange, angular quartz, feldspar grains with gravel up to ~10mm

SANDY CLAY (~30/70), light brown, angular quartz grains with yellow skins

SANDY CLAY, light brown, rounded, well sorted qtz grains

Northern Territory Government

Palaeovalley Groundwater Project

RN018599

LOCATION: *Mt Wedge*

TOTAL DEPTH (m): *473.9*

AIRLIFT SALINITY (µS/cm): *12000*

DATE STARTED: *23.11.2010*

CONSTRUCTED DEPTH (mBGL): *443*

DRILLING RIG: *Ingersol Rand*

NORTHING: *7428756*
WGS 84 Zone 53

DATE COMPLETED: *10.12.2010*

CASING HEIGHT (m): *0.5*

DRILLER: *I Mcmasters*

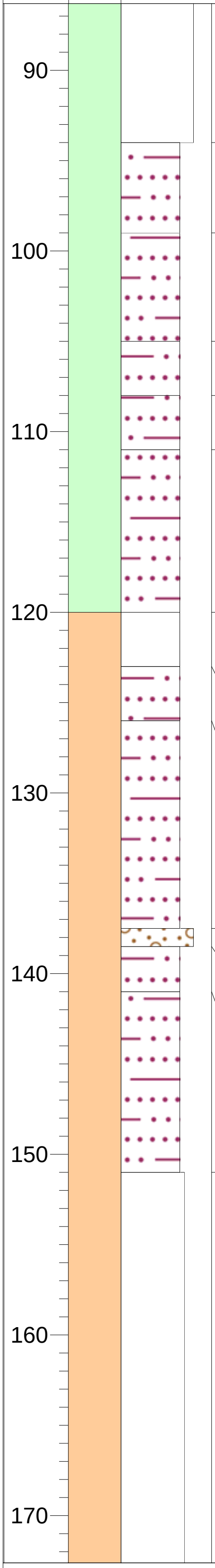
EASTING: *530967*
WGS 84 Zone 53

ELEVATION:

STANDING WATER LEVEL (mbgl): *30.2*

LOGGED BY: *M Woodgate*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS



GRAVEL - fairly clean, well sorted angular-subangular quartz, lithic, calcite

SANDY CLAY, light brown, stiff

SANDY CLAY, mod reddish brown, fine-med quartz, fine mica flakes

SANDY CLAY (~20/80), mod reddish brown, fine qtz SAND, stiff clay

SANDY CLAY, mottled, limonite stained, quartz grains with yellow skins.

SANDY CLAY (~30/70), yellowish grey, reddish brown, limonite staining dark grey patches.

CLAYSTONE & SANDY CLAY with trace GRAVEL, yellowish grey, mottled white, pale olive and moderate reddish brown, angular quartzitic gravel and sand.

SANDY CLAY, slightly mottled with very light grey and pale greenish yellow. Fine-med quartz sand with yellow & red skins

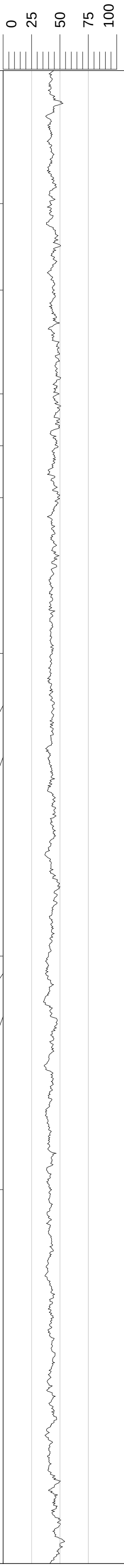
SANDY CLAY, mottled white, pale olive, red brown, sand includes quartz, minor laterite & other lithic

GRAVEL, angular, poorly sorted quartz and lithic gravel.

SANDY CLAY, white and pale olive, minor mottling red brown, limonite, fine to course quartz and lithic sand.

SANDY CLAY, pale greenish yellow with blue grey streaks. Sand is angular-rounded poorly sorted quartz.

CLAYEY SAND ~50/50 (Like a beach SAND bound in CLAY). Pale olive green.Fine-medium well sorted rounded quartz sand



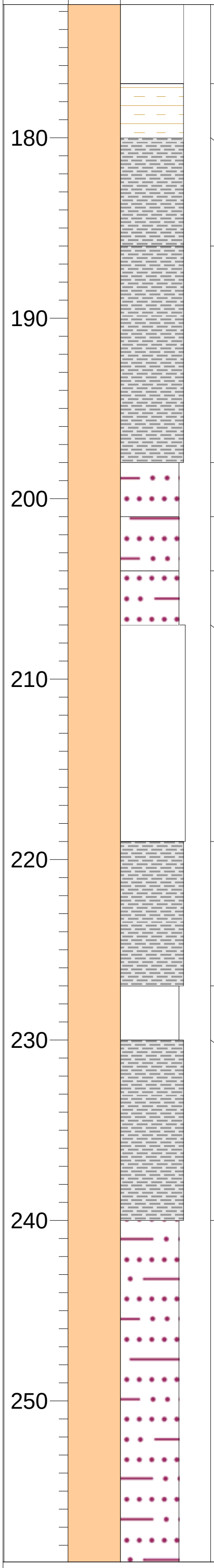
158mm steel casing

Palaeovalley Groundwater Project

RN018599

LOCATION: *Mt Wedge*
TOTAL DEPTH (m): *473.9*
AIRLIFT SALINITY (µS/cm): *12000*
DATE STARTED: *23.11.2010*
CONSTRUCTED DEPTH (mBGL): *443*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7428756*
DATE COMPLETED: *10.12.2010*
CASING HEIGHT (m): *0.5*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *530967*
ELEVATION:
STANDING WATER LEVEL (mbgl): *30.2*
LOGGED BY: *M Woodgate*

DEPTH (metres)	Formation	LITHOLOGY	GAMMA (cps)	REMARKS	WELL CONSTRUCTION DETAILS



CLAYEY SANDSTONE, pale olive,minor limonite, very fine-coarse moderately sorted, quartz sand

CLAYEY SAND, pale olive, quartz, dark flecks

CLAYEY SAND, pale olive slightly mottled, firm clay

SANDY CLAY, olive brown, medium-very coarse, poorly sorted subangular quartz sand

SANDY CLAY, pale olive, medium-coarse sand

SANDY CLAY ~60/40, pale olive, medium-coarse subangular-rounded quartz sand with minor yellow skins

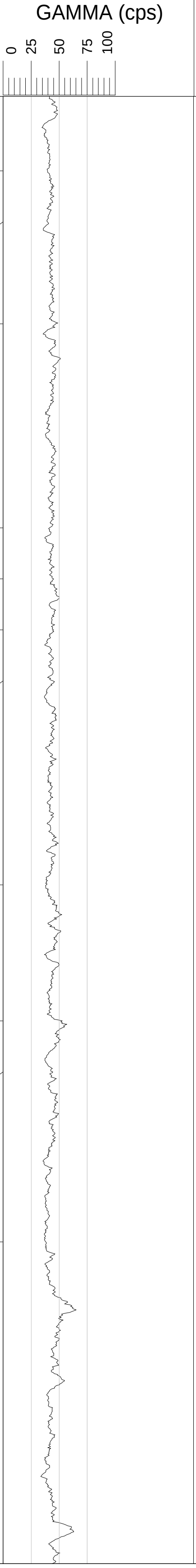
CLAYEY SAND & trace GRAVEL, pale olive, fine, subangular quartz sand with biotite flecks.

CLAYEY SAND, yellowish grey with limonite patches, Fine-coarse angular-subrounded quartz sand.

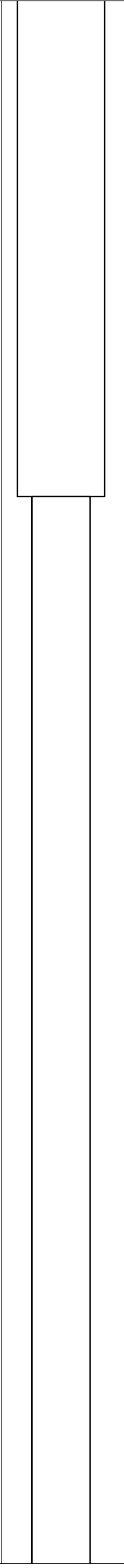
GRAVELLY CLAYEY SAND, light grey, limonite stains, very coarse angular quartz sand with muscovite flakes

CLAYEY SAND, yellowish grey, limonite in patches, fine-coarse qtz sand.

SANDY CLAY, yellowish grey, fine to medium angular quartz sand, minor biotite



EC 1,415, seepage



Northern Territory Government

Palaeovalley Groundwater Project RN018599

LOCATION: *Mt Wedge*
TOTAL DEPTH (m): *473.9*
AIRLIFT SALINITY (µS/cm): *12000*
DATE STARTED: *23.11.2010*
CONSTRUCTED DEPTH (mBGL): *443*
DRILLING RIG: *Ingersol Rand*
NORTHING: WGS 84 Zone 53 *7428756*
DATE COMPLETED: *10.12.2010*
CASING HEIGHT (m): *0.5*
DRILLER: *I Mcmasters*
EASTING: WGS 84 Zone 53 *530967*
ELEVATION:
STANDING WATER LEVEL (mbgl): *30.2*
LOGGED BY: *M Woodgate*

DEPTH (metres) | Formation | LITHOLOGY | GAMMA (cps) | REMARKS | WELL CONSTRUCTION DETAILS

260
270
280
290
300
310
320
330
340

Mount Wedge Clay

SANDY CLAY (~40/60) yellowish grey, fine angular sand, fragment of shell, some oxidised sfcs

SANDY CLAY (~20/80) mottled red, yellowish grey sticky clay with fine angular quartz sand.

SANDY CLAY, greyish orange pink, apple green specks, quartz, feldspar, minute black flecks

a/a

a/a

SANDY CLAY, mottled as per 270-273

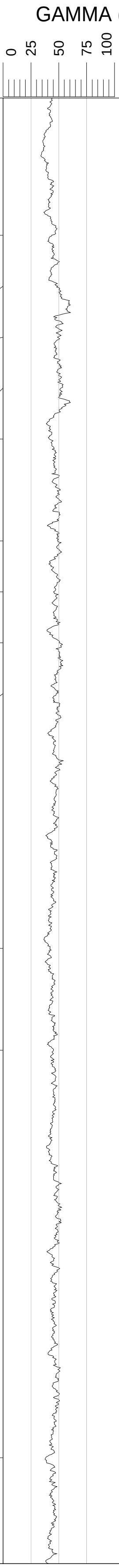
SANDY CLAY (~20/80), mottled

SANDY CLAY, with dark greenish yellow firm patches, mottled limonite & red throughout. Fine, angular to subangular quartz sand.

SANDY CLAY, light greenish grey with fine angular quartz sand.

SANDY CLAY, light greenish grey with fine-coarse angular quartz sand.Biotite inclusions on coarse grains.Calcareous in places.

SANDY CLAY, light olive grey, fine, angular, with a trace of coarse, quartz sand, scattered black flecks



114mm steel casing

Northern Territory Government

Palaeovalley Groundwater Project

RN018599

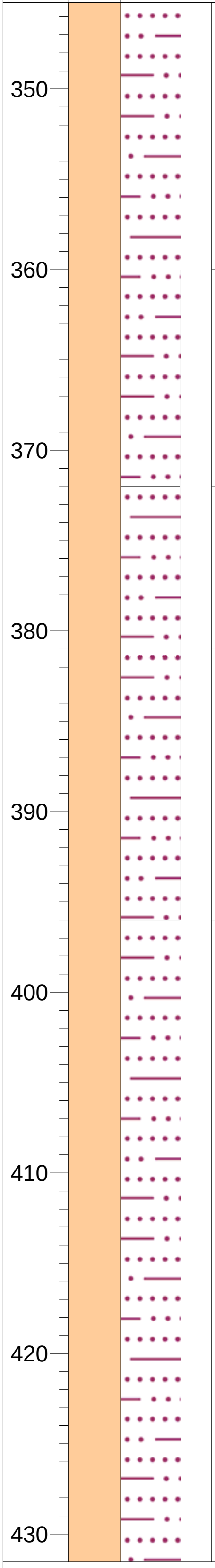
LOCATION: *Mt Wedge*
TOTAL DEPTH (m): *473.9*
AIRLIFT SALINITY (μS/cm): *12000*

DATE STARTED: *23.11.2010*
CONSTRUCTED DEPTH (mBGL): *443*
DRILLING RIG: *Ingersol Rand*

NORTHING: *7428756*
WGS 84 Zone 53
DATE COMPLETED: *10.12.2010*
CASING HEIGHT (m): *0.5*
DRILLER: *I Mcmasters*

EASTING: *530967*
WGS 84 Zone 53
ELEVATION:
STANDING WATER LEVEL (mbgl): *30.2*
LOGGED BY: *M Woodgate*

DEPTH (metres)	Formation	LITHOLOGY	GAMMA (cps)	REMARKS	WELL CONSTRUCTION DETAILS



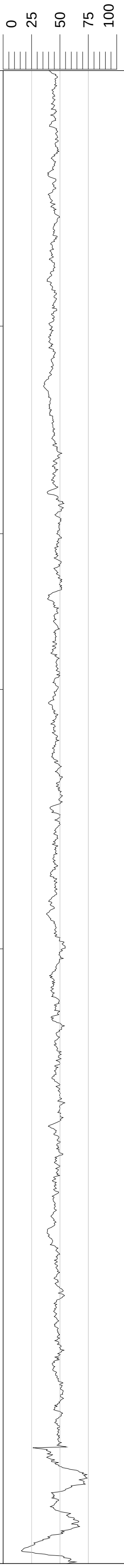
SANDY CLAY ~50/50, very light grey, mainly fine, angular quartz sand, carbonaceous matrix in places

SANDY CLAY, light grey

SANDY CLAY, light grey, very fine quartz SAND, well sorted and angular.

SANDY CLAY, yellowish grey, very fine SAND, increase in limonite, apple green mineral - 5cm band of GRAVEL

SANDY CLAY, yellowish grey, very fine, angular SAND, quartz, mica flakes, pyritic dark grey rock. Quartz clean.



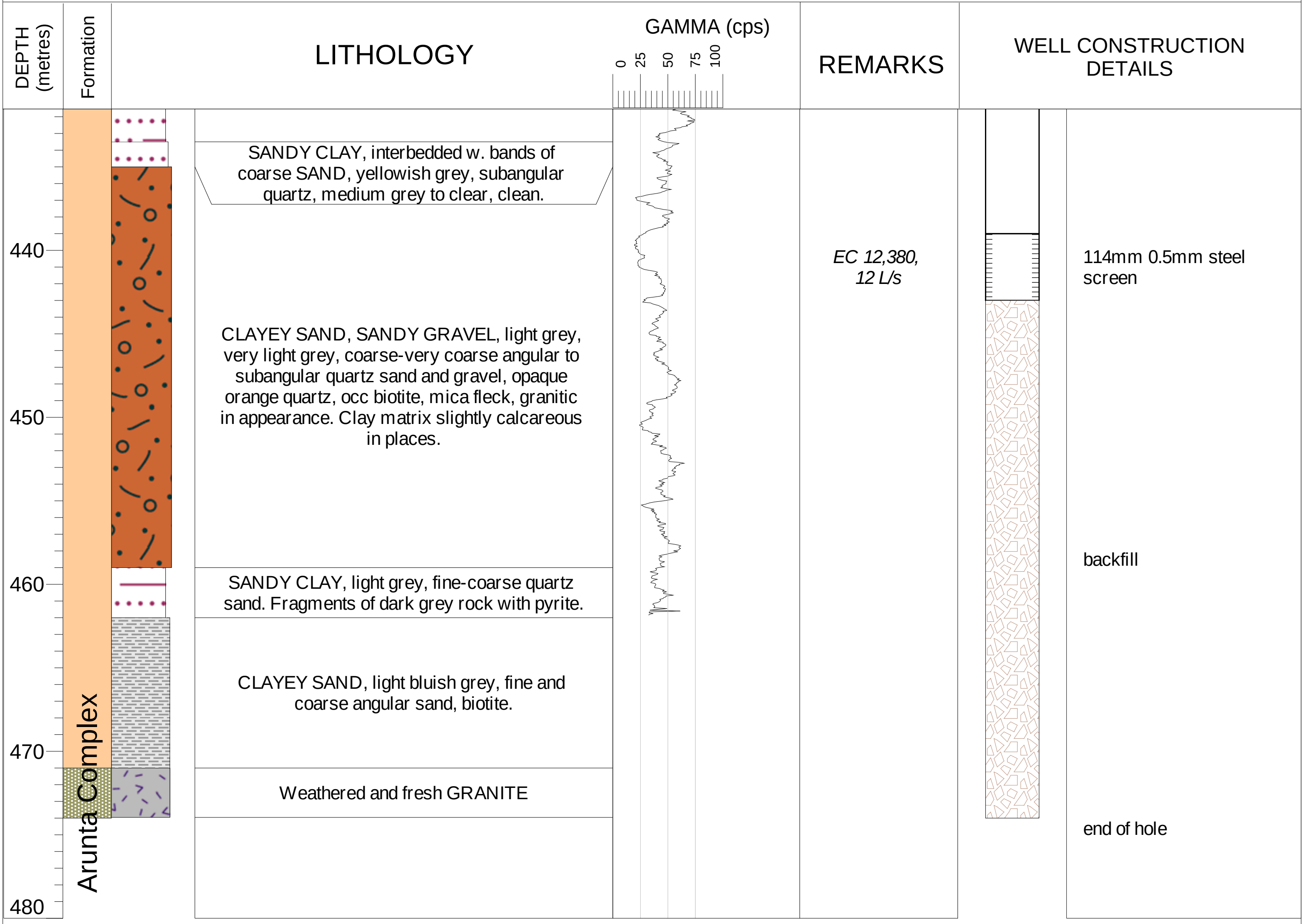
Palaeovalley Groundwater Project RN018599

LOCATION: *Mt Wedge*
TOTAL DEPTH (m): *473.9*
AIRLIFT SALINITY (µS/cm): *12000*

DATE STARTED: *23.11.2010*
CONSTRUCTED DEPTH (mBGL): *443*
DRILLING RIG: *Ingersol Rand*

NORTHING: WGS 84 Zone 53 *7428756*
DATE COMPLETED: *10.12.2010*
CASING HEIGHT (m): *0.5*
DRILLER: *I Mcmasters*

EASTING: WGS 84 Zone 53 *530967*
ELEVATION:
STANDING WATER LEVEL (mbgl): *30.2*
LOGGED BY: *M Woodgate*



SANDY CLAY, interbedded w. bands of coarse SAND, yellowish grey, subangular quartz, medium grey to clear, clean.

CLAYEY SAND, SANDY GRAVEL, light grey, very light grey, coarse-very coarse angular to subangular quartz sand and gravel, opaque orange quartz, occ biotite, mica fleck, granitic in appearance. Clay matrix slightly calcareous in places.

SANDY CLAY, light grey, fine-coarse quartz sand. Fragments of dark grey rock with pyrite.

CLAYEY SAND, light bluish grey, fine and coarse angular sand, biotite.

Weathered and fresh GRANITE

EC 12,380, 12 L/s

114mm 0.5mm steel screen

backfill

end of hole

Appendix 7 – Hydrogeochemical data for Central Mount Wedge Basin

This appendix contains the results of laboratory analyses for groundwater samples from two bores in the Central Mount Wedge Basin, collected for the *Palaeovalley Groundwater Project*.

Table A7.1: Hydrogeochemical data for bores in the Central Mount Wedge Basin.

Bore ID & sample depth	**Sampling date**	**pH**	**EC**	**Alkalinity**	**CO_3**	**HCO_3**	**OH**	**TSS**	**TDS**	**NO_2_N**	**NO_2**	**NO_3**	**Cl**	**PO_4**
		units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
RN18599 (deep)	9/3/11	8.2	8,800	216	<1	216	<1	890	6,260	0.02	0.08	12.1	2,640	0.015
RN16694 (shallow)	9/3/11	8.5	2,520	274	13	262	<1	<10	1,530	<0.005	<0.02	24.5	497	0.015
Drinking water guidelines*										0.9		50		

Table A7.1 (cont…): Hydrogeochemical data for the Central Mount Wedge Basin.

Bore ID & sample depth	**NH_3**	**F**	**Hardness**	**Ca**	**K**	**Mg**	**Na**	**SiO_2**	**SO_4**	**Ag**	**Al**	**As**	**B**	**Ba**	**Be**	**Br**	**Cd**
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN18599 (deep)	0.005	0.4	1,970	467	26	195	1,080	52.2	365	<10	>LWR	2.5	180	200	1	2,450	<0.2
RN16694 (shallow)	<0.005	0.6	433	90.4	21.5	50.4	349	44.8	241	<10	<20	1	380	<50	<1	1,370	<0.2
Drinking water guidelines		1.5								100		7.0	4,000	700			

Table A7.1 (cont…): Hydrogeochemical data for the Central Mount Wedge Basin.

Bore ID & sample depth	**Cr**	**Cu**	**Fe**	**Hg**	**I**	**Mn**	**Mo**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**U**	**Zn**
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
RN18599 (deep)	40	20	<LWR	<0.1	150	585	<5	20	18	<0.2	11	<10	27.4	50
RN16694 (shallow)	<5	<10	<20	<0.1	260	<5	<5	<2	<1	<0.2	6	<10	9.17	<10
Drinking water guidelines	50	2,000		1	100	500	50	20	10		10		20	-

*Australian Drinking Water Guidelines, National Water Quality Management Strategy, NHMRC/NRMMC, 2004