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Site Characterisation - Technical Report
WALLERBERDINA

NATIONAL RADIOACTIVE WASTE MANAGEMENT FACILITY

Site Characterisation - Technical Report - Wallerberdina

Client: Commonwealth Department of Industry, Innovation and Science

ABN: 74 599 608 295

Prepared by

AECOM Australia Pty Ltd
Level 28, 91 King William Street, Adelaide SA 5000, Australia
T +61 8 7223 5400 F +61 8 7223 5499 www.aecom.com
ABN 20 093 846 925

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Prepared by / Reviewed by

Flora, Fauna and Conservation	Prepared by	Matthew McDonnell Floora De Wit Jonathan Billington
	Reviewed by	Cameron Miller
Radiation, Background and Risks	Prepared by	Ross McFarland
	Reviewed by	James Rusk
Climatic Conditions and Climate Change	Prepared by	Michelle Wilson Allan Klindworth
	Reviewed by	Allan Klindworth Rebecca Miller
Bush Fire Risks	Prepared by	Terramatrix
	Reviewed by	James Rusk Cameron Miller
Hydrology and Flood Risks	Prepared by	Michael Turnley
	Reviewed by	Sam Marginson
Impacts of Nearby Human Activities and Land Use Planning	Prepared by	Tom Hateley
	Reviewed by	Kylie Schmidt
Geology, Hydrogeology, Geochemistry, Geotechnical and Soils	Prepared by	Melinda Morris Joseph Tan James Rusk
	Reviewed by	Damien Finlayson Kylie Schmidt James Tuff
Landform Stability	Prepared by	Sandra Brizga
	Reviewed by	Damien Finlayson James Rusk

Seismic Risks	Prepared by	Andreas Skarlatoudis Paul Somerville
	Reviewed by	Hong Kie Thio
Transport Considerations	Prepared by	Joshua Ware
	Reviewed by	Peter Hislop
Waste Emissions	Prepared by	Neville Tawoma
	Reviewed by	Chani Lokuge
Utilities and Energy Considerations	Prepared by	Gordon Peebles
	Reviewed by	Kylie Schmidt
Renewable Energy Considerations	Prepared by	Rachel Hogan
	Reviewed by	Angela Rozali Abbie McQueen

Revision History

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Limitations Statement

Limitations Statement

AECOM Australia Pty Ltd (AECOM) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of the Department of Industry, Innovation and Science and only those third parties who have been authorised in writing by AECOM to rely on this Report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

It is prepared in accordance with the scope of work and for the purpose outlined in the contract dated 31 January 2018.

The methodology adopted and sources of information used by AECOM are outlined in this the Report.

Where this Report indicates that information has been provided to AECOM by third parties, AECOM has made no independent verification of this information except as expressly stated in the Report. AECOM assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between February and July 2018, and is based on the conditions encountered and information reviewed at the time of preparation. AECOM disclaims responsibility for any changes that may have occurred after this time.

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This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The seismic or borehole logs reviewed indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the uniformity of conditions and on the frequency and method of sampling. The behaviour of groundwater and some aspects of chemicals in soil and groundwater are complex. Our assessment is based upon the data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AECOM must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time.

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Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.

Executive Summary

Executive Summary

The Australian Government is committed to identifying a site for the National Radioactive Waste Management Facility (NRWMF) that will permanently dispose of Australia's low level radioactive waste and temporarily store intermediate level radioactive waste. Sites being considered have been identified through a voluntary community nomination process.

The Department of Industry, Innovation and Science ('the Department') established a NRWMF Task Force to lead a site nomination and selection process in accordance with the requirements of the National Radioactive Waste Management Act (2012). Three sites were shortlisted for Site Characterisation for the purpose of conducting a technical assessment to evaluate siting the NRWMF including the Lyndhurst and Napandee sites near Kimba, South Australia and the Wallerberdina site near Hawker, South Australia.

AECOM Australia Pty Ltd (AECOM) was engaged by the Department to conduct Site Characterisation studies at the three shortlisted sites. The studies are focused on characterising the surface and subsurface environments within and surrounding nominated 100 hectare study areas being considered for siting of the NRWMF. The studies also comprise a preliminary assessment of constraints and options for the enabling infrastructure that would be required to develop and operate the NRWMF. This Technical Report outlines the methods and results for the Site Characterisation studies at the Wallerberdina site.

A range of key site characteristics or criteria were developed with reference to Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and International Atomic Energy Agency (IAEA) guidelines relating to the selection and evaluation of sites being considered for the siting of radioactive waste facilities.

In Australia, the siting and licensing of controlled facilities such as the proposed NRWMF are governed by the *National Radioactive Waste Management Act (2012), Australian Radiation Protection and Nuclear Safety Act (1998)* and *Australian Radiation Protection and Nuclear Safety Regulations (1999)*. The ARPANSA Regulatory Guide 'Siting of Controlled Facilities' (2014) outlines criteria which should be taken into account when screening potential sites for controlled facilities. Similarly, the International Atomic Agency (IAEA) Safety Standard 'Site Survey and Site Selection for Nuclear Installations' provides clear guidance on site characteristics to be considered for facilities such as the NRWMF. The requirements of these pieces of legislation and guidelines have been taken into account in developing the site characteristic criteria used in the Site Characterisation studies which are shown in the table below. As the abovementioned legislation and guidelines are all encompassing and are relevant to all site selection characteristics, they are not specifically referenced in the table.

Table 1 Site Assessment Summary - Wallerberdina

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Flora & Fauna	To characterise the flora and fauna present on and adjacent to the site and identify any significant or threatened species and supporting habitats which could preclude use of the site for the proposed NRWMF.	*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *Native Vegetation Act 1991* (SA) *National Parks and Wildlife Act 1972* (SA).	Absence of Commonwealth or State threatened species and supporting habitat, minimal requirement for vegetation clearance.	The Wallerberdina site has no threatened ecological communities. There are no EPBC Act listed species with potential for occurrence; but one flora (Desert Lime) and one fauna (Elegant Parrot) State listed species have the potential to be present, which require further surveys to determine likelihood of occurrence and significance of potential impacts.
Conservation and special use areas	To identify any Conservation or Recreational Parks in close proximity to the site and Aboriginal heritage or State and Local listed heritage sites which could preclude use of the site for the proposed NRWMF.	*National Parks and Wildlife Act 1972* (SA) *Heritage Places Act 1993* (SA).	Absence of Parks (National Parks, Conservation Parks, Conservation Reserves, Recreational Parks, Wilderness Protected Areas and native vegetation Heritage Agreements) and Aboriginal or State and Local heritage sites on or adjacent to the site.	The Wallerberdina site does not have any National or State parks and reserves nearby. Twenty six registered and three restricted Aboriginal heritage sites are located in the local area away from the site. A cultural heritage assessment is being undertaken at Wallerberdina, independent of the studies outlined in this report.
Radiation, background and risks	Establish a baseline for future environmental monitoring (to inform possible licence application) and identify potential elevated background conditions that could affect safety of personnel.	IAEA-TECDOC-1363 Guidelines for radioelement mapping using gamma ray spectrometry data. IAEA NS-R-3 (Rev.1) Site Evaluations for Nuclear Installations.	Background radiation levels within the ARPANSA Action Levels for workplaces. Background radiation levels are not sufficiently elevated to impact on the effectiveness of environmental monitoring.	Published historical radiometric aerial survey data obtained on a 200 m grid that covers site and surrounds reported background radiation levels that are not elevated, at around 1% of the ARPNSA Action levels for workplaces.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Climate change and long term environmental scenarios	Establish existing climatic conditions for the site based on historic average and identify likely changes to climate based on projections and identify resultant key hazards that could impact on the future NRWMF and workers.	AS5534-2013 Climate change adaptation for settlement and infrastructure – A risk based approach. IAEA SSG-18 Specific Safety Guide Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations.	Future climate change conditions where the frequency and intensity of climatic events have minimal impacts or where design measures can mitigate risks.	Potential climate change impacts include higher intensity rainfall events, extreme heat and fire weather. These events have the potential to impact on variables including worker safety, infrastructure damage, waste transport, flooding, power supply and maintenance costs amongst others. Potential climate change impacts should be used to inform design and operation of the NRWMF should it proceed at this site.
Bushfire Risks	Characterise bushfire threat from factors including vegetation/ fuel hazard at local and landscape level, site slopes, frequency/ severity of bushfire weather conditions and assess the likelihood and nature of bushfire impact based on potential for ignition, development and approach in landscape.	AS 3959-2009 Construction of Buildings in Bushfire Prone Areas. Department of Environment, Water and Natural Resources, 2012. Overall Fuel Hazard Guide for South Australia.	Combination of climatic conditions, fuel loadings, topography and ability to create buffers which minimises the risk and potential severity of bushfires.	The bushfire hazard at Wallerberdina is low, due to the lesser hazard nature of the vegetation on and around the site and the benign topography. The site would only be exposed to a relatively low intensity grass or scrub fire that would not pose a significant hazard if appropriate bushfire protection measures are provided.
Impacts of Nearby Human Activities and Land Use Planning	Identify existing and potential future land uses on, or in proximity to the site, (sensitive land uses, extractive or hazardous activities) that may adversely impact on the site or be impacted by the NRWMF.	IAEA Safety Requirements NS-R-3 (Rev.1) Site Evaluations for Nuclear Installations. Flinders Ranges Council Development Plan; consolidated 25 October 2012.	Absence of sensitive land uses (e.g. residences) or land uses that could directly or indirectly impact the NRWMF (e.g. mining tenements, hazardous facilities, airfields) in proximity to the site.	The site is well separated from adversely affecting development and sensitive land uses. The existence of a number of mineral and geothermal tenements over and within close proximity to the Wallerberdina site, if developed, may have the potential to directly or indirectly impact the NRWMF or its enabling infrastructure.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Hydrology and Flood Risks	Assess potential localised flooding (water logging or extreme rainfall) or episodic major flooding or avulsion potential from upstream catchments now, and as a result of climate change, that could impact operations and site access without mitigation measures.	IAEA SSG-18 Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff (ARR): A Guide to Flood Estimation, Commonwealth of Australia.	Minimal catchment areas and watercourses draining into the site, an absence of 'hydrophobic' soils, high soil conductivity rates and lower intensity rainfall events.	Drainage lines are present through the site. Hookina Creek passes through and outside the southern edge of Walleberdina Station, from around 3.5 km from the site. A tributary of Hookina Creek is 1.5 km east of the site. Anecdotal evidence is that during the major episodic floods in 1955 and 2005 the floodwaters of Hookina Creek did not reach the site. To quantify the flood risks, a hydrological model was prepared and 2D hydraulic modelling undertaken. The modelling indicates that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 annual exceedance probability, AEP). For the 1 in 2000 AEP flood, depths are typically in the range 0.25 to 0.5 m with isolated areas up to 1 m. This poses constraints on the site that will require the investigation and design of appropriate mitigation measures (e.g. consideration of installation of bunds and levees) should Wallerberdina be further considered for the NRWMF.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Geology, hydrogeology, geochemistry, geotechnical and soils	Characterise the site sub-surface environment to determine geological, hydrogeological and geochemical characteristics.	AS1726 – 2017 Australian Standard Geotechnical Site Investigations. AS1289 series Australian Standard Method of testing soils for engineering purposes. AS/NZS 5667.1 Water quality – Sampling Guidance on the design of sampling programs, sampling techniques and preservation and handling of samples. NUDLC, 2012 *Minimum Construction Requirements for Water Bores in Australia V3* developed by the National Uniform Drillers Licensing Committee, Third Edition, February 2012.	Deep watertable, low potential for vertical or horizontal migration of water through underlying soil, poor quality groundwater, presence of subsurface material with chemical attenuation properties, limited or no groundwater users, absence of geotechnical hazards (potential for slope instability, soil liquefaction, collapsing or expansive soils, subsidence due to ground features, long-term settlement, soil scour and erodibility).	The geological, hydrogeological, soil and geotechnical conditions at the site do not present hazards or constraints that would not be manageable through appropriate design and operational protocols. Groundwater in the watertable aquifer was found to be present at depths in excess of 20 metres. There are a series of aquifers within the top 100m subsurface profile with yield and quality potential for a local site groundwater supply. Given the lack of reticulated water supply, groundwater may have the potential to be used for a range of beneficial uses for the NRWMF (some requiring additional pre-treatment). The presence of clay, low salinity and moderately alkaline pH are favourable soil properties for attenuation in the unlikely event of a subsurface release of waste material. This is due to the inherent characteristics of the subsurface environment to exchange charged particles (ions) during the interaction of potential fluids migrating through the unsaturated zone above the watertable and the natural soil within that zone of migration. There are however, some soil horizons where the ion exchange potential is lower than others due to naturally occurring levels of exchangeable sodium. Geotechnical hazards are unlikely to be present at the site based on current data but further investigations would be required for site specific aspects such as design of footings and structures.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Landform stability	Identify geomorphological processes (including fluvial, aeolian, slope/ mass movement) with potential to impact on long term site stability.	No recognised applicable standards or guidelines.	Stable landform, minimal potential for slope or mass movement processes.	The site is situated on the Hookina Creek alluvial fan and likely to be subject to episodic fluvial geomorphological processes during rare large flood events. During extended dry periods, the site may be affected by the deposition of aeolian sediment from adjacent dune fields or further afield as well as wind erosion. Such processes have the potential to impact on the long term stability of the site if mitigation and monitoring measures are not employed. Further hydraulic modelling is required to consider risks posed by avulsion, floodplain scour and sedimentation.
Seismic activity	Characterise potential seismic hazards with emphasis on active faults beneath or near the site, near surface faults and the presence of ridge crests in the site vicinity.	IAEA SSG-9 Seismic Hazards in Site Evaluation for Nuclear Installations, relevant peer-reviewed technical information listed in the methodology and scope and other IAEA documents listed in the reference section.	Absence of potentially active faults that could cause surface faulting through the NRWMF, near-surface faults that could cause folding or other deformation within the NRWMF, nearby faults that could cause hanging wall or rupture directivity effects which amplify ground motions and ridge crests which amplify ground motions.	Seismic data obtained from field surveys across the site indicates, with a high level of confidence (excluding the possibility of one-off faulting), the absence of potentially active faults in the foundation, but the potential for near-surface faults beneath or near the foundation. The Western Range front faults are assumed to exist in the nearby area; a seismic survey line across the site is suggested to identify the location of these faults should this site be further considered for the NRWMF. Seismic hazards from ground shaking and deformation should be able to be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods based on currently available data.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Transport considerations	Assess proximity of the site to waste sources and characterise the national, regional and local transport networks (including multi-modal) to enable safe site access and egress.	ARPANSA, 2014. The Code for the Safe Transport of Radioactive Material. ARPANSA (2008) Code of Practice for the Safe Transport of Radioactive Materials. Austroads Guide to Road Design National Heavy Vehicle Regulator, 2017. Performance-Based Standards Scheme – Network Classification Guidelines and Performance-Based Standards Scheme – Vehicle Certification Rules.	Major highway access from waste sources around Australia, good local access road network with minimal upgrade requirements and potential for multi-modal transport options.	The central location in SA makes the sites suitable for receipt of wastes from a variety of sources and is well served by major road networks. Local roads will need to be upgraded and sealed to accommodate frequent B-Double movements and infrequent ODOM vehicles. Multiple culvert crossings may need to be installed to accommodate the number of watercourses that cross the access routes.
Capacity to deal with facility wastes and emissions	Assess availability and proximity of facilities to treat, recycle or dispose of all generated waste streams and consider the potential for on-site treatment, recycling and disposal.	Applicable waste classification, treatment and disposal criteria and guidelines.	Proximity to suitable waste management facilities and site attributes that can accommodate potential onsite waste management options.	Given the site's location (130 km from Port Augusta), there are a limited number of waste and recycling depots capable of receiving and/or accepting waste generated from the Project. However, certain waste types (e.g. hazardous and/or Listed Waste) may need to be treated and disposed of on-site or pre-treated and then sent off-site for management, due to the lack of suitable nearby waste disposal facilities. Further definition of waste streams and volumes as the facility design progresses is required to refine the assessment.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Utilities, energy and infrastructure	Assess the proximity to, and capacity of, key services and utilities at and near the site (power, water, wastewater, gas telecommunications, and storm water).	Relevant Australian Standards to apply at detailed design phase.	Close proximity to all required services and utilities with minimal upgrade and connection requirements.	There is an absence of most services and utilities in the vicinity of the site (water, wastewater, gas, telecommunications and storm water) apart from power. Distance and terrain between the site and Hawker means that installation of a network of groundwater extraction bores and desalination plant on site should be further assessed as an alternative supply option to a potable water supply main from Hawker and/or potential upgrades to, and expansion of, the existing Hawker groundwater extraction and water treatment plant. Design solutions and construction of enabling utility infrastructure will mitigate issues of proximity and capacity of existing utilities in the local area.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Renewable or non-renewable natural resources and the site potential to use renewable resources	Assess availability of renewable resources in the site area to provide power to the site and offset grid supplied energy.	Relevant Australian Standards to apply at detailed design phase.	Location which has high potential to generate renewable energy, particularly solar and wind resources, which can be harnessed by technology in a manner which will increase the (network) reliability of power supply to the site.	The Wallerberdina site is located in an area of high solar exposure and is in a low wind resource area. The site is relatively close to the transmission network (either via a new substation directly to the 132kV transmission line or to the existing transmission line substation). While the Wallerberdina site has electrical proximity to a transmission line, the line is still at the edge of the NEM network with ageing assets. The inclusion of renewable energy for generation on site, as well as supporting energy storage technologies such as batteries (short term) and diesel (long term), should be further considered and could provide both commercial and power reliability benefits to the project. Consideration of the grid constraints, reliability, and potential connection points are key considerations for determining the amount of solar PV (the most suitable technology for the site) and storage required.

The Wallerberdina site is well separated from adversely affecting development and sensitive land uses, however mineral tenements in the local area, if they proceed to development for extraction, could have direct or indirect impact on the NRWMF and its enabling infrastructure.

There are a number of potential environmental hazards identified at Wallerberdina that would likely require mitigation or management should the proposed NRWMF be further considered at the site. These include ground shaking or deformation from earthquakes, localised flooding, catchment flooding from rare episodic flood events including the potential for deposition of fluvial material and avulsion of Hookina Creek, wind erosion or mass movement of sands.

A hydrological model and subsequent 2D hydraulic modelling indicates that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 annual exceedance probability, AEP). For the 1 in 2000 AEP flood, depths are typically in the range 0.25 to 0.5 m with isolated areas up to 1 m. This poses constraints on the site that will require the investigation and design of appropriate mitigation measures (e.g. consideration of installation of bunds and levees) should Wallerberdina be further considered for the NRWMF. Further, as the site is situated on the Hookina Creek alluvial fan and located nearby to dune fields, mitigation and monitoring measures will need to be employed. Additional hydraulic modelling is required to consider risks posed by avulsion, floodplain scour and sedimentation in order to develop appropriate design and operational management measures.

Groundwater in the watertable aquifer was found to be present at depths >20 m below ground surface across the site which would provide good separation between the base of any proposed NRWMF and groundwater. The water table aquifer is of reasonable water quality and yield. Given the lack of reticulated water supply, groundwater may have the potential to be used for a range of uses for the NRWMF (some requiring additional pre-treatment).

There is a high level of confidence (excluding the possibility of one-off faulting) on the absence of potentially active faults in the foundation beneath the site. Seismic hazards in the form of ground shaking and ground deformation associated with the potential for near-surface faults or major faults in the foundation in the vicinity of the site (yet to be identified) should be able to be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods.

There are no threatened ecological communities within the site nor is there a likelihood of occurrence of Commonwealth listed species. One State listed flora and one fauna species has the potential for occurrence but has not historically been identified. Habitats present on the site also exist in surrounding areas.

The site is well served by major road networks with several local unsealed road access options. Multiple culvert crossings in addition to other upgrades may need to be installed to accommodate the number of watercourses that cross the local access routes.

There is an absence of most services and utilities in the vicinity of the site (water, wastewater, gas, telecommunications and storm water) apart from power. Communications towers would need to be constructed to connect to mobile phone and data communications. Distance and terrain between the site and Hawker means that installation of a network of groundwater extraction bores and desalination plant on site should be considered as a potential alternative supply option to a potable water supply main from Hawker and/or potential upgrades to, and expansion of, the existing groundwater extraction and water treatment plant at Hawker. The inclusion of renewable energy for generation on site, as well as supporting energy storage technologies such as batteries (short term) and diesel (long term), has the potential to provide both commercial and power reliability benefits to the project. The capacity and constraints of the enabling infrastructure will need to be addressed through design or other measures to meet the NRWMF requirements.

The identified site characteristic hazards and constraints of enabling infrastructure can typically be mitigated via design solutions (e.g. use of thick reinforced-concrete mat foundations to protect structures from ground movements, or construction of levees to protect the site or structures from flooding). Potential design issues and mitigation measures that could be employed have been identified to address enabling infrastructure constraints and environmental hazards, or to protect environmental values. The Site Characterisation and NRWMF design works are running in parallel and will inform the other as the site selection process progresses. A detailed options assessment and concept design for the enabling infrastructure has also commenced.

A separate safety case document must be prepared as part of the license application to the regulator ARPANSA, prior to any approval for construction and operation of the NRWMF on the preferred site. The safety case will consider not only site characteristics with potential safety impacts, but also the NRWMF design and operational activity measures and mitigations employed to appropriately mitigate site characteristic hazards, and the transport, storage and disposal of radioactive wastes. A safety in design process will also need to be followed by the designer to address design requirements for safety of the site personnel.

A second stage of more detailed Site Characterisation studies will be conducted once a preferred site is selected by the responsible Minister. Assessment data gaps and recommendations for additional work scope items to fill such gaps have been identified for this second stage. The development of a robust conceptual site model and environmental dataset will support the development of a safety case for the NRWMF and applications for licensing and environmental approvals. Baseline conditions must also be established to enable future surveillance and monitoring during construction and operation of the NRWMF.

1.0

Introduction

1.0 Introduction

Background

The Australian Government is committed to identifying a site for the National Radioactive Waste Management Facility (NRWMF) that will permanently dispose of Australia's low level radioactive waste and temporarily store intermediate level radioactive waste. Sites being considered have been identified through a voluntary community nomination process.

There is currently no disposal facility for low level radioactive waste in Australia. Waste is stored at more than 100 locations around the country, of which many are running out of storage capacity or were never engineered for the storage of such waste. The NRWMF will provide a safe and secure facility for the consolidation and management of Australia's current and future radioactive waste in a sustainable manner that safeguards the environment. All radioactive waste will be received at the facility in a solid form and packaged in a manner that meets the Waste Acceptance Criteria.

Low level radioactive waste to be permanently disposed of at the new facility includes protective clothing and equipment from medical procedures; laboratory wastes such as paper, glassware and plastic; contaminated soil and discarded smoke detectors and emergency exit signs. Low level waste emits radiation at levels which require minimal shielding during transport, storage and handling.

Intermediate level waste to be temporarily stored at the new facility contains radioactive material at a concentration that requires shielding for safe handling and transport and includes waste from the production of radiopharmaceuticals, waste generated by the reprocessing of spent research reactor fuel and disused radioactive sources from industry and medicine. In line with international best practice, Australia's intermediate level waste is stored in individually manufactured, tested and quality assured shielded containers that are physically secure and shielding of the radiation.

The engineering design of the proposed NRWMF is occurring in parallel with the Site Characterisation studies and Cultural Heritage Assessments of the sites.

NRWMF Site Characterisation Study

The Commonwealth Department of Industry, Innovation and Science ('the Department') established a NRWMF Task Force to lead a site nomination and selection process in accordance with the requirements of the National Radioactive Waste Management Act (2012). Three sites were shortlisted for Site Characterisation for the purpose of conducting a technical assessment to evaluate siting the NRWMF including the Lyndhurst and Napandee sites near Kimba, South Australia and the Wallerberdina site near Hawker, South Australia.

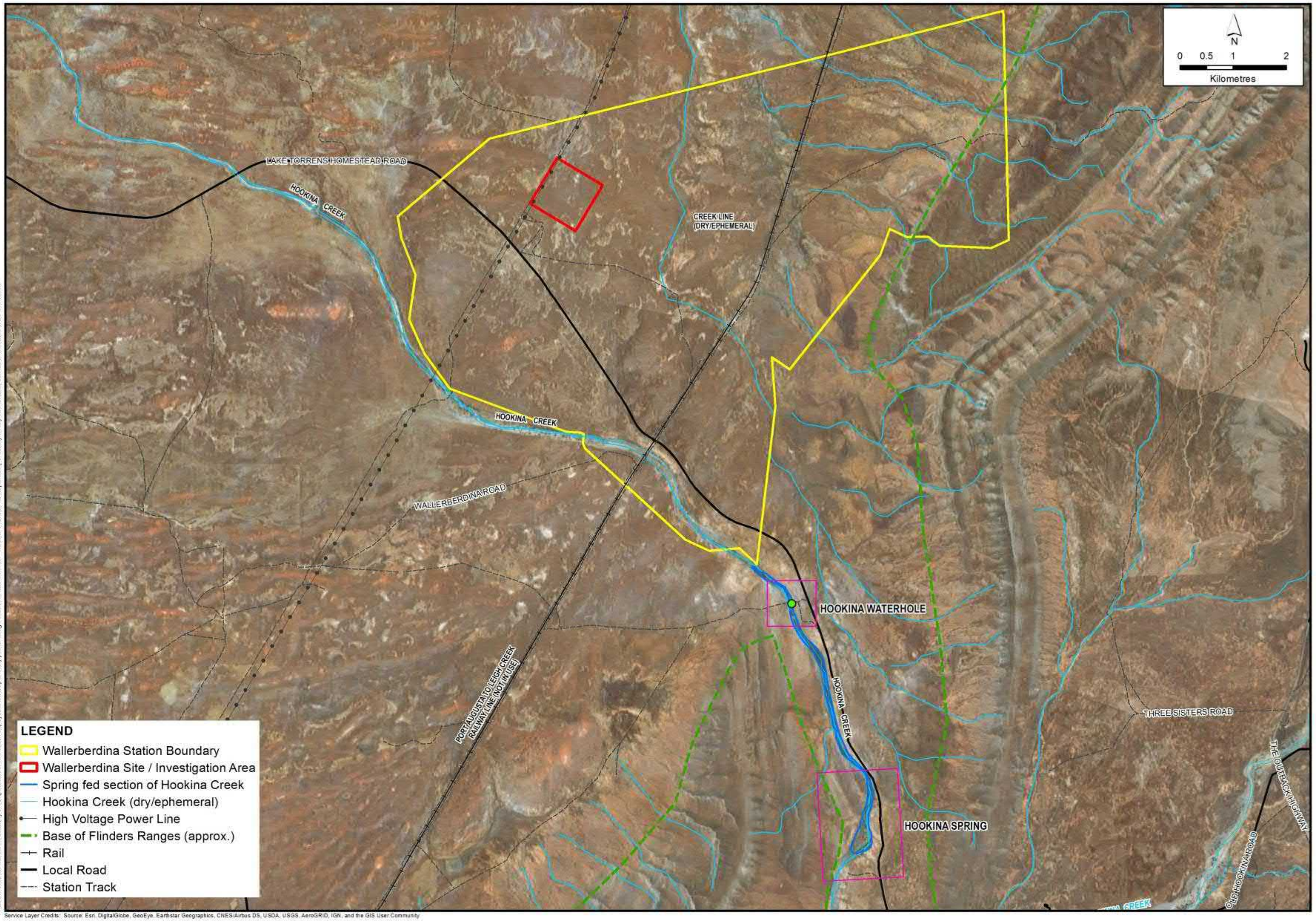
The Department has a comprehensive and ongoing stakeholder communications and engagement program underway within each local community.

AECOM Australia Pty Ltd (AECOM) was commissioned by the Department to conduct Site Characterisation studies at the three shortlisted sites. The works are focused on characterising the surface and subsurface environments within and surrounding the nominated 100 hectare study area being considered for potential siting of the NRWMF. The works also comprise a preliminary assessment of constraints and options for enabling infrastructure that would be required to develop and operate the NRWMF. This report outlines the methods used and results of the Site Characterisation studies undertaken at the Wallerberdina site. The location of Wallerberdina and study area (referred hereafter as 'the site' is displayed in Figure 1 below and described in Table 2 below.

Table 2 Site Identification Details

Site Name	Wallerberdina Station
Site Description	Flinders Ranges Way, Hundred of Cotabena
Land Parcel	Certificate of Title Volume 5934 Folio 550 and Crown Lease Volume 1215 Folio 28 (Deposited Plans 45041 Parcels 30 -33 and Deposited Plans 45041 Parcels 40-43). The site within Wallerberdina Station is located within Parcel 30. The railway line and corridor is not part of the Station.

Figure 1 Site Location Plan



The general site setting can be summarised as follows:

- The site is located approximately 30 km north-west from the township of Hawker;
- The site is a 37 km drive from Hawker, accessed via existing formed unsealed roads from the Outback Highway including Yappala Road and Lake Torrens Homestead Road;
- The Stirling North (Port Augusta) to Telford (Leigh Creek) railway line runs through the site but is no longer in use due to close of the Leigh Creek coal mine and closure of the Port Augusta Power Station that it provided fuel for;
- A high voltage power line runs along the western boundary of the site;
- The site is located within an arid area, in a warm temperate climate zone characterised by hot summers with moderate humidity and low annual rainfalls predominantly during the winter and spring months;
- The site is located on an alluvial plain to the west of the western edge of the foothills of the Flinders Ranges;
- Wallerberdina Station is currently used for grazing of cattle. Land in the local and regional area is also predominantly used for grazing of cattle on native pasture, with other land uses including tourism and conservation;
- An ephemeral and dry section of Hookina Creek is located more than 3 km south of the site. Further upstream along Hookina Creek, Hookina Waterhole and Hookina Spring (registered Aboriginal sites) are located outside Wallerberdina Station at 8 km and 12 km respectively from the site. Spring fed water does not typically flow along Hookina Creek as far as the Wallerberdina Station boundary;
- There are a number of areas of native vegetation conserved under heritage agreements in the local area including an area directly adjacent the north-western corner of the site on property held by the owner of the nominated site which is in excellent condition vegetation. Fragmented patches of native vegetation within the site were of good condition, with linear corridors of mallee trees in degraded condition;
- The site is well separated from adversely affecting development and sensitive land uses; and
- The nearest occupied dwelling is understood to be located approximately 12 km from the site.

Site Characterisation studies have been undertaken for the purpose of providing a technical assessment to determine whether any environmental hazards and values, or enabling infrastructure constraints exist that are considered to present ‘fatal flaws’ that would preclude further consideration of siting of the NRWMF at the Wallerberdina site.

A review of available published information, field observations and survey data pertaining to the surface and subsurface environment and enabling infrastructure considerations has been prepared for assessment against key site characteristic criteria. The criteria were established with reference to Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and International Atomic Energy Agency (IAEA) guidelines relating to the selection, evaluation and environmental safety case of sites being considered for the siting of radioactive waste facilities.

Site characteristic values and hazards, or infrastructure constraints can often be mitigated by the facility design. Potential design issues and mitigation measures that could be employed to address them have been identified but will require further refinement throughout the site selection and design process. The Site Characterisation and facility design are running in parallel and will inform the other as the site selection process progresses.

A second stage of more detailed Site Characterisation works will be conducted once a preferred site is selected by the responsible Minister.

Assessment data gaps and recommendations for additional work scope items to fill such gaps have been provided for this second stage. The development of a robust conceptual site model and environmental dataset will support the development of a safety case for the NRWMF and applications for licensing and environmental approvals. Baseline conditions must also be established to enable future surveillance and monitoring during construction and operation of the NRWMF.

2.0

Surface Environment

2.0 Surface Environment

A desktop and selective field assessment of the surface environmental conditions within the site and surrounds is outlined below. The characteristics of the surface environment covered in this assessment include flora, fauna, conservation values, and hazards associated with climate, bushfire, background radiation, flooding and nearby human activities under current and future potential land uses.

Site characteristic assessment criteria that have the potential, either alone or in combination with other criteria, to impact on siting of the NRWMF were developed. Published and anecdotal information relevant to the site and the local and regional area was reviewed. A site inspection, an ecological field survey and an aerial survey to digitally map the terrain/ topography (using LiDAR) of the site and immediate surrounds were also undertaken. The desktop and field data of the surface environment was interpreted for assessment against the site characteristic criteria.

Site characteristic values and hazards can often be mitigated by the facility design. Potential design issues and mitigation measures that could be employed to address them have been identified. The Site Characterisation and facility design are running in parallel and will inform the other as the site selection process progresses.

Assessment data gaps and recommendations for additional work scope items to fill such gaps in a more detailed second stage of the Site Characterisation studies are provided for each of surface environmental characteristics.

2.1 Flora, Fauna and Conservation

2.1.1 Methodology and Results

2.1.1.1 Site Characteristic Criteria

The key site characteristic criteria relevant to flora, fauna and conservation include:

Flora and Fauna

- presence and condition of native vegetation;
- presence of Commonwealth listed threatened species and habitat; and
- presence of State listed threatened species.

For assessment purposes two of the above key criteria have been broken up into sub criteria as follows:

- presence of Commonwealth listed threatened species and habitat
  - presence of Threatened Ecological Communities;
  - presence of threatened flora species;
  - presence of threatened fauna species;
  - presence of threatened fauna habitat; and
  - presence of Migratory species.
- presence of State listed threatened species and habitat
  - presence of threatened flora species; and
  - presence of threatened fauna species.

Conservation

- proximity and value of Parks (National Parks, Conservation Parks, Conservation Reserves, Recreational Parks, Wilderness Protected areas and native vegetation Heritage Agreements);
- proximity of Aboriginal heritage sites; and
- proximity of Commonwealth, state and local heritage sites.

2.1.1.2 Desktop Methods and Results

Legislative Context

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the main piece of Federal legislation protecting biodiversity in Australia. All Matters of National Environmental Significance (MNES) are listed under the EPBC Act. These include:

- listed threatened species and ecological communities;
- migratory species protected under international agreements;
- Ramsar wetlands of international importance;
- the Commonwealth marine environment;
- world Heritage properties;
- national Heritage places;
- Great Barrier Reef Marine Park;
- a water resource, in relation to coal seam gas development and large coal mining development; and
- nuclear actions.

If an action is likely to have a significant impact on a MNES, this action must be referred to the Minister for the Environment for a decision on whether assessment and approval is required under the EPBC Act.

The EPBC Act provides the legal framework and categories for the protection of flora and fauna species. Species can be listed as threatened, migratory or marine under the EPBC Act. Species at risk of extinction are recognised at a Commonwealth level under section 179 of the EPBC Act and are categorised in one of six categories as outlined in Table 3. Species may be listed as Marine under section 248 of the EPBC Act.

Migratory species are animals that migrate to Australia and its external territories or pass over Australian waters during annual migrations. Listed migratory species include those listed in the:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention);
- China-Australia Migratory Bird Agreement (CAMBA);
- Japan-Australia Migratory Bird Agreement (JAMBA); and
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

Table 3 Categories of Species Listed under Schedule 179 of the EPBC Act

Conservation	Code Category
Ex	**Extinct Taxa** which at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
ExW	**Extinct in the Wild** Taxa which is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
CE	**Critically Endangered** Taxa which at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
E	**Endangered** Taxa which is not critically endangered and it is facing a very high risk of extinction in the wild in the immediate or near future, as determined in accordance with the prescribed criteria.
V	**Vulnerable** Taxa which is not critically endangered or endangered and is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
CD	**Conservation Dependent** Taxa which at a particular time if, at that time: the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.

Communities can be classified as Threatened Ecological Communities (TECs) under the EPBC Act. The EPBC Act protects Australia's ecological communities by providing for:

- identification and listing of ecological communities as threatened;
- development of conservation advice and recovery plans for listed ecological communities;
- recognition of key threatening processes; and
- reduction of the impact of these processes through threat abatement plans.

Categories of federally listed TECs are described in the table below.

Table 4 **Categories of TECs listed under the EPBC Act**

Code	Category
CE	**Critically Endangered** If, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future.
E	**Endangered** If, at that time, it is not critically endangered and is facing a very high risk of extinction in the wild in the near future.
V	**Vulnerable** If, at that time, it is not critically endangered or endangered, and is facing a high risk of extinction in the wild in the medium-term future.

In South Australia, the Department of Environment, Water and Natural Resources (DEWNR) works with Natural Resource Management Boards to implement State environment legislation across eight natural resource management regions in South Australia. A number of pieces of legislation provide provision for the management natural resources, including:

- National Parks, Conservation Parks, Conservation Reserves, Recreational Parks, Wilderness Protected areas the *National Parks and Wildlife Act 1972* (NPW Act), *Crown Land Management Act 2009* (CLM Act) or the *Wilderness Protection Act 1992* (WP Act);
- Non-Aboriginal heritage sites of significance and Aboriginal heritage sites;
- Local Heritage places in South Australia;
- Native vegetation (for conservation, to control the clearance of native vegetation and to outline the mechanisms for Heritage Agreements (i.e. a conservation area on private land, which are ongoing or perpetual);
- Wildlife (for conservation and management of threatened species under the *National Parks and Wildlife NPW Act*); and
- Natural resources (protection, pest management, etc).

Table 5 **Categories of Threatened Species under the NPW Act**

Code	Category
Endangered	Listed under Schedule 7. A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E (defined in Section V IUCN, 2001), for Endangered and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable	Listed under Schedule 8. A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (defined in Section V IUCN, 2001), and it is therefore considered to be facing a high risk of extinction in the wild.
Rare	Listed under Schedule 9. A taxon is considered rare if it is in decline and those that naturally have limited presence. This category does not follow the IUCN Red List.

Desktop Methods

Flora and fauna comprises of vegetation and ecological communities (native and invasive), and fauna and habitat (including habitat corridors). Conservation comprises of conservation and special use areas. A review of publicly available literature and relevant database searches was undertaken to describe the existing environment and identify potential occurrence of significant flora, vegetation and fauna species. A 10 km expanded Study Area around Wallerberdina site was covered by the desktop assessment. This ensured that contextual information was considered during the assessment. Following this, an assessment of likelihood of occurrence was undertaken based on information gathered during this exercise.

The following databases were utilised to inform the desktop review:

- Department of the Environment and Energy (DoEE, 2018) *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool. Accessed 15/02/2018 at http://www.environment.gov.au/webgis-framework/apps/pmst/pmst.jsf;
- South Australian Department of Environment, Water and Natural Resources (DEWNR) Biological Database of South Australia (BDBSA) for threatened flora and fauna species listed under the South Australian *National Parks and Wildlife Act 1972* (NPW Act). Data request sent to DEWNR on 15/02/2018 through http://www.environment.sa.gov.au/Science/Information_data/Biological_databases_of_South_Australia. Received data from DEWNR on the 20/02/2018;
- NatureMaps vegetation mapping administered by DEWNR. Accessed 15/02/2018 at http://spatialwebapps.environment.sa.gov.au/naturemaps/?locale=en-us&viewer=naturemaps;
- Aerial imagery;
- The South Australian Department of State Development (DSD), Register of Aboriginal Sites and Objects. Data request sent to DSD on 19/02/18. Received data on 2 March 2018;
- Park resources provided on the DEWNR website including a report and map of Protected Areas of South Australia (December 2016 edition), accessed at http://www.environment.sa.gov.au/managing-natural-resources/park-management/parks-boundaries; and
- SA Heritage Places Database, accessed at http://maps.sa.gov.au/heritagesearch/HeritageSearchLocation.aspx.

Likelihood of Occurrence

A likelihood of occurrence assessment was completed for all conservation significant species and communities that were identified from the desktop review. The likelihood of occurrence assessment considered both the Wallerberdina site and expanded Study Area. This ensured that indirect impacts on conservation significant species and communities may be considered in the planning phase of the Project.

The likelihood assessment considers the presence of suitable habitat, number of records, date of records, and proximity of known records in relation to the Wallerberdina Site and expanded Study Area. The year of records and number of records were also taken into account to verify the accuracy of location data and the commonality of the species.

Five categories are used for the assessment, including:

- **Unlikely**: No preferred/suitable habitat present. Species unlikely to be present on the site at any time or during any season. No records of species/community in expanded Study Area.
- **Low**: Potentially suitable habitat present lacking condition, specific floristic or complexity data. Species may visit or fly over however habitat is unlikely to be considered critical to the survival of the species. No recent records of species/community in expanded Study Area.
- **Moderate**: Preferred habitat (or parts thereof) present and is of size suitable for supporting species (individual or population). One or more recent records of species/community in expanded Study Area.
- **High**: Suitable habitat is present. Several recent records of species/community in expanded Study Area.
- **Present**: Species known to be present, confirmed records in Wallerberdina site and suitable habitat is present.

Desktop Results – Commonwealth Listed Species

The Commonwealth Department of Environment Protected Matters Search Tools (PMST) search for Wallerberdina identified eight threatened species and eight migratory species and 13 marine species protected under the EPBC Act that may potentially occur, including three threatened flora species, five threatened fauna species, eight migratory bird species and 13 marine bird species. Tables listing each of these species are provided within the Field Methods and Results section. The outputs of the search are provided within Appendix A.

There were no threatened ecological communities (TECs) identified as potentially occurring within the expanded Study Area or broader search area. It can therefore be confidently assumed that no TECs occur within Wallerberdina. Three flora species listed as threatened under the EPBC Act were identified in the PMST report. None of these species have been historically recorded in the broader search area. For this reason, and the lack of suitable habitat, none of these species are considered to have a Likely or a Moderate likelihood of occurrence.

Five fauna species listed as threatened under the EPBC Act were identified in the PMST report, including four birds and one mammal. None of the threatened fauna species are known to occur within the expanded Study Area. A lack of suitable habitat and known records in the expanded Study Area have led to the Low to Unlikely likelihood of occurrence within the expanded Study Area and Wallerberdina site. In particular, the lack of wetland habitats preferred by the Curlew Sandpiper, Night Parrot, Painted Snipe and Yellow-footed Rock-wallaby lead to their exclusion as limitations for the Wallerberdina site. Their inclusion in the PMST report is likely a result of the proximity to the Flinders Ranges and associated creeks and Lake Torrens National Park, neither of which occurs within the broader search area.

Eight Migratory fauna species were identified in the PMST search. None of these species are known to occur within the broader search area. Migratory species identified are typically associated with wetland type habitats.

Desktop Results – State Ecological Values

Wallerberdina Station is a pastoral lease which has been historically stocked with sheep and cattle. Native vegetation present within the expanded Study Area comprises grazed Chenopod shrubland. The considerable history of grazing will have reduced species richness of native herbs and recruitment of juvenile chenopod species.

Figure 2 Wallerberdina Site 2 Chenopod Shrubland

The desktop review considered that three State listed threatened flora species may potentially occur within the Wallerberdina expanded Study Area. Two species are also listed under the EPBC Act and are not discussed further in this section. The Rare flora species, Desert Lime (*Citrus glauca*) was recorded in 1993 within the broader search area to the south of Wallerberdina Station. This species is associated with a variety of soil types including heavy brown clays, desert loams, red earths and also on the sandy loam soils found on the Western Myall (*Acacia papyrocarpa*) plains north of Port

Augusta. Associated vegetation is often chenopod shrublands such as Bluebush (*Maireana sedifolia*) or Blackbush (*M. pyrimidata*), but may also include other small trees such as Blackoak (*Casuarina pauper*) or Bullock Bush (*Alectryon oleifolius*), and various *Senna* or *Eremophila* species.

Desert Lime habitat is common in the local and regional area. It therefore has a Moderate likelihood of occurrence.

The desktop review identified nine fauna species listed as threatened under the NPW Act that may potentially occur within the expanded Study Area. Eight species also listed under the EPBC Act which are not further discussed. One fauna species, the Elegant Parrot (*Neophema elegans*), listed as Rare under the NPW Act and is known to occur within broader search area. This species was recorded along The Outback Highway in 2004, approximately 14 km from the Wallerberdina expanded Study Area. The species utilises open forests, woodlands, Mallee, Mulga, and Salt Marsh habitats considered common in the local and regional area. Presence of suitable habitat and a known record in the broader search area means this species has a Moderate likelihood of occurrence within the Wallerberdina expanded Study Area.

A BDBSA search identified six weed species declared under the *Natural Resource Management Act*, including two Weeds of National Significance (WoNS) listed by Australian governments.

Weeds that may be present include Salvation Jane (*Echium plantagineum*), African Boxthorn *(Lycium ferocissimum*) – WoNS, Buffel Grass (*Cenchrus ciliaris*), Mesquite (*Prosopis juliflora*) – WoNS, Bathurst Burr (*Xanthium spinosum*) and Three-corner Jack (*Rumex hypogaeus*). Of these weeds, two species are also listed as Weeds of National Significance (WoNS).

Conservation and Special Use Areas

No protected Parks were identified as occurring within the expanded Study Area. Two Parks that are closest to the Wallerberdina site include Ikara-Flinders Ranges National Park located approximately 30 km east of Wallerberdina site, and Lake Torrens National Park located approximately 30 km west of the Wallerberdina site.

No World Heritage Properties or National Heritage Places were identified during the desktop review as occurring in the expanded Study Area.

The desktop review did not identify any state heritage sites listed under the *Heritage Places Act 1993* or listings of Local Heritage Places in Development Plans within 10 km of the sites or in the broader surrounding area.

No State Heritage sites listed under the *Heritage Protection Act* or Local Heritage Places listed in Development Plans are known to occur within the expanded Study Area. The closest heritage agreement is Heritage Agreement Number: 1353, Date Registered: 12/04/2006, File number: 2005/1026, property (CT/6030/457). This Agreement is approximately 35 km northeast of the Wallerberdina site.

There are several Aboriginal Heritage Sites protected under the *Aboriginal Heritage Act* that occur within the expanded Study Area, including 26 registered/reported Sites and three Restricted Sites that are within 10 km of the Wallerberdina site (DSD, 2018). These include archaeological, cultural and burial sites, which are concentrated along Hookina Creek and are identified in Appendix A.

A cultural heritage assessment of Wallerberdina Station has been commissioned and is being reported under a separate cover.

2.1.1.3 Field Methods and Results

Flora, vegetation and fauna habitat at the Wallerberdina site were assessed to determine the ecological value of native vegetation and fauna habitat present, with a particular focus on identifying potential environmental constraints present within the site and surrounding area. The above outlined desktop assessment was completed to identify potential occurrence of significant flora, vegetation and fauna species (recognised as being threatened or in need of protection under relevant State and Commonwealth legislation). A preliminary field survey was then undertaken to verify the desktop assessment results and gather additional data to validate the assessment against the site characteristic criteria. The field survey covered the site and a ‘buffer zone’ of 1 km surrounding the site.

Flora and Vegetation

A field flora survey was undertaken by an AECOM Botanist with experience undertaking field surveys in South Australia and Western Australia. The survey area was traversed on foot and by vehicle on 17 April, 2018.

Methods described in the Native Vegetation Council Bushland Assessment Manual (2017) were used to collect floristic data within areas of remnant native vegetation. Four representative 1 hectare (ha) unbounded quadrats were used to collect data.

Quadrats were given a unique site name and the following collected:

- Species list (including height and foliage cover) of dominant species only;
- Photograph;
- Waypoint;
- Site observations;
- Weed cover rating;
- Regeneration;
- Level of impact;
- Litter cover;
- Hollow-bearing trees (presence); and
- Tree health.

Data collected from the four non-permanent quadrats informed the condition and vegetation type mapping completed for the survey area and can be used as an out-of-season baseline dataset for future monitoring or guiding targeted surveys where required.

The flora survey data records are provided within Appendix A.

Vegetation types

The field survey confirmed that no Threatened Ecological Communities occur within the vicinity of the Wallerberdina site. The area comprised of Chenopod shrublands with scattered sand dune systems which supported taller hardy shrubs and grasses. Vegetation extends for kilometres in all directions and appeared homogenous across the flat terrain. Traversing the site on foot revealed minor variation in floristic composition of vegetation. This was, in one instance, a reflection of current impacts using vegetation condition decline which has been described and mapped as a discreet vegetation type. One isolated sand dune system was recorded east of the Site representing the second vegetation type of the survey area. The three vegetation types are described and mapped in Table 6 and Figure 3.

Table 6 Vegetation types recorded within the survey area including code, description and photograph

Code	Vegetation Description	Photograph
A1	Chenopod shrubland. Isolated Casuarina pauper Mid isolated *Casuarina pauper* over *Maireana Astrotricha, Sclerolaena obliquicuspis* and *Dissocarpus paradoxus* low chenopod shrubland. Homogenous vegetation type of the local area recorded on the plains with some rocks including quartz on surface. Erosion evident from water, wind and impacts from livestock. Vegetation type represented by Wal 1 and 2.	
A2	Tall open shrubland Tall open shrubland *Acacia victoriae* subsp. *victoriae* and *Dodonaea viscosa* subsp. *angustissima* over *Maireana Astrotricha, Rhagodia spinescens* and *Zygochloa paradoxa* low open shrubland. Recorded on sandy rises and sand dunes. Erosion from wind and impacts from grazing evident. Vegetation type represented by Wal 4.	
A3	Very open Chenopod shrubland Mid open shrubland *Nitraria billardierei, Enchylaena tomentosa* var. *tomentosa*, *Atriplex stipitata* and *Maireana brevifolia* with isolated *Acacia oswaldii*. Recorded around old water tank. As an historical water point for livestock, the area is characterised by high percentage of exposed topsoil which has eroded over time from wind. Very low biodiversity and likely to have significant weed presence following rain. Vegetation type represented by Wal 3.	

Vegetation condition

Vegetation condition mapping was based on a method applied in the Eremaean Botanical Province in Western Australia. The condition scale refers to the impact of disturbance and the ability of the community to regenerate (Table 7).

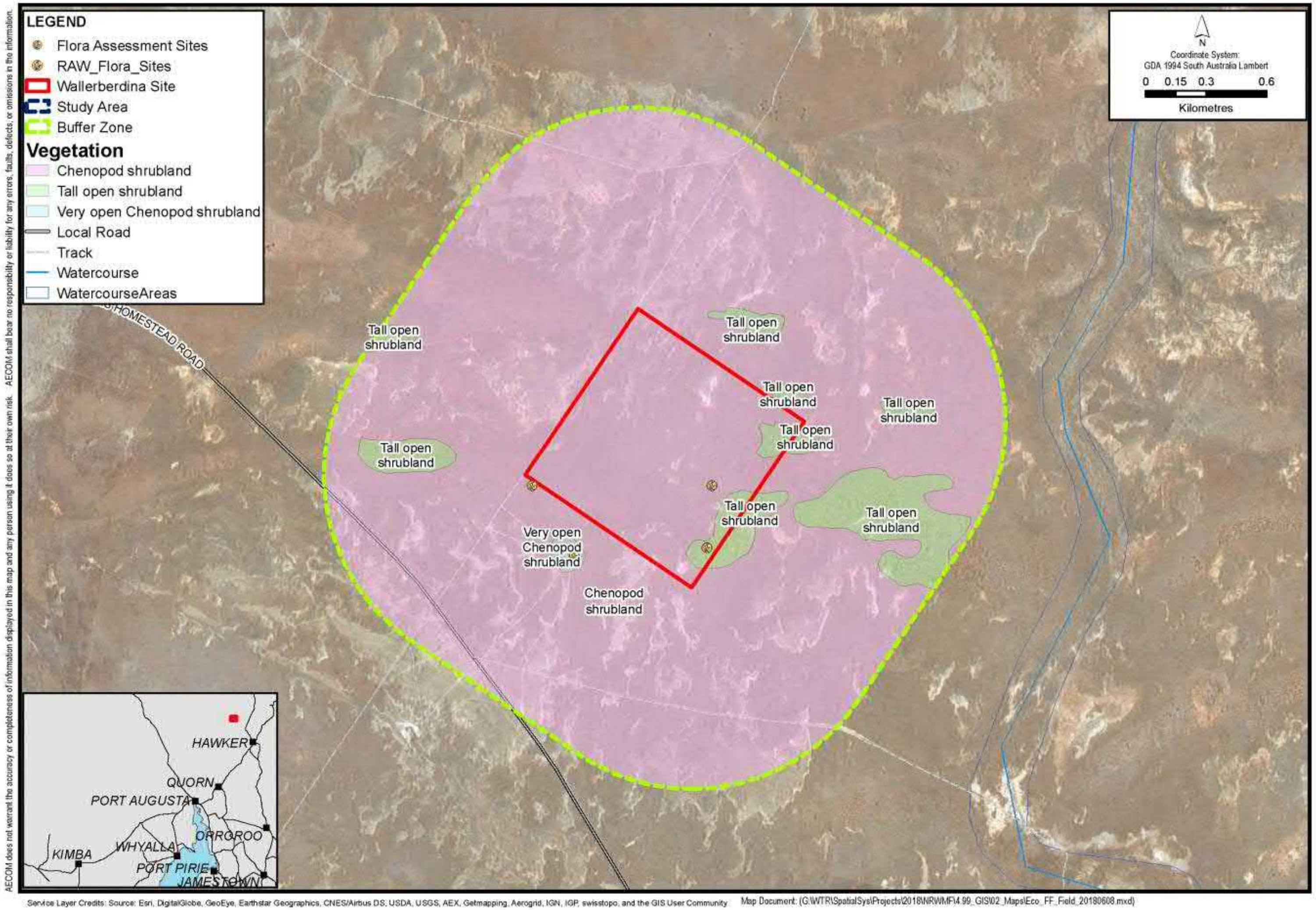
Flora diversity at Wallerberdina is low. Eighteen native species and one weed species were recorded. Impacts from grazing and erosion are the likely contributing factors for lack of regeneration (seedlings), high percentage of bare ground, scalding of the soil surface, and absence of a cryptogram crust.

Vegetation condition was mapped as Good to Degraded. Areas of vegetation degradation were considered to be as a result of grazing and surface erosion. No recruitment was evident in the vegetation communities and species richness was considered low. While this could be attributable to recent dry months, experience in the region has shown that the removal of livestock has a significant impact on vegetation regeneration.

Table 7 Vegetation condition scale (Trudgen, 1991)

Vegetation Condition	Description
Excellent	Pristine or nearly so, no obvious signs of damage caused by human activities since European settlement.
Very Good	Some relatively slight signs of damage caused by human activities since European settlement. For example, some signs of damage to tree trunks caused by repeated fire, the presence of some relatively non-aggressive weeds, or occasional vehicle tracks.
Good	More obvious signs of damage caused by human activity since European settlement, including some obvious impact on the vegetation structure such as that caused by low levels of grazing or slightly aggressive weeds.
Poor	Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of human activities since European settlement, such as grazing, partial clearing, frequent fires, or aggressive weeds.
Degraded	Severely impacted by grazing, very frequent fires, clearing or a combination of these activities. Scope for some regeneration but not to a state approaching good condition without intensive management. Usually with a number of weed species present including very aggressive species.
Completely Degraded	Areas that are completely or almost completely without native species in the structure of their vegetation; i.e. areas that are cleared or ‘parkland cleared’ with their flora comprising weed or crop species with isolated native trees or shrubs.

Figure 3 Vegetation type and condition



Threatened flora

A desktop review identified three flora species listed as threatened under the *Environment, Protection and Biodiversity Conservation Act 1999* (EPBC Act and one species listed as rare under the *National Parks and Wildlife Act 1972* Act (NPW Act) as potentially being present at the Wallerberdina site (Table 8). Of these, only the State listed rare Desert Lime (*Citrus glauca*) has been previously recorded (in 1993) slightly more than 10 km away from the Site (Figure 4). This species was not recorded during the field survey; however, it is still recognised as a potential constraint. Suitably targeted surveys will be required to ascertain its absence or presence with a reasonable level of confidence in the event that the Wallerberdina site is considered further for siting of the NRWMF.

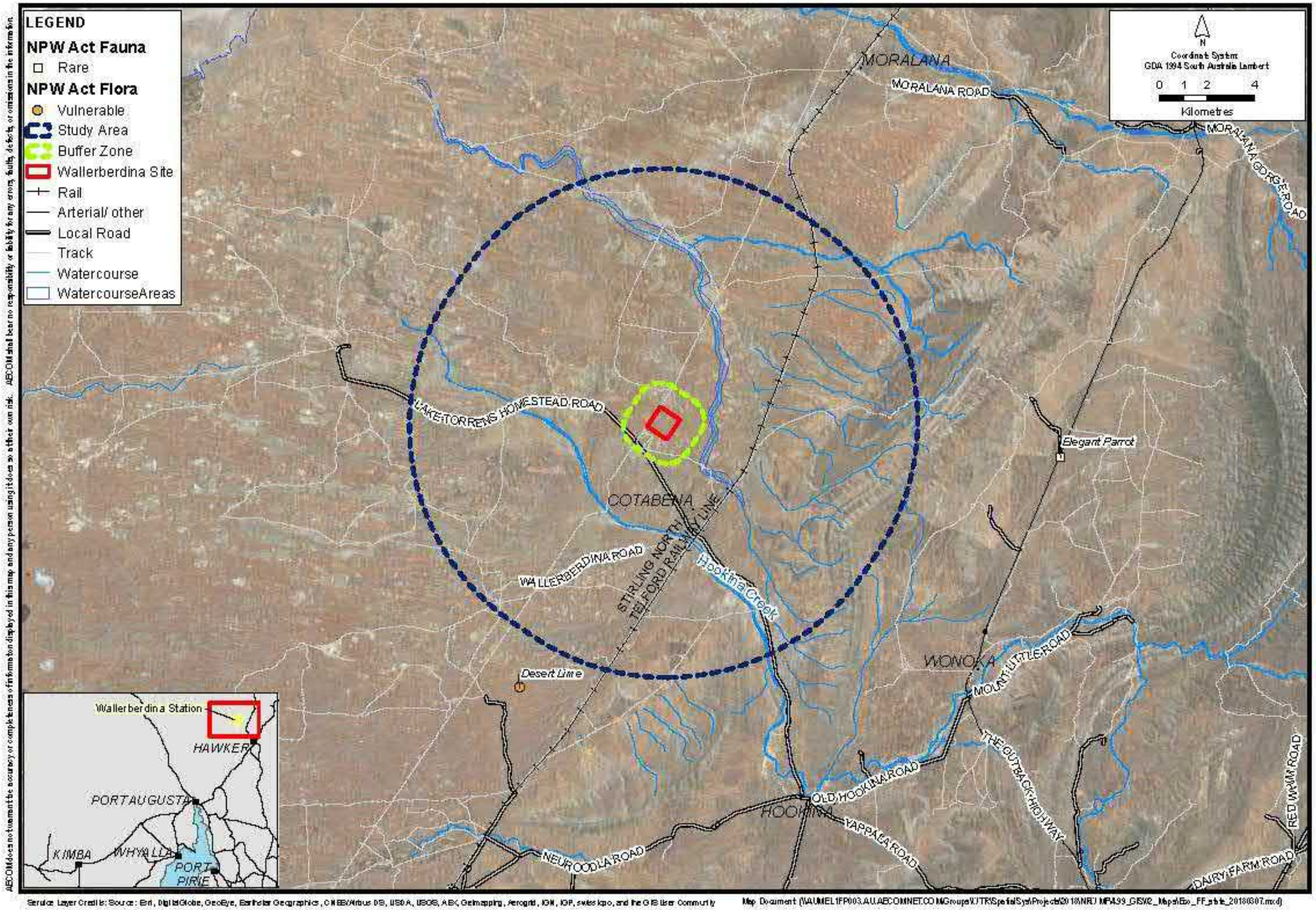
There are no historical records of the three EPBC Act listed Threatened flora species within 10 km of the Site. Two of the species are associated with habitat found on the ranges, while the third species is associated with ephemeral creeks. These three species are considered unlikely to occur within the Site.

Table 8 Threatened Flora Species including EPBC Act Status, Habitat and Likelihood of Occurrence

Taxon	EPBC Act[1]	NPW Act[1]	Habitat	Desktop Result	Post-Field Survey
Caladenia tensa Greencomb Spider-orchid	E		Grows in Cypress-pine/Yellow Gum Woodland, Heathy Woodland and Mallee on sands and sandy loams derived from aeolian sand deposits	Unlikely	Unlikely
Codonocarpus pyramidalis Slender Bell-fruit	V		Slender Bell-fruit occurs in the Northern Lofty Ranges, Flinders Ranges and eastern regions of South Australia. Slender Bell-fruit grows on the crests and slopes of low ridges, hills and along creeks in loamy sand or sandy clay loam.	Unlikely	Unlikely
Frankenia plicata	E		Frankenia plicata occurs in South Australia, from north of Port Augusta along the Stuart Highway to the Northern Territory border and from Port Augusta north-east to Maree. Frankenia plicata grows in a range of habitats, including on small hillside channels, which take the first run-off after rain.	Unlikely	Unlikely
Citrus glauca Desert Lime	-	R	Variety of soil types including heavy brown clays, desert loams, red earths and also on the sandy loam soils found on the Western Myall (*Acacia papyrocarpa*) plains north of Port Augusta. Associated vegetation is often chenopod shrublands such as Bluebush (*Maireana sedifolia*) or Blackbush (*M. pyrimidata*), but may also include other small trees such as Blackoak (*Casuarina pauper*) or Bullock Bush (*Alectryon oleifolius*), and various *Senna* or *Eremophila* species.	Moderate	Moderate

1. EN Endangered, VU Vulnerable, R Rare

Figure 4 Threatened flora records within the expanded Study Area



Weeds

The one weed species recorded was *Citrullus colocynthis* also known as Bitter Apple or Paddy Melon. This species is not listed as a Declared Plant or a Weed of National Significance (WoNS). Under the NVC (2017) Vegetation Guide, the species is considered a level 1 threat defined as “generally only invade disturbed bushland. Often widespread and abundant but not considered a significant threat to biodiversity, unless present at very high densities”. A small number of individuals were observed at one location.

No other declared pests or WoNS as identified in the desktop assessment were recorded during the field survey.

Fauna and Fauna Habitat

The field survey was undertaken by a senior AECOM Zoologist with experience in similar environments. Fauna surveys occurred concurrently with the aforementioned flora surveys. As per the flora survey, the survey area was traversed on foot and by vehicle

Detailed notes were collected on habitat attributes of the survey area such as waterways, woodlands, shrub-lands and the presence of rocky outcrops. Habitat assessments focused on the identification of preferred habitat for threatened fauna species identified as having potential to occur in the area during the desktop investigations.

Whilst traversing the site, habitat features such as fallen woody debris were actively searched and incidental observations of fauna recorded. The presence of scats, tracks and other traces were also recorded.

It was initially proposed that three discrete bird surveys be completed, however, due to a lack of faunal activity and relatively homogenous habitat values across survey area, breaking the site into discrete areas was not considered appropriate. As an alternative, one continuous bird survey was taken across the entire area assessed.

Fauna Habitats

Within the proposed site footprint, faunal habitat was noted to be highly homogenous and characterised as a sparse shrub layer with some organic litter interspersed with by large areas of bare ground (sand). Isolated trees were often in a state of decline or dead. Dead trees in particular provided good refuge in the form of fallen woody debris likely to provide cover and foraging opportunities for small ground dwelling reptiles and mammals.

Figure 5 Representative photo of habitat within the site footprint

Habitat values within the Study Area were largely consistent with that observed within the site footprint with the exception of areas of tall open shrub land to the south- east of the site. These areas align with A2 and A3 vegetation mapping as described above.

The A2 area provided extensive areas of woody debris, perching and nesting opportunities for birds. Undulating terrain in this area provided further habitat complexity with depressions formed in the sand by sheltering animals at the base of tussocks prevalent and often positioned at the base of gentle slopes. The area was also noted to have prevalent scats and tracks though the majority are thought to have been left there by transient species such as kangaroos.

Figure 6 Open shrubland

The A3 area also provided some additional habitat to that found within the site footprint with sparse tree cover providing perching and nesting opportunities. However, this area of vegetation was far more disturbed, open, provided less shade and cover and was positioned on flat terrain. As a watering point for stock, this location did provide some additional cover in the form of anthropogenic debris with old iron sheeting present.

It should also be noted that a number of drainage lines were identified to the north- western boundary of the site. These drainage lines have the potential to provide habitat suitable for aquatic species and migratory bird species during extreme weather events though the extent of their value could not be accurately assessed during the dry period in which the field assessment occurred.

Fauna Diversity

No threatened fauna species were recorded. Fauna observed was restricted to common birds, reptiles and mammals. In all, 20 species were observed (across the total area assessed) of which all but three are considered indigenous to the site. Indigenous species included Singing Honey-eater *Gavicalis virescens*, White-back Wood Swallow *Cheramoeca leucosterna*, Brown Falcon *Falco berigora*, Red Kangaroo *Macropus rufus*, Western Grey Kangaroo *Macropus fuliginosus*, Painted Dragon *Ctenophorus pictus* and Ringed Brown Snake *Pseudonaja modesta*. A complete list of fauna species observed is presented in Table 9.

Figure 7 Painted Dragon

Of the 20 species, pest species identified at the site consisted of feral cat (footprints and scats), and European Rabbit *Oryctolagus cuniculus* (pelt) while the remains of Sheep (skeleton) were also observed. Rabbit burrows were noted across the assessed area but no signs of living rabbits were observed.

Given the nature of fauna surveys undertaken, the identification of four reptile species is considered significant and may serve as an indicator that the site provides opportunities for a diverse number of small ground dwelling reptiles and mammals. While the site was noted to be grazed and the presence of exotic faunal groups clearly evident, no evidence of past cropping or tilling was observed, and as such, it is considered that near natural assemblages of such faunal groups may persist on the site.

Table 9 Observed fauna

Common Name	Scientific Name	EPBC	NPW
Birds			
Australian Pipit	*Anthus australis*	-	-
Australian Raven	*Corvus coronoides*	-	-
Black-fronted dotterel	*Elseyornis melanops*	-	-
Brown Falcon	*Falco berigora*	-	-
Crested pigeon	*Ocyphaps lophotes*	-	-
Emu	*Dromaius novaehollandiae*	-	-
Singing Honeyeater	*Gavicalis virescens*	-	-
Wedge-tailed Eagle	*Aquila audax*	-	-
Welcome Swallow	*Hirundo neoxena*	-	-
White-backed Swallow	*Cheramoeca leucosterna*	-	-
Whistling Kite	*Haliastur sphenurus*	-	-
Zebra Finch	*Taeniopygia guttata*	-	-
Mammals			
European Rabbit	*Oryctolagus cuniculus*	-	-
Feral Cat	*Felis catus*	-	-

Common Name	Scientific Name	EPBC	NPW
Sheep	*Ovis aries*	-	-
Red Kangaroo	*Macropus rufus*	-	-
Western Grey Kangaroo	*Macropus fuliginosus*	-	-
Reptiles			
Central Bearded Dragon	*Pogona vitticeps*	-	-
Painted Dragon	*Ctenophorus pictus*	-	-
Ringed Brown Snake	*Pseudonaja modesta*	-	-
Shingleback Lizard	*Tiliqua rugosa*	-	-

Threatened Fauna Species

Five fauna species listed as threatened under the EPBC Act were identified in the PMST report including four birds and one mammal. None of these threatened fauna species are known to occur within the expanded Study Area. The location of threatened fauna records is presented in Figure 8.

Eight Migratory fauna species were also identified. None of these species are known to occur within the expanded Study Area. Migratory species identified are typically associated with wetland type habitats. Such habitat is not identified within the Wallerberdina site or the buffer zone. Lack of suitable habitat and known records have led to the low likelihood of occurrence with all species considered Unlikely or of Low likelihood.

One fauna species *Neophema elegans*, the Elegant Parrot, listed as Rare under the State NPW Act was identified and has been historically recorded in the local area. This species was recorded along The Outback Highway in 2004, approximately 14 km from the Wallerberdina site. The species utilises open forests, woodlands, Mallee, Mulga, and Salt Marsh habitats considered common in the local and regional area. Presence of suitable habitat and a known record means this species has a Moderate likelihood of occurrence within the Wallerberdina site.

The likelihood of threatened fauna species was reassessed following the completion of the field survey. Consistent with the outcome of the desktop assessment, no threatened fauna species as identified by the PMST and BDBSA extract are considered likely to occur within the site or the immediate surrounds (1 km buffer zone) with the exception of Elegant Parrot *Neophema elegans*. This species was not observed during the field survey but is known to occur in the area and within areas of similar habitat. While the site and buffer zone may provide foraging opportunities for the species, such habitat is likely to form a very small component of its overall foraging area and the absence of hollow bearing trees means the species would not nest at the site. Given the lack of suitable breeding habitat, non-detection during the field survey and a paucity of records the species likelihood has been revised to low.

Whilst no species identified during the desktop assessment are considered to have a greater than low likelihood of occurrence, caution is recommended when considering the importance of the site for threatened fauna. Despite the relatively limited scope of fauna surveys completed by AECOM at the Site, it should be noted that of the seventeen native fauna species identified, five are additional to that identified in the BDBSA with three of those been reptile species (Ringed Brown Snake, Shingleback lizard *Tiliqua rugosa* and Painted Dragon). Further, discussion with Aboriginal Representative's while conducting the site assessment indicated the presence of "small hopping mice" (identified during pit-fall trapping conducted in proximity to the site) and the presence of species such as Bustard's *Ardeotis australis* observed in the local area despite their absence in the database searches. Survey outcomes coupled with anecdotal evidence is considered to highlight the under studied / surveyed nature of the site and locality and that detailed fauna surveys, particularly those targeting small ground dwelling fauna having the potential to identify threatened species not identified during the desktop assessment.

On this basis, it is recommended that if the Wallerberdina site be selected for further investigation, discussions be had with the Department of Environment and Water to identify if there are further fauna species that require consideration in the approval and permitting process.

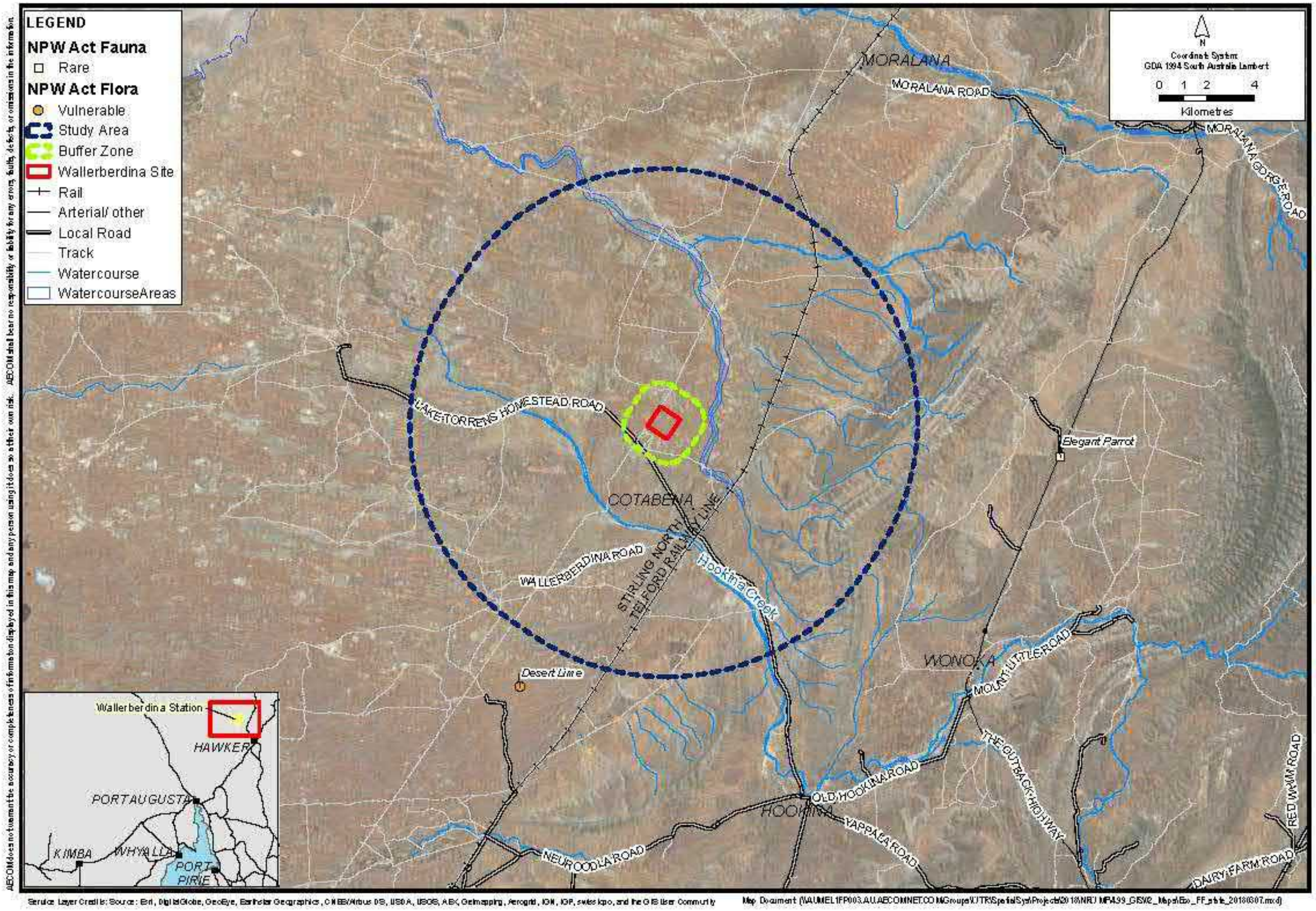
Table 10 Threatened Fauna Species including Likelihood of Occurrence

Taxon	EPBC Status	NPW Status	Habitat	Within Site	Within Expanded Study Area
Actitis hypoleucos Common Sandpiper	Mi, Ma	-	Edges of saltwater to fresh waterbodies and wetlands, including estuaries, lakes, drainage lines, tidal watercourses and mudflats; occasionally beaches and rocky headlands; mainly spring-summer non-breeding migrant	Unlikely	Low
Apus pacificus Fork-tailed Swift	Mi, Ma	-	Aerial over a wide range of habitats, from inland to coast; spring-summer non-breeding migrant	Low	Low
Calidris acuminata Sharp-tailed Sandpiper	Mi, Ma	-	Prefers the grassy edges of shallow inland freshwater wetlands. It is also found around sewage farms, flooded fields, mudflats, mangroves, rocky shores and beaches.	Unlikely	Unlikely
Calidris ferruginea Curlew Sandpiper	CR	-	Coastal estuaries, bays and shallow wetlands, tidal mudflats and sandflats; mainly spring-summer non-breeding migrant.	Unlikely	Unlikely
Calidris melanotos Pectoral Sandpiper	Mi, Ma	-	Shallow freshwater or brackish wetlands, including swamps, flooded grasslands, sewage ponds, occasionally tidal flats and saltmarshes.	Unlikely	Unlikely
Gallinago hardwickii Latham's Snipe	Mi, Ma	R	Wet grasslands and pastures, open and wooded swamps; spring-summer non-breeding migrant	Unlikely	Unlikely
Motacilla cinerea Grey Wagtail	Mi, Ma	-	The grey wagtail is found around fast-flowing mountain streams, often in forested areas, as well as lowland watercourses such as canals and rivers.	Unlikely	Unlikely
Motacilla flava Yellow Wagtail	Mi, Ma	-	The yellow wagtail occurs in a variety of damp or wet habitats with low vegetation, from rush pastures, meadows, hay fields and marshes to damp steppe and grassy tundra.	Unlikely	Unlikely
Neophema elegans Elegant Parrot	Mi, Ma	R	Inhabits open forests, woodlands, mallee, mulga, salt marsh.	Low	Moderate
Pedionomus torquatus Plains-wanderer	CR	EN	Low, open native grasslands, typically with sward less than 1m high, with extensive inter-tussock spaces and high diversity of small herbs; sometimes in unimproved pastures or crops.	Low	Low

Taxon	EPBC Status	NPW Status	Habitat	Within Site	Within Expanded Study Area
Petrogale xanthopus xanthopus Yellow-footed Rock-wallaby	VU	VU	The Yellow-footed Rock-wallaby inhabits rocky outcrops in semi-arid country, ranging from sandstones, limestones and conglomerates in the Flinders Ranges, to granites in the Gawler Ranges and Olary Hills. Some colonies are found in association with permanent fresh water, often around soaks at the edge of rock faces, while other colonies appear to exist without a reliable water supply.	Unlikely	Unlikely
Pezoporus occidentalis Night Parrot	EN	EN	Extinct in south-eastern Australia; historical records from arid and semi-arid chenopod shrublands, spinifex (Triodia) on stony rises, flats around salt lakes and flooded claypans.	Unlikely	Unlikely
Rostratula benghalensis Australian Painted Snipe	EN, Mi, Ma	VU	Generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. They also use inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains. Typical sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of lignum Muehlenbeckia or canegrass or sometimes tea-tree (Melaleuca).	Unlikely	Unlikely

CR Critically endangered, EN Endangered, VU Vulnerable, R Rare, Mi Migratory, Ma Marine

Figure 8 Threatened fauna records within the expanded Study Area



2.1.2 Assessment Against Criteria

An assessment against the site characteristic criteria based on the outcomes of the desktop and field assessments is tabulated below (Table 11)

Table 11 Summary of Flora, Fauna and Conservation Assessment

Key Criteria	Site Conditions	Constraints / hazards
Presence and condition of native vegetation The Site comprises native vegetation across its entirety.		
Presence and condition of native vegetation	Chenopod shrubland present across 100 ha of Site (100% cover). Condition is likely to be degraded as a result of grazing.	Presence of remnant native vegetation across the site. However, vegetation is common in the local and regional area.
Presence of Commonwealth listed threatened species and habitat No Threatened Ecological Communities (TECs) present, no species listed under EPBC Act known to occur within the expanded Study Area.		
Presence of Threatened Ecological Communities	No TECs within expanded Study Area	None identified.
Presence of threatened flora species	No threatened flora known to occur.	None identified.
Presence of threatened fauna species	No threatened fauna known to occur.	None identified. No constraints pending consultation with Department of Environment and Water.
Presence of threatened fauna habitat	Habitat common and widespread.	None identified. No constraints pending consultation with Department of Environment and Water.
Presence of Migratory species	No suitable habitat present for Migratory species.	None identified.
Presence of State listed threatened species and habitat One flora species (Desert Lime) and one fauna species (Elegant Parrot) known to occur within or close to the expanded Study Area. Their presence within Wallerberdina site and the immediate buffer zone to be verified during more detailed field surveys.		
Presence of threatened flora species	One species known to occur in habitat types present within site and Buffer Zone.	None identified.
Presence of threatened fauna species	One species known to occur, habitat unlikely to be present within Site and Buffer Zone.	None identified. No constraints pending consultation with Department of Environment and Water
Proximity and value of Parks (National Parks, Conservation Parks, Conservation Reserves, Recreational Parks and Wilderness Protected areas) None present.		
Proximity and value of Parks	Ikara-Flinders Ranges and Lake Torrens National Parks +30 km from Site.	None identified.
Proximity of registered Aboriginal heritage sites None within Study Area. Numerous registered Sites in close proximity.		
Proximity of Aboriginal heritage sites	26 registered Sites and three Restricted Sites in local area.	Assessed under another study.

Key Criteria	Site Conditions	Constraints / hazards
Proximity of Commonwealth, state and local heritage sites No significant sites present within expanded Study Area.		
State and Local Heritage Sites	No State or Local Heritage Sites present.	None identified.

2.1.3 Design Issues and Mitigation Measures

The clearing of native vegetation within the Wallerberdina Site would be unavoidable for development. These areas may subsequently require management and protection to avoid direct or indirect impacts. In particular, woodlands are considered suitable habitat for conservation significant species, of which there are a few patches on the south-east border of Site.

- Access to both sites is possible via Lake Torrens Homestead Road and associated tracks.
- Appreciable land degradation in adjacent vegetation as a result of development should be managed, including erosion, surface water runoff and clearing beyond approved boundaries.
- It is likely that Aboriginal Heritage sites in the area will require management and protection measures to ensure the sites are not damaged or disturbed.

2.1.4 Data Gaps and Recommendations for Stage 2 Work Program

As stated above, survey outcomes coupled with anecdotal evidence is considered to highlight the under studied / surveyed nature of the site and locality. Detailed fauna surveys, particularly those targeting small ground dwelling fauna are recommended should the site be further considered and have the potential to identify threatened species not identified during the desktop assessment.

On this basis, it is recommended that if this site be selected for further investigation discussions be held with the Commonwealth Department of Environment and Water to identify if there are further fauna species that require consideration in the approval and permitting process.

One Flora species, *Neophema elegans*, the Elegant Parrot, listed as Rare under the SA NPW Act may occur within the Site. It is recommended that a pre-clearance survey be undertaken to ascertain the presence or absence of this State significant species. A targeted survey effort should be undertaken, implementing robust systematic survey design methods to maximise detectability of species.

2.1.4.1 Data Gaps and Limitations

The flora and vegetation survey was completed on 17 to 19 April 2018 following a period of hot dry conditions. Lack of rainfall for months leading up to the survey has excluded the majority of annual species and prevented species identification due to lack of suitable material. In particular, weed species presence was insignificant. This may differ from post-wet conditions when annual weeds including daisies and grasses emerge. As such, the flora and vegetation dataset would be seen as preliminary, and lack the level of detail that may be required to inform environmental approvals and development of management plans.

The lack of preceding rainfall is also considered to have reduced fauna activity at the site due to a lack of foraging resources and potential reduction in habitat complexity. Fauna populations at the site are likely to be dynamic with both diversity and abundance of fauna likely to be dependent on prevailing climatic conditions. Survey timing both in terms of time of the year and time of the day are considered sub- optimal.

2.1.4.2 Recommendations for Stage 2 Work Program

Recommendations for work scope items for further investigations include:

- consultation with Department of Environment and Water to identify if there are further fauna species that require consideration in the approval and permitting process;
- Targeted fauna surveys during ideal survey season; and
- Flora and vegetation assessment during ideal survey season.

2.2 Radiation, Background and Risks

2.2.1 Methodology and Results

2.2.1.1 Site Characteristic Criteria

This desktop assessment of radiation, background and risks, address the key site suitability criteria:

Elevated background radiation conditions that could affect safety of personnel or impact future environmental monitoring

This criteria has been developed with reference to ARPANSA guidelines (2014) and IAEA standards (2011, 2016) which outline the need to establish the radiological baseline/ background radiation conditions during site characterisation and prior to submitting a license application for the NRWMF.

For context, it is noted that construction and operational workers could be exposed to natural background radiation either through the ingestion of dust, direct contact with site material, or the inhalation of radon gas (which has intruded into buildings) from the decay of decay of uranium and thorium.

Effective background radiation conditions must be established at the site, to enable environmental monitoring and surveillance to occur at an operational facility against a well-defined baseline.

2.2.1.2 Desktop Methods and Results

A desktop review of available published background radiation survey data was undertaken. Databases reviewed included the Geosciences Australia Geophysical Archive Data Delivery System (GADDS) for radiometrics which has a resolution of 100 metres and ARPANSA's 1990 Radon mapping.

It is also understood that the SA Government has recently commissioned geophysical fly-overs of the whole state completing radiometric surveys on a 200 m resolution. However, this data has been delayed in publication (now expected in late 2018).

Alluvial sediment with outcropping rocks (siltstones of the Wilpena Group) dominate this region, with Cambrian carbonates of the Hawker Group and Billy Springs Formation. The 1988 survey of the radiation background levels (GADDS) reported 12Bq/m^3 for the Flinders Ranges Region and for the "Outback" Region (covered by Wallerberdina).

2.2.1.3 Field Methods and Results

No aerial or on-ground field radiation surveys were undertaken during this assessment.

2.2.2 Assessment Against Criteria

Results from published historical radiometric data do not indicate the presence of elevated background radiation conditions that could affect safety of personnel or impact future environmental monitoring.

2.2.3 Design Issues and Mitigation Measures

Based on the above assessment, no mitigation measures are required to protect worker safety during construction of the NRWMF.

2.2.4 Data Gaps and Recommendations for Stage 2 Work Program

Due to the coarse nature of the available historical data for background radiation, a "ground truthing" exercise is recommended. A ground based survey should comprise traverses across the site and immediate surrounds, using gamma ray spectrometers to map the background radiation. This is recommended given the elevated thorium levels to the east of the site. The observed data will be interpreted with reference to changes environmental features such as the topography, geology and soil types and with comparison against aerial radiometric data.

Details of the proposed scope and methodology for this field survey works would be prepared with reference to IAEA (2003) Guidelines for Radioelement Mapping Using Gamma Ray Spectrometry Data, IAEA-TECDOC-1363. These guidelines note that while many naturally occurring elements have radioactive isotopes, only potassium, and the uranium and thorium decay series have radioisotopes that produce gamma rays of sufficient energy and intensity to be measured by gamma ray spectrometry.

Radioelement concentrations in surface and subsurface soils, rock and groundwater should also be analysed to establish baseline conditions across the site and any potential risk to site workers from use of or contact with these materials.

2.3 Climatic Conditions and Climate Change

Extreme weather events and longer term changes in climate may impact operation of the future NRWMF. This report presents the outcomes of the Stage 1 Desktop Assessment, providing a summary of the potential material climate change related impacts to the site and future NRWMF.

More detailed consideration and assessment of these material impacts is required in order to determine the significance of the impacts, resulting design issues and the need for mitigation measures. Extreme weather events related to rainfall, heat, and fire weather are likely to pose the greatest number of impacts. These impacts include damaging assets, disrupting power supply to the site, disrupting transport networks and affecting the health and safety risks to operators. Potential impacts to the site are summarised in Table 12.

Historic climate data and future climate projections are provided in this report to support other site characterisation investigations being undertaken, or more detailed assessments of risk in later stages of the project. In summary, the site is located in a warm temperate climate zone characterised by hot summers, with moderate humidity and low annual rainfall, predominately during the winter and spring months. A hotter and drier future climate is projected with an increased intensity of heavy rainfall events.

The projected changes in climate and identified impacts are not reasons to preclude the site from further consideration. However, it is acknowledged that the projected changes in climate will influence the site characterisation impacts assessed by studies contained in this report and that the identified impacts should be considered in the assessment of the site and design of the future NRWMF and development of operational management practices.

No additional data requirements are requested from the Stage 2 Field Program to support the climate change assessment. However, it is recommended that more detailed assessment of the impacts identified in this report be undertaken to inform the detailed design.

2.3.1 Methodology

The desktop assessment identified the historic and projected future climate conditions and associated hazards relevant to the site and the future NRWMF. The following steps were taken:

- Identification of the closest weather station and collation of historical climate data from the Bureau of Meteorology;
- Identification of the relevant Natural Resource Management (NRM) sub-cluster through geographic information system (GIS) analysis of site location and NRM boundary;
- Identification of the relevant climate hazards based on a review of the International Atomic Energy Agency (IAEA) Specific Safety Guide No. SSG-18 (2011): Metrological and Hydrological Hazards in Site Evaluation for Nuclear Installations; and
- Collation of climate projections from the *Climate Change in Australia Technical Report* (2015) and NRM cluster reports.

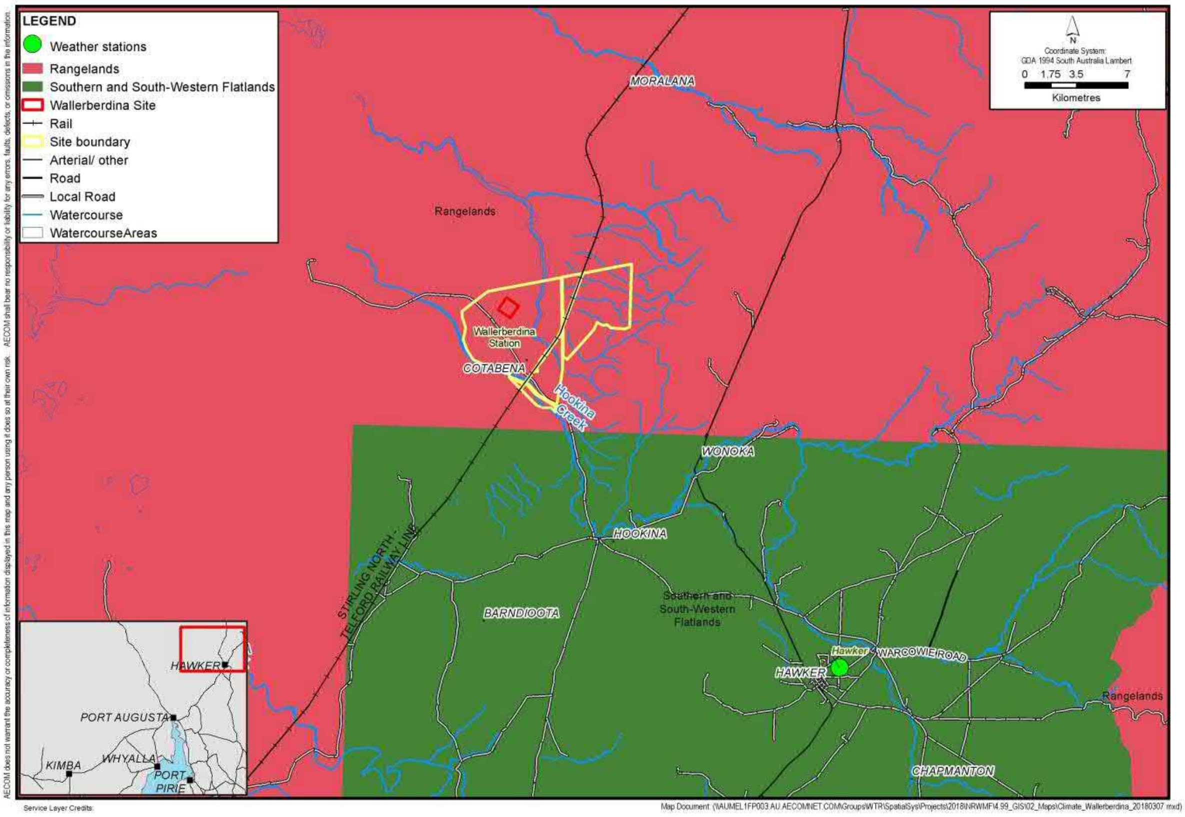
To determine potential impacts to the site and the future NRWMF arising from those hazards, the project team drew on its experience in undertaking climate change risk assessments for infrastructure projects and communities. The potential impacts arising from hazards were then discussed with specialists addressing other site suitability characteristics to confirm if the impacts are likely to be material and could be managed through design or operational management practices.

2.3.1.1 Data used in Desktop Assessment

Historical climate data was required to provide context for the changes in climate conditions indicated by the climate projections (refer to Appendix B). Historical climate data was obtained from the Bureau of Meteorology for the closest weather station, Hawker (refer to Figure 9). Data was collected for the following climate variables, mean maximum and minimum temperature, hottest day recorded, annual rainfall, mean 9am and 3pm humidity and wind speed. Additional data on the historical average number of hottest days over 35 ^{o}C, frost and severe fire days were obtained from the 2015 CSIRO and the Australian Bureau of Metrology (BoM) Technical Report (CSIRO & BOM 2015).

Climate projections for the site were obtained from the 2015 CSIRO and BoM Climate Change in Australia *Rangelands Cluster Report* (refer to Appendix B). The cluster is one of eight natural NRM clusters used to develop climate projections across Australia. The clusters correspond to the broad-scale climate and biophysical regions of Australia. Each cluster is divided into sub clusters, with the Wallerberdina site located in the Southern Sub - Cluster as seen in Figure 9.

Figure 9 Location of the Wallerberdina site, relevant weather stations and Natural Resource Management Clusters used to determine climate projections.



Given the anticipated long life of the proposed asset, climate projections are provided for two timeframes (2030 and 2090) and two Representative Concentration Pathways (RCPs[1]) (RCP 4.5 (lower emissions) and RCP 8.5 (high emissions)). A summary of these projections is outlined in Table 13, a detailed table of climate projections are available in Appendix B.

For 2030, projections for RCP 8.5 are provided as for the last ten years global concentrations of greenhouse gasses have tracked along this emissions pathway (DELWP, 2015). For 2090, projections are provided for RCP 4.5 and RCP 8.5 to provide an upper and lower range for how the climate may change.

Due to the inherent uncertainties involved in developing climate projections, the CSIRO & BOM (2015) assign statements of confidence. These statements either relate to:

- the level of confidence in specific, absolute or percentage changes in climate variables. These statements refer to a level of agreement in the results produced by the climate models, with the higher level of agreement across models increasing the level of confidence. In the Rangelands Cluster report (Watterson, I. et al. 2015, p44), the levels of agreement are defined as "…'medium' being more than 60% of models, 'high ' more than 75%, 'very high ' more than 90%, and 'substantial' agreement on a change outside the 10th to 90th percentile range of model natural variability". A definition for 'low' is not provided.
- the level of confidence in the trend of change where specific projections are not available (e.g. for changes in extreme rainfall and changes in extreme heat). These statements are more general in nature and do not have a quantitative definition. The following five levels of confidence are used: *very low, low, medium, high and very high.*

[1] Representative Concentration Pathways (RCP) are a set of greenhouse gas concentration and emission pathways that are used to support research on impacts and potential policy responses to climate change.

- The confidence levels associated with climate projections are summarised in Table 14 and detailed in Appendix B.

2.3.1.2 Site Characteristic Criteria

Given the high level nature of the desktop assessment, the following two assessment criteria have been identified for climate change:

- Key hazards that could impact the future NRWMF and workers: identification of the hazards, their impact and the site characteristic or enabling infrastructure element they relate to; and
- Change in frequency or intensity of climate hazards: The projected change in climate hazards that may affect the site or future NRWMF. This also includes the degree of confidence in the projections.

2.3.2 Assessment Against Criteria

2.3.2.1 Assessment Criteria 1 - Key hazards that could impact the future NRWMF and workers

Table 12 outlines the potential impacts to the site and future NRWMF and associated hazards. The hazards that are associated with the most number of identified impacts include extreme rainfall, extreme heat and fire weather. The identified impacts are not a reason to preclude the site from further consideration; however, the impacts will need to be considered in the design of the future NRWMF and development of operational management practice

Table 12 Impacts arising from climate hazards and relevant site characteristic or enabling infrastructure element

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Increased electricity demand for onsite cooling (e.g. air conditioning, cooling for power generation or energy storage)	Extreme Heat	Material concern to the safe operation of the NRWMF Impact can be managed through the design	- Utilities, energy and infrastructure
OHS risks to staff and personnel during construction and operation	Extreme Heat Extreme Rainfall Extreme Wind Fire Weather Hail Lightning	Material concern to the safe operation of the NRWMF. Impact can be managed through the design	- Water - Risks from the surrounding environments (e.g. bushfires). - Climatic conditions (Wind & flood) - Site characteristics which have the potential to impact on site safety

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Increased degradation, damage or failure of assets and supporting infrastructure (e.g. road surfaces, monitoring systems, cooling systems, electrical equipment, monitoring and communication systems, concrete and concrete joints, steel, asphalt, protective cladding, coatings, sealants, timber, masonry, pipework, transmission cables, earthen bunds, solar panels)	Extreme Heat Extreme Rainfall Extreme Wind Fire Weather Hail Lightning Increased Average Temperature Solar Radiation Frost	Material concern to the safe operation of the NRWMF Impact can be managed through the design and operational management practices	- Vegetation and Ecological Communities - Risks from the surrounding environments (e.g. bushfires) - Climatic conditions – Wind and Flood - Site characteristics which have the potential to impact on site safety - Renewable or non-renewable natural resources and the potential to use renewable resources - Transport considerations - Utilities, energy and infrastructure
Disruption of power supply to the site as a result of impacts to the electricity transmission and distribution network	Extreme Heat Extreme Rainfall Extreme Wind Fire Weather Lightning	Material concern to the safe operation of the NRWMF Impact can be managed through the design	- Risks from the surrounding environments (e.g. bushfires) - Climatic conditions – Wind and Flood - Utilities, energy and infrastructure

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Erosion of landscape and vegetation	Extreme Rainfall	Material concern to the safe operation of the NRWMF Impact can be managed operational management practices	- Vegetation and Ecological Communities - Soil and other substrates - Water - Conservation and special use area - Climatic conditions – Wind and Flood
Disruption to construction and operations as a result of inundation, or fire, in close proximity to facilities or transport networks	Extreme Rainfall Fire Weather	Material concern to the safe operation of the NRWMF Impact can be managed through the design and operational management practices	- Risks from the surrounding environments (e.g. bushfires) - Climatic conditions – Wind and Flood - Site characteristics which have the potential to impact on site safety - Transport considerations
Damage to, or failure of, off-site storage or disposal facilities	Extreme Rainfall Extreme Wind Fire Weather Hail	Material concern to the safe operation of the NRWMF Impact can be managed operational management practices	- Water - Capacity to deal with NRWMF wastes and emissions (impacts to off-site facilities) - Risks from the surrounding environments (e.g. bushfires) - Climatic conditions – Wind and Flood - Transport considerations

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Reduced capacity or shutdown of onsite renewable energy generation (e.g. wind, solar, geothermal)	Wind Fire Weather Reduced Average Rainfall Increased Average Temperature Hail Extreme Heat	Material concern to the safe operation of the NRWMF Impact can be managed through the design and operational management practices	- Climatic conditions – Wind and Flood - Renewable or non-renewable natural resources and the potential to use renewable resources - Utilities, energy and infrastructure
Reduced availability and quality of water supply	Extreme Rainfall Fire Weather Increased Average Temperature Reduced Average Rainfall	Material concern to the safe operation of the NRWMF Impact can be managed through the design and operational management practices	- Geology and geotechnical characteristics (incl. groundwater) - Water - Risks from the surrounding environments (e.g. bushfires) - Site characteristics which have the potential to impact on site safety - Utilities, energy and infrastructure

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Increased maintenance costs of NRWMF and supporting infrastructure (roads, pavements) as materials need to be replaced more often and/or with more resilient materials	Increased Average Temperature Extreme Heat Extreme Rainfall Extreme Wind Fire Weather Hail Solar Radiation Frost	Material concern to the safe operation of the NRWMF Impact can be managed through the design and operational management practices	- Transport considerations
Damage to infrastructure foundations and buried assets due to ground movement as a result of drying soils, changed soil composition, freeze / thaw cycle and potential changes in groundwater levels	Reduced Average Rainfall Soil Moisture Evapotranspiration Extreme Rainfall Frosts	Material concern to the safe operation of the NRWMF Impact can be managed through the design	- Geology and geotechnical characteristics (incl. groundwater) - Soil and other substrates - Water - Site characteristics which have the potential to impact on site safety - Utilities, energy and infrastructure

Impact	Climate Hazard/s	Significance and Potential Ability to Manage the Impact	Relevant Site Characteristic or Enabling Infrastructure Element
Increased potential for dust storms which may create health and safety risks and impact operations, including efficiency of solar panels	Soil Moisture Reduced Average Rainfall	Material concern to the safe operation of the NRWMF. Impact can be managed through the design and operational management practices	- Soil and other substrates - Site characteristics which have the potential to impact on site safety - Renewable or non-renewable natural resources and the potential to use renewable resources

2.3.2.2 Assessment Criteria 2 – Climate change projections for the site

The site is located in the 'hot dry summer, cool winter' climate zone characterised by hot summers and low annual rainfall (~300 mm per year at Hawker, SA) (BoM 2018). Rainfall occurs predominately during the winter and spring months.

The average diurnal temperature range is approximately 15 °C each month, with an annual mean maximum temperature of 25.2 °C and a mean minimum of 10.7 °C (Hawker weather station). A mean number of 31 days below 2 °C occur per annum indicating potential frost days. Based on measurements from 1967 to 2010, mean wind speeds vary between 8.5 km/h at 9am and 11.5 km/h at 3pm (BoM, 2018).

Table 2 provides a summary of the historic climate data and projected changes for 2090. Additional detail on the source of the projections as well as projections for 2030 are provided in Appendix B. As outlined in Table 14, no projections are available for changes in lightning or hail.

The long term (2090) climate projections for RCP 8.5 indicate that there will be a hotter and drier future climate in the region due to overall decrease in the amount of annual rainfall, increase in average temperature and annual number of days above 35 °C. Evapotranspiration rates are projected to increase, alongside a reduction in the number of frosts, soil moisture and relative humidity. The intensity of heavy rainfall events is also projected to increase.

The projected changes in climate are not a reason to preclude the site from further consideration, however, it is acknowledged that the projected changes in climate will influence the impacts associated with other site characteristics outlined in this report.

Table 13 Historic climate and climate change projections

Climate Variable	Historic Climate (Hawker weather station)	2090 RCP 8.5 Rangelands
Mean maximum Temperature (°C)	25.2	+4.3 (+2.8 to +5.2)
Days over 35 (°C)	20 (1995 baseline)	47 (38 to 57)
Severe fire danger days per year (FFDI > 50) (Ceduna)	11.1 (1995 baseline)	21.1 to 37.9
Frost (days with min. temp. <2 °C) (Adelaide / Alice Springs)	1.1 / 3.3 (1981-2010 baseline) [1]	0.0 (0.0 to 0.0) / 2.1 (6.0 to 0.8)
Rainfall (mm)	308.6	-4 (-29 to +13)
Rainfall Intensity	N/A	There is high confidence that the intensity of heavy rainfall extremes will increase in both clusters, but there is low confidence in the magnitude of this change.
Relative humidity (%)	Mean 9am: 56 Mean 3pm: 36	-2.6 (-5.1 to +0.4)
Evapotranspiration (%)	N/A	+10.5 (+6.4 to +14.5)
Solar radiation (%)	N/A	-0.3 (-1.8 to +1.4)
Soil moisture	N/A	-1.7 (-5.9 to -0.5)
Average wind speed	Mean 9am: 8.5 Mean 3pm: 11.5	+0.7 (-2.4 to +2)

2.3.3 Design Issues and Mitigation Measures

The risks associated with climate change can typically be managed through a combination of design solutions and operational management approaches. Table 12 summarises the potential impacts to the site and future NRWMF to be considered in the design and operational phases. The table identifies the site characteristic or enabling infrastructure element that each impact relates to, whether the impacts are likely to be material and if they can be managed through design or operational management practices. More detailed consideration and assessment of these impacts is required by the site characteristic or enabling infrastructure element in order to determine the most appropriate design and operational management solutions.

When considering the impacts in the design phase it will be important to consider how the frequency or intensity of impacts is likely to change over the operational lifespan of the future NRWMF, rather than just considering historical climate data.

2.3.4 Data Gaps and Recommendations for Stage 2 Work Program

2.3.4.1 Data Gaps and Limitations

Climate projections are inherently uncertain due to limits in the theoretical understanding of the Earth's climate, in the numerical modelling of the climate and in the emission scenarios used to inform climate modelling. These uncertainties are reflected in the 'confidence' statements included with each of the climate projections (as shown in Appendix B). Providing projections for multiple RCPs also assists in addressing the issue of uncertainties with projections by providing a range of potential changes.

A summary of the statements of confidence is presented in Table 14. The projections included in this report are limited to the end of the century. The lifespan of the future NRWMF and closure requirements (e.g. capping) may extend beyond this period.

Table 14 Summary of level of confidence assigned to climate projections.

Climate Hazard	Summary of level of confidence in projected change in frequency / trend for both Rangelands NRM unless noted. 2030 and 2090 (RCP8.5)
Extreme Heat	Very high confidence
Extreme Rainfall	High confidence in the direction of change, but low confidence in the magnitude of change
Fire weather	Low confidence in the Rangelands
Frost	High confidence
Wind speed	Medium model agreement
Hail	No projections available. "Climate models do not yet simulate the dynamics of the climate system well enough at small scales to predict changes in hail, thunderstorms and tornadoes"(CCA Ltd 2016 p19)
Lightning	
Average Temperature	Very high model agreement
Evapotranspiration	Very high model agreement
Solar Radiation	High model agreement in 2030 and Medium model agreement in 2090
Soil Moisture	Medium model agreement in the Rangelands

2.3.4.2 Recommendations for Stage 2 Work Program

Stage 2 of the study seeks to collect data via a program of field works. No additional data requirements are requested from the Stage 2 Field Program to support the climate change desktop assessment. However, it is recommended that the relevant site characteristic or enabling infrastructure element identified in this report as being impacted by climate hazards consider their data requirements to enable a more detailed assessment of the significance of the identified impacts.

2.3.4.1 Recommended Process for Undertaking a More Detailed Assessment

To support the detailed design process it is recommended that a more detailed assessment of the impacts identified in this report be undertaken. This section outlines the recommended process for undertaking a more detailed assessment which should be used to inform the design process.

Initial risk identification and rating

The information contained in this report should be used to inform an initial climate risk assessment. The risk assessment will identify and rate the risks that extreme weather events and longer term changes in climate may pose to the achievement of the project objectives. A risk management framework will need to be established including likelihood and consequence definitions and ratings). The framework should be aligned with the project's risk framework and *AS5334 – Climate Change Adaptation for Settlements and Infrastructure – A Risk Based Approach*.

Validating at a Design workshop

The findings of the initial risk assessment should be confirmed and evaluated as a part of a Design Workshop with key technical specialists. The workshop should also be used to identify adaptation actions, or risk control measures that need to be incorporated into the design, or future operational procedures.

Climate change impact assessment report

Following the workshop, a climate change impact assessment report should be developed to document the findings of the risk assessment process and the recommended adaptation responses. Guidance will also be presented on the key considerations that need to be integrated into design. For example specific recommendations on how consideration of changes extreme rainfall should be integrated into the work undertaken by the hydrological, hydrogeological, and geotechnical specialists.

2.4 Bushfire Risks

2.4.1 Methodology and Results

The Wallerberdina site is located within Outback Communities located adjacent the Flinders Range Council. The site is not located within a bushfire protection area.

Bushfire management consultant Terramatrix Pty Ltd has undertaken a desktop-based assessment of the following key characteristics contributing to the bushfire hazard at the site:

- Topography (slope and aspect);
- Vegetation (distribution and nature of the fuel hazard);
- Climate and weather (temperature, wind, relative humidity and frequency of elevated fire danger days); and
- Bushfire characteristics (likelihood of ignition and development of a bushfire with potential to impact the site, credible scenarios, flame lengths and rates of spread).

The assessment focuses on the nature of the bushfire hazard at the site, rather than the likelihood or consequence of loss or damage by bushfire (risk) to a potential NRWMF, which would require a more detailed analysis of the vulnerability of assets and infrastructure that may be developed at the site, and which, it is assumed will be the same regardless of the location.

2.4.1.1 Site Characteristic Criteria

AS 3959-2009 compliance is invoked by the National Construction Code (NCC) as a deemed-to-satisfy pathway for meeting the bushfire protection requirements of the Building Code of Australia (BCA)2 (ABCB, 2016). The AS 3959-2009 site assessment methodology requires an assessment of the vegetation and topography within 100m of a site or building, to determine the applicable Bushfire Attack Level (BAL) construction standard for the building based on the nature of the anticipated bushfire attack3 (for an explanation of BALs see Table 24).

For the purposes of this study, as a precaution, the site assessment zone was extended to 200m i.e. 200m around the two 100ha site options (see Figure 10).

The site characteristic criteria relevant to determining bushfire hazards at a site comprise:

Vegetation

- The extent and nature of the fuel hazard posed by the vegetation at and immediately surrounding the site (within 200 of the site) and at the wider landscape level (within 1km, and extending up to 20km, around the site).

Topography

- Effective and site slopes that may influence bushfire behaviour and impacts, at the site and landscape scale.

Weather

- Frequency and severity of bushfire weather conditions that will influence fire behaviours.

Such conditions may be experienced, based on climatic factors including relative humidity (%), temperature (C˚), wind speed (km/h) and direction, and the return interval (frequency) of days of elevated fire danger.

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[2] The BCA comprises Volumes 1 and 2 of the National Construction Code (NCC).
[3] A determination of the applicability, or otherwise, of the NCC to the proposed NRWMF is beyond the scope of this study and has not been undertaken. The AS 3959-2009 methodology has been applied, due to the common acceptance of the methodology (or a variation of it) in building and planning jurisdictions across Australia, as a benchmark for determining a building's level of exposure to a bushfire hazard and the commensurate BAL construction standard.

Bushfire scenarios and impacts

Likelihood and nature of bushfire impacts that may be experienced based on potential for ignition and development in the surrounding landscape and factors such as the approach, spread, and flux (of a fire)

2.4.1.2 Desktop Methods and Results

AECOM generated data used in the assessment comprised the following:

- Spatial files with a geographic extent of approximately 2 km around the site, comprising cadastre, roads, site boundaries, 1 m contours (generated from LiDAR aerial data with a vertical accuracy of 0.1 m), and surface water features and drainage lines; and
- Spatial files with vegetation type mapping prepared based on field surveys by AECOM with a geographic extent of at least 1 km around the site.

All other layers and data shown in maps or referred to in this report were obtained, or generated by Terramatrix.

2.4.1.2.1 Vegetation

Vegetation on and around the site was identified based on:

- South Australian government GIS-based mapping and data portals available online (Location SA Map Viewer, 2018; Nature Maps, 2018);
- AECOM observations made during a site inspection performed on 21 February 2018;
- AECOM's desktop assessment of Flora and Fauna (contained within); and
- Google Earth imagery.

The fuel hazard posed by, and bushfire characteristics associated with, the vegetation was determined according to:

- Classification as per AS 3959-2009 vegetation groups and types (Standards Australia, 2011);
- Major Vegetation Group (MVG) and Major Vegetation Subgroup (MVS) descriptors for the Native Vegetation Information System (NVIS) (Keith and Pellow, 2015);
- South Australian prescribed burning guide (DENR, 2011); and
- Other published literature (e.g. Cruz *et al.*, 2010; Cruz *et al.*, 2013).

2.4.1.2.2 Topography

The topography was assessed based on elevation model of the site and surrounds to more than 3 km was created by AECOM with 1 m contours from LiDAR aerial survey data collected with a vertical accuracy of 0.1 m. Slopes were determined by rise over run calculations using the 1m and 10m contour data.

2.4.1.2.3 Weather

Terramatrix obtained synoptic weather data for the Bureau of Meteorology (BOM) weather stations at Hawker which is closest to the sites and considered representative of weather that could be experienced. The data was sorted and refined, and selected records analysed to generate a record of relative humidity, temperature, wind (speed and direction). The return period (frequency) of days of elevated fire danger was calculated following the Generalised Extreme Value (GEV) analysis method (Douglas, 2013; Douglas *et al.*, 2015).

2.4.1.2.4 Bushfire scenarios and impacts

Credible bushfire scenarios, and the hazard posed by them, were determined based on the analysis of vegetation, topography and fire weather conditions. The assessment was further informed by:

- Analysis of incident data from 1 May 2009 to 30 June 2015, for South Australian Country Fire Service (CFS) brigades located within approximately 30km of each site (Data SA, 2018);

- Fire history records (*ibid.*);
- Development Plan and Bushfire Protection Area[4] mapping (Location SA Map Viewer, 2018);
- Population density data (*ibid.*); and
- Rate of spread, flame length and Radiant Heat Flux (RHF) calculations using the detailed ‘Method 2’ procedure of AS 3959-2009 (Standards Australia, 2011).

2.4.1.3 Field Methods and Results

No site inspections were undertaken by Terramatrix in the conduct of this assessment.

However field survey data was obtained by AECOM which was used to update the initial assessment, including:

- Digital map of the topography obtained using LiDAR from an aerial survey; and
- A map of the vegetation types developed on the basis of on-ground survey (reported herein).

2.4.2 Assessment Against Criteria

2.4.2.1 Vegetation

Figure 10 shows the extent of potentially classifiable vegetation within the 200m assessment zone around the Wallerberdina site. Darker areas of the imagery in the map show vegetation cover, whilst lighter areas appear to be non-vegetated or very sparsely vegetated. Classified vegetation is vegetation that is deemed hazardous from a bushfire perspective according to the AS 3959-2009 methodology.

The classification system uses a generalised description of vegetation based on the AUSLIG (Australian Natural Resources Atlas: No. 7 - Native Vegetation) classification system. The classification should be based on the mature (long-term) state of the vegetation and the likely fire behaviour that it will generate.

2.4.2.1.1 Grassland

Based on the AECOM vegetation mapping, descriptions and photographs (see Figure 10), it is considered that all of the vegetation likely best accords with the Grassland (Group D) classification under AS 3959-2009. Grassland comprises a range of low growing vegetation types including low open shrubland, hummock and tussock grasslands, and is defined as: ‘*All forms, including situations with shrubs and trees, if the overstorey foliage cover is less than 10%*’ (Standards Australia, 2011).

Grassland areas can be excluded from classification, as non-hazardous vegetation, if they are grazed or cropped to less than 100mm high, in accordance with the criteria in AS 3959-2009 (see exclusion criteria below).

A grassland classification matches the data obtained by AECOM during the 22 February 2018 site inspection and flora and fauna desktop assessment provided herein, as well as more recent site mapping of vegetation by AECOM. AECOM notes that the Wallerberdina Station is a pastoral lease, historically stocked with sheep and cattle that has been operating since the 1970s with native vegetation within the site and surrounds comprising grazed Chenopod shrubland.

SA native vegetation mapping identifies the overwhelming majority of vegetation on and around the site as comprising Major vegetation group (MVG) 22 Chenopod shrublands, samphire shrublands and forelands, Major vegetation subgroup (MVS) Chenopod shrublands (Location SA Map Viewer, 2018). The structural descriptors for MVG 22 include:

- Structure varies from mid-dense shrubland up to two m tall in the most productive sites, to mixed low sparse shrubland/grassland less than 0.3 m tall on dry stony plains, to succulent forbland of varying density up to one m tall in hypersaline substrates.

[4] Designated bushfire protection areas in South Australia are subject to bushfire related planning and building requirements based on the level of bushfire risk determined for the site. Bushfire planning policies for bushfire protection areas can be found in local Development Plans (Government of South Australia, 2012).

- A matrix of grasses and forbs between the shrubs is highly variable in cover and composition, depending on drought cycles and the seasonal timing of rainfall events *(DEE, 2017)*.

Photographs provided by AECOM show a light and variable extent of grass cover with low open shrubs, interspersed with non-vegetated patches of exposed soil.

SA native vegetation mapping shows areas of MVG Other Grassland, Herbland, Sedgeland and Rushland, MVS Other tussock grasslands also occur, but they appear to be outside the site (>approximately 1km).

2.4.2.1.2 Shrubland

If cessation of grazing results in the development of areas of taller, denser shrub vegetation, that on average do not exceed to 2m in height, they may be classifiable as Low Shrubland, under the Shrubland group in AS 3959-2009. This is defined as *'Shrubs <2 m high; greater than 30% foliage cover. Understoreys may contain grasses. Acacia and Casuarina often dominant in the arid and semi-arid zones*' (Standards Australia, 2011).

The distinction between low shrubland and grassland is however, of limited importance, as the fire impacts from both vegetation types, including vegetation setback distances to achieve radiant heat safety thresholds are very similar (see Section 2.4.2.4.2).

2.4.2.1.3 Non-hazardous vegetation

Exclusion from classification is provided for in AS 3959-2009 when the size, configuration and nature of the fuel hazard in vegetation is not likely to generate a bushfire of sufficient size and intensity to justify a building response. Excluded vegetation is deemed to be non-hazardous and therefore excluded from classification according to the following criteria:

i. 'Vegetation of any type that is more than 100m from the site;
ii. Single areas of vegetation less than 1ha in area and not within 100m of other areas of vegetation being classified;
iii. Multiple areas of vegetation less than 0.25ha in area and not within 20m of the site or each other;
iv. Strips of vegetation less than 20m in width (measured perpendicular to the elevation exposed to the strip of vegetation) regardless of length and not within 20m of the site or each other, or other areas of vegetation being classified;
v. Non-vegetated areas, including waterways, roads, footpaths, buildings and rocky outcrops; and
vi. Low threat vegetation including grassland managed in a minimal fuel condition, maintained lawns, golf courses, maintained public reserves and parklands, vineyards, orchards, cultivated gardens, commercial nurseries, nature strips and windbreaks. Note: Minimal fuel condition means there is insufficient fuel available to significantly increase the severity of the bushfire attack (recognizable as short-cropped grass for example, to a nominal height of 100mm)' (Standards Australia, 2011).

2.4.2.1.4 Summary of Assessment of Extent and Nature of Fuel Hazard from Vegetation at Local and Landscape Scales

Most, if not all, of the vegetation on and around Wallerberdina, likely best accords with the Grassland (Group G) classification under AS 3959-2009. If cessation of grazing results in areas of taller, denser shrub vegetation, that on average does not exceed 2 m in height, the vegetation may be classifiable as Low Shrubland. The distinction between low shrubland and grassland is, however, not of particular significance as the fire impacts from both vegetation types, including vegetation setback distances to achieve radiant heat safety thresholds are very similar.

The vegetation in the surrounding landscape does not pose a significant threat or appreciably influence the location of the NRWMF within the site. The vegetation has a relatively low fuel hazard. Setbacks of the NRWMF from unmanaged vegetation should be commensurate with the desired radiant heat flux safety thresholds for, and construction standards of, assets and buildings.

Figure 10 Wallerberdina site assessment zone for bushfire hazard assessment.

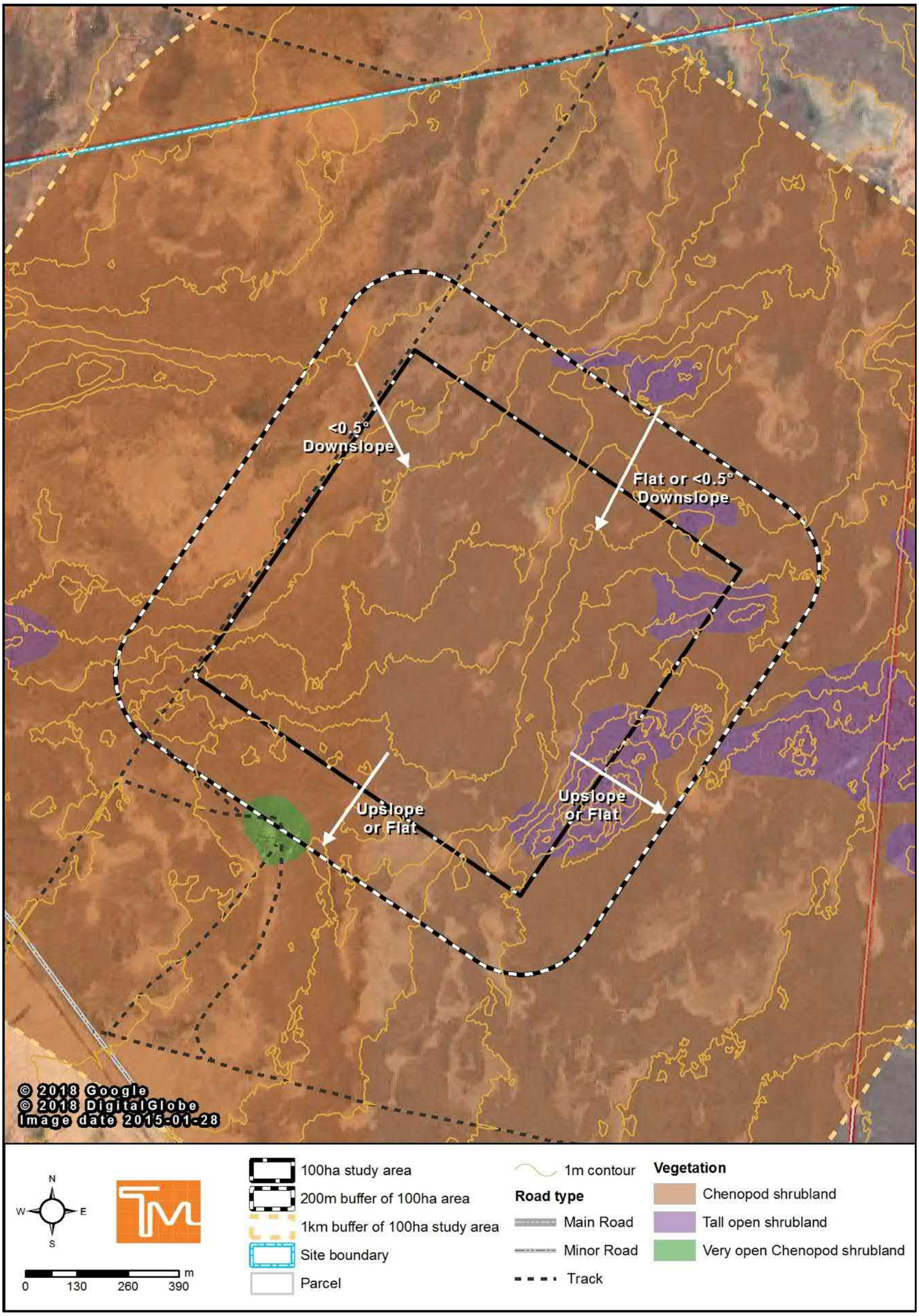


Figure 11 Wallerberdina landscape assessment to 3km

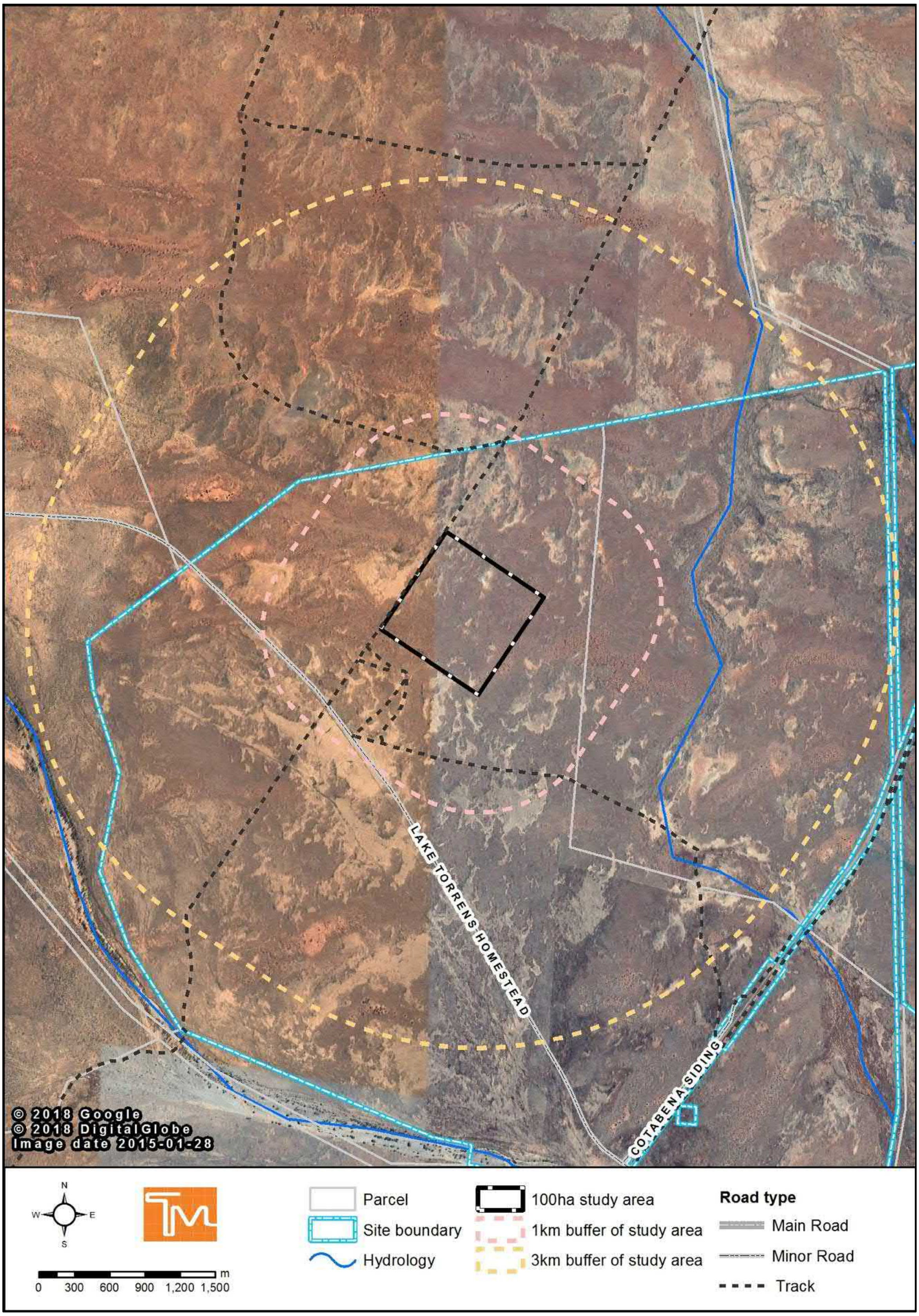
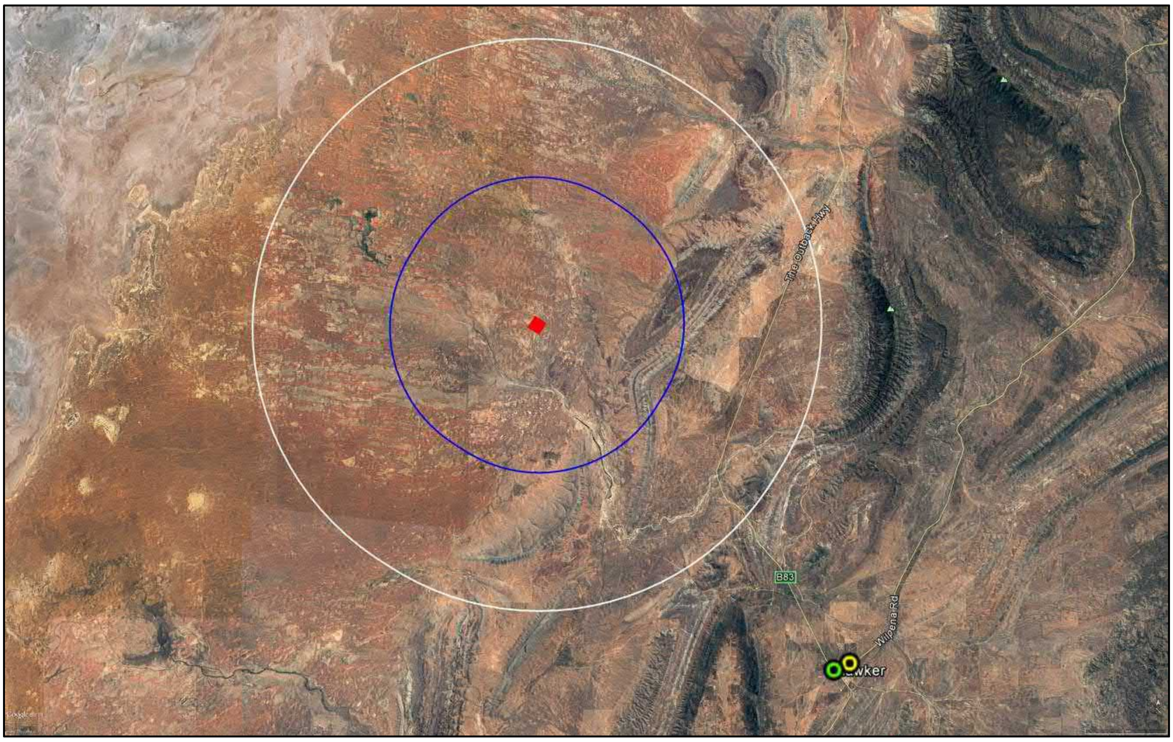


Figure 12 The landscape surrounding the Wallerberdina 100 ha site (shown in red fill).

A 10km buffer of the sites is shown in blue outline and a 20km buffer is shown in white outline. The yellow circle shows the location of the BOM weather station from which weather data was obtained and analysed (see Section 2.4.2.3). The green circle identifies the location of the nearest CFS brigade (see Section 2.4.2.4.3).



2.4.2.2 Topography

The AS 3959-2009 methodology requires that the 'effective slope' be identified to determine applicable setback distances for buildings from hazardous vegetation. This is the slope of land under the classified vegetation that will most significantly influence the bushfire attack on a building. Two broad types apply:

- Flat and/or Upslope - land that is flat or on which a bushfire will be burning downhill in relation to the development. Fires burning downhill (i.e. on an upslope) will generally be moving more slowly with a reduced intensity.
- Downslope - land under the classified vegetation on which a bushfire will be burning uphill in relation to the development. As the rate of spread of a bushfire burning on a downslope (i.e. burning uphill towards a development) is significantly influenced by increases in slope, downslopes are grouped into five classes in 5˚ increments from 0˚ up to 20˚.

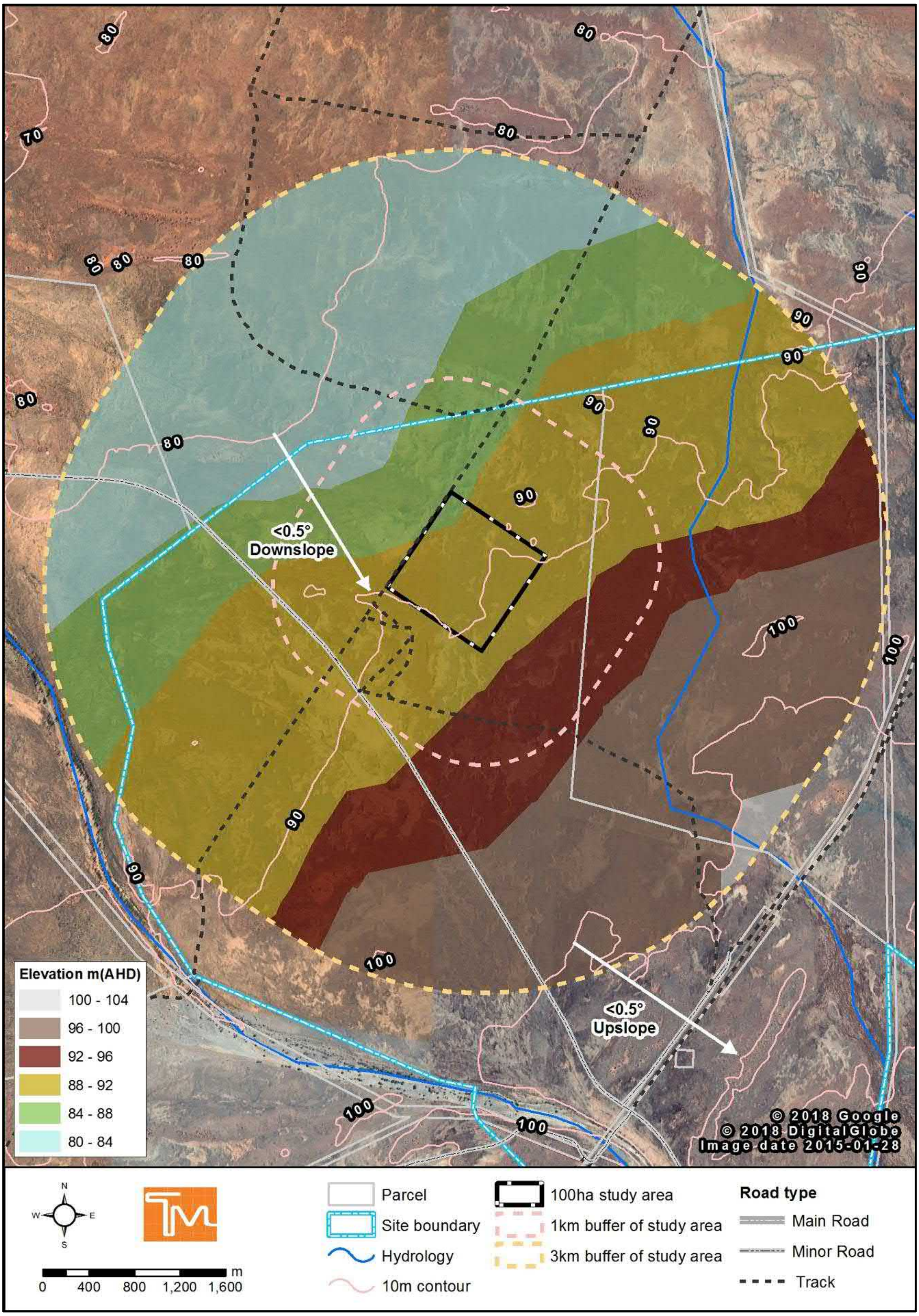
As shown in Figure 13, there is slight decrease in elevation from the southeast to the northwest of the site. However, the gradient is <0.5˚ and this slight slope will not significantly influence bushfire behaviour. The land is effectively flat with a benign topography that is not an appreciable influence on the bushfire hazard or risk at this site.

A 0˚ slope gradient (applied to flat land and all upslopes) would be applicable for determining asset setback distances/APZs at the site.

2.4.2.2.1 Summary of Assessment of Topography that may Influence Fire Behaviour

Overall, the land is flat with a benign topography. A 0˚ slope gradient would likely be applicable for determining asset setback distances/APZs at the site. The topography is not conducive to severe fire behaviour and is not an appreciable influence on the bushfire hazard or risk at Wallerberdina.

Figure 13 Elevation map for Wallerberdina based on 10m contours.



2.4.2.3 Weather

The Forest Fire Danger Index (FFDI) and the Grassland Fire Danger Index (GFDI) are typically used to represent both the level of bushfire threat and difficulty of suppression on a given day, based on weather (and fuel) conditions. The indices are used for predicting fire behaviour including the difficulty of suppression, forecasting Fire Danger Ratings (FDRs) and determining an appropriate level of preparedness for emergency services. Table 15 displays the FDRs, their FFDI range and the description of conditions for each FDR.

Table 15 Fire Danger Ratings (AFAC, 2009; CFS, 2017)

Forest Fire Danger Index	Fire Danger Rating (FDR)	Total Fire Ban	Description of conditions
100+	Catastrophic (Code Red)	Yes	The worst conditions for a bush or grass fire. If a fire starts and takes hold, it will be extremely difficult to control. It will take significant firefighting resources and cooler conditions to bring it under control. Spot fires will start well ahead of the main fire and cause rapid spread of the fire. Embers will come from many directions. Homes are not designed or constructed to withstand fires in these conditions. The safest place to be is away from bushfire prone areas.
75-99	Extreme	Yes	Fires will be uncontrollable, unpredictable and fast moving – flames will be higher than roof tops. People will die and be injured. Hundreds of homes and businesses will be destroyed. Only well prepared, well-constructed and actively defended houses are likely to offer safety during a fire. Thousands of embers will be blown around. Spot fires will move quickly and come from many directions, up to 6 km ahead of the fire.
50-74	Severe	Yes	Fires will be uncontrollable and move quickly– flames may be higher than roof tops. There is a chance people may die and be injured. Some homes and businesses will be destroyed. Well prepared and actively defended houses can offer safety during a fire. Expect embers to be blown around. Spot fires may occur up to 4 km ahead of the fire
25-49	Very High	May be declared.	Fires can be difficult to control – flames may burn into the tree tops. There is a low chance people may die or be injured. Some homes and businesses may be damaged or destroyed. Well prepared and actively defended houses can offer safety during a fire. Embers may be blown ahead of the fire. Spot fires may occur up to 2 km ahead of the fire.
12-24	High	No	Fires can be controlled. Loss of life is highly unlikely and damage to property will be limited. Well prepared and actively defended houses can offer safety during a fire. Embers may be blown ahead of the fire. Spot fires can occur close to the main fire.
0-11	Low – Moderate	No	Fires can be easily controlled. Little to no risk to life and property.

2.4.2.3.1 Grass Fire Danger Index analysis

Analysis of weather data has been undertaken to calculate a 'historical' fire danger index representative of the hazard associated with weather conditions during elevated FDRs at a BOM station location selected to be representative of conditions at each site. Analysis was undertaken for each day during the fire season period (October-April) that the required weather data inputs were available.

Table 16 summarises the attributes of the closest BOM station at Hawker was selected as the most representative of fire weather that may be experienced.

Table 16 Summary of BOM station attributes.

Attribute	Hawker
Distance and direction from Wallaberdina	31km to southeast
Elevation	315m
BOM Station No.	019017
BOM district name	Upper North
Opened	1 Jan 1882
Data available	Synoptic
Date of oldest 3pm record with all inputs*	1st October 1967
Date of most recent 3pm record with all inputs*	30 April 2015
% of 3pm records with all inputs*	92%
No. of years with 3pm records with all inputs*	49

Record with all inputs= 3pm data available for all three attributes for calculating GFDI i.e. relative humidity, temperature and wind speed.

Synoptic (3 hourly) data were available for both stations. The data was sorted to select only those records for which there were complete inputs available to calculate the fire danger index i.e. relative humidity (%), temperature (˚C) and wind speed (km/h). Only 3pm synoptic data was used, based on the assumption that 3pm records were the most likely of the synoptic data to be representative of the peak fire danger for each day. Cruz *et al.* (2013) identify that 3pm is the mid-point of the daily time period when fire weather conditions peak and shrub and heath fires are more than 50% likely to be sustained and will spread). Only those 3pm records for days during the fire season period (i.e. 1st October – 30th April) were used.

It was considered that the GFDI was more applicable to the fire conditions at the three sites than the FFDI. This is due to the prevalence of grassland and other fuels in the landscape in which fire behaviour is influenced more by wind speed, for which the GFDI is the more sensitive index at higher winds than the FFDI (Yeo *et al.*, 2014). Accordingly, an estimate of the GFDI was calculated from each daily 3pm record for which the inputs were available.

It should be noted that GFDI requires an estimate of the degree of grass curing[5] as a key input. As this input was not available or able to be calculated, it was assumed to be 100% for all records in the GFDI calculations. This will likely result in a conservative, over-estimate of the GFDI, especially during spring and early summer when grass may not be fully cured[6]. Note that the GFDI analysis has been undertaken to assist in assessing the appropriateness of design fire inputs. It does not necessarily equal the actual GFDI or fire weather conditions that may have occurred at a site[7].

[5] Curing is defined as the process by which grasses senesce i.e. become dormant or die and dry out, and is measured as the percentage of dead material present (CFA, 2014).
[6] Note that in pastoral landscapes in southern Australia, grasslands and crops will comprises a mosaic of fuel conditions (Cruz *et al.*, 2015).
[7] Uncertainty values for calculated FDIs, especially GFDIs, resulting from the imprecision of the input values, are very significant and may cross a number of FDR classes (Yeo *et al.*, 2014).

For consistency with AS 3959-2009, the GFDI calculation used the equation for the McArthur Mark 4 Grassland Fire Danger Meter (Purton 1982; Yeo *et al.*, 2014). Following GFDI analysis, the GEV method was then used to determine the return period (recurrence) of annual maximum GFDI values for each station.

Table 17 Record of the six years with the highest GFDI for the station.

Year	Month	Day	Temperature (˚C)	Relative humidity (%)	Wind speed (km/h)	GFDI
Hawker						
1980	11	17	37.5	12	64.8	236
2005	12	27	40.3	11	57.2	193
2003	12	9	39.8	12	55.4	170
1988	10	3	34.5	9	55.4	163
1996	11	13	33	8	55.4	162
2002	10	22	31.3	7	55.4	161

Table 18 GEV recurrence intervals for various GFDI/FDR thresholds.

Fire weather threshold (FFDI)	Equivalent GFDI[8]	Recurrence Interval (yrs)	
		Hawker	
Severe fire danger (FFDI 50)	70	1.3	
AS 3959-2009 (FFDI 80)[9]	110	2.9	
Catastrophic fire danger (FFDI 100)	130	4.3	

Table 17 and Table 18 show summary results of the GFDI analysis. They reveal the significantly more severe fire weather conditions on days of elevated fire danger.

The applicable South Australian GFDI 110 threshold for building protection in AS 3959-2009, is likely to occur approximately every 2.9 years at Hawker. A day of fire danger is likely to occur every 4.3 years at Hawker.

2.4.2.3.2 Temperature, relative humidity and wind

At Wallerberdina across the fire season the 3pm mean monthly temperatures at Wallerberdina from around 25 to 33 °C mean relative humidity is generally between 25 and 35 % and mean wind speed varies from around 10 to 13 km/hr.

Table 19 Mean daily 3pm weather conditions during the fire season (Oct – April).

Attribute	Mean 3pm value during the fire season
	Hawker
Relative humidity (%)	28.4
Temperature (˚C)	28.7
Wind speed (km/h)	11.6

[8] Deemed equivalent value by AS 3959-2009 (Standards Australia, 2011).
[9] An FFDI 80 (deemed equivalent to GFDI 110 by AS 3959-2009) applies throughout SA bushfire protection areas to determine vegetation setback distances from classified vegetation and associated building construction standards.

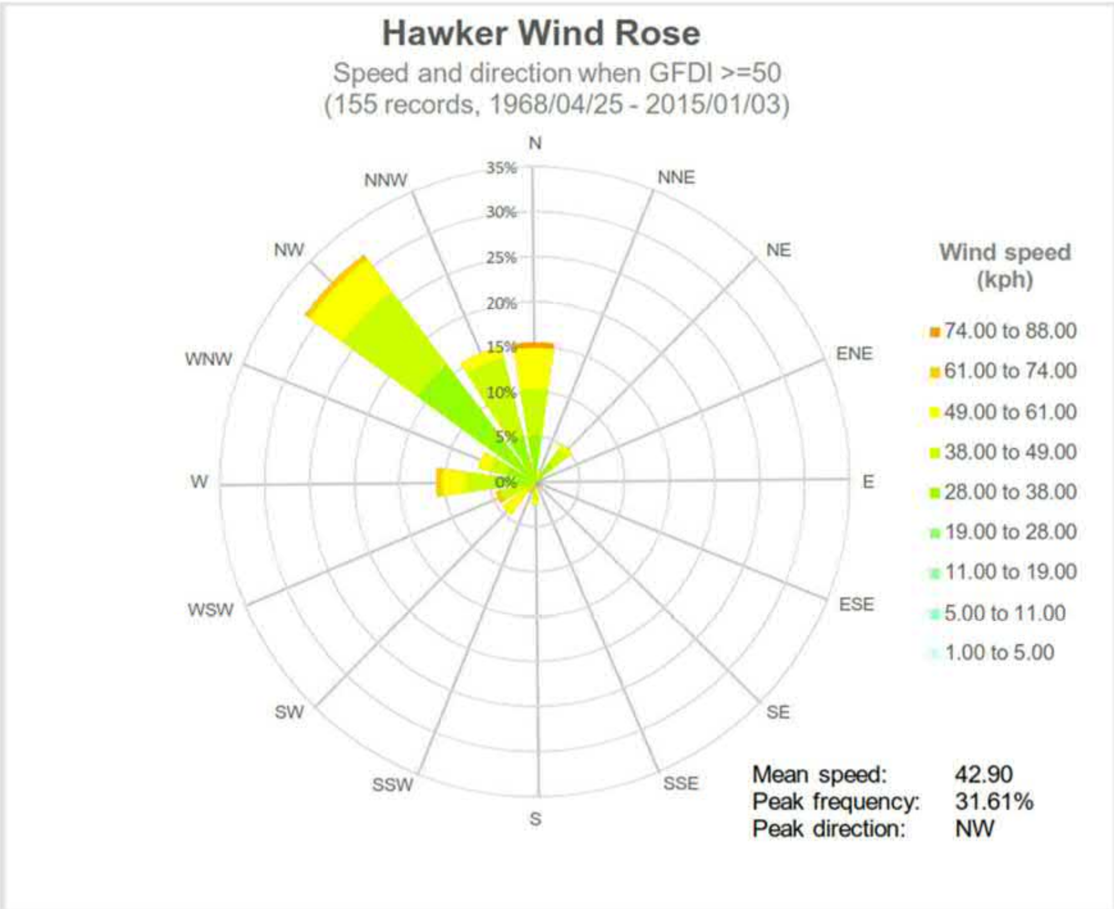
2.4.2.3.3 Wind speed and direction

As wind speed and direction is a major influence on fire behaviour in grass and shrub fuels, further analysis of wind data was undertaken to compare wind data for the two BOM sites.

A wind rose for each weather station was generated to show the wind speeds and directions of wind, at 3pm on days of elevated fire danger (i.e. when calculated GFDI was >=50) during the fire danger period. The results are provided in Figure 14.

The Hawker data for Wallerberdina show the dominance of strong north-westerly winds during fire weather conditions.

Figure 14 Hawker wind rose for 3pm records during the fire season months when calculated GFDI >= 50.



2.4.2.3.4 Climate change

The weather analysis is based on historical data that may correlate poorly with future fire weather due to the impact of climate change, which is predicted to generate hotter and drier conditions across southeast Australia.

A 2007 study of bushfire weather across southeast Australia under various climate change scenarios concluded that by 2020 there could be up to a 4% increase in mean FFDI under low global warming scenarios, and up to 10% under high global warming scenarios. By 2050 the increased projected change in mean FFDI was 8% to 30% under the low and high scenarios respectively (Lucas *et al.*, 2007).

The same study identified the potential for a significantly increased number of elevated FDRs, as shown in Table 20.

Table 20 Percentage change in the number of days with very high and extreme fire weather – 2020 and 2050, relative to 1990 (Lucas *et al.*, 2007).

Fire Danger	2020		2050	
	Low global warming (0.4˚C)	High global warming (1˚C)	Low global warming (0.7˚C)	High global warming (2.9˚C)
Very High	+2-13%	+10-30%	+5-23%	+20-100%
Extreme	+5-25%	+15-65%	+10-50%	+100-300%

Climate analysis provided by AECOM identifies for Wallerberdina, that from 2030 to 2090:

- Mean maximum daily temperatures could increase by up to 1.4˚C to 5.2˚C;
- Mean 3pm relative humidity could decrease by up to 1.8% to 5.1%; and
- Mean 3pm wind speed could decrease by up to 1.2 km/h, or increase by up to 2km/h.

2.4.2.3.5 Summary of Assessment of Frequency and Severity of Bushfire Weather Conditions that will Influence Fire Behaviour

Analysis of historical BOM data from the Hawker weather station (located 31km southeast of Wallerberdina), identifies that a day of Severe fire danger is likely to occur approximately once every 1.3 years at Wallerberdina, whilst a day of Catastrophic fire danger is likely to occur approximately every 4.3 years.

The applicable GFDI 110 fire weather threshold for building protection in AS 3959-2009, is likely to occur approximately every 2.9 years. During the fire season, the mean 3pm values for relative humidity, temperature and wind speed are 28.4%, 28.7˚C, and 11.6km/h respectively.

On days of elevated fire danger north-westerly winds are most likely to be experienced, however, strong winds from the north and west are also likely to occur.

Under Severe or higher fire weather conditions, strong (average 43km/h) north-westerly winds are most likely to be experienced. Less frequent, but also associated with high wind speeds, are northerly or westerly winds.

It should be noted that the historical weather analysis may correlate poorly with future fire weather due to the impact of climate change, which is predicted to generate hotter and drier conditions across south-eastern Australia, including potential for significantly more frequent, severe and elevated fire danger days.

2.4.2.4 Bushfire scenarios

Based on the analysis of vegetation, topography and weather on days of elevated fire danger, credible bushfire scenarios are identified and their potential impacts analysed, including the potential for the ignition and development of a bushfire in the surrounding landscape.

2.4.2.4.1 Grass or scrub fire

Weather analysis for Hawker shows a significant likelihood of winds from the northwest under elevated fire danger conditions. Strong northerly or westerly winds are also likely. The Wallerberdina site is however, northwest of the Hawker BOM station, in more exposed flatter, rangelands country which may result in different wind patterns. Notwithstanding, the hazard in all directions around the site is very similar in terms of topography and vegetation, dominated by low open shrublands and/or grasslands on more or less flat land.

The rate and direction of fire spread will be determined by the wind speed and direction. A fire approaching the site could be fast moving but it would likely be a relatively low intensity fire with a highly variable rate of spread and flame lengths, dependent on the amount and continuity of the fuel hazard.

A bushfire would not pose a significant or unacceptable risk to the site if appropriate low threat setbacks can be provided around assets commensurate with their vulnerability to bushfire attack.

2.4.2.4.2 Bushfire impacts

Rate of spread, flame length and RHF

The detailed Method 2 procedure of AS 3959-2009 was used to calculate potential rates of spread, flame lengths and RHF that may result from a grass or shrub fire impacting the Wallerberdina site.

The AS 3959-2009 'default' inputs for weather, fuel and radiant heat impacts have been applied, based on both the FFDI 80 value (GFDI 110) that applies in SA for determining BAL construction standards and a higher, more precautionary, FFDI 100 (GFDI 130) input (i.e. Catastrophic FDR conditions, and which applies for determining BALs in Victorian non-alpine areas and some NSW regions). The inputs and results for a range of RHF safety thresholds for both a grassland fire scenario and a fire in shrubland, are summarised in Table 21.

Table 21 Summary of Method 2 calculations for a fire in Grassland and Shrubland.

Attribute				
Input				
Vegetation	**Grassland**		**Shrubland**	
FFDI	80	100	80	100
Deemed equivalent GFDI	110	130	110	130
Flame temp (K)	1090			
Flame emissivity	0.95			
Flame width (m)	100			
Heat of combustion (kJ/kg)	18,600			
Average vegetation height (m)	n/a		1.5	
Wind speed (km/h)	45			
Overall fuel load (t/ha)	4.5		15	
Effective slope (°)	0			
Site slope (°)	0			
Output				
'Steady state' rate of spread (km/h)	14.3	16.9	2.9	2.9
Flame length (m)	6.9	7.5	7.7	7.7
Asset/Vegetation setbacks (m) for RHF threshold				
Distance to reach 40 kW/m^2	5.8	6.3	6.5	6.5
Distance to reach 29 kW/m^2	7.9	8.6	8.9	8.9
Distance to reach 19 kW/m^2	11.8	12.8	13.2	13.2
Distance to reach 12.5 kW/m^2	17.5	18.8	19.3	19.3
Distance to reach 10 kW/m^2	21.1	22.7	23.5	23.5
Distance to reach 2 kW/m^2	67.7	71.2	72.8	72.8

The results of the AS 3959-2009 method 2 calculations show anticipated rates of spread of 14 – 17km/h and flame lengths of 7-8m for a grassfire under the two FFDI/GFDI scenarios. Whilst a grass fire forward rate of spread could be significantly faster than a fire in the shrubland vegetation, the RHF setbacks are very similar. The shrubland (and grassland) setbacks are likely conservative as the presumed overall fine fuel load of 15t/ha may be overly high for the semi-arid/arid vegetation that occurs around the site.

Note that the rate of spread and flame length (and hence RHF setbacks) do not change for a shrubland fire under the two GFDI/FFDI scenarios, as the shrub and heath equation used does not include FFDI or GFDI as an input, but applies the wind speed, which in AS 3959-2009 is presumed to be 45km/h.

The appropriate setback to reduce RHF to reach an acceptable risk, depends on the vulnerability of future assets and infrastructure to RHF and the desired safety threshold. The RHF threshold range of 12.5 kW/m2 to 40 kW/m2 is commensurate with the range of BAL construction standards from BAL-12.5 to BAL-40 under AS 3959-2009 (see Table 24).

The RHF threshold of 10kW/m^2 is applied in some jurisdictions for 'vulnerable' developments such as schools, hospitals, aged care facilities, and similar development where large numbers of people may gather or be accommodated away from their usual place of residence. It is the upper RHF limit to which fire fighters in protective clothing can be exposed for short periods of time.

The RHF threshold of 2kW/m^2 is the upper limit for human exposure without protective clothing and is applied in Victoria for determining appropriate setbacks for sheltering in the open at a Neighbourhood Safer Place (NSP 'Place of Last Resort').

It is important to note that the Method 2 calculations are applied to determine setbacks for built assets based on RHF exposure levels. They may not appropriately represent actual anticipated fire behaviour. Advances have occurred in fire science and rate of spread modelling since the development of AS 3959-2009 and these models are likely to more accurately represent actual fire behaviour than those in AS 3959-2009.

For example, for grass and shrub and heath fuels, fuel moisture content as well as wind speed is an important determinant of fire behaviour that is not a direct input into the Method 2 calculation. *'Fire spread sustainability was primarily a function of litter fuel moisture content with wind speed having a secondary but still significant effect. The continuity of fine fuels close to ground level was also significant. Onset of active crowning was mostly determined by wind speed'* (Cruz *et al.*, 2013).

A West Australian study of fire ignitions also showed that fuel moisture content was a better predictor of fires than weather or fire danger variables that combine fuel availability and wind inputs. This is because the moisture content of surface litter is strongly linked to the sustainability of ignition and the availability of fuels to support combustion, whereas wind contributes more to fire spread (Plucinski, 2014).

<u>Smoke, embers and wind</u>

Other potential bushfire impacts that should be considered in the design of the NRWMF include vulnerability to smoke, embers and wind.

Embers are the most common cause of building loss from bushfire and can arrive well in advance of a discernible fire front and continue for a long time after a fire. Grassfires however, do not typically generate significant ember attack, although the presence of any small areas of trees or shrubs may be a local source of embers.

Strong winds, can increase the vulnerability of a building to ember attack by dislodging materials or opening gaps in the building fabric where embers could lodge. The impact of wind during a bushfire event is considered similar but not extreme at this site and an appropriate design response can adequately mitigate the wind effects.

It is desirable that future buildings aim to facilitate wind flow over the building and maintenance (e.g. cleaning of gutters) and avoid complex roof lines with may allow build-up of debris (e.g. accumulation of leaves and bark) and trap embers. Walls and eaves should similarly avoid or minimise re-entrant corners and other features that may trap debris and embers.

2.4.2.4.3 Potential for ignition and fire development

Human-caused ignitions are the main source of wildfires in south-eastern Australia and population density has been found to be the most important variable related to the location of ignitions (Collins *et* *al.*, 2015). Human-caused fires are also more likely to occur on weekends and public holidays (Plucinski, 2014).

The population density in the landscape around the site very low, listed as 0.0 people per square km in the unincorporated area around Wallerberdina (2006 data (Location SA Map Viewer, 2018)).

CFS incident data for local brigades (within approximately 20-30km of the site 'as the crow flies') was examined for the occurrence of incidents in the landscape around the site that did, or could, generate a bushfire with the potential to threaten the site. Table 22 show the CFA brigade closest to the site.

Data was analysed for the period 1 May 2009 to 30 June 2015. The results are provided in Table 23. Note that other incident types not selected may also generate fires that could threaten the site e.g. building, vehicle or rubbish fires.

Table 22 CFS brigades closest to Wallerberdina.

Brigade	Distance and direction from site
Hawker	31km to southeast

Table 23 CFS incident data for brigades within 20-30km of the site.

Site	Wallerberdina
Incident/Brigade	**Hawker**
Grass or Stubble Fire	6
Scrub and Grass Fire	4
Tree Fire	0
Haystack	0
Grain / Crop Fire	0
Lightning (No Fire)	0
Forest Fire	0
Unauthorised Burning	0
Attempt to Burn	0
Total	**10**

Grass, grass stubble, and scrub fires are the most common in the landscape surrounding the site, reflecting the pastoral landscape. The remoteness of the Wallerderdina site, with less human activity, is indicated by the lower number of callouts by the Hawker brigade.

The data is provided for comparison purposes only, as a guide to the possibility of ignitions and fire development and is not a measure of bushfire risk at any site. It indicates the fire suppression resourcing available around each site and the record of incidents and human activity that may result in bushfire ignition. Note that some records may be the same fire/incident that more than one local brigade has attended.

2.4.2.4.4 Summary of Assessment of Likelihood and Nature of Bushfire Impact

The most likely fire threat is from a grass or grass and scrub fire caused by an accidental or natural ignition on the site or in the surrounding landscape. It would most likely impact the site from those directions most typically associated with days of elevated fire danger in south-eastern Australia (i.e. from the north, northwest, west or southwest). The rate and direction of fire approach and spread would be determined by the wind speed and direction, with topography a negligible influence.

Based on AS 3959-2009 presumptions about fire behaviour, anticipated rates of spread of 14 – 17km/h and flame lengths of 7-8m could result from a grassfire impacting under elevated fire danger conditions. Whilst the forward rate of spread of a grassfire could be significantly faster than a fire in Shrubland vegetation, the Radiant Heat Flux (RHF) setback distances for assets from hazardous vegetation, are very similar. The appropriate setback to reduce RHF to reach an acceptable risk depends on the vulnerability of future assets and infrastructure to RHF, the agreed design fire conditions (e.g. fire weather) and the desired safety threshold.

In addition to an appropriate BAL construction standard commensurate with the setback from vegetation, other potential bushfire impacts that should be considered in the design of the NRWMF include vulnerability to smoke, embers and wind. Embers are the most common cause of building loss from bushfire and can arrive well in advance of a discernible fire front and continue for a long time after a fire. However, ember attack is not likely to be significant, although, if any areas of trees or shrubs in proximity to the NRWMF were to ignite, they may be a local source of embers.

The bushfire hazard at Wallerberdina is low, due to the lesser hazard nature of the vegetation on and around the site and the benign topography. It does not preclude the development occurring. The site would only be exposed to a relatively low intensity grass or scrub fire that would not pose a significant hazard if appropriate bushfire protection measures are provided.

Mitigation measures should include low threat setbacks around assets commensurate with their vulnerability to bushfire attack, in addition to adequate provision of water for firefighting, access for emergency vehicles and personnel, and appropriate bushfire emergency management arrangements.

2.4.3 Design Issues and Mitigation Measures

The bushfire hazard at Wallerberdina is relatively low due to the lesser hazard nature of the vegetation on and around the site and the benign topography. The site is not in a SA Bushfire Protection Area that identifies the bushfire risk level and where specific planning and building controls apply (Location SA Map Viewer, 2018).

The Wallerberdina site would likely only be exposed to a lesser intensity grassfire that should not pose a significant hazard if appropriate bushfire protection measures are provided.

A summary discussion of each main protection and mitigation measure is provided below.

2.4.3.1 Buildings – BAL construction standards

If future buildings are constructed to an appropriate BAL construction standard, it is considered they will be adequately protected and will not require specific design features to protect against bushfire attack, unless the buildings need to protect assets with a particular vulnerability to smoke, wind, embers or radiant heat.

All BAL construction standards above BAL-Low are 'deemed to satisfy' the National Construction Code requirement that applicable buildings be designed and constructed to reduce the risk of ignition from a bushfire, appropriate to the:

(a) *'potential for ignition caused by burning embers, radiant heat or fame generated by a bushfire*
(b) *intensity of the bushfire attack on the building'* (ABCB, 2016).

An explanation of BAL options is provided in Table 24. A minimum BAL-12.5 construction standard for all future buildings is likely appropriate, if the buildings can achieve an appropriate setback from any hazardous vegetation (see for example the distances identified in Table 21 and discussed in Section 2.4.2.4.2).

Table 24 BAL construction standards (adapted from Standards Australia, 2011).

Bushfire Attack Level (BAL)	Risk Level	Construction elements are expected to be exposed to…	Comment
BAL-Low	VERY LOW: There is insufficient risk to warrant any specific construction requirements but there is still some risk.	No specification.	At 4kW/m^2 pain to humans after 10 to 20 seconds exposure. Critical conditions at 10kW/m^2 and pain to humans after 3 seconds. Considered to be life threatening within 1 minute exposure in protective equipment.
BAL-12.5	LOW: There is risk of ember attack.	A radiant heat flux not greater than 12.5 kW/m^2	At 12.5kW/m^2 standard float glass could fail and some timbers can ignite with prolonged exposure and piloted ignition.
BAL-19	MODERATE: There is a risk of ember attack and burning debris ignited by windborne embers and a likelihood of exposure to radiant heat.	A radiant heat flux not greater than 19 kW/m^2	At 19kW/m^2 screened float glass could fail.
BAL-29	HIGH: There is an increased risk of ember attack and burning debris ignited by windborne embers and a likelihood of exposure to an increased level of radiant heat.	A radiant heat flux not greater than 29 kW/m^2	At 29kW/m^2 ignition of most timbers without piloted ignition after 3 minutes exposure. Toughened glass could fail.
BAL-40	VERY HIGH: There is a much increased risk of ember attack and burning debris ignited by windborne embers, a likelihood of exposure to a high level of radiant heat and some likelihood of direct exposure to flames from the fire front.	A radiant heat flux not greater than 40 kW/m^2	At 42kW/m^2 ignition of cotton fabric after 5 seconds exposure (without piloted ignition).
BAL- FZ (Flame Zone)	EXTREME: There is an extremely high risk of ember attack and a likelihood of exposure to an extreme level of radiant heat and direct exposure to flames from the fire front.	A radiant heat flux greater than 40 kW/m^2	At 45kW/m^2 ignition of timber in 20 seconds (without piloted ignition).

2.4.3.2 Other assets and infrastructure

The vulnerability of other assets and infrastructure to the mechanisms of bushfire attack (smoke, embers, wind, radiant heat and flame contact) will need to be determined and adequate setbacks provided, e.g. to protect essential services such as exposed telecommunication, power, sewerage, drainage, heating/cooling or water infrastructure. Additional design and construction features may be required if the assets have a particular vulnerability.

2.4.3.3 Asset Protection Zones (APZs) and vegetation management

APZs around buildings should be provided, for a distance commensurate with their construction standard and/or desired RHF safety threshold under agreed design fire conditions. All vegetation in the APZs should be managed in a low threat state, as non-hazardous vegetation, including grass no more than 100mm high with few shrubs or trees. Future landscaping should not increase the hazard around the buildings/assets.

Other assets may also need to be provided with an appropriate APZ including access roads and essential infrastructure.

The creation and maintenance of appropriately sized and strategically located APZs, should be considered across the balance of the site and/or appropriate 'whole of site' vegetation management (e.g. grazing) implemented beyond the building setback areas. This should aim to ensure that any fire originating from an ignition on the site does not have significant potential to develop and threaten neighbouring properties. It would also serve to slow and help control or extinguish a fire burning onto the site and threatening assets and infrastructure.

2.4.3.4 Water and access

Provision of an adequate water supply will need to be provided for fire-fighting, to the satisfaction of the relevant fire authority (presumably the CFS). This should include consideration of an appropriate reticulated water system dedicated for firefighting with adequate pumps, hydrants and other outlets/hoses.

A sufficient capacity of static water, as an additional supply, should be provided in a non-combustible, above ground tank(s), with appropriate fittings and access for emergency services.

2.4.4 Data Gaps and Recommendations for Stage 2 Work Program

2.4.4.1 Data Gaps and Limitations

Key data gaps in the bushfire hazard assessment include:

- The configuration and layout of the development including type and location of buildings and other assets and infrastructure;
- Information on the vulnerability of future assets associated with the NRWMF including the number of people that will be present on the site at any time and the nature of their occupancy; and
- Agreement about the appropriate design fire conditions for calculating APZs.

2.4.4.2 Recommendations for Stage 2 Work Program

Further work will require a specialist bushfire consultant to conduct a site visit and an assessment to determine BALs and extent of APZs once concept design and asset layout plan is completed. Appropriate design fire inputs and RHF safety thresholds also need to be agreed.

2.5 Hydrology and Flood Risks

2.5.1 Methodology and Results

AECOM has prepared a detailed Desktop Assessment for the Wallerberdina site focused on Surface Water. This assessment addresses surface water only, with the scope and methodology to address groundwater at the site incorporated within the Geology, Geotechnical and Geochemical characteristics section.

Assessment of the presence and seasonality of surface waters, including retention structures such as dams, has been addressed as part of a review of hydrological processes and flood risks at the site. The assessment is generally based on relevant existing publicly available data sources, with site based data utilised where available. The types of data include:

- Rainfall depth and intensity data;
- River flow data;
- Topographical data – e.g. watercourses;
- Terrain elevation data – e.g. digital terrain models (LiDAR, SRTM);
- Satellite and aerial photography;
- Soils information; and
- Anecdotal flood information.
- A subsequent flood study was also undertaken for the site and is detailed in this section.

2.5.1.1 Site Characteristic Criteria

The key criteria used to assess the site for use as a NRWMF are informed by the International Atomic Energy Agency (IAEA) Specific Safety Guide SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (IAEA SSG-18, 2011). The guide lists a number of key criteria used to assess siting nuclear installations. The guide also addresses an extended range of nuclear installations, including spent fuel storage facilities. Given this, it has been used to inform the characterisation of the site.

AECOM has undertaken a preliminary assessment of surface water (hydrology) at the Wallerberdina site. The key criteria considered include the following:

- Free from localised flooding (water logging or extreme rainfall) – this may lead to disruption of site operations and potentially lead to the dispersion of radioactive material;
- Free from major flooding from a range of sources including from waterways, bodies of water or from sudden releases of water from natural or artificial storages– potentially leading to structural failures of the NRWMF resulting in the potential dispersion of radioactive material;
- Have site access during flood events – ensuring staff and emergency services can access the site for both normal operational and emergency response activities; and
- Not be subject to flooding as a result of changes in rainfall and runoff from the catchment over time (climate induced change).

2.5.1.2 Desktop Methods and Results

AECOM reviewed water databases relevant to the Wallerberdina site. The following data and search results were accessed, and where data was available, were utilised to complete this assessment:

Publicly available mapping and report datasets accessed from on-line databases:

- Data SA South Australian Government Data Directory map viewers; specifically:
    - *Location SA Map Viewer* http://location.sa.gov.au/viewer/
      Location SA Map Viewer is a public-facing application to enable citizens to visualise much of the state government data in the Location SA repository. Where this data is available for download the user is provided with a link to data.sa.gov.au.

  - *WaterConnect https://www.waterconnect.sa.gov.au/Pages/Home.aspx*
    WaterConnect has the latest information about South Australia's water resources and flood awareness, providing direct access to water-related publications and data. Available river flow data in the vicinity of the site was interrogated using the map function. Links to any relevant flood reports and visualisation of known flood extents was provided by the Flood Awareness Map portal.

- GIS watercourse data from Geosciences Australia
- Water information from the Australian Hydrological Geospatial Fabric (Geofabric) (http://www.bom.gov.au/water/geofabric/)

  The Geofabric is a specialised Geographic Information System (GIS). It registers the spatial relationships between important hydrological features such as rivers, water bodies, aquifers and monitoring points. For this study, it has been used to determine the presence of significant waterways, their alignments and catchment areas.

- Planning Scheme overlay data – e.g. Land Subject to Inundation Overlay (LSIO)

  Planning schemes often have overlays that delineate flood prone land as LSIO or floodway zones

- Aerial photography (from various open sources)

  Satellite and other aerial photography is available from a range of open sources (e.g. Google Earth and Google Map Satellite) and is used to visually identify key overland flow paths, waterways, dams and other infrastructure that may obstruct overland flows.

- Geoscience Australia National 1 arc second (~30m) SRTM Digital Elevation Model Version 1.0, Hydrologically Enforced (DEM-H): https://ecat.ga.gov.au/geonetwork/srv/eng/search#!aac46307-fce8-449d-e044-00144fdd4fa6

  The 1 second Shuttle Radar Topography Mission (SRTM) Digital Elevation Models Version 1.0 comprises three surface models: the Digital Elevation Model (DEM), the Smoothed Digital Elevation Model (DEM-S) and the Hydrologically Enforced Digital Elevation Model (DEM-H). The DEMs were derived from the SRTM data acquired by NASA in February 2000. The DEM-H captures flow paths based on SRTM elevations and mapped stream lines, and supports delineation of catchments and related hydrological attributes. The vertical accuracy of the data has been tested and shown to be in the order of +/- 7.6 m (95th percentile).

- Rainfall Intensity Frequency Duration (IFD) information from the Bureau of Meteorology http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016

  This is a standard industry tool to calculate rainfall intensities and total depths of rainfall for locations across Australia. The tool uses the procedures and data contained in the industry guideline called Australian Rainfall and Runoff (ARR, 2016).

- Existing flood studies and flood extent mapping from the Australian Flood Risk Information Portal (http://www.ga.gov.au/flood-study-web/#/search)

  This national web portal is similar to the SA WaterConnect Flood Awareness Map web portal described above. The portal was used to identify any existing flood studies, reports and GIS flood mapping available in the vicinity of the site.

- Anecdotal historic flood information from a number of sources:
  - Historical background on the Port Augusta to Leigh Creek rail line, including that the Hookina Creek bridge was destroyed in the 1955 flood (https://history.flindersranges.com.au/mining/coal/)
  - Drone footage captured in most recent times showing scouring and uprooted trees along the banks, inferred due to the 1955 flood (https://www.youtube.com/watch?v=rEwqTZw5NbI) and (https://www.youtube.com/watch?time_continue=5&v=M4KWddf32oM)

    - o 2007 aerial oblique flood photos (http://www.hawkermotors.com.au/ArialAlbum/index.htm)

Specific project datasets:

- LiDAR terrain elevation data and associated drainage lines (via RPS Group Plc)
- LiDAR (Light Detection and Ranging) is a remote sensing method that uses light from a pulsed laser to measure distances to the Earth, typically from a plane. It is typically used to capture a digital terrain model (DTM) of the ground surface. The method has been used to capture a DTM of the Wallerberdina site with a vertical accuracy of +/- 100mm. From the DTM, drainage lines have been extracted along low points in the terrain. Localised depressions have been included in the drainage line assessment by assuming they can fill with water and will spill in the predominant drainage direction.
- Soils information

  The Desktop Assessment includes available soils information for the site. The soils information informs the hydrology, infiltration losses and hence likely runoff and water logging.
- Climate and climate change information

  The Desktop Assessments includes available climate and climate change information for the site. The climate and climate change information informs the rainfall intensities, evaporation losses and hence likely runoff and water logging.

Flood study (undertaken for this assessment):

A Hydrological study for Wallerberdina was undertaken by Hydrology and Risk Consultants (HARC, 2018)

The study determined hydrographs on Hookina Creek and local catchments for placement into a hydraulic model (TUFLOW) as part of a hydraulic (flood) study of the site. The RORB hydrological modelling software was used to generate hydrographs for infrequent, rare and extreme flood events. Infrequent events included the 20, 10, 5 and 2% annual exceedance probability (AEP) design floods. These events are referred by the report as the 1 in 5, 10, 20 and 50 AEP events. Rare events included the 1 in 100, 1000 and 2000 AEP design floods. The extreme event was the Probable Maximum Flood (PMF). The hydrographs were developed in accordance with the methods in Australian Rainfall and Runoff (ARR, 2016). RORB was run in Monte-Carlo simulation mode to estimate the flood frequency quantiles for flood events. Details of the methodology and results from the study are included in Appendix C. Table 25 presents a summary of the peak flows and critical duration storms.

Table 25 Summary of peak flows

AEP (1 in x)	Hookina Creek		Local Catchments	
	Peak Flow (m^3/s)	Duration (hour)	Peak Flow (m^3/s)	Duration (hour)
5	473	6	70	3
10	922	6	128	3
20	1490	9	193	3
50	2420	9	294	2
100	3180	9	376	2
1000	6120	9	671	2
2000	7140	9	771	2
PMF (approx.)	40500	3	3410	2

Hydraulic modelling by AECOM Australia (AECOM, 2018)

The hydraulic modelling determined flood risks at the site. The modelling was undertaken using a 2D hydraulic model (TUFLOW). The model was established using existing one metre resolution LiDAR terrain data and, where LiDAR was not available, Shuttle Radar Topography Mission (SRTM) terrain data. The model was run using flows from the hydrological study (HARC, 2018). The hydraulic modelling determined flood heights, depths, velocities, bed shear stress and stream power for the range of AEP events available from the hydrological modelling. Details of the methodology and selected key results are included in Appendix C.

From the modelling, it was determined that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 AEP). The 1 in 100 year AEP flood depths are illustrated in Figure 15 and Figure 16, with the more extreme 1 in 2000 year flood depths illustrated in Figure 17 and Figure 18.

Figure 15 1 in 100 year AEP flood depth

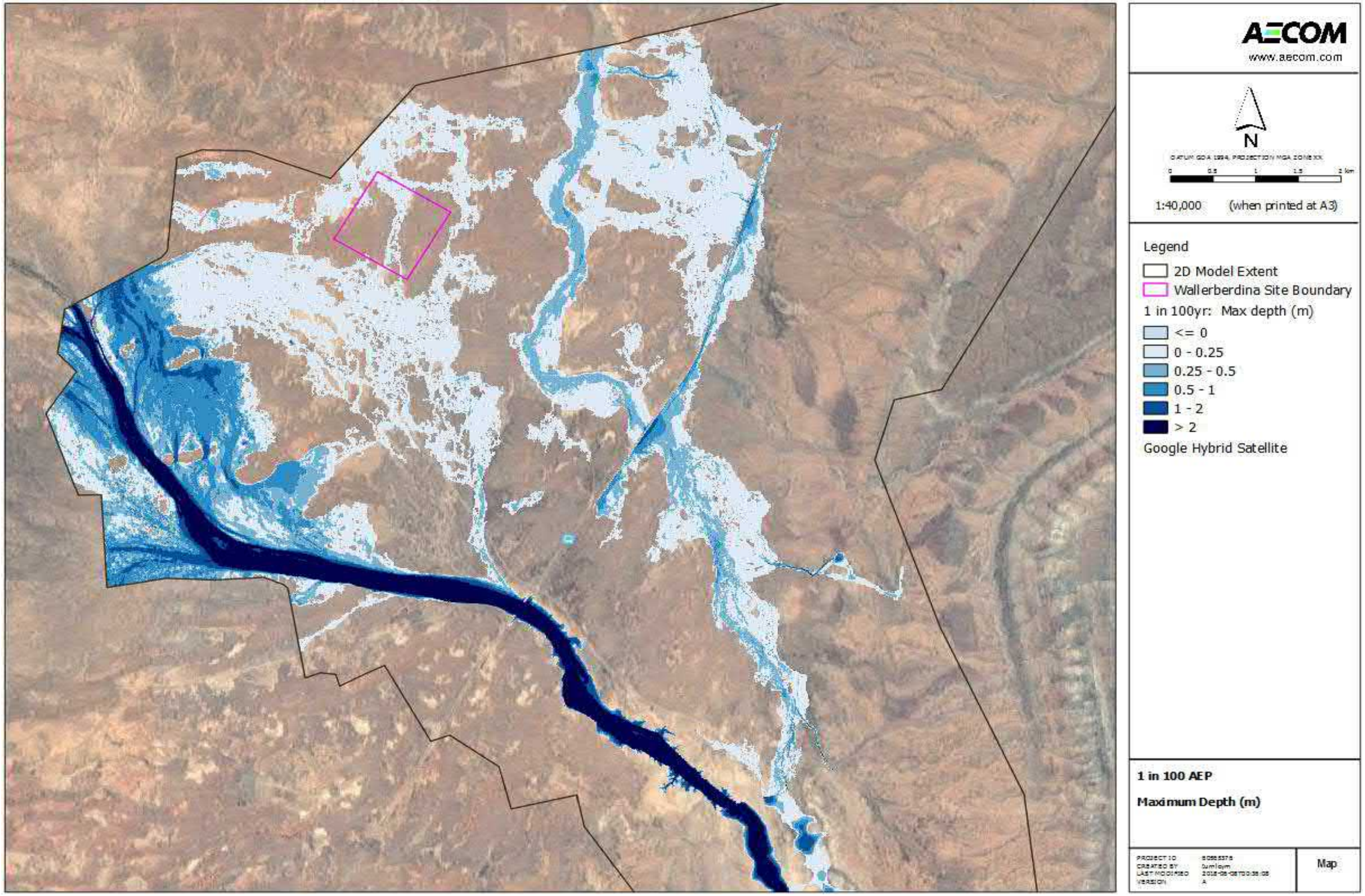


Figure 16 1 in 100 year AEP flood depth (site)

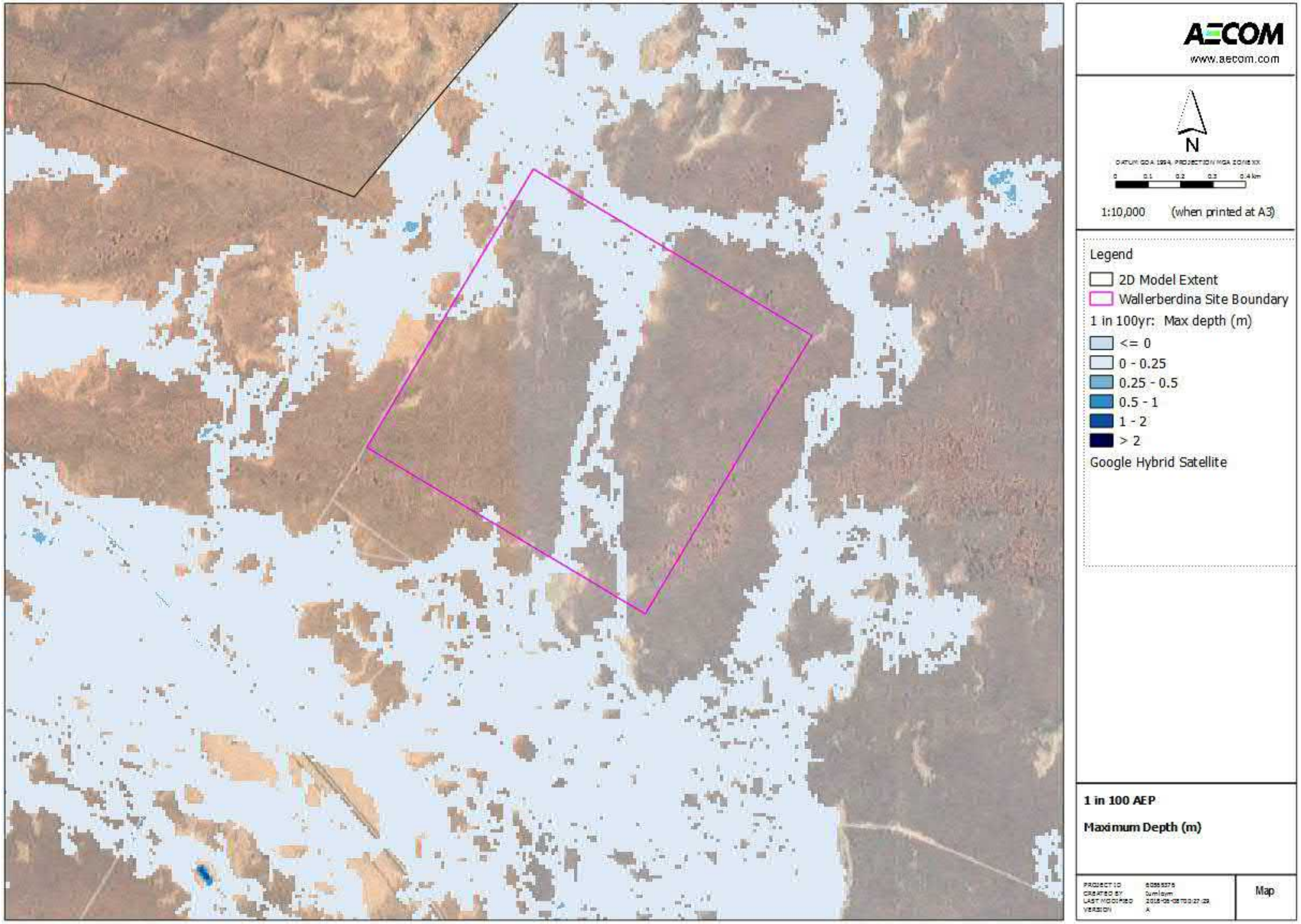


Figure 17 1 in 2000 year AEP flood depth

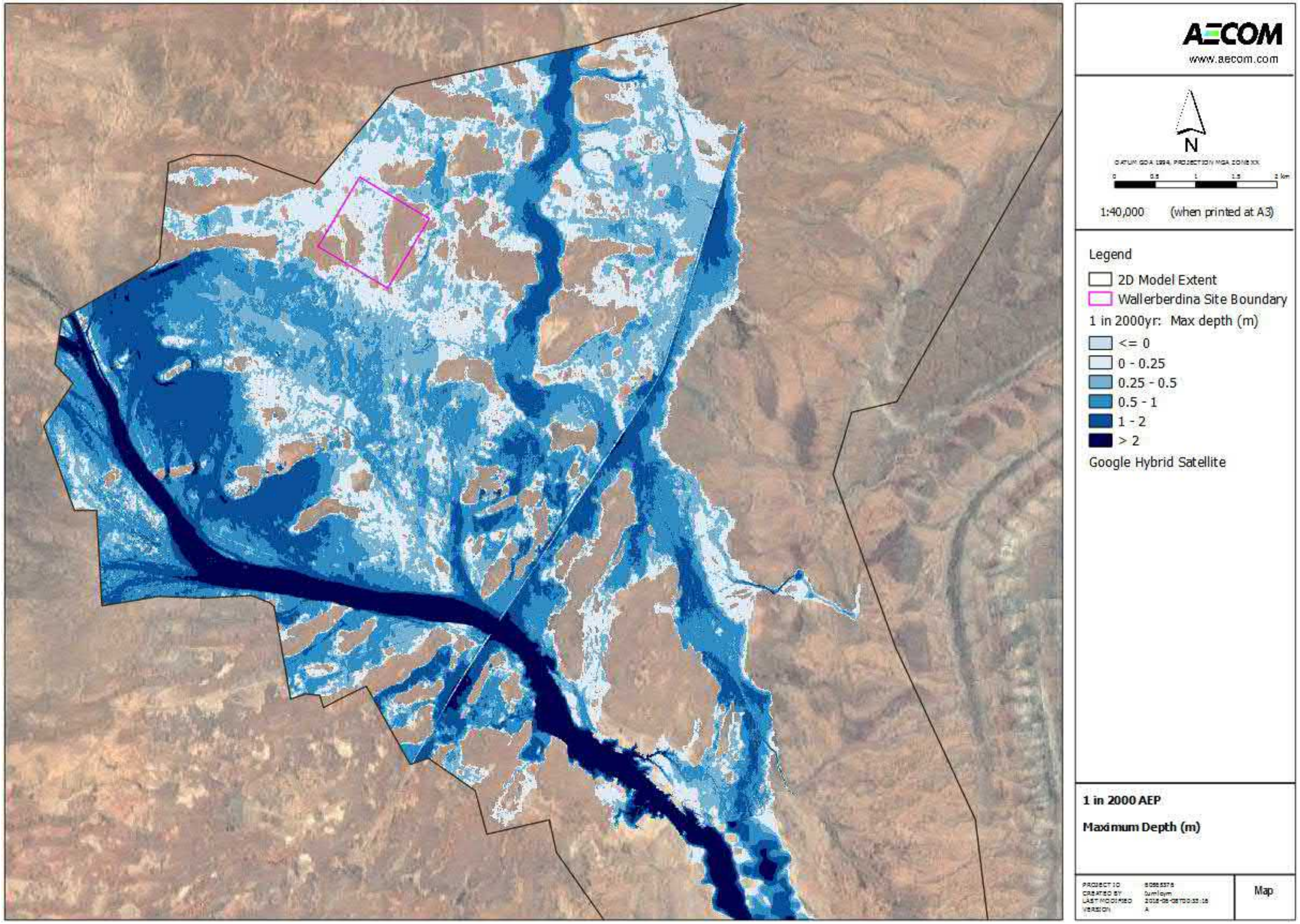
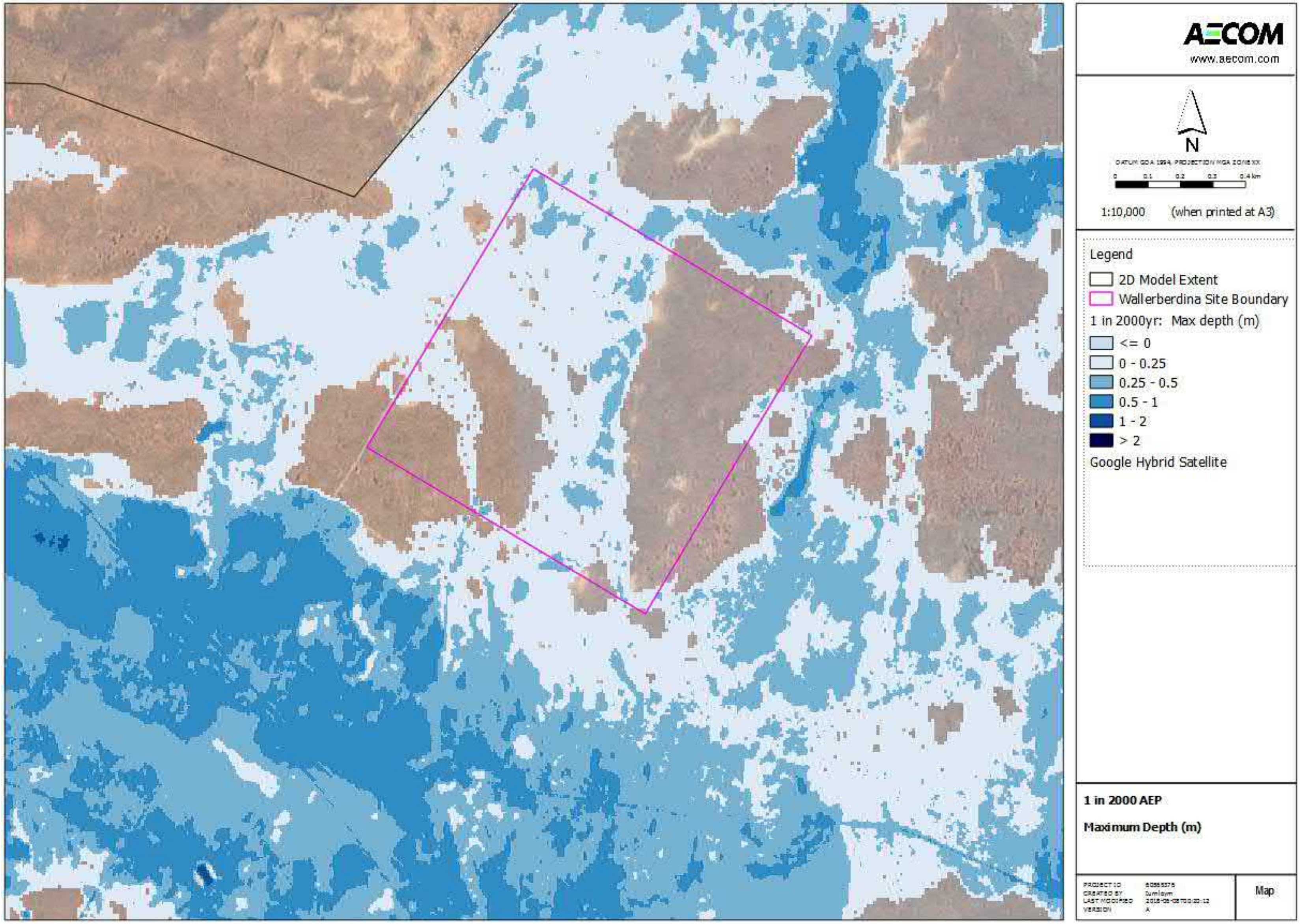

AECOM
www.aecom.com
N
1:40,000 (when printed at A3)
Legend
2D Model Extent
Wallerberdina Site Boundary
1 in 2000yr: Max depth (m)
<= 0
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
Google Hybrid Satellite
1 in 2000 AEP
Maximum Depth (m)
Map

Figure 18 1 in 2000 year AEP flood depth (site)



2.5.2 Field Methods and Results

As part of the field assessment, approximate bridge and culvert dimensions were collected to inform the flood model of the site. The data is presented in Appendix C. At the time of building the flood model, only the field data was available.

No further field datasets were collected for the hydrology and flood risk component of the assessment.

2.5.3 Assessment Against Criteria

Assessment Criteria 1 – Localised flooding (water logging or extreme rainfall)

The available topographic and Geofabric information are illustrated in Figure 19 and Figure 20. From Figure 6, it can be seen that Hookina Creek is located approximately 3.5 km from the site boundary. There is a non-perennial depression approximately 1 km to the east of the site. The Geofabric data indicates the upstream catchment areas for these watercourses to be in the order of 1700 km^2 and 30 km^2 respectively. Figure 20 illustrates the LiDAR elevation data and the associated drainage lines in the vicinity of the site. There are clearly local drainage paths through the site. These serve relatively small localised catchments and are therefore considered minor. The slopes are typically in the order of 0.3% to 0.5%, with some areas on the site being steeper to approximately 1%. These slopes are relatively flat. It is expected that overland flows through the site from the local catchments would be relatively small and generally slow moving. This was confirmed by the flood modelling (AECOM, 2018).

The flood modelling indicated that drainage lines through the site are subject to localised flooding in events up to the 1 in 100 AEP, as illustrated in Figure 15 and Figure 16. The flows are shallow, typically in the range 0 to 0.25 m deep. These could be managed through typical mitigation measures as outlined in the design mitigations section below. For rare and extreme flood events, the site is subject to deeper flows that break from Hookina Creek and the non-perennial depression, as illustrated in Figure 17 and Figure 18. These flows are deeper, for the 1 in 2000 AEP they are typically in the range 0.25 to 0.5 m, with isolated areas up to 1 m deep. These pose constraints on the site which will require appropriate mitigation measures. A discussion on major flooding associated with Hookina Creek and the distributary / non-perennial depression is provided above.

In addition to the flood study, there is rainfall Intensity Frequency Duration (IFD) data from the BoM, as well as some soil profile information from the soil and other substrates desktop assessment. The IFD data provides a range of 'design' rainfall intensities for a given storm frequency and duration. The data for frequent and rare events, both in terms of rainfall intensity (mm/hr) and total rainfall depth (mm for the given event) are presented in Table 26 to Table 29 . The IFD data can be compared to available soil profile data to determine whether it is likely that soil profiles in the vicinity of the site are likely to result in water logging or generate significant runoff.

If the soil is not 'hydrophobic' (repels water when it first wets) and the soil conductivity rates (the rate at which water can soak into the ground) exceeds the rate of rainfall, it is unlikely that significant runoff or waterlogging will occur. Soils are assessed within the subsurface environment chapter of this report. There is no reference soil profile near the site from which to obtain hydraulic conductivity data to compare to the values in in Table 26 to Table 29. There is only anecdotal information that the site does not have a history of waterlogging or pooling of water (source: Deirdre Mckenzie, 21 Feb 2018).

Figure 19 Topography and Geofabric

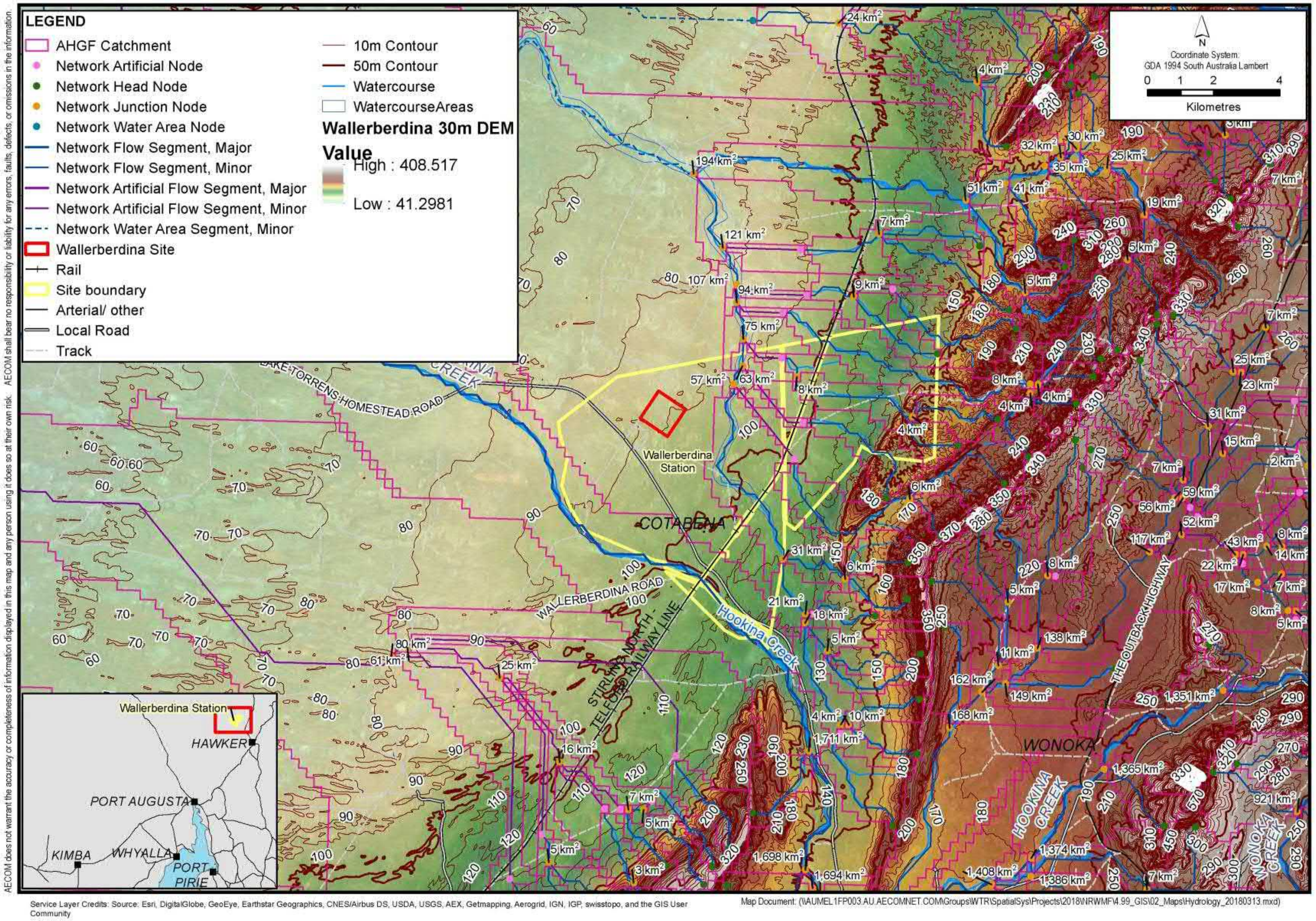


Figure 20 Drainage lines from LiDAR data

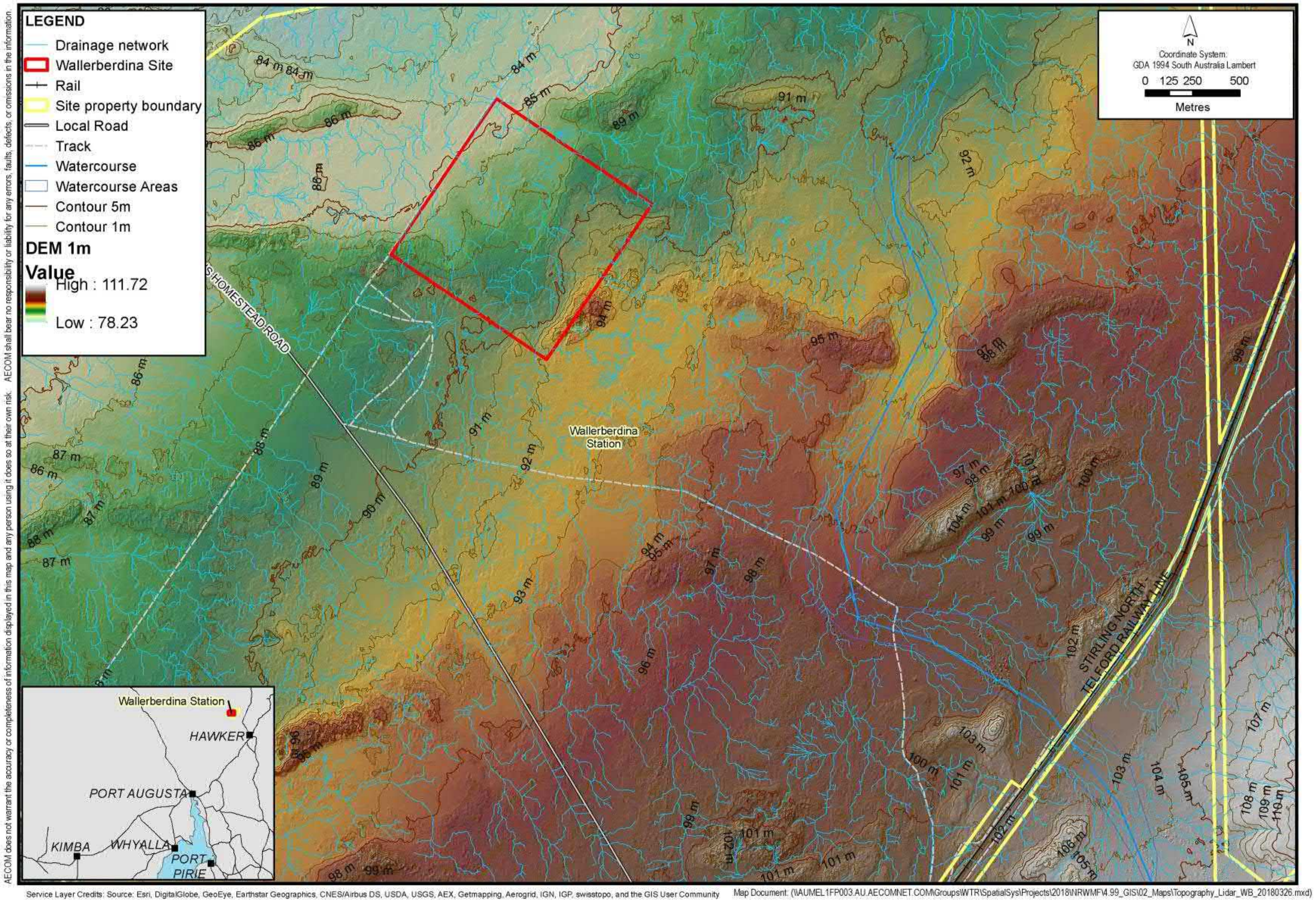


Table 26 Rainfall depths for frequent to infrequent events (mm)

Duration	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
1 min	1.15	1.38	2.18	2.79	3.45	4.4	5.21
2 min	1.95	2.34	3.69	4.7	5.78	7.38	8.73
3 min	2.67	3.2	5.04	6.43	7.91	10.1	12
4 min	3.29	3.96	6.24	7.96	9.8	12.5	14.8
5 min	3.84	4.62	7.29	9.31	11.5	14.7	17.3
10 min	5.84	7.03	11.1	14.3	17.6	22.5	26.6
15 min	7.16	8.63	13.7	17.5	21.6	27.6	32.7
30 min	9.57	11.5	18.2	23.4	28.8	36.8	43.6
1 hour	12.2	14.7	23	29.4	36.3	46.3	54.8
2 hour	15.3	18.2	28.4	36.1	44.4	56.7	67.1
3 hour	17.4	20.7	32	40.6	49.8	63.5	75.2
6 hour	21.7	25.7	39.2	49.6	60.9	77.5	91.6
12 hour	26.9	31.6	48	60.7	74.5	94.6	112
24 hour	32.3	38	57.9	73.2	89.8	114	135
48 hour	37	43.7	67	84.9	104	133	157
72 hour	39	46.2	71.1	90.2	111	141	167
96 hour	40	47.4	73.1	92.8	114	145	173
120 hour	40.7	48.2	74.1	94	116	148	175
144 hour	41.3	48.8	74.6	94.6	116	149	177
168 hour	41.8	49.2	74.7	94.8	117	149	177

Table 27 Rainfall depths for rare events (mm)

Duration	Annual Exceedance Probability (AEP)				
	1 in 100	1 in 200	1 in 500	1 in 1000	1 in 2000
24 hour	135	159	194	225	260
48 hour	157	184	225	260	299
72 hour	167	196	240	279	322
96 hour	173	203	250	290	336
120 hour	175	208	256	298	346
144 hour	177	210	260	303	353
168 hour	177	212	262	306	357

Table 28 Rainfall intensities for frequent to infrequent events (mm/hr)

Duration	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
1 min	68.8	82.8	131	168	207	264	313
2 min	58.5	70.2	111	141	173	221	262
3 min	53.3	64	101	129	158	202	239
4 min	49.4	59.3	93.5	119	147	188	222
5 min	46.1	55.4	87.4	112	138	176	208
10 min	35	42.2	66.8	85.6	106	135	160
15 min	28.6	34.5	54.7	70.1	86.5	111	131
30 min	19.1	23	36.5	46.7	57.7	73.7	87.2
1 hour	12.2	14.7	23	29.4	36.3	46.3	54.8
2 hour	7.65	9.12	14.2	18.1	22.2	28.3	33.5
3 hour	5.81	6.89	10.7	13.5	16.6	21.2	25.1
6 hour	3.62	4.28	6.53	8.27	10.1	12.9	15.3
12 hour	2.24	2.63	4	5.06	6.2	7.89	9.32
24 hour	1.35	1.58	2.41	3.05	3.74	4.75	5.62
48 hour	0.77	0.91	1.4	1.77	2.17	2.76	3.27
72 hour	0.541	0.641	0.987	1.25	1.54	1.96	2.33
96 hour	0.417	0.494	0.761	0.966	1.19	1.52	1.8
120 hour	0.34	0.402	0.617	0.784	0.963	1.23	1.46
144 hour	0.287	0.339	0.518	0.657	0.808	1.03	1.23
168 hour	0.249	0.293	0.445	0.564	0.694	0.887	1.06

Table 29 Rainfall intensities for rare events (mm/hr)

Duration	Annual Exceedance Probability (AEP)				
	1 in 100	1 in 200	1 in 500	1 in 1000	1 in 2000
24 hour	5.62	6.61	8.09	9.38	10.8
48 hour	3.27	3.83	4.68	5.41	6.23
72 hour	2.33	2.73	3.34	3.87	4.47
96 hour	1.8	2.12	2.6	3.03	3.5
120 hour	1.46	1.73	2.13	2.48	2.88
144 hour	1.23	1.46	1.8	2.11	2.45
168 hour	1.06	1.26	1.56	1.82	2.12

Assessment Criteria 2 – Major flooding from upstream catchments

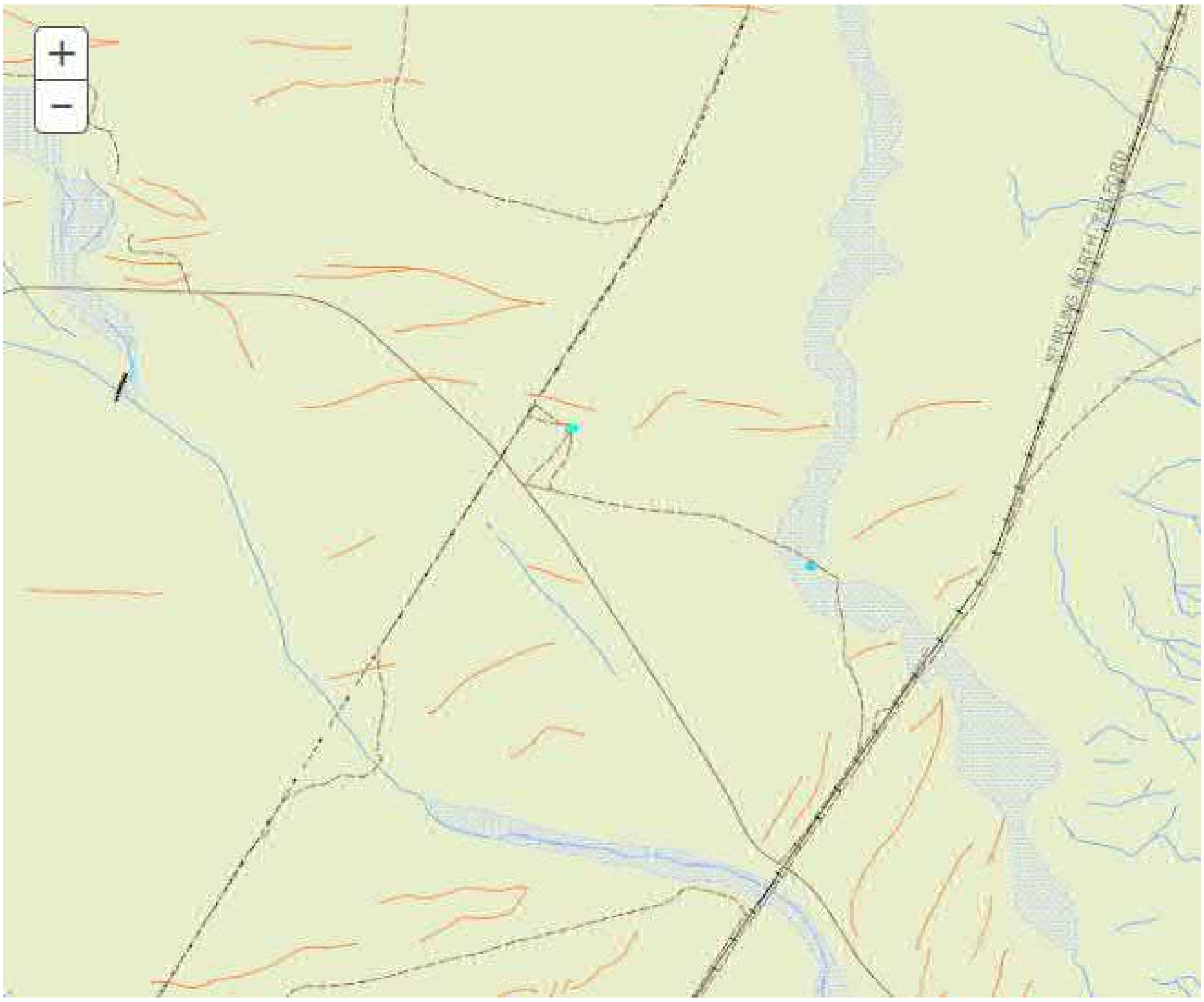
As discussed above, the available topographic and Geofabric information are illustrated in Figure 15. From Figure 19 it can be seen that Hookina Creek is located approximately 3.5 km from the site boundary. There is a non-perennial depression approximately 1 km to the east of the site. The Geofabric data lists the upstream catchment areas for these watercourses to be in the order of 1700 km^2 and 30 km^2 respectively. There is also the Stirling North – Telford Railway Line, which is elevated relative to the floodplain. There are no significant dams or reservoirs in proximity to the site.

Based on a review of all of the available data sources, there is limited relevant flood information for these significant watercourses. The catchments are quite large, and therefore likely to produce significant runoff during infrequent and rare flood events. There is an indication that the watercourses are flood prone based on the Flood Awareness Map portal, illustrated in Figure 21. The magnitude of the flood event producing these extents is not quantified. There is also evidence of flooding found by interpreting the aerial photography, which shows alluvium and signs of greener vegetation along the floodplains. There is also anecdotal information that Hookina Creek flooded in 1955 and 2007. The advice received is that flood waters from these events did not reach the site (source: Deirdre Mckenzie, 21 Feb 2018). While the anecdotal evidence and aerial photography broadly support the conclusion that these historic floods did not reach the site, it is likely that larger (more rare) events, the kind that are to be designed for under IAEA SSG-18, may affect the site.

To quantify the risks, a flood study was subsequently undertaken as part of this assessment. The flood study consisted of a hydrological model, documented in Appendix C, and a hydraulic model, documented in Appendix C. The 1 in 100 AEP flood depths from the assessment are illustrated in Figure 15 and Figure 16, with the more extreme 1 in 2000 AEP flood depths illustrated in Figure 17 and Figure 18. From these figures it can be seen that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 AEP). For the 1 in 2000 AEP flood, depths are typically in the range 0.25 to 0.5 m with isolated areas up to 1 m. The modelling shows that for the flood events analysed, the depth and duration of inundation in smaller localised events is relatively shallow, slow moving (<0.25 m/s) and rises and falls typically within a day. For the 1 in 2000 AEP, the breakout from Hookina Creek reaches the site approximately 16 hours after the commencement of rainfall, peaks at around 19 hours with velocities in the porder of 0.5 to 0.75 m/s, then falls progressively over the next day. Note: each flood event is different, but it is not expected that flood water in the vicinity of the site will remain for weeks or months following an event. The flooding poses constraints on the site that will require the investigation and design of appropriate mitigation measures should Wallerberdina be further considered for the NRWMF.

The hydraulic modelling was undertaken using a 2D fixed bed hydraulic model, where the underlying terrain does not change in time in response to the calculated flood characteristics. The geomorphological assessment (Theme B) determined the there is a risk of migration and avulsion of Hookina Creek. While Hookina Creek is located approximately 3.5 km from the site boundary, and the non-perennial depression approximately 1 km to the east of the site, there is a risk that over successive major flood events the nature of the floodplain will change. This could potentially pose constraints on the site, and as such, will require further detailed investigations as part of the Stage Two assessment, should Wallerberdina be further considered for the NRWMF.

Figure 21 Flood Awareness Map portal – Watercourses and areas classified as 'flood prone' (blue hatching)



Information on significant permanent and temporary surface water obstructions was reviewed. The presence of significant permanent water bodies within the upstream catchment, such as lakes and large dams or storage reservoirs, were reviewed using topographic and aerial photographic data. The presence of temporary water holding structures, such as elevated road and rail embankments, were reviewed using the flood study, as well as available topographic and digital elevation datasets, site inspections and local knowledge from members of the community.

The assessment determined that there are no significant permanent surface water obstructions and one temporary surface water obstruction upstream of the site. The temporary obstruction is the Stirling North – Telford Railway Line. While the railway line is elevated and has significant sized box culverts beneath it, during a significant flood event, there is potential for large debris and/or high volumes of sediment and debris to move into the structures and block them. While it is not expected that this will pose a significant risk to the site, due to the non-perennial watercourse between the railway and the site, it would require further analyses to determine whether blockage is likely (e.g. using ARR2016) and what the consequences of a breach would be to the site.

Assessment Criteria 3 – Site access during flood events

The Wallerberdina site is accessed via the Lake Torrens Homestead Road. There is anecdotal evidence that the 1955 and 2007 floods cut access along the road, and hence to the site (source: Deirdre Mckenzie, 21 Feb 2018). The 1955 event was the larger of the two, depositing significant sized woody debris (stumps) which are still evidenced today. The floods also damaged the Stirling North – Telford Railway Line.

The results of the flood study also highlights that the key access roads will be overtopped by smaller infrequent events such as the 1 in 5 or 1 in 10 AEP. These will be generally shallow water and are not likely to cause significant damage to the existing road infrastructure. The larger, rarer flood events will cut the access roads in multiple locations and are likely to cause significant damage to the existing road infrastructure. Based on the modelling, the events would typically be over within a few days.

Assessment Criteria 4 – Change in Risks of Flooding Due to Changes in Rainfall and Runoff with Time

IAEA SSG-18 highlights the need to assess changes in hazards with time. Climatic variability and climate change may affect the frequency and severity of floods. The Desktop Assessments in this report addressing climate and climate change, identified trends in rainfall out to 2090. Based on the RCP 8.5 2090 Scenario, for Wallerberdina, the average annual rainfall depth of 309 mm is expected to reduce by 9% (estimated range is -37% to +6 % for the 10th to 90th percentile). While annual rainfall is expected to reduce, rainfall is expected to occur less frequently with greater intensity. The average annual temperatures are expected to increase by 4.3°C (+2.8°C to +5.2°C for the 10th to 90th percentile).

There is an industry 'rule of thumb' that for every one degree increase in average annual maximum temperature, rainfall intensity increases by 5%. Thus, for Wallerberdina, this equates to an approximate 20% increase in rainfall intensity. The impact of this will be an increase in the magnitude of floods experienced in the catchment and an increased frequency and severity of potential road closures. The impacts of these changes on the site will require additional hydrological and hydraulic modelling as part of the Stage Two assessment should the Wallerberdina site be further considered.

2.5.4 Design Issues and Mitigation Measures

Based on the desktop assessment, there are a number of design and mitigation measures that could be considered to manage potential flooding hazards at the site. These are summarised in Table 30.

Table 30 Climate Change Design Issues and Mitigation Measures

Design Issue	Potential Mitigation Measure
Local overland flows through site	Localised filling and regrading of the site. Potential diversion drains
Water-logging	Surface and subsurface drainage design to control surface runoff and saturation of the soil profile
Large flood affecting site	Bund / Levee
Flood prone access	Upgrade local roads and drainage structures Provide an alternative access route

2.5.5 Data Gaps and Recommendations for Stage 2 Work Program

2.5.5.1 Data Gaps and Limitations

The flood modelling conducted as part of this assessment helped to address the general lack of existing available information on flooding in the area. The modelling itself encountered a number of data gaps and limitations:

- Lack of available data for the 1955 and 2007 flood events, limiting the calibration and verification of the hydrological and hydraulic models.
- Approximations made to estimate the PMF event (refer to details in the Hookina Creek Hydrology report, Appendix C).
- Dimensions and levels of railway bridges and culverts were approximated based on a site visit and levels estimated from the existing LiDAR data.
- Insufficient existing LiDAR data immediately downstream of the site limiting the extent of the 2D hydraulic model and potentially influencing the results near the northern corner of the site.
- Insufficient existing LiDAR data upstream of the LiDAR dictating that lower accuracy SRTM terrain data was used. The area in the model covered by the SRTM data is critical to determining

the flow split between Hookina Creek and the northern non-perennial stream / distributary. This has led to uncertainty in the flow distribution, hence influencing simulated flood behaviour at the site.

- Further information to support the adopted hydrological rainfall loss parameters for the catchment.

2.5.5.2 Recommendations for Stage 2 Work Program

To enable a more detailed assessment of the site, for the Stage 2 field data collection program it is recommended that:

- The approximate bridge and culvert structure dimensions and levels are updated with field survey.
- The existing LiDAR data is extended further upstream and downstream of the site. This will enable the flow split between Hookina Creek and the floodplain to be determined with more confidence, hence increasing the confidence in the flood levels at the site.
- Update the flood modelling accordingly.

It would also be desirable to obtain:

- Soil hydraulic conductivity tests at a number of sites through the Hookina Creek catchment.

2.6 Impacts of Nearby Human Activities and Land Use Planning

2.6.1 Methodology and Results

A detailed desktop assessment for the Wallerberdina site was undertaken to investigate risks from the potential impacts of human activities.

The desktop assessment included a review of relevant publicly accessible databases, planning documents and property information.

To determine the likely impact of human activities on a NRWMF on the Wallerberdina site, the following considerations informed the assessment:

- Identification of current land uses on the subject site and surrounding properties; including identifying separation distances from current sensitive land uses and recreational and tourist areas;
- Development Plan/Zoning review of the site and surrounding properties, to ascertain development potential and future land uses envisaged on the land and adjacent properties;
- Identification of any current and recently approved development applications on the site and within the locality;
- Population density assessment within the locality, including future trends;
- Identification of any mineral, petroleum, geothermal and gas leases and tenements (exploration & production) on the site and within the locality;
- Identification of any major chemical/ fertiliser or oil facilities, mines and mineral deposits, military facilities, broadcasting and communication networks, intensive primary production and bulk handling facilities within the locality;
- Identification of transport infrastructure on the land and within the locality, including airfields, main roads, tourist routes and railway lines;
- Review of any flight path and crash data within the area (commercial, private and agricultural);
- Review of water extraction (e.g. from surface water, rainwater, groundwater) and nature of usage (potable, irrigation, stock watering, etc.) around the site and local area – information on this item was obtained during the hydrology and hydrogeology assessments; and
- Location and nature of water retention structures that could lead to flooding – information addressed under the hydrological/ flood risk assessment.

2.6.1.1 Site Characteristic Criteria

The following Site Characteristic Criteria have been determined to be relevant to impacts of nearby human activities and land use planning:

Assessment Criteria 1 – Existing and potential future land uses that may adversely impact the site

Assessment Criteria 2 – Existing and potential future sensitive land uses on the site and in surrounding areas

The criteria have been formed having regard to IAEA Specific Safety Guides SSG-35 *Site Survey and Site Selection for Nuclear Installations* and IAEA Safety Requirements NS-R-3 (Rev.1) *Site Evaluations for Nuclear Installations.*

Criteria 1 – Existing and potential future land uses that may adversely impact the site

The intent of Criteria 1 is to identify the presence of, and future potential for, development on the site and within the locality that may adversely impact the potential use of the site for the NRWMF.

For the purpose of the assessment development that may adversely affect the NRWMF has been considered to include:

- Major extractive industries;
- Chemical and fertiliser storage facilities;

- Airfields;
- Major transport infrastructure;
- Military facilities; and
- Broadcasting and communication networks.

These uses have the potential to create hazardous human induced events which may affect the proposed NRWMF.

In addition to the above listed development, intensive primary production development, including bulk handling/storage facilities and intensive animal keeping have also been considered. Given the rural characteristics of the area there is potential for these types of facilities to be developed, and as such, they were added to the considerations.

Intensive primary production activities have been considered as potential origins for human induced hazards associated with the risks relating to fires and high frequency of heavy vehicle transportation.

Criteria 2 – Existing and potential future sensitive land uses on the site and in surrounding areas

The intent of Criteria 2 is to identify current sensitive land uses and potential for future sensitive land uses on the site or within the locality. The encroachment of such sensitive land uses has the potential to impact and be impacted by the construction and operations of the proposed NRWMF.

For the purposes of the assessment sensitive land uses considered under Criteria 2 include:

- Residential development (single dwellings & townships);
- Tourist development and areas (conservation and recreation areas);
- Commercial, Industrial and Employment developments; and
- Community facilities and areas.

2.6.1.2 Desktop Methods and Results

The following key resources were accessed and utilised to complete this assessment:

- Department of Environment, Water and Nature Resources online mapping tool – NatureMaps;
- Government of South Australia online mapping tool - Location SA;
- Department of Planning, Transport and Infrastructure online mapping tool – Property Location Browser (PLB);
- Department of State Development South Australian Resources Information Geoserver mapping tool;
- Google Maps;
- Land Not within a Council Area (Flinders) Development Plan; consolidated 29 November 2012;
- The Flinders Ranges Council Development Plan, consolidated 20 June 2013;
- Australian Bureau of Statistics - Population Data;
- Australian Transport Safety Bureau – civil aviation accident and incidents data;
- Department of Planning, Transport and Infrastructure, SA Planning Portal – Public Register; and
- Discussion with staff from The Flinders Ranges Council.

Review of Data

The following is a summary of the data review.

The assessment focusses on land uses and development within an 8 kilometre buffer area around the site. The 8 kilometre buffer has been established having regard to the screening value examples outlined in Table II-1 of Annex II in IAEA Specific Safety Guides SSG-35 *Site Survey and Site Selection for Nuclear Installations.*

Notwithstanding the above, where relevant any notable features outside of the buffer area have also been identified.

Existing Land Uses

The site is contained within the boundary of a Pastoral Lease. As confirmed by a site visit and via discussions with the lessee, the land is vacant and has a longstanding historical use of agricultural, namely grazing.

Primary production is the predominant land use of the adjoining properties and other parcels of land throughout the wider locality, which are also principally held under Pastoral Leases.

There are various types of infrastructure located within 2 kilometres of the site, which includes:

- ElectraNet transmission line to the west;
- Disused Leigh Creek-Port Augusta Railway Line approximately 2 kilometres to the east; and
- Communications tower approximately 4 kilometres to the south east.

Based on a review of aerial photography, no sensitive land uses were identified within 8 kilometres of the site. The nearest sensitive land uses consist of:

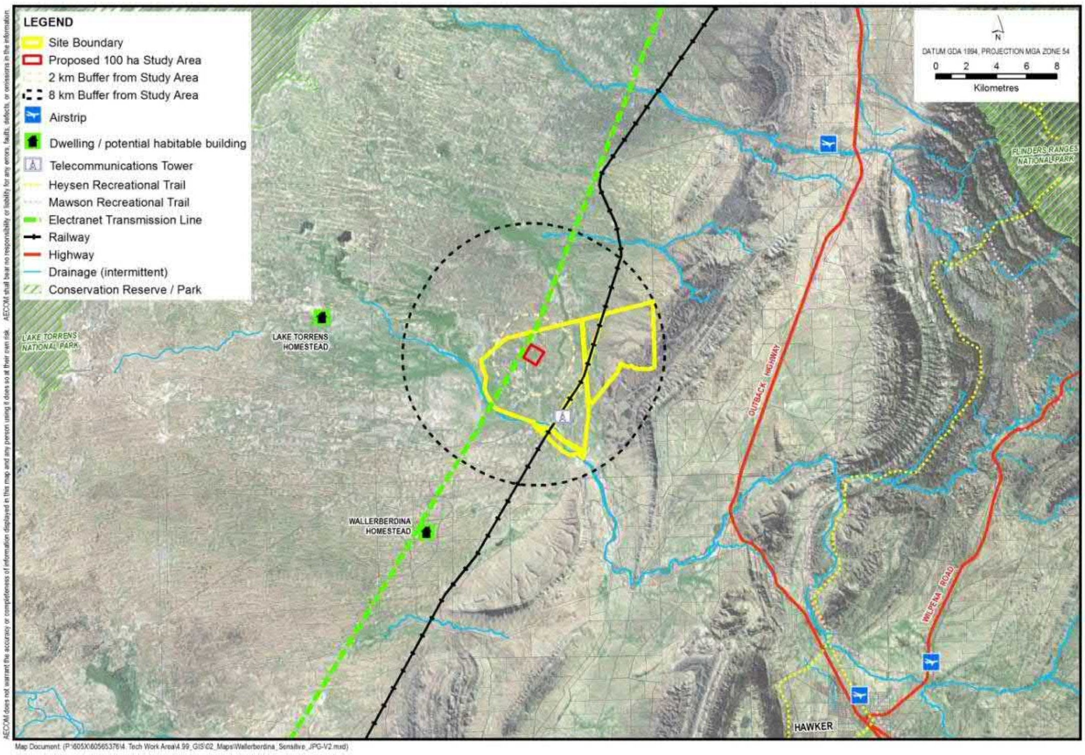
- The Lake Torrens Homestead which is located approximately 12 kilometres to the west;
- The Wallerberdina Homestead located approximately 13 kilometres to the south-south-west; and
- Hawker located approximately 30 kilometres south east of the site, which is the closest township.

Other sensitive uses in the wider locality include two tourist/recreation walking trails and National Parks including:

- The Mawson and Heysen Trails which are located approximately 12 kilometres and 17 kilometres respectively east from the site; and
- The Lake Torrens National Park is located approximately 30 kilometres to the east and the Ikara-Flinders Ranges National Park is located approximately 30km to the north west of the site.

The key existing features within locality as described above are depicted in Figure 22 below.

Figure 22 Key existing features within the locality



Development Plan Review

The *Development Act 1993* is South Australia's core legislation dealing with the planning and development system. The Development Act requires all areas of the state, including councils and areas not covered by a council area, to have a designated development plan.

A development plan is a statutory policy document, which guides the type of development that is envisaged to occur within a particular area and provides the basis against which development assessment decisions are made. The purpose of the reviewing the development plan related to the site and surrounding properties is to identify the types of land uses and development that may be established on the surrounding properties in the future.

The relevant Development Plan for the site and surrounding areas is the *Land Not Within a Council Area (Flinders) Development Plan*, consolidated 29 November 2012. The review of the Development Plan identified the following:

- The Wallerberdina site and the land immediately surrounding the site are located within the Pastoral Zone. The intent of the Pastoral Zone is to preserve the natural environment and character of the zone, whilst grazing of livestock and associated development, including dwellings for pastoralist and employees are the predominant land use/form of development envisaged in the zone. Wind farms are also contemplated in the zone which is consistent with policy within the majority of primary production and rural zones across the State.

- The land to the east of the disused Leigh Creek-Port Augusta railway line is held within the Environment Class B Zone. The primary intent of the Environment Class B Zone is to conserve the natural character and environment of the area, including scenic features. Policy also seeks to protect the landscape from the adverse effects of mining exploration and operations and to limit the construction of buildings and infrastructure within the zone.

- The development plan also contains council wide policy which guides development generally across the entire area affected by the development plan. Relevant council wide policy encourages non-rural development to be established within and adjacent existing townships or within other appropriate zones.

The boundary of the Flinders Ranges Council is located approximately 8 kilometres south of the site, with the relevant development plan being the *Flinders Ranges Council Development Plan*. This identified:

- The land to the south within the Flinders Ranges Council area is located within either the Primary Production Zone or Rural Landscape Protection Zone. The overall intent of policy within the Primary Production Zone is consistent with Pastoral Zone and similarly, the policy within Rural Landscape Protection Zone is consistent the Environmental Class B Zone.

In summary, the primary intent of the development plan policy reviewed for the site and surrounding land is to conserve the natural character and environment of the area. As such, development desired in the area is limited to farming and wind farms. The development plan policy also promotes that urban and other forms of development be established within existing townships or appropriate zones.

Based on the current development plan policy, the likelihood of any urban development adversely affecting the potential future use of the Wallerberdina site for the NRWMF is very low.

Current and Recently approved Development Applications

A review of South Australians Government's planning portal identified no recent development applications have been lodged or approved within the site or on surrounding properties.

The purpose of this review was to identify development that may be approved, but yet to be constructed.

Due to the proximity of the Flinders Ranges Council, approximately 8 kilometres to the south of the site, a review of the Flinders Ranges Council Development Registers 2015-2018 was also undertaken. No recent development applications or approvals were identified on land within 8 kilometres of the site within the Flinders Ranges Council.

Population Assessment

The Wallerberdina site is situated in the suburb of Flinders Ranges as identified in the Australian Bureau of Statistics (ABS) Census Data. The suburb of Flinders Ranges recorded a population of 104 in 2016. ABS changed their data collecting boundaries in 2016, therefore there was no population data recorded in the 2011 Census for the suburb of Flinders Ranges.

The nearest local government area is the Flinders Ranges Council and census data for the Council shows the population has decreased from 1,722 in 2011 to 1,643 in 2016.

Hawker is the closest town to the Wallerberdina site. Hawker experienced an increase of population from 246 in 2011 to 341 in 2016.

The review of ABS indicates a decline in population within the region, notwithstanding an increase in population for the township of Hawker.

Mineral, Petroleum, Geothermal and Gas Leases and Tenements

A review of Department of State Development South Australian Resources Information Geoserver mapping tool (SARIG) was completed to identify any current Mineral, Petroleum, Geothermal and Gas Leases and Tenements over or within proximity of the site. The presence of leases and tenements could indicate the potential for mining and other extractive activities to occur in the future.

Based on the review, there is one mineral exploration licence application which exists over the site and a number of applications and licences within 8 kilometres of the site. Table 31 provides detail of each application and license identified, and Figure 23 below illustrates the location of each tenement with respect to the site.

Table 31 Leases and Tenements

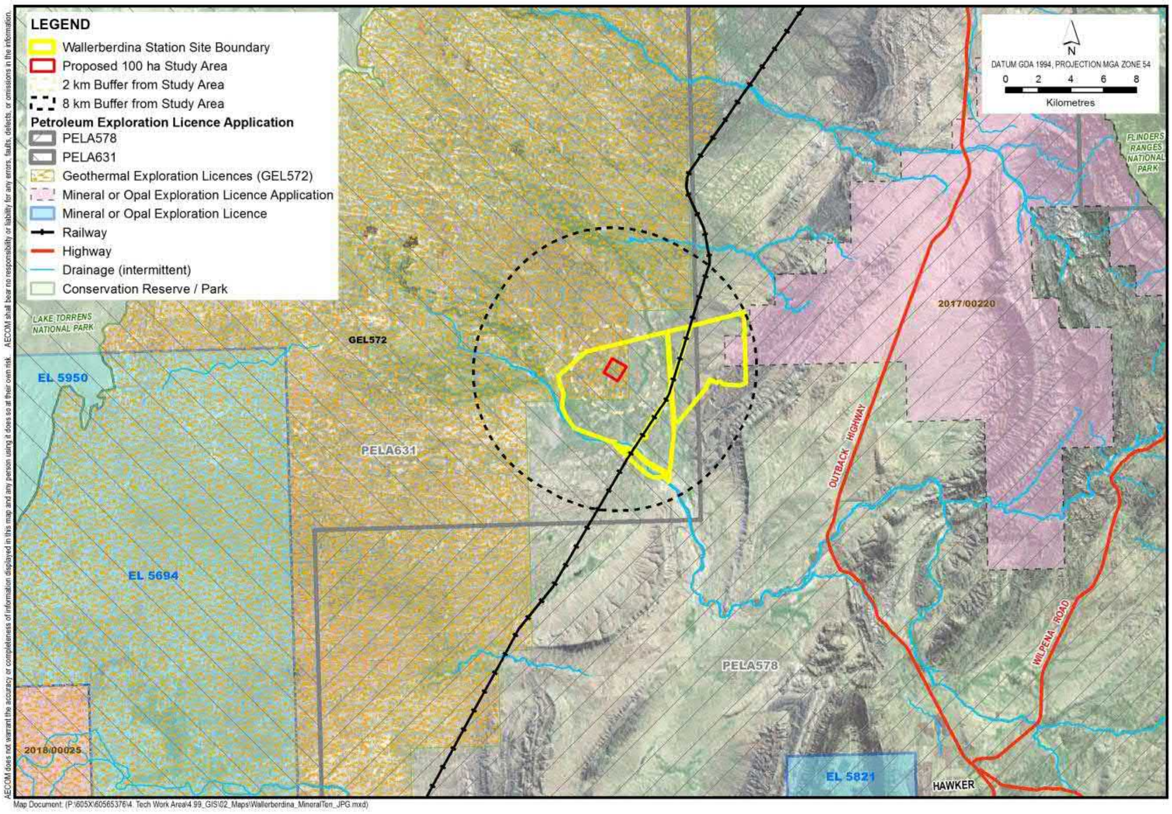
Tenement No.	Tenement Applicant/Owner	Tenement Type	Distance from Site
PELA 631	NAVGAS Pty Ltd	Petroleum Exploration Licence Application	Covers the site
GEL 572	Torrens Energy (SA) Pty Ltd	Geothermal Exploration Licence – Expiry Date 26/07/2022	Covers the site
PELA 578	NAVGAS Pty Ltd	Petroleum Exploration Licence Application	4km to the east & 8km to the south
2017/00220	Alliance Craton Explorer Pty Ltd	Mineral Exploration Licence Application – (Uranium)	6km to the east

The Torrens Project, which is a joint venture between Argonaut Resources and Aeris, was identified in the preliminary investigations as a large scale exploration activity which was proposed to occur within the wider locality. The project recently received approval for exploration activities within EL 5614. The tenement area is located approximately 102 kilometres to the north, north-west of the proposed site. As the tenement is located towards the western boundary of the lake, it is assumed that access to the tenement area is to be provided from the western side of Lake Torrens.

Given the separation distance from the site and the anticipated access route, the activities associated with this project are not expected to impact the potential NRWMF site.

Unlike other development which is assessed pursuant to the *Development Act 1993*, in South Australia the *Mining Act 1971* and the *Petroleum and Geothermal Act 2000* are the core legislation relating to mining, petroleum, gas and geothermal activities.

Figure 23 Location of each tenement



Major chemical/ fertiliser or oil facilities, mines and mineral deposits, military facilities, broadcasting and communication networks, intensive primary production and bulk handling facilities

These forms of development that may adversely affect the NRWMF include:

- major chemical/ fertiliser or oil facilities;
- military facilities;
- broadcasting and communication networks; and
- intensive primary production and bulk handling facilities.

None of these land uses were identified within 8 kilometres of the site.

Current and future potential for mines and mineral deposits is addressed above.

A communication tower is located 4 kilometres to the south east of the site. The types of installation on the tower were not identified as part of the desktop assessment. Further investigation in relation to the potential impact of this facility on the NRWMF may be required as part of the next stage of assessment if Wallerberdina is further considered.

Other notable infrastructure identified within the wider locality includes the Moomba to Port Bonython Liquids pipeline which is located approximately 19 kilometres south of the site.

The nearest military facility is located at Cultana which is approximately 105 kilometres to the south west of the site.

Major Transport Infrastructure

Transport infrastructure identified within the locality of the site consists of:

- Leigh Creek – Port Augusta Rail line is located to the east of the site. This rail line is currently not in use as a consequence of the closure of the Port Augusta Power Station and Leigh Creek coal mine;
- Outback Highway which is located approximately 11 kilometres to the east of the site; and
- A number of small airstrips within the region. The nearest airstrip to the site is located approximately 23.5 kilometres to the north east. Another two airstrips are located adjacent to Hawker approximately 30 kilometres to the south east of the site.

The above features are identified on Figure 23 above.

Flight Path and Crash Data

As noted above, a number of airstrips exist within the wider locality of the site. These are relatively small airstrips and are principally used for emergency services, tourism (chartered flights), farming and private purposes.

No flight path data was available, however, given the characteristics of the locality and nature and use of the airstrips in the region, it is not anticipated that the site would be located within a major flight path area.

The Hawker Aerodrome located to the north east of the town is the only sealed runway identified and is the main airstrip in the region. The distance of the airport from the site via the existing road network is approximately 39 kilometres.

The Hawker Aerodrome is not a CASA registered aerodrome.

Staff from the Flinders Ranges Council advised that the aerodrome accommodates approximately 1 to 5 flights per week, however, this number increases during tourist season, particularly when Lake Eyre fills with water. The Hawker runway is orientated north-south, and as such, aircraft approach and take-off movements would unlikely be aligned towards the site which are located to the north west of the airstrip.

A review of the Australian Transport Safety Bureau aviation accidents and incidents data was undertaken.

The Australian Transport Safety Bureau is currently investigating an accident which related to a collision with terrain involving a McDonnell Douglas 369D helicopter on 17 July 2016 (AO-2016-078). The crash site is located approximately 10 kilometres north of the proposed NRWMF site. During aerial surveying, the engine lost power and the helicopter collided with terrain, resulting in serious injuries to the pilot and passengers.

Since 1991 the only other recordable accident or incident within the area was for a collision with terrain involving a Cessna C206, VH-TND at Rawnsley Park on 2 August 2014 (AO-2014-135). This crash site is approximately 40km to the east of the site.

Water extraction and Water Retention Structures

These issues have been investigated as part of Flora, Fauna and Conservation (2.1) and Climatic Conditions and Climate Change (2.3) – refer to relevant assessment

2.6.2 Assessment Against Criteria

The following provides a summary of the investigations which are relevant to Site Characteristic Criteria A and B.

Criteria 1 - Existing and potential future land uses that may adversely impact the site

Based on the data review, the findings for existing and potential land uses that may adversely impact the site indicate:

- No development that may adversely affect the NRWMF was identified on the site or within 8 kilometres of the site. In addition no recent development applications have been lodged or approved for such development within the site or on the land within 8 kilometres of the site.

- Based on the current development plan policy, the likelihood of adversely impacting development occurring in proximity of the site in the future would be low.
- A communication tower is located to the south east of the site. The types of installation on the tower were not identified as part of the desktop assessment and thus, further investigation in relation to the potential impact of this NRWMF may be required as part the next stage of assessment.
- The nearest transport infrastructure is the Port Augusta to Leigh Creek rail line which is located to the approximately 2 kilometres to the east of the site. This rail line is currently not is use. The site is well separated from other major transport infrastructure including main roads and airfields.
- A number of mineral and geothermal tenements exist within and in close proximity of the site. The existence of these tenements could result in the potential for extractive industry activities to occur in the future adjacent the proposed site. These tenements will be further assessed in the next phase of investigations should Wallerberdina be given further consideration for location of the NRWMF.

Criteria 2 - Existing and potential future sensitive land uses on the site and in surrounding areas

Based on the data review, the findings of existing and potential sensitive land uses are:

- No sensitive land uses where identified with 8 kilometres of the site. The nearest dwelling to the site is the Lake Torrens Homestead which is located approximately 12 kilometres to the west. Other sensitive uses in the wider locality include tourist hiking trails; however, these are located between 12 and 17 kilometres from the site.
- Based on the relevant zoning, dwellings in association with pastoral activities are envisaged on land within and surrounding site. The potential for more intensive residential or urban development to be established within proximity of the site is very low based on the current development plan policy and considering the declining population trend within the region.

Assessment Summary

The site is well separated from adversely affecting development and sensitive land uses.

The land zoning, together with the physical characteristic of land within the locality and declining population trend, suggests that the likelihood of adversely affecting (with the excepting of mining) and sensitive development being developed in proximity of the site in the future is unlikely.

A key consideration is the existence of a number of mineral and geothermal tenements over and within close proximity to the Wallerberdina site. If these tenements proceed to production, the associated activities may have the potential to impact the NRWMF.

2.6.3 Design Issues and Mitigation Measures

The design of the NRWMF should consider setback distances from the project and property boundaries to maximum separation distances to other properties and uses (existing and future).

Further, consideration should be given to the establishment of buffers around the site to restrict the encroachment of uses that have the potential to adversely impact the NRWMF, in particular future mining activities. Such buffers could be formed by planning scheme amendments, land acquisition or legislation changes. This issue will be considered at the next stage of the assessment.

2.6.4 Data Gaps and Recommendations for Stage 2 Work Program

2.6.4.1 Data Gaps and Limitations

No significant data gaps were identified as part of the desktop study.

2.6.4.2 Recommendations for Stage 2 Work Program

It is recommended that further investigations be undertaken to identify whether there is any further information available on the mining tenements in the vicinity and whether there is a likelihood that exploration activities could result in development of mining operations in the future.

3.0

Subsurface Environment

3.0 Subsurface Environment

Findings of the desktop and selective field assessments of the subsurface environmental conditions within the site and surrounds is outlined below. The characteristics of the subsurface environment covered in this assessment include hazards associated with stability of the landscape and landforms, soils, geology and hydrogeology (including geotechnical stability and geochemistry), and seismicity.

Site characteristic assessment criteria that have the potential, either alone or in combination with other criteria, to impact on siting of the NRWMF were developed. Desktop and anecdotal information relevant to the site and the local and regional area was reviewed. An on-ground seismic survey, a borehole drilling and test pitting program, geophysical and geotechnical field tests, and the analysis of soil and groundwater sample samples was also carried out. The desktop and field data of the surface environment interpreted for assessment against the site characteristic criteria.

Site characteristic values and hazards can often be mitigated by the NRWMF design. Potential design issues and mitigation measures that could be employed to address them have been identified. The Site Characterisation and NRWMF design are running in parallel and will inform the other as the site selection process progresses.

Assessment data gaps and recommendations for additional work scope items to fill such gaps in a more detailed second stage of the Site Characterisation studies are provided for each of subsurface environmental characteristics.

3.1 Geology, Hydrogeology and Geochemistry, Geotechnical and Soil

3.1.1 Methodology and Results

3.1.1.1 Site Characteristic Criteria

Subsurface characteristics favourable for meeting the three assessment objectives for this investigation are as follows:

Table 32 Geological, Hydrogeological, Geochemical, Geotechnical and Soil Site Characteristic Criteria

Assessment Objective	Site Characteristic Criteria	Preferred Characteristic
Infrastructure Foundation Stability	Presence of collapsing or expansive soils	Relatively flat topography Cohesive soil profile Watertable at depth (>10m)[11]
	Slope instability	
	Subsidence due to ground features	
	Long-term settlement	
	Scour and erosion processes	
	Potential of soil liquefaction	
Soil Quality	Detrimental soil quality properties that may lead to degradation and hydraulic properties that may increase the severity of flooding or erosion	Soils that are not saline, sodic, dispersive, do not have an aggressive pH, nor prone are waterlogging
In-situ Water Supply	Current or potential beneficial uses of groundwater	Presence of a pumpable groundwater supply aquifer (Yield min. 175 m^3/d or 2 L/s)
		Water Quality - Potable to brackish salinity groundwater[10]
Potential for Subsurface Solute Transport	Subsurface material with chemical attenuation properties	Subsurface with acid buffering capacity and surface sites for adsorption and ion exchange
	Depth to groundwater and vertical connectivity between groundwater horizons Potential for vertical migration of solutes through sediments or bedrock	Deep (>10m)[11] regional watertable & piezometric surfaces
		No perched watertable
		Few or widely (vertical) separated aquifers
		Thick, impermeable to low permeability aquitards
	Potential for horizontal migration of solutes through saturated sediments or bedrock	Low horizontal hydraulic gradient
		No, few or distant third-party groundwater users/receptors

[10] For the purposes of this assessment potable (< 1,000 mg/L as Total dissolved salts: TDS) water quality is more favourable than brackish (< 5,000 mg/L as TDS) which is more favourable than saline (>10,000 mg/L as TDS).
[11] 10m depth to saturated subsurface conditions is considered sufficiently “deep” to avoid interactions with deep building or infrastructure foundations/footings or buried services (i.e. within 2m of ground surface), including an allowance for capillary rise in potential fine grained sediments within the vadose zone and the natural seasonal/diurnal variation in groundwater levels which cumulatively may vary cycle over a range of several meters

3.1.1.2 Desktop Methods and Results

A desktop review has been undertaken and reported (AECOM, 2018). The Natural Resource Management Setting for the site provides the context for the density of information available for review.

The *Natural Resources Management Act 2004* divides South Australia into eight regions. This is to ensure that the natural resources of each area are managed in an appropriate and sustainable way.

The WaterConnect database provides an overview of the Natural Resource Management (NRM) Regions and the management areas within those areas.

A summary of the relevant management areas relevant to Wallerberdina site is provided in Table 33.

Table 33 Natural Resource Management zones for Wallerberdina

NRM Categories	Management Zone
NRM Region	South Australia Arid Lands (SAAL)
Surface Water Basin	Lake Torrens
Groundwater	• South Australian Arid Lands Non Prescribed Groundwater Area • Non-Prescribed Groundwater Management Zone - Low competition for resources with low consumptive use and use of the water resource is uncapped or has not been fully allocated.
Surface Water	• South Australian Arid Lands Non Prescribed Surface Water Area • Non Prescribed Surface Water Zone

By virtue of the site being located in a non-prescribed area, the groundwater resources are not extensively relied on and available information is often sparse or of poor quality.

It is noted that the absence of information does not imply that a range of beneficial uses of the groundwater and surface water do not exist locally. For example, without documented evidence, the presence of groundwater dependent ecosystems or the potential for groundwater systems to support *stygofauna*[12] beneath the site or immediate surrounds cannot be discounted.

The desktop study reviewed publicly available reports and mapping datasets accessed from on-line databases which are listed in the references section of this report. The aim of the desktop study was to understand the hydrogeological setting of the site and surrounds with respect to the assessment criteria listed above and to inform a planned drilling program to gather specific sub-surface information within the nominated site.

Soil and Geotechnical Desktop Overview

AECOM reviewed publically accessible databases and literature relating to relevant soils and geotechnical conditions at the Wallerberdina site, as specified in the references section. There was no published site- specific information on the soil or geochemical profile underlying the site or the broader local area.

Information reviewed for the likely soil conditions underlying Wallerberdina Station have been sourced from map coverages provided by the Location SA Map Viewer and ASRIS on-line data bases. Information provided for these coverages are compiled from individual land resource surveys completed over many years using various methods and cover the parts of Australia where 1:50,000 to 1:250,000 (approximately) land resource surveys have been undertaken.

The investigation area covered by detailed mapping of the soils of Southern South Australia (Hall *et al*, 2009) does not extend to Wallerberdina Station and as such no Level 5 detail on soils is available.

ASRIS Level 4 Australian Soil Classification is a spatial dataset of mapped soil units with attribution of ASRIS level 4 descriptors as stated in the ASRIS Technical Specification. The Australian Soil Classification (Isbell 2002) is recorded to the Soil Order level. The dataset is applicable at scales of

[12] Stygofauna are any fauna that live in groundwater systems or aquifers, such as caves and fissures.

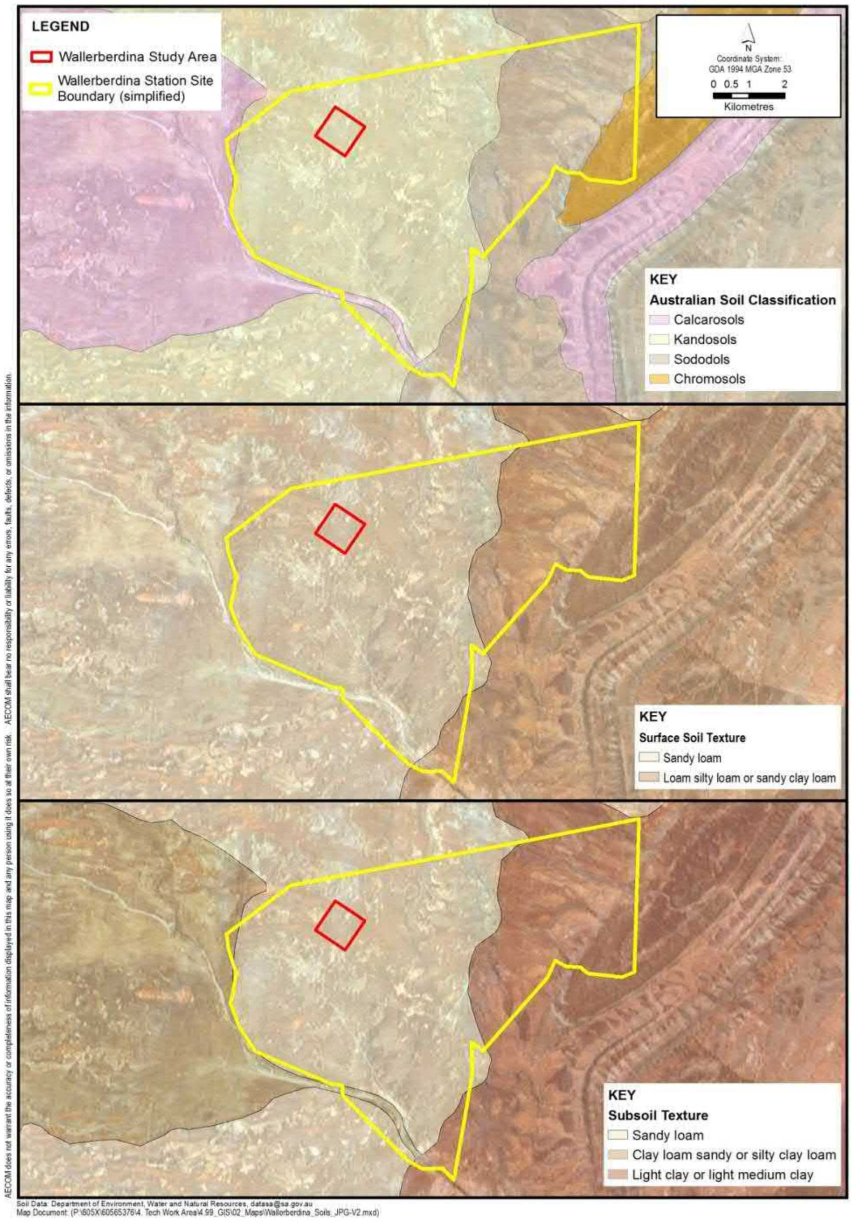
around 1:250,000 (approximately) or broader. It includes reconnaissance scale land resource survey, or summaries of information compiled from level 5 information.

ASRIS map view provides mapped extents based on area weighted averages for a given unit. The available Level 4 ASRIS data are shown spatially on Figure 24.

ASRIS Level 4 presented as Figure 24 shows the graphical breakdown of the assigned soil order to the sites and the landform element proportions.

The Atlas of Australian Acid Sulfate Soils was compiled by CSIRO to provide a consistent national coverage. Based on the ASRIS map interrogation function, all three soil subgroups at the Wallerberdina Station site are identified as Cp (p4), as having an extremely low probability of occurrence (mapped at a source map scale of 1:2M) under the Acid Sulfate Soil Classification risk assessment criteria. It is noted that confidence Level 4 is ascribed to this risk assessment as it is a provisional classification inferred from surrogate data with no on ground verification.

Figure 24 Soil distribution map for Wallerberdina Station



The general description of a Kandosol is reflective of the description of the surface and subsoil types in the attached soil distribution map. Kandosols are not calcareous throughout.

Table 34 summarises the assessment based on only of the likelihood of the presence of the geotechnical hazards at the site.

Table 34 Desktop Assessment of Potential Geohazards

Geohazard	Likelihood	Findings
Slope instability	Unlikely	Based on the ground elevation data from NatureMaps (Feb, 2018), the proposed site isolated on a flat area with an elevation of approximately 90 mAHD. This was consistent with the landforms observed through site observations of very gentle slopes. Significant seismic events have the potential to lead to ground deformation and/or shaking which could result in mass movement.
Soil liquefaction	Unlikely	Generally, soils susceptible to liquefaction are non-cohesive soils such as sand and gravels occurring in loosely deposited conditions below the water table (IAEA Safety Guide No. NS-G-3.6). Based on the desktop data, that while sands and gravels are present at the site, it is considered unlikely for soil liquefaction due to deep groundwater (> 20 m bgs) present at the site as identified based on the review of registered well data from WaterConnect.
Presence of collapsing or expansive soil	Possible	The site is underlain by Holocene floodplain sediments, modern stream alluvium and high-level terrace flood deposits; cobbles, gravel, sand, silt and clay. Based on the anticipated surface soils, there is a potential for presence of collapsing or expansive soils.
Subsidence due to underground features	Unlikely	With reference to 1:250,000 Parachilna Sheet SH 54-13 in the SA Geological Atlas Series, there are no natural features such as caverns and a review of topographic maps and SARIG database suggests it is unlikely that human-made features such as underground mines are present.
Long term settlement	Unlikely	Based on the surface geology information, it is unlikely for site soils to present long term settlement issues.
Scour and erosion processes	Unlikely	The semi-arid environment and severe rainfall events provide the potential for flash flooding in drainage channels and adjacent low lying areas, wind erosion of sandy material, and water erosion from localised flooding and catchment scale flooding (break-up out Hookina Creek and its tributary which may lead to deposition of sediment), and the potential for avulsion of Hookina Creek and its tributary).

Geology and Hydrogeology Assessment Overview

The desktop study did not identify any site-specific lithological or geochemical information on the geological subsurface profile underlying the site.

Assessment of the geological profile was primarily reliant on mapped surficial extents and on-line data base queries via the WaterConnect and SARIG search engines.

All registered bores within a 10 km radius of the site are shown on Figure 25 with collated relevant information provided in Appendix D. The hydrogeological assessment has been based predominantly on a bore reconnaissance study conducted by AECOM during a site inspection on the 21st of February 2018 and a state a government technical report (Watt *et al*, 2012) which infers groundwater conditions outside the nominated project site at a regional scale.

Some lithological data was available for a stock well (6534-360) located within the Wallerberdina Station site boundary. The most detailed lithological data was provided for a diamond drill hole located approximately 8 km north east of the site (DHET-01). An exploration hole drilled using rotary blade and mud (CT4) is located approximately 9 km south of the site also provides indicative information on the stratigraphic sequence in the vicinity of the site.

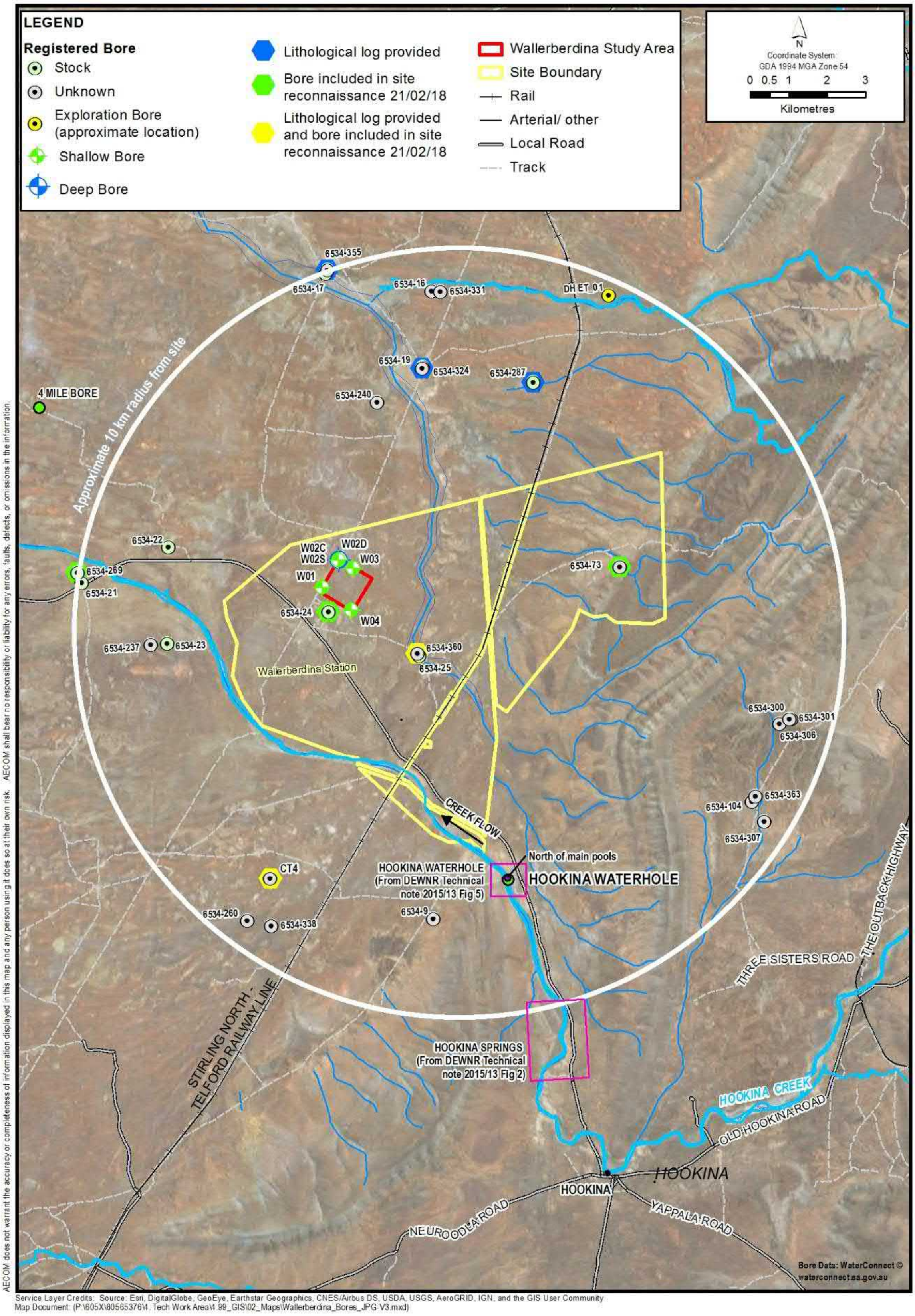
Figure 25 also shows the location of an unregistered bore east of the study identified during drilling works conducted between April and May 2018. Bores installed as part intrusive work program are also shown on the plan. These bores are discussed in greater detail in Section 3.1.1.3.

In addition to review of the existing available information, non-intrusive surveys of the site were also undertaken at the desktop assessment stage.

A seismic survey of the site was undertaken by Velseis Pty Ltd (Velseis) on behalf of AECOM in February 2018 to inform the drilling program planned for the site. The aim of the seismic survey was to identify any sub-surface structural features and to estimate the depth to basement (indurated rock) at depths between the surface and 200 m below ground. A preliminary assessment of the site specific data obtained and interpreted by Velseis is included herein as Appendix D.

In addition Geophysical Services provider to AECOM, Daishsat Pty Ltd (Daishsat), was commissioned to undertake a review of existing and company held geophysical datasets pertaining to the site and surround. A staff geophysicist with over 40 years' experience undertook a preliminary desktop assessment of the available geophysical data sets to ascertain whether significant basement structures exist below or adjacent the site. This preliminary interpretation of sub-surface conditions was refined with the processing of existing airborne magnetic survey information included here as Appendix D.

Figure 25 Wallerberdina Station –Bores within a 10 km radius (including newly installed bores)



Inferred Geological and Hydrogeological Profile

Regional geological setting

Information on the surficial geological cover has been sourced from the Parachilna Sheet SI 54-13 Geological Map Series 1:250,000 scale.

Figure 26 shows the location of the Wallerberdina Station site in relation to the mapped surficial coverage which is covered in undifferentiated Quaternary Holocene-aged sediments from depositional environments including sand dunes, low angle slope deposits, alluvial drainage channels and flood plains. The nominated site is inferred to be underlain by drainage channel alluvium.

The Flinders Ranges occur to the east with the nearest outcropping rocks being Proterozoic aged siltstones of the Wilpena Group approximately 1 km to the east of the broader Wallerberdina Station site boundary, and at least 5 km east of the nominated site.

The tectonic sketch from the Parachilna 1:250,000 geological map sheet is reproduced as Figure 27 with the approximate area of the Wallerberdina Station site and surrounds shown as a green circle.

Most of the Wallerberdina Station site is situated on a veneer of Quaternary aged alluvial (water-borne) and colluvial (slope-wash) deposits which in turn overlay sediments on the eastern fringe of the Tertiary aged Pirie-Torrens Basin. Deformation within the Flinders Ranges to the east is evidenced by the number of anticlinal and synclinal folds with a number of diapirs (i.e. outcropping domes of bedrock), the closest being the Moralana Diapir to the north-east of the site.

The closest regionally mapped fault shown on Figure 27 is orientated north-south and occurs north of the site, within the Pirie-Torrens Basin.

Figure 26 Wallerberdina Station Geology Modified from 1:250,000 Parachilna Sheet SI 54-13 (2012)

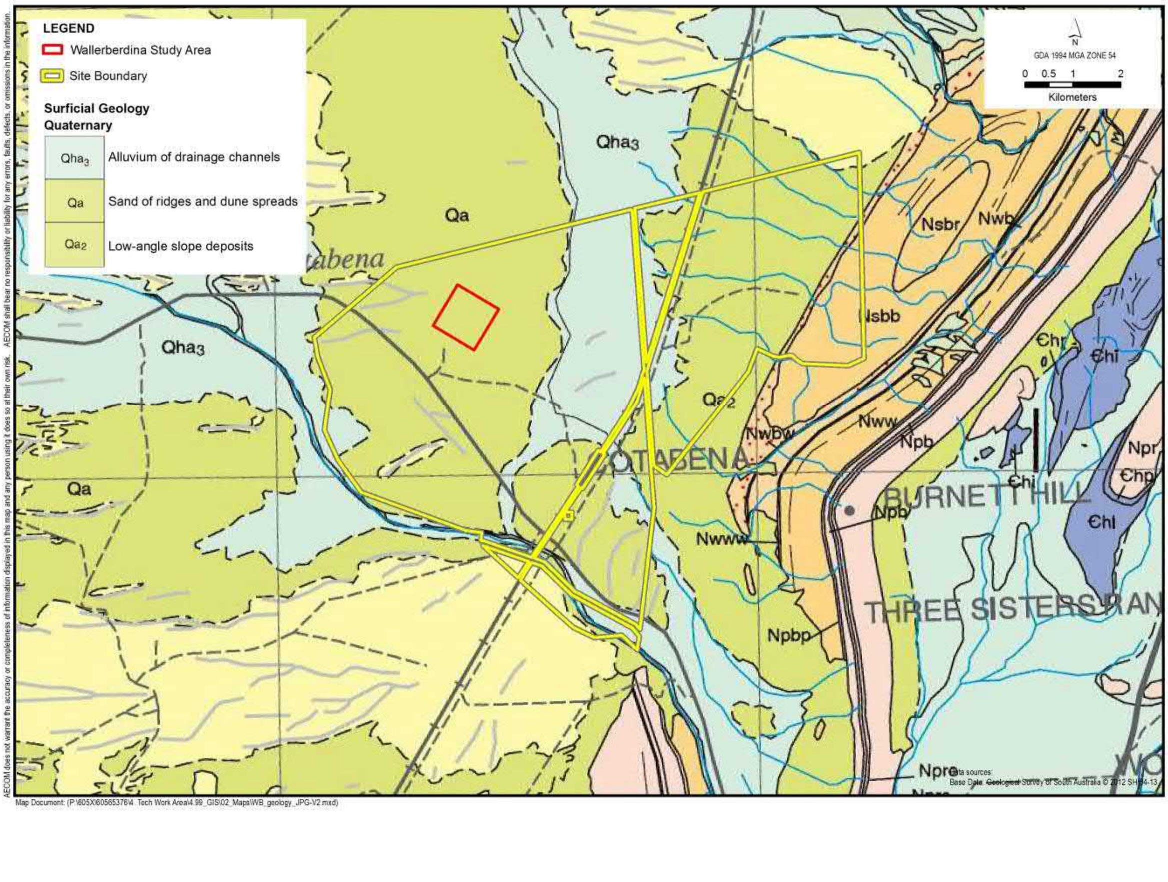
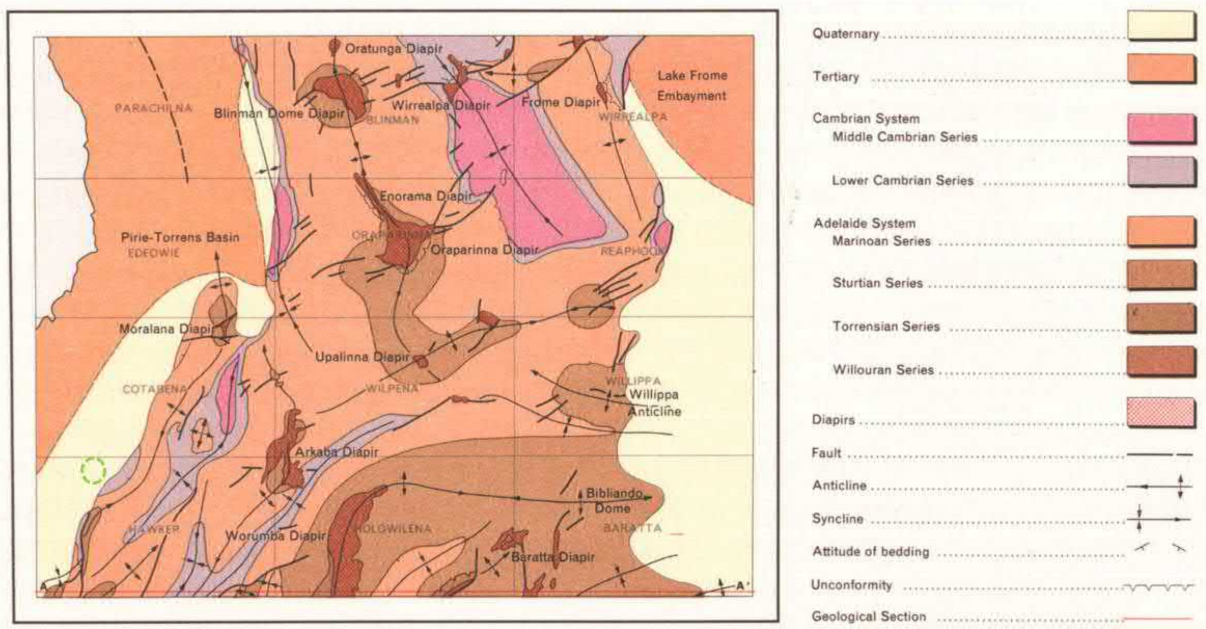


Figure 27 Tectonic Sketch excerpt from Parachilna SI 54-13 1:250 000 Geological Map Sheet (1966)



Watt *et al* (2012) provide an excellent summary of the recent geological setting (Cainozoic) for the Torrens Basin which appears to underlie the site (see Figure 28) which has been paraphrased here.

Figure 28 Location of the Torrens Basin (from Watt et al, 2012)

- The Torrens Basin contains sediments of fluvio-lacustrine depositional environments (Eocene and Miocene age) and overlies Precambrian and Cambrian rocks (Alley & Benbow 1995).
- Work by Martin et al (1998) suggests that Tertiary sediments within the Torrens Basin are likely to range in thickness from 80 m up to 270 m. The fluvio-lacustrine Cotabena Formation contains partly carbonaceous, fine to coarse-grained sand, silt, and sandstones with occasional thin carbonaceous clay beds; including lignites. The overlying Neuroodla Formation is commonly about 100 m thick and generally comprises green, grey to black argillaceous and white calcareous mudstone.
- It is likely that the Neuroodla Formation forms a confining bed to the deeper Tertiary aquifers of the Cotabena Formation (Alley & Benbow 1995).
- Quaternary sediments overlying the Torrens Basin consist of clays, gravels and sands, with some areas of surface limestone and aeolian sands. An unnamed sandy gravel outwash alluvium occurs along the eastern margin of the Torrens Basin between Lake Torrens and the Flinders Ranges.

The findings of the Daishsat investigation indicate:

- No airborne radiometric data has been identified that covers the Wallerberdina site, however the current South Australian regional surveys will provide detailed coverage in the months ahead.
- The regional South Australian magnetic image shows the area under consideration lying within a low response magnetic domain. There is no indication of regional structures or possible intrusions that would impact on any of the proposed site. There is, however a slight variation in the regional magnetic image to indicate a magnetic response from within the shallow surface sediments. This

was inferred to be due to small concentrations of magnetite in the surface sediments and does not indicate subsurface structures.

- Processing of the regional magnetic data produced images showing a “mottled” or crazed appearance which is inferred to be due to very small variations in magnetite content in the near surface sediments. Modelling of these features in the Daishsat interpretation report indicates depths of between 30 and 100 metres. These minor linear features generally follow the predominant wind direction (north-west – south-east).
- The dynamic range of the magnetic response over the site is less than 40 nano-teslas. The existing survey configuration of 100 metre flight lines is considered to be sufficient to show localised magnetic changes in the upper 100 metres of surface rocks.
- There are no magnetic features in the area of the investigation site at Wallerberdina that would indicate shallow, magnetic basement rocks or structural features that impact the site. The low magnetic response would indicate a high probability of sedimentary rocks.

A seismic survey was undertaken at the site with the objective to map any structure and if possible examine the potential for hydrological connectivity between the basement and shallow sediments. The scope of work undertaken by the project’s seismic survey contractor, Velseis, was tailored to maintain fold and horizon continuity, ranging from <40 to 200 m depth. Given the shallow depth and variable survey objectives, a 4 m geophone and shot interval was undertaken. The lighter energy source Mini-SOSIE technique was deployed which minimised vegetation disturbance and reduced the likelihood of contaminating primary reflected energy.

Two seismic lines orientated diagonally within the 1 km^2 Wallerberdina site were completed by Velseis over two days commencing the 26th February 2018.

Once the data was acquired Velseis generated a refraction solution to provide an indication of the depth to the weathered / un-weathered boundary. Velseis then provided a preliminary interpretation of the processed data which is attached as Appendix D. It is noted that given the lack of borehole control available at the time of the survey, only more prominent potential structures have been inferred and given the complexity of the data smaller scale structures are also likely to be present.

The preliminary interpretation of the Velseis acquired data indicates:

- The shallowest inferred structural feature was interpreted to be at greater than 80 m depth. A potential palaeochannel was interpreted to occur at approximately 200 to 210 m with no faulting above a depth of around 280 m.
- The approximate base of weathering was inferred to extend from less than 10 to 15 m with the inferred top of competent rock occurring at approximately 50 m depth.
- A significant thickness of horizontally layered unstructured consolidated rock is inferred to extend from approximately 100 to 260 m depth.

The entire Velseis Powerpoint presentation is appended for reference (Appendix D).

Inferred Lithological Profile

The interpretation of the sub-surface lithological profile was found to be consistent with the available lithological data.

The limited lithological information available for review (presented in Appendix D) supports the preliminary interpretations of the site specific seismic data; specifically:

- Greater thicknesses of unconsolidated sediments are likely to increase with locations to the west, away from the ranges and towards the Torrens Basin. Bore 6534-360, located approximately west of the site is logged by the driller as comprising unconsolidated sediments to the end of hole at a depth of 44 m.
- Crystalline basement may be overlain by a significant thickness (>200 m) of Tertiary aged lacustrine and fluvial deposits likely comprising the Neuroodla and Cotabena Formations.
- The interpreted seismic survey data suggests horizontally layered strata with the top of competent rock approximately 30 to 50 m depth which is unstructured until depths of greater than 260 m.

Inferred Hydrogeological Setting

Regional

The Wallerberdina Station location is situated within the South Australian Arid Lands NRM Region. DEWNR Tech Report 2012/01 (Watt *et al*, 2011) indicates the following:

- Nearly all groundwater in the Flinders Ranges occurs in weathered and fractured indurated sedimentary rock aquifers. Some limestone layers have dissolution cavities that can supply high yields. Minor aquifers also occur in unconsolidated sand and gravel sediments of Quaternary age at the base of the ranges.
- Nearly all groundwater within the broader Adelaide Geosyncline is suitable for stock water and while potable groundwater exists in most parts of the Flinders Ranges, volumes are generally insufficient for large-scale development (Read, 1987).
- The regional distribution of groundwater salinity in the vicinity of the site is variable but possibly brackish to saline.
- The regional distribution of groundwater standing water levels in the vicinity of the site are likely to be 20 to 50 m below ground level with variable well yields (<1 to >10 L/s but mostly <1 L/s).

The site is approximately equally distanced between the Flinders Ranges to the east and Lake Torrens to the west. Groundwater flow is anticipated to be from the east with rainfall upon the Flinders Ranges being the main source of recharge to the aquifers, westwards towards Lake Torrens which is a terminal basin. Terminal basins retain water with no outflows, equilibrating through evaporation. Lake Torrens mainly exists as an ephemeral salt lake however after extreme rainfall events the lake can discharge to the Spencer Gulf.

A Department of Environment, Water and Natural Resources (DEWNR) study on the origins of Hookina Springs, located around 5 km to the south east, may provide some insight into deeper hydrogeological conditions present within the vicinity of the site (Barnett *et al,* 2015). The report suggests that Hookina Springs is fed from deeper geological units via faulting which may provide a conduit for groundwater discharge from deeper aquifers. This suggests an upward vertical hydraulic gradient exists between the deeper water bearing units and the watertable aquifer.

It is noted that the Hookina Springs source is located over 10 km south of the site and therefore it is not expected that there would be direct correlation between the hydrogeological setting on the plains compared with that of the spring's origin within outcrops of the ranges. Further, it is noted that Hookina Creek at its closest point to the site is dry with only a relatively short section of the creek maintaining surface flows upstream of the site at Hookina Springs and Hookina Waterhole.

A summary of the key findings of this report are provided in Appendix D and its location proximate to the site is shown on Figure 29**.**

Local

Database bore summary information for bores within a 10 km radius of the Wallerberdina Station site is provided in Appendix D. Based on the existing use of groundwater for stock watering purposes at Wallerberdina Station (6534-360) and in the surrounding area, a well reconnaissance survey was initially conducted by AECOM during a site inspection on the 21st of February 2018.

Of note:

- Nine of the 26 registered bores identified within the search area are listed for stock use of which six are operational. Yields for wells vary between 0.13 L/s and 2 L/s with salinities between 2,000 mg/L and 8,300 mg/L (as total dissolved solids - TDS), averaging approximately 4,800 mg/L.
- Operational stock watering bores were drilled to depths between of 30 and 50m with standing water levels ranging from around12 to 28 m (as measured at the time of well installation).
- Unit numbers 6534-24 (stock bore), 6534-25 and its replacement 6534-360 (named East Yallala Bore) and 6534-73 (named Murrays Bore) all lie within the Wallerberdina Station site but outside the nominated site. Well 6534-269 is an operational stock bore located outside the Wallerberdina Station property boundary, approximately 4 km east. These wells were included in a

reconnaissance study undertaken by AECOM. WaterConnect summary information and updated standing water level information and well photographs are provided in Appendix D.

- The standing water level at 6534-360 was recorded at 29.3 m below the top of casing (m bTOC) in February 2018, slightly lower than originally recorded in June 2016 (28 m). This bore was drilled to 44 m and water was intersected between 33 and 40 m bgs with a yield of 0.5 L/s. The driller's log for this bore suggests that it is installed within unconsolidated sediments extending to the base of the bore.

Registered well search information suggested groundwater at depths of approximately 20 m bgs with relatively high salinities (>10,000 mg/L Total Dissolved Solids).

3.1.1.3 Field Methods and Results

On the basis of the information gathered and reviewed as part of the desktop assessment, the drilling and test pitting program for Wallerberdina Station included allowance investigation boreholes of up to 50 m depth to intersect the watertable aquifer within inferred unconsolidated sediments, a deep borehole up to 230 m depth to intersect (if possible) the underlying indurated basement rock and for six test pits to around 3 m depth to infill locations in between the boreholes.

The location of each test pit and bore is displayed in Figure 29.

Prior to any ground disturbance or off-track driving, cultural heritage clearance was undertaken at each proposed drilling and test pit location and along the routes between locations. Elders from Viliwarinha Yura Aboriginal Corporation and an archaeologist from RPS were present to carry out clearance of the work areas. Drilling and test pit locations were adjusted to minimise disturbance to the landscape.

In addition, given the documented use of groundwater for stock water supply, an extension of the well reconnaissance was incorporated into the drilling program. Where time allowed, reconnaissance also included documenting surface flow rates and water chemistry at Hookina Springs and Hookina Waterhole.

Geophysical wireline logging was incorporated into the program to assist in identifying additional water bearing zones between the watertable aquifer and groundwater intersected within the basement rock.

In order to provide sub-surface information specific to the site a drilling program was undertaken with the primary objectives of:

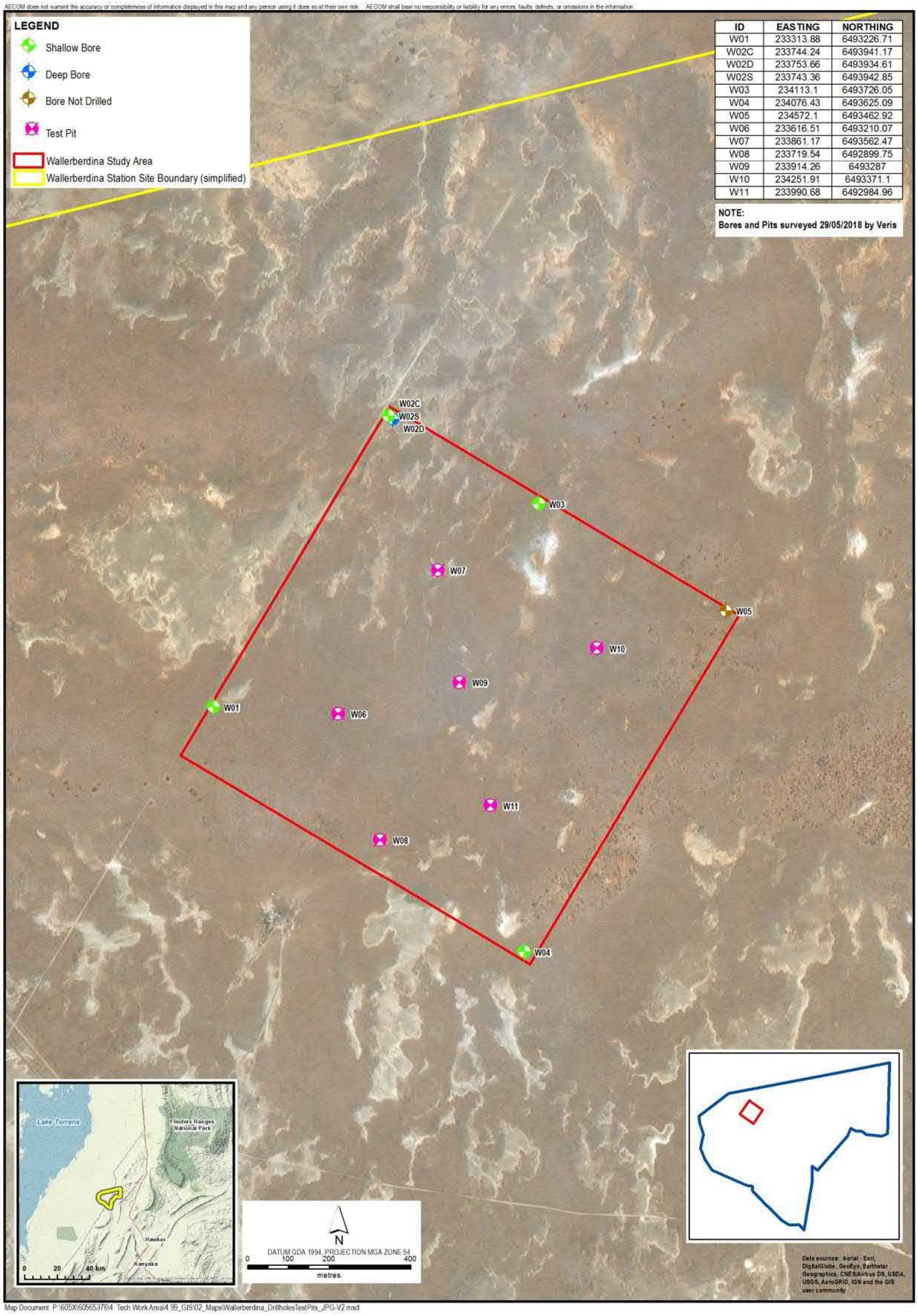
- Identify the depth, flow direction and water quality of the watertable aquifer within unconsolidated sediments.
- Identify the depth to the consolidated bedrock and assess the water quality and likely interaction between the deeper and shallower water bearing zones.
- Describe and geophysically log the lithological profile beneath the site in order to identify zones of permeable and less permeable sediments.

Drilling, Sampling & Bore Construction Program

Borehole Drilling

Investigation borehole drilling was carried out by Numac Drilling using a track mounted Geoprobe 8140 Sonic rig for bore holes less than 50 m depth. A truck mounted Camacchio 450 diamond coring rig was used to drill the deep location W02D. A total of six holes were drilled (labelled W01, W02S, W02C, W02D, W03, W04). Six bores were installed at four investigation sites W01; W02, W03 and W04. Three bores were installed at site W02 – W02S targeting the watertable aquifer, W02C targeting a conglomerate aquifer below the watertable aquifer and W02D, a deep aquifer investigation bore. Investigation bore locations are shown in Figure 29.

Figure 29 Location of investigation bores and test pits within Wallerberdina



Sonic Drilling

All shallow bores were drilled using sonic coring with the casing advance methodology from surface. Sonic drilling uses high quality (fresh) water as a drilling fluid in order to aid coring and hole flushing. The sonic drilling used a 140 mm diameter core barrel inside a 155 mm diameter temporary casing (which was withdrawn once drilling was completed). The drill and casing string progressed in 1.5 or 3.0 m lengths depending on the required drilling or sampling run. Shorter runs were also employed to improve recovery.

In general, bores used 6 – 10 m^3 of water to achieve final depth, depending on the amount of circulation losses. Cores of drilled sediments were continuously recovered as drilling proceeded and lithologies were recorded on-site by an experienced and qualified AECOM geologist/hydrogeologist.

Diamond Drilling (W02D only)

Diamond coring at W02D was achieved using a triple tubed HQ3 diameter coring assembly. Coring was completed in 1.0-3.0 m length drill runs depending on the ground conditions or sampling requirements. Several mud additives appropriate to water bore drilling we used for drilling W02 including dispersible viscosifying polymers, biodegradable detergents, and shale stabilising additive (‘X-shear’). Three mud pits we excavated in the soil adjacent to the rig to improve the effectiveness of the mud system. Solid stem auguring was completed from surface to 15.2 m where competent ground was encountered. Coring commenced from this depth until the final hole depth of 236.1metres.

A series of casing lengths were grouted into the bore hole to stabilise the hole during drilling. This included a 175mm PVC conductor casing (0-5 m bgs), 140mm PWT steel casing (0-6 m depth) and 114 mm HWT Steel casing (0-27 m depth). Unsupported coring commenced below 27.0 m.

The initial target for the deep bore at W02D was the indurated bedrock. However, coal and inorganic sands were still the predominant lithological unit at 220.5 m depth. Due to the extensive depth of the open drill hole, a decision was made to ream the hole and install and pressure-grout HTW steel casing to mitigate the possibility of the open hole collapsing. The mudstone provided a competent base for pressure-grouting of the steel casing with the casing seated at 196 m.

Open hole drilling recommenced through the steel casing to a final depth of 236.1 m. The bore was then completed as a deep aquifer groundwater observation bore.

Cores of drilled sediments were continuously recovered as drilling proceeded and lithologies were recorded by on-site by an experienced and qualified AECOM geologist/hydrogeologist. Bore logs are provided in Appendix D.

A number of attempts to collect U63 samples were unsuccessful due to high stiffness of the encountered clays deforming the sample tube during both sonic and HQ rig attempts. Core samples were wrapped in plastic and selected samples submitted to SMS Geo laboratories for permeability testing. Due to the test duration, an update from the laboratory as to the suitability of these core samples for permeability testing is still outstanding at the time of reporting.

All retrieved core was logged and photographed in the field.

Geotechnical Testing from Bores

Geotechnical information was collected throughout the borehole drilling, mainly focused on the ground profile for top 15 m depth. The geotechnical investigation methods included geotechnical logging of soils, in-situ testing and collection of samples for laboratory testing.

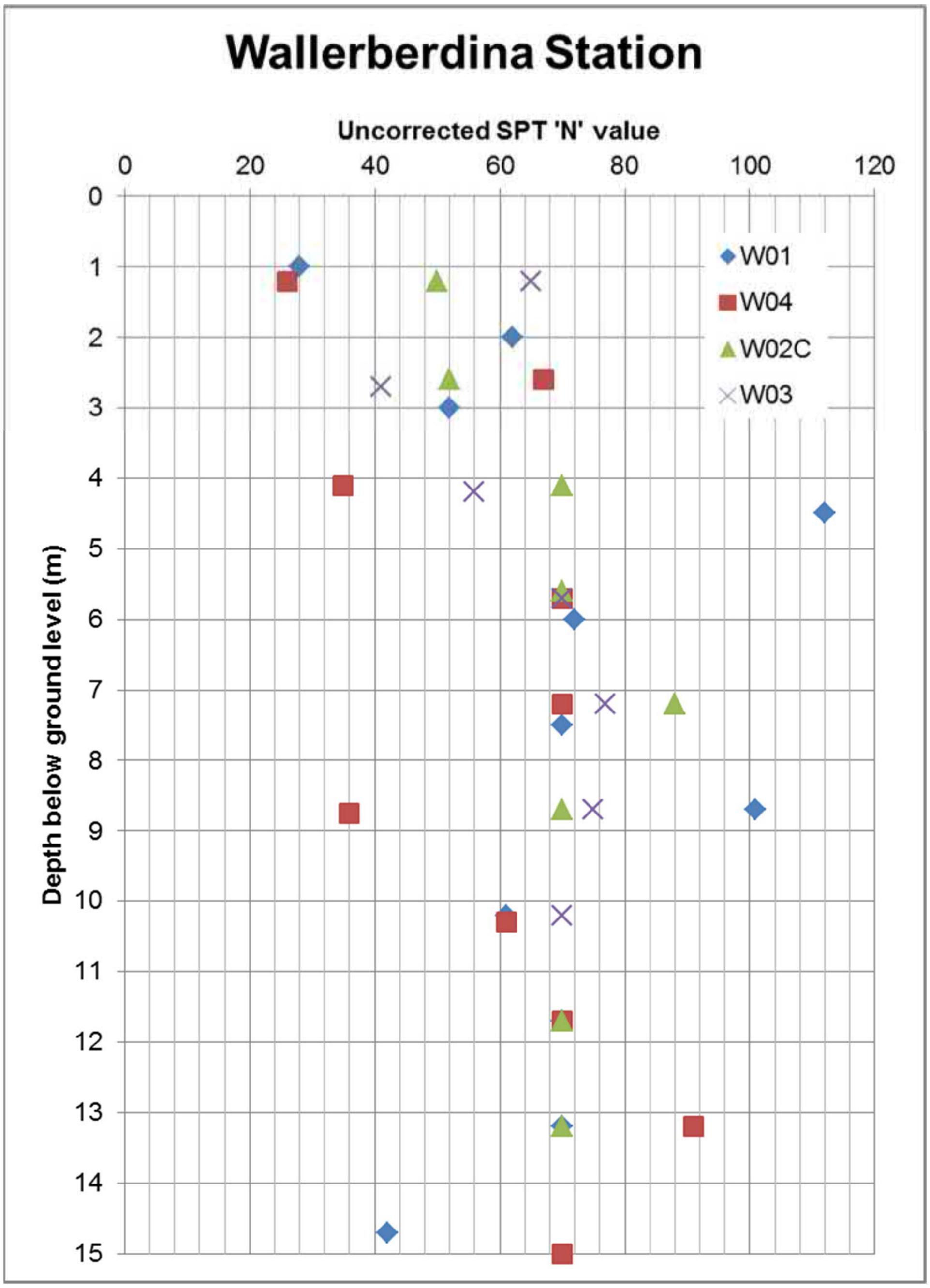
The geotechnical information collected included:

- Soil profile logging to 15 m depth;
- Insitu testing of Standard Penetration Testing (SPT) conducted at nominally 1.5 m interval in accordance with AS1289.6.3.2 to 15 m depth; and
- Collecting of disturbed samples recovered from top 15 m depth.

It is noted that laboratory results for U63 samples selected for permeability testing were not available at the time of reporting.

Figure 30 presents the summary of uncorrected SPT values recorded with depth (within top 15m depth). Where refusal was met during the SPT, this is shown with the uncorrected SPT value of 70 for graphical purposes.

Figure 30 Uncorrected SPT Values with Depth



Geophysical Logging

Downhole geophysics (wireline logging) was conducted in all holes to refine lithologies and observations made during the drilling process.

The contractor engaged for this work was Borehole Wireline. Details of the types of logging undertaken are as follows:

- Deep Well – W02D (Completed 31 May 2018). Upon reaching target depth, wireline logging was completed in the un-constructed bore through the temporary sonic casing and into the un-cased fresh bedrock at the base of the hole. The following tools were run to provide a geophysical profile over the full lithology sequence into bedrock:

- Natural Gamma
- Neutron Porosity
- Compensated Density, Resolution Matched Density and Density Correction
- Spontaneous Potential
- Resistivity
- Acoustic Scanner

- Shallow Wells (8 May 2018 & 31 May 2018). Logging of shallow wells was completed after construction, within the PVC cased borehole. Due to the limited annulus diameter (50 mm) of the constructed boreholes, the following tools were run:
  - Natural gamma
  - Dual induction.

Geophysical logs have been incorporated into the final lithological and construction logs for each borehole. The logs are provided in Appendix D.

Observation Bore Construction and Development

All investigation boreholes were converted to groundwater observation bores. Bore construction details are provided in Table 35.

Shallow Bore Construction (<60 m bgs):

Shallow bores were constructed using 50 mm diameter class 18uPVC casing with a 0.4 mm slotted screen. Bores W02S, W03 and W04 were screened over 6 m length, and bores W01 and W02C were installed with a 3 m screen. A filter-pack consisting of 8/16” washed river sands was introduced to fill the external annulus of the bore casing between the casing and the natural sediments and gravity fed from surface to a depth of a 1 m above the top of screen.

A seal consisting of 3/8” bentonite pellets were gravity fed from surface until a thickness of 3m above the top of the gravel-pack was obtained. Pellets were hydrated and allowed to cure for a minimum of 1 hr. The remaining annulus was then backfilled to surface with a cement grout with 5% bentonite. The grout was mixed at surface and tremmie piped down the annulus in 200 L batches. The surface completion of the bores consists of lockable, recycled plastic blue monument seated approximately 0.9m above ground level.

Deep Well Construction (W02D):

The deep bore was reamed (drilled to a wider diameter) from surface to 220.5 m to allow HWT steel casing to be pressure-cement grouted into place. The cement grout was allowed to set for 24hrs. An open cored section below the steel casing was then cored from 220.5 to 236.1 m (end of hole) forming an unscreened (open) well interval.

Wireline logging of W02D prior to well development indicated that the hole had collapsed back to 206 m with the open hole extending from 196 to 206 m.

The surface completion of the bores consists of lockable, recycled plastic yellow monument, seated approximately 0.9 m above ground level.

All bore locations were further protected from damage by the erection of cattle panels around the monuments (see photograph below).

Figure 31 Bore headworks completion at W02S and W02C

Bore Development

In line with Section 12 of the *Minimum Construction Requirements for Water Bores in Australia, Edition 3,* bore development was undertaken to optimise bore performance by removing any drilling fluids (water or mud) introduced into the aquifer during drilling, stabilising the gravel filter pack, and ensuring groundwater obtained during sampling events is representative of groundwater from the aquifer.

Following construction all newly constructed bores were developed (pumped to remove residual drilling fluids and improve groundwater flow through screens).

The shallow bores W01, W03, and W04 were initially purged of sediment and drilling fluids using a hired 400 cubic feet/minute (cfm) air compressor attached to a 1/5" tremmie pipe. Due to the low permeability and slow recoveries, development was completed using a bailer. Bores W02S and W02C exhibited much greater permeability and were able to be developed with air only.

- Shallow bore W02S was able to be air lifted continuously for 1 hour at 0.17 L/s
- Intermediate bore W02C was able to be air lifted continuously for 1 hour at 0.33 L/s
- Deep bore W02D was initially air lifted in stages due to retained drilling fluids. Development on the second day, where the measured water level was inferred to be representative of the aquifer, resulted in 120 L being removed over an hour and on this basis the yield was estimated to be low (0.033 L/s).

The bores W03 and W04 were lower yielding than the other bores and were bailed dry twice with approximately 10 L removed prior to the bore becoming dry. The development yields from the bores suggest the yield potential for bores screened across the water table varies.

The development yields from the bores suggest the yield potential for the water table aquifer is variable but generally low and the deeper aquifer is low.

Bore development and sampling records are provided as Appendix D.

Table 35 Bore Construction Details – Wallerberdina

						metres below ground level			metres AHD		
Bore ID	Install Date	Easting	Northing	Borehole diam (mm)	pvc casing diam (mm)	Original Bore Depth	Screen/ Open Hole	Sand	Casing RL	Ground RL	Standpipe RL
W01	6/05/2018	233313.88	6493226.71	160	50	22.5	19.5-22.5	19.0-22.5	86.61	85.63	86.72
W02S	15/05/2018	233743.36	6493942.85	160	50	51	48.0-51.0	19.0-26.5	84.94	84.11	85.07
W02C	11/05/2018	233744.24	6493941.17	155.3	101.2	236.1	196-206^	47.0-51.0	84.94	84.11	85.11
W02D	31/05/2018	233750.00	6493939.00	160	50	24	18.0-24.0	-	84.98	84.03	^^
W03	17/05/2018	234113.10	6493942.85	160	50	27	21.0-27.0	17.0-24.0	87.34	87.42	87.42
W04	10/05/2018	234076.43	6492625.09	160	50	26.5	20.5-26.5	20.5-27.0	92.42	92.54	92.54

Notes:

Surveying by Veris conducted 30/05/18, survey data presented in Appendix D.
Depths are in metres below pvc casing unless otherwise stated
AHD = Australian Height Datum
RL = Reduced Level to common datum being metres below AHD
^ extent of open hole logged by Borehole Wireline on 31/05/18 (see borelog for details)
^^ monument casing not installed at the time of surveying.

Test Pit Excavation , DCP and Laboratory Testing

Six (6) test pits were excavated within the footprint of the 100 hectare site at Wallerberdina. The test pits were excavated using a mini-digger. All the test pits were excavated to a nominal depth of 3.0 m and generally one bulk sample was collected from each test pit for geotechnical laboratory testing. At the completion of the test pitting, the test pit was backfilled with spoil and compacted with the excavator by tracking.

The field investigation was performed under the direction of a geotechnical engineer who was responsible for logging the recovered samples in general accordance with the visual-tactile methods outlined in AS 1726 “Geotechnical Site Investigations”, collecting disturbed samples of selected soils and photographing the test pit. Bulk soil samples were collected for geotechnical laboratory testing. Discrete soil samples were also collected and placed into snaplock bags and laboratory supplied jars for environmental laboratory testing. Samples were submitted to the NATA accredited laboratories for testing under chain of custody procedures. A limited number of samples were collected for laboratory analysis with the aim of identifying any geotechnical hazards or detrimental soil quality properties within the soil types present.

The test pit locations carried out at each site and photograph of the test pit are presented in Figure 29 with logs and photographs provided in Appendix D.

Dynamic cone penetration tests (DCP) were undertaken adjacent to test pits in general accordance with AS1289.6.3.2 to a target nominal depth of 3.0 mbgl. Blows were measured every 100 mm of penetration. At some DCPs locations, refusal was encountered which is summarised in Table 36.

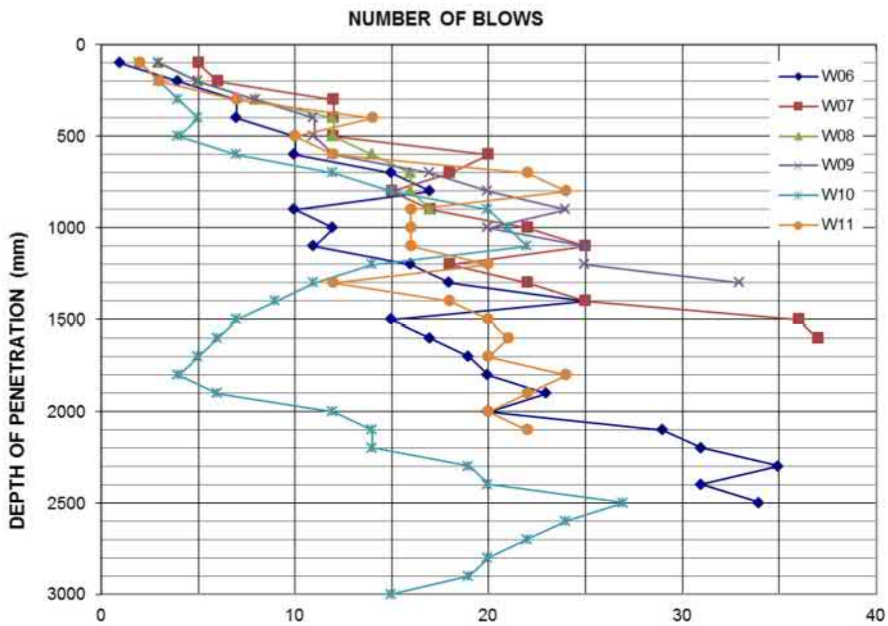
Figure 32 presents a summary of DCP results recorded number of blows per 100 mm with depth.

Table 36 Summary of DCPs Termination Depth

DCP No.	Termination Depth (mbgl)
W06	2.6
W07	1.7
W08	0.9*
W09	1.4
W10	3.0
W11	2.2

* DCP broken and test was terminated at that level.

Figure 32 DCP Blows per 100 mm with depth



The objective of the environmental laboratory testing was to collect information from laboratory test results to identify the presence and nature of any detrimental soil quality properties. The soil samples were submitted to NATA accredited laboratory ALS Environmental for analysis of pH, electrical conductivity, and exchangeable cations (to calculate the cation exchange capacity and exchangeable sodium percentage).

The objective of the geotechnical laboratory testing was to collect further geotechnical information from laboratory test results to further inform the site characterisation and assessment against criteria (geohazards).

The nominated laboratory testing included the following:

- Moisture content;
- Particle size distribution;
- Atterberg limits;
- Standard compaction test;
- California Bearing Ratio (CBR) remoulded at 98% standard maximum dry density);
- Emerson Class
- Undisturbed permeability (selected samples from deep drilling program)

Laboratory analytical reports and tables are provided within Appendix D.

Observed Soil and Geological Profile

The geological profile for the site, as typified by the deep bore W02D is as follows:

Table 37 Representative Stratigraphy – Bore W02D

Depth From (m)	Depth To (m)	Strata	**Relative Permeability** (H/M/L)
0.0	6.8	Clayey Silt	L
6.8	8.2	Gravelly Silt	H/M
8.2	17.7	Clayey Silt	M/L
17.7	20.5	Clay	L
20.5	24.5	Sand	H
24.5	26.9	Clayey Sand	M/L
26.9	28.0	Sand	H
28.0	30.0	Clayey Sand	M/L
30.0	32.8	Sand	H
32.8	34.7	Sandy Clay	L
34.7	36.5	Sand	H
36.5	39.7	Sandy Clay/Clay	L
51.6	45.6	Clay	L
45.6	48.6	Sandy Gravel	H
48.6	51.5	Conglomerate (Fractured)	H
51.5	66.0	Clay	L
66.0	68.5	Sand	H
68.5	71.2	Breccia	M
71.2	72.5	Conglomerate	H
71.5	78.5	Clay	L
78.5	81.5	Sand	H
81.5	88.5	Clay	L
88.5	95.5	Sand	H
95.5	98.5	Silty Sand	M
98.5	103.5	Clay	L
103.5	109.0	Sand (Clayey)	M
109.0	111.5	Clay	L
111.5	115.0	Sandstone	M
115.0	122.5	Mudstone	L
122.5	125.0	Sandstone	M
125.0	133.5	Mudstone	L

133.5	141.5	Sandstone	M
141.5	143.0	Mudstone	L
143.0	144.0	Shale/Sandstone	L
144.0	160.0	Mudstone	L
160.0	161.0	Sandstone	M
161.0	167.5	Mudstone	L
167.5	168.7	Claystone	L
168.7	171.6	Mudstone	L
171.6	188.4	Sandstone	M
188.4	188.6	Mudstone	L
1886.	189.5	Sand	H
189.5	198.5	Mudstone	L
198.5	200.2	Sandy Clay	L-M
200.2	203.8	Sandstone	M
203.8	207.4	Sand	H
207.4	208.2	Lignite	L-M
208.2	210.5	Carbonaceous Sandstone	M
210.5	216.2	Sandstone	M
216.2	219.5	Sand	H
219.5	221.3	Sandstone	M
221.3	229.5	Sand	H
229.5	230.8	Clayey Sand	H-M
230.8	231.2	Lignite	L-M
231.2	231.5	Sand	H
231.5	233.5	Mudstone	L
233.5	235.3	Silty Sand	H-M
235.3	236.1	Sand	H

The relative subsurface strata permeability above is approximated from industry accepted ranges of saturated permeability and hydraulic conductivity (Table 2.2, Freeze and Cherry,1979) where strata range from near impermeable unfractured metamorphic and igneous rocks and shale to highly permeable gravel or karst limestone. Strata above the watertable (i.e. unsaturated or vadose zone) will have a lower permeability than the equivalent saturated permeability due to complex hydrostatic and pore pressure process that occur at an interstitial scale. The above approximations assume the applicable strata are saturated. For the purpose of this assessment, the relative permeabilities are based on the following literature ranges:

Table 38 Table of Relative Coefficients of Permeability

Relative Permeability	Range of Equivalent Strata	Permeability (k = darcy)	Hydraulic conductivity (K = cm/s)
Low (L)	Shale, unfractured rock to unweathered clay	1×10^{-8} to 1×10^{-4}	1×10^{-11} to 1×10^{-7}
Medium (M)	Weathered clay to fine sand	1×10^{-4} to 1×10^{1}	1×10^{-7} to 1×10^{-2}
High (H)	Fine sand to coarse gravel or karst limestone	1×10^{1} to 1×10^{5}	1×10^{-2} to 1×10^{2}

Undisturbed cored samples of aquitard/aquiclude material were collected during the investigation borehole drilling program and submitted for laboratory permeability testing. Three samples were collected and tested from the site.

Table 39 Laboratory Testing Results – Undisturbed Aquitard / Aquiclude Permeability

Borehole	Depth (m)	Strata	K (cm/sec)	K (m/d)	Testing Laboratory	Testing Standard
W02D	33.0 – 33.3	Sandy clay	3×10^{-9}	2.6×10^{-6}	GroundScience	AS1289.6.7.3
W02C	36.9 – 37.3	Clay	6×10^{-11}	5.2×10^{-8}	GHD	AS1289.6.7.3
W02D	49.2 – 49.5	Conglomerate	4×10^{-11}	3.5×10^{-8}	GroundScience	AS1289.6.7.3

The results for this site confirm the literature estimated relative permeabilities for the strata at the depths indicated and based on the representative stratigraphic sequence adopted from investigation borehole W02D. While the core sample W02D (49.2-49.5) is suggestive of a very low intrinsic (primary) coefficient of permeability (4×10^{-11} cm/s), this unit as a whole is likely to have a significantly higher coefficient due to secondary permeability (fracturing) within the rock. Based on drilling fluid loss identified during the drilling of this unit, fractures within the conglomerate have the potential to yield groundwater at a sufficient volume to supply or augment water supply to the site with groundwater.

The profile at the site is considered largely a low energy alluvial depositional environment with silts interspersed with shorter higher energy deposition periods. Strata mainly consist of clays, silts and sands and occasion gravelly units. An indurated conglomerate unit was encountered in several boreholes including at W02D (48.6 m) and W01 (35.7 m). This unit is polymictic with clasts of quartzite, shale and limestone within a sandy matrix and calcareous cement (see photograph below).

The shallow soil profile across the site typically comprises a silty sand clayey silt at the surface underlain by either a clayey sand or clay with gypsum and occasional inclusions of gravels to at least 3 m depth. The only exception is investigation location, test pit W10, in which silt sand was observed from surface to 3 m depth. Landscape scale mapping reported in the desktop assessment above had suggested a sandy loam at surface and within the subsoil would be present. It is inferred that the variability within the soil profile is likely due to sediment deposition between weathered dunal features in the landscape.

The laboratory analytical results for soil samples from test pits W07 and W08 (clay dominant profiles) and W10 (silty sand profile) has been interpreted[13] collected from surface to around 2.5 m depth, suggests that soils are of moderately alkaline pH throughout, non-saline at surface becoming slightly to moderately saline from around 2 m depth, vary from a very low to low cation exchange capacity, and are non-sodic at surface with sodicity likely increasing with depth and becoming sodic or strongly sodic and potentially dispersive.

[13] Hazelton, P. and Murphy, B. 2007. *Interpreting Soil Results: What do the Numbers Mean?,* CSIRO Publishing.

Figure 33 Core box showing intersected conglomerate at W02D

The conglomerate unit intersected at W02D is possibly the sub-surface extension of the conglomerate observed outcropping at the Hookina Springs and Hookina Waterhole and was encountered at shallower depths at W01 and W04. Photographs of sonic core samples obtained from W01 and W04 are shown in comparison to the Hookina Waterhole conglomerate below.

Figure 34 Comparison of intersected conglomerate with outcropping conglomerate

Conglomerate outcrop at Hookina Springs – 26/05/18

Conglomerate outcrop at Hookina Waterhole – 10/05/18

Comparison of sonic core sample from W01 (35.5 - 35.7 m bgs) with Hookina Waterhole outcrop – 10/05/18

Comparison of sonic core sample from W04 (26.0 - 26.1 m bgs) with Hookina Waterhole outcrop – 10/05/18

In general, the sub-surface profile may be summarised as alluvial clay with interbedded moderate permeability sand – gravel lenses from the surface, intersected by a high-permeability, dipping, conglomerate at 50 - 35 mAHD, depending on the location on the site. Lithology grades to low permeability siltstone / mudstone with interbedded by layers of high permeability sand / sandstone.

From the data obtained the main water bearing / high permeability zones (separated by clay / siltstone / mudstone units) have been identified as:

- Although not obvious during the investigation drilling program, there is potential for the development of transient perched water in gravelly sand resting on a clay layer. The clay floor is at ~ 16 m depth (~70 mAHD) at most locations however a permeable gravelly zone was intersected at a shallower depth at W04 (9.2 – 9.6 m bgs). Field indications were that this zone was not productive however this assessment was complicated by the presence of water added as drilling fluid during sonic drilling. . This gravel is not always present, e.g. W02 site is mostly clay.
- Water table ~ 21 m depth (~64 mAHD), in sand / gravel.
- First confined aquifer in gravelly sand found from 30.5 - 40 m depth (~55 mAHD), likely to be hydraulically connected to the underlying conglomerate unit.
- Conglomerate - 3 m thick, top at around 30-35 mAHD.
- Sand – 3 m thick, top at around -5 mAHD.
- Sand – 3 m thick, top at around -28 mAHD.
- Sandstone – 3 m thick, top at around -38 mAHD.
- Sandstone – 6 m thick, top at around -50 mAHD.
- Sandstone – 13 m thick, top at around -93 mAHD.

- Sandstone / sand, grading to carbonaceous sandstone, grading to lignite, from -116 to -147.5 mAHD.
- Sand – from -151 to -155 mAHD.

Groundwater Sampling & Laboratory Analysis

Groundwater Gauging

Groundwater levels in all bores were gauged at construction completion, throughout development to monitor water quality recovery, and prior to collection of groundwater samples after sufficient recovery time.

Groundwater levels collected prior to sampling are considered stable and representative of the ambient groundwater condition.

Standing groundwater levels recorded in the shallow bores immediately prior to sampling on the 23 May 2018 are as follows:

Table 40 Gauging Data for Wallerberdina Investigation Bores

Bore No	Date	Reduced Level (Top of casing mAHD)	Groundwater Level (m below top of casing)	Reduced Groundwater Level (mAHD)
W01	23/5/18	86.61	21.81	64.80
W02S	23/5/18	84.94	20.75	64.19
W02C	23/5/18	84.94	20.67	64.27
W03	23/5/18	87.34	22.91	64.43
W04	23/5/18	92.42	26.74	65.68

Watertable levels (Bores W01, W02S, W03 and W04) are in excess of 20 m depth across the site. The reduced levels of groundwater in the shallow aquifer, based on water levels reported in 23 May 2018, range from 65.68 mAHD in Bore W04 on the southern corner of the site to 64.19 mAHD at Bore W02S in the northern corner portion of the site.

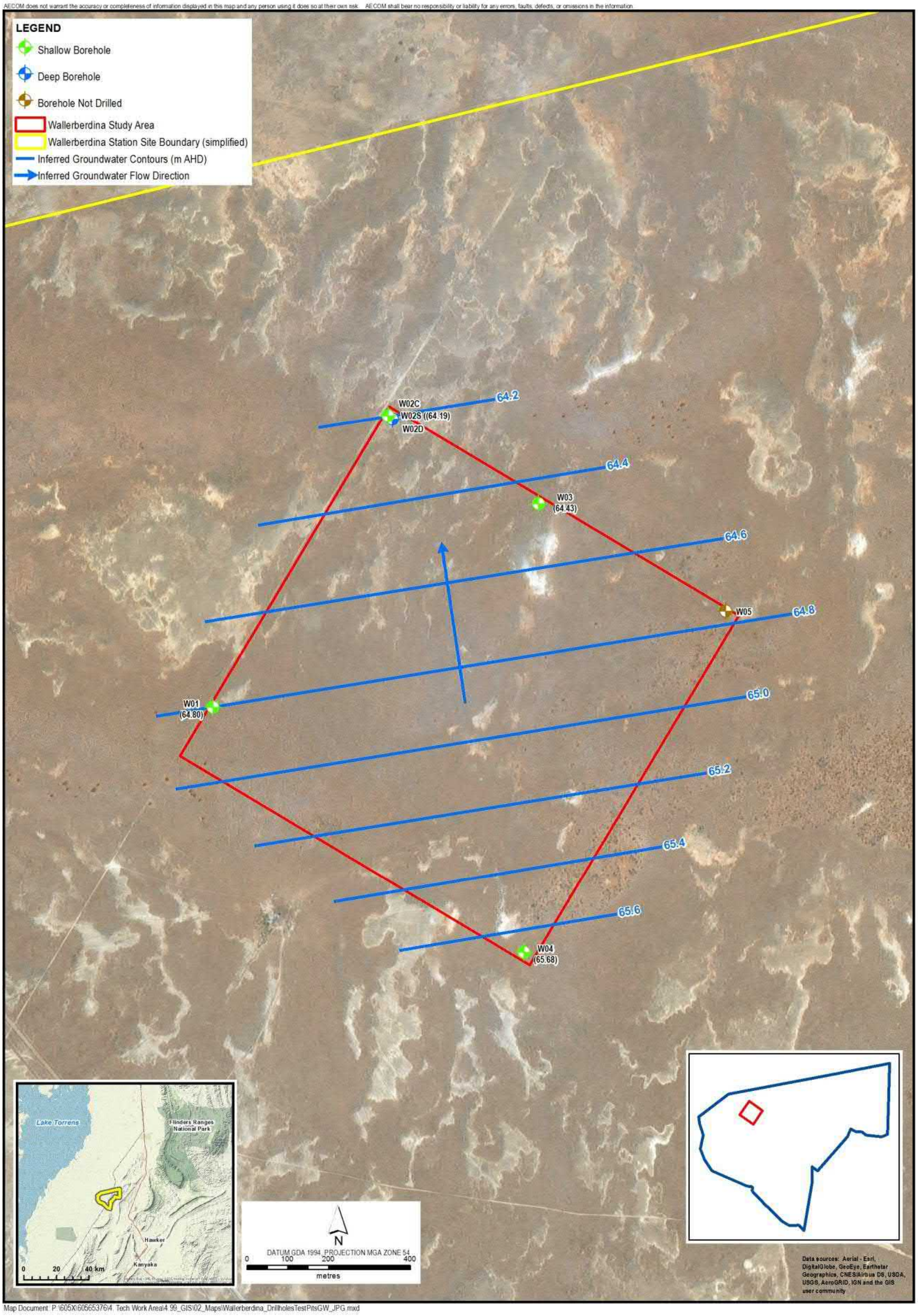
The inferred groundwater contour map across the site based on the above data is shown as Figure 35**.** The inferred direction of horizontal groundwater flow in the watertable aquifer is to the north-north-west at a hydraulic gradient of around 0.001. The direction of flow confirms the expected ultimate discharge point for the groundwater flowing below the site is Lake Torrens, around 25 km to the north west of the site (at the closest point).

Groundwater flow is largely dependent on both the pressure gradient (hydraulic gradient) and the conductive property (hydraulic conductivity) of the transiting material (usually and aquifer). The migration of water through an aquifer is dependent on the coefficient of permeability of an aquifer and a low hydraulic gradient within the aquifer or between aquifers. The rate of movement will therefore depend on the relative orders of magnitude of the above properties. In an aquifer of comparable hydraulic conductivity, an hydraulic gradient of 1.0, that is one meter drop in hydraulic head per meter horizontal (or vertical) distance is considered very high, and the relative migration of groundwater would be high, compared to an almost flat gradient of 0.0001 (i.e. a 1 meter loss in hydraulic head per 10,000 meters or 10 km of flow-path distance) is considered very low and would represent a regional groundwater flow pattern. The inferred horizontal hydraulic gradient on this site at 0.001 is an order of magnitude between the two, neither high nor very low. In terms of assessing this site as having a low or very low hydraulic gradient, it can be considered that in relative terms from the perspective of groundwater migration, an hydraulic gradient of a lower order or orders of magnitude would be preferable.

There appears to be an upward vertical hydraulic gradient of around 0.1 m over a vertical distance of around 20 m between the conglomerate aquifer (W02C) and the overlying alluvium watertable aquifer (W02S). This equates to a vertical hydraulic gradient of 0.005.

Groundwater within W02D was found to stabilise around at around 175 metres below top of casing (around -90 mAHD as of 1 June 2018, see Appendix D). This level is likely to be unrepresentative of the piezometric surface due to the collapsed bottom section of the hole below the casing. A substantial thickness of interbedded claystone and mudstone inferred to comprise the Neuroodla Formation overlies the carbonaceous sands and sandstone inferred to represent the Cotabena Formation and the connectivity between shallower water bearing units and the deeper zone is not well understood. Corrective work may be required to restore deep aquifer water-level data to this hole

Figure 35 Interpreted Groundwater Contours and Inferred Flow Direction 23/05/18 – Watertable Aquifer Wallerberdina Station



A review of nearby registered groundwater bores from the South Australian WaterConnect database shows a number of bores within a 5 km radius of the site. Figure 36 below shows bores registered for the purpose of stock watering and a reported operational status. The inferred direction of groundwater flow from site derived groundwater level data suggests watertable groundwater flow is to the north-north-west. While there are several registered operating stock watering bores reported within 5 km of the site, several located to the north-west or north east of the site and are sited lateral to the direction of groundwater flow. There are a number of registered operational stock watering bores located in the down hydraulic gradient direction of the site, Bores 6534-5, 6534-10 and 6523-12 at distances of approximately 17 km, 12 km and 20 km respectively.

Figure 36 WaterConnect registered bore information and inferred watertable aquifer flow direction (23/05/18)

Groundwater Sampling and Analysis

Groundwater sampling was undertaken by trained AECOM field staff in general accordance with AECOM standard procedures which have been developed with reference to the following guidance documents:

- AS NZS 5667.1 – 1998: Water Quality - Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples;
- AS NZS 5667.11 -1998: Water Quality - Sampling - Guidance on sampling of groundwaters;
- EPA Victoria, 2000, A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Wastes, Publication 441, March 2000;
- EPA Victoria, 2000, Groundwater Sampling Guidelines, Publication 669, April 2000;
- EPA Victoria, 2006, Hydrogeological Assessment (Groundwater Quality) Guidelines, Publication 668, September 2006;
- EPA, South Australia, 2007, Regulatory monitoring and testing *Groundwater sampling*, June 2007; and
- NEPC, 2009. National Environmental Protection (Assessment of site contamination) Measure. Schedule B (2): Guideline on data collection, sample design and reporting. National Environment Protection Council, Canberra.

Given reporting dates and the extension of the drilling program past initial estimates, it was assessed that grab sampling of groundwater using a disposable bailer soon after development would provide indicative water chemistry information suitable for inclusion in this technical report.

Following development, groundwater bores were sampled using disposable bailers. The aim was to collect groundwater field chemistry data during the sampling round and compare it with development records to provide evidence of stabilised conditions indicative of native groundwater.

Field parameters (Dissolved Oxygen, Electrical Conductivity, pH, Redox Potential and Temperature) were recorded on-site at the time of groundwater sample collection.

Appendix D provides the sampling records and includes a table summarising the field chemistry parameters at each bore prior to collecting the sample. Well development records are also included for comparison showing that grab sample field chemistry was comparable to that of the stabilised conditions observed at the end of the well development phase.

Groundwater samples and Quality Assurance/Quality Control (QA/QC) samples (equipment rinse blanks) were sent by courier, under Chain of Custody protocols (COC), to the primary laboratory (ALS Melbourne). An inter-lab field duplicate was collected to represent reporting precision for sampling conducted on the 1 June 2018 and was sent by courier to the secondary laboratory (ALS Sydney). No trip blanks were collected as the analytical program did not extend to volatile organic compounds.

Quality assurance and control measures were incorporated into the groundwater sampling and analysis works to ensure that the specified data quality objectives could be achieved and to demonstrate accuracy, precision, comparability, representativeness and completeness with regard to the data generated. The data validation guidelines adopted by AECOM provide a consistent approach for the evaluation of analytical data. These guidelines are based upon data validation guidance documents published by the United States Environmental Protection Agency's contract Laboratory Program (US EPA 2017)[14] and the NEPM (National Environment Protection Council (NEPC, 1999))[15]. The process involves the checking of analytical procedure compliance and an assessment of the

[14] US EPA (2017) Superfund Contract Laboratory Program National Functional Guidelines for Data Review, https://www.epa.gov/clp/superfund-clp-national-functional-guidelines-data-review

[15] NEPC (1999) National Environment Protection (Assessment of Site Contamination) Measure 1999, National Environment Protection Council, amended 2013

accuracy and precision of analytical data form a range of QA/QC measures, generated from sampling and analytical programs.

Specific elements that have been checked and assessed for this project are:

- A comparison of field data to laboratory data;
- Preservation and storage of samples upon collection and during transport to the laboratory;
- Sample holding times;
- Use of appropriate analytical and field sampling procedures;
- Required Limits Of Reporting (LORs);
- Frequency of conducting quality control measurements;
- Rinsate blank results;
- Laboratory blank results;
- Field duplicate and triplicate results;
- Laboratory duplicate results;
- Matrix spike results;
- Surrogates spike results; and
- The occurrence of apparently unusual or anomalous results, e.g. laboratory results that appear to be inconsistent with field observations or measurements.

The data validation process identified no major quality assurance/quality control issues in the field or laboratory datasets that could have a material implication to decision-making on the project.

Available laboratory reports and a tabulated summary of groundwater chemistry including a QA/QC assessment is provided in Appendix D.

The relative potential for use of groundwater at the site (raw, untreated condition) is summarized below with several major chemical parameters compared against national quality guidelines (NHMRC 2011 Drinking Water Guidelines and ANZECC 2000 Fresh and Marine Water Quality Guidelines). The selection of parameters is not the full suite analysed however the relative suitability of the groundwater for the major potential beneficial uses can be established from the selected sub-set.

Table 41 Groundwater Quality vs National Guidelines for Beneficial Uses of Water – Selected Analytes: Wallerberdina

		National Quality Guideline					Laboratory Reported Groundwater Quality (by borehole)					
	Analyte	**1**	**2**	**3**	**4**	**5**	**W01**	**W02S**	**W02C**	**W02D**	**W03**	**W04**
Major Parameters	**TDS***	1,200	3,000 to 13,000	400 to 7,800	65 to 3,250	1,000	2,800	3,300	3,490	22,000	3,300	3,250
	pH	6.5 to 8.5	-	-	6.5 to 9.0	5.0 to 9.0	8.1	7.9	7.9	7.1	7.9	8.0
	SO_4	250	2,000	-	-	400	603	715	664	141	688	688
	Cl	5.0	-	40 to 700	-	400	1,030	1,310	1,330	10,700	1,320	1,270
Metals	**Fe**	0.3	-	0.2	-	0.3	3.7	11.7	0.3	308	37.9	8.8
	As	0.01	0.5 to 5.0	0.1	0.013 to 0.024	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Hg	0.001	0.002	0.002	0.0006	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nutrient	**NO_3****	50	400	-	0.7	10	2.7	1.1	1.6	0.4	1.4	1.5

Number Codes to Beneficial Use Guidelines

1 – Drinking Water (Raw: Acceptable) : NHMRC (2011)

2 – Agriculture (Stock watering): ANZECC (2000)

3 – Agriculture (Irrigation) : ANZECC (2000)

4 – Maintenance of Freshwater Ecology: ANZECC (2000)

5 – Primary Contact Recreation: ANZECC (2000)

Notes –

All units expressed as mg/L

* - laboratory reported units as electrical conductivity (EC) converted to total dissolved solids (mg/L) = EC * 0.65

** - laboratory reported NO_3 as N concentrations are unit converted to NO_3 as NO_3 where 1 mg/l NO_3 as N = 4.43 mg/l NO_3 as NO_3

SO_4 – sulphate, Cl – chloride, Fe – iron, As – arsenic, Hg – mercury, NO_3 - nitrate

In summary, and based on data collected in the field, the groundwater in the watertable aquifer and conglomerate is of neutral to slightly alkaline pH and predominantly mildly brackish (<3,500 mg/L as TDS), with the salinity reported in most bores indicating it would be suitable for most consumptive and recreational beneficial uses however some desalinisation would be required for drinking water applications. It is noted that the conglomerate aquifer appears to be very similar in water chemistry to that of the adjacent shallow watertable aquifer (at least at the W02 location) and coupled with the very similar groundwater elevations at W02C and W02S indicates interaction between these water bearing zones. The slight upward vertical hydraulic gradient between W02C (64.27 mAHD) and W02S (64.19 mAHD) suggests that the watertable aquifer in this portion of the site may be partially recharged by the conglomerate aquifer.

The deeper water bearing zone intersected by W02D is of neutral pH and significantly more saline (>20,000 mg/L TDS) than the watertable aquifer beneath the site. Although not summarised in the above table, the groundwater chemistry from the deep aquifer in borehole W02D is higher in some dissolved metals, total manganese and iron likely reflecting the different source host aquifer chemistry.

Additional Field Reconnaissance

Existing Bore and Creek Survey

Field reconnaissance data collected during the drilling program duration is summarised in Table 42.

A reconnaissance survey of existing groundwater bores was completed on Wallerberdina Station and surrounding properties on the 21, 23 and 24 of April 2018 concurrently with the drilling program. Key tasks of the survey were to measure the standing water level (SWL), bore condition & construction and topography. Where practicable a grab sample was collected and water quality parameters were recorded.

A total of 12 existing bore locations on three properties were visited. Coordinates from the WaterConnect database were used to locate the bores using a hand held GPS. Five bores could not be located having either become obsolete of destroyed.

Water quality parameters were assessed from grab samples where practicable using a smart troll meter to give dissolved oxygen, temperature, redox, EC, and TDS. Several bores had pump infrastructure in place and SWL and/or grab samples could not be collected.

The standing water level (SWL) was able to be measured at six bores. SWL ranged from 29.34 m below top of casing (m btoc) at 6534-360 located within the Wallerberdina Station site to 2.364 m btoc at Murrays Bore (6534-73) located on the foothills of the ranges to the east, adjacent a drainage line.

These levels showed some variation to those recorded during the initial site visit by AECOM in February 2018 (see Appendix D**)** with the water level at Murrays Bore being approximately 0.7 m lower in April suggesting seasonal fluctuations in groundwater along creek lines are likely to be significant.

In addition to the existing bore survey, flow rates and field chemistry was also recorded for surface water flowing at Hookina Springs and Hookina Waterhole. Anecdotal evidence from the VYAC escorts suggested changed conditions at these locations over the duration of the drilling program (commenced 17 April 2018 and completed 1 June 2018) with water levels and flow rates observed to have increased at the time of recording (26 May 2018), possibly due to rainfall experienced in the area on the 3 May 2018. Surface flow at both locations was estimated at 1.5 L/s which is significantly less than 20 L/s documented by Barnett et al (2015) at the Springs.

It is noted that the field recorded electrical conductivity (EC) readings for the surface water at the Springs and Waterhole (~4,000 µS/cm) were slightly lower than the range recorded for shallow bores on site (field EC ~4,300 to ~5,700 µS/cm) and for the conglomerate bore (~6,100 µS/cm). In general, shallow groundwater beneath the site was observed to be less saline than in bores surveyed in the surrounding area.

Groundwater intersected by W02D was significantly saltier (EC~33,400 µS/cm) than shallower groundwater bearing zones (watertable and conglomerate).

Table 42 Field reconnaissance information - April to May 2018

Bore ID / Location	Local Name	Date	Coordinates (GPS)	Topography	Access & Permissions	Head Elevation	Construction	Head Works	SWL (mbtoc)	Total Depth (m btoc)	Dip Meter Water Quality	Bailer Water Quality	Comments
6534-24	West Yallala	21/04/2018	233460 6492593	Flat lying, sandy.	Wallerberdina Stn	0 m agl	Steel - rusting badly.	Steel, flush with ground surface (snapped off).	23.93	27.05 mbtoc	EC = 4707 uS/cm Temp = 24.6 Deg	EC = 6675.3 uS/cm TDS = 3989 ppm pH = 8.22 Redox = 146.1 mV DO = 3.30 ppm	Total depth likely deeper. Steel fragments fallen into bore casing suspected. Measured as dry on 21/02/18 by AECOM possibly caught on debris within bore.
6534-360	East Yallala	21/04/2018	235780 6491508	Flat lying, bare sandy soil, no vegetation.	Wallerberdina Stn	0.53m agl	PVC 150mm	PVC stickup only	29.345	42.45	EC = 6923 uS/cm Temp = 24.5 Deg	NA	No bailer sample collected. Pump in way.
6534-73	Murrays Bore	21/04/2018	241258 6493702	Sloping with rocky ground	Wallerberdina Stn	0.73m agl	PVC 140mm	PVC stickup in cemented pad	2.364	NA	EC = 5510 uS/cm Temp = 27.5 Deg	EC = 6792.2 uS/cm TDS = 4386.8 ppm pH = 7.1 Redox = 102.3 mV DO = 2.46 ppm Temp = 25.7	Adjecent to dry creek with some soaks visible where animals obtain water. Shallower SWL measured in 21/02/18 (1.6 mbtoc) with total depth of 39 m btoc.
6534-22	Home Bore	21/04/2018	229347 6494359	Sandy, located ontop of low dunes near Cotabena Outhouse.	Cotabena Stn	0.18m agl	PVC 140mm with steel outer layer in head works.	PVC and steel	NA	NA	NA	EC = 10863.3 uS/cm TDS = 7002.5 ppm pH = 6.95 Redox = 234.7 mV DO = 6.45 ppm Temp = 25.5	Headworks sealed with pump installed. Turned on pump, allowed to flush then grab sample collected.
6534-23		24/04/2018	see govt dataset	Flat flood plain with flood debris evident.	Wallerberdina Stn	NA	NA	NA	NA	NA	NA	NA	No bore located at govt coordinates. Landholder said he was not aware of a bore at this location.
6534-237		24/04/2018	see govt dataset	Flat flood plain with flood debris evident.	Wallerberdina Stn	NA	NA	NA	NA	NA	NA	NA	No bore located at govt coordinates. Landholder said he was not aware of a bore at this location.
6534-21		21/04/2018	see govt dataset	Flat and sandy.	Cotabena Stn	NA	NA	NA	NA	NA	NA	NA	No bore located at govt coordinates. Likely to eb obselete/destroyed given date of installation.
6534-269	Big Bore	21/04/2018	226918 6493557	Flat and sandy.	Cotabena Stn	0.12m agl	Steel casing 140mm	0.12m steel casing stickup in concrete pad.	16.44	NA	EC = 10860 uS/cm Temp = 23.13 Deg	NA	No total depth or bailer sample due to pump infrastructure
6534-240		24/04/2018	NA	NA	Morelana Stn	NA	NA	NA	NA	NA	NA	NA	Could not locate
6534-19		24/04/2018	NA	NA	Morelana Stn	NA	NA	NA	NA	NA	NA	NA	No bore located at govt coordinates. Likely an obselete bore.
6534-324		24/04/2018	235903 6498937	Flat lying, no vegetation, sandy soil.	Morelana Stn	0.66m agl	PVC (130mm) with steel outer in head works.	Steel casing in concrete pad.	18.36	NA		EC = 9081.2 uS/cm TDS = 5814.7 ppm pH = NA Redox = 246.7 mV DO = 7.4 ppm Temp = 25.7	Clear witth slight organic odour. Pump in place so could not get total depth.
6534-287		24/04/2018	Not located	NA	Morelana Stn	NA	NA	NA	NA	NA	NA	NA	NA
Unknown	4 mile	23/04/2018	225937 6497912	low sand dunes, partially vegetated.	Cotabena Stn	0.7m agl			11.85	NA	EC = 6830 uS/cm Temp = 24.5 Deg	NA	Pump in place so no bailer or total depth obtained.
Hookina Waterhole		26/05/2018	238160 6485554	Terraced conglomerate outcrop, reeds and flowing water	VYAC escort	NA	NA	NA	NA	NA		EC = 3818 uS/cm pH = 8.13 Redox = 38.8 mV DO = 8.56 ppm Temp = 16.84	Water flowing between upper and lower level of conglomerate cascade, flow rate estimated at 1.5 L/s. VYAC observation that flow had increased since start of drilling program, possibly from rain event on 3/05/18.
Hookina Springs		26/05/2018	239653 6482120	Occassional conglomerate outcrop, densely vegetated, mainly reeds.	VYAC escort	NA	NA	NA	NA	NA		EC = 3932 uS/cm pH = 7.94 Redox = 32.8 mV DO = 7.65 ppm Temp = 17.94	Water flowing, flow rate estimated at 1.6 L/s. VYAC observation that flow had increased since start of drilling program, possibly from rain event on 3/05/18.

3.1.2 Assessment Against Criteria

The assessment criteria for geological, hydrogeological, geochemical, soil and geotechnical characteristics of the site are tabulated in Section 3.1.1.1. Data collected during the recent field investigations has allowed AECOM to make an assessment against the criteria/ preferred site characteristic.

3.1.2.1 Objective: Infrastructure Foundation Stability

Objective: Infrastructure Foundation Stability

Characteristic criteria: Liquefaction potential, collapsing or expansive soils, slope instability, subsidence due to ground features, long-term settlement

Preferred Characteristic: Relatively flat topography

The site exhibits a relatively flat topography sloping gradually from east to west, with localised undulating ground surfaces observed across the site due to the low angle sand ridges and dune spreads. Generally, this was consistent with the findings of desktop assessment. Based on the site topography and observations, the site is considered unlikely to be constrained by slope instability.

Preferred Characteristic: Watertable at depth (>10 m)

Water table of depths exceed 20 m across the site

Preferred Characteristic: Cohesive soil profile

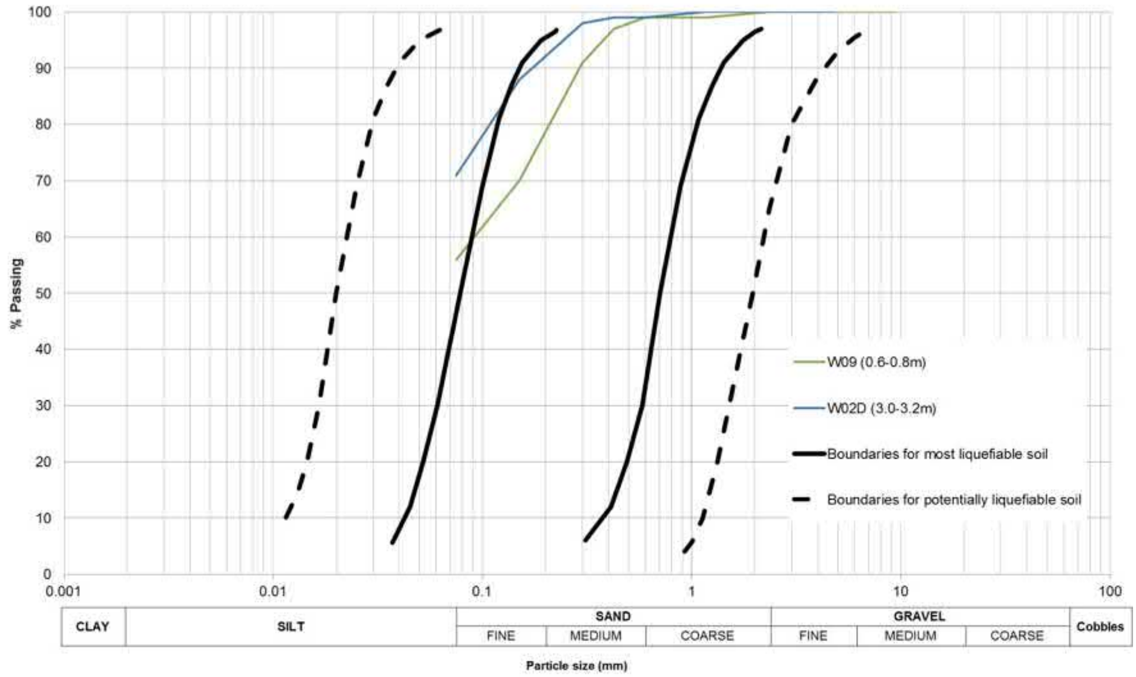
Liquefaction

Liquefiable soils create a significant hazard for infrastructure during the seismic events. Liquefaction refers to the significant loss of strength and stiffness resulting from the generation of excess pore water pressure in saturated, predominantly cohesionless soils such as sand and gravel. IAEA Safety Guide No. NS-G-3.6 provides a list of evaluation criteria to assess liquefaction potential. Some of the key conditions for liquefaction to occur include:

- The soil is saturated (i.e. below the water table);
- The soil is predominantly coarse grained;
- The soil is loose (relative density less than about 40 percent); and
- The ground motion is sufficiently strong.

One of the site characterisation measurements commonly used for evaluation of liquefaction potential includes characterisation of grain size distribution. It has been long recognised that saturated sands, silty sands and gravelly sands are susceptible to liquefaction (Fell, et al., 2005). Figure 37 shows the boundaries suggested in 1985 by USNRC with particle size distribution of tested materials.

Figure 37 Particle Size Distribution of Tested Materials



Based on above figure, most of the tested site materials are not liquefiable soil. The site investigation identified deep groundwater levels (>20 m depth), and soil material that was predominantly cohesive materials with generally high DCP and SPT indicating a dense conditions. Therefore, it is unlikely that the soils encountered onsite would become liquefied during an earthquake event.

Collapsing or Expansive Soils

Collapsing soils are generally found in semi-arid regions. These soils are commonly associated with loess and other fine grained aeolian soils. Internal soil support, which is considered to provide temporary strength, is derived from a number of sources. Included are capillary tension, which provides temporary strength in partially saturated fine-grained cohesionless soils; cementing agents, which may include iron oxide, calcium carbonate, or clay in the clay welding, of grains; and other agents, which include silt bonds, clay bonds, and clay bridges (Hunt, 2005). These soils are liable to collapse upon wetting with resulting settlement.

Based on the soil profile encountered, generally the top 15 m depth of subsurface profile consisted of interbedded of clay, silt, sand and gravel of alluvium origin. This suggests that the site is unlikely to have collapsing soils present. Some parts of the site include sand ridges and dune spreads but high DCP values were encountered throughout these areas.

Various empirical methods can be used for the identification of collapsing soil. Table 43 shows the criteria for identification of collapsible soils using physical properties developed by several authors.

Table 43 Criteria for Identification of Collapsible Soils

Author	Criteria	Conditions to Identify Collapse	Soil Conditions
Priklonskij (1952)	$Kd = \frac{LL - w_0}{LL - PL}$	Kd < 0	Highly collapsible
		1 > Kd > 0	Collapsible
		Kd > 1	Non-collapsible
Kassif & Henkin (1967)	$K = \gamma_d \times w_0$	K < 15	Collapsible

Notes: LL – Liquid Limit; W_0 – Moisture Content; PL – Plastic Limit; γ_d – dry density

Calculations and classification to determine the collapsible behaviour of the tested soils using indicated criteria in Table 43 are presented in Table 44. Based on empirical assessment, the materials found onsite were classified as non-collapsible soils.

Table 44 Results of Collapse Identification and Classification based on the Physical Parameters

Sample	Parameter		Classification	
	Kd	K	Kd	K
W09 (0.6-0.8m)	1.7	24*	Non-collapsible	Non-collapsible
W02D (3.0-3.2m)	1.6	-	Non-collapsible	-

Notes: Kd – Priklonskij (1952); K – Kassif & Henkin (1967); * assumed the material compacted to 95% standard compaction & at optimum moisture content.

Expansive soils are also generally found in semi-arid region. The soils undergo volume changes upon wetting and drying, thereby causing ground heave and settlement problems.

Based on site investigation findings, cohesive materials (clay or silt) were found throughout the soil profile. These materials were generally in a dry condition and groundwater levels were generally found at a deeper depth (>20 m depth). As a result, it is not expected that the cohesive materials will experience wetting and drying effects (shrinking or swelling), due to the groundwater depth and the arid low rainfall environment.

Many tests and empirical methods have been developed to assess shrink-swell potential of soils. Indirect methods involve the use of soil properties and classification schemes to estimate shrink-swell potential is commonly used in site characterisation stage. Table 45 shows the criteria for identification of expansive soils using physical properties developed by several authors.

Table 45 Criteria for Identification of Expansive Soils

Author	Criteria	Degree of Expansion
Daksanamurthy and Raman (1973) using liquid limit	LL > 70	Very high
	50 – 70	High
	35 – 50	Medium
	20 – 35	Low
Holtz and Gibbs (1956) using plasticity index	PI > 35	Very high
	25 – 35	High
	18 – 25	Medium
	PI < 18	Low
Public Works Department (1977); Mills et al. (1980); Hicks (2007) using linear shrinkage	LS >22	Very high
	17 – 22	High
	12 – 17	Medium
	LS < 12	Low

Notes: LL – Liquid Limit; PI – Plasticity Index; LS – Linear Shrinkage

Figure 38 presents the plasticity chart for the soils tested from site. Classification to determine the swell potential of the tested soils using indicated criterial in Table 45 are presented in Table 46. Based on empirical assessment, the materials found onsite were classified as low swell potential.

Figure 38 Plasticity Chart for Tested Materials

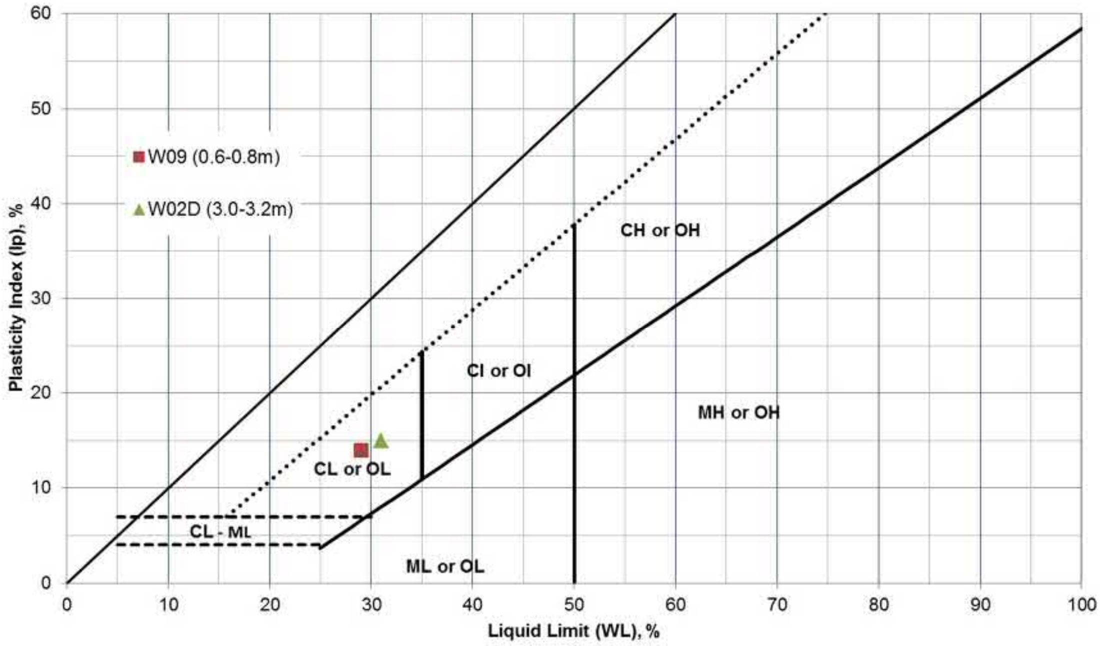


Table 46 Results of Swell Potential Classification based on the Physical Parameters

Sample	Swell Potential Classification		
	[1]	[2]	[3]
W09 (0.6-0.8m)	Low	Low	Low
W02D (3.0-3.2m)	Low	Low	Low

Notes: [1] Daksanamurthy and Raman (1973); [2] Holtz and Gibbs (1956); [3] Public Works Department (1977); Mills et al. (1980); Hicks (2007)

Scour and Erosion Processes

Tunnelling susceptibility refers to the likelihood of tunnels forming in a body of a soil as a consequence of water flow through the soil (Hazelton & Murphy, 2007). A soil that is easily detached and transported by water flow usually means that soil is highly dispersible material.

Some localised scour and erosion was observed in generally low lying areas with low vegetation growth. The very gentle slope of the site and low rainfall means the site is unlikely to have scour and erosion processes.

The Emerson Crumb test identifies dispersive soil behaviour (AS 1289.3.8.1 “Determination of Emerson Class Number of a Soil”). Test results indicate the site soils are class 4 which indicates a soil with non-dispersion with presence of calcium carbonate (calcite) or calcium sulfate (gypsum) within the soil.

Long-term Settlement and Subsidence

Settlement is one of the important factors associated with deformation of foundations supporting the buildings or infrastructure. Long term settlement is generally associated with soft clay deposits, compressible soils or deep fill.

Based on the site investigation findings, it is considered unlikely for long term settlement to occur as a result of site soils as no fill was observed and the natural soils encountered were in a dense and dry condition. Short-term and elastic settlement are anticipated which can be mitigated through engineering design and construction techniques.

Ground subsidence generally arises from natural occurrences or as a result of human activities that change an environmental condition. The site is generally located in an area of with undisturbed ground with minimal amount of surface disturbances (limited to unsealed access road along the boundary of the site.

No signs of ground subsidence were observed and no natural features such as caverns and human-made features such as underground mines that will contribute to the ground subsidence were identified.

Based on the observations, the site is considered unlikely to be subject to ground subsidence due to underground features.

Objective: Soil Quality

Characteristic Criteria: Detrimental soil quality properties that may lead to degradation and hydraulic properties that may increase the severity of flooding or erosion

Preferred Characteristic: Soils that are not saline, sodic, dispersive, do not have an aggressive pH, nor prone are waterlogging

Intrusive investigations were undertaken to describe soil profiles present at a number of locations across the site. Laboratory testing of soils sampled at discrete intervals from surface to the subsurface up to around 2.5 m depth was undertaken at a few investigation locations to identify the nature and presence of any detrimental soil quality properties.

The presence of clayey soil types immediately beneath the surface soil across most of the site is inferred likely to be relatively poorly-draining. From around 2 m depth the soils are slightly to moderately saline and sodic to strongly sodic within the underlying clays. The clay subsurface is indicated to be potentially dispersive in nature. The soil profile is neither aggressive in acidity or alkalinity.

Strongly sodic and/ or slightly to moderately saline soils, if present in the subsurface and exposed or used as fill for construction, are likely to lead to land degradation from one or more processes including surface crusting/ hardening, dispersion of clay fines, and restrictions on the healthy growth of plants. Strongly sodic clayey soils are also highly susceptible to severe gully erosion and being poorly drained, have the potential to increase the ponding of surface water.

Objective: Groundwater Supply

Characteristic Criteria: Current and potential beneficial uses of groundwater

Preferred Characteristic: Presence of a pumpable groundwater supply aquifer

Yield potential of sand aquifers below or including the conglomerate aquifer is inferred likely to exceed the required minimum level of 175 m^3/d for a pumpable supply aquifer.

Preferred Characteristic: Potable to brackish salinity groundwater

Groundwater quality in watertable and conglomerate aquifers is brackish salinity.

Objective: Potential for Subsurface Solute Transport

Characteristic Criteria: Potential for vertical migration of solutes and vertical connectivity between groundwater horizons

Preferred Characteristic: Presence of thick, impermeable to low permeability aquitards

Interbedded sand/silt/clay and gravel horizons comprising the alluvium overlie interbedded sandstone/mudstone/claystone horizons of the inferred Neuroodla Formation are known regionally to form an aquitard to the underlying Cotabena Formation carbonaceous sands/sandstone. The degree of interaction between multiple water bearing zones is currently unknown.

Preferred Characteristic; Lack of perched watertable

A perched watertable was not identified during drilling program, however, the presence of shallow gravelly bands underlain by less permeable material at some locations provide the potential for seasonal perched horizons.

Preferred Characteristic: Deep (>10m) regional watertable & piezometric surfaces

Water table and deep aquifer piezometric surfaces are reported at depths exceeding 20 m

Preferred Characteristic: Few or widely (vertical) separated aquifers

Numerous aquifers were identified. The degree of vertical separation requires further assessment.

Preferred Characteristic: Presence of subsurface material with chemical attenuation properties.

The presence of clay, low salinity and moderately-alkaline pH are favourable soil properties for attenuation. Relatively high (although variable) levels of exchangeable sodium with depth are, however, likely to lead to a detrimental impact on the capacity of the soil for attenuation, as may be observed in horizons with generally low cation exchange capacities. Attenuation studies, developing distribution coefficients and cation exchange/surface sorption models, will provide a greater level of detail.

Preferred Characteristic: Low horizontal hydraulic gradient

A moderate regional horizontal hydraulic gradient value of around 0.001 is present in the water table aquifer and while this in not considered a high gradient, a lower gradient would be preferable.

Preferred Characteristic: No, few or distant third-party groundwater receptors

Groundwater use for stock watering is evident within a 10 km radius of the site with either the watertable aquifer or conglomerate aquifer (or both) likely to be intersected by stock bores (based on anecdotal information only). No registered bores are located nearby in the inferred down hydraulic gradient direction of the site. Hookina Creek is inferred to be located up and cross hydraulic gradient from the site.

The above findings are summarised in the table below.

Table 47 Summary of Findings: Site Characteristic Criteria Assessment

Assessment Objective	Site Characteristic Criteria	Preferred Characteristic	Assessment Against Preferred Characteristic
Infrastructure Foundation Stability	Presence of collapsing or expansive soils	Relatively flat topography Cohesive soil profile Watertable at depth (>10m)	Present
	Slope instability		
	Subsidence due to ground features		
	Long-term settlement		
	Scour and erosion processes		
	Potential of soil liquefaction		
	Presence of collapsing or expansive soils		
Soil Quality	Detrimental soil quality properties that may lead to degradation and hydraulic properties that may increase the severity of flooding or erosion	Soils that are not saline, sodic, dispersive, do not have an aggressive pH, nor prone are waterlogging	The subsurface clayey soils, if exposed may restrict healthy plant growth, be prone to crusting, waterlogging, and dispersion of clay fines as they are moderately saline and strongly sodic

Assessment Objective	Site Characteristic Criteria	Preferred Characteristic	Assessment Against Preferred Characteristic
Ground Water Supply	Current of potential beneficial uses of groundwater	Presence of a pumpable groundwater supply aquifer (Yield min. 175 m^3/d or 2 L/s)	Present
		Water Quality - Potable to brackish salinity groundwater*	Present
Potential for Subsurface Solute Transport	Subsurface material with chemical attenuation properties	Subsurface with acid buffering capacity and surface sites for adsorption and ion exchange	Present (indicative)
	Depth to groundwater and vertical connectivity between groundwater horizons Potential for vertical migration of solutes through sediments or bedrock	Deep (>10m) regional watertable & piezometric surfaces	Present
		No perched watertable	Not observed, but potential at some locations
		Few or widely (vertical) separated aquifers	Absent
		Thick, impermeable to low permeability aquitards	Absent
	Potential for horizontal migration of solutes through saturated sediments or bedrock	Low horizontal hydraulic gradient	Absent
		No, few or distant third-party groundwater users/receptors	Present

3.1.3 Design Issues and Mitigation Measures

Geology, Hydrogeology and Geochemistry

A groundwater monitoring borehole network, targeting all identified aquifers below the site at numerous locations both within and outside the waste storage NRWMF boundary is required to establish baseline conditions prior to construction.

Soils and Geotechnical

Detrimental Soil Quality Properties

The layout of the NRWMF, and the footings and civil design should have regard to the presence of surface and subsurface soils with detrimental chemical or hydraulic properties which, if unmanaged, could lead to environmental degradation or localised surface water ponding or flooding.

The clayey subsoils being poor draining, sodic and moderately saline in nature if excavated and used as general fill have the potential to be detrimental due to the potential high susceptibility to erosion, ponding of surface water due to a surface crust/ hardening, and the dispersion of clay fines within surface water.

Foundations

Foundation design for the NRWMF infrastructure should include the potential for large bearing pressures, dynamic loading and often strict tolerance on both total and differential settlements. In addition to this section, the Seismic section of this report should also be referred to for additional commentary on foundations.

The site is predominantly underlain by undifferentiated Quaternary Holocene-aged sediments. Generally, shallow foundations and deep foundations are the two common systems available to transfer the superstructure loads to the ground.

Shallow foundation design should be carried out in accordance with AS 2870 and pile foundations designed in accordance with AS2159, considering available site geotechnical information. Unsuitable materials may be treated by excavation and replaced with engineered compacted fill. Ground improvements may be necessary for subsurface materials found that are not capable of carrying the infrastructure loadings. Site preparation for the foundation should be carried out in accordance with AS3798. Subsurface wetting can significantly impact structures founded on shallow foundation. The foundation backfill or structural fill should be adequately compacted and have positive surface drainage to prevent water ponding. It should be noted that the geotechnical investigations conducted as part of this study were to characterise the site and further, detailed investigations will be required for design of structures and foundations should the NRWMF be further considered at this site.

Foundation design should also make reference to the seismic risks and design issues included in Section 3.3.

Earthworks/ Construction Materials

Construction of the NRWMF will require several construction materials including:

- General and select fill for bulk and detailed earthworks;
- Sub-base course and base course pavement materials;
- General fill and structural fill for the foundation systems;
- Concrete aggregates and sands.

A borrow source assessment should be completed for the preferred site. Detailed investigation will be required during subsequent phases of the project to confirm the construction material availability. It appears that the in-situ material at the site would only be suitable to be used as general bulk earthwork and most of the other construction materials (e.g. pavement and structural fill) would need to be imported from local quarry/borrow source. Re-use of site soils should consider the soil quality properties noted above.

General earthwork requirements are presented in the AS 3798-2007 “Guidelines on Earthworks for Commercial and Residential Development”. Topsoils or severely root-affected subsoil are unsuitable to support the proposed loadings or for incorporation in fill, and should be stripped off and removed to spoil. The base of any ground to be filled should be examined to ensure all deleterious and loose material is removed prior to placing and compacting engineered fill. General fill utilised on the site should comprise suitable materials free from organic soils, construction waste and other deleterious materials.

Excavatability

Based on the findings of the site investigation, it is anticipated that the soil within the proposed sites should be excavatable with standard earthmoving equipment without significant issues.

3.1.4 Data Gaps and Recommendations for Stage 2 Work Program

Geology, Hydrogeology and Geochemistry

The aim of any Stage 2 Field Program would be to build a robust Conceptual Site Model (CSM) which describes the relationships between potential sources of impacts, receptors and exposure pathways between those sources and receptors.

As outlined in the National Environment Protection (Assessment of Site Contamination) Measure Schedule B2 Site Characterisation (NEPC, 1999) a CSM is an essential part of all site assessments. The preliminary CSM is developed based on information gained from the desktop review and the planned site specific intrusive works. The initial CSM will be developed as part of the technical reporting stage of the works and will identify key data gaps. The CSM will be continually refined as additional information is acquired.

At the site characterisation stage, prior to any development of the site, identifying the complete and potential exposure pathways and potential receptors are the key objectives of the CSM development.

Works to fill remaining data gaps will be aimed at building confidence in the preliminary Conceptual Site Model.

It is envisaged that the Stage 2 field work will target collection of hydraulic data for the aquifer(s) identified from Stage 1, with an expanded hydraulic and water quality investigation of any potential deeper aquifers and aquitards identified below the watertable aquifer within the unconsolidated sequence at each site.

Key elements of the Stage 2 program will be developed to:

- Collect aquifer parameter information by:
  - Designing a pump test trial
  - Undertaking pump testing to provide hydraulic conductivity, transmissivity and storativity/specific storage characteristics.
- Better understand receptors by:
  - Undertaking a door knock of neighbouring properties to identify any unregistered groundwater use
  - Expand the original bore reconnaissance survey to include any unregistered bores to confirm that no users of the groundwater exist in the inferred down hydraulic gradient direction of the site
  - Expanded groundwater gauging event to include suitable bores (if any) outside the site to confirm regional groundwater flow direction in the watertable aquifer in addition to local flow direction indicated by the site monitoring network
  - Based on updated groundwater flow direction information, re-appraise the presence of down hydraulic gradient receptors (e.g. groundwater users and ecosystems) including potential for additional drilling which may include bores adjacent to the Hookina Creek at reaches close to the site and bores installed into shallower gravel horizons to assess whether seasonal perched water are present
  - Testing the watertable aquifer for the presence of stygofauna to confirm whether Groundwater Dependent Ecosystems exist beneath the site.
- Better understand exposure and migration pathways by:
  - Assessing whether potential pathways actually exist for example whether faults connect shallow and deeper water bearing zones by undertaking additional investigations such as;
    - 3D seismic across the entire site or extended seismic lines beyond the site,
    - Where faults have been inferred from the enhanced magnetic images, more reliable results will be obtained by the inclusion of detailed gravity data over the survey area,
    - Targeted drilling at faults and inferred intersecting fault planes if interconnection is considered likely given the balance of available site specific data,
    - Target and assess and confirm potential perched watertable conditions above the regional watertable.
    - Clean the bottom section of borehole W02D and install slotted casing to prevent future formation collapse and restore water-level data confidence.
  - Assessing the chemical attenuation potential of subsurface materials at the site by conducting specific studies involving a series of batch tests that could be used as inputs to model reactive transport and attenuation using industry-leading software such as

PHREEQC[19]. The model would also provide an understanding of the potential movement of ions in groundwater, especially where low pH environments may lead to increased mobility.

- Assessing migration and chemical fate and transport vertically through the vadose zone and laterally through the saturated zones using current versions of industry standard models e.g. MODFLOW[20] and MT3D to terminal discharge points.

Soils and Geotechnical

Additional targeted investigations and soil analytical testing should be undertaken within the footprint of the preferred layout of the NRWMF within the site (which will be influenced by a range of site characteristics including topography) to further inform the nature and presence of detrimental soil quality and hydraulic properties.

Additional detailed geotechnical site investigation is recommended for the selected site and should consider the proposed site layouts, structure loadings and coverage of the site.

Geotechnical in-situ and laboratory testing should be conducted with samples obtained by borehole drilling and test pitting. The interpretation of the laboratory data with the field data will provide inputs for the parameters for use in the engineering design.

[19] Parkhurst, D.L., and Appelo, C.A.J., 2013, Description of input and examples for PHREEQC version 3—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Techniques and Methods, book 6, chap. A43, 497 p

[20] MODFLOW is the U.S. Geological Survey's modular hydrologic model commonly used to simulate three-dimensional (3D) groundwater flow. The MT3D is a groundwater solute transport code also released by USGS which can accommodate flow terms calculated by MODFLOW packages.

3.2 Landform Stability

3.2.1 Methodology and Results

A desktop assessment of the geomorphology of the nominated study area ('the site') within the Wallerberdina Station site has been undertaken by Brizga Environmental with the objective of identifying and assessing key threats to long-term site stability.

3.2.1.1 Site Characteristic Criteria

The key geomorphological site suitability assessment criterion is to identify processes (including fluvial, aeolian, slope/ mass movement) with the potential to impact on long term site stability.

Assessment against this criterion has been employed via consideration of the following aspects:

- Landforms
- Drivers of geomorphological processes
- Key geomorphological processes with potential to impact on long term site stability.

3.2.1.2 Desktop Methods and Results

The characterisation methodology and data sources utilised are outlined below for aspects relevant to the assessment criteria.

Landforms

The landforms at each site were characterised based on:

- Published 1:250,000 topographic maps – to establish the regional context;
- Digital elevation models of each site prepared by AECOM based on detailed LiDAR survey;
- Published geological mapping (1:250,000);
- Aerial imagery (Google Earth); and
- Subsurface data from bores and test pits at the Wallerberdina site provided by AECOM;
- Relevant geomorphological literature as cited; and
- Assessments of other aspects of the subsurface environment undertaken by AECOM as part of the present study.

Underlying drivers of Geomorphological Processes

Underlying drivers of geomorphological processes include climate, tectonics and base level. Base level is the lowest level to which running water can flow and erode.

Rainfall interacts with site landforms to generate catchment runoff, streamflows and overbank flood flows as well as infiltration to soil water and groundwater, which in turn affect fluvial and slope processes. Rainsplash can also directly erode the ground surface. Wind is important for aeolian processes, including the formation and movement of dunes. Relevant climatic characteristics were identified based on literature as cited.

Information on surface water flows was obtained from the assessment of hydrology and flood risks undertaken by AECOM as part of the present study which included two-dimensional hydraulic modelling using the TUFLOW model.

Tectonics and seismicity were assessed based on relevant geomorphological literature and online historical earthquake data (Location SA Map Viewer http://location.sa.gov.au/). Geomorphological implications of seismic activity include:

- The effects of earthquake vibrations on landform stability – e.g. mass movement and liquefaction;
- Direct alteration of landforms, including vertical displacement (e.g. uplift or subsidence) or horizontal displacement (e.g. offsetting or rifting) of the land surface;

- Altering the relationship of land surfaces to sea level, with implications for the influence of coastal processes and base level;
- Secondary responses such as the incision of uplifted alluvial fans or deposition in areas of subsidence (Quigley et al. 2010).

Sea level and other coastal drivers are not examined in this report because the nominated site is situated inland well above present sea levels. However, over geological timescales, large changes in sea level are possible. For example, around 20,000 years ago, sea level was around 125 m below present (Lewis et al. 2012). By comparison, the elevation of the Wallberberdina site is approximately 95 m above present sea level. The Wallerberdina Station site drains to Lake Torrens (a terminal lake) rather than the sea, and in this instance, Lake Torrens defines the present base level for Hookina Creek.

Key Geomorphological Processes

Key geomorphological processes were identified based on:

- Inferences from landforms and geomorphological drivers; and
- Relevant geomorphological literature as cited.

The two-dimensional TUFLOW hydraulic modelling undertaken by AECOM was used to inform the assessment of fluvial geomorphological processes. This modelling was used to define the inundation regime of the Wallerberdina site. A hydrological study by Hydrology and Risk Consultants was used to generate hydrographs for infrequent, rare and extreme flood events (HARC, 2018). A two-dimensional TUFLOW hydraulic model was used to determine flow depth, velocity and direction, shear stress and stream power across the Hookina Creek alluvial fan including the study site. The hydraulic modelling results are discussed below in the section on fluvial processes.

3.2.1.3 Field Methods and Results

A site inspection was carried out by geomorphologist Dr Sandra Brizga on 19 July 2018.

The site inspection confirmed evidence of dynamic geomorphological processes on the floodplain near Hookina Creek, including:

- relatively recent avulsion, indicated by a line of dead/ dying trees along a creek channel that bypasses a more active channel);
- a sand and gravel splay; and
- extensive flood debris (timber) along active floodplain flow paths.

The geomorphology of the site was observed to be consistent with less frequent inundation than the currently more active areas closer to the Hookina Creek channel, which is consistent with the hydraulic modelling outcomes.

Scattered rounded gravels, of likely fluvial origin, were observed to be present on the floodplain surface.

A clay pan was observed, which was associated with a minor topographic depression and minor erosion was evident at the edges of the clay pan associated with surface runoff.

The evidence of erosion in a low gradient area suggested that the soil may have a high susceptibility to erosion, which requires further assessment in the future.

3.2.2 Assessment Against Criteria

Geology and Landforms

Figure 19 shows the digital elevation model output from an acquired LiDAR (Light Detection And Ranging) airborne topographic survey. The Wallerberdina site is situated on the western piedmont of the Flinders Ranges in the Pirie-Torrens Basin (Bourne 1996). In particular, it is situated on the alluvial fan of Hookina Creek, a major stream flowing from the Flinders Ranges to Lake Torrens.

The discussion of geology and landforms is based on 1:250,000 Parachilna Map Sheet (SH54-13) supplemented by key notes from Reid and Preiss (1999). Figure 26 is based on the 2012 map sheet and provides detailed mapping of Cainozoic deposits and is more consistent with landforms observed from aerial imagery than earlier geological mapping.

The geology map indicates that the Wallerberdina study site is situated on Quaternary (Pleistocene to Holocene) alluvium associated with the alluvial fan of Hookina Creek. This formation consists of cobbles, gravel, sand silt and clay; red-brown and often poorly sorted. It includes consolidated and dissected terrace and distal fan deposits that may have incipient soil horizons, gibber spreads and gypseous materials (Reid and Preiss 1999).

The Hookina Creek alluvial fan extends from Hookina to Lake Torrens (Figure 26). At the head of the fan, where Hookina Creek emerges from the Flinders Ranges, a major distributary diverges to the north, joining up with Etowie Creek and then flowing to Lake Torrens. The main channel of Hookina Creek bifurcates into smaller distributary channels as it flows towards Lake Torrens, some of the distributaries ending in distal fan deposits.

Lake Torrens, a salty playa lake or salina, is situated approximately 25 km to the west of the site. Holocene aeolian quartz dune sand and sand spreads extend eastwards from Lake Torrens to the western edge of the site, overlying the downstream part of the Hookina Creek alluvial fan. Longitudinal (or seif) dunes are a prominent feature of the aeolian deposits. Bourne (1996) noted that deltaic deposition on the bed of Lake Torrens indicates that flood water and sediment from the larger streams, such as Hookina Creek, occasionally reaches the lake. It is likely that the alluvial and aeolian sediments are intercalated, with dry periods of aeolian processes being interrupted by episodic fluvial deposition during rare large flood events.

AECOM provided logs with information on subsurface conditions from six boreholes and six shallow test pits (see Figure 29 **and** Appendix D). The borehole data shows silt, clay and fine sand deposits with lenses of fluvial gravels as evident within the borelogs. The fluvial gravels include mudstone, sandstone, quartzite, shale and claystone, consistent with their source being rock formations in the Flinders Ranges. The test pit data show mainly sand and fines (clay and silt) with traces of gypsum. Some gravels were present, including at test pits W10 (2 m bgl) and W06 (1.4 m bgl). The gravel lenses are indicative of high energy flow conditions and past channel locations, indicating that the site has been subject to high energy flows consistent with the main stream channel or distributary flow paths. The age of each of the sediment layers is not been dated.

Drivers of Geomorphological Processes

Climate

The climate of the Wallerberdina site is semi-arid. AECOM provided Brizga Environmental with a summary of historical rainfall data for the Hawker Weather Station and climate change projections for this site, which indicate that:

- mean annual rainfall is 308.6 mm;
- climate projections indicate little change in mean annual rainfall in the 2030 and 2090 scenario but a small decrease in mean annual rainfall in the 2090 scenario; and
- climate change projections indicate that the intensity of heavy rainfall will increase.

The rainfall regime is highly variable, with prolonged dry periods occasionally punctuated by rare intense rainfall events. This is illustrated by the history of filling of Lake Torrens, which has filled only twice since European settlement in 1989 and 1878 (Bye et al. 1989). Haberlah et al (2010) highlighted the “interaction between dust storms and flooding rains”, reflecting alternating dry and wet periods.

Wind is also important from a geomorphological viewpoint, as it drives aeolian processes. The potential risks to the site from dune migration shall be further assessed in future by reviewing historical climate records of wind direction and speed across the seasons, and the potential assesment of the historical extent of dune fields from historical aerial photographs.

The climatic regime has two distinct elements from a geomorphological perspective. The first consists of long dry periods when there is no rainfall or streamflow (other than local spring-fed flows in the Flinders Ranges) and geomorphological processes are dominated by the effects of wind (e.g. dune movement, deflation of unvegetated surfaces, loess deposition), weathering processes. The second consists of infrequent large floods that disrupt the dry periods and drive fluvial processes such erosion and deposition in Hookina Creek, avulsion, floodplain scour and floodplain sedimentation.

Base Level

The maximum extent of Lake Torrens in flood is not known. Online searches have provided information about two historical flood events, 1989 and 1878 (Bye et al. 1989, Williams et al. 1998). Bye et al (1989) reported that average peak water level in Lake Torrens in 1989 was approximately 31.4 m AHD with an average depth of water in the lake of 1.4 m, but with oscillations in water level by up to 0.6 m due to wind-blown seiching. The reported elevation of the lake water level is significantly lower than the land elevations in the site (generally over 85 m).

Tectonics and Seismicity

AECOM has assessed seismic hazards which are discussed within the relevant section of this report. Liquefaction risks are addressed in the geological and geotechnical section of this report. The potential geomorphological implications of seismic and tectonic activity within an alluvial fan zone include stream channel avulsion in response to tilting of the fan surface, and instream erosion and/or deposition resulting from changes in the longitudinal profile of the stream channel.

Geomorphological Processes

The geomorphological evolution and Quaternary history of the valley fills and alluvial fans of the Flinders Ranges have been investigated in a number of previous studies, including by Bourne (1996), Quigley et al (2007) and extensive work by Williams and his co-workers (e.g. Haberlah et al. 2010). These studies reveal a dynamic landscape subject to significant changes associated with tectonic and climatic influences. Present-day processes alternate between extended dry periods, dominated by aeolian processes and weathering, and infrequent but large floods causing significant fluvial activity.

Fluvial

Fluvial geomorphological processes have major significance for the Wallerberdina site, which is situated on the Hookina Creek alluvial fan. The semiarid climate and highly variable rainfall regime mean that long periods of fluvial inactivity are punctuated by rare extreme events.

The two-dimensional hydraulic modelling results are consistent with geomorphological evidence that indicates that the Hookina Creek alluvial fan is active under the present climatic regime. The hydraulic modelling indicates that hydraulic loadings within the main channel of Hookina Creek are high, even in more frequent events such as the 1 in 50 year AEP flood event as well as in larger flood events, which is consistent with observations of historical erosion in the creek channel.

Hookina Creek Migration

The Wallerberdina site is situated approximately 3.5 km from Hookina Creek at the nearest point. Hookina Creek is subject to infrequent large floods that cause significant stream erosion. The site is downstream from where Hookina Creek emerges from a narrow valley in the Flinders Range onto the alluvial fan.

The two-dimensional hydraulic model prepared by AECOM results indicate high hydraulic loadings in the main channel of Hookina Creek, which is expected to lead bank erosion and channel migration in Hookina Creek. This may result in Hookina Creek migrating towards the study sites, possibly contributing to a stream breakout or avulsion into a distributary flow path.

Avulsion

As noted above, Hookina Creek has several distributaries, which are indicative of the creek being subject to changes in course by avulsion. Many Australian rivers and streams are subject to avulsions on alluvial fans and floodplains, and numerous palaeochannels provide extensive evidence of this process. Two historical avulsion events have been investigated in detail by the author – Tambo River at Bruthen (1890) and Thomson River near Heyfield (1952).

Avulsions typically occur in large floods, and tectonics may also be a contributory factor. The high degree of rainfall variability and seismic activity in the site increase the susceptibility of Hookina Creek to avulsion.

Geomorphological changes within the channel of Hookina Creek (e.g. channel blockages, bank washouts) may also contribute to the avulsion process.

The two-dimensional hydraulic modelling conducted by AECOM shows that Hookina Creek is hydraulically connected to the north-eastern distributary channel, and flows break out into distributary flow paths at several points along the alluvial fan. A breakout from Hookina Creek towards the Wallerberdina study site occurs in the 1 in 100 year annual exceedance probability (AEP) flow (Figure 39). More significant breakouts occur in larger flood events, at first from Hookina Creek (Figure 40) and then from the north-eastern distributary in the later stages of the event (Figure 41).

The pattern of flow breakouts from Hookina Creek is consistent with a tendency for the main stream to change course by avulsion, with the main flow shifting into a distributary channel such as the north-eastern distributary of Hookina Creek, or forming a new channel starting at a break-out point. This presents a risk to the Wallerberdina study site that requires further assessment, as an avulsion of Hookina Creek or even a redistribution of flow amongst the various floodplain flow paths could increase the exposure of the site to fluvial processes or even result in the diversion of Hookina Creek through the site. The occurrence of fluvial gravels at relatively shallow depths within the floodplain sediments at the study site indicates that Hookina Creek and/or distributaries have historically or pre-historically flowed through the Wallerberdina study site, and may reoccupy the site in the future. Further consideration of this issue is required should Wallerberdina progress as a potential site for the NRWMF.

Figure 39 Modelled flow velocities for 1 in 100 year AEP flood event

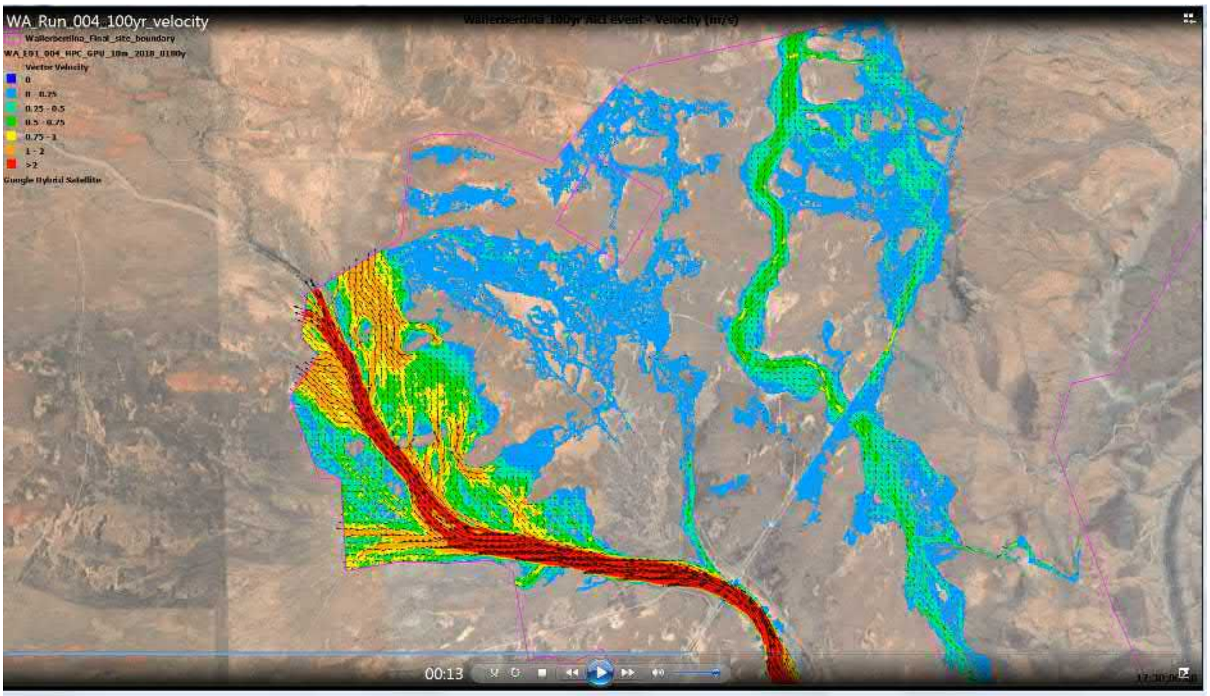


Figure 40 Modelled flow velocities for 1 in 2000 year AEP flood event – earlier stage

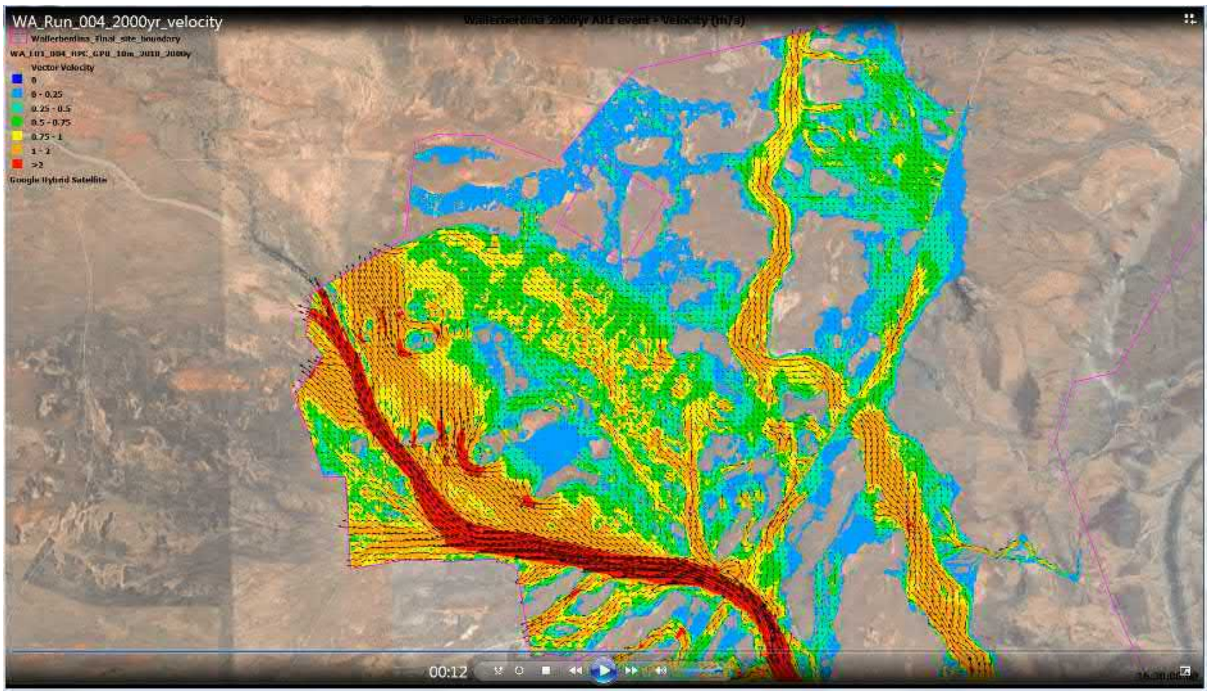
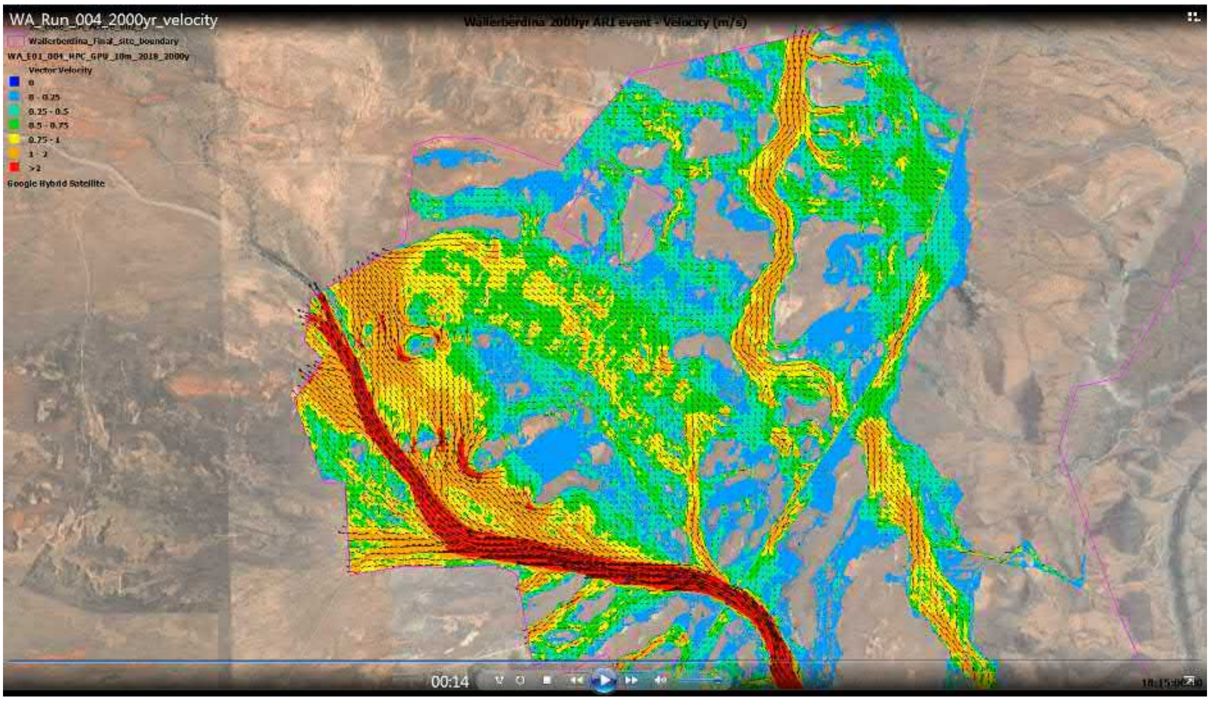


Figure 41 Modelled flow velocities for 1 in 2000 year AEP flood event – later stage



Floodplain Scour and Sedimentation

The Wallerberdina Station study site is situated the floodplain of Hookina Creek. Recently deposited fans and lobes of sediment are apparent on parts of the floodplain close to the creek channel, and the gemorphology of the site suggests that it is formed of similar, possibly older, deposits. The presence of fluvial gravels at shallow depths in the bores and test pits also provides evidence of high-energy fluvial deposition, however the time period in which this occurred is not known without dating the material.

The hydraulic model shows that parts of the study site are inundated the 1 in 100 year AEP flood event by overflows from Hookina Creek as well as local runoff (Figure 39). There is more extensive and deeper inundation in the 1 in 2000 year AEP flood event (Figure 41). Flows in floods up to this magnitude are generally quite shallow (up to 0.5 m deep), therefore stream power is relatively low (less than 20 N/m.s for flows up to the 1 in 2000 year AEP flood) even though velocity and shear stress is locally elevated. Velocities are generally less than 0.75 m/sec but locally higher (Figure 41). Bed shear stress values range up to 50 N/m^2. Photographs show that the floodplain vegetation cover is patchy due to the semiarid climate, therefore there is a risk of surface erosion along the main flow threads.

If an avulsion of Hookina Creek occurs, as discussed above, or a change in the pattern of flood overflows from Hookina Creek or the north-eastern distributary, the site could potentially be subject to higher energy flow conditions during floods. This would in time, as avulsion events occur, lead to greater degrees of erosion and sedimentation, potentially including the delivery of coarser sediments (e.g. gravels) to the study site.

Aeolian

The study site is situated a short distance to the east of a Holocene dune field extending from Lake Torrens. There is a possibility that the dunes will migrate eastward, into the site, particularly if the vegetation cover on the dunes is disrupted (e.g. by drought, fire or human activities).

Extensive loess deposits have been identified in valley fill deposits in the Flinders Ranges, including the Hookina Creek valley, and deposition of fine wind-blown sediment from Lake Torrens or arid areas further afield may occur in the site.

There is also a risk that the ground surface in the site may be eroded by the wind, particularly where there are gaps in vegetation. This will depend on surface cover and the texture and cohesiveness of the surface materials.

Summary

The Wallerberdina site is situated on the Hookina Creek alluvial fan and is likely to be subject to episodic fluvial geomorphological processes during rare large flood events. Potentially relevant fluvial processes include avulsion of Hookina Creek, floodplain sedimentation and scour and lateral migration of Hookina Creek. Seismic activity has the potential to exacerbate the risk of channel instability and avulsion of Hookina Creek.

During extended dry periods, the site may be affected by the deposition of aeolian sediment from adjacent dune fields or further afield as well as wind erosion.

Episodic fluvial geomorphological processes have the potential to impact on the long-term stability of the site. Any facility constructed at the site would need to incorporate mitigation measures to address the geomorphological risks as well as ongoing monitoring including the fluvial dynamics of Hookina Creek as well as the site. The monitoring program would need to be continued for the life of the facility and provision would also need to be made implement additional measures, potentially including works to constrain the movement of Hookina Creek if necessary. Such measures may have geomorphological and environmental implications extending beyond the works site.

3.2.3 Design Issues and Mitigation Measures

Geomorphological issues must be adequately assessed and addressed if the NRWMF is to be constructed on the Wallerberdina site within an active alluvial fan.
If levees are used to divert flows from the study site (or part of it), their impact on flow patterns and hydraulic loadings should be assessed to ensure that they do not increase the risk of floodplain scour or avulsion.

3.2.4 Data Gaps and Recommendations for Stage 2 Work Program

The hydraulic modelling that has been undertaken for the current stage of the study has several limitations in regard to assessing geomorphological risks:

- There are uncertainties regarding the interaction between Hookina Creek and the north-eastern distributary, which have linkages upstream of the area covered by the detailed topographic data. This has implications for assessing the risk of avulsion of Hookina Creek into the north-eastern distributary as well as flow patterns across the Hookina Creek alluvial fan.
- The TUFLOW hydraulic model is a fixed-bed model. It assumes no changes in channel or floodplain topography. The development of an avulsion is likely to involve initial scour altering flow patterns to cause further scour the propagation of erosion. This feedback effect has not been simulated in the present model.

More detailed hydraulic modelling would be required to address these limitations, should the investigations for the Wallerberdina site to be progressed to the next stage. This modelling should also consider in further detail, where there are any limitations in the capacity of railway bridges and culverts with surcharged hydraulic loadings which could lead to catastrophic failures.

Dating of uppermost gravel lenses in the subsurface soil profile may be worthwhile to determine the frequency of occurrence of high energy flow conditions and past channel locations.

Additional intrusive investigations and soil testing should be undertaken to assess the erodibility of surface and subsurface soils.

Further inspection of the site and the Hookina Creek floodplain should be undertaken by a geomorphologist to support the Stage 2 work program.

3.3 Seismic Risks

A detailed review of a draft of this section was provided by Clark (2018d), containing interpretations of data and suggestions for further analysis of those data and for further data collection.

3.3.1 Methodology and Results

The objective of this study is to evaluate information that has an influence on the seismic hazards at the potential NRWMF site at Wallerberdina. This information is also being used form input into seismic hazard analyses, the methodology for which is described in Somerville and Moriwaki (2002), which would be performed in the design phase. Seismic ground motion hazard analysis requires the use of earthquake source models including both fault sources and distributed earthquake sources (e.g. Hall et al., 2007), and ground motion prediction models (e.g. Somerville et al., 2009). Seismic fault displacement and ground deformation hazard analysis requires the use of fault models (e.g. Thio and Somerville, 2016).

The four criteria listed in 3.3.1.1 below describe two different categories of earthquake hazard. The first two criteria describe several types of ground deformation that could potentially disrupt the site, including surface fault displacement, folding, and other forms of ground deformation due to earthquake faulting. The third and fourth criteria describe ground shaking hazard.

A neotectonic feature is defined as one that has hosted measurable displacement in the current crustal stress regime (Machete, 2000; Clark et al., 2011), i.e. within the last 5-10 Ma in Australia (Sandiford et al. 2004) but is not necessarily an active fault. Verifying these features as active faults (or not) is an ongoing process. In Australia, the rate of earthquake activity on most active faults and neotectonic features is estimated from the amount of vertical displacement of landscape features they are inferred to have caused due to dip-slip (reverse) faulting. The inferred displacements are typically in the range of several tens of metres to several hundred metres, and the ages over which they are assumed to have occurred are typically 5 to 10 million years, yielding fault slip rates in the approximate range of 0.01 to 0.1 mm/yr, and recurrence intervals in the tens of thousands to hundreds of thousands of years or more. Consequently, the slip rates are typically averaged over a much longer time interval than the 100,000 year interval which might be considered to be an appropriate upper limit of engineering significance. Hence, as stated by Clark (2009), it is unclear whether long term slip rates (and the recurrence estimates based upon them) are appropriate for probabilistic seismic hazard assessment.

Further, there is evidence for pronounced episodic surface rupture behaviour on many Australian faults (e.g. Crone et al. 1997; Clark et al. 2011; 2012). Typically, clusters of several surface faulting events occur with intervals between events of several tens of thousands of years, separated by intervals of hundreds of thousands or millions of years without surface faulting. Conventional seismic hazard analysis assumes that earthquakes on faults occur randomly in time, at an average rate that is controlled by the long term average slip rate of the fault. However, it is unclear whether long term slip rates (and the recurrence estimates based upon them) are appropriate representations of the temporal and spatial clustering of surface faulting earthquakes for probabilistic seismic hazard assessment.

Two primary data sets were used in this study: the earthquake catalogue and the neotectonic feature database described above and illustrated in Figure 42 through Figure 46. Each of these data sets provides information about both of the earthquake hazards addressed above: ground deformation and ground shaking. The neotectonic feature database contains geological structures that could potentially be active faults. The earthquake catalogue contains earthquakes, which always occur on active faults, but unless their magnitudes are quite large, their fault dimensions are quite small and so they may not break the ground surface and appear as surface faults, especially in non-cratonic regions of Australia including the Northern Flinders Ranges. Consequently, it is usually not possible to associate small earthquakes with individual mapped faults in Australia, and this is found to be the case in the Flinders Ranges (Love et al., 2006). Nevertheless, for large earthquakes, we expect that faults such as those in the central Flinders Ranges that are identified as having hosted displacement in the current stress regime are expected to also generate large earthquakes in the future.

Conversely, there are typically numerous mapped faults close to or in the region surrounding any site in Australia, but most or all of these faults are “bedrock faults” (ones that do not displace geologically recent materials such as alluvium). These faults were once active but are not known to be currently active, although they potentially could be reactivated under the current stress regime if they are favourably oriented. This is a further reason why the correlation between small historical earthquakes and individual mapped faults in Australia is generally not very strong.

At most sites that are distant (several tens of km) from faults in Australia, the probabilistic ground shaking hazard is dominated by randomly occurring earthquakes that are modelled by distributed earthquake sources. At near fault sites (within a few tens of km of active faults), identified faults also make a significant contribution to the ground shaking hazard at a site in Australia. Also, these nearby faults could potentially cause ground deformation at the site.

Clark et al (2011, 2012) made an Australia-wide assessment of active faulting based on neotectonic features. They analysed a catalogue of 333 neotectonic features, 47 of which are associated with named fault scarps. The data were derived from analysis of Digital Elevation Models (DEMs), aerial photos, satellite imagery, geological maps and consultation with state survey geologists and a range of other earth scientists. The catalogue varies in completeness because sampling is biased by the available databases, the extent of unconsolidated sedimentary cover, and the relative rates of landscape and tectonic processes. Clark et al. (2011, 2012) assessed their confidence that each feature in their data base is a neotectonic feature (active in the past 5 to 10 million years), using the rankings of A: Definite; B: Probable and C: Possible. The distribution of numbers of features in each category is A: 17%, B: 32% and C: 51%.

The earliest records of earthquakes in Australia go back only about 180 years, and instrumental recordings of earthquakes have only been made for the past century. Geoscience Australia (2018) assessed the completeness of detection of earthquakes in their revised earthquake catalogue. The Wallerberdina site is located in the Gawler Craton neotectonic domain. In both this domain and the adjacent Northern Flinders Ranges neotectonic domain, the detection and location of earthquakes became complete in 1900 for earthquake magnitudes Mw of 6 and larger, and it was not until 1966 that the detection and location of earthquakes of magnitude Mw 3.0 or larger became complete.

The recurrence intervals of surface faulting earthquakes in Australia are thought to typically lie in the range of 10,000 to 100,000 years during seismically active periods (Clark et al., 2011, 2012), so the historical earthquake catalogue provides a very limited picture of earthquake potential in Australia. It would be preferable to have an earthquake catalogue that is complete for a much longer period of time in order to have a better understanding of the earthquake potential of Australia. Conversely, the current assessment of neotectonic features is based on activity within the past 5-10 Ma. It would be preferable to be able to identify potentially active faults in geologically recent materials such as alluvium in more recent geological time in order to be more confident that they are currently active.

These limitations notwithstanding, the locations of historical earthquake epicentres have a strong spatial association with the locations of neotectonic features in the study region, as shown in Figure 46. This is true for the Flinders Ranges and their southward continuation in the Mount Lofty Ranges on the east side of Spencer Gulf, and for the faults on the eastern margin of the Eyre Peninsula on the west side of Spencer Gulf. There is a clear association of faults and historical earthquakes, shown in Figure 46, with the topography of the Flinders and Mount Lofty Ranges shown in Figure 47, indicating that large earthquakes occurring on these faults are building the ranges (Braun et al., 2009; Clark, 2010; Sandiford et al., 2013; Clark et al. (2014).

3.3.1.1 Site Characteristic Criteria

ARPANSA (2016) states that: “In accordance with Government policy, ARPANSA has adopted the ‘trusted international standard’ (TIS) principle http://www.arpansa.gov.au/Regulation/ibp/index.cfm, under which additional requirements should not be imposed beyond international best practice, unless it can be demonstrated that there is a good reason to do so. This regulatory guide is based on the accepted standards published by the International Atomic Energy Agency (IAEA). The relevant IAEA Guidelines for seismic hazard evaluation are excerpted from IAEA Seismic Safety Guide SSG-9 (2000).

This report addresses the following four key criteria:

Absence of potentially active faults that could cause surface faulting through the NRWMF

Hazards due to surface fault displacement are sensitive to the precise locations of faults, and can potentially be avoided if the precise locations of faults are know with certainty and if the occurrence of faulting at other locations can be ruled out with high confidence. However, it is well know that distributed faulting can occur off the main fault strand, and in particular, for the reverse and thrust faults that constitute most of the faults in South Australia, it is expected that there may be significant faulting and deformation on the hanging wall of these faults.

IAEA (2000) Chapter 8 Potential for Fault Displacement at the Site, states on page 31, under the heading “Capable Fault Issues for New Sites:”

> *“8.8. Where reliable evidence shows that there may be a capable fault with the potential to affect the safety of a plant at a site, the feasibility of design, construction and safe operation of a plant at this site should be re-evaluated and, if necessary, an alternative site should be considered.”*

Absence of near-surface faults that could cause folding or other deformation within the NRWMF

Hazards due to near-surface faults that can cause ground deformation can potentially be avoided if the precise locations of the faults are know with certainty and if the occurrence of faulting at other locations can be ruled out with high confidence. However, it is well know that ground deformation can occur off the main fault strand, and in particular, for the reverse and thrust faults that constitute most of the faults in South Australia, it is expected that there may be significant folding and deformation on the hanging wall of these faults.

IAEA (2000) Chapter 8 Potential for Fault Displacement at the Site, states on page 31, under the heading “Capable Fault Issues for New Sites:”

> *“8.8. Where reliable evidence shows that there may be a capable fault with the potential to affect the safety of a plant at a site, the feasibility of design, construction and safe operation of a plant at this site should be re-evaluated and, if necessary, an alternative site should be considered.”*

Absence of nearby faults that could cause hanging wall or rupture directivity effects, which amplify ground motions

IAEA (2000) Chapter 5: Evaluation of the Ground Motion Hazard does not identify any specific conditions that should be avoided if possible. However, there are several readily identifiable conditions that can cause large ground motion levels at sites close to faults. These include two near-fault effects that are prominent within about 20 km of an active fault: rupture directivity effects and hanging wall effects.

In the rupture directivity effect (Somerville et al., 1997), the propagation of fault rupture at a speed that is almost as large as the speed of shear waves in rock causes most of the wave energy from the fault to arrive in a single large pulse of ground motion.

The hanging wall is the ground that lies above a dipping fault. In the hanging wall effect (Abrahamson and Somerville, 1996), the ground motion on hanging wall sites is amplified by the proximity of the site to a large part of the underlying fault plane.

Absence of ridge crests, which amplify ground motions

IAEA (2000) Chapter 5: Evaluation of the Ground Motion Hazard does not identify any specific conditions that should be avoided if possible. However, there are several readily identifiable conditions that can cause very large ground motion levels. These include topographic amplification effects (EC8, 2003).

It is well know that earthquake ground motion can be significantly amplified at sites on or near the crests of steep topographic slopes. Incorporation of topographic amplification effects in design ground motions has been codified in Eurocode 8 (EC8, 2003), which models topographic amplification as a function of the ratio H/L, where H is the height of the slope and L is its horizontal length. EC8 incorporates surface topography via the soil ground motion amplification parameter ST, which varies between 1.2 and 1.4 depending on the slope angle and the topographic feature. Typically, for mean slope angles < 15 degrees (H/L < 0.27), topographic effects can be neglected. For isolated cliffs and slopes near the top edge, ST ≥ 1.2 is recommended. For ridges with crest width significantly less than the base and slope height H > 30 m, the recommended values are ST ≥ 1.2 and ST ≥ 1.4 for mean slope angle exceeding 15 degrees and 30 degrees respectively. The highest values apply near the top of the slopes while the amplification factor can be assumed to linearly decrease towards the base, where it becomes unity. The suggested amplification factors are increased by at least 20% in the case of soil layer more than 5 m thick.

3.3.1.2 Desktop Data Collection

Clark, D. (2018a) performed a desktop study of crustal architecture in the region under consideration, documenting the presence of geologically recent fault displacements in the region. Clark (2018b) performed a desktop study of the neotectonic setting of the sites, addressing neotectonic features (28) that are potentially active faults. This study made use of an updated version of the neotectonic feature database for Australia compiled by Clark et al. (2011). Clark (2018c) performed a preliminary interpretation of LiDAR data at the site. The hydrological study of Barnett et al. (2015) was also used to assess earthquake faulting potential at the site.

Geoscience Australia (2018, unpublished) provided a revised Australian earthquake catalogue for use in this study. In a probabilistic seismic ground motion hazard analysis for a site, it is necessary to consider potential earthquake sources within approximately 300km of the site. Figure 42 shows a map of historical earthquake epicentres in the study region that extends that distance from the sites, using the Geoscience Australia (2018) earthquake catalogue.

Figure 42 Historical seismicity within about 300 km of the site locations, shown by the yellow stars, based on the Geoscience Australia (2018) revised earthquake catalogue.

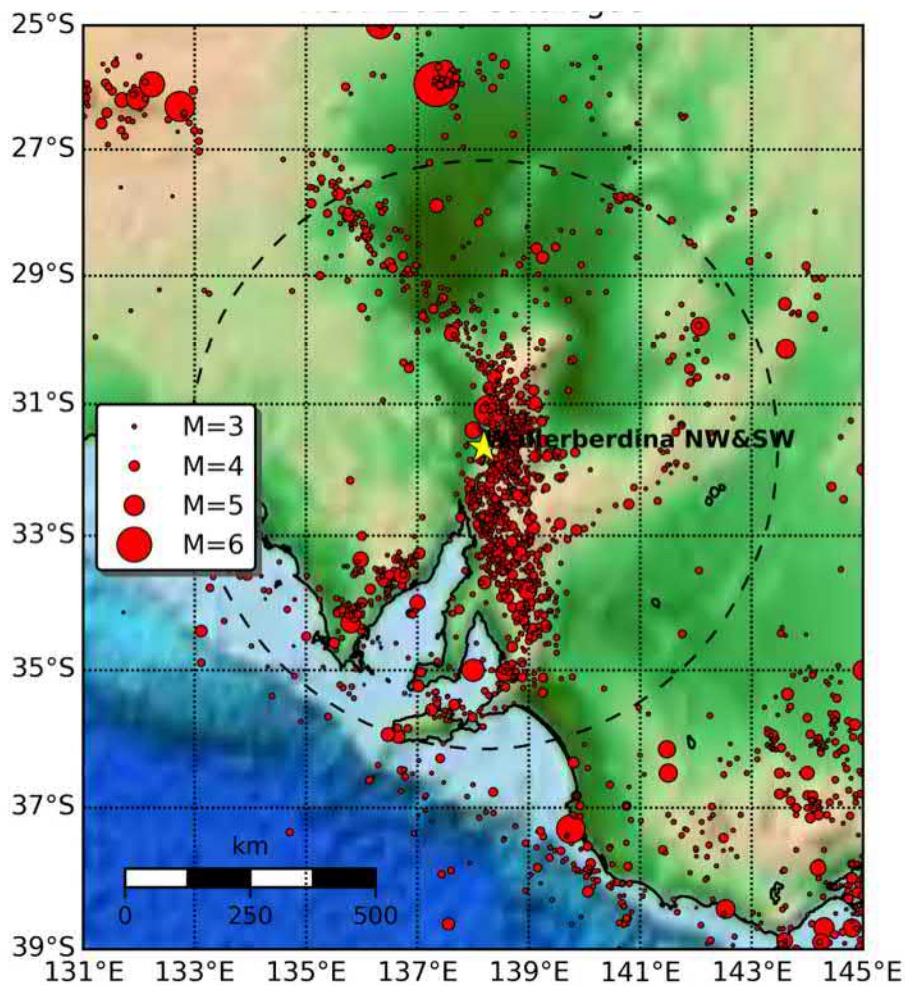


Figure 43 shows identified neotectonic features (potential active faults) in the same region from Clark et al. (2011), and Figure 44 shows the superposition of these features on the earthquake epicentre map. There is a clear association of faults and historical earthquakes shown in Figure 46, with the topography of the Flinders and Mount Lofty Ranges shown in Figure 47.
Use was made of topographic maps to assess the potential for topographic amplification of ground motions at the site.

Figure 43 Map of neotectonic features and site locations. Source: Clark, 2018b

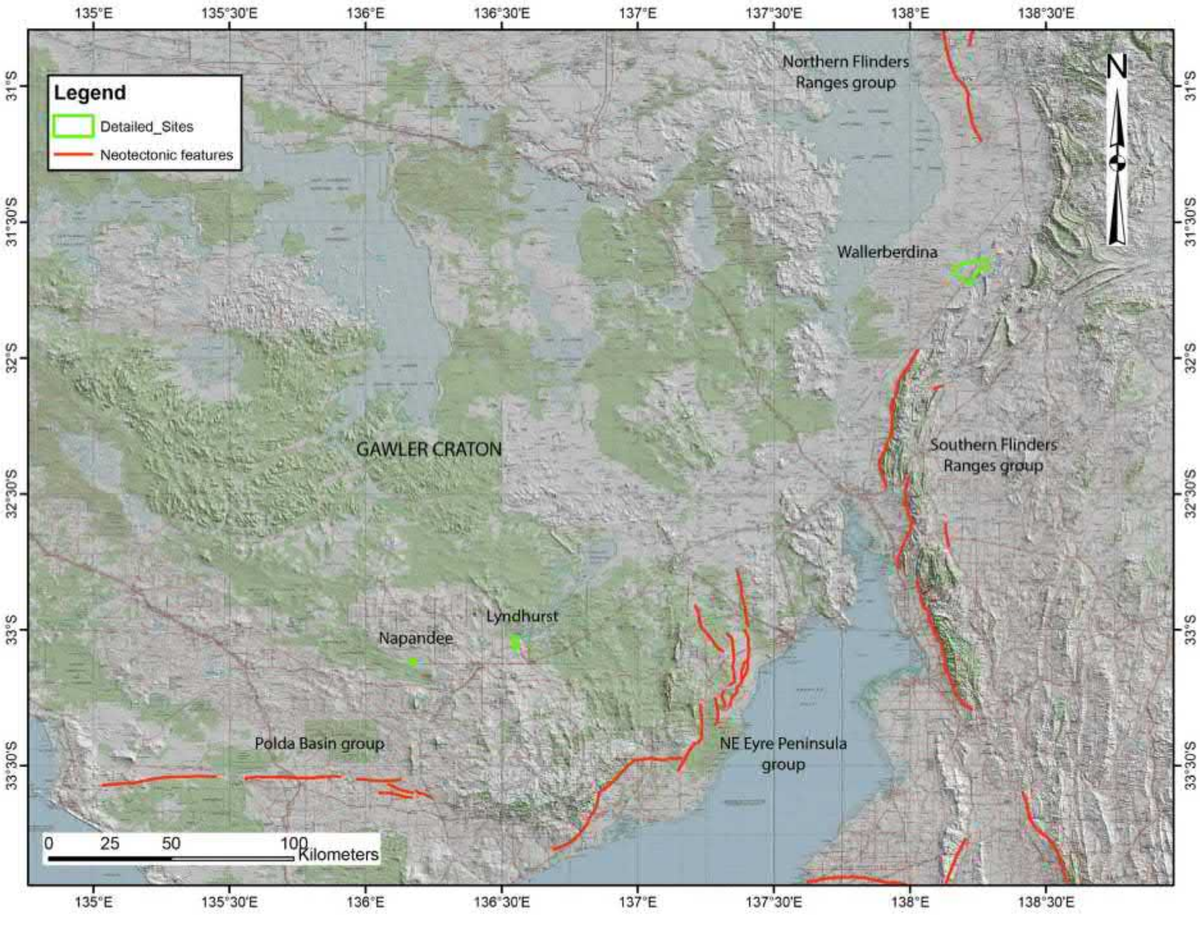


Figure 44 Neotectonic features in the study region based on Clark et al. (2011).

The top edges of the faults are shown by dark lines and their surface projections are shown by the coloured bands.

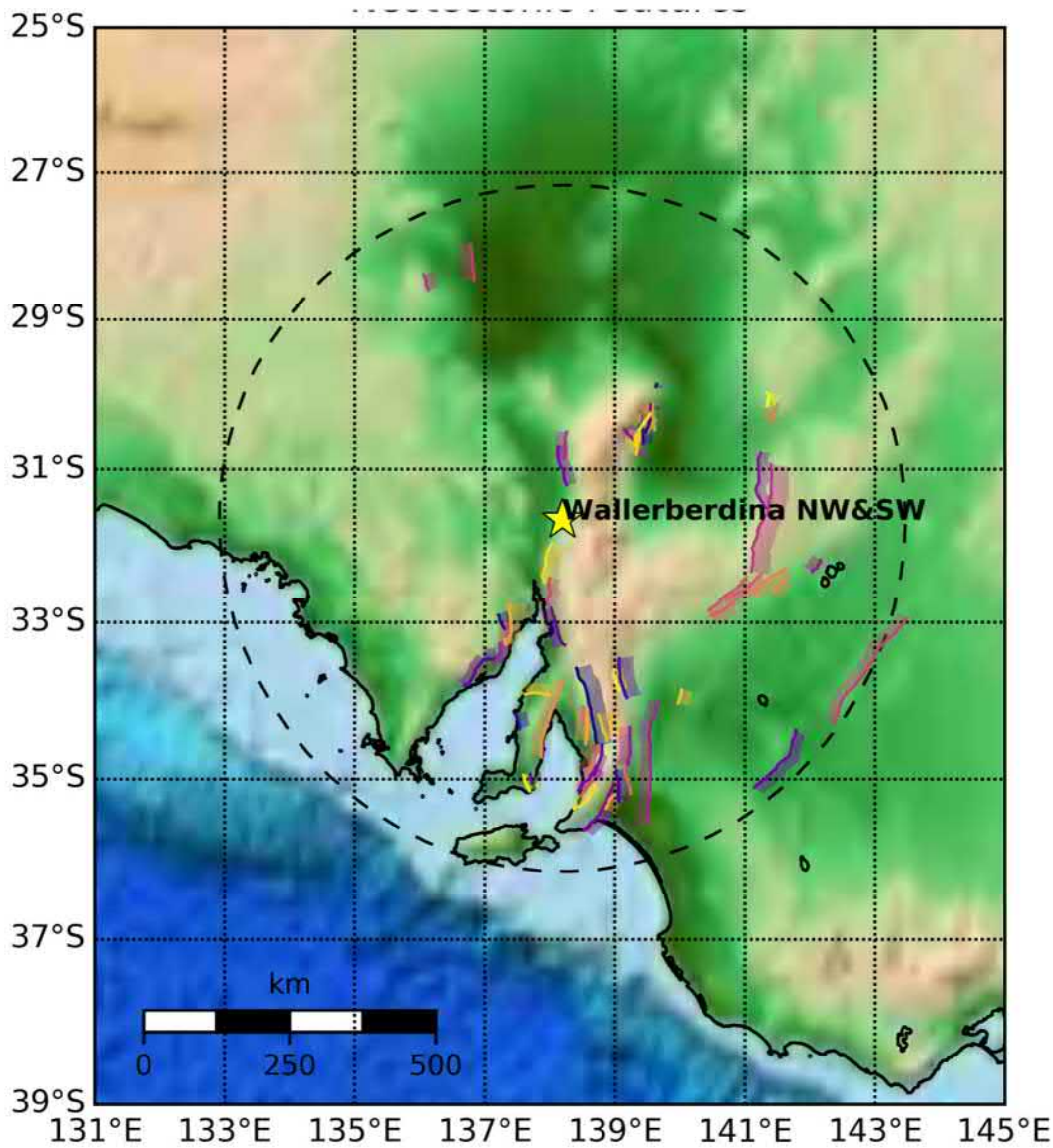


Figure 45 Legend for neotectonic features in the study region based on Clark et al. (2011).

Figure 46 Neotectonic features and historical earthquakes for the study region based on Clark et al. (2011) and Geoscience Australia (2018) respectively.

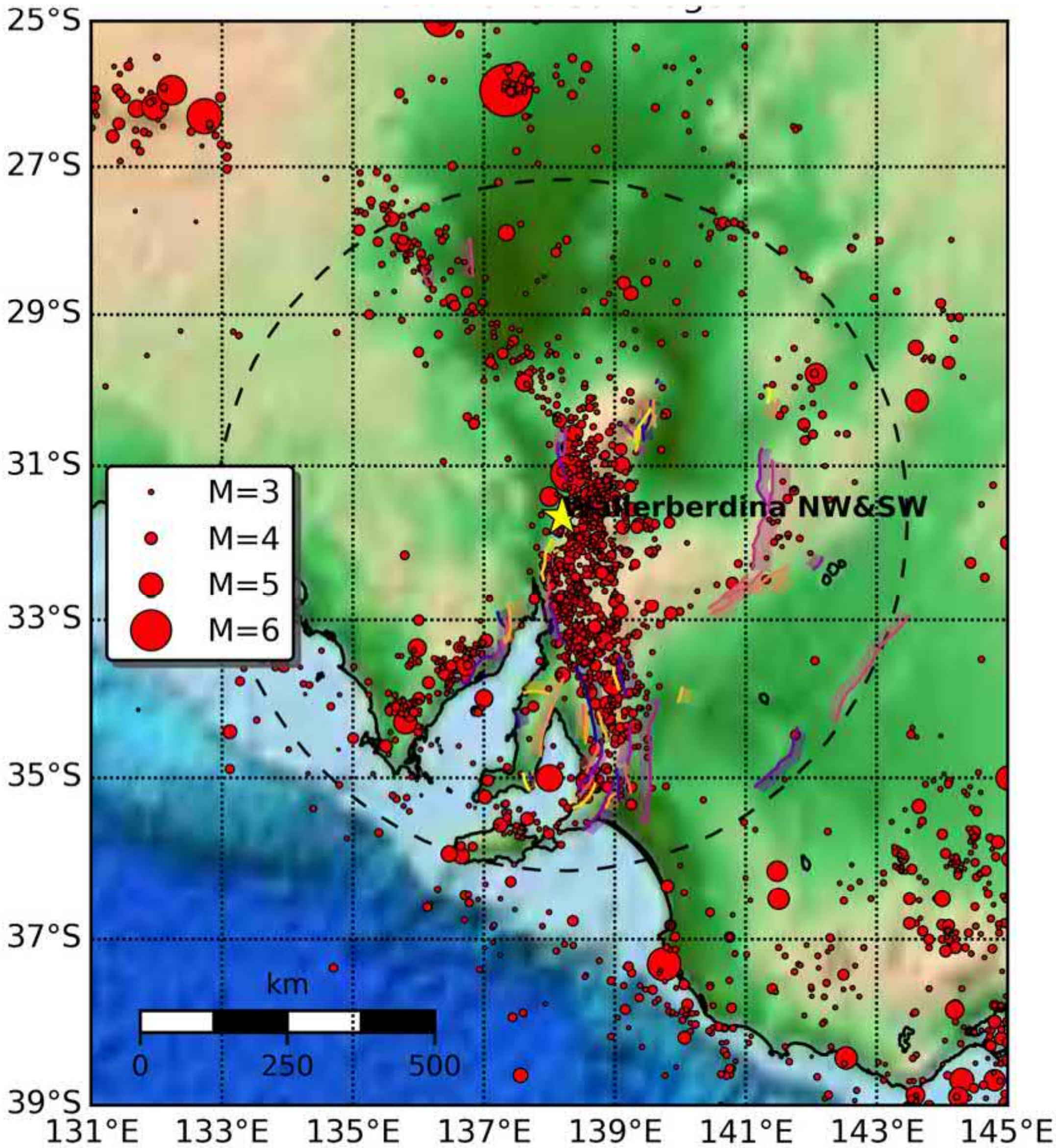
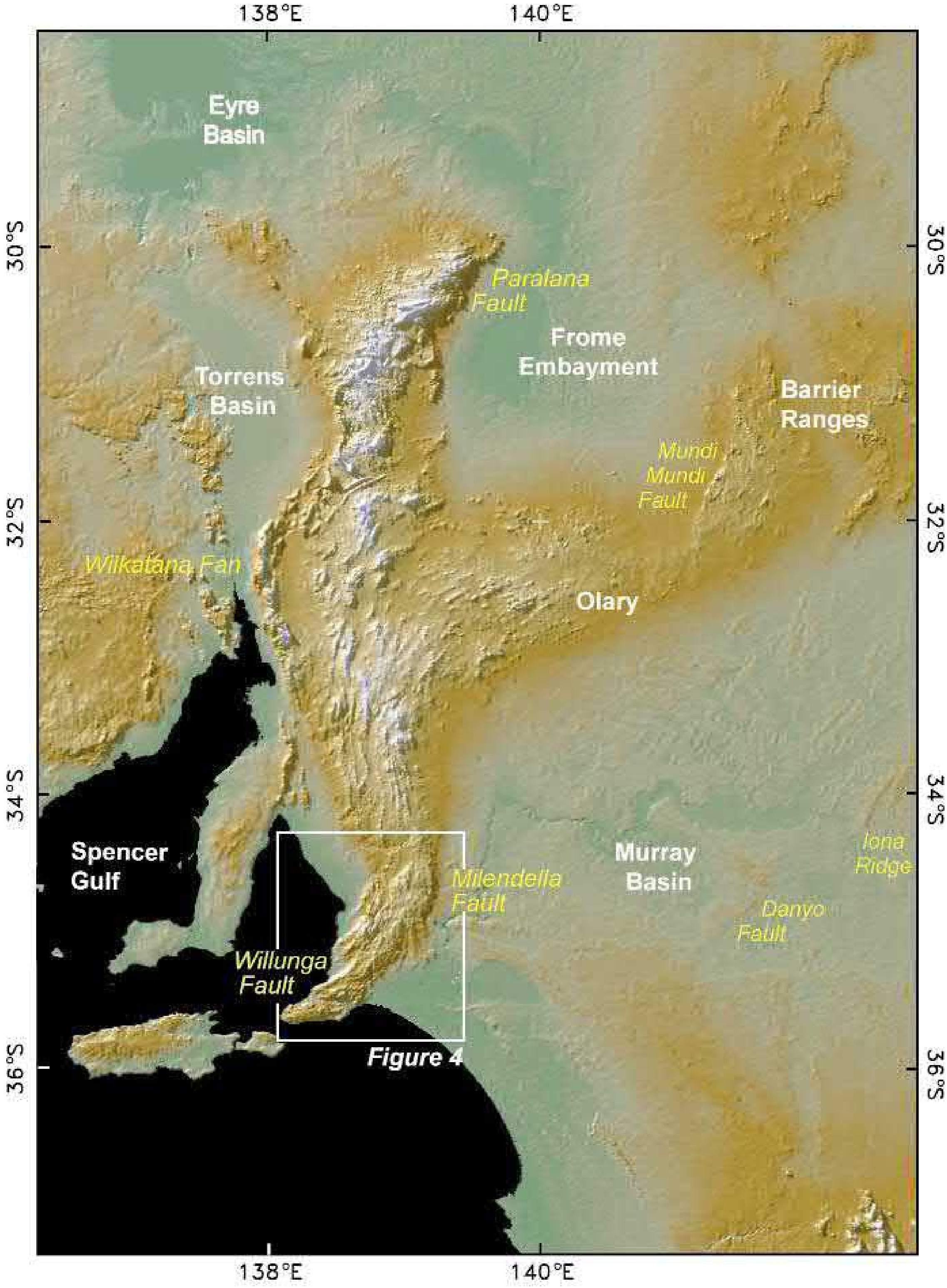


Figure 47 Topography of the Flinders and Mount Lofty Ranges. Source: Sandiford et al., 2013.



3.3.1.3 Field Data

Two shallow seismic reflection profiles together with a preliminary interpretation, described below, were obtained at the Wallerberdina site by Velseis Pty Ltd (Velseis) - these are named Wallerberdina NW. Two additional shallow seismic reflection profiles were obtained at Wallerberdina SW, and a further two shallow seismic reflection profiles were obtained at Wallerberdina E.

Daishsat Pty Ltd (Daishsat) undertook an airborne survey of magnetics and radiometrics for the Wallerberdina site, and a preliminary desktop assessment of the available geophysical data sets at the site.

3.3.2 Review Against Criteria

Clark (2018b) states that:

> *"The Wallerberdina Station site occurs on the western range front of the central Flinders Ranges…. Sandiford (2003b) and Quigley et al. (2006) suggested that 30–50% of the present-day elevation of the Flinders Ranges relative to adjacent piedmonts has developed in the last 5 Ma. This implies significant neotectonic throw on the range bounding faults (e.g. several hundred metres"*

This reflects the fact that the western range front of the central Flinders Ranges is part of the most readily identifiable and prominent active fault and earthquake generating feature in Australia, as illustrated in Figure 42 to Figure 47 The western range front and the faults that generate it are imaged in the cross sections shown in Figure 49 and Figure 50, and their locations are shown in Figure 48.

Figure 48 Location of the Wallerberdina Station site and seismic lines traversing the western range front of the central Flinders Ranges. Source: Clark (2018a).

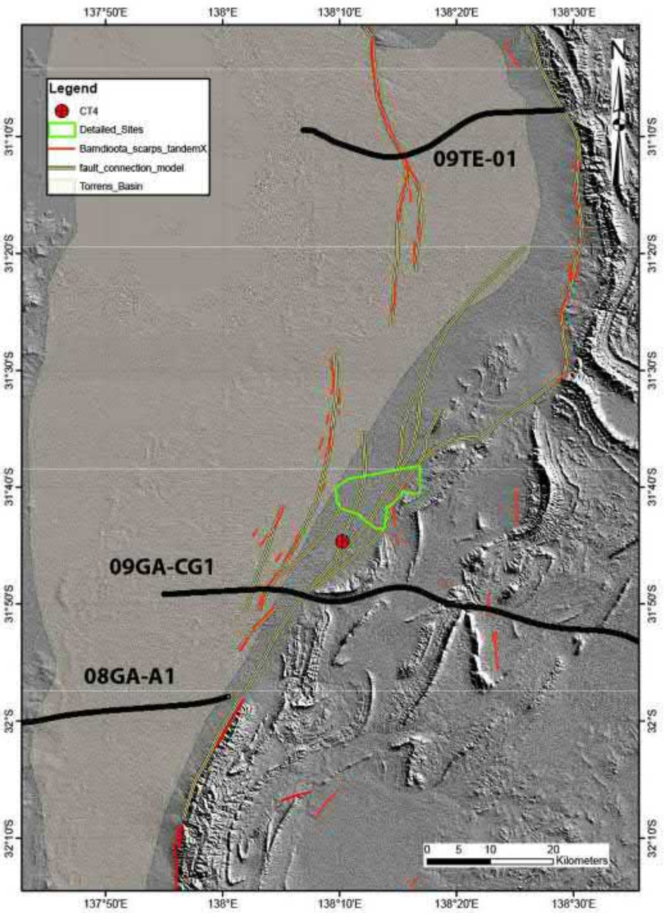


Figure 49 Seismic reflection profile 09TE-01 across the western range front of the central Flinders Ranges.

The location is shown in Figure 49. The upper blue line shows the base of the Cenozoic sediments. Source: Clark (2018a) from Carr et al. (2010).

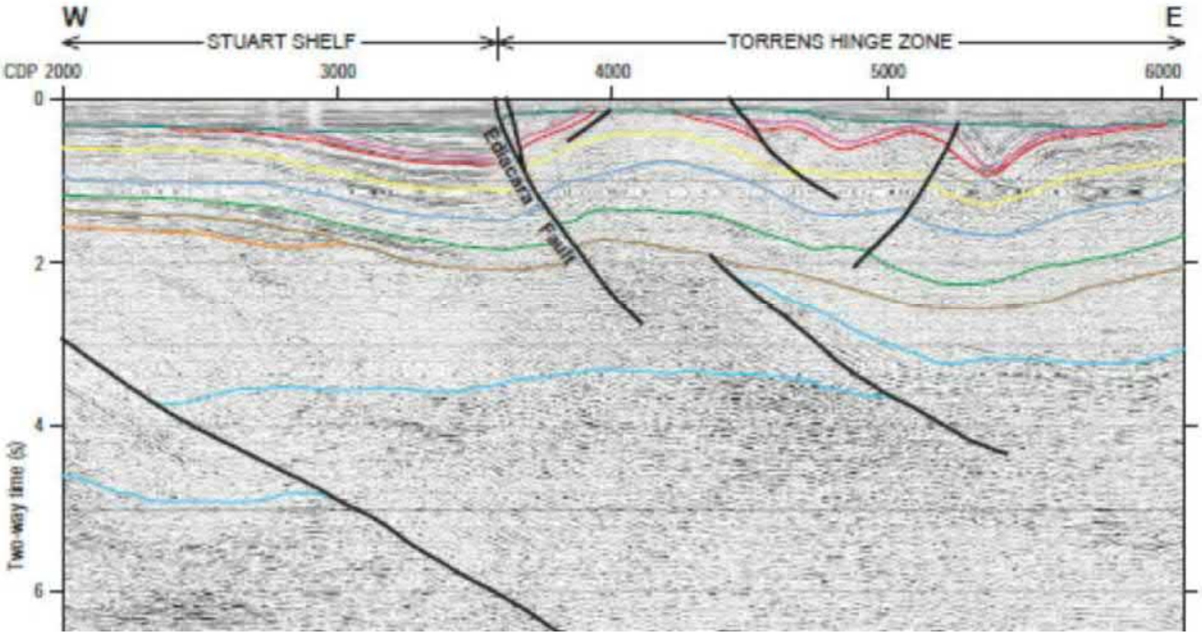
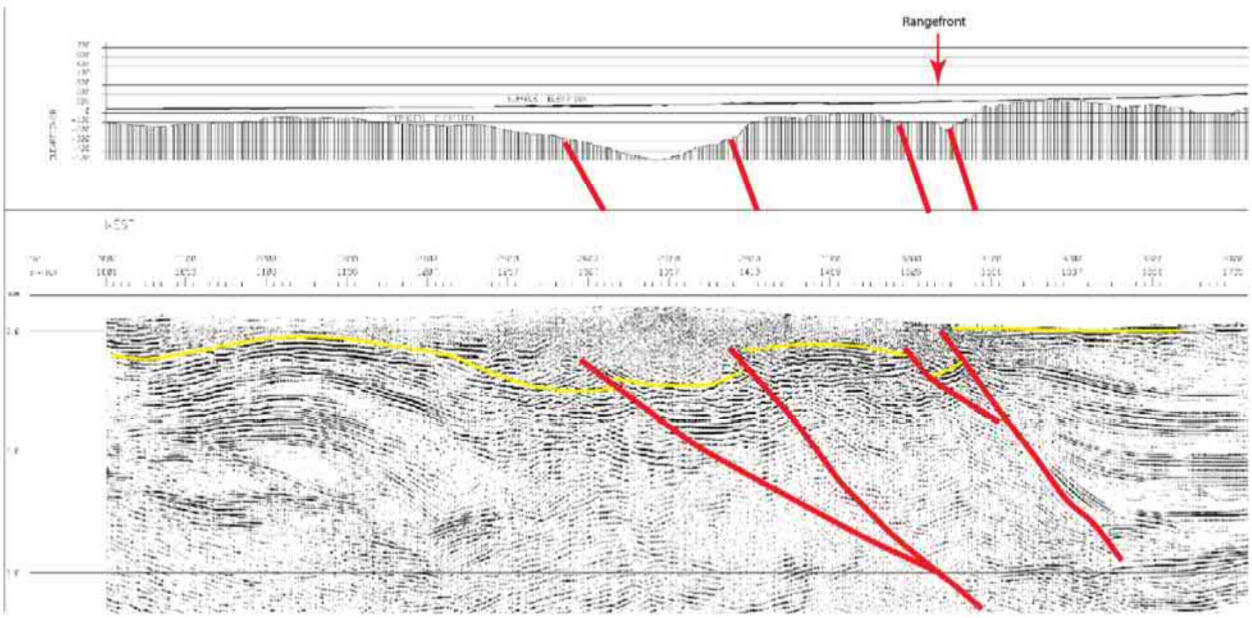


Figure 50 Seismic reflection profile 09GA-CG1 across the western range front of the central Flinders Ranges

The location is shown in Figure 49. The yellow line shows the base of the Cenozoic sediments. Source: Clark (2018a), from Preiss et al. (2010).



Seismic line 09TE-01 traverses the Ediacara scarp to the north of Wallerberdina (Figure 49). The interpretation of this line by Carr et al. (2010) confirms that the Ediacara fault is associated with a significant displacement of the Cenozoic section (66ma), whose base is shown by the yellow line. Similarly, the interpretation of seismic line 09GA-CG1 (Figure 50), located just south of Wallerberdina

(Figure 48), indicates displacement of Cenozoic sediments at four major fault splays. These profiles demonstrate the occurrence of mountain building earthquakes on the western range front of the central Flinders Ranges in geologically recent time both north and south of the Wallerberdina Station site.

The Wallerberdina site lies between the Ediacara Fault to the north and the Wilkatana Fault to the south. Clark (2017) states that:

> *The range front changes orientation between the Wilkatana and Ediacara/Mt Deception faults, forming a large-scale bend, concave to the west. Range front and basin-bounding faults shortcut the bend to the west, forming an anastomosing network of splays. Interrogation of TanDEM-X DEM data revealed the presence of many discontinuous scarp segments which are interpreted to represent the remnants of the scarps consequent of Quaternary surface rupturing earthquakes. Generally good correlation of scarp segments with lineaments visible in magnetic imagery has allowed for the development of a fault connection model."*

The multiple strands of the interpreted fault connection model at Wallerberdina identified by Clark (2018b) are shown by the yellow lines in Figure 48. The locations of these interpreted subsurface faults are shown in Figure 52 together with the boundaries of the Wallerberdina North West and Wallerberdina South West sites and the locations of Velseis shallow seismic lines.

Clark (2018b) states that the model differs in some places, but is generally consistent with, faults mapped using geophysical and borehole data by the Geological Survey of South Australia. Evidence for the southern extension of these interpreted faults was also found immediately south of the Wallerberdina Station site in the Hookina Stream region (Barnett et al., 2015). Figure 53 shows major faults interpreted from aeromagnetic survey data together with earthquake epicentres. It is not clear whether these faults are currently active faults, but their association with topographic features suggests that they could be. Barnett et al. (2015) attribute the uplift of the Hookina River conglomerates to these faults (Figure 54 and Figure 55). These conglomerates are located just south of the southernmost tip of the Wallerberdina Station site. If this interpretation is correct, it implies that the tectonic uplift rate due to faulting exceeds the erosion rate at this location. However, Quigley et al. (2007) note that climatic controls on range-front sedimentation are also important in the adjacent Wilkatana region to the south of Wallerberdina.

Further evidence of geologically recent deformation due to faulting is provided in the LiDAR profiles interpreted by Clark (2018). Figure 56 shows a change in slope coincident with uplift of 2.5m, with the location of a possible subsurface neotectonic feature identified by Clark (2018b), the easternmost of the three that lie within the Wallerberdina Station site (Figure 52). This feature lies to the east of the Wallerberdina North West and Wallerberdina South West sites.

Figure 56 shows fault scarps, with heights of about 2m, inferred from LiDAR data to lie on either side of a possible subsurface neotectonic feature (identified in the fault connection model) that lies near the eastern edge of the Wallerberdina North West site (Figure 52), and the western scarp is located within the Wallerberdina North West site. Two shallow seismic reflection profiles were obtained at the Wallerberdina North West site by Velseis Pty Ltd (Velseis), included as Appendix D. Line 03 does not intersect the inferred fault, but the easternmost end of Line 04 does, as shown by the purple dashed line in Figure 57.

The interpreted Lines 04 and 03 obtained at the Wallerberdina site (North West), shown in Figure 58 and Figure 59, contain horizontal layering that may represent lakebed sediments. Faulting of these sediments appears to be confined to their base. . However, Geoscience Australia (2015) point out that there is subtle evidence consistent with the presence of modest displacement fault propagation folds above Velseis-interpreted basement faults, particularly in line #4, but also in lines #5 and #6 at the described below. It is important to determine the age of these sediments so that the recency of faulting in them can be assessed. It is likely that they are Eocene in age (50 million years old). There is no clear sign of shallow faulting in the upper layers, and there is no good candidate for a large vertical displacement basement fault that might correspond to the subsurface fault inferred by Clark (2018b). The 2m scarp heights shown in Figure 56 may be at the limit of resolution of the shallow seismic profile, given the current lack of borehole control.

One interpretation of the Wallerberdina Northwest and Southwest seismic profiles is that there is possible evidence for fault propagation folds, an apparent east-facing monoclinal fold deeper in the basin strata, and the potential association of these features with the 2 m high scarps described above that may be active faults. The raw (unmigrated) seismic stacks should be checked to see that the fold has not been breached in the upper section, which may indicate a fault displacement hazard at the site. The potential for reprocessing or filtering the seismic data to enhance reflections in the upper 60 m of section might also be explored. Both potential sources of fault displacement hazard in the western sites relate to underlying faults with low total Cenozoic displacement and hence low slip rates (~3-4 m/Myr slip averaged over the period Pliocene to Recent assuming a 30° dipping fault). AECOM intends to pursue these investigations, which would be implemented in Stage 2 work. Meanwhile, AECOM's (2018) Interim Seismic Hazard Assessment concluded that potential sources of folding and surface faulting like these present a negligible level of hazard at the site. This Assessment considered slip rates as high as 150m/Myr (50 times higher than the interpreted values) and found that even at that slip rate the potential for significant surface displacement hazard at the site is negligible for a return period of 2,500 years.

Two shallow seismic reflection profiles were obtained at the Wallerberdina South West site by Velseis Pty Ltd (Velseis), included as Appendix D. Both Lines 6 and 5, shown in Figure 60 and Figure 61 respectively, intersect the inferred feature described above in relation to Wallerberdina North West site, but there is no sign of shallow faulting on either line. These profiles image flat lying sediments similar to those imaged in the Wallerberdina North West section in Figure 59. Possible candidates for basement faults corresponding to Clark's (2018b) interpreted subsurface fault are at CDP800 on Line 5 and CDP650 on Line 6. The LiDAR interpretation by Clark (2018c) does not bear directly on the Wallerberdina South West site.

Two shallow seismic reflection profiles were obtained at Wallerberdina East by Velseis Pty Ltd (Velseis), included as Appendix D. Figure 62 shows the locations of seismic lines in the east part of the Wallerberdina site, and the seismic profiles are shown in Figure 63 and Figure 64. In these figures, interpreted faults are shown by blue lines that extend down to depths of 420 m, and where possible, interpreted slip direction is indicated. It is inferred that the strongest reflectors may be lakebed sediments that shallow by about 250m from NW to SE in Figure 63, which may reflect the draping of sediments on uplifted bedrock. The depth to the base of weathering in Figure 63 is very shallow, about 15m, and the interpreted faults all lie below a depth of 80m. Further to the southeast, there are several faults that reach depths as shallow as 80m, some of which seem to exhibit normal faulting.

It is possible that these lakebed sediments formed in a graben structure like the one on the right hand side of Figure 50 inferred in the seismic profile just south of the Wallerberdina site. The flat lying lakebed sediments in Figure 58 and Figure 60 may correspond to the flat lying layers to the west of the graben in Figure 65, which is part of Figure 50. As is the case in Figure 65, the thickness of the lakebed sediments on the west side of Wallerberdina is less than that to the east - the former have thicknesses of about 200 m whereas the latter have a thickness of as much as 350 m. This difference in thickness suggests the presence of a fault between the Wallerberdina NW and SW profiles to the west and the Wallerberdina E to the east. If this interpretation is correct, then there are faults a few km on either side (east and west) of the Wallerberdina site, and the main range front fault may lie a few km further east of the eastern one of those two faults.

The analysis of LiDAR data by Clark (2018c) does not bear directly on the Wallerberdina East site, but is shows a change in slope across an interpreted fault that lies to the east of the Wallerberdina East site. The change in slope corresponds to a vertical uplift of about 2m.

Figure 66 shows neotectonic features from Clark et al. (2011) and historical seismicity from the 2018 Geoscience Australia earthquake catalogue in the vicinity of the Wallerberdina North West and South West sites.

Daishsat (2018) concluded that although only regional data have been examined from the existing 1:250 000 geology map, drill-holes, gravity and magnetic data, there is no evidence to suggest the presence of shallow basement or structures at the Wallerberdina Station site.

Figure 51 Geological setting, mapped scarps, and interpreted fault connection model for the Wallerberdina site.

The Ediacara Fault and the Wilkatana Fault as well as other fault scarps are shown by orange lines, and the interpreted fault connection model is shown by yellow lines. Figure 52 shows that one of the inferred faults (the westernmost one of three) passes through the Wallerberdina North West and Wallerberdina South West sites. Source: Clark (2018b).

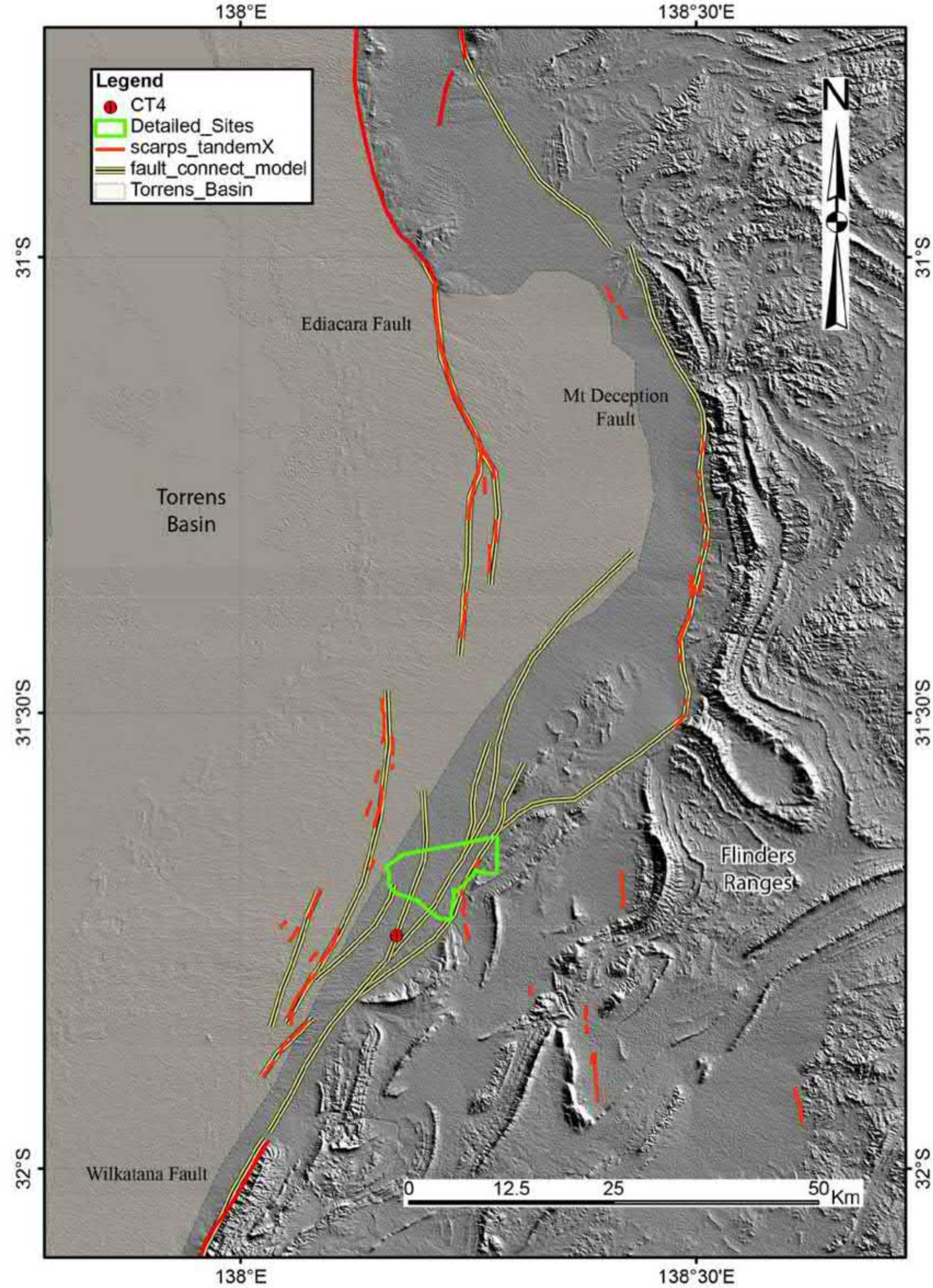


Figure 52 Locations of the site (red rectangles), Velseis shallow seismic lines (purple lines), and possible subsurface neotectonic features identified in the fault connection model of Clark (2018b) (green lines).

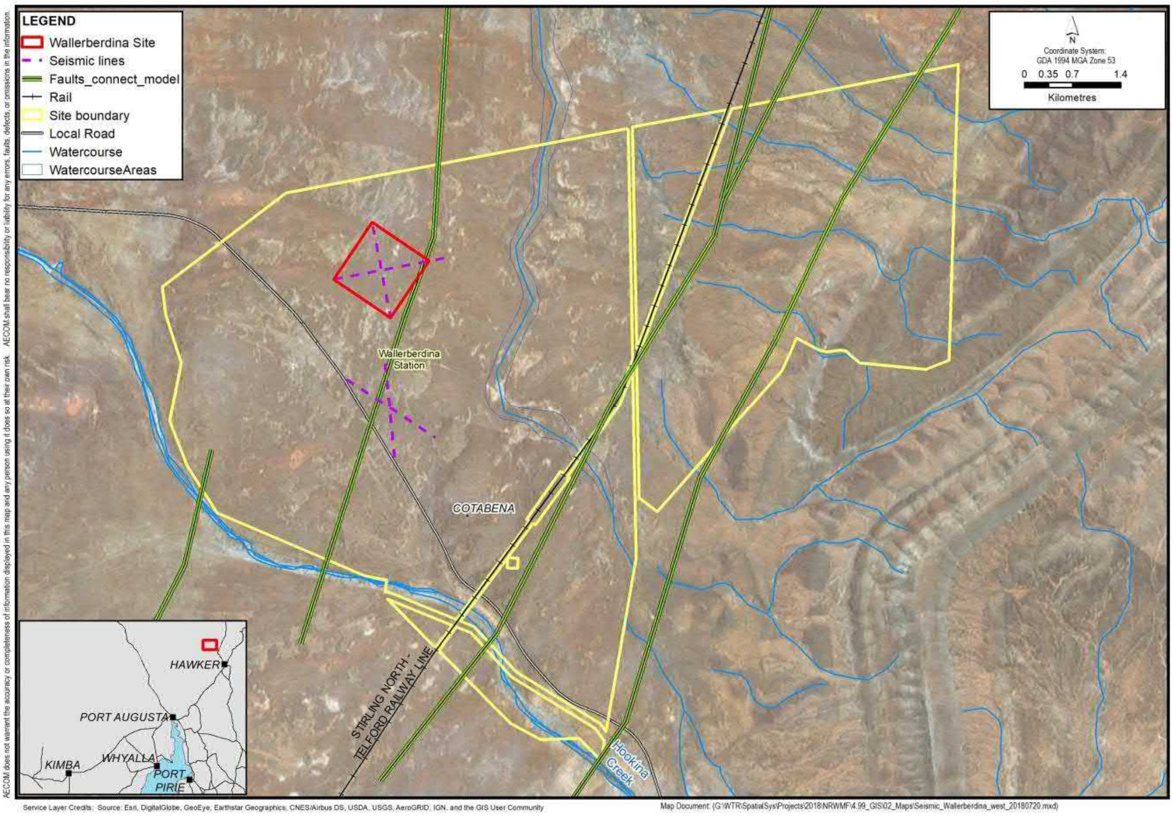


Figure 53 Seismic activity and major faults in the Hookina Spring area. Source: Barnett et al. (2015), 2015.

The southern part of the Wallerberdina Station site lies at the top centre of this map.

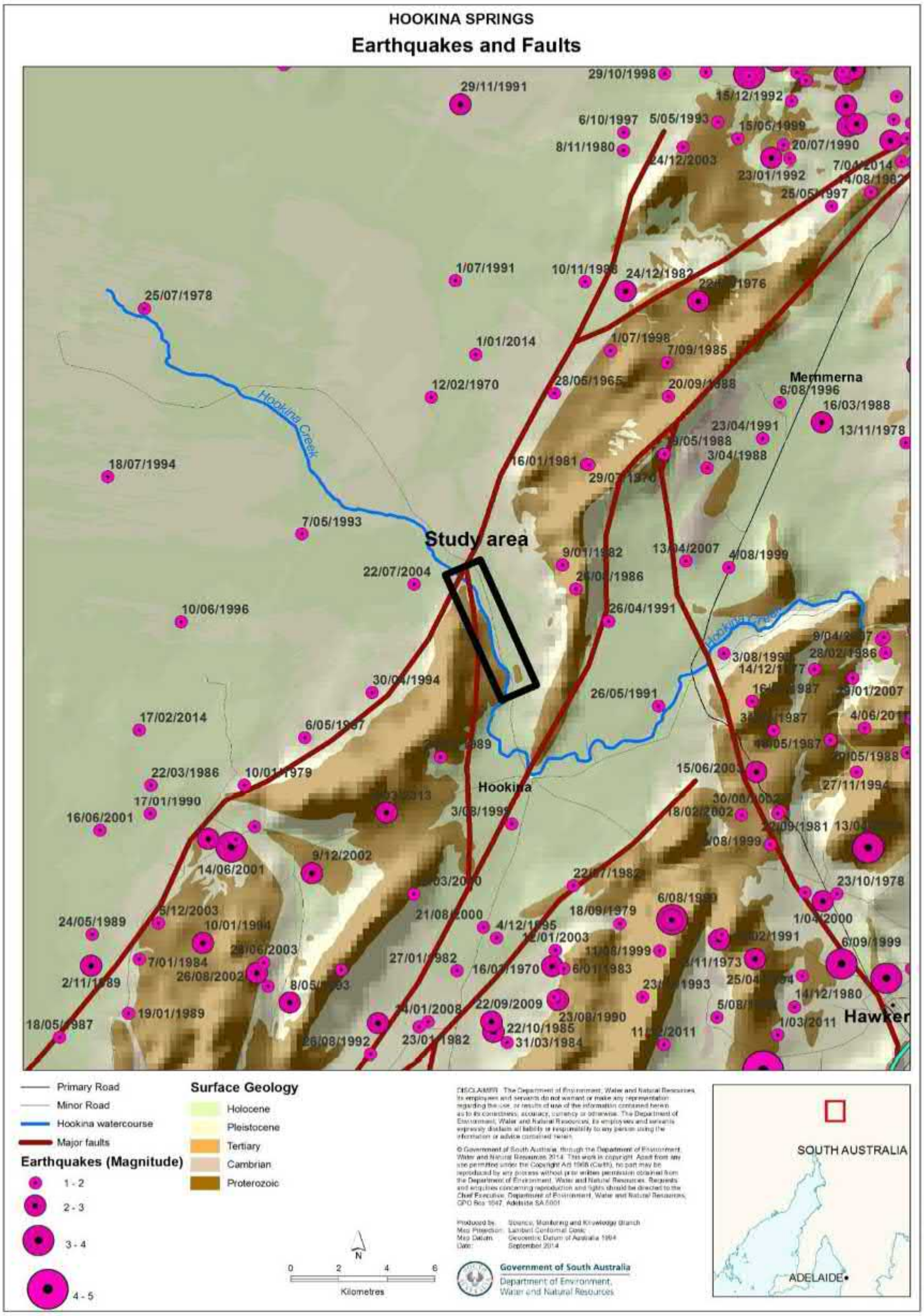


Figure 54 Uplift of the creek bed conglomerate in the Hookina Spring area. Source: Barnett et al., 2015.

Figure 55 Schematic section along Hookina Creek indicating uplift of the creek bed conglomerate. Source: Barnett et al., 2015.

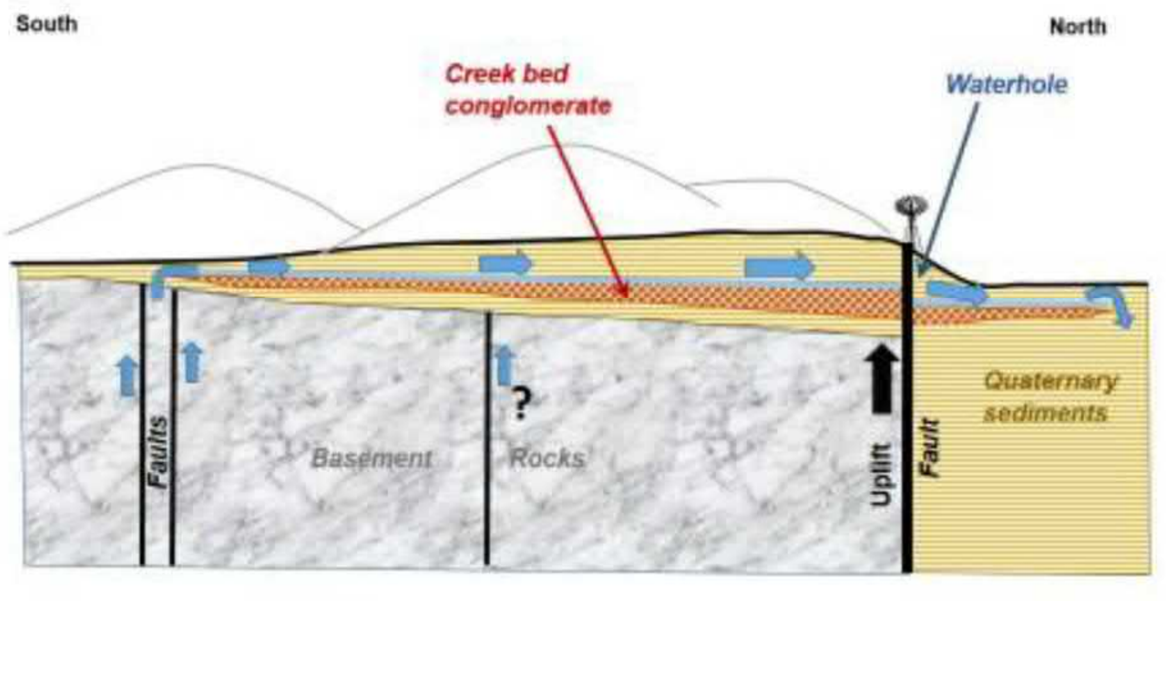


Figure 56 Range front at the northeast of the Wallerberdina site. Source: Clark (2018c).

Red arrows mark points where stream patterns change. The red line indicates the location of the topographic profile shown in the lower panel, which displays a change in slope.

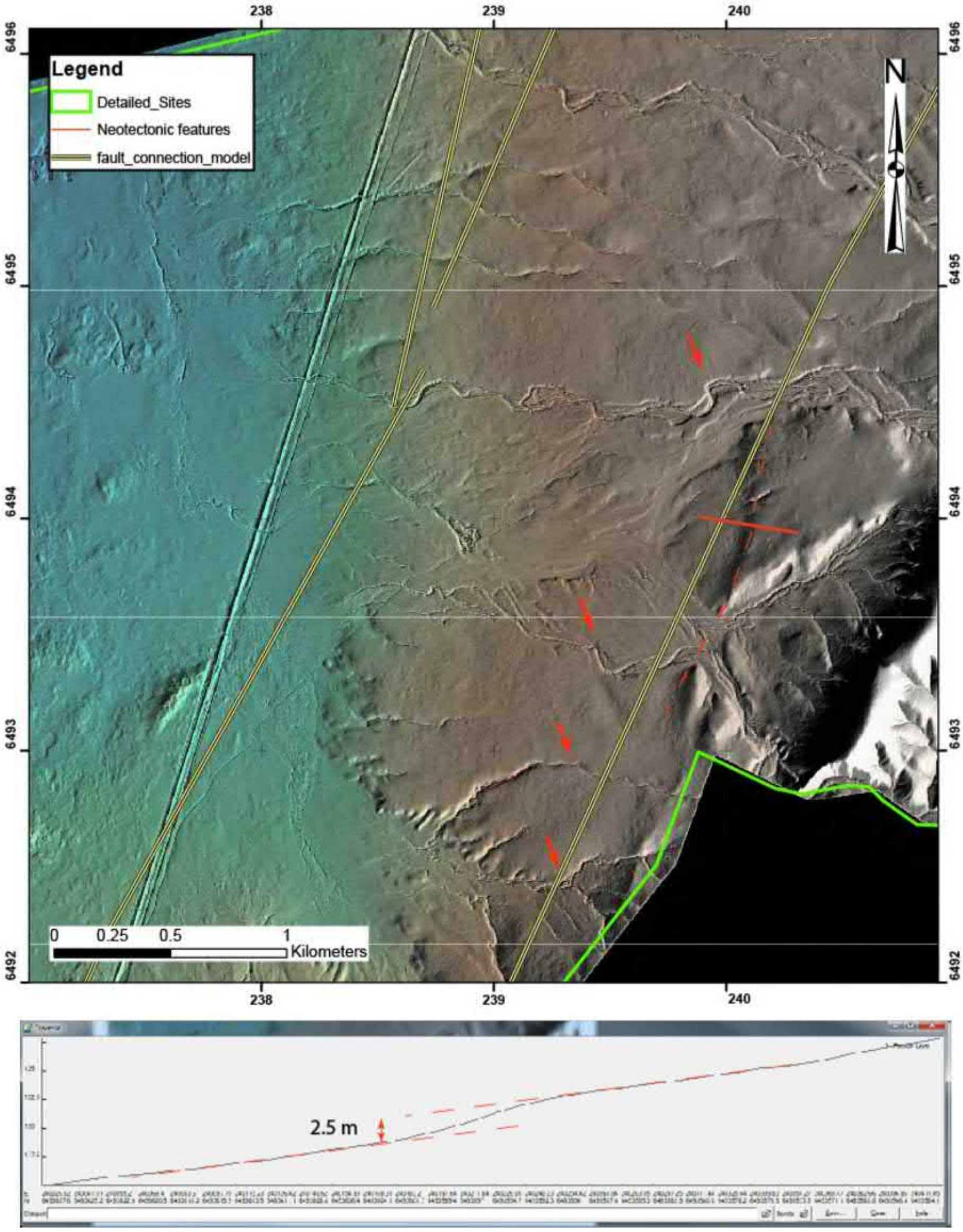
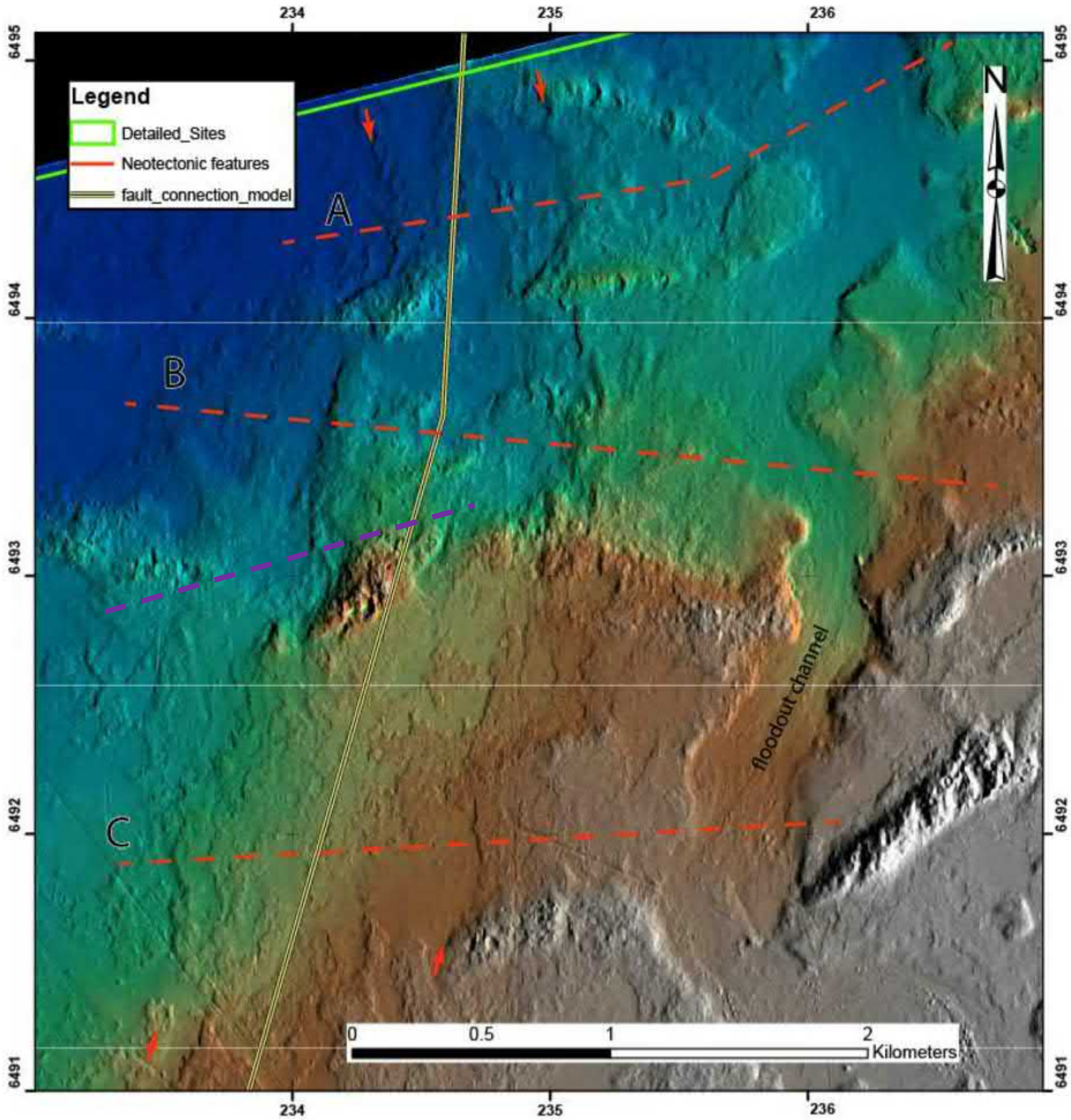


Figure 57 Top: Linear scarps (red arrows) bracketing possible subsurface neotectonic feature (identified in the fault connection model) for the northwest of the Wallerberdina site. Source: Clark (2018c).

The dashed purple line shows the location of the Velseis Line 04 whose profile is shown in Figure 53. Bottom: Profile B across linear scarps (red arrows) on either side of a possible subsurface neotectonic feature (identified in the fault connection model) for the Wallerberdina North West site.



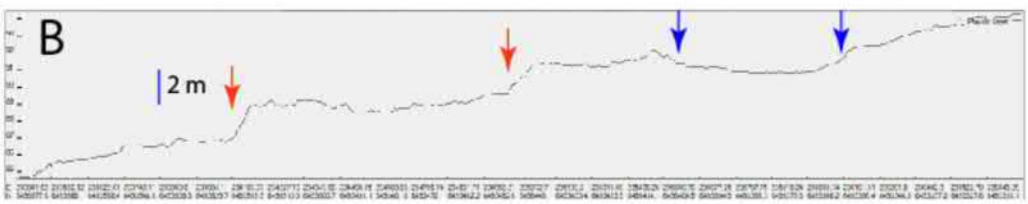


Figure 58 Wallerberdina North West 04 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom).

The location of the line is shown in Figure 52. Source: Velseis.

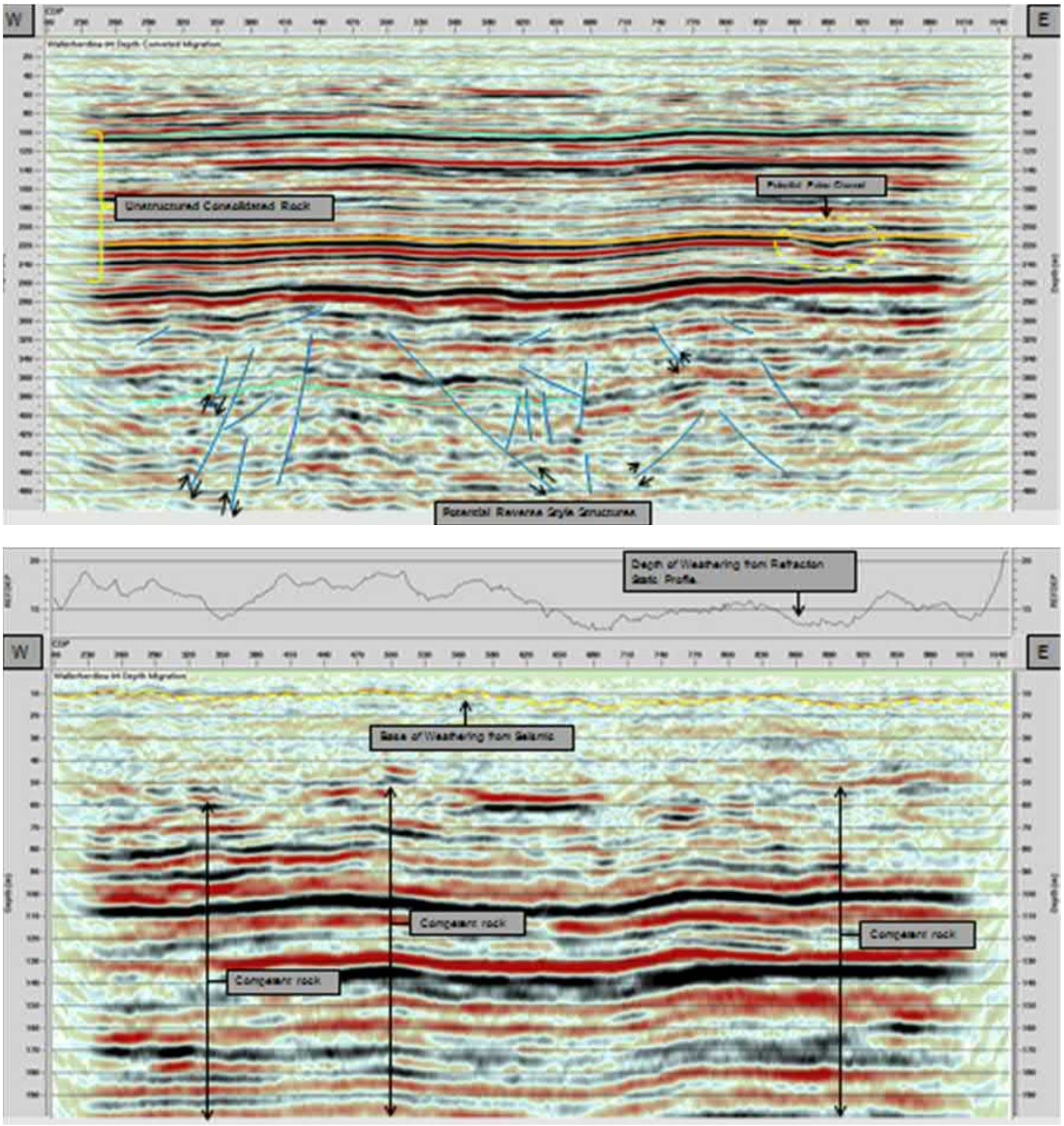


Figure 59 Wallerberdina North West 03 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom).

The location of the line is shown in Figure 52. Source: Velseis.

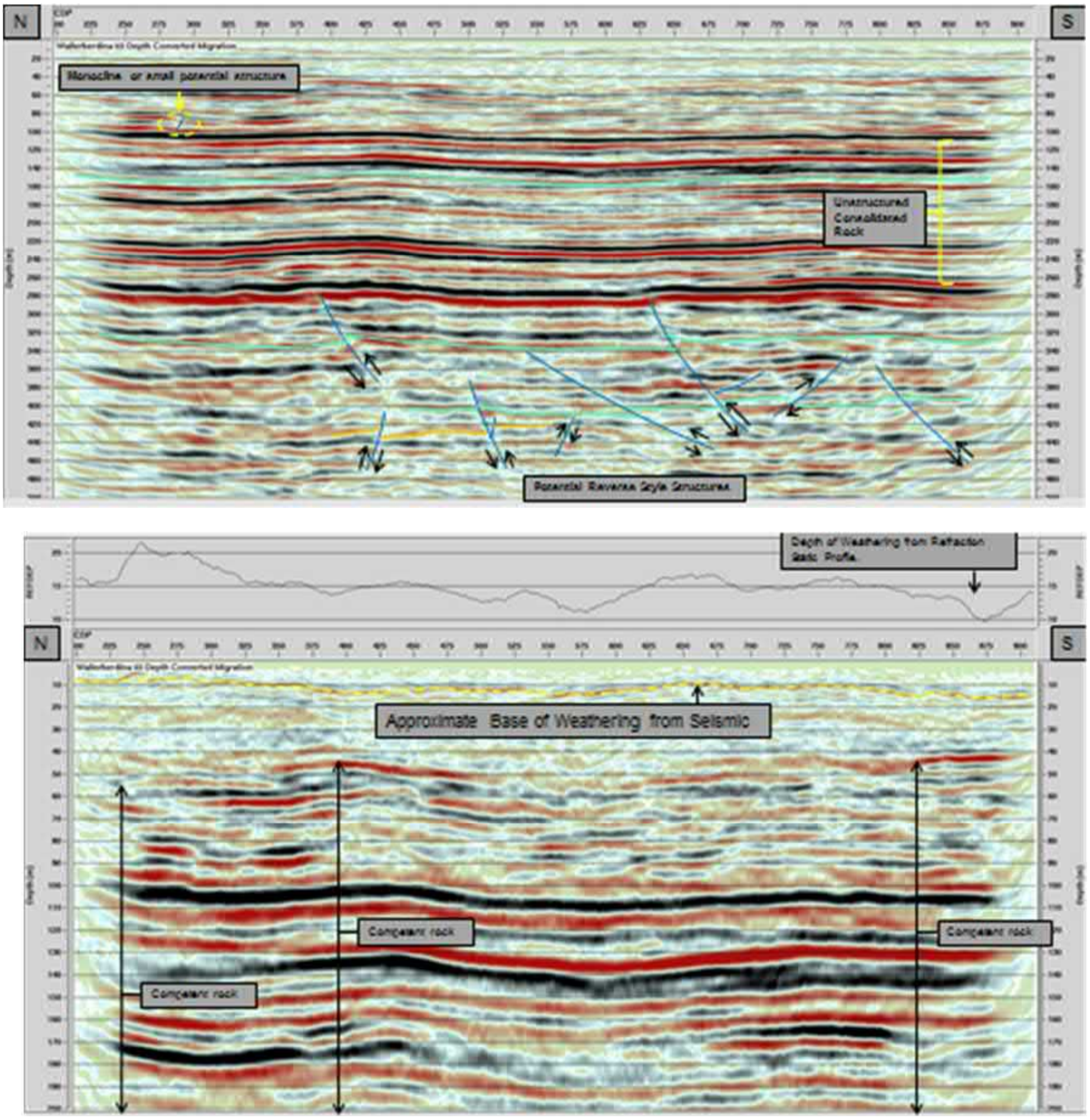


Figure 60 Wallerberdina South West 06 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom). Source: Velseis.

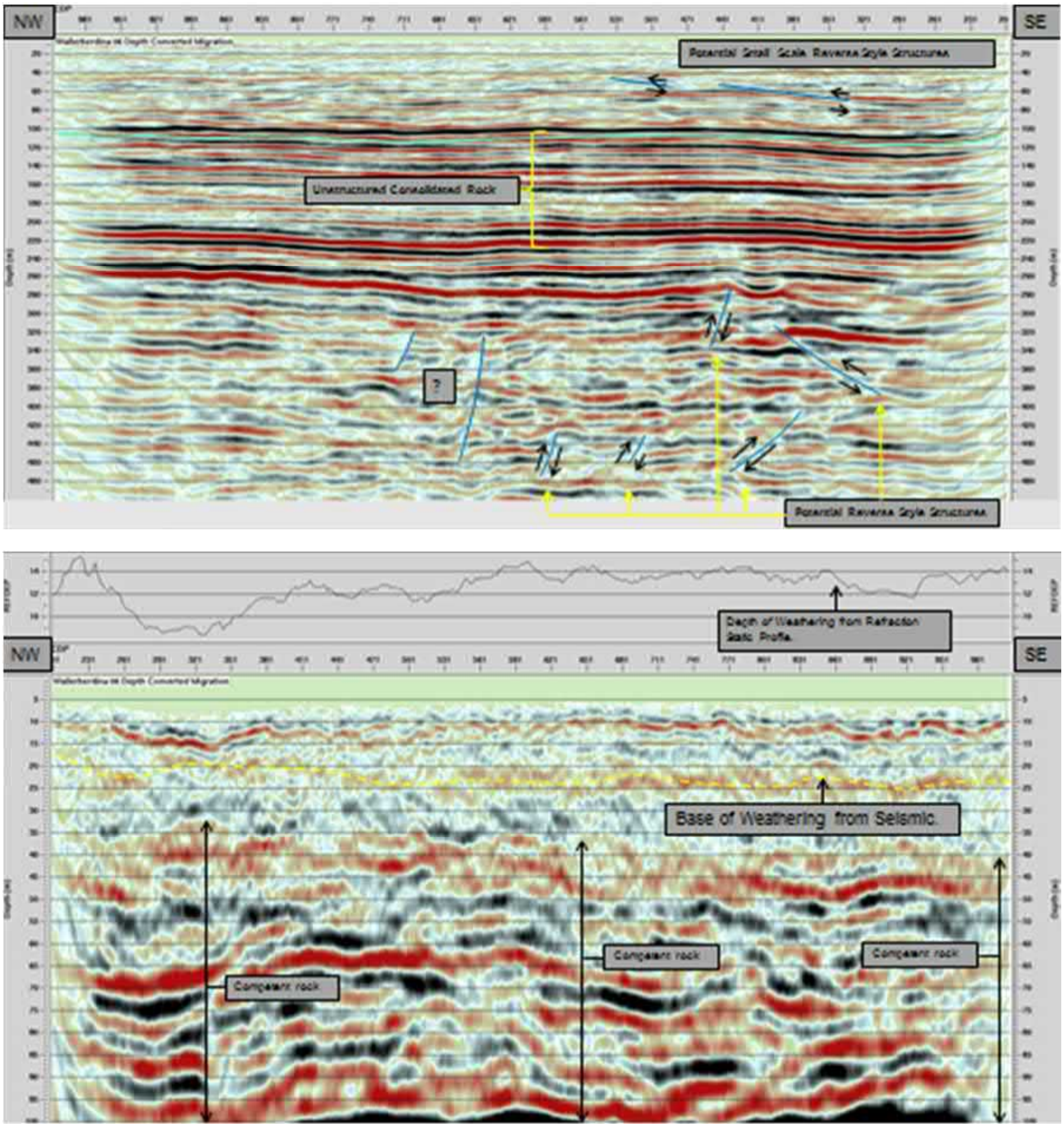


Figure 61 Wallerberdina South West 05 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom). Source: Velseis.

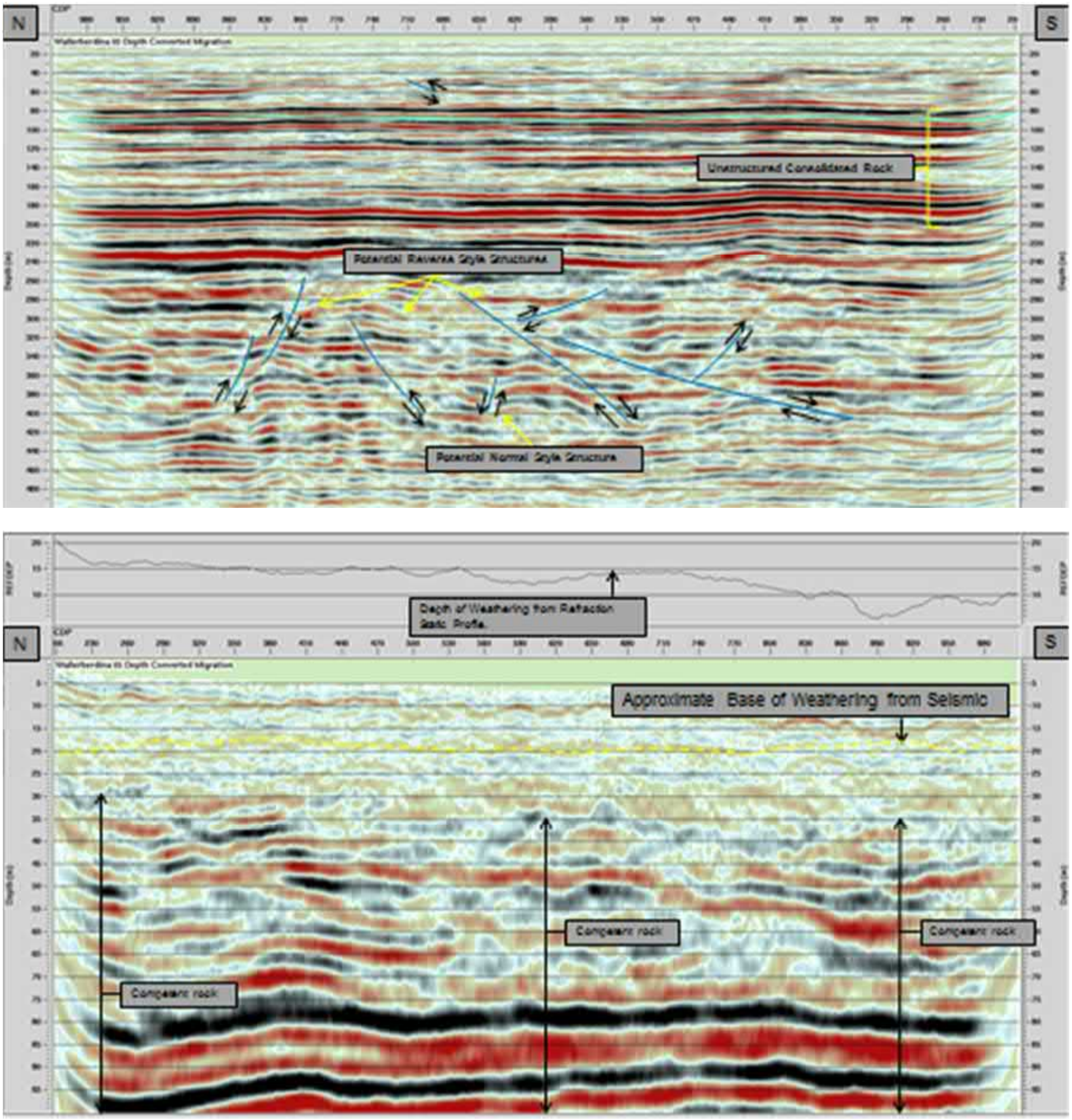


Figure 62 Location of the Wallerberdina East, Velseis shallow seismic lines (purple lines), and possible subsurface neotectonic features identified in the fault connection model of Clark (2018b) (green lines).

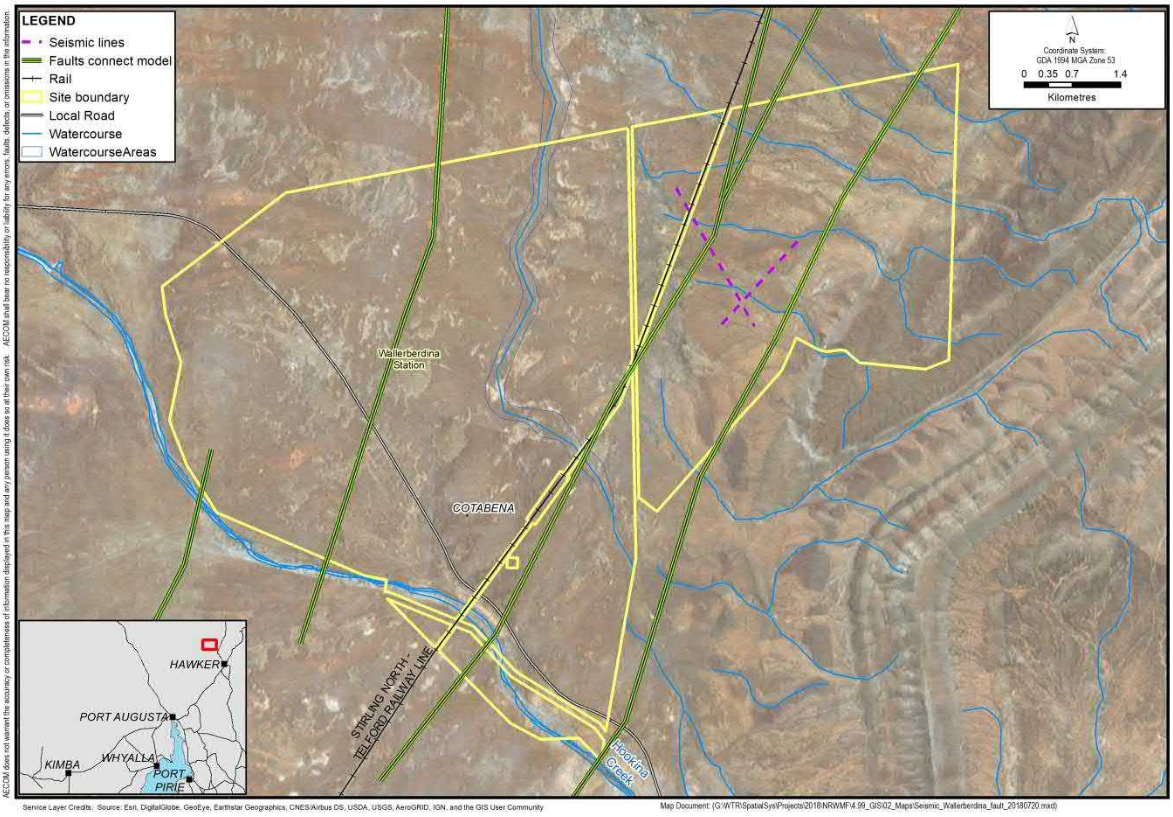


Figure 63 Wallerberdina East 01 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom). Source: Velseis.

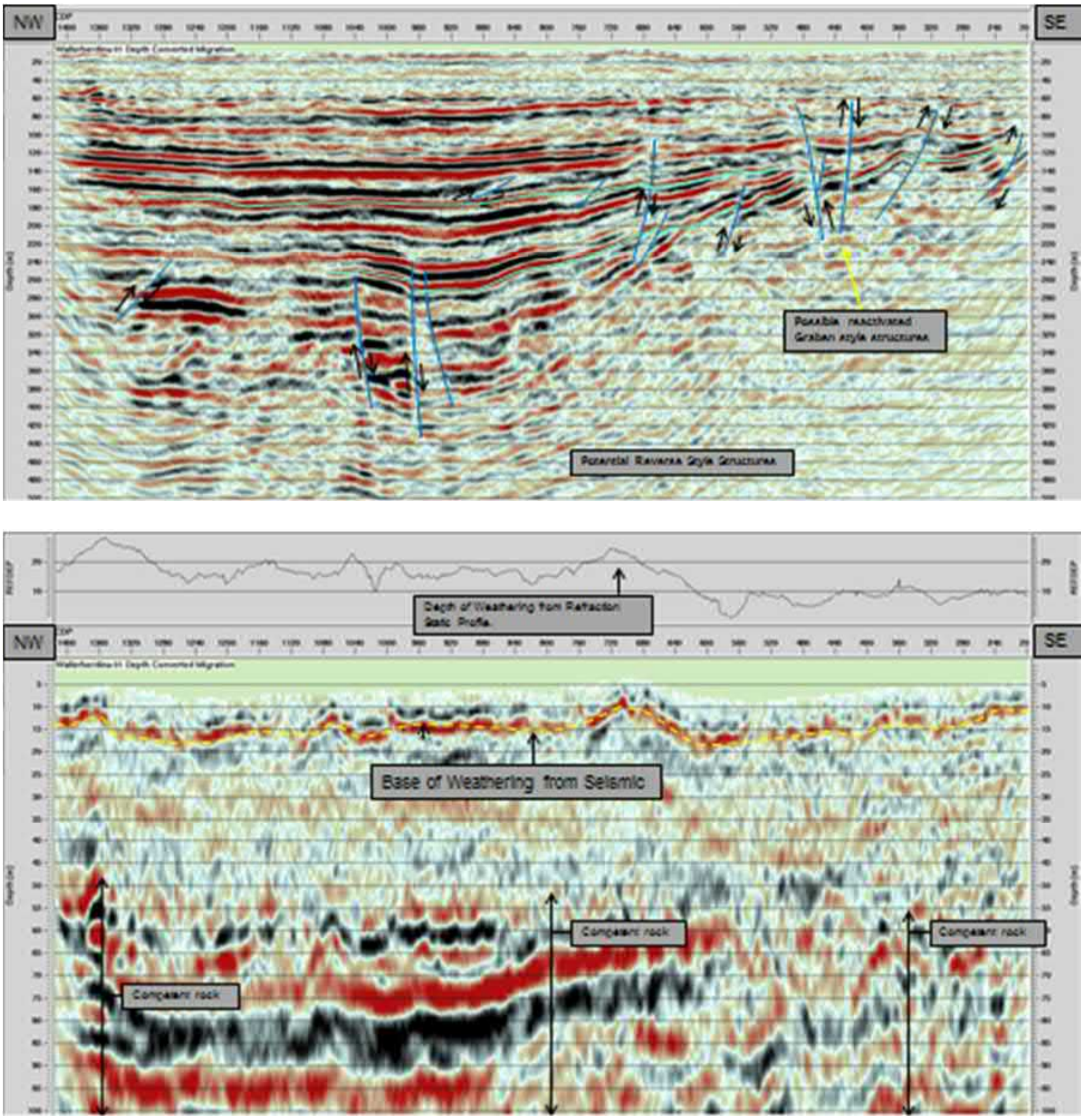


Figure 64 Wallerberdina East 01 Depth Converted Migrated Stack Interpreted Structure (top) and Interpreted Section at Near Surface (bottom). Source: Velseis.

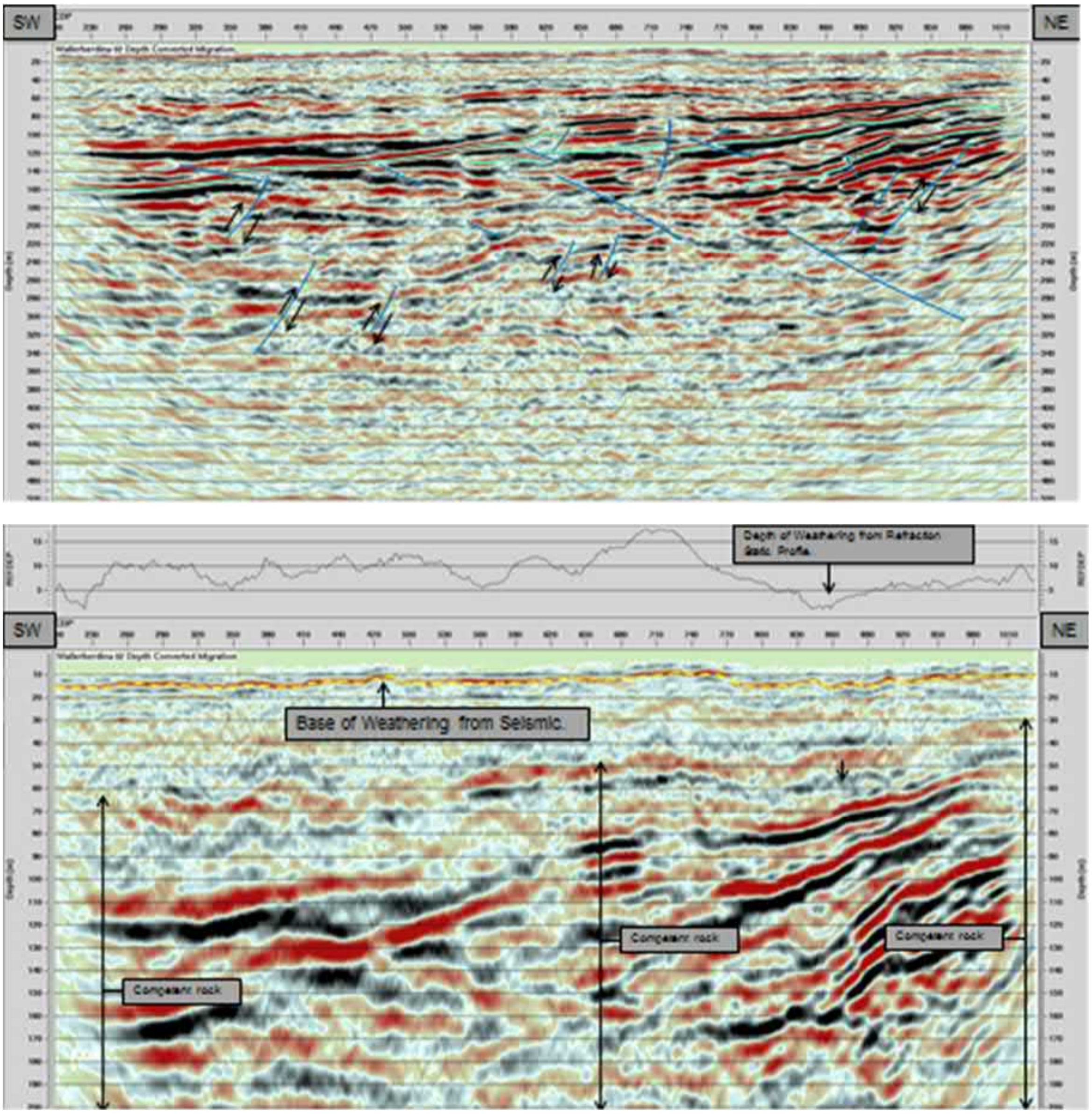


Figure 65 Seismic reflection profile 09GA-CG1 across the western range front of the central Flinders Ranges just south of Wallerberdina. Modified from Clark (2018a), from Preiss et al. (2010).

The yellow line shows the base of the Cenozoic sediments. The projected locations of the Wallerberdina NW & SW and E Velseis lines are indicate by the letters above the profile.

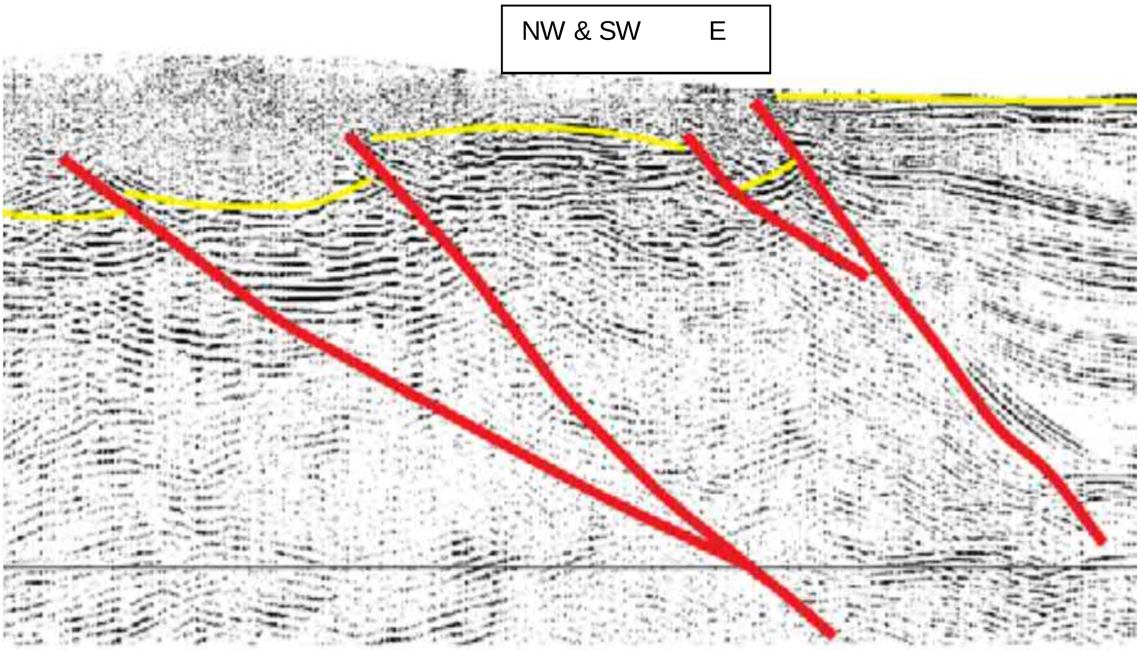
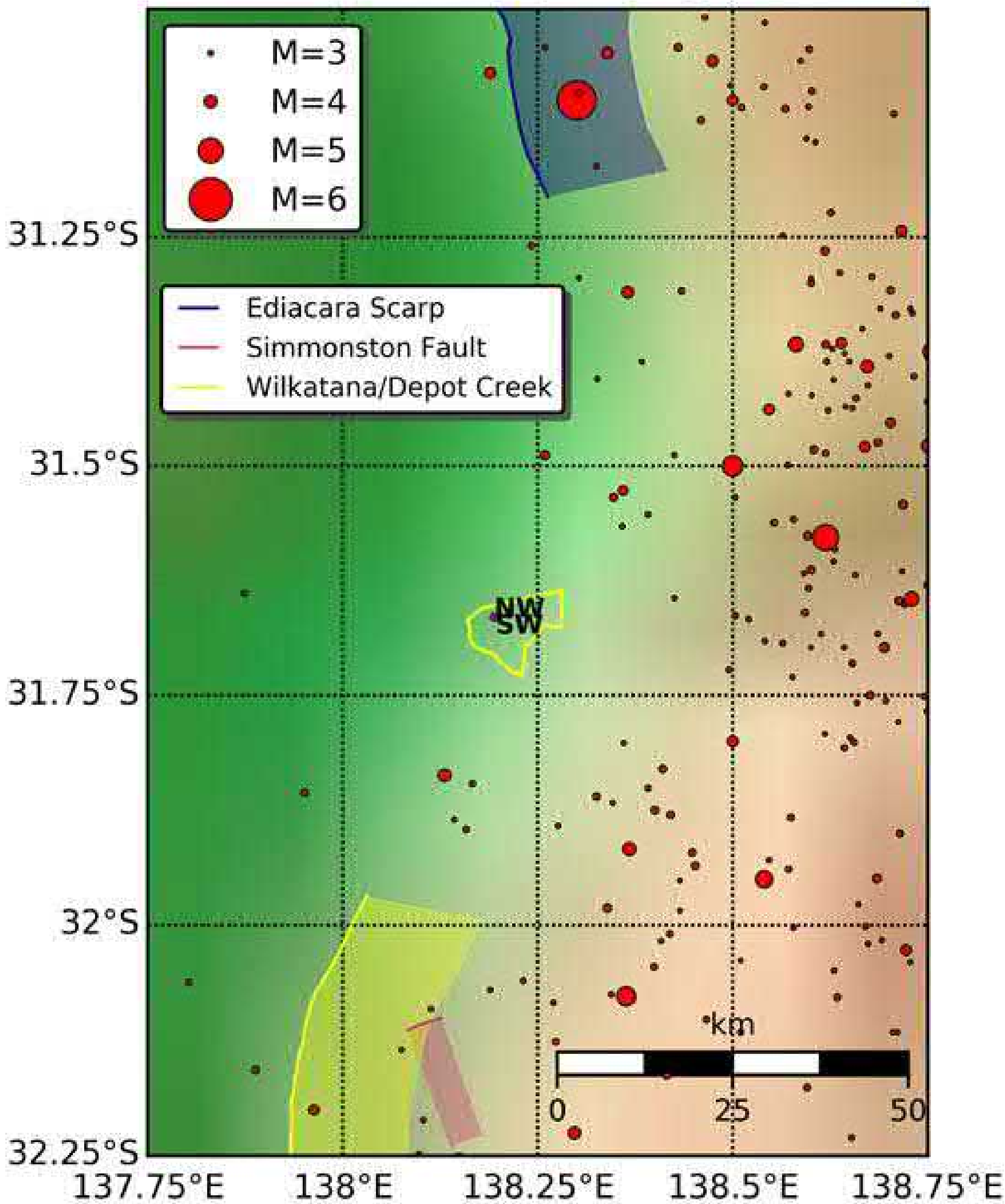


Figure 66 Neotectonic features and historical earthquakes for the Wallerberdina site based on Clark et al. (2011) and Geoscience Australia (2018).

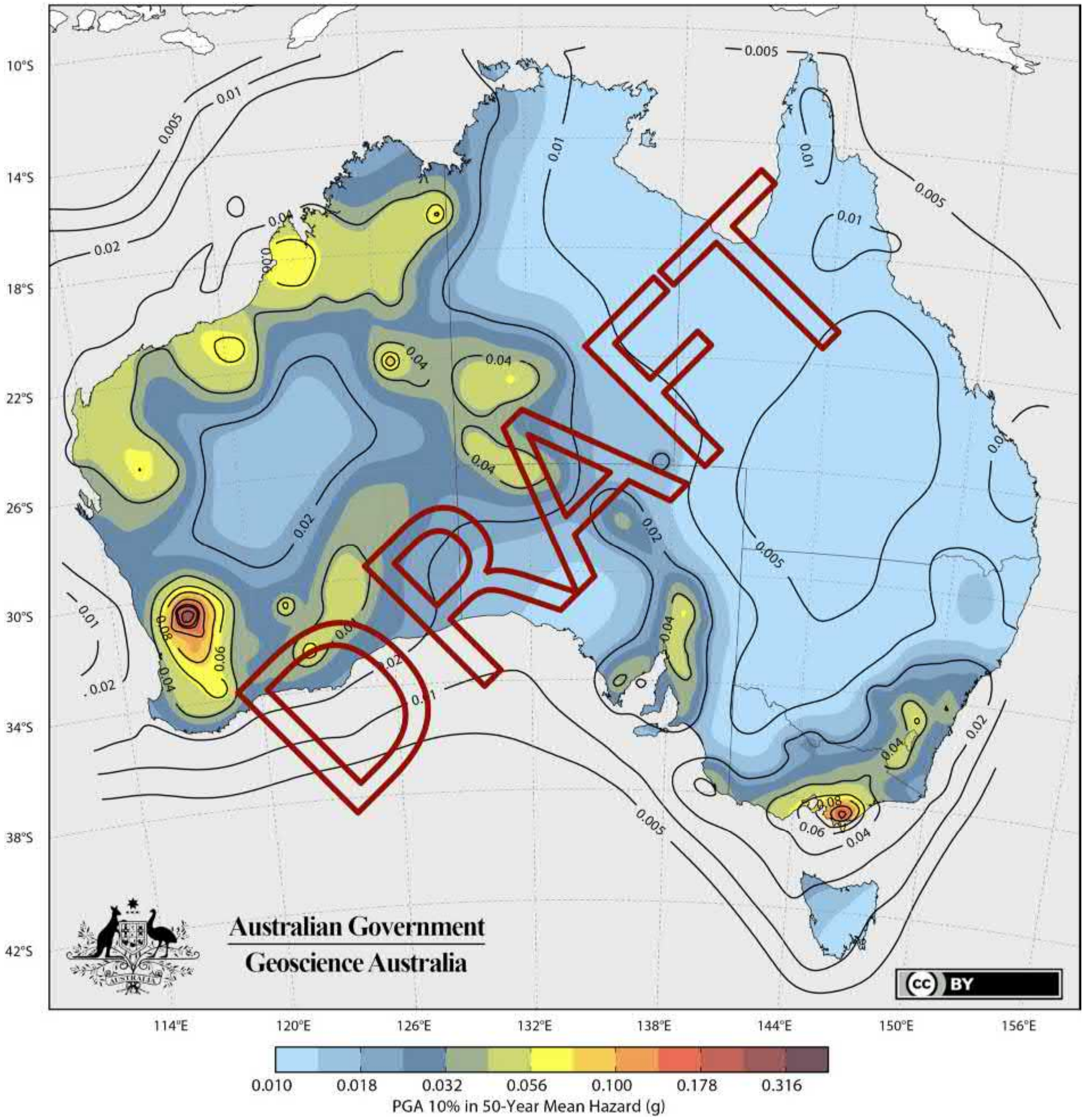
The top edges of the faults are shown by dark lines and their surface projections are shown by the coloured bands.



A provisional seismic hazard map of Australia is shown in Figure 67. The map shows peak acceleration having a 10% probability of exceedance in 50 years for site class B_e. The hazard value at the Wallerberdina North West site is approximately 5%g, which is well below the damage threshold for ordinary structures.

Figure 67 Provisional peak ground acceleration (PGA) as proposed for the AS1170.4–2018 as of May 2017. Source: Allen et al. (2017).

Note: values from the NSHA18 within this map are in draft form only and the hazard contours are likely to change prior to the completion of the final model by June 2018.



3.3.2.1 Assessment Criterion 1 - Absence of potentially active faults in the foundation

The interpreted fault connection model of Clark (2018b) contains an inferred fault that intersects the Wallerberdina North West and Wallerberdina South West sites, and analysis of LiDAR data by Clark (2018c) suggests the association of this subsurface feature with fault scarps in the Wallerberdina North West site. However, none of these features is evident in the Velseis seismic profiles from the Wallerberdina North West and Wallerberdina South West sites. AECOM concludes that this criterion is largely satisfied because of the absence of major recent faulting in the Velseis profiles at the site. One interpretation of the Wallerberdina Northwest and Southwest seismic profiles. Is that there is possible subtle evidence for fault propagation folds, an apparent east-facing monoclinal fold deeper in the basin strata, and the potential association of these features with the 2 m high scarps described above that may be active faults. Further seismic field investigations should be undertaken should the Wallerberdina site be further considered to enable more detailed evaluation of this area and the surrounding broader site, along with deep drilling at the Wallerberdina east site to provide stratigraphic control for the Wallerberdina #1 and #2 seismic lines.

3.3.2.2 Assessment Criterion 2 - Absence of near-surface faults below and near the foundation

As noted above, there is evidence for the absence of recent shallow faulting in the foundations of the site from the Velseis profiles at the site The undisturbed appearance of the lakebed sediments in these profiles suggests that they have not been disturbed by shallow subsurface faulting, If the lakebed sediments are Eocene in age, this means they have been undisturbed for 50 million years. However, it is likely that there are faults nearby if the interpretation of Figure 50 is correct, so this criterion is satisfied at a lower level of confidence that Criterion 1. One interpretation of the Wallerberdina Northwest and Southwest seismic profiles is that there is possible subtle evidence for fault propagation folds, an apparent east-facing monoclinal fold deeper in the basin strata, and the potential association of these features with the 2 m high scarps described above that may be active faults. Further seismic field investigations should be undertaken should the Wallerberdina site be further considered to enable more detailed evaluation of this area and the surrounding broader site, along with deep drilling at the Wallerberdina east site to provide stratigraphic control for the Wallerberdina #1 and #2 seismic lines.

3.3.2.3 Assessment Criterion 3 - Absence of nearby faults

Regardless of the precise locations of faults addressed in relation to assessment criteria 1 and 2, it is clear that the Wallerberdina site lies on the western range front of the central Flinders Ranges (Clark, 2018a), and is located within 20 km of major faults. For example, the multiple strands of the interpreted fault connection model (green lines in Figure 52) all have the potential to generate near-fault rupture directivity effects and hanging wall effects. The fault strands are interpreted to dip down to the east, and so the Wallerberdina site is located on the hanging wall of one or more of these fault strands. It has not yet been demonstrated which if any of these fault strands is active. However, comparison of seismic lines from the eastern and western sites suggest that the Tertiary Torrens Basin is deeper at the eastern sites than the western sites. This is consistent with the interpretation of deep crustal seismic data (Clark, 2018a, Figure 24) to the south of the sites, which indicates several faults are present near the western range front, and suggests that there is a basin-deforming fault present between the eastern and western sites. Accordingly, considering the likely presence of active fault strands near the Wallerberdina site, AECOM concludes that these sites are subject to near-fault strong ground motion conditions which will need to be considered in the design phase.

A provisional seismic hazard map of Australia (Figure 67, Allen *et al*., 2017) shows that the peak acceleration having a 10% probability of exceedance in 50 years for site class B_e at the Wallerberdina site is approximately 5%g. AECOM expects that seismic design of the NRWMF would be based on a higher ground motion level having a lower probability of exceedance, and that consideration of near fault rupture directivity and hanging wall effects could require higher design ground motions. A preliminary estimate of the peak accelerations having a 2% to 1% probability of exceedance in 50 years for site class B_e (annual exceedance probabilities of 1/2,500 to 1/5,000) is 15%g to 20%g. IAEA (2000) does not indicate any ground motion conditions that should be avoided, and seismic design for these levels is expected to be straightforward, even in the presence of nearby faults.

3.3.2.4 Assessment Criterion 4 - Absence of ridgecrests at the site

Ridge crests can amplify earthquake ground motions. The sites do not have slopes large enough to generate topographic amplification based on Eurocode 8 criteria. The site therefore satisfies this criterion.

3.3.2.5 Summary Assessment

The table below provides a summary of the qualitative desktop assessment of site characteristic criteria for seismic hazards. It should be noted that this assessment is based on available data and that further seismic investigations have been recommended in this report.

Table 48 Desktop Assessment Summary of Site Conditions against Seismic Criteria

Assessment Criterion	Site Condition	Confidence
Absence of potentially active faults in the foundation	Absent based on neotectonic and deep seismic data and shallow seismic data	Moderate
Absence of near-surface faults beneath or near the foundation	May be present based on neotectonic and deep seismic data	Moderate
Absence of nearby faults	Likely to be present based on neotectonic and deep seismic data	Moderate
Absence of ridgecrests	Absent based on topographic maps	Very High

Summary of Interim Seismic Hazard Assessment

An interim seismic hazard assessment was done at the Wallerberdina site (AECOM, 2018) to assess the sensitivity of the hazard levels to uncertainty in earthquake source parameters, including the locations and slip rates of potentially active nearby faults. For ground shaking hazard, the sensitivity of probabilistic ground motion to the following five parameters was assessed: distance to the fault, location of the site with respect to the fault (foot wall or hanging wall); dip angle of the fault, slip rate of the fault; and earthquake recurrence model of the fault. For ground deformation hazard, the main focus of the sensitivity analyses was the amount of secondary (sympathetic, or triggered) faulting that a main faulting event might cause at the site, considering the site's distance from the main fault.

For a low level hazard facility, the SSE seismic design parameters following IAEA (2001) and IAEA (2003) guidance would have an annual exceedance probability of 1/1,000, and for an intermediate level hazard facility they would have an annual exceedance probability of 1/2,000. Although the NRWMF will temporarily store both low level and intermediate level waste, it will permanently store only low level waste, not intermediate level waste, so the appropriate SSE values for NRWMF would lie in the range of 1/1,000 to 1/2,000 based on IAEA (2001) and IAEA (2013). In this study, we chose to estimate ground motion hazard and surface faulting hazard levels for an AEP of 1/2500.

We found the ground shaking hazard is particularly sensitive to two parameters: fault slip rate, and the choice of earthquake recurrence model. It is moderately sensitive to fault location including hanging wall effects. It is otherwise not very sensitive to fault location, or to dip angle. The largest peak accelerations that we obtained for an AEP of 1/2,500 are about 0.4g, which are typical of the hazard levels having an AEP of 1/500 used for the design of ordinary buildings in seismically active regions; the best estimate is about 0.15g, about one third that level. These ground shaking levels can be readily mitigated if the characteristics of near fault ground motions are taken into consideration in design.

We found the ground deformation hazard level is very sensitive to fault location because the probability of secondary rupture decreases rapidly away from the main fault trace. Secondary fault displacement hazard was found to be zero for annual exceedance probabilities above 1/50,000 for the most severe case studied, far smaller than 1/2,500. Even if there were a primary fault displacement hazard (with the fault in the site foundation, which we do not consider to be present),, the annual exceedance probability would be zero for annual exceedance probabilities above 1/2,500 for the most severe case studied. Ground deformation hazard can be mitigated by the use of a thick mat foundation.

3.3.3 Design Issues and Mitigation Measures

This section addresses two categories of seismic hazard: ground deformation and ground shaking.

3.3.3.1 Ground Deformation Hazard

For new sites, IAEA (2006) recommends that:

> *"Where reliable evidence shows that there may be a capable fault with the potential to affect the safety of a plant at a site, the feasibility of design, construction and safe operation of a plant at this site should be re-evaluated and, if necessary, an alternative site should be considered."*

To the extent that ground deformation hazards due to earthquake faulting are found to be present at the site in the course of future investigations, it would be necessary to develop such design procedures. At present, there are no codified procedures for such design. However, in recent years there is a considerable body of knowledge that could be used in developing design for ground deformation hazard (Bray, 2001; Kerr et al., 2003; Oettle et al., 2013; 2015; Van Dissen et al. (2006). The following summary of available approaches is taken from Oettle et al. (2013)

Fault-induced angular distortion and lateral ground strain can cause beams to yield and eventually lead to structural collapse. When avoidance is not possible, geotechnical mitigation strategies can be employed. These strategies include spreading fault displacement over a large area, causing the structure to respond with rigid-body movement, and diverting the fault rupture around the structure. The effectiveness of these strategies can vary from protecting life safety to preventing significant damage and can be effective for a range of fault displacements. Earth fills should be sufficiently thick and ductile to prevent the underlying fault dislocation from developing at the ground surface. Thick reinforced-concrete mat foundations can be especially effective in shielding the superstructure from the damaging effects of the underlying ground movements. Although more challenging to implement, because they require accurate fault characterization, several fault diversion strategies also prove effective at protecting structures from fault movement.

3.3.3.2 Ground Shaking Hazard

The Wallerberdina site is subject to near fault rupture directivity effects and hanging wall effects. As described above, IAEA (2000) does not indicate any ground motion conditions that should be avoided. However, the design ground motions for the NRWMF should take account of near-fault effects.

Near-fault ground motions are different from ordinary ground motions in that they often contain strong coherent dynamic long period pulses and permanent ground displacements (Somerville, 2002). The dynamic motions are dominated by a large long period pulse of motion that occurs on the horizontal component perpendicular to the strike of the fault, caused by rupture directivity effects. Near fault recordings from recent earthquakes indicate that this pulse is a narrow band pulse whose period increases with magnitude, as expected from theory (Somerville, 2003). This magnitude dependence of the pulse period causes the response spectrum to have a peak whose period increases with magnitude, such that the near-fault ground motions from moderate magnitude earthquakes may exceed those of larger earthquakes at intermediate periods (around 1 second). The static ground displacements in near-fault ground motions are caused by the relative movement of the two sides of the fault on which the earthquake occurs. These displacements are discontinuous across a fault having surface rupture, and can subject a building that straddles a fault to significant differential displacements. The static ground displacements occur at about the same time as the large dynamic motions, indicating that the static and dynamic displacements need to be treated as coincident loads.

The response spectrum alone is not an adequate representation of near-fault ground motion characteristics, because it does not adequately represent the demand for a high rate of energy absorption presented by near-fault pulses (Somerville et al., 2000; Alavi and Krawinkler, 2000). This is especially true for high ground motion levels that drive structures into the non-linear range, invalidating the linear elastic assumption on which the elastic response spectrum is based. To fully portray the response of structures to near-fault ground motions, nonlinear time history analysis may be required. Fortunately, near fault ground motions containing forward rupture directivity are simple enough to be represented by simple time domain pulses, thus simplifying the specification of ground motion time histories for use in structural response analyses. Equations relating the period of the pulse to the earthquake magnitude, and the effective velocity of the pulse to the earthquake magnitude and distance, have been developed. The directivity pulse can be combined with the static fault displacement to provide a complete description on near-fault ground motions. The effect of the simultaneous dynamic and static ground motions on the response of a structure should be analysed using time histories that include both types of motion. Whittaker et al. (2003) provide guidance for the selection of near-fault ground motion time histories for use in design and analysis of structures.

Australian Standard AS1170.4 (Standards Australia, 2007) does not specify design procedures for near-fault conditions. However, near-fault conditions are addressed in ASCE 7-16, Chapter 11: Seismic Design Criteria, Part 11.4.1 Near fault Sites (ASCE, 2017; Kircher, 2017), which are defined as sites within 15 km of the surface projection of an active fault capable of producing a Mw 7 or larger earthquake, or sites within 10 km of the surface projection of an active fault capable of producing a Mw 6 or larger earthquake. Design and mitigation measures addressing the ductility demands of near-fault ground motions can be based on the ASCE 7-16 standards.

3.3.4 Data Gaps and Recommendations for Stage 2 Work

Although the Wallerberdina site is thought to be located near the western range front of the central Flinders Ranges, those faults were not imaged by the Velseis seismic profiles conducted for this assessment. This may have been because those profiles were of limited extent. It is important that a continuous east-west seismic profile across the Wallerberdina site be obtained to identify the locations of the range front faults. This is needed to confirm the absence of surface faulting at the site (Criterion 1), and to further assess the potential for ground deformation hazard (Criterion 2) and fault slip rates and near fault ground motion conditions (Criterion 3).

To the extent that ground deformation hazards due to earthquake faulting are found to be present at the site in the course of further investigations, the IAEA (2000) and McConnell et al (1993) guidelines could be used to develop an approach to the identification and investigation of fault displacement hazards. McConnell et al. (1993) suggest an approach that leads to the identification of three types of faults: Type III faults - need not be investigated in detail; Type II faults - candidates for detailed investigation; Type I faults - should be investigated in detail because they are subject to displacement and are of sufficient length and located such that they may affect repository design and/or performance or could provide significant input into models used to assess repository performance. The faults described in 3.1.1.2 of this report would be Type I Faults.

4.0

Enabling Infrastructure Considerations

4.0 Enabling Infrastructure Considerations

A desktop and limited field assessment was undertaken to consider the nature and significance of any constraints of existing enabling infrastructure required to construct and operate the NRWMF including power (renewable and non-renewable options), transport, utilities (including communications, water) and non-radioactive waste infrastructure.

Site characteristic assessment criteria that have the potential, either alone or in combination with other criteria, to impact on siting of the NRWMF were developed. Published and anecdotal information relevant to the site, local and regional area was reviewed and vehicular inspections of road infrastructure was undertaken to inform assessment against the site characteristic criteria.

Options for the provision of the enabling infrastructure have been outlined along with potential design issues and mitigation measures.

Data gaps and uncertainties in our understanding of the proximity, capacity and constraints of enabling infrastructure for connection and provision to the site with reference to the site characteristic criteria have been outlined below along with recommendations for further data to be collected. It is noted that AECOM has also been commissioned to further the assessment of options and to prepare a concept design for the preferred option for each enabling infrastructure element. This work will be informed by detail on the NRWMF requirements and the provision of information by existing enabling infrastructure asset owners.

4.1 Transport

4.1.1 Methodology and Results

A study of the Wallerberdina site was undertaken to investigate site access, possible transport routes to the proposed site and any key constraints arising from the existing site conditions. The assessment also considered multi-modal transport options such as sea, rail and road access. It should be noted that high level decisions regarding transportation modes such as sea and rail as alternatives to road transport have not been made and would require consideration by the Commonwealth. Accordingly, this review only documents sea and rail transport as options based on existing infrastructure with further decision making and detailed assessment required should these modes be given serious consideration. The construction and operational requirements of the site are also considered at a high level noting that the NRWMF design and operational aspects are still in progress.

This study included a review of aerial imagery, state road authority classifications / restrictions and operational information provided by Australian Nuclear Science and Technology Organisation (ANSTO). Additional data requirements / gaps have been highlighted. This assessment considered the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) code for the Safe Transport of Radioactive Materials as well Australian and local road design guidelines. International safety standards for radioactive materials were also considered.

4.1.1.1 Site Characteristic Criteria

The overall objective of the desktop assessment for the Wallerberdina site is to evaluate the capacity of the overall and local road network to carry the required loads and the overall complexity of transport logistics. As such, the following criteria were used to assess the characteristics of the site:

- Proximity to waste source locations and implications for transport routes and modes.
- Capacity of overall access routes (including potential for multi modal transport) for transport of wastes in conformance with ARPANSA guidelines.
- Capacity of localised network (reliability and proximity) for supply, staff and emergency access.
- Road and infrastructure upgrade requirements.

4.1.1.2 Methods and Results

The following data was used in this assessment:

- Aerial imagery;
- Road and rail GIS datasets (sourced 05/03/2018);
- State road authority traffic volumes and heavy vehicle restrictions (sourced 05/03/2018);
- Operational information provided by ANSTO (provided 28/02/2018); and
- Images taken from site visits (obtained 05/05/2018).

4.1.2 Assessment Against Criteria

The potential NRWMF site is located 30 km north east of Hawker SA (referred to as Wallerberdina) and will generate additional traffic during both the construction and operational phases. The operational phase will involve the movement of facility staff and the transport of waste to the site. Radioactive waste is currently stored at various facilities around Australia such as Woomera, SA, Lucas Heights, NSW and various hospitals / laboratories around Australia.

Multi-modal methods of waste transport (road, rail and sea) are considered as part of this assessment and will involve the movement of B-doubles, semi-trailers and very infrequent movements of large TN81 containers (four over the operational life of the NRWMF). The capacity of the site to accommodate the required heavy vehicle and over-dimensional and / or over-mass movements during the construction and operation phases will be considered.

4.1.2.1 Existing Conditions

The Wallerberdina site is located west of The Outback Highway (state arterial road) on private land and is serviced by unsealed local roads.

4.1.2.1.1 Arterial Road Network

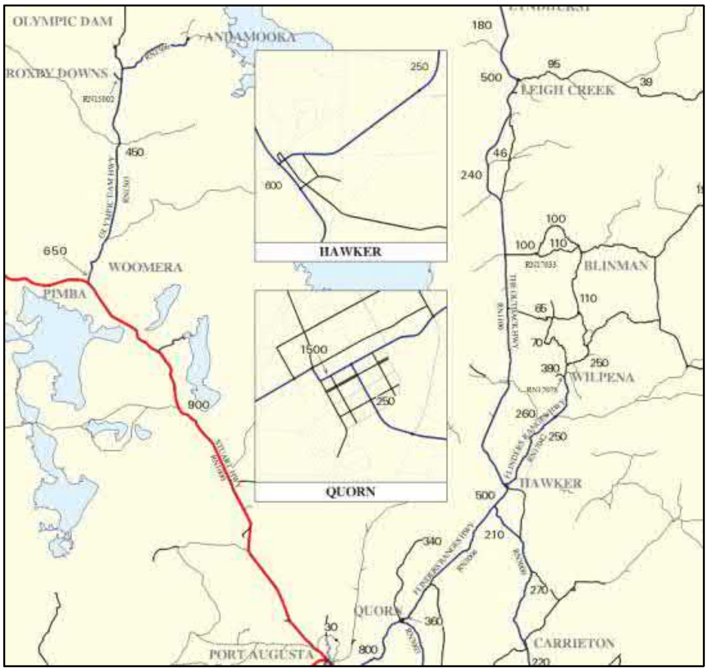
The arterial road that will provide primary access to the local road network (subsequently the site) is the Outback Highway and is shown in Table 49.

Table 49 Arterial roads surround the site

Arterial Road	Road Management Authority	Road Category	AADT
The Outback Highway	DPTI	Arterial	260

The Outback Highway is a two-way, sealed and marked road with a designated speed limit of 110 km/hr. Annual Average Daily Traffic (AADT) estimates are provided for the state-managed arterial roads in the vicinity of the site, as shown in Figure 68. The Outback Highway has low AADT, with traffic flows of 260 vehicles / day along the section between Hawker and Leigh Creek.

Figure 68 Annual Average Daily Traffic Estimate 24 hour two way flows (Department of Planning, Transport and Infrastructure, 2015)



4.1.2.1.2 Approved Heavy Vehicle Routes

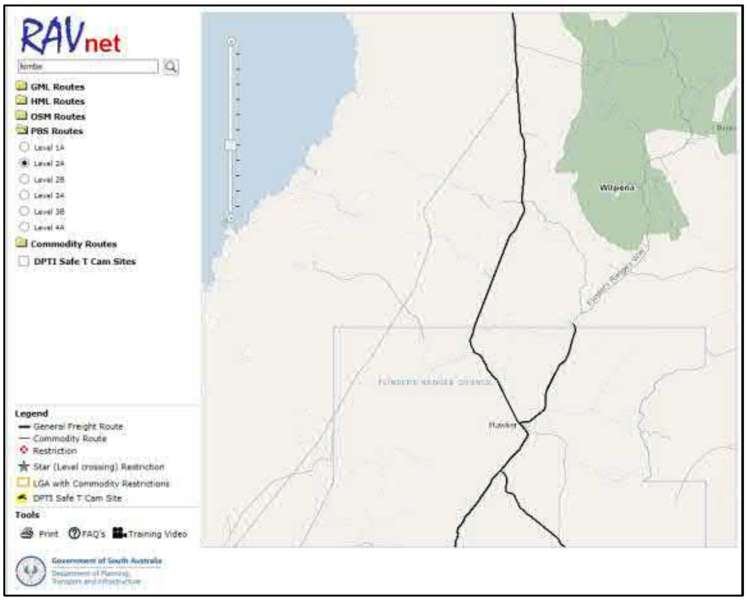
The Performance Based Standards (PBS) scheme provides the operating environment for the vehicles that fit within the specified PBS categories. In turn they provide limits and restrictions for the categories of vehicles on the road network as a way of maintaining safety, vehicle productivity and infrastructure quality standards. The performance levels are classified according the vehicle length as shown in Table 50 and RAVnet, accessed via the DPTI website (2016a), identifies the approved routes for each class.

Figure 69 indicates the access routes for the PBS category of level 2B vehicles, such as 26m B-double configurations which would be the largest type of vehicles used for most of the construction and operational activities (with the exception of the over-weight loads transporting the TN81 Containers which occurs very infrequently). The Outback Highway is the only road in the vicinity of the sites that is classified as a PBS approved route.

Table 50 PBS route network classification (National Transport Commision, 2008)

	Network Access by Vehicle Length (m)	
Vehicle Performance Level	**Access Class A**	**Access Class B**
Level 1	L ≤ 20	
Level 2	L ≤ 26	26 < L ≤ 36.5
Level 3	L ≤ 36.5	36.5 < L ≤ 42
Level 4	L ≤ 53.5	53.5 < L ≤ 60

Figure 69 Approved restricted access vehicle routes approved under PBS Level 2A (Department of Planning, Transport and Infrastructure, 2018)



4.1.2.1.3 Local Roads

The area surrounding the potential site has a local road network mostly consisting of unsealed, low trafficked roads. Some are all-weather roads however may be less suitable for carrying heavy loads during the winter months as a result of rainfall. The site is bounded to the south by Lake Torrens Homestead Road and to the west by unnamed vehicle tracks (refer to Figure 70 and Figure 71 below).

Figure 70 Lake Torrens Homestead Road

Figure 71 Unnamed vehicle tracks

4.1.2.1.4 Townships

Hawker

Hawker is located 30 km southeast of the site with a population of approximately 340. Flinders Ranges Way runs through the centre of the town meaning potential transportation impacts (social, economic etc.) on the community and sensitive users must be considered. Potential sensitive users include (but are not limited to):

- Hawker Area School
- Hawker Memorial Hospital

4.1.2.1.5 Rail

The disused Cotabena Railway (refer to Figure 72) that was used to transport materials between the Leigh Creek Coal Mine (closed in 2015) and Port Augusta is located east of the proposed site. There is potential to use this to transport waste materials to the site. However, this would require additional works such as the construction of a siding to the NRWMF and remediation of the existing rail line. It should also be noted that the use of rail to transport waste will require transfer from one mode of transport to another. This process would be subject to relevant approvals. Many existing intermodal facilities are in built-up urban areas.

Figure 72 Cotabena Railway

4.1.2.1.6 Proximity to Ports

There is potential to have waste shipped from Port Kembla, NSW to key port locations such as Whyalla and Port Pirie. From here waste would either be shipped via road or rail to the site. This will likely be necessary for the infrequent transportation of TN81 containers which also require the use of over-dimensional vehicles for transport via road.

The port of Port Pirie is operated by Flinders Ports and the port of Whyalla is operated by OneSteel. The capacity of the Whyalla port will be influenced by third party access arrangements (AECOM Australia Pty Ltd., 2018).

The previous South Australian Government has pledged a $2 billion infrastructure package which would involve the development of a new commodities port in the Upper Spencer Gulf region (ABC News, 2018). There may be potential in the future for this port to be utilised in the transport of waste to the NRWMF.

4.1.2.2 Waste Source Locations

The waste to be stored at the NRWMF is expected to originate from:

Woomera, SA

A CSIRO research facility is located at Woomera and has been identified as a key source of low-level waste (Department of Industry, Innovation and Science, 2018). The Wallerberdina site is located approximately 300 km away from Woomera on the National Highway Network (via Port Augusta). There are not expected to be any significant constraints on the movement of low level waste via this section of the National Highway Network.

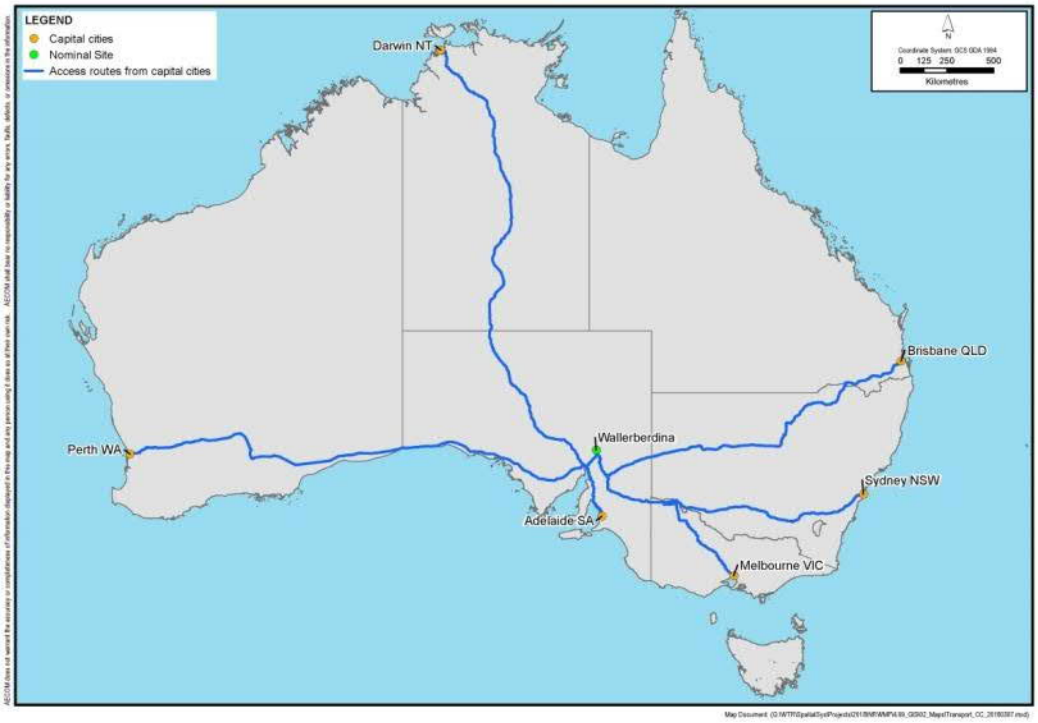
Lucas Heights, NSW

The ANSTO facility is located at Lucas Heights and stores large portions of Australia's low level and intermediate level waste (Department of Industry, Innovation and Science, 2018). The Wallerberdina site is located approximately 1600 km away from Lucas Heights on the National Highway network.

Hospitals and Laboratories

Nuclear medicine and radiology are a key source of radioactive waste. For the purposes of this assessment, transport routes from hospitals located in state capital cities have been assessed. The site's location in relation to state capital cities is shown in Figure 73.

Figure 73 Access routes from capital cities



4.1.2.3 Construction Phase

Vehicles used to transport materials and components to the proposed site during construction are expected to originate from the following locations:

Table 51 Origin on construction materials and components

Material / Component	Descriptions	Likely origin on associated transport to site
Locally manufactured or sources components	Various	Greater Metropolitan Adelaide and Eyre Peninsula
Construction materials	Steel reinforcing, concrete, quarry material etc.	Greater Metropolitan Adelaide and Eyre Peninsula
Labour	Staff and contractors	Greater Metropolitan Adelaide and Local Region

Based on the current reference design of the NRWMF, no construction components are expected to fall into the over-dimensional and / or over-mass category for access on the road network. Due to the amount of concrete required to construct the NRWMF and the lack of a local concrete batching plant, it is likely that temporary batching plant be built on-site. This would reduce the total number of vehicle movements during the construction and operational phases of the project.

Locally manufactured and sourced components are likely to be transported to the site in general access vehicles and can therefore use most of the surrounding road network for access. However, this is dependent on a number of the existing unsealed roads and intersections surrounding the site being upgraded to suitable standards. This will likely both involve widening and sealing existing roads and intersections as well as potentially constructing entirely new roads. In later sections, different access routes through the local road network are discussed.

Table 52 Maximum limits for general access (National Heavy Vehicle Regulator, 2016)

Dimension	Maximum Limit	Units
Gross Mass	42.5	Tonne
Width	2.5	Metre
Height	4.3	Metre
Length*	19.0	metre

*Refers to an articulated vehicle

Labour associated with the construction of the proposed NRWMF will likely arrive on site via passenger vehicles or 4WD vehicles from towns surrounding the sites. There is also potential for on-site accommodation for construction personnel.

When determining potential access routes for both construction and operation vehicles, the following factors were considered:

- Capacity of the routes for all weather access and the structural capacity of the road infrastructure (pavement and bridges / culverts)
- Limitations of the existing road network (vertical and horizontal geometry)
- The general impact on road users and surrounding communities

The total number of vehicles required for construction is not currently known. A detailed assessment of the impact construction activities will have on the wider network will need to be undertaken as part of future works.

4.1.2.4 Operational Phase

As per information provided by the Australian Nuclear Science and Technology Organisation (ANSTO), the following assumptions were made regarding the size of vehicles and frequency of trips made when transporting waste to the NRWMF:

Table 53 Operational vehicle size and movement frequency

Item	Size & Weight of Load	Peak Frequency
TN81 Container (or similar)	130 tonnes – over-dimensional and over-mass	1 p/a for the first 2 years 1 in 2035 1 in 2055
Intermediate Level Waste (shielded containers)	B-Double – estimated max weight of 50 tonnes	1 movement/bi-weekly for 4 years
Low Level Waste	Semi-trailer – max payload weight capacity of 35 tonnes Exceptional packages may increase to 70 tonnes	1 movement/bi-weekly for 4 years

As shown in Table 53, the largest vehicle that will typically need to access the site will be the B-doubles used to transport intermediate level waste. However, when TN81 containers need to be transported to the site it will be necessary to do so via over-dimensional and / or over-mass vehicles.

ANSTO has also advised that there will be approximately 20 personnel on site during typical operations which represents up to 40 vehicle movements per day as staff move to and from the site.

Due to the overall low traffic volumes experienced in this region, this is expected to have minimal impact on the wider road network.

4.1.2.4.1 Over-dimensional and Over-mass Requirements for Operations

An aspect of the operation phase for the NRWMF is the movement of TN81 Containers used to transport intermediate level waste. The TN81 Containers are 6.5 metres long, 3 metres in diameter and weigh approximately 100 tonnes when empty (Australia Nuclear Science and Technology Organisation, 2011). Therefore, the use of an over-dimensional / mass vehicle is required.

Figure 74 TN81 Container being transported (Department of Industry, Innovation and Science, 2016)

Further investigations into the type of vehicle required and suitable transport routes will be performed as part of the Stage 2 works. As shown in Figure 74, it is likely that a prime mover and low loader combination will be necessary to transport the container over the road network.

4.1.2.5 Proposed Access Routes

4.1.2.5.1 Woomera

Access to the site from Woomera will be via the National Highway Network as described below:

1. Olympic Dam Highway (B97)
2. Stuart Highway (A87)
3. Princes Highway (A1) – through Port Augusta
4. Flinders Ranges Way (B83)
5. The Outback Highway (B83)

There is no feasible alternate route along the National Highway Network to travel between Woomera and Wallerberdina. This is mainly due to there being no approved B-double routes that do not run through Port Augusta between Woomera and Wallerberdina, and Olympic Dam Highway terminating north of Woomera at Olympic Dam.

Figure 75 Access route from Woomera

As part of the Upper Spencer Gulf Regional Infrastructure Plan developed by AECOM, a number of proposed major projects were identified which would improve the road infrastructure in an around Port Augusta. These projects are as follows (AECOM Australia Pty Ltd., 2018):

- Duplication of the Port Augusta Bridge to avoid occurrences of complete shutdown. This would improve the efficiency of freight movements and user safety.
- Upgrading the Yorkeys Crossing heavy-vehicle bypass route with all-weather treatment. This crossing is used by over-dimensional vehicles to bypass the Port Augusta Bridge. This bridge has restrictions in place for over-dimensional vehicles greater than 4.0 m wide and 5.8 m high (Department of Planning, Transport and Infrastructure, 2012).

These projects will improve heavy vehicle access through Port Augusta if implemented.

4.1.2.5.2 Lucas Heights

Road access to the sites from Lucas Heights will likely be via the National Highway Network as described below:

1. Hume Highway (M31)
2. Sturt Highway (A20)
3. Goyder Highway (B64)
4. Barrier Highway (A32)
5. Orroroo – Peterborough Road (B56)
6. RM Williams Way (B80)
7. Barndioota Road / The Outback Highway (B83)

Figure 76 Access routes from Lucas Heights

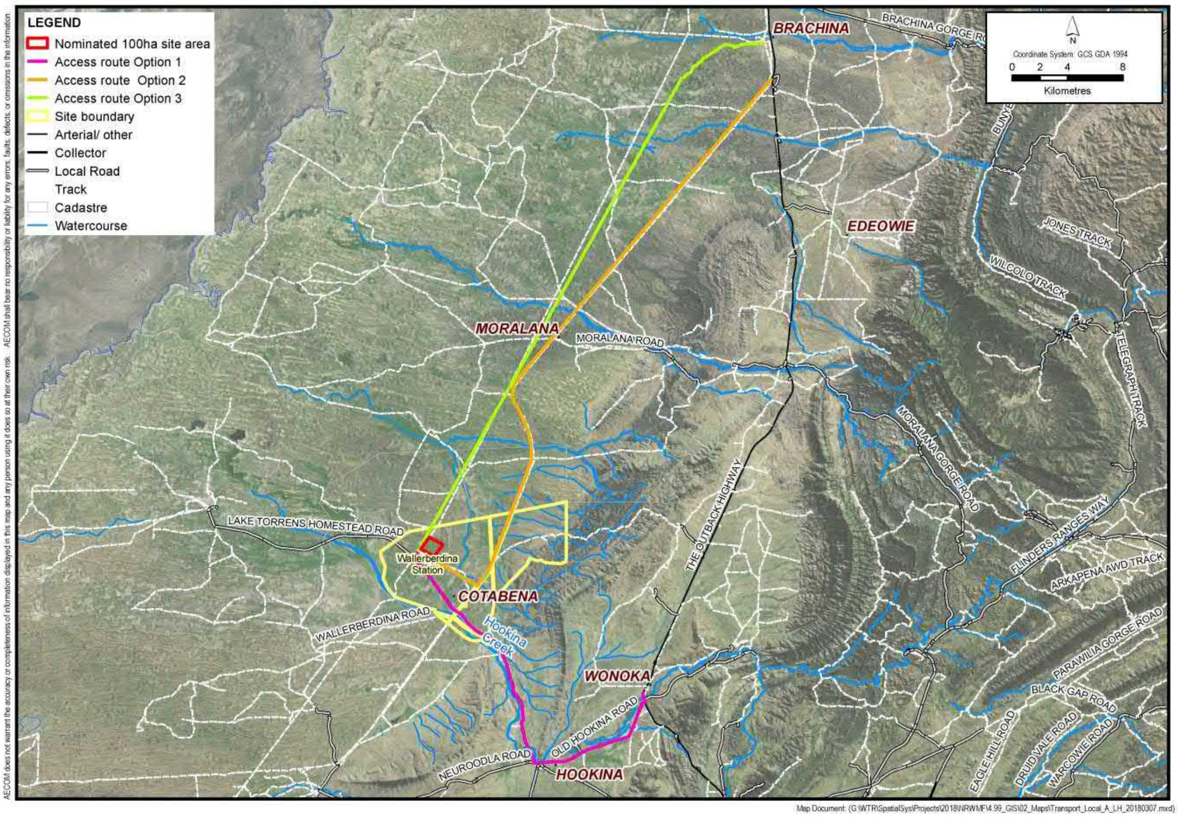
Further investigations will need to consider the local road network through key towns and cities along the proposed routes to determine if there are approved heavy vehicle routes that will allow shipments to bypass these towns. Future investigations will further narrow down this route to minimise the number of towns / cities that are travelled through and select a preferred route.

4.1.2.5.3 Local Road Access to the Site

Access to the site from the National Highway Network is discussed in previous sections. Three options have been highlighted which utilise local roads to access the Wallerberdina site. These options are described below and shown in Figure 77;

- Option 1: Lake Torrens Homestead Road
- Option 2: Construct a new road parallel to the existing rail line
- Option 3: Construct a new road to approach the site from the north.

Figure 77 Local access routes



It should be noted that this not an exhaustive list of access options and additional options may be considered in future investigations. Access routes that utilised existing tracks to the east of the site were discounted early due to the challenging terrain.

As can be seen in Figure 77 there are a number of watercourses that cross each of the proposed access options at various locations. A detailed hydrological assessment will need to be undertaken to determine stormwater drainage requirements.

Due to the large number of vehicles required to access the site during construction and operation, it is recommended that all access routes be both widened and sealed to accommodate the projected heavy vehicle requirements.

A qualitative assessment of the advantages and disadvantages of local road options is summarised in Table 54 below:

Table 54 Option comparison

Option	Description	Advantages	Disadvantages
Option 1	Old Hookina Road / Neuroodla Road / Lake Torrens Homestead Road	• Shortest route of the three options (approx. 26 km) • Utilises existing unsealed roads	• Lake Torrens Homestead road has a history of flooding and runs parallel to a significant flow path
Option 2	Construct a new road parallel to the existing rail line	• Terrain is likely to be relatively flat given its proximity to the rail line • Rail line would have been built up to reduce the risk of flooding	• Requires the construction of approximately 48 km of sealed roadway
Option 3	Construct a new road to approach the site from the north	• Provides direct access to the site from the north which minimises the risk of flooding from Hookina Creek	• Requires the construction of approximately 46 km of sealed roadway

Additional commentary on the site's performance against the characterisation criteria is included in following sections.

4.1.2.6 Assessment Criteria 1 – Proximity to Waste Source Locations

Given the Wallerberdina site's location in central South Australia, it is in a good location to receive waste from hospitals and laboratories from around Australia despite the significant distances to some of the waste sources. The site is approximately 1600 km from Lucas Heights and 300 km from Woomera via the National Highway Network. There is also potential for waste to be shipped to Whyalla or Port Pirie and then transported via road or rail to the site.

4.1.2.7 Assessment Criteria 2 – Capacity of Overall Access Routes

Access to the site would primarily be via the national highway network which is typically approved as a B-double route. This will be suitable for all movements of waste to the NRWMF excluding the very infrequent shipments of the TN81 Containers. These over-dimensional and over-mass loads will require permits to be approved by relevant state road authorities prior to their transport. As mentioned previously, it may be possible to have these containers shipped from Port Kembla to ports such as Whyalla and Port Pirie which would substantially reduce their impact on the wider road network if this transport option was selected. Transport of waste to Port Augusta via rail would also reduce the impact on the road network. The variety and quality of overall transport options means the Wallerberdina site satisfies this criterion.

4.1.2.8 Assessment Criteria 3 – Capacity of Local Road Network

The local roads that surround the site are typically unsealed, low trafficked roads. Some of these are all-weather roads but are likely to be less suitable for carrying heavy loads particularly during the winter months. Hookina Creek is located south of the proposed site and runs parallel to Lake Torrens Homestead Road.

There is a history of flooding at this location and several watercourses have been identified which intersect potential access routes to the north of the site. If a large flood event were to occur, it is possible that access to the NRWMF may be cut off if appropriate flood mitigation measures are not being undertaken. This could be mitigated by scheduling waste deliveries to avoid the 'wet season' in the area with corresponding maintenance to inspect and re-establish roadways following significant rainfall events, or by sealing the roads and implementing appropriate stormwater management solutions. Based on the current status of local roads, the Wallerberdina site does not satisfy this criterion but appropriate flood mitigation measures and road upgrades are feasible.

4.1.2.9 Assessment Criteria 4 – Upgrade Requirements

Due to the frequent use of the local road network by B-double vehicles during both the construction and operational phases, it is recommended that any access routes be both sealed and widened to suit these vehicle movements. This may also be necessary to accommodate the very infrequent over-dimensional and over-mass (ODOM) vehicles necessary to transport the TN81 Containers. This would result in up to 48 km of sealed roads needing to be constructed.

The sealing of these roads is also recommended as it would mitigate any damage that large flood events may subject to an unsealed road network. Given the number of watercourses that cross the proposed access routes, it is likely that a number of culverts/crossings would need to be installed as a stormwater management measure. It is important to note that these would need to be designed such that they could accommodate the loading caused by the B-doubles and over-dimensional vehicles. This would also likely require the construction of embankments and / or road formations.

4.1.2.10 Summary

An assessment of the site has been undertaken against the above criteria and is summarised in Table 55. This is intended to provide a high level overview of the site's performance based on existing conditions and highlight any key criteria which may limit its selection.

Table 55 Site performance against characteristic criteria

Assessment Criteria	Criteria Satisfied	Comments
Proximity of Waste Source Locations	✓	Site's location within central South Australia is an ideal location to receive waste from around the country.
Capacity of Overall Access Routes	✓	The site is within close proximity to the national highway network and shipping ports (Whyalla and Port Pirie).
Capacity of Local Road Network	×	The existing roads are unsealed and have a history of flooding. Potential route options approaching the site from the north require the construction of new road reserve.
Upgrade Requirements	×	Roads will need to be upgraded to accommodate frequent B-Double movements and infrequent ODOM vehicles. Multiple culvert crossings may need to be installed to accommodate the number of watercourses that cross the access routes.

The infrastructure costs to facilitate the construction and operation of the NRWMF will be considered as part of the enabling works.

4.1.3 Design Issues and Mitigation Measures

4.1.3.1 Road Upgrades

The local roads leading to and surrounding the site are primarily unsealed, low trafficked roads which may not be suitable for frequent B-double movements and infrequent over-dimensional and over-mass vehicle movements. It is recommended that any potential access roads are either sealed or have the existing unsealed surface improved (subject to appropriate maintenance requirements) and widened to accommodate these vehicle movements. Note that these required upgrades will be further considered as part of the enabling works.

4.1.3.2 Rail Upgrades and Potential Use of Port Facilities

As mentioned previously, the disused Cotabena Railway which was used to transport coal between Port Augusta and the Leigh Creek Coal Mine is located to the east of the sites. If the option of transporting waste via rail to the site is pursued, the rail line will need to be recommissioned. A spur / siding would need to be constructed to connect the site to the rail line. This would also require significant rehabilitation of the railway to ensure it is suitable for the transport of waste. Further evaluation of the use of the Ports described earlier in this section will be required as there is potential for wastes to be shipped to these Ports and for rail and road connections from the Ports to the proposed facility.

4.1.3.3 Stormwater Management

Multiple watercourses have been identified that intersect the proposed access roads. Given the history of flooding in this area, infrastructure upgrades will need to consider suitable stormwater management methods (culvert crossings etc.). Any culverts would need to be designed such they could accommodate loadings caused by the B-Doubles, over-dimensional vehicles and rail movements (if applicable).

4.1.4 Data Gaps and Recommendations for Stage 2 Work Program

The following sections detail the relevant data gaps and recommendations for work to be undertaken as part of the Stage 2 Work Program once a preferred site is nominated. It should be noted that high level designs of the enabling infrastructure (roads and utilities etc.) will be completed as part of the enabling works. These will be used to inform relevant stakeholders when nominating a preferred site.

4.1.4.1 Data Gaps and Limitations

Key gaps in the available data include:

- Detailed survey of local road network to determine its condition, width, formation and traffic volumes;
- Operational procedures for the NRWMF (shift hours, number of staff etc.); and
- Frequency and volumes of waste to be delivered during operations requires clarification.

4.1.4.2 Recommendations for Stage 2 Work Program

Further works to be undertaken as part of the Stage 2 data collection include:

- Additional site investigations to determine the geometry and quality of the road network; and
- Refining of access routes through the National Highway Network and local road network.

4.2 Waste

During the NRWMF site characterisation desktop assessment, AECOM investigated considerations that are likely to pose constraints for the future use of the potential site at Wallerberdina Station for the NRWMF. . Following the desktop study, AECOM contacted the identified waste management facilities to obtain further information which would inform on the technical assessment. This report outlines the methodology and results obtained.

4.2.1 Methodology and Results

4.2.1.1 Site Characteristic Criteria

The following site characteristic criteria were used in this study:

1. Availability and proximity of facilities to treat, recycle or dispose of all generated waste streams.

During the desktop analysis, AECOM recorded the number of existing licenced waste infrastructure around the proposed Wallerberdina Station site location. The major types of waste infrastructure relevant to this assessment are as follows:

- **Landfill/Refuse Depot** - a waste disposal site used for the controlled deposit of solid waste onto land
- **Material Recovery Facility (MRF)** - a depot for the treatment of waste for resource recovery, other than a composting depot.
- **Transfer Station -** a depot for the reception and aggregation of waste streams prior to their transport to another depot or location for further sorting, resource recovery or disposal.
- **Container Deposit Legislation (CDL) depot -** a depot for the reception of certain beverage types covered by the CDL.

Identifying the different types of waste infrastructure in the local region will enable assessment of key logistical issues and associated costs related to the collection, transport, treatment and disposal of each waste stream generated from the Project. For example, potential cost implications due to unavailability of facilities to handle particular waste stream(s), or significant transport distances could support the case for constructing an onsite waste management facility.

2. Potential for on-site treatment, recycling and disposal.

In order to assess potential collection, treatment, recycling and disposal options, it is important to first understand the characteristics and types of waste likely to be generated from the Project. A preliminary assessment of the potential waste generated during construction and operation of the site was conducted.

4.2.1.2 Desktop Methods and Results

4.2.1.2.1 Methodology

The desktop assessment involved research and reviewing available information in regards to waste management and the NRWMF. This included analysis of background information, reference design documents[21] and a review of South Australia's waste management legislation[22]. Furthermore, the use of aerial photography, Google maps and South Australia's council maps[23] enabled AECOM to locate the proposed Wallerberdina site and existing waste infrastructure around it.

The built facility general arrangement obtained from the reference design enabled the identification of typical waste streams anticipated at the NRWMF. This information was critical in assessing any potential on site and off site waste management/disposal options. Approximate distances to offsite waste treatment, recovery and disposal infrastructure were estimated using Google mapping tools.

[21] WSP (2016). Reference Design Modules for Site Characterisation
[22] EPA Environmental Info. Waste Management. Available at: http://www.epa.sa.gov.au/environmental_info/waste_management [Accessed 7-14 March 2018].
[23] Local Government Association of South Australia. Council Map. Available at: https://www.lga.sa.gov.au/councilmaps [Accessed 9-14 March 2018].

It is imperative to note that only licensed waste infrastructure were evaluated using licensing information obtained from the South Australia Environment Protection Authority (EPA)[24]. As part of the Stage 2 works, targeted investigations would be undertaken to confirm the availability and capacities of the identified off site facilities to accept waste generated from the Project.

Referenced data used in the desktop assessment is listed below:

- EPA (2009). Waste Guidelines. Waste Definitions. (EPA 842/09).
- EPA (Version 22.2.2018). South Australia Environment Protection 1993
- EPA (Version 24.11.2011). South Australia Environment Protection (Waste to Resources) Policy 2010.
- EPA (2009). Waste Guidelines (EPA 842/09)
- Office of Green Industries SA (2015). South Australia's Waste Strategy 2015-2020.
- WSP (2016). Reference Design Modules for Site Characterisation.
- Zero Waste SA (2018). South Australia's Waste and Resource Recovery Infrastructure Plan.
- EPA Environmental Info (Waste Management). Available at: http://www.epa.sa.gov.au/environmental_info/waste_management [Accessed 7-14 March 2018].
- EPA Environmental Authorisations (Licenses). Available at: http://www.epa.sa.gov.au/data_and_publications/environmental_authorisations_licences [Accessed 7 - 14 March 2018].
- Local Government Association of South Australia (Council Map). Available at: https://www.lga.sa.gov.au/councilmaps [Accessed 9 - 14 March 2018].

[24] EPA Data & Publications. Environmental Authorisations. Available at: http://www.epa.sa.gov.au/data_and_publications/environmental_authorisations_licences [Accessed 7-14 March 2018]

4.2.1.2.2 Results

The following section summarises the anticipated waste generated during the construction and operation stages of the Project based on the desktop review. *This table would need to be reviewed and updated with waste generation rates, as the design of the NRWMF progresses.*

Construction Works Waste Types

Construction activities are anticipated to generate the following waste streams (Table 56).

Table 56 Construction Waste Generation

Waste Type
Main Construction Works
Construction and Demolition (C&D) Waste (Mixed)
Construction and Demolition (C&D) Waste (Inert)
Ferrous and non-ferrous metals (sheet metals, steel, etc.)
Paper and cardboard
Dry recyclable general waste
Putrescible waste (e.g. food waste)
Packaging materials, including wood, plastic, cardboard and metals
Hazardous and/or Listed waste (e.g. asbestos)
Wastewater; pump out septage (sewage)
Plant Maintenance during construction
Empty oil (and other) drums/tins (e.g. fuel, chemicals, paints, spill clean ups)
Air filters and rags
Waste Oil
Wastewater (from pump maintenance activities)
Oil filters
Batteries

Operation Waste Types

The radioactive wastes to be managed at the NRWMF have not been described or considered in this assessment as this is not a waste stream which will be disposed of off-site. At the time of writing this report, data on Equivalent Full Time Employees (EFTEs), area schedules and/or floor plans for the proposed NRWMF had not been determined, and therefore the anticipated waste generation rates (quantities) were not estimated. *As noted earlier, this table would be updated with waste generation rates, as the design and operation plans for the NRWMF progress to the next stage of development*.

However; AECOM has identified the potential waste generation areas based on the Reference Design Modules for Site Characterisation. Table 57 shows the types of infrastructure and associated types of waste to be generated.

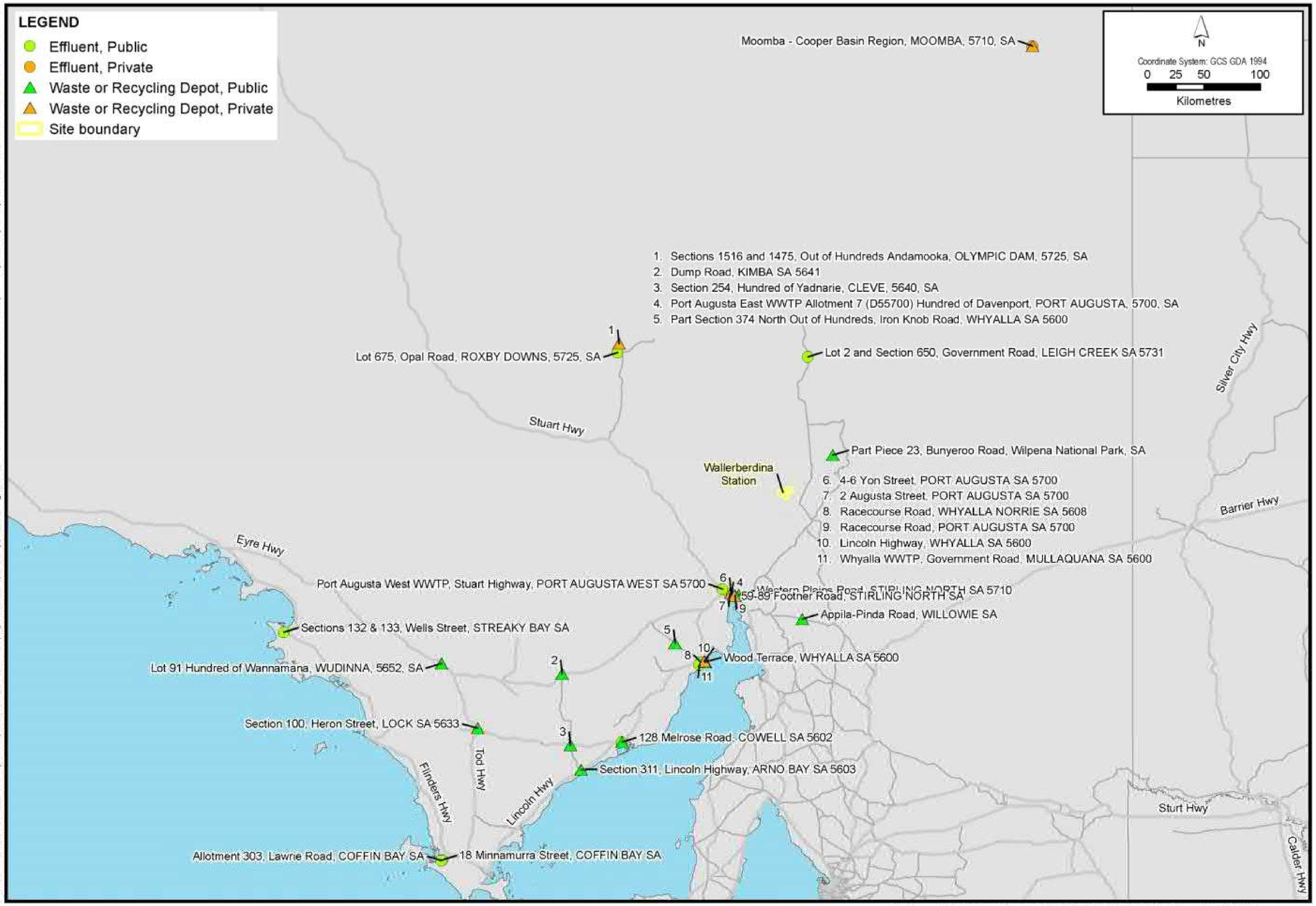
Table 57 Potential Waste Generating Areas - NRWMF

Type of Infrastructure/Activity	Typical Waste Generated	Estimated Waste Quantities
Guard house	Commercial and Industrial (C&I) Waste (General)*	Minor
Helipad	N/A	N/A
Visitor carpark	N/A	N/A
Security Building	Commercial and Industrial (C&I) Waste (General)	Minor
Administration Area	Commercial and Industrial (C&I) Waste (General)	Minor
Information Station	N/A	N/A
Water and non-radioactive area	N/A	N/A
Power and Communication area	N/A	N/A
Construction and Maintenance	Commercial and Industrial (C&I) Waste (General), Construction and Demolition (C&D) Waste (Mixed), Waste Oil, Batteries, Scrap Metal, Used Tyres, E-Waste, Waste Fill, Whole Used Tyres, Waste Fuel, Hazardous/Listed Waste (e.g. asbestos)	Minor
Stormwater Detention Basin (Drainage & Treatment)	N/A	N/A
Radioactive Waste Storage Facilities	N/A	N/A

Assessment criterion 1: Availability and proximity of facilities to treat recycle or dispose of all generated waste streams

Figure 78 shows the different waste and recycling facilities identified to potentially receive waste from the Wallerberdina Station site and Table 58 shows further details of waste types, license details and approximate distances of waste facilities within 200 km from the potential site.

Figure 78 Identified waste and resource recovery facilities to potentially receive waste at the Wallerberdina Station site



Map Document: (G:\WTR\SpatialSys\Projects\2018\NRWMF\4.99_GIS\02_Maps\Waste_WB_20180322.mxd)

Table 58 Existing waste infrastructure within 200km of the proposed Wallerberdina Station site and types of waste accepted

License Holder	The Flinders Ranges Council (Hawker)	Minister for Sustainability, Environment and Conservation	Corporation of the City of Port Augusta	Waste Management Pacific (S.A.) Pty Limited	District Council of Mount Remarkable
Licensed Activities	Waste or Recycling Depot	Waste or recycling depots (waste for resource recovery or transfer) Waste or recycling depots (solid waste for on-site disposal)	Waste or Recycling Depot	Waste recycling depot (waste for resource recovery or transfer)	Waste or recycling depots (solid waste for on-site disposal)
Site Address	Hawker Refuse Depot, Dump Road, Hawker 5434, SA	Part Piece 23, Bunyeroo Road, Wilpena National Park, SA	Western Plains Road, STIRLING NORTH SA 5710	59-89 Footner Road, STIRLING NORTH SA	Appila-Pinda Road, WILLOWIE SA
Waste Type	Permitted to Receive (Yes/No)				
Asbestos Waste (or Asbestos containing Material)	Not specified	No	Yes	Yes	No
Friable asbestos	Not specified	No	Yes	No	No
Non-friable asbestos	Not specified	No	Yes	Yes	No
CDL - Containers	Not specified	No	No	Not specified	No
Construction and Demolition Waste (C&D) (Inert)	Yes	No	Yes	Yes	Yes
Construction and Demolition Waste (C&D) (Mixed)	Yes	No	No	Yes	Yes
Commercial and Industrial Waste (C&I) (General)	Yes	Yes	No	Yes	Yes
Compostable Organic Waste	Not specified	No	Yes	Yes	Yes
E-waste	Yes	Yes	No	Yes	Yes
Ferrous and non-ferrous metals	Not specified	Yes	No	No	No
Green Waste	Yes	Yes	Yes	Yes	Yes
Hazardous Waste	No	No	No	No	No
Lead acid batteries (Batteries)	Yes	No	Yes	Yes	No
Listed Waste	No	No	No	Yes	Yes
Shredded Tyres	Not specified	No	No	No	Yes
Scrap Metal	Not specified	No	No	Yes	No
Used Tyres	Not specified	No	No	Yes	Yes
Waste Fuel	Yes	No	Yes	Yes	No
Waste Fill	Not specified	No	Yes	Yes (Conditions apply)	Yes
Waste Oil	Yes	No	Yes	Yes	No
Other Parameters					
License Expiry Date	31 March 2019	28 February 2023	30 April 2019	30 April 2021	30 April 2021
Approximately distance to proposed site	38 km	130km	135km	139 km	175km

Assessment criterion 2: Potential for onsite treatment, recycling and disposal

Waste management requirements/disposal options

Waste arising from the construction phase would need to be transported to licensed off-site facilities for material reuse/recovery purposes before final disposal. Potential destinations include waste transfer stations, material recovery facilities (MRFs) and landfills (classified as waste and/or recycling depots).

According to the information provided in Table 58 there are waste streams which would potentially be generated at the Wallerberdina Station site, however not accepted at some of the nearby waste and/or recycling depots. These waste streams may need to be managed on-site.

Table 59 shows a summary of potential waste management options for waste generated at the Wallerberdina Station site.

Table 59 Details of waste management at the proposed Wallerberdina Station site

Waste Type	Potential for on-site management	Nearest off-site facility accepting waste type
Commercial and Industrial Waste (C&I) (General)	Source-separate organics (for on-site composting/worm farms) Recycling and residual waste to off-site facilities	The Flinders Range Council (Approx. 38km)
Construction and Demolition Waste (C&D) (Inert)	To off-site facilities	The Flinders Range Council (Approx. 38km)
Construction and Demolition Waste (C&D) (Mixed)	To off-site facilities	The Flinders Range Council (Approx. 38km)
E-waste	To off-site facilities	The Flinders Range Council (Approx. 38km)
Friable and non-friable asbestos	To off-site facilities	Corporation of the City of Port Augusta (Approx. 135km)
Ferrous and Non-ferrous metal	To off-site facilities	Minister for Sustainability, Environment and Conservation (Approx. 130km)
Green Waste	On-site processing (composting/worm farms)	The Flinders Range Council (Approx. 38km)
Hazardous Waste	Pre-treatment prior to off-site disposal	No site within (at least) 160km
Listed Waste	Pre-treatment prior to off-site disposal	District Council of Mount Remarkable (Approx. 175km)
Scrap Metal	To off-site facilities	No site within (at least) 175km
Used Tyres	To off-site facilities	District Council of Mount Remarkable (Approx. 175km)
Waste Fuel	To off-site facilities	The Flinders Range Council (Approx. 38km)
Waste Fill	If suitable, use on site as fill material or sent to an off-site facility	Corporation of the City of Port Augusta (Approx. 135km)
Waste Oil	To off-site facilities	The Flinders Range Council (Approx. 38km)

Potential on-site waste treatment options at the NRWMF will depend on the waste streams generated and the distance and suitability of the off-site disposal or resource recovery facilities. Potential on-site treatment options could include on-site organics processing. Implementation of source-separation of organic waste from the general waste stream would result in a cleaner organics stream suitable for on-site composting or worm farms, thereby reducing the amount of residual waste requiring disposal at an off-site landfill/disposal facility.

4.2.1.3 Field Methods and Results

4.2.1.3.1 Methodology

AECOM contacted (via telephone and email) the existing licensed waste facilities within 200km of the Wallerberdina Station site (as identified during the desktop study) to confirm if these facilities were still active, the waste types accepted, and capacity/estimated remaining life. Stakeholders contacted included local councils and private waste contractors operating the facilities.

4.2.1.3.2 Results

Additional information obtained during this phase of the assessment are presented in Table 60.

Table 60 Waste management facilities within 200km of Wallerberdina Station site - Additional Information

Operator/Licence Holder	Waste Management Facility	Approximate Distance from potential site	Types of waste accepted/not accepted	Estimated Remaining life/Capacity
The Flinders Ranges Council	Hawker (Refuse Depot) Landfill	38 km	• Residential/Domestic waste • No listed waste or liquid waste accepted (as per EPA Licence) • Referred to The Flinders Ranges Council's website for additional information on waste types accepted[25].	Limited Capacity
Corporation of the City of Port Augusta	Waste or Recycling Depot	135km	Awaiting information from City of Port Augusta Council	TBC
Waste Management Pacific (S.A.) Pty Limited	Waste recycling depot (waste for resource recovery or transfer)	139km	All waste except hazardous waste	> 20 years
District Council of Mount Remarkable	None**	175km	N/A	N/A

C&I – Commercial and Industrial
***District Council of Mount Remarkable indicated that there was no waste management facility in their Council.*

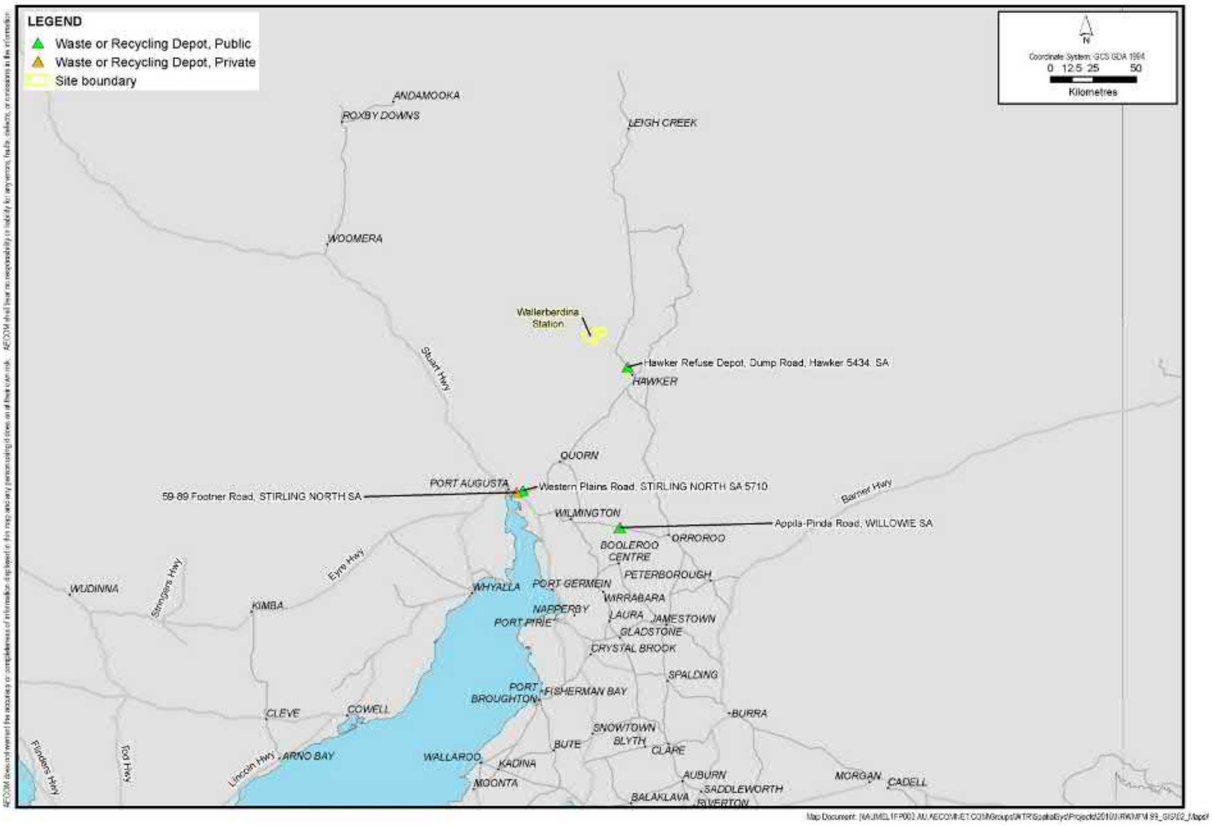
[25]The Flinders Range Council, South Australia. Waste Management. Available at http://www.frc.sa.gov.au/waste . [Accessed 30 May 2018]

4.2.2 Assessment Against Criteria

Assessment criteria 1: Availability and proximity of facilities to treat, recycle or dispose of all generated waste streams.

Figure 79 indicates the location of the waste management facilities within 200 km of the potential Wallerberdina site.

Figure 79 Identified waste and resource recovery facilities within 200km of the Wallerberdina Station site



The waste and recycling facility located at: Part Piece 23, Bunyeroo Road, Wilpena National Park, South Australia identified during the desktop study accepts a limited range of waste types (based on information on the EPA license) and was eliminated from further consideration in the technical assessment.

The closest licensed waste management facility to the Wallerberdina Station site is a landfill (Hawker Refuse Depot) located at Dump Road, Hawker, South Australia (within approx. 38km from the proposed site). Information obtained from Flinders Range Council indicated that this landfill now has limited capacity and is only licenced by the EPA for domestic waste.

Waste Management Pacific (S.A.) Pty Limited is a privately operated waste transfer station located at 59-89 Footner Road, Stirling North, South Australia. This facility accepts all types of waste except hazardous waste.

The District Council of Mt Remarkable has indicated that there are no active waste facilities in the local government area.

Summary
It should be noted that further discussions and arrangements with Councils and private waste contractors will be required to affirm acceptance of waste generated from the Project at the potential facilities**.**
Furthermore, there appears to be no potential waste facilities within 200km of the Wallerberdina Station site that accept hazardous and listed waste.

Assessment criteria 2: Potential for on-site treatment, recycling and disposal

Onsite treatment of waste generated from the Project would be applicable to organic waste and hazardous and listed waste.

Organic waste – implementation of source separation of organic waste from the general waste stream would result in a cleaner organics stream suitable for on-site composting or worm farms, thereby reducing the amount of residual waste requiring disposal at off-site disposal facilities. This would require establishment of an on-site organics processing facility.

Hazardous and/or Listed waste – hazardous and/or listed waste could require pre-treatment on-site prior to off-site disposal. At the time of writing this report (during the technical assessment stage), there were no facilities identified within 200 km of the proposed Wallerberdina Station site that could accept hazardous or listed waste. This would potentially require on-site processing (e.g. an on-site incinerator, depending on the nature of the hazardous or listed waste generated) unless alternative arrangements are made.

Summary

On-site treatment of waste at the proposed Wallerberdina Station site would still require off-site waste recycling and disposal facilities [for other waste types that would be generated by the Project, for example residual solid waste, packaging waste, etc.].

4.2.3 Design Issues and Mitigation Measures

Potential waste management options that could be employed at the Wallerberdina Station site are based on the site characteristic criteria discussed in Section 4.2.2, and may include:

- constructing a waste management facility at the proposed site (e.g. waste storage room, composting facility)
- treating hazardous / listed waste
- transporting waste to off-site disposal and/or recycling depots

4.2.3.1.1 Design Issues

Design issues related to the above options include, but are not limited to:

- Materials of construction
- Buffer distances (sensitive receptors will be identified depending on the option considered)
- Air emissions from potential on-site waste management infrastructure/activities e.g. waste incinerator
- Supporting infrastructure (e.g. safe road access and routes for the anticipated waste collection vehicles to waste facilities)

It is worth noting that other design considerations are linked to site specific issues identified in other site characterisation assessments found elsewhere in this report. As a result, reference would be made to design and mitigation measures identified in these other sections.

Table 61 Relevant site characteristic or enabling infrastructure element impacting design and site characteristics

Site characteristic or enabling infrastructure	Possible design impact(s)
Conservation and special use area	• Buffer distances (proximity to sensitive receptors)
Risks from the surrounding environments (e.g. bushfires)	• Safety considerations (e.g. storage requirements for flammable waste material) • Materials of construction
Climatic conditions	• Safety considerations • Materials of construction
Climate change and long term environmental scenarios	
Site characteristics which have the potential to impact on site safety	• Safety considerations
Risks from the potential impacts of human activities on the site	• Planning/zoning, and regulatory issues
Transport considerations	• Distances to waste and recycling facilities • Safe access /routes for waste collection vehicles • Potential road upgrades
Utilities, energy and infrastructure	• Wastewater treatment systems, power requirements etc.

4.2.3.1.2 Mitigation Measures

Wastes (e.g. mixed solid wastes) generated by the NRWMF are assumed to be transported to off-site waste transfer stations or disposal facilities. Certain waste types (e.g. hazardous and/or Listed Waste) may need to be treated and disposed on-site or pre-treated and then sent off-site for management.

As a result, potential waste containment, treatment and storage facilities would be designed for satisfactory performance to minimise the impacts of waste. Some of the mitigation measures include:

- Waste and environmental management plans (etc.)
- Design of waste storage facilities according to the Building Code of Australia (BCA) and other relevant Australian Standards
- Spill kits and implementation of appropriate chemical storage requirements
- Conformance to air quality and monitoring regulations
- Emergency procedures

4.2.4 Data Gaps and Recommendations for Stage 2 Work Program

4.2.4.1 Data Gaps and Limitations

- Types and quantities of waste generated during the construction and operation phases based on the proposed design of the NRWMF. A list of anticipated waste generated from the Project (Table 56 and Table 57) would need to be presented to the relevant building design and planning teams with knowledge of NRWMF construction and operation details for confirmation.
- Confirmation of availability and capacity of the potential waste management infrastructure identified in the region to accept waste generated by the Project. This could include discussions with local councils and private waste contractors.

4.2.4.2 Recommendations for Stage 2 Work Program

A Stage 2 work plan would be prepared with the objective of preparing concept design and capital cost estimates for new on-site waste management infrastructure and in further quantifying waste streams, end of-life of waste facilities and management and waste reduction options for each waste stream based on a summary of applicable regulations and guidelines.

The following scope of work has been proposed for Stage 2 works:

1. Waste Characterisation

Review of updated NRWMF design and operation plans / reports provided by the NRWMF Design team to enable, identification of waste types and quantities to be generated from the proposed development during the construction and operation phases.

2. Identification of waste management options

This part of the study will involve the identification of potential solutions for management of each type of waste generated, including considerations from collection, transport, processing and disposal.

3. Existing Facilities Assessment

Investigations on capacity and suitability of the existing resource recovery and disposal sites to accept waste generated from the Project, consisting primarily of targeted site inspections of existing waste facilities located in the local region around the site and additional discussions with local waste contractors and Councils.

4. Waste management options analysis

Based on the information collected, a high level options analysis will be undertaken for both the construction and operation phases of the Project. This analysis will include a high level cost-benefit analysis as well as a non-financial analysis taking into account environmental, social, regulatory and technical issues for each option. The outcome of the options analysis will be a recommendation on how each waste stream should be managed taking into consideration both off-site and on-site options.

4.3 Utilities

4.3.1 Methodology

The general methodology used for the development of this assessment of the enabling Utilities, Energy and Infrastructure was to review the available service and utility data to assess the site characteristic criteria in regards to available service/utility connections. This included the following tasks:

1. Access the publicly available databases and review the available information for the following utilities and services:
    - Power
    - Water supply main
    - Gas (reticulated network)
    - Telecommunications
    - Wastewater (reticulated network)
    - Stormwater
2. Review of the aerial photography databases and websites – this source was utilised to identify the site location, extents and any above ground infrastructure.
3. Review of site visit photographs and notes to enable confirmation of utility infrastructure.

The list of databases and information sources utilised is as below:

- Verification of above and below ground utilities using aerial photography sources, site visits and photographs.
- Reference to the Dial Before You Dig (DBYD) system to obtain local utility/service maps from the specified providers.
- Reference to the National Map website to obtain utility data, ground levels, distances, etc.
- Reference to utility and service provider website for further information on specific sites and data.
- Reference to infrastructure provider websites for further information on specific plant and systems.
- Australian Energy Market Operator (AEMO).
- Australian Renewable Energy Mapping Infrastructure (AREMI).
- SA Power Networks Distribution Annual Planning Report 2017/18 to 2021/22.
- Government of South Australia, Location SA Map Viewer.
- Essential Services Commission of South Australia (ESCOSA).
- Input of load requirements from memo.

4.3.1.1 Site Characteristic Criteria

Assessment criteria developed to address the availability and vulnerability of site services are detailed in the table below.

Table 62 Assessment Criteria

	Power	Water Supply Main	Wastewater (Reticulation)	Telecommunications	Gas (Reticulation)	Stormwater
1. Proximity to Site	X	X	X	X	X	X
2. Nature of Service/ Utility and capacity/ constraints	X		X	X	X	X

The assessment of each of the utilities/services was undertaken to gain an understanding of the existing infrastructure on or near to site and the scale of the requirements to extend the infrastructure to the Wallerberdina site.

4.3.1.2 Desktop Data Collection

The data sources accessed to obtain the range of data is listed below along with the data that data sources were accessed:

- Dial Before You Dig (DBYD) – utility service plans database – data access March 2018
- Aerial Photography – Google Maps accessed between 7th and 14th March 2018
- Location SA – Website utilised to provide additional SA Water and SAPN data, accessed between 7th March 2018 and 14th March 2018.
- National Broadband Network (nbn) Rollout Map – accessed 7th to 13th March 2018
- National Map – Website for map-based access to spatial data from Australian Government agencies. – accessed 7th to 13th March 2018
- SA Water website – data on Hawker water supply – accessed 13th March 2018.

The various sources of information that were accessed were assumed to be correct at the time and have been cross referenced to verify their authenticity where possible.

4.3.2 Review Against Criteria

The following utilities and services have been assessed with regard to the characteristic criteria set out in Table 62.

4.3.2.1 Utility/Service Assessment

An assessment was undertaken for each of the utilities/services listed below by reviewing the data sources listed in Section 4.3.1.2. The following describes the infrastructure which is assessed to be available within a distance to the site that is deemed feasible for connection.

4.3.2.1.1 Power

Assessment Criterion 1 Proximity to site

The site considered for Wallerberdina is close (< 1km) to the 132 kV Leigh Creek South Tee to Neuroodla Tee. It is also approximately 20km from the closest substation, Neuroodla. This can be seen in Figure 80 below from AREMI showing in red the 132kV transmission line, and the green line showing the distance from the closest transmission substation.

Figure 80 AREMI – Site Map

The image in Figure 81 also shows the 132kV line running adjacent on the West side of the site.

Figure 81 Wallerberdina – Site photograph looking North showing existing 132kV line

The proximity to the 132kV line and the substation provide two options that can be considered for the Wallerberdina site:

- Building a new substation for connecting directly to the 132kV Leigh Creek South Tee to Neuroodla Tee line; or
- Building a medium voltage line to the existing Neuroodla substation.

Building new substation

Building of a new substation would require liaising with ElectraNet (Transmission Network Service Provider) to build a 132/11kV substation specifically used for the site. 11kV is the recommended voltage level for the power requirements of the site.

Building medium voltage line to Neuroodla substation

The Neuroodla Substation operates a medium voltage level of 33kV. Therefore the ~20km line connecting the site locations back to the substation would also be 33kV. This arrangement would also need to take into account both the line requirements as well as an appropriately sized kiosk required for the connection.

Characteristic Criteria 2 Nature of service, capacity and constraints

In the Distribution Annual Planning Report from SA Power Networks, it is stated that there are “No current limitations on primary distribution feeders under normal conditions in the upper north region in the next two years.”

The Neuroodla 132/33kV transformer has a nameplate rating of 5 MVA, with load expected to only be around 1MVA under current conditions over the next ~5years. This space capacity of 4MVA could be used for connecting the NRWMF.

There are no current power constraints if connection were to be straight into the 132 kV Leigh Creek South Tee to Neuroodla Tee line.

Typically, connecting to the transmission network provides a higher reliability than connecting to the distribution network. “Regions supplied by long, radial distribution feeders (remote from the transmission network) typically receive the greatest total minutes off supply”. Therefore it would be expected that the highest power reliability would be to connect straight into the 132kV Leigh Creek South Tee to Neuroodla Tee line.

However, due to closure of the Leigh Creek coal mine in 2015, load required at the end of the transmission network (Leigh Creek Coalfield) has decreased substantially. ElectraNet are proposing numerous options for managing the network, including decommissioning the Decommission the Neuroodla – Leigh Creek South – Leigh Creek Coalfield 132kV lines.

If connecting to the 132kV transmission line directly is the preferred option, discussions with ElectraNet should be conducted in the near term to understand the future of the 132kV Leigh Creek South Tee to Neuroodla Tee line.

Reliability also decreases as line lengths increase. This should be considered when assessing potentially building a 33kV line from the NWRMF to the Neuroodla substation.

4.3.2.1.2 Water Supply Main

Assessment Criterion 1 – Proximity of water supply infrastructure to site

The closest potable water main supply to the Wallerberdina site is in the town of Hawker which is located approximately 31km to the southeast and is not favourable in terms of connecting the site to the town supply.

Assessment criterion 2 - Nature of service, capacity and constraints

The water supply in the town of Hawker is fed via a groundwater supply which was considered saline by the town’s residents (although it met the Australian Drinking Water Guidelines (2011). The town of Hawker therefore installed a desalination plant to treat the water. The desalination plant is capable of producing 500kL of water per day and reduces the salt levels to less than 600milligrams per litre.

Groundwater could therefore be utilised as an alternate supply if supplemented with the relevant infrastructure.

Figure 82 below shows the location of the site in relation to the town of Hawker (31km to the south-east).

As noted in the design issues section the distance and terrain between the site and Hawker effectively rules out the connection to the existing system and leads toward the installation of a groundwater bore and desalination plant on site.

Figure 82 Google Map image showing location of site in relation to Hawker.

4.3.2.1.3 Wastewater

Assessment Criterion 1 – Proximity of wastewater infrastructure to site

There is no wastewater infrastructure within 30km of the site location and no wastewater networks in the region where connection could take place. However, it is noted that Stormwater will most likely be dealt with on-site via a combination of diversion of clean Stormwater around the site and collection and potential treatment and/or reuse of stormwater falling on the site.

Assessment Criterion 2 - Nature of service, capacity and constraints

Future construction and operational estimates of wastewater volumes and the preferred option for management of wastewater is yet to be determined by the NRWMF designer. Design issues and options for wastewater, grey water and trade waste are outlined below. No discussion of capacity or constraints if therefore provided.

4.3.2.1.4 Telecommunications

The preliminary information provided to AECOM regarding the minimum telecommunication requirements for the site are as stated below:

- Mobile and landline coverage – 100% availability
- Minimum of 10 phones available within the facility (VoIP)

- Mobile coverage across entire 100 Ha site
- Data connection of minimum 25Mbps

Utilising the data available on the National Map website the following points were identified with regard to the existing communications n1etworks:

- The broadband coverage in the project area is rated as the lowest availability (E).
- NBN's fixed wireless service is not available in this area.
- 3G mobile coverage is available, where mobile broadband services are available; they will typically offer speeds of between 1-20 Mbps downstream and up to 3 Mbps upstream.
- ADSL median speed is 6.31 Mbps

Assessment Criterion 1 – Proximity of communications infrastructure to site

The existing telecommunications network in the region of the project site is limited to a copper wire connection to a residential property approximately 2.5km from the site. This connection would be inadequate for the requirements of the proposed NRWMF.

Assessment Criterion 2 - Nature of service, capacity and constraints

As noted in the design issues section below which discusses capacity and constraints, to provide a suitable telecommunication link to the Wallerberdina site, installation of additional equipment would be required. The town of Hawker (33km to the West of the site) is serviced by the Sky Muster satellite. Due to the distance and the terrain between the proposed site and the town of hawker it is not deemed an option to connect the two systems. To provide the required mobile coverage across the site a mobile repeater tower would require to be constructed on site. An installation of this type could be used to allow connection to a mobile network or data connection for adjacent landowners.

4.3.2.1.5 Gas

There is no reticulated gas infrastructure located within the region. The nearest town of Hawker which is 30 km to the south-east of the site does not have a reticulated gas supply. The onsite requirements for gas (if any) would be required to be considered in the NRWMF design.

4.3.2.1.6 Stormwater

Assessment Criterion 1 – Proximity of stormwater infrastructure to site

There is no reticulated stormwater infrastructure located with the project boundary or within the surrounding area. The existing topography is undulating and stormwater runoff would flow naturally to nearby watercourses.

Assessment Criterion 2 - Nature of service, capacity and constraints

The stormwater network required would need to be designed to specifically deal with the capacity and address constraints for all flow within the site. Any overland flow would be diverted around the site boundaries.

4.3.2.2 Utility/ Service Assessment Summary before implementing design mitigations

Table 63 below indicates whether the site satisfies the assessment criteria in relation to the proximity to, capacity and constraints of the existing utilities and services. Where no utility is present in the vicinity of the site, it will not satisfy the proximity criteria (and the capacity criteria). Where there is infrastructure in the vicinity of the site but it does not have sufficient capacity to facilitate the construction / operation of the site it will not satisfy the capacity criteria.

Table 63 Existing Site Utility Characteristic Criteria (prior to implementing any mitigation measures)

Service / Utility	Criteria 1 - Proximity	Criteria 2 - Capacity	Comments
Power	✓	✓	The site is within close proximity to the existing 132 kV Leigh Creek to Neuroodla line. It is possible for a medium voltage line to be built to connect to the existing Neuroodla substation.
Water Supply Main	×	×	Closest water main supply is approximately 31 km to the south east.
Wastewater	×	×	There is no wastewater infrastructure within 30 km of the site.
Telecommunications	×	×	Existing network in the region of the site is inadequate for the proposed NRWMF.
Gas	×	×	There is no reticulated gas infrastructure located within the region.
Stormwater	×	×	There is no reticulated stormwater infrastructure in the area surrounding the site.

Section 4.3.3 discusses the utility/service issues within the site and the infrastructure required to be constructed to meet the specifications required on site.

4.3.3 Design Issues and Mitigation Measures

The following sub sections list the potential design issues with the various services/utilities and potential mitigation measures which could be deployed to overcome the various issues.

4.3.3.1 Power

The Wallerberdina site has two access points to suitable grid connection points. There are no constraints on the network based on projected load requirements (~2MVA) while the transmission and distribution networks remain in their current form. Due to the closure of the Leigh Creek Coalfield, engagement with ElectraNet should be conducted to determine whether the 132kV Leigh Creek South Tee to Neuroodla Tee line will be decommissioned within the next few years. Connection directly to the 132kV line adjacent to site provides higher reliability (noting potential decommissioning) and also is likely to cost approximately twice as much as building a 20km 33kV line to connect to the Neuroodla substation.

4.3.3.2 Water Supply Main

The site is located approximately 33km to the West of the town of Hawker which relies on a groundwater bore combined with a desalination plant to provide the water supply. The distance and terrain between the site and Hawker effectively rules out the connection to the existing system and leads toward the installation of a groundwater bore and desalination plant on site.

A network of groundwater extraction bores would be required to be installed. The water would then be pumped to an onsite desalination plant similar to that show in the figure below.

Figure 83 Desalination Plant Example (Desal Systems)

The treated water would then be pumped to storage tanks on site for Fire Fighting Supply, process use and general use.

The viability of this option will require further hydrogeological investigations to be conducted at the site to assess groundwater quantity and quality.

4.3.3.3 Wastewater

The existing site has no wastewater connections within a suitable distance to allow a connection therefore the potential options relate to treatment of the wastewater on site. Therefore the wastewater must be or treated on site or stored and removed from site.

There are various options with respect to the handling and treatment of the various discharges across the proposed site. Utilising the Reference Design supplied by ANSTO it can be established that there will likely be two separate waste networks on site. The wastewater outputs should be separated into wastewater, grey water and trade waste flows. The following describes potential sources from each:

- Wastewater – Discharge generated from sources that have faecal contamination.
- Grey water – Discharge generated from sources such as sinks, showers, kitchens without faecal contamination.
- Trade waste –Discharge generated from industrial activities, this may be of a high volume and/or contaminated.

Options have been investigated for the site and these are detailed below:

Wastewater Option 1 – Subsurface Effluent Disposal System and Trade Waste Evaporation Pond

A subsurface effluent disposal system would require the design of a reticulated network, septic tank and an irrigation field. When designing this system reference should be made to the location of the irrigation field in relation to any groundwater bores used on or off site and the potential for contamination. The existing geological conditions on site would require assessment as to whether the treated effluent would infiltrate through the specific geological conditions on site.

Wastewater Option 2 – Holding Tanks and Evaporation Pond

Holding tanks could be suitable to store wastewater discharge in large tanks (sized to accommodate the maximum discharge). The holding tanks would be emptied by tankers on a regular basis therefore negating the need for a treatment system on site. The costs for the septic tank maintenance would be ongoing and would be a consideration.

Wastewater Option 3 – On-site Treatment Plant and Evaporation Pond

The installation of a packaged treatment plant to treat the wastewater discharge could be considered. A packaged treatment plant such as an Aerobic Wastewater Treatment System which uses accelerated natural biological processes could be used to treat the wastewater. This system would then be combined with an irrigation network to dispose of the treated water. A typical system would require minimal maintenance, and this could be undertaken by the supplier at a minimal cost.

Trade Waste Option

A Trade Waste evaporation pond would be require to have an impermeable liner which is sized to consider the site meteorological conditions and with the require freeboard. The settled solids material would either require off-site disposal or potentially be retained in a storage facility on site (dependant of the level of contamination). Alternatively a Trade Waste collection tank would be required.

4.3.3.4 Telecommunications

To provide a suitable telecommunication link to the Wallerberdina site, installation of additional equipment will be required. Through investigation of Government websites and data there are two suitable options for providing the communications requirement which are set out in Section 4.3.2.1.4. The options are described below:

- Connection to the Sky Muster satellite via the installation of a satellite communications tower. This would provide a private connection to the communications network and therefore a greater surety of connection speed. An individual connection to the Sky Muster satellite can provide a maximum speed of 75Mbps therefore several connections may be required to provide the required minimum data connection speed of 25Mbps. To provide the required mobile coverage across the 100Ha site a mobile repeater tower would require to be constructed on site.
- An installation of this type could be used to allow connection to a mobile network or data connection for adjacent landowners.
- Reviewing the NBN website it states that the town of Hawker (33km to the West of the site) is serviced by the Sky Muster satellite. Due to the distance and the terrain between the proposed site and the town of hawker it is not deemed an option to connect the two systems.

4.3.3.5 Gas

The onsite requirements for gas would be required to be considered in the NRWMF design. It is envisaged that gas would be trucked to site and on-site gas storage tanks would be filled on a regular basis.

The factors to discuss during further stages of the design would be:

- Gas requirements – heating, kitchen areas, power generation, etc.
- Location and size of gas storage tanks – small gas cylinders for kitchen, heating use or large “bullet” tanks for greater onsite capacity.
- Safety requirements around gas storage delivery and tanks onsite.

4.3.3.6 Stormwater

Stormwater requirements will be required to be considered in the NRWMF design. This would include consideration of diversion of stormwater generated in upstream catchments around the site and also management of stormwater generated on-site, including detention and treatment. Stormwater re-use may be considered in the NRWMF design.

The recommended stormwater design philosophy would be to collect and treat all stormwater generated on site due to the lack of any infrastructure to connect in the surrounding area. Due to the type of facility, it would be prudent to minimise any perceived negativity around the potential for stormwater runoff entering nearby watercourses.

4.3.3.7 Utility/Service Assessment Summary after implementation of design mitigations

Table 64 below indicates whether the site satisfies the characterization criteria after the proposed design mitigation measures. After the construction of suitable enabling utility infrastructure, both the proximity and capacity criteria will be satisfied.

Table 64 Proposed Site Utility Characteristic Criteria upon implementation of design mitigation measures

Service / Utility	Criteria 1 - Proximity	Criteria 2 - Capacity	Comments
Power	✓	✓	There are no constraints on the network based on projected load requirements. There is potential to either construct a new substation or connect to the existing Neuroolda substation
Water Supply Main	✓	✓	Distance and terrain between the site and Hawker suggests the installation of a network of groundwater extraction bores and desalination plant on site as an alternative supply option to a potable water supply main from Hawker and potential upgrades to and expansion of its existing groundwater extraction and water treatment plant.
Wastewater	✓	✓	The existing site has no wastewater connections within a suitable distance. Therefore wastewater must be treated on site or stored and removed from site.
Telecommunications	✓	✓	Connection to the Sky Muster satellite will likely be required.
Gas	✓	✓	It is expected that gas will be transported to site and on-site gas storage tanks would be filled on a regular basis.

Service / Utility	Criteria 1 - Proximity	Criteria 2 - Capacity	Comments
Stormwater	✓	✓	It is recommended that stormwater would be collected and treated on site.

The relative cost to undertake the required engineering upgrades to facilitate the construction / operations of the NRWMF will be further detailed as part of the enabling works.

4.3.4 Data Gaps and Recommendations for Stage 2 Work / Enabling Works

The following sections detail the relevant data gaps and recommendations for work to be undertaken as part of the Stage 2 Work Program once a preferred site is nominated. It should be noted that high level designs of the enabling infrastructure (roads and utilities etc.) will be completed as part of the enabling works. These will be used to inform relevant stakeholders when nominating a preferred site.

4.3.4.1 Data Gaps

4.3.4.1.1 Power

The information required to allow progression of the power supply assessment is as listed below:

- Detailed load profiles
- Details of criticality of supply for NRWMF
- Incorporating potential for generation as well as load

4.3.4.1.2 Water Supply

The following information is required to progress the water supply assessment:

- Water consumption rates to be confirmed
- Existing and potential expansion of capacity of the existing water supply (groundwater) within Hawker
- Confirmation of Fire Fighting Water requirements
- Confirmation of ground water supply issues

4.3.4.1.3 Telecommunications

The following information required to allow progression of the telecommunications assessment is as listed below:

- Specific telecommunication requirements for the site
- The specific requirements for the Sky Muster satellite system and the required infrastructure and the number of connections required.
- The number of and location of mobile repeater stations
- Confirmation of reliability of the satellite system

4.3.4.2 Recommendations for Stage 2 Field Program Data Collection

The following is a list of recommendations for the additional data collection which is required for a more detailed assessment of the site characteristic criteria to be undertaken. It should be noted that the design of enabling infrastructure will be considered as part of the enabling works. The following items will be considered as part of the enabling works.

4.3.4.2.1 Power

- Discussions with ElectraNet and SA Power Networks
- Feasibility modelling of connection of load/generation to network
- Verification of power supply requirements

4.3.4.2.2 Water Supply

- Discussions with SA Water with regard to existing and potential expansion of capacity of the existing water supply (groundwater) within Hawker.
- Confirmation of potential on-site groundwater extraction constraints and quality issues.

4.3.4.2.3 Telecommunications

- Discussions with NBN regarding the Sky Muster satellite option
- Verification of telecommunication requirements.

4.4 Renewable Energy

4.4.1 Methodology and Results

This desktop study has assessed the different renewable energy technologies that could be used at Wallerberdina. The technologies were assessed as a means of potentially offsetting the energy load requirements of the facility.

AECOM has conducted a literature review of publicly available information on different renewable energy generation technologies that are available in the Australian market. The generation technologies assessed are:

- Solar Photovoltaic (PV);
- Solar Thermal;
- Wind;
- Geothermal;
- Hydro; and
- Tidal / wave.

Information was gathered on the following topics for each generation type:

- Availability of resource in vicinity of site;
- Strategic costings (indicative Levelised Cost of Energy (LCOE), Capital Expenditure (Capex) and Operating Expenditure (Opex));
- Risks;
- Technical characteristics;
- Pathways to construction; and
- Estimates of time to market.

4.4.1.1 Site Characteristic Criteria

The key criterion is the appropriateness of renewable energy resource options to provide renewable power sources to the site (and the local site setting to generate renewable energy).

Considerations relevant to the criteria are outlined below.

4.4.1.1.1 Resource availability

For each technology investigated, the availability of the resource in proximity to the site was assessed.

4.4.1.1.2 Technology Risk

The maturity of the technology and the process used was assessed in relation to activities in the vicinity of the NRWMF.

4.4.1.1.3 Cost

The commercial implication of each technology was assessed.

4.4.1.1.4 Scalability

Scalability and modularity of the technologies were assessed.

4.4.1.2 Desktop Methods and Results

4.4.1.2.1 Solar PV

Australia has the highest solar radiation per square metre of any continent [3] globally. Installations of solar PV technology have increased significantly over the past few years internationally and in

Australia. Globally, there is over 300 GW of solar PV plants installed with improvements being implemented as confidence in the technology continues to increase.

One of the main factors for this increased uptake is the significant reduction in costs, with The Climate Council Australia noting that “Solar costs have dropped 58% in five years and are expected to continue to fall by a further 40-70% by 2040” [2]. Compared to electricity prices for new coal power stations at A$160/MWh, solar PV is expected to continue to drop below A$110/MWh as more systems are installed [2].

The key drivers of declining costs and improved economic viability of large scale solar PV include:

- Declining technology costs (mass production and increased competition)
- Increased scale of deployment in Australia
- High Large Scale Generation Certificate and electricity prices
- Availability of federal grant funding and access to financing

Project site and technology selection has a major influence on the Capex, Opex and Levelised Cost of Energy.

Solar PV technology has the added benefit of modularisation. Different sized solar farms can be designed and built to suit available land area. The modularity of the system also reduces down-time of the system, as some components can be repaired or replaced without affecting the other parts of the system (e.g. panel replacement). The asset life of a solar farm is around 25-30 years.

Solar PV panels can be installed as either a fixed structure that has the panels locked in place with no moving parts, or mounted on tracking devices that change the orientation of the panel to maximise exposure to sunlight. These can either be single-axis tracking (SAT) devices, which change the orientation along one axis, or dual-axis tracking (DAT), which can change orientation along two axes. Fixed tilt systems are the simplest for installation and operation. While SAT systems increase performance (typically by 15-20% depending on the location), they require more land for the same total capacity and have a higher Capex and Opex. However, in the last couple of years the cost of SAT systems in Australia has fallen more rapidly than for fixed tilt solar and is now often preferred for new projects where available space and topography allow.

Wallerberdina resource

South Australia is known for having a high solar resource. In Figure 84 below, it can be seen that South Australia has some of the highest mean direct normal exposure of solar in Australia (>23 MJ/m^2/year). In particular, the Wallerberdina site (shown circled in black), is in an area of high solar exposure.

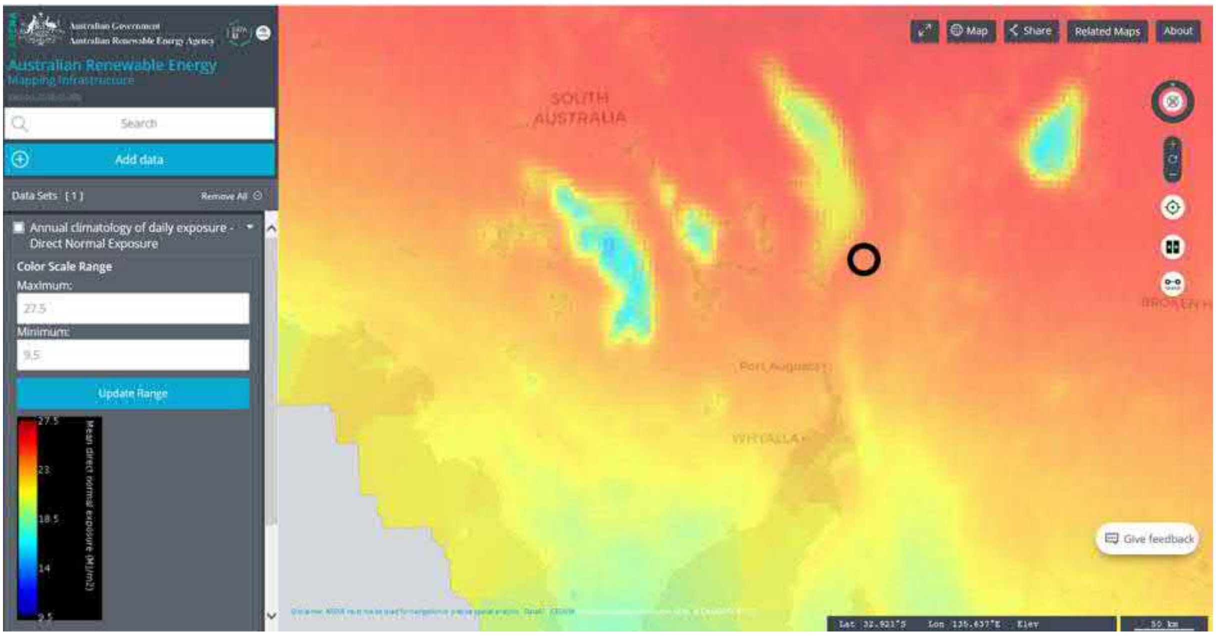
The area of very high exposure makes it worthwhile to consider the site as offering potential for installing solar as a generation source. However, considerations for solar PV also need to include temperature and potential for soiling of the panels.

Solar PV panels derate in high temperatures. According to the Bureau of Meteorology [4], high ambient temperatures in the Hawker region (weather station in proximity to the Wallerberdina site) average over 30^{o}C from October to March and could cause the power output of the panels to derate by about 2% from the specified rating [5].

In areas with little rainfall, additional manual cleaning of panels would be required to ensure the performance of the panels is not significantly reduced from soiling. Soiling can cause around 0.2% losses per day when there is no rain or cleaning. The average annual soiling losses could range from 1% to 4% depending on the site and cleaning regime.

These factors need to be considered in detailed design and commercial considerations for solar PV technologies.

Figure 84 Solar Resource in Wallerberdina Region [1]



Solar PV metrics for utility scale projects

Table 65 Strategic costs and other key metrics for Solar PV [6,7,8,9,10,11,12,13,14,15,16] [26]

Metric	Lower limit	Typical	Upper limit
Levelised Cost of Energy	\$58/MWh	\$98/MWh	\$171/MWh
Capex	\$1.1M/MW	\$2.1M/MW	\$2.6M/MW
Opex - Variable	\$0/MWh	\$0/MWh	\$0/MWh
Opex – Fixed	\$11,000/MW/year	\$28,000/MW/year	\$57,000/MW/year
Time to Market [27]	1 year	1.5 years	3 years
Land required	0.5 ha/MW_{dc} ($5.5m^2/kW_{dc}$) (roof mount fixed)	1.8 ha /MW_{dc} (ground mount)	2ha / MW_{dc} (ground mount tracking)

Assessment of Solar PV for Wallerberdina

Solar PV technology is relatively low cost compared to other forms of renewable generation and has the benefit of scalability. The Wallerberdina area has high irradiance; derating for temperature and soiling would need to be considered in detailed design. Solar PV technology is well known, with numerous qualified and certified designers and installers, and poses a low safety risk for operation. The nearby region of Port Augusta has many parties interested in construction of solar farms and has one of the largest solar farms in Australia is currently under construction [17].

4.4.1.2.2 Solar Thermal

This section focuses on solar thermal technology for electricity generation. Solar thermal technology can also be used for heating purposes as another means to offset energy use by using technology such as solar hot water. These heating systems are very typical and commonly used throughout Australia. In further detailed design, solar thermal heating systems could be investigated by the NRWMF designers for overall site efficiencies.

[26] Prices based on states with large numbers of utility solar farm installations
[27] Time to market includes development and design, approval, construction, commissioning

Solar thermal (electricity generation) technology is based on harnessing the sun's heat energy by concentrating sunlight reflected from mirrored surfaces to a receiver. The high temperature is then harnessed by passing a fluid (such as water, molten salt or synthetic oil) through a focal point (or tubes, depending on the design). Finally, steam turbines use the steam to generate electricity [6].

Some solar thermal systems can also store the heat energy before it is used to produce steam. This facilitates the plant to continue producing electricity even when sunlight is unavailable or below ideal radiation levels [6]. These systems are also called Concentrated Solar Power (CSP) systems. There are multiple types of CSP technologies and the figures provided in our analysis are based on one type, called 'Central Receiver'.

Commercial capacity of Concentrated Solar Power (CSP) systems have been concentrated in a few countries around the world, mostly Spain and the United States, but numerous projects are being developed in the Middle East, North Africa, as well as in Australia, India, China and South Africa [18]. CSP systems have not had the same accelerated growth as seen with solar PV. Competition from lower-cost solar PV is challenging deployment, as evidenced by some projects in the United States having converted from CSP to solar PV. However its market penetration may increase by virtue of its suitability for integration with a fossil fuel plant and storage, which can enhance its value through dispatchability [18].

Currently, the installed costs of CSP systems are high compared to wind and solar PV; current installed costs per MW are as high as twice the cost of other renewable systems [18].

Solar thermal technologies are not typically scalable and tend to be installed for generation more than 50MW due to the cost effectiveness of larger thermal masses. The life of the asset is similar to typical thermal generation plants, in excess of 40 years. [19].

Technical risks of thermal solar developments include molten salt leaks, safety risks, including instances of fires and explosions at facilities, and the risk of inadequate solar radiation.

Wallerberdina resource

South Australia is known for having a high solar resource. Solar thermal technology requires direct sunlight (solar PV can still produce energy in diffuse light situations). South Australia has some of the best resource in the world for direct exposure. In Figure 84, above, it can be seen that South Australia has some of the highest mean direct normal exposure of solar in Australia (>23 MJ/m^2/year). The Wallerberdina site (shown circled in black), is in an area of moderate/high solar exposure as shown in Figure 84, above.

Solar thermal metrics for utility scale projects

Table 66 Strategic costs and other key metrics for Solar thermal [18, 6, 9, 20, 21] [28]

Metric	Lower limit	Typical	Upper limit
Levelised Cost of Energy	$119/MWh	$185/MWh	$300/MWh
Capex	$5M/MW	$7M/MW	$9M/MW
Opex - Variable	$4/MWh	$7/MWh	$13/MWh
Opex – Fixed	$65,000/MW/year	$70,000/MW/year	$76,000/MW/year
Time to Market[29]	5 years	6 years	10 years

Assessment of Solar thermal for Wallerberdina

Solar thermal technology has not been well developed in Australia and remains at costs double that of other renewable technologies. In the nearby region of Whyalla, a new solar thermal plant is being built to prove the suitability of this technology in the region. Local Australian contractors are inexperienced with design, development and construction of solar thermal facilities and international involvement would likely be required.

[28] Based on adjusted global and local figures.
[29] Time to market includes development and design, approval, construction, commissioning

4.4.1.2.3 Wind

Wind generation technology is one of the most mature renewable energy technologies available, and remains the lowest cost renewable generation type. Wind farms are heavily dependent on location; an area with suitable open land as well as consistency in wind speed at the correct height and availability of wind is required to efficiently operate. These topology factors heavily influence the turbine selection and layout.

Wind generation is considered to be the fastest growing renewable energy technology in Australia with a current share of 4.9% of Australia's primary energy consumption [22].

The five key components that impact the Levelised Cost of Energy are up-front capital costs (Capex), ongoing operating costs (Opex), cost of financing, performance (capacity factor) and project design life.

All five of these cost drivers are continually seeing improvements with large scale wind energy development. The most significant improvements have recently come from capacity factor increases and reduction in capital expenditure. Capacity factor is increasing for wind turbines due to the increasing hub height and capacity of the turbines and the larger rotor diameters being installed. As the industry continues to mature, financing costs and project contingencies continue to be reduced.

Additionally, turbine component durability and reliability continues to improve.

It is expected that there would be a period of very limited to nil reduction in costs from 2021-2024. Most grade one wind farm sites (with high wind resource and favourable planning conditions) will have been used up by project developers by the early 2020's and sites with lower wind resource in more challenging geographies would be available for construction [18].

Being a mature technology, wind energy is well understood by the industry and is considered a low risk technology. The main challenge for the implementation of wind energy generation in Australia is the changing requirements of the management of quality and stability of the transmission system due to relatively sudden changes in electrical output sent into the system. Wind energy has an increasing level of penetration into the electricity network (along with solar PV) which is inherently variable in output due to the variability of meteorological conditions.

The typical asset life of Wind farms is 20-25 years [23] for utility scale farms. Small scale wind turbines are not common in Australia.

Wallerberdina resource

The area for Wallerberdina shows a relatively low wind resource area as outlined in Figure 85 below (Wallerberdina is the black circle). Wallerberdina is in a region of green colour, representing a lower wind resource that the lighter yellow areas. The surrounding Flinders Ranges have a higher resource but additional land procurement would be required along with potentially challenging development approvals. Transmission between a wind farm in a satisfactory resource area back to the NRWMF at Wallerberdina would need to be assessed for cost effectiveness. Additionally, some turbines derate at high temperatures and some stop operating at temperatures between 40^{o}C and 45^{o}C. This region reaches these temperatures and must be taken into account when considering annual output.

Figure 85 Wind resource at Wallerberdina site [1]

Wind metrics

Table 67 Strategic costs and other key metrics for wind [6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 21]

Metric	Lower limit	Typical	Upper limit
Levelised Cost of Energy	$60/MWh	$92/MWh	$120/MWh
Capex	$2.2M/MW	$2.5M/MW	$2.8M/MW
Opex - Variable	$0/MWh	$8/MWh	$16/MWh
Opex – Fixed	$19,000/MW/year	$35,000/MW/year	$55,000/MW/year
Time to Market[30]	4.5 year	6 years	9 years
Land required (Permanent Direct Impact Area land use)	<0.1 ha /MW	0.2 ha /MW	>1.5 ha /MW
Land required (Total wind farm area)	<10 ha /MW	25 ha /MW	>70 ha /MW

Assessment of Wind for Wallerberdina

Wind turbines are a well-established technology and comparatively low cost for renewable technologies. There is limited wind resource in the direct vicinity of the Wallerberdina site and additional land would need to be sourced to provide the power from an area of greater wind resource. Community support is critical for the NRWMF and additional visual impacts from wind turbines, noise of turbines and additional land use would need to be considered. Conversely, community support for renewable energy and generation support into the grid may be welcomed by the community, landowners and stakeholders.

4.4.1.2.4 Geothermal

Geothermal power production is based on using the heat of the earth as an energy source. Geothermal energy can be drawn from the hot water circulating among rocks below the earth's surface, or by pumping cold water into the hot rocks and returning the heated water to the surface. This can drive steam turbines to produce electricity [24]. Temperatures as low as 30°C can be used for

[30] Time to market includes development and design, approval, construction, commissioning

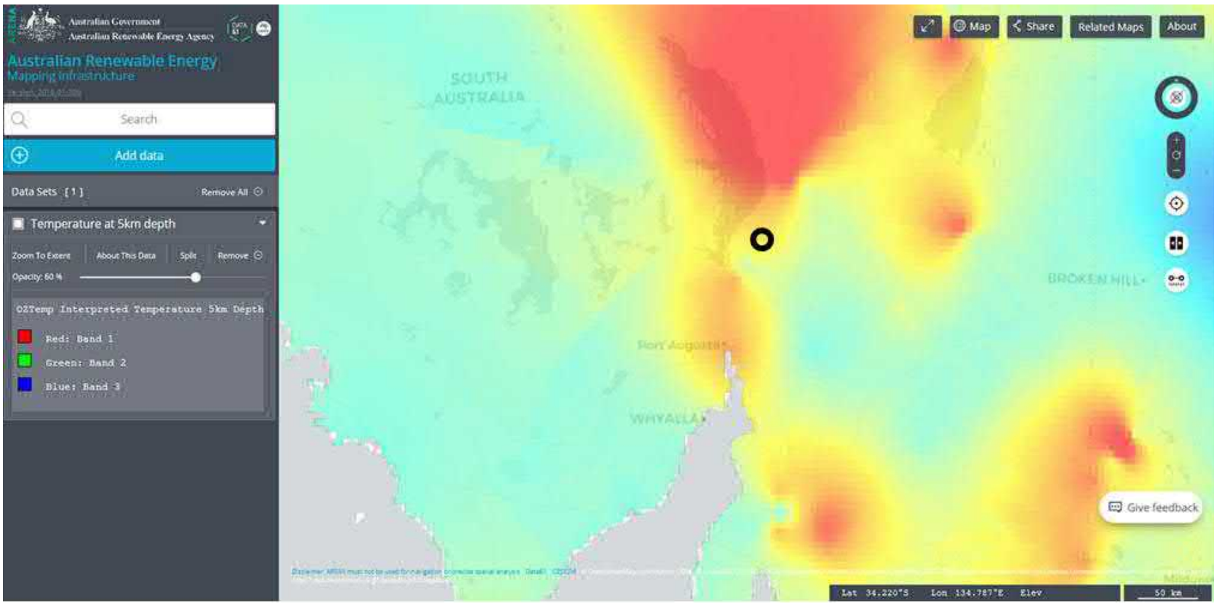
direct use applications and temperatures in excess of 100°C can be used for generating electricity. Currently drilling technology limits economic development of geothermal resources to a maximum depth of about five kilometres. Thus, companies are exploring for regions of elevated temperatures at five kilometres deep or less [25]. Geothermal energy has the potential to provide constant and baseload power due to the stable resource.

Geothermal technologies are not well developed in Australia. While studies have been conducted into potential locations, most current projects in Australia are still at proof-of-concept or early demonstration stage [24]. Capital costs are high due to the significant infrastructure requirements and novelty of the technology in Australia. As geothermal power production in Australia requires drilling into the surface (elsewhere in the world the heat is more accessible through natural phenomenon such as geysers), there is the potential for drilling to cause instability in the region surrounding the source. There is also the potential for releasing gases from the earth's surface [26].

Wallerberdina Resource

The area for Wallerberdina shows a high geothermal resource area as outlined in Figure 86 below (the black circle is Wallerberdina). Wallerberdina is in a region of yellow/orange, representing warmer temperatures. The band colours are based on interpreted temperatures at 5 km depth from the OZTemp data set [27]

Figure 86 Geothermal resource at Wallerberdina site [1]



Geothermal Metrics

Metrics have not been assessed for the geothermal assessment due to limited history of projects in Australia.

Assessment of Geothermal for Wallerberdina

The risks associated with causing unstable land, potential release of gases and high capital costs make geothermal technology a high risk technology for use as a potential power source for the NRWMF.

4.4.1.2.5 Hydro

Hydro generation or hydropower generates electricity by capturing, storing and diverting water through hydro turbines and associated generation equipment. This involves the construction of a dam to restrict the flow of water, only allowing water to flow when electricity is to be generated. It is a mature dispatchable generation technology.

Hydropower systems range from less than 1MW to well over 1,000 MW, although in Australia most of our hydro generation capacity comes from a small number of large hydropower plants, the largest of which are associated with the Snowy Hydro scheme in NSW and Victoria. Hydropower is the largest source of renewable energy generation in Australia. In relation to the total electricity generated, both renewable and non-renewable, hydropower plants generated a total of 5.9% [6].

Hydropower schemes are broadly classified by the three main types:

- Run-of-river scheme - which usually has a small weir to divert flow rather than a large dam and no appreciable storage. As such, run-of-river schemes can only generate electricity when there is sufficient river flow. Consequently, it has no energy storage and although generation can be varied within the constraints of the available flow, it is not a form of reliable dispatchable generation.
- Reservoir storage scheme – where the water is stored in a reservoir that is restrained by a dam constructed upstream of the powerhouse. Stored water provides energy storage making reservoir storage schemes a form of fully dispatchable generation.
- Pumped storage scheme – where it works on the same idea of using flowing water from a high point to a low point to drive a turbine. Electricity demand peaks are met by releasing the stored water from the upper pond and running the turbine. The upper pond is replenished by the electric pumps during periods of low demand, making this an energy storage scheme.

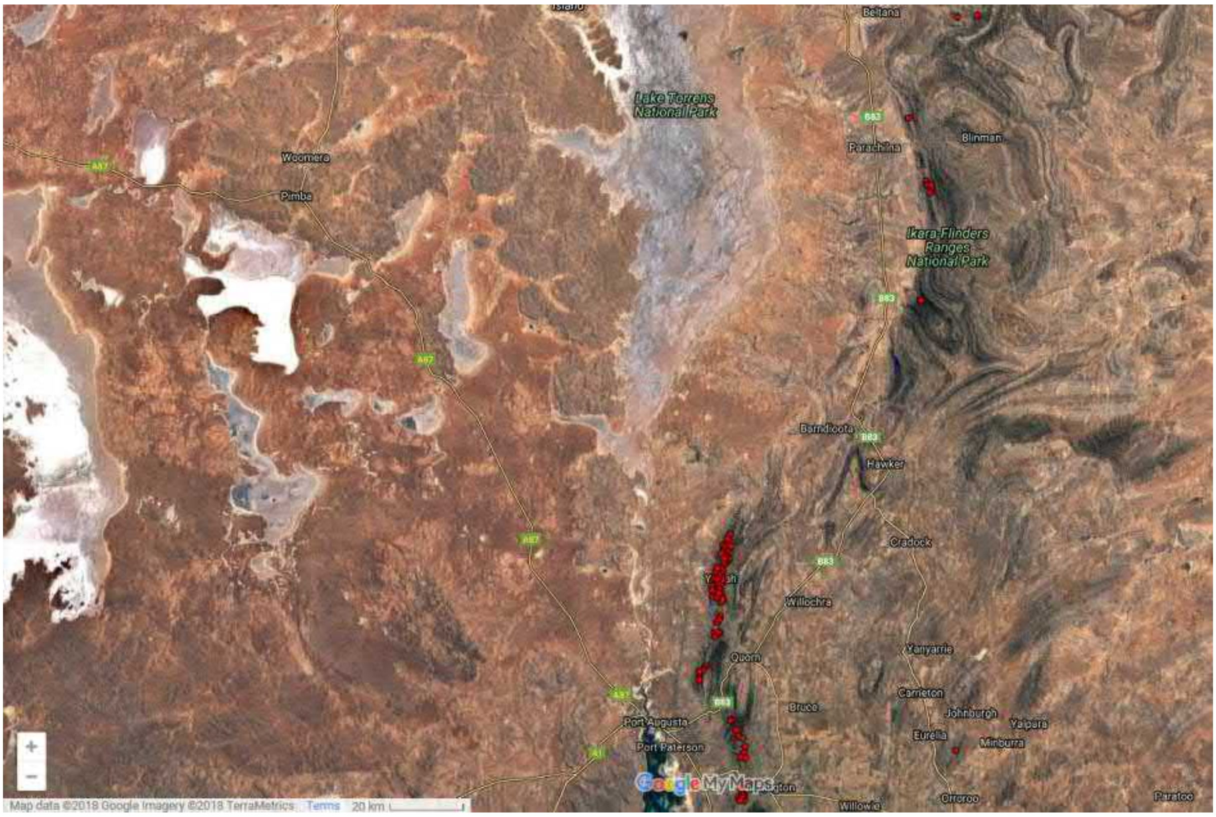
Due to the large scale of typical hydropower projects, a considerable amount of project funding and capital investment is necessary. Development of new large scale-hydropower projects in Australia also poses significant environmental impacts, particularly via the construction of associated dams and reservoirs. Furthermore, concerns regarding climate change and reliability of future water sources (i.e. droughts) present significant risk for future developments.

Wallerberdina Resource

The area for Wallerberdina is a dry landscape with limited natural water sources in the vicinity. Lake Torrens, in close proximity, is a salt lake. It is Australia’s second largest lake but has only filled with water once in the past 150 years [28].

While pumped hydro is a form of storage, rather than generation, noted below is potential sites identified through studies recently conducted by the Australian National University. The image below shows the identified sites near the Wallerberdina region. The surrounding Flinders Ranges have potential sites nominated but the transmission between the pumped hydro sites back to the NRWMF at Wallerberdina would unlikely be cost effective.

Figure 87 Pumped Hydro atlas, red circles indicate identified potential pumped hydro sites [29]



Hydro (pumped hydro – storage) Metrics

Table 68 Strategic costs and other key metrics for hydro (pumped hydro – storage) [18, 6, 21, 20, 30, 31, 32]

Metric	Lower limit	Typical	Upper limit
Levelised Cost of Energy	$57/MWh (161/MWh pumped)	$138/MWh ($190/MWh pumped)	$337/MWh ($220/MWh pumped)
Capex	$3M/MW	$5M/MW	$8M/MW
Opex - Variable	$5/MWh	$6/MWh	$7/MWh
Opex – Fixed	$3,000/MW/year	$19,000/MW/year	$35,000/MW/year
Time to Market[31]	3 years	7 years	20 years
Land required	Varies greatly	Varies greatly	Varies greatly

Assessment of Hydro for Wallerberdina

While some sites have been identified in the surrounding Flinders Ranges for pumped hydro, the scale of a pumped hydro installation does not align with the core business. Run-of-river or reservoir schemes are not possible due to the limited water supply in the region.

4.4.1.2.6 Tidal / Wave

Tidal and wave power has not been considered due to the distance from the site to the sea (~100km).

4.4.1.3 Field Methods and Results

No field studies have been conducted for assessment of the renewable energy resource on site.

[31] Time to market includes development and design, approval, construction, commissioning

4.4.2 Assessment Against Criteria

The key assessment criteria applicable to considerations of renewable energy for the NRWMF include the appropriateness of renewable energy resource options to provide renewable power sources to the site including the potential for the local site setting to generate renewable energy.

A summary of the key renewable energy technologies assessed is provided below.

The key technologies assessed were:

- **Utility-scale solar PV**: Australia is a key area for developments of utility scale solar PV because it has good solar resource. Utility-scale solar PV costs have reduced significantly in Australia in recent years which has yielded improved economic viability. The technology is NEG (National Energy Guarantee) compliant for emissions, but not with reliability as it is not dispatchable at all times. Also, it cannot provide ancillary services without energy storage included.
- **Solar thermal**: Solar thermal generation for electricity generation is currently expensive compared to other renewables, but there is high potential for cost reduction. Australia's experience to date with solar thermal is one of limited success but with strong learnings and continued interest. It is consistent with the NEG requirements for emissions and reliability and can provide ancillary services, but it is currently expensive compared to wind energy and solar PV, which has challenged its deployment. However, the potential for cost reduction going forward is very high, and is currently supported through ARENA funded research and development initiatives. Solar thermal technologies can also be used in the form of solar thermal heaters to offset heating loads (such as hot water); a well understood and implemented technology.
- **Wind**: Wind farms have increasingly sophisticated adaptive capability, as recent technology advances have seen fewer turbines needed to produce the same amount energy. Cost reductions enjoyed over the last few years, however, are expected to stall from 2021-2024, as the availability of most grade one wind farms diminishes. While wind generation is consistent with the NEG for emissions, it is inconsistent from a reliability perspective as it is not dispatchable, except in the case of storage being added. Accordingly, the main challenge for the implementation of wind energy generation across Australia is the changing requirements for the management of transmission stability and quality, as the penetration of variable renewable energy generation, increases in the NEM wide energy mix.
- **Geothermal**: Geothermal technology is relatively novel in Australia. Most projects are in the proof of concept stage or early demonstration. Costs vary dramatically depending on the resource availability and infrastructure required. The technology also poses potential risks for land stability and release of gases.
- **Hydro/ (pumped hydro – storage)**: Hydro generation has high development costs and potential environmental impacts, but it is renewable and dispatchable. Pumped hydro storage offers storage at a large scale, which can add flexibility to the power grid. Development may be impacted by high capital costs, long development timeframes, and potential environmental impacts. It is compliant with the NEG requirements around emissions and reliability, and is capable of offering ancillary services.
- **Tidal/ Wave**: Tidal and wave generation technology is not common in Australia. Studies are currently being undertaken to assess the viability of sites in Australia but most projects are still in early assessment phase.

The technologies assessed above are summarised in Table 69

Table 69 Technology suitability for Wallerberdina

Column heading	Utility-scale solar PV	Solar thermal	Wind	Geothermal	Hydro	Tidal/ Wave
Abundance of resource	High	High	Low	Moderate	Low	Low
Risk	Low	High	Moderate	High	High	High
Cost	Low	Moderate	Low	High	Moderate	-
Scalability	High	Moderate	Moderate	Moderate	High	-

4.4.3 Design Issues and Mitigation Measures

South Australia has some challenging network reliability conditions and potential instability. "Regions supplied by long, radial distribution feeders (remote from the transmission network) typically receive the greatest total minutes off supply" [33]. Based on the study conducted on the grid condition options for the Wallerberdina site (Utilities and Energy considerations), the site is close to the transmission network (either via a new substation directly to the 132kV transmission line or to the existing transmission line substation). While the Wallerberdina site has electrical proximity to a transmission line, the line is still at the edge of the NEM network with aging assets.

The inclusion of renewable energy for generation on site, as well as supporting energy storage technologies such as batteries (short term) and diesel (long term), is expected to provide both commercial and power reliability benefits to the project.

Consideration of the grid constraints, reliability, and potential connection points are key considerations for determining the amount of solar PV (the most suitable technology for the site) and storage required.

The critical loads would need to be considered, as well as the required redundancy for the site.

Further analysis into the potential of a fully islanded (microgrid) system may:

- increase site reliability (if able to switch between island and grid mode), or
- avoid grid network connection costs (if installed as a permanent islanded microgrid)

Care should be taken with storage of energy at a NRWMF, as fuel or some types of batteries are a high energy source and can be an explosive or fire risk.

These options will be considered as part of a more detailed renewable energy options assessment prior to the preparation of a concept design for the preferred option.

4.4.4 Data Gaps and Recommendations for Stage 2 Work Program

4.4.4.1 Data Gaps and Limitations

The information provided in Renewable Energy considerations is a preliminary assessment with more information required to continue the assessment of the energy load and power requirements.

Additional information requested as part of the Enabling Works includes:

- Load profiles (daily profiles including seasonal variation);
- Critical loads;
- Facility power equipment (e.g. switchrooms);
- Site security requirements (e.g. how the buffer zone can be used);
- Community perspective and development requirements for area surrounding the 100 ha designated site;
- Minimum load requirements;

- Maximum load requirements (construction and operation);
- Understanding the risk associated with radioactive material near electrical equipment (e.g. for installation on roofs and vault mounted technologies); and
- Site SLD.

4.4.4.2 Recommendations for Stage 2 Work Program

Further works are covered by the requirements of the Enabling Works options assessment.

5.0

Summary of Technical Assessment

5.0 Summary of Technical Assessment

The table below provides a summary of the Site Characterisation studies conducted by AECOM. The studies were undertaken to enable an assessment against site characteristic criteria developed with reference to ARPANSA guidelines and IAEA standards relating to the selection and evaluation of sites being considered for the siting of radioactive waste facilities.

It should also be noted that the assessments contained in the below table make no allowance for design solutions or operational management measures which could be implemented to mitigate or offset existing hazards or constraints.

The site is well separated from adversely affecting development and sensitive land uses, however, mineral tenements in the local area, if they proceed to development for extraction, could have direct or indirect impact on the NRWMF and its enabling infrastructure.

There are a number of potential environmental constraints identified at Wallerberdina that would likely require mitigation or management should the proposed NRWMF be further considered at the site. These include ground shaking or deformation from earthquakes, localised flooding, catchment flooding from rare episodic flood events including the potential for deposition of fluvial material and avulsion of Hookina Creek, wind erosion or mass movement of sands.

A hydrological model and subsequent 2D hydraulic modelling indicates that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 annual exceedance probability, AEP). For the 1 in 2000 AEP flood, depths are typically in the range 0.25 to 0.5 m with isolated areas up to 1 m. This poses constraints on the site that will require the investigation and design of appropriate mitigation measures (e.g. consideration of installation of bunds and levees) should Wallerberdina be further considered for the NRWMF. Further, as the site is situated on the Hookina Creek alluvial fan and located nearby to dune fields, mitigation and monitoring measures will need to be employed to address its long term stability. Additional hydraulic modelling is required to consider risks posed by avulsion, floodplain scour and sedimentation in order to develop appropriate design solutions and operational management measures.

Groundwater in the watertable aquifer was found to be present at depths greater than 20 m below ground surface across the site which would provide good separation between the base of any proposed NRWMF and groundwater. The water table aquifer is of reasonable water quality and yield. Given the lack of reticulated water supply, groundwater may be used for a range of beneficial uses for the NRWMF (some requiring additional pre-treatment).

There is a high level of confidence (excluding the possibility of one-off faulting) of the absence of potentially active faults in the foundation beneath the site. Seismic hazards in the form of ground shaking and ground deformation associated with the potential for near-surface faults or major faults in the foundation in the vicinity of the site (yet to be identified) should be able to be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods.

There are no threatened ecological communities within the site nor is there a likelihood of occurrence of Commonwealth listed species. One of each of a State listed flora and fauna species has the potential for occurrence but has not historically been identified. Habitats present on the site also exist in surrounding areas.

The site is well served by major road networks with several local unsealed road access options. Multiple culvert crossings in addition to other upgrades may need to be installed to accommodate the number of watercourses that cross the local access routes.

There is an absence of most services and utilities in the vicinity of the site (water, telecommunications and stormwater) apart from power. Communications towers would need to be constructed to connect to mobile phone and data communications. Distance and terrain between the site and Hawker means that installation of a network of groundwater extraction bores and desalination plant on site should be an alternative supply option to a potable water supply main from Hawker and potential upgrades to and expansion of its existing groundwater extraction and water treatment plant. The inclusion of renewable energy for generation on site, as well as supporting energy storage technologies such as batteries (short term) and diesel (long term), would provide both commercial and power reliability benefits to the project.

IAEA (2015) provides a range of safety related criteria to be considered in the siting process including extreme meteorological events (e.g. high winds, bushfire, flooding, dust storms), geotechnical hazards (e.g. slope stability), seismic hazards which could result in in ground displacement (from ground deformation or shaking), bushfire, transport considerations (access/ egress routes and access to emergency facilities) and risks from potential impacts of human activities (e.g. air traffic, mining or quarrying, surface transportation, other hazardous facilities). The assessed characteristics of the Wallerberdina site indicate that its location in the presence of large alluvial floodplain adjacent to Hookina Creek may present a potential material risk to access/ egress and site operations from episodic rare flooding events. The nature and recency of major fault lines in the local surrounds, is yet to be adequately assessed, may also represent a potential material risk to site infrastructure from ground surface motion and displacement. The site is subject to extreme meteorological hazards including high temperatures and occasional dust storms may impact on the safety of site personnel and the NRWMF, without mitigation through design and management measures.

A hospital is located within Hawker, which is an approximate 40 km drive south-east from the site. An aerodrome is located close to Hawker, from which an air ambulance (Royal Flying Doctor Service) can provide medical evacuation to a major hospital in Adelaide.

The capacity and constraints of the enabling infrastructure will need to be addressed through design or other measures to meet the NRWMF requirements.

Based on the assessments conducted to date, the identified site characteristic hazards and enabling infrastructure constraints should generally be able to be mitigated via design solutions (e.g. use of thick reinforced-concrete mat foundations to protect structures from ground movements, or construction of levees to protect the site or structures from flooding). Potential design matters and mitigation measures that could be employed have been considered to address enabling infrastructure constraints, environmental hazards and to protect environmental values. The Site Characterisation and NRWMF design works are running in parallel and will inform the other as the site selection process progresses. A detailed options assessment and concept design for the enabling infrastructure has also commenced.

A separate safety case document must be prepared as part of the licence application to the regulator ARPANSA, prior to any approval for construction and operation of the NRWMF on the preferred site. The safety case will consider not only site characteristics with potential safety impacts, but also the NRWMF design and operational activity measures and mitigations employed to appropriately mitigate site characteristic hazards, and the transport, storage and disposal of radioactive wastes. A safety in design process will also need to be followed by the designer to address design requirements for safety of the site personnel.

A second stage of more detailed Site Characterisation studies will be conducted once a preferred site is selected by the responsible Minister. Assessment data gaps and recommendations for additional work scope items to fill such gaps have been provided for this second stage. The development of a robust conceptual site model and environmental dataset will support the development of a safety case for the NRWMF and applications for licensing and environmental approvals. Baseline conditions must also be established to enable future surveillance and monitoring during construction and operation of the NRWMF.

Table 70 Site Assessment Summary - Wallerberdina

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Flora & Fauna	To characterise the flora and fauna present on and adjacent to the site and identify any significant or threatened species and supporting habitats which could preclude use of the site for the proposed NRWMF.	*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *Native Vegetation Act 1991* (SA) *National Parks and Wildlife Act 1972* (SA).	Absence of Commonwealth or State threatened species and supporting habitat, minimal requirement for vegetation clearance.	The Wallerberdina site has no threatened ecological communities. There are no EPBC Act listed species with potential for occurrence; but one flora (Desert Lime) and one fauna (Elegant Parrot) State listed species have the potential to be present, which require further surveys to determine likelihood of occurrence and significance of potential impacts.
Conservation and special use areas	To identify any Conservation or Recreational Parks in close proximity to the site and Aboriginal heritage or State and Local listed heritage sites which could preclude use of the site for the proposed NRWMF.	*National Parks and Wildlife Act 1972* (SA) *Heritage Places Act 1993* (SA).	Absence of Parks (National Parks, Conservation Parks, Conservation Reserves, Recreational Parks, Wilderness Protected Areas and native vegetation Heritage Agreements) and Aboriginal or State and Local heritage sites on or adjacent to the site.	The Wallerberdina site does not have any National or State parks and reserves nearby. Twenty six registered and three restricted Aboriginal heritage sites are located in the local area away from the site. A cultural heritage assessment is being undertaken at Wallerberdina, independent of the studies outlined in this report.
Radiation, background and risks	Establish a baseline for future environmental monitoring (to inform possible licence application) and identify potential elevated background conditions that could affect safety of personnel.	IAEA-TECDOC-1363 Guidelines for radioelement mapping using gamma ray spectrometry data. IAEA NS-R-3 (Rev.1) Site Evaluations for Nuclear Installations.	Background radiation levels within the ARPANSA Action Levels for workplaces. Background radiation levels are not sufficiently elevated to impact on the effectiveness of environmental monitoring.	Published historical radiometric aerial survey data obtained on a 200 m grid that covers site and surrounds reported background radiation levels that are not elevated, at around 1% of the ARPNSA Action levels for workplaces.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Climate change and long term environmental scenarios	Establish existing climatic conditions for the site based on historic average and identify likely changes to climate based on projections and identify resultant key hazards that could impact on the future NRWMF and workers.	AS5534-2013 Climate change adaptation for settlement and infrastructure – A risk based approach. IAEA SSG-18 Specific Safety Guide Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations.	Future climate change conditions where the frequency and intensity of climatic events have minimal impacts or where design measures can mitigate risks.	Potential climate change impacts include higher intensity rainfall events, extreme heat and fire weather. These events have the potential to impact on variables including worker safety, infrastructure damage, waste transport, flooding, power supply and maintenance costs amongst others. Potential climate change impacts should be used to inform design and operation of the NRWMF should it proceed at this site.
Bushfire Risks	Characterise bushfire threat from factors including vegetation/ fuel hazard at local and landscape level, site slopes, frequency/ severity of bushfire weather conditions and assess the likelihood and nature of bushfire impact based on potential for ignition, development and approach in landscape.	AS 3959-2009 Construction of Buildings in Bushfire Prone Areas. Department of Environment, Water and Natural Resources, 2012. Overall Fuel Hazard Guide for South Australia.	Combination of climatic conditions, fuel loadings, topography and ability to create buffers which minimises the risk and potential severity of bushfires.	The bushfire hazard at Wallerberdina is low, due to the lesser hazard nature of the vegetation on and around the site and the benign topography. The site would only be exposed to a relatively low intensity grass or scrub fire that would not pose a significant hazard if appropriate bushfire protection measures are provided.
Impacts of Nearby Human Activities and Land Use Planning	Identify existing and potential future land uses on, or in proximity to the site, (sensitive land uses, extractive or hazardous activities) that may adversely impact on the site or be impacted by the NRWMF.	IAEA Safety Requirements NS-R-3 (Rev.1) Site Evaluations for Nuclear Installations. Flinders Ranges Council Development Plan; consolidated 25 October 2012.	Absence of sensitive land uses (e.g. residences) or land uses that could directly or indirectly impact the NRWMF (e.g. mining tenements, hazardous facilities, airfields) in proximity to the site.	The site is well separated from adversely affecting development and sensitive land uses. The existence of a number of mineral and geothermal tenements over and within close proximity to the Wallerberdina site, if developed, may have the potential to directly or indirectly impact the NRWMF or its enabling infrastructure.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Hydrology and Flood Risks	Assess potential localised flooding (water logging or extreme rainfall) or episodic major flooding or avulsion potential from upstream catchments now, and as a result of climate change, that could impact operations and site access without mitigation measures.	IAEA SSG-18 Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff (ARR): A Guide to Flood Estimation, Commonwealth of Australia.	Minimal catchment areas and watercourses draining into the site, an absence of 'hydrophobic' soils, high soil conductivity rates and lower intensity rainfall events.	Drainage lines are present through the site. Hookina Creek passes through and outside the southern edge of Walleberdina Station, from around 3.5 km from the site. A tributary of Hookina Creek is 1.5 km east of the site. Anecdotal evidence is that during the major episodic floods in 1955 and 2005 the floodwaters of Hookina Creek did not reach the site. To quantify the flood risks, a hydrological model was prepared and 2D hydraulic modelling undertaken. The modelling indicates that the site is subject to shallow flooding in smaller localised flood events, and deeper flows breaking out from Hookina Creek during more extreme flood events (> 1 in 100 annual exceedance probability, AEP). For the 1 in 2000 AEP flood, depths are typically in the range 0.25 to 0.5 m with isolated areas up to 1 m. This poses constraints on the site that will require the investigation and design of appropriate mitigation measures (e.g. consideration of installation of bunds and levees) should Wallerberdina be further considered for the NRWMF.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Geology, hydrogeology, geochemistry, geotechnical and soils	Characterise the site sub-surface environment to determine geological, hydrogeological and geochemical characteristics.	AS1726 – 2017 Australian Standard Geotechnical Site Investigations. AS1289 series Australian Standard Method of testing soils for engineering purposes. AS/NZS 5667.1 Water quality – Sampling Guidance on the design of sampling programs, sampling techniques and preservation and handling of samples. NUDLC, 2012 *Minimum Construction Requirements for Water Bores in Australia V3* developed by the National Uniform Drillers Licensing Committee, Third Edition, February 2012.	Deep watertable, low potential for vertical or horizontal migration of water through underlying soil, poor quality groundwater, presence of subsurface material with chemical attenuation properties, limited or no groundwater users, absence of geotechnical hazards (potential for slope instability, soil liquefaction, collapsing or expansive soils, subsidence due to ground features, long-term settlement, soil scour and erodibility).	The geological, hydrogeological, soil and geotechnical conditions at the site do not present hazards or constraints that would not be manageable through appropriate design and operational protocols. Groundwater in the watertable aquifer was found to be present at depths in excess of 20 metres. There are a series of aquifers within the top 100m subsurface profile with yield and quality potential for a local site groundwater supply. Given the lack of reticulated water supply, groundwater may have the potential to be used for a range of beneficial uses for the NRWMF (some requiring additional pre-treatment). The presence of clay, low salinity and moderately alkaline pH are favourable soil properties for attenuation in the unlikely event of a subsurface release of waste material. This is due to the inherent characteristics of the subsurface environment to exchange charged particles (ions) during the interaction of potential fluids migrating through the unsaturated zone above the watertable and the natural soil within that zone of migration. There are however, some soil horizons where the ion exchange potential is lower than others due to naturally occurring levels of exchangeable sodium. Geotechnical hazards are unlikely to be present at the site based on current data but further investigations would be required for site specific aspects such as design of footings and structures.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Landform stability	Identify geomorphological processes (including fluvial, aeolian, slope/ mass movement) with potential to impact on long term site stability.	No recognised applicable standards or guidelines.	Stable landform, minimal potential for slope or mass movement processes.	The site is situated on the Hookina Creek alluvial fan and likely to be subject to episodic fluvial geomorphological processes during rare large flood events. During extended dry periods, the site may be affected by the deposition of aeolian sediment from adjacent dune fields or further afield as well as wind erosion. Such processes have the potential to impact on the long term stability of the site if mitigation and monitoring measures are not employed. Further hydraulic modelling is required to consider risks posed by avulsion, floodplain scour and sedimentation.
Seismic activity	Characterise potential seismic hazards with emphasis on active faults beneath or near the site, near surface faults and the presence of ridge crests in the site vicinity.	IAEA SSG-9 Seismic Hazards in Site Evaluation for Nuclear Installations, relevant peer-reviewed technical information listed in the methodology and scope and other IAEA documents listed in the reference section.	Absence of potentially active faults that could cause surface faulting through the NRWMF, near-surface faults that could cause folding or other deformation within the NRWMF, nearby faults that could cause hanging wall or rupture directivity effects which amplify ground motions and ridge crests which amplify ground motions.	Seismic data obtained from field surveys across the site indicates, with a high level of confidence (excluding the possibility of one-off faulting), the absence of potentially active faults in the foundation, but the potential for near-surface faults beneath or near the foundation. The Western Range front faults are assumed to exist in the nearby area; a seismic survey line across the site is suggested to identify the location of these faults should this site be further considered for the NRWMF. Seismic hazards from ground shaking and deformation should be able to be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods based on currently available data.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Transport considerations	Assess proximity of the site to waste sources and characterise the national, regional and local transport networks (including multi-modal) to enable safe site access and egress.	ARPANSA, 2014. The Code for the Safe Transport of Radioactive Material. ARPANSA (2008) Code of Practice for the Safe Transport of Radioactive Materials. Austroads Guide to Road Design National Heavy Vehicle Regulator, 2017. Performance-Based Standards Scheme – Network Classification Guidelines and Performance-Based Standards Scheme – Vehicle Certification Rules.	Major highway access from waste sources around Australia, good local access road network with minimal upgrade requirements and potential for multi-modal transport options.	The central location in SA makes the sites suitable for receipt of wastes from a variety of sources and is well served by major road networks. Local roads will need to be upgraded and sealed to accommodate frequent B-Double movements and infrequent ODOM vehicles. Multiple culvert crossings may need to be installed to accommodate the number of watercourses that cross the access routes.
Capacity to deal with facility wastes and emissions	Assess availability and proximity of facilities to treat, recycle or dispose of all generated waste streams and consider the potential for on-site treatment, recycling and disposal.	Applicable waste classification, treatment and disposal criteria and guidelines.	Proximity to suitable waste management facilities and site attributes that can accommodate potential onsite waste management options.	Given the site's location (130 km from Port Augusta), there are a limited number of waste and recycling depots capable of receiving and/or accepting waste generated from the Project. However, certain waste types (e.g. hazardous and/or Listed Waste) may need to be treated and disposed of on-site or pre-treated and then sent off-site for management, due to the lack of suitable nearby waste disposal facilities. Further definition of waste streams and volumes as the facility design progresses is required to refine the assessment.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Utilities, energy and infrastructure	Assess the proximity to, and capacity of, key services and utilities at and near the site (power, water, wastewater, gas telecommunications, and storm water).	Relevant Australian Standards to apply at detailed design phase.	Close proximity to all required services and utilities with minimal upgrade and connection requirements.	There is an absence of most services and utilities in the vicinity of the site (water, wastewater, gas, telecommunications and storm water) apart from power. Distance and terrain between the site and Hawker means that installation of a network of groundwater extraction bores and desalination plant on site should be further assessed as an alternative supply option to a potable water supply main from Hawker and/or potential upgrades to, and expansion of, the existing Hawker groundwater extraction and water treatment plant. Design solutions and construction of enabling utility infrastructure will mitigate issues of proximity and capacity of existing utilities in the local area.

Site Characteristic	Objective of Assessment	Key Legislation, Standards and Guidelines	Preferred Site Characteristics	Assessment Findings
Renewable or non-renewable natural resources and the site potential to use renewable resources	Assess availability of renewable resources in the site area to provide power to the site and offset grid supplied energy.	Relevant Australian Standards to apply at detailed design phase.	Location which has high potential to generate renewable energy, particularly solar and wind resources, which can be harnessed by technology in a manner which will increase the (network) reliability of power supply to the site.	The Wallerberdina site is located in an area of high solar exposure and is in a low wind resource area. The site is relatively close to the transmission network (either via a new substation directly to the 132kV transmission line or to the existing transmission line substation). While the Wallerberdina site has electrical proximity to a transmission line, the line is still at the edge of the NEM network with ageing assets. The inclusion of renewable energy for generation on site, as well as supporting energy storage technologies such as batteries (short term) and diesel (long term), should be further considered and could provide both commercial and power reliability benefits to the project. Consideration of the grid constraints, reliability, and potential connection points are key considerations for determining the amount of solar PV (the most suitable technology for the site) and storage required.

6.0

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6.0 References

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6.1.1 Flora, Fauna and Conservation

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Publicly available datasets accessed from on-line databases

Data SA South Australian Government Data Directory map viewers; specifically:

- Location SA Map Viewer http://location.sa.gov.au/viewer/

  A public-facing application to enable citizens to visualise much of the state government data in the Location SA repository. Where this data is available for download the user is provided with a link to data.sa.gov.au.

- WaterConnect https://www.waterconnect.sa.gov.au/Pages/Home.aspx

  WaterConnect has the latest information about South Australia's water resources, providing direct access to water-related publications and data. Available lithological, depth to groundwater and hydrogeochemistry information in the vicinity of the site was interrogated using the map function. The site also provides links to technical reports for the groundwater management areas and these reports were reviewed to provide broader geological and hydrogeological context.

- South Australian Resources Information Geoserver (SARIG) https://map.sarig.sa.gov.au/

  SARIG is a secure online map based web application that delivers state wide geological and geospatial data. Available exploration drill hole data and historical mining tenements were identified using the map function. The site provides links to mining reports that contain further data that may provide context for sub-surface mineralogy and lithology in the vicinity of the subject site.

- Australian Soil Research Information System (ASRIS) http://www.asris.csiro.au/

  ASRIS provides online access to the best publicly available information on soil and land resources in a consistent format across Australia. Available soil data in the vicinity of the site was interrogated using the map function. Specific reference soil profiles and soil characterisation site information accessed from ASRIS is provided via links below.

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Appendix A

Flora, Fauna and Conservation

Appendix A Flora, Fauna and Conservation

Wallerberdina Station PMST Search

Australian Government
Department of the Environment and Energy

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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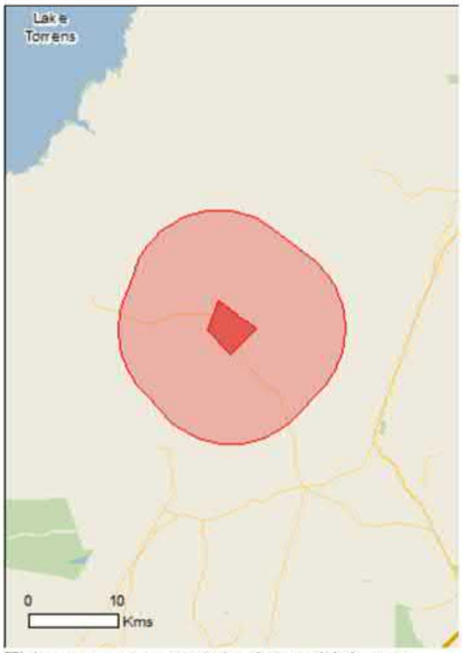

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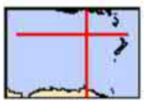


Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	8
Listed Migratory Species:	8

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	13
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	17
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Pedionomus torquatus Plains-wanderer [906]	Critically Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Extinct within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Mammals		
Petrogale xanthopus xanthopus Yellow-footed Rock-wallaby (SA and NSW) [66646]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Caladenia tensa Greencomb Spider-orchid, Rigid Spider-orchid [24390]	Endangered	Species or species habitat may occur within area
Codonocarpus pyramidalis Slender Bell-fruit, Camel Poison [19507]	Vulnerable	Species or species habitat may occur within area
Frankenia plicata [4225]	Endangered	Species or species habitat likely to occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Yappala	SA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Carrichtera annua Ward's Weed [9511]		Species or species habitat likely to occur within area
Lycium ferocissimum African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Prosopis spp. Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-31.647153 138.175917,-31.646422 138.17626,-31.646422 138.17626,-31.670531 138.213339,-31.693174 138.188277,-31.671846 138.165274,-31.647153 138.175917

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

Wallerberdina Flora Data

Wallerberdina Flora Data

Native Plant Life form	
All strata of vegetation heavily impacted and native vegetation represented by only scattered plants	
All strata of vegetation impacted with limited structural diversity, largely uniform age classes and reduced vegetation cover	X
At least one strata of vegetation has been impacted, with reduced structural diversity, elements may be missing (such as plant species that provide specific structural features e.g. sedges or mid layer shrubs) and reduce vegetation cover	
Limited impacts on native vegetation, with a diversity of structural features and a varied age class, with only a minor loss in structurally diversity, vegetation cover or structural elements	
All strata of vegetation present, litlte or no sign of distrubance. A varity of life forms and assocaited age classes present. Vegetation cover near complete	

Regeneration	
No regeneration present	X
Very low regeneration, conisting of highly scattered juvinille plants but a limited number of species	
Regeneration present, consisting of multiple individual juvinelle plants but a limited number of species	
Multiple species regenerating, but low numbers of juvenile plants	
Multiple species regenerating with multiple individual juviniles present with varying age classes	

"Treeless in its natural state (refer to manual)? Y/N				Y
Fallen Timber/debris (log size = that of canopy species (+ emergent species if present)				4.5
Log diameter	None	Limited and sparse	Numerous	Score
Trunk Size	0	2	3	0.5
Branch size	0	0.5	1	0.5
Litter	Little or none	Sparse and/or patchy littler layer	Dense and more or less continuous litter layer	Score
Litter	0	0.5	1	0.5

Native: Exotic Understorey Biomass	3
Included dead material if attached & recognisable as native	
% native	
76%+	3
40-75%	2
May-40	1
<5	0

Hollow-bearing Trees (sm hollows = <5cm, large hollows =>5cm)	NA
None	0
Sm hollows only	1
Large +/- sm hollows in very small proportion of	2
Large +/- sm hollows scattered but not common	3
Large +/- sm hollows common in trees	4
Large +/- sm hollows in a large majority of trees	5

Tree Health (excl. long-dead trees)	NA
<10% dieback	5
10-25% dieback, few braches dead	4
26-50% dieback,many braches dead	3
51-75% dieback, most branches dead +/- epicormic growth	2
76-99% dieback, most epicormic growth dead	1
100% dieback	0

Bare Ground	2
excludes soil crust, litter, exposed rock	
>51% of site bare ground	0
31-50% bare ground	1
21-30% bare ground	2
11-20% bare ground	3
5-10% bare ground	4
<5% bare ground	5

Bushland assessment for small sites (<0.5 ha) or narrow linear sites (<5m wide)

Weed Scores	
Does the site contain plant species declared under the NRM Act 2004	0
Cover rating for all delcared weeds	0
Does the site contain environmental weeds (introduced plants with the capacity to invade and exclude native species from bushland. This typically includes species with a BCM weed threat rating of 3, 4 or 5).	0
Cover rating for all environmental weeds	0

Cover Rating	
Not many, cover <1%	1
Plentiful, cover <1%	1a
Covering 1 - 5%	2
Covering 6 - 25%	3
Covering 26 - 50%	4
Covering 51 - 75%	5
Covering >75%	6

Vegetation Association Description:

Recorder/s: Floora de Wit

Wallerberdina Flora Data

Native Plant Life form	
All strata of vegetation heavily impacted and native vegetation represented by only scattered plants	
All strata of vegetation impacted with limited structural diversity, largely uniform age classes and reduced vegetation cover	
At least one strata of vegetation has been impacted, with reduced structural diversity, elements may be missing (such as plant species that provide specific structural features e.g. sedges or mid layer shrubs) and reduce vegetation cover	X
Limited impacts on native vegetation, with a diversity of structural features and a varied age class, with only a minor loss in structurally diversity, vegetation cover or structural elements	
All strata of vegetation present, litite or no sign of distrubance. A varity of life forms and assocaited age classes present. Vegetation cover near complete	

Regeneration	
No regeneration present	X
Very low regeneration, consisting of highly scattered juvinille plants but a limited number of species	
Regeneration present, consisting of multiple individual juvinelle plants but a limited number of species	
Multiple species regenerating, but low numbers of juvenile plants	
Multiple species regenerating with multiple individual juviniles present with varying age classes	

Bushland assessment for small sites (<0.5 ha) or narrow linear sites (<5m wide)

"Treeless in its natural state (refer to manual)? Y/N				Y
Fallen Timber/debris (log size = that of canopy species (+ emergent species if present)				5.5
Log diameter	None	Limited and sparse	Numerous	Score
Trunk Size	0	2	3	2
Branch size	0	0.5	1	0.5
Litter	Little or none	Sparse and/or patchy littler layer	Dense and more or less continuous litter layer	Score
Litter	0	0.5	1	3

Hollow-bearing Trees (sm hollows = <5cm, large hollows =>5cm)	NA
None	0
Sm hollows only	1
Large +/- sm hollows in very small proportion of trees	2
Large +/- sm hollows scattered but not common	3
Large +/- sm hollows common in trees	4
Large +/- sm hollows in a large majority of trees	5

Tree Health (excl. long-dead trees)	NA
<10% dieback	5
10-25% dieback, few braches dead	4
26-50% dieback,many braches dead	3
51-75% dieback, most branches dead +/- epicormic growth	2
76-99% dieback, most epicormic growth dead	1
100% dieback	0

Native: Exotic Understorey Biomass	3
Included dead material if attached & recognisable as native	
% native	
76%+	3
40-75%	2
May-40	1
<5	0

Bare Ground	2
excludes soil crust, litter, exposed rock	
>51% of site bare ground	0
31-50% bare ground	1
21-30% bare ground	2
11-20% bare ground	3
5-10% bare ground	4
<5% bare ground	5

Weed Scores	
Does the site contain plant species declared under the NRM Act 2004	0
Cover rating for all delcared weeds	0
Does the site contain environmental weeds (introduced plants with the capacity to invade and exclude native species from bushland. This typically includes species with a BCM weed threat rating of 3, 4 or 5).	0
Cover rating for all environmental weeds	0

Cover Rating	
Not many, cover <1%	1
Plentiful, cover <1%	1a
Covering 1 - 5%	2
Covering 6 - 25%	3
Covering 26 - 50%	4
Covering 51 - 75%	5
Covering >75%	6

Vegetation Association Description:

Recorder/s: Floora de Wit

Bushland Assessment	Site	Wal 2		Date:	19-Apr-18		Zone	
	Datum	GDA	E:	234157	N:	6493119	Ph dir'n:	

d=dominant, v=voucher, p=planted, R=regen (perennials).

Native spp.	Ht (cm)		Cover (%)	Weed spp.	Ht (cm)	Cover (%)
Hakea leucoptera subsp. leucoptera	160	0	0.1			
Dissocarpus paradoxus	30	1	1.5			
Enneapogon avenaceus	15	1	1			
Euphorbia tannensis subsp. eremophila		1				
Maireana astrotricha	40	#	15			
Maireana aphylla						
Maireana astrotricha	20	1	1			
Sclerolaena obliquicuspis	30	2	2			

Wallerberdina Flora Data

Native Plant Life form	
All strata of vegetation heavily impacted and native vegetation represented by only scattered plants	
All strata of vegetation impacted with limited structural diversity, largely uniform age classes and reduced vegetation cover	
At least one strata of vegetation has been impacted, with reduced structural diversity, elements may be missing (such as plant species that provide specific structural features e.g. sedges or mid layer shrubs) and reduce vegetation cover	X
Limited impacts on native vegetation, with a diversity of structural features and a varied age class, with only a minor loss in structurally diversity, vegetation cover or structural elements	
All strata of vegetation present, litite or no sign of distrubance. A varity of life forms and assocaited age classes present. Vegetation cover near complete	

Regeneration	
No regeneration present	X
Very low regeneration, conisting of highly scattered juvinille plants but a limited number of species	
Regeneration present, consisting of multiple individual juvinelle plants but a limited number of species	
Multiple species regenerating, but low numbers of juvenile plants	
Multiple species regenerating with multiple individual juviniles present with varying age classes	

"Treeless in its natural state (refer to manual)? Y/N				Y
Fallen Timber/debris (log size = that of canopy species (+ emergent species if present)				3
Log diameter	None	Limited and sparse	Numerous	Score
Trunk Size	0	2	3	0
Branch size	0	0.5	1	0
Litter	Little or none	Sparse and/or patchy littler layer	Dense and more or less continuous litter layer	Score
Litter	0	0.5	1	3

Native: Exotic Understorey Biomass	3
Included dead material if attached & recognisable as native	
% native	
76%+	3
40-75%	2
May-40	1
<5	0

Hollow-bearing Trees (sm hollows = <5cm, large hollows =>5cm)	0
None	0
Sm hollows only	1
Large +/- sm hollows in very small proportion of trees	2
Large +/- sm hollows scattered but not common	3
Large +/- sm hollows common in trees	4
Large +/- sm hollows in a large majority of trees	5

Tree Health (excl. long-dead trees)	5
<10% dieback	5
10-25% dieback, few braches dead	4
26-50% dieback,many braches dead	3
51-75% dieback, most branches dead +/- epicormic growth	2
76-99% dieback, most epicormic growth dead	1
100% dieback	0

Bare Ground	0
excludes soil crust, litter, exposed rock	
>51% of site bare ground	0
31-50% bare ground	1
21-30% bare ground	2
11-20% bare ground	3
5-10% bare ground	4
<5% bare ground	5

Bushland assessment for small sites (<0.5 ha) or narrow linear sites (<5m wide)

Weed Scores	
Does the site contain plant species declared under the NRM Act 2004	0
Cover rating for all delcared weeds	0
Does the site contain environmental weeds (introduced plants with the capacity to invade and exclude native species from bushland. This typically includes species with a BCM weed threat rating of 3, 4 or 5).	0
Cover rating for all environmental weeds	0

Cover Rating	
Not many, cover <1%	1
Plentiful, cover <1%	1a
Covering 1 - 5%	2
Covering 6 - 25%	3
Covering 26 - 50%	4
Covering 51 - 75%	5
Covering >75%	6

Vegetation Association Description:

Recorder/s: Floora de Wit

Bushland Assessment	Site	Wal 3		Date:		19-Apr-18	Zone	
	Datum	GDA	E:	233470	N:	6492723	Ph dir'n:	

d=dominant, v=voucher, p=planted, R=regen (perennials).

Native spp.	Ht (cm)	Cover (%)				**Weed spp.**	Ht (cm)	Cover (%)
Acacia oswaldii	400	1						
Atriplex stipitata	30	1						
Enchylaena tomentosa var. tomentosa	40	4						
Maireana brevifolia	40	1						
Nitraria billardierei	120	5						

Wallerberdina Flora Data

Native Plant Life form	
All strata of vegetation heavily impacted and native vegetation represented by only scattered plants	
All strata of vegetation impacted with limited structural diversity, largely uniform age classes and reduced vegetation cover	X
At least one strata of vegetation has been impacted, with reduced structural diversity, elements may be missing (such as plant species that provide specific structural features e.g. sedges or mid layer shrubs) and reduce vegetation cover	
Limited impacts on native vegetation, with a diversity of structural features and a varied age class, with only a minor loss in structurally diversity, vegetation cover or structural elements	
All strata of vegetation present, litite or no sign of distrubance. A varity of life forms and assocaited age classes present. Vegetation cover near complete	

Regeneration	
No regeneration present	X
Very low regeneration, consisting of highly scattered juvinille plants but a limited number of species	
Regeneration present, consisting of multiple individual juvinelle plants but a limited number of species	
Multiple species regenerating, but low numbers of juvenile plants	
Multiple species regenerating with multiple individual juviniles present with varying age classes	

Bushland assessment for small sites (<0.5 ha) or narrow linear sites (<5m wide)

"Treeless in its natural state (refer to manual)? Y/N				Y
Fallen Timber/debris (log size = that of canopy species (+ emergent species if present)				3
Log diameter	None	Limited and sparse	Numerous	Score
Trunk Size	0	2	3	2
Branch size	0	0.5	1	0.5
Litter	Little or none	Sparse and/or patchy littler layer	Dense and more or less continuous litter layer	Score
Litter	0	0.5	1	0.5

Hollow-bearing Trees (sm hollows = <5cm, large hollows =>5cm)	NA
None	0
Sm hollows only	1
Large +/- sm hollows in very small proportion of trees	2
Large +/- sm hollows scattered but not common	3
Large +/- sm hollows common in trees	4
Large +/- sm hollows in a large majority of trees	5

Tree Health (excl. long-dead trees)	NA
<10% dieback	5
10-25% dieback, few braches dead	4
26-50% dieback,many braches dead	3
51-75% dieback, most branches dead +/- epicormic growth	2
76-99% dieback, most epicormic growth dead	1
100% dieback	0

Native: Exotic Understorey Biomass	3
Included dead material if attached & recognisable as native	
% native	
76%+	3
40-75%	2
May-40	1
<5	0

Bare Ground	0
excludes soil crust, litter, exposed rock	
>51% of site bare ground	0
31-50% bare ground	1
21-30% bare ground	2
11-20% bare ground	3
5-10% bare ground	4
<5% bare ground	5

Weed Scores	
Does the site contain plant species declared under the NRM Act 2004	0
Cover rating for all delcared weeds	0
Does the site contain environmental weeds (introduced plants with the capacity to invade and exclude native species from bushland. This typically includes species with a BCM weed threat rating of 3, 4 or 5).	0
Cover rating for all environmental weeds	0

Cover Rating	
Not many, cover <1%	1
Plentiful, cover <1%	1a
Covering 1 - 5%	2
Covering 6 - 25%	3
Covering 26 - 50%	4
Covering 51 - 75%	5
Covering >75%	6

Vegetation Association Description:

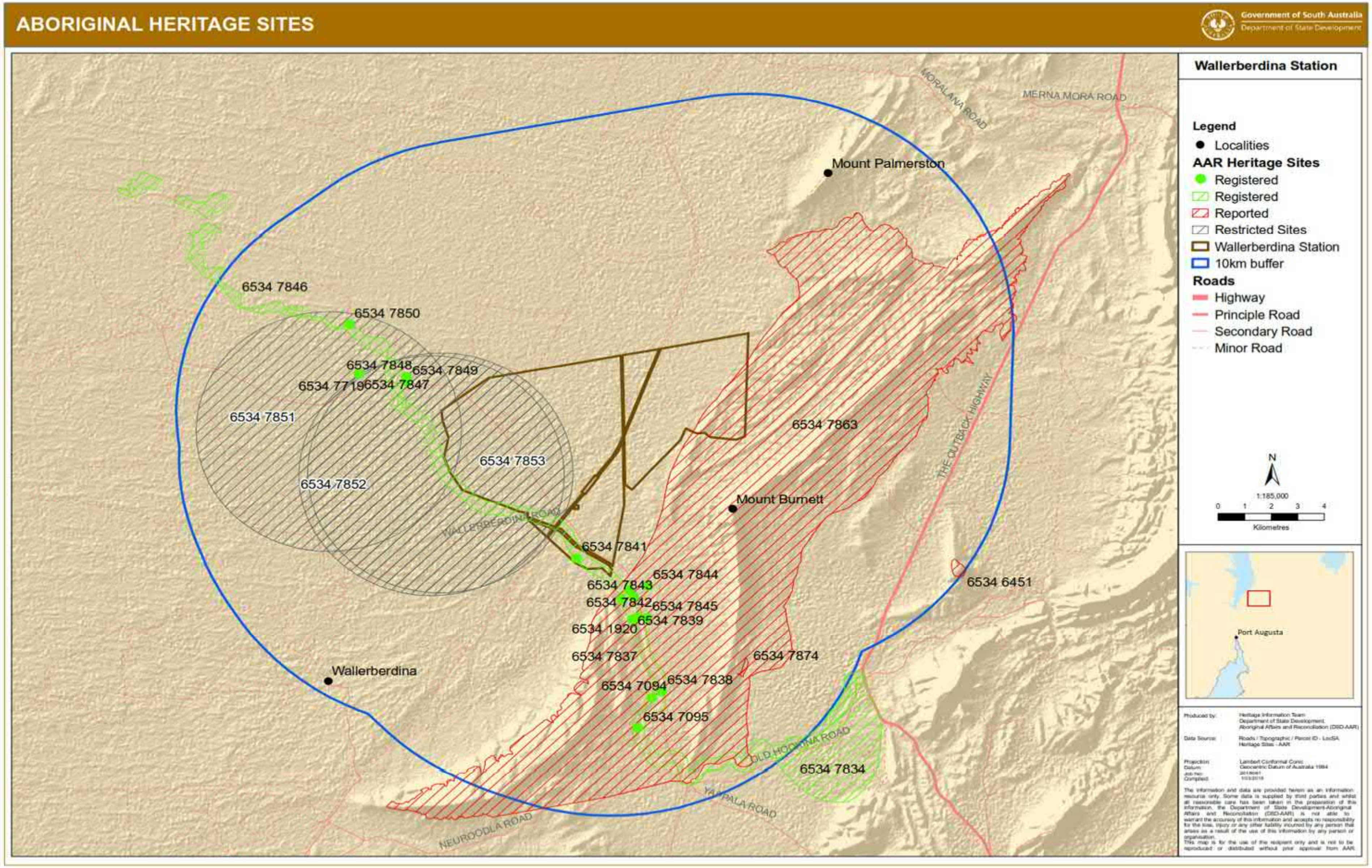
Recorder/s: Floora de Wit

Bushland Assessment	Site	Wal 4		Date:	19-Apr-18	Zone	
	Datum	GDA	E:	234151	N: 6492798	Ph dir'n:	

d=dominant, v=voucher, p=planted, R=regen (perennials).

Native spp.	Ht (cm)	Cover (%)				Weed spp.	Ht (cm)	Cover (%)
Acacia victoriae subsp. victoriae	250	2				Citrullus colocynthis		0.1
Dodonaea viscosa subsp. angustissima	400	4						
Enneapogon avenaceus	10	1						
Zygochloa paradoxa	40	0.5						
Maireana astrotricha	40	14						
Maireana astrotricha								
Rhagodia spinescens	40	0.5						

Wallerberdina Aboriginal Heritage Sites



Appendix B

Climatic Conditions and Climate Change

Appendix B Climatic Conditions and Climate Change

Climate Data: Hawker Weather Station & Rangelands NRM Cluster

Variable	Annual historic trend	Climate change projections	RCP 8.5 2030 scenario		RCP 4.5 2090 Scenario		RCP 8.5 2090 scenario	
Weather station: Hawker			Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence
Mean maximum daily temperature (°C) [1]	25.2	Absolute change	+1.1 (+0.7 to +1.4)	Very high model agreement on substantial increase	+2.2 (+1.2 to +2.8)	Very high model agreement on substantial increase	+4.3 (+2.8 to +5.2)	Very high model agreement on substantial increase
Mean minimum daily temperature (°C) [1]	10.7	Absolute change	+1 (+0.6 to +1.3)	Very high model agreement on substantial increase	+1.8 (+1.2 to +2.4)	Very high model agreement on substantial increase	+3.8 (+3 to +4.6)	Very high model agreement on substantial increase
Days above 35 °C (Adelaide)[2]	20 (1995 baseline)	Absolute change	26 (24 to 29 (RCP 4.5)	Very high confidence that projected warming will result in more frequent, and hotter, hot days	32 (29 to 38)	Very high confidence that projected warming will result in more frequent, and hotter, hot days	47 (38 to 57)	Very high confidence that projected warming will result in more frequent, and hotter, hot days
Highest recorded temperature (°C) [3]	46 (Jan 2003)	N/A	Heat related extremes are projected to increase at a similar rate as projected mean temperature with a substantial increase in the number of warm spell days					

Variable	Annual historic trend	Climate change projections	RCP 8.5 2030 scenario		RCP 4.5 2090 Scenario		RCP 8.5 2090 scenario	
Weather station: Hawker			Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence
Frost (days with min. temp. <2 °C) (Adelaide / Alice Springs)[4]	1.1 / 3.3 (1981-2010 baseline)	Absolute change	0.5 (0.8 to 0.4) / 24 (28 to 19) (RCP 4.5)	High confidence in a substantial decrease	0.2 (0.4 to 0.1) / 13 (20 to 8.4)	High confidence in a substantial decrease	0.0 (0.0 to 0.0) / 2.1 (6.0 to 0.8)	High confidence in a substantial decrease
Severe fire danger days per year (FFDI > 50) (Ceduna) [5]	11.1 (1995 baseline)	Absolute change	19.1 to 25.2	Low confidence in the projections of future fire weather for the rangelands, however if and when bushfire does occur in future climates it can be expected to exhibit more extreme behaviour.	21.0 to 25.2	Low confidence in the projections of future fire weather for the rangelands, however if and when bushfire does occur in future climates it can be expected to exhibit more extreme behaviour.	21.1 to 37.9	Low confidence in the projections of future fire weather for the rangelands, however if and when bushfire does occur in future climates it can be expected to exhibit more extreme behaviour.
Rainfall (mm) [1]	308.6	Percentage change	-2 (-10 to +8)	High model agreement on little change	- 5 (-19 to +7)	Medium model agreement on little change	-4 (-29 to +13)	Medium agreement on decrease
Rainfall intensity [6]	N/A	N/A	There is high confidence that the intensity of heavy rainfall extremes will increase in the cluster, but there is low confidence in the magnitude of this change.					

Variable	Annual historic trend	Climate change projections	RCP 8.5 2030 scenario		RCP 4.5 2090 Scenario		RCP 8.5 2090 scenario	
Weather station: Hawker			Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence	Most likely – 50th percentile (10th- 90th percentile)	Degree of confidence
Evapotranspiration (%) [1]	N/A	Percentage change	+2.7 (+1.1 to +4.8)	Very high model agreement on substantial increase	+4.7 (+2.6 to +7.1)	Very high model agreement on substantial increase	+10.5 (+6.4 to +14.5)	Very high model agreement on substantial increase
Mean 9 am relative humidity (%) [1]	56	Percentage change	-0.8 (-1.8 to +0.8)	Medium model agreement on little change	-1.6 (-3.7 to +0.3)	Medium model agreement on substantial decrease	-2.6 (-5.1 to +0.4)	High model agreement on substantial decrease
Mean 3 pm relative humidity (%) [1]	36	Percentage change						
Mean 9 am wind speed (km/h) [1]	8.5	Percentage change	-0.1 (-1.2 to +1)	Medium model agreement on little change	-0.4 (-2 to +0.8)	High model agreement on little change	+0.7 (-2.4 to +2)	Medium model agreement on increase
Mean 3 pm wind speed (km/h) [1]	11.5	Percentage change						
Solar radiation (%) [1]	N/A	Percentage change	0 (-1.2 to 1.1)	High model agreement on little change	-0.4 (-0.8 to 1.5	Medium model agreement on little change	-0.3 (-1.8 to +1.4)	Medium model agreement on little change
Soil moisture (%) [1]	N/A	Percentage change	-0.7 (-3.4 to +0.2)	Medium model agreement on little change	-1.5 (-3.5 to +0.5)	Medium model agreement on substantial decrease	-1.7 (-5.9 to -0.5)	Medium model agreement on substantial decrease

[1] Projection data obtained from Climate Change in Rangelands, CSIRO & BOM 2015. Figures obtained from Appendix, Table 1 Southern Sub Cluster.

[2] Projection data obtained from Climate Change in Australia Technical Report, Table 7.1.2 (projection for Adelaide), CSIRO & BOM 2015.

[3.] Qualitative projection analysis obtained from Climate Change in Australia Rangelands, Chapter 4, Section 4.2.1 Extremes (p20), CSIRO & BOM 2015

[4] Projection data obtained from Climate Change in Australia Technical Report, Table 7.1.3 (projections for Adelaide and Alice Springs), CSIRO & BOM 2015.

[5] Baseline and projection data obtained from Climate Change in Australia Rangelands Cluster Report, CSIRO & BOM 2015. Figures obtained from Appendix Table 2. Fire weather is estimated using the McArthur Forest Fire Danger Index (FFDI); where FFDI exceeds 50, fire weather is deemed 'severe'.

[6] Qualitative projection analysis obtained from Climate Change in Australia Rangelands, Chapter 4, Section 4.4.1 Heavy Rainfall Events (p26), CSIRO & BOM 2015

Appendix C

Hydrology and Flood Risks

Appendix C Hydrology and Flood Risks

Bridge and Culvert Dimensions

Approximate bridge and culvert dimensions were captured as part of the field work. The data was captured and sent via image to expedite the hydraulic modelling. The railway bridge over Hookina Creek is covered in its own site note (*Site Note 1.jpg*). The location of each remaining structure and the reference to the site note image is illustrated in Figure 88 below. Each of the site notes are presented in Figure 89 to Figure 93.

Figure 88 Structure location – GPS points and site note name

Figure 89 Railway bridge over Hookina Creek (Site Not 1.jpg)

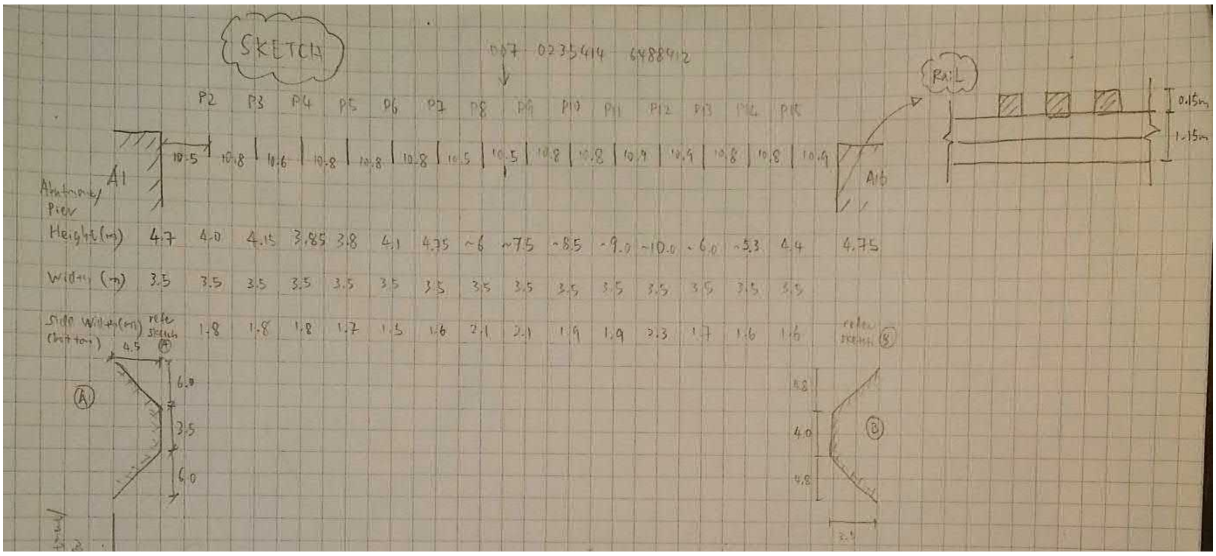


Figure 90 Structure at GPS point 013 (Site Note 2.jpg)

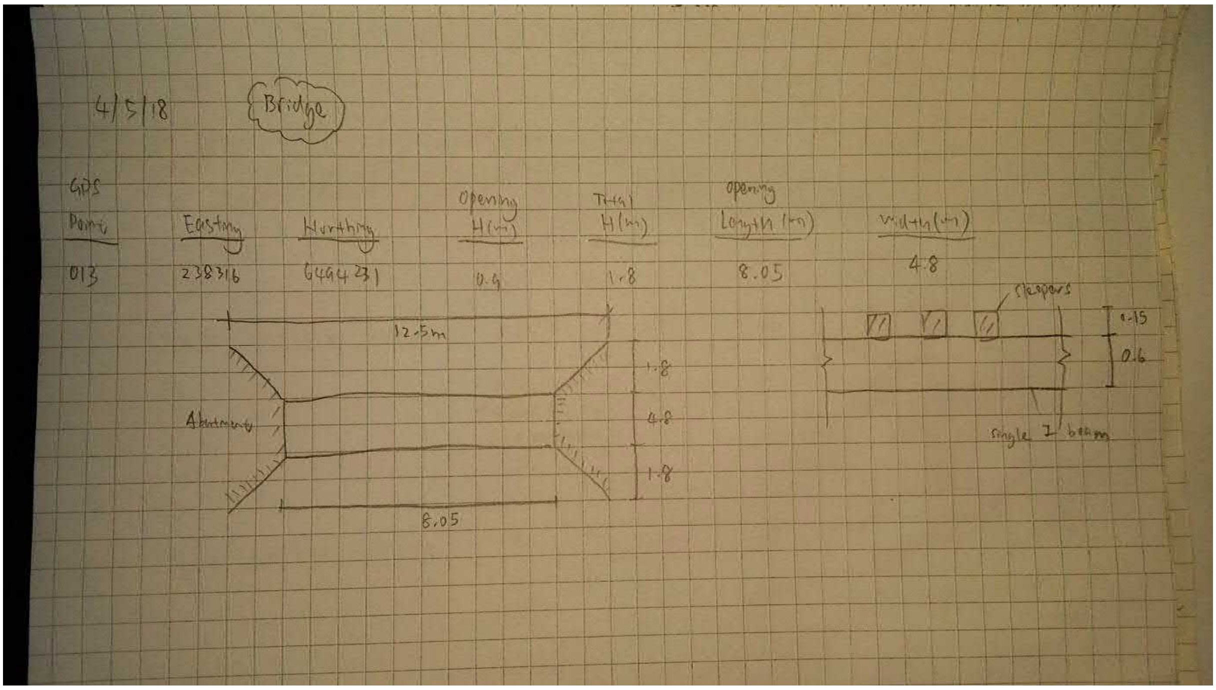
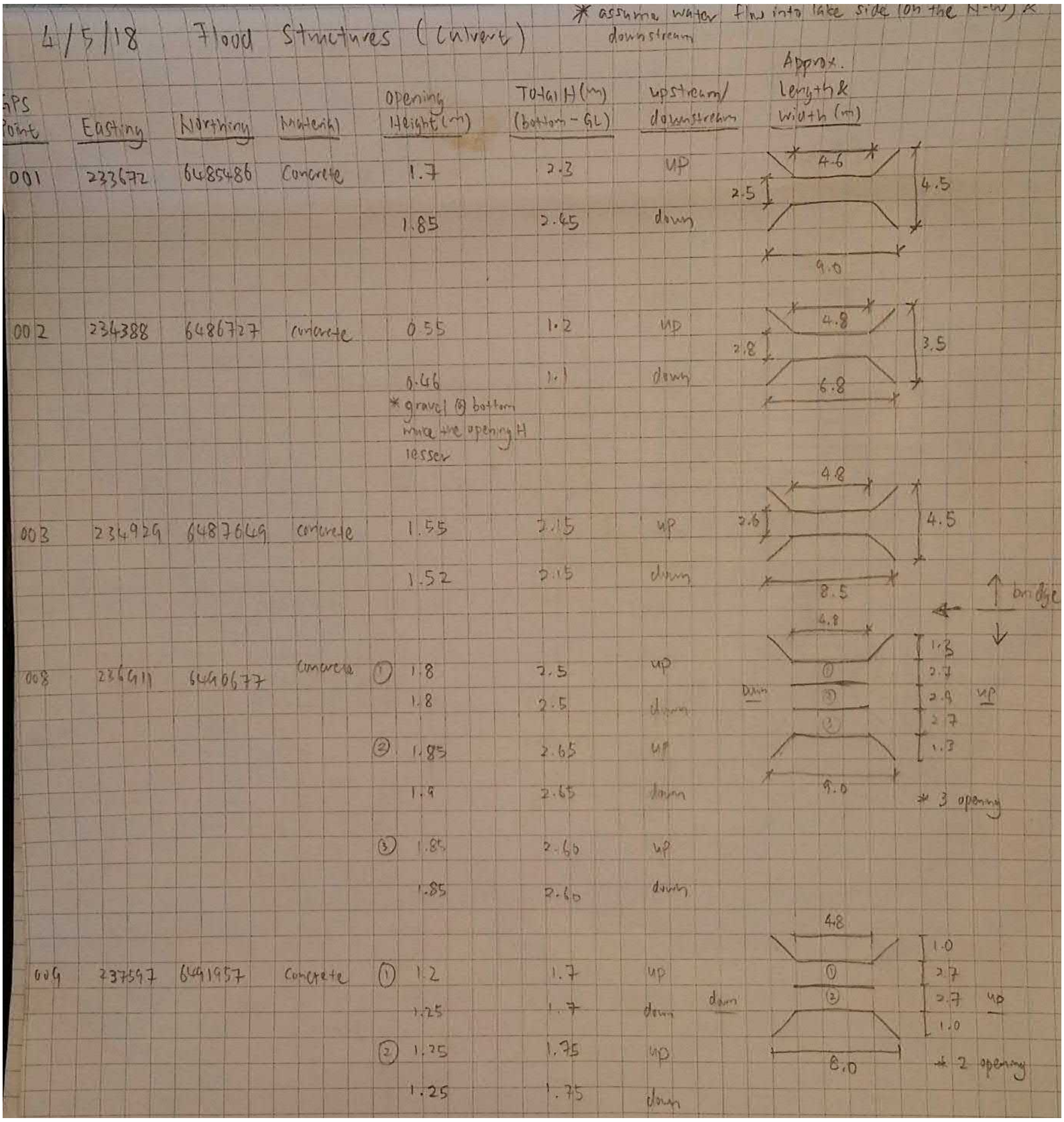


Figure 91 Structures at GPS points 001 to 009 (Site Not 3.jpg)

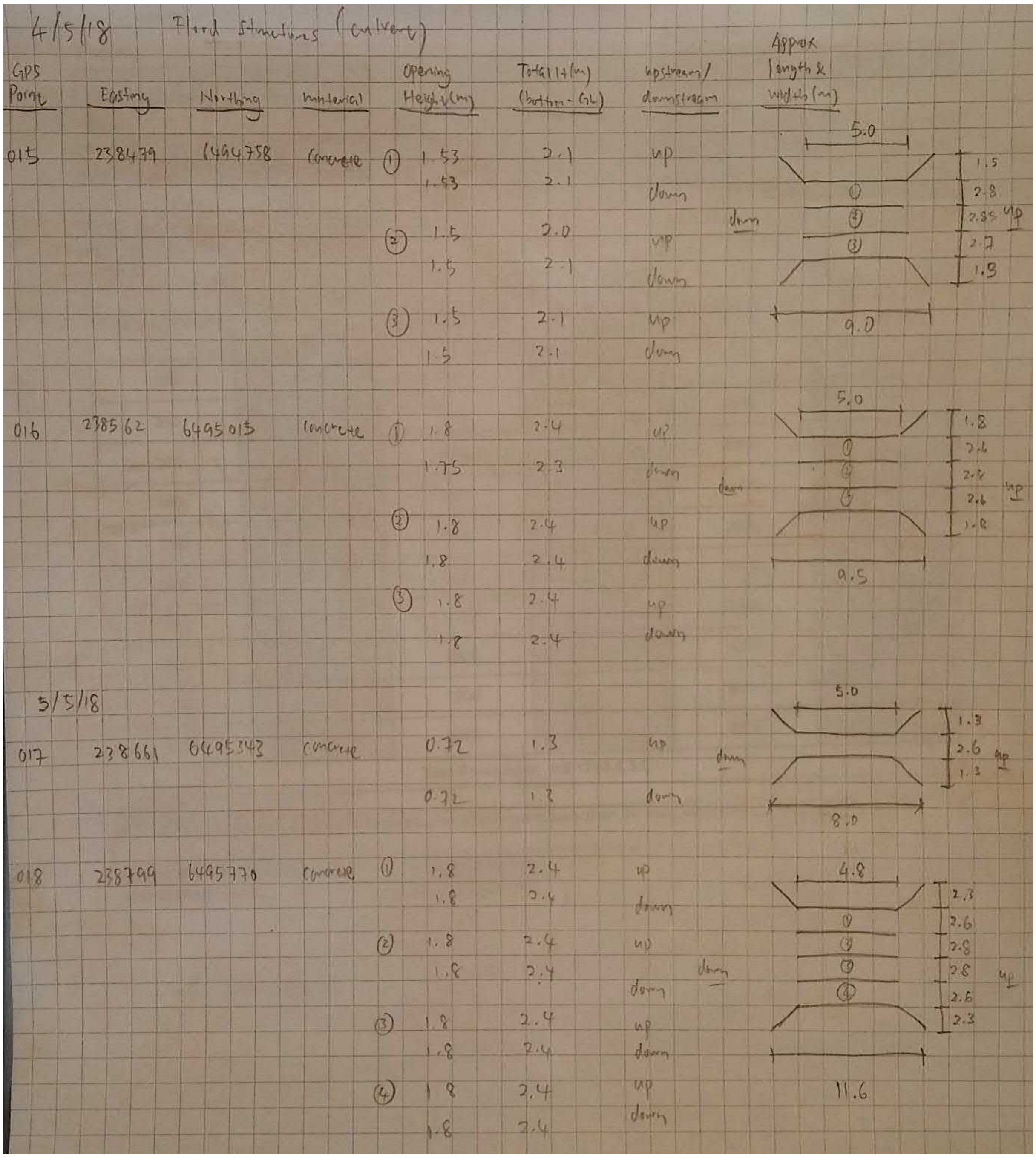


4/5/18 Flood Structures (Culvert)

* assume water flow into lake side (on the N-W) x downstream

GPS Point	Easting	Northing	Material	Opening Height (m)	Total H (m) (bottom – GL)	upstream/ downstream	Approx. Length & Width (m)
001	233672	6485486	Concrete	1.7	2.3	up	4.6, 2.5, 4.5, 9.0
				1.85	2.45	down	
002	234388	6486727	concrete	0.55	1.2	up	4.8, 2.8, 3.5, 6.8
				0.46 * gravel @ bottom make the opening H lesser	1.1	down	
003	234929	6487649	concrete	1.55	2.15	up	4.8, 2.6, 4.5, 8.5, bridge
				1.52	2.15	down	
008	236411	6490677	concrete	(1) 1.8	2.5	up	4.8, 9.0, 1.3, 2.7, 2.9, 2.7, 1.3, up, down, * 3 opening
				1.8	2.5	down	
				(2) 1.85	2.65	up	
				1.9	2.65	down	
				(3) 1.85	2.60	up	
				1.85	2.60	down	
009	237597	6491957	Concrete	(1) 1.2	1.7	up	4.8, 8.0, 1.0, 2.7, 2.7, 1.0, up, down, * 2 opening
				1.25	1.7	down	
				(2) 1.25	1.75	up	
				1.25	1.75	down	

Figure 92 Structures at GPS points 015 to 018 (Site Note 4.jpg)



4/5/18 Flood Structures (culvert)

GPS Point	Easting	Northing	material		Opening Height (m)	Total Ht (m) (bottom - GL)	upstream/ downstream	Approx length & width (m)
015	238479	6494758	Concrete	1	1.53	2.1	up	
					1.53	2.1	down	
				2	1.5	2.0	up	
					1.5	2.1	down	
				3	1.5	2.1	up	
					1.5	2.1	down	
016	238562	6495015	Concrete	1	1.8	2.4	up	
					1.75	2.3	down	
				2	1.8	2.4	up	
					1.8	2.4	down	
				3	1.8	2.4	up	
					1.8	2.4	down	

5/5/18

GPS Point	Easting	Northing	material		Opening Height (m)	Total Ht (m) (bottom - GL)	upstream/ downstream	Approx length & width (m)
017	238661	6495343	Concrete		0.72	1.3	up	
					0.72	1.3	down	
018	238799	6495770	Concrete	1	1.8	2.4	up	
					1.8	2.4	down	
				2	1.8	2.4	up	
					1.8	2.4	down	
				3	1.8	2.4	up	
					1.8	2.4	down	
				4	1.8	2.4	up	
					1.8	2.4	down	

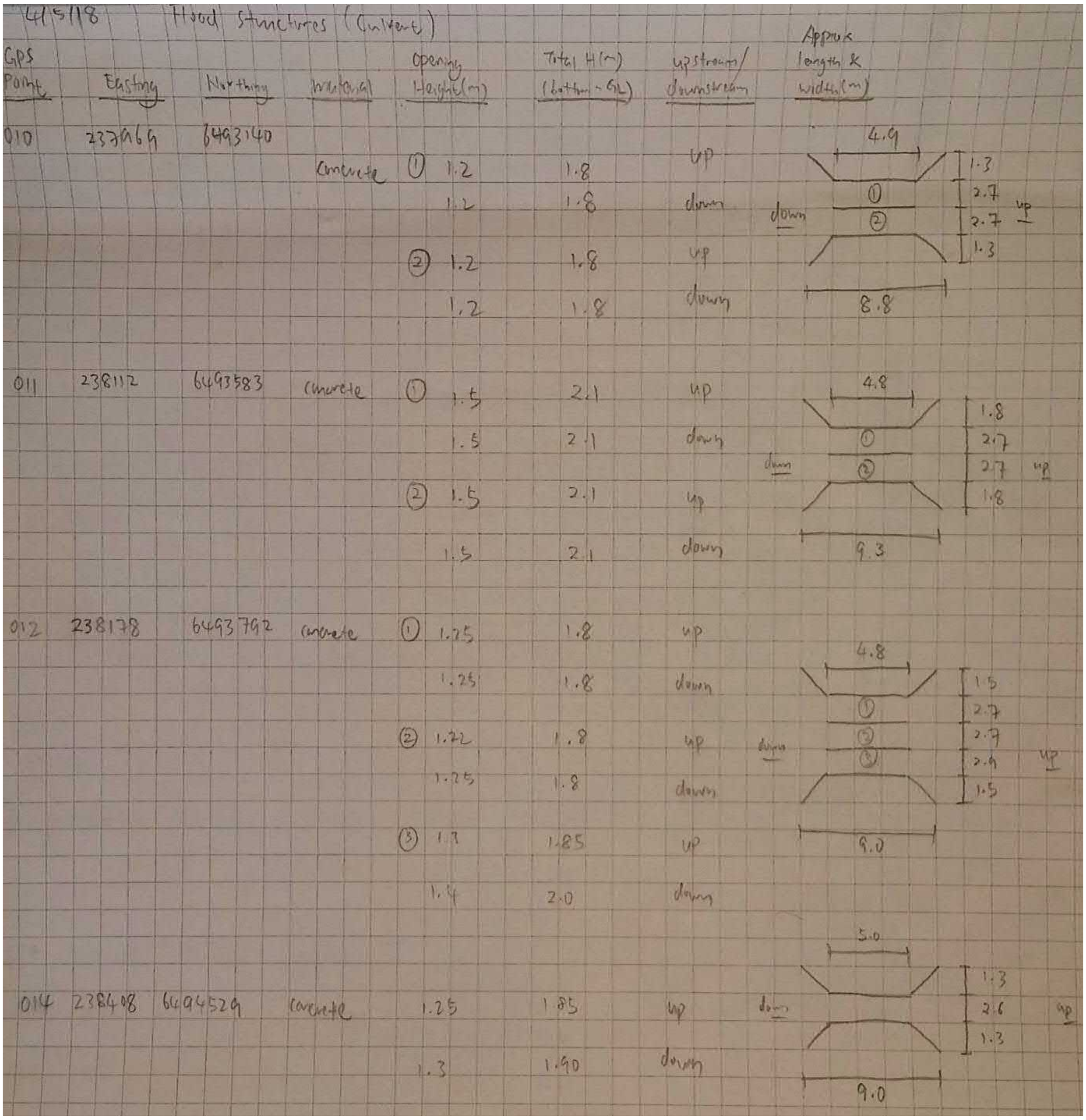
5.0
1.5
2.8
2.85
2.7
1.3
up
down
9.0

5.0
1.8
2.6
2.7
2.6
1.8
up
down
9.5

5.0
1.3
2.6
1.3
up
down
8.0

4.8
2.3
2.6
2.8
2.8
2.6
2.3
up
down
11.6

Figure 93 Structures at GPS points 010 to 014 (Site Note 5.jpg)


4/5/18 Flood Structures (Culvert)

GPS Point	Easting	Northing	Material	Opening Height(m)	Total H(m) (bottom - GL)	upstream/downstream
010	237969	6493140	Concrete	① 1.2	1.8	up
				1.2	1.8	down
				② 1.2	1.8	up
				1.2	1.8	down
011	238112	6493583	Concrete	① 1.5	2.1	up
				1.5	2.1	down
				② 1.5	2.1	up
				1.5	2.1	down
012	238178	6493792	Concrete	① 1.25	1.8	up
				1.25	1.8	down
				② 1.22	1.8	up
				1.25	1.8	down
				③ 1.3	1.85	up
				1.4	2.0	down
014	238408	6494529	Concrete	1.25	1.85	up
				1.3	1.90	down

hydrology and risk
CONSULTING

National Radiation Waste Management Facility
Site Characterisation - Hookina Creek

Hydrology Report

Final

07/06/2018

Contents

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Copyright and Limitation

1. Introduction

Hookina Creek is located in the Southern Flinders Ranges, South Australia. The creek flows into Lake Torrens and has a catchment area of approximately 2000 km^2 with the catchment extending eastward. The catchment is characterised by low ranges and hills with some higher ridges. It has a mixed cover of low open woodland, shrubland and mallee scrub. Flows are characteristic of the semi-arid nature of the catchment with long periods between flows.

The scope of the project is to provide hydrographs on Hookina Creek for placement into a hydraulic model (TUFLOW). Hydrographs are required for the 1 in 5, 10, 20, 50, 100, 1000, 2000 AEP and PMF events. Figure 1-1 shows the location of the study area along with the catchment area.

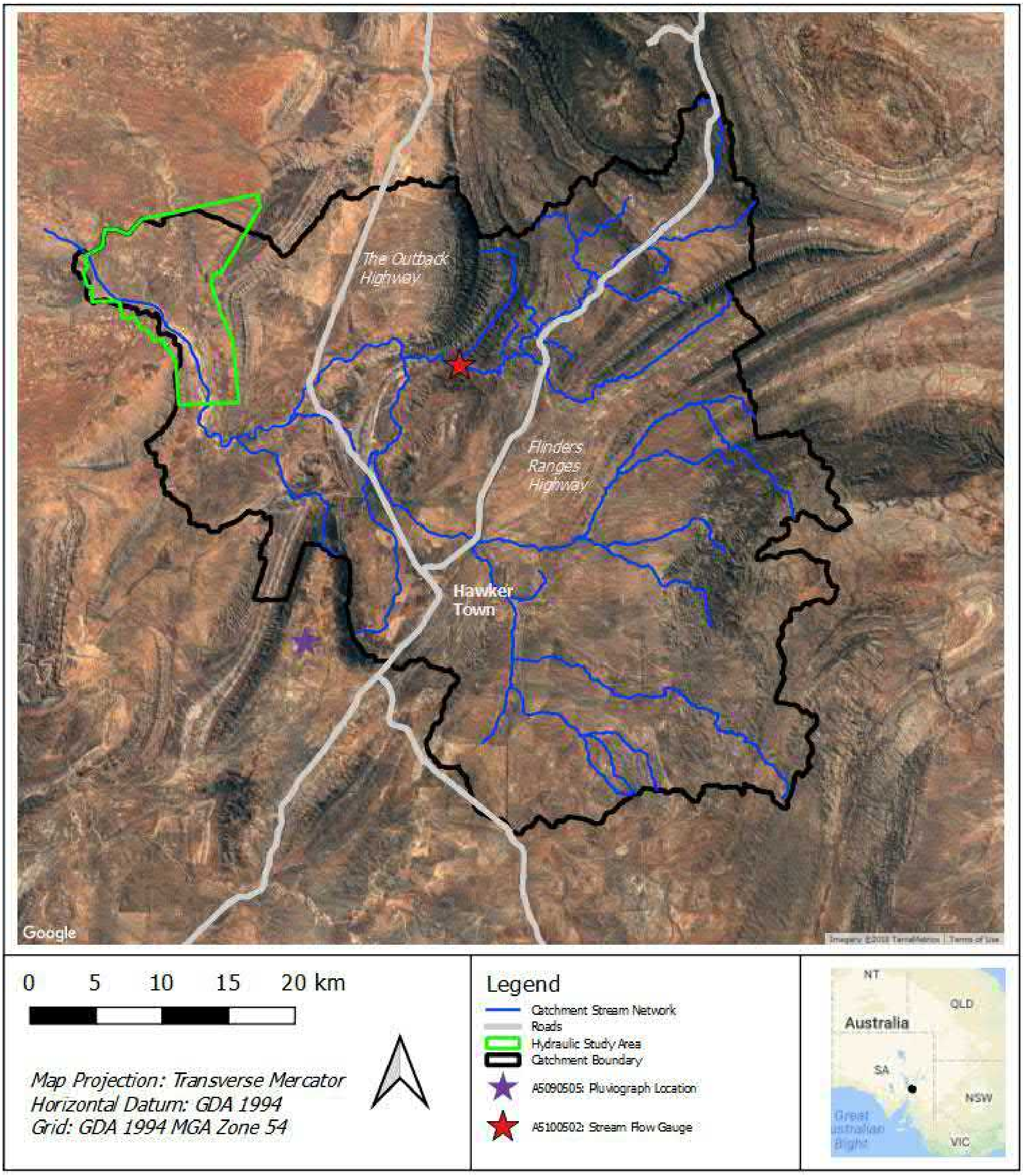


Figure 1-1 Study and Catchment Area

2. Methods

This section of the report describes the methods adopted for this project.

2.1 Review of the data

A review of the streamflow and rainfall data was undertaken to determine the events to be used for calibration of the rainfall runoff model and the streamflow gauges to include in the verification process. The results of the calibration and verification process are described in Section 4 and Section 6 respectively.

2.2 Rainfall runoff model development

A rainfall runoff model, RORB, was established for the catchment. RORB (Laurenson and Mein, 1995; Laurenson et al., 2010) is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non-linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal distribution of rainfall as well as losses, and can model flows at any number of points throughout a catchment (including upstream and downstream of reservoirs). RORB also has the capacity to use a Monte Carlo approach to produce design flood estimates that incorporate the joint probability of several factors that influence flood characteristics.

2.3 Rainfall runoff model calibration

RORB models are based on catchment geometry and topographic data, and the two principal parameters are k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. A value of 0.8 was adopted for the non-linearity parameter, m, for this study, which is recommended by Laurenson et al. (2010) and recommended in Book 8 of Australian Rainfall and Runoff (Nathan and Weinmann, 2016) for modelling very large and extreme flood events. The routing parameter, k_c, is typically selected by calibrating the RORB model to historic floods. The selection of k_c is discussed in Section 4.

The remaining RORB model parameters represent rainfall losses, using either an initial loss/continuing loss model, or an initial loss/proportional loss (i.e. runoff coefficient) model. An initial loss/continuing loss model was adopted for this study because it is more appropriate for modelling very large and extreme floods (Hill et al., 2014). The selection of losses is discussed in Section 6.

In general, the calibration approach was:

- Adjustment of the k_c to achieve a fit to the shape of the recorded hydrograph. The model was run interactively with various trial values of k_c, and the value giving best reproduction of the observed data was adopted.
- Initial loss directly affects the start of the hydrograph rise, but also affects the time distribution of rainfall excess and hence the hydrograph peak, especially for long storms with large variations of intensity. The continuing loss generally affects the hydrograph volume. The initial and continuing loss were adjusted in conjunction to attempt to match the start of the hydrograph rise and achieve a reasonable fit between the modelled and observed hydrograph volumes.

2.4 Design flood inputs

The estimation of design floods has traditionally been based on the 'design event' approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 2-1 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are 'AEP-neutral', that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

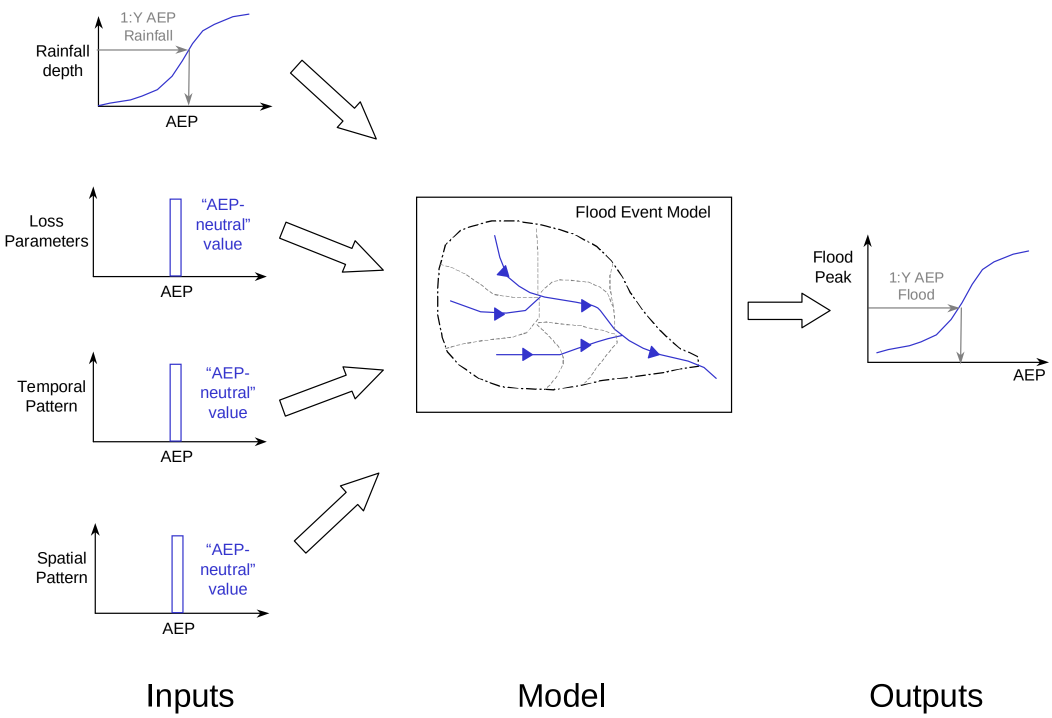
This approach suffers from the limitations that:

- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such as the seasonal variation of inputs) becomes rapidly more complex and less easy to defend.

Joint probability techniques offer an improvement to the traditional design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated catchment, or a large storm on a dry catchment. In probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to incorporate some of the complexities in the natural environment in that the influence of all probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The method is easily adapted to focus on only those aspects that are most relevant to the problem. For example as illustrated in Figure 2-2 it is possible to adopt single 'AEP-neutral' values for some inputs (in this case the manner in which rainfalls are spatially distributed over the catchment), and full distributions for other more important inputs, such as losses and temporal patterns.

The application of joint probability approaches to flood estimation is widely acknowledged to be a more thorough and defensible approach to design flood estimation than the design event approach in Australian practice, and has been incorporated in the 2016 version of Australian Rainfall and Runoff (ARR) (Ball et al., 2016).



n Figure 2-1 Schematic illustration of the design event approach

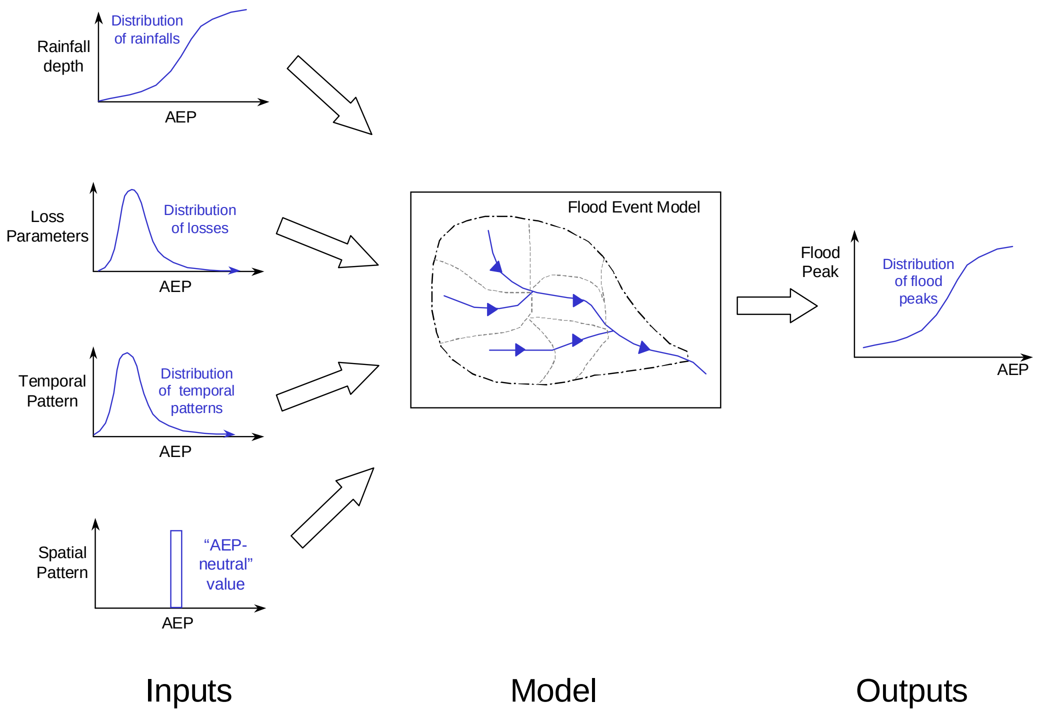
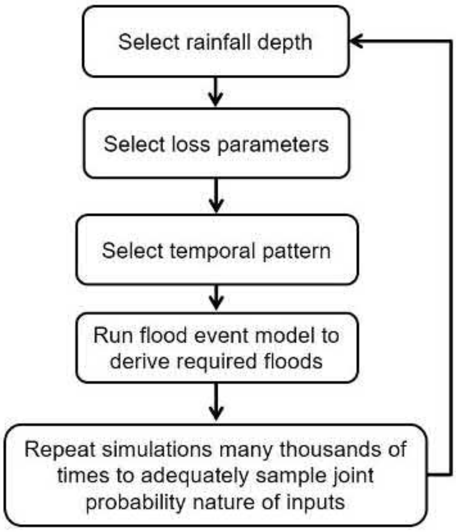


Figure 2-2 Schematic illustration of the joint probability approach

The joint probability framework adopted for the study was developed by Nathan et al (2002, 2003) and is summarised in Figure 2-3. In essence the approach involves undertaking numerous model simulations, where the model inputs are sampled from non-parametric distributions that are based either on readily available design information or on the results of recent research.



n **Figure 2-3 Overview of adopted joint probability framework**

In developing the joint probability framework particular attention was given to ensuring that the model inputs and the manner in which they were incorporated was consistent with the current Book 8 of ARR (Nathan and Weinmann, 2016). The following briefly describes the main inputs, and how they relate to established design information.

Select rainfall depth. Rainfall depths were stochastically sampled from the cumulative distribution of rainfall depths described in Section 5. The relationship between rainfall depth and AEP for a given burst duration was based directly on the Australian Rainfall and Runoff Book 8 guidelines.

Select storm losses. Storm initial losses were stochastically sampled from a nonparametric distribution that was determined from the analysis of a large number catchments across Australia (Hill et al., 2014). The limited number of investigations that have explored the correlation between initial and continuing loss values have concluded that there is little systematic dependence between the two. There is little information regarding the correlation between initial and continuing loss rates, and since antecedent conditions have most influence on initial loss rates, in this study the continuing loss rates were held constant (Section 5.5). Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

Select temporal pattern. Temporal patterns were randomly selected from a sample of temporal patterns relevant to the catchment area and duration of the storm. The temporal patterns were derived from large historic storms that have been observed in the region (Section 5.3).

Monte Carlo simulation. Simulations were undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 100 probability of exceedance, a reduced number of simulations were undertaken over a specified number of probability intervals. In this study, the rainfall frequency curve was divided into 100 intervals uniformly spaced over the standardised normal probability domain, and 250 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered.

2.5 Verification

The initial and continuing losses estimated for calibration events may be biased towards low values because large floods are more likely to be produced for catchments with wet antecedent conditions. Therefore, while a small sample of historic events provides useful data for the selection of RORB model routing parameters, these events provide less information about the appropriate losses to use in design flood modelling because the manner in which losses vary with rainfall depends on chance. Therefore, suitable initial and continuing loss values were estimated through a verification process, which involved setting up design files using the design inputs described in Section 2.4 and varying the losses until there was an acceptable match between the RORB model results and flood frequency analyses of historic peak flows and regional flood frequency estimates. The verification process is discussed in Section 6.

2.6 Design flood hydrology

The RORB model was run in the joint probability framework, with the design inputs and the adopted routing parameters, initial and continuing losses to generate design flood frequency curves and inflow hydrographs.

The design hydrology was generated considering two unique scenarios. One, a storm that covers the whole catchment, with an aim to produce design flows at the base of Hookina Creek. And two, a storm that is centred on the coincident catchment within the hydraulic study area (Figure 1-1). Design both of these scenarios have been run separately to determine flows at each of the focus AEPs.

2.7 Estimation of deterministic Probable Maximum Flood

Deterministic Probable Maximum Floods (PMF) were derived. The deterministic PMF was estimated using an approach consistent with Section 4 of ARR Book 8 (Nathan and Weinmann, 2016):

- initial loss of 0 mm;
- continuing loss rate of 1 mm/h; and
- most conservative peak flood derived from the ten temporal patterns in the Monte Carlo sample that was used for estimation of design floods.

3. Information used in hydrological analysis

This section describes the key information used in the hydrological investigation.

3.1 Streamflow Gauges

There are two streamflow gauges located throughout the catchment. At the start of the project a review of the streamflow gauges was undertaken to ascertain the most suitable streamflow gauges to use for this project.

The streamflow gauge stations available are shown in Table 3-1. The location of the streamflow gauge stations is shown in Figure 1-1. Streamflow data was downloaded from the DEWNR water monitoring site (https://www.waterconnect.sa.gov.au/Systems/RTWD/Pages/Default.aspx).

Table 3-1 Streamflow Gauge Data considered for Calibration and Verification

Station Number	Name	Date of Available Data	Maximum Gauged Level (m)	Maximum Gauged Date	Catchment Area
A5100502	Mernmerna Creek at Sugarloaf Hill	20/09/1973–06/11/1991	5.12	12/03/1989	344
A5100503	Warrumarldunha Hill Channel at Hawker	25/08/1997 – 04/08/2003	1.85	14/04/2000	7

The main gauged used for this investigation was A5100502 (Mernmerna Creek at Sugarloaf Hill) as it has the longest period of record and the largest catchment area.

3.2 Pluviograph data

A pluviograph is an instrument that records the amount of rainfall that has fallen over a period of time. The pluviograph was used to determine the temporal pattern of rainfall over the catchment for the calibration event. The details of the pluviograph used are shown in Table 3-2. The pluviograph location is shown in Figure 1-1. Information at the pluviograph was supplied by the DEWNR.

Table 3-2 Pluviograph data

Station No.	Name	Latitude	Longitude	Start Date	End Date	Source
A5090505	The Oaks Rain	-31.937	138.328	20/10/1983	Current	DEWNR

3.3 Daily rainfall data

The primary source of data used to determine spatial patterns of rainfall were the daily AWAP rainfall data. The AWAP data were downloaded from the Bureau of Meteorology website (Raupach et al., 2009). The AWAP data provide a spatial (5 kilometre resolution) distribution of daily rainfall across the Australian continent. The AWAP data use model-data fusion methods to combine both measurements and modelling to estimate rainfall.

The AWAP data were checked for consistency with the sum of rainfall recorded at the pluviograph.

3.4 Event chosen for calibration

The events chosen for calibration of the hydrological model was determined by examining the streamflow record in conjunction with available pluviograph information. The event chosen for calibration was March 1989. Ideally another event or two would have been used but the data was not available.

Figure 3-1 shows the recorded flows at A5100502 (Mernmerna Creek at Sugarloaf Hill) with the event chosen for calibration highlighted with a black circle. The event was chosen as it is clearly the largest event recorded at the site.

It is important to note, that due to the limited availability of gauge data, it wasn't possible to consider other known large flood events, such as 2007 and 1955.

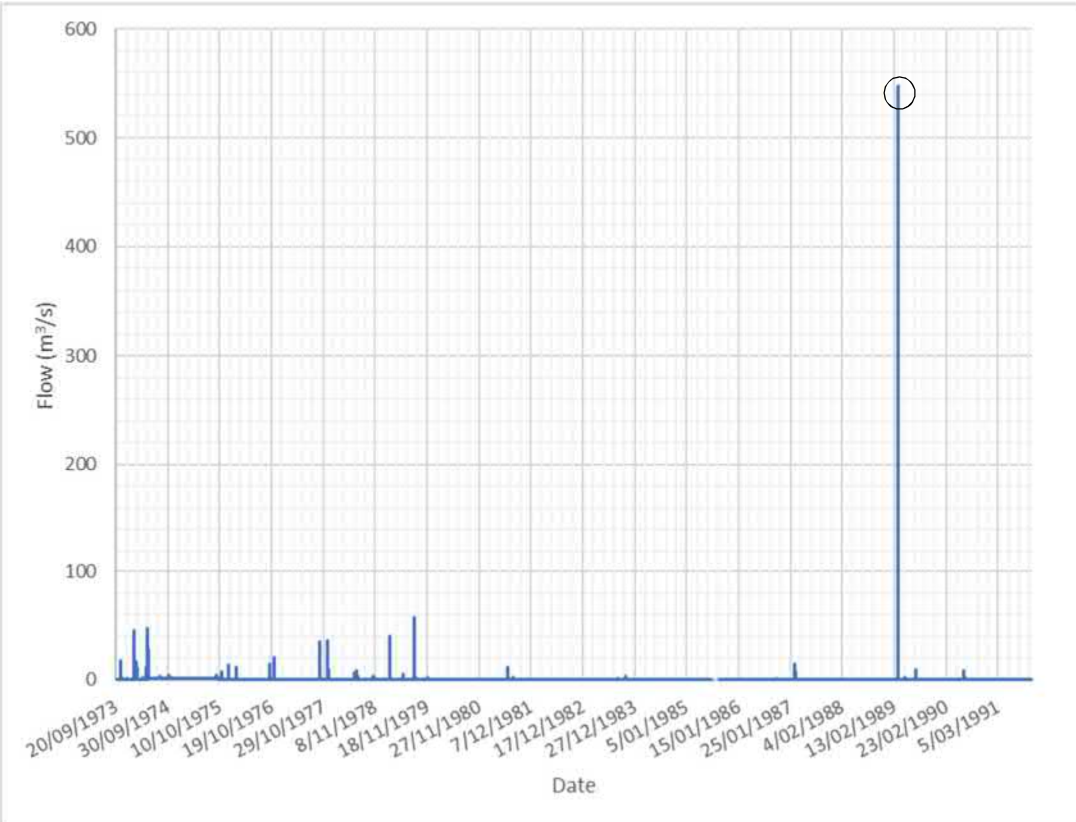


Figure 3-1 Streamflow information at A5100502 (Mernmerna Creek at Sugarloaf Hill). Event used in calibration is circled.

4. Rainfall runoff model

4.1 Model layout

The rainfall runoff model RORB was used to model the rainfall-runoff relationship of the catchment. In general terms, development of a RORB model entails sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storage locations. The RORB model development was based on the hydrologically enforced Shuttle Radar Topography Mission (SRTM) terrain Digital Elevation Model (DEM). The DEMs were derived from the SRTM data acquired by NASA in February 2000 (Gallant et al., 2011) and were publicly released under Creative Commons licensing from November 2011.

Four different types of reaches can be defined in RORB, each having different properties and different relative delay time. The reach types are identified as 1 for natural, 2 for excavated but unlined, 3 for lined channel or pipe and 4 for drowned reach. Drowned reaches were used within the storages; natural reaches were used for all other reaches. Excavated and lined channel reaches (types 2 and 3) are normally only applied in urbanised areas and hence were not used in this study.

Impervious fractions are required for each subarea. For rural areas the imperious fraction is usually assumed to be zero.

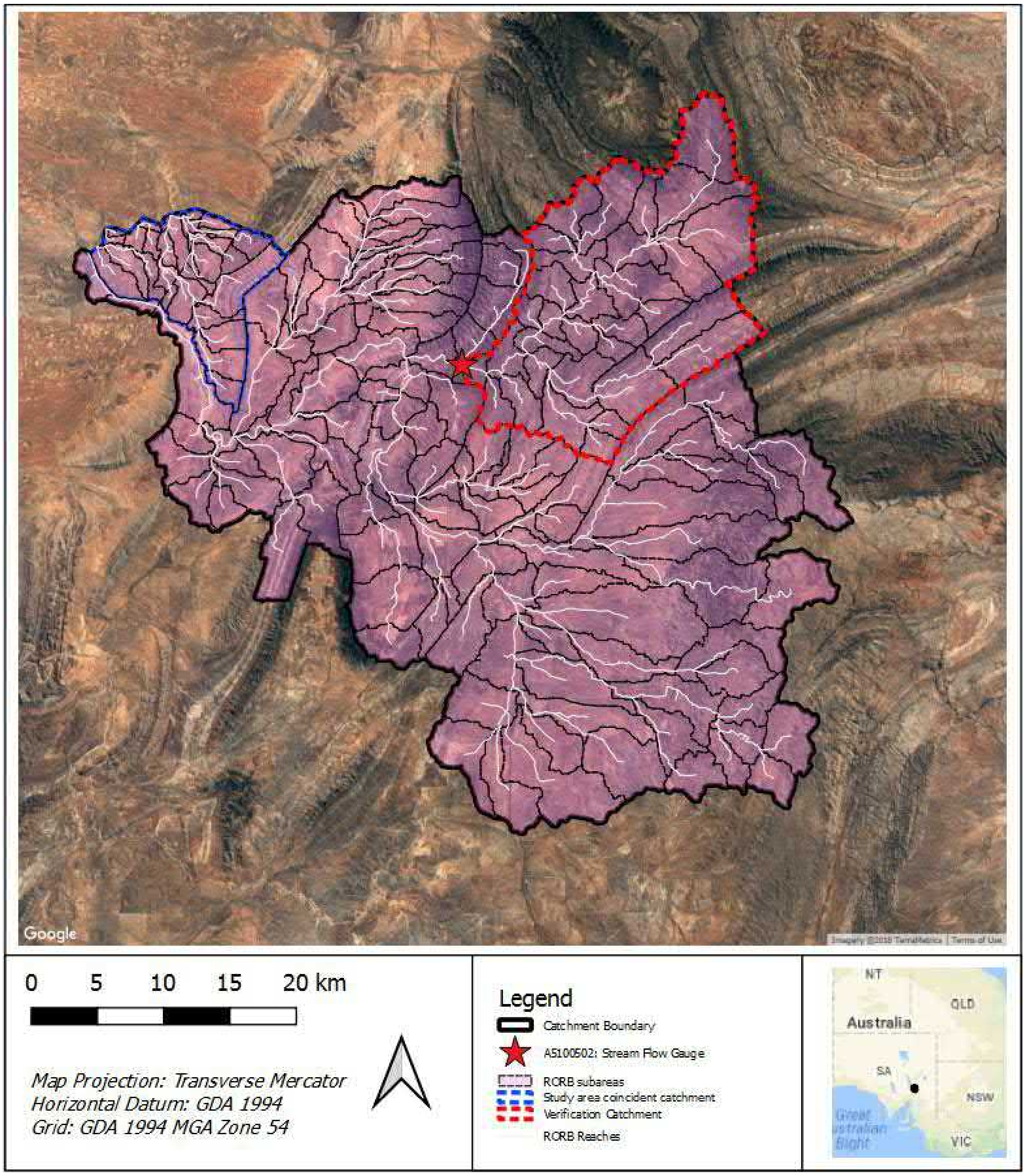
The RORB model was configured in a GIS framework using ArcRORB (Hydrology and Risk Consulting, 2016).

For the calibration event the rainfall depths were estimated for each subarea to account for the spatial variation of rainfall across the catchment. Rainfall depths were estimated by interpolating the AWAP rainfall data to the RORB model subarea centroids. The temporal distribution of rainfall was estimated by assigning the patterns from the available pluviograph.

The RORB model transforms the rainfall excess of a given storm event into a flood hydrograph. In order to compare the RORB model's simulated hydrograph with the recorded or observed hydrograph, it is normally necessary to remove the baseflow component from the recorded hydrograph. However, for this investigation no baseflow was removed as the river is ephemeral and baseflow is negligible.

4.2 Calibration

Calibration of the RORB model was undertaken by setting up a storm file for March 1989 and running the RORB model with routing parameters and losses such that a match was achieved against the recorded hydrograph at A5100502. Details of the RORB model are shown in Figure 4-1.



n **Figure 4-1 RORB model layout**

Figure 4-2 shows the pluviograph information available at A5090505. The pluviograph was used to derive the temporal distribution across the catchment.

Rainfall depths were initially estimated by interpolating the AWAP rainfall data to the RORB model subarea centroids. The AWAP rainfall distribution was checked against the pluviograph information and was found to be consistent for this event. Therefore, the absolute rainfall depths were estimated from AWAP for this event. Figure 4-3 shows the rainfall depths across the catchment for the storm event.

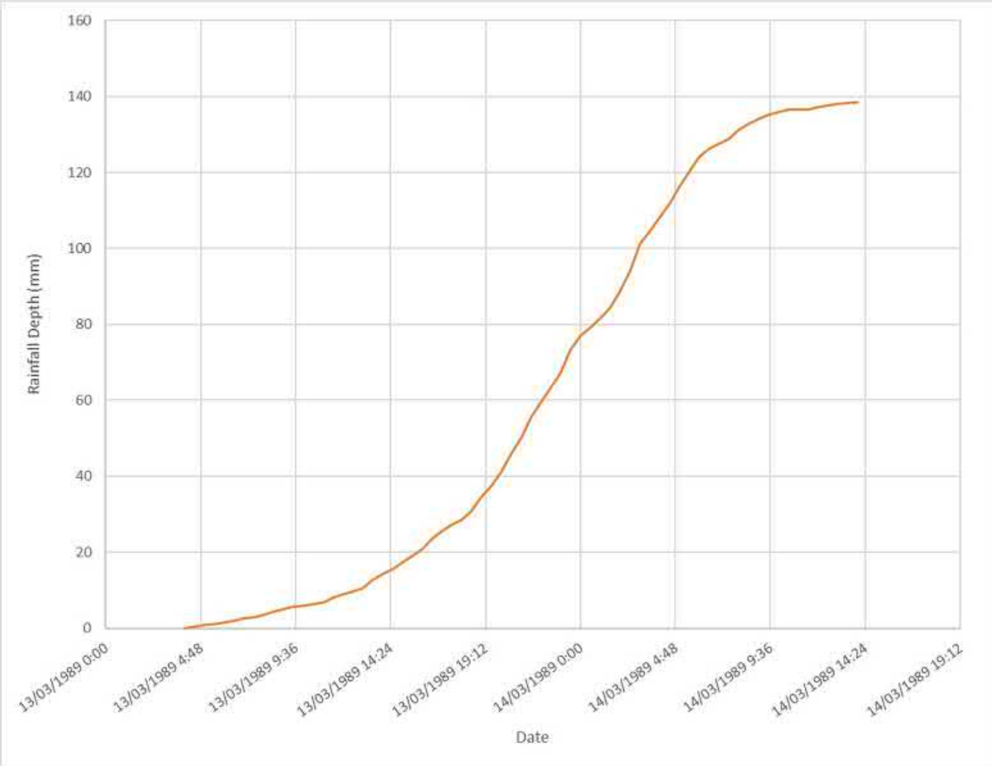


Figure 4-2 Temporal patterns of rainfall depths extracted from pluviograph (A5090505) for the March 1989 event

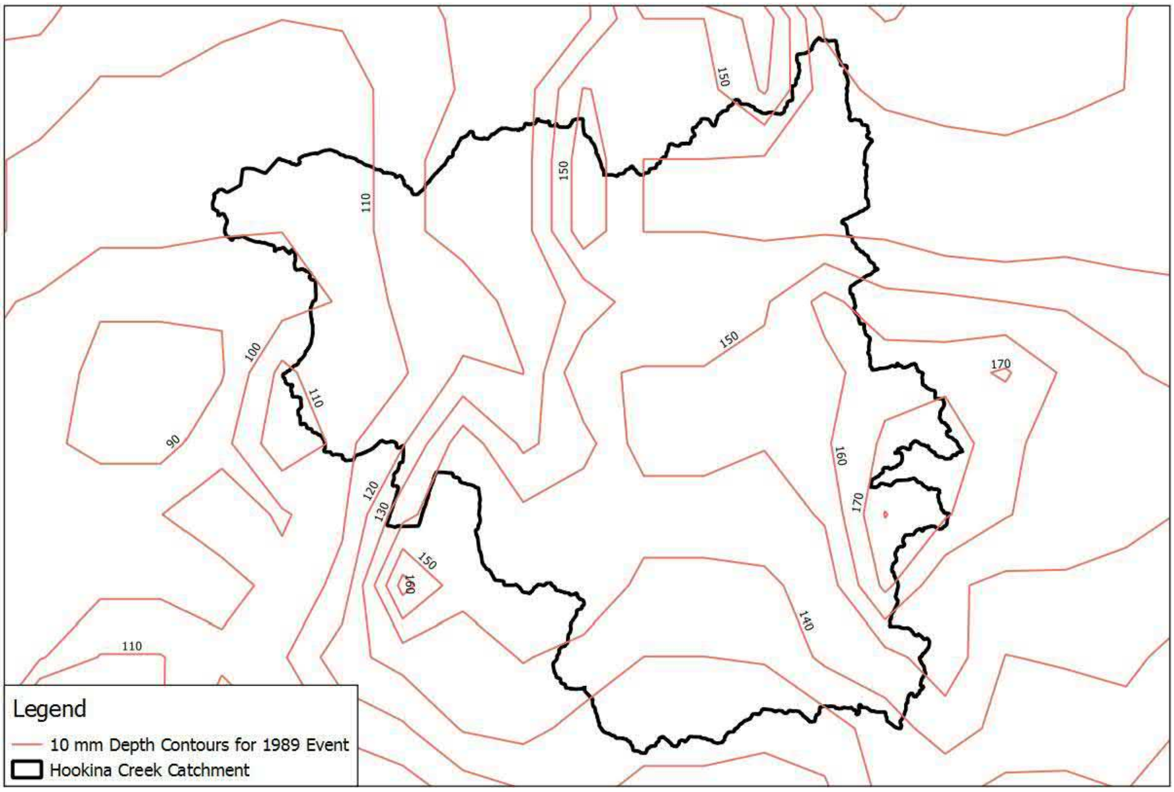


Figure 4-3 Spatial pattern of rainfall depths for the March 1989 event

A summary of the calibration result for the March 1989 event is shown in Table 4-1 with the hydrograph shown in Figure 4-4.

Table 4-1 Summary of calibration parameters values and key model output for the event in March 1989

Gauge	k_c	m	IL (mm)	CL (mm/h)	Peak(m^3/s)		Volume (m^3)	
					Calculated	Recorded	Calculated	Recorded
A5100502	7.0	0.8	55	2.85	531	535	1.37E+07	1.43E+07

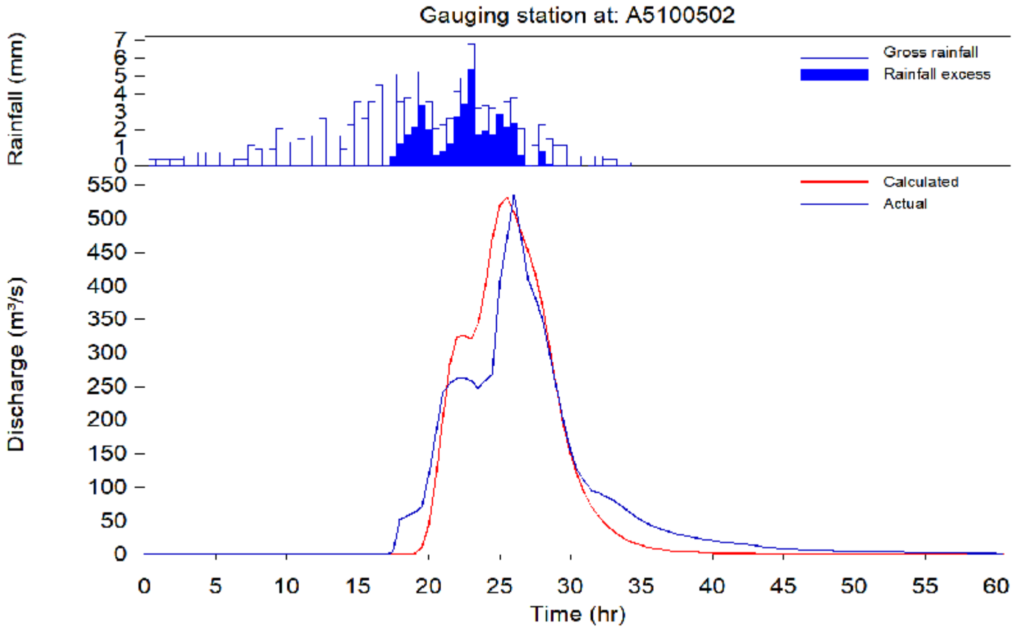


Figure 4-4 RORB calibration at A5100502 – March 1989

4.3 Summary of routing parameters

A good calibration was achieved for the 1989 event. As with all hydrological modelling, the variation between the recorded and modelled hydrograph can be due to a number of things i.e. change in catchment conditions, data errors, rainfall variability and the RORB model being only a representation of a variable and complex rainfall runoff process.

Table 4-2 summarises the calibrated k_c values from the calibration process.

Table 4-2 k_c Values from calibration

Event	k_c	d_{av}*	k_c/d_{av}
A5100502	7.0	21.61	0.32

* d_{av} is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model)

The k_c/d_{av} values shown in Table 4-2 are typically lower than those found in Pearse et. al. (2002). In which used a large database of routing parameters collated by the CRC for Catchment Hydrology to derive a prediction equation applicable to Australia. The k_c/d_{av} values ranged from 0.61 to 2.13.

Regional Parameters

For the South Australia arid regions ARR 2016 recommends using Kemp, 1993 which is shown in equation 1.

$$k_c = 7.06\, A^{0.71} \left(\frac{RF}{1000}\right)^{2.79} \qquad (1)$$

Where A is the area in km^2 (344 km^2)

RF is the mean annual rainfall (less than 308 mm)

There is a daily rainfall gauge located at Hawker (019017). Rainfall is recorded from 1882 to date where the average annual rainfall is 308 mm. Using equation 1 gives a k_c estimate of 16.7.

Dr David Kemp has recently reviewed the relationship published in 1993 for k_c values in arid areas. The derived relationship, for the Northern Flinders Ranges with annual rainfall less than 300mm to 350 mm is $k_c = 0.33A^{0.52}$ (unpublished). For the A5100502 catchment the new relationship gives a k_c estimate of 6.9, which is similar to the value derived from the calibration. Discussions with Dr David Kemp indicated that lower k_c values, than would normally be used, are typical for arid catchments.

Arrunha Creek

In 2017 HARC undertook a hydrological investigation for Arrunha Creek, which is located approximately 130 kilometres north of Hookina Creek. Arrunha Creek also flows into Lake Torrens. A RORB model was established for the Arrunha Creek catchment and calibrated to three events. Table 4-3 summarises the k_c/d_{av} values adopted for Arrunha Creek. Table 4-3 shows that the values are similar to the value for the calibration at A5100502.

Table 4-3 Arrunha Creek – Summary of k_c/d_{av}

Event	k_c/d_{av}
April 2010	0.31
September 2010	0.26
January 2001	0.25
Adopted	0.27

4.4 Adopted routing parameters

The choice of k_c for the Hookina Creek catchment was largely based on the calibration result however, the results from the calibration were compared to the previous investigation on Arrunha Creek and the regional estimates. The k_c and m value adopted for the Hookina Creek catchment are shown in Table 4-4.

Table 4-4 Hookina Creek – Adopted Parameters

Event	m	k_c	d_{av*}	k_c/d_{av}
A5100502	0.8	7.0	21.61	0.32
Outlet	0.8	20.0	61.7	0.32

5. Design rainfall and losses

Design rainfall depths were derived for the catchment and used in the verification process (refer to Section 6). Separate Design rainfalls with adjusted areal reduction factors were developed for both the whole catchment and the verification catchment, as well as the coincident catchment developed within the hydraulic study area (Figure 4-1).

5.1 Design Burst Rainfall Depths

5.1.1 Design rainfall for events more common than 1 in 2000 AEP

1 in 2 to 1 in 2000 AEP

Catchment average point design rainfall depths for burst durations between 6 and 168 hours, and AEP 1 in 2 to 1 in 100, were estimated using the latest IFD (2017) analysis available from the Bureau of Meteorology (http://www.bom.gov.au/water/designRainfalls/revised-ifd/). For burst durations between 24 and 168 hours, and AEP 1 in 100 to 1 in 2000 AEP were estimated using the latest IFD (2017) analysis also available from the Bureau of Meteorology.

Durations of 12 hours and shorter

Jordan et al (2005) used rainfall records for twelve pluviographs around Australia, and an approach similar to the CRC-FORGE method to estimate growth factors for short burst durations. These growth factors were applied to burst durations of 12 hours and less, and were also re-scaled so that the 1 in 100 AEP point rainfall depth matched the updated IFD analysis. The growth factors applied to the 18 hour storm duration were an average of the growth factors used for the 12 hour and 24 hour durations.

5.1.2 Areal reduction factors

The point rainfall estimates were converted to areal values using the areal reduction factors from Jordan et al. (2016) available via the new ARR data hub (Geoscience Australia, 2017). Conceptually, these factors account for the fact that larger catchments are less likely to experience high intensity storms over the whole catchment.

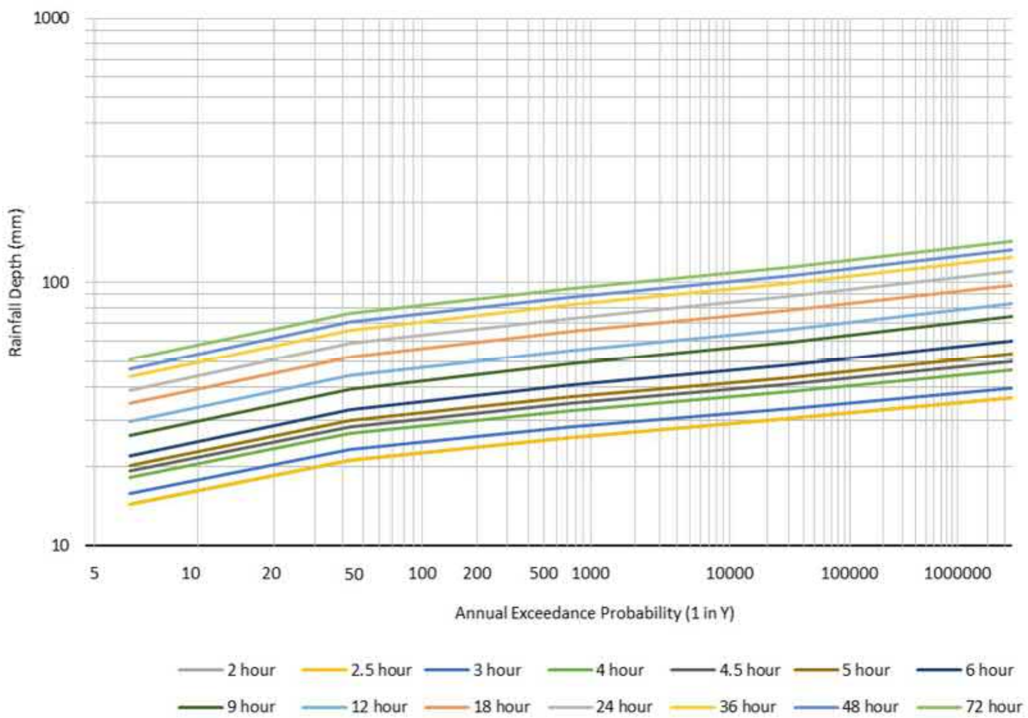
5.1.3 PMP Estimates

PMP estimates for burst durations between 24 and 72 hours were obtained using the GSAM method (BoM, 2006), and the GSDM method was used for durations between 1 and 3 hours (BoM, 2003). PMP depths for durations between 3 and 24 hours were estimated by developing an enveloping curve of PMP depths versus durations.

The AEP assigned to the PMP is a function of the method used in its derivation. The recommendations by Laurenson and Kuczera (1999) are for a lower limit of 1 in 10^7 for catchments less than 100 km², and for the AEP of the PMP to vary as a power function of catchment area to an AEP of 1 in 10^4 for a catchment area of 100 000 km². For the Hookina Creek catchment to the project site the catchment area is 1696 km². Hence the AEP of the PMP for that catchment is estimated to be 1 in 547,000.

5.1.4 Adopted design rainfall depths

Design rainfall depths adopted for the verification are shown in Figure 5-1. The verification gauge design rainfall chart and the local catchment design rainfall charts are included in Appendix A.



n Figure 5-1 Design Rainfall Depths for Hookina Creek to inflow to hydralulic study area.

5.2 Spatial patterns

The design spatial patterns for the short and long duration events were based on the methods as outlined in the GSDM (BoM, 2003) and GSAM (BoM, 2006) approach respectively.

5.3 Temporal patterns

Due to the hydrologic characteristics of the catchments, short duration storms proved critical for all AEPs considered. For the shorter duration storms, the sample of temporal patterns used have been derived by Jordan et al (2005).

All spatial and temporal patterns in the sets used for sampling were given equal probability of selection in the Monte Carlo simulation.

5.4 Pre-burst rainfall depths and temporal patterns

For the shorter durations, the pre-burst patterns from Jordan et al (2005) were applied. These pre-burst patterns are applied to the selected temporal pattern as a percentage of burst depth. This pattern is redistributed for each duration modelled.

5.5 Losses

There are two key types of loss models that are typically adopted when modelling design floods:

- Initial loss/continuing loss
- Initial loss/proportional loss

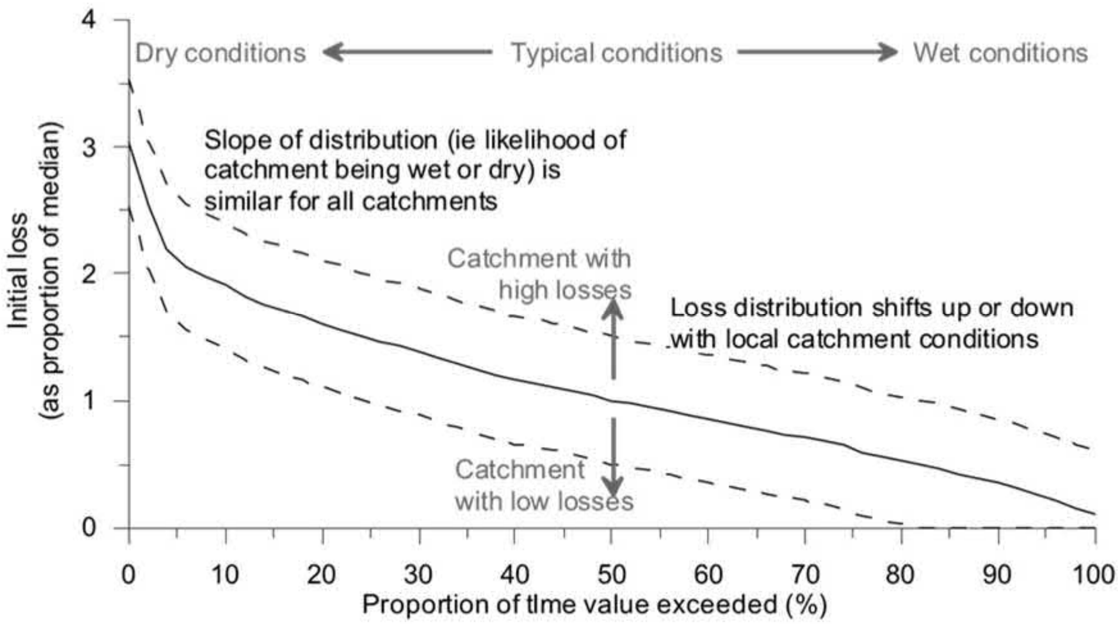
Investigations by Hill et al. (2014) as part of the ARR 2016 revision (Hill and Thomson, 2016) were inconclusive as to which loss model works best. Even for catchments where one of the loss models performed better for a majority of events, there were still some events for which the other approach was better. Similarly, there was no obvious relationship between the relative performance of the loss models and hydro-climatic or catchment characteristics.

The advice in ARR is that the initial loss/continuing loss model is most suitable for design flood modelling, because it can be used to estimate flood peaks and volumes for all AEPs. In contrast, it is often difficult to derive unbiased estimates of flood quantiles using the initial loss/proportional loss model over the same range of AEPs. The initial loss/proportional loss model underestimates peak flows for extreme floods if the proportional loss is not varied appropriately with AEP; and to date there is little evidence about how proportional loss varies with AEP. Therefore, for this study an initial loss-continuing loss model was adopted.

The shape of the initial loss distribution used in the design flood modelling was derived by Hill et al. (2014) from flood modelling results for a large number of catchments across Australia. Hill et al. (2014) developed a non-dimensional distribution of initial loss values for each catchment, by representing initial losses as a proportion of the median loss. This allowed the distributions of initial losses across different catchments to be directly compared. The standardised distributions exhibited a high degree of consistency, and suggested that while the magnitude of initial losses may vary between different catchments, the shape of the distribution does not. That is, while it may be expected that typical loss rates vary from one catchment to another, the likelihood of a catchment being in a relatively dry or wet state is similar for all catchments. The adopted distribution of initial loss is shown in Figure 5-2.

The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

Values for the median initial loss and constant continuing loss rate for each of the catchments were estimated by verifying the flood quantiles produced by RORB to flood frequency analyses of observed flood peaks. Details of the verification process and the adopted losses are given in Section 6.



n Figure 5-2 Cumulative probability distribution of initial loss, as a ratio of the median initial loss, adopted for design flood estimation (adopted from Hill et al., 2014)

6. Model verification

6.1 Method

Current practice in design flood estimation includes verification of the results from rainfall runoff modelling (such as RORB) against flood frequency analysis from observed streamflows, where available. The initial and continuing losses estimated for calibration events may have a low bias because large floods are more likely to occur on catchments with wet antecedent conditions. Therefore, while a small sample of historic events provides useful data for the selection of RORB model routing parameters, these events provide less information about the appropriate losses to use in design flood modelling because the manner in which losses vary with rainfall depends on chance.

However, for this catchment the streamflow information is of insufficient length to have confidence in the estimates. Therefore, for this catchment the same losses used for Arrunha Creek (i.e. IL = 20 mm and CL = 3.5 mm/hr) were adopted for Hookina Creek.

To check the appropriateness of adopting the Arrunha Creek losses for Hookina Creek a verification run was undertaken at the streamflow gauge A5100502 (Mernmerna Creek at Sugarloaf Hill). Annual maxima were extracted at A5100502 where there is 18 years of data. For the gauge the flood frequency analyses involved fitting a distribution to the annual maxima using FLIKE.

RORB was run in Monte Carlo simulation mode to estimate flood frequency quantiles for flood events with AEP of 10%, 5%, 2% and 1%. In all of the RORB model simulations, a value of 0.8 was adopted for the routing non-linearity parameter, m, which is consistent with guidance for simulation of large and extreme floods in ARR (Nathan and Weinmann, 2016). The value of the routing delay parameter, k_c, was adopted from the values identified from calibration of flood events (refer to Table 4-2). The verification process concentrated upon checking that the median initial loss and continuing loss rate parameters adopted from the Arrunha Creek catchment were appropriate.

The verification process effectively anchors the estimates of design flood peaks from the RORB model across the range between 10% and 1% AEP. The verification process improved confidence in design flood estimates from the RORB model, in addition to calibration to selected flood events, because:

- calibration was restricted only to a subset of flood events for which there were adequate pluviograph rainfall data to model the flood in RORB, whereas all gauged flood peaks may be adopted in the verification process, permitting the use of a longer data set of floods and often resulting in the consideration of larger flood events; and
- loss parameters typically vary across a wide range between individual flood events, due to variations in antecedent climatic conditions. Calibration to a small number of flood events provides an unreliable basis for estimating initial and continuing loss parameters, whereas the

verification process fits the loss parameters to a much larger sample of flood events and therefore provides a considerably more reliable basis for estimation of loss parameters for design flood event modelling.

6.2 Results

Figure 6-1 shows the distribution and the confidence limits. Figure 6-1 demonstrates that the RORB model provides a reasonable match to the distribution fitted to gauged annual maxima with a k_c of 7.0, median IL of 20 mm and CL of 3.5 mm/h. As mentioned previously, given the lack of data at the streamflow gauge site and the flood frequency being heavily influenced by the one large event recorded at the site (refer to Figure 3-1) the verification runs were undertaken to check if the losses adopted from the Arrunha Creek verification were appropriate rather than adjusting losses to match a flood frequency curve which has a large amount of uncertainty.

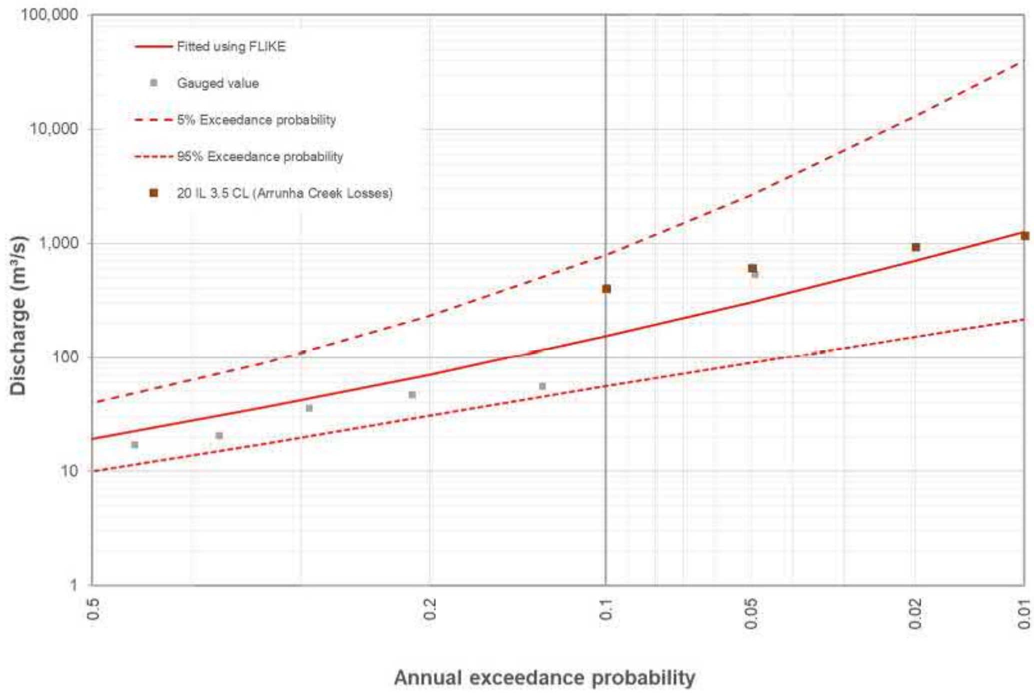


Figure 6-1 Flood frequency curves and verification with RORB model Monte Carlo run outputs for flood quantiles between 10% and 1% AEP (for k_c of 9.2, median IL of 20 mm and CL of 3.5 mm/h)

6.3 Adopted Parameters

Table 6-1 summarises the parameters adopted for the verification of the RORB model.

Table 6-1 Summary of Parameters

Parameter	Value
k_c (A5100502)	7
k_c (Outlet)	20
m	0.8
IL (mm)	20
CL (mm/h)	3.5

7. Design flood hydrology

The RORB model (Section 4) was run in the joint probability framework described in Section 2, with the design inputs summarised in Sections 5 and the adopted initial and continuing losses (Section 6).

7.1 Hydrographs

The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. However, hydrographs were required for input to the hydraulic model. Therefore, hydrographs were extracted from the RORB model and were chosen to match the peak flows.

Hydrographs were required for the Hookina Creek catchment and the localised catchments. For the Hookina Creek catchment the design storms were centred on the centroid of the catchment. For the localised catchments the design storms were centred on the localised catchments. Of note with the localised catchments is that the RORB model is coarse, with the focus of the investigation being on the Hookina Creek catchment. If the localised flows prove to be critical in the decision making process then, it is recommended, that the RORB model be revised to incorporate more detail of the local catchments.

A summary of the peak flows for each of the AEP events is shown in Table 7-1. The location of the peak flows provided is shown in Figure 7-1.

n Table 7-1 Summary of Peak Flows

AEP (1 in x)	Hookina Creek		North Outflow	
	Peak Flow (m^3/s)	Duration (hour)	Peak Flow (m^3/s)	Duration (hour)
5	473	6	70	3
10	922	6	128	3
20	1490	9	193	3
50	2420	9	294	2
100	3180	9	376	2
1000	6120	9	671	2
2000	7140	9	771	2

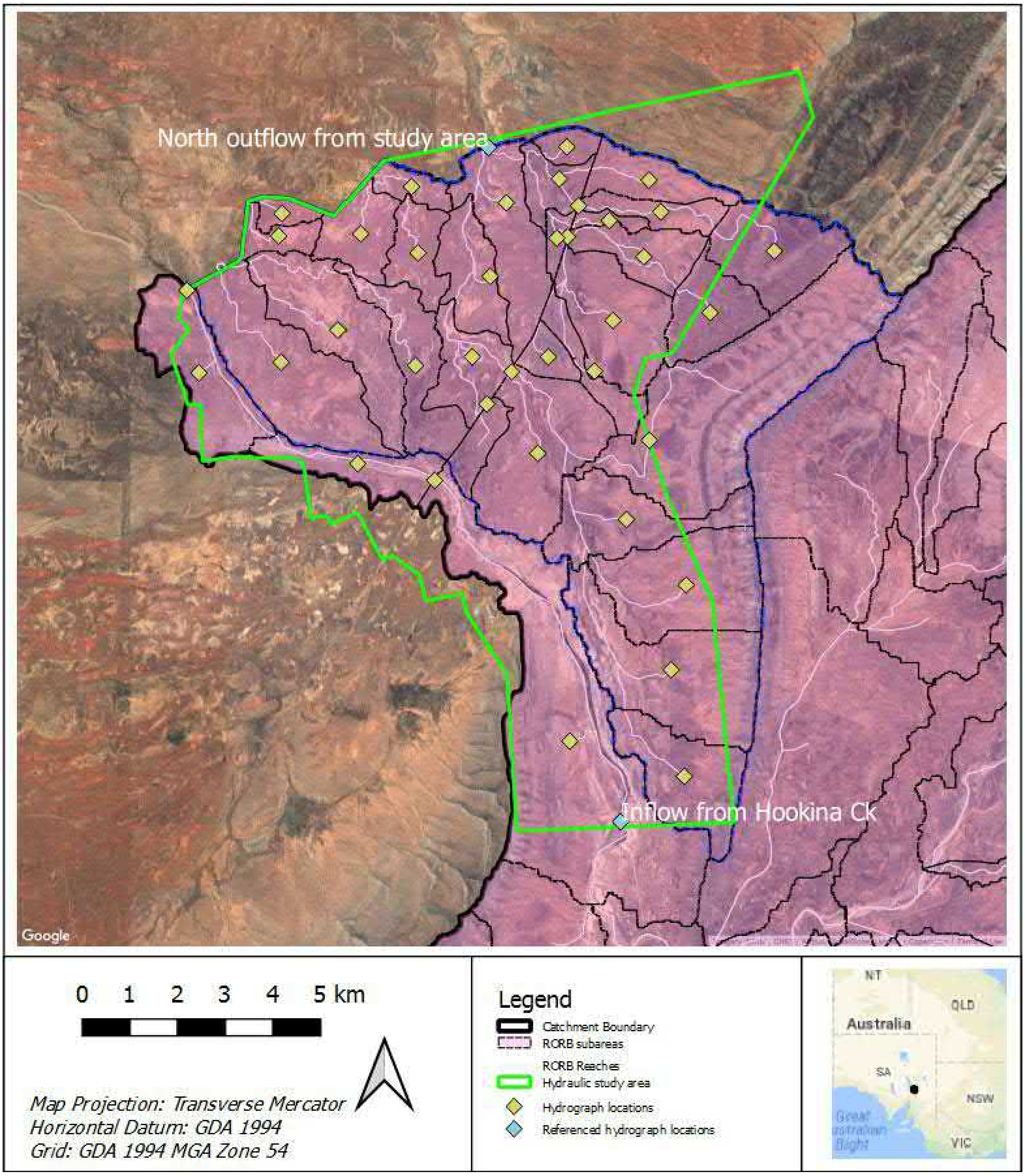


Figure 7-1 Location of Results Shown in Table 7-1.

7.2 Probable Maximum Flood (PMF)

The definition of the Probable Maximum Flood (PMF) provided in Book 8 of ARR is the flood resulting from the Probable Maximum Precipitation under the worst catchment conditions that can be reasonably expected to occur (Nathan and Weinmann, 2016). While simple in concept, the estimation of the PMF requires many assumptions regarding the “reasonableness” of various flood producing factors such as the areal and temporal distribution of the PMP, initial and continuing losses and in particular how they combine. Different selections of inputs can have a marked influence on the magnitude of the PMF, and its exceedance probability.

For this study, an assessment of the PMF was undertaken with the initial loss and continuing losses being set to 0 and 1 mm/h respectively. The temporal patterns were selected from the Monte Carlo sample to maximise the outflow.

The PMF reported for Hookina Creek is thought to be conservative as the result is sensitive to the adopted value of the routing parameter k_c. This adopted value is lower than typical values from wetter climates but is consistent with values in arid regions as observed and reported by Dr David Kemp. There is a lack of empirical information on how routing parameters may vary with flood magnitude and therefore ARR Book 8 recommends that the routing parameters are held constant. It may be that the runoff processes (and hence routing parameters) vary with flood magnitude for the Hookina Creek catchment but there is no basis for making such an adjustment.

In addition, papers such as “The disparity between extreme rainfall events and rare floods - with emphasis on the semi-arid American West” by Osterkamp et. al. (2000) indicate that arid and semi-arid catchments tend to produce higher PMF flows than humid catchments.

If the PMF is to be adopted as the design flood then it is recommended that the reasonableness of the estimates is assessed. Book 8 of ARR provides guidance on assessing the reasonableness of PMF estimates based upon the implied shift in probability with respect to the AEP of the PMP and also the conditional probability of exceedance given the PMP.

Table 7-2 shows the PMF flow for different duration storms.

Table 7-2: PMF Flows

Event Duration	Flow (m^3/s) Hookina Creek	Flow (m^3/s) North Outflow
1 hr	21400	2400
2 hr	40200	3410
3 hr	40500	2870
6 hr	37500	2560

8. Conclusion

This part of the study has derived hydrographs for the Hookina Creek catchment.

The hydrology was analysed through a RORB rainfall-runoff model. Calibration of the model was undertaken on the streamflow gauge A5100502 (Mernmerna Creek at Sugarloaf Hill). In addition to the calibration results, details from a previous investigation on Arrunha Creek were used to adopt the appropriate parameters for Hoookina Creek.

Hydrographs derived from the RORB model and were provided for the 1 in 5, 10, 20, 50, 100, 1000, 2000 AEP and PMF events.

The PMF reported for Hookina Creek is thought to be conservative. If the PMF is to be adopted as the design flood then it is recommended that the reasonableness of the estimates is assessed.

In addition, if the localised flows prove to be critical in the decision making process then, it is recommended, that the RORB model be revised to incorporate more detail of the local catchments.

9. References

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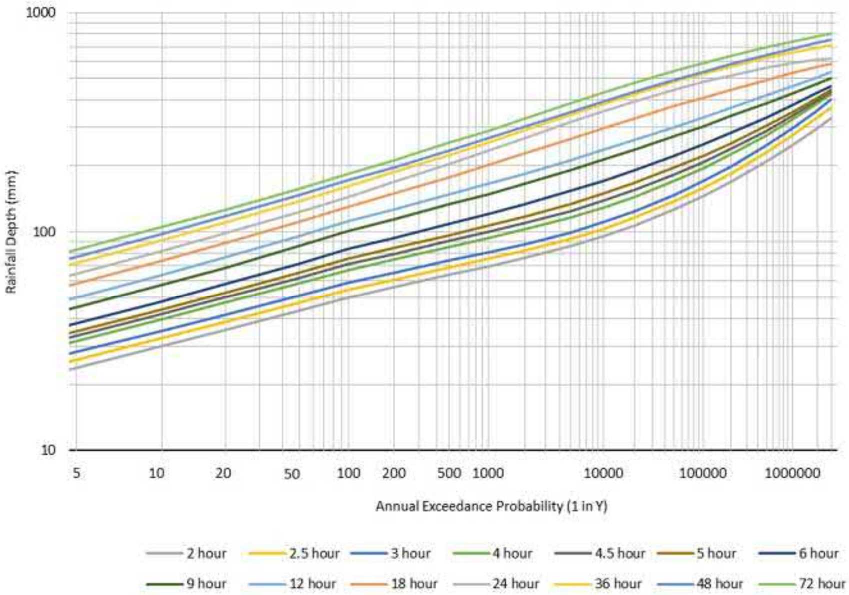
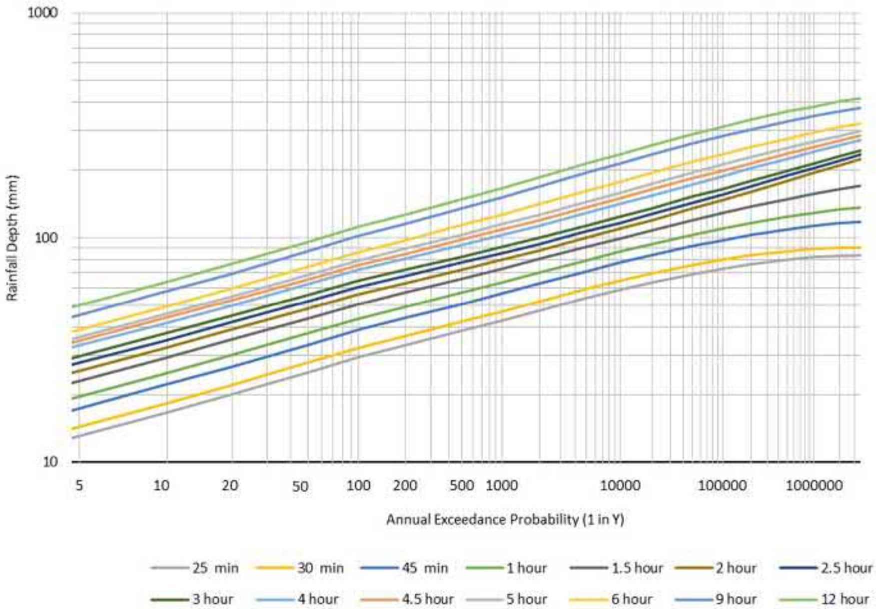
Appendix A



A-1 Design Rainfall Depths for A5100502 verification catchment



A-2 Design Rainfall Depths for the local catchment

Hydraulic Modelling Report

C1 Introduction

A review of the available information revealed that little was known about the nature of flooding on Hookina Creek and its floodplain. There was anecdotal information available on the 1955 and 2007 floods, but no flood extents or other recorded information. Anecdotally, the site did not flood, however there was no objective evidence to support that experience. There was also evidence from the geomorphological assessment that the floodplain may be quite active. There was a need to quantify the magnitude of the floods that would engage the floodplain and the flow depths, speeds and stresses the floodplains were under. To determine this information, hydrological and hydraulic modelling was required.

To determine this information, the proposed scope of work involved the following key tasks:

- Prepare a TUFLOW 2D flood model of the Wallerberdina site using existing available LiDAR data
- Estimate PMF and 1%AEP flow rates using ‘rapid’ / approximate methods
- Model flood behaviour to establish the risk to the site
- If the site is flooded, if required, undertake comprehensive hydrological modelling
- Update the TUFLOW flood models to include the revised flows
- Document outcomes in a concise report
- Provide data outputs to the project’s geomorphologist to update the assessment of the significance of fluvial processes and avulsion/change to the watercourses

The modelling approach is documented in Section C2.

C2 Approach

AECOM proposed to undertake the flood assessment of Wallerberdina in two stages. The first stage would determine whether it’s likely the site is flood prone, and if so, the second stage would determine the magnitude of the design flood event that inundates the site and the risks to the site during these floods (height and depth of water, velocity and shear stresses). The detail of each stage follows.

C2.1 Stage One:

Stage One (parts A & B) - approximate PMF and 1% AEP flood modelling - will consist of the following:

- Part A:
  - Develop a 2D TUFLOW flood model of the study using the existing LiDAR terrain data captured by others
  - Incorporate data on key structures (bridges and culverts) based on the best available information. This data will need to be sourced from rail authorities, and if not available, will limit the accuracy of the modelling work and potentially delay the modelling
  - Estimate the Probable Maximum Flood (PMF) flowrate based on an approximate technique (Hydrological Recipes, 1996)
  - Run the peak flow through the TUFLOW model and establishing approximate flood heights, depths, velocities, bed shear stress and stream power
- If the sites are inundated, then do Part B:
  - Use the Regional Flood Frequency Estimator (RFFE) to estimate the 1% AEP flood flow rate and the flow rates at the 5% and 95% confidence limits
  - Run these 3 flows through the TUFLOW model and establishing approximate flood extents, heights, depths, velocities, bed shear stresses and stream power
- Prepare a very concise letter report with associated figures to inform the geomorphologist
- If we do not proceed to Stage Two - geomorphological interpretation of the study results

C2.2 Stage Two

If Stage One shows that the site is inundated, it will be necessary to refine the hydrology and run the model for a range of different magnitude floods to establish the risk profile of the site. Stage Two will consist of the following:

- Develop a hydrological model of the Hookina Creek catchment. Due to the significance of the project, AECOM engaged industry leading specialist hydrology company, Hydrology and Risk Consulting (HARC), to undertake the work
- Using the model, develop critical hydrographs for a range of flood magnitudes from frequent through to extremely rare (1 in 5 AEP through to the PMF)
- Run the events through the TUFLOW model from Stage One
- Establish flood extents, heights, depths, velocities, bed shear stresses and stream power for each magnitude flood event
- Prepare a very concise letter report with associated figures to inform the geomorphologist
- Geomorphological interpretation of the study results

C3 Available Data

The key available datasets used to formulate the hydraulic model were:

- LiDAR terrain data - 0.1m vertical accuracy (file: WB_1m_DEM.flt)
- Shuttle Rader Topography Mission (SRTM) terrain data – (file: ELVIS_SRTM_Download_sr_gda94z54_transformed.asc)
- Aerial photos (for estimating Manning's n roughness)
- Approximate bridge and culvert dimensions captured as part of a site visit.

C4 Hydraulic Modelling

The hydraulic modelling was undertaken using the TUFLOW flood modelling software (www.TUFLOW.com). TUFLOW is based on the shallow water equations. It is capable of simulating 1d (pipes and culverts), 2D (floodplains) and linked 1D/2D (connections from 1D elements, such as culverts, into the floodplain represented in 2D). For modelling speed, the 2018 HPC 64 bit version of TUFLOW version was used, running on GPU hardware (graphics card).

C4.1 Model Schematisation

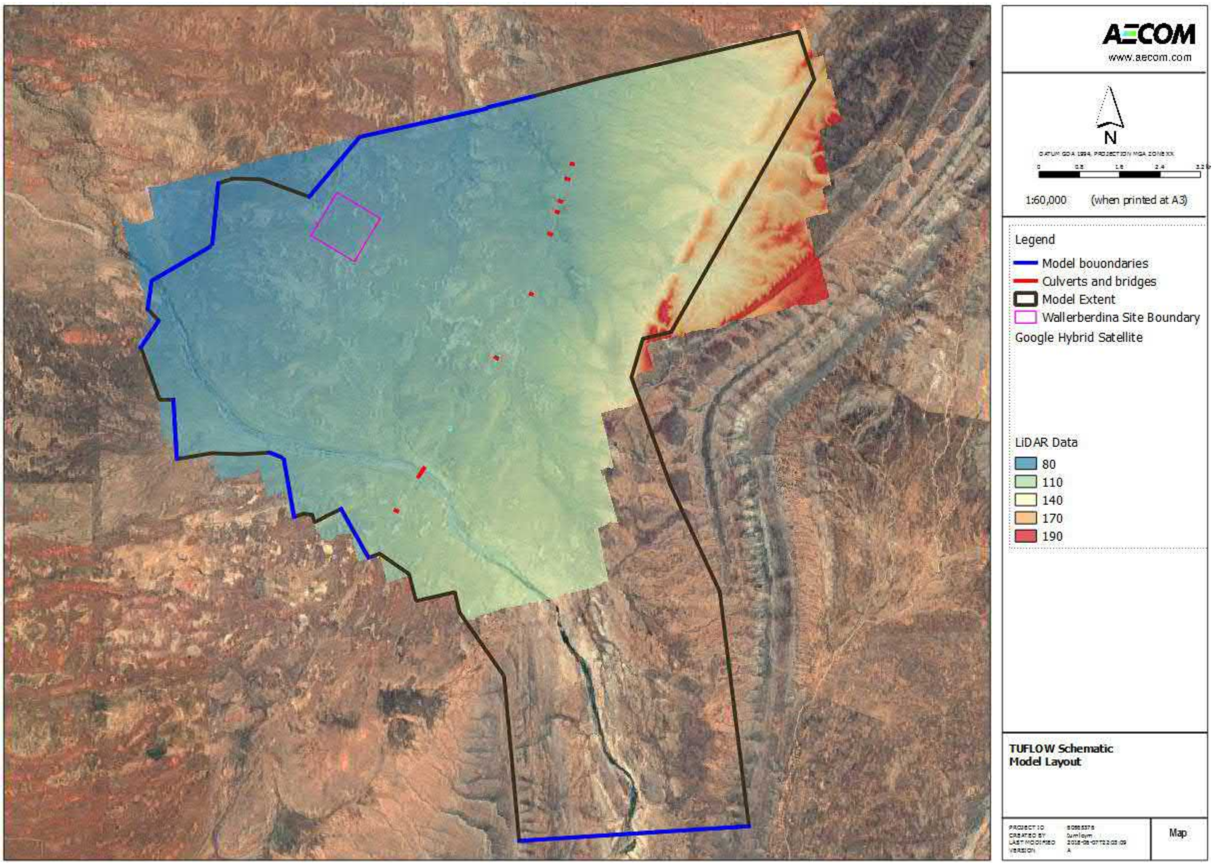
The 2D model area was established to cover the extent of the available LiDAR data and key hydraulic features. Key features included the railway line and associated waterway crossings. It also included an area upstream of the LiDAR data containing significant interaction between Hookina Creek, a distributary and other key local flowpaths. The distributary and local flowpaths form a non-perennial waterway that runs north and east of the site. These areas had to be represented in the model, and therefore had to use low accuracy SRTM terrain data. This data had to be adjusted to improve the match in elevation where it met the higher accuracy LiDAR data. The model's schematic layout is illustrated in Figure 94.

The model was established using a 10m 2D grid cell resolution. This resolution was selected to provide sufficient detail of the hydraulic controls, while not resulting in excessive model run times. The choice of a 10m grid cell size was sensitivity tested by running the model with a 5m grid size and comparing the results. The comparison indicted that there were no significant differences in the results, with differences generally less than a few millimetres. Given this, the 10 m grid size was adopted.

The model requires the hydraulic roughness of the terrain to be defined. The roughness is defined using Manning's n values. As the floodplain and waterway are similar in roughness, a single value was adopted across the model. Based on calibration data from another project with similar terrain and vegetation cover, also located within the South Australian arid zone, the same 0.04 Mannings n roughness value was adopted.

Bridge and culvert structures were incorporated into the model. Structure design drawings, or as-constructed drawings, were not available at the time of the study. The dimensions were estimated during a site visit. The structure locations and dimensions are presented in Appendix C.

Figure 94 Approximate PMF hydrograph



C4.2 Inflow Boundary Conditions

Stage One PMF and 1% AEP inflow boundary conditions were derived using approximate methods. Approximate methods were used as the results from this modelling were purely to determine whether it was likely the site was subject to flooding.

Approximate PMF

The approximate PMF flowrate was calculated using the approximate technique outlined in the reference Hydrological Recipes (1996). The equations are represented below.

$$Q_p = 129.1\ A^{0.616} \qquad [r^2=0.95,\ S_e=+36\%\ -26\%,\ n=56]$$

$$V = 497.7\ A^{0.984} \qquad [r^2=0.98,\ S_e=+39\%\ -28\%,\ n=56]$$

$$T_p = 1.062 \times 10^{-4}\ A^{-1.057}\ V^{1.446} \qquad [r^2=0.89,\ S_e=+42\%\ -29\%,\ n=38]$$

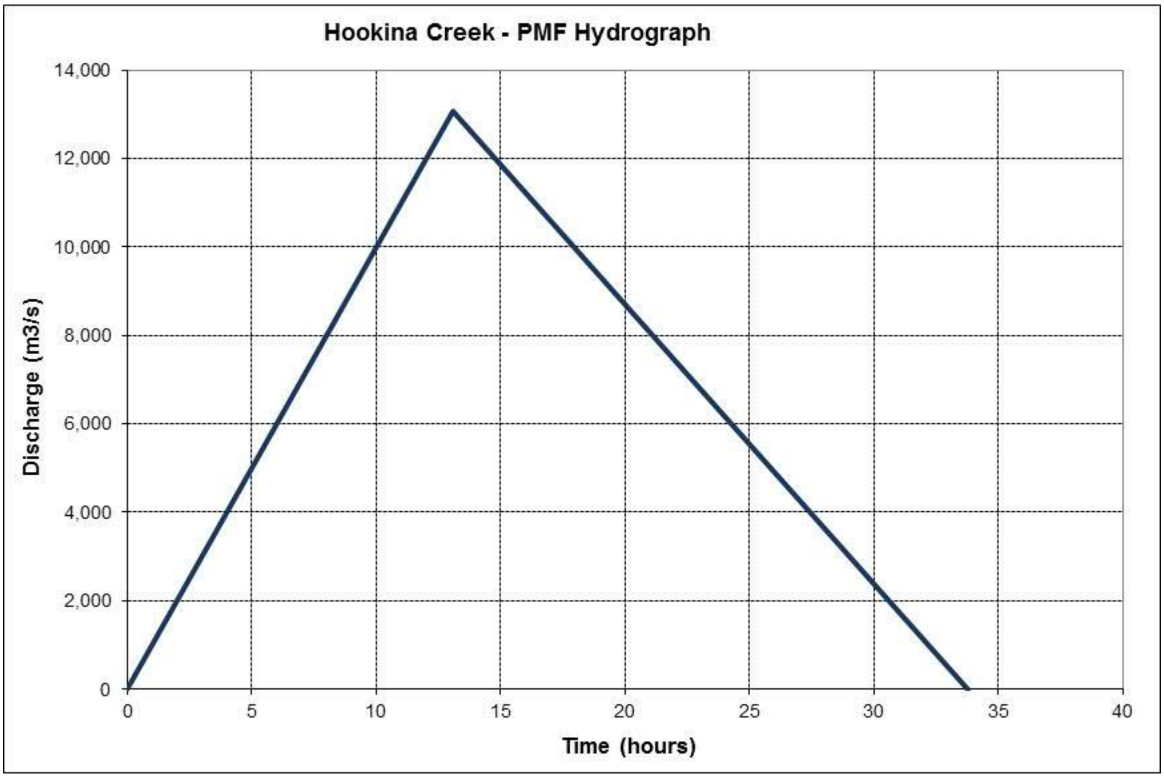
$$T_r = \frac{V}{1.8Q_p}$$

where

Q_p	peak flow $[m^3s^{-1}]$
A	catchment area $[km^2]$
V	hydrograph volume [ML]
T_p	time to peak of the hydrograph [h]
T_r	length of hydrograph [h] derived by mass balance

Based on an approximate catchment area of 1800 km^2, which includes the local catchments within the site, the estimate PMF is 13100 m^3/s. The time to peak and length of hydrograph are 13 hours and 34 hours respectively. The hydrograph is illustrated in Figure 95.

Figure 95 Approximate PMF hydrograph



Regional Flood Frequency Estimation model (RFFE)

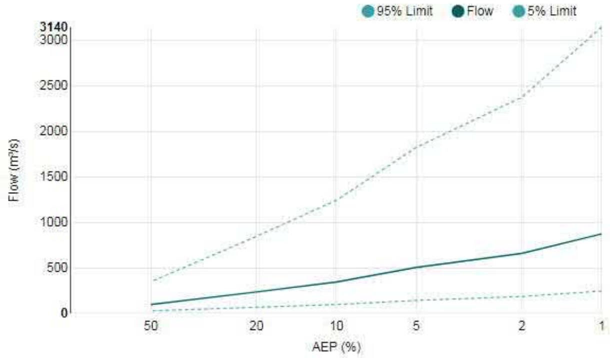
The RFFE model was used to estimate the 1% AEP flood flow rate and the flow rates at the 5% and 95% confidence limits (https://rffe.arr-software.org/). At the time of this study, the arid zone within the model was disabled. The results from the arid zone region of the model were currently under review. AECOM were able to access the older version of the model through the ARR team. The results are therefore indicative only and are subject to change. The results are illustrated in Figure 96.

From the figure it can be seen that the 1% AEP estimated flow is 871 m^3/s, with 5% lower and 95% upper confidence limit values of 244 m^3/s and 3140 m^3/s respectively. These flows were used to form hydrographs with the same peak and length of hydrograph times as the approximate PMF hydrograph.

Figure 96 RFFE model output (from currently disabled RFFE Arid Zone model)

RFFE About Limitations Publications Acknowledgments Changelog Logged in as ARR

Results | Regional Flood Frequency Estimation Model



*The catchment is outside the recommended catchment size of 0.5 to 1,000 km^2. Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	96.1	26.9	346
20	234	65.5	844
10	343	96.1	1240
5	504	141	1820
2	657	184	2370
1	871	244	3140

Input Data	
Date/Time	2018-05-23 14:24
Catchment Name	Catchment1
Latitude (Outlet)	-31.6732
Longitude (Outlet)	138.1539
Latitude (Centroid)	-31.81
Longitude (Centroid)	138.48
Catchment Area (km^2)	1800.0*
Distance to Nearest Gauged Catchment (km)	29.39
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.650485
2% AEP 6 Hour Rainfall Intensity (mm/h)	13.991619
Rainfall Intensity Source (User/Auto)	Auto
Region	Arid and Semi-arid
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto

C4.3 Downstream Boundary Conditions

The downstream boundary conditions for the hydraulic model were set as stage-discharge relationships. The shapes of the floodplain at the boundary, as well as its slope, were based on the LiDAR data. The TUFLOW software uses this information to automatically calculate the stage-discharge relationship at each boundary location. The location of the boundaries is illustrated in the schematic model layout, Figure 94.

C4.3 Model Outputs

The model was run for the PMF, RFFE and 5% and 95 % confidence limit flood events. 2D model map outputs (results) were produced for the following variables:

- Height
- Depth
- Velocity
- Bed shear stress
- Stream power

The results were produced as a time series at 15 minute intervals throughout the simulation, as well as maximums for each simulation.

C5 Stage One Results and Discussion

For Stage One Part A, the TUFLOW model was run for the approximate PMF flood event. While model outputs were obtained for flood heights, depths, velocities, bed shear stress and stream power, only the depths were mapped. This was done to determine whether the site was likely to be inundated. If the site was inundated, it was a trigger to progress to Stage One Part B and subsequently the more detailed hydraulic modelling included in Stage Two. The approximate PMF depth map is illustrated in Figure 94.

As can be seen from Figure 94, the site is subject to flooding from the approximate PMF to a depth of around 1m. Given this, the modelling progressed to Part B, with the RFFE 1% AEP flows.

For Stage One Part B, the model was run for the three RFFE 1% AEP flood events. The depth results were mapped, as illustrated in Figure 95 to Figure 96. From the RFFE 95% upper confidence limit results, it was concluded that the site is likely to be inundated during large design flood events. As a result, it was recommended that the Stage Two hydraulic modelling proceed.

Figure 97 Approximate PMF flood depth

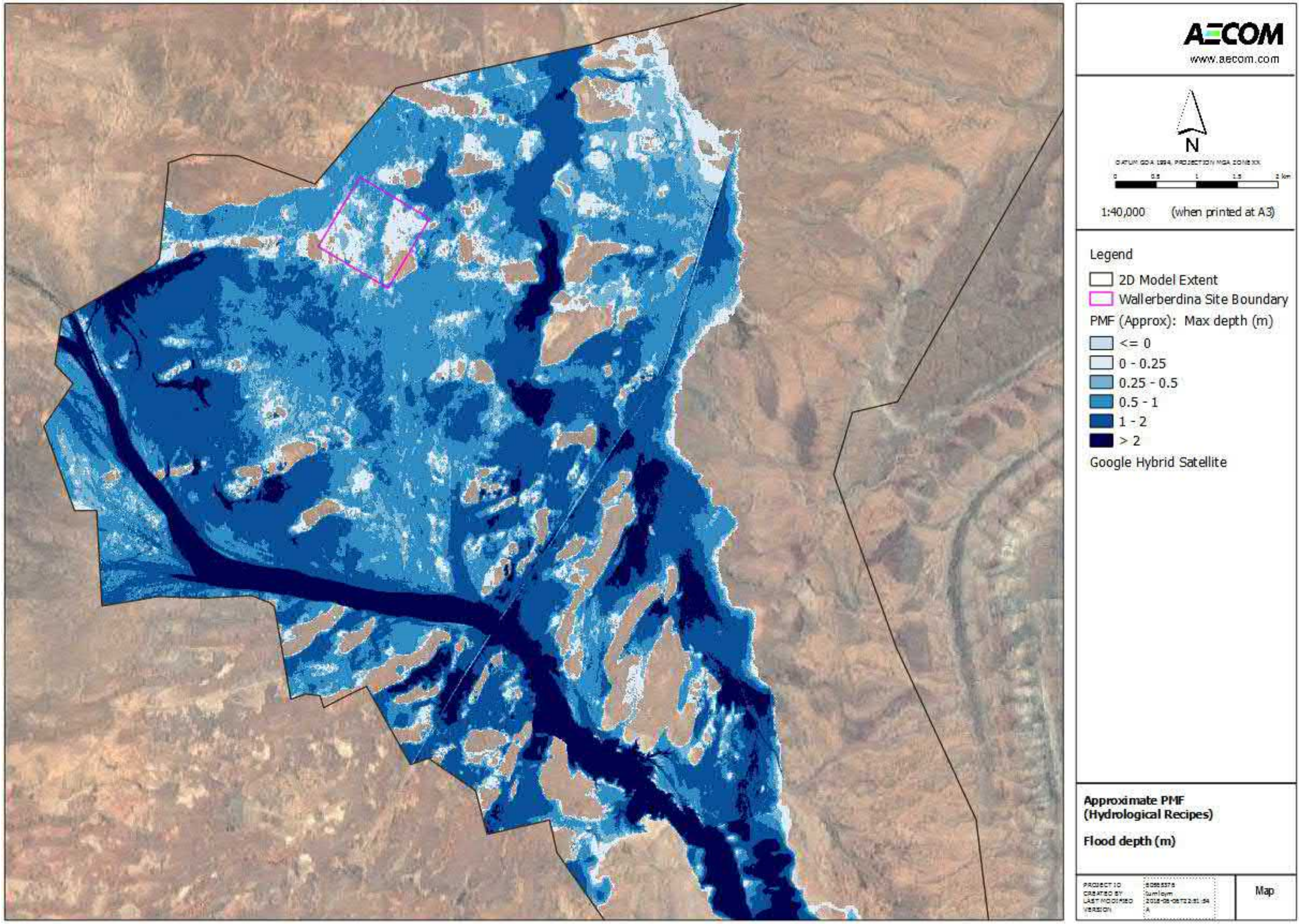


Figure 98 RFFE 1% AEP (5% lower confidence limit) flood depth

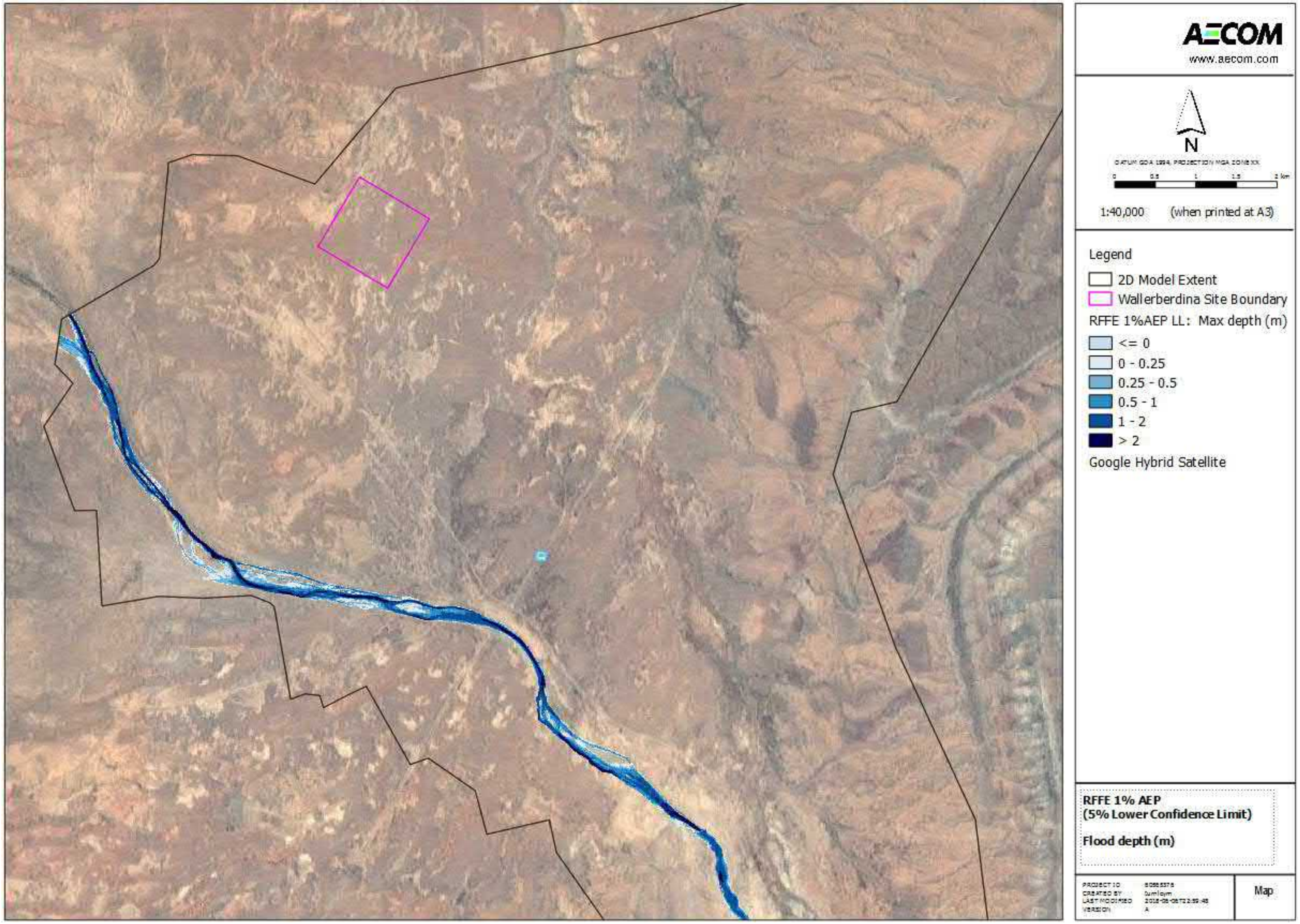

www.aecom.com
N
1:40,000 (when printed at A3)
Legend
2D Model Extent
Wallerberdina Site Boundary
RFFE 1%AEP LL: Max depth (m)
<= 0
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
Google Hybrid Satellite
RFFE 1% AEP
(5% Lower Confidence Limit)
Flood depth (m)
PROJECT ID
CREATED BY
LAST MODIFIED
VERSION
A
Map

Figure 99 RFFE 1% AEP flood depth

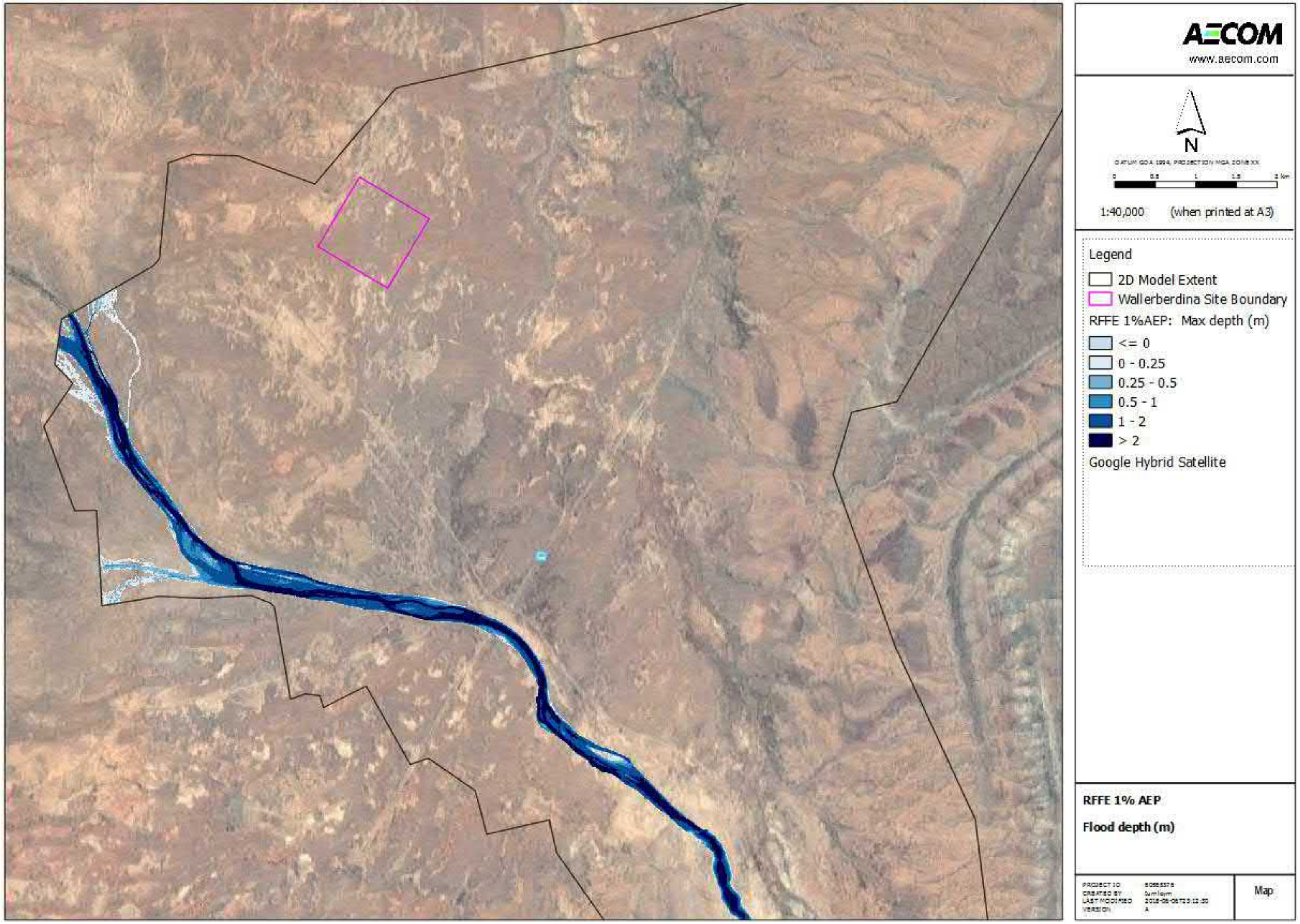
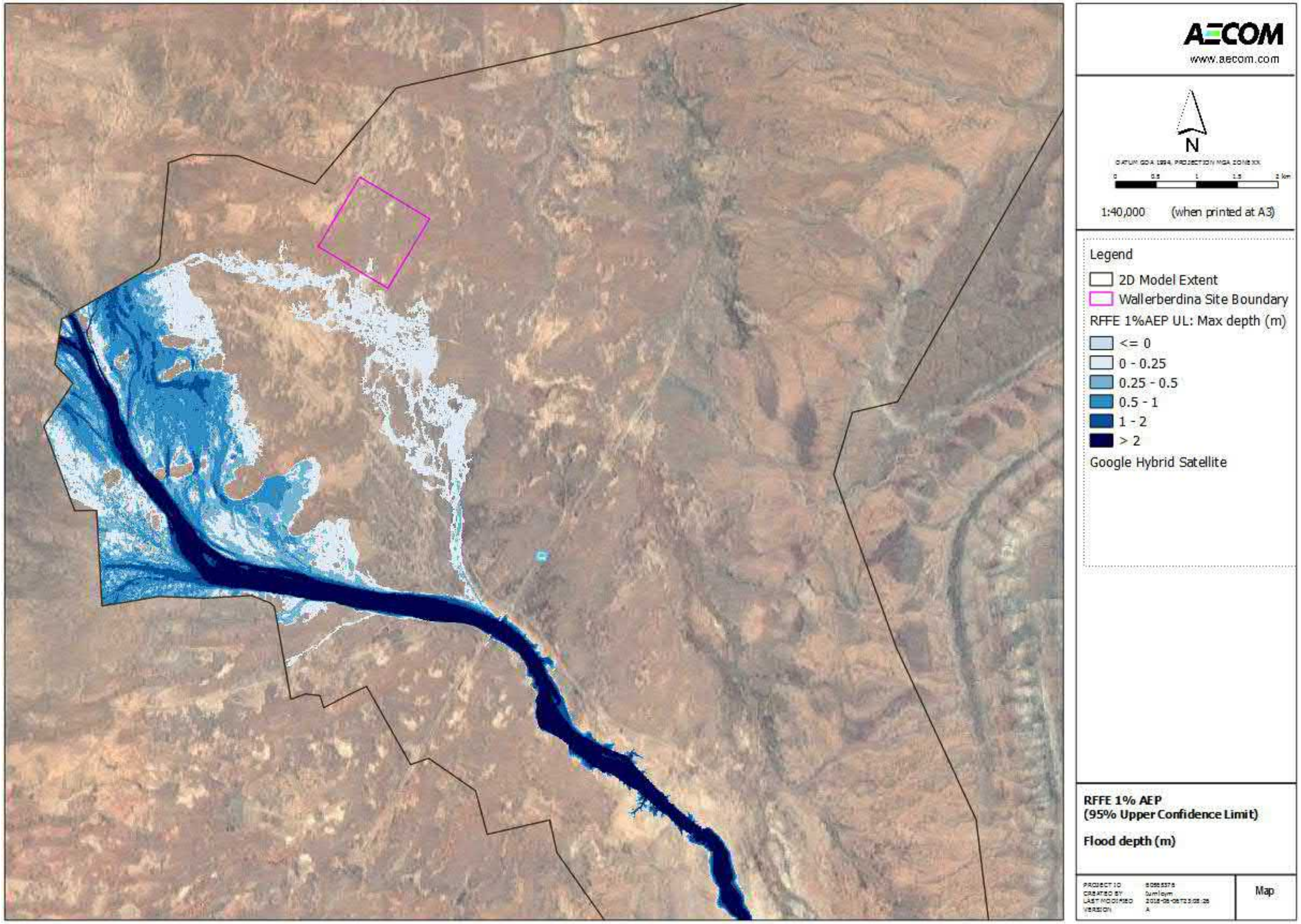


Figure 100 RFFE 1% AEP (95% upper confidence limit) flood depth



C6 Stage Two Results and Discussion

The hydraulic model was run for the hydrographs determined by the separate Hookina Creek Hydrology Study (HARC, 2018). The details of the methodology and results from the study are included in Appendix C. Table 71 presents a summary of the peak flows and critical duration storm.

Table 71 Summary of peak flows

AEP (1 in x)	Hookina Creek		Local Catchments	
	Peak Flow (m^3/s)	Duration (hour)	Peak Flow (m^3/s)	Duration (hour)
5	473	6	70	3
10	922	6	128	3
20	1490	9	193	3
50	2420	9	294	2
100	3180	9	376	2
1000	6120	9	671	2
2000	7140	9	771	2
PMF **	40500	3	3410	2

** *The PMF is a conservative estimate from the RORB model*

Key results from modelling were animated to provide the project's geomorphologist insight into flood behaviour and threshold values. From the results, it was shown that for events up to the 1 in 50 AEP, flows were largely contained within Hookina Creek and localised flowpaths distributed across the floodplain. For flood events larger than the 1 in 50 AEP, flows from Hookina Creek break out of the main channel downstream of railway bridge and move across the floodplain toward the site. Given this behaviour, flood animations were produced for all design events from the 1 in 50 AEP to 1 in 2000 AEP. The PMF was not animated due to its extreme nature. A summary of the animations produced is presented in Table 72.

Table 72 Summary of result animations

AEP (1 in x)	Parameter	Filename
50	Bed shear stress Depth Stream power Velocity	WA_Run_004_50yr_bed_shear_stress.avi WA_Run_004_50yr_depth.avi WA_Run_004_50yr_stream_power.avi WA_Run_004_50yr_velocity.avi
100	Bed shear stress Depth Stream power Velocity	WA_Run_004_100yr_bed_shear_stress.avi WA_Run_004_100yr_depth.avi WA_Run_004_100yr_stream_power.avi WA_Run_004_100yr_velocity.avi
1000	Bed shear stress Depth Stream power Velocity	WA_Run_004_1000yr_bed_shear_stress.avi WA_Run_004_1000yr_depth.avi WA_Run_004_1000yr_stream_power.avi WA_Run_004_1000yr_velocity.avi
2000	Bed shear stress Depth Stream power Velocity Velocity (full model extent)	WA_Run_004_2000yr_bed_shear_stress.avi WA_Run_004_2000yr_depth.avi WA_Run_004_2000yr_stream_power.avi WA_Run_004_2000yr_velocity.avi WA_Run_004_2000yr_velocity_whole_model.avi

Figure 101 1 in 5 AEP Maximum Flood Depth (m)

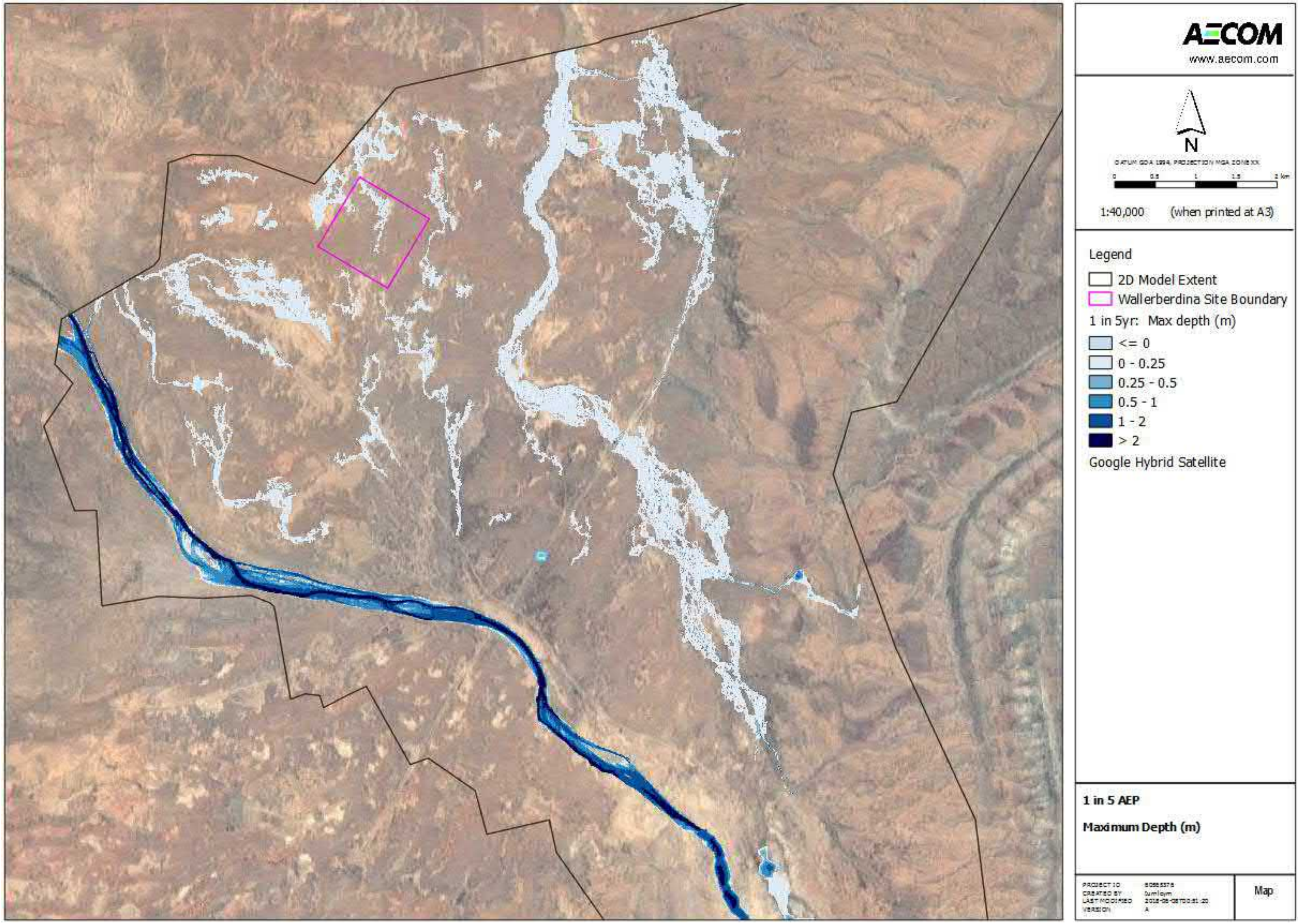


Figure 102 1 in 10 AEP Maximum Flood Depth (m)

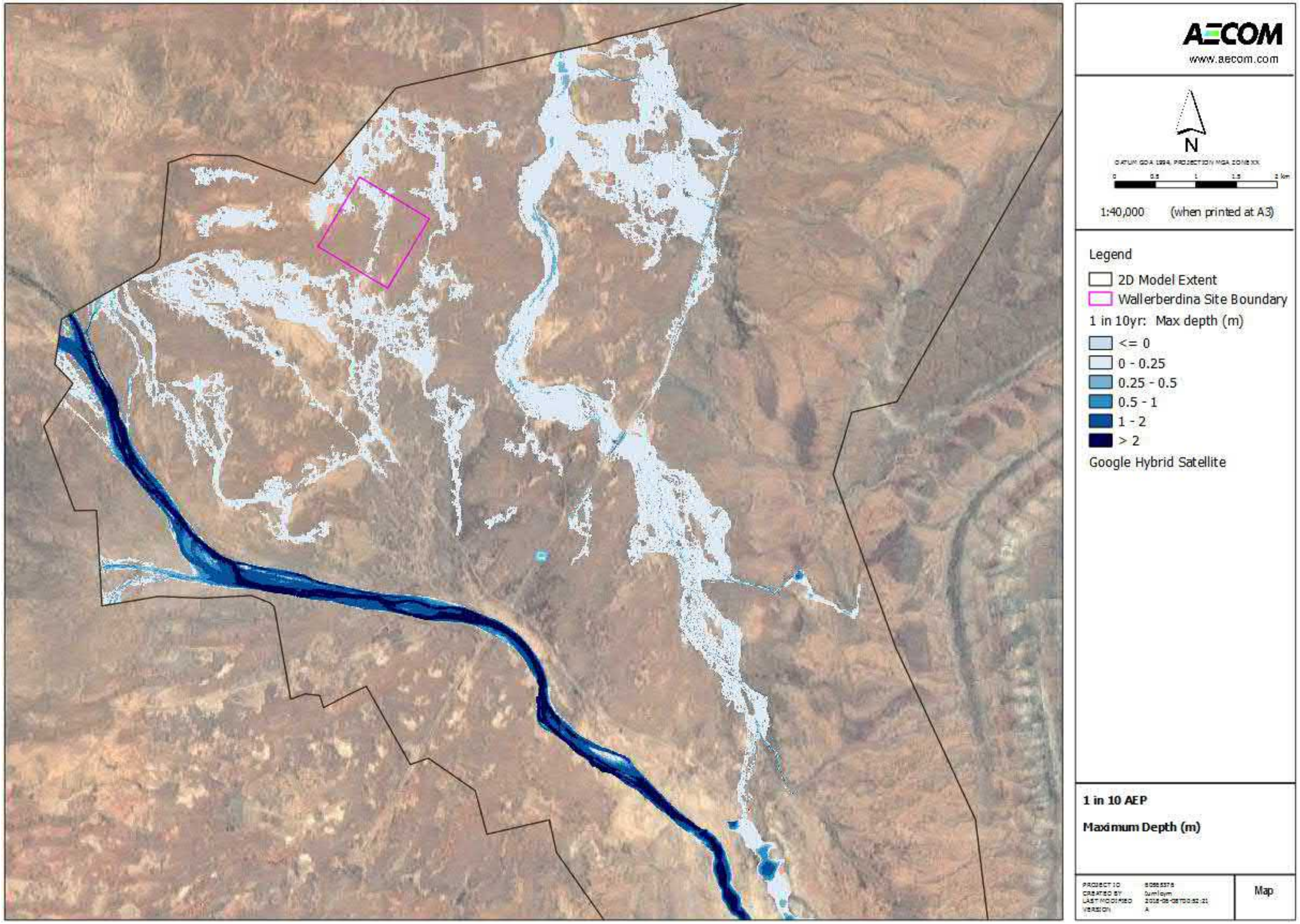


Figure 103 1 in 20 AEP Maximum Flood Depth (m)

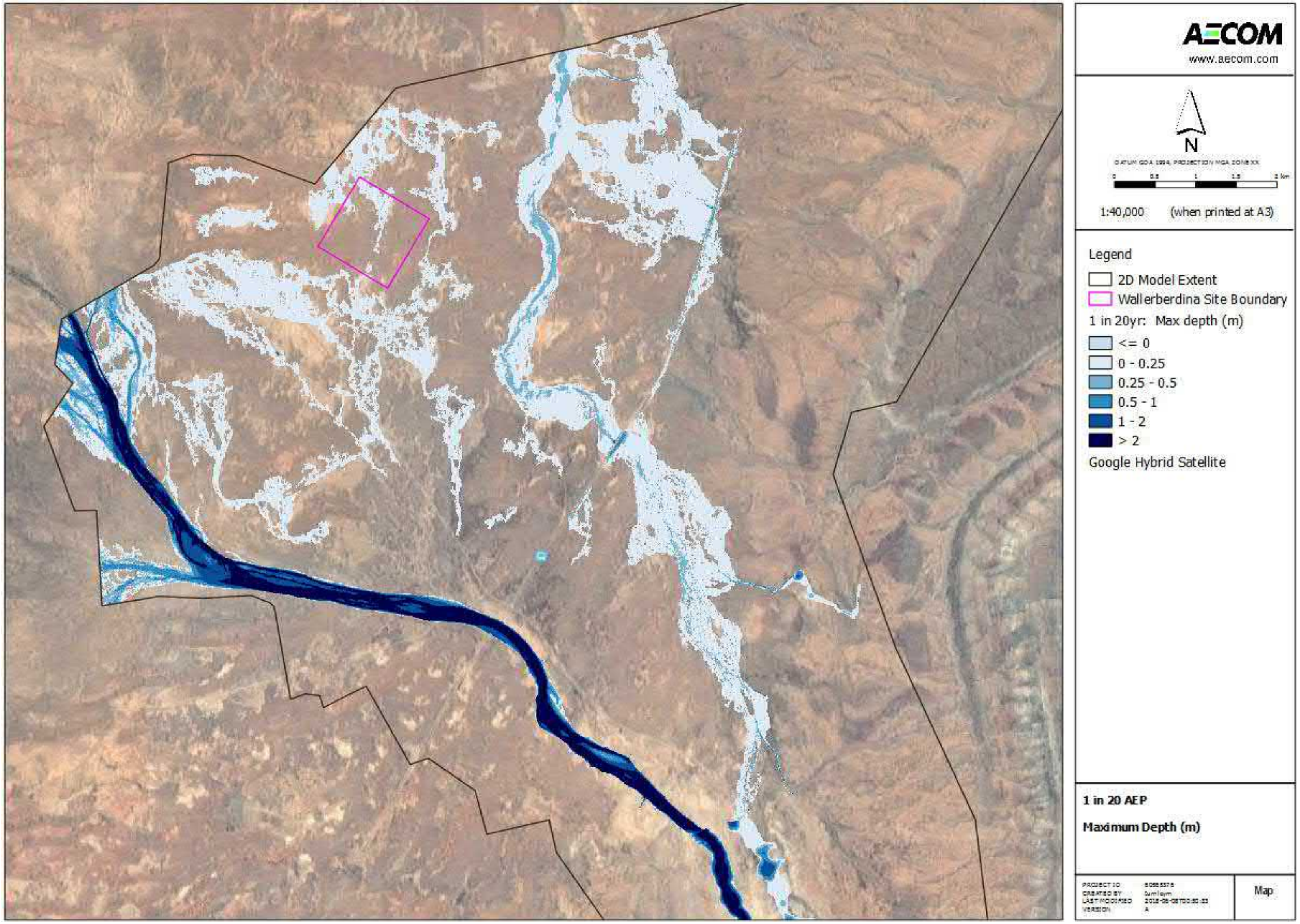


Figure 104 1 in 50 AEP Maximum Flood Depth (m)

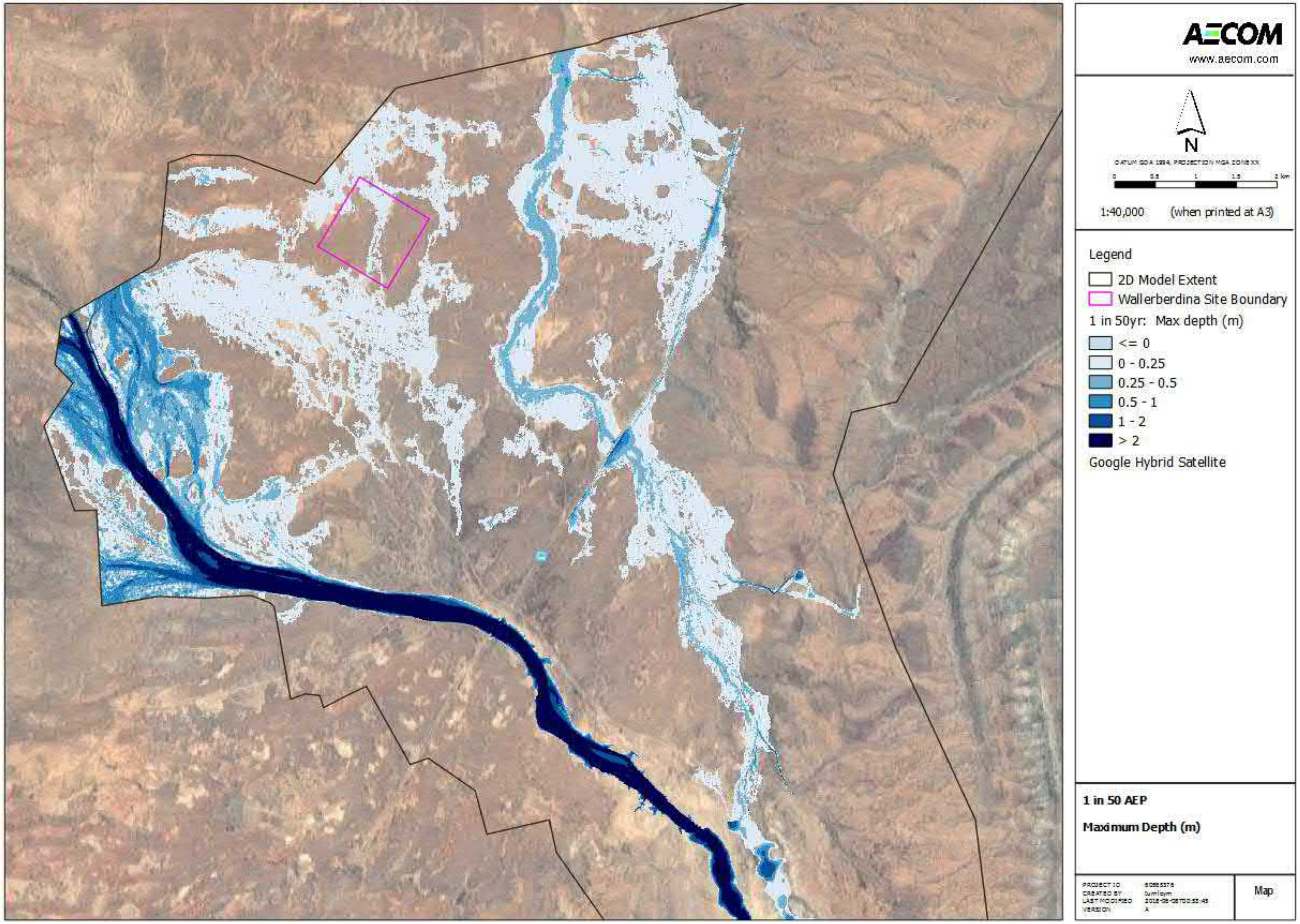


Figure 105 1 in 100 AEP Maximum Flood Depth (m)

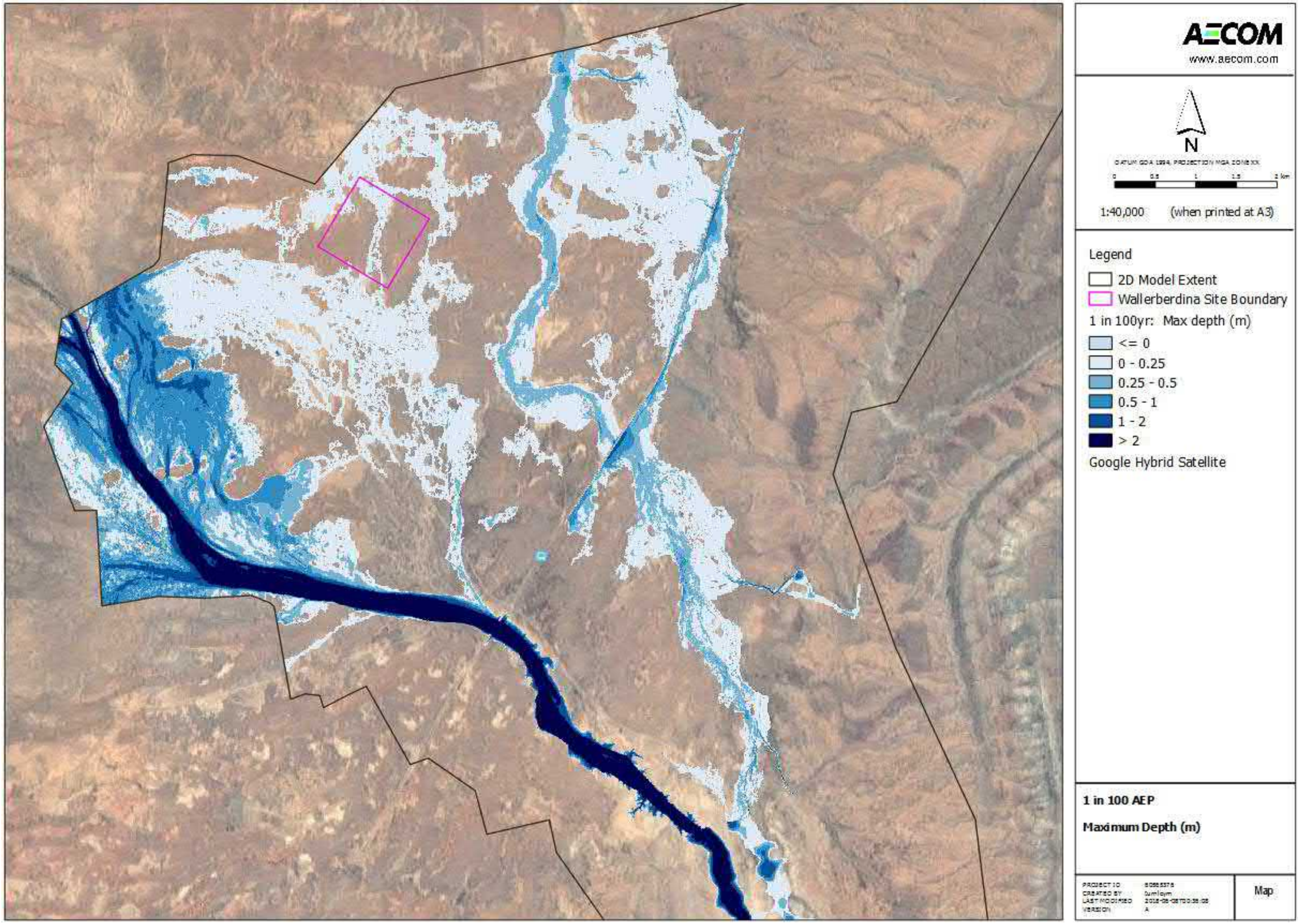


Figure 106 1 in 1000 AEP Maximum Flood Depth (m)

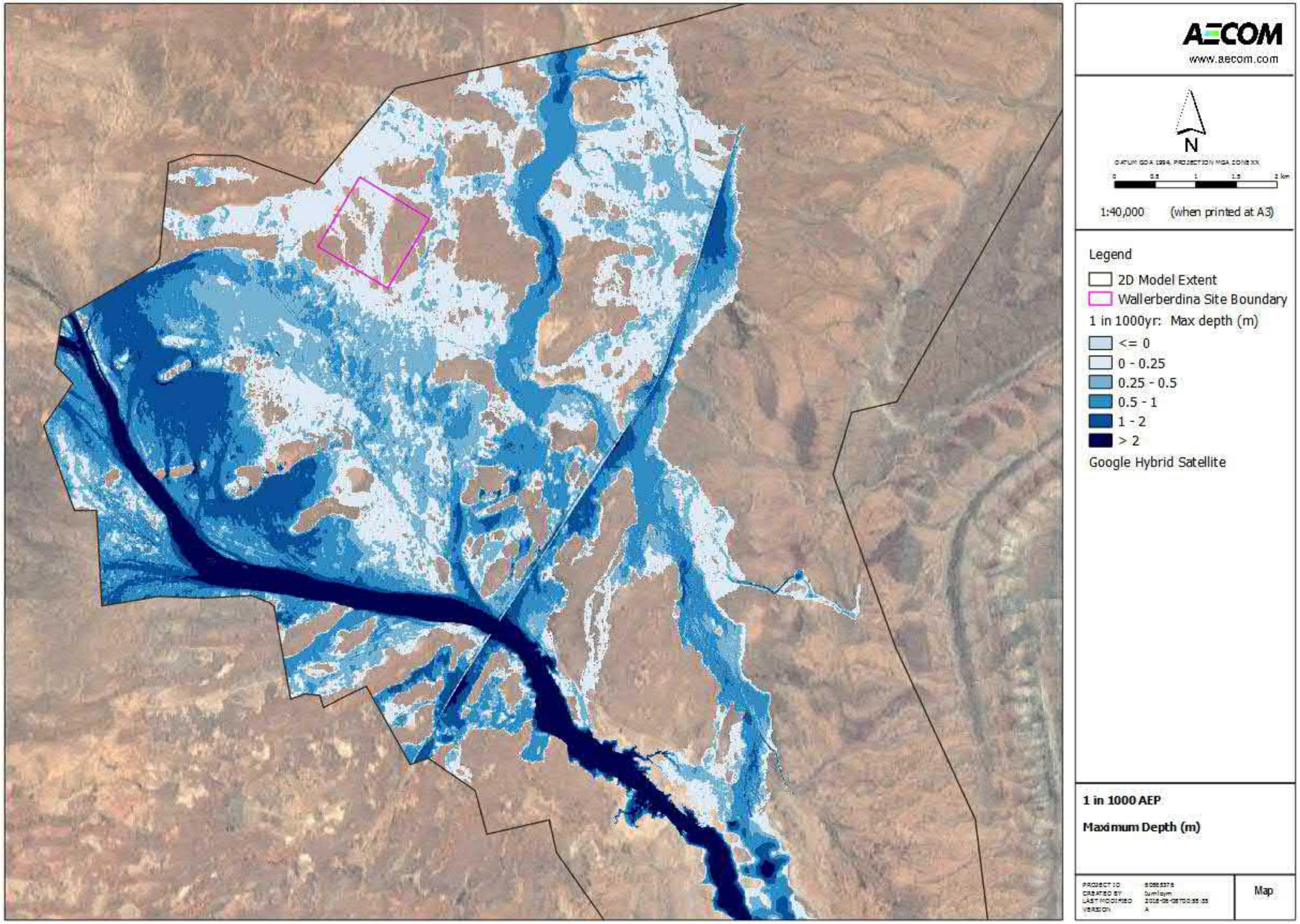


Figure 107 1 in 2000 AEP Maximum Flood Depth (m)

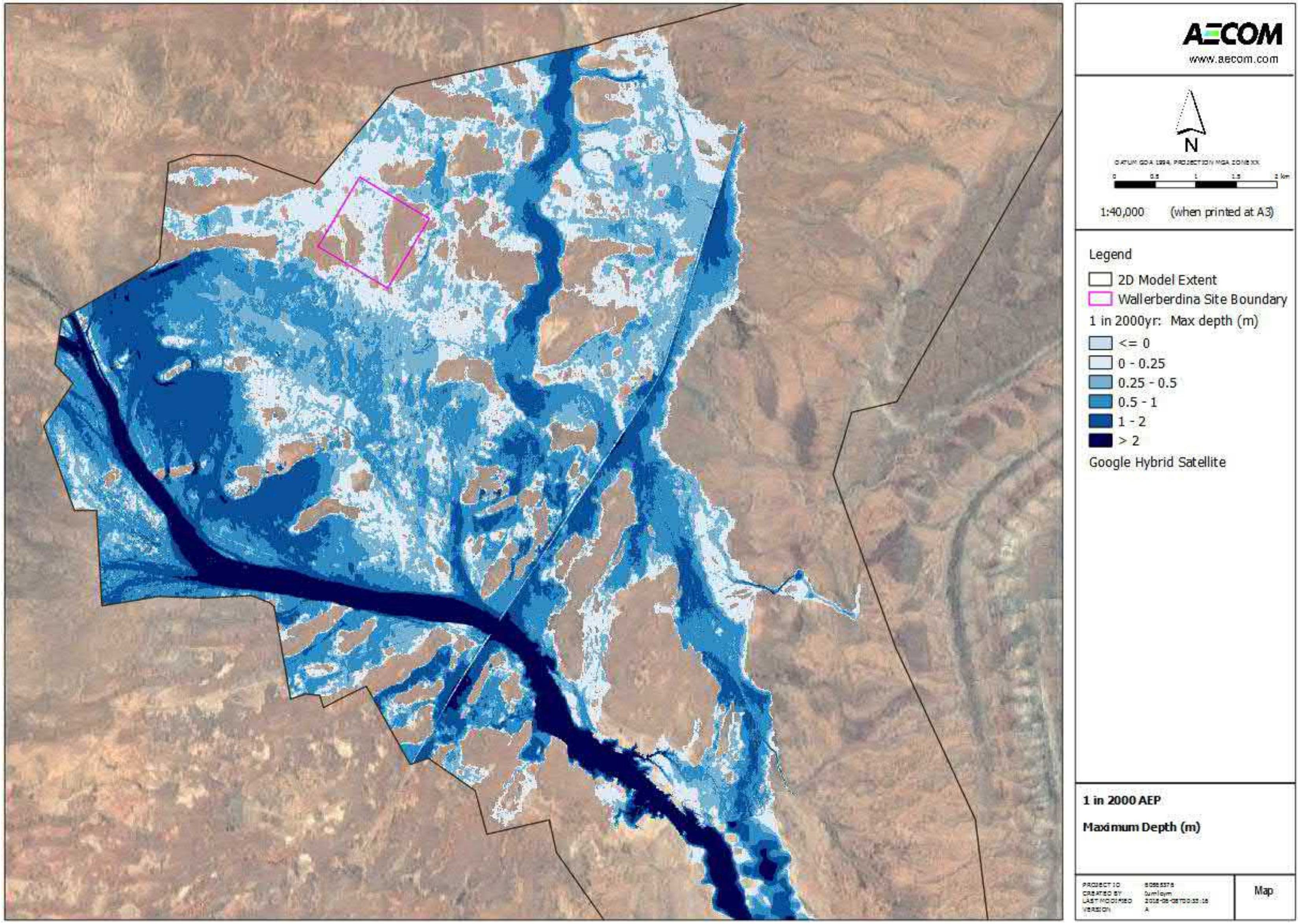
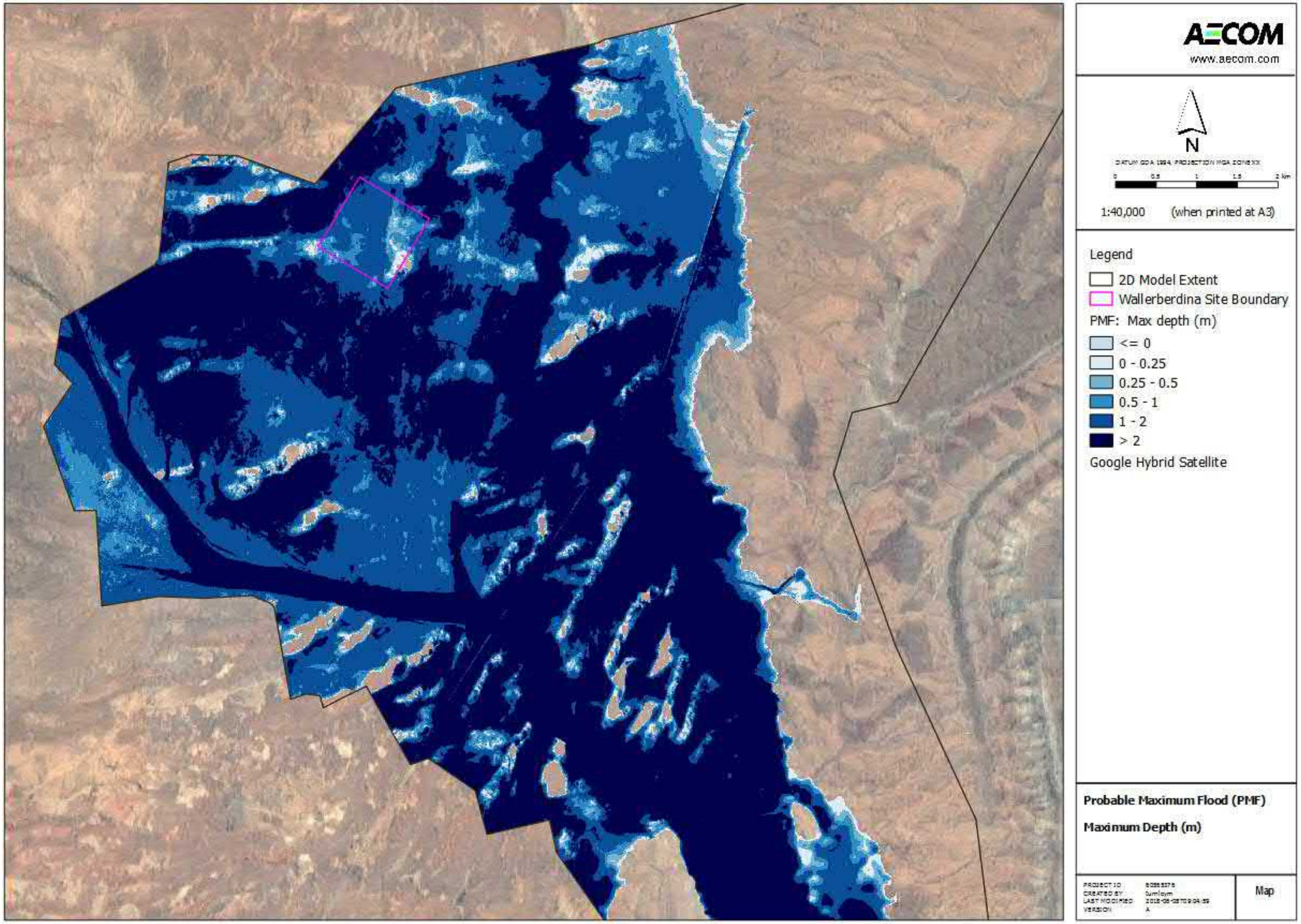


Figure 108 PMF Maximum Flood Depth (m)



C7 Conclusion and recommendations

The Wallerberdina site was hydraulically modelled to determine the flood behaviour of the region under different design flood events. TUFLOW was used to model the behaviour using design floods estimated from a RORB hydrological model (Appendix C). The modelling results were mapped and animated using GIS.

The results determined that the site is subject to local and catchment wide flooding. Local catchment runoff surrounding and through the site is relatively shallow, generally in the range 0 to 0.25m. This could the mitigated through design. Catchment wide flooding, emanating from breakouts from Hookina Creek and from the distributary / non-perennial stream, poses a more significant constraint. For events larger than 1 in 50 AEP, flows break out from Hookina Creek just downstream of the main railway bridge and head toward the site. In the 1 in 1000 and 1 in 2000 AEP flood events, the depths of flooding on the site are typically in the range 0.25 to 0.5 m, with isolated areas up to 1m deep. These are significant and will require the investigation and deign of appropriate mitigation measures.

The results, in particular the animations of flood behaviour, were provided to the project's geomorphologist for review. The animations included flood depth, velocity, bed shear stress and stream power at 15 minute increments throughout each flood event. Outcomes from the review were incorporated into the Landscape and Landforms assessment.

Appendix D

Geology, Hydrogeology and Geochemistry, Geotechnical and Soil

Appendix D Geology, Hydrogeology and Geochemistry, Geotechnical and Soil

Inferred Lithological Profile

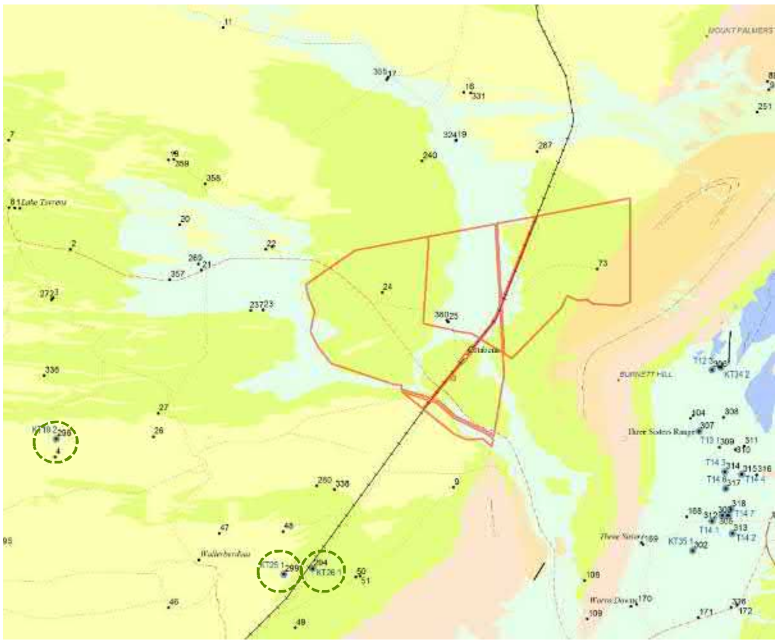
SARIG and WaterConnect database searches show limited lithological profiles.

General information on potential depth to basement was provided by Wayne Crowley (Principal Geologist – Geological Survey of South Australia – GSSA - email query response 10 January 2018). Feedback indicates that the subject site is located on the plains between the Flinders Ranges and Lake Torrens. Due to its proximity close to the ranges, shallow basement (of the rocks comprising the ranges) might be expected to be present, and become generally deeper westwards. GSSA drillholes are noted the GSSA Drillholes Stratigraphy GIS layer within, or closer than 8 km to the Wallerberdina property. The Drillholes Stratigraphy GIS layer (viewable and downloadable on SARIG) is a geologist verified interpretation of the stratigraphy of boreholes. The closest holes to the Wallerberdina property are, to the southwest, and in a similar geological setting:

- KT192 basement at 209 m
- KT251 basement at greater than 66 m
- KT261 basement at 101 m.

The locations of these drill holes are shown with a green circle below and support the interpretation that basement depths increase away from the ranges based on KT192 being the most westerly investigation location.

Figure 109 Map provided by Geological Survey of SA showing SAGRIG drillhole locations



A WaterConnect registered bore search for a 10 km radius from the centre of the site provides four driller's log descriptions available for bores on the western side of the ranges which are included a summary table.

The drillers' lithological descriptions for units 6534-324, 6534-355 and 6534-360 suggest a full thickness of unconsolidated sediments extending up to 57 m bgs. Inferred basement is encountered based on the drillers' description of competent logs at 6534-284 (shale from 45 m bgs).

Drillers' Logs downloaded from WaterConnect 06/03/18

Unit Number	Date logged	Driller's Name	Logged depth from (m)	Logged depth to (m)	Lithology Code	Description
6534-287	25/03/1999	THOMAS D D	0	10	CLYU	Red clay with hard bars
			10	15	CLYU	Yellow clay
			15	45	CLYU	Mainly white clay with some pink seams
			45	58	SHLE	Blue shale
			58	59	ROCK	Broken blue rock
			59	64	ROCK	Hard blue rock
6534-324	7/07/2006	THOMAS D D	0	7	CLYU	Silty brown clay
			7	42	CLYU	Stiff brown clay
			42	43	SAND	Sand and gravel, cutting water
6534-355	2/02/2015	WAGENKNECHT P	0	3	CLYU	Red CLAY
			3	9	CLYU	Sandy CLAY with limestone chips
			9	13	CLYU	Red CLAY
			13	17	SAND	Red clayey SAND
			17	19	CLYU	Sandy CLAY and gravel
			19	21	SAND	Red SAND and gravel
			21	30	SAND	Red SAND with sandstone bands
			30	38	SAND	Red SAND with clay bands
			38	39	LMST	Hard LIMESTONE
			39	48.5	CLYU	Red sandy CLAY
			48.5	51	SAND	Red SAND
			51	57	CLYU	Red sandy CLAY
6534-360	1/06/2016	WAGENKNECHT P	0	13	CLYU	Red silty CLAY
			13	44	CLYU	Red and brown sandy CLAY with gravel layers

Note:

AECOM inferred changes in broad rock type key:

Unconsolidated sediments

Weathered basement

Basement

Daishsat identified historical mining tenement reports that identified a detailed diamond core log (DH ET_01) associated with exploration north of Wallerberdina Station (SARIG company report ENV11925 by Salisbury Resources Limited). Details on the SAGRIG report are included in Daishsat's report (Appendix D) with the log included below. The location of this exploration drill hole approximated from the map provided by Daishsat is shown on Figure 109 and is at a similar distance away from the base of the Flinders Ranges. The log presented suggests competent rock is not encountered until approximately 207 m bgs (described as a brecciated mudstone). The lithological log also shows that the uppermost 100 m of the geological sequence is dominated by clay sediments. Clays have low permeability and thus impede groundwater flow and its presence and thickness is favourable when considering scenarios where the restriction of groundwater flow is advantageous.

Figure 110 Drill Hole DH ET_01 (from SAGRIG Company Report No. ENV11925)

DRILL HOLE RESULT

Drill Hole Coordinates 0240996E 6501157N

From (m)	To (m)	Graphic Log	Lithological Log	Formation	Age
0	10		Bn clay & gravel pebbles		Quaternary
10	34		Choc bn clay-qtzite frags	Neuroodla	Tertiary
34	58		greyish bn clay & qtzite frags	Neuroodla	Tertiary
58	86		Bn clay	Neuroodla	Tertiary
86	104		Greyish Grn-bn clay	Neuroodla	Tertiary
104	120		Grey Grn clay	Cotabena	Tertiary
120	160		Light bn fine sand & silt	Cotabena	Tertiary
160	207		Dk Grey/blk f sand/silt carbonaceous	Cotabena	Tertiary
207	233		Pink brecciated mudstone	Curdimurka sub-group	Adelaidean
233	246		Brecciated qtzite Diss pyrite	"	Adelaidean
246	253		Brecciated mudstone	"	Adelaidean
253	269		Carbonate/lst breccia disseminated pyrite	"	Adelaidean
269	280		Sandst breccia	"	Adelaidean
280	304		alternating sltst/sst breccia + Carb Disseminated pyrite & hematite	"	Adelaidean
304	327.6		Basic volcanics brecciated chlorite & epidote	Wooltana/ Beda Volcanics	Adelaidean

An exploration hole drilled using rotary blade and mud (CT4) is located approximately 9 km south of the site also provides indicative information on the stratigraphic sequence in the vicinity of the site.

The bore completion report is attached to this appendix and infers the following sequences were intersected:

Depth Range	Interpreted Sequence CT4
0.0 - 135.0 metres	Pliocene (Recent)
135.0 – 242.0 metres	Namba Formation (?Miocene)
242.0 – 280.2 metres	Upper Eyre Formation (?Eocene)
280.2 – 313.0 metres	Lower Eyre Formation (?Eocene)

It is noted that lignite and lignitic clayey sand was inferred to comprise as the last unit of CT4 (Lower Eyre Formation) despite drilling loss recorded from 300 m to the base of the hole (313 m). Lignite is a precursor to black coal, typically brown to black in colour and may retain some of the original peat (organic matter) structure or texture. Notes within SARIG Env03171 report containing the CT4 log suggest a preliminary interpretation of Quaternary sediments to a depth of 113 m overlying Tertiary aged Neuroodla Formation (113 to 280 m) overlying Cotabena Formation (280 m to 313 m). This is consistent with the lithology of the DH-ET01 log provided in the SARIG Env11925 report.

The limited lithological information supports the preliminary interpretations of the site specific seismic data; specifically:

- Greater thicknesses of unconsolidated sediments are likely to increase with locations to the west, away from the ranges and towards the Torrens Basin. Well 6534-360, located approximately west of the site is logged by the driller as comprising unconsolidated sediments to the end of hole at 44 m bgs.
- Crystalline basement may be overlain by a significant thickness (>200 m) of Tertiary aged lacustrine and fluvial deposits likely comprising the Neuroodla and Cotabena Formations.
- The interpreted seismic survey data suggests horizontally layered strata with the top of competent rock approximately 30 to 50 m bgs which is unstructured until depths of greater than 260 m bgs.

Inferred Hydrogeological Setting

There is currently no site specific groundwater information indicative of the hydrostatigraphy or hydrogeochemistry underlying the nominated site within the Wallerberdina Station site. The results of the WaterConnect registered well search within a 10 km radius of the centre of the Wallerberdina Station site are shown on Figure 111.

A drilling program is planned to intersect the unconfined regional water table aquifer and to understand the top of the underlying consolidated rock profile including interaction between deeper water bearing horizons and the water table. Sampling and laboratory analysis of the saturated and unsaturated media will be incorporated into the intrusive fieldwork program.

Natural Resource Management Setting

The Natural Resources Management Act 2004 divides South Australia into eight regions. This is to ensure that the natural resources of each area are managed in an appropriate and sustainable way.

The WaterConnect database provides an overview of the Natural Resource Management (NRM) Regions and the management areas within those areas. A summary of the relevant management areas in relation to Wallerberdina Station is provided below.

Natural Resource Management zones for Wallerberdina Station

NRM Categories	Management Zone
NRM Region	South Australia Arid Lands (SAAL)
Surface Water Basin	Lake Torrens
Groundwater	• South Australian Arid Lands Non Prescribed Groundwater Area • Non-Prescribed Groundwater Management Zone - Low competition for resources with low consumptive use and use of the water resource is uncapped or has not been fully allocated.
Surface Water	• South Australian Arid Lands Non Prescribed Surface Water Area • Non Prescribed Surface Water Zone

The Wallerberdina Station location is situated within the South Australian Arid Lands NRM Region. DEWNR Tech Report 2012/01 (Watt *et al*, 2011) indicates the following:

- Nearly all groundwater in the Flinders Ranges occurs in weathered and fractured indurated sedimentary rock aquifers. Some limestone layers have dissolution cavities that can supply high yields. Minor aquifers also occur in unconsolidated sand and gravel sediments of Quaternary age at the base of the ranges.
- The regional distribution of groundwater salinity in the vicinity of the site to be variable but possibly brackish to saline.
- The regional distribution of groundwater standing water levels in the vicinity of the site are likely to be 20 to 50 m below ground level with variable well yields (<1 to >10 L/s but mostly <1 L/s).

Registered Bore Search Results

Database bore summary information for bores within a 10 km radius of the Wallerberdina Station site is attached.

Of note:

- Nine of the 26 registered wells identified within the search area are listed for stock use of which six are operational. Yields for wells vary between 0.13 L/s and 2 L/s with salinities between <2,000 mg/L Total Dissolved Solids (TDS) and ~8,300 mg/L TDS, averaging approximately 4,800 mg/L.
- Operational stock watering bores were drilled to between ~30 and ~50 m bgs with standing water levels ranging from ~12 to ~28 m bgs.
- Unit numbers 6534-24 (stock bore), 6534-25 and its replacement 6534-360 (named East Yallala Bore) and 6534-73 (named Murrays Bore) all lie within the Wallerberdina Station site but outside the nominated sites. Well 6534-269 is an operational stock bore located outside the Wallerberdina Station property boundary, approximately 4 km east. These wells were included in a reconnaissance study undertaken by AECOM. WaterConnect summary information and updated standing water level information is provided below. Well photographs are attached.
- The standing water level at 6534-360 was recorded at 29.3 m below the top of casing (m bTOC) in February 2018, slightly lower than originally recorded in June 2016 (28 m). This well was drilled to 44 m and water was intersected between 33 and 40 m bgs with a yield of 0.5 L/s. The driller's log for this well suggests that it is installed within unconsolidated sediments extending to the base of the well.

Figure 111 Summary of selected registered bores include the AECOM site reconnaissance – 21/02/18, basemap from WaterConnect on-line query 13/03/18

Supporting Information

A Department of Environment, Water and Natural Resources (DEWNR) study on the origins of Hookina Springs may provide some insight into deeper hydrogeological conditions at the site (Barnett *et al*, 2015).

It is noted that the Hookina Springs source is located approximately 10 km south of the Wallerberdina Station site within the Flinders Ranges and therefore it is not expected that there would be direct correlation between hydrogeological setting on the plains compared with that of the Springs' origin within the ranges.

Relevant extracts from the DEWNR report to this assessment:

> *"The geological outcrops appear to be much more complex than the published geology suggests. The occurrence of lush vegetation coincides with two south-west to north-east trending faults that seem to control the direction of Hookina Creek and a tributary. This suggests that faulting may provide a conduit for groundwater discharge from deeper aquifers, which appear to be the Wonoka Formation or possibly the Bonney Sandstone."*

Figure 112 Hookina Spring inferred source area (from Barnett et al, 2015)

Figure 2. Geology and source of springs

Figure 112 from Barnett et al (2015) shows inferred geology and faults in vicinity of Hookina Spring.

- *The springs were found not to have a readily distinguishable or accessible discrete source which is commonly observed in many other Springs elsewhere in South Australia. The flow appears to progressively increase downstream to the main Pungka Pudanha waterhole where the channel is restricted and was gauged by the Department of Environment, Water and Natural Resources (DEWNR) to flow at a reasonably constant 20 L/sec*[32]*.*
- *An indicator that groundwater discharge has been occurring for a considerable period of time is the presence of a very hard cemented conglomerate in the creek bed which appears just downstream of where the first signs of discharge were observed. The area of exposed conglomerate at the main waterhole exhibits widespread fracturing and local vertical upward displacement, which strongly suggests the area is still seismically and tectonically active. This is supported by anecdotal evidence from traditional owners who have regularly felt earth tremors in the area, and have observed less water in the waterhole, with the deeper pools appearing shallower.*

In addition Daishsat (Appendix D) identified potentially relevant information in the SARIG Company Report ENV11925 (p104) for the area to the north east of the site.

- *The Merna Mora area can be divided into two hydro-geological provinces:*

[32] Field reconnaissance by AECOM on the 26/05/18 indicated flow rates of 1.5 L/s at Hookina Waterhole and 1.6L/s at Hookina Springs.

  - *The Torrens Basin along the western margin which has generally poor-quality ground water with small yields (Read, 1987[33]) and,*
  - *The Flinders Ranges in which ground water of highly variable quality is stored in fractured and/or weathered indurated sedimentary rocks and minor aquifers in alluvium. Priess, W.V., 1999[34] reported bores at Commodore railway siding and Bunyeroo Creek to the north of Merna Mora yielded 4400kl/day with salinities of 550 and 1400 mg/L in Quaternary fine sand and gravel.*

- *Good quality water has been intersected near Brachina Gorge with yields of up to 20L/sec (Read 1987) and also occurs in a natural water hole at the entrance to Wilpena Pound. A recorded water intersected during coal exploration drilling in the Quorn/Hawker area with salinities ranging from 1962 – 10490 mg/L and flow rates of 0.2 – 1.4 L/sec.*

Assessment of Groundwater Beneficial Use

An assessment of the current and potential beneficial use of the groundwater within the regional water table aquifer at the site, predominantly made on information for bore 6534-360, has been made with reference to Section 3.4 of the SA EPA Guidance Document:

- SA EPA, 2009 – Site contamination: Guidelines for the assessment and remediation of groundwater contamination, February 2009.

The beneficial use assessment examines the suitability of current and future uses based on a number of criteria including:

- Aquifer characteristics that make it suitable for abstraction (e.g. hydraulic conductivity, saturated aquifer thickness, storativity, specific yield)
- Hydraulic connectivity and the potential for impacts to migrate between water bearing zones and affect beneficial use of other aquifers
- Existing nature and type of groundwater users in the area
- Realistic limitations on the basis of groundwater salinity.

The beneficial use assessment presents probable realistic uses mainly based on available salinity and yield data from the WaterConnect registered well search however supporting information has also been considered.

In addition, an assessment of the likely environmental values ascribed to the unconfined groundwater in the vicinity of the site has been undertaken with reference to the SA EPP Policy:

- SA EPP (Water Quality), 2015 -South Australian Environment Protection (Water Quality) Policy 2015 under the Environment Protection Act 1993. Government of South Australia.

[33] Read, RE 1987, *Flinders Ranges planning area, water resources and development*, Report Book 87/71, Department of Mines and Energy, South Australia
[34] Preiss, WV 1999, *The Adelaide Geosyncline of South Australia and its significance in Neoproterozoic continental reconstruction*, Report Book 99/00006, Geological Survey Branch, Department of Primary Industries and Resources South Australia, Adelaide

Applicable Environmental Value (EPP 2015) and Beneficial Use Assessment – Watertable Aquifer

Environmental Value	Probable Applicable Environmental Value (EPP 2015)	Probable Realistic Beneficial Use	Justification
Potable use	No as TDS >1,200 mg/L	Possible	Given the brackish salinity, variable yield and sparseness of wells within the area any significant use of the aquifer for drinking water purposes would require multiple wells and additional treatment (e.g. desalinisation) or dilution with rainwater. Give the lack of alternative water sources in the area potential utilisation of brackish groundwater for potable use cannot be discounted.
Aquatic ecosystems (fresh and marine waters)	Potential	Possible	At its closest point the Hookina Creek is located approximately 3 km southwest of the site. The creek is dry at this point and it does not appear to be receiving baseflow from groundwater discharge at this location. Groundwater-surface water interactions are not well understood. Potential for upward leakage from deeper aquifers upstream of site (Barnett *et al*, 2015).
Recreation and Aesthetics	Potential	Potential	Although recreational use is considered to be unlikely with no registered domestic bores located within 10 km radius of the site, potential for use of groundwater for domestic purposes such as use of shallow groundwater for filling swimming pools cannot be excluded if sufficient yields are available.
Industrial use	NA	Yes	Potential for commercial/industrial use of groundwater possible as limited well data suggests potential industrial use in the vicinity of the site if sufficient yields are available.
Agriculture (irrigation)	Potential as TDS <3,000 mg/L one well	No	Potential for use of groundwater for irrigation is considered marginal as only one registered bore reported TDS <3,000 mg/L. The Wallerberdina Station area is a pastoral farming district with no evidence of irrigated horticulture within a 10 km radius of the site.
Agriculture (stock watering)	Yes as TDS typically >3,000 mg/L but <13,000 mg/L	Yes	The available salinity and yield information suggests that stock watering is a beneficial use of groundwater beneath the Wallerberdina Station site and surrounds. This is confirmed by water quality testing of newly installed bores monitoring the watertable within the site.
Aquaculture	Yes as TDS typically >3,000 mg/L but <13,000 mg/L	Yes	Aquaculture is not considered a likely beneficial use of groundwater, however current or future use of groundwater for such purposes cannot be definitively excluded.

WELL COMPLETION REPORT

Drillhole C/T4 (EL371-1)

Drill hole C/T4 was drilled to obtain stratigraphic information on the Tertiary sequence on the eastern edge of the Pirie-Torrens Basin.

The hole intersected the following sequence:

0.0 - 135.0 metres	Pliocene - Recent
135.0 - 242.0 metres	Namba Formation (?Miocene)
242.0 - 280.2 metres	Upper Eyre Formation (?Eocene)
280.2 - 313.0 metres	Lower Eyre Formation (?Eocene)

The hole was drilled by Thompson Drilling Co. Pty. Limited Mayhew 1000 rig. 4.3/4" hole was drilled from surface to Total Depth of 313 metres using blade bits and a bentonite/natural clay/water mud stabilised with lignosulfonate. Cuttings samples were collected from the flow line every two metres of drilling and logged on site. On completion of drilling, SP, short normal resistivity, gamma ray and density logs were run in the hole by Geoscience Associates. The hole was plugged back to surface with sulfate resistant cement/mud and abandoned.

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COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Sheet 1

Project: Pirie-Torrens Basin Investigation E. L. 371 **Date:** 16th November, 1978 19

Hole No. C/T4 **Location.** 11km west of Motpena 31°44'S 138°10'15" E **Angle** 90° **Azimuth** **Collar R. L.** **Drilling Method.** Rotary Mayhew

Logged by S. K. Chaku **Drilled by** Thompson Drilling Co. Pty. Ltd. **Total Depth.** 310 metres

From metres	To metres	Advanced	Recovered	Sample No	Description	Assay						
0	2				reddish brown sandy clay							
2	4				reddish brown sandy-silty clay - clay dominating sand. Quartz grains							
					subrounded with other assorted sand grains							
4	6				reddish brown sandy-silty clay - proportion of sand to clay decreasing -							
					pliable clay							
6	8				white - with minor red brown - sandy clay. Most quartz grains sub							
					rounded and Fe stained. Soft							
8	10				as above							
10	12				as above							
12	14				as above							
14	16				very lt grey - with r. brown - sandy clay. r.b. clay dominant							
16	18				as above							
18	20				as above, with minor hard white sandy clay frags. Minor assorted							
					subrounded gravel pebbles							
20	22				hard white with r.b. patches of sandy clay - sand dominant. Quartz							
					grains subrounded, Fe stained, possibly calcareous							
22	24				as above							
24	26				light red med. grained sand with minor clay. Quartz grains subrounded							
					clean and Fe stained quartz mixed other assorted grains							
26	28				white with r. b. sandy clay - as at 20m - 22m							
28	30				lt. r.b. silty clay (with minor frags of hard white clay sand?)							
30	32				hard white, with minor r.b. patches of dominantly sand, subrnded qutz, Fe stained, calcareous							

Copies to: Project Geologist, Originator, Exploration Manager.

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Sheet 2

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Project: Date: 19

Hole No. C/T4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
32	34				as for 30m - 32m						
34	36				white to v. lt grey silty clay with minor hard white sandy clay frags						
36	38				lt grey to white silty sandy clay - soft - pliable						
38	40				as above						
40	42				hard r.b. to white lt grey clayey grit with silty clay as above						
42	44				soft lt grey to white silty clay - soft and pliable						
44	46				lt r.b. silty clay with minor hard frags						
46	48				lt brown silty clay						
48	50				as above						
50	52				as above						
52	54				lt r. brown silty clay with minor grey green clay						
54	56				as above						
56	58				as above						
58	60				hard lt brown to grey sandy grit with minor clay - hard drilling						
60	62				lt grey silty clay with minor hard grit frags						
62	64				hard sandy grit frags with silty clay as above (possibly silcrete band)						
64	66				lt r.b. silty clay with minor lt grey clay						
66	68				as above - with minor hard sandy grit						
68	70				as above - with minor purlish grey silty clay						
70	72				hard sandy grit with minor silcrete and minor gravel pebbles (subrnded)						
72	74				medium - coarse grained moderately sorted sand, gravel. 50% each approx.						
74	76				as above with minor sandy clay						

Copies to: Project Geologist, Originator, Exploration Manager.

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OH1

Sheet 3

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Project: Date: 19

Hole No. C/T_4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
76	78				as above						
78	80				as above						
80	82				as above with minor clay						
82	84				r. b. sand-silty clay with minor sand						
84	86				as above						
86	88				r. b. sand-silty clay with minor gravel						
88	90				r. brown with minor lt grey sand silty clay						
90	92				as above - stiff						
92	94				as above - stiff						
94	96				as above (with minor sand and gravel?)						
96	98				as above						
98	100				as above						
100	102				as above						
102	104				as above						
104	106				as above						
106	108				lt brown with lt grey silty clay - silt						
108	110				as above						
110	112				lt r. b. sandy clay with minor silcrete fragments						
112	114				lt r. b. sandy clay with minor lt grey sandy clay						
114	116				as above						
116	118				lt brown silty clay - stiff with minor sand -(or gravel?)						
118	120				lt brown silty clay - stiff - with minor grey patches						

Copies to: Project Geologist, Originator, Exploration Manager.

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Sheet 4

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Date: 19

Project:

Hole No. C/T4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
120	122				lt brown silty clay - stiff - with grey patches						
122	124				lt brown silty clay with grey patches (hard sand grit frags?)						
124	126				lt grey with lt brown silty clay						
126	128				lt grey clay with minor lt brown clay						
128	130				as above - minor sand?						
130	132				dominantly lt. grey clay - stiff - Fe mottled. Minor Fe mottled grit band						
					possibly very small						
132	134				lt grey clay with heavy Fe mottling - stiff						
134	136				lt grey green clay - minor Fe mottling - stiff						
136	138				as above						
138	140				as above						
140	142				as above						
142	144				as above						
144	146				as above						
146	148				as above with minor band Fe mottled - grit band						
148	150				as above						
150	152				lt grey clay - Fe mottled - stiff						
152	154				as above						
154	156				as above						
156	158				lt grey green clay - Fe mottled - stiff						
158	160				as above						
160	162				as above						

Copies to: Project Geologist, Originator, Exploration Manager.

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043

Sheet 5

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Project: Date: 19

Hole No. C/T_4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
162	164				Greenish grey clay - minor Fe mottling						
164	166				lt grey claystone with minor hard grit - Fe mottled - and sand						
166	168				sand with d. r. brown clay and minor lt grey clay						
168	170				lt grey claystone with minor d.r. brown clay and minor sand						
170	172				d.r. brown clay (Fe) with minor lt grey clay - sand						
172	174				as above						
174	176				as above						
176	178				dusky r.b. clay - Fe - with sand . Dark yellowish orange soft pliable						
					minor clay						
178	180				as above						
180	182				d. gray r.b. clay (sample considered contaminated)						
182	184				d. grey clay (not much sample-contaminated)						
184	186				d. grey olive clay - with soft white limestone (fizzes with acid)						
186	188				light-dark grey clay with minor soft white limestone						
188	190				light grey-olive grey clay with minor soft white limestone - soft and						
					pliable						
190	192				olive grey clay - pliable - stiff - with minor white soft limestone						
192	194				light grey to grey-green clay, stiff, with v. minor white soft limestone						
194	196				dominantly white soft (limestone) (calcareous clay) with minor light						
					grey clay						
196	198				light grey to white clay - soft - (with minor white calcareous clay						
					or limestone						

Copies to: Project Geologist, Originator, Exploration Manager.

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Sheet 6

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Project: Date: 19

Hole No. C/T4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
198	200				light grey to white clay - possibly calcareous						
200	202				light grey-green clay with some Fe mottling						
202	204				light grey-green clay with minor white calcareous white clay						
204	206				dark yellowish orange soft pliable clay with minor dark red clay (Fe						
206	208				as above						
208	210				as above with minor (?) sand (stained quartz gravel poorly sorted,						
					subrounded, medium grained)						
210	212				as above						
212	214				as above with dark red brown sandy grit clay, few (gypsum) frags						
214	216				as above						
216	218				dark greyish olive green claystone - stiff						
218	220				as above						
220	222				greyish olive green claystone - stiff						
222	224				as above						
224	226				greyish olive green claystone - massive - stiff						
226	228				greyish green claystone, massive with minor limestone						
228	230				as above						
230	232				greyish olive green claystone with some dark tones, with minor lst						
232	234				greyish olive green claystone						
234	236				greyish olive green claystone with some dark tones,						
236	238				as above with minor limestone						
238	240				as above						

Copies to: Project Geologist, Originator, Exploration Manager.

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045

Sheet 7

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Date:

Project:

Hole No. C/T4 . Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay				
240	242				greyish olive green claystone with hard dusky red brown claystone, sandy					
242	244				as above					
244	246				dark red brown clayey sand with hard gritty sandstone					
246	248				dark red brown sandy clay with hard gritty sandstone					
248	250				dark red brown sandy clay with (hard gritty sand stone)					
250	252				grey green claystone with hard white limestone (with minor sandy clay)					
252	254				as above					
254	256				grey green claystone with minor sandy clay					
256	258				grey green claystone with white to off-white limestone (in places hard)					
258	260				grey green claystone					
260	262				grey green claystone with dark olive grey claystone					
262	264				as above					
264	266				grey green claystone					
266	268				as above					
268	270				as above					
270	272				as above					
272	274				as above					
274	276				as above					
276	278				grey green claystone with carbonaceous mud					
278	280				carbonaceous dark grey mudstone or clay (possibly lignitic)					
280	282				as above					
282	284				carbonaceous mudstone or clay - minor pyrite					

Copies to: Project Geologist, Originator, Exploration Manager.

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sheet 8

COMMONWEALTH ALUMINIUM CORPORATION LIMITED
EXPLORATION DEPARTMENT
DRILLING LOG

Project: Date: 19

Hole No. C/T_4 Location. Angle Azimuth Collar R. L. Drilling Method.

Logged by Drilled by Total Depth.

From	To	Advanced	Recovered	Sample No	Description	Assay					
284	286				carbonaceous mudstone - considerable amount of pyrite -(could						
					possibly be minor sand)						
286	288				carbonaceous mudstone - minor pyrite						
288	290				as above						
290	292				carbonaceous mudstone						
292	294				carbonaceous mudstone - minor pyrite						
294	296				clean pyritic quartz sand with carbonaceous clay. (Sand very minor						
					amount) (very large grains of pyrite)						
296	298				clean pyritic quartz sand (very small sample)						
298	300				clean pyritic sand with minor carbonaceous mud or clay (v. small sample)						
300	302										
302	304										
304	306				almost no sample returned. May be carbonaceous clay mudstone sequence						
306	308				with clean pyritic quartz sand						
308	310										
					END OF HOLE						

Copies to: Project Geologist, Originator, Exploration Manager.

(3171-8)

COMALCO

SOUTH AUSTRALIA
LAKE TORRENS

EL 371 C/T4

COMPOSITE WELL LOG - DRILL HOLE ~~C/T3~~

Compiled: A.H.W.	Revised:	Drawn: S.H.
Date: March, 1979	Scale: 1 : 200	Drg No: S.A. - 79 - 148

Location:
Latitude 31°44'00" S
Longitude: 138°10'15" E

Date Spudded: 16 - 11 - 78
Date completed: 17 - 11 - 78

Drilled by: Thompson Drilling Co.
Drill: Mayhew 1000
Well site Geologist SKC / GC

Logged by: Geoscience Associates
Logging unit: AL - 7
Logger: Waldron

Elevation: m a.s.l.
Casing: Nil
Hole diameter $4\frac{3}{4}$" from 0 to T.D. 312
from to

Logs run:	S.P.	Resistivity:		Gamma ray:	Density
Logged depth	313·2 m	312·6 m		312·6 m	312·2 m
S.P. scale	080	Resistivity scale: Hi	Range (Full scale)	200	10 K
Paper speed:	1 cm/m	1 cm/m		1 cm/m	
Logging speed	9 m/min	9 m/min		9 m/min	9 m/min
Probe size:	2"	2"		2"	
Type:	$\frac{3}{4}$" x 1"	$\frac{3}{4}$" x 1"			
Bias:	080	- 1000			

Background count cps. 12
Probe number: 326
Time constant: 2 sec — 0·5 sec
Standard (cps): 4327
Dead Time: 6
Amp gain: 600 — 600
Ratemeter No 906
K factor $3·9 \times 10^{-6}$
Rmf 0·3 ohms at 38 °C

Digital readout
Time base (sec)
Rm 0·25 ohms at 39 °C

Bore Hole medium bentonite / water B.H.T.

Sand / sandstone
Silt / siltstone
Dolomite
Clay / claystone
Limestone
Gravel / conglomerate
Lignite / coal
Sandy / silty / clayey

py - pyritic qtz - quartzose fld - feldspathic lit - lithic mic - micaceous carb - carbonaceous

BIT TYPE | CASING & PLUGS | LITHOLOGY PERCENTAGE LOG | DEPTH (m) | INTERPRETED LITHOLOGY | S.P. | RESISTIVITY | GAMMA RAY | γ γ (DENSITY) | LITHOLOGICAL DESCRIPTION | STRATIGRAPHIC COLUMN

P.B.T.S. Hughes Blue Devil
60 sacks sulfate resistant Portland A cement

LITHOLOGICAL DESCRIPTION

- Clay, reddish brown, sandy, silty sand grains are qtz, sub rounded, Fe stained
- Clay, white, soft sandy
- Clay, light grey - brown, sandy
- Clay, hard, white, with patches of red - brown clay, locally very sandy
- Sand, qtz, medium grained, sub rounded
- Clay, white, silty, soft
- Clay, red - brown, silty
- Clay, white to red brown, silty
- Grit, hard, sandy, possibly silcreted
- Clay, as above
- Gravel, sandy, medium coarse
- Clay, as above
- Sand, grit and pebbles, fe stained, clayey
- Clay, as above
- Sand, grit and pebbles
- Clay, red - brown, sandy, silty
- Clay, light brown, sandy, stiff
- Clay, ~~light grey~~, stiff r/b sandy
- Clay, light ~~grey~~, sandy, stiff brown Minor grey
- Clay, light grey, hematite blebs mottled
- Clay, light grey - green
- Clay, dk red - brown
- Clay, dk gy
- Lime mud, white, soft
- Lime mud, white, soft
- Clay, light grey - green, soft plastic, with sandy bands
- Sand, qtz, subrounded, med grained
- Clay, yellow - orange, passing down to olive green, stiff claystone.
- Sandstone, gravelly, qtz
- Clay, olive - green, stiff
- Clay, gravelly, pebbly, sandy with sand lenses
- Clay, as above
- Lime, mud, white, soft
- Clay, olive - green, with patches of white lime mud limestone claystone
- Lignitic, clayey sand, pyritic, qtz, fine to medium
- Sand, pyritic, qtz, fine - medium rounded
- Lignite, sandy, soft pyritic
- Lignitic clayey qtz sand as above

STRATIGRAPHIC COLUMN

WILLAWORTINNA FORMATION — PLIOCENE - RECENT
MIOCENE
UPPER EYRE FORMATION — EOCENE
LOWER EYRE FORMATION

T.D. 313m

Wallerberdina Station 10 km radius registered well search results - WaterConnect query 06/03/18

Drill Hole No.	Unit No	Obs Well No.	drillhole class	Aquifer	Orig drilled depth	Orig drilled date	cased_to	case min diam	purpose	latest status	latest status date	standing water level (m)	reduced swl (m AHD)	water level date	Total Dissolved Solids (mg/L)	Electrical Conductivity (uS/cm)	salinity date	pH	pH date	yield (L/s)	yield date	MGA easting	MGA northing	Decimal Long	Neg Decimal Lat	water info	salinity	water chemistry	geophys_log	drill log	lith log
33846	6534-9		WW		65.23	8/08/1951						45.72	65.98	8/08/1951						0.27	8/08/1951	236190	6484586	138.215	-31.7438	Y	N	N	N	N	N
33853	6534-16		WW																			236141	6500956	138.219	-31.5963	N	N	N	N	N	N
33854	6534-17		WW		42	26/01/1980			STK	BKF	2/02/2015	20.9	53.64	26/01/1980	6533	11400	26/01/1980					233385	6501416	138.19	-31.5915	Y	Y	N	N	N	N
33856	6534-19		WW					152	STK	OPR		22.26	57.12	26/01/1980	4330	7666	26/01/1980					235923	6498971	138.216	-31.6141	Y	Y	N	N	N	N
33858	6534-21		WW		49.38	26/07/1951		125	STK	OPR		12.19	66.75	26/07/1951	6340	11086	26/07/1951			0.51	26/07/1951	227032	6493345	138.121	-31.6627	Y	Y	Y	N	N	N
33859	6534-22		WW		36.5	23/01/1980		152	STK	OPR		15	65	23/01/1980	8286	14300	23/01/1980					229294	6494273	138.145	-31.6549	Y	Y	N	N	N	N
33860	6534-23		WW		36.88	1/03/1937	36.88	127	STK	OPR		12.19	70.27	27/07/1951	4652	8221	27/07/1951			0.38	27/07/1951	229257	6491769	138.144	-31.6775	Y	Y	Y	N	N	N
33861	6534-24		WW		26	22/01/1980		153	STK	OPR		22.37	67.78	22/01/1980	3032	5414	22/01/1980					233460	6492593	138.189	-31.671	Y	Y	N	N	N	N
33862	6534-25		WW		31	22/01/1980			STK	BKF	1/06/2016	28.45	71.38	22/01/1980	3350	5970	1/06/2016					235821	6491442	138.213	-31.6819	Y	Y	N	N	N	N
33910	6534-73		WW		36.7	22/01/1980		153							3236	5771	22/01/1980			0.13	1/01/1980	241050	6493761	138.269	-31.6622	N	Y	N	N	N	N
33941	6534-104		WW																			244505	6487653	138.304	-31.7181	N	N	N	N	N	N
34074	6534-237		WW		43.5	14/10/1980	43.5	132				15	66.04	14/10/1980	7619	13197	14/10/1980	7.1	14/10/1980	0.63	14/10/1980	228828	6491726	138.14	-31.6778	Y	Y	N	N	N	N
34077	6534-240		WW		55	23/09/1981	53.9	112				21.2	58.8	23/09/1981	3840	6820	23/09/1981	7.3	23/09/1981	0.5	23/09/1981	234733	6498065	138.204	-31.622	Y	Y	N	N	N	N
34097	6534-260		WW		44.5	12/06/1986	43.2					29.8	71.41	4/12/1986	1939	3490	4/12/1986	7.2	12/06/1986	0.5	12/06/1986	231353	6484536	138.164	-31.7431	Y	Y	N	N	N	N
34106	6534-269		WW		44.2	2/12/1989	44	134	STK	OPR		15.1	63.38	2/12/1989						0.62	2/12/1989	226920	6493615	138.12	-31.6603	Y	N	N	N	N	N
175401	6534-287		WW		64	25/03/1999	60	127	STK			10	86.14	25/03/1999	4210	7460	25/03/1999			1	25/03/1999	238802	6498579	138.247	-31.6183	Y	Y	N	N	Y	N
179586	6534-307		MW		145	23/01/1997				BKF	23/01/1997											244822	6487129	138.307	-31.7228	N	N	N	N	N	N
179767	6534-301		MW		121	11/12/1996				BKF	11/12/1996											245522	6489799	138.315	-31.6989	N	N	N	N	N	N
179768	6534-306		MW		121	30/01/1997				BKF	30/01/1997											245222	6489679	138.312	-31.7	N	N	N	N	N	N
185090	6534-300		MW		139	11/12/1996				BKF	11/12/1996											245472	6489799	138.314	-31.6989	N	N	N	N	N	N
218905	6534-324		WW		43	7/07/2006	40	127				20		7/07/2006	4222	7480	7/07/2006			1	7/07/2006	235905	6498941	138.216	-31.6144	Y	Y	N	N	Y	N
234387	6534-331		MW		276	17/11/2006																236380	6500934	138.222	-31.5965	N	N	N	N	N	N
256005	6534-338		MW		312	17/11/1978																231978	6484398	138.171	-31.7445	N	N	N	N	N	N
285430	6534-355		WW		57	2/02/2015	47	142				16.5		2/02/2015						2	2/02/2015	233437	6501509	138.191	-31.5907	Y	N	N	N	Y	N
289764	6534-360		WW		44	1/06/2016	28	142				28		1/06/2016						0.5	1/06/2016	235780	6491508	138.213	-31.6813	Y	N	N	N	Y	N
290308	6534-363		WW		41.5	5/08/2016	29.5	146				27		5/08/2016	6430	11220	5/08/2016			0.5	5/08/2016	244597	6487780	138.305	-31.7169	Y	Y	N	N	Y	N

Basemap from WaterConnect online query conducted 13/03/18 https://www.waterconnect.sa.gov.au/Systems/GD/Pages/Default.aspx

View looking towards study areas on low topographical relief from the foothills near Murrays Bore (6534-73).

Unit 6534-73 – Murrays Bore showing location adjacent drainage line, black tank and solar panel visible.

Close up of Murrays Bore set up. Water level was measured at 1.6 m below top of casing, total well depth was 39 m below top of casing on 21/02/18.

Kangaroo scratching into creek bed for shallow groundwater near Murrays Bore.

Well 6534-360 (East Yallala Bore) replacing 6534-25, solar pump relaces windmill for stock water.

Standing water level measured at 29.3 m below top of casing on 21/02/18.

Well 6534-360 pump, power and tank set up.

Well west of Hookina Creek outside of Wallerberdina Station property (6534-269). Standing water level measured at 16.1 m below top of casing on 21/02/18. Generator on site. Cattle observed nearby. Water trough adjacent well.

Close up of pump set up at well west of Hookina Creek (6534-269)

Well 6534-24, measured as dry at 24.8 m below top of casing on 21/02/18.

Recorded as an operational stock bore with an original standing water level of 22.37 m in 1980, total depth 26 m.

DAISHSAT
GEODETIC SURVEYORS

Wallerberdina Station

Geophysical Data Interpretation
NRWMF Site Characterisation Project

Preliminary Desktop Review
NRWMF Site Characterisation Project

DAISHSAT

Australia's Leading Provider of GPS Positioned Gravity Surveys

Author: Bernie Stockill **Date:** 25/04/2018

Contents

Preliminary Desktop Review
NRWMF Site Characterisation Project

DAISHSAT
Australia's Leading Provider of GPS Positioned Gravity Surveys

Author: Bernie Stockill **Date:** 25/04/2018

1.0 Introduction

Daishsat is an Australian owned and operated geophysical surveying company which has been proudly based in Murray Bridge South Australia for over 23 years.

The company completes high quality ground gravity and geodetic surveys for clients in the government and private sectors throughout Australia and around the globe. In addition to gravity surveys, Daishsat undertakes detailed airborne magnetic and radiometric surveys using both helicopter and fixed wing platforms.

Bernie Stockill is a Daishsat geophysicist with over 40 years' experience in collecting, reviewing and interrogating geophysical data sets. Bernie has previously undertaken a review of internally held and publicly available on-line database information in the vicinity of the NRWMF Site Characterisation Project short listed sites that included Wallerberdina.

Dr James Hanneson is a highly regarded South Australian consulting geophysicist with vast experience in interpretation and modelling of airborne magnetic data. James is considered a specialist in the South Australian Gawler Craton domain, and has undertaken sophisticated modelling and interpretation of geophysical data for many of the major exploration companies working in the region.

A desktop study identified an airborne survey dating from 1996 that completely surrounds the target area (SARIG Lake Torrens 1996SA004_pt1). This survey was flown on 100m line spacing and a nominal flying height of 40 metres. No radiometric data was collected as part of this survey. The quality of this data was considered suitable for the interpretation required. A TMI image of this survey showing the full survey extents is provided with this report.

This report provides an interpretation of the geophysical data collected over the Wallerberdina area and includes Dr Hanneson's in-depth modelling and interpretation report. The study area of 1km^2 has been defined and an extended survey area of approximately 16 km^2 surrounding the proposed site was covered to provide sufficient contrasting background data to give meaningful results.

A TMI geophysical image produced as a result of the airborne survey are included with this report. Selected images are also displayed within the report.

2.0 Geology

2.1 Overview

The study area under consideration at Wallerberdina Station is the magenta square shown below. The area is approximately 1km^2 and is located on recent surface sediments adjacent to the Flinders Ranges.

Relevant geological data for the Parachilna 1:250 000 Sheet SH54-13 was provided in the preliminary study.

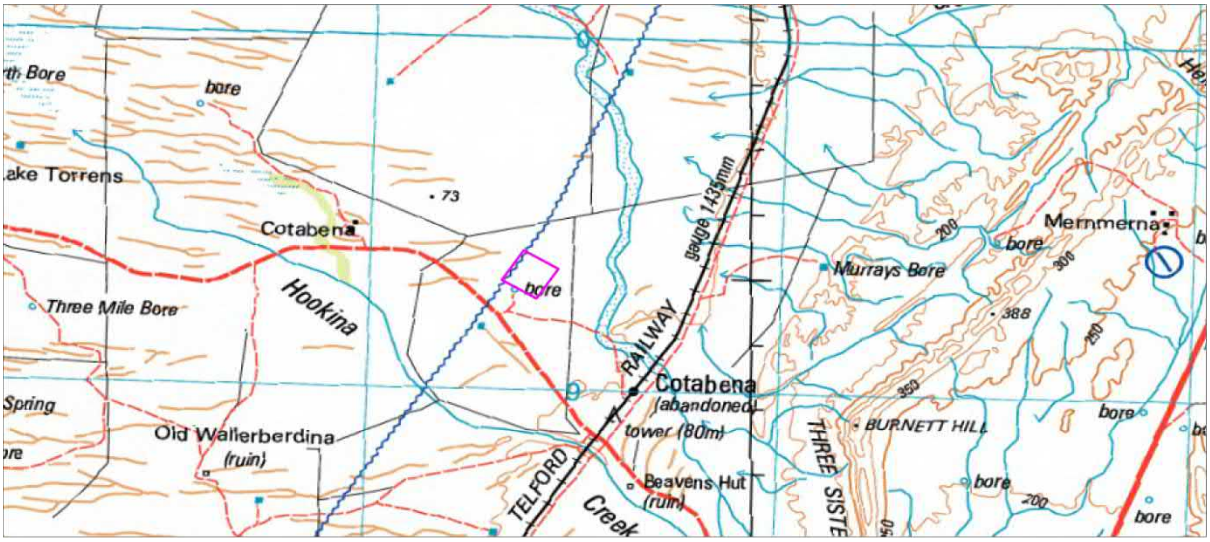

Image 1 Wallerberdina Survey Site outline on topographic background

2.2 Geology of the Wallerberdina area

Surface cover over the target area and adjacent surrounds is shown as Qa and consists of alluvial sediments (Image 2). The nearest outcropping rocks are siltstones of the Wilpena Group approximately 8 km to the east of the target area.

There is nothing obvious from the surface geology to indicate rock type or structures in the geological basement rocks. The area does not appear to be covered by recent sand dunes.

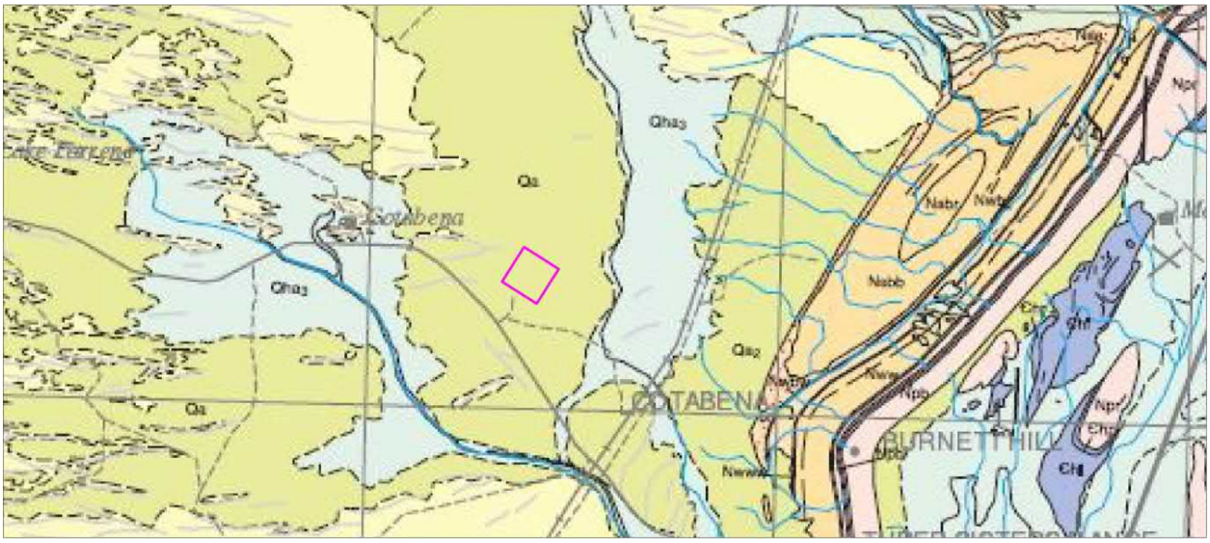

Image 2 Wallerberdina Survey Site outline on geology background

3.0 Gravity

3.1 Overview

Gravity coverage over the broader Wallerberdina Site and selected study area is very sparse with only 1970 regional 7.0km (Approx.) stations surrounding the site. Data quality is unknown, but being pre-GPS and regional, it is likely that values are of a lower quality when compared with the adjacent exploration data. The more recent exploration data (SARIG 2009 to the east, and 2007 to the west) covers areas of exploration interest in much greater detail at about 500m station interval, although this data is at least 7km from the site. There is insufficient coverage to allow any modelling of the gravity data or input into the magnetic modelling.

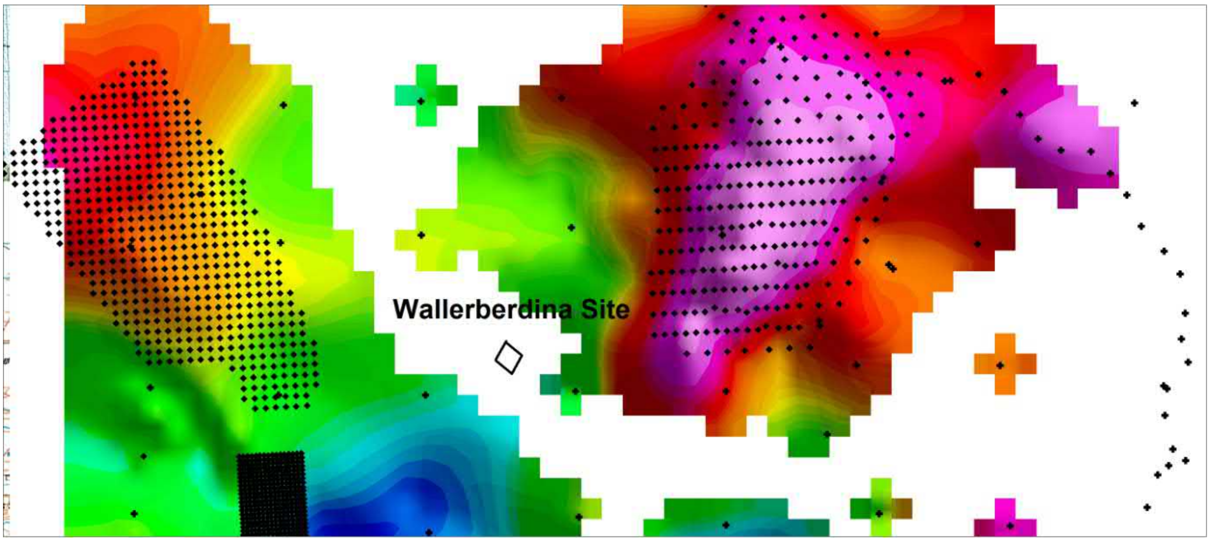

Image 3 Wallerberdina Bouguer Image showing gravity station coverage.

3.2 Regional Gravity in the Wallerberdina area

A visual appraisal of the regional gravity data available (Image 3) shows that the site area is unlikely to have underlying shallow, dense basement rocks. The relatively featureless low response shown in the area surrounding the site would indicate deep, uniform, possibly sedimentary basement with little change within 3-4 kilometres of the site.

At the station spacing present, any short wavelength gravity response from the upper 500 metres will not be evident in the data. A 400m x 400m grid of stations surrounding the target area would provide sufficient coverage to delineate any gravity response in sedimentary rocks in the near surface. If shallow structures were identified, infill traverses would provide the necessary information to define any significant areas. Wide spaced (1 or 2 km) gravity stations collected along roads would complete the regional response.

No structural features are evident.

4.0 Magnetics

4.1 Overview

Daishsat did not collect new magnetic data at the Wallerberdina Station site or the selected study area. Data available from the South Australian SARIG website consisted of magnetic data only (no radiometric data available) from the Lake Torrens survey (1996SA004_pt1). Data was collected on east-west lines at 100 metre line spacing at a nominal flying height of 50 metres above ground surface (Image 4). Part of the line coverage over the investigation site is shown in Image 5. The survey was flown in 1996.

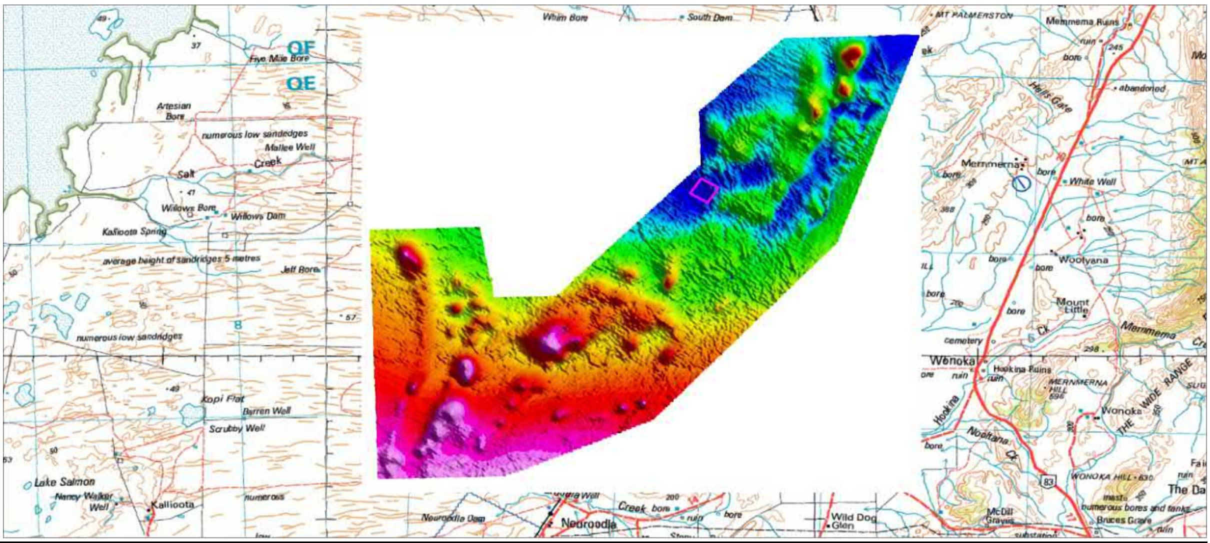

Image 4 Wallerberdina site – Lake Torrens 1996SA004_pt1 TMI image.

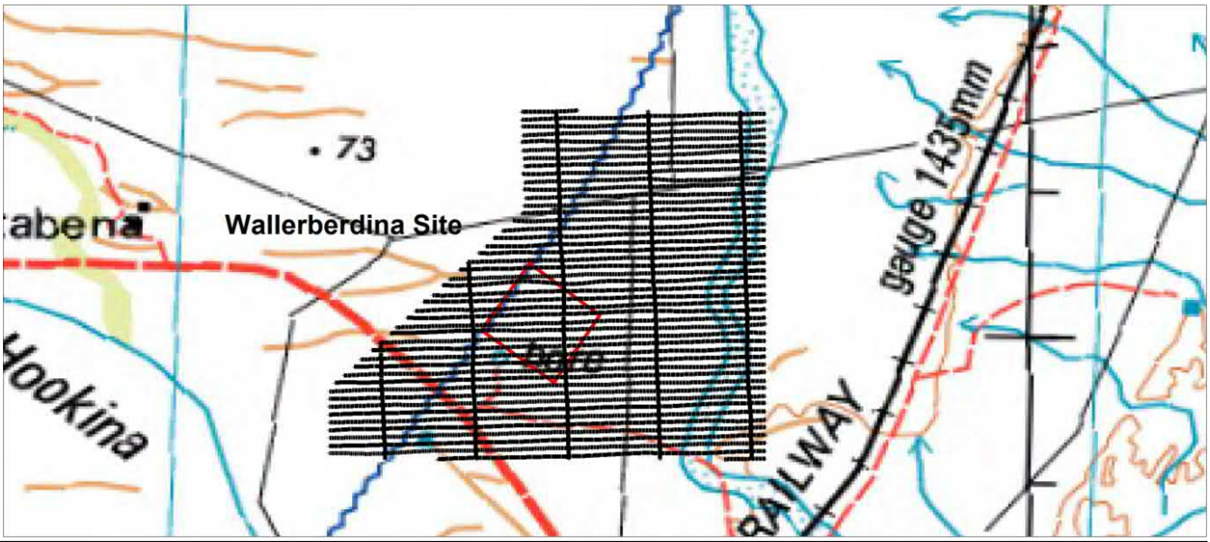

Image 5 Wallerberdina site – Lake Torrens 1996SA004_pt1 flight lines (part).

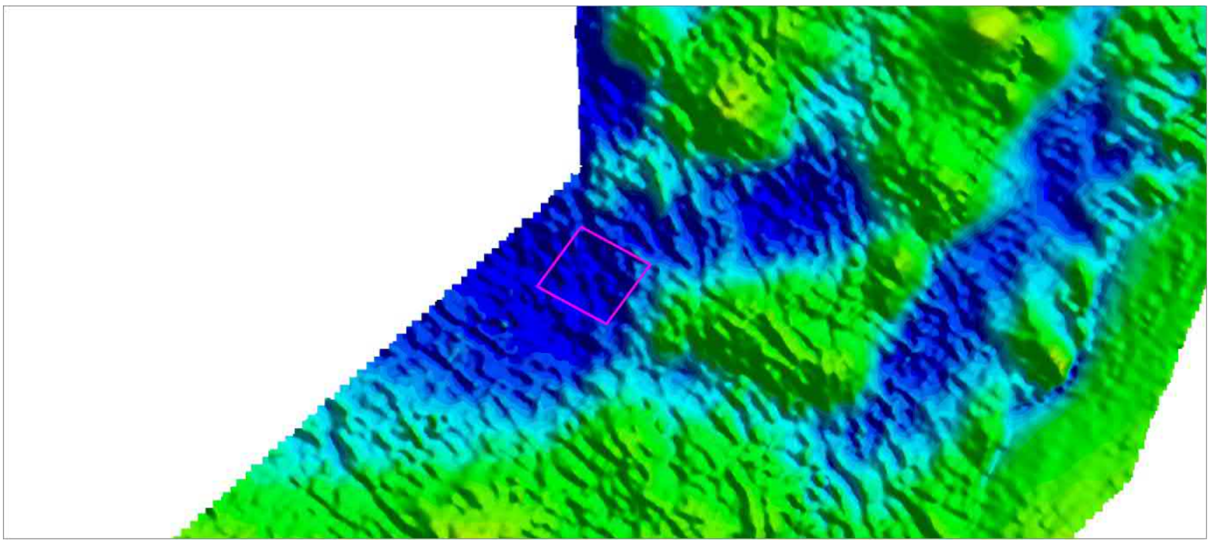

Image 6 Wallerberdina site – Lake Torrens 1996SA004_pt1 TMI image detail.

4.2 Interpretation

Past experience has shown that the "mottled" or crazed appearance on the magnetic image (Image 6.) is due to very small variations in magnetite content in the near surface sediments. Modelling of these features in the Hanneson Interpretation Report indicates depths of between 30 and 100 metres. These minor linear features generally follow the predominant wind direction (north-west – south-east).

This mottled feature is common throughout central Australia and is possibly due to wind action concentrating the heavier materials that would include magnetite. Investigations into this phenomenon in central Queensland stratigraphic drill cores by the author, revealed very thin zones (2-3 metres) of magnetite with no apparent change in the host rocks. The presence of the magnetite was only confirmed with the use of a magnetic susceptibility meter. In Queensland this magnetite occurrence can be directly linked to the Winton Formation, and where it has been eroded and the underlying Mackunda Formation exposed, the high frequency shallow magnetic signal is not observed.

Paleochannels may also be the concentrating action to produce the pattern seen on the image, however in this case it manifests as a magnetic "low" and is likely to involve weathering of the magnetite.

The shallow magnetic sources modelled in the Interpretation Report indicate the dominance of these features, however they do not constitute a significant geological presence.

The dynamic range of the magnetic response over the site is less than 40 nano-teslas. The survey configuration of 100 metre flight lines would be sufficient to show localised magnetic changes in the upper 100 metres of surface rocks.

There are no magnetic features in the area of the investigation site at Wallerberdina that would indicate shallow, magnetic basement rocks or structural features that impact the site. The low magnetic response would indicate a high probability of sedimentary rocks.

5.0 Radiometrics

There is no radiometric data covering the Wallerberdina site.

6.0 Conclusion

The airborne magnetic survey configuration of 100 metre line spacing is sufficient to define the magnetic response at Wallerberdina. No Radiometric data is available for this site.

There is no pattern in the magnetic response to indicate shallow basement or structural features occurring in the near surface. The magnetic response is very low, indicating non-magnetic rocks, possibly only a thick sequence of sedimentary rocks within the investigation site. As well as indicating no magnetic bodies present in the near surface rocks, there is no evidence of a shallow magnetic basement.

Gravity data available for this site is very poor, and no existing stations are located within 3 kilometres of the site. The lack of magnetic response may indicate a deep section of sedimentary rocks and gravity may provide some additional detail in this environment.

7.0 Referenced Data

The attached interpretation report by James Hanneson provides the detailed modelling and interpretation of the magnetic data from Wallerberdina. A magnetic image of the complete airborne survey is included.

Data Item	Media	Source	Size	Date Completed	Date Accessed
SA State Gravity Image - SA_GRAV	Geotiff Image	SARIG Digital Download	528.437Mb	2015	Jan-18
SA State Magnetic Image - SA_TMI_RTP	Geotiff Image	SARIG Digital Download	528.437Mb	2015	Jan-18
SH54_13 Parachilna 1:250 000 Geology Map	PDF	SARIG Digital Download	6.605Mb		Jan-18
SH5413 DHGeochem	CSV: XL Spreadsheets	SARIG Digital Download	3.05Mb		Feb-18
SH5413 drillholeDetail	CSV: XL Spreadsheets	SARIG Digital Download	0.808Mb		Feb-18
SH5413 rockSamples	CSV: XL Spreadsheets	SARIG Digital Download	3.26Mb		Feb-18
ENV11925 Salisbury Resources Reports	PDF	SARIG Historical Mineral Reports	25.731Mb	2014	Feb-18
SARIG On-line Gravity database	Digital, CSV or ASCII	SARIG		Download 2017	Jan-18
Geoscience Australia GADDS on-line gravity database	Digital, CSV or ASCII	Geoscience Australia		Download 2017	Jan-18
Daishsat data	CSV	Daishsat	22.991Mb	Aug-17	Jan-18
Daishsat Open File SA Company Gravity database V3	CSV	Daishsat	22.089Mb	Sep-17	Jan-18
1996SA004_Lake Torrens pt1_mag_GDA94 Airborne Magnetic survey	ER Mapper Grids, ASCII Line data	SARIG Digital Download	256Mb	Aug-12	Feb-18
Ancilliary Reports:ENV09094; ENV11181; ENV11182; ENV12422; ENV10519, ENV11925	PDF	SARIG Historical Mineral Reports			Feb-18
Wallerberdina magnetic image	tiff image	Daishsat	23.5Mb	Apr-18	Apr-18
Wallerberdina Model	PDF	Daishsat/Hanneson	1.7Mb	Apr-18	Apr-18

AMG James E. Hanneson, PhD Consulting Geophysicist

ADELAIDE MINING GEOPHYSICS Pty Ltd 24 Justine Street, Flagstaff Hill, South Australia, Australia, 5159
ABN 77 085 429 698 tel: (08) 8370-7493 fax: (08) 8370-7364 email: jim.hanneson@bigpond.com

MEMORANDUM

To:	Bernard Stockill Business Development Manager Daishsat Geodetic Surveyors *via* email: *bernie.stockill@daishsat.com*	**Affiliation:**	Daishsat Ltd Murray Bridge South Australia
From:	J.E. Hanneson	**Costing:**	
Date:	24 April, 2018	**Reference:**	AMG18/12
Subject:	**A Magnetic Susceptibility Model for the Wallerberdina Area, Daishsat Geodetic Surveyors Ltd, South Australia**		

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1. INTRODUCTION AND SUMMARY

A magnetic susceptibility model for the Wallerberdina Area east of Lake Torrens, South Australia, is described below, whose calculated magnetic response is an approximate simulation the data collected in 1996 and obtained by you from the South Australian government archive. As with earlier reports (Hanneson, 2018a, 2018b), the objective of this work is to asses the magnetic field data for evidence of faulting in order to form an opinion on the structural stability of the area. I understand that the thickness of the cover rocks is unknown and that no gravity data available.

In summary, the area is magnetically bland and it is this very low relief that permits the use of fine colour intervals that in turns suggest minor variations that seem likely to be cause by sand dunes in which less than 0.1 percent concentrations of magnetite would adequately explain the responses. These concentrations seem to be very shallow with very limited depth extents. Areas of relative magnetic lows are irregular and/or sinuous in shape and can be explained by invoking shallow depressions (paleochannels?) in the surface, perhaps with Tertiary infill and magnetite concentrations that are depleted by less than one tenth of a percent compared to the surrounding rock. There is no clear evidence of faulting, although a NW straight-line magnetic low along the northeast boundary of the area of immediate interest (see Figures 1 and 2.2) might represent a paleochannel following a line of weakness in the bedrock.

Additional insight into the geological nature of the area would be forthcoming if gravity and TEM data were available, and obtaining such data is recommended. I would be pleased to write proposals for the collection of such data to further investigate the physical properties of this apparently structurally stable area.

2. DATA

Figure 1.1 shows the surface topography based on the difference between the GPS height and the radar altimeter; however, minor mislevelling is apparent which I have not tried to correct. The residual topographic image in Figure 1.2 was created by smoothing the original data to obtain a version of the regional trends, and forming the difference.

Figure 1.1 shows the flight lines, and the diamond shaped outline is the immediate area of interest indicated in an email from you. The lines appear skewed for having been flown on the early AMG grid before conversion to MGA/GDA94.

Likewise, Figures 2.1 and 2.2 show the magnetics and residual magnetics. The magnetics would appear bland in regional images where the range of values requires coarse colour intervals. Here, however, the total variation throughout the area is barely 40nT, again permitting fine colour intervals that reveal many short wavelength features.

3. MODEL

A magnetic susceptibility model has been developed for the area, and the calculated magnetic response of the model, shown in Figure 3.1, is an approximate simulation of the data in Figure 2.1. A residual of the magnetic model response is shown in Figure 3.2 for comparison with the data residual in Figure 2.2. The computational method has been described by Talwani (1960, 1961) and the writer (Hanneson, 2003).

The tops of the polygonal model bodies are drawn black in plans Figures 3.1 and 3.2 and alone and in colour in Figure 4, where the colours depend on their physical properties in accordance with the background colours in the inset phase/scatter diagram (Hanneson, 2003). Magnetite is dense (5gm/cc), and even though there is no gravity data at this time, densities have been assigned to the magnetic bodies based on the estimated concentrations of magnetite (in a felsic lithology). Thus, weakly magnetic bodies are yellow-green in colour, becoming bluer for higher susceptibilities. Bodies drawn in stippled blue have negative susceptibility contrasts and represent units that are relatively depleted in magnetite compared to the surrounding areas. Model body numbers are posted at the centroid of each body.

Lines labelled P1 to P15 in Figure 4 give the locations of cross-sections through the model that are shown in Figures 5.1 to 5.13. The cross-sections also show profiles of the calculated magnetic model response (dotted) and the magnetic data (solid) to help assess the accuracy of the simulation.

Figure 6 shows where each model body plots on the combined phase/scatter diagram, from which can be read the density and magnetic susceptibility as well as the inferred concentrations of magnetite. Because of their low susceptibilities, all bodies plot close to the non-anomalous “Host Rock” vertex of the phase/scatter diagram.

Table 1 following the diagrams gives additional details of the model, including depth to top, depth extent, magnetic susceptibility and estimated magnetite concentrations and more.

All bodies are vertical because the anomaly amplitudes are not strong enough to suggest otherwise.

4. DISCUSSION

4.1 Preamble

When a model response simulates the data the model is said to be *permitted* by the data, however, no model is ever *required* by the data. Because many models can have the same calculated response, the data must be seen as ambiguous; consequently, selecting one model that simulates the data, rather than another that may simulate the data equally well, is an act of interpretation. Any model used for further work should therefore be subjected to geological assessment and rejected if information emerges that is at variance with the model, or if its credibility is deemed unreliable.

A slightly larger area was windowed than the immediate area of interest (diamond shaped outline in Figure 1) that you indicated. Faults and lineaments, evident at larger scales, often disappear at finer scales.

4.2 Sand Dunes and Paleochannels

While the total topographic variation across the area is barely 20 metres, the fine colour intervals in the image make many small but weak variations apparent. A similar effect is seen in the magnetic image (Figure 2.1) and in the residual magnetic image (Figure 2.2). The high correlation between topography and residual magnetics seen in an earlier report (Hanneson, 2018b) is less evident at Wallerberdina, but the wavelengths of the magnetic and topographic variations are similar.

The aeromagnetic image seems noisy, as do the data profiles in Figures 5.1 to 5.13. There are enough line-to-line correlations, however, to suggest that the noise is real geological signal rather than related to any lack of precision in the measurements. I note that the same is true of the digital elevations and that the mean wavelength of the "chatter" is similar in the two images.

The model is deemed approximate because it was not possible to simulate all of the variations in the data in the time allocated, but further improvement of the simulation requires only further effort. Enough of these small anomalies have been simulated, however, to permit the conclusion that they arise from shallow accumulations of magnetite with very limited depth extents. The magnetic highs might therefore be caused by the wind-blown sorting of magnetite in dunes.

The magnetic lows are harder to explain but might be caused by deeper erosion (paleochannels?) and magnetite depletion through weathering processes. They are irregular in shape and often sinuous -- more in the nature of paleochannels than what one might expect of bedrock structures. Most bodies that simulate these lows are shallow, 20 to 50 meters, and have similar low values for depth extent. The typical susceptibility contrasts of -0.002 SI suggest that these features comprise about 0.01 percent less magnetite than the surrounding rocks. Gravity data would determine if the interpreted paleochannels are also gravity lows or if another explanatory mechanism is needed -- such as areas swept clean of magnetite complimentary to its accumulation in dunes.

Large, deep, irregular Bodies 2 and 3 in Figure 4 help to simulate the broad highs in the far north and in the south east of the area; they are interpreted to represent rocks with barely 0.2 percent more magnetite than the surrounding country rock at depths of several hundred metres. The large deep stippled-blue Body 5 might represent an intrusive with about 0.1 percent less magnetite than the surrounding rocks.

4.3 The Effectiveness of Gravity and AEM for further Assessment of the Area

Figure A1 in the Appendix is a replot of the cross-section in Figure 5.6 after assigning to the postulated paleochannels a negative density contrast. For a bedrock density of, say, 2.65 gm/cc, and unconsolidated infill of density 1.85 gm/cc (Telford, 1980), a reasonable assumed density contrast would be -0.8 gm/cc; consequently, Bodies 90, 70, 106 and 109 were given this value before computing the gravity response along line P6 of the model. No gravity data is available so the data profile (long dashes) is simply a flat line in Figure A2, but the calculated response (short dashes) of the less dense supposed paleochannels is conspicuous and shows gravity lows of up to half a milligal. This is twenty times as great as typical measurement noise and if such depressions exist they would clearly be detectable.

Assessing the effectiveness of airborne TEM [AEM] is more difficult because the conductivity structure of the earth at Wallerberdina is unknown. However an archive sample of the results from the helicopter borne RepTEM AEM system is shown in Figure A2 and was collected on the Gulf St Vincent coast of South Australia. The data comprises the profile amplitudes for 21 time channels in the upper panel, which can be converted to an apparent-conductivity *versus* apparent-depth image [CDI] using a method similar to that described by Fullagar (1989). The western third of the CDI shows a typical section with perhaps 10m of conductive cover over 8 milliSiemens/m (125 Ωm) ground. Progressing eastward, a power line occurs at 765600E, to the east of which conductivities increase in the 50 to 200m depth range before encountering extreme conductivities at 768500E over tidal flats through which the system does not penetrate.

5. RECOMMENDATIONS

Detailed gravity and AEM are recommended to provide information on the density and electrical conductivity of the geological units in the area, whereas at present, inferences can only be made about the magnetic susceptibility.

5. REFERENCES

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Hanneson, J.E., 2018; A Magnetic Susceptibility Model for the Lyndhurst Area, Daishsat Geodetic Surveyors Ltd, South Australia, 18 April.

Talwani, M., 1961, Computation with the help of a digital computer of the magnetic anomalies caused by bodies of arbitrary shape, Geophysics, V26, p203.

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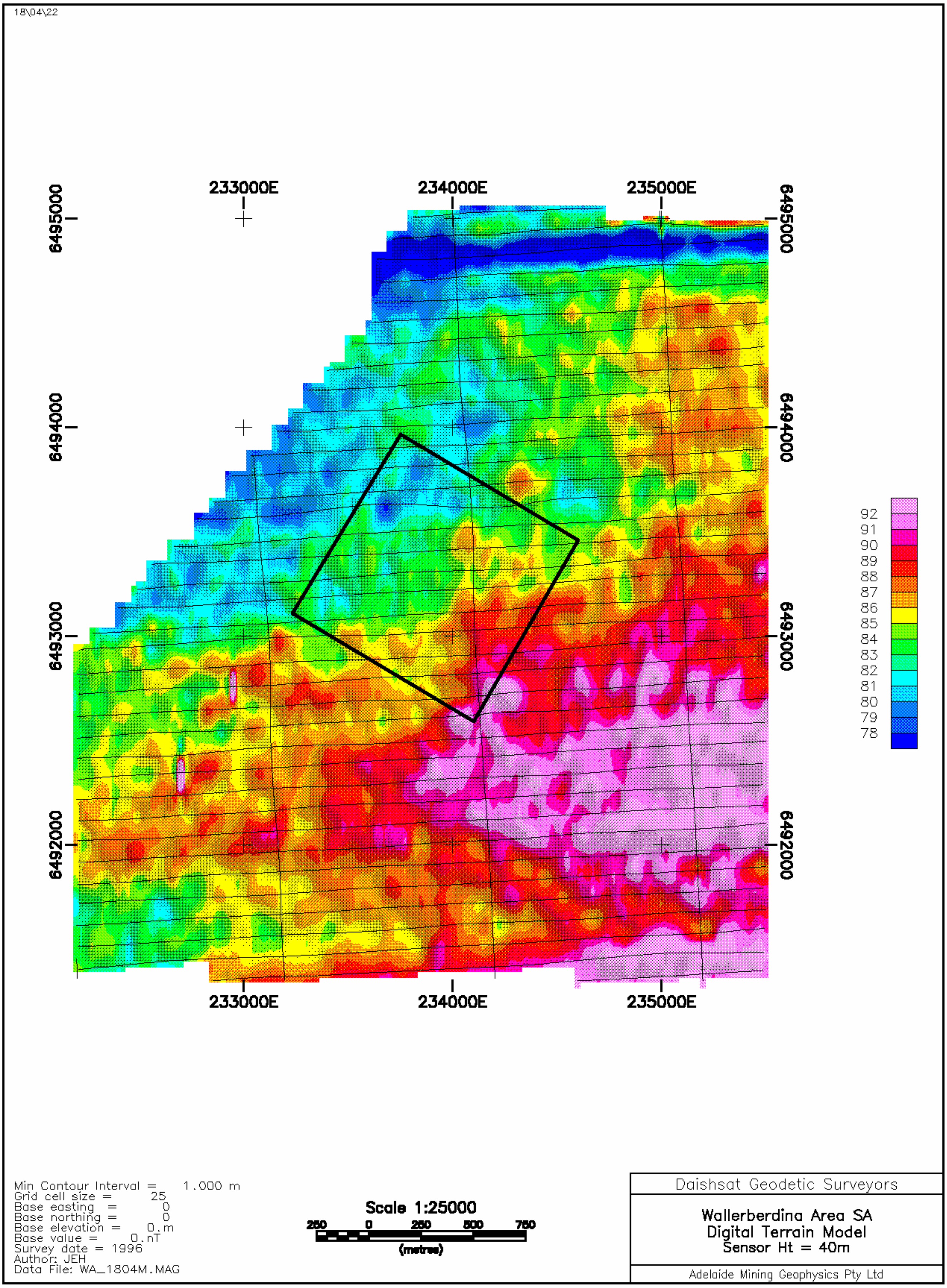
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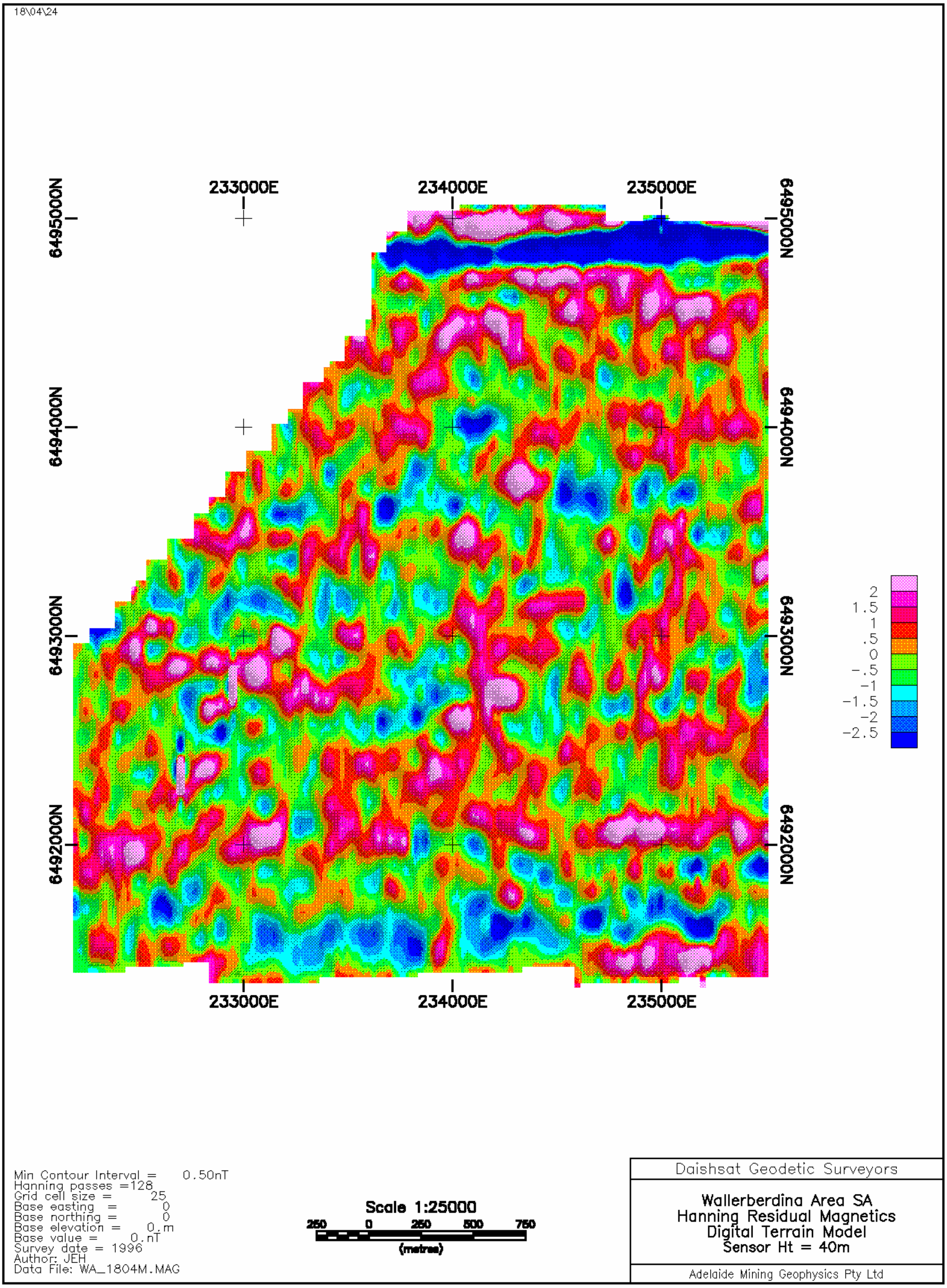
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Digital Terrain Model
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 1.1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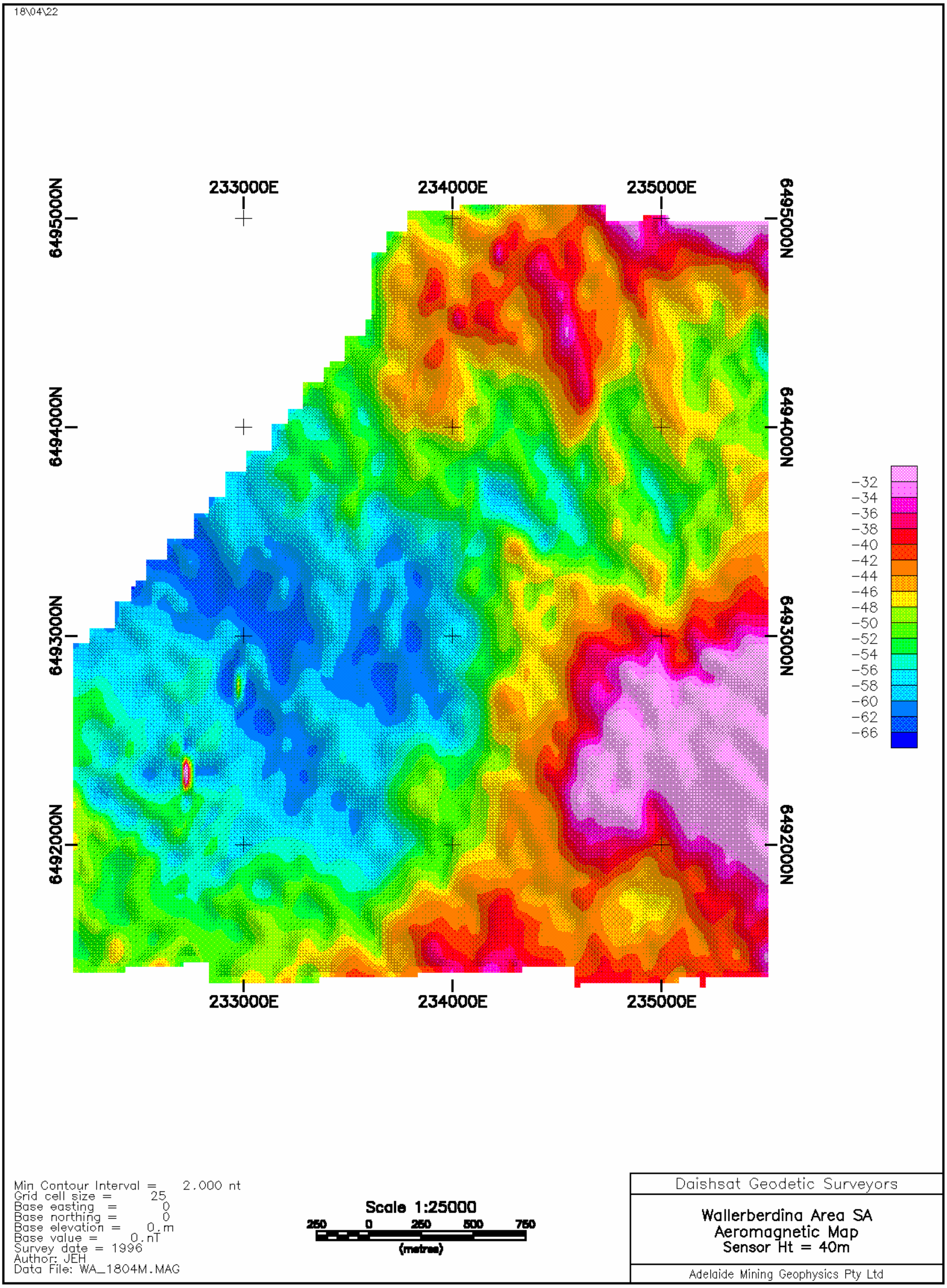
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Hanning Residual Magnetics
Digital Terrain Model
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 1.2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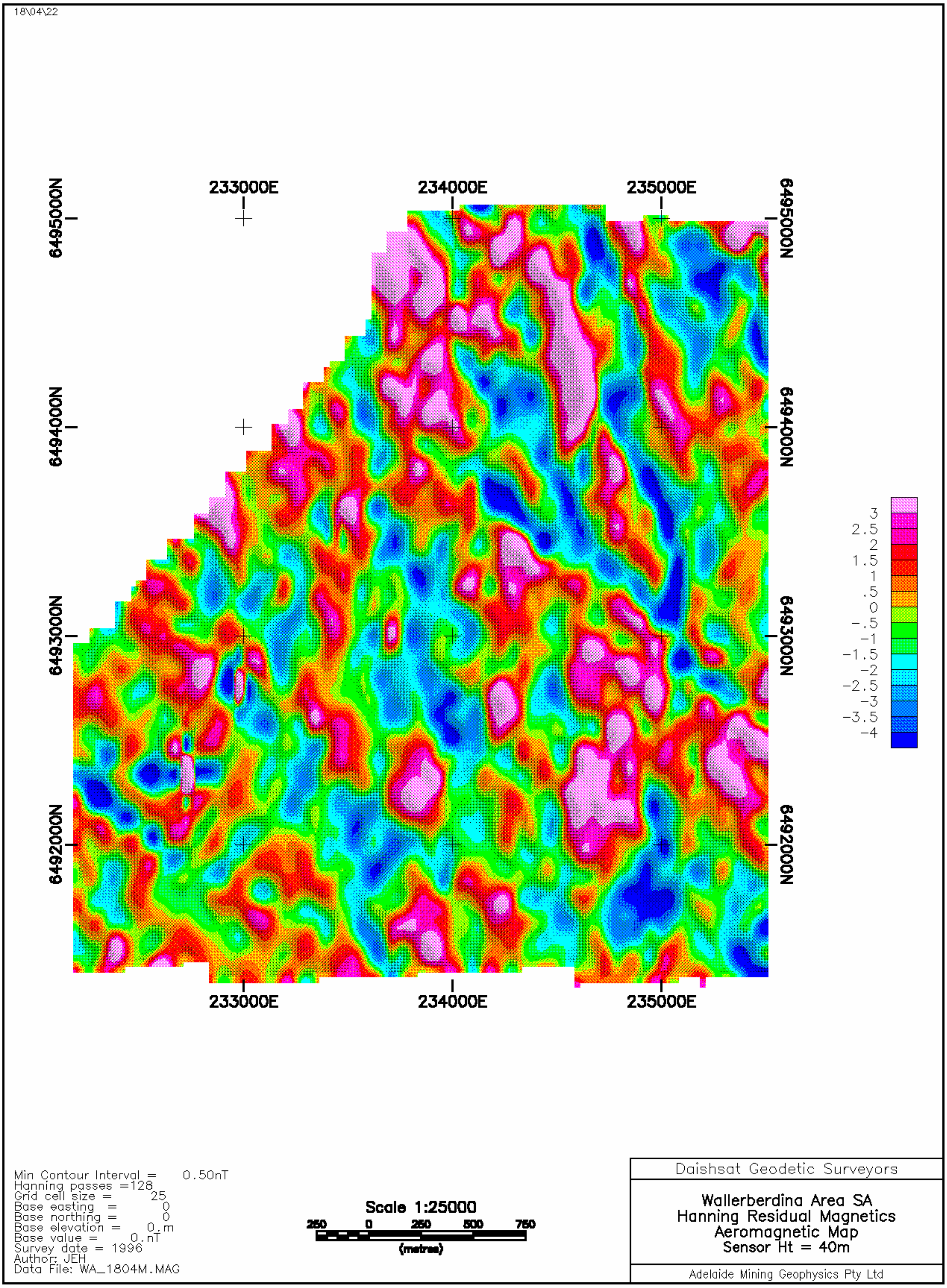
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Aeromagnetic Map
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 2.1



18\04\22
233000E
234000E
235000E
6495000N
6494000N
6493000N
6492000N
3
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
Min Contour Interval = 0.50nT
Hanning passes =128
Grid cell size = 25
Base easting = 0
Base northing = 0
Base elevation = 0.m
Base value = 0.nT
Survey date = 1996
Author: JEH
Data File: WA_1804M.MAG
Scale 1:25000
250 0 250 500 750
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Hanning Residual Magnetics
Aeromagnetic Map
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 2.2

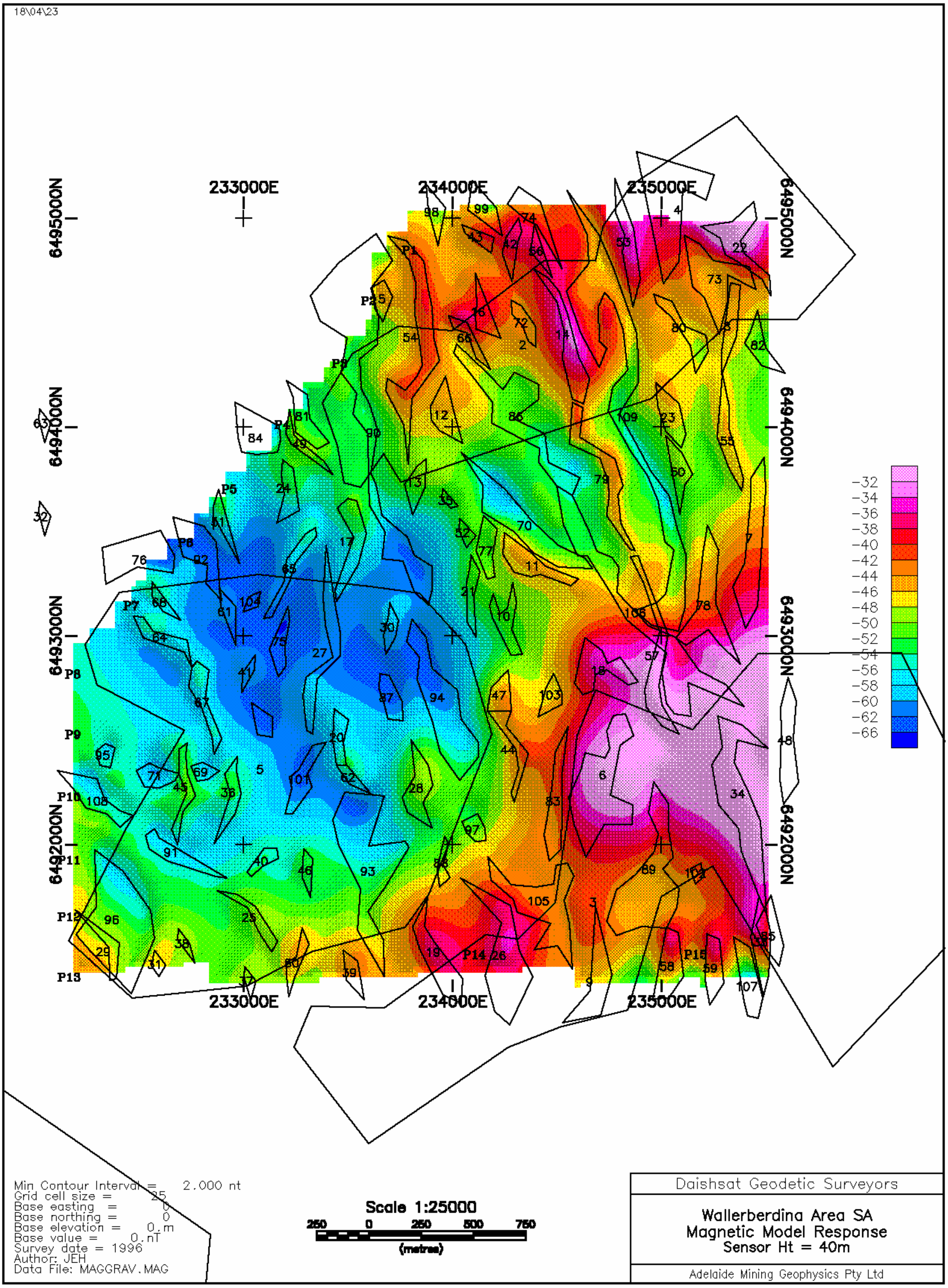
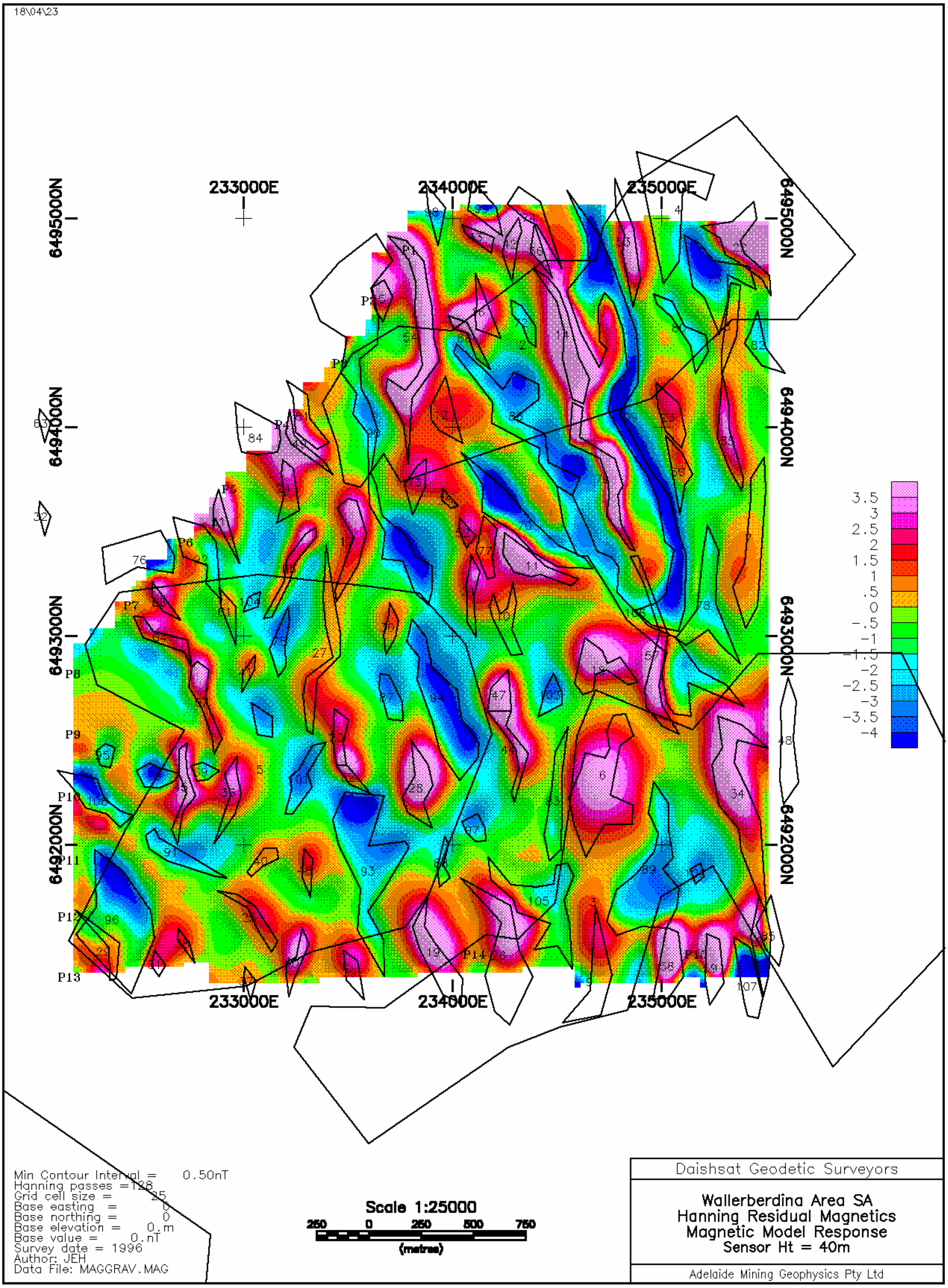

18\04\23
233000E
234000E
235000E
6495000N
6494000N
6493000N
6492000N
-32
-34
-36
-38
-40
-42
-44
-46
-48
-50
-52
-54
-56
-58
-60
-62
-66
Min Contour Interval = 2.000 nt
Grid cell size = 25
Base easting = 0
Base northing = 0
Base elevation = 0.m
Base value = 0.nT
Survey date = 1996
Author: JEH
Data File: MAGGRAV.MAG
Scale 1:25000
250 0 250 500 750
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Magnetic Model Response
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 3.1



18\04\23
233000E
234000E
235000E
6495000N
6494000N
6493000N
6492000N
3.5
3
2.5
2
1.5
1
.5
0
-.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
Min Contour Interval = 0.50nT
Hanning passes =128
Grid cell size = 25
Base easting = 0
Base northing = 0
Base elevation = 0.m
Base value = 0.nT
Survey date = 1996
Author: JEH
Data File: MAGGRAV.MAG
Scale 1:25000
250 0 250 500 750
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Hanning Residual Magnetics
Magnetic Model Response
Sensor Ht = 40m
Adelaide Mining Geophysics Pty Ltd

Figure 3.2

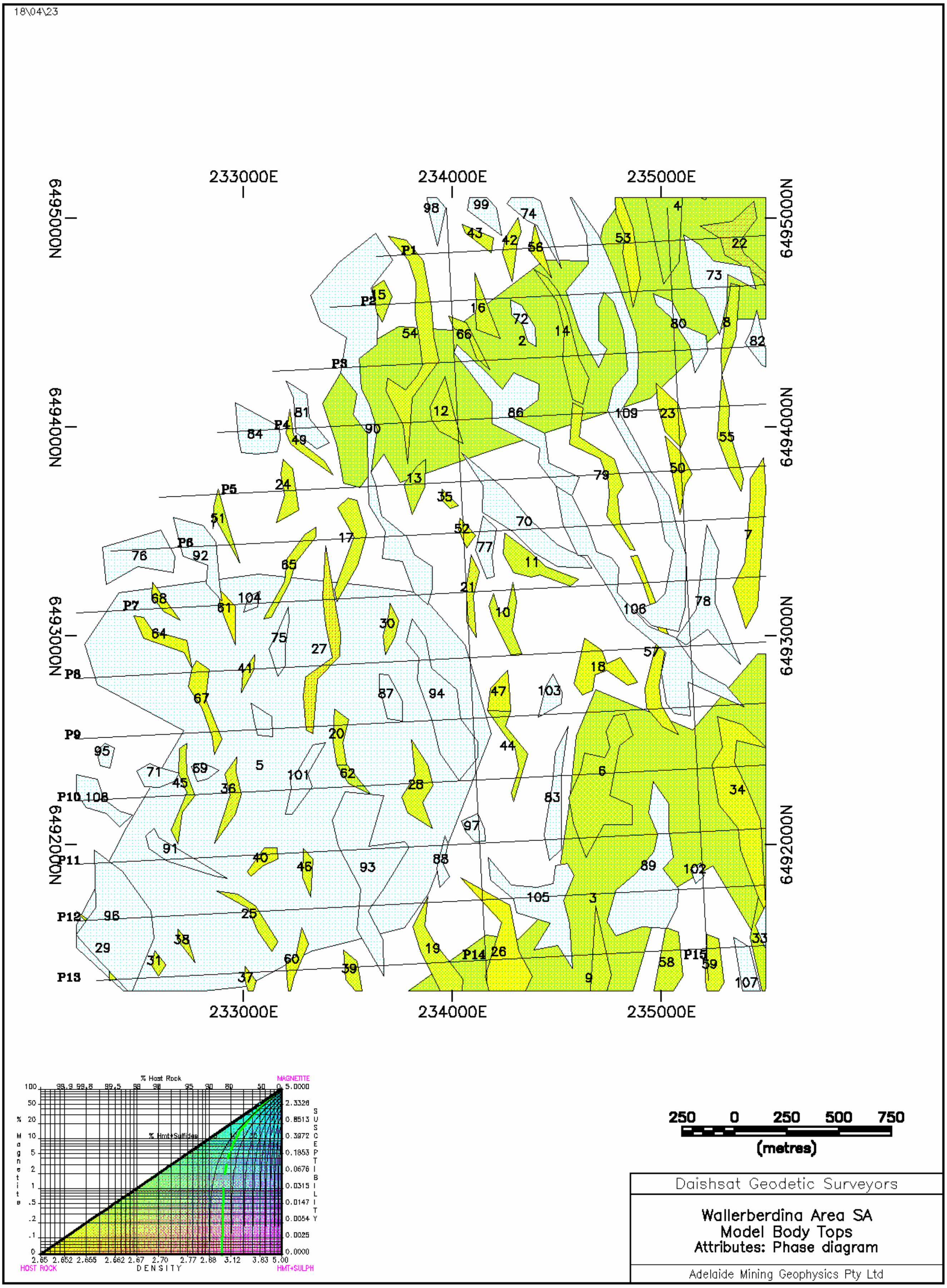
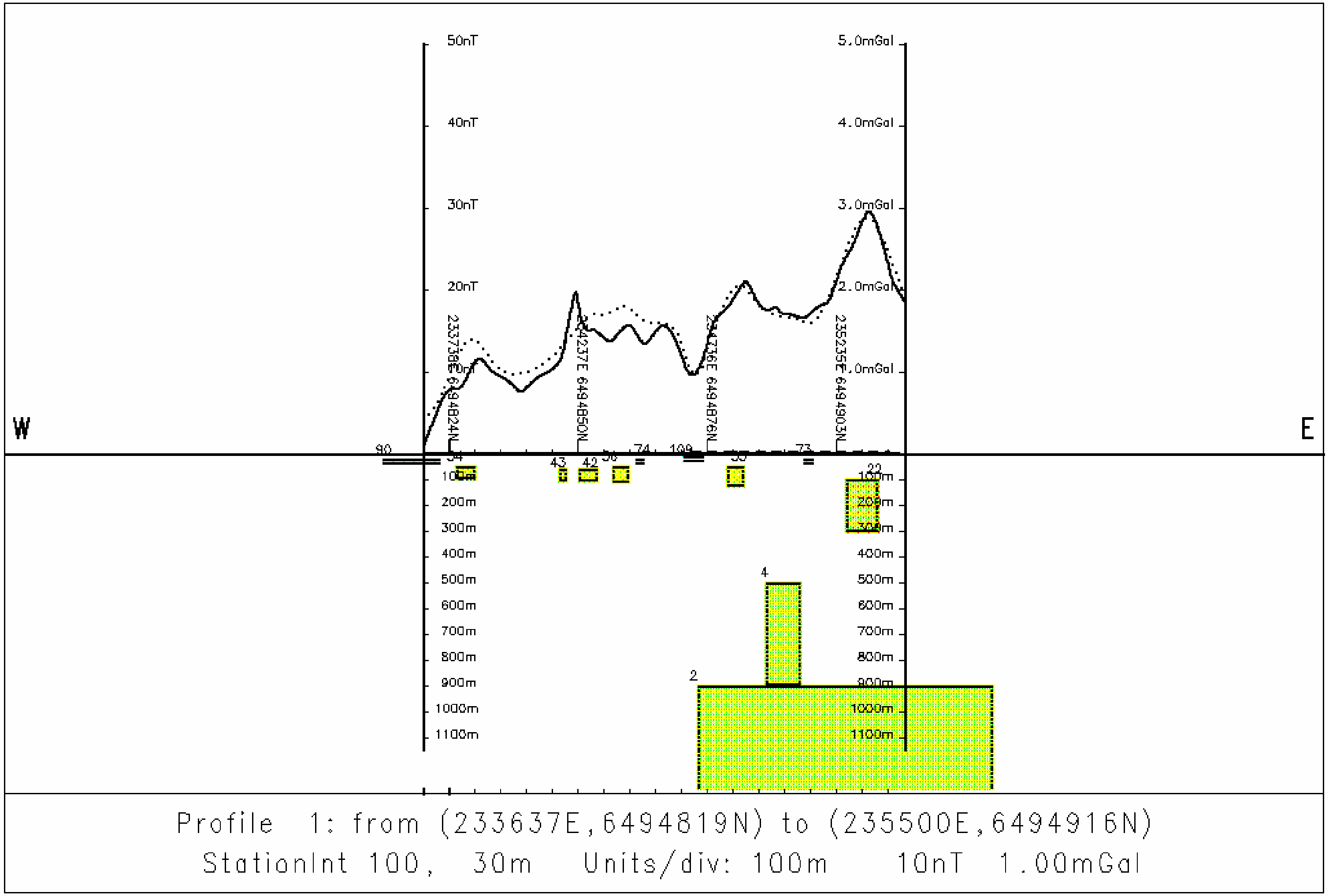
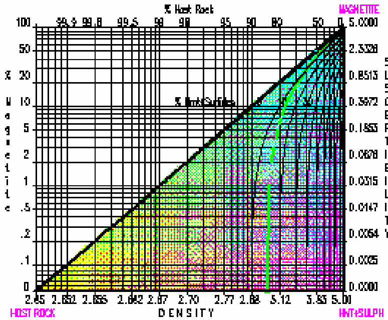

18\04\23
233000E
234000E
235000E
6495000N
6494000N
6493000N
6492000N
% Host Rock
MAGNETITE
% Hmt+Sulfides
% Magnetite
SUSCEPTIBILITY
DENSITY
HOST ROCK
HMT+SULPH
250 0 250 500 750
(metres)
Daishsat Geodetic Surveyors
Wallerberdina Area SA
Model Body Tops
Attributes: Phase diagram
Adelaide Mining Geophysics Pty Ltd

Figure 4.

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
2	0.006(0.006)	2.655(0.005)	900.
4	0.008(0.008)	2.657(0.007)	500.
22	0.005(0.005)	2.657(0.007)	100.
42	0.003(0.003)	2.653(0.003)	60.
43	0.003(0.003)	2.653(0.003)	60.
53	0.002(0.002)	2.652(0.002)	50.
54	0.003(0.003)	2.653(0.003)	50.
56	0.002(0.002)	2.652(0.002)	50.
73	-0.001(-0.001)	2.652(0.002)	20.
74	-0.001(-0.001)	2.652(0.002)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.





MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

Adelaide Mining Geophysics Pty Ltd

Figure 5.1

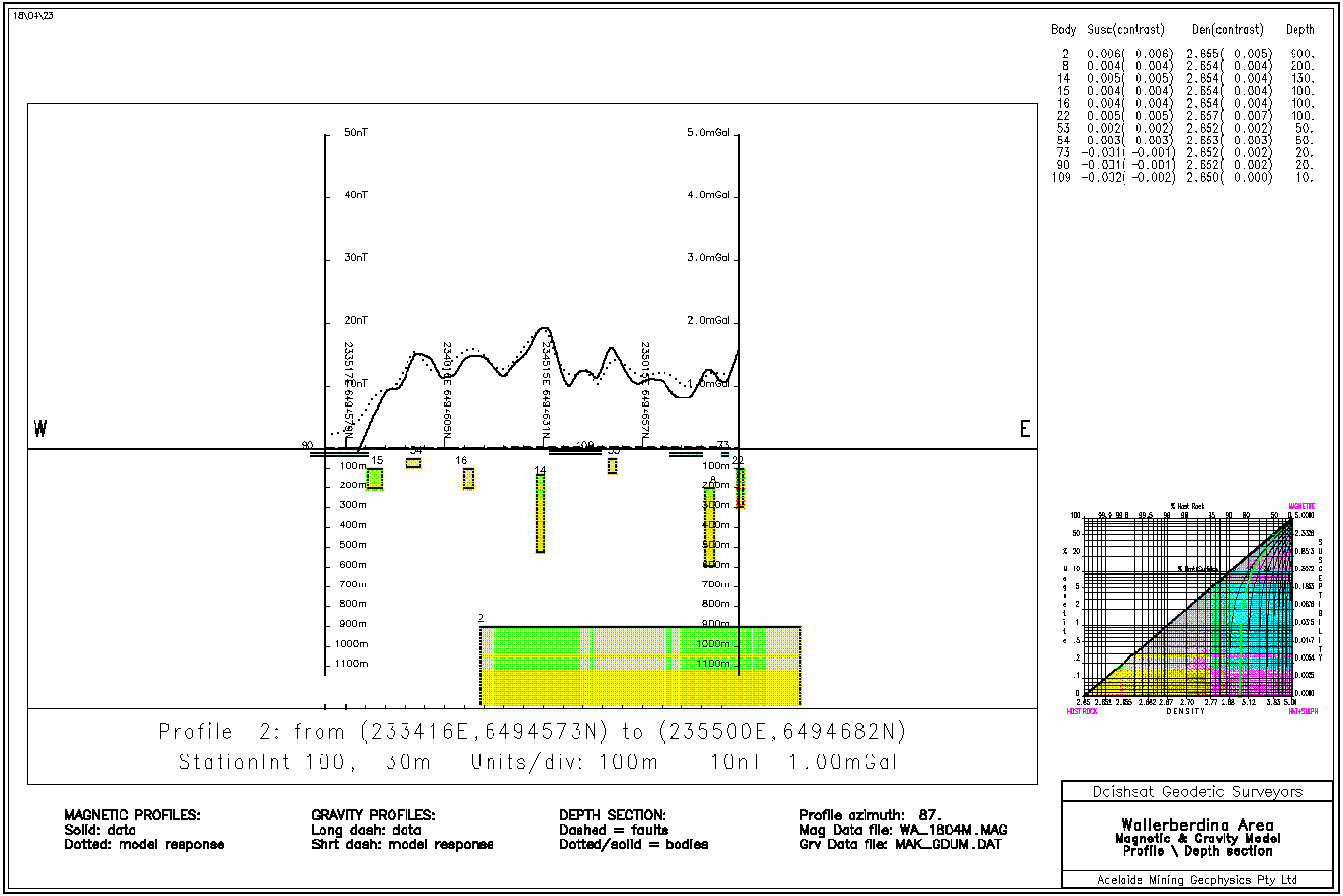
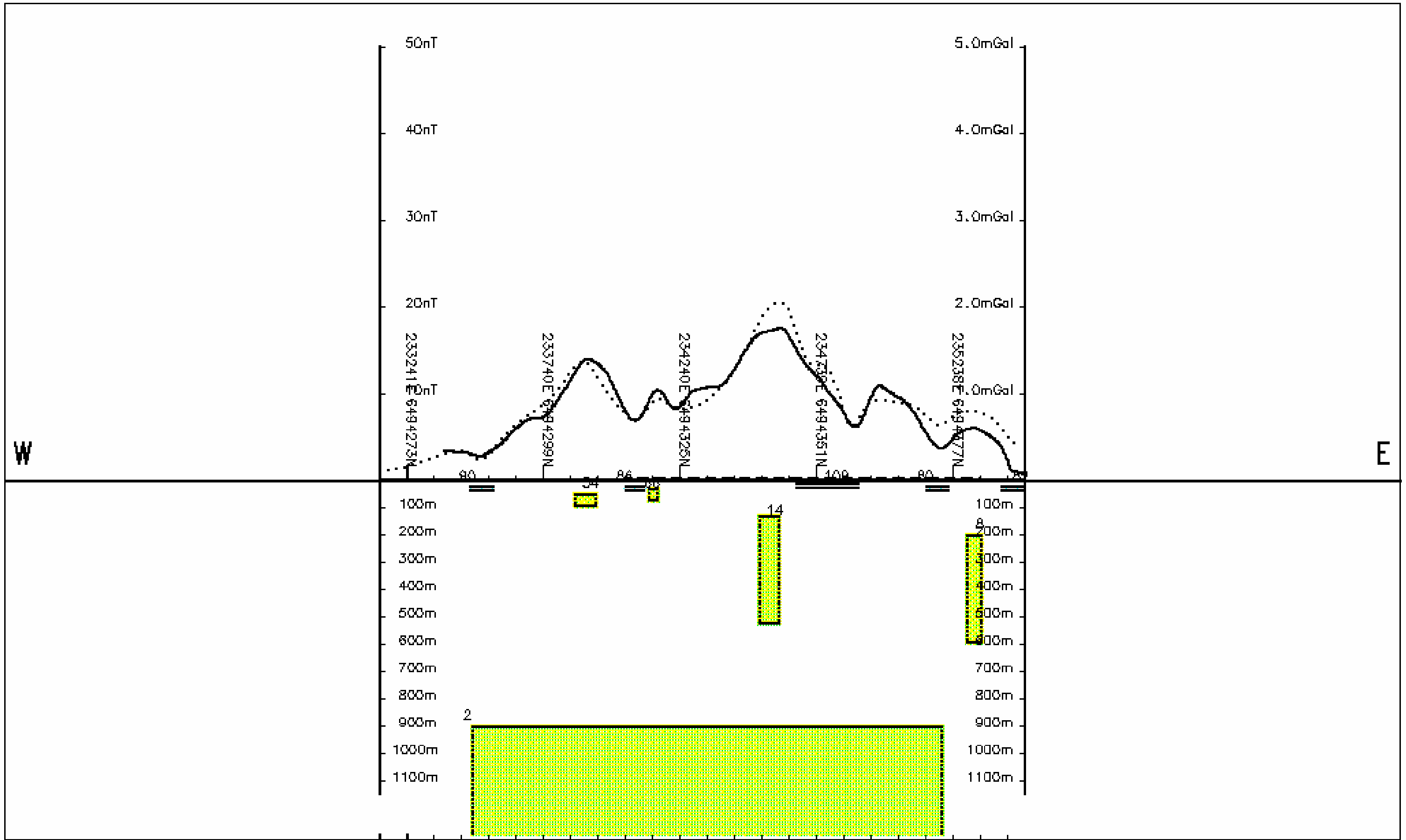

18\04\23
Body Susc(contrast) Den(contrast) Depth
2 0.006(0.006) 2.655(0.005) 900.
8 0.004(0.004) 2.654(0.004) 200.
14 0.005(0.005) 2.654(0.004) 130.
15 0.004(0.004) 2.654(0.004) 100.
16 0.004(0.004) 2.654(0.004) 100.
22 0.005(0.005) 2.657(0.007) 100.
53 0.002(0.002) 2.652(0.002) 50.
54 0.003(0.003) 2.653(0.003) 50.
73 -0.001(-0.001) 2.652(0.002) 20.
90 -0.001(-0.001) 2.652(0.002) 20.
109 -0.002(-0.002) 2.650(0.000) 10.
W
E
50nT
40nT
30nT
20nT
10nT
5.0mGal
4.0mGal
3.0mGal
2.0mGal
1.0mGal
233517E 6494579N
234016E 6494605N
234515E 6494631N
235015E 6494657N
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
Profile 2: from (233416E,6494573N) to (235500E,6494682N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd
% Host Rock
MAGNETITE
HOST ROCK
DENSITY
HMT+SULPH
SUSCEPTIBILITY

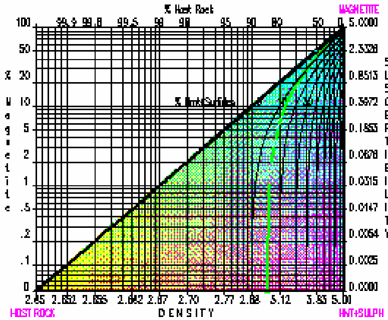
Figure 5.2

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
2	0.006(0.006)	2.655(0.005)	900.
8	0.004(0.004)	2.654(0.004)	200.
14	0.005(0.005)	2.654(0.004)	130.
54	0.003(0.003)	2.653(0.003)	50.
66	0.004(0.004)	2.654(0.004)	30.
80	-0.001(-0.001)	2.652(0.002)	20.
82	-0.001(-0.001)	2.652(0.002)	20.
86	-0.001(-0.001)	2.652(0.002)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.



Profile 3: from (233141E,6494267N) to (235500E,6494391N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal



MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

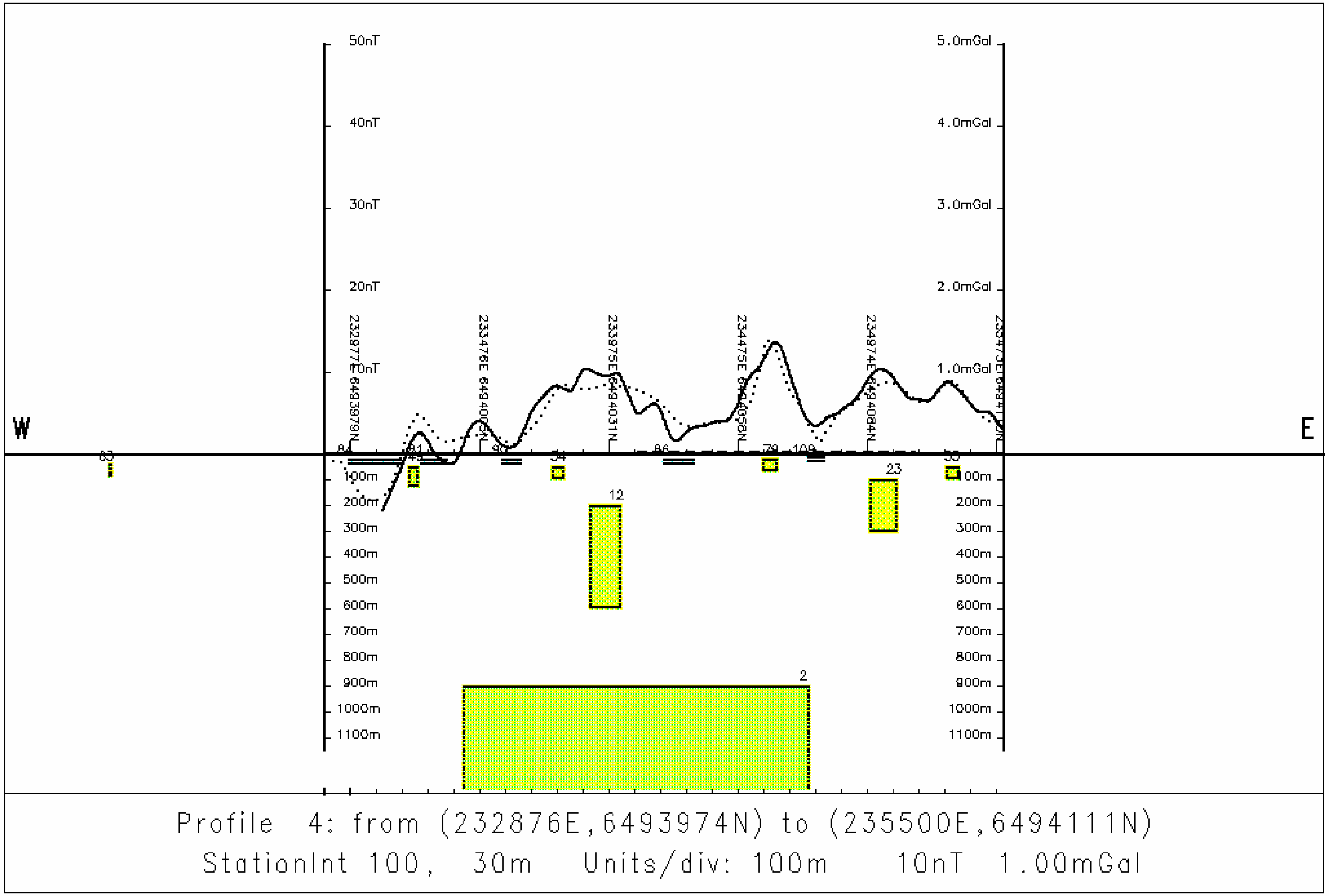
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

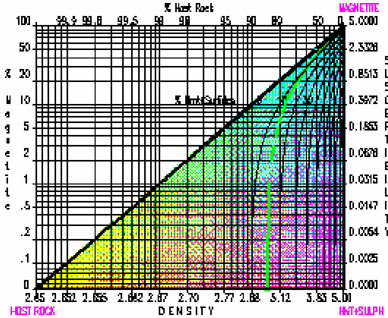
Adelaide Mining Geophysics Pty Ltd

Figure 5.3

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
2	0.006(0.006)	2.655(0.005)	900.
12	0.004(0.004)	2.654(0.004)	200.
23	0.002(0.002)	2.652(0.002)	100.
49	0.003(0.003)	2.653(0.003)	50.
54	0.003(0.003)	2.653(0.003)	50.
55	0.003(0.003)	2.653(0.003)	50.
63	0.004(0.004)	2.653(0.003)	40.
79	0.003(0.003)	2.653(0.003)	20.
81	-0.001(-0.001)	2.652(0.002)	20.
84	-0.002(-0.002)	2.650(0.000)	20.
86	-0.001(-0.001)	2.652(0.002)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.





MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

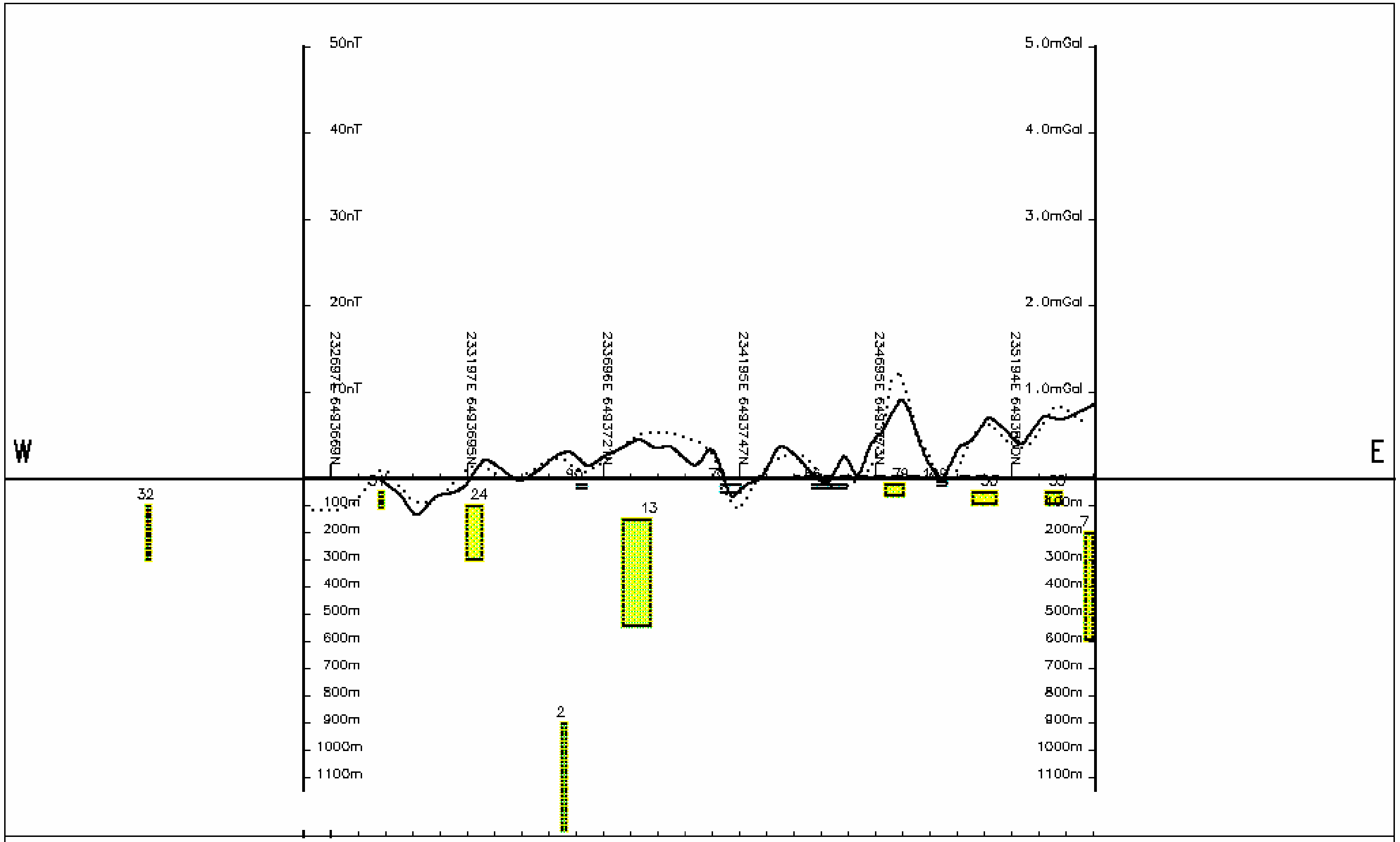
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

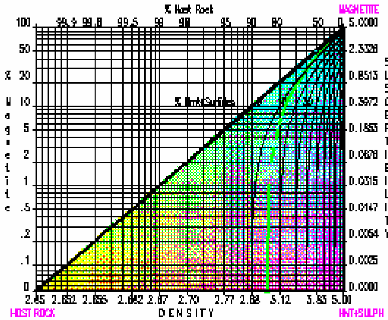
Adelaide Mining Geophysics Pty Ltd

Figure 5.4

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
2	0.006(0.006)	2.655(0.005)	900.
7	0.002(0.002)	2.652(0.002)	200.
13	0.005(0.005)	2.654(0.004)	150.
24	0.003(0.003)	2.653(0.003)	100.
32	0.004(0.004)	2.653(0.003)	100.
50	0.002(0.002)	2.652(0.002)	50.
51	0.004(0.004)	2.654(0.004)	50.
55	0.003(0.003)	2.653(0.003)	50.
70	-0.002(-0.002)	2.650(0.000)	20.
79	0.003(0.003)	2.653(0.003)	20.
86	-0.001(-0.001)	2.652(0.002)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.





Daishsat Geodetic Surveyors

Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

Adelaide Mining Geophysics Pty Ltd

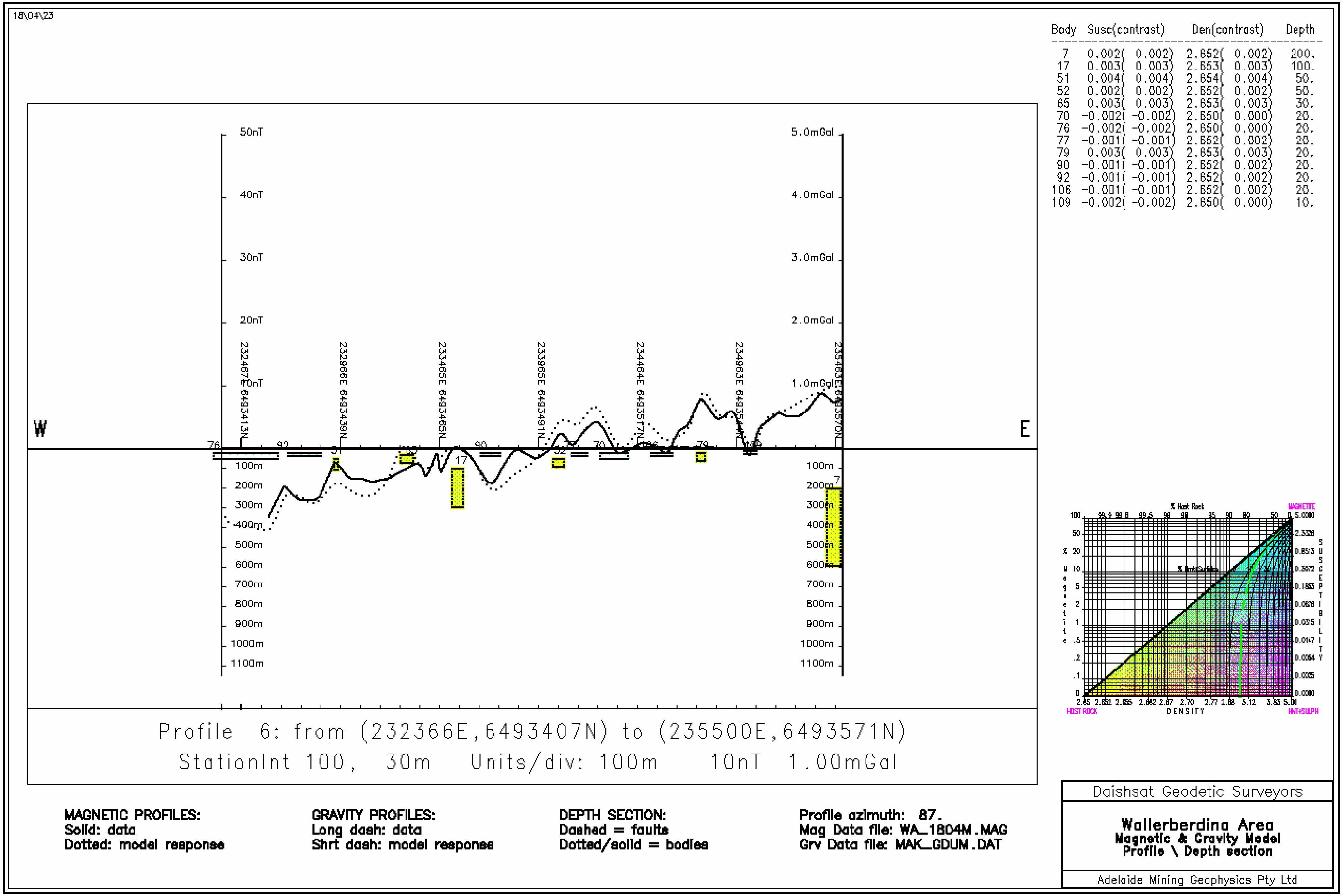
MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Figure 5.5

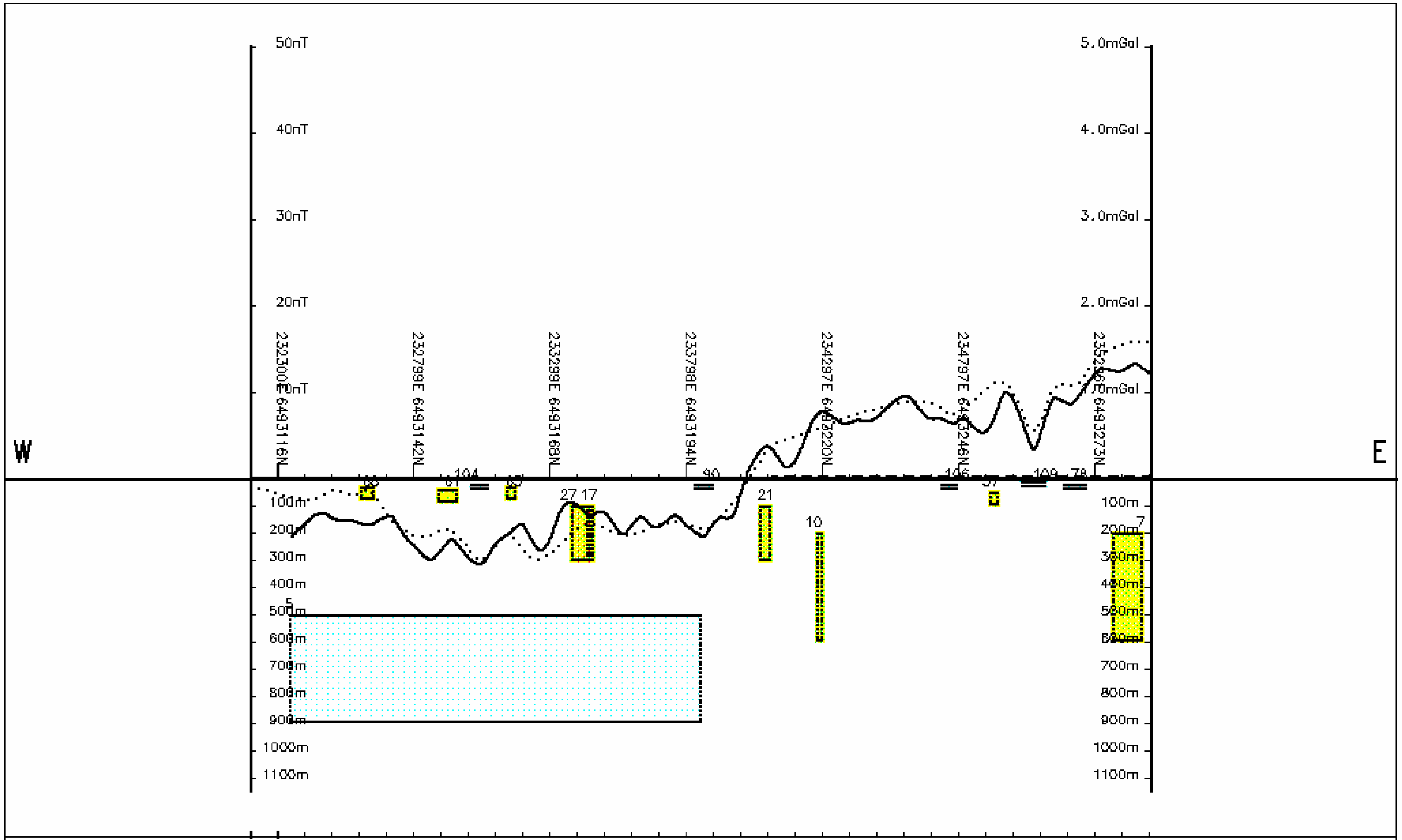


Body	Susc(contrast)	Den(contrast)	Depth
7	0.002(0.002)	2.652(0.002)	200.
17	0.003(0.003)	2.653(0.003)	100.
51	0.004(0.004)	2.654(0.004)	50.
52	0.002(0.002)	2.652(0.002)	50.
65	0.003(0.003)	2.653(0.003)	30.
70	-0.002(-0.002)	2.650(0.000)	20.
76	-0.002(-0.002)	2.650(0.000)	20.
77	-0.001(-0.001)	2.652(0.002)	20.
79	0.003(0.003)	2.653(0.003)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
92	-0.001(-0.001)	2.652(0.002)	20.
106	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.

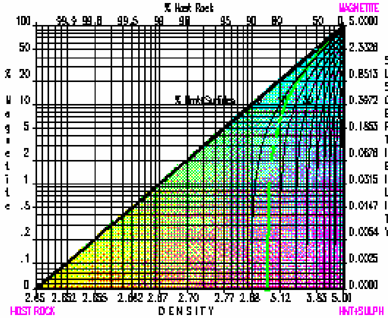
Figure 5.6

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
5	-0.001(-0.001)	2.650(0.000)	500.
7	0.002(0.002)	2.652(0.002)	200.
10	0.004(0.004)	2.654(0.004)	200.
17	0.003(0.003)	2.653(0.003)	100.
21	0.004(0.004)	2.653(0.003)	100.
27	0.002(0.002)	2.653(0.003)	100.
57	0.002(0.002)	2.652(0.002)	50.
61	0.001(0.001)	2.651(0.001)	40.
65	0.003(0.003)	2.653(0.003)	30.
68	0.002(0.002)	2.652(0.002)	30.
78	-0.001(-0.001)	2.652(0.002)	20.
90	-0.001(-0.001)	2.652(0.002)	20.
104	-0.001(-0.001)	2.652(0.002)	20.
106	-0.001(-0.001)	2.652(0.002)	20.
109	-0.002(-0.002)	2.650(0.000)	10.



Profile 7: from (232200E,6493110N) to (235500E,6493283N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal



MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

Adelaide Mining Geophysics Pty Ltd

Figure 5.7

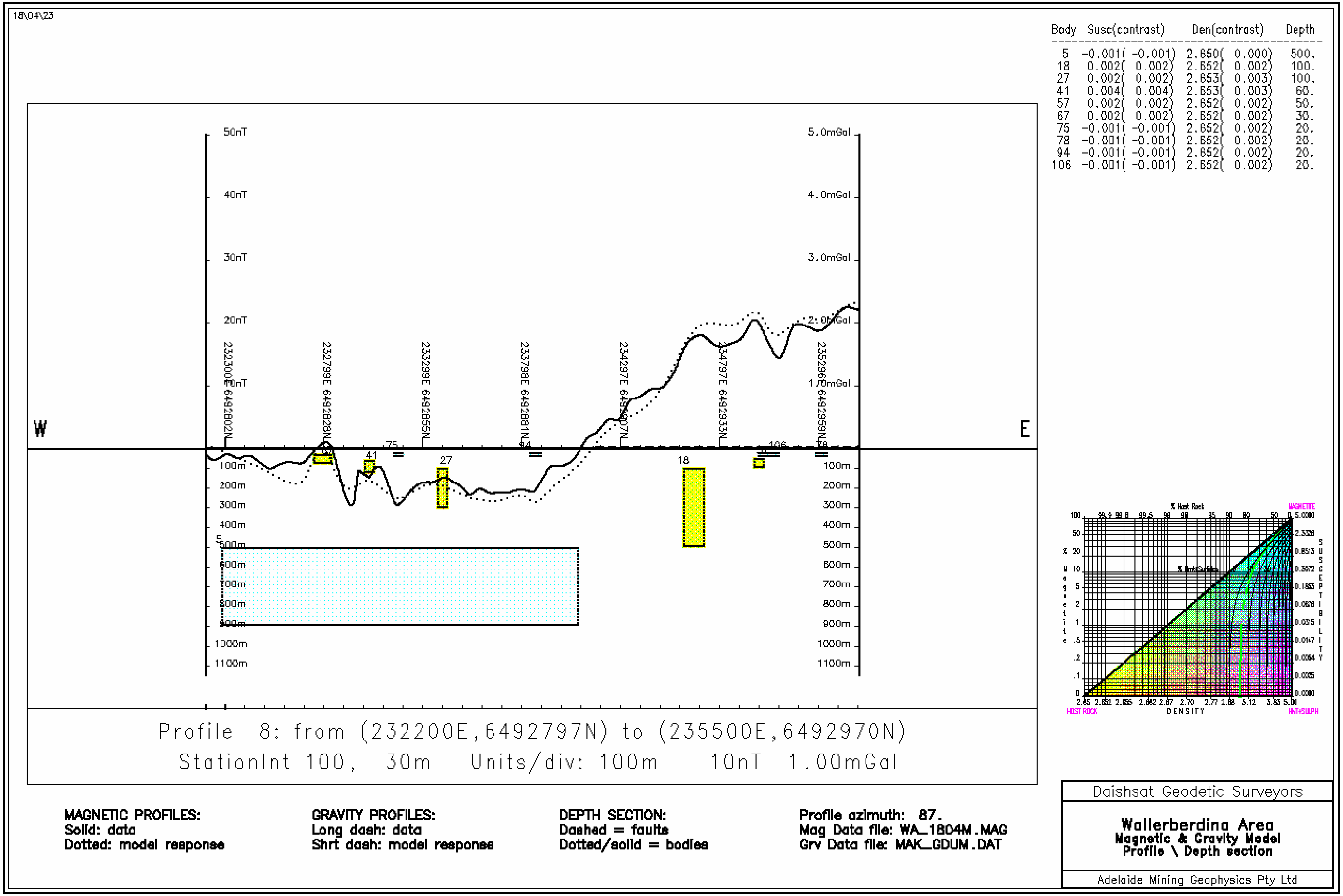
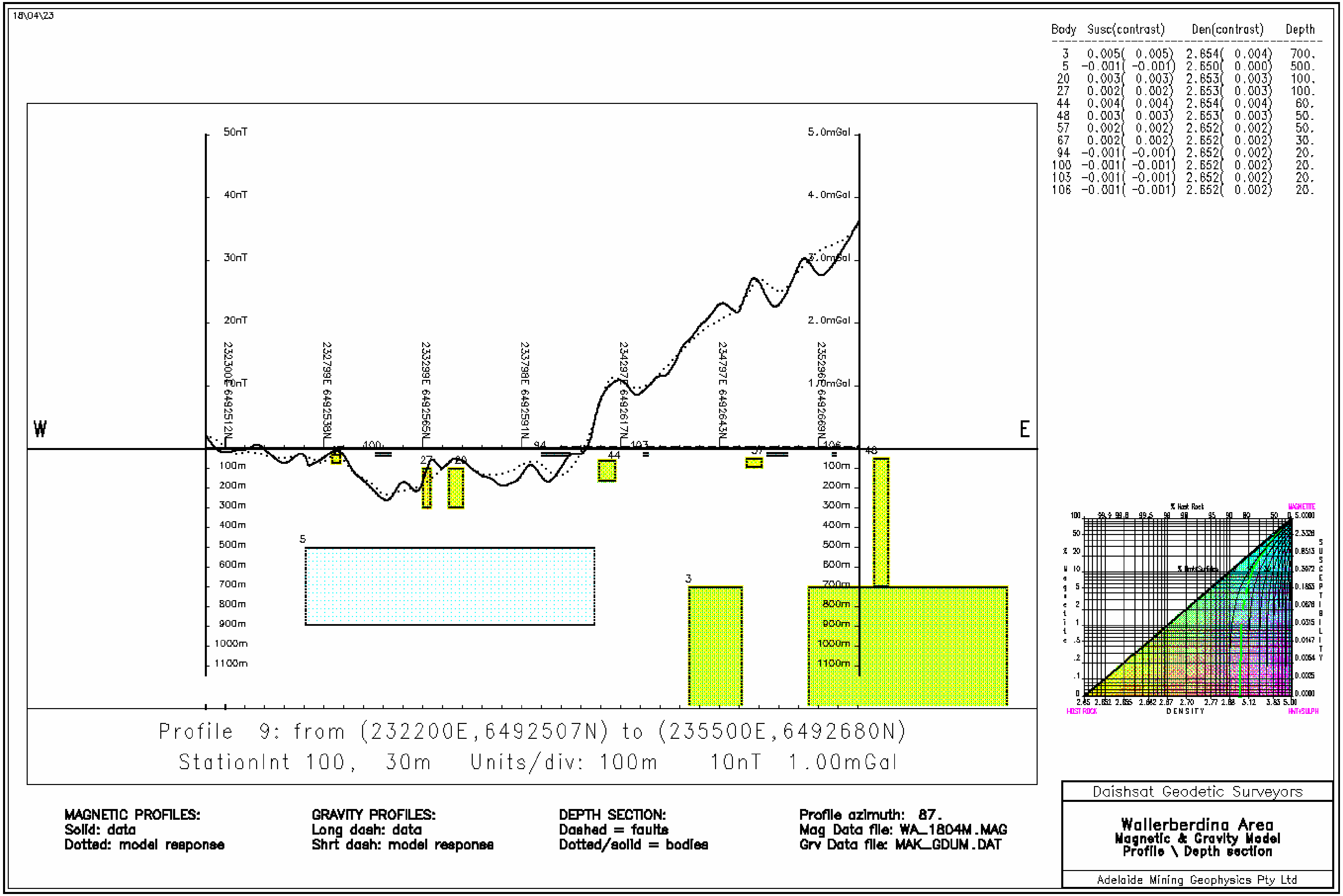

18\04\23
Body Susc(contrast) Den(contrast) Depth
5 -0.001(-0.001) 2.650(0.000) 500.
18 0.002(0.002) 2.652(0.002) 100.
27 0.002(0.002) 2.653(0.003) 100.
41 0.004(0.004) 2.653(0.003) 60.
57 0.002(0.002) 2.652(0.002) 50.
67 0.002(0.002) 2.652(0.002) 30.
75 -0.001(-0.001) 2.652(0.002) 20.
78 -0.001(-0.001) 2.652(0.002) 20.
94 -0.001(-0.001) 2.652(0.002) 20.
106 -0.001(-0.001) 2.652(0.002) 20.
50nT
40nT
30nT
20nT
10nT
5.0mGal
4.0mGal
3.0mGal
2.0mGal
1.0mGal
W
E
232300E 6492802N
232799E 6492829N
233299E 6492855N
233798E 6492881N
234297E 6492907N
234797E 6492933N
235296E 6492959N
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
Profile 8: from (232200E,6492797N) to (235500E,6492970N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd
DENSITY

Figure 5.8



Body	Susc(contrast)	Den(contrast)	Depth
3	0.005(0.005)	2.654(0.004)	700.
5	-0.001(-0.001)	2.650(0.000)	500.
20	0.003(0.003)	2.653(0.003)	100.
27	0.002(0.002)	2.653(0.003)	100.
44	0.004(0.004)	2.654(0.004)	60.
48	0.003(0.003)	2.653(0.003)	50.
57	0.002(0.002)	2.652(0.002)	50.
67	0.002(0.002)	2.652(0.002)	30.
94	-0.001(-0.001)	2.652(0.002)	20.
100	-0.001(-0.001)	2.652(0.002)	20.
103	-0.001(-0.001)	2.652(0.002)	20.
106	-0.001(-0.001)	2.652(0.002)	20.

Figure 5.9

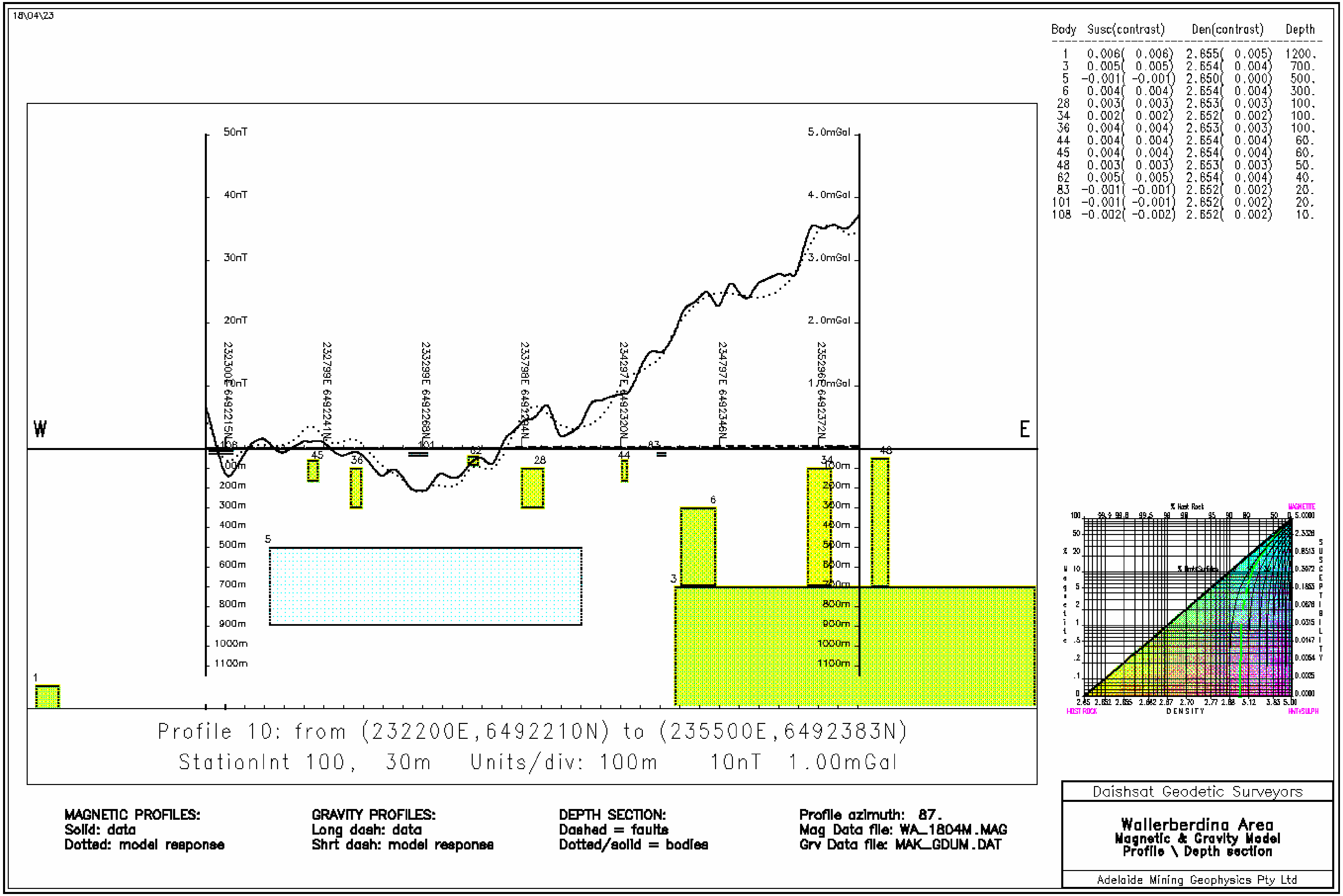

18\04\23
Body Susc(contrast) Den(contrast) Depth
1 0.006(0.006) 2.655(0.005) 1200.
3 0.005(0.005) 2.654(0.004) 700.
5 -0.001(-0.001) 2.650(0.000) 500.
6 0.004(0.004) 2.654(0.004) 300.
28 0.003(0.003) 2.653(0.003) 100.
34 0.002(0.002) 2.652(0.002) 100.
36 0.004(0.004) 2.653(0.003) 100.
44 0.004(0.004) 2.654(0.004) 60.
45 0.004(0.004) 2.654(0.004) 60.
48 0.003(0.003) 2.653(0.003) 50.
62 0.005(0.005) 2.654(0.004) 40.
83 -0.001(-0.001) 2.652(0.002) 20.
101 -0.001(-0.001) 2.652(0.002) 20.
108 -0.002(-0.002) 2.652(0.002) 10.
W
E
50nT
40nT
30nT
20nT
10nT
5.0mGal
4.0mGal
3.0mGal
2.0mGal
1.0mGal
232300E 6492215N
232799E 6492241N
233299E 6492268N
233798E 6492294N
234297E 6492320N
234797E 6492346N
235296E 6492372N
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
Profile 10: from (232200E,6492210N) to (235500E,6492383N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd
DENSITY
HOST ROCK
MAGNETITE

Figure 5.10

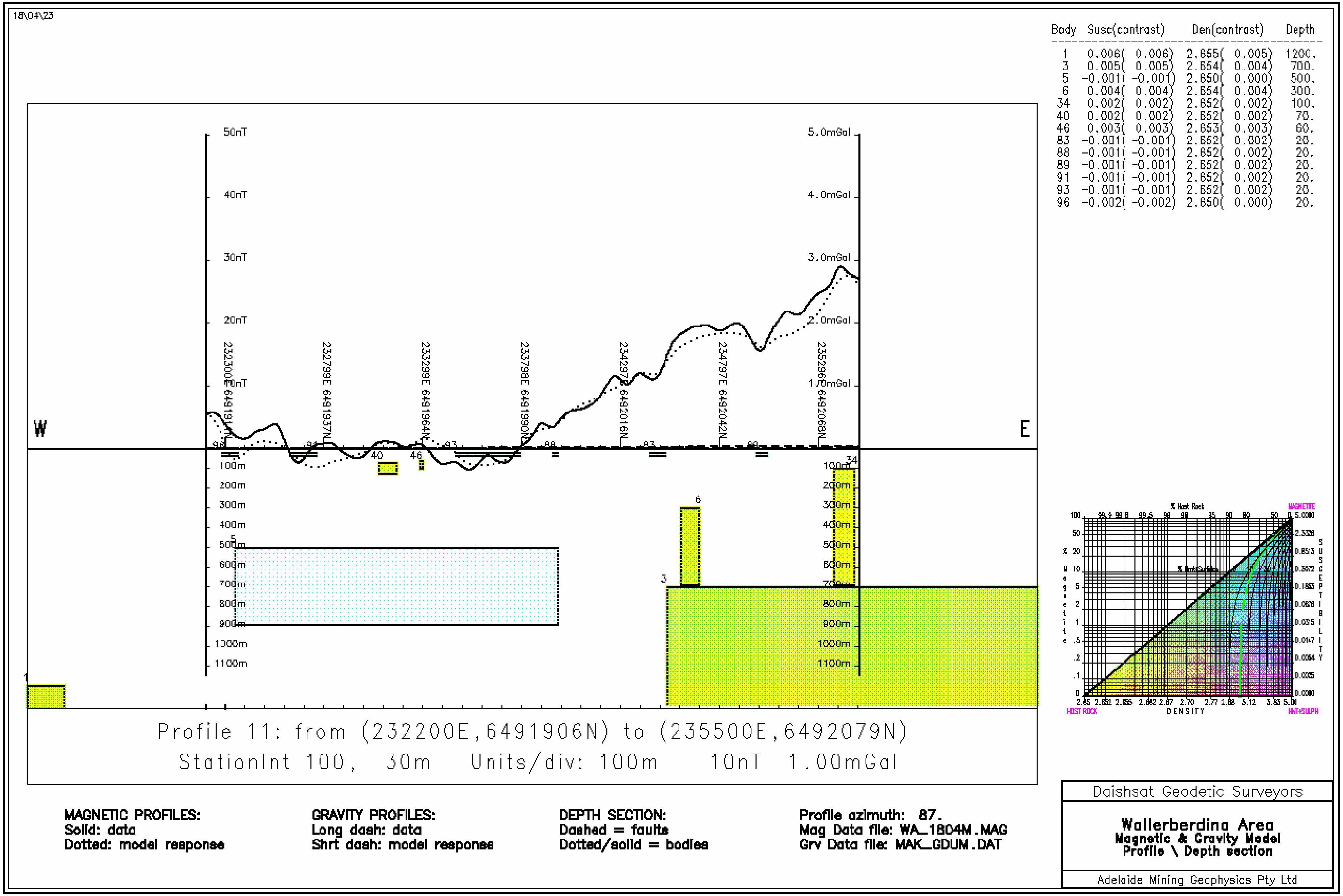

18\04\23
Body Susc(contrast) Den(contrast) Depth
1 0.006(0.006) 2.655(0.005) 1200.
3 0.005(0.005) 2.654(0.004) 700.
5 -0.001(-0.001) 2.650(0.000) 500.
6 0.004(0.004) 2.654(0.004) 300.
34 0.002(0.002) 2.652(0.002) 100.
40 0.002(0.002) 2.652(0.002) 70.
46 0.003(0.003) 2.653(0.003) 60.
83 -0.001(-0.001) 2.652(0.002) 20.
88 -0.001(-0.001) 2.652(0.002) 20.
89 -0.001(-0.001) 2.652(0.002) 20.
91 -0.001(-0.001) 2.652(0.002) 20.
93 -0.001(-0.001) 2.652(0.002) 20.
96 -0.002(-0.002) 2.650(0.000) 20.
W
E
50nT
40nT
30nT
20nT
10nT
5.0mGal
4.0mGal
3.0mGal
2.0mGal
1.0mGal
232300E 6491911N
232799E 6491937N
233299E 6491964N
233798E 6491990N
234297E 6492016N
234797E 6492042N
235296E 6492068N
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
Profile 11: from (232200E,6491906N) to (235500E,6492079N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd

Figure 5.11

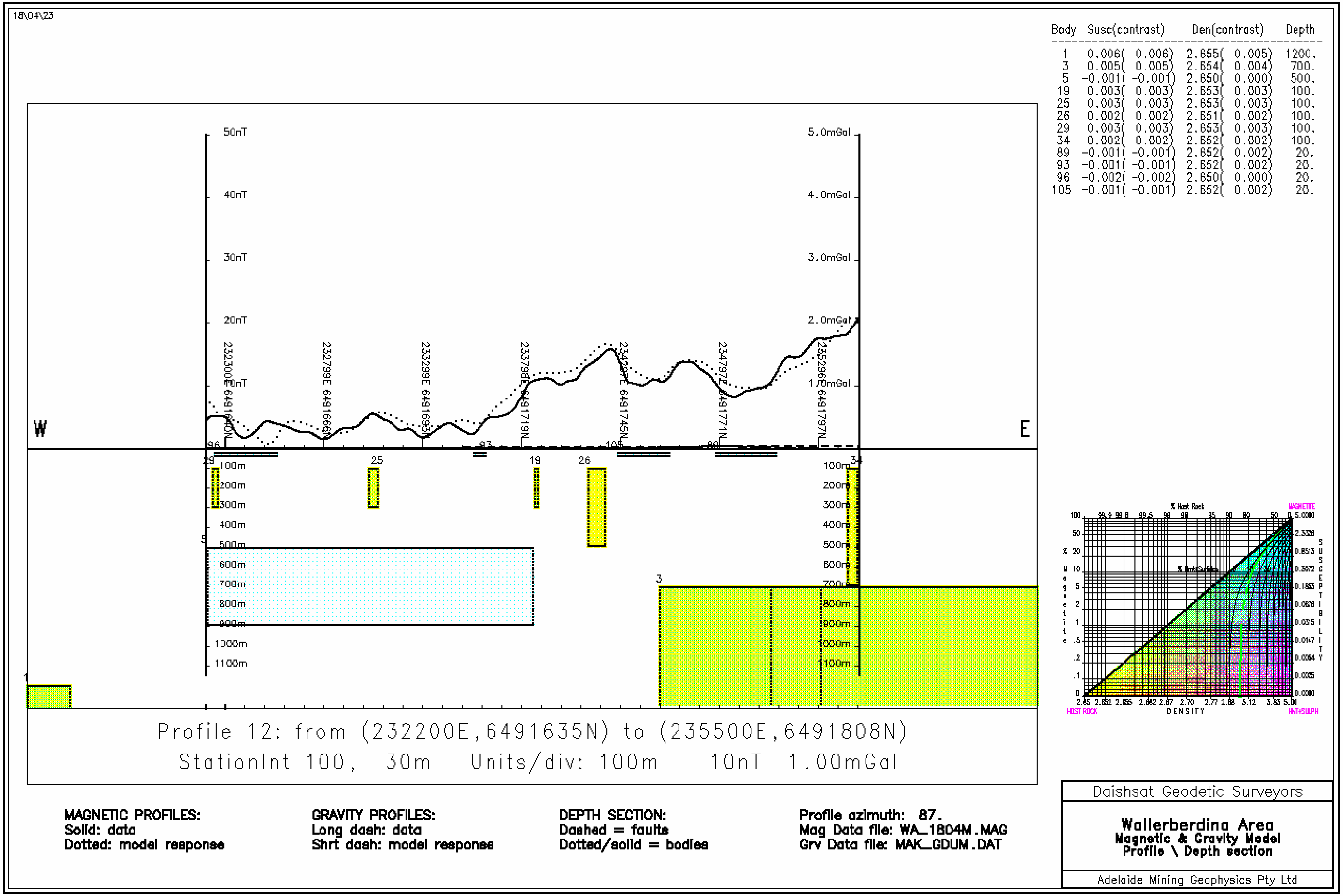
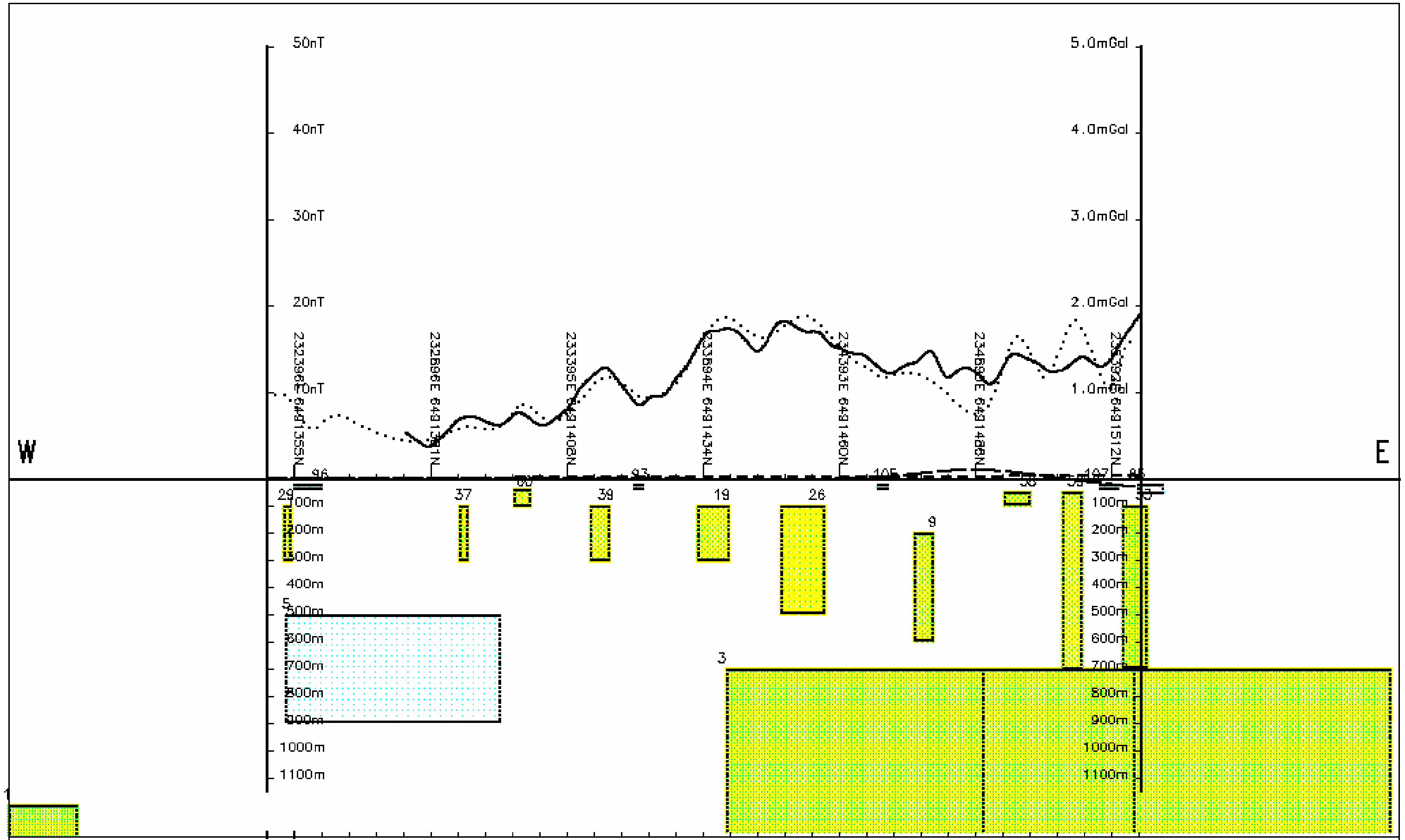

18\04\23
Body Susc(contrast) Den(contrast) Depth
1 0.006(0.006) 2.655(0.005) 1200.
3 0.005(0.005) 2.654(0.004) 700.
5 -0.001(-0.001) 2.650(0.000) 500.
19 0.003(0.003) 2.653(0.003) 100.
25 0.003(0.003) 2.653(0.003) 100.
26 0.002(0.002) 2.651(0.002) 100.
29 0.003(0.003) 2.653(0.003) 100.
34 0.002(0.002) 2.652(0.002) 100.
89 -0.001(-0.001) 2.652(0.002) 20.
93 -0.001(-0.001) 2.652(0.002) 20.
96 -0.002(-0.002) 2.650(0.000) 20.
105 -0.001(-0.001) 2.652(0.002) 20.
W
E
50nT
40nT
30nT
20nT
10nT
5.0mGal
4.0mGal
3.0mGal
2.0mGal
1.0mGal
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
Profile 12: from (232200E,6491635N) to (235500E,6491808N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd
DENSITY
HOST ROCK
MAGNETITE

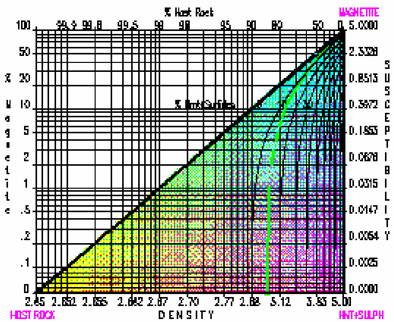
Figure 5.12

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
1	0.006(0.006)	2.655(0.005)	1200.
3	0.005(0.005)	2.654(0.004)	700.
5	-0.001(-0.001)	2.650(0.000)	500.
9	0.004(0.004)	2.654(0.004)	200.
19	0.003(0.003)	2.653(0.003)	100.
26	0.002(0.002)	2.651(0.002)	100.
29	0.003(0.003)	2.653(0.003)	100.
33	0.005(0.005)	2.652(0.002)	100.
37	0.004(0.004)	2.653(0.003)	100.
39	0.003(0.003)	2.653(0.003)	100.
58	0.004(0.004)	2.654(0.004)	50.
59	0.003(0.003)	2.653(0.003)	50.
60	0.002(0.002)	2.652(0.002)	40.
85	-0.002(-0.002)	2.650(0.000)	20.
93	-0.001(-0.001)	2.652(0.002)	20.
96	-0.002(-0.002)	2.650(0.000)	20.
105	-0.001(-0.001)	2.652(0.002)	20.
107	-0.002(-0.002)	2.650(0.000)	20.



Profile 13: from (232296E,6491350N) to (235500E,6491518N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal



MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: 87.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

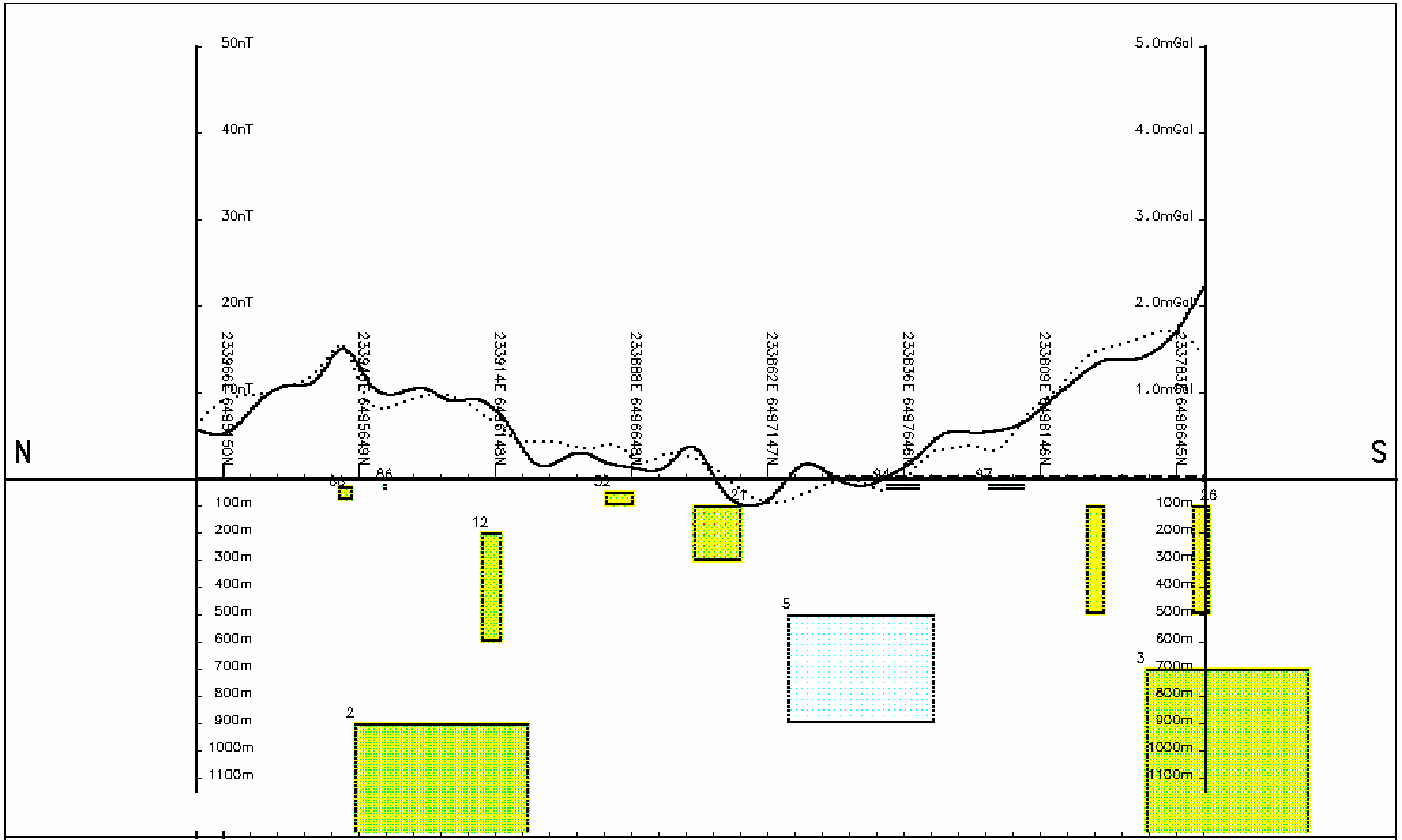
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

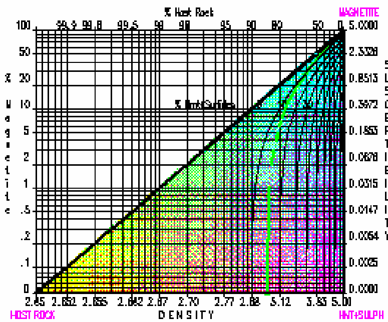
Adelaide Mining Geophysics Pty Ltd

Figure 5.13

18\04\23

Body	Susc(contrast)	Den(contrast)	Depth
2	0.006(0.006)	2.655(0.005)	900.
3	0.005(0.005)	2.654(0.004)	700.
5	-0.001(-0.001)	2.650(0.000)	500.
12	0.004(0.004)	2.654(0.004)	200.
21	0.004(0.004)	2.653(0.003)	100.
26	0.002(0.002)	2.651(0.002)	100.
52	0.002(0.002)	2.652(0.002)	50.
66	0.004(0.004)	2.654(0.004)	30.
86	-0.001(-0.001)	2.652(0.002)	20.
94	-0.001(-0.001)	2.652(0.002)	20.
97	-0.001(-0.001)	2.652(0.002)	20.





Profile 14: from (234165E,6491350N) to (233971E,6495050N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal

MAGNETIC PROFILES:
Solid: data
Dotted: model response

GRAVITY PROFILES:
Long dash: data
Shrt dash: model response

DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies

Profile azimuth: -3.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT

Daishsat Geodetic Surveyors

Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section

Adelaide Mining Geophysics Pty Ltd

Figure 5.14

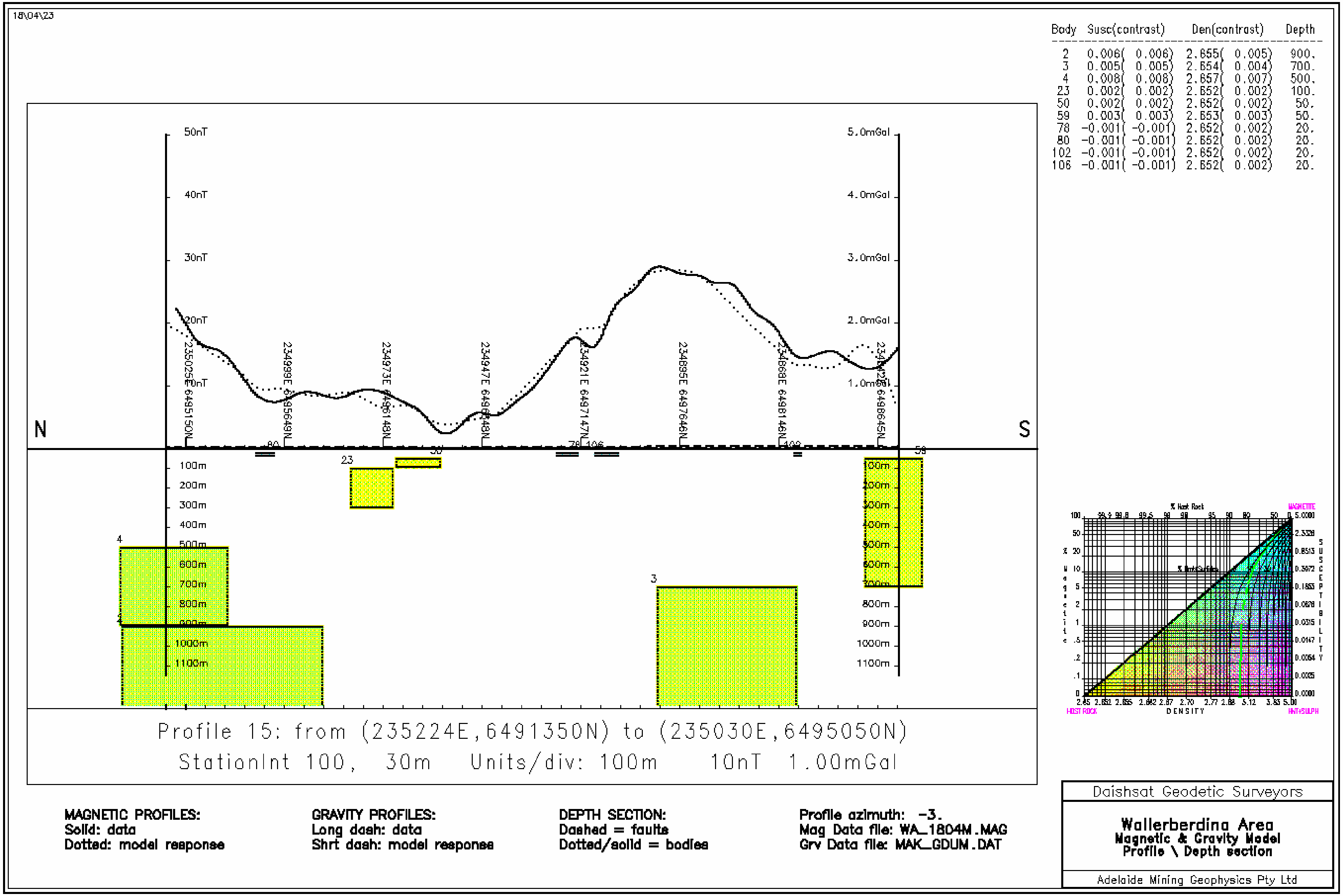

18\04\23
Body Susc(contrast) Den(contrast) Depth
2 0.006(0.006) 2.655(0.005) 900.
3 0.005(0.005) 2.654(0.004) 700.
4 0.008(0.008) 2.657(0.007) 500.
23 0.002(0.002) 2.652(0.002) 100.
50 0.002(0.002) 2.652(0.002) 50.
59 0.003(0.003) 2.653(0.003) 50.
78 -0.001(-0.001) 2.652(0.002) 20.
80 -0.001(-0.001) 2.652(0.002) 20.
102 -0.001(-0.001) 2.652(0.002) 20.
106 -0.001(-0.001) 2.652(0.002) 20.
N
S
Profile 15: from (235224E,6491350N) to (235030E,6495050N)
StationInt 100, 30m Units/div: 100m 10nT 1.00mGal
MAGNETIC PROFILES:
Solid: data
Dotted: model response
GRAVITY PROFILES:
Long dash: data
Shrt dash: model response
DEPTH SECTION:
Dashed = faults
Dotted/solid = bodies
Profile azimuth: -3.
Mag Data file: WA_1804M.MAG
Grv Data file: MAK_GDUM.DAT
Daishsat Geodetic Surveyors
Wallerberdina Area
Magnetic & Gravity Model
Profile \ Depth section
Adelaide Mining Geophysics Pty Ltd

Figure 5.15

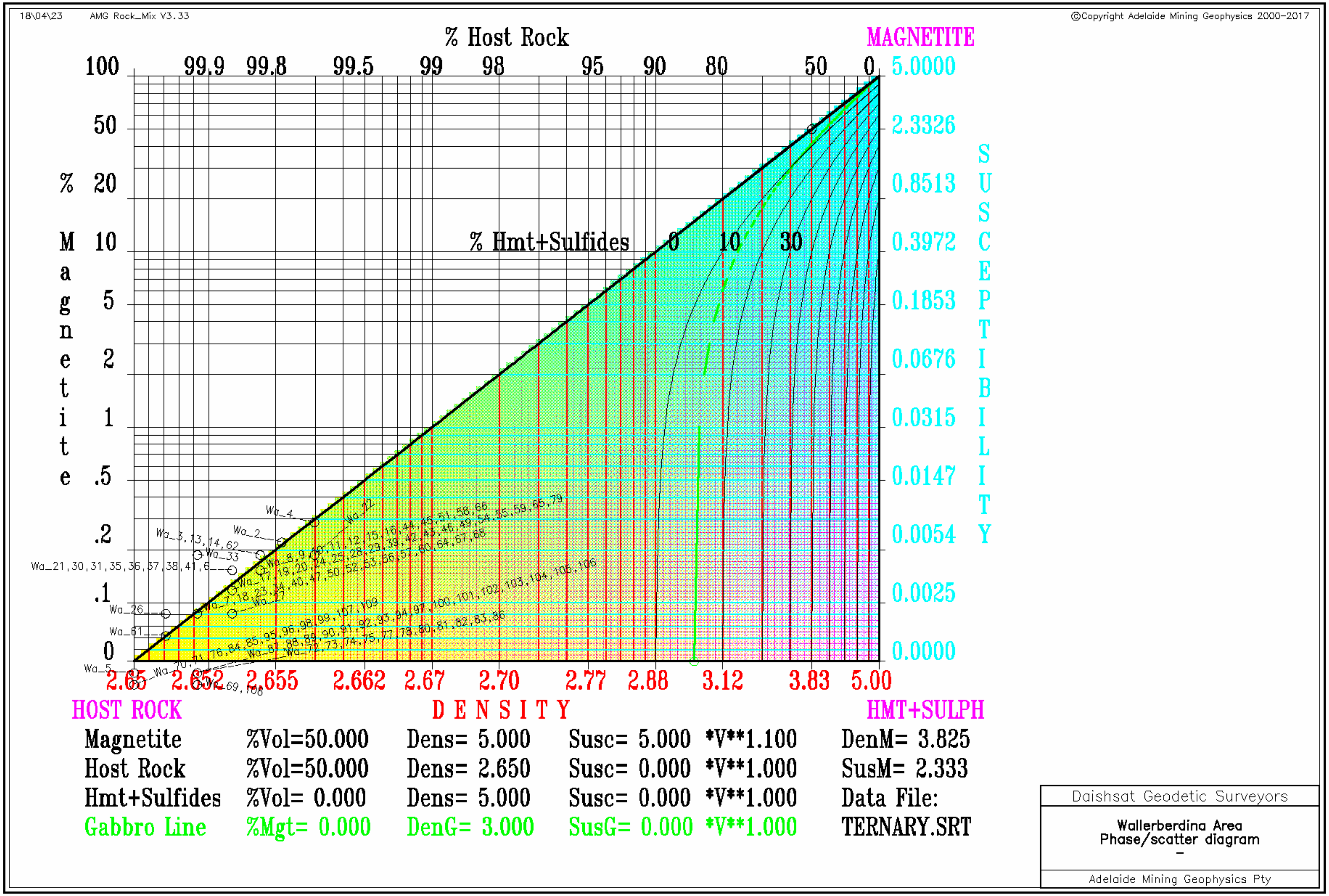

18\04\23 AMG Rock_Mix V3.33
©Copyright Adelaide Mining Geophysics 2000-2017
% Host Rock
MAGNETITE
% Magnetite
% Hmt+Sulfides
SUSCEPTIBILITY
HOST ROCK
DENSITY
HMT+SULPH
Magnetite %Vol=50.000 Dens= 5.000 Susc= 5.000 *V**1.100 DenM= 3.825
Host Rock %Vol=50.000 Dens= 2.650 Susc= 0.000 *V**1.000 SusM= 2.333
Hmt+Sulfides %Vol= 0.000 Dens= 5.000 Susc= 0.000 *V**1.000 Data File:
Gabbro Line %Mgt= 0.000 DenG= 3.000 SusG= 0.000 *V**1.000 TERNARY.SRT
Daishsat Geodetic Surveyors
Wallerberdina Area
Phase/scatter diagram
Adelaide Mining Geophysics Pty

Figure 6.

Table 1. Magnetic/Gravity Model specification report for use with Plan Map of Body Tops

```
Title:   Wallerberdina Area
Client:  Daishsat Geodetic Surveyors
User:    Adelaide Mining Geophysics Pty Ltd

Magnetic data file name:  WA_1804M.MAG
Gravity  data file name:  MAK_GDUM.DAT

Intensity = 57930.        Declination =   7.
Inclination = -64.        Magnetometer height:  40.0m
Gravimeter height:  0.0m

Hmt+sulf Density = 5.00   Magnetite Density  = 5.00
Magnetite MagSus = 5.00   Power Law Exponent = 1.10
CountryRock Dens = 2.65   Mafic Rock Density = 3.00
CountryRock Susc = 0.00

Number of Bodies   =109   Number of Faults =  0
Number of Profiles = 15   Gauss quad order = 10
Station Int = 100 &  30    Scales =  10n/div & 1.00mGal/div
```

Body	No of Verts	Depth	Dip Extnt	Plng Azmth	Plng	Susc (SI)	Rem Dec	Rem Inc	K-Ratio	Density t/m**3	App%Mgt	App%Hmt (Felsic)	Volume m**3	ExcessMass tonnes	Total Mass tonnes	Centroid E	Centroid N
1	8	1200.	1000.	0.	90.	0.0060	0.	90.	0.00	0.005	0.22	0.00	0.212E+10	0.110E+08	0.562E+10	231685	6490933
2	19	900.	500.	0.	90.	0.0060	0.	90.	0.00	0.005	0.22	0.00	0.941E+09	0.489E+07	0.250E+10	234348	6494392
3	20	700.	800.	0.	90.	0.0050	0.	90.	0.00	0.004	0.19	0.00	0.269E+10	0.118E+08	0.715E+10	234687	6491724
4	6	500.	400.	0.	90.	0.0080	0.	90.	0.00	0.007	0.29	0.00	0.399E+08	0.271E+06	0.106E+09	235090	6495039
5	16	500.	400.	0.	90.	-0.0013	0.	90.	0.00	0.000	-	-	0.119E+10	0.000E+00	0.315E+10	233092	6492360
6	16	300.	400.	0.	90.	0.0045	0.	90.	0.00	0.004	0.17	0.00	0.396E+08	0.159E+06	0.105E+09	234731	6492333
7	8	200.	400.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.236E+08	0.448E+05	0.625E+08	235430	6493465
8	5	200.	400.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.798E+07	0.287E+05	0.212E+08	235328	6494482
9	5	200.	400.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.157E+08	0.566E+05	0.417E+08	234668	6491342
10	10	200.	400.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.845E+07	0.304E+05	0.224E+08	234254	6493093
11	9	200.	400.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.118E+08	0.425E+05	0.313E+08	234396	6493333
12	6	200.	400.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.928E+07	0.334E+05	0.246E+08	233958	6494056
13	5	150.	400.	0.	90.	0.0050	0.	90.	0.00	0.004	0.19	0.00	0.572E+07	0.252E+05	0.152E+08	233829	6493735
14	11	130.	400.	0.	90.	0.0050	0.	90.	0.00	0.004	0.19	0.00	0.139E+08	0.613E+05	0.370E+08	234538	6494441
15	5	100.	100.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.110E+07	0.394E+04	0.291E+07	233658	6494613
16	5	100.	100.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.151E+07	0.544E+04	0.401E+07	234135	6494551
17	8	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.614E+07	0.172E+05	0.163E+08	233504	6493450
18	12	100.	400.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.137E+08	0.260E+05	0.363E+08	234710	6492833
19	8	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.769E+07	0.215E+05	0.204E+08	233920	6491483
20	7	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.274E+07	0.767E+04	0.726E+07	233458	6492512
21	8	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.262E+07	0.839E+04	0.696E+07	234089	6493214
22	12	100.	200.	0.	90.	0.0050	0.	90.	0.00	0.007	0.19	0.10	0.741E+07	0.504E+05	0.197E+08	235388	6494860
23	6	100.	200.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.439E+07	0.835E+04	0.116E+08	235044	6494045
24	6	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.334E+07	0.936E+04	0.886E+07	233204	6493705
25	7	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.296E+07	0.827E+04	0.784E+07	233040	6491649
26	8	100.	400.	0.	90.	0.0015	0.	90.	0.00	0.002	0.06	0.00	0.318E+08	0.477E+05	0.844E+08	234235	6491468
27	12	100.	200.	0.	90.	0.0020	0.	90.	0.00	0.003	0.08	0.04	0.807E+07	0.226E+05	0.214E+08	233376	6492918
28	8	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.579E+07	0.162E+05	0.154E+08	233839	6492269

Body	No of Verts	Depth	Dip Extnt	Plng Azmth	Plng	Susc (SI)	Rem Dec	Rem Inc	K-Ratio	Density t/m**3	App%Mgt	App%Hmt (Felsic)	Volume m**3	ExcessMass tonnes	Total Mass tonnes	Centroid E	N
29	5	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.265E+07	0.741E+04	0.702E+07	232341	6491486
30	6	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.179E+07	0.574E+04	0.476E+07	233701	6493040
31	4	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.840E+06	0.269E+04	0.223E+07	232588	6491426
32	4	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.875E+06	0.280E+04	0.232E+07	232042	6493571
33	6	100.	600.	0.	90.	0.0050	0.	90.	0.00	0.002	0.19	-0.11	0.160E+08	0.305E+05	0.425E+08	235486	6491531
34	14	100.	600.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.574E+08	0.109E+06	0.152E+09	235377	6492243
35	4	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.645E+06	0.206E+04	0.171E+07	233978	6493647
36	7	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.325E+07	0.104E+05	0.864E+07	232940	6492248
37	4	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.877E+06	0.281E+04	0.233E+07	233025	6491344
38	4	100.	200.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.779E+06	0.249E+04	0.207E+07	232718	6491525
39	4	100.	200.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.217E+07	0.607E+04	0.575E+07	233521	6491386
40	6	70.	60.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.534E+06	0.101E+04	0.142E+07	233094	6491919
41	4	60.	60.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.266E+06	0.850E+03	0.705E+06	233023	6492824
42	6	60.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.643E+06	0.180E+04	0.170E+07	234289	6494876
43	4	60.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.380E+06	0.106E+04	0.101E+07	234121	6494910
44	9	60.	100.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.168E+07	0.604E+04	0.445E+07	234278	6492453
45	10	60.	100.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.154E+07	0.555E+04	0.409E+07	232710	6492276
46	4	60.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.366E+06	0.102E+04	0.971E+06	233305	6491875
47	5	60.	100.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.151E+07	0.288E+04	0.402E+07	234234	6492714
48	8	50.	650.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.233E+08	0.654E+05	0.619E+08	235604	6492498
49	8	50.	70.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.728E+06	0.204E+04	0.193E+07	233281	6493919
50	5	50.	50.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.882E+06	0.168E+04	0.234E+07	235092	6493783
51	6	50.	60.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.668E+06	0.241E+04	0.177E+07	232894	6493544
52	4	50.	50.	0.	90.	0.0025	0.	90.	0.00	0.002	0.10	0.00	0.261E+06	0.601E+03	0.693E+06	234060	6493493
53	7	50.	70.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.191E+07	0.364E+04	0.507E+07	234831	6494886
54	19	50.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.350E+07	0.979E+04	0.928E+07	233811	6494429
55	7	50.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.118E+07	0.332E+04	0.314E+07	235329	6493934
56	3	50.	60.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.480E+06	0.911E+03	0.127E+07	234412	6494842
57	12	50.	50.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.197E+07	0.373E+04	0.521E+07	234967	6492904
58	5	50.	50.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.156E+07	0.563E+04	0.415E+07	235040	6491416
59	5	50.	650.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.135E+08	0.379E+05	0.359E+08	235246	6491407
60	7	40.	60.	0.	90.	0.0025	0.	90.	0.00	0.002	0.10	0.00	0.670E+06	0.154E+04	0.178E+07	233244	6491432
61	4	40.	50.	0.	90.	0.0010	0.	90.	0.00	0.001	0.04	0.00	0.486E+06	0.486E+03	0.129E+07	232924	6493114
62	4	40.	50.	0.	90.	0.0050	0.	90.	0.00	0.004	0.19	0.00	0.333E+06	0.146E+04	0.884E+06	233513	6492323
63	4	40.	50.	0.	90.	0.0035	0.	90.	0.00	0.003	0.14	0.00	0.219E+06	0.700E+03	0.581E+06	232042	6494016
64	7	30.	50.	0.	90.	0.0022	0.	90.	0.00	0.002	0.09	0.00	0.808E+06	0.170E+04	0.214E+07	232611	6492991
65	9	30.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.858E+06	0.240E+04	0.228E+07	233231	6493320
66	6	30.	50.	0.	90.	0.0040	0.	90.	0.00	0.004	0.15	0.00	0.453E+06	0.163E+04	0.120E+07	234069	6494425
67	9	30.	50.	0.	90.	0.0020	0.	90.	0.00	0.002	0.08	0.00	0.109E+07	0.206E+04	0.288E+07	232813	6492681
68	4	30.	50.	0.	90.	0.0022	0.	90.	0.00	0.002	0.09	0.00	0.323E+06	0.679E+03	0.857E+06	232609	6493158
69	5	20.	30.	0.	90.	-0.0020	0.	90.	0.00	0.002	-	-	0.208E+06	0.396E+03	0.553E+06	232807	6492347
70	11	20.	30.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.210E+07	0.000E+00	0.556E+07	234358	6493528
71	7	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.297E+06	0.000E+00	0.788E+06	232587	6492329
72	7	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.221E+06	0.420E+03	0.586E+06	234341	6494498
73	10	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.114E+07	0.217E+04	0.303E+07	235267	6494708
74	6	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.480E+06	0.912E+03	0.127E+07	234379	6495002
75	7	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.300E+06	0.570E+03	0.796E+06	233184	6492971
76	6	20.	40.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.215E+07	0.000E+00	0.570E+07	232515	6493364
77	6	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.363E+06	0.690E+03	0.963E+06	234171	6493405
78	12	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.112E+07	0.212E+04	0.296E+07	235213	6493145
79	14	20.	50.	0.	90.	0.0030	0.	90.	0.00	0.003	0.12	0.00	0.191E+07	0.534E+04	0.506E+07	234729	6493750
80	9	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.452E+06	0.858E+03	0.120E+07	235097	6494475
81	7	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.467E+06	0.887E+03	0.124E+07	233296	6494050

Body	No of Verts	Depth	Dip Extnt	Plng Azmth	Plng	Susc (SI)	Rem Dec	Rem Inc	K-Ratio	Density t/m**3	App%Mgt	App%Hmt (Felsic)	Volume m**3	ExcessMass tonnes	Total Mass tonnes	Centroid E	N
82	6	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.345E+06	0.656E+03	0.915E+06	235475	6494392
83	9	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.638E+06	0.121E+04	0.169E+07	234493	6492207
84	7	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.725E+06	0.000E+00	0.192E+07	233070	6493948
85	5	20.	30.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.676E+06	0.000E+00	0.179E+07	235524	6491560
86	18	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.169E+07	0.322E+04	0.449E+07	234317	6494049
87	7	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.325E+06	0.617E+03	0.861E+06	233697	6492704
88	6	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.140E+06	0.267E+03	0.372E+06	233958	6491912
89	16	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.218E+07	0.414E+04	0.577E+07	234953	6491880
90	31	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.407E+07	0.773E+04	0.108E+08	233634	6493973
91	7	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.445E+06	0.845E+03	0.118E+07	232666	6491962
92	8	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.768E+06	0.146E+04	0.204E+07	232809	6493364
93	13	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.248E+07	0.471E+04	0.658E+07	233608	6491873
94	13	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.180E+07	0.343E+04	0.478E+07	233939	6492705
95	5	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.135E+06	0.000E+00	0.357E+06	232337	6492428
96	8	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.271E+07	0.000E+00	0.719E+07	232383	6491639
97	6	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.194E+06	0.369E+03	0.515E+06	234108	6492071
98	4	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.248E+06	0.000E+00	0.658E+06	233913	6495029
99	4	20.	30.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.561E+06	0.000E+00	0.149E+07	234153	6495046
100	5	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.205E+06	0.389E+03	0.542E+06	233086	6492585
101	9	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.446E+06	0.847E+03	0.118E+07	233278	6492313
102	4	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.729E+05	0.138E+03	0.193E+06	235173	6491863
103	5	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.240E+06	0.455E+03	0.635E+06	234477	6492716
104	4	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.822E+05	0.156E+03	0.218E+06	233042	6493163
105	16	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.151E+07	0.287E+04	0.401E+07	234423	6491728
106	23	20.	20.	0.	90.	-0.0010	0.	90.	0.00	0.002	-	-	0.239E+07	0.454E+04	0.633E+07	234886	6493109
107	6	20.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.541E+06	0.000E+00	0.143E+07	235420	6491320
108	9	10.	20.	0.	90.	-0.0020	0.	90.	0.00	0.002	-	-	0.572E+06	0.109E+04	0.152E+07	232311	6492207
109	37	10.	20.	0.	90.	-0.0020	0.	90.	0.00	0.000	-	-	0.391E+07	0.000E+00	0.104E+08	234846	6494046

APPENDIX

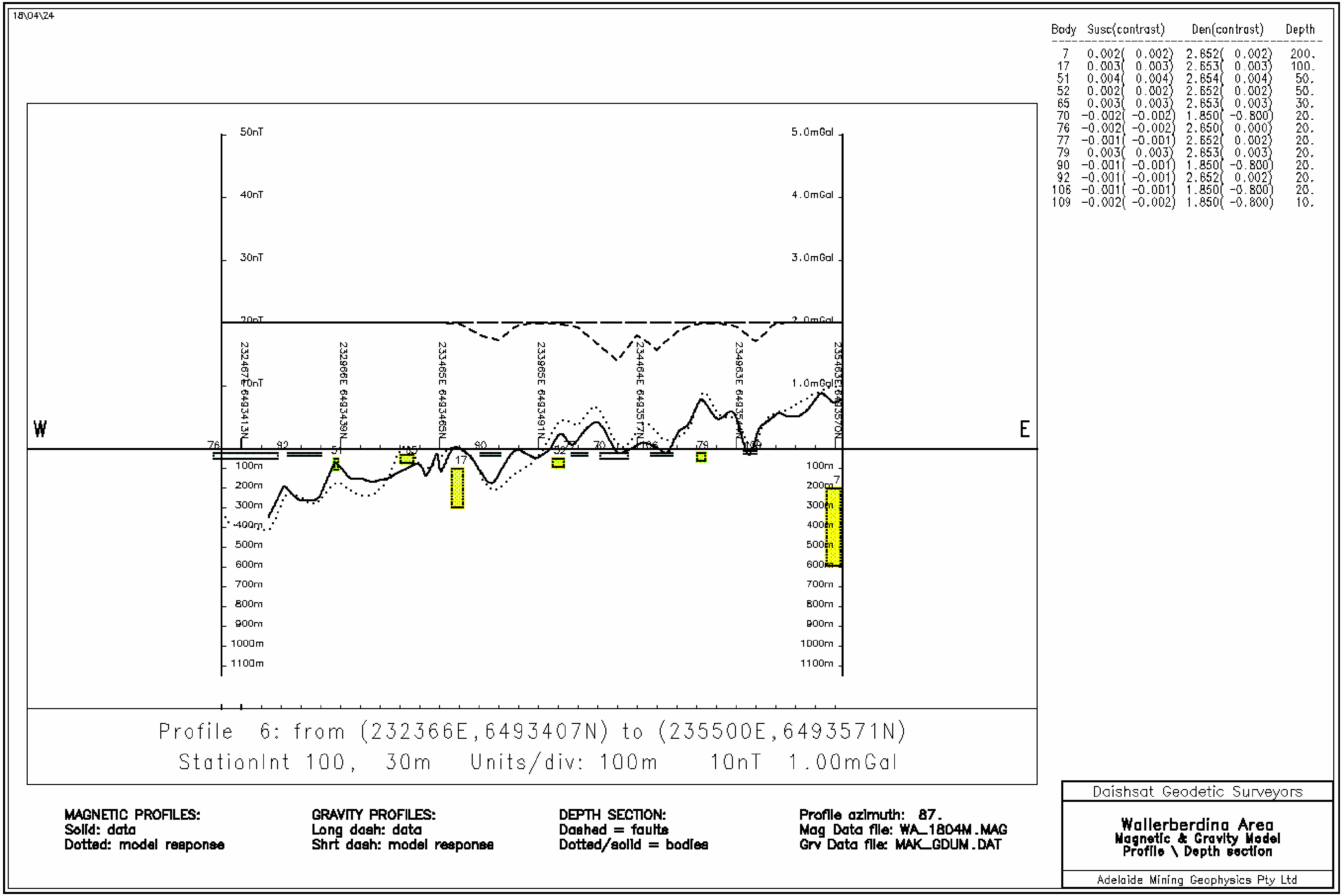


Figure A1. When Bodies 90, 70, 106 and 109 (magnetite depleted paleochannels?) are given a negative density contrast expected for unconsolidated cover the calculated gravity responses of the bodies (short dashed line) generate conspicuous troughs, which, if seen in gravity data would corroborate the paleochannel interpretation.

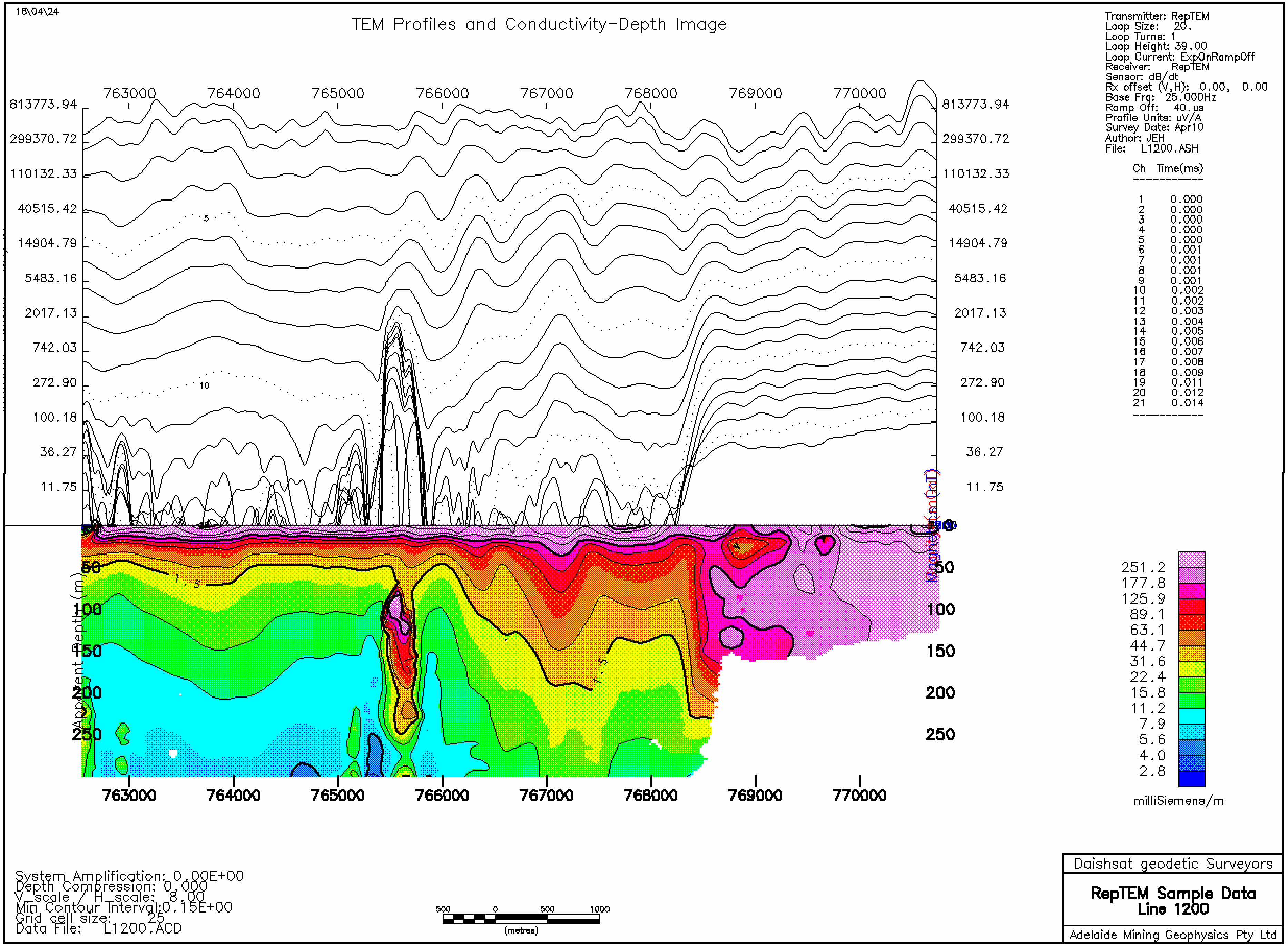


Figure A2 Sample AEM data (profiles) from the York Peninsula, SA, with conductivity-depth section (image)

AECOM

Wallerberdina North West Area
Seismic Interpretation

The following slides present the un-interpreted and interpreted depth converted stacks, in colour contour format. Red events are troughs, black events are peaks.

A base map illustrating the positions of each seismic line is included in slide 3.

The two seismic lines have been depth converted so the vertical axis reads in metres. The depth indicated on section will contain some error, given the lack of velocity control, but provide a good approximation for evaluating the seismic sections and depth of weathering profiles.

An un-interpreted depth section is included for each seismic line, as flicking between this and the interpreted section illustrates the zone of reduced amplitude often observed where fault planes are seismically imaged. Flicking between these two slides can help the user understand why structures are interpreted as presented.

Given the lack of borehole control, only more prominent potential structures have been identified. Given the complexity of the data, it should be noted that smaller scale structures are also likely to be present.

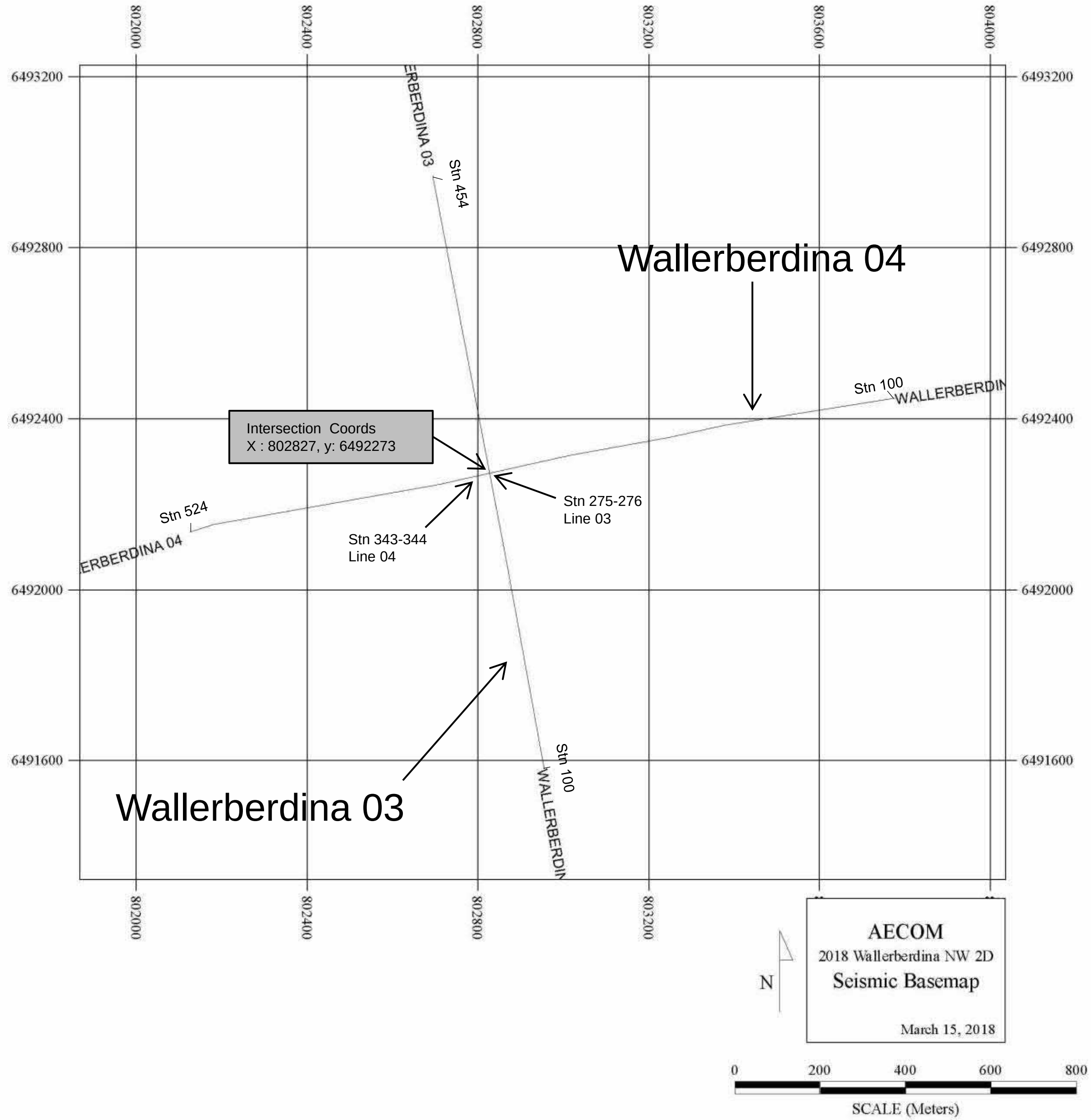
Depth of Weathering profiles, derived from refraction statics, have been annotated across the top of each interpreted section. Slides 6 and 9 zoom in on the shallow areas of each line and provide more detail on depth of weathering along each section, including the approximate position of the top of the non weathered competent rocks.

There is some discrepancy between the two depth of weathering solutions, which is due to limited Vo control in the static solution and minor velocity variability in stacking velocities. However, both solutions provide the best guide available to determine weathering profile trends across each section. The depth of weathering provided by the statics solution should be the preferred solution.

Potential Faulting is annotated by blue planes. Where possible, potential slip direction is indicated at the fault plane.

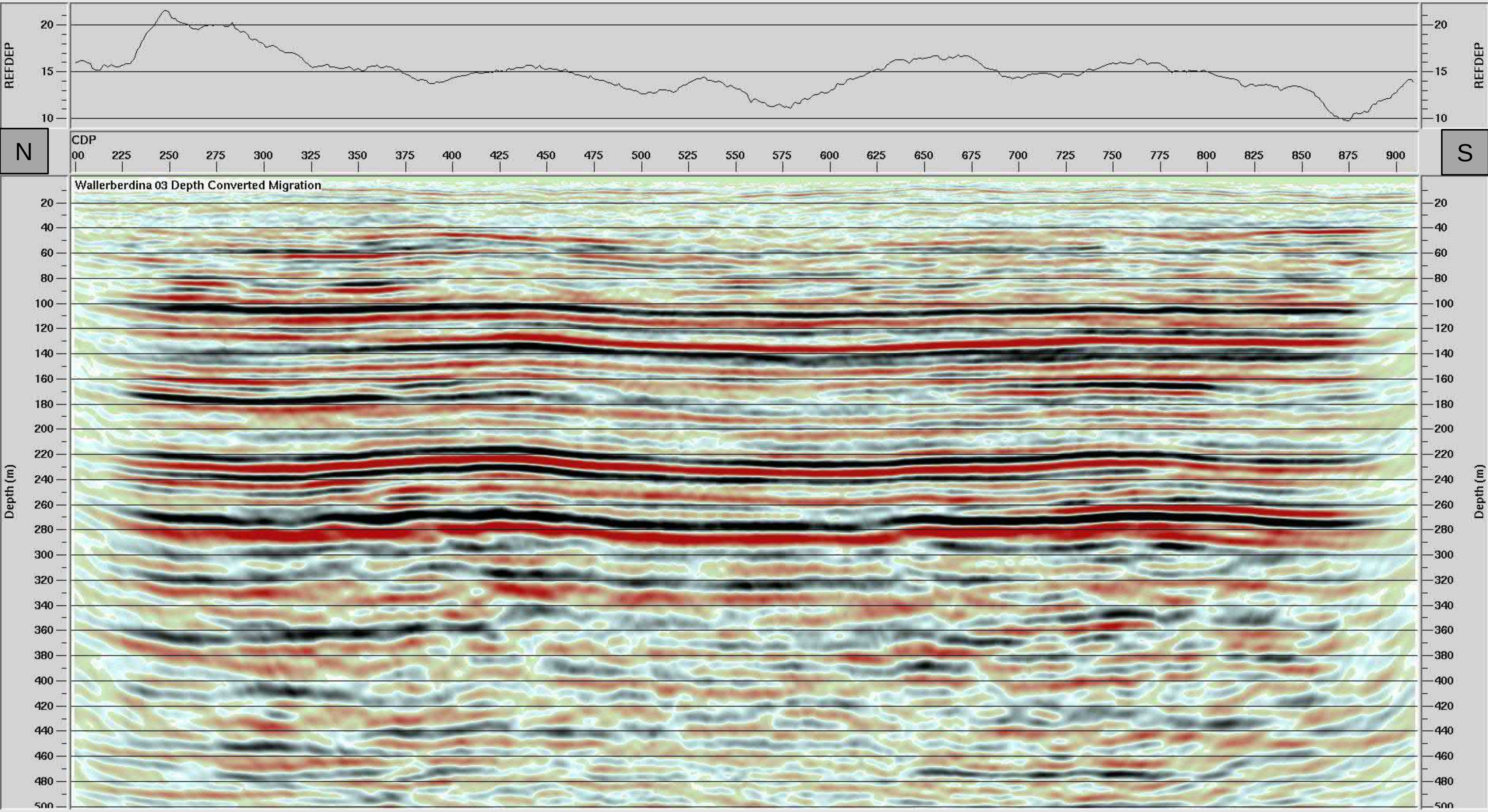
Where possible, stratigraphic horizons have been interpreted across some interpreted structures and are indicated by the aqua and orange horizons.

It must be noted that until online borehole data becomes available, these interpreted sections are preliminary, and may alter with further information.

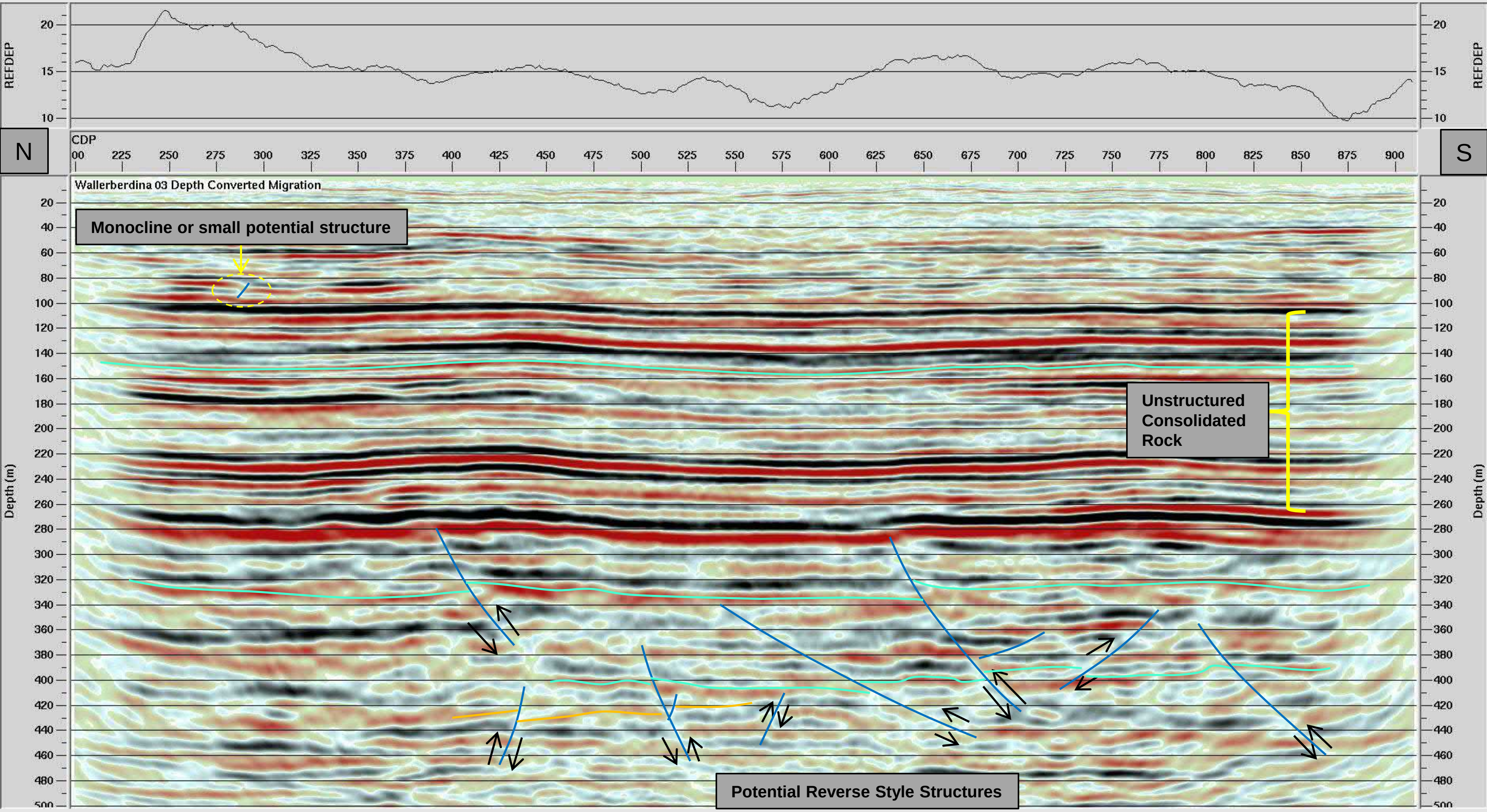


802000
802400
802800
803200
803600
804000
6493200
6492800
6492400
6492000
6491600
ERBERDINA 03
Stn 454
Wallerberdina 04
Stn 100
WALLERBERDIN
Intersection Coords
X : 802827, y: 6492273
Stn 524
ERBERDINA 04
Stn 275-276
Line 03
Stn 343-344
Line 04
Stn 100
WALLERBERDIN
Wallerberdina 03
AECOM
2018 Wallerberdina NW 2D
Seismic Basemap
March 15, 2018
N
0
200
400
600
800
SCALE (Meters)

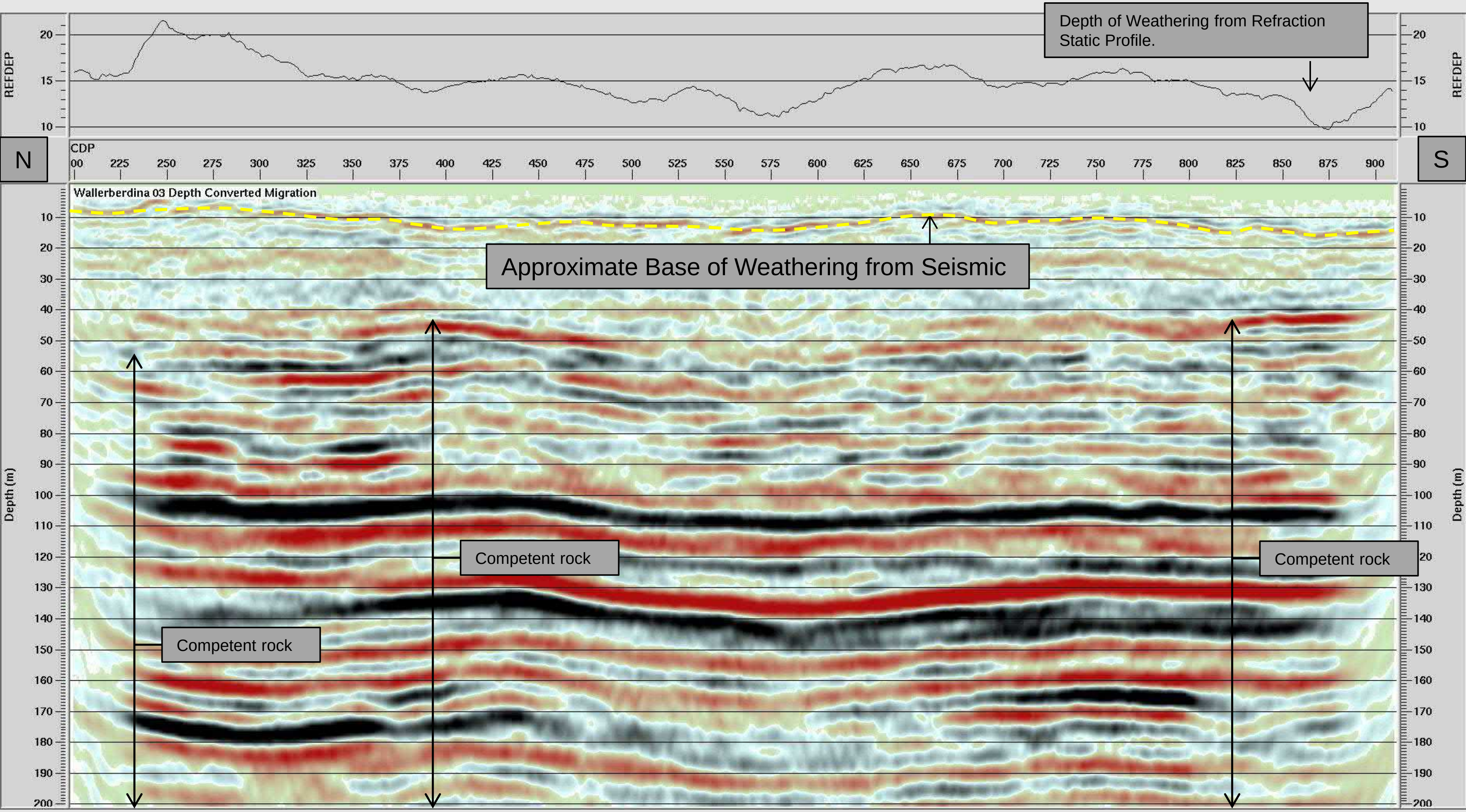
Wallerberdina 03 Depth Converted Migrated Stack
No Interpretation



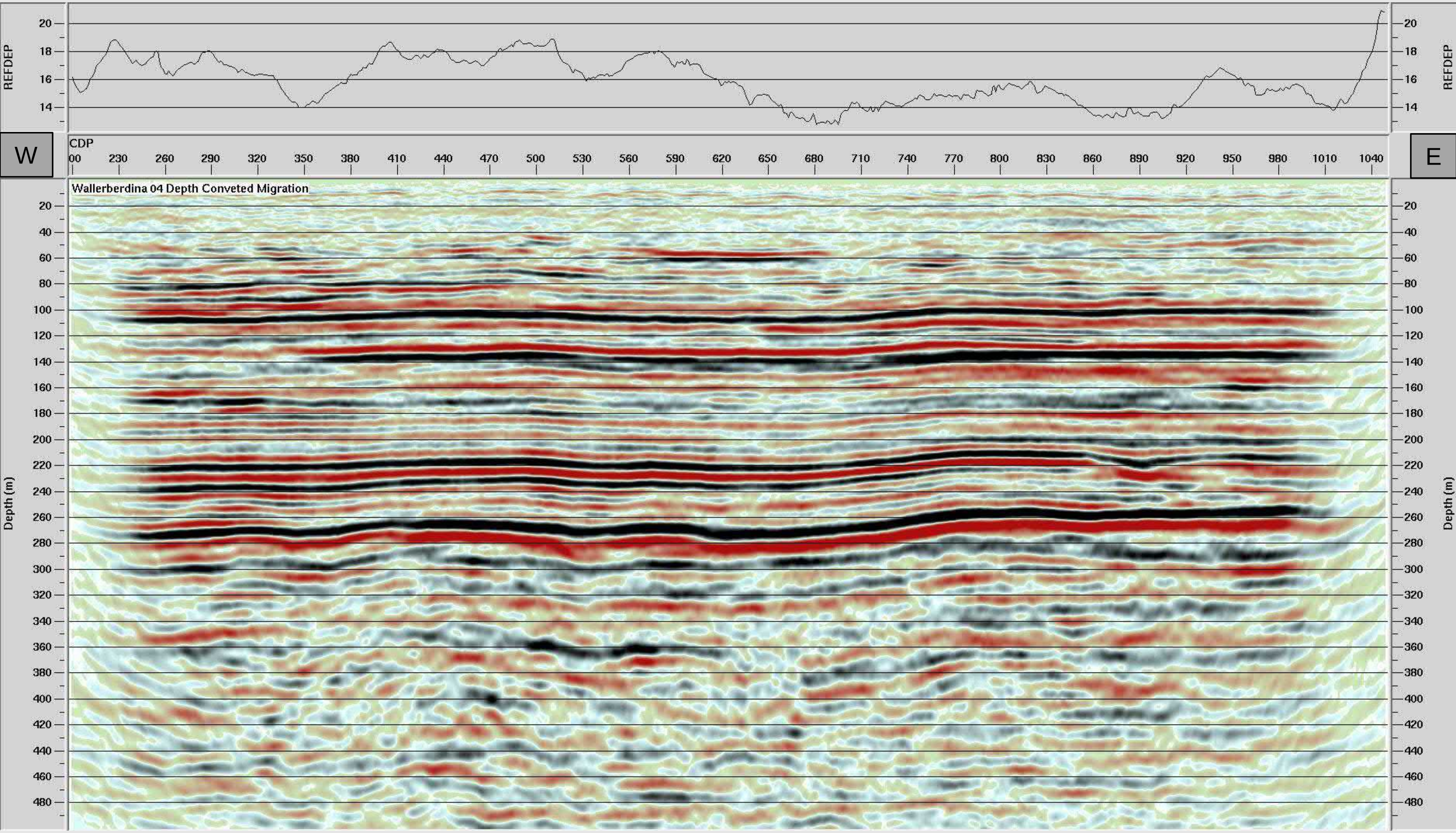
Wallerberdina 03 Depth Converted Migrated Stack
Interpreted Structure



Wallerberdina 03 Depth Converted Migrated Stack
Interpreted Section at >100m to surface



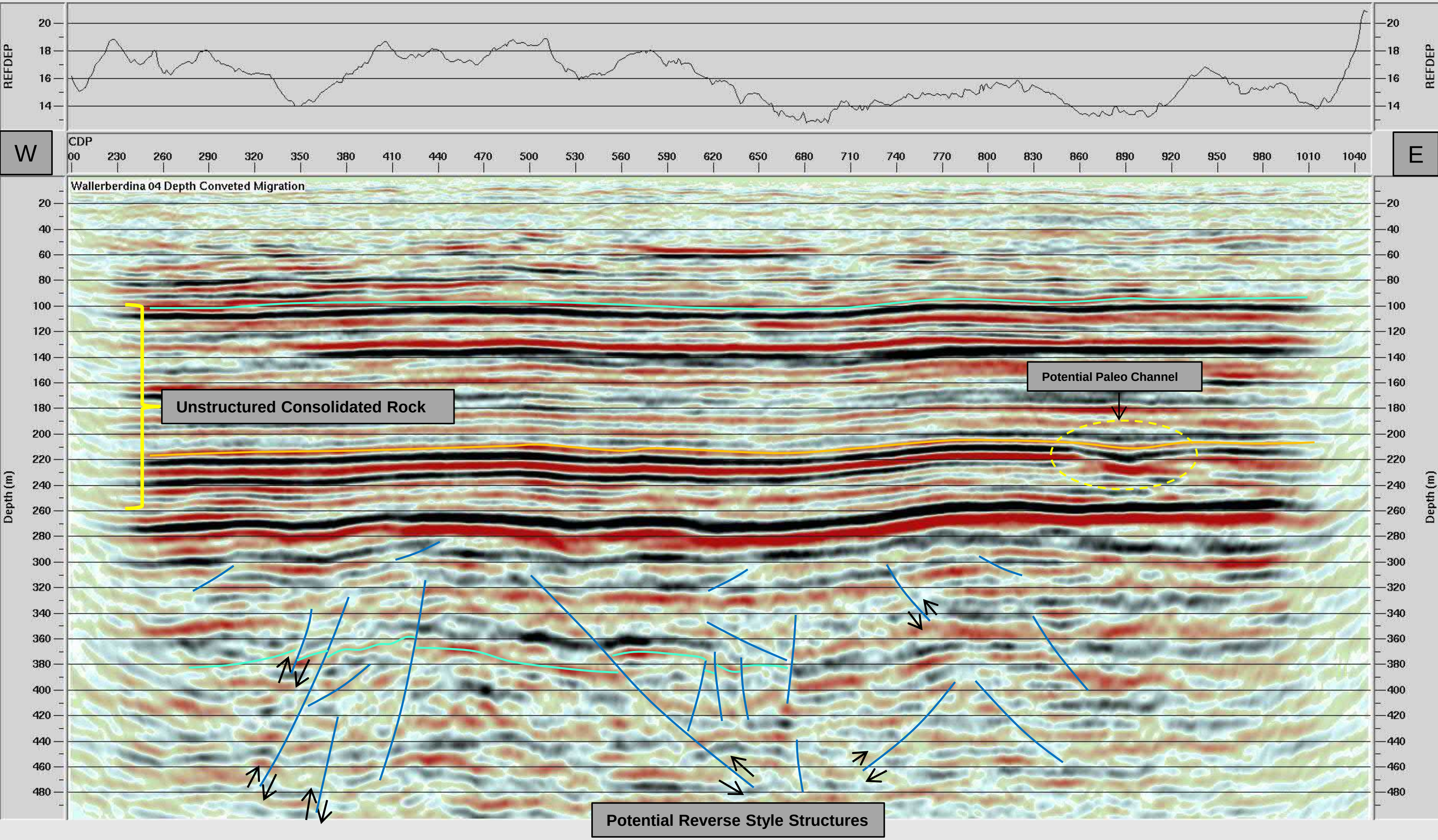
Wallerberdina 04 Depth Converted Migrated Stack
No Interpretation



16 March, 2018
Velseis Processing

AECOM
2018 2D Seismic Program

Wallerberdina 04 Depth Converted Migrated Stack
Interpreted Structure

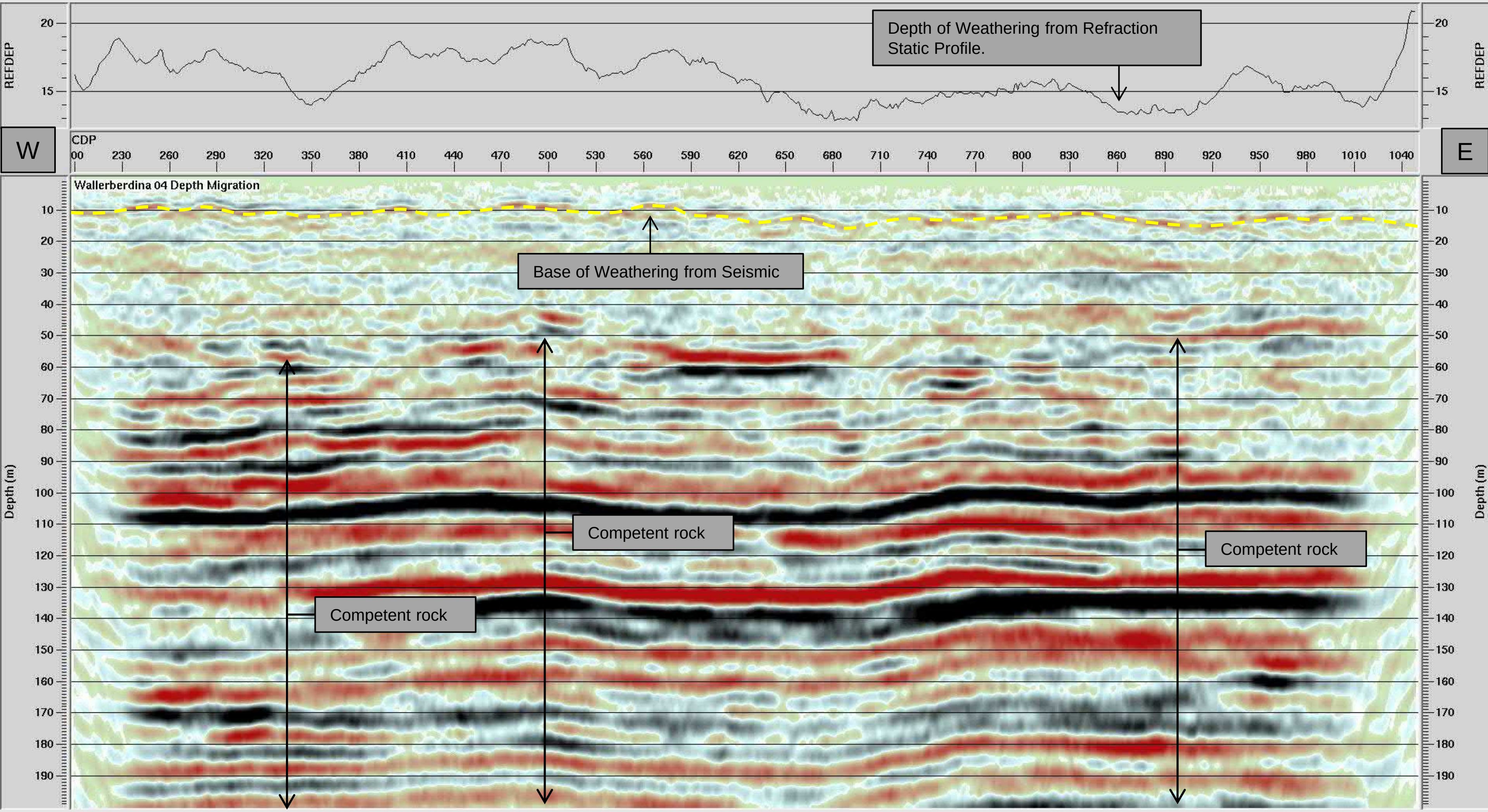


Velseis

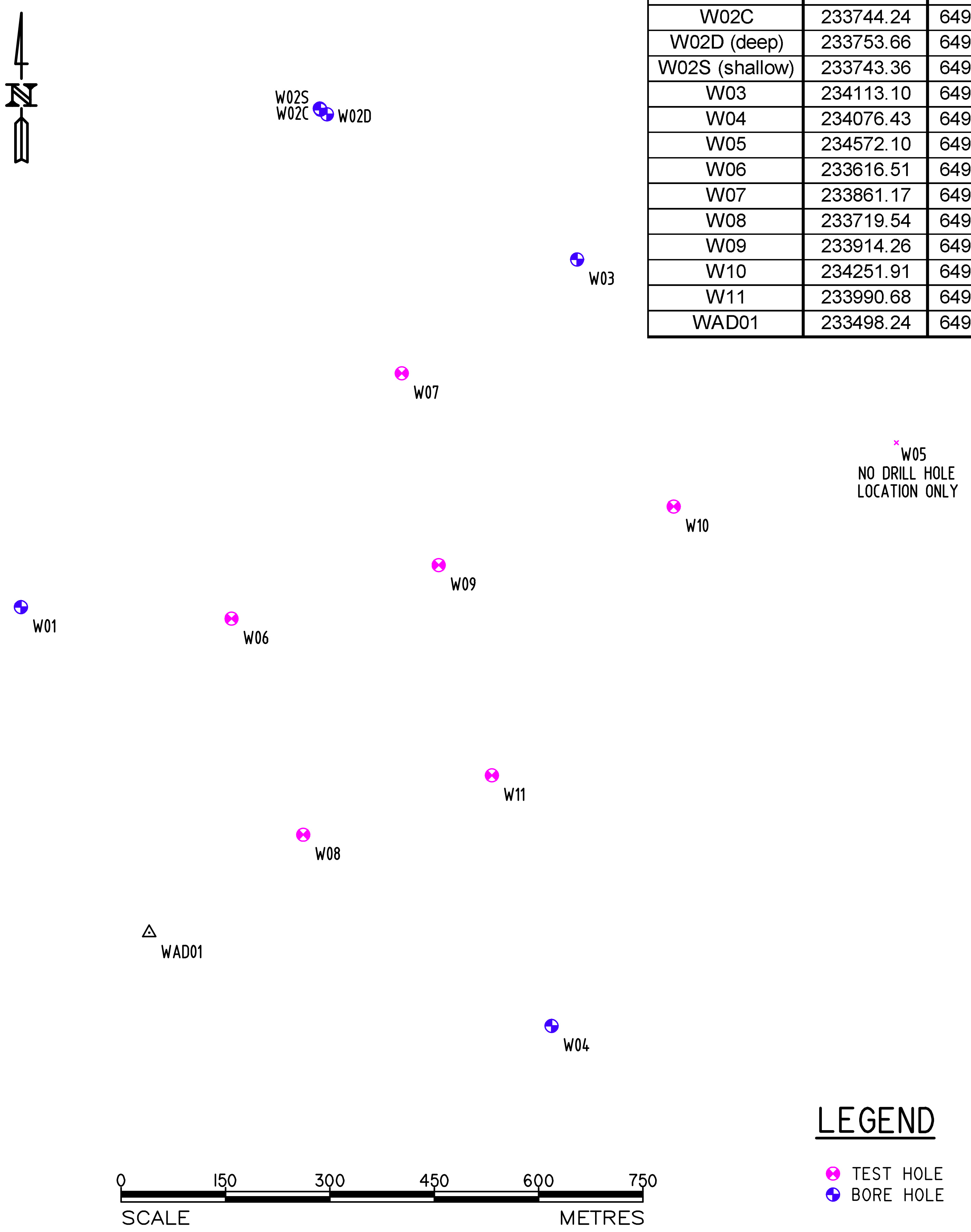
16 March, 2018
Velseis Processing

AECOM
2018 2D Seismic Program

Wallerberdina 04 Depth Converted Migrated Stack
Interpreted Section at near surface



Point ID	East	North	PVC Pipe RL	Lid RL	Ground RL	RL	Description
W01	233313.88	6493226.71	86.615	86.720	85.631		50mm PVC BORE TOP
W02C	233744.24	6493941.17	84.938	85.109	84.109		50mm PVC BORE TOP
W02D (deep)	233753.66	6493934.61	84.981 (Estimate)		84.032	84.481 (Casing)	50mm PVC BORE TOP (0.5m above Casing)
W02S (shallow)	233743.36	6493942.85	84.938	85.086	84.111		50mm PVC BORE TOP
W03	234113.10	6493726.05	87.337	87.425	86.367		50mm PVC BORE TOP
W04	234076.43	6492625.09	92.424	92.538	91.477		50mm PVC BORE TOP
W05	234572.10	6493462.90			88.140		No Hole Drilled_Surface RL
W06	233616.51	6493210.07			86.509		Test Hole_Surface RL
W07	233861.17	6493562.47			86.054		Test Hole_Surface RL
W08	233719.54	6492899.75			89.130		Test Hole_Surface RL
W09	233914.26	6493287.00			87.146		Test Hole_Surface RL
W10	234251.91	6493371.10			89.510		Test Hole_Surface RL
W11	233990.68	6492984.96			88.246		Test Hole_Surface RL
WAD01	233498.24	6492758.99				89.165	DROPPER-SURVEY BASE



W02D BORE

W02 BORES

DEVELOP
WITH
CONFIDENCE ™

veris

Ground Floor, 22 Chancery Lane
Adelaide SA 5000
08 8100 5700
adelaide@veris.com.au
veris.com.au
ABN 25 098 991 210

0	5/6/18	KS	RHH	FIRST ISSUE
NO	DATE	DRN	CHKD	DESCRIPTION

This plan is not intended for attachment to sale contract documents

OUR REF: 300256_D3_rev0.DWG
CONTOUR INTERVAL: -
DATUM: MGA94 Zone54, AHD
SCALE: 1:7500 ORIGINAL SHEET SIZE: A3
DATE OF SURVEY: 30/5/2018 RHH
DRAWING No: 300256_D3 REV 0 SHEET No: 1 OF 1

AECOM AUSTRALIA PTY LTD
BORE HOLE LOCATIONS

WALLERBERDINA
30km NORTH OF HAWKER

AECOM

Engineering Summary Log

BOREHOLE No. W01

Sheet: 1 of 4

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	04/05/2018	**Driller:**	Numac Drilling
Project:	NRWMF - Site Characterisation	**Logged by:**	JR	**End Date:**	06/05/2018	**Drill Rig:**	Sonic Geoprobe
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1		

Hole Diameter:	125 mm	**Easting:**	233313.9 m	**RL:**	85.6 m
Inclination:	-90°	**Northing:**	6493226.7 m	**Ver. Datum:**	AHD
Bearing:	N/A	**Hor. Proj/Dat:**	MGA94/GDA94-54M	**Surface:**	Sand

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

Casing Top RL: 86.62 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 12/05/2018

0.6 above ground to 0.0 m: Steel Monument

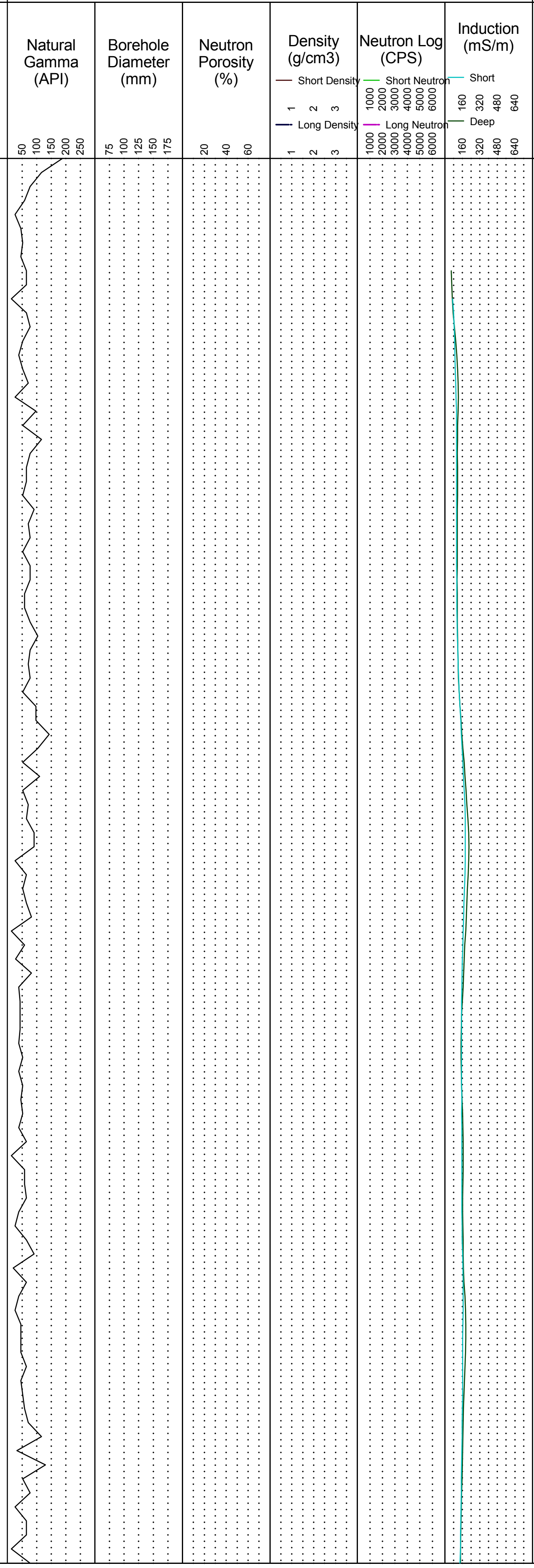
0.0 to 19.0 m: CEMENT/ BENTONITE GROUT

0.0 to 19.5 m: Solid Pipe

Log

Reduced Level (m) / Depth (m)	Water	Field Tests	Samples	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer	Misc Laboratory Testing	Geochemical Testing	Geological Unit (Geotech. Unit)
0.0 – 0.5					TOPSOIL: grass and shrub roots							
0.5 – 1.0 (85)				ML-CL	clayey SILT: low to medium plasticity; orange-brown; CLAY(10-20%): with trace, very fine grained sand							
1.0 – 2.0 (84)		SPT:11,12,16 N=28	BAG JAR	CH-CI	silty CLAY: medium to high plasticity; light brown to brown; SILT(15-30%): with patches of white crystalline matter throughout, calcareous (fizz with acid)							
2.0 – 5.5 (83, 82, 81)		SPT:14,29,33 N=62 SPT:13,22,30 N=52 SPT:23,41,71 N=112		CH	CLAY: high plasticity; light brown to brown; trace fine grained sand							
5.5 – 9.0 (80, 79, 78, 77)		SPT:23,31,41 N=72 SPT:36,72,R N=R SPT:10,38,63 N=101		CL	silty CLAY: low plasticity; orange-brown; SAND(5-10%): very fine grained, ferruginous, iron stained, no odour							
9.0 – 9.5 (76)				CI-CL	sandy CLAY: low to medium plasticity; orange-brown; SAND(15%): very fine grained, poorly graded							
10.0				SP								

Downhole Wireline



Laboratory Testing

Geology

AECOM

Engineering Summary Log

BOREHOLE No. W01
Sheet: 2 of 4

Client:	Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 04/05/2018	**Driller:** Numac Drilling	**Hole Diameter:**	125 mm	**Easting:** 233313.9 m	**RL:**	85.6 m
Project:	NRWMF - Site Characterisation	**Logged by:** JR	**End Date:** 06/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:**	-90°	**Northing:** 6493226.7 m	**Ver. Datum:**	AHD
Location:	Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:**	N/A	**Hor. Proj/Dat:** MGA94/GDA94-54M	**Surface:**	Sand

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) (Short Density, Long Density); Neutron Log (CPS) (Short Neutron, Long Neutron); Induction (mS/m) (Short, Deep); Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Piezometer details:
Casing Top RL: 86.62 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 12/05/2018

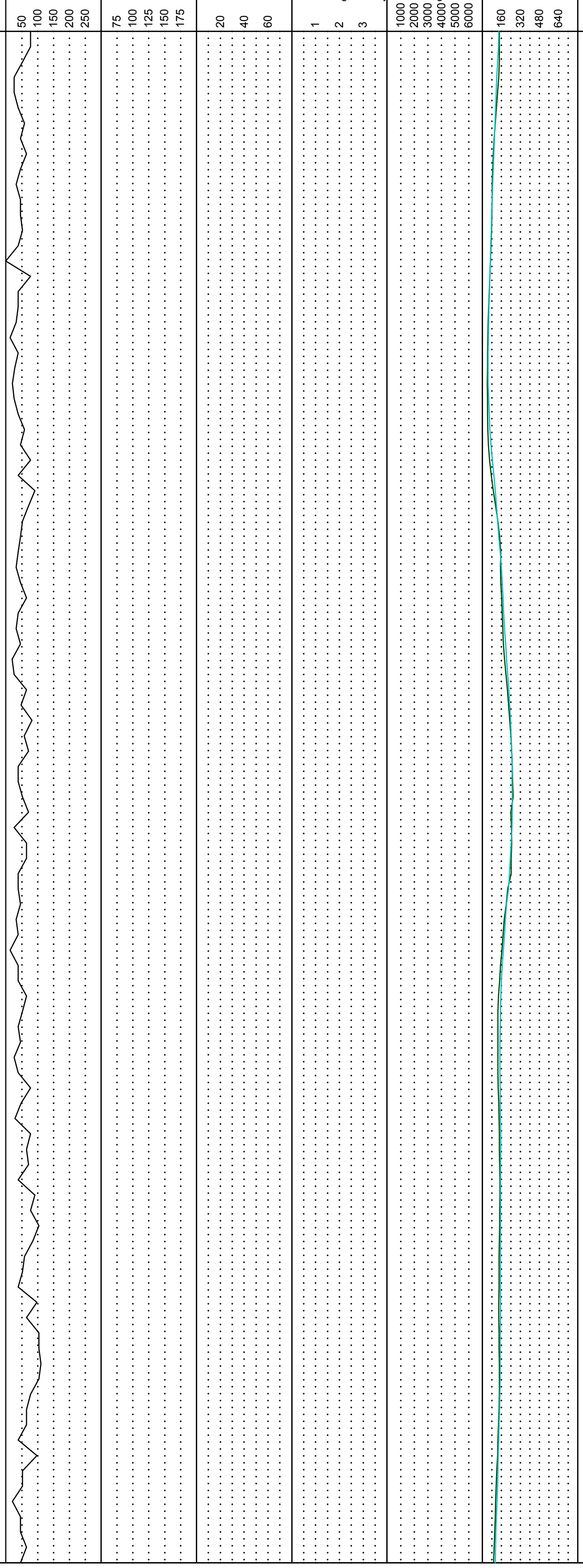
Depth scale (m): 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0
Reduced level scale (m): 75, 74, 73, 72, 71, 70, 69, 68, 67, 66

Field tests:

Depth (m)	Field Tests
~10.5	SPT:18,28,33 N=61
~12.0	SPT:19,32,50/120mm N=R
~13.5	SPT:22,37,50/135mm N=R
~15.0	SPT:11,15,27 N=42

Material description:

Classification Symbol	Description
SP	SAND: very fine to fine grained; light brown; with ferruginous orange staining, with trace quartzite gravel *(continued)*
SW	gravelly SAND: very fine to fine grained; brown; GRAVEL(20%): rounded, of quartzite and siltstone, well graded (5-25mm)
CH-CI	sandy CLAY: medium to high plasticity; light brown; SAND(5-15%), very fine grained
CH-CI	CLAY: medium to high plasticity; light brown to dark brown; with irregular, mottled orange zones
SP-SC	sandy CLAY: sand is very fine grained
CH-CI	CLAY: medium to high plasticity; light brown to dark brown; with irregular, mottled orange zones from 16.00 m: irregular calcareous concretions
ML-CL	clayey SILT: low to medium plasticity; orange-brown; with trace fine grained sand and indurated calcareous concretions throughout



Client: Department of Industry, Innovation and Science | **Project No:** 60565376 | **Start Date:** 04/05/2018 | **Driller:** Numac Drilling | **Hole Diameter:** 125 mm | **Easting:** 233313.9 m | **RL:** 85.6 m
Project: NRWMF - Site Characterisation | **Logged by:** JR | **End Date:** 06/05/2018 | **Drill Rig:** Sonic Geoprobe | **Inclination:** -90° | **Northing:** 6493226.7 m | **Ver. Datum:** AHD
Location: Wallerberdina Station | **Checked by:** HS | **Location Meth.:** dGPS0.1 | **Bearing:** N/A | **Hor. Proj/Dat:** MGA94/GDA94-54M | **Surface:** Sand
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data | Material Description | Rock Condition | Piezometer Details | Downhole Wireline | Laboratory Testing | Geology

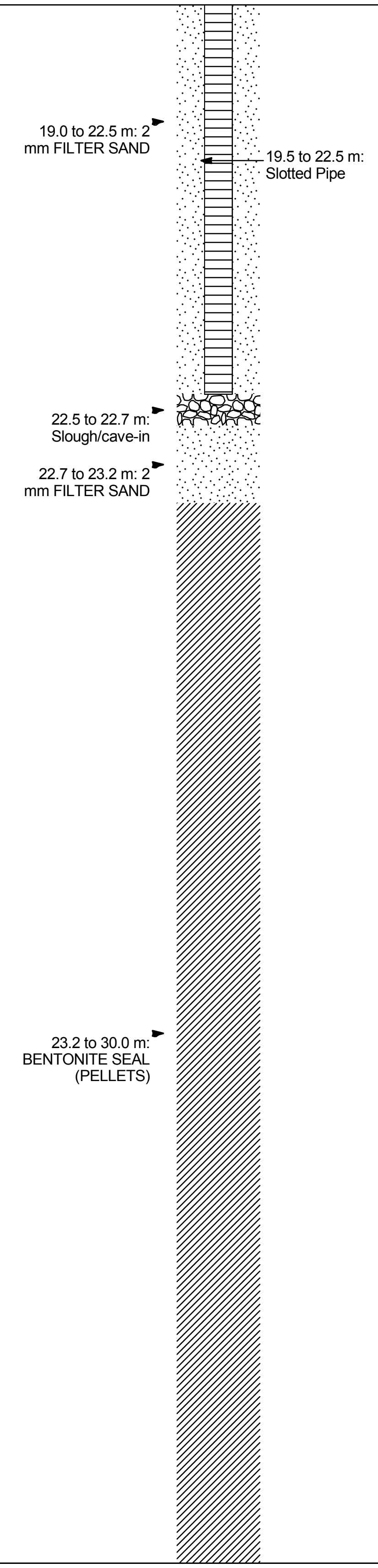
Reduced Level (m) / Depth (m) | Water | Field Tests | Samples | Graphic Log | Classification Symbol | Description | Weathering/ Consistency | TCR (SCR) [RQD] (%) | Core Photo | Optical and Accoustic Televiewer (N E S W)

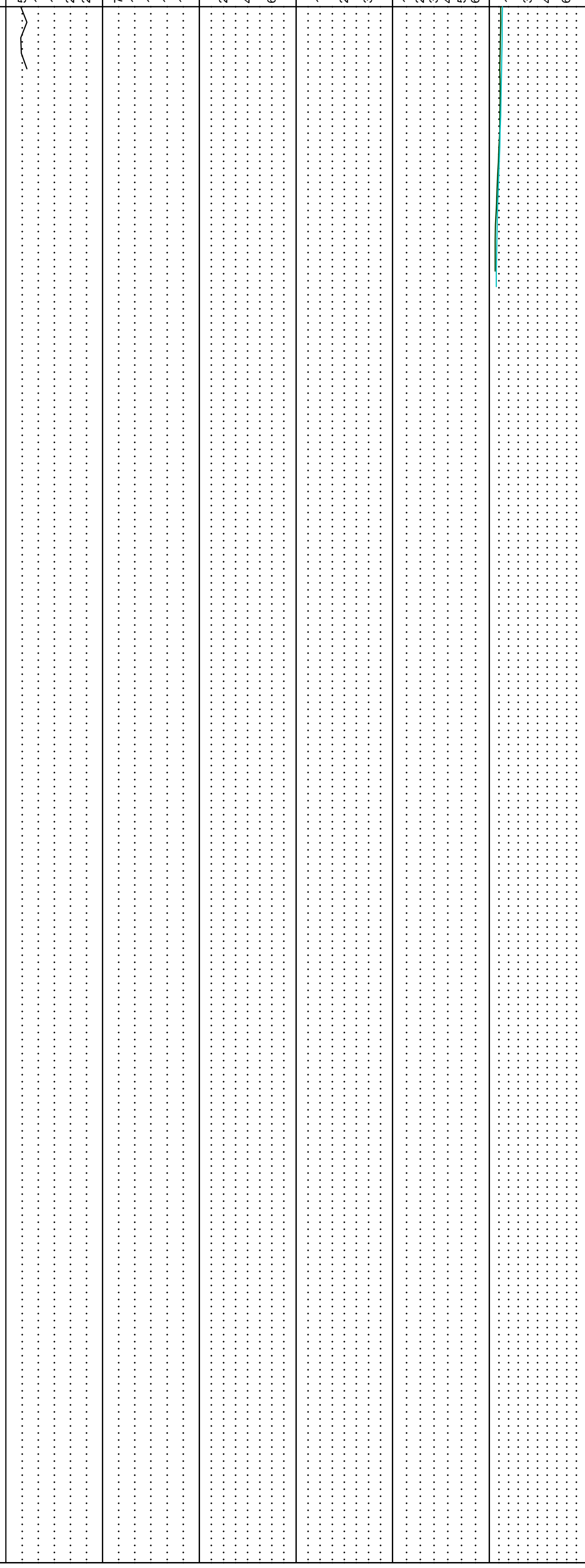
Casing Top RL: 86.62 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 12/05/2018

Natural Gamma (API) 50 100 150 200 250 | Borehole Diameter (mm) 75 100 125 150 175 | Neutron Porosity (%) 20 40 60 | Density (g/cm3) — Short Density — Long Density 1 2 3 | Neutron Log (CPS) — Short Neutron — Long Neutron 1000 2000 3000 4000 5000 6000 | Induction (mS/m) — Short — Deep 160 320 480 640 | Misc Laboratory Testing | Geochemical Testing | Geological Unit *(Geotech. Unit)*

Depth (m)	Water	Samples	Classification Symbol	Description
to ~20.6			ML-CL	clayey SILT: low to medium plasticity; orange-brown; with trace fine grained sand and indurated calcareous concretions throughout *(continued)*
~20.6 to ~21.7	∇ 21.0		SP	SAND: very fine to fine grained; poorly graded, trace clay/silt contact inferred (core loss). Water strike at 21.0 mbgs.
~21.7 to ~22.7			GW	GRAVEL: dark grey to red; polymict, quartzite, sandstone, mudstone. Grading to fine gravel at base, sub-rounded. Cobbles rounded to sub-rounded, up to 8mm in diameter.
~22.7 to ~27.2		CS BAG JAR (~23.4–23.7)	CH	CLAY: high plasticity; light brown-orange; with irregular calcareous concretions
~27.2 to ~28.6			SC	clayey SAND: very fine to fine grained; light brown-orange; iron stained
~28.6 to 30.0			CH	CLAY: high plasticity; light brown-orange; with irregular calcareous concretions

Depth (m): 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0, 24.5, 25.0, 25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0
Reduced Level (m): 65, 64, 63, 62, 61, 60, 59, 58, 57, 56





Client: Department of Industry, Innovation and Science | **Project No:** 60565376 | **Start Date:** 04/05/2018 | **Driller:** Numac Drilling | **Hole Diameter:** 125 mm | **Easting:** 233313.9 m | **RL:** 85.6 m

Project: NRWMF - Site Characterisation | **Logged by:** JR | **End Date:** 06/05/2018 | **Drill Rig:** Sonic Geoprobe | **Inclination:** -90° | **Northing:** 6493226.7 m | **Ver. Datum:** AHD

Location: Wallerberdina Station | **Checked by:** HS | **Location Meth.:** dGPS0.1 | **Bearing:** N/A | **Hor. Proj/Dat:** MGA94/GDA94-54M | **Surface:** Sand

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 86.62 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 3.00 m; Development Date: 12/05/2018

Depth (m)	Classification Symbol	Description	Piezometer Details
to 30.3	CH	CLAY: high plasticity; light brown-orange; with irregular calcareous concretions *(continued)*	30.0 to 35.7 m: CEMENT/ BENTONITE GROUT
30.3–31.0	SP	gravelly SAND: very fine to fine grained; light brown-orange; poorly graded, cobbles of sandstone (up to 150mm)	
31.0–32.7		NO CORE: from 31.00m to 32.70m: assumed in loose sand/gravel	
32.7–33.7		NO CORE: from 31.00m to 32.70m: assumed in sand	
33.7–34.2	GP	GRAVEL: brown; some sand and sub-rounded to rounded cobbles of quartz	
34.2–35.3	CL	gravelly CLAY: low plasticity; grey, red-brown, light brown; fine grained sand, angular quartz gravel and subangular cobbles in a orange-brown matrix	
35.3–35.7		CONGLOMERATE: fine to medium gravel, indurated, calcareous cement	
35.7		*Borehole W01 log continued as cored log from m.*	

Column headings: Field Data (Reduced Level (m) / Depth (m), Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/ Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API) 50 100 150 200 250; Borehole Diameter (mm) 75 100 125 150 175; Neutron Porosity (%) 20 40 60; Density (g/cm3) Short Density, Long Density 1 2 3; Neutron Log (CPS) Short Neutron, Long Neutron 1000 2000 3000 4000 5000 6000; Induction (mS/m) Short, Deep 160 320 480 640); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Depth scale: 30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5, 35.0, 35.5, 36.0, 36.5, 37.0, 37.5, 38.0, 38.5, 39.0, 39.5, 40.0

Reduced level scale: 55, 54, 53, 52, 51, 50, 49, 48, 47, 46

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Engineering Summary Log

BOREHOLE No. **W02C**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 11/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233744.2 m	**RL:** 84.1 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 14/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493941.2 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.94 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 3.00 m; Development Date: 16/05/2018. 0.6 above ground to 0.0 m: Steel Monument

Depth (m)	Field Tests	Classification Symbol	Description
0.0		ML	clayey SILT: low plasticity; orange-brown; trace organics and fine grained sand
1.20	SPT:19,23,27 N=50		at 1.20 m: trace fine to medium, rounded gravel
2.00			at 2.00 m: increase in clay content
2.4		CI-CL	CLAY: low to medium plasticity; orange-brown; with silt and trace sands and gravel (extremely weathered calcrete)
2.6	SPT:16,24,28 N=52		
3.1			becoming medium to high plasticity
4.2	SPT:20,40,50/120mm N=R		
5.4			becoming red-brown
5.7	SPT:41,50/90mm N=R		
6.0		CH-CI	CLAY: medium to high plasticity; red-brown; trace fine grained sand and poorly graded gravel, trace weakly indurated lens with quartz crystals growing
7.2	SPT:24,40,48 N=88	CI	CLAY: medium plasticity; red-brown; with fine to coarse, rounded gravel of mudstone, sandstone and quartz
7.8		CL	CLAY: low plasticity; brown; trace fine grained sand and black organics up to 3mm in diameter
8.9	SPT:15,31,50/120mm N=R		

Column headings: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Piezometer Details; Downhole Wireline: Natural Gamma (API) 50 100 150 200 250; Borehole Diameter (mm) 75 100 125 150 175; Neutron Porosity (%) 20 40 60; Density (g/cm3) — Short Density, — Long Density 1 2 3; Neutron Log (CPS) — Short Neutron, — Long Neutron 1000 2000 3000 4000 5000 6000; Induction (mS/m) — Short, — Deep 160 320 480 640; Laboratory Testing: Misc Laboratory Testing, Geochemical Testing; Geology: Geological Unit *(Geotech. Unit)*

Reduced levels: 84, 83, 82, 81, 80, 79, 78, 77, 76, 75. Depths: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0

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Engineering Summary Log

BOREHOLE No. **W02C**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 11/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233744.2 m	**RL:** 84.1 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 14/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493941.2 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

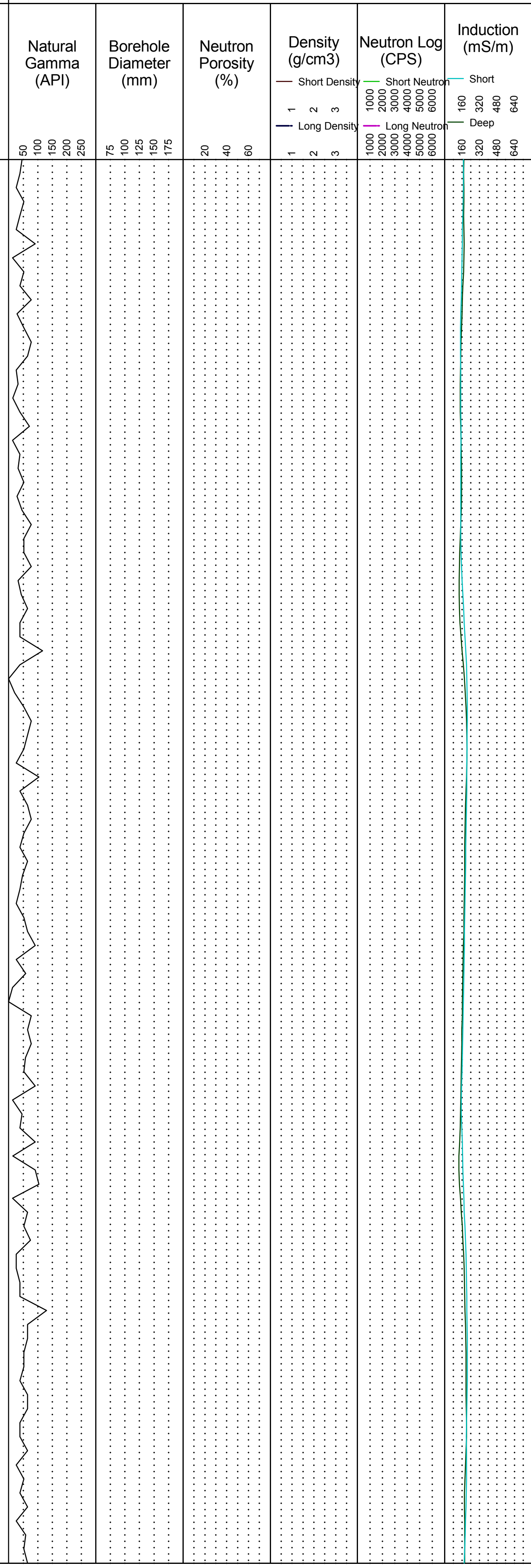
Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Piezometer Details; Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) (Short Density, Long Density); Neutron Log (CPS) (Short Neutron, Long Neutron); Induction (mS/m) (Short, Deep); Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Piezometer Details:
Casing Top RL: 84.94 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 16/05/2018

Depth (m)	Field Tests	Classification Symbol	Description
10.0 – 12.8	SPT:43,50/95mm N=R (at ~11.8 m)	CL	CLAY: low plasticity; brown; trace fine grained sand and black organics up to 3mm in diameter *(continued)* from 10.00 m: indurated nodules throughout, trace iron oxide veins from 10.90 m to 11.30 m: some fine to coarse grained angular sand (5-10%), moderately graded
12.8 – 17.2	SPT:27,50/120mm N=R (at ~13.3 m)	CI-CL	CLAY: low to medium plasticity; fine grained; grey mottled red-brown; with silt and some fine grained sand (5-10%), poorly graded from 13.30 m: trace sand (<5%), medium plasticity
17.2 – 17.4		GC	clayey GRAVEL: fine to coarse grained; rounded to sub-rounded; red-brown; of quartz, shale and claystone, with clay and fine to coarse grained sand (10-15%), well graded
17.4 – 20.0		CI	CLAY: medium plasticity; grey mottled red-brown; trace fine grained sand. Water strike inferred at ~22.0 mbgs

Reduced Levels: 74, 73, 72, 71, 70, 69, 68, 67, 66, 65



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Engineering Summary Log

BOREHOLE No. **W02C**
Sheet: 3 of 7

Client: Department of Industry, Innovation and Science | **Project No:** 60565376 | **Start Date:** 11/05/2018 | **Driller:** Numac Drilling | **Hole Diameter:** 160 mm | **Easting:** 233744.2 m | **RL:** 84.1 m

Project: NRWMF - Site Characterisation | **Logged by:** TS | **End Date:** 14/05/2018 | **Drill Rig:** Sonic Geoprobe | **Inclination:** -90° | **Northing:** 6493941.2 m | **Ver. Datum:** AHD

Location: Wallerberdina Station | **Checked by:** HS | **Location Meth.:** dGPS0.1 | **Bearing:** N/A | **Hor. Proj/Dat:** MGA94/GDA94-54H | **Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

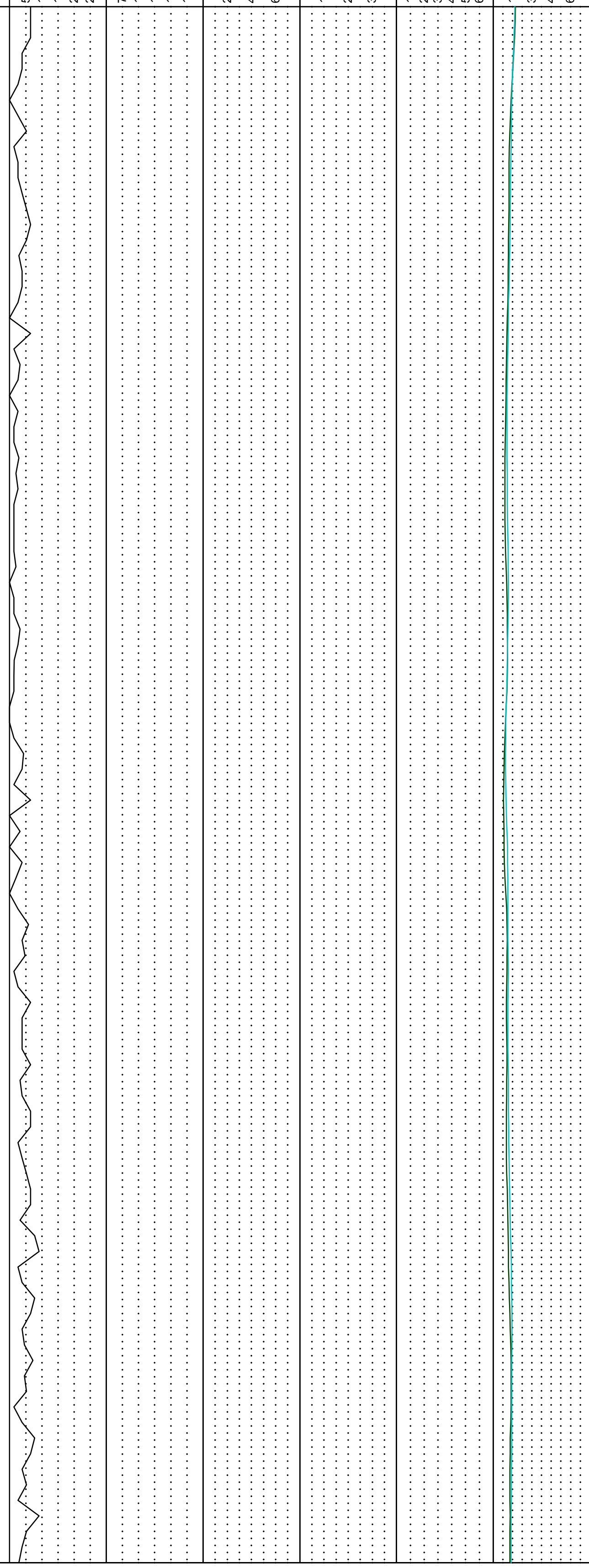
Field Data | Material Description | Rock Condition | Piezometer Details | Downhole Wireline | Laboratory Testing | Geology

Casing Top RL: 84.94 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 16/05/2018

Depth (m)	Water	Classification Symbol	Description
20.0–22.0	∇ at 22.0	CI	CLAY: medium plasticity; grey mottled red-brown; trace fine grained sand. Water strike inferred at ~22.0 mbgs *(continued)*
22.0–26.0			NO CORE: fine to coarse grained, medium to high strength sandstone returns
26.0–27.6		ML-CL	clayey SILT: low to medium plasticity; brown-grey; trace fine grained sands and black organics from 27.20 m to 27.30 m: indurated band
27.6–28.4		CL	gravelly CLAY: low plasticity; red-brown; with fine to coarse grained, angular to sub-angular gravel (20%), trace fine grained sand
28.4–30.0		CH-CI	CLAY: medium to high plasticity; grey mottled brown; with fine grained sand (10-20%) at 28.80 m: sandy CLAY at 29.80 m: sandy CLAY

Piezometer Details:
0.0 to 44.0 m: CEMENT/ BENTONITE GROUT
0.0 to 48.0 m: Solid Pipe

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep



Laboratory Testing: Misc Laboratory Testing | Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

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Engineering Summary Log

BOREHOLE No. **W02C**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 11/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233744.2 m	**RL:** 84.1 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 14/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493941.2 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 μS/cm)

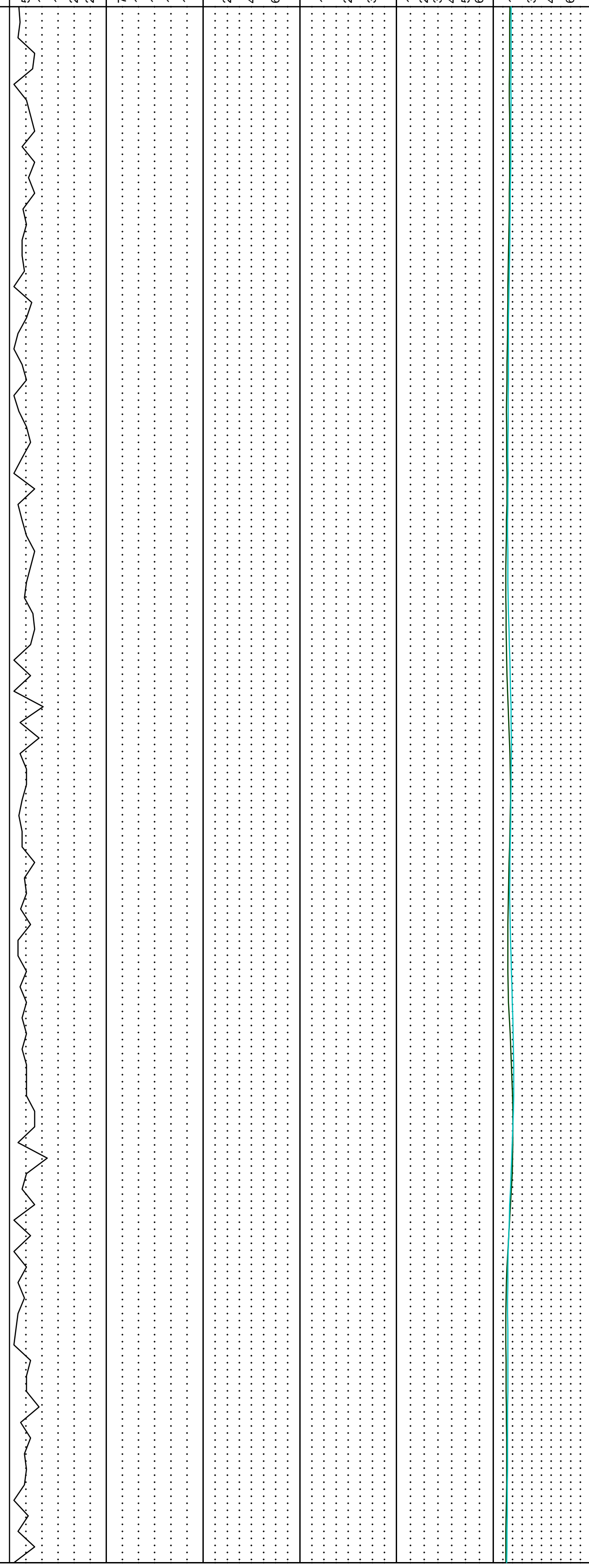
Piezometer Details
- **Casing Top RL:** 84.94 m AHD
- **Response Zone Top RL:** -
- **Response Zone Base RL:** -
- **Length of Response Zone:** 3.00 m
- **Development Date:** 16/05/2018

Depth (m)	Samples	Classification Symbol	Description	Misc Laboratory Testing
30.0–31.1		CH-CI	CLAY: medium to high plasticity; grey mottled brown; with fine grained sand (10-20%) *(continued)* at 30.10 m: sandy CLAY	
31.1–31.6		GC	clayey GRAVEL: fine to coarse grained; sub-angular; with fine to medium grained sand, clay matrix	
31.6–36.1		CL	sandy CLAY: low plasticity; brown; with fine grained sand (15-20%), trace black organics and gravel lenses at 31.65 m: fine to coarse, angular gravel lense at 31.85 m: fine to coarse, angular gravel lense at 32.40 m: fine to medium, angular gravel lense from 34.30 m: grey mottled brown, heavily indurated, very low to medium strength becoming grey mottled red-brown	
36.1–37.4	BAG JAR (37.0–37.4)	CH	CLAY: high plasticity; brown; trace black organic bands/veins, trace fine grained sand	W02D_36.9-37.3m: Permeability: 6.0×10^{-11} m/sec
37.4–40.0		CH-CI	CLAY: medium to high plasticity; brown-grey; trace fine grained sand (5-10%) and gravel (<5%) from 38.50 m: with fine to coarse, angular to sub-rounded gravel (10%) at 39.50 m: trace fine to medium gravel (<5%)	

Reduced Level (m): 54, 53, 52, 51, 50, 49, 48, 47, 46, 45

Depth (m): 30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5, 35.0, 35.5, 36.0, 36.5, 37.0, 37.5, 38.0, 38.5, 39.0, 39.5, 40.0

Downhole Wireline



Field Data: Water | Field Tests | Samples

Rock Condition: Weathering/Consistency | TCR (SCR) [RQD] (%) | Core Photo | Optical and Accoustic Televiewer (N E S W)

Laboratory Testing: Misc Laboratory Testing | Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

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Engineering Summary Log

BOREHOLE No. W02C
Sheet: 5 of 7

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	11/05/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	160 mm
Project:	NRWMF - Site Characterisation	**Logged by:**	TS	**End Date:**	14/05/2018	**Drill Rig:**	Sonic Geoprobe	**Inclination:**	-90°
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A

Easting:	233744.2 m	**RL:**	84.1 m
Northing:	6493941.2 m	**Ver. Datum:**	AHD
Hor. Proj/Dat:	MGA94/GDA94-54H	**Surface:**	Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data: Reduced Level (m) / Depth (m); Water; Field Tests; Samples

Material Description: Graphic Log; Classification Symbol; Description

Rock Condition: Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W)

Piezometer Details:
Casing Top RL: 84.94 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 3.00 m
Development Date: 16/05/2018

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) – Short Density, Long Density; Neutron Log (CPS) – Short Neutron, Long Neutron; Induction (mS/m) – Short, Deep

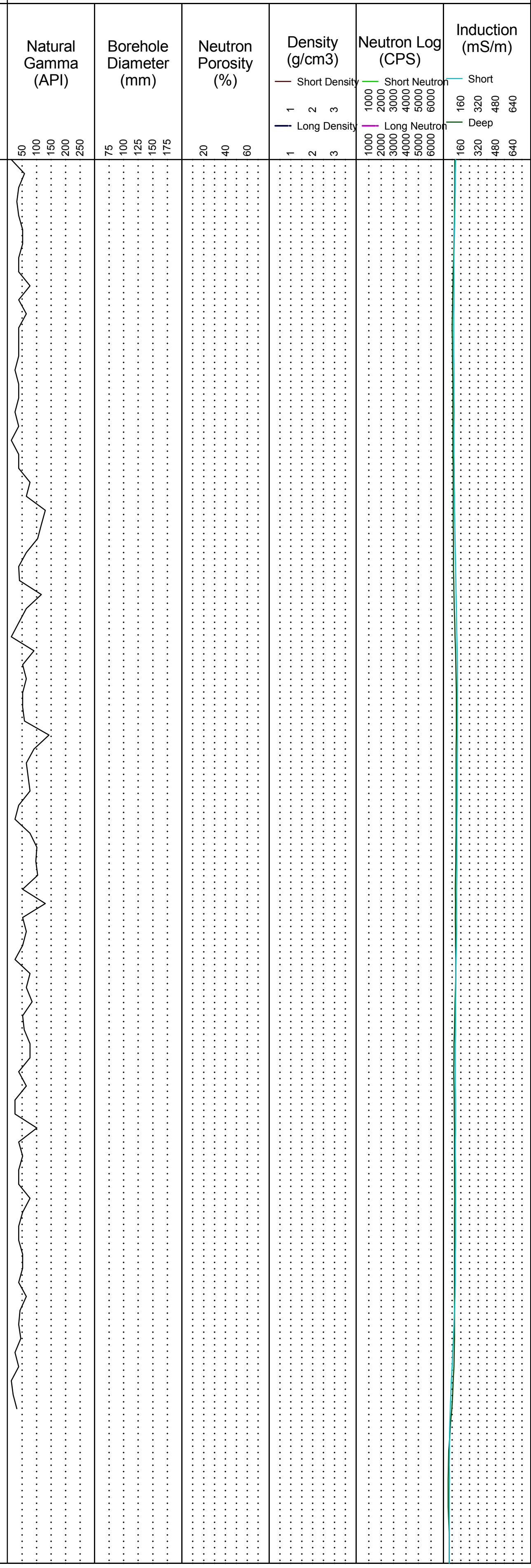
Laboratory Testing: Misc Laboratory Testing; Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Depth (m)	Classification Symbol	Description
to ~41.3		gravelly CLAY: non-plastic; fine grained; brown-grey; with fine to coarse, angular to rounded gravel (20%) and fine to coarse grained sand (10-20%), well graded from 40.60 m to 40.70 m: indurated fine to medium grained sands
~41.3 – 42.6	CI-CL	CLAY: low to medium plasticity; grey mottled brown; trace fine grained sand and fine to medium gravel, moderately graded
~42.6 – 43.2	GC	clayey GRAVEL: fine to coarse grained; sub-rounded to sub-angular; brown; of quartz and sedimentary, with clay (20%) and fine to coarse grained sand (10-20%), well graded
~43.2 – 46.5	CH	CLAY: high plasticity; grey mottled orange-brown; trace fine grained sand from 45.80 m: with black organic materials throughout
~46.5 – 47.4	CI	sandy CLAY: medium plasticity; fine grained; grey mottled brown; sand is fine grained (10-20%)
~47.4 – 49.0		NO CORE: Not recovered - likely very stiff clays
49.0 – 50.0		CONGLOMERATE: inferred, no sample recovered Refer to W02D for description

Depth scale (m): 40.5, 41.0, 41.5, 42.0, 42.5, 43.0, 43.5, 44.0, 44.5, 45.0, 45.5, 46.0, 46.5, 47.0, 47.5, 48.0, 48.5, 49.0, 49.5, 50.0
Reduced Level (m): 44, 43, 42, 41, 40, 39, 38, 37, 36, 35

Piezometer:
44.0 to 47.0 m: BENTONITE SEAL (PELLETS)
47.0 to 51.0 m: 2 mm FILTER SAND
48.0 to 51.0 m: Slotted Pipe



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Engineering Summary Log

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 11/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233744.2 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 14/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493941.2 m
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)					

RL: 84.1 m **Ver. Datum:** AHD **Surface:** Clay

Piezometer Details: Casing Top RL: 84.94 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 3.00 m; Development Date: 16/05/2018

Reduced Level (m) / Depth (m)	Water	Field Tests	Samples	Graphic Log	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer	Piezometer Details	Natural Gamma (API)	Borehole Diameter (mm)	Neutron Porosity (%)	Density (g/cm3)	Neutron Log (CPS)	Induction (mS/m)	Misc Laboratory Testing	Geochemical Testing	Geological Unit (Geotech. Unit)
34 / 50.5–51.0						CONGLOMERATE: inferred, no sample recovered Refer to W02D for description *(continued)*														
33–25 / 51.0–60.0						*Borehole W02C log continued as cored log from m.*														

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Engineering Summary Log

BOREHOLE No. W02D

Sheet: 1 of 25

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

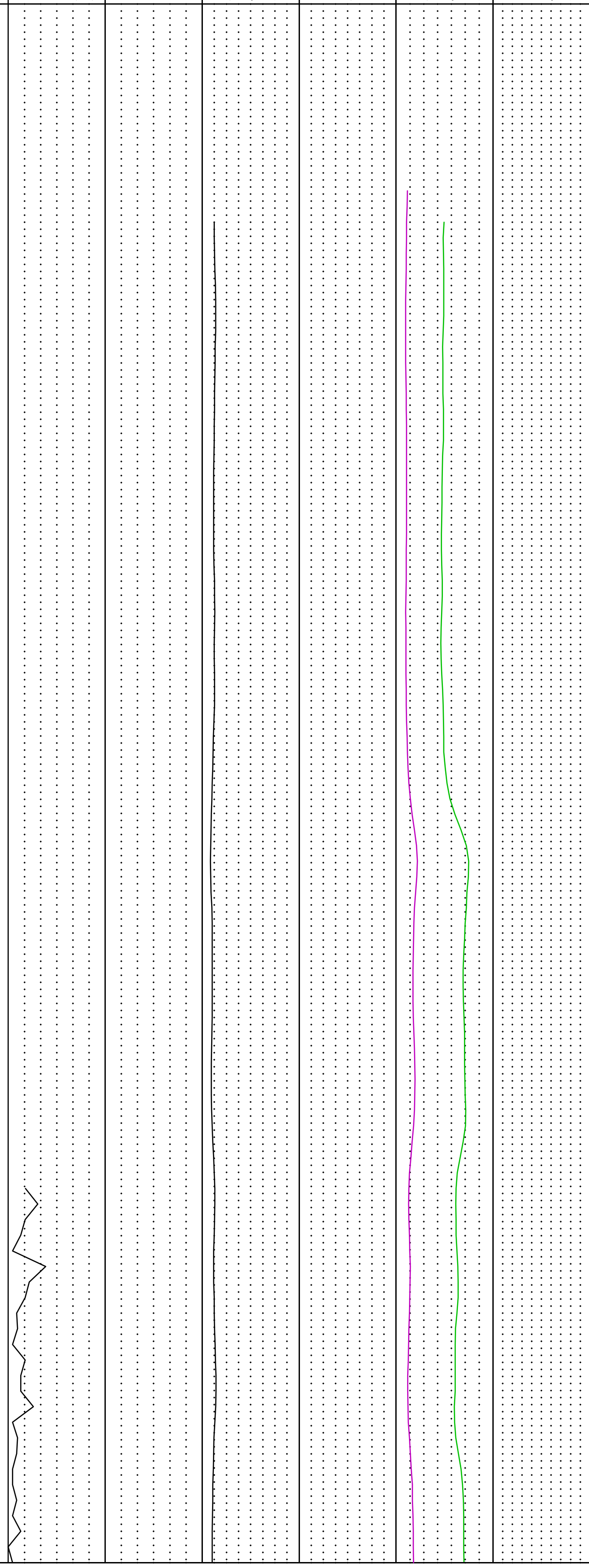
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

0.6 above ground to 0.0 m: Steel Monument

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep



Reduced Level (m) / Depth (m)	Samples	Classification Symbol	Description
84 / 0.0	ESW02D_0.0-0.1	ML	clayey SILT: low plasticity; light brown, brown; trace fine very fine sand and grass roots from 0.20 m: roots absent from 0.50 m: brown-cream; small clumps of material 3 to 10 mm diameter break in fingers, potential laterite clasts
1.2		ML	clayey SILT: low plasticity; light brown to yellow-brown; trace fine grained sand, poor graded
81 / 3.0	U63 U63_3.0-3.2		
4.5		ML	clayey SILT: low plasticity; yellow-brown to orange; trace very fine grained sand (10 - 15%), poorly graded from 6.00 m: white to yellow; firm / indurated clasts 5 to 10 mm in diameter break in fingers
6.8		ML	gravelly SILT: low plasticity; orange-brown; gravel is fine to medium (5 to 20 mm), sub-rounded, shale and fine grained sandstone, trace fine grained sand
8.2		ML	clayey SILT: low plasticity; brown-orange; trace very fine grained sand (5 - 10%), poorly graded
10.0			

Column headings: Field Data (Reduced Level (m) Depth (m), Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline; Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

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Engineering Summary Log

Client: Department of Industry, Innovation and Science
Project: NRWMF - Site Characterisation
Location: Wallerberdina Station
Drilling Water: Potable water sourced from Kimba (measured EC ~300 μS/cm)

Project No: 60565376
Logged by: JR / MM
Checked by: HS

Start Date: 19/04/2018
End Date: 28/05/2018
Location Meth.: dGPS0.1

Driller: Numac Drilling
Drill Rig: Commachio 450

Hole Diameter: 96-155 mm
Inclination: -90°
Bearing: N/A

Easting: 233753.7 m
Northing: 6493934.6 m
Hor. Proj/Dat: MGA94/GDA94-54H

RL: 84.0 m
Ver. Datum: AHD
Surface: Grass

Piezometer Details

Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Classification Symbol	Description
(continued) – 14.5	ML	clayey SILT: low plasticity; brown-orange; trace very fine grained sand (5 - 10%), poorly graded *(continued)* from 11.00 m: trace fine to medium (5 to 10 mm), sub-rounded, Quartzite gravel
14.5 – 15.2	ML	gravelly SILT: low plasticity (does not roll); orange-brown; trace fine (2 to 5 mm), sub-rounded, Quartzite and Shale gravel, clay and fine grained sand
15.2 – 17.7	CL	silty CLAY: low plasticity; orange-brown; trace very fine sand from 16.65 m to 16.71 m: fine to medium (5 to 20 mm), well rounded gravel band
17.7 – 20.0	CI-CL	CLAY: low to medium plasticity; orange-brown, mottled light grey; trace very fine sand from 19.24 m to 19.45 m: indurated irregular blobs, light grey

Column headings: Field Data (Reduced Level (m) / Depth (m); Water; Field Tests; Samples) | Material Description (Graphic Log; Classification Symbol; Description) | Rock Condition (Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer N E S W) | Piezometer Details | Downhole Wireline | Laboratory Testing (Misc Laboratory Testing; Geochemical Testing) | Geology (Geological Unit *(Geotech. Unit)*)

Depth scale: 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0
Reduced Level scale: 74, 73, 72, 71, 70, 69, 68, 67, 66, 65

Downhole Wireline

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Engineering Summary Log

BOREHOLE No. W02D

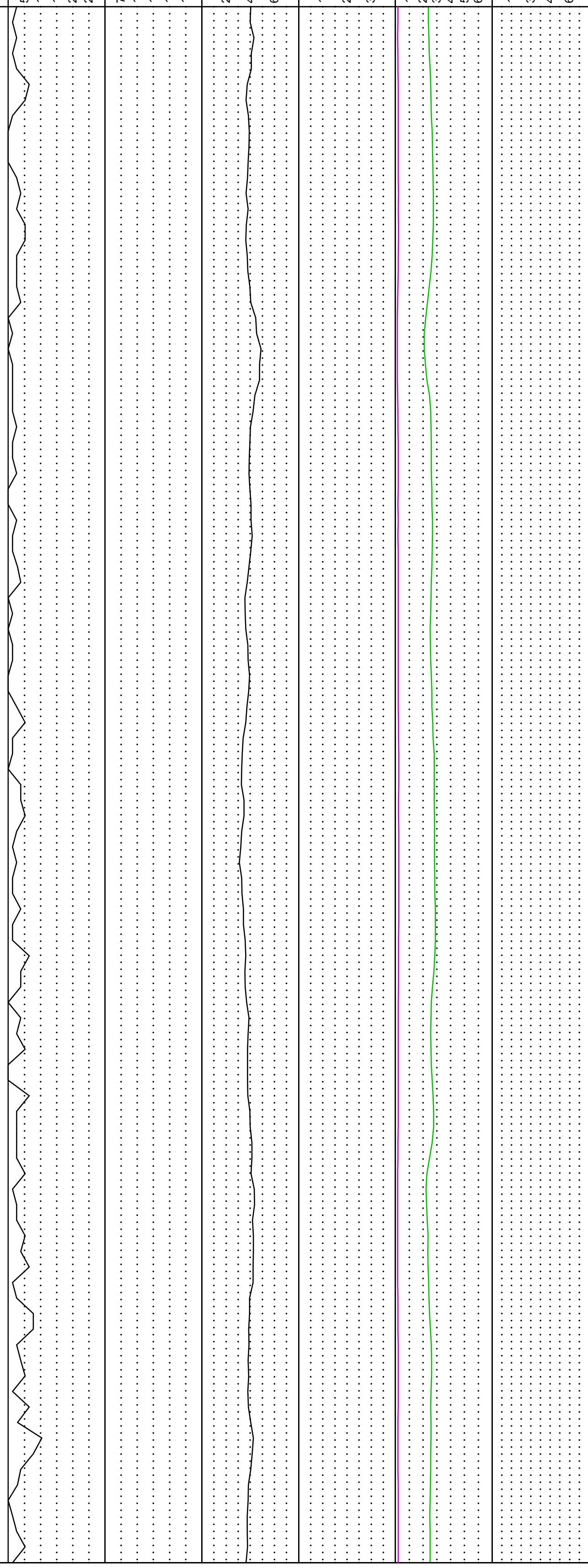
Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Columns: Field Data (Reduced Level (m) / Depth (m), Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API), Borehole Diameter (mm), Neutron Porosity (%), Density (g/cm3) – Short Density, Long Density; Neutron Log (CPS) – Short Neutron, Long Neutron; Induction (mS/m) – Short, Deep); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Depth (m)	Water	Samples	Classification Symbol	Description
– 20.6			CI-CL	CLAY: low to medium plasticity; orange-brown, mottled light grey; trace very fine sand *(continued)*
20.6 – 21.5	▽ 21.0		SP	silty SAND: very fine grained; brown-orange; trace clay, water stirke at ~21.2m
21.5 – 21.85		W02D_21.5-21.8	CH	CLAY: high plasticity; brown-orange
21.85 – 22.0			SM	silty SAND: very fine to fine grained; orange-brown, mottled grey; friable, poorly sorted
22.0 – 23.7				NO CORE: 22.00 m to 23.70 m in saturated sands
23.7 – 24.55		W02D_24.1-24.2	SP	SAND: fine grained; orange-brown; ferruginous, trace silt, friable, poorly sorted
24.55 – 26.9		W02D_24.6-24.7	SP	clayey SAND: very fine to fine grained; orange-brown, mottled grey-white; with indurated concretions and bands up to 15 mm thick, poorly sorted from 25.72 m to 25.76 m: hard indurated band
26.9 – 27.3		W02D_27.1-27.2	SP	SAND: fine grained; brown-grey; friable
27.3 – 27.5				NO CORE: 27.30 m to 27.50 m
27.5 – 27.9				NO CORE: 27.50 m to 27.90 m
27.9 – 29.95		W02D_28-28.3 W02D_28.3-28.4	SC	clayey SAND: fine grained; orange-brown, mottled grey; ferruginous, poorly sorted from 29.30 m to 29.35 m: indurated band
29.95 –			SP	



Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A

Easting:	233753.7 m	**RL:**	84.0 m
Northing:	6493934.6 m	**Ver. Datum:**	AHD
Hor. Proj/Dat:	MGA94/GDA94-54H	**Surface:**	Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Depth (m)	Samples	Classification Symbol	Description	Misc Laboratory Testing
30.0–32.06	W02D_30.2-30.3	SP	SAND: very fine to fine grained; light brown - orange; variably indurated, friable to moderately hard, quartzofeldspathic in composition, ferruginous, poorly sorted *(continued)*	
32.06–32.56			NO CORE: 32.06 m to 32.56 m, likely in gravel	
32.56–32.8		SP	gravelly SAND: fine to medium grained; brown-orange; gravel is fine to coarse (5 to 45 mm), sub-rounded, quartzite, sandstone and shale, ferruginous	
32.8–34.70	W02D_33.0-33.3; W02D_33.3-33.4	SC	sandy CLAY: medium to high plasticity; orange-brown, mottled grey; trace fine grained sand, ferruginous, indurated bands	W02D_33.0-33.3m: Permeability (U63): 3.0 x 10^{-9} m/sec
34.70–36.38			NO CORE: 34.70 m to 36.38 m, likely lost in gravel or gravelly sand	
36.38–36.6		GM	gravelly SILT: brown-orange; gravel is medium to coarse (10 to 30 mm), rounded, Quartzite and Shale	
36.6–38.2	W02D_36.5-36.8; W02D_36.8-36.9	SC	sandy CLAY: medium to high plasticity; dark brown - orange; trace very fine grained sand	
38.2–39.70		CH-CI	CLAY: medium to high plasticity; light-brown, brown, indurated streaks/blotches of white - light grey; trace organic black specks	
39.70–40.60			NO CORE: 39.70 m to 40.60 m, likely lost in gravel	

Reduced Level (m): 54, 53, 52, 51, 50, 49, 48, 47, 46, 45

Depth (m): 30.5, 31.0, 31.5, 32.0, 32.5, 33.0, 33.5, 34.0, 34.5, 35.0, 35.5, 36.0, 36.5, 37.0, 37.5, 38.0, 38.5, 39.0, 39.5, 40.0

Downhole Wireline: Natural Gamma (API) 50–250; Borehole Diameter (mm) 75–175; Neutron Porosity (%) 20–60; Density (g/cm3) 1–3, Short Density, Long Density; Neutron Log (CPS) 1000–6000, Short Neutron, Long Neutron; Induction (mS/m) 160–640, Short, Deep

Column headings: Field Data (Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/ Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline; Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

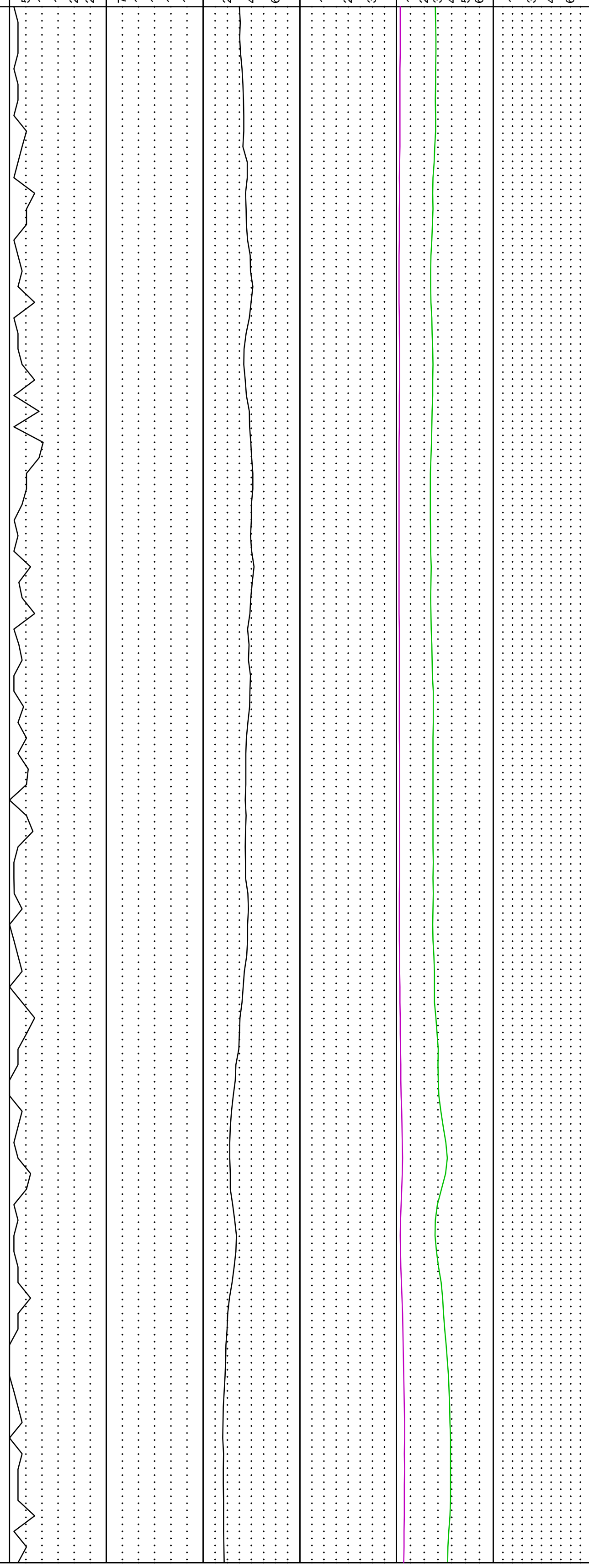
Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Depth (m)	Samples	Classification Symbol	Description	Misc Laboratory Testing
40.5			NO CORE: 39.70 m to 40.60 m, likely lost in gravel *(continued)*	
40.6	W02D_41.27-41.55; W02D_41.55-41.65	CI-MH	silty CLAY: medium to high plasticity; orange-brown, mottled grey and red; with irregular carbonaceous specks, trace very fine grained sand	
44.45			from 44.45 m to 44.74 m: Indurated band, slow drilling.	
45.6	W02D_45.5-45.7	SP	gravelly SAND: fine to medium grained; dark brown to orange; friable, quartzofeldspathic composition, gravel is coarse to cobble sized (50 to 200 mm), sub-rounded, quartzite, sandstone, shale and conglomerate	
46.5		GP	GRAVEL: fine grained to cobble sized; quartzite, siltstone, quartz conglomerate, dark grey to white, trace fine to medium grained sand	
47.12			NO CORE: 47.12 m to 47.66 m	
47.66		GP	GRAVEL: as above	
48.6			CONGLOMERATE: polymict, medium to coarse grained; light grey, orange-red; clasts fine to coarse gravel with cobbles, rounded to sub-rounded, sandstone quartzite, shale, dolomite, hard indurated, slightly calcareous, loss of water returns in fracture at 49.6m, H-VH	W02D_49.25-49.51m: Permeability (U63): 4.0×10^{-11} m/sec

Reduced Level (m): 44, 43, 42, 41, 40, 39, 38, 37, 36, 35

Depth (m): 40.5, 41.0, 41.5, 42.0, 42.5, 43.0, 43.5, 44.0, 44.5, 45.0, 45.5, 46.0, 46.5, 47.0, 47.5, 48.0, 48.5, 49.0, 49.5, 50.0

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep



Engineering Summary Log

BOREHOLE No. W02D

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)					

RL: 84.0 m **Ver. Datum:** AHD **Surface:** Grass

Piezometer Details

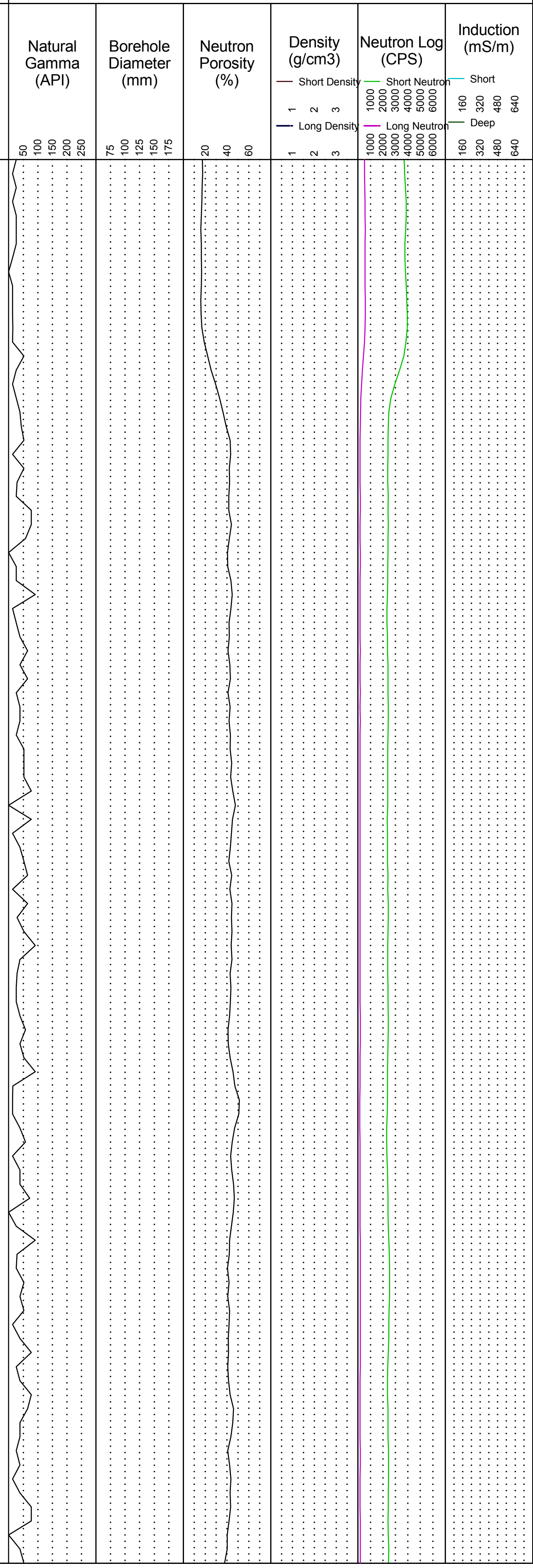
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Samples	Classification Symbol	Description
50.0–51.5			CONGLOMERATE: polymict, medium to coarse grained; light grey, orange-red; clasts fine to coarse gravel with cobbles, rounded to sub-rounded, sandstone quartzite, shale, dolomite, hard indurated, slightly calcareous, loss of water returns in fracture at 49.6m, H-VH *(continued)* from 50.50 m to 50.59 m: fracture zone at 50.74 m: open fracture with iron stained sand and clay
51.5–55.1	W02D_52.0-52.24 W02D_52.24-52.32	CH-CI	CLAY: medium to high plasticity; brown-orange, mottled white; with black organic flecks throughout, trace very fine to fine sand, calcareous, H-VH from 53.15 m to 53.45 m: hard indurated zone, with concretions, veinlets, calcareous (reacts with acid) from 54.65 m to 54.85 m: Indurated calcareous zone
55.1–55.35		CL	sandy CLAY: low plasticity; orange-brown; sand is very fine to fine, poorly graded, trace black carbonaceous flecks
55.35–55.8		CH-CI	CLAY: medium to high plasticity; brown-orange; with irregular calcareous veins and concretions, trace very fine sand
55.8–56.92			NO CORE: 55.80 m to 56.92m, barrel blocked
56.92–60.0		CI-CL	silty CLAY: low to medium plasticity; brown-orange; with irregular zones up to 50 to 150 mm of calcareous veinlets and black carbonaceous specks, trace fine sands from 59.22 m to 59.31 m: calcareous white concretions

Depth (m): 50.5, 51.0, 51.5, 52.0, 52.5, 53.0, 53.5, 54.0, 54.5, 55.0, 55.5, 56.0, 56.5, 57.0, 57.5, 58.0, 58.5, 59.0, 59.5, 60.0
Reduced Level (m): 34, 33, 32, 31, 30, 29, 28, 27, 26, 25

Columns: Field Data (Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline; Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Downhole Wireline



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Engineering Summary Log

BOREHOLE No. **W02D**

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm	**Easting:**	233753.7 m
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°	**Northing:**	6493934.6 m
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A	**Hor. Proj/Dat:**	MGA94/GDA94-54H
RL:	84.0 m	**Ver. Datum:**	AHD	**Surface:**	Grass						

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Downhole Wireline columns: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep

Other columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer; Misc Laboratory Testing; Geochemical Testing; Geological Unit (Geotech. Unit)

Depth (m)	Classification Symbol	Description
60.0 – 64.45	CI-CL	silty CLAY: low to medium plasticity; brown-orange; with irregular zones up to 50 to 150 mm of calcareous veinlets and black carbonaceous specks, trace fine sands *(continued)*
63.22 – 63.30		from 63.22 m to 63.30 m: fractured calcareous zone
64.45 – 65.30	CL	sandy CLAY: low plasticity; light brown-orange; with irregular calcareous concretions, trace very fine sand,
65.30 – 65.90		NO CORE: 65.30 m to 65.90 m
65.90 – 66.65	SC	clayey SAND: very fine grained; light brown-orange; with white-grey irregular calcareous inclusions (very indurated)
66.65 – 66.97	SP	SAND: very fine to fine grained; light brown-orange; massive, trace silt/clay
66.97 – 68.19		NO CORE: 66.97 m to 68.19 m, likely lost in saturated loose sand
68.19 – 68.5	SP	SAND: fine to medium grained; light brown
68.5 – 70.0		BRECCIA: light brown to white; altered sandstone cobbles with irregular calcareous veins and clay infill. Alteration halos at clay and calcareous infill boundaries. Vertical fractures and very irregular coarse gravel at base

Depth scale: 60.5, 61.0, 61.5, 62.0, 62.5, 63.0, 63.5, 64.0, 64.5, 65.0, 65.5, 66.0, 66.5, 67.0, 67.5, 68.0, 68.5, 69.0, 69.5, 70.0

Reduced Level scale: 24, 23, 22, 21, 20, 19, 18, 17, 16, 15

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Engineering Summary Log

BOREHOLE No. **W02D**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)						

Piezometer Details

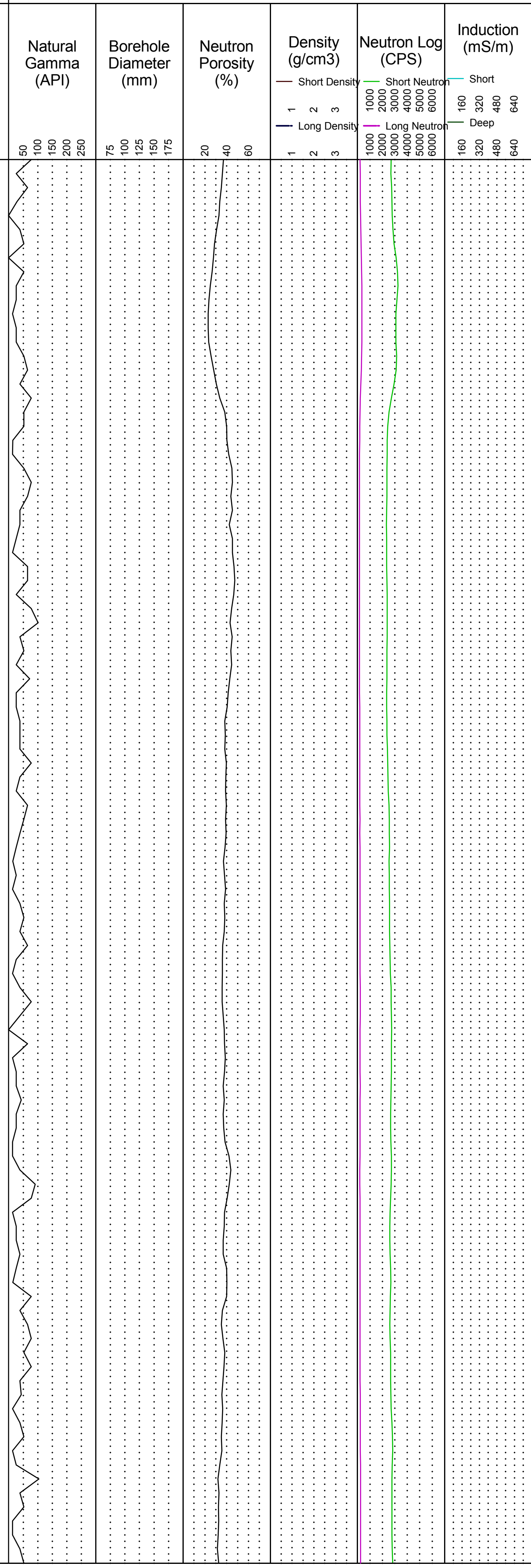
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Columns: Field Data (Reduced Level (m) / Depth (m), Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API), Borehole Diameter (mm), Neutron Porosity (%), Density (g/cm3) Short Density / Long Density, Neutron Log (CPS) Short Neutron / Long Neutron, Induction (mS/m) Short / Deep); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Depth (m)	Classification Symbol	Description
70.00		NO CORE: 70.00 m to 71.20 m, likely in gravel
71.20		CONGLOMERATE: medium to coarse grained; light grey to dark grey-red; clasts are fine to coarse grained, sub-rounded, quartz, iron indurated sandstone and mudstone in a fine to medium grained sand matrix, matrix is fractured in upper 200 mm, followed by indurated conglomerate at 71.52 m: 30mm brown clay layer
71.55		NO CORE: 71.55 m to 72.50 m, likely wash out in clay
72.50	CH	CLAY: high plasticity; brown-orange; with fine grained sand and medium grained, sub-angular sandstone gravel band 100 mm thick
72.80		NO CORE: 72.80 m to 73.35 m
73.35	CH-CI	CLAY: medium to high plasticity; dark brown-orange; with black organic streaks and indurated calcareous infilled veins
74.70	CH-CI	CLAY: medium to high plasticity; brown-orange; trace fine sand
75.17		NO CORE: 75.17 m to 75.27 m
75.27	CH-CI	silty CLAY: medium to high plasticity; dark brown-orange; with carbonaceous fragments and laminations (1 to 2 mm) thick
78.70	SC	SAND: fine grained; brown-orange; carbonaceous specks decreasing in size with depth, with clay and silt (10 - 20%) from 79.54 m to 80.22 m: calcareous alteration and white indurated veins, spaced approximately 150 mm

Depth scale (m): 70.5, 71.0, 71.5, 72.0, 72.5, 73.0, 73.5, 74.0, 74.5, 75.0, 75.5, 76.0, 76.5, 77.0, 77.5, 78.0, 78.5, 79.0, 79.5, 80.0

Reduced level scale (m): 14, 13, 12, 11, 10, 9, 8, 7, 6, 5



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Engineering Summary Log

BOREHOLE No. **W02D**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

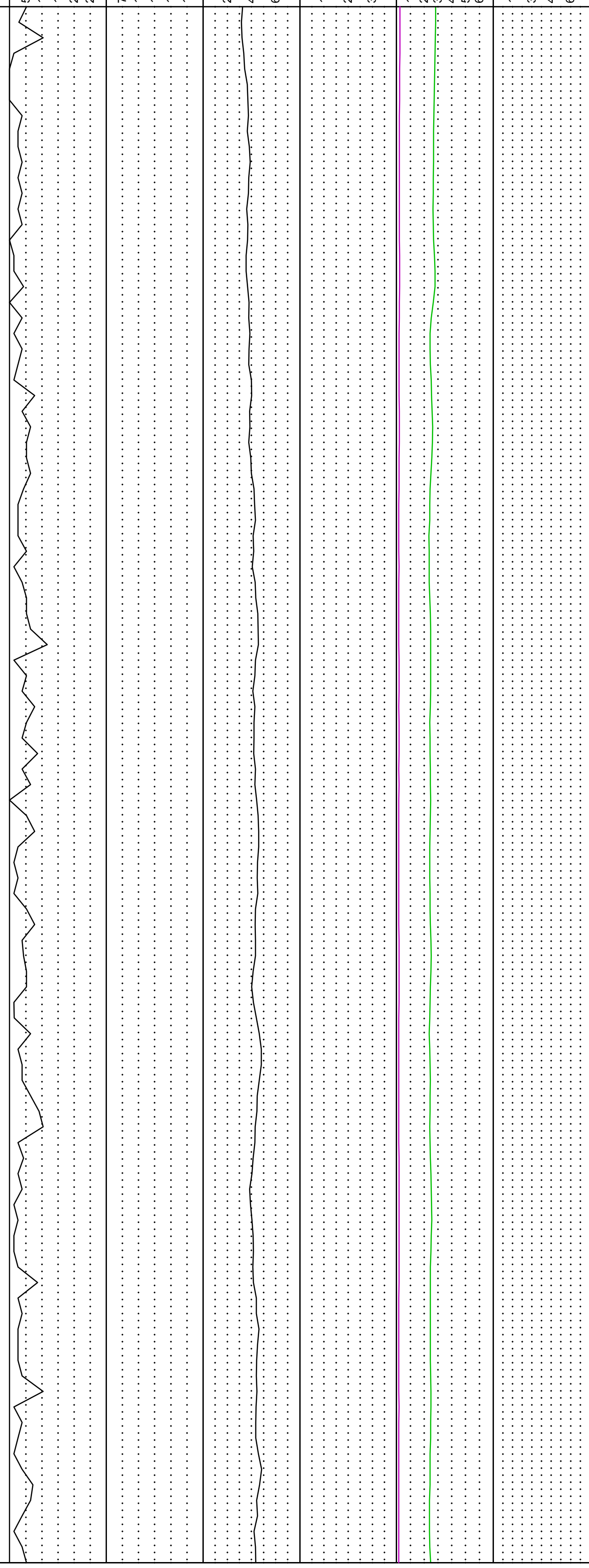
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Depth (m)	Classification Symbol	Description
80.0–80.31	SC	
80.31–80.95		NO CORE: 80.31 m to 80.95 m, likely in loose saturated sand
80.95–81.5	SP	SAND: fine grained; light brown; saturated massive, quartzofeldspathic in composition
81.5–82.6	CL	sandy CLAY: dark brown-orange, irregular dark grey-black spot (2 to 5 mm); massive, calcareous veined zones indurated
82.6–83.85		NO CORE: 82.60 m to 83.85 m: in fractured broken clay with calcareous veining
83.85–88.7	CL	sandy CLAY: dark brown-orange, irregular dark grey-black spot (2 to 5 mm) from 84.83 m to 84.94 m: brecciated calcareous veined zone, hard from 85.42 m to 85.47 m: calcareous vein and breccia from 85.79 m to 85.89 m: calcareous veining and alteration, indurated from 86.76 m to 86.91 m: brecciated zone, calcareous alteration
88.7–89.5	CI-CL	silty CLAY: low to medium plasticity; light brown; with black irregular fine gravel sized clasts (3 to 5 mm), more prevalent than previous unit, massive at 89.25 m: calcareous altered vein
89.5–90.0	CI-CL	silty CLAY: low to medium plasticity; brown-orange; irregular black altered spots, with indurated calcareous veining and alteration zones

Depth scale: 80.5, 81.0, 81.5, 82.0, 82.5, 83.0, 83.5, 84.0, 84.5, 85.0, 85.5, 86.0, 86.5, 87.0, 87.5, 88.0, 88.5, 89.0, 89.5, 90.0; Reduced Level: 4, 3, 2, 1, 0, -1, -2, -3, -4, -5

Column headings: Field Data (Reduced Level (m) Depth (m), Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API) 50 100 150 200 250; Borehole Diameter (mm) 75 100 125 150 175; Neutron Porosity (%) 20 40 60; Density (g/cm3) Short Density, Long Density 1 2 3; Neutron Log (CPS) Short Neutron, Long Neutron 1000–6000; Induction (mS/m) Short, Deep 160 320 480 640); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)



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Engineering Summary Log

BOREHOLE No. **W02D**

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A

Easting:	233753.7 m	**RL:**	84.0 m
Northing:	6493934.6 m	**Ver. Datum:**	AHD
Hor. Proj/Dat:	MGA94/GDA94-54H	**Surface:**	Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

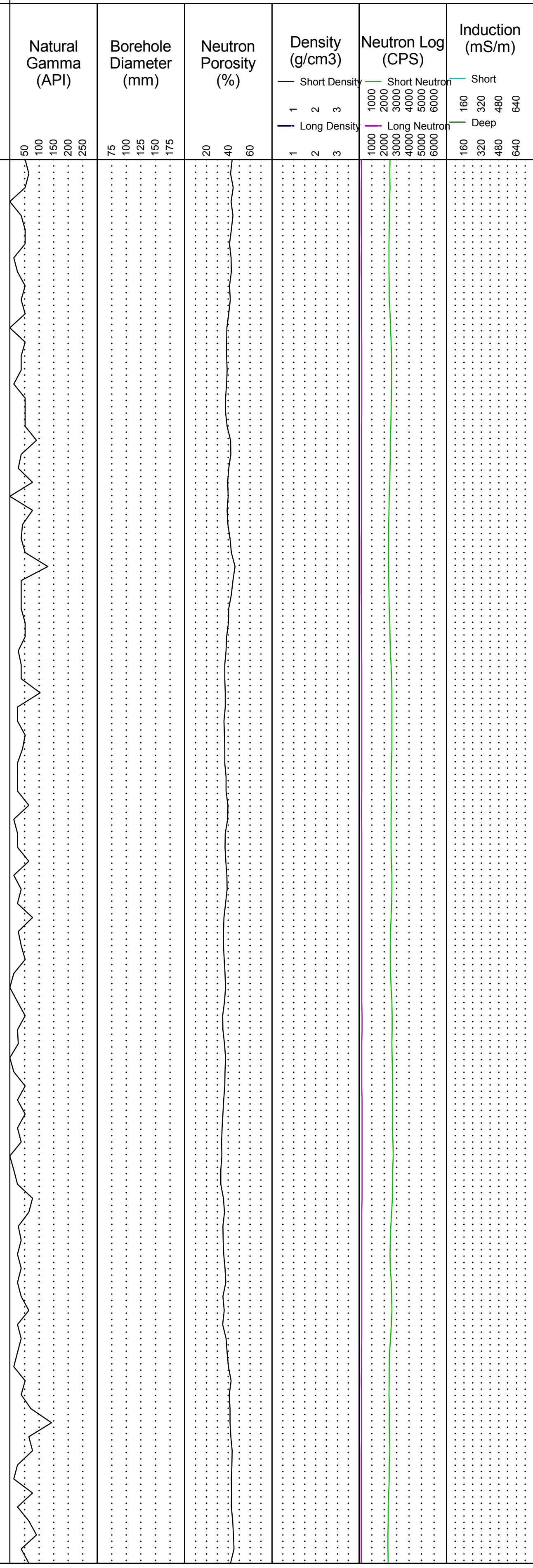
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Reduced Level (m)	Depth (m)	Graphic Log	Classification Symbol	Description
-6			CI-CL	silty CLAY: low to medium plasticity; brown-orange; irregular black altered spots, with indurated calcareous veining and alteration zones *(continued)*
	90.5			
-7	91.0			from 91.05 m to 91.75 m: circular calcareous alteration, closely spaced
	91.5			
-8	92.0			
	92.5			
-9	93.0			
	93.5			
-10	94.0			
	94.5			
-11	95.0			
	95.5		SC	clayey SAND: fine grained; brown-orange, irregular white-grey patches; massive, calcareous veining and alteration
-12	96.0			
	96.5			
-13	97.0			
	97.5			
-14	98.0			
	98.5		CH	CLAY: high plasticity; brown; trace fine grained sand
-15	99.0			NO CORE: 99.02 m to 99.36 m
	99.5		CH-CI	CLAY: medium to high plasticity; brown-orange; with black irregular spots (possibly carbonaceous), ferruginous / iron mottled staining, calcareous veining and alteration, massive
	100.0			

Column headings: Field Data (Water, Field Tests, Samples); Material Description; Rock Condition (Weathering/ Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline; Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Piezometer: 0.0 to 196.0 m: CEMENT/ BENTONITE GROUT; 0.0 to 196.0 m: 114 mm (HWT) STEEL CASING

Downhole Wireline



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Engineering Summary Log

BOREHOLE No. W02D

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

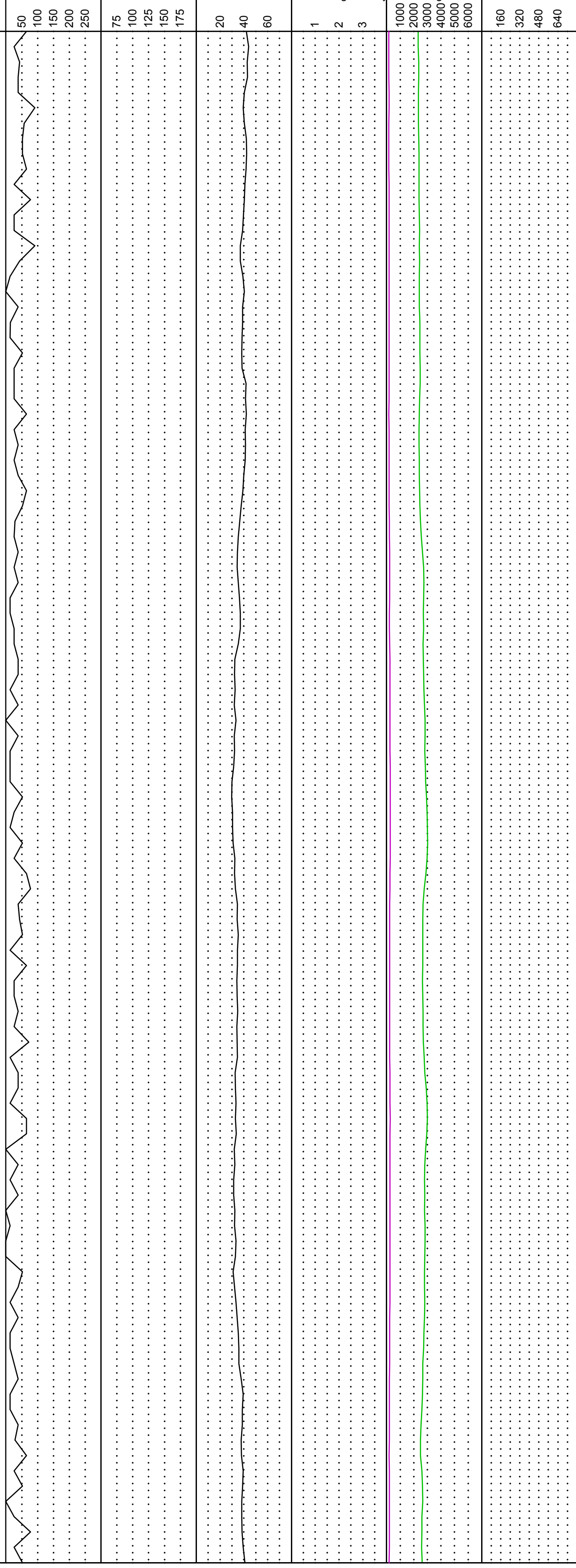
Columns: Reduced Level (m) Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep; Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Piezometer Details:
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Classification Symbol	Description
100.0 – 103.3	CH-CI	CLAY: medium to high plasticity; brown-orange; with black irregular spots (possibly carbonaceous), ferruginous / iron mottled staining, calcareous veining and alteration, massive *(continued)*
103.3 – 104.05	SC	clayey SAND: fine grained; orange-brown; irregular iron staining, quartz observed as main grain type
104.05 – 104.89		NO CORE: 104.05 m to 104.89 m
104.89 – 107.3	SC	clayey SAND: fine grained; orange-brown; 10 - 20% fines (clay / silt) from 105.01 m to 105.39 m: brecciated / veined zones (calcareous)
107.3 – 107.95	SP	SAND: fine grained; light brown; moist to wet
107.95 – 108.50		NO CORE: 107.95 m to 108.50 m, lost in saturated sand
108.50 – 108.8	SP	SAND: fine grained; light brown to orange; saturated, poorly graded, trace fines (clay/silt)
108.8 – 110.0	CH-CI	CLAY: medium to high plasticity; brown-orange; irregular calcareous alteration throughout from 109.22 m to 109.43 m: major pink-white vein with internal calcite infilled veinlets (slow reaction with acid)

Depth scale: 100.5, 101.0, 101.5, 102.0, 102.5, 103.0, 103.5, 104.0, 104.5, 105.0, 105.5, 106.0, 106.5, 107.0, 107.5, 108.0, 108.5, 109.0, 109.5, 110.0

Reduced Level: -16, -17, -18, -19, -20, -21, -22, -23, -24, -25



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Engineering Summary Log

BOREHOLE No. **W02D**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

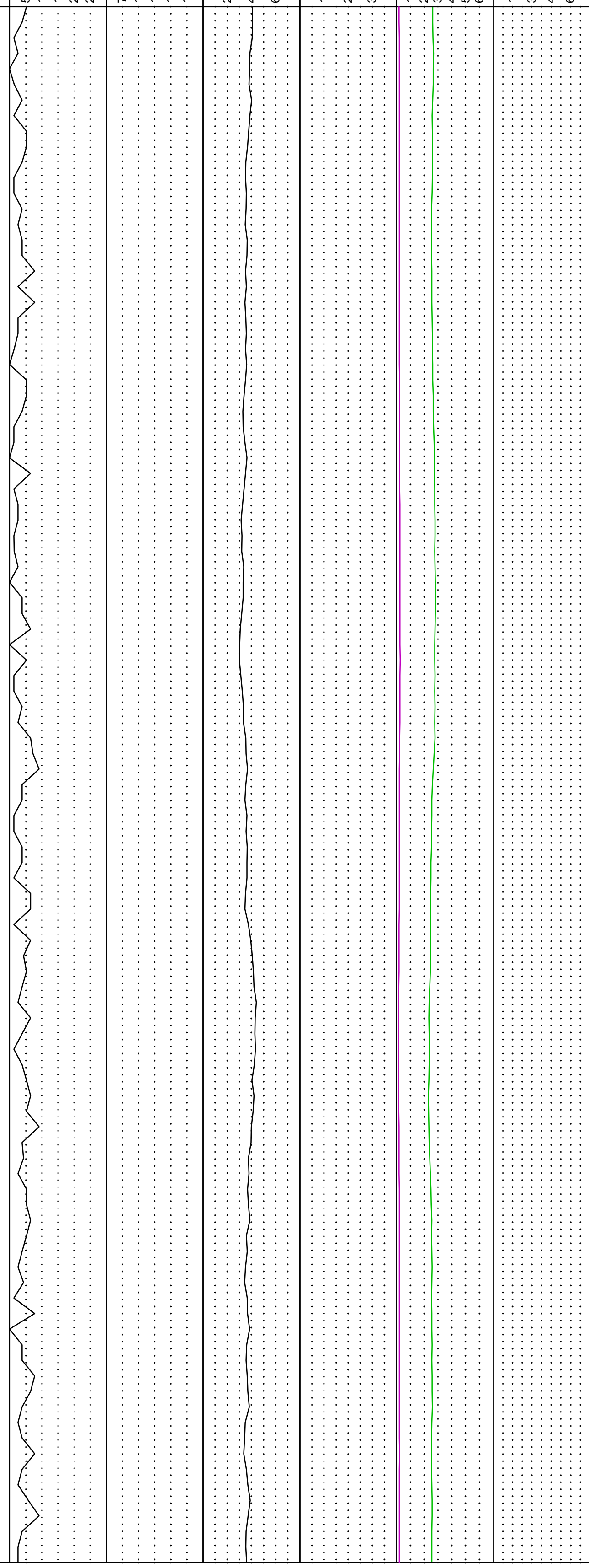
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Reduced Level (m) / Depth (m)	Graphic Log	Classification Symbol	Description	Weathering/ Consistency
-26 / 110.5 – 111.5	Clay	CH-CI	CLAY: medium to high plasticity; brown-orange; irregular calcareous alteration throughout *(continued)*	
			from 110.80 m to 111.40 m: irregular iron staining	
-28 / 112.0 – 115.0	Sandstone		SANDSTONE: fine grained; grey; with orange-red iron staining, massive, with clay (5-10%), possible alteration product, XW- HW, L	XW-HW
			from 114.20 m to 114.40 m: fractured, VL	
			L	
-31 / 115.5 – 120.0	Mudstone		MUDSTONE: orange-red, with irregular grey patches; massive, with fine grained sand (10-20%) in matrix, iron staining, (remoulds to medium to high plasticity Clay), driller notes rapid consumption of drilling muds due to formation clays/silts., HW, VL	HW
			from 116.68 m to 117.32 m: dark grey-black; thinly laminated (1 - 3 mm)	
			becoming dominant light grey; mottle orange-red less decreasing	

Column headings: Field Data (Water, Field Tests, Samples); Material Description; Rock Condition (TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API) 50 100 150 200 250; Borehole Diameter (mm) 75 100 125 150 175; Neutron Porosity (%) 20 40 60; Density (g/cm3) Short Density, Long Density 1 2 3; Neutron Log (CPS) Short Neutron, Long Neutron 1000–6000; Induction (mS/m) Short, Deep 160 320 480 640); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Depth scale: 110.5, 111.0, 111.5, 112.0, 112.5, 113.0, 113.5, 114.0, 114.5, 115.0, 115.5, 116.0, 116.5, 117.0, 117.5, 118.0, 118.5, 119.0, 119.5, 120.0; RL: -26, -27, -28, -29, -30, -31, -32, -33, -34, -35



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Engineering Summary Log

BOREHOLE No. **W02D**

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

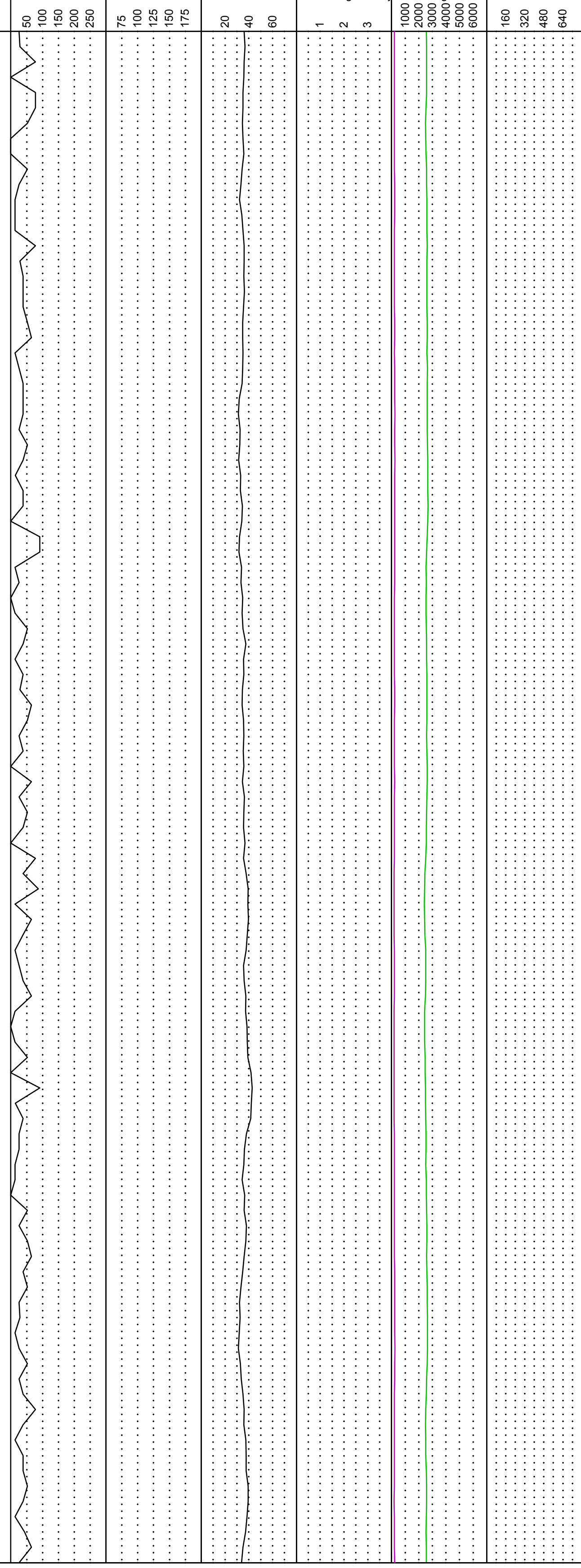
Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Piezometer Details; Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep; Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	RL (m)	Description	Weathering/Consistency
120.5 – 122.2	-36 – -38	MUDSTONE: orange-red, with irregular grey patches; massive, with fine grained sand (10-20%) in matrix, iron staining, (remoulds to medium to high plasticity Clay), driller notes rapid consumption of drilling muds due to formation clays/silts., HW, VL *(continued)*	HW
122.2 – 125.2	-38 – -41	SANDSTONE: fine grained; light grey-orange; with clay (10-25%), iron stained, HW, VL-L	
~124.1	-40	XW	XW
~124.5		VL	
124.70		from 124.70 m: highly fractured weak zone, friable, HW	HW
125.2 – 126.0	-41 – -42	MUDSTONE: light grey, red-orange staining; ferruginous, HW, L	
126.00 – 126.10	-42	NO CORE: 126.00 m to 126.10 m, HW, L	
126.10 – 129.8	-42 – -45	SILTSTONE: orange, light grey; massive; iron stained, fine grained sand, trace clay in matrix, HW, VL	HW
127.77 – 127.85		from 127.77 m to 127.85 m: clay band, light grey, soft	

Depth scale: 120.5, 121.0, 121.5, 122.0, 122.5, 123.0, 123.5, 124.0, 124.5, 125.0, 125.5, 126.0, 126.5, 127.0, 127.5, 128.0, 128.5, 129.0, 129.5, 130.0
RL scale: -36, -37, -38, -39, -40, -41, -42, -43, -44, -45



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Engineering Summary Log

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm	**Easting:**	233753.7 m
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°	**Northing:**	6493934.6 m
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A	**Hor. Proj/Dat:**	MGA94/GDA94-54H

RL: 84.0 m | **Ver. Datum:** AHD | **Surface:** Grass

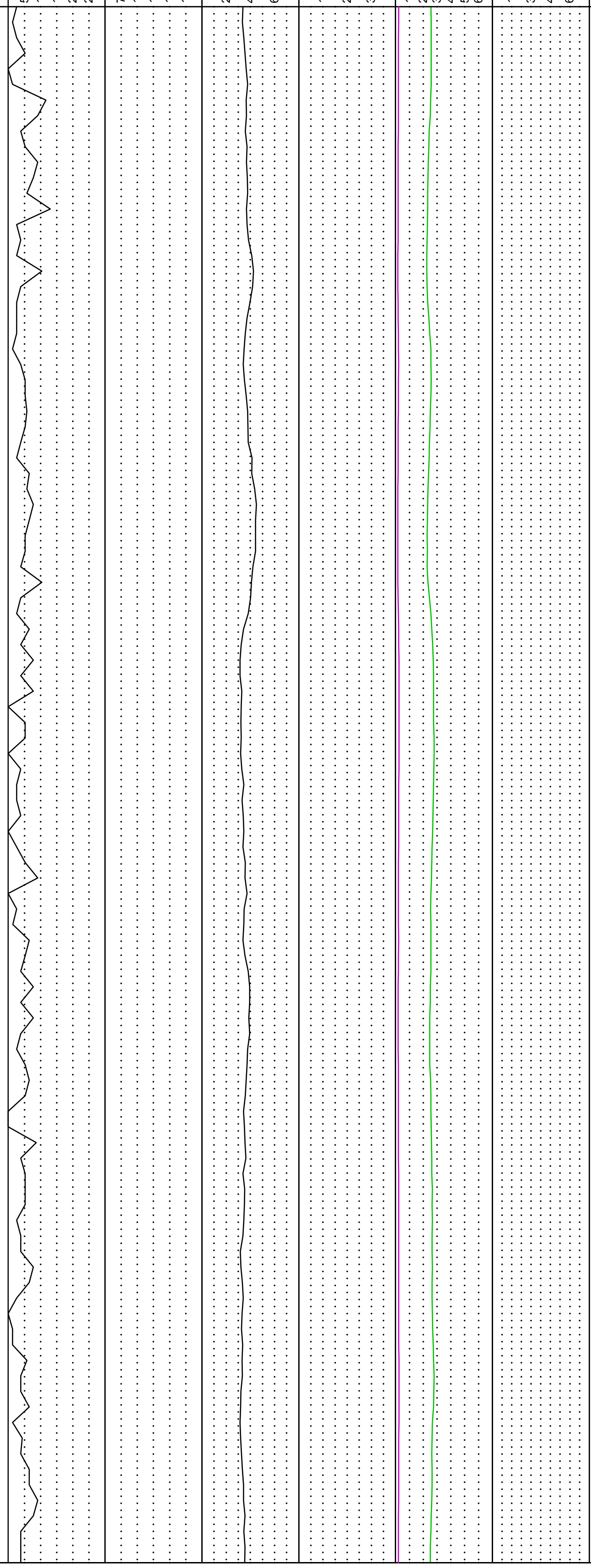
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) (Short Density, Long Density); Neutron Log (CPS) (Short Neutron, Long Neutron); Induction (mS/m) (Short, Deep); Misc Laboratory Testing; Geochemical Testing; Geological Unit (*Geotech. Unit*)

Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

- 130.0–133.7 m: MUDSTONE: grey to orange-red; generally massive; iron stained, minimal defects, trace fine grained quartz grains, (remoulds to medium to high plasticity Clay), HW, VL *(continued)* — HW
- 133.7 m: SANDSTONE: fine to medium grained; light grey to light orange; massive; iron stained, quartz rich, iron cemented nodules, with clay (5 - 10%) in matrix,, HW, VL
- MW, L — MW
- VL
- L
- from 136.32 m to 136.56 m: Claystone bed
- longitudinal fracture (no infill, rough)
- from 139.18 m to 139.25 m: low plasticity; light grey-orange; trace quartz sand, XW — XW
- NO CORE: 139.25 m to 139.90 m, XW, L



Client: Department of Industry, Innovation and Science
Project: NRWMF - Site Characterisation
Location: Wallerberdina Station
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Project No: 60565376
Logged by: JR / MM
Checked by: HS

Start Date: 19/04/2018
End Date: 28/05/2018
Location Meth.: dGPS0.1

Driller: Numac Drilling
Drill Rig: Commachio 450

Hole Diameter: 96-155 mm
Inclination: -90°
Bearing: N/A

Easting: 233753.7 m
Northing: 6493934.6 m
Hor. Proj/Dat: MGA94/GDA94-54H

RL: 84.0 m
Ver. Datum: AHD
Surface: Grass

Piezometer Details
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Reduced Level (m)	Description	Weathering/Consistency
140.0–141.65	-56 to -57.65	SANDSTONE: fine grained; light grey-orange; iron stained, quartz rich, with clay / silt (10%) in matrix, HW, L *(continued)* VL L	HW
141.65–142.9		MUDSTONE: light grey-orange; iron stained and alteration, dense, (remoulds to high plasticity Clay), dense, HW, L	
142.9–144.25		Interbedded SHALE and SANDSTONE (70%): fine grained; grey-orange; with laminations and beds (5 - 30 mm) of Mudstone (30%), light grey, bedded at 0 - 10°, HW, L	
144.25–147.55		MUDSTONE: light grey to light orange; with thin variably spaced light grey laminations, difficult/slow drilling, extra hole flushing required between drill runs., MW, L from 145.85 m to 145.91 m: indurated white band, hard, H L from 146.61 m to 146.99 m: light grey indurated sand, very fine grained, iron staining, H VL	MW
147.55–150.0	-63.55 to -66	MUDSTONE: light grey; smooth, high density, with laminations of Sandstone (10%), very fine to fine grained, some cross bedded iron stained specs throughout, more induration in sandstone, MW- SW, L	MW-SW

Depth scale: 140.5, 141.0, 141.5, 142.0, 142.5, 143.0, 143.5, 144.0, 144.5, 145.0, 145.5, 146.0, 146.5, 147.0, 147.5, 148.0, 148.5, 149.0, 149.5, 150.0
Reduced level scale: -56, -57, -58, -59, -60, -61, -62, -63, -64, -65

Columns: Field Tests; Samples; Graphic Log; Classification Symbol; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Laboratory Testing: Misc Laboratory Testing, Geochemical Testing; Geology: Geological Unit *(Geotech. Unit)*

Downhole Wireline

AECOM

Engineering Summary Log

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Depth (m)	Description	Weathering/ Consistency
150.0 – 150.93	MUDSTONE: light grey; smooth, high density, with laminations of Sandstone (10%), very fine to fine grained, some cross bedded iron stained specs throughout, more induration in sandstone, MW- SW, L *(continued)* from 150.10 m to 150.30 m: indurated very fine grained sand, interval	MW-SW
150.93 – 153.50	MUDSTONE: grey to dark grey; massive; with poorly developed laminations (20 - 30 mm) of Sandstone (10%), fine grained, iron stained, iron cemented nodules throughout, calcareous, fizzes in acid (remoulds to medium to high plasticity Clay), MW- SW, L MW	MW
153.50 – 153.90	NO CORE: 153.50 m to 153.90 m, MW, L	
153.90 – 160.0	MUDSTONE: (as above), calcareous throughout, driller notes loss of ~50% of water returns., MW- SW, L from 156.00 m: irregular iron staining VL-L from 158.75 m to 158.91 m: cemented zone (calcareous), MW, H VL-L becoming dark green-grey	MW-SW; MW (from 158.75)

Reduced Level (m): -66 to -76

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep

Laboratory Testing: Misc Laboratory Testing | Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Client: Department of Industry, Innovation and Science
Project: NRWMF - Site Characterisation
Location: Wallerberdina Station
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Project No: 60565376
Logged by: JR / MM
Checked by: HS

Start Date: 19/04/2018
End Date: 28/05/2018
Location Meth.: dGPS0.1

Driller: Numac Drilling
Drill Rig: Commachio 450

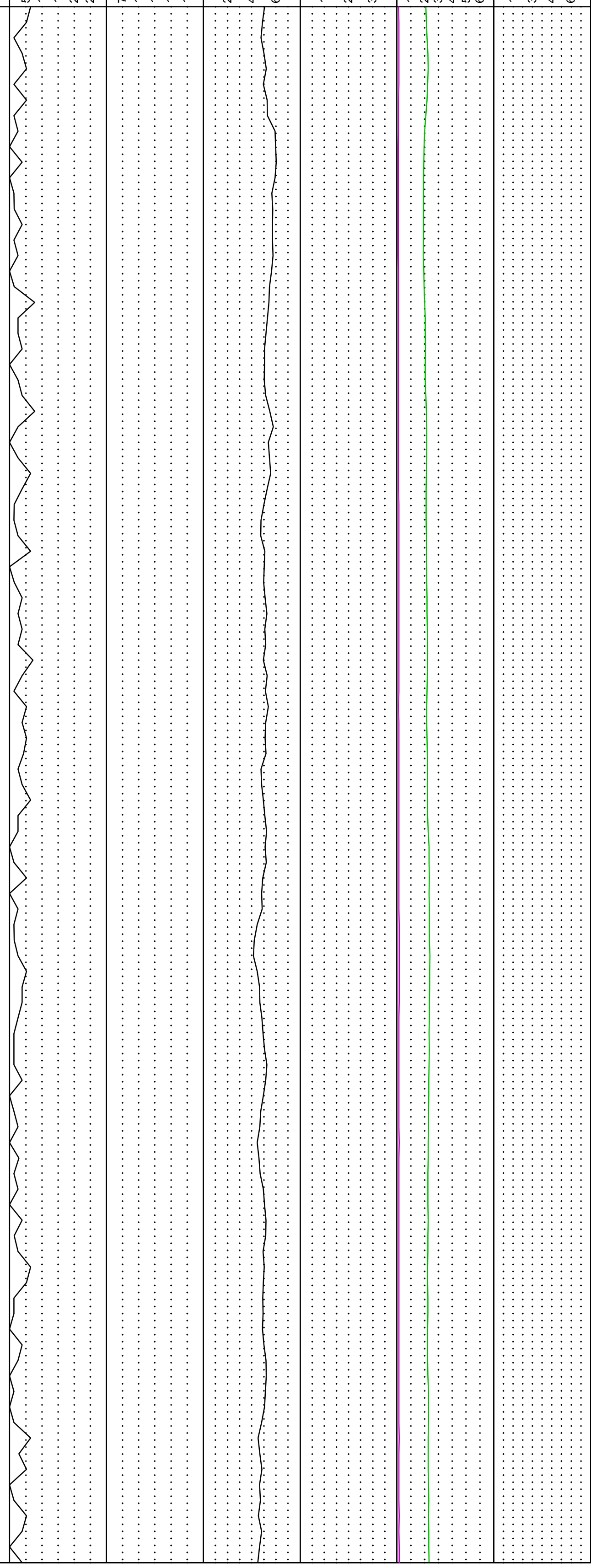
Hole Diameter: 96-155 mm
Inclination: -90°
Bearing: N/A

Easting: 233753.7 m
Northing: 6493934.6 m
Hor. Proj/Dat: MGA94/GDA94-54H

RL: 84.0 m
Ver. Datum: AHD
Surface: Grass

Field Data				Material Description			Rock Condition				Piezometer Details	Downhole Wireline						Laboratory Testing		Geology
Reduced Level (m) Depth (m)	Water	Field Tests	Samples	Graphic Log	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer N E S W	Casing Top RL: 84.98 m AHD Response Zone Top RL: - Response Zone Base RL: - Length of Response Zone: 11.67 m Development Date: 31/05/2018	Natural Gamma (API) 50 100 150 200 250	Borehole Diameter (mm) 75 100 125 150 175	Neutron Porosity (%) 20 40 60	Density (g/cm3) Short Density / Long Density 1 2 3	Neutron Log (CPS) Short Neutron / Long Neutron 1000 2000 3000 4000 5000 6000	Induction (mS/m) Short / Deep 160 320 480 640	Misc Laboratory Testing	Geochemical Testing	Geological Unit *(Geotech. Unit)*
-76 / 160.0 – 160.7						SANDSTONE: very fine to fine grained; dark green-grey; poorly sorted, with 10 - 20 % silt/clay in matrix, with white tubular shell fragments up to 5 mm, calcareous, SW, L	SW													
160.7 – 163.3						MUDSTONE: dark grey - dark green; massive; trace fine to medium grained quartz sands (5 - 10%), white tubular fossils 2 - 5 mm, calcareous and orange iron staining, SW, L														
163.3 – 167.4						MUDSTONE: dark grey - grey; predominantly massive; trace very fine to fine grained sand (10%), poorly developed laminations deposited at 0 - 10°, weakly calcareous, (remoulds to medium to high plasticity Clay), SW, L XW, soil SW, L	XW SW													
167.4 – 168.7						CLAYSTONE: high plasticity; light grey; massive; very smooth, SW, L														
168.7 – 170.0 / -86						MUDSTONE: medium to high plasticity; grey - dark grey; 5-10 % very fine sand, SW, L														

Depth scale (m): 160.5, 161.0, 161.5, 162.0, 162.5, 163.0, 163.5, 164.0, 164.5, 165.0, 165.5, 166.0, 166.5, 167.0, 167.5, 168.0, 168.5, 169.0, 169.5, 170.0
Reduced Level (m): -76, -77, -78, -79, -80, -81, -82, -83, -84, -85



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Engineering Summary Log

BOREHOLE No. **W02D**

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm	**Easting:**	233753.7 m
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°	**Northing:**	6493934.6 m
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A	**Hor. Proj/Dat:**	MGA94/GDA94-54H

RL: 84.0 m **Ver. Datum:** AHD **Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Reduced Level (m) / Depth (m)	Description	Weathering/ Consistency
170.0 – 171.6	MUDSTONE: medium to high plasticity; grey - dark grey; 5-10 % very fine sand, SW, L *(continued)*	SW
171.6 – 173.75	SANDSTONE: very fine to fine grained; with poorly sorted clay, low plasticity, dark grey - green, with trace of orange iron staining, moist, SWL measured at 20.2 mbgs on 02/05/2018., SW, L from 172.54 m to 173.05 m: weak and green alteration, some polished surface in clasts	
173.75 – 174.5	NO CORE: 173.75 m to 174.5 m, SW, L	
174.5 – 176.0	SANDSTONE: weak from cemented. Sand is fine to very fine grained, SW, L	SW
176.0 – 177.5	SANDSTONE: trace of clay, fine to medium grained, light grey, massive, becoming slightly green or grey, SW, L	
177.5 – 179.7	NO CORE: 177.5 m to 179.70 m in low strength sandstone, SW, L	
179.7 – 180.0	SANDSTONE: fine to very fine grained; trace of clay, light grey to grey or green, massive, SW, L	SW

Depth scale: 170.5, 171.0, 171.5, 172.0, 172.5, 173.0, 173.5, 174.0, 174.5, 175.0, 175.5, 176.0, 176.5, 177.0, 177.5, 178.0, 178.5, 179.0, 179.5, 180.0; RL: -86 to -95

Column headings: Field Data (Water, Field Tests, Samples); Material Description (Graphic Log, Classification Symbol, Description); Rock Condition (Weathering/Consistency, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer N E S W); Piezometer Details; Downhole Wireline (Natural Gamma (API), Borehole Diameter (mm), Neutron Porosity (%), Density (g/cm3) Short Density / Long Density, Neutron Log (CPS) Short Neutron / Long Neutron, Induction (mS/m) Short / Deep); Laboratory Testing (Misc Laboratory Testing, Geochemical Testing); Geology (Geological Unit *(Geotech. Unit)*)

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 μS/cm)

Piezometer Details

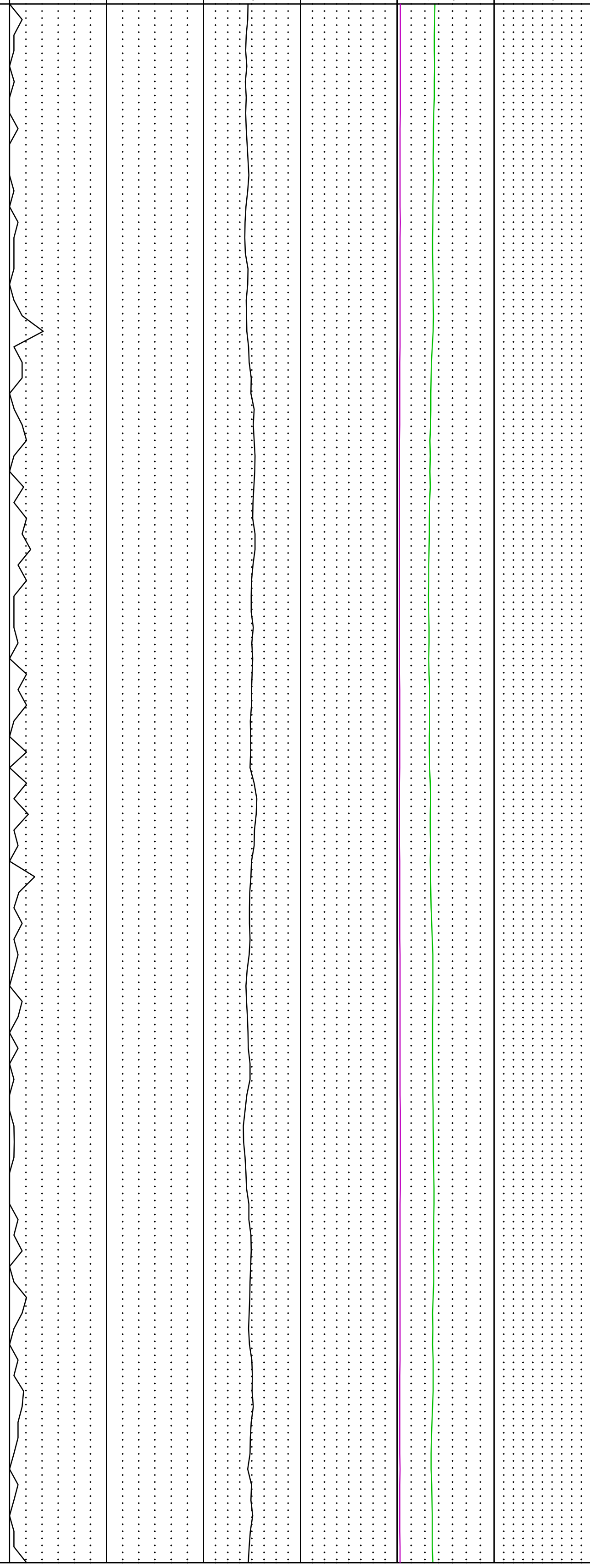
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Description	Weathering/ Consistency
to 180.5	SANDSTONE: fine to very fine grained; trace of clay, light grey to grey or green, massive, SW, L *(continued)*	SW
180.5 – 181.6	NO CORE: 180.5 m to 181.6 m, SW, L	
181.6 – 182.6	SANDSTONE: very fine to fine grained; light brown to red-brown; massive; trace of fines becoming fine grained, grey siltstone beneath, SW, L	SW
182.6 – 185.7	SANDSTONE: very fine grained; light grey; massive; trace of clay/ silt, SW, L	
185.7 – 186.5	NO CORE: 185.7 m to 186.5 m, SW, L	
186.5 – 188.4	SANDSTONE: very fine grained; light grey - dark grey; massive; trace of fines, SW, L	SW
188.4 – 188.6	MUDSTONE: high plasticity; grey; massive, SW, L	
188.6 – 189.6	SAND: low plasticity; massive; fine to very fine sand, SW, M	
189.6 – 190.0	MUDSTONE: medium plasticity; light grey - light brown; massive, SW, M	

Depth scale (m): 180.5, 181.0, 181.5, 182.0, 182.5, 183.0, 183.5, 184.0, 184.5, 185.0, 185.5, 186.0, 186.5, 187.0, 187.5, 188.0, 188.5, 189.0, 189.5, 190.0

Reduced Level (m): -96, -97, -98, -99, -100, -101, -102, -103, -104, -105

Downhole Wireline



Columns also present: Water, Field Tests, Samples, Graphic Log, Classification Symbol, TCR (SCR) [RQD] (%), Core Photo, Optical and Accoustic Televiewer (N E S W), Laboratory Testing (Misc Laboratory Testing, Geochemical Testing), Geology (Geological Unit *(Geotech. Unit)*)

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Engineering Summary Log

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details:
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Reduced Level (m)	Depth (m)	Water	Field Tests	Samples	Graphic Log	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer	Misc Laboratory Testing	Geochemical Testing	Geological Unit (Geotech. Unit)
-106	190.5, 191.0						MUDSTONE: medium plasticity; light grey - light brown; massive, SW, M *(continued)*	SW						
-107	191.5						MUDSTONE: low to medium plasticity; grey; massive, SW, L							
-108 to -114	192.0, 192.5, 193.0, 193.5, 194.0, 194.5, 195.0, 195.5, 196.0, 196.5, 197.0, 197.5, 198.0, 198.5													
-115	199.0, 199.5, 200.0						sandy CLAY: low plasticity; grey; fine to medium grained sand, massive, SW, L							

Downhole Wireline

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Engineering Summary Log

BOREHOLE No. W02D
Sheet: 21 of 25

Client: Department of Industry, Innovation and Science
Project: NRWMF - Site Characterisation
Location: Wallerberdina Station
Drilling Water: Potable water sourced from Kimba (measured EC ~300 μS/cm)

Project No: 60565376
Logged by: JR / MM
Checked by: HS

Start Date: 19/04/2018
End Date: 28/05/2018
Location Meth.: dGPS0.1

Driller: Numac Drilling
Drill Rig: Commachio 450

Hole Diameter: 96-155 mm
Inclination: -90°
Bearing: N/A

Easting: 233753.7 m
Northing: 6493934.6 m
Hor. Proj/Dat: MGA94/GDA94-54H

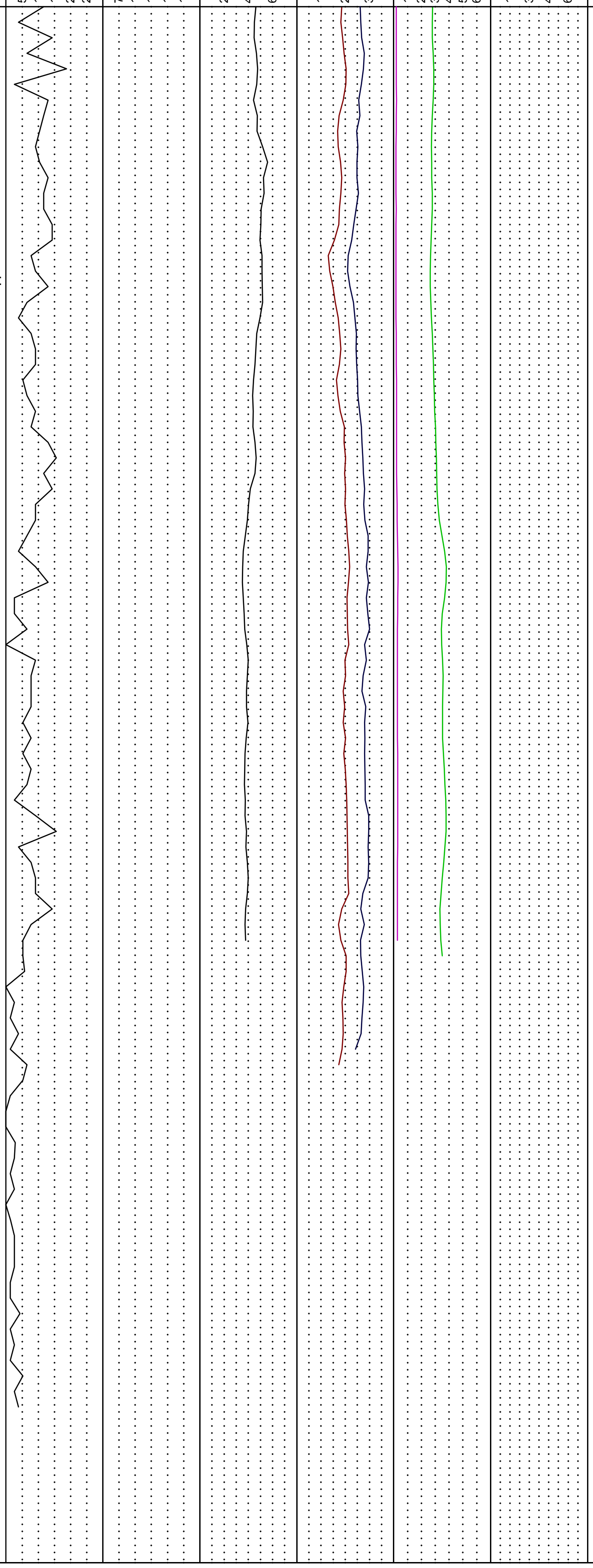
RL: 84.0 m
Ver. Datum: AHD
Surface: Grass

Piezometer Details
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Depth (m)	Classification Symbol	Description	Weathering/ Consistency
200.2–204.0		SANDSTONE: fine grained; grey - lighter grey; massive; indurated fragments, residual of sand, SW, L	SW
204.0–204.1	SP	SAND: fine grained; light grey - light brown, SW, L	
204.0–204.4		NO CORE: 204 m to 204.4 m, SW, L	
204.4–205.1	SP	SAND: fine grained; light grey - light brown, SW, L	SW
205.1–207.3		NO CORE: 205.1 m to 207.3 m, SW, L	
207.4–208.3	Pt	LIGNITE: black - brown; organic sand and clay, some angular gravel fragments, FR, L	FR
208.3–209.5	SP	CARBONACEOUS SANDSTONE: fine to medium grained; black; massive; poorly graded, H2S odour., FR, L	
209.5–210.5		NO CORE: 209.5 m to 210.5 m, FR, L	

Piezometer: 196.0 to 207.7 m: 96 mm HQ corehole

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep



Laboratory Testing: Misc Laboratory Testing; Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1	
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)			

Hole Diameter: 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m	
Inclination: -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD	
Bearing: N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass	

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep

Laboratory Testing: Misc Laboratory Testing; Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Depth (m)	Description	Weathering/Consistency	Piezometer
209.5–210.5	NO CORE: 209.5 m to 210.5 m, FR, L *(continued)*		
210.5–216.2	SANDSTONE: fine to medium grained; black, FR, L ~213.1: becoming fine grained	FR	
216.2–216.5	SAND: mottled black-grey, FR, L		196.0 to 236.1 m: OPEN HOLE
216.5–218.2	NO CORE: 216.5 m to 218.2 m, FR, L		
218.2–219.5	SAND: black - brown; massive, L		
219.5–220.0	SANDSTONE: fine to coarse grained; brown; massive; carbonaceous, strong H2S odours., L		

Depth scale: 210.5, 211.0, 211.5, 212.0, 212.5, 213.0, 213.5, 214.0, 214.5, 215.0, 215.5, 216.0, 216.5, 217.0, 217.5, 218.0, 218.5, 219.0, 219.5, 220.0
Reduced Level: -126, -127, -128, -129, -130, -131, -132, -133, -134, -135

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 19/04/2018	**Driller:** Numac Drilling	**Hole Diameter:** 96-155 mm	**Easting:** 233753.7 m	**RL:** 84.0 m
Project: NRWMF - Site Characterisation	**Logged by:** JR / MM	**End Date:** 28/05/2018	**Drill Rig:** Commachio 450	**Inclination:** -90°	**Northing:** 6493934.6 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details: Casing Top RL: 84.98 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 11.67 m; Development Date: 31/05/2018

Depth (m)	Description	Piezometer Details
220.2 – 221.3	SANDSTONE: fine to coarse grained; brown; massive; carbonaceous, strong H2S odours., L *(continued)*	
221.3 – 222.3	NO CORE: 221.3 m to 222.3 m, L	207.7 to 236.0 m: CAVE-IN
222.3 – 222.5	SAND: very fine grained; with laminate, brown - lighter brown, L	
222.5 – 226.9	NO CORE: 222.5 m to 226.9 m, L	
226.9 – 227.1	SAND: fine to medium grained; grey, L	
227.1 – 229.5	NO CORE: 227.1 m to 229.5 m, L	
229.5 – 230.0	clayey SAND: fine to medium grained; brown-grey, L	

Column headings: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Piezometer Details; Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) (Short Density, Long Density); Neutron Log (CPS) (Short Neutron, Long Neutron); Induction (mS/m) (Short, Deep); Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Reduced levels: -136 to -146; Depth scale: 220.5, 221.0, 221.5, 222.0, 222.5, 223.0, 223.5, 224.0, 224.5, 225.0, 225.5, 226.0, 226.5, 227.0, 227.5, 228.0, 228.5, 229.0, 229.5, 230.0

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Engineering Summary Log

BOREHOLE No. W02D

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	19/04/2018	**Driller:**	Numac Drilling	**Hole Diameter:**	96-155 mm
Project:	NRWMF - Site Characterisation	**Logged by:**	JR / MM	**End Date:**	28/05/2018	**Drill Rig:**	Commachio 450	**Inclination:**	-90°
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1			**Bearing:**	N/A

Easting:	233753.7 m	**RL:**	84.0 m
Northing:	6493934.6 m	**Ver. Datum:**	AHD
Hor. Proj/Dat:	MGA94/GDA94-54H	**Surface:**	Grass

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data: Reduced Level (m) / Depth (m); Water; Field Tests; Samples

Material Description: Graphic Log; Classification Symbol; Description

Rock Condition: Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W)

Piezometer Details:
Casing Top RL: 84.98 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 11.67 m
Development Date: 31/05/2018

Downhole Wireline: Natural Gamma (API) 50 100 150 200 250; Borehole Diameter (mm) 75 100 125 150 175; Neutron Porosity (%) 20 40 60; Density (g/cm3) — Short Density, — Long Density 1 2 3; Neutron Log (CPS) — Short Neutron, — Long Neutron 1000 2000 3000 4000 5000 6000; Induction (mS/m) — Short, — Deep 160 320 480 640

Laboratory Testing: Misc Laboratory Testing; Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Classification Symbol	Description
	clayey SAND: fine to medium grained; brown-grey, L *(continued)*
	LIGNITE: black; coal, H2S odour., L
	SAND: fine grained; dark brown, L
	MUDSTONE: dark brown - grey; fine sandstone laminations, poorly developed, L
	silty SAND: fine grained; brown, L
	NO CORE: 234.5 m to 235.3 m, L
SP	SAND: fine grained; grey; poorly graded., L
	Borehole W02D log continued as cored log from 15.20 m.

Depth scale (m): 230.5, 231.0, 231.5, 232.0, 232.5, 233.0, 233.5, 234.0, 234.5, 235.0, 235.5, 236.0, 236.5, 237.0, 237.5, 238.0, 238.5, 239.0, 239.5, 240.0

Reduced Level (m): -146, -147, -148, -149, -150, -151, -152, -153, -154, -155

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Engineering Summary Log

BOREHOLE No. **W02S**
Sheet: 1 of 3

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 14/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233743.4 m	**RL:** 84.1 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 15/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493942.9 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data: Reduced Level (m) / Depth (m) | Water | Field Tests | Samples

Material Description: Graphic Log | Classification Symbol | Description

Rock Condition: Weathering/ Consistency | TCR (SCR) [RQD] (%) | Core Photo | Optical and Accoustic Televiewer (N E S W)

Piezometer Details

Casing Top RL: 84.94 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: -
Development Date: 16/05/2018

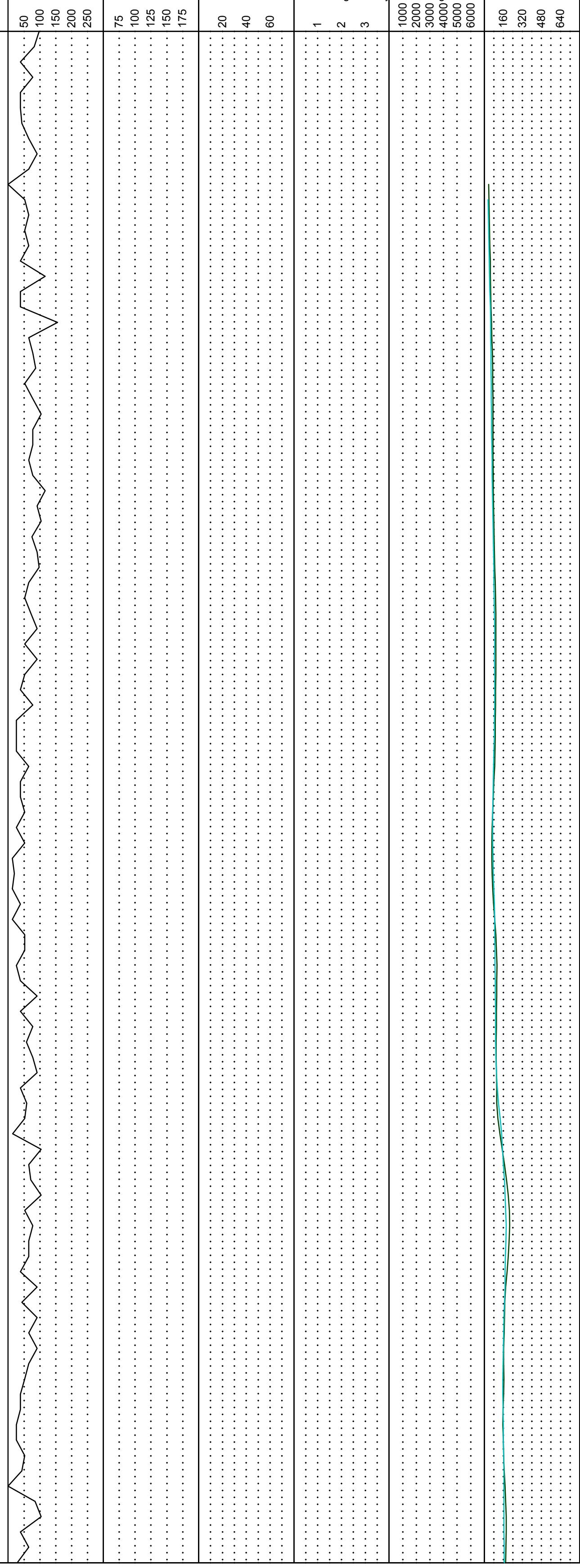
Downhole Wireline: Natural Gamma (API) | Borehole Diameter (mm) | Neutron Porosity (%) | Density (g/cm3) — Short Density, Long Density | Neutron Log (CPS) — Short Neutron, Long Neutron | Induction (mS/m) — Short, Deep

Laboratory Testing: Misc Laboratory Testing | Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

Depth (m)	Classification Symbol	Description	Piezometer Details
0.0	ML	clayey SILT: low plasticity; orange-brown; trace organics and fine grained sand	0.6 above ground to 0.0 m: Steel Monument
1.20		at 1.20 m: trace fine to medium, rounded gravel	
2.00		at 2.00 m: increase in clay content	
2.4	CI-CL	CLAY: low to medium plasticity; orange-brown; with silt and trace sands and gravel (extremely weathered calcrete)	
		becoming medium to high plasticity	
		becoming red-brown	
6.1	CH-CI	CLAY: medium to high plasticity; red-brown; trace fine grained sand and poorly graded gravel, trace weakly indurated lens with quartz crystals growing	
7.3	CI	CLAY: medium plasticity; red-brown; with fine to coarse, rounded gravel of mudstone, sandstone and quartz	
7.9	CL	CLAY: low plasticity; brown; trace fine grained sand and black organics up to 3mm in diameter	0.0 to 16.0 m: CEMENT/BENTONITE GROUT

Reduced Level (m): 84, 83, 82, 81, 80, 79, 78, 77, 76, 75
Depth (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0



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Engineering Summary Log

BOREHOLE No. **W02S**
Sheet: 2 of 3

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 14/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233743.4 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 15/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493942.9 m
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H

RL: 84.1 m | **Ver. Datum:** AHD | **Surface:** Clay

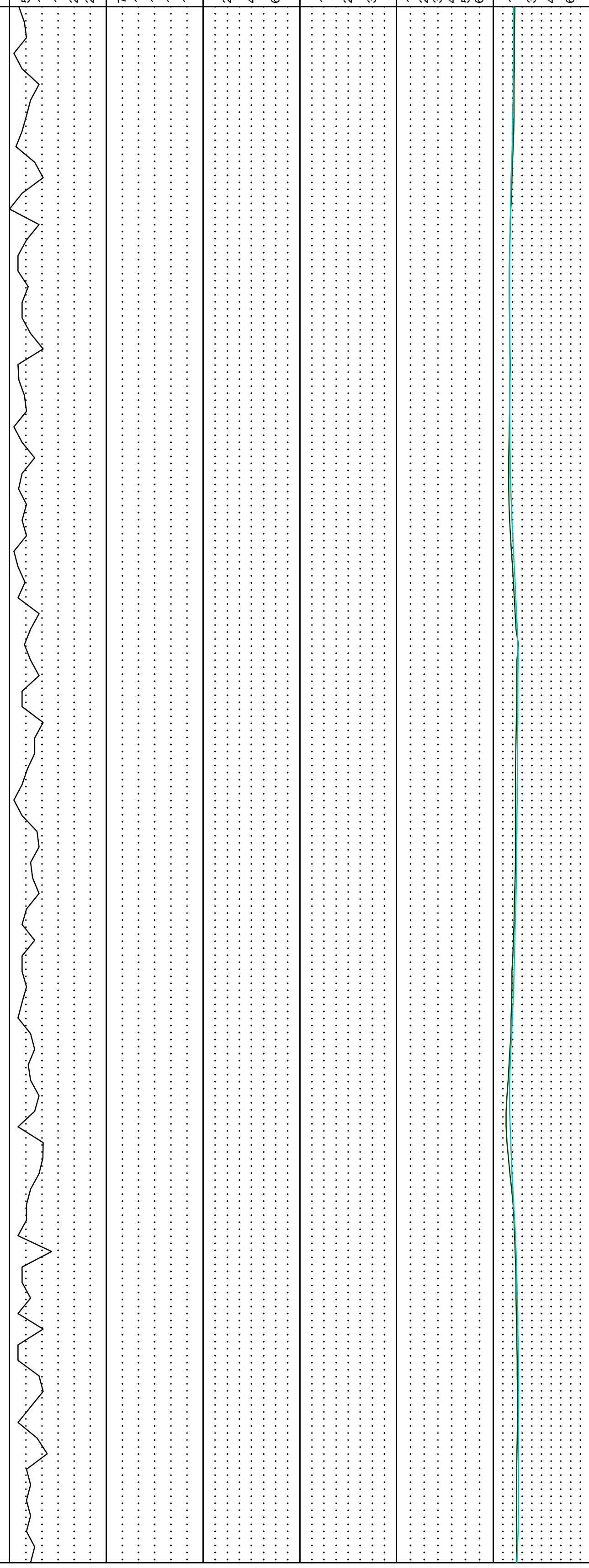
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data: Reduced Level (m) / Depth (m); Water; Field Tests; Samples
Material Description: Graphic Log; Classification Symbol; Description
Rock Condition: Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W)
Piezometer Details: Casing Top RL: 84.94 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: -; Development Date: 16/05/2018
Downhole Wireline: Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) — Short Density, Long Density; Neutron Log (CPS) — Short Neutron, Long Neutron; Induction (mS/m) — Short, Deep
Laboratory Testing: Misc Laboratory Testing; Geochemical Testing
Geology: Geological Unit *(Geotech. Unit)*

Depth (m)	Classification Symbol	Description
10.0	CL	CLAY: low plasticity; brown; trace fine grained sand and black organics up to 3mm in diameter *(continued)* from 10.00 m: indurated nodules throughout, trace iron oxide veins from 10.90 m to 11.30 m: some fine to coarse grained angular sand (5-10%), moderately graded
12.9	CI-CL	CLAY: low to medium plasticity; fine grained; grey mottled red-brown; with silt and some fine grained sand (5-10%), poorly graded from 13.30 m: trace sand (<5%), medium plasticity
17.2	GC	clayey GRAVEL: fine to coarse grained; rounded to sub-rounded; red-brown; of quartz, shale and claystone, with clay and fine to coarse grained sand (10-15%), well graded
17.4	CI	CLAY: medium plasticity; grey mottled red-brown; trace fine grained sand. Water Strike inferred at ~22.0 mbgs

Piezometer details:
- 0.0 to 20.5 m: Solid Pipe
- 16.0 to 19.0 m: BENTONITE SEAL (PELLETS)

Reduced levels: 74, 73, 72, 71, 70, 69, 68, 67, 66, 65
Depths: 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, 16.0, 16.5, 17.0, 17.5, 18.0, 18.5, 19.0, 19.5, 20.0



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Engineering Summary Log

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 14/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 233743.4 m	**RL:** 84.1 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 15/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493942.9 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

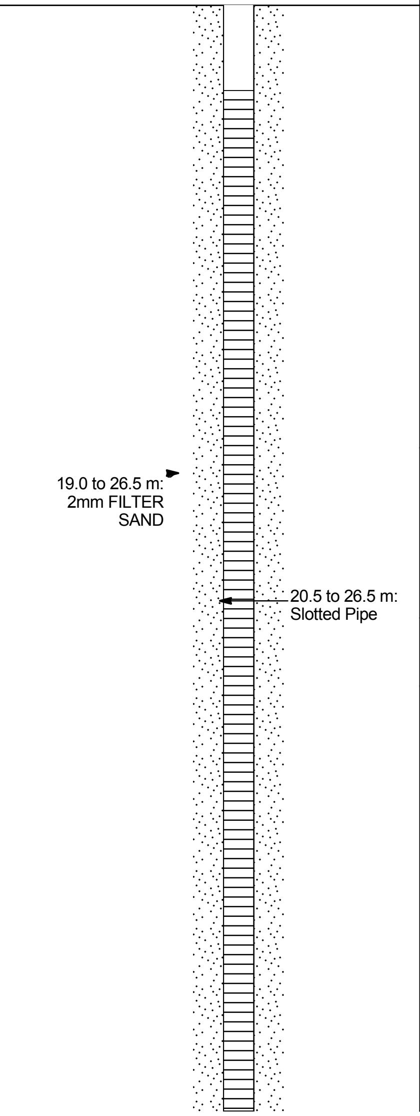
Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

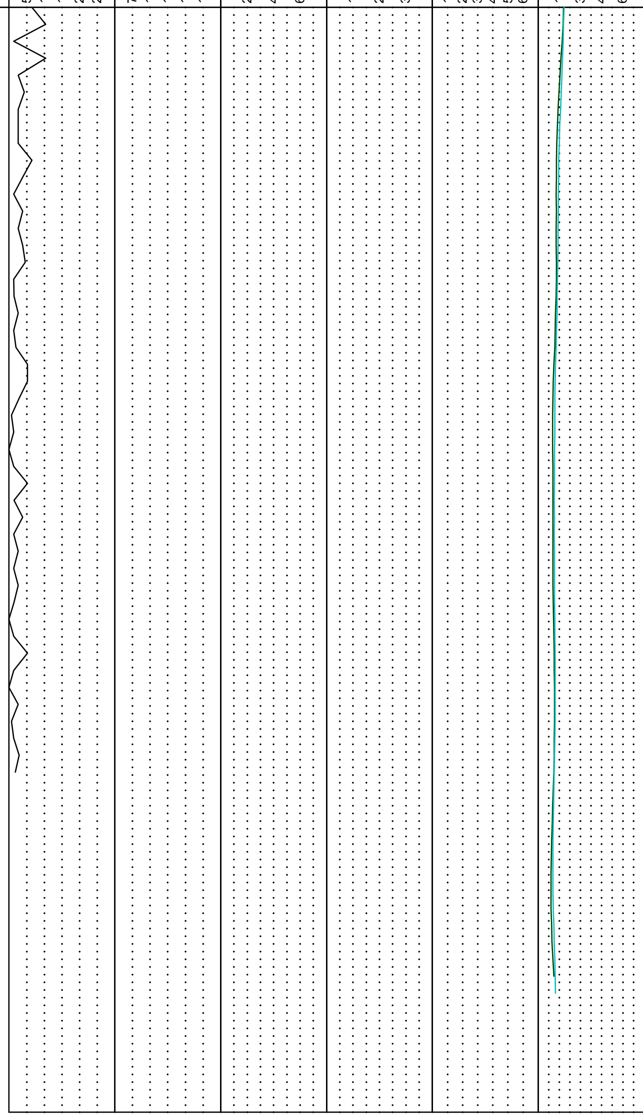
Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Natural Gamma (API); Borehole Diameter (mm); Neutron Porosity (%); Density (g/cm3) – Short Density, Long Density; Neutron Log (CPS) – Short Neutron, Long Neutron; Induction (mS/m) – Short, Deep; Misc Laboratory Testing; Geochemical Testing; Geological Unit *(Geotech. Unit)*

Casing Top RL: 84.94 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: -
Development Date: 16/05/2018

Depth (m)	Classification Symbol	Description
20.0 – 22.0	CI	CLAY: medium plasticity; grey mottled red-brown; trace fine grained sand. Water Strike inferred at ~22.0 mbgs *(continued)*
22.0 – 26.0		NO CORE: fine to coarse grained, medium to high strength sandstone returns
26.0 – 26.5	ML-CL	clayey SILT: low to medium plasticity; brown-grey; trace fine grained sands and black organics, indurated bands
26.5		*Borehole W02S log continued as cored log from m.*

Depth scale: 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0, 24.5, 25.0, 25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0
Reduced Level scale: 64, 63, 62, 61, 60, 59, 58, 57, 56, 55





AECOM

Engineering Summary Log

BOREHOLE No. **W03**
Sheet: 1 of 3

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 16/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 234113.1 m	**RL:** 86.4 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 17/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493726.1 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

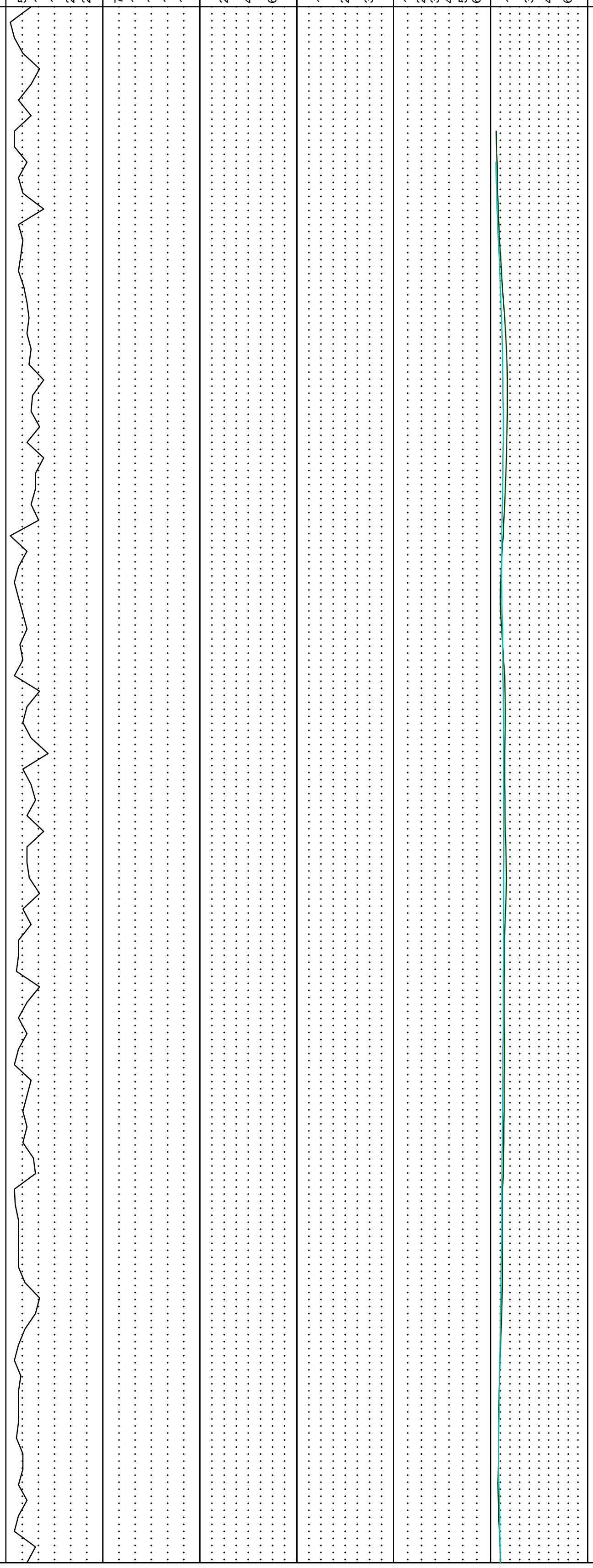
Casing Top RL: 87.34 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 6.00 m
Development Date: 23/05/2018

Depth (m)	Field Tests	Classification Symbol	Description
0.0		CH	CLAY: high plasticity; orange-brown; trace organics, white indurated nodules up to 15mm in diameter
1.5	SPT:14,29,36 N=65		becoming brown
2.0			at 2.00 m: grades to dark brown, trace fine grained sand, organic rich
3.0	SPT:14,18,23 N=41		
3.3		CL	CLAY: low plasticity; brown; with fine sands (5-10%)
4.1			becoming silty CLAY with sand (10-20%), red-brown
4.3		CH-CI	CLAY: medium to high plasticity; brown; trace fine to medium grained sand (<5%), poorly graded, trace organics
4.5	SPT:8,22,34 N=56		
5.8			from 5.80 m to 6.00 m: low to medium plasticity; red-brown
6.0	SPT:20,38,50/125mm N=R		
7.5	SPT:12,32,45 N=77		
8.6		CL	silty CLAY: low plasticity; red-brown; some fine grained sand (5-10%), trace indurated nodules
9.0	SPT:12,27,48 N=75		
9.1			clayey SILT: non-plastic; brown; with fine grained sand (10-15%)
9.8		GW	GRAVEL: fine to coarse grained; rounded; well graded, of sandstone, quartz and shale
10.0		CL	

Reduced Level (m): 86 (0.5 m), 85 (1.5 m), 84 (2.5 m), 83 (3.5 m), 82 (4.5 m), 81 (5.5 m), 80 (6.5 m), 79 (7.5 m), 78 (8.5 m), 77 (9.5 m)

Piezometer:
0.6 above ground to 0.0 m: Steel Monument
0.0 to 14.0 m: CEMENT/BENTONITE GROUT
0.0 to 18.0 m: Solid Pipe

Downhole Wireline



Field Data				Material Description			Rock Condition				Piezometer Details	Laboratory Testing		Geology
Reduced Level (m) Depth (m)	Water	Field Tests	Samples	Graphic Log	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer N E S W		Misc Laboratory Testing	Geochemical Testing	Geological Unit *(Geotech. Unit)*

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Engineering Summary Log

BOREHOLE No. W03

Sheet: 2 of 3

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 16/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 234113.1 m	**RL:** 86.4 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 17/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493726.1 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

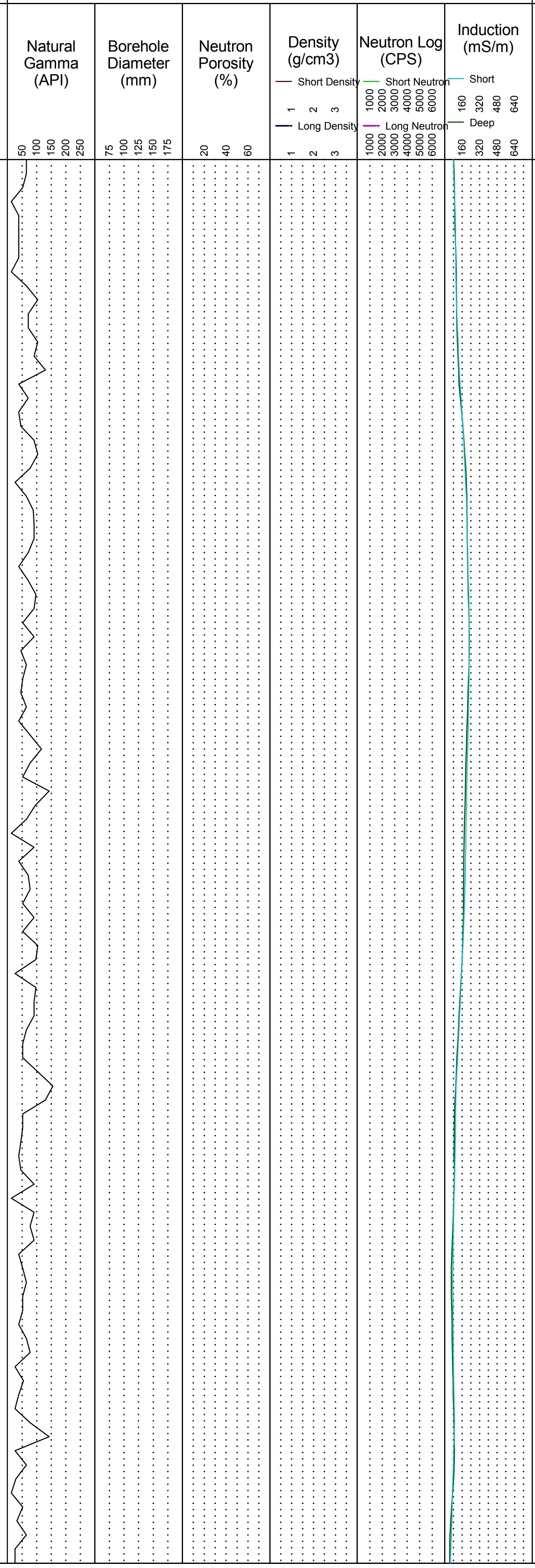
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Field Data | **Material Description** | **Rock Condition** | **Piezometer Details** | **Downhole Wireline** | **Laboratory Testing** | **Geology**

Columns: Reduced Level (m) Depth (m) | Water | Field Tests | Samples | Graphic Log | Classification Symbol | Description | Weathering/ Consistency | TCR (SCR) [RQD] (%) | Core Photo | Optical and Accoustic Televiewer (N E S W) | Piezometer | Natural Gamma (API) | Borehole Diameter (mm) | Neutron Porosity (%) | Density (g/cm3) | Neutron Log (CPS) | Induction (mS/m) | Misc Laboratory Testing | Geochemical Testing | Geological Unit *(Geotech. Unit)*

Piezometer details: Casing Top RL: 87.34 m AHD; Response Zone Top RL: -; Response Zone Base RL: -; Length of Response Zone: 6.00 m; Development Date: 23/05/2018

Depth (m)	RL (m)	Water	Field Tests	Class. Symbol	Description	Piezometer
10.0–11.0	76 (10.5)		SPT:16,40,50/120mm N=R	CL	sandy CLAY: low plasticity; brown; with fine to medium gained sand (10-20%), angular to sub-rounded *(continued)* at 10.60 m: rootlets	
11.0–17.2	75 (11.5), 74 (12.5), 73 (13.5), 72 (14.5), 71 (15.5), 70 (16.5)			CI-CL	silty CLAY: low to medium plasticity; grey mottled brown; zones of induration, trace black organics and fine sands at 12.60 m: with fine to medium grained sand (10-15%)	14.0 to 17.0 m: BENTONITE SEAL (PELLETS)
17.2–17.9	69 (17.5)			ML	sandy SILT: low plasticity; grey mottled brown; with fine grained, angular sand, very poorly graded	
17.9–19.0	68 (18.5)			ML-CL	clayey SILT: low to medium plasticity; with fine grained sand (5-10%)	
19.0–19.6				CH-CI	CLAY: medium to high plasticity; grey mottled red-brown; trace fine grained sand (<5%),trace black organics. water strike at 19.5 mbgs	
19.6–20.0	67 (19.5)	▽ (19.5)		SM	silty SAND: fine grained; sub-rounded; red-brown; mostly sedimentary rock fragments and quartz, with silts and some organics, water strike at 19.5 mbgs.	



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Engineering Summary Log

BOREHOLE No. W03

Sheet: 3 of 3

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 16/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 234113.1 m	**RL:** 86.4 m
Project: NRWMF - Site Characterisation	**Logged by:** TS	**End Date:** 17/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6493726.1 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54H	**Surface:** Clay

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

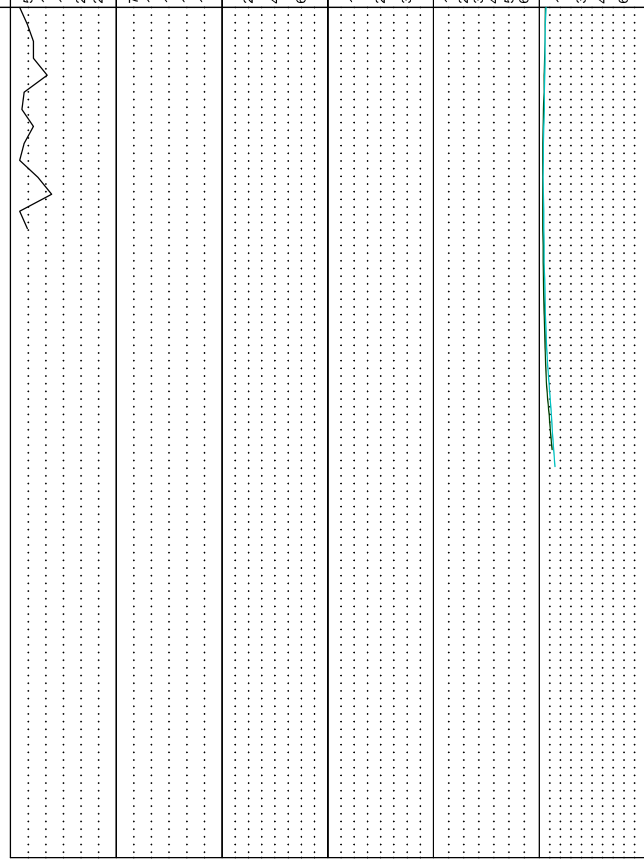
Piezometer Details

Casing Top RL: 87.34 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 6.00 m
Development Date: 23/05/2018

Reduced Level (m)	Depth (m)	Water	Field Tests	Samples	Graphic Log	Classification Symbol	Description	Weathering/ Consistency	TCR (SCR) [RQD] (%)	Core Photo	Optical and Accoustic Televiewer (N E S W)	Piezometer Details
66, 65	20.5, 21.0, 21.5					SM	silty SAND: fine grained; sub-rounded; red-brown; mostly sedimentary rock fragments and quartz, with silts and some organics, water strike at 19.5 mbgs. *(continued)*					17.0 to 24.2 m: 2mm FILTER SAND; 18.0 to 24.0 m: Slotted Pipe
64	22.0, 22.5					GW	GRAVEL: fine and coarse grained; rounded; grey; of quartz, shale, claystone and sandstone, trace rounded cobbles(<130mm), well graded					
63	23.0, 23.5					CH	CLAY: high plasticity; grey mottled red-brown; trace fine to coarse grained sand and silts, indurated bands					
62	24.0, 24.5, 25.0					CH	CLAY: high plasticity; red-brown; black organic veins throughout, trace fine to medium grained sand (<5%)					24.2 to 25.0 m: BENTONITE SEAL (PELLETS)
61, 60, 59, 58, 57	25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0						*Borehole W03 log continued as cored log from m.*					

Downhole Wireline

Natural Gamma (API): 50 100 150 200 250
Borehole Diameter (mm): 75 100 125 150 175
Neutron Porosity (%): 20 40 60
Density (g/cm3): Short Density 1 2 3; Long Density 1 2 3
Neutron Log (CPS): Short Neutron 1000 2000 3000 4000 5000 6000; Long Neutron 1000 2000 3000 4000 5000 6000
Induction (mS/m): Short 160 320 480 640; Deep 160 320 480 640



Laboratory Testing: Misc Laboratory Testing | Geochemical Testing

Geology: Geological Unit *(Geotech. Unit)*

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Engineering Summary Log

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	08/05/2018	**Driller:**	Numac Drilling
Project:	NRWMF - Site Characterisation	**Logged by:**	MM	**End Date:**	10/05/2018	**Drill Rig:**	Sonic Geoprobe
Location:	Wallerberdina Station	**Checked by:**	HS	**Location Meth.:**	dGPS0.1		

Hole Diameter:	160 mm	**Easting:**	234076.4 m	**RL:**	91.5 m
Inclination:	-90°	**Northing:**	6492625.1 m	**Ver. Datum:**	AHD
Bearing:	N/A	**Hor. Proj/Dat:**	MGA94/GDA94-54J	**Surface:**	Sand

Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

Casing Top RL: 92.42 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 6.00 m
Development Date: 22/05/2018

0.6 above ground to 0.0 m: Steel Monument

0.0 to 18.5 m: CEMENT/BENTONITE GROUT

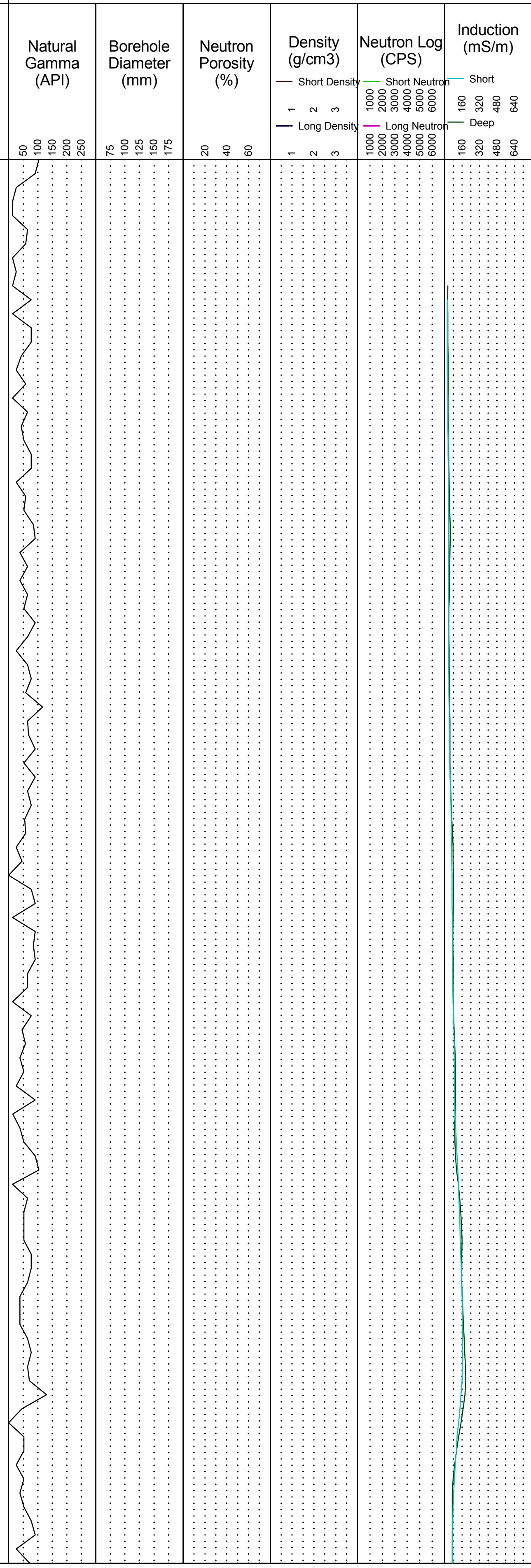
Field Data and Material Description

Depth (m)	Reduced Level (m)	Field Tests	Samples	Classification Symbol	Description
0.0			BAG JAR	SC	clayey SAND: fine grained; orange-brown; some silt, clay(loamy texture) and saltbush sticks.
1.2–1.65		SPT:9,13,13 N=26			
2.0			BAG JAR		from 2.00 m: becoming silty, low plasticity, trace carbonate nodules, minor calcareous mottling
2.6		SPT:17,28,39 N=67	BAG JAR	CL	silty CLAY: low plasticity; orange-brown; SAND(5-10%): very fine grained,dry calcareous nodules and light brown calcareous mottling(20-30%)
4.0		SPT:14,12,23 N=35		SC	clayey SAND: fine grained; orange-brown; grading between clayey SAND and silt to silty CLAY with very fine grained sand
5.8		SPT:13,50/145mm N=R			
7.0				ML-CL	clayey SILT: low to medium plasticity; orange-brown
7.3		SPT:12,36,50/145 N=R			
8.8		SPT:10,14,22 N=36			
9.3				GW	GRAVEL: rounded to sub-rounded; quartz gravel in an orange-brown clayey SAND matrix
9.7				SC	clayey SAND: uniform, no gravel present

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0
Reduced Level scale: 91, 90, 89, 88, 87, 86, 85, 84, 83, 82

Column headings: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Rock Condition: Weathering/ Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Laboratory Testing: Misc Laboratory Testing; Geochemical Testing; Geology: Geological Unit *(Geotech. Unit)*

Downhole Wireline



AECOM

Engineering Summary Log

BOREHOLE No. W04

Client: Department of Industry, Innovation and Science	**Project No:** 60565376	**Start Date:** 08/05/2018	**Driller:** Numac Drilling	**Hole Diameter:** 160 mm	**Easting:** 234076.4 m	**RL:** 91.5 m
Project: NRWMF - Site Characterisation	**Logged by:** MM	**End Date:** 10/05/2018	**Drill Rig:** Sonic Geoprobe	**Inclination:** -90°	**Northing:** 6492625.1 m	**Ver. Datum:** AHD
Location: Wallerberdina Station	**Checked by:** HS	**Location Meth.:** dGPS0.1		**Bearing:** N/A	**Hor. Proj/Dat:** MGA94/GDA94-54J	**Surface:** Sand

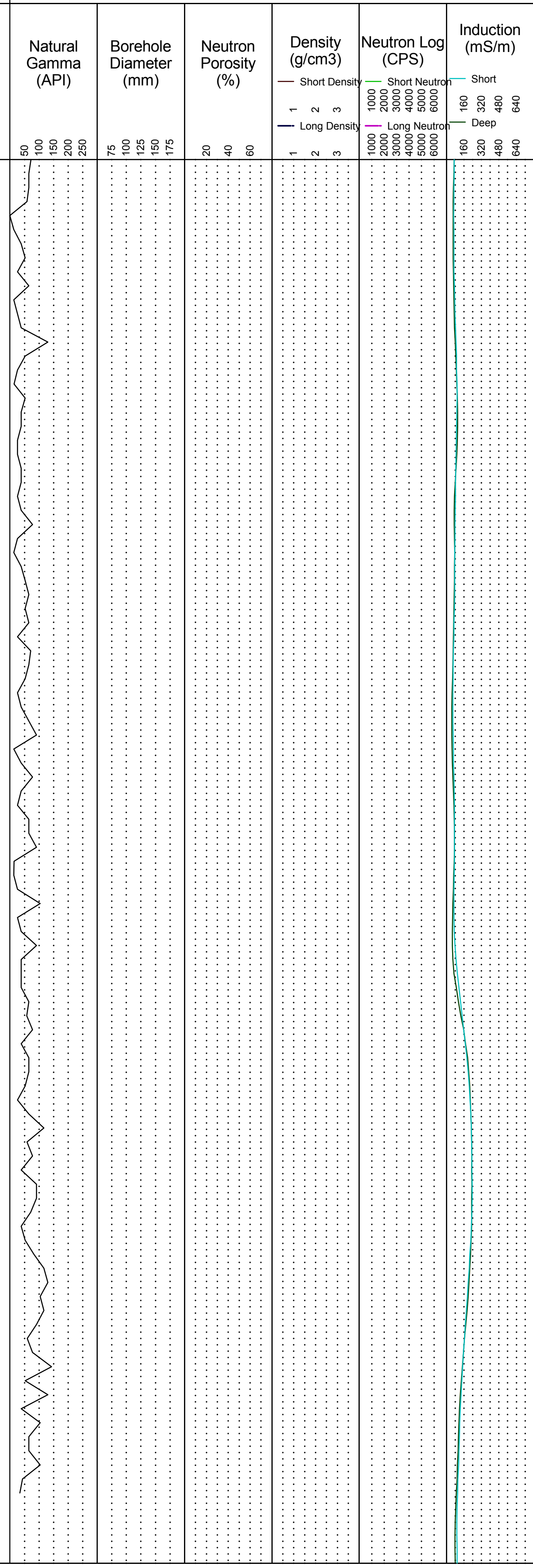
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Piezometer Details

Casing Top RL: 92.42 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 6.00 m
Development Date: 22/05/2018

Reduced Level (m)	Depth (m)	Field Tests	Classification Symbol	Description	Piezometer Details
			SC	clayey SAND: fine to very fine grained; orange-brown; CLAY: low plasticity, occasional light grey calcareous mottles	
81	10.5	SPT:15,28,33 N=61			0.0 to 21.0 m: Solid Pipe
	11.0				
80	11.5			at 11.50 m: some black speckling	
	12.0	SPT:15,50/150 N=R		from 12.00 m: friable	
				NO CORE: from 12.20 to 13.20m	
79	12.5				
	13.0				
			SC	clayey SAND: fine grained; orange-brown; some light brown mottles (<20%), trace black speckles	
78	13.5	SPT:13,42,49 N=91			
	14.0				
				NO CORE: from 14.20 to 15.00m	
77	14.5				
	15.0		SW-SC	SAND: fine to medium grained; orange-brown; quartz grains, some black speckling, in a clayey sand matrix	
76	15.5	SPT:14,31,39 N=70			
	16.0			COBBLE/GRAVEL BAND: rounded to subangular quartz	
			CL	gravelly CLAY: low plasticity; orange-brown; with some calcareous, light brown mottles,angular quartz gravel(20%) and small, sub-rounded, calcareous gravel nodules	
75	16.5				
	17.0				
74	17.5				
	18.0		SC	clayey SAND: fine grained; orange-brown with light brown mottles; calcareous zones throughout	
73	18.5				
	19.0				
72	19.5				18.5 to 20.5 m: BENTONITE SEAL (PELLETS)
	20.0				

Downhole Wireline



Misc Laboratory Testing	Geochemical Testing	Geological Unit *(Geotech. Unit)*

AECOM

Engineering Summary Log

BOREHOLE No. W04

Client: Department of Industry, Innovation and Science
Project: NRWMF - Site Characterisation
Location: Wallerberdina Station
Drilling Water: Potable water sourced from Kimba (measured EC ~300 µS/cm)

Project No: 60565376
Logged by: MM
Checked by: HS

Start Date: 08/05/2018
End Date: 10/05/2018
Location Meth.: dGPS0.1

Driller: Numac Drilling
Drill Rig: Sonic Geoprobe

Hole Diameter: 160 mm
Inclination: -90°
Bearing: N/A

Easting: 234076.4 m
Northing: 6492625.1 m
Hor. Proj/Dat: MGA94/GDA94-54J

RL: 91.5 m
Ver. Datum: AHD
Surface: Sand

Field Data | Material Description | Rock Condition | Piezometer Details | Downhole Wireline | Laboratory Testing | Geology

Casing Top RL: 92.42 m AHD
Response Zone Top RL: -
Response Zone Base RL: -
Length of Response Zone: 6.00 m
Development Date: 22/05/2018

Columns: Reduced Level (m) / Depth (m); Water; Field Tests; Samples; Graphic Log; Classification Symbol; Description; Weathering/Consistency; TCR (SCR) [RQD] (%); Core Photo; Optical and Accoustic Televiewer (N E S W); Natural Gamma (API) (50 100 150 200 250); Borehole Diameter (mm) (75 100 125 150 175); Neutron Porosity (%) (20 40 60); Density (g/cm3) (1 2 3) — Short Density, Long Density; Neutron Log (CPS) (1000 2000 3000 4000 5000 6000) — Short Neutron, Long Neutron; Induction (mS/m) (160 320 480 640) — Short, Deep; Misc Laboratory Testing; Geochemical Testing; Geological Unit (*Geotech. Unit*)

Depth (m)	RL	Water	Samples	Classification Symbol	Description
20.0–21.0	71			SC	clayey SAND: fine grained; orange-brown with light brown mottles; calcareous zones throughout *(continued)*
21.0–22.0	70			SW-SC	clayey SAND: fine grained; orange-brown with light brown mottles; some clay fines
22.0–22.3				SW	gravelly SAND: brown and orange-brown; brown speckles at base and large, rounded gravel of quartz. Water strike inferred at 22.3
22.3–22.6	69	▽ (22.5)	BAG		NO CORE: from 22.30 to 22.60m
22.6–26.0	68, 67, 66			GW	sandy GRAVEL: sandy GRAVEL to sandy GRAVEL: medium to coarse grained, rounded to sub-rounded quartz gravel and cobbles, some fines
26.0–26.3			BAG		CONGLOMERATE
26.3–26.9	65				NO CORE: from 26.00 to 26.30m
26.9–27.6	64				gravelly CLAY: fine grained sand in a red-brown clay matrix, with large, sub-rounded to rounded gravel and cobbles
27.6–28.0					sandy CLAY: orange-brown, cobbles
28.0–28.5				SC	clayey SAND
28.5	63, 62				*Borehole W04 log continued as cored log from m.*

Depth scale: 20.5, 21.0, 21.5, 22.0, 22.5, 23.0, 23.5, 24.0, 24.5, 25.0, 25.5, 26.0, 26.5, 27.0, 27.5, 28.0, 28.5, 29.0, 29.5, 30.0

Piezometer details:
20.5 to 27.0 m: 2mm FILTER SAND
21.0 to 27.0 m: Slotted Pipe
27.0 to 28.4 m: BENTONITE SEAL (PELLETS)

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TEST PIT W06

Sheet: 1 of 1

Client:	Department of Industry, Innovation and Science			**Project No:**	60565376	**Start Date:**	09/05/2018
Project:	NRWMF - Site Characterisation			**Logged by:**	JT	**End Date:**	09/05/2018
Location:	Wallerberdina Station			**Checked by:**	KS	**Location Meth.:**	dGPS0.1
Contractor:	Hawker Earthmoving	**Pit Length**	3.5	**Easting:**	233616.5 m	**Surface level:**	86.5 mRL
		Pit Width:	0.5	**Northing:**	6493210.1 m	**Ver. Datum:**	AHD
Equipment:	Kubota KX121-3 (4 tonne)	**Orientation:**		**Hor. Proj/Dat:**	MGA94/GDA94-54J	**Surface:**	Topsoil
		Pit Depth:	3.1				

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, orange-brown, with roots	D				JAR
			SM	Silty SAND: fine to medium grained, orange-brown, trace of roots					
			SC	Clayey SAND: fine to medium grained, orange-brown					
	1			at 1.00 m: with gypsum, fine to coarse gravel sized white fragments					
				at 1.40 m: band of fine to coarse sized gravels, rounded to subrounded, grey, 200 mm thick					JAR
	2						B		BAG
									JAR
	3			*W06 terminated at 3.10 m.* *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks: 0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

2018_ANZ_ENV_03. TEST PIT LOG NRWMF_20180608.GPJ AECOM_5-00.GDT AECOM_5-00AA WITH A3 LOG_REVISED_V2.GLB 10.6.2018

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TEST PIT W07

Sheet: 1 of 1

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	08/05/2018
Project:	NRWMF - Site Characterisation	**Logged by:**	JT	**End Date:**	08/05/2018
Location:	Wallerberdina Station	**Checked by:**	KS	**Location Meth.:**	dGPS0.1
Contractor:	Hawker Earthmoving	**Easting:**	233861.2 m	**Surface level:**	86.1 mRL
		Northing:	6493562.5 m	**Ver. Datum:**	AHD
Equipment:	Kubota KX121-3 (4 tonne)	**Hor. Proj/Dat:**	MGA94/GDA94-54J	**Surface:**	Topsoil

Pit Length 3.5
Pit Width: 0.5
Orientation:
Pit Depth: 3.2

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, light-brown/yellow-brown, with roots	D				
			CL	CLAY: low plasticity; light-brown/yellow-brown, trace of gypsum, fine to medium gravel sized white fragments	w<PL				JAR
	1								BAG JAR
	2								JAR
	3								
				W07 terminated at 3.20 m. *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks: 0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

TEST PIT W08

Sheet: 1 of 1

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	09/05/2018
Project:	NRWMF - Site Characterisation	**Logged by:**	JT	**End Date:**	09/05/2018
Location:	Wallerberdina Station	**Checked by:**	KS	**Location Meth.:**	dGPS0.1
Contractor:	Hawker Earthmoving; **Pit Length** 3.5	**Easting:**	233719.5 m	**Surface level:**	89.1 mRL
	Pit Width: 0.5	**Northing:**	6492899.8 m	**Ver. Datum:**	AHD
Equipment:	Kubota KX121-3 (4 tonne); **Orientation:**	**Hor. Proj/Dat:**	MGA94/GDA94-54J	**Surface:**	Topsoil
	Pit Depth: 3.2				

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, orange-brown, with roots	D				JAR
			SC	Clayey SAND: fine to medium grained, orange-brown, with gypsum, fine to coarse gravel sized white fragments					
	1								JAR
	2								JAR
	3								BAG
				W08 terminated at 3.20 m. *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks: 0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

AECOM

TEST PIT W09

Sheet: 1 of 1

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	08/05/2018
Project:	NRWMF - Site Characterisation	**Logged by:**	JT	**End Date:**	08/05/2018
Location:	Wallerberdina Station	**Checked by:**	KS	**Location Meth.:**	dGPS0.1
Contractor:	Hawker Earthmoving	**Easting:**	233914.3 m	**Surface level:**	87.1 mRL
		Northing:	6493287.0 m	**Ver. Datum:**	AHD
Equipment:	Kubota KX121-3 (4 tonne)	**Hor. Proj/Dat:**	MGA94/GDA94-54J	**Surface:**	Topsoil

Pit Length 3.5
Pit Width: 0.5
Orientation:
Pit Depth: 3

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, light-brown/yellow-brown, with roots	D				JAR
			CL	CLAY: low plasticity; light-brown/yellow-brown, trace of gypsum, fine to medium gravel sized white fragments	w<PL				
							B		BAG
	1								JAR
	2			at 2.00 m: colour becoming brown/dark-brown					JAR
	3			*W09 terminated at 3.00 m.* *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks:
0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

AECOM

TEST PIT W10

Sheet: 1 of 1

Client:	Department of Industry, Innovation and Science	**Project No:**	60565376	**Start Date:**	08/05/2018
Project:	NRWMF - Site Characterisation	**Logged by:**	JT	**End Date:**	08/05/2018
Location:	Wallerberdina Station	**Checked by:**	KS	**Location Meth.:**	dGPS0.1
Contractor:	Hawker Earthmoving	**Pit Length** 3.5	**Easting:** 234251.9 m	**Surface level:**	89.5 mRL
		Pit Width: 0.5	**Northing:** 6493371.1 m	**Ver. Datum:**	AHD
Equipment:	Kubota KX121-3 (4 tonne)	**Orientation:**	**Hor. Proj/Dat:** MGA94/GDA94-54J	**Surface:**	Topsoil
		Pit Depth: 3			

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, orange-brown, with roots	D				JAR
			SM	Silty SAND: fine to medium grained, light-brown/yellow-brown			B		BAG
	1			from 1.00 m: with gypsum, fine to medium gravel sized white fragments					JAR
	2			at 2.00 m: trace of gravels, fine to medium sized, rounded to subrounded					JAR
	3			*W10 terminated at 3.00 m.* *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks: 0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

AECOM

TEST PIT W11

Sheet: 1 of 1

Client: Department of Industry, Innovation and Science		**Project No:** 60565376		**Start Date:** 08/05/2018	
Project: NRWMF - Site Characterisation		**Logged by:** JT		**End Date:** 08/05/2018	
Location: Wallerberdina Station		**Checked by:** KS		**Location Meth.:** dGPS0.1	
Contractor: Hawker Earthmoving	**Pit Length** 3.5	**Easting:** 233990.7 m		**Surface level:** 88.2 mRL	
	Pit Width: 0.5	**Northing:** 6492985.0 m		**Ver. Datum:** AHD	
Equipment: Kubota KX121-3 (4 tonne)	**Orientation:**	**Hor. Proj/Dat:** MGA94/GDA94-54J		**Surface:** Topsoil	
	Pit Depth: 3.3				

Groundwater Data and Comments	Depth (m)	Graphic Log	Classification	LITHOLOGICAL DESCRIPTION	Moisture	Consistency/ Relative Density	Sample Interval	PID (ppm)	Sample ID
	0		SM	Topsoil: Silty SAND: fine to medium grained, orange-brown, with roots	D				JAR
			CL	CLAY: low plasticity; light-brown/yellow-brown, trace of gypsum, fine to medium gravel sized white fragments	w<PL		B		BAG
	1								JAR
	2								JAR
	3								
				W11 terminated at 3.30 m. *Target depth*					
	4								
	5								
	6								
	7								
	8								
	9								

Remarks:
0.00 m: ES & QC: Environmental sample & quality control sample
1.00 m: BS: Bulk sample for geotechnical analysis

Test Pits Photographs - Wallerberdina

W06

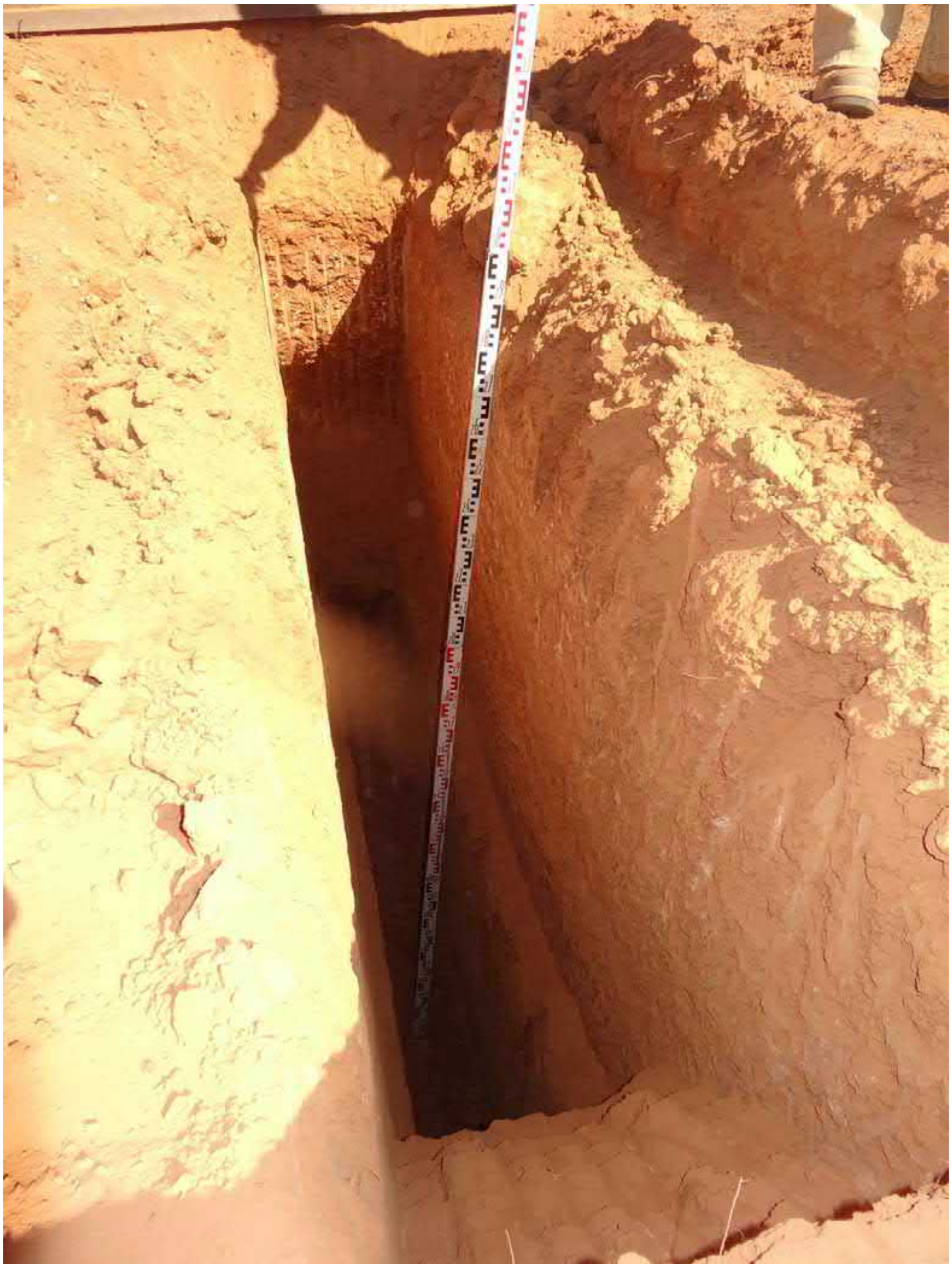
W07

W08

W09

W10

W11



Field Chemistry Parameters

Field Chemistry Parameters - Wallerberdina

Sample ID	Development Period	Sample Date	pH	Lab pH	Lab EC (uS/cm)	EC (uS/cm)	Estimated TDS (mg/L)	DO (mg/L)	Redox (mV)	Temp (^oC)	Field Observations
W01	08/05/18-12/05/18	23/05/2018	7.87	8.13	4310	4299.3	2795	4.28	-30.1	20.73	Grab sample obtained with dedicated disposable bailer, brown/grey with low turbidity during sample collection with bailer. Hydrogen sulphide odour consistent with low oxygen conditions.
W02S	16/05/18-17/05/18	23/05/2018	7.14	7.95	5080	5660	3679	7.91	48	22	Grab sample obtained with dedicated disposable bailer, brown/grey with low turbidity during sample collection with bailer.
W02C	16/05/2018	23/05/2018	7.68	7.91	5370	6123	3980	7.1	46.2	23.07	Grab sample obtained with dedicated disposable bailer, brown/grey with low turbidity during sample collection with bailer.
W02D	31/05/18-01/06/18	1/06/2018	7.48	7.14	32700	33440	21736	2.92	-18.9	19.14	Grab sampled from second day of airlift development. Grey brown with reddish tinge, high turbidity, no odour. Total volume airlifted 1200 L. Order of magnitude difference in salinity from shallower water bearing zones.
W03	18/05/18-22/05/18	23/05/2018	7.78	7.94	5130	5481.2	3563	6.86	59.8	22.91	Grab sample obtained with dedicated disposable bailer, brown with high turbidity during sample collection with bailer.
W04	12/05/18-22/05/18	23/05/2018	7.71	7.97	5000	5443.3	3538	4.46	54.9	21.02	Grab sample obtained with dedicated disposable bailer, brown/grey with low to moderate turbidity during sample collection with bailer.
Hookina Waterhole	-	26/05/2018	8.1	-	-	3802.5	2472	8.59	38.9	16.9	Yield estimate 1.5L/s, clear, low turbidity, no odour. Field parameters only. No sample collected.
Hookina Springs	-	26/05/2018	7.94	-	-	3932	2556	7.65	32.8	17.9	Yield estimate 1.6L/s, clear, low turbidity, no odour. Field parameters only. No sample collected.

Total Dissolved Solids (TDS) estimated from EC (uS/cm) x 0.65
SWL = Standing Water Level
EC = Electrical Conductivity
DO = Dissolved Oxygen
Redox = Redox potential (uncorrected field measurement)
Laboratory reported pH and EC (batch EM1808537)

ANZ

FQM - Groundwater Sampling and Purging Record

AECOM

Q4AN(EV)-405-FM1

Project Name:	NRWMF	Project Number:	60565376	PM Name:	James Rush	Bore ID:	WØ1
Client:	DIIS	Project Location:	Walle - bedina	Fieldwork Staff:	M. Morris	Sample Date:	8/5/18
						Well Development or Well Sampling Event? (circle)	

General Bore Information				Parameter Info	Decontamination	Sampling Method		Hydrasleeve info		
Date of GW Level:	9/5/17	Bore Radius (mm): diam	165mm	Chem Kit Serial No.:	Decontaminated	Low Flow Pump rate:		Hydrasleeve Size:		Monitoring sequence followed (number in order):
Depth to GW (m-pvc):	~22.95m	Screen Interval (m):	3m	Chem Kit Model:	Dedicated	Intake depth:		Hydrasleeve Type:		Gauging
Bore Depth (m-pvc):	~23.5m	Casing Radius (mm): diam	50mm	Corrected Redox: Y / N	✓ Disposable	✓ Bailer	Hydrasleeve	Sampling Depth (m-pvc):		Hydrasleeve in
Depth to Product (m-pvc):	—	Cover Type (gatic/stick up):		(The correction to apply is probe dependent)	Other (specify)	Peristaltic Pump	Waterra	Hydrasleeve install time:		Hydrasleeve out
Product Thickness (m):	—	Bore Locked (YES/NO):		Parameter method: Downhole		Other (specify)		Sampling Start Time:		Parameters
1m stickup	.5	Key Type (if applicable):		✓ Retrieved						
Calculated bore volume (L):	10L	Includes/excludes bore annulus (circle)		# purge volumes removed:		Total purged volume (L):				

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
	3pm	5.5L	~21m	—	7.75	1569	10.21	171.8	21.5	Red/brown, turbid, no odour
9/5/18	7am	11L	~21.77m	—	4.77	2572	8.03	190	15.25	Orange brown, opaque to translucent no odour
9/5/18	9am	20L	~21.79m	—	6.02	3097	7.95	139.6	18.9	" slightly less turbid.
10/5/18	10:30	20L	~21.79	—	8.07	3242	7.67	140.9	18.7	Translucent orange/brown, mod turb.
11/5	1100	40L	21.78	—	4.28	3630	7.80	145	19.6	Turbid Br/Gy
12/5	1411	60		—	3.95	3,381	7.24	207	21.65	" " possibly stable ??
	1050	80		—	4.18	5,555	7.85	252	20.06	
										✓ Development considered complete
	Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Note: WSM could not calibrate therefore parameters are indicative only.

Analytes Sampled for:		Bottles Collected			QA/QC Information	Field Comments
Field Filtered:	Unfiltered:	x 40 mL Vial (HCl)	x 50 mL Ferrous	x 80 mL metals (HNO$_3$)		Bore volume calculation, bore condition, fate of tubing, redox correction etc.
		x 40 mL Vial (H$_2$SO$_4$)	x 100 mL Amber	x 250 mL Plastic		

Field Comments:

165mm diam rods = R = 0.085 m

50mm diam casing = 0.025 m = r

for h = 1m

$BV = \pi r^2 h + (\pi R^2 h - \pi r^2 h) 0.2$

$= 0.00196 + 0.0039$

$= 0.0058 \text{ m}^3$ or 5.8 L/m.

wet bore volume calc.

Note: fresh, low TDS water used in drilling (~10,000L).

SWL ~ 21.7 bTOC

EOH = 23.5 mbTOC

h ~ 1.8.

BV ~ 10.5 L

Approval and Distribution

Fieldwork Staff Signature	13/5/18 Date	M. Morris WSM Checker Name and Signature	31/5/18 Date
WSM for JR Project Manager Signature	31/5/18 Date	Distribution: Project Central File	

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FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

Project Name:	NRWMF Site Characterisation	**Project Number:**	60535376	**PM Name:**	James Rusk	**Sample Date:**	WO1
Client:	CDIIS	**Project Location:**	Kimba, Lyndhurst and Wallerbadie	**Fieldwork Staff:**	Tim Smith JE	**Well Development or Well Sampling Event? (circle)**	

General Bore Information

Date of GW Level:	23.5.18	Bore Radius (mm):	65mm
Depth to GW (m-pvc):	21.815	Screen Interval (m):	3m
Bore Depth (m-pvc):	23.5	Casing Radius (mm):	50
Depth to Product (m-pvc):	—	Cover Type (gatic/stick up):	
Product Thickness (m):	—	Bore Locked (YES/NO):	
		Key Type (if applicable):	

Parameter Info

Chem Kit Serial No.:

Chem Kit Model:

Corrected Redox: Y / N

(The correction to apply is probe dependent)

Parameter method: Downhole / Retrieved

Decontamination

Decontaminated

Dedicated

Disposable

Other (specify)

Sampling Method

Low Flow Pump rate:

Intake depth:

Bailer / Hydrasleeve

Peristaltic Pump / Waterra

Other (specify)

Hydrasleeve Info

Hydrasleeve Size:	Monitoring sequence followed (number in order):
Hydrasleeve Type:	
Sampling Depth (m-pvc):	Gauging
Hydrasleeve Install time:	Hydrasleeve in
Sampling Start Time:	Hydrasleeve out
	Parameters

Calculated bore volume (L): 10L Includes/ excludes bore annulus (circle) | # purge volumes removed: — | Total purged volume (L): —

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
12.5.18	10.50	80	21.78	—	4.18	5555	7.85	252	20.06	Brown grey low turb.
23.5.18	18.15	3	21.815	—	4.28	42993	7.87	-30.1	20.73	" " " H2S odour
		→ Sampled								
		Acceptable Parameter Range:			± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for

Field Filtered:

Unfiltered:

Bottles Collected

	x 40 mL Vial (HCl)		x 60 mL Ferrous		x 60 mL metals (HNO_3)
	x 40 mL Vial (H_2SO_4)		x 100 mL Amber		x 250 mL Plastic

QA/QC Information

Field Comments

Bore volume calculation, bore condition, fate of tubing, redox correction etc

Grab sampled with disp. bailer
WM.

Approval and Distribution

Fieldwork Staff Signature	23.5.18 Date	M. Mo... WM Checker Name and Signature	31/5/18 Date
For JR WM Project Manager Signature	31/5/18 Date	Distribution: Project Central File	

ECOM

ANZ

FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

W02 S

Project Name:	NRWMF Site Characterisation	Project Number:	60535376	PM Name:	James Rusk	Sample Date:	16-05-2018
Client:	CDIIS	Project Location:	Kimba, Lyndhurst and Wallerbadi	Fieldwork Staff:	Tim Smith	Well Development or Well Sampling Event? (circle)	

General Bore Information		Parameter Info.	Decontamination	Sampling Method	Hydrasleeve Info.	
Date of GW Level: 16/5/18	Bore Radius (mm): 50	Chem Kit Serial No.:	Decontaminated	Low Flow Pump rate:	Hydrasleeve Size:	Monitoring sequence followed (number in order):
Depth to GW (m-pvc): 20.18	Screen Interval (m): 26-20	Chem Kit Model:	Dedicated	Intake depth:	Hydrasleeve Type:	Gauging
Bore Depth (m-pvc): 27.30	Casing Radius (mm): 50	Corrected Redox: Y / N	Disposable	Bailer / Hydrasleeve	Sampling Depth (m-pvc):	Hydrasleeve in
Depth to Product (m-pvc): –	Cover Type (gatic/stick up):	(The correction to apply is probe dependent)	Other (specify)	Peristaltic Pump / Waterra	Hydrasleeve Install time:	Hydrasleeve out
Product Thickness (m): –	Bore Locked (YES/NO): during	Parameter method: Downhole		Other (specify)	Sampling Start Time:	Parameters
	Key Type (if applicable):	Retrieved				
Calculated bore volume (L): 38L	Includes/excludes bore annulus (circle)	# purge volumes removed: –		Total purged volume (L): –		

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
16/5	845	1			6.98	1324	11.7	27	19.3	pH is very alt Bailing
	924	20			6.85	858	10.03	341	21.87	
	936	40			8.74	833	8.91	326	21.40	Airlifting Orange Turbid
	959	60			8.57	793	8.80	286	22.32	as above, fresher than conglomerate.
	1004	80			8.59	982	8.69	304	22.23	as above, less turbid
	1030	160			8.56	6108	7.89			Clear, no sediment calibrated pH
	1041	180			8.68	4600	8.07	653	21.40	but possibly failed EC calibration
	1341	200			9.62	5079	8.03	122	22.48	water is still fresh
	1349	220			8.35	5184	8.16	187	22.63	tastes fresh when reading incorrect
17/5	1045	350			8.38	5883	8.07	137	20.39	definitely not as salty as 5900 EC! Clear
	Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		Bottles Collected						QA/QC Information	Field Comments
Field Filtered:	Unfiltered:		x 40 mL Vial (HCl)		x 60 mL Ferrous	x 60 mL metals (HNO_3)			Bore volume calculation, bore condition, fate of tubing, redox correction etc.
			x 40 mL Vial (H_2SO_4)		x 100 mL Amber	x 250 mL Plastic			NO SAMPLE TAKEN DURING DEVELOPMENT

NO SAMPLE TAKEN DURING DEVELOPMENT

H = 27.3 − 20.18   6 m screen

= 7.12 m

∴ 6 × 6 L/m = 36 L

+ 1.12 × 2 = 2.24

38.24 L = 8 V (total).

Approval and Distribution

T Smith
Fieldwork Staff Signature

Date

M. Mam
Checker Name and Signature

31/5/18
Date

For JR
Project Manager Signature

31/5/18
Date

Distribution: Project Central File

Drilling Water: EC 368 pH 9 @ 0900
578 pH 8.8 @ 1400

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FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

Project Name: NRWMF	Project Number: 60535776	PM Name: JR	Bore ID: W025		
Client: COIIS	Project Location: Wallerawang	Fieldwork Staff: TE	Sample Date: 23.5.18		
			Well Development or Well Sampling Event? (circle		

General Bore Information		Parameter Info.	Decontamination	Sampling Method	Hydrasleeve Info.	
Date of GW Level: 23.5.18	Bore Radius (mm): dia 60	Chem Kit Serial No.	☐ Decontaminated	☐ Low Flow Pump rate:	Hydrasleeve Size:	Monitoring sequence followed (number in order):
Depth to GW (m-pvc): 20.75	Screen Interval (m): 26-20	Chem Kit Model: Smartroll	☑ Dedicated	Intake depth:	Hydrasleeve Type:	Gauging
Bore Depth (m-pvc): 27.30	Casing Radius (mm): dia 50	Corrected Redox: Y / N	☐ Disposable	☑ Bailer ☐ Hydrasleeve	Sampling Depth (m-pvc):	Hydrasleeve in
Depth to Product (m-pvc):	Cover Type (gatic/stick up):	(The correction to apply is probe dependent)	☐ Other (specify)	☐ Peristaltic Pump ☐ Waterra	Hydrasleeve install time:	Hydrasleeve out
Product Thickness (m):	Bore Locked (YES/NO): Atlas	Parameter method: ☐ Downhole		☐ Other (specify)	Sampling Start Time:	Parameters
	Key Type (if applicable):	☑ Retrieved				

Calculated bore volume (L): 58 | includes/ excludes bore annulus (circle) | # purge volumes removed: — | Total purged volume (L): —

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
16.5.18	10.45	—	20.78	—	8.38	5883	8.07	137	20.39	Brown grey, low turb
23.5.18	10.40	—	20.75	—	7.91	8460	7.14	48	22.00	" " "
	→ Sampled									
	Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		Bottles Collected						QA/QC Information	Field Comments
Field Filtered:	Unfiltered:		x 40 mL Vial (HCl)		x 60 mL Ferrous	x 60 mL metals (HNO_3)			Bore volume calculation, bore condition, lots of tubing, redox correction etc.
			x 40 mL Vial (H_2SO_4)		x 100 mL Amber	x 250 mL Plastic			grab sample obtained with disp. bailer WM.

Approval and Distribution

[signature]	23.5.18	M. Mom WM	31/5/18
Fieldwork Staff Signature	Date	Checker Name and Signature	Date
For JR WM	31/5/18	Distribution: Project Central File	
Project Manager Signature	Date		

FQM - Groundwater Sampling and Purging Record

W02 C

Project Name:	NRWMF Site Characterisation	Project Number:	60536376	PM Name:	James Rusk	Sample Date:	16-05-2018
Client:	CDIIS	Project Location:	Kimba, Lyndhurst and Wallerbadi	Fieldwork Staff:	Tim Smith	Well Development or Well Sampling Event? (circle)	

General Bore Information				Parameter Info	Decontamination	Sampling Method		Hydrasleeve info	
Date of GW Level:	16/5/18	Bore Radius (mm):	50	Chem Kit Serial No.:	Decontaminated	Low Flow Pump rate:		Hydrasleeve Size:	Monitoring sequence followed (number in order):
Depth to GW (m-pvc):	20.31	Screen Interval (m):	51-48	Chem Kit Model: Smartroll	Dedicated	Intake depth:		Hydrasleeve Type:	
Bore Depth (m-pvc):	51.7	Casing Radius (mm):	50	Corrected Redox: Y / N	Disposable	Bailer	Hydrasleeve	Sampling Depth (m-pvc):	Gauging
Depth to Product (m-pvc):	-	Cover Type (gatic/stick up):		(The correction to apply is probe dependent)	Other (specify)	Peristaltic Pump	Waterra	Hydrasleeve Install time:	Hydrasleeve in
Product Thickness (m):	-	Bore Locked (YES/NO):		Parameter method: Downhole	Airlift	Other (specify)		Sampling Start Time:	Hydrasleeve out
		Key Type (if applicable):		Retrieved					Parameters

Calculated bore volume (L): 75 | Includes / excludes bore annulus (circle) | # purge volumes removed: — | Total purged volume (L): —

Water Quality Parameters

Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
0906	1			8.96	1063	11.35	159	20.49	Clear Air lifting
0914	20			8.45	3395	12.01	191	22.05	
0923	40			8.76	4282	9.51	375	21.38	
0937	60			8.43	4908	8.54	355	21.50	Brown/Grey Cloudy
				8.41	4989	8.43	352	21.39	
14	100			8.71	5762	8.12	259	21.29	
1410	160			8.48	6107	8.06	265	22.64	
1415	200			8.47	6162	8.00	265	23.04	
1418	240			8.47	6127	8.00	271	22.94	
1421	280			8.71	6193	8.00	299	23.09	
1427	320			8.66	6130	7.98	362	22.81	
					✓	✓		✓	
Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for		Bottles Collected			QA/QC Information	Field Comments
Field Filtered:	Unfiltered:	x 40 mL Vial (HCl)	x 60 mL Ferrous	x 60 mL metals (HNO_3)		Bore volume calculation, bore condition, fate of tubing, redox correction etc.
		x 40 mL Vial (H_2SO_4)	x 100 mL Amber	x 250 mL Plastic		

Field Comments:

No sample collected during development
more saline than shallow
40L/1min 57s
~20L/min

H = 51.7 − 20.31 = 31.39
screen section 51.7 − 48.7 mbpvc
Bv = 3 x 6L/m = 18L
above screen ≈ 2L/m
∴ h = 48.7 − 20.31 = 28.39 m
x2
≈ 57L + 18L
Total BV ≈ 75L

Approval and Distribution

T. Smith / J. Elsworth — Fieldwork Staff Signature — Date
M. Moni — Checker Name and Signature — 31/5/18 — Date
For JR — Project Manager Signature — 31/5/18 — Date

Distribution: Project Central File

ANZ

FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

Project Name:	NRNMF	Project Number:	60535576	PM Name:	JR
Client:	CDIIS	Project Location:	Wallerawang	Fieldwork Staff:	JF

Bore ID: W02C
Sample Date: 23.5.18
Well Development or Well Sampling Event? (circle)

General Bore Information		Parameter Info	Decontamination	Sampling Method	Hydrasleeve Info.	
Date of GW Level: 23.5.18	Bore Radius (mm): 50	Chem Kit Serial No.:	Decontaminated	Low FlowPump rate:	Hydrasleeve Size:	Monitoring sequence followed (number in order):
Depth to GW (m-pvc): 20.87	Screen Interval (m): 51-48	Chem Kit Model: Smartroll	Dedicated	Intake depth:	Hydrasleeve Type:	
Bore Depth (m-pvc): 51.70	Casing Radius (mm): 50	Corrected Redox: Y / N	Disposable	Bailer / Hydrasleeve	Sampling Depth (m-pvc):	Gauging
Depth to Product (m-pvc):	Cover Type (gatic/stick up):	(The correction to apply is probe dependent)	Other (specify)	Peristaltic Pump / Waterra	Hydrasleeve install time:	Hydrasleeve in
Product Thickness (m):	Bore Locked (YES/NO):	Parameter method: Downhole		Other (specify)	Sampling Start Time:	Hydrasleeve out
	Key Type (if applicable):	Retrieved				Parameters

Calculated bore volume (L): NA | Includes/ excludes bore annulus (circle) | # purge volumes removed: — | Total purged volume (L): —

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
16.5.18	14:29	—	20.31	—	8.46	6130	7.98	36.2	22.81	Brown grey, low turb
23.5.18	16:20	—	20.87	—	7.10	6123	7.68	46.2	23.07	" " " "
	→ Sampled									
Acceptable Parameter Range:					± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		Bottles Collected			QA/QC Information	Field Comments
Field Filtered:	Unfiltered:	x 40 mL Vial (HCl)	x 60 mL Ferrous	x 60 mL metals (HNO_3)		Bore volume calculation, bore condition, fate of tubing, redox correction etc.
		x 40 mL Vial (H_2SO_4)	x 100 mL Amber	x 250 mL Plastic		grab sample c bailer WM

Approval and Distribution

[signature] 23.5.18
Fieldwork Staff Signature | Date

M. Morris WM 31/5/18
Checker Name and Signature | Date

for JR WM 31/5/18
Project Manager Signature | Date

Distribution: Project Central File

ANZ

FQM - Groundwater Sampling and Purging Record

MW03

AECOM

Q4AN(EV)-405-FM1

Project Name:	NRWMF Site Characterisation	**Project Number:**	60535376	**PM Name:**	James Rusk	**Sample Date:**	23.5.18
Client:	CDIIS	**Project Location:**	Kimba, Lyndhurst and Wallerbadi	**Fieldwork Staff:**	Tim Smith	**Well Development or Well Sampling Event? (circle)**	Both

General Bore Information		Parameter Info	Decontamination	Sampling Method	Hydrasleeve Info	
Date of GW Level: 15-5-18	Bore Radius (mm): 160	Chem Kit Serial No.:	Decontaminated	Low Flow Pump rate:	Hydrasleeve Size:	Monitoring sequence followed (number in order):
Depth to GW (m-pvc): 22.593	Screen Interval (m): 3	Chem Kit Model:	Dedicated	Intake depth:	Hydrasleeve Type:	
Bore Depth (m-pvc): 25.585	Casing Radius (mm): 50	Corrected Redox: Y / N	Disposable	Bailer / Hydrasleeve	Sampling Depth (m-pvc):	Gauging
Depth to Product (m-pvc): —	Cover Type (gatic/stick up)	(The correction to apply is probe dependent)	Other (specify)	Peristaltic Pump / Waterra	Hydrasleeve Install time:	Hydrasleeve in
Product Thickness (m): —	Bore Locked (YES/NO):	Parameter method: Downhole		Other (specify)	Sampling Start Time:	Hydrasleeve out
	Key Type (if applicable):	Retrieved		—		Parameters
Calculated bore volume (L): 18L	Includes/ excludes bore annulus (circle)	# purge volumes removed: —		Total purged volume (L):		

Water Quality Parameters

Date	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
18.5.18	AM	5.0	~~22.593~~	—	9.50	11834.0	8.66	86.5	15.90	Brown, high turb
20.5.18	AM	1.0	23.920	—	5.61	2713.8	8.02	85.5	22.04	clear, low turb
	AM	5.0	–	–	5.26	3176.2	7.95	81.6	23.54	Brown, high turb
	AM	10.0	–	–	5.79	3284.3	7.96	101.9	22.76	" " " "
		Dry @ 11L								
22.5.18	14:05	0.0	22.916							
	14:15	5.0	—	—	6.74	5326.2	7.79	59.7	23.34	Brown, low-mod turb.
	14:20	5.0	—	—	6.10	5094.1	7.80	51.0	23.19	Brown, high turb.
	14:30	10.0	—	—	6.87	5123.0	7.79	53.7	23.04	" " " "
left for 10 min	14:40	12.0	—	—	6.52	5209.0	7.79	49.0	22.81	" " " "
		15.0	—	—	6.92	5105.4	7.81	49.0	22.40	" " " "
		18.00	Dry @ 18L		6.40	5142.2	7.81	47.2	22.46	" " " "
23.5.18	15:30	—	22.915	—	6.86	5481.2	7.78	59.8	22.91	" " " " Sampled
		Acceptable Parameter Range:			± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		Bottles Collected			QA/QC Information	Field Comments
Field Filtered:	**Unfiltered:**	x 40 mL Vial (HCl)	x 60 mL Ferrous	x 60 mL metals (HNO_3)		Bore volume calculation, bore condition, fate of tubing, redox correction etc.
		x 40 mL Vial (H_2SO_4)	x 100 mL Amber	x 250 mL Plastic		

BV for 1m of column, R = 0.08 3m, r = 0.025m

BV = 0.0196 − ((0.024 − 0.0196)) gravel pack porosity of 0.2 (20%) × 0.2 ≈ 5.6 L/m for screened interval

H = 25.585 − 22.593 = 2.992 × 6 L/s ≈ 18 L

Approval and Distribution

[signature]	23.5.18	M. Mom [signature]	30/5/18
Fieldwork Staff Signature	Date	Checker Name and Signature	Date
For JR [signature]	30/5/18		
Project Manager Signature	Date	Distribution: Project Central File	

FQM - Groundwater Sampling and Purging Record

Q4AN(EV)-405-FM1

NO4

Project Name:	NRWMF Site Characterisation	Project Number:	60535376	PM Name:	James Rusk	Sample Date:	
Client:	CDIIS	Project Location:	Kimba, Lyndhurst and Wallerbadi	Fieldwork Staff:	Tim Smith	Well Development or Well Sampling Event? (circle)	

General Bore Information

Date of GW Level:	11-5-18	Bore Radius (mm):	50
Depth to GW (m-pvc):	23.9	Screen Interval (m):	22-27
Bore Depth (m-pvc):	27.8	Casing Radius (mm):	50
Depth to Product (m-pvc):	–	Cover Type (gatic/stick up):	
Product Thickness (m):	–	Bore Locked (YES/NO):	after sampling
		Key Type (if applicable):	
Calculated bore volume (L):	23.4	Includes/ excludes bore annulus (circle)	

Parameter Info.

Chem Kit Serial No.:
Chem Kit Model: SMART ROLL
Corrected Redox: Y / N
(The correction to apply is probe dependent)
Parameter method: Downhole / Retrieved

Decontamination

Decontaminated
Dedicated
Disposable
Other (specify)

Sampling Method

Low Flow Pump rate:
Intake depth:
Bailer / Hydrasleeve
Peristaltic Pump / Waterra
Other (specify)

Hydrasleeve Info.

Hydrasleeve Size:
Hydrasleeve Type:
Sampling Depth (m-pvc):
Hydrasleeve Install time:
Sampling Start Time:

Monitoring sequence followed (number in order): Gauging; Hydrasleeve in; Hydrasleeve out; Parameters

purge volumes removed: –
Total purged volume (L): –

Water Quality Parameters

Date	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
12/5	1440	5		–	7.93	1409	8.00	205	22.57	Brown-Grey, Turbid, Brown
	1500	10		–	9.00	1078	8.51	274	22.63	Dry after 10L
13/5	1125	20			5.79	2922	7.91	273	21.29	Dry after 10L
17/5	1004	30			4.62	4351	7.56	107	20.23	Brown-Grey, Turbid, Dry after 7L
20/5	15:00	0	26735	–						
	15:10	1	–	–	3.61	5244	7.66	84.2	24.51	Brown grey, low/mod turbid.
	15:22	5	–	–	4.60	5380	7.68	75.2	24.33	Brown grey, mod turb.
	15:30	9	–	–	4.51	5421	7.72	64.6	24.01	" " "
		Dry @ 9L								
22/5	15:19	0	26.732	–						
	15:23	1	–	–	5.15	5269.9	7.70	50.3	21.47	Brown grey low turb
	15:30	5	–	–	5.60	5340.5	7.69	48.3	20.79	" " low mod turb
	15:40	9	–	–	4.25	5494.9	7.69	48.5	21.86	" " " "
	Dry @ 9L	Acceptable Parameter Range:			± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for

Field Filtered: –
Unfiltered: –

Bottles Collected

	x 40 mL Vial (HCl)		x 60 mL Ferrous		x 60 mL metals (HNO_3)
	x 40 mL Vial (H_2SO_4)		x 100 mL Amber		x 250 mL Plastic

QA/QC Information

Field Comments

Bore volume calculation, bore condition, fate of tubing, redox correction etc.

Bore pump & riser(?) ... removed ... Sand in base of bore.
No sample collected during development

$H = 27.8 - 23.9 = 3.9\,m \times 6L/m$
$BV = 23.4\,L$

Approval and Distribution

Fieldwork Staff Signature

Date

For JR NW
Project Manager Signature

30/5/18
Date

M. Mom NM
Checker Name and Signature

30/5/18
Date

Distribution: Project Central File

ANZ

FQM - Groundwater Sampling and Purging Record

AECOM

Q4AN(EV)-405-FM1

Project Name:	NRNMF	Project Number:	60535576	PM Name:	JR	Bore ID:	W04
Client:	CDHS	Project Location:	wollenbundung	Fieldwork Staff:	JE	Sample Date:	23.5.18
						Well Development or Well Sampling Event? (circle)	

General Bore Information

- Date of GW Level: 23.5.18
- Depth to GW (m-pvc): 26.735
- Bore Depth (m-pvc): 28.590
- Depth to Product (m-pvc): —
- Product Thickness (m): —
- Bore Radius (mm): 65
- Screen Interval (m): 22-27
- Casing Radius (mm): 50
- Cover Type (gatic/stick up): S
- Bore Locked (YES/NO):
- Key Type (if applicable):

Parameter Info.

- Chem Kit Serial No.:
- Chem Kit Model: Smartroll
- Corrected Redox: Y / N
- (The correction to apply is probe dependent)
- Parameter method: Downhole / Retrieved

Decontamination

- Decontaminated
- Dedicated
- Disposable
- Other (specify)

Sampling Method

- Low Flow Pump rate:
- Intake depth:
- Bailer
- Hydrasleeve
- Peristaltic Pump
- Waterra
- Other (specify)

Hydrasleeve Info.

- Hydrasleeve Size:
- Hydrasleeve Type:
- Sampling Depth (m-pvc):
- Hydrasleeve Install time:
- Sampling Start Time:

Monitoring sequence followed (number in order): Gauging; Hydrasleeve in; Hydrasleeve out; Parameters

Calculated bore volume (L): 11L includes/excludes bore annulus (circle) # purge volumes removed: — Total purged volume (L):

Water Quality Parameters

	Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
22/5/18	15:40	9	—	—	4.25	5494.9	7.69	48.5	21.06	Brown grey, low-mod turb.
23/5/18	14:20	—	—	—	4.46	5443.3	7.71	54.9	21.02	" " "
	→ Sampled									
	Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for: Field Filtered: / Unfiltered:

Bottles Collected

x 40 mL Vial (HCl)	x 60 mL Ferrous	x 60 mL metals (HNO_3)
x 40 mL Vial (H_2SO_4)	x 100 mL Amber	x 250 mL Plastic

QA/QC Information

Field Comments

Bore volume calculation, bore condition, fate of tubing, redox correction etc.

H = 28.59 − 26.735 = 1.855m
× ≈ 6L/m
≈ 11L = BV.

Approval and Distribution

Fieldwork Staff Signature — Date: 23.5.18

Checker Name and Signature: M. Mom — Date: 30/5/18

Project Manager Signature: For JR — Date: 30/5/18

Distribution: Project Central File

ANZ

FQM - Groundwater Sampling and Purging Record

WO2D

Q4AN(EV)-405-FM1

Project Name:	NRWMF Site Characterisation	**Project Number:**	60535376		
Client:	CDIIS	**Project Location:**	Kimba, Lyndhurst and Wallerbadi	**PM Name:**	James Rusk
				Fieldwork Staff:	~~Tim Smith~~ Steve P
Sample Date:	31.5.18	Well Development or Well Sampling Event? (circle)	Well Development		

General Bore Information

Date of GW Level:	31.5.18	Bore ~~Radius~~ dia (mm):	101.2 mm
Depth to GW (m-pvc):	HWT casing	~~Screen Interval~~ (m):	openhole
Bore Depth (m-pvc):	206 m *	Casing ~~Radius~~ (mm):	100 mm
Depth to Product (m-pvc):	/	Cover Type (gatic/stick up):	stick up
Product Thickness (m):	/	Bore Locked (YES/NO):	YES
* Borehole wireline		Key Type (if applicable):	padlock
Calculated bore volume (L):		Includes/ excludes bore annulus (circle)	

Parameter Info

Chem Kit Serial No.:	—
Chem Kit Model:	Smartroll
Corrected Redox: Y / N	N
(The correction to apply is probe dependent)	
Parameter method: Downhole / Retrieved	Retrieved
# purge volumes removed:	

Decontamination

- Decontaminated
- Dedicated
- Disposable
- Other (specify) ✓ Airlift

Sampling Method

- Low Flow Pump rate:
- Intake depth:
- Bailer
- Hydrasleeve
- Peristaltic Pump
- Waterra
- Other (specify) ✓ from airlift

Total purged volume (L): 990L by end of day

Hydrasleeve Info

		Monitoring sequence followed (number in order):
Hydrasleeve Size:		Gauging
Hydrasleeve Type:		Hydrasleeve in
Sampling Depth (m-pvc):		Hydrasleeve out
Hydrasleeve Install time:		Parameters
Sampling Start Time:		

Water Quality Parameters

Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
1055		4.98		0.97	10774	9.51	3.9	21.4	-110m First water in well — 10min Air
1020 Start									-190m
1132	- Yield 0								-1135 Stopped
1250	Start	55.58							-201m Can't get water to surface - as the
1218	Start								compressor is not powerful enough
138 Start		143	meters						-177m 125m - No water
228	200	22.74	1L/min	6.69	10932	9.23	62.6	20.2	red Br/High turb, no odour
~~300~~ ~~240~~ 340		90 ÷							~~red~~
320	530	114		15.9	12192	9.13	16.4	22.11	Grey Brown HT No Odour
328	625	126	-	5.52	19905	9.21	18.2	22.58	" " " " "
339	740	143	-	4.96	33571	9.23	49.2	23.47	" " " " "
350	890	159	-	5.59	39145	9.26	75.1	23.38	" " " "
400	990	172	-	4.50	40423	9.05	90.6	23.70	" " " "
		Acceptable Parameter Range:		± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for

Field Filtered:	Unfiltered:

Bottles Collected

	x 40 mL Vial (HCl)		x 60 mL Ferrous		x 60 mL metals (HNO_3)
	x 40 mL Vial (H_2SO_4)		x 100 mL Amber		x 250 mL Plastic

QA/QC Information

Field Commets

Bore volume calculation, bore condition, fate of tubing, redox correction etc.

100 mm

$\pi r^2 = 3.14 \times (0.05)^2$

$= 0.0785\ m^3/m$

$= 78.5\ L/m$

Original drill depth = 236.1m below HWT stick up which was extended by 0.5m before monument cover installed.

Approval and Distribution

Steve Partridge — 31.5.18
Fieldwork Staff Signature — Date

M. Morris — 06/06/18
Checker Name and Signature — Date

For JR — 06/06/18
Project Manager Signature — Date

Distribution: Project Central File

ANZ

Q4AN(EV)-405-FM1

FQM - Groundwater Sampling and Purging Record

W02D

Project Name:	NRWMF Site Characterisation	**Project Number:**	60535376	**PM Name:**	James Rusk
Client:	CDIIS	**Project Location:**	Kimba, Lyndhurst and Wallerbadie	**Fieldwork Staff:**	~~Tim Smith~~ S. Partridge

Sample Date: 31.5.18 / 1/6/18

Well Development or Well Sampling Event? (circle)

General Bore Information

- Date of GW Level: 1/6/18
- Depth to GW (m-pvc): 174.46
- Bore Depth (m-pvc): 206
- Depth to Product (m-pvc): –
- Product Thickness (m): –
- Calculated bore volume (L):
- Bore Radius (mm): dia 100mm
- Screen Interval (m): 196-206
- Casing Radius (mm): –
- Cover Type (gatic/stick up): 6
- Bore Locked (YES/NO):
- Key Type (if applicable): padlocked
- Includes/ excludes bore annulus (circle)

Parameter Info.

- Chem Kit Serial No.: –
- Chem Kit Model: Smartroll
- Corrected Redox: Y / N
- (The correction to apply is probe dependent)
- Parameter method: Downhole / Retrieved
- \# purge volumes removed:

Decontamination

- Decontaminated
- Dedicated
- Disposable
- Other (specify)

Sampling Method

- Low Flow Pump rate:
- Intake depth:
- Bailer
- Hydrasleeve
- Peristaltic Pump
- Waterra
- Other (specify) air lift.
- Total purged volume (L): 1200L cummulative from 31/5/18.

Hydrasleeve Info.

- Hydrasleeve Size:
- Hydrasleeve Type:
- Sampling Depth (m-pvc):
- Hydrasleeve Install time:
- Sampling Start Time:

Monitoring sequence followed (number in order):

- Gauging
- Hydrasleeve in
- Hydrasleeve out
- Parameters

Water Quality Parameters

Time	Cumulative Vol. Removed (L)	SWL (m-pvc)	Pump Rate	DO (ppm or mg/L)	E.C. (mS/cm or µS/cm)	pH	Redox (mV)	Temp °C	Odour, Colour, Turbidity
413	1100	188	–	5.70	40918	9.15	49	23.16	Grey Brown - slightly Brownish - HT, No odour
432	Finish → yield for approx 10 min → >1 L/min → trickle								
1/6 830 - SWL 174.46									
850	1180	196	–	1.77	35030	8.99	-76.1	19.08	- Grey Brown - SH reddish tinge
955	1200	196	–	2.92	33440	7.48	-18.9	19.14	no odour, High turb
									waited 1 hr for recharge.
									got approx 20 lt out
									Sampled
Acceptable Parameter Range:				± 10%	± 3%	± 0.05	± 10 mV	± 0.2 °C	± 10% turbidity (if using a turbidity meter)

Analytes Sampled for:		Bottles Collected						QA/QC Information
Field Filtered:	**Unfiltered:**	4	x 40 mL Vial (HCl)		x 60 mL Ferrous	2	x 60 mL metals (HNO_3)	Q01
metals	rest		x 40 mL Vial (H_2SO_4)	1	x 100 mL Amber	3	x 250 mL Plastic	
					~~Ab~~	1	Yellow	
		1	Purple	1	1Lt Met	1	Blue	

Field Comments

Bore volume calculation, bore condition, fate of tubing, redox correction etc.

Depths measured 0.5m below final TOC point. openhole = 196-206 m b casing before ex. MM not original drilled depth = 236.1 m

Approval and Distribution

S. Partridge	01/06/18	M. Moon MM	06/06/18
Fieldwork Staff Signature	**Date**	**Checker Name and Signature**	**Date**
For JR MM	06/06/18		
Project Manager Signature	**Date**	**Distribution:** Project Central File	

↓ 14mm rain

Wallerberdina Gauging Sheet

Well ID	Depth mbpvc	Stand up m	Date	SWL mbpvc	Date	SWL	Date	SWL	Date	SWL	Date	SWL	Date	SWL		Date	SWL
W01	23.4	0.995	~~21.795~~ 25/5/18	21.775	26/5/18	21.765	27/5/18	–	28/5/18	No ACCESS to site	29/5/18	21.818	30/5/18	21.825	31/5/18	1/6/18	21.828
W02S	27.3	0.85		20.58		20.56		20.55				20660		20.661	20.638	~~20.645~~	20645
W02C	52	0.90		20.545		20.53		20.535				20.620		20.622	20.610	~~20.617~~	20.617
W03	25.3	0.97		22.875		22.87		–				22.925		22.926			22.938
W04	28.14	0.96		26.685		26.69		–				26.748		26.753			26.765
W02D (in progress)														72.24 (Devel)	post Devel	pre Devel	~~178.46~~.

(174.46m + 0.5m for final extension) = 174.96 mb final casing height.

Water Level Probe = Aqua Dipper Pro 300m (10EEDIP300BE). from Thermofisher

Recorders: M. Morris 25/5 – 28/5
S. Partridge 29/5 – 01/06

[signature]

AECOM

Project

File/Ref No.

By

Page

Date

Groundwater Analytical Chemistry - Wallerberdina

Groundwater Analytical Chemistry - Wallerberdina

Reporting Group	Analyte	Unit	LOR	W01	W02S	W02C	W02D		W03	W04	RB01
			Field_ID	W01_23/05/18	W02S_23/05/18	W02S_23/05/18	W02D_01/06/18	Q01_20180601	W03_23/05/18	W04_23/05/18	RB01
			Sample_Type	Normal	Normal	Normal	Normal	Field duplicate (inter-lab)	Normal	Normal	Rinse blank
			Sampled_Date	23/05/018	23/05/2018	23/05/2018	1/06/2018	1/06/2018	23/05/2018	23/05/2018	23/05/2018
			Lab_Report	EM1808537	EM1808537	EM1808537	EM180976/ EM1809078	ES1816445/ ES1816499	EM1808537	EM1808537	EM1808537
General	pH	pH unit	0.01	8.13	7.95	7.91	7.14	7.52	7.94	7.97	6.01
	Electrical Conductivity (EC)	µS/cm	1	4310	5080	5370	32700	34900	5130	5000	-
Radionuclides	Gross alpha	Bq/L	-	Pending	Pending	Pending	Pending	Pending	Pending	Pending	-
	Gross beta activity - 40 K	Bq/L	-	Pending	Pending	Pending	Pending	Pending	Pending	Pending	-
Dissolved Metals (15 NEPM)	Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.00	<0.001	<0.001	<0.001
	Boron	mg/L	0.05	0.66	0.64	0.7	0.08	0.09	0.65	0.68	<0.05
	Barium	mg/L	0.001	0.06	0.092	0.028	0.306	0.282	0.08	0.064	<0.001
	Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Cobalt	mg/L	0.001	0.002	<0.001	0.002	0.024	0.022	<0.001	<0.001	<0.001
	Chromium	mg/L	0.001	<0.001	<0.001	0.004	<0.001	<0.001	0.002	0.001	<0.001
	Copper	mg/L	0.001	<0.001	<0.001	0.005	0.027	0.028	<0.001	<0.001	<0.001
	Manganese	mg/L	0.001	0.308	0.045	0.006	3.56	3.43	0.111	0.151	0.002
	Nickel	mg/L	0.001	0.001	<0.001	0.001	0.504	0.503	<0.001	<0.001	<0.001
	Lead	mg/L	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Selenium	mg/L	0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001
	Vanadium	mg/L	0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Zinc	mg/L	0.005	0.005	0.01	0.096	0.71	0.694	0.01	0.011	<0.01
	Lithium	mg/L	0.001	0.05	0.049	0.056	0.132	0.138	0.05	0.053	<0.005
	Strontium	mg/L	0.001	2.8	3.44	3.5	1.14	10.8	3.17	3.32	0.002
	Thorium	mg/L	0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
	Uranium	mg/L	0.001	0.006	0.006	0.006	<0.001	<0.001	0.006	0.006	<0.001
	Bromine	mg/L	0.1	1.5	1.9	1.9	32.8	38.9	1.8	1.9	0.1
	Iodine	mg/L	0.1	0.2	0.2	0.2	<0.1	<0.1	0.2	0.3	<0.1
	Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Total Metals	Manganese	mg/L	0.001	0.637	0.195	0.018	7.51	5.8	1.37	0.297	-
	Iron	mg/L	0.05	3.7	11.7	0.32	308	216	37.9	8.82	-
Nutrients	Nitrite as N	mg/L	0.01	0.01	0.01	0.02	<0.01	<0.01	0.02	0.01	-
	Nitrate as N	mg/L	0.01	0.61	0.25	0.37	0.12	<0.1	0.32	0.34	-
	Nitrite + Nitrate as N	mg/L	0.01	0.62	0.26	0.39	0.12	<0.1	0.34	0.35	-
Other	Fluoride	mg/L	0.1	2	1.6	1.6	0.5	0.4	1.6	1.5	<0.1
	Silicon	mg/L	0.05	18.3	<0.05	8.22	1.66	-	7.96	7.92	
	Dissolved Sulphide as S2-	-	mg/L	<0.1	0.1	<0.1	<2.0	<0.1	<0.1	<0.1	
Alkalinity	Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1
	Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1
	Bicarbonate Alkalinity as CaCO3	mg/L	1	232	170	242	108	125	186	240	1
	Total Alkalinity as CaCO3	mg/L	1	232	170	242	108	125	186	240	1
Organic Matter	Dissolved Organic Carbon (DOC)	-	mg/L	2	2	2	-	-	4	3	-
	Total Organic Matter (TOC)*	-	mg/L	-	-	-	24	277	-	-	-
Major Ions	Calcium	mg/L	1	88	163	151	699	627	146	142	<1
	Magnesium	mg/L	1	97	154	154	221	201	137	151	<1
	Sodium	mg/L	1	615	938	828	1550	1380	861	883	<1
	Potassium	mg/L	1	15	16	24	7760	6970	14	18	<1
	Sulphate (as SO4-)	mg/L	1	603	715	664	148	141	688	688	<1
	Chloride	mg/L	1	1030	1310	1330	10700	10500	1320	1270	<1
	Total Anions	meq/L	0.01	46.2	55.2	56.2	307	302	55.3	54.9	0.02
	Total Cations	meq/L	0.01	39.5	62	56.8	319	286	56.4	58.4	<0.01
	Ionic Balance	%	0.01	7.85	5.78	0.58	1.9	2.64	0.98	3.03	-

Notes:
Not analysed/ Not calculated
LOR: Limit of Reporting
Bq/L = Becquerals per litre
mg/L: milligrams per Litre
µg/L: micrograms per litre
Pending: Preliminary report EM1808537 issued 01/06/18 & updated 07/06/18 for available data, other analytes due 12/06/18
Pending: Report EM1809078 for gross alpha/gross beta due 19/06/18
Pending: Report ES1816449 for gross alpha/gross beta due 19/06/18
*TOC analysis performed as sample was unfiltered in the field due to high sediment load
Query to labs on reported TOC and Strontiumfor W02D and duplicate to double check concentrations 11/06/18

CERTIFICATE OF ANALYSIS

Work Order	: **EM1808537**	Page	: 1 of 6
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 25-May-2018 10:45
Order number	: 60565376.4.0	Date Analysis Commenced	: 25-May-2018
C-O-C number	: ----	Issue Date	: 13-Jun-2018 15:29
Sampler	: JE		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nikki Stepniewski	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC
Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020F: EM1808537-006 dissolved manganese result has been confirmed by re-preparation and re-analysis
- EA010-P: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- Gross Alpha and Beta Activity analyses are performed by ALS Fyshwick (NATA Accreditation number 992).
- ED093F:EM1808537_002 has been confirmed for major cations by re-preparation and re-analysis.
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Sub-Matrix: WATER (Matrix: WATER)				W01	W02C	W03	W04	W02S
				23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00
				EM1808537-001	EM1808537-002	EM1808537-003	EM1808537-004	EM1808537-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.13	7.91	7.94	7.97	7.95
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	4310	5370	5130	5000	5080
EA250: Gross Alpha and Beta Activity								
Gross alpha	----	0.05	Bq/L	0.48	0.28	0.48	0.44	0.38
Gross beta activity - 40K	----	0.10	Bq/L	0.36	0.26	0.32	0.38	0.42
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	232	242	186	240	170
Total Alkalinity as CaCO3	----	1	mg/L	232	242	186	240	170
ED040F: Dissolved Major Anions								
Silicon	7440-21-3	0.05	mg/L	18.3	8.22	7.96	7.92	<0.05
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	603	664	688	688	715
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	1030	1330	1320	1270	1310
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	88	151	146	142	163
Magnesium	7439-95-4	1	mg/L	97	154	137	151	154
Sodium	7440-23-5	1	mg/L	615	828	861	883	938
Potassium	7440-09-7	1	mg/L	15	24	14	18	16
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L	0.66	0.70	0.65	0.68	0.64
Barium	7440-39-3	0.001	mg/L	0.060	0.028	0.080	0.064	0.092
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L	0.002	0.002	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L	<0.001	0.004	0.002	0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.005	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L	0.308	0.006	0.111	0.151	0.045
Nickel	7440-02-0	0.001	mg/L	0.001	0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001

Sub-Matrix: **WATER**
(Matrix: **WATER**)

				W01	**W02C**	**W03**	**W04**	**W02S**
				23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00	23-May-2018 00:00
				EM1808537-001	**EM1808537-002**	**EM1808537-003**	**EM1808537-004**	**EM1808537-005**
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L	**0.005**	**0.096**	**0.010**	**0.011**	**0.010**
Lithium	7439-93-2	0.001	mg/L	**0.050**	**0.056**	**0.050**	**0.053**	**0.049**
Strontium	7440-24-6	0.001	mg/L	**2.80**	**3.50**	**3.17**	**3.32**	**3.44**
Thorium	7440-29-1	0.001	mg/L	**0.002**	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L	**0.006**	**0.006**	**0.006**	**0.006**	**0.006**
Bromine	7726-95-6	0.1	mg/L	**1.5**	**1.9**	**1.8**	**1.9**	**1.9**
Iodine	7553-56-2	0.1	mg/L	**0.2**	**0.2**	**0.2**	**0.3**	**0.2**
EG020T: Total Metals by ICP-MS								
Manganese	7439-96-5	0.001	mg/L	**0.637**	**0.018**	**1.37**	**0.297**	**0.195**
Iron	7439-89-6	0.05	mg/L	**3.70**	**0.32**	**37.9**	**8.82**	**11.7**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**2.0**	**1.6**	**1.6**	**1.5**	**1.6**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.61**	**0.37**	**0.32**	**0.34**	**0.25**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.62**	**0.39**	**0.34**	**0.35**	**0.26**
EK085F: Dissolved Sulfide as S2-								
Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	**0.1**
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**46.2**	**56.2**	**55.3**	**54.9**	**55.2**
Total Cations	----	0.01	meq/L	**39.5**	**56.8**	**56.4**	**58.4**	**62.0**
Ionic Balance	----	0.01	%	**7.85**	**0.58**	**0.98**	**3.03**	**5.78**
EP002: Dissolved Organic Carbon (DOC)								
Dissolved Organic Carbon	----	1	mg/L	**2**	**2**	**4**	**3**	**2**

Sub-Matrix: WATER
(Matrix: WATER)

				RB01	----	----	----	----
				23-May-2018 00:00	----	----	----	----
				EM1808537-006	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.01**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**2**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**1**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**1**	----	----	----	----
ED040F: Dissolved Major Anions								
Silicon	7440-21-3	0.05	mg/L	<0.05	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	<1	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	----	----	----	----
Magnesium	7439-95-4	1	mg/L	<1	----	----	----	----
Sodium	7440-23-5	1	mg/L	<1	----	----	----	----
Potassium	7440-09-7	1	mg/L	<1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.001**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----

Sub-Matrix: WATER
(Matrix: WATER)

				RB01	----	----	----	----
				23-May-2018 00:00	----	----	----	----
				EM1808537-006	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Lithium	7439-93-2	0.001	mg/L	<0.001	----	----	----	----
Strontium	7440-24-6	0.001	mg/L	<0.001	----	----	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	----	----	----	----
Bromine	7726-95-6	0.1	mg/L	<0.1	----	----	----	----
Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**0.02**	----	----	----	----
Total Cations	----	0.01	meq/L	<0.01	----	----	----	----

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM1808537**	Page	: 1 of 8
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 25-May-2018
Order number	: 60565376.4.0	Date Analysis Commenced	: 25-May-2018
C-O-C number	: ----	Issue Date	: 13-Jun-2018
Sampler	: JE		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

[illegible]

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

[illegible]	[illegible]	[illegible]
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nikki Stepniewski	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC
Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA005P: pH by PC Titrator (QC Lot: 1683362)									
EM1808541-001	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	8.06	8.15	1.11	0% - 20%
EM1808537-006	RB01	EA005-P: pH Value	----	0.01	pH Unit	6.01	5.21	14.3	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 1683360)									
EM1808530-002	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	1310	1360	4.05	0% - 20%
EM1808535-002	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	3830	3800	0.786	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 1683364)									
EM1808541-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	2370	2280	3.79	0% - 20%
EM1808537-006	RB01	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	2	1	0.00	No Limit
EA250: Gross Alpha and Beta Activity (QC Lot: 1690356)									
EM1808537-001	W01	EA250-LSC: Gross alpha	----	0.05	Bq/L	0.48	0.49	2.38	No Limit
		EA250-LSC: Gross beta activity - 40K	----	0.1	Bq/L	0.36	0.62	53.5	No Limit
EM1808546-006	Anonymous	EA250-LSC: Gross alpha	----	0.05	Bq/L	10.0	10.4	3.41	No Limit
		EA250-LSC: Gross beta activity - 40K	----	0.1	Bq/L	38.2	38.6	1.06	No Limit
ED037P: Alkalinity by PC Titrator (QC Lot: 1683361)									
EM1808535-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	104	106	1.16	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	104	106	1.16	0% - 20%
EM1808537-006	RB01	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	1	<1	0.00	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	1	<1	0.00	No Limit
ED040F: Dissolved Major Anions (QC Lot: 1681596)									
EM1808546-004	Anonymous	ED040F: Silicon	7440-21-3	0.05	mg/L	19.0	18.5	2.98	0% - 20%

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
ED040F: Dissolved Major Anions (QC Lot: 1681596) - continued									
EM1808537-001	W01	ED040F: Silicon	7440-21-3	0.05	mg/L	18.3	18.1	1.24	0% - 20%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 1681595)									
EM1808546-004	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1230	1240	0.497	0% - 20%
EM1808537-001	W01	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	603	602	0.00	0% - 20%
ED045G: Chloride by Discrete Analyser (QC Lot: 1681593)									
EM1807682-018	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	176	179	1.56	0% - 20%
EM1808537-005	W02S	ED045G: Chloride	16887-00-6	1	mg/L	1310	1310	0.355	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 1683420)									
EM1808537-002	W02C	ED093F: Calcium	7440-70-2	1	mg/L	151	141	6.58	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	154	144	6.77	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	828	805	2.84	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	24	19	19.1	0% - 20%
EM1808546-004	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	284	281	1.10	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	792	782	1.30	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	10200	10000	1.46	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	123	120	2.52	0% - 20%
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1683417)									
EM1808539-004	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0002	<0.0002	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.012	0.012	0.00	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.002	<0.002	0.00	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.098	0.098	0.00	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	0.004	0.004	0.00	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.002	<0.002	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.002	0.002	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.002	<0.002	0.00	No Limit
		EG020A-F: Lithium	7439-93-2	0.001	mg/L	0.112	0.110	2.42	0% - 20%
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.148	0.146	0.833	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.002	<0.002	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.010	<0.010	0.00	No Limit
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.02	<0.02	0.00	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.02	<0.02	0.00	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	4.38	4.30	1.91	0% - 20%
		EG020A-F: Bromine	7726-95-6	0.1	mg/L	88.3	86.7	1.81	0% - 20%
		EG020A-F: Iodine	7553-56-2	0.1	mg/L	0.2	0.2	0.00	No Limit
EM1808537-001	W01	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.060	0.064	7.28	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Laboratory Duplicate (DUP) Report					
				LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1683417) - continued									
EM1808537-001	W01	EG020A-F: Cobalt	7440-48-4	0.001	mg/L	0.002	0.002	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lithium	7439-93-2	0.001	mg/L	0.050	0.053	4.14	0% - 20%
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.308	0.327	6.13	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.001	0.001	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.005	0.005	0.00	No Limit
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	0.66	0.69	5.15	0% - 50%
		EG020A-F: Bromine	7726-95-6	0.1	mg/L	1.5	1.7	9.69	0% - 50%
		EG020A-F: Iodine	7553-56-2	0.1	mg/L	0.2	0.3	0.00	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1683419)									
EM1808546-004	Anonymous	EG020B-F: Strontium	7440-24-6	0.001	mg/L	2.54	2.60	2.44	0% - 20%
		EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.002	<0.002	0.00	No Limit
		EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.002	<0.002	0.00	No Limit
EM1808537-001	W01	EG020B-F: Strontium	7440-24-6	0.001	mg/L	2.80	3.00	7.01	0% - 20%
		EG020B-F: Thorium	7440-29-1	0.001	mg/L	0.002	0.001	0.00	No Limit
		EG020B-F: Uranium	7440-61-1	0.001	mg/L	0.006	0.006	0.00	No Limit
EG020T: Total Metals by ICP-MS (QC Lot: 1683414)									
EM1808482-004	Anonymous	EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.00	No Limit
EM1808537-001	W01	EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.637	0.601	5.83	0% - 20%
		EG020A-T: Iron	7439-89-6	0.05	mg/L	3.70	3.97	7.09	0% - 20%
EG035F: Dissolved Mercury by FIMS (QC Lot: 1683418)									
EM1808539-004	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EM1808537-001	W01	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 1683363)									
EM1808537-006	RB01	EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EM1808546-008	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EK057G: Nitrite as N by Discrete Analyser (QC Lot: 1681594)									
EM1808546-005	Anonymous	EK057G: Nitrite as N	14797-65-0	0.01	mg/L	0.10	0.10	0.00	No Limit
EM1808537-001	W01	EK057G: Nitrite as N	14797-65-0	0.01	mg/L	0.01	<0.01	0.00	No Limit
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 1694616)									
EM1808537-001	W01	EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	0.62	0.62	0.00	0% - 20%
EK085F: Dissolved Sulfide as S2- (QC Lot: 1683781)									
EM1808537-001	W01	EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EM1808546-005	Anonymous	EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	1.5	1.8	18.7	No Limit
EP002: Dissolved Organic Carbon (DOC) (QC Lot: 1694024)									

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP002: Dissolved Organic Carbon (DOC) (QC Lot: 1694024) - continued									
EM1808537-001	W01	EP002: Dissolved Organic Carbon	----	1	mg/L	2	2	0.00	No Limit
EM1808546-006	Anonymous	EP002: Dissolved Organic Carbon	----	1	mg/L	7	6	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report: Result	Laboratory Control Spike (LCS) Report: Spike Concentration	Spike Recovery (%): LCS	Recovery Limits (%): Low	Recovery Limits (%): High
EA010P: Conductivity by PC Titrator (QCLot: 1683360)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1412 µS/cm	100	85	119
EA010P: Conductivity by PC Titrator (QCLot: 1683364)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1412 µS/cm	99.5	85	119
EA250: Gross Alpha and Beta Activity (QCLot: 1690356)								
EA250-LSC: Gross alpha	----	0.05	Bq/L	<0.05	1751 Bq/L	99.4	70	130
EA250-LSC: Gross beta activity - 40K	----	0.1	Bq/L	<0.10	3342 Bq/L	99.8	70	130
ED037P: Alkalinity by PC Titrator (QCLot: 1683361)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	106	88	109
ED040F: Dissolved Major Anions (QCLot: 1681596)								
ED040F: Silicon	7440-21-3	0.05	mg/L	<0.05	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1681595)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	108	92	115
				<1	100 mg/L	106	92	115
ED045G: Chloride by Discrete Analyser (QCLot: 1681593)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	103	88	118
				<1	1000 mg/L	108	88	118
ED093F: Dissolved Major Cations (QCLot: 1683420)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	5 mg/L	94.4	93	110
ED093F: Magnesium	7439-95-4	1	mg/L	<1	5 mg/L	95.2	91	110
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	98.0	90	109
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	95.8	89	109
EG020F: Dissolved Metals by ICP-MS (QCLot: 1683417)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	97.5	91	107
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	103	82	113
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	87.6	84	106
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	88.8	84	104
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	87.8	83	103
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	96.6	83	106
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	93.9	82	103
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	92.2	83	105
EG020A-F: Lithium	7439-93-2	0.001	mg/L	<0.001	0.1 mg/L	106	82	110
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	90.6	83	105
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	94.2	82	106

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG020F: Dissolved Metals by ICP-MS (QCLot: 1683417) - continued								
EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	96.8	82	109
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	87.6	83	106
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	98.3	85	109
EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	0.5 mg/L	100.0	84	116
EG020A-F: Bromine	7726-95-6	0.1	mg/L	<0.1	----	----	----	----
EG020A-F: Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----
EG020F: Dissolved Metals by ICP-MS (QCLot: 1683419)								
EG020B-F: Strontium	7440-24-6	0.001	mg/L	<0.001	0.1 mg/L	98.4	83	109
EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.001	0.1 mg/L	101	84	110
EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.001	0.1 mg/L	101	82	108
EG020T: Total Metals by ICP-MS (QCLot: 1683414)								
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	98.8	88	111
EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	101	80	120
EG035F: Dissolved Mercury by FIMS (QCLot: 1683418)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.01 mg/L	99.1	81	114
EK040P: Fluoride by PC Titrator (QCLot: 1683363)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	109	85	112
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1681594)								
EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	0.5 mg/L	107	94	107
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1694616)								
EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.5 mg/L	98.0	89	114
EK085F: Dissolved Sulfide as S2- (QCLot: 1683781)								
EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	0.5 mg/L	99.4	82	116
EP002: Dissolved Organic Carbon (DOC) (QCLot: 1694024)								
EP002: Dissolved Organic Carbon	----	1	mg/L	<1	10 mg/L	97.3	71	121

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1681595)							
EM1808537-002	W02C	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	100 mg/L	# Not Determined	70	130
ED045G: Chloride by Discrete Analyser (QCLot: 1681593)							

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	High
ED045G: Chloride by Discrete Analyser (QCLot: 1681593) - continued							
EM1807682-019	Anonymous	ED045G: Chloride	16887-00-6	400 mg/L	99.9	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 1683417)							
EM1808537-001	W01	EG020A-F: Arsenic	7440-38-2	0.2 mg/L	110	85	131
		EG020A-F: Beryllium	7440-41-7	0.2 mg/L	102	73	141
		EG020A-F: Barium	7440-39-3	0.2 mg/L	103	75	127
		EG020A-F: Cadmium	7440-43-9	0.05 mg/L	96.4	81	133
		EG020A-F: Chromium	7440-47-3	0.2 mg/L	98.8	71	135
		EG020A-F: Cobalt	7440-48-4	0.2 mg/L	106	78	132
		EG020A-F: Copper	7440-50-8	0.2 mg/L	101	76	130
		EG020A-F: Lead	7439-92-1	0.2 mg/L	101	75	133
		EG020A-F: Manganese	7439-96-5	0.2 mg/L	119	64	134
		EG020A-F: Nickel	7440-02-0	0.2 mg/L	103	73	131
		EG020A-F: Vanadium	7440-62-2	0.2 mg/L	100	73	131
		EG020A-F: Zinc	7440-66-6	0.2 mg/L	106	75	131
EG020T: Total Metals by ICP-MS (QCLot: 1683414)							
EM1808482-004	Anonymous	EG020A-T: Manganese	7439-96-5	1 mg/L	90.9	73	123
EG035F: Dissolved Mercury by FIMS (QCLot: 1683418)							
EM1808537-002	W02C	EG035F: Mercury	7439-97-6	0.01 mg/L	88.9	70	120
EK040P: Fluoride by PC Titrator (QCLot: 1683363)							
EM1808537-003	W03	EK040P: Fluoride	16984-48-8	5 mg/L	123	70	130
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1681594)							
EM1808537-002	W02C	EK057G: Nitrite as N	14797-65-0	0.5 mg/L	102	80	114
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1694616)							
EM1808537-002	W02C	EK059G: Nitrite + Nitrate as N	----	0.5 mg/L	86.1	70	130
EP002: Dissolved Organic Carbon (DOC) (QCLot: 1694024)							
EM1808537-002	W02C	EP002: Dissolved Organic Carbon	----	100 mg/L	81.9	70	130

ALS Environmental

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM1808537**	Page	: 1 of 8
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 25-May-2018
Site	: NRWMF Site Characterisation	Issue Date	: 13-Jun-2018
Sampler	: JE	No. of samples received	: 6
Order number	: 60565376.4.0	No. of samples analysed	: 6

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	EM1808537--002	W02C	**Sulfate as SO4 - Turbidimetric**	14808-79-8	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA005P: pH by PC Titrator						
Clear Plastic Bottle - Natural						
W01, W02C, W03, W04, W02S, RB01	----	----	----	29-May-2018	23-May-2018	**6**

Outliers : Frequency of Quality Control Samples

Matrix: **WATER**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Laboratory Control Samples (LCS)					
Major Anions - Dissolved	0	20	0.00	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	***Sample Date***	*Extraction / Preparation*			*Analysis*		
Container */ Client Sample ID(s)*		***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	23-May-2018	×

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	20-Jun-2018	✓
EA250: Gross Alpha and Beta Activity							
Clear Plastic Bottle - Unspecified; Lab-acidified (EA250-LSC)							
W01, W02C, W03, W04, W02S	**23-May-2018**	**----**	----	----	**31-May-2018**	19-Nov-2018	✓
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	06-Jun-2018	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural (ED040F)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**28-May-2018**	20-Jun-2018	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	20-Jun-2018	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	20-Jun-2018	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Filtered; Lab-acidified (ED093F)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	20-Jun-2018	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG020B-F)							
W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	19-Nov-2018	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EG020A-T) W01, W02C, W03, W04, W02S	**23-May-2018**	**29-May-2018**	19-Nov-2018	✓	**29-May-2018**	19-Nov-2018	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG035F) W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**31-May-2018**	20-Jun-2018	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P) W01, W02C, W03, W04, W02S, RB01	**23-May-2018**	**----**	----	----	**29-May-2018**	20-Jun-2018	✓
EK057G: Nitrite as N by Discrete Analyser							
Clear Plastic Bottle - Natural (EK057G) W01, W02C, W03, W04, W02S	**23-May-2018**	**----**	----	----	**25-May-2018**	25-May-2018	✓
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser							
Clear Plastic Bottle - Sulfuric Acid (EK059G) W01, W02C, W03, W04, W02S	**23-May-2018**	**----**	----	----	**04-Jun-2018**	20-Jun-2018	✓
EK085F: Dissolved Sulfide as S2-							
Clear Plastic Bottle - Zn Acetate/NaOH-FLOCCULATED (EK085F) W01, W02C, W03, W04, W02S	**23-May-2018**	**----**	----	----	**29-May-2018**	30-May-2018	✓
EP002: Dissolved Organic Carbon (DOC)							
Amber DOC Filtered- Sulfuric Preserved (EP002) W01, W02C, W03, W04, W02S	**23-May-2018**	**----**	----	----	**01-Jun-2018**	20-Jun-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type / *Analytical Methods*	*Method*	Count *QC*	Count *Regular*	Rate (%) ***Actual***	Rate (%) ***Expected***	*Evaluation*	*Quality Control Specification*
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	4	40	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Organic Carbon	EP002	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	2	18	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Gross Alpha and Beta Activity	EA250-LSC	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	5	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	2	17	**11.76**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	2	40	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Organic Carbon	EP002	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Gross Alpha and Beta Activity	EA250-LSC	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	0	20	**0.00**	**5.00**	✗	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Method Blanks (MB) - Continued							
Conductivity by PC Titrator	EA010-P	2	40	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Organic Carbon	EP002	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Gross Alpha and Beta Activity	EA250-LSC	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Organic Carbon	EP002	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Gross Alpha and Beta Activity	EA250-LSC	WATER	In house: Referenced to ASTM D7283-06: Determination of gross alpha and gross beta radioactivity in water samples by Liquid Scintillation Counting (LSC).
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Major Anions - Dissolved	ED040F	WATER	In house: Referenced to APHA 3120. The 0.45µm filtered samples are determined by ICP/AES for Sulfur and/or Silcon content and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Analytical Methods	Method	Matrix	Method Descriptions
Dissolved Metals by ICP-MS - Suite B	EG020B-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Mercury by FIMS	EG035F	WATER	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45µm filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite as N by Discrete Analyser	EK057G	WATER	In house: Referenced to APHA 4500-NO2- B. Nitrite is determined by direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Nitrate as N by Discrete Analyser	EK058G	WATER	In house: Referenced to APHA 4500-NO3- F. Nitrate is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	WATER	In house: Referenced to APHA 4500-NO3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Chemical Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Sulfide as S2-	EK085F	WATER	In house: Referenced to APHA 4500-S2- D. Water samples are flocculated in the field using AlCl3. The clear supernatant is and immediately precipitated when transferred to a predosed caustic/zinc acetate preserved sample container. After the supernatant is discarded, the resultant precipitate is then coloured using methylene blue indicator and measured using UV-VIS detection at 664nm. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Organic Carbon	EP002	WATER	In house: Referenced to APHA 5310 B. This method is compliant with NEPM (2013) Schedule B(3) . Samples are combusted at high termperature in the presence of an oxidative catalyst. The evolved carbon dioxide is quantified using an IR detector.

Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals	EN25	WATER	In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **EM1808537**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: melinda.morris@aecom.com	E-mail	: peter.ravlic@alsglobal.com
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Facsimile	: +61 08 83661001	Facsimile	: +61-3-8549 9626
Project	: 60565376	Page	: 1 of 3
Order number	: 60565376.4.0	Quote number	: EM2017URSSA0002 (EN/004/16)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: NRWMF Site Characterisation		
Sampler	: JE		

Dates

Date Samples Received	: 25-May-2018 10:45	Issue Date	: 29-May-2018
Client Requested Due Date	: 12-Jun-2018	Scheduled Reporting Date	: **12-Jun-2018**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 2	Temperature	: 6.5°C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 6 / 6

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please direct any queries related to sample condition / numbering / breakages to Client Services.**
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- **Analytical work for this work order will be conducted at ALS Springvale, ALS Sydney and ALS Canberra.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Radiological analysis will be undertaken by ALS WRG Canberra, NATA accreditation no. 992, site no. 1531. The estimated TAT for this analysis is 15 working days.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EA010P Electrical Conductivity (PCT)	WATER - EA250-LSC Gross Alpha and Beta Activity	WATER - EG020F Dissolved Metals by ICP/MS	WATER - EK085F Dissolved Sulfide as S2-	WATER - EP002 Dissolved Organic Carbon (DOC)	WATER - NT-01 & 02A Ca, Mg, Na, K, Cl, SO4, Alkalinity & Fluoride	WATER - W-03 15 Metals (NEPM Suite)
EM1808537-001	23-May-2018 00:00	W01	✓	✓	✓	✓	✓	✓	✓
EM1808537-002	23-May-2018 00:00	W02C	✓	✓	✓	✓	✓	✓	✓
EM1808537-003	23-May-2018 00:00	W03	✓	✓	✓	✓	✓	✓	✓
EM1808537-004	23-May-2018 00:00	W04	✓	✓	✓	✓	✓	✓	✓
EM1808537-005	23-May-2018 00:00	W02S	✓	✓	✓	✓	✓	✓	✓
EM1808537-006	23-May-2018 00:00	RB01	✓		✓			✓	✓

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EA005P pH (PCT)	WATER - EG020T Total Metals by ICP/MS (including digestion)	WATER - EG052F Silicon Silicon by ICPAES (ED040F)	WATER - EK058G Nitrate as N by Discrete Analyser
EM1808537-001	23-May-2018 00:00	W01	✓	✓	✓	✓
EM1808537-002	23-May-2018 00:00	W02C	✓	✓	✓	✓
EM1808537-003	23-May-2018 00:00	W03	✓	✓	✓	✓
EM1808537-004	23-May-2018 00:00	W04	✓	✓	✓	✓
EM1808537-005	23-May-2018 00:00	W02S	✓	✓	✓	✓
EM1808537-006	23-May-2018 00:00	RB01	✓		✓	

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER**

Evaluation: = Holding time breach ; ✓ = Within holding time.

Method Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received Date	Samples Received Evaluation	Instructions Received Date	Instructions Received Evaluation
EA005-P: pH by PC Titrator							
RB01	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----
W01	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----
W02C	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----
W02S	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----
W03	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----

W04	Clear Plastic Bottle - Natural	----	23-May-2018	25-May-2018		----	----

Requested Deliverables

ADELAIDE URS CORP

- *AU Certificate of Analysis - NATA (COA)	Email	adelaide@ursCORP.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	adelaide@ursCORP.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	adelaide@ursCORP.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	adelaide@ursCORP.com
- Chain of Custody (CoC) (COC)	Email	adelaide@ursCORP.com
- EDI Format - ENMRG (ENMRG)	Email	adelaide@ursCORP.com
- EDI Format - ESDAT (ESDAT)	Email	adelaide@ursCORP.com

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	ap_customerservice.anz@aecom.com

MELINDA MORRIS

- *AU Certificate of Analysis - NATA (COA)	Email	melinda.morris@aecom.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	melinda.morris@aecom.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	melinda.morris@aecom.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	melinda.morris@aecom.com
- A4 - AU Tax Invoice (INV)	Email	melinda.morris@aecom.com
- Chain of Custody (CoC) (COC)	Email	melinda.morris@aecom.com
- EDI Format - ENMRG (ENMRG)	Email	melinda.morris@aecom.com
- EDI Format - ESDAT (ESDAT)	Email	melinda.morris@aecom.com

FREIGHT

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS: JE		SIGNED:	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

UPDATED COC BY
MELINDA 17/05/18

Please forward QC field duplicates to ALS Sydney

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical Conductivity, Major Anions & Cations, Si & Alkalinity & Iodine & Bromine & Fluorine – 500ml Green	Dissolved Metals – NEPM 15 (W-3) + Li, Sr, Th, U – 60ml Red/Green bottle (Field Filtered)	Dissolved Nitrate (as N) - 60ml Purple 2 day holding time	Dissolved Organic Carbon – 40ml Purple Vial (Field Filtered)	Total Metals (Fe, Mn) – 60ml Red/Green unfiltered	Dissolved Sulfide – 125ml Yellow	Gross alpha and Gross beta - 1 L Red/Green unpreserved	TRH/BTEXN/PAH/Phenols (W-24) + OC and OP (W-12) - 100ml Amber + 40 ml vials
1	wallerberdina			W	W01	23.5.18				1	1	1	1	1	1	1	HOLD
2	〃	〃		W	W02C	〃 〃				1	1	1	1	1	1	1	HOLD
3	〃	〃		W	W03	〃 〃				1	1	1	1	1	1	1	HOLD
4	〃	〃		W	W04	〃 〃				1	1	1	1	1	1	1	HOLD
5	〃	〃		W	W02S	〃 〃				1	1	1	1	1	1	1	HOLD
6	〃	〃		W	RB01	〃 〃				1	1						HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
								TOTAL									

Custody Seal ?	Y N NA	RELINQUISHED BY: JE	CHECKED:		CONTAINER TYPE AND PRESERVATIVE CODES
Samples Cold ?	Y N NA	DATE: 24.5.18	TIME:		P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
Comments:		RECEIVED BY:	CHECKED:		S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
		DATE:	TIME:		Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

25/5/18 @ 11.18am

Environmental Division
Melbourne
Work Order Reference
EM1808537

Telephone : + 61-3-8549 9600

CERTIFICATE OF ANALYSIS

Work Order	: **EM1809076**	Page	: 1 of 4
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018 10:25
Order number	: 60565376.4.0	Date Analysis Commenced	: 06-Jun-2018
C-O-C number	: ----	Issue Date	: 08-Jun-2018 12:52
Sampler	: SP		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 2		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nikki Stepniewski	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK085F: EM1809076 #1- Sample has been diluted prior to analysis due to matrix effect. LOR has been raised accordingly.
- EA010-P: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- ED040F:EM1809076_001 has been diluted prior to silicon analysis due to sample matrix. LOR has been raised accordingly.
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- This is a split batch of EM1809078 due to fast turnaround requested. Gross alpha & Gross beta analysis on a standard TAT.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

[illegible]

Sub-Matrix: **WATER** (Matrix: **WATER**)	[illegible]			**W02D_20180601**	----	----	----	----
	[illegible]			01-Jun-2018 00:00	----	----	----	----
[illegible]	[illegible]	[illegible]	[illegible]	**EM1809076-001**	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.14**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**32700**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**108**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**108**	----	----	----	----
ED040F: Dissolved Major Anions								
Silicon	7440-21-3	0.05	mg/L	**1.66**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**148**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**10700**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**699**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**221**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**1550**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**7760**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	**0.08**	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.306**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.024**	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.027**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**3.56**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.504**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.710**	----	----	----	----

Sub-Matrix: WATER
(Matrix: WATER)

				W02D_20180601	----	----	----	----
				01-Jun-2018 00:00	----	----	----	----
				EM1809076-001	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Lithium	7439-93-2	0.001	mg/L	**0.132**	----	----	----	----
Strontium	7440-24-6	0.001	mg/L	**1.14**	----	----	----	----
Thorium	7440-29-1	0.001	mg/L	**0.002**	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	----	----	----	----
Bromine	7726-95-6	0.1	mg/L	**32.8**	----	----	----	----
Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----
EG020T: Total Metals by ICP-MS								
Manganese	7439-96-5	0.001	mg/L	**7.51**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**308**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.5**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.12**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.12**	----	----	----	----
EK085F: Dissolved Sulfide as S2-								
Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<2.0	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**307**	----	----	----	----
Total Cations	----	0.01	meq/L	**319**	----	----	----	----
Ionic Balance	----	0.01	%	**1.90**	----	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**24**	----	----	----	----

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **EM1809076**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: melinda.morris@aecom.com	E-mail	: peter.ravlic@alsglobal.com
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Facsimile	: +61 08 83661001	Facsimile	: +61-3-8549 9626
Project	: 60565376	Page	: 1 of 3
Order number	: 60565376.4.0	Quote number	: EM2017URSSA0002 (EN/004/16)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: NRWMF Site Characterisation		
Sampler	: SP		

Dates

Date Samples Received	: 05-Jun-2018 10:25	Issue Date	: 05-Jun-2018
Client Requested Due Date	: 07-Jun-2018	Scheduled Reporting Date	: **07-Jun-2018**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 5.8°C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 2 / 1

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please direct any queries related to sample condition / numbering / breakages to Client Services.**
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- **Analytical work for this work order will be conducted at ALS Springvale.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- This is a split batch of EM1809078 due to fast turnaround requested. Gross alpha & Gross beta analysis on a standard TAT.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

 No sample container / preservation non-compliance exists.

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EA010P Electrical Conductivity (PCT)	WATER - EG020F Dissolved Metals by ICP/MS	WATER - EG052F Silicon Silicon by ICPAES (ED040F)	WATER - EK058G Nitrate as N by Discrete Analyser	WATER - EK085F Dissolved Sulfide as S2-	WATER - NT-01 & 02A Ca, Mg, Na, K, Cl, SO4, Alkalinity & Fluoride	WATER - W-03 15 Metals (NEPM Suite)
EM1809076-001	01-Jun-2018 00:00	W02D_20180601							

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	(On Hold) WATER No analysis requested	WATER - EA005P pH (PCT)	WATER - EG020T Total Metals by ICP/MS (including digestion)	WATER - EP005 Total Organic Carbon (TOC)
EM1809076-001	01-Jun-2018 00:00	W02D_20180601				
EM1809076-002	[01-Jun-2018]	Unlabelled bottle				

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER** Evaluation: = Holding time breach ; = Within holding time.

Method Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received Date	Samples Received Evaluation	Instructions Received Date	Instructions Received Evaluation
EA005-P: pH by PC Titrator							
W02D_20180601	Clear Plastic Bottle - Natural	----	01-Jun-2018	05-Jun-2018		----	----
EK057G: Nitrite as N by Discrete Analyser							
W02D_20180601	Clear Plastic Bottle - Natural	----	03-Jun-2018	05-Jun-2018		----	----

Requested Deliverables

ADELAIDE URS CORP		
- *AU Certificate of Analysis - NATA (COA)	Email	adelaide@ursCORP.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	adelaide@ursCORP.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	adelaide@ursCORP.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	adelaide@ursCORP.com
- Chain of Custody (CoC) (COC)	Email	adelaide@ursCORP.com
- EDI Format - ENMRG (ENMRG)	Email	adelaide@ursCORP.com
- EDI Format - ESDAT (ESDAT)	Email	adelaide@ursCORP.com
ALL INVOICES		
- A4 - AU Tax Invoice (INV)	Email	ap_customerservice.anz@aecom.com
MELINDA MORRIS		
- *AU Certificate of Analysis - NATA (COA)	Email	melinda.morris@aecom.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	melinda.morris@aecom.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	melinda.morris@aecom.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	melinda.morris@aecom.com
- A4 - AU Tax Invoice (INV)	Email	melinda.morris@aecom.com
- Chain of Custody (CoC) (COC)	Email	melinda.morris@aecom.com
- EDI Format - ENMRG (ENMRG)	Email	melinda.morris@aecom.com
- EDI Format - ESDAT (ESDAT)	Email	melinda.morris@aecom.com

QUALITY CONTROL REPORT

Work Order	: **EM1809076**	Page	: 1 of 7
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018
Order number	: 60565376.4.0	Date Analysis Commenced	: 06-Jun-2018
C-O-C number	: ----	Issue Date	: 08-Jun-2018
Sampler	: SP		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 2		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nikki Stepniewski	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA005P: pH by PC Titrator (QC Lot: 1703710)									
EM1809064-001	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	6.96	6.97	0.144	0% - 20%
EM1809096-005	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	6.77	5.83	14.9	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 1703711)									
EM1809064-001	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	187	188	0.746	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 1703709)									
EM1809056-002	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	<1	<1	0.00	No Limit
ED040F: Dissolved Major Anions (QC Lot: 1704718)									
EM1809076-001	W02D_20180601	ED040F: Silicon	7440-21-3	0.05	mg/L	1.66	1.50	10.3	No Limit
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 1704721)									
EM1809076-001	W02D_20180601	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	148	149	0.00	0% - 20%
ED045G: Chloride by Discrete Analyser (QC Lot: 1704720)									
EM1809115-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	12	12	0.00	0% - 50%
EM1809076-001	W02D_20180601	ED045G: Chloride	16887-00-6	1	mg/L	10700	10600	0.888	0% - 20%
ED093F: Dissolved Major Cations (QC Lot: 1703891)									
EM1808913-023	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	337	348	3.19	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	520	539	3.62	0% - 20%
		ED093F: Sodium	7440-23-5	1	mg/L	1820	1880	2.80	0% - 20%
		ED093F: Potassium	7440-09-7	1	mg/L	58	59	1.87	0% - 20%
EM1809069-001	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	39	37	5.10	0% - 50%
		ED093F: Magnesium	7439-95-4	1	mg/L	26	24	6.68	0% - 50%
		ED093F: Sodium	7440-23-5	1	mg/L	1970	1920	2.28	0% - 20%

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
ED093F: Dissolved Major Cations (QC Lot: 1703891) - continued									
EM1809069-001	Anonymous	ED093F: Potassium	7440-09-7	1	mg/L	908	886	2.41	0% - 20%
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1703892)									
EM1809010-019	Anonymous	EG020B-F: Strontium	7440-24-6	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1703893)									
EM1809056-007	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.005	0.005	0.00	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.008	0.009	0.00	No Limit
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	0.003	0.003	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.054	0.053	2.71	0% - 20%
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lithium	7439-93-2	0.001	mg/L	0.003	0.003	0.00	No Limit
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.008	0.008	0.00	No Limit
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.008	0.008	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.208	0.205	1.16	0% - 20%
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.00	No Limit
		EG020A-F: Bromine	7726-95-6	0.1	mg/L	0.4	0.4	0.00	No Limit
		EG020A-F: Iodine	7553-56-2	0.1	mg/L	0.4	0.4	0.00	No Limit
EG020T: Total Metals by ICP-MS (QC Lot: 1703885)									
EM1809021-076	Anonymous	EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.001	0.001	0.00	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.00	No Limit
EM1809076-001	W02D_20180601	EG020A-T: Manganese	7439-96-5	0.001	mg/L	7.51	7.23	3.85	0% - 20%
		EG020A-T: Iron	7439-89-6	0.05	mg/L	308	293	5.18	0% - 20%
EG035F: Dissolved Mercury by FIMS (QC Lot: 1703890)									
EM1808913-012	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EM1809010-019	Anonymous	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 1703712)									
EM1809096-005	Anonymous	EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EK057G: Nitrite as N by Discrete Analyser (QC Lot: 1704719)									
EM1809076-001	W02D_20180601	EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	0.00	No Limit
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 1704066)									
EM1808851-009	Anonymous	EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	0.03	0.03	0.00	No Limit
EK085F: Dissolved Sulfide as S2- (QC Lot: 1704998)									
EM1809076-001	W02D_20180601	EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<2.0	<2.0	0.00	No Limit

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EP005: Total Organic Carbon (TOC) (QC Lot: 1704188)									
EM1809076-001	W02D_20180601	EP005: Total Organic Carbon	----	1	mg/L	24	23	0.00	0% - 20%

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA010P: Conductivity by PC Titrator (QCLot: 1703711)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1412 µS/cm	102	85	119
ED037P: Alkalinity by PC Titrator (QCLot: 1703709)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	101	88	109
ED040F: Dissolved Major Anions (QCLot: 1704718)								
ED040F: Silicon	7440-21-3	0.05	mg/L	<0.05	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1704721)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	97.8	92	115
				<1	100 mg/L	108	92	115
ED045G: Chloride by Discrete Analyser (QCLot: 1704720)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	92.7	88	118
				<1	1000 mg/L	108	88	118
ED093F: Dissolved Major Cations (QCLot: 1703891)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	5 mg/L	105	93	110
ED093F: Magnesium	7439-95-4	1	mg/L	<1	5 mg/L	99.4	91	110
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	100	90	109
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	98.7	89	109
EG020F: Dissolved Metals by ICP-MS (QCLot: 1703892)								
EG020B-F: Strontium	7440-24-6	0.001	mg/L	<0.001	0.1 mg/L	102	83	109
EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.001	0.1 mg/L	106	84	110
EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.001	0.1 mg/L	99.1	82	108
EG020F: Dissolved Metals by ICP-MS (QCLot: 1703893)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	101	91	107
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	89.5	82	113
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	97.9	84	106
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	100	84	104
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	89.2	83	103
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	97.5	83	106
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	97.4	82	103
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	96.3	83	105
EG020A-F: Lithium	7439-93-2	0.001	mg/L	<0.001	0.1 mg/L	95.6	82	110
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	91.6	83	105
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	96.4	82	106
EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	100	82	109

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EG020F: Dissolved Metals by ICP-MS (QCLot: 1703893) - continued								
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	92.5	83	106
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	101	85	109
EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	0.5 mg/L	98.7	84	116
EG020A-F: Bromine	7726-95-6	0.1	mg/L	<0.1	----	----	----	----
EG020A-F: Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----
EG020T: Total Metals by ICP-MS (QCLot: 1703885)								
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	98.4	88	111
EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	99.8	80	120
EG035F: Dissolved Mercury by FIMS (QCLot: 1703890)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.01 mg/L	105	81	114
EK040P: Fluoride by PC Titrator (QCLot: 1703712)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	104	85	112
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1704719)								
EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	0.5 mg/L	101	94	107
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1704066)								
EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.5 mg/L	93.5	89	114
EK085F: Dissolved Sulfide as S2- (QCLot: 1704998)								
EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	0.5 mg/L	93.2	82	116
EP005: Total Organic Carbon (TOC) (QCLot: 1704188)								
EP005: Total Organic Carbon	----	1	mg/L	<1	100 mg/L	96.9	81	109

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
				Concentration	MS	Low	High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1704721)							
EM1809077-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	100 mg/L	90.4	70	130
ED045G: Chloride by Discrete Analyser (QCLot: 1704720)							
EM1809077-001	Anonymous	ED045G: Chloride	16887-00-6	400 mg/L	106	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 1703893)							
EM1809056-007	Anonymous	EG020A-F: Arsenic	7440-38-2	0.2 mg/L	96.6	85	131
		EG020A-F: Beryllium	7440-41-7	0.2 mg/L	98.2	73	141
		EG020A-F: Barium	7440-39-3	0.2 mg/L	95.1	75	127
		EG020A-F: Cadmium	7440-43-9	0.05 mg/L	98.9	81	133

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	High
EG020F: Dissolved Metals by ICP-MS (QCLot: 1703893) - continued							
EM1809056-007	Anonymous	EG020A-F: Chromium	7440-47-3	0.2 mg/L	91.4	71	135
		EG020A-F: Cobalt	7440-48-4	0.2 mg/L	95.7	78	132
		EG020A-F: Copper	7440-50-8	0.2 mg/L	98.3	76	130
		EG020A-F: Lead	7439-92-1	0.2 mg/L	93.4	75	133
		EG020A-F: Manganese	7439-96-5	0.2 mg/L	93.0	64	134
		EG020A-F: Nickel	7440-02-0	0.2 mg/L	91.9	73	131
		EG020A-F: Vanadium	7440-62-2	0.2 mg/L	93.2	73	131
		EG020A-F: Zinc	7440-66-6	0.2 mg/L	90.5	75	131
EG020T: Total Metals by ICP-MS (QCLot: 1703885)							
EM1809021-076	Anonymous	EG020A-T: Manganese	7439-96-5	1 mg/L	98.4	73	123
EG035F: Dissolved Mercury by FIMS (QCLot: 1703890)							
EM1808924-001	Anonymous	EG035F: Mercury	7439-97-6	0.01 mg/L	# 55.2	70	120
EK040P: Fluoride by PC Titrator (QCLot: 1703712)							
EM1809096-006	Anonymous	EK040P: Fluoride	16984-48-8	5 mg/L	113	70	130
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1704719)							
EM1809115-001	Anonymous	EK057G: Nitrite as N	14797-65-0	0.5 mg/L	99.1	80	114
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1704066)							
EM1808851-010	Anonymous	EK059G: Nitrite + Nitrate as N	----	0.5 mg/L	85.1	70	130

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM1809076**	Page	: 1 of 8
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018
Site	: NRWMF Site Characterisation	Issue Date	: 08-Jun-2018
Sampler	: SP	No. of samples received	: 2
Order number	: 60565376.4.0	No. of samples analysed	: 1

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
EG035F: Dissolved Mercury by FIMS	EM1808924--001	Anonymous	**Mercury**	7439-97-6	55.2 %	70-120%	**Recovery less than lower data quality objective**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method / **Container** / Client Sample ID(s)	*Extraction / Preparation* Date extracted	Due for extraction	**Days overdue**	*Analysis* Date analysed	Due for analysis	**Days overdue**
EA005P: pH by PC Titrator						
Clear Plastic Bottle - Natural W02D_20180601	----	----	----	06-Jun-2018	01-Jun-2018	**5**
EK057G: Nitrite as N by Discrete Analyser						
Clear Plastic Bottle - Natural W02D_20180601	----	----	----	06-Jun-2018	03-Jun-2018	**3**

Outliers : Frequency of Quality Control Samples

Matrix: **WATER**

Quality Control Sample Type / Method	Count QC	Count Regular	Rate (%) Actual	Rate (%) Expected	Quality Control Specification
Laboratory Control Samples (LCS)					
Major Anions - Dissolved	0	1	0.00	5.00	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)					
Total Organic Carbon	0	1	0.00	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation* Date extracted	Due for extraction	Evaluation	*Analysis* Date analysed	Due for analysis	Evaluation
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P) W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	01-Jun-2018	×

Matrix: **WATER**

Evaluation: ✗ = Holding time breach ; ✓ = Within holding time.

Method	Sample Date	Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	15-Jun-2018	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural (ED040F)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Filtered; Lab-acidified (ED093F)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG020B-F)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	28-Nov-2018	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EG020A-T)							
W02D_20180601	**01-Jun-2018**	**06-Jun-2018**	28-Nov-2018	✓	**06-Jun-2018**	28-Nov-2018	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG035F)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
EK057G: Nitrite as N by Discrete Analyser							
Clear Plastic Bottle - Natural (EK057G)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	03-Jun-2018	✗
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser							
Clear Plastic Bottle - Sulfuric Acid (EK059G)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
EK085F: Dissolved Sulfide as S2-							
Clear Plastic Bottle - Zn Acetate/NaOH-FLOCCULATED (EK085F)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	08-Jun-2018	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EP005: Total Organic Carbon (TOC)							
Amber VOC Vial - Sulfuric Acid (EP005)							
W02D_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type / *Analytical Methods*	*Method*	*Count* QC	*Count* Regular	*Rate (%)* **Actual**	*Rate (%)* **Expected**	*Evaluation*	*Quality Control Specification*
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	1	7	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	8	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	7	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	1	**100.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	1	1	**100.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	2	13	**15.38**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	14	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	1	**100.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	8	**12.50**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	0	1	**0.00**	**5.00**	✗	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	13	**7.69**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	5	**40.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	8	**12.50**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Matrix: **WATER**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Method Blanks (MB) - Continued							
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	13	**7.69**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	7	**14.29**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	5	**20.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	0	1	**0.00**	**5.00**	✗	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Major Anions - Dissolved	ED040F	WATER	In house: Referenced to APHA 3120. The 0.45µm filtered samples are determined by ICP/AES for Sulfur and/or Silcon content and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Metals by ICP-MS - Suite B	EG020B-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Analytical Methods	Method	Matrix	Method Descriptions
Dissolved Mercury by FIMS	EG035F	WATER	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45µm filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite as N by Discrete Analyser	EK057G	WATER	In house: Referenced to APHA 4500-NO2- B. Nitrite is determined by direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Nitrate as N by Discrete Analyser	EK058G	WATER	In house: Referenced to APHA 4500-NO3- F. Nitrate is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	WATER	In house: Referenced to APHA 4500-NO3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Chemical Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Sulfide as S2-	EK085F	WATER	In house: Referenced to APHA 4500-S2- D. Water samples are flocculated in the field using AlCl3. The clear supernatant is and immediately precipitated when transferred to a predosed caustic/zinc acetate preserved sample container. After the supernatant is discarded, the resultant precipitate is then coloured using methylene blue indicator and measured using UV-VIS detection at 664nm. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3)
Total Organic Carbon	EP005	WATER	In house: Referenced to APHA 5310 B, The automated TOC analyzer determines Total and Inorganic Carbon by IR cell. TOC is calculated as the difference. This method is compliant with NEPM (2013) Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals	EN25	WATER	In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3)

split batch of EM1809078

FREIGHT **URGENT**

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format. email address: adelaide@urscorp.com	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171		SCANNED 5/6/18
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Steve Partridge	SIGNED:	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

ARRANGED FOR SHORT TURNAROUND ON AVAILABLE ANALYTES

Please forward QC field duplicates to ALS Sydney

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical Conductivity, Major Anions & Cations, Si & Alkalinity & Iodine & Bromine & Fluorine – 500ml Green	Dissolved Metals – NEPM 15 (W-3) + Li, Sr, Th, U – 60ml Red/Green bottle (Field Filtered)	Dissolved Nitrate (as N) - 60ml Purple 2 day holding time	~~Dissolved~~ Total Organic Carbon – 40ml Purple Vial ~~(Field Filtered)~~ P/2 5/6/18	Total Metals (Fe, Mn) – 60ml Red/Green unfiltered	Dissolved Sulfide – 125ml Yellow	Gross alpha and Gross beta - 1 L Red/Green unpreserved	TRH/BTEXN/PAH/Phenols (W-24) + OC and OP (W-12) - 100ml Amber + 40 ml vials
	~~[illegible]~~																HOLD
1	[illegible]	W02D	water	Primary	W02D-20180601	1/6/18	12	2	14	1	1	1	1	1	1	1	HOLD
	"	W02D	"	QC	QC01 -20190601	1/6/18	22	2	14	1	1	1	1	1	1	1	HOLD
																	HOLD
					Q01 BP 5/6												HOLD
2)		Extra sample			Unlabelled	1x 500ml unpreserved green bottle BN 5/6											HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD

Environmental Division
Melbourne
Work Order Reference
EM1809076

Telephone : +61-3-8549 9600

Custody Seal? Y N NA	RELINQUISHED BY: P	CHECKED:	
Samples Cold? Y N NA	DATE: 4/6/18	TIME: 1200	
Comments:	RECEIVED BY:	CHECKED:	
	DATE:	TIME:	

CONTAINER TYPE AND PRESERVATIVE CODES
P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

[illegible] (AM)
5/6, 10:25

CERTIFICATE OF ANALYSIS

Work Order	: **EM1809078**	Page	: 1 of 2
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018 10:25
Order number	: 60565376.4.0	Date Analysis Commenced	: 14-Jun-2018
C-O-C number	: ----	Issue Date	: 25-Jun-2018 14:41
Sampler	: SP		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Gross Alpha and Beta Activity analyses are performed by ALS Fyshwick (NATA Accreditation number 992).
- LOR for gross alpha and beta in sample raised due to the high amount of solid and Potassium present.
- This is a split batch of EM1809076 due to fast turnaround requested. Gross alpha & Gross beta analysis will be reported in this batch on a standard TAT.

Sub-Matrix: **WATER** (Matrix: **WATER**)				**W02D _20180601**	**----**	**----**	**----**	**----**
				01-Jun-2018 00:00	----	----	----	----
				EM1809078-001	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA250: Gross Alpha and Beta Activity								
Gross alpha	----	0.05	Bq/L	<0.50	**----**	**----**	**----**	**----**
Gross beta activity - 40K	----	0.1	Bq/L	<10	**----**	**----**	**----**	**----**

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM1809078**	Page	: 1 of 3
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018
Order number	: 60565376.4.0	Date Analysis Commenced	: 14-Jun-2018
C-O-C number	: ----	Issue Date	: 25-Jun-2018
Sampler	: SP		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA250: Gross Alpha and Beta Activity (QC Lot: 1726229)									
EM1809078-001	W02D _20180601	EA250-LSC: Gross alpha	----	0.05	Bq/L	<0.50	<0.50	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA250: Gross Alpha and Beta Activity (QCLot: 1726229)								
EA250-LSC: Gross alpha	----	0.05	Bq/L	<0.05	1751 Bq/L	99.3	70	130
EA250-LSC: Gross beta activity - 40K	----	0.1	Bq/L	<0.10	3342 Bq/L	99.7	70	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM1809078**	Page	: 1 of 4
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 05-Jun-2018
Site	: NRWMF Site Characterisation	Issue Date	: 25-Jun-2018
Sampler	: SP	No. of samples received	: 1
Order number	: 60565376.4.0	No. of samples analysed	: 1

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA250: Gross Alpha and Beta Activity							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EA250-LSC)							
W02D _20180601	**01-Jun-2018**	----	----	----	**14-Jun-2018**	28-Nov-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: ✗ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Gross Alpha and Beta Activity	EA250-LSC	1	9	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Gross Alpha and Beta Activity	EA250-LSC	2	9	**22.22**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Gross Alpha and Beta Activity	EA250-LSC	1	9	**11.11**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Gross Alpha and Beta Activity	EA250-LSC	WATER	In house: Referenced to ASTM D7283-06: Determination of gross alpha and gross beta radioactivity in water samples by Liquid Scintillation Counting (LSC).

Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **EM1809078**

Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
E-mail	: melinda.morris@aecom.com	E-mail	: peter.ravlic@alsglobal.com
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Facsimile	: +61 08 83661001	Facsimile	: +61-3-8549 9626
Project	: 60565376	Page	: 1 of 2
Order number	: 60565376.4.0	Quote number	: EM2017URSSA0002 (EN/004/16)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: NRWMF Site Characterisation		
Sampler	: SP		

Dates

Date Samples Received	: 05-Jun-2018 10:25	Issue Date	: 05-Jun-2018
Client Requested Due Date	: 19-Jun-2018	Scheduled Reporting Date	: **19-Jun-2018**

Delivery Details

Mode of Delivery	: Carrier	Security Seal	: Intact.
No. of coolers/boxes	: 1	Temperature	: 5.8°C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 1 / 1

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please direct any queries related to sample condition / numbering / breakages to Client Services.**
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- **Analytical work for this work order will be conducted at ALS Canberra.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- This is a split batch of EM1809076 due to fast turnaround requested. Gross alpha & Gross beta analysis will be reported in this batch on a standard TAT.
- Radiological analysis will be undertaken by ALS WRG Canberra, NATA accreditation no. 992, site no. 1531. The estimated TAT for this analysis is 15 working days.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	Client sampling date / time	Client sample ID	WATER - EA250-LSC Gross Alpha and Beta Activity
EM1809078-001	01-Jun-2018 00:00	W02D _20180601	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ADELAIDE URS CORP		
- *AU Certificate of Analysis - NATA (COA)	Email	adelaide@ursCORP.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	adelaide@ursCORP.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	adelaide@ursCORP.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	adelaide@ursCORP.com
- Chain of Custody (CoC) (COC)	Email	adelaide@ursCORP.com
- EDI Format - ENMRG (ENMRG)	Email	adelaide@ursCORP.com
- EDI Format - ESDAT (ESDAT)	Email	adelaide@ursCORP.com
ALL INVOICES		
- A4 - AU Tax Invoice (INV)	Email	ap_customerservice.anz@aecom.com
MELINDA MORRIS		
- *AU Certificate of Analysis - NATA (COA)	Email	melinda.morris@aecom.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	melinda.morris@aecom.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	melinda.morris@aecom.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	melinda.morris@aecom.com
- A4 - AU Tax Invoice (INV)	Email	melinda.morris@aecom.com
- Chain of Custody (CoC) (COC)	Email	melinda.morris@aecom.com
- EDI Format - ENMRG (ENMRG)	Email	melinda.morris@aecom.com
- EDI Format - ESDAT (ESDAT)	Email	melinda.morris@aecom.com

Split batch of EM1809076

Gross Alpha/beta only

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER:	melinda.morris@aecom.com 0408 387 495		
		SAMPLERS:	Steve Partridge	SIGNED:	
PROJECT NO:	60565376.4.0				ANALYSIS REQUIRED

COMMENTS: SPECIAL HANDLING/STORAGE

ARRANGED FOR SHORT TURNAROUND ON AVAILABLE ANALYTES

Please forward QC field duplicates to ALS Sydney

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical Conductivity, Major Anions & Cations, Si & Alkalinity & Iodine & Bromine & Fluorine – 500ml Green	Dissolved Metals – NEPM 15 (W-3) + Li, Sr, Th, U – 60ml Red/Green bottle (Field Filtered)	Dissolved Nitrate (as N) - 60ml Purple 2 day holding time	Dissolved Organic Carbon – 40ml Purple Vial (Field Filtered)	Total Metals (Fe, Mn) – 60ml Red/Green unfiltered	Dissolved Sulfide – 125ml Yellow	Gross alpha and Gross beta - 1 L Red/Green unpreserved	TRH/BTEXN/PAH/Phenols (W-24) + OC and OP (W-12) - 100ml Amber + 40 ml vials
	~~watesbottle~~																HOLD
1	wallesbottle	W02D	water	Primary	W02D-20180601	1/6/18	12	2	14	1	1	1	1	1	1	1	HOLD
2	"	W02D	"	QC	QC01-20180601	1/6/18	22	2	14	1	1	1	1	1	1	1	HOLD
																	HOLD
					QD1 BP 5/6												HOLD
																	HOLD
																	HOLD
																	HOLD
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																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
																	HOLD
								TOTAL									

Environmental Division
Melbourne
Work Order Reference
EM1809078

Telephone : + 61-3-8549 9600

Custody Seal? Y N NA	RELINQUISHED BY: PB	CHECKED:		CONTAINER TYPE AND PRESERVATIVE CODES
Samples Cold? Y N NA	DATE: 4/6/18	TIME: 1200		P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
Comments:	RECEIVED BY:	CHECKED:		S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass B
	DATE:	TIME:		Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

Kasie (Au)
5/6, 10:25

CERTIFICATE OF ANALYSIS

Work Order	: **ES1816445**	Page	: 1 of 4
Amendment	: **1**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018 11:00
Order number	: 60565376.4.0	Date Analysis Commenced	: 06-Jun-2018
C-O-C number	: ----	Issue Date	: 15-Jun-2018 18:57
Sampler	: STEVE PARTRIDGE		
Site	: ----		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK059G-EK058G: LOR raised for NOx - Nitrate on sample 1 due to sample matrix.
- EG020: Bromine and Iodine quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.
- EN055: Ionic Balance out of acceptable limits due to analytes not quantified in this report.
- Amendment (13/06/2018): This report has been amended to add Silicon to sample Q01_20180601 as per the request received from Melinda Morris.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Sub-Matrix: WATER
(Matrix: WATER)

				Q01_20180601	----	----	----	----
				01-Jun-2018 00:00	----	----	----	----
				ES1816445-001	--------	--------	--------	--------
				Result	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.52**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**34900**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**125**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**125**	----	----	----	----
ED040F: Dissolved Major Anions								
Silicon	7440-21-3	0.05	mg/L	**33.8**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**141**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**10500**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**627**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**201**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**1380**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**6970**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	**0.09**	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.282**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.022**	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.028**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**3.43**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.503**	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.694**	----	----	----	----

Sub-Matrix: WATER (Matrix: WATER)				Q01_20180601	----	----	----	----
				01-Jun-2018 00:00	----	----	----	----
				ES1816445-001	--------	--------	--------	--------
				Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Lithium	7439-93-2	0.001	mg/L	**0.138**	----	----	----	----
Strontium	7440-24-6	0.001	mg/L	**10.8**	----	----	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	----	----	----	----
Bromine	7726-95-6	0.1	mg/L	**38.9**	----	----	----	----
Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----
EG020T: Total Metals by ICP-MS								
Manganese	7439-96-5	0.001	mg/L	**5.80**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**216**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.4**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.10	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.10	----	----	----	----
EK085F: Dissolved Sulfide as S2-								
Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**302**	----	----	----	----
Total Cations	----	0.01	meq/L	**286**	----	----	----	----
Ionic Balance	----	0.01	%	**2.64**	----	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**277**	----	----	----	----

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES1816445**	Page	: 1 of 7
Amendment	: **1**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018
Order number	: 60565376.4.0	Date Analysis Commenced	: 06-Jun-2018
C-O-C number	: ----	Issue Date	: 15-Jun-2018
Sampler	: STEVE PARTRIDGE		
Site	: ----		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

NATA

Accreditation No. 825
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ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key :
- Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
- CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
- LOR = Limit of reporting
- RPD = Relative Percentage Difference
- # = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EA005P: pH by PC Titrator (QC Lot: 1706519)									
ES1816237-007	Anonymous	EA005-P: pH Value	----	0.01	pH Unit	6.33	6.33	0.00	0% - 20%
ES1816445-001	Q01_20180601	EA005-P: pH Value	----	0.01	pH Unit	7.52	7.49	0.400	0% - 20%
EA010P: Conductivity by PC Titrator (QC Lot: 1706521)									
ES1816237-007	Anonymous	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	14	13	0.00	0% - 50%
ES1816445-001	Q01_20180601	EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	34900	34700	0.612	0% - 20%
ED037P: Alkalinity by PC Titrator (QC Lot: 1706520)									
ES1816237-007	Anonymous	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	4	3	0.00	No Limit
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	4	3	0.00	No Limit
ES1816445-001	Q01_20180601	ED037-P: Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	0.00	No Limit
		ED037-P: Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	125	122	2.48	0% - 20%
		ED037-P: Total Alkalinity as CaCO3	----	1	mg/L	125	122	2.48	0% - 20%
ED040F: Dissolved Major Anions (QC Lot: 1726166)									
ES1817167-009	Anonymous	ED040F: Silicon	7440-21-3	0.05	mg/L	7.04	6.96	1.11	0% - 20%
ES1817083-001	Anonymous	ED040F: Silicon	7440-21-3	0.05	mg/L	0.69	0.68	0.00	0% - 50%
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QC Lot: 1706262)									
ES1816239-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	163	166	1.52	0% - 20%
ES1816390-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	<1	0.00	No Limit
ED045G: Chloride by Discrete Analyser (QC Lot: 1706263)									
ES1816239-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	263	263	0.00	0% - 20%
ES1816390-001	Anonymous	ED045G: Chloride	16887-00-6	1	mg/L	2	2	0.00	No Limit
ED093F: Dissolved Major Cations (QC Lot: 1707464)									

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
ED093F: Dissolved Major Cations (QC Lot: 1707464) - continued									
ES1816333-001	Anonymous	ED093F: Calcium	7440-70-2	1	mg/L	38	38	0.00	0% - 20%
		ED093F: Magnesium	7439-95-4	1	mg/L	2	2	0.00	No Limit
		ED093F: Sodium	7440-23-5	1	mg/L	9	9	0.00	No Limit
		ED093F: Potassium	7440-09-7	1	mg/L	4	4	0.00	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1707462)									
ES1816333-001	Anonymous	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	0.001	0.002	0.00	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.013	0.013	0.00	0% - 50%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	0.002	0.002	0.00	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.003	0.003	0.00	No Limit
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lithium	7439-93-2	0.001	mg/L	0.003	0.002	0.00	No Limit
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	0.010	0.012	13.0	0% - 50%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	<0.005	0.00	No Limit
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.00	No Limit
		EG020A-F: Bromine	7726-95-6	0.1	mg/L	<0.1	<0.1	0.00	No Limit
		EG020A-F: Iodine	7553-56-2	0.1	mg/L	<0.1	<0.1	0.00	No Limit
ES1816445-001	Q01_20180601	EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Barium	7440-39-3	0.001	mg/L	0.282	0.279	1.24	0% - 20%
		EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Cobalt	7440-48-4	0.001	mg/L	0.022	0.022	0.00	0% - 20%
		EG020A-F: Copper	7440-50-8	0.001	mg/L	0.028	0.028	0.00	0% - 20%
		EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-F: Lithium	7439-93-2	0.001	mg/L	0.138	0.139	0.893	0% - 20%
		EG020A-F: Manganese	7439-96-5	0.001	mg/L	3.43	3.41	0.448	0% - 20%
		EG020A-F: Nickel	7440-02-0	0.001	mg/L	0.503	0.494	1.68	0% - 20%
		EG020A-F: Zinc	7440-66-6	0.005	mg/L	0.694	0.694	0.00	0% - 20%
		EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-F: Boron	7440-42-8	0.05	mg/L	0.09	0.09	0.00	No Limit
		EG020A-F: Bromine	7726-95-6	0.1	mg/L	38.9	39.8	2.16	0% - 20%
		EG020A-F: Iodine	7553-56-2	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1707465)									

Sub-Matrix: **WATER**

Laboratory Duplicate (DUP) Report

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG020F: Dissolved Metals by ICP-MS (QC Lot: 1707465) - continued									
ES1816445-001	Q01_20180601	EG020B-F: Strontium	7440-24-6	0.001	mg/L	10.8	10.8	0.0541	0% - 20%
		EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
EG020T: Total Metals by ICP-MS (QC Lot: 1707519)									
ES1816247-003	Anonymous	EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	0.00	No Limit
ES1816475-001	Anonymous	EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.118	0.128	8.00	0% - 20%
		EG020A-T: Iron	7439-89-6	0.05	mg/L	0.24	0.24	0.00	0% - 20%
EG035F: Dissolved Mercury by FIMS (QC Lot: 1707463)									
ES1816445-001	Q01_20180601	EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EK040P: Fluoride by PC Titrator (QC Lot: 1709915)									
ES1816445-001	Q01_20180601	EK040P: Fluoride	16984-48-8	0.1	mg/L	0.4	0.4	0.00	No Limit
EK057G: Nitrite as N by Discrete Analyser (QC Lot: 1706261)									
ES1816239-001	Anonymous	EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	0.00	No Limit
ES1816390-001	Anonymous	EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	0.00	No Limit
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QC Lot: 1707495)									
ES1816445-001	Q01_20180601	EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.10	<0.10	0.00	No Limit
EK085F: Dissolved Sulfide as S2- (QC Lot: 1711614)									
ES1816331-001	Anonymous	EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1	0.00	No Limit
EP005: Total Organic Carbon (TOC) (QC Lot: 1708490)									
ES1816306-007	Anonymous	EP005: Total Organic Carbon	----	1	mg/L	<1	<1	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	*CAS Number*	*LOR*	*Unit*	*Result*	*Concentration*	*LCS*	*Low*	*High*
EA010P: Conductivity by PC Titrator (QCLot: 1706521)								
EA010-P: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	2000 µS/cm	104	95	113
ED037P: Alkalinity by PC Titrator (QCLot: 1706520)								
ED037-P: Total Alkalinity as CaCO3	----	----	mg/L	----	200 mg/L	108	81	111
				----	50 mg/L	99.1	70	130
ED040F: Dissolved Major Anions (QCLot: 1726166)								
ED040F: Silicon	7440-21-3	0.05	mg/L	<0.05	5 mg/L	114	91	123
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1706262)								
ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	25 mg/L	108	82	122
ED045G: Chloride by Discrete Analyser (QCLot: 1706263)								
ED045G: Chloride	16887-00-6	1	mg/L	<1	10 mg/L	117	81	127
				<1	1000 mg/L	108	81	127
ED093F: Dissolved Major Cations (QCLot: 1707464)								
ED093F: Calcium	7440-70-2	1	mg/L	<1	50 mg/L	96.4	80	114
ED093F: Magnesium	7439-95-4	1	mg/L	<1	50 mg/L	97.5	90	116
ED093F: Sodium	7440-23-5	1	mg/L	<1	50 mg/L	96.4	82	120
ED093F: Potassium	7440-09-7	1	mg/L	<1	50 mg/L	96.0	85	113
EG020F: Dissolved Metals by ICP-MS (QCLot: 1707462)								
EG020A-F: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	91.3	85	114
EG020A-F: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	95.2	85	115
EG020A-F: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	92.9	82	110
EG020A-F: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	90.7	84	110
EG020A-F: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	92.9	85	111
EG020A-F: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	91.1	82	112
EG020A-F: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	91.1	81	111
EG020A-F: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	90.7	83	111
EG020A-F: Lithium	7439-93-2	0.001	mg/L	<0.001	0.1 mg/L	93.1	79	117
EG020A-F: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	92.6	82	110
EG020A-F: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	86.9	82	112
EG020A-F: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	89.0	85	115
EG020A-F: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	93.2	83	109
EG020A-F: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	95.8	81	117
EG020A-F: Boron	7440-42-8	0.05	mg/L	<0.05	0.5 mg/L	105	85	115
EG020A-F: Bromine	7726-95-6	0.1	mg/L	<0.1	----	----	----	----
EG020A-F: Iodine	7553-56-2	0.1	mg/L	<0.1	----	----	----	----

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report Result	Laboratory Control Spike (LCS) Report Spike Concentration	Spike Recovery (%) LCS	Recovery Limits (%) Low	Recovery Limits (%) High
EG020F: Dissolved Metals by ICP-MS (QCLot: 1707465)								
EG020B-F: Strontium	7440-24-6	0.001	mg/L	<0.001	0.1 mg/L	95.2	81	113
EG020B-F: Thorium	7440-29-1	0.001	mg/L	<0.001	0.1 mg/L	97.6	85	115
EG020B-F: Uranium	7440-61-1	0.001	mg/L	<0.001	0.1 mg/L	94.6	85	115
EG020T: Total Metals by ICP-MS (QCLot: 1707519)								
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	91.2	85	113
EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	96.3	85	117
EG035F: Dissolved Mercury by FIMS (QCLot: 1707463)								
EG035F: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.01 mg/L	95.4	83	105
EK040P: Fluoride by PC Titrator (QCLot: 1709915)								
EK040P: Fluoride	16984-48-8	0.1	mg/L	<0.1	5 mg/L	98.2	82	116
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1706261)								
EK057G: Nitrite as N	14797-65-0	0.01	mg/L	<0.01	0.5 mg/L	112	82	114
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1707495)								
EK059G: Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	0.5 mg/L	102	91	113
EK085F: Dissolved Sulfide as S2- (QCLot: 1711614)								
EK085F: Dissolved Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	0.5 mg/L	116	80	120
EP005: Total Organic Carbon (TOC) (QCLot: 1708490)								
EP005: Total Organic Carbon	----	1	mg/L	<1	10 mg/L	93.2	72	120

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA (QCLot: 1706262)							
ES1816239-001	Anonymous	ED041G: Sulfate as SO4 - Turbidimetric	14808-79-8	10 mg/L	# Not Determined	70	130
ED045G: Chloride by Discrete Analyser (QCLot: 1706263)							
ES1816239-001	Anonymous	ED045G: Chloride	16887-00-6	250 mg/L	109	70	130
EG020F: Dissolved Metals by ICP-MS (QCLot: 1707462)							
EP1806724-001	Anonymous	EG020A-F: Arsenic	7440-38-2	1 mg/L	100	70	130
		EG020A-F: Beryllium	7440-41-7	1 mg/L	96.7	70	130
		EG020A-F: Barium	7440-39-3	1 mg/L	97.9	70	130
		EG020A-F: Cadmium	7440-43-9	0.25 mg/L	94.7	70	130
		EG020A-F: Chromium	7440-47-3	1 mg/L	94.4	70	130

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report Spike Concentration	SpikeRecovery(%) MS	Recovery Limits (%) Low	Recovery Limits (%) High
EG020F: Dissolved Metals by ICP-MS (QCLot: 1707462) - continued							
EP1806724-001	Anonymous	EG020A-F: Cobalt	7440-48-4	1 mg/L	98.2	70	130
		EG020A-F: Copper	7440-50-8	1 mg/L	97.7	70	130
		EG020A-F: Lead	7439-92-1	1 mg/L	90.7	70	130
		EG020A-F: Manganese	7439-96-5	1 mg/L	90.2	70	130
		EG020A-F: Nickel	7440-02-0	1 mg/L	97.0	70	130
		EG020A-F: Vanadium	7440-62-2	1 mg/L	94.5	70	130
		EG020A-F: Zinc	7440-66-6	1 mg/L	98.0	70	130
EG020T: Total Metals by ICP-MS (QCLot: 1707519)							
ES1816264-001	Anonymous	EG020A-T: Manganese	7439-96-5	1 mg/L	92.2	70	130
EG035F: Dissolved Mercury by FIMS (QCLot: 1707463)							
EP1806566-010	Anonymous	EG035F: Mercury	7439-97-6	0.01 mg/L	98.1	70	130
EK040P: Fluoride by PC Titrator (QCLot: 1709915)							
ES1816445-001	Q01_20180601	EK040P: Fluoride	16984-48-8	5 mg/L	109	70	130
EK057G: Nitrite as N by Discrete Analyser (QCLot: 1706261)							
ES1816239-001	Anonymous	EK057G: Nitrite as N	14797-65-0	0.5 mg/L	114	70	130
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser (QCLot: 1707495)							
ES1816445-001	Q01_20180601	EK059G: Nitrite + Nitrate as N	----	0.5 mg/L	72.0	70	130
EP005: Total Organic Carbon (TOC) (QCLot: 1708490)							
ES1816306-008	Anonymous	EP005: Total Organic Carbon	----	100 mg/L	80.5	70	130

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES1816445**	Page	: 1 of 7
Amendment	: **1**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018
Site	: ----	Issue Date	: 15-Jun-2018
Sampler	: STEVE PARTRIDGE	No. of samples received	: 1
Order number	: 60565376.4.0	No. of samples analysed	: 1

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Matrix Spike (MS) Recoveries							
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	ES1816239--001	Anonymous	**Sulfate as SO4 - Turbidimetric**	14808-79-8	Not Determined	----	**MS recovery not determined, background level greater than or equal to 4x spike level.**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EA005P: pH by PC Titrator						
Clear Plastic Bottle - Natural Q01_20180601	----	----	----	06-Jun-2018	01-Jun-2018	**5**
EK057G: Nitrite as N by Discrete Analyser						
Clear Plastic Bottle - Natural Q01_20180601	----	----	----	06-Jun-2018	03-Jun-2018	**3**

Outliers : Frequency of Quality Control Samples

Matrix: **WATER**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Matrix Spikes (MS)					
Dissolved Sulfide as S2-	0	4	0.00	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method	*Sample Date*	*Extraction / Preparation*			*Analysis*		
Container */ Client Sample ID(s)*		***Date extracted***	*Due for extraction*	*Evaluation*	***Date analysed***	*Due for analysis*	*Evaluation*
EA005P: pH by PC Titrator							
Clear Plastic Bottle - Natural (EA005-P) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	01-Jun-2018	×
EA010P: Conductivity by PC Titrator							
Clear Plastic Bottle - Natural (EA010-P) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
ED037P: Alkalinity by PC Titrator							
Clear Plastic Bottle - Natural (ED037-P) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	15-Jun-2018	✓
ED040F: Dissolved Major Anions							
Clear Plastic Bottle - Natural (ED040F) Q01_20180601	**01-Jun-2018**	**----**	----	----	**14-Jun-2018**	29-Jun-2018	✓
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA							
Clear Plastic Bottle - Natural (ED041G) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED045G: Chloride by Discrete Analyser							
Clear Plastic Bottle - Natural (ED045G) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	29-Jun-2018	✓
ED093F: Dissolved Major Cations							
Clear Plastic Bottle - Filtered; Lab-acidified (ED093F) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓
EG020F: Dissolved Metals by ICP-MS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG020B-F) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	28-Nov-2018	✓
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EG020A-T) Q01_20180601	**01-Jun-2018**	**07-Jun-2018**	28-Nov-2018	✓	**07-Jun-2018**	28-Nov-2018	✓
EG035F: Dissolved Mercury by FIMS							
Clear Plastic Bottle - Filtered; Lab-acidified (EG035F) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓
EK040P: Fluoride by PC Titrator							
Clear Plastic Bottle - Natural (EK040P) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓
EK057G: Nitrite as N by Discrete Analyser							
Clear Plastic Bottle - Natural (EK057G) Q01_20180601	**01-Jun-2018**	**----**	----	----	**06-Jun-2018**	03-Jun-2018	×
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser							
Clear Plastic Bottle - Sulfuric Acid (EK059G) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓
EK085F: Dissolved Sulfide as S2-							
Clear Plastic Bottle - Zn Acetate/NaOH-FLOCCULATED (EK085F) Q01_20180601	**01-Jun-2018**	**----**	----	----	**08-Jun-2018**	08-Jun-2018	✓
EP005: Total Organic Carbon (TOC)							
Amber VOC Vial - Sulfuric Acid (EP005) Q01_20180601	**01-Jun-2018**	**----**	----	----	**07-Jun-2018**	29-Jun-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	17	**11.76**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	2	**50.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	4	**25.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	6	**16.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	2	3	**66.67**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	3	**33.33**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	2	**50.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	2	18	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH by PC Titrator	EA005-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	2	16	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	8	**12.50**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Alkalinity by PC Titrator	ED037-P	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Chloride by Discrete Analyser	ED045G	2	17	**11.76**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	4	**25.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	8	**12.50**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Chloride by Discrete Analyser	ED045G	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Conductivity by PC Titrator	EA010-P	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Method Blanks (MB) - Continued							
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite B	EG020B-F	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	1	4	**25.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Anions - Dissolved	ED040F	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Major Cations - Dissolved	ED093F	1	3	**33.33**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	8	**12.50**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
Chloride by Discrete Analyser	ED045G	1	17	**5.88**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Mercury by FIMS	EG035F	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Metals by ICP-MS - Suite A	EG020A-F	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Dissolved Sulfide as S2-	EK085F	0	4	**0.00**	**5.00**	×	NEPM 2013 B3 & ALS QC Standard
Fluoride by PC Titrator	EK040P	1	6	**16.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	1	2	**50.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Nitrite as N by Discrete Analyser	EK057G	1	18	**5.56**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	16	**6.25**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Organic Carbon	EP005	1	8	**12.50**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH by PC Titrator	EA005-P	WATER	In house: Referenced to APHA 4500 H+ B. This procedure determines pH of water samples by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Conductivity by PC Titrator	EA010-P	WATER	In house: Referenced to APHA 2510 B. This procedure determines conductivity by automated ISE. This method is compliant with NEPM (2013) Schedule B(3)
Alkalinity by PC Titrator	ED037-P	WATER	In house: Referenced to APHA 2320 B This procedure determines alkalinity by automated measurement (e.g. PC Titrate) using pH 4.5 for indicating the total alkalinity end-point. This method is compliant with NEPM (2013) Schedule B(3)
Major Anions - Dissolved	ED040F	WATER	In house: Referenced to APHA 3120. The 0.45µm filtered samples are determined by ICP/AES for Sulfur and/or Silcon content and reported as Sulfate and/or Silica after conversion by gravimetric factor.
Sulfate (Turbidimetric) as SO4 2- by Discrete Analyser	ED041G	WATER	In house: Referenced to APHA 4500-SO4. Dissolved sulfate is determined in a 0.45um filtered sample. Sulfate ions are converted to a barium sulfate suspension in an acetic acid medium with barium chloride. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO4-2 concentration is determined by comparison of the reading with a standard curve. This method is compliant with NEPM (2013) Schedule B(3)
Chloride by Discrete Analyser	ED045G	WATER	In house: Referenced to APHA 4500 Cl - G.The thiocyanate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form non-ionised mercuric chloride.in the presence of ferric ions the librated thiocynate forms highly-coloured ferric thiocynate which is measured at 480 nm APHA 21st edition seal method 2 017-1-L april 2003
Major Cations - Dissolved	ED093F	WATER	In house: Referenced to APHA 3120 and 3125; USEPA SW 846 - 6010 and 6020; Cations are determined by either ICP-AES or ICP-MS techniques. This method is compliant with NEPM (2013) Schedule B(3) Sodium Adsorption Ratio is calculated from Ca, Mg and Na which determined by ALS in house method QWI-EN/ED093F. This method is compliant with NEPM (2013) Schedule B(3) Hardness parameters are calculated based on APHA 2340 B. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Metals by ICP-MS - Suite A	EG020A-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Dissolved Metals by ICP-MS - Suite B	EG020B-F	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. Samples are 0.45µm filtered prior to analysis. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.

Analytical Methods	Method	Matrix	Method Descriptions
Dissolved Mercury by FIMS	EG035F	WATER	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Samples are 0.45µm filtered prior to analysis. FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the filtered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
Fluoride by PC Titrator	EK040P	WATER	In house: Referenced to APHA 4500-F C: CDTA is added to the sample to provide a uniform ionic strength background, adjust pH, and break up complexes. Fluoride concentration is determined by either manual or automatic ISE measurement. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite as N by Discrete Analyser	EK057G	WATER	In house: Referenced to APHA 4500-NO2- B. Nitrite is determined by direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Nitrate as N by Discrete Analyser	EK058G	WATER	In house: Referenced to APHA 4500-NO3- F. Nitrate is reduced to nitrite by way of a chemical reduction followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results. This method is compliant with NEPM (2013) Schedule B(3)
Nitrite and Nitrate as N (NOx) by Discrete Analyser	EK059G	WATER	In house: Referenced to APHA 4500-NO3- F. Combined oxidised Nitrogen (NO2+NO3) is determined by Chemical Reduction and direct colourimetry by Discrete Analyser. This method is compliant with NEPM (2013) Schedule B(3)
Dissolved Sulfide as S2-	EK085F	WATER	In house: Referenced to APHA 4500-S2- D. Water samples are flocculated in the field using AlCl3. The clear supernatant is and immediately precipitated when transferred to a predosed caustic/zinc acetate preserved sample container. After the supernatant is discarded, the resultant precipitate is then coloured using methylene blue indicator and measured using UV-VIS detection at 664nm. This method is compliant with NEPM (2013) Schedule B(3)
Ionic Balance by PCT DA and Turbi SO4 DA	EN055 - PG	WATER	In house: Referenced to APHA 1030F. This method is compliant with NEPM (2013) Schedule B(3)
Total Organic Carbon	EP005	WATER	In house: Referenced to APHA 5310 B, The automated TOC analyzer determines Total and Inorganic Carbon by IR cell. TOC is calculated as the difference. This method is compliant with NEPM (2013) Schedule B(3)

Preparation Methods	Method	Matrix	Method Descriptions
Digestion for Total Recoverable Metals	EN25	WATER	In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3)

spilt batch of EM1809078

URGENT

FREIGHT

Batch as ES

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Steve Partridge	SIGNED:	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

ARRANGED FOR SHORT TURNAROUND ON AVAILABLE ANALYTES

Please forward QC field duplicates to ALS Sydney

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical Conductivity, Major Anions & Cations, Si & Alkalinity & Iodine & Bromine & Fluorine – 500ml Green	Dissolved Metals – NERM 15 (W-3) + Li, Sr, Th, U – 60ml Red/Green bottle (Field Filtered)	Dissolved Nitrate (as N) - 60ml Purple 2 day holding time	~~Dissolved~~ Total Organic Carbon – 40ml Purple Vial ~~(Field Filtered)~~ P/R 5/6/18	Total Metals (Fe, Mn) – 60ml Red/Green unfiltered	Dissolved Sulfide – 125ml Yellow	Gross alpha and Gross beta - 1 L Red/Green unpreserved	TRH/BTEXN/PAH/Phenols (W-24) + OC and OP (W-12) - 100ml Amber + 40 ml vials
	~~wellsbottle~~																HOLD
1	wellsbottle	W02D	water	Primary	W02D-20180601	1/6/18	12	Z	14	1	1	1	1	1	1	1	HOLD
	"	W02D	"	QC *	QC01-20180601	1/6/18	22	Z	14	1	1	1	1	1	1	1	HOLD
					Q01 BP 5/6												HOLD
				* Batch as ES													HOLD
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							ES1816499										HOLD
							into										HOLD
																	HOLD
																	HOLD
																	HOLD

Environmental Division
Sydney
Work Order Reference
ES1816445

Telephone : + 61-2-8784 8555

Custody Seal?	Y N NA	RELINQUISHED BY:	P	CHECKED:	
Samples Cold?	Y N NA	DATE:	4/6/18	TIME:	
Comments:		RECEIVED BY:		CHECKED:	
		DATE:		TIME:	

Split WO

CONTAINER TYPE AND PRESERVATIVE CODES:
P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Pre... ...Acid Preserved Glass Bottle;
S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Pre...
Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

Lab / Analysis:
Organised By / Date: Name (Au...) 5/6,
Relinquished By / Date: 10:25
Connote / Courier:
WO No: ES1816445
Attach By PO / Internal Sheet:

Fax: 6/6/18 11:30am

URGENT

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order : **ES1816445**

Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: melinda.morris@aecom.com	E-mail	: peter.ravlic@alsglobal.com
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Facsimile	: +61 08 83661001	Facsimile	: +61-2-8784 8500
Project	: NRWFM Site Characterisation	Page	: 1 of 3
Order number	: 60565376.4.0	Quote number	: EM2017URSSA0002 (EN/004/16)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: STEVE PARTRIDGE		

Dates

Date Samples Received	: 06-Jun-2018 11:00	Issue Date	: 06-Jun-2018
Client Requested Due Date	: 08-Jun-2018	Scheduled Reporting Date	: **08-Jun-2018**

Delivery Details

Mode of Delivery	: Undefined	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 5.9'C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 1 / 1

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Gross Alpha & Beta has split into ES1816445.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- **Sample(s) requiring volatile organic compound analysis received in airtight containers (ZHE).**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

✓ **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EA005P pH (PCT)	WATER - EA010P Electrical Conductivity (PCT)	WATER - EG020F Dissolved Metals by ICP/MS	WATER - EK058G Nitrate as N by Discrete Analyser	WATER - EK085F Dissolved Sulfide as S2-	WATER - NT-01 & 02 Ca, Mg, Na, K, Cl, SO4, Alkalinity	WATER - W-03 15 Metals (NEPM Suite)
ES1816445-001	01-Jun-2018 00:00	Q01_20180601	✓	✓	✓	✓	✓	✓	✓

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EG020T Total Metals by ICP/MS (including digestion)	WATER - EP005 Total Organic Carbon (TOC)
ES1816445-001	01-Jun-2018 00:00	Q01_20180601	✓	✓

Proactive Holding Time Report

The following table summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory.

Matrix: **WATER** Evaluation: = Holding time breach ; ✓ = Within holding time.

Method Client Sample ID(s)	Container	Due for extraction	Due for analysis	Samples Received Date	Samples Received Evaluation	Instructions Received Date	Instructions Received Evaluation
EA005-P: pH by PC Titrator							
Q01_20180601	Clear Plastic Bottle - Natural	----	01-Jun-2018	06-Jun-2018		----	----
EK057G: Nitrite as N by Discrete Analyser							
Q01_20180601	Clear Plastic Bottle - Natural	----	03-Jun-2018	06-Jun-2018		----	----

Requested Deliverables

ADELAIDE URS		
- *AU Certificate of Analysis - NATA (COA)	Email	adelaide@urs.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	adelaide@urs.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	adelaide@urs.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	adelaide@urs.com
- Chain of Custody (CoC) (COC)	Email	adelaide@urs.com
- EDI Format - ENMRG (ENMRG)	Email	adelaide@urs.com
- EDI Format - ESDAT (ESDAT)	Email	adelaide@urs.com
ALL INVOICES		
- A4 - AU Tax Invoice (INV)	Email	ap_customerservice.anz@aecom.com
MELINDA MORRIS		
- *AU Certificate of Analysis - NATA (COA)	Email	melinda.morris@aecom.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	melinda.morris@aecom.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	melinda.morris@aecom.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	melinda.morris@aecom.com
- Chain of Custody (CoC) (COC)	Email	melinda.morris@aecom.com
- EDI Format - ENMRG (ENMRG)	Email	melinda.morris@aecom.com
- EDI Format - ESDAT (ESDAT)	Email	melinda.morris@aecom.com

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1816499**	Page	: 1 of 2
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018 11:00
Order number	: 60565376.4.0	Date Analysis Commenced	: 14-Jun-2018
C-O-C number	: ----	Issue Date	: 25-Jun-2018 14:02
Sampler	: STEVE PARTRIDGE		
Site	: ----		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Gross Alpha and Beta Activity analyses are performed by ALS Fyshwick (NATA Accreditation number 992).
- LOR for gross alpha and beta in sample raised due to the high amount of solid and Potassium present.

Sub-Matrix: **WATER**
(Matrix: **WATER**)

				Q01_20180601	**----**	**----**	**----**	**----**
				01-Jun-2018 00:00	----	----	----	----
				ES1816499-001	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA250: Gross Alpha and Beta Activity								
Gross alpha	----	0.05	Bq/L	<0.50	----	----	----	----
Gross beta activity - 40K	----	0.1	Bq/L	<10	----	----	----	----

Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1816499**	Page	: 1 of 2
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018 11:00
Order number	: 60565376.4.0	Date Analysis Commenced	: 14-Jun-2018
C-O-C number	: ----	Issue Date	: 25-Jun-2018 14:02
Sampler	: STEVE PARTRIDGE		
Site	: ----		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Gross Alpha and Beta Activity analyses are performed by ALS Fyshwick (NATA Accreditation number 992).
- LOR for gross alpha and beta in sample raised due to the high amount of solid and Potassium present.

Sub-Matrix: **WATER**
(Matrix: **WATER**)

				Q01_20180601	**----**	**----**	**----**	**----**
				01-Jun-2018 00:00	----	----	----	----
				ES1816499-001	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA250: Gross Alpha and Beta Activity								
Gross alpha	----	0.05	Bq/L	<0.50	----	----	----	----
Gross beta activity - 40K	----	0.1	Bq/L	<10	----	----	----	----

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **ES1816499**	Page	: 1 of 3
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018
Order number	: 60565376.4.0	Date Analysis Commenced	: 14-Jun-2018
C-O-C number	: ----	Issue Date	: 25-Jun-2018
Sampler	: STEVE PARTRIDGE		
Site	: ----		
Quote number	: EN/004/16		
No. of samples received	: 1		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Titus Vimalasiri	Metals Teamleader	Radionuclides, Fyshwick, ACT

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA250: Gross Alpha and Beta Activity (QC Lot: 1726229)									
EM1809078-001	Anonymous	EA250-LSC: Gross alpha	----	0.05	Bq/L	<0.50	<0.50	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA250: Gross Alpha and Beta Activity (QCLot: 1726229)								
EA250-LSC: Gross alpha	----	0.05	Bq/L	<0.05	1751 Bq/L	99.3	70	130
EA250-LSC: Gross beta activity - 40K	----	0.1	Bq/L	<0.10	3342 Bq/L	99.7	70	130

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES1816499**	Page	: 1 of 4
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Telephone	: +61-2-8784 8555
Project	: NRWFM Site Characterisation	Date Samples Received	: 06-Jun-2018
Site	: ----	Issue Date	: 25-Jun-2018
Sampler	: STEVE PARTRIDGE	No. of samples received	: 1
Order number	: 60565376.4.0	No. of samples analysed	: 1

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER** Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / *Container / Client Sample ID(s)*	*Sample Date*	*Extraction / Preparation* Date extracted	*Due for extraction*	*Evaluation*	*Analysis* Date analysed	*Due for analysis*	*Evaluation*
EA250: Gross Alpha and Beta Activity							
Clear Plastic Bottle - Unspecified; Lab-acidified (EA250-LSC)							
Q01_20180601	**01-Jun-2018**	**----**	----	----	**14-Jun-2018**	28-Nov-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Gross Alpha and Beta Activity	EA250-LSC	1	9	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Gross Alpha and Beta Activity	EA250-LSC	2	9	**22.22**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Gross Alpha and Beta Activity	EA250-LSC	1	9	**11.11**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Gross Alpha and Beta Activity	EA250-LSC	WATER	In house: Referenced to ASTM D7283-06: Determination of gross alpha and gross beta radioactivity in water samples by Liquid Scintillation Counting (LSC).

split batch of EM1809078

URGENT

FREIGHT

Batch as ES 20/6/18

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St, Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			5/6/18
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Steve Partridge	SIGNED:	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

ARRANGED FOR SHORT TURNAROUND ON AVAILABLE ANALYTES

Please forward QC field duplicates to ALS Sydney

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical Conductivity, Major Anions & Cations, Si & Alkalinity & Iodine & Bromine & Fluorine – 500ml Green	Dissolved Metals – NEPM 15 (W-3) + Li, Sr, Th, U – 60ml Red/Green bottle (Field Filtered)	Dissolved Nitrate (as N) - 60ml Purple 2 day holding time	~~Dissolved~~ Total Organic Carbon – 40ml Purple Vial (~~Field Filtered~~) P/2	Total Metals (Fe, Mn) – 60ml Red/Green unfiltered	Dissolved Sulfide – 125ml Yellow	Gross alpha and Gross beta - 1 L Red/Green unpreserved	TRH/BTEXN/PAH/Phenols (W-24) + OC and OP (W-12) - 100ml Amber + 40 ml vials
	~~wellesbottle~~																HOLD
1	wellesbottle	W02D	water	Primary	W02D -20180601	1/6/18	12	Z	14	1	1	1	1	1	1	1	HOLD
1	"	W02D	"	QC *	QC01 -20180601	1/6/18	22	Z	14	1	1	1	1	1	1	1	HOLD
																	HOLD
					Q01 - BP 5/6												HOLD
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Subcon / Forward Lab / Split WO Batch as ES

Lab / Analysis: CANBERRA / Gross α & β

Organised By / Date:

Relinquished By / Date:

Connote / Courier:

WO No:

Attach By PO / Internal Sheet:

Environmental Division
Sydney
Work Order Reference
ES1816499

Telephone : + 61-2-8784 8555

Custody Seal ?	Y N NA	RELINQUISHED BY: P	CHECKED:		CONTAINER TYPE AND PRESERVATIVE CODES
Samples Cold ?	Y N NA	DATE: 4/6/18	TIME: 1206		P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Pre...
Comments:		RECEIVED BY:	CHECKED:		S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Pre... ...Acid Preserved Glass Bottle;
		DATE:	TIME:		Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

Name (Am) 5/6, 10:25

URGENT

Fasi 6/6/18 11:30am

ALS Environmental

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES1816499**		
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: melinda.morris@aecom.com	E-mail	: peter.ravlic@alsglobal.com
Telephone	: +61 08 83661000	Telephone	: +61-2-8784 8555
Facsimile	: +61 08 83661001	Facsimile	: +61-2-8784 8500
Project	: NRWFM Site Characterisation	Page	: 1 of 2
Order number	: 60565376.4.0	Quote number	: EM2017URSSA0002 (EN/004/16)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: STEVE PARTRIDGE		

Dates

Date Samples Received	: 06-Jun-2018 11:00	Issue Date	: 06-Jun-2018
Client Requested Due Date	: 08-Jun-2018	Scheduled Reporting Date	: **20-Jun-2018**

Delivery Details

Mode of Delivery	: Undefined	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 5.9'C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 1 / 1

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Gross Alpha and Beta Analysis to be conducted by ALS Canberra
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months) from receipt of samples.
- Radiological analysis will be undertaken by ALS WRG Canberra, NATA accreditation no. 992, site no. 1531. The estimated TAT for this analysis is 15 working days.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Client sampling date / time*	*Client sample ID*	WATER - EA250-LSC Gross Alpha and Beta Activity
ES1816499-001	01-Jun-2018 00:00	Q01_20180601	✔

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ADELAIDE URS CORP		
- *AU Certificate of Analysis - NATA (COA)	Email	adelaide@ursCORP.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	adelaide@ursCORP.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	adelaide@ursCORP.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	adelaide@ursCORP.com
- Attachment - Report (SUBCO)	Email	adelaide@ursCORP.com
- Chain of Custody (CoC) (COC)	Email	adelaide@ursCORP.com
- EDI Format - ENMRG (ENMRG)	Email	adelaide@ursCORP.com
- EDI Format - ESDAT (ESDAT)	Email	adelaide@ursCORP.com
ALL INVOICES		
- A4 - AU Tax Invoice (INV)	Email	ap_customerservice.anz@aecom.com
MELINDA MORRIS		
- *AU Certificate of Analysis - NATA (COA)	Email	melinda.morris@aecom.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	melinda.morris@aecom.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	melinda.morris@aecom.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	melinda.morris@aecom.com
- Attachment - Report (SUBCO)	Email	melinda.morris@aecom.com
- Chain of Custody (CoC) (COC)	Email	melinda.morris@aecom.com
- EDI Format - ENMRG (ENMRG)	Email	melinda.morris@aecom.com
- EDI Format - ESDAT (ESDAT)	Email	melinda.morris@aecom.com

Soil Analytical Chemistry - Wallerberdina

Soil Analytical Chemistry - Wallerberdina

		Sample ID	W07_0.2-0.4m	QC301-08052018	W07_1.1-1.2m	W07_2.3-2.4m	W08_0.0-0.2m	W08_1.1-1.2 m	W08_2.2-2.3 m	W10_0.0-0.2m	W10_1.1-1.2m	W10_2.0-2.1m
		Sample Date	8/05/2018	-	8/05/2018	8/05/2018	9/05/2018	9/05/2018	9/05/2018	8/05/2018	8/05/2018	8/05/2018
		Description	Silty SAND topsoil	Field duplicate for W07_0.2-0.4m	CLAY	CLAY	Silty SAND topsoil	Clayey SAND	Clayey SAND	Silty SAND topsoil	Silty SAND	Silty SAND
		Lab Batch	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975	EM1807975
Laboratory Analyte	**LOR**	**Unit**										
pH	0.1	pH unit	8.1	8.2	8.2	8.1	8.1	8.1	8.2	8	8.2	8.2
Electrical Conductivity	1	µS/cm	153	404	407	1520	63	208	1480	64	159	564
Electrical Conductivity (Saturated Paste)	1	µS/cm	551	764	1490	5950	214	455	4720	252	469	2990
Exchangeable Cations on Alkaline Soils												
Exchangeable Calcium	0.2	meq/100g	9.8	4.7	6.4	5.6	4	4.8	5.1	4.9	4.7	3.6
Exchangeable Magnesium	0.2	meq/100g	2.5	2.6	2.8	3	0.9	2.2	3.3	0.9	1.5	3.5
Exchangeable Potassium	0.2	meq/100g	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.5	<0.2	0.4
Exchangeable Sodium	0.2	meq/100g	1.2	2.2	3.3	1.2	<0.2	1.1	2.6	<0.2	0.6	2.3
Cation Exchange Capacity (CEC)	0.2	meq/100g	14.1	10.1	12.9	10.2	5.3	8.5	11.4	6.4	6.9	9.8
Exchangeable Sodium Percent (ESP)	0.2	%	8.4	21.3	25.8	11.8	<0.2	13.2	22.9	<0.2	8	23.3

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM1807975**	Page	:
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 15-May-2018 14:15
Order number	: 60565376.task 4.0	Date Analysis Commenced	: 16-May-2018
C-O-C number	: ----	Issue Date	: 23-May-2018 15:49
Sampler	: JT		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 30		
No. of samples analysed	: 10		

NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC

□□□ □ □□□ □ □□□

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- pH analysis is done under non-stirring condition.
- EA010-P: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- EA032 (Saturated Paste EC): NATA accreditation does not cover the performance of this service.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EA032: EM1807975 #5 and 21 have been confirmed by reanalysis.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Sub-Matrix: SOIL (Matrix: SOIL)				W07-0.2-0.4	W07-1.1-1.2	W07-2.3-2.4	W08-0-0.2	W08-1.1-1.2
				08-May-2018 00:00	08-May-2018 00:00	08-May-2018 00:00	09-May-2018 00:00	09-May-2018 00:00
				EM1807975-004	EM1807975-005	EM1807975-006	EM1807975-007	EM1807975-008
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	8.1	8.2	8.1	8.1	8.1
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	153	407	1520	63	208
EA032: Electrical Conductivity (saturated paste)								
Electrical Conductivity (Saturated Paste)	----	1	µS/cm	551	1490	5950	214	455
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	9.8	6.4	5.6	4.0	4.8
ø Exchangeable Magnesium	----	0.2	meq/100g	2.5	2.8	3.0	0.9	2.2
ø Exchangeable Potassium	----	0.2	meq/100g	0.6	0.4	0.4	0.4	0.4
ø Exchangeable Sodium	----	0.2	meq/100g	1.2	3.3	1.2	<0.2	1.1
ø Cation Exchange Capacity	----	0.2	meq/100g	14.1	12.9	10.2	5.3	8.5
ø Exchangeable Sodium Percent	----	0.2	%	8.4	25.8	11.8	<0.2	13.2

Sub-Matrix: **SOIL**
(Matrix: **SOIL)**

				W08-2.2-2.3	W10-0-0.2	W10-1.1-1.2	W10-2.0-2.1	QC301-08052018
				09-May-2018 00:00	08-May-2018 00:00	08-May-2018 00:00	08-May-2018 00:00	08-May-2018 00:00
				EM1807975-009	EM1807975-013	EM1807975-014	EM1807975-015	EM1807975-021
				Result	Result	Result	Result	Result
EA001: pH in soil using 0.01M CaCl extract								
pH (CaCl2)	----	0.1	pH Unit	**8.2**	**8.0**	**8.2**	**8.2**	**8.2**
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	**1480**	**64**	**159**	**564**	**404**
EA032: Electrical Conductivity (saturated paste)								
Electrical Conductivity (Saturated Paste)	----	1	µS/cm	**4720**	**252**	**469**	**2990**	**764**
ED006: Exchangeable Cations on Alkaline Soils								
ø **Exchangeable Calcium**	----	0.2	meq/100g	**5.1**	**4.9**	**4.7**	**3.6**	**4.7**
ø **Exchangeable Magnesium**	----	0.2	meq/100g	**3.3**	**0.9**	**1.5**	**3.5**	**2.6**
ø **Exchangeable Potassium**	----	0.2	meq/100g	**0.4**	**0.5**	<0.2	**0.4**	**0.6**
ø **Exchangeable Sodium**	----	0.2	meq/100g	**2.6**	<0.2	**0.6**	**2.3**	**2.2**
ø **Cation Exchange Capacity**	----	0.2	meq/100g	**11.4**	**6.4**	**6.9**	**9.8**	**10.1**
ø **Exchangeable Sodium Percent**	----	0.2	%	**22.9**	<0.2	**8.0**	**23.3**	**21.3**

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM1807975**	Page	: 1 of 3
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 15-May-2018
Order number	: 60565376.task 4.0	Date Analysis Commenced	: 16-May-2018
C-O-C number	: ----	Issue Date	: 23-May-2018
Sampler	: JT		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 30		
No. of samples analysed	: 10		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

[illegible]

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

[illegible]	[illegible]	[illegible]
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Client sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Recovery Limits (%)*
EA001: pH in soil using 0.01M CaCl extract (QC Lot: 1644872)									
EM1807975-004	W07-0.2-0.4	EA001: pH (CaCl2)	----	0.1	pH Unit	8.1	8.2	1.23	0% - 20%
EM1807975-021	QC301-08052018	EA001: pH (CaCl2)	----	0.1	pH Unit	8.2	8.1	1.23	0% - 20%
EA010: Conductivity (QC Lot: 1644995)									
EM1807975-004	W07-0.2-0.4	EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	153	149	2.45	0% - 20%
EM1807975-021	QC301-08052018	EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	404	335	18.7	0% - 20%
EA032: Electrical Conductivity (saturated paste) (QC Lot: 1657877)									
EM1807975-004	W07-0.2-0.4	EA032: Electrical Conductivity (Saturated Paste)	----	1	µS/cm	551	578	4.78	0% - 20%
EM1807975-021	QC301-08052018	EA032: Electrical Conductivity (Saturated Paste)	----	1	µS/cm	764	833	8.64	0% - 20%
ED006: Exchangeable Cations on Alkaline Soils (QC Lot: 1663132)									
EM1807901-097	Anonymous	ED006: Exchangeable Sodium Percent	----	0.2	%	25.9	26.0	0.00	0% - 20%
		ED006: Exchangeable Calcium	----	0.2	meq/100g	20.4	19.8	2.80	0% - 20%
		ED006: Exchangeable Magnesium	----	0.2	meq/100g	7.0	6.8	3.04	0% - 20%
		ED006: Exchangeable Potassium	----	0.2	meq/100g	0.7	0.6	0.00	No Limit
		ED006: Exchangeable Sodium	----	0.2	meq/100g	9.8	9.6	2.45	0% - 20%
		ED006: Cation Exchange Capacity	----	0.2	meq/100g	37.9	36.9	2.77	0% - 20%
EM1807975-015	W10-2.0-2.1	ED006: Exchangeable Sodium Percent	----	0.2	%	23.3	21.9	6.33	0% - 20%
		ED006: Exchangeable Calcium	----	0.2	meq/100g	3.6	4.2	15.9	0% - 20%
		ED006: Exchangeable Magnesium	----	0.2	meq/100g	3.5	2.1	47.7	0% - 50%
		ED006: Exchangeable Potassium	----	0.2	meq/100g	0.4	0.2	66.4	No Limit
		ED006: Exchangeable Sodium	----	0.2	meq/100g	2.3	1.8	21.2	0% - 50%
		ED006: Cation Exchange Capacity	----	0.2	meq/100g	9.8	8.5	14.9	0% - 20%

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA010: Conductivity (QCLot: 1644995)								
EA010: Electrical Conductivity @ 25°C	----	1	µS/cm	<1	1413 µS/cm	101	95	105
EA032: Electrical Conductivity (saturated paste) (QCLot: 1657877)								
EA032: Electrical Conductivity (Saturated Paste)	----	1	µS/cm	<1	1413 µS/cm	100	70	130
ED006: Exchangeable Cations on Alkaline Soils (QCLot: 1663132)								
ED006: Exchangeable Calcium	----	0.2	meq/100g	<0.2	33 meq/100g	87.1	80	120
ED006: Exchangeable Magnesium	----	0.2	meq/100g	<0.2	32 meq/100g	80.2	80	120
ED006: Exchangeable Potassium	----	0.2	meq/100g	<0.2	2.2 meq/100g	96.4	80	120
ED006: Exchangeable Sodium	----	0.2	meq/100g	<0.2	5.6 meq/100g	92.1	80	120
ED006: Cation Exchange Capacity	----	0.2	meq/100g	<0.2	----	----	----	----
ED006: Exchangeable Sodium Percent	----	0.2	%	<0.2	----	----	----	----

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM1807975**	Page	: 1 of 5
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 15-May-2018
Site	: NRWMF Site Characterisation	Issue Date	: 23-May-2018
Sampler	: JT	No. of samples received	: 30
Order number	: 60565376.task 4.0	No. of samples analysed	: 10

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Outliers : Analysis Holding Time Compliance

Matrix: **SOIL**

Method / Container / Client Sample ID(s)		Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Days overdue	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Days overdue
EA001: pH in soil using 0.01M CaCl extract							
Soil Glass Jar - Unpreserved							
W07-0.2-0.4,	W07-1.1-1.2,	16-May-2018	15-May-2018	**1**	----	----	----
W07-2.3-2.4,	W10-0-0.2,						
W10-1.1-1.2,	W10-2.0-2.1,						
QC301-08052018							
EA010: Conductivity							
Soil Glass Jar - Unpreserved							
W07-0.2-0.4,	W07-1.1-1.2,	16-May-2018	15-May-2018	**1**	----	----	----
W07-2.3-2.4,	W10-0-0.2,						
W10-1.1-1.2,	W10-2.0-2.1,						
QC301-08052018							

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: ✘ = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Extraction / Preparation: Due for extraction	Extraction / Preparation: Evaluation	Analysis: Date analysed	Analysis: Due for analysis	Analysis: Evaluation
EA001: pH in soil using 0.01M CaCl extract								
Soil Glass Jar - Unpreserved (EA001)								
W07-0.2-0.4,	W07-1.1-1.2,	**08-May-2018**	**16-May-2018**	15-May-2018	✘	**16-May-2018**	16-May-2018	✓
W07-2.3-2.4,	W10-0-0.2,							
W10-1.1-1.2,	W10-2.0-2.1,							
QC301-08052018								
Soil Glass Jar - Unpreserved (EA001)								
W08-0-0.2,	W08-1.1-1.2,	**09-May-2018**	**16-May-2018**	16-May-2018	✓	**16-May-2018**	16-May-2018	✓
W08-2.2-2.3								

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation: Date extracted	Due for extraction	Evaluation	Analysis: Date analysed	Due for analysis	Evaluation
EA010: Conductivity								
Soil Glass Jar - Unpreserved (EA010)								
W07-0.2-0.4, W07-2.3-2.4, W10-1.1-1.2, QC301-08052018	W07-1.1-1.2, W10-0-0.2, W10-2.0-2.1,	**08-May-2018**	**16-May-2018**	15-May-2018	×	**16-May-2018**	13-Jun-2018	✓
Soil Glass Jar - Unpreserved (EA010)								
W08-0-0.2, W08-2.2-2.3	W08-1.1-1.2,	**09-May-2018**	**16-May-2018**	16-May-2018	✓	**16-May-2018**	13-Jun-2018	✓
EA032: Electrical Conductivity (saturated paste)								
Soil Glass Jar - Unpreserved (EA032)								
W07-0.2-0.4, W07-2.3-2.4, W10-1.1-1.2, QC301-08052018	W07-1.1-1.2, W10-0-0.2, W10-2.0-2.1,	**08-May-2018**	**----**	----	----	**21-May-2018**	04-Nov-2018	✓
Soil Glass Jar - Unpreserved (EA032)								
W08-0-0.2, W08-2.2-2.3	W08-1.1-1.2,	**09-May-2018**	**----**	----	----	**21-May-2018**	05-Nov-2018	✓
ED006: Exchangeable Cations on Alkaline Soils								
Soil Glass Jar - Unpreserved (ED006)								
W07-0.2-0.4, W07-2.3-2.4, W10-1.1-1.2, QC301-08052018	W07-1.1-1.2, W10-0-0.2, W10-2.0-2.1,	**08-May-2018**	**22-May-2018**	05-Jun-2018	✓	**22-May-2018**	05-Jun-2018	✓
Soil Glass Jar - Unpreserved (ED006)								
W08-0-0.2, W08-2.2-2.3	W08-1.1-1.2,	**09-May-2018**	**22-May-2018**	06-Jun-2018	✓	**22-May-2018**	06-Jun-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Electrical Conductivity (1:5)	EA010	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (Saturated Paste)	EA032	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Exchangeable Cations on Alkaline Soils	ED006	2	11	**18.18**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
pH in soil using a 0.01M CaCl2 extract	EA001	2	10	**20.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Electrical Conductivity (1:5)	EA010	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (Saturated Paste)	EA032	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Exchangeable Cations on Alkaline Soils	ED006	1	11	**9.09**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Electrical Conductivity (1:5)	EA010	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Electrical Conductivity (Saturated Paste)	EA032	1	10	**10.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Exchangeable Cations on Alkaline Soils	ED006	1	11	**9.09**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
pH in soil using a 0.01M CaCl2 extract	EA001	SOIL	In house: Referenced to Rayment and Lyons (2011) 4B3 (mod.) or 4B4 (mod.) 10 g of soil is mixed with 50 mL of 0.01M CaCl2 and tumbled end over end for 1 hour. pH is measured from the continuous suspension. This method is compliant with NEPM (2013) Schedule B(3)
Electrical Conductivity (1:5)	EA010	SOIL	In house: Referenced to Rayment and Lyons 3A1 and APHA 2510. Conductivity is determined on soil samples using a 1:5 soil/water leach. This method is compliant with NEPM (2013) Schedule B(3)
Electrical Conductivity (Saturated Paste)	EA032	SOIL	In house: Referenced to USEPA 600/2 - 78 - 054 - conductivity determined on a saturated paste.
Exchangeable Cations on Alkaline Soils	* ED006	SOIL	In house: Referenced to Soil Survey Test Method C5. Soluble salts are removed from the sample prior to analysis. Cations are exchanged from the sample by contact with alcoholic ammonium chloride at pH 8.5. They are then quantitated in the final solution by ICPAES and reported as meq/100g of original soil.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
pH in soil using a 0.01M CaCl2 extract	EA001-PR	SOIL	In house: Referenced to Rayment and Higginson 4B1, 10 g of soil is mixed with 50 mL of 0.01M CaCl2 and tumbled end over end for 1 hour. pH is measured from the continuous suspension. This method is compliant with NEPM (2013) Schedule B(3) (Method 103)
Exchangeable Cations Preparation Method (Alkaline Soils)	ED006PR	SOIL	In house: Referenced to Rayment and Lyons 2011 method 15C1.
Exchangeable Cations Preparation Method	ED007PR	SOIL	In house: Referenced to Rayment & Higginson (1992) method 15A1. A 1M NH4Cl extraction by end over end tumbling at a ratio of 1:20. There is no pretreatment for soluble salts. Extracts can be run by ICP for cations.
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of reagent grade water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.

Environmental Division
Melbourne
Work Order Reference
EM1807975

Telephone : + 61-3-8549 9600

Analysis rec'd 16/5/18 18:03 – ALS PR

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Joseph Tan	SIGNED: JT	
PROJECT NO:	60565376.task 4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

URGENT batching required

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID			Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
1	NRWMF SCP	WALLERBERDINA	Soil	Primary	W06	-	0-0.2	09/05/18	1 Jar, 1 Bag	NA	2					1
2	NRWMF SCP	WALLERBERDINA	Soil	Primary	W06	-	1.3-1.4	09/05/18	1 Jar, 1 Bag	NA	2					1
3	NRWMF SCP	WALLERBERDINA	Soil	Primary	W06	-	2.5-2.6	09/05/18	1 Jar, 1 Bag	NA	2					1
4	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	-	0.2-0.4	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
5	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	-	1.1-1.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
6	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	-	2.3-2.4	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
7	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	-	0-0.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
8	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	-	1.1-1.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
9	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	-	2.2-2.3	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
10	NRWMF SCP	WALLERBERDINA	Soil	Primary	W09	-	0.0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
11	NRWMF SCP	WALLERBERDINA	Soil	Primary	W09	-	1.1-1.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
12	NRWMF SCP	WALLERBERDINA	Soil	Primary	W09	-	2.0-2.1	08/05/2018	1 Jar, 1 Bag	NA	2					1
13	NRWMF SCP	WALLERBERDINA	Soil	Primary	W10	-	0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
14	NRWMF SCP	WALLERBERDINA	Soil	Primary	W10	-	1.1-1.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
15	NRWMF SCP	WALLERBERDINA	Soil	Primary	W10	-	2.0-2.1	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
16	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11	-	0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
											TOTAL	9	9	0	0	7

Custody Seal ?	Y N NA	RELINQUISHED BY:	JR	CHECKED:	JR
Samples Cold ?	Y N NA	DATE:	14/05/2018	TIME:	900
Comments:		RECEIVED BY:	Anitha (Rani)	CHECKED:	
		DATE:	15/5	TIME:	14:45

CONTAINER TYPE AND PRESERVATIVE CODES
P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

AECOM PROJECT - CHAIN OF CUSTODY

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PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Joseph Tan	SIGNED: JT	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
17	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11 - 1.0-1.1	08/05/2018	1 Jar, 1 Bag	NA	2					1
18	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11 - 2.3-2.4	08/05/2018	1 Jar, 1 Bag	NA	2					1
19	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC309 - 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
20	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC310 - 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
21	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC301 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
22	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC302 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
23	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC311 - 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
24	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC312 - 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
25	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC303 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
26	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC304 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
27	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC307 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
28	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC308 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
29	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC305 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
30	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC306 - 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
									TOTAL	1	1	0	0	13

Custody Seal ?	Y N NA	RELINQUISHED BY:	JR	CHECKED: JR	
Samples Cold ?	Y N NA	DATE:	14/05/2018	TIME: 900	
Comments:		RECEIVED BY:	Anitha	CHECKED:	15/5
		DATE:		TIME:	14:45

CONTAINER TYPE AND PRESERVATIVE CODES

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S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;

Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

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Environmental Division
Melbourne
Work Order Reference
EM1807975

Telephone : + 61-3-8549 9600

Analysis rec'd 16/5/18 18:03 -- ALS PR

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format. email address: adelaide@urscorp.com	FOR LABORATORY USE ONLY
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171		
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Joseph Tan	SIGNED: JT	
PROJECT NO:	60565376.task 4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

URGENT batching required

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID		Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
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3	NRWMF SCP	WALLERBERDINA	Soil	Primary	W06	- 2.5-2.6	09/05/18	1 Jar, 1 Bag	NA	2					1
4	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	- 0.2-0.4	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
5	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	- 1.1-1.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
6	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07	- 2.3-2.4	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
7	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	- 0-0.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
8	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	- 1.1-1.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
9	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08	- 2.2-2.3	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
10	NRWMF SCP	WALLERBERDINA	Soil	Primary	W09	- 0.0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
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16	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11	- 0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
										TOTAL	9	9	0	0	7

Custody Seal ?	Y N NA	RELINQUISHED BY: JR	CHECKED: JR	CONTAINER TYPE AND PRESERVATIVE CODES	
Samples Cold ?	Y N NA	DATE: 14/05/2018	TIME: 900	P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar	
Comments:		RECEIVED BY: Amitha (Rami)	CHECKED: 15/5	S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;	
		DATE:	TIME: 14:45	Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other	

An 16/5

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.
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PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	FOR LABORATORY USE ONLY
FAX NO:	08 7223 5499	FAX NO:		
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER:	melinda.morris@aecom.com 0408 387 495	
PROJECT NO:	60565376.4.0	SAMPLERS:	Joseph Tan	SIGNED: JT

COMMENTS: SPECIAL HANDLING/STORAGE

14/5

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID		Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
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20	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC310	- 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
21	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC301	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
22	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC302	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
23	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC311	- 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
24	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC312	- 09052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
25	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC303	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
26	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC304	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
27	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC307	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
28	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC308	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
29	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC305	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
30	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC306	- 08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
										TOTAL	1	1	0	0	13

Custody Seal ? Y N NA	RELINQUISHED BY:	JR	CHECKED:	JR
Samples Cold ? Y N NA	DATE:	14/05/2018	TIME:	900
Comments:	RECEIVED BY:	Anitha	CHECKED:	
	DATE:	15/5	TIME:	14:45

CONTAINER TYPE AND PRESERVATIVE CODES

P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar

S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;

Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

Environmental Division
Melbourne
Work Order Reference
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Telephone : + 61-3-8549 9600

Analysis rec'd 15/5/18 18:03 - ALS PR

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	FOR LABORATORY USE ONLY
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PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Joseph Tan	SIGNED: JT	
PROJECT NO:	60565376.task 4.0				

COMMENTS: SPECIAL HANDLING/STORAGE

URGENT batching required

ANALYSIS REQUIRED

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID		Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
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4	NRWMF SCP	WALLERBERDINA	Soil	Primary	W07 -	0.2-0.4	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
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7	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08 -	0-0.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
8	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08 -	1.1-1.2	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
9	NRWMF SCP	WALLERBERDINA	Soil	Primary	W08 -	2.2-2.3	09/05/18	1 Jar, 1 Bag	NA	2	1	1			
10	NRWMF SCP	WALLERBERDINA	Soil	Primary	W09 -	0.0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
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13	NRWMF SCP	WALLERBERDINA	Soil	Primary	W10 -	0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
14	NRWMF SCP	WALLERBERDINA	Soil	Primary	W10 -	1.1-1.2	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
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16	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11 -	0-0.2	08/05/2018	1 Jar, 1 Bag	NA	2					1
										TOTAL	9	9	0	0	7

Custody Seal ?	Y N NA	RELINQUISHED BY:	JR	CHECKED: JR	CONTAINER TYPE AND PRESERVATIVE CODES
Samples Cold ?	Y N NA	DATE:	14/05/2018	TIME: 900	P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
Comments:		RECEIVED BY:	Amitha (Rami)	CHECKED: 15/4	S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
		DATE:		TIME: 14:45	Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

Am 16/5

AECOM PROJECT - CHAIN OF CUSTODY

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PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER: melinda.morris@aecom.com 0408 387 495			
		SAMPLERS:	Joseph Tan	SIGNED: JT	
PROJECT NO:	60565376.4.0				ANALYSIS REQUIRED

COMMENTS: SPECIAL HANDLING/STORAGE

LAB ID	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID			Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	pH, Electrical conductivity (1:5), electrical conductivity (saturated paste)	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)			HOLD
17	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11	-	1.0-1.1	08/05/2018	1 Jar, 1 Bag	NA	2					1
18	NRWMF SCP	WALLERBERDINA	Soil	Primary	W11	-	2.3-2.4	08/05/2018	1 Jar, 1 Bag	NA	2					1
19	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC309	-	09052018	9 08/05/2018	1 Jar, 1 Bag	NA	2					1
20	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC310	-	09052018	9 08/05/2018	1 Jar, 1 Bag	NA	2					1
21	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC301	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2	1	1			
22	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC302	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
23	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC311	-	09052018	9 08/05/2018	1 Jar, 1 Bag	NA	2					1
24	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC312	-	09052018	9 08/05/2018	1 Jar, 1 Bag	NA	2					1
25	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC303	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
26	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC304	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
27	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC307	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
28	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC308	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
29	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC305	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
30	NRWMF SCP	WALLERBERDINA	Soil	QA\QC	QC306	-	08052018	08/05/2018	1 Jar, 1 Bag	NA	2					1
											TOTAL	1	1	0	0	13

Custody Seal?	Y N NA	RELINQUISHED BY:	JR	CHECKED: JR	CONTAINER TYPE AND PRESERVATIVE CODES
Samples Cold?	Y N NA	DATE:	14/05/2018	TIME: 900	P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
Comments:		RECEIVED BY:	Anitha	CHECKED: 15/5	S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
		DATE:		TIME:	Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

14:45

CERTIFICATE OF ANALYSIS

Work Order	: **EM1807311**	Page	: 1 of 5
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 03-May-2018 09:25
Order number	: 60565376 4.0	Date Analysis Commenced	: 04-May-2018
C-O-C number	: ----	Issue Date	: 09-May-2018 16:26
Sampler	: JR		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 2		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nancy Wang	2IC Organic Chemist	Melbourne Organics, Springvale, VIC

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Benzo(a)pyrene Toxicity Equivalent Quotient (TEQ) is the sum total of the concentration of the eight carcinogenic PAHs multiplied by their Toxicity Equivalence Factor (TEF) relative to Benzo(a)pyrene. TEF values are provided in brackets as follows: Benz(a)anthracene (0.1), Chrysene (0.01), Benzo(b+j) & Benzo(k)fluoranthene (0.1), Benzo(a)pyrene (1.0), Indeno(1.2.3.cd)pyrene (0.1), Dibenz(a.h)anthracene (1.0), Benzo(g.h.i)perylene (0.01). Less than LOR results for 'TEQ Zero' are treated as zero.

Sub-Matrix: WATER (Matrix: WATER)				QC301_20180423	----	----	----	----
				23-Apr-2018 00:00	----	----	----	----
				EM1807311-002	--------	--------	--------	--------
				Result	----	----	----	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	<0.001	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	----	----	----	----
Barium	7440-39-3	0.001	mg/L	<0.001	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	<1.0	----	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	----	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	----	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	----	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	----	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	----	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	----	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	----	----	----	----
4-Chloro-3-methylphenol	59-50-7	1.0	µg/L	<1.0	----	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	----	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	----	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	----	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	----	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	----	----	----	----

Sub-Matrix: WATER
(Matrix: WATER)

				QC301_20180423	----	----	----	----
				23-Apr-2018 00:00	----	----	----	----
				EM1807311-002	--------	--------	--------	--------
				Result	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
Fluorene	86-73-7	1.0	µg/L	<1.0	----	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	----	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	----	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	----	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	----	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	----	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	----	----	----	----
^ Sum of polycyclic aromatic hydrocarbons	----	0.5	µg/L	<0.5	----	----	----	----
^ Benzo(a)pyrene TEQ (zero)	----	0.5	µg/L	<0.5	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	----	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	1.0	%	45.5	----	----	----	----
2-Chlorophenol-D4	93951-73-6	1.0	%	90.5	----	----	----	----
2.4.6-Tribromophenol	118-79-6	1.0	%	43.2	----	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	1.0	%	91.6	----	----	----	----
Anthracene-d10	1719-06-8	1.0	%	98.7	----	----	----	----
4-Terphenyl-d14	1718-51-0	1.0	%	99.0	----	----	----	----

[illegible]

Sub-Matrix: **WATER**

[illegible]	[illegible]	[illegible] s [illegible]	
		[illegible]%	[illegible]
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10	46
2-Chlorophenol-D4	93951-73-6	23	104
2.4.6-Tribromophenol	118-79-6	28	130
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	36	114
Anthracene-d10	1719-06-8	51	119
4-Terphenyl-d14	1718-51-0	49	127

ALS Environmental

QUALITY CONTROL REPORT

Work Order	: **EM1807311**	Page	: 1 of 7
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Contact	: Peter Ravlic
Address	: Level 28, 91 King William Street ADELAIDE SA, AUSTRALIA 5000	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 08 83661000	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 03-May-2018
Order number	: 60565376 4.0	Date Analysis Commenced	: 04-May-2018
C-O-C number	: ----	Issue Date	: 09-May-2018
Sampler	: JR		
Site	: NRWMF Site Characterisation		
Quote number	: EN/004/16		
No. of samples received	: 2		
No. of samples analysed	: 1		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nancy Wang	2IC Organic Chemist	Melbourne Organics, Springvale, VIC

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
EG020T: Total Metals by ICP-MS (QC Lot: 1617809)									
EM1807257-012	Anonymous	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	0.0003	0.0003	0.00	No Limit
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	3.32	3.29	0.671	0% - 20%
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Barium	7440-39-3	0.001	mg/L	0.087	0.084	3.29	0% - 20%
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	0.013	0.013	0.00	0% - 50%
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	0.014	0.014	0.00	0% - 50%
		EG020A-T: Copper	7440-50-8	0.001	mg/L	0.326	0.327	0.00	0% - 20%
		EG020A-T: Lead	7439-92-1	0.001	mg/L	0.057	0.057	0.00	0% - 20%
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.322	0.330	2.59	0% - 20%
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	0.028	0.028	0.00	0% - 20%
		EG020A-T: Zinc	7440-66-6	0.005	mg/L	0.056	0.054	4.78	0% - 50%
		EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	0.02	0.02	0.00	No Limit
		EG020A-T: Boron	7440-42-8	0.05	mg/L	0.20	0.21	7.68	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	11.7	11.8	0.676	0% - 20%
EM1807303-003	Anonymous	EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
		EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Barium	7440-39-3	0.001	mg/L	0.024	0.022	5.28	0% - 20%
		EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Copper	7440-50-8	0.001	mg/L	0.229	0.221	3.81	0% - 20%
		EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	0.00	No Limit
		EG020A-T: Manganese	7439-96-5	0.001	mg/L	0.007	0.008	0.00	No Limit
		EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	0.00	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EG020T: Total Metals by ICP-MS (QC Lot: 1617809) - continued									
EM1807303-003	Anonymous	EG020A-T: Zinc	7440-66-6	0.005	mg/L	0.041	0.041	0.00	No Limit
		EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	0.00	No Limit
		EG020A-T: Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	0.00	No Limit
		EG020A-T: Iron	7439-89-6	0.05	mg/L	0.12	0.12	0.00	No Limit
EG035T: Total Recoverable Mercury by FIMS (QC Lot: 1623670)									
EM1807235-001	Anonymous	EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EM1807318-030	Anonymous	EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	0.00	No Limit
EP075(SIM)A: Phenolic Compounds (QC Lot: 1617220)									
EM1807226-005	Anonymous	EP075(SIM): Phenol	108-95-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Chlorophenol	95-57-8	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Methylphenol	95-48-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Nitrophenol	88-75-5	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4-Dimethylphenol	105-67-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4-Dichlorophenol	120-83-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.6-Dichlorophenol	87-65-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 4-Chloro-3-methylphenol	59-50-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4.6-Trichlorophenol	88-06-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4.5-Trichlorophenol	95-95-4	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 3- & 4-Methylphenol	1319-77-3	2	µg/L	<2.0	<2.0	0.00	No Limit
		EP075(SIM): Pentachlorophenol	87-86-5	2	µg/L	<2.0	<2.0	0.00	No Limit
EM1807226-001	Anonymous	EP075(SIM): Phenol	108-95-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Chlorophenol	95-57-8	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Methylphenol	95-48-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2-Nitrophenol	88-75-5	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4-Dimethylphenol	105-67-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4-Dichlorophenol	120-83-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.6-Dichlorophenol	87-65-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 4-Chloro-3-methylphenol	59-50-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4.6-Trichlorophenol	88-06-2	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 2.4.5-Trichlorophenol	95-95-4	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): 3- & 4-Methylphenol	1319-77-3	2	µg/L	<2.0	<2.0	0.00	No Limit
		EP075(SIM): Pentachlorophenol	87-86-5	2	µg/L	<2.0	<2.0	0.00	No Limit
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QC Lot: 1617220)									
EM1807226-005	Anonymous	EP075(SIM): Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	0.00	No Limit
		EP075(SIM): Naphthalene	91-20-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Acenaphthylene	208-96-8	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Acenaphthene	83-32-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Fluorene	86-73-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Phenanthrene	85-01-8	1	µg/L	<1.0	<1.0	0.00	No Limit

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	LOR	Unit	Original Result	Duplicate Result	RPD (%)	Recovery Limits (%)
				Laboratory Duplicate (DUP) Report					
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QC Lot: 1617220) - continued									
EM1807226-005	Anonymous	EP075(SIM): Anthracene	120-12-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Fluoranthene	206-44-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Pyrene	129-00-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benz(a)anthracene	56-55-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Chrysene	218-01-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(b+j)fluoranthene	205-99-2 205-82-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(k)fluoranthene	207-08-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Indeno(1.2.3.cd)pyrene	193-39-5	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Dibenz(a.h)anthracene	53-70-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(g.h.i)perylene	191-24-2	1	µg/L	<1.0	<1.0	0.00	No Limit
EM1807226-001	Anonymous	EP075(SIM): Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	0.00	No Limit
		EP075(SIM): Naphthalene	91-20-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Acenaphthylene	208-96-8	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Acenaphthene	83-32-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Fluorene	86-73-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Phenanthrene	85-01-8	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Anthracene	120-12-7	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Fluoranthene	206-44-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Pyrene	129-00-0	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benz(a)anthracene	56-55-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Chrysene	218-01-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(b+j)fluoranthene	205-99-2 205-82-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(k)fluoranthene	207-08-9	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Indeno(1.2.3.cd)pyrene	193-39-5	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Dibenz(a.h)anthracene	53-70-3	1	µg/L	<1.0	<1.0	0.00	No Limit
		EP075(SIM): Benzo(g.h.i)perylene	191-24-2	1	µg/L	<1.0	<1.0	0.00	No Limit

Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EG020T: Total Metals by ICP-MS (QCLot: 1617809)								
EG020A-T: Arsenic	7440-38-2	0.001	mg/L	<0.001	0.1 mg/L	104	90	110
EG020A-T: Beryllium	7440-41-7	0.001	mg/L	<0.001	0.1 mg/L	97.2	88	113
EG020A-T: Barium	7440-39-3	0.001	mg/L	<0.001	0.1 mg/L	101	88	112
EG020A-T: Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.1 mg/L	102	86	111
EG020A-T: Chromium	7440-47-3	0.001	mg/L	<0.001	0.1 mg/L	98.4	87	109
EG020A-T: Cobalt	7440-48-4	0.001	mg/L	<0.001	0.1 mg/L	104	88	113
EG020A-T: Copper	7440-50-8	0.001	mg/L	<0.001	0.1 mg/L	101	87	108
EG020A-T: Lead	7439-92-1	0.001	mg/L	<0.001	0.1 mg/L	102	88	109
EG020A-T: Manganese	7439-96-5	0.001	mg/L	<0.001	0.1 mg/L	101	88	111
EG020A-T: Nickel	7440-02-0	0.001	mg/L	<0.001	0.1 mg/L	103	87	111
EG020A-T: Selenium	7782-49-2	0.01	mg/L	<0.01	0.1 mg/L	107	85	113
EG020A-T: Vanadium	7440-62-2	0.01	mg/L	<0.01	0.1 mg/L	102	88	112
EG020A-T: Zinc	7440-66-6	0.005	mg/L	<0.005	0.1 mg/L	103	87	113
EG020A-T: Boron	7440-42-8	0.05	mg/L	<0.05	0.5 mg/L	92.4	88	118
EG020A-T: Iron	7439-89-6	0.05	mg/L	<0.05	0.5 mg/L	102	80	120
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1623670)								
EG035T: Mercury	7439-97-6	0.0001	mg/L	<0.0001	0.01 mg/L	94.8	81	114
EP075(SIM)A: Phenolic Compounds (QCLot: 1617220)								
EP075(SIM): Phenol	108-95-2	1	µg/L	<1.0	5 µg/L	47.8	20	49
EP075(SIM): 2-Chlorophenol	95-57-8	1	µg/L	<1.0	5 µg/L	90.4	46	103
EP075(SIM): 2-Methylphenol	95-48-7	1	µg/L	<1.0	5 µg/L	78.3	43	98
EP075(SIM): 3- & 4-Methylphenol	1319-77-3	2	µg/L	<2.0	10 µg/L	73.1	41	92
EP075(SIM): 2-Nitrophenol	88-75-5	1	µg/L	<1.0	5 µg/L	93.1	44	114
EP075(SIM): 2.4-Dimethylphenol	105-67-9	1	µg/L	<1.0	5 µg/L	95.5	43	115
EP075(SIM): 2.4-Dichlorophenol	120-83-2	1	µg/L	<1.0	5 µg/L	92.5	48	111
EP075(SIM): 2.6-Dichlorophenol	87-65-0	1	µg/L	<1.0	5 µg/L	93.0	50	116
EP075(SIM): 4-Chloro-3-methylphenol	59-50-7	1	µg/L	<1.0	5 µg/L	93.3	49	110
EP075(SIM): 2.4.6-Trichlorophenol	88-06-2	1	µg/L	<1.0	5 µg/L	87.0	48	113
EP075(SIM): 2.4.5-Trichlorophenol	95-95-4	1	µg/L	<1.0	5 µg/L	93.3	47	115
EP075(SIM): Pentachlorophenol	87-86-5	2	µg/L	<2.0	10 µg/L	# 30.6	48	130
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QCLot: 1617220)								
EP075(SIM): Naphthalene	91-20-3	1	µg/L	<1.0	5 µg/L	92.9	48	110
EP075(SIM): Acenaphthylene	208-96-8	1	µg/L	<1.0	5 µg/L	97.0	49	124
EP075(SIM): Acenaphthene	83-32-9	1	µg/L	<1.0	5 µg/L	99.1	53	117

Sub-Matrix: **WATER**

Method: Compound	CAS Number	LOR	Unit	Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Recovery Limits (%)	
				Result	Concentration	LCS	Low	High
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QCLot: 1617220) - continued								
EP075(SIM): Fluorene	86-73-7	1	µg/L	<1.0	5 µg/L	104	54	118
EP075(SIM): Phenanthrene	85-01-8	1	µg/L	<1.0	5 µg/L	97.7	57	119
EP075(SIM): Anthracene	120-12-7	1	µg/L	<1.0	5 µg/L	# 114	51	113
EP075(SIM): Fluoranthene	206-44-0	1	µg/L	<1.0	5 µg/L	91.3	59	123
EP075(SIM): Pyrene	129-00-0	1	µg/L	<1.0	5 µg/L	102	58	123
EP075(SIM): Benz(a)anthracene	56-55-3	1	µg/L	<1.0	5 µg/L	82.7	52	126
EP075(SIM): Chrysene	218-01-9	1	µg/L	<1.0	5 µg/L	83.7	55	123
EP075(SIM): Benzo(b+j)fluoranthene	205-99-2 205-82-3	1	µg/L	<1.0	5 µg/L	89.8	52	131
EP075(SIM): Benzo(k)fluoranthene	207-08-9	1	µg/L	<1.0	5 µg/L	76.9	57	126
EP075(SIM): Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	5 µg/L	70.9	56	126
EP075(SIM): Indeno(1.2.3.cd)pyrene	193-39-5	1	µg/L	<1.0	5 µg/L	82.9	53	123
EP075(SIM): Dibenz(a.h)anthracene	53-70-3	1	µg/L	<1.0	5 µg/L	77.0	53	125
EP075(SIM): Benzo(g.h.i)perylene	191-24-2	1	µg/L	<1.0	5 µg/L	79.9	53	125
EP080/071: Total Petroleum Hydrocarbons (QCLot: 1617222)								
EP071-SV: C10 - C14 Fraction	----	50	µg/L	<50	4331 µg/L	96.0	56	120
EP071-SV: C15 - C28 Fraction	----	100	µg/L	<100	16952 µg/L	102	58	134
EP071-SV: C29 - C36 Fraction	----	50	µg/L	<50	8695 µg/L	101	53	143
EP071-SV: C10 - C36 Fraction (sum)	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions (QCLot: 1617222)								
EP071-SV: >C10 - C16 Fraction	----	100	µg/L	<100	6292 µg/L	97.9	56	120
EP071-SV: >C16 - C34 Fraction	----	100	µg/L	<100	22143 µg/L	101	53	149
EP071-SV: >C34 - C40 Fraction	----	100	µg/L	<100	1677 µg/L	105	49	143
EP071-SV: >C10 - C40 Fraction (sum)	----	100	µg/L	<100	----	----	----	----

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **WATER**

Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
				Concentration	MS	Low	High
EG020T: Total Metals by ICP-MS (QCLot: 1617809)							
EM1807257-012	Anonymous	EG020A-T: Arsenic	7440-38-2	1 mg/L	85.8	82	118
		EG020A-T: Beryllium	7440-41-7	1 mg/L	80.7	79	121
		EG020A-T: Barium	7440-39-3	1 mg/L	91.4	80	114
		EG020A-T: Cadmium	7440-43-9	0.25 mg/L	84.6	75	129
		EG020A-T: Chromium	7440-47-3	1 mg/L	88.7	80	118

Sub-Matrix: **WATER**

				Matrix Spike (MS) Report			
				Spike	SpikeRecovery(%)	Recovery Limits (%)	
Laboratory sample ID	Client sample ID	Method: Compound	CAS Number	Concentration	MS	Low	High
EG020T: Total Metals by ICP-MS (QCLot: 1617809) - continued							
EM1807257-012	Anonymous	EG020A-T: Cobalt	7440-48-4	1 mg/L	87.1	82	120
		EG020A-T: Copper	7440-50-8	1 mg/L	81.5	81	115
		EG020A-T: Lead	7439-92-1	1 mg/L	83.5	83	121
		EG020A-T: Manganese	7439-96-5	1 mg/L	89.5	73	123
		EG020A-T: Nickel	7440-02-0	1 mg/L	88.9	80	118
		EG020A-T: Vanadium	7440-62-2	1 mg/L	93.6	81	119
		EG020A-T: Zinc	7440-66-6	1 mg/L	85.4	74	116
EG035T: Total Recoverable Mercury by FIMS (QCLot: 1623670)							
EM1807235-002	Anonymous	EG035T: Mercury	7439-97-6	0.01 mg/L	98.9	70	130
EP075(SIM)A: Phenolic Compounds (QCLot: 1617220)							
EM1807226-003	Anonymous	EP075(SIM): Phenol	108-95-2	5 µg/L	# 49.1	15	49
		EP075(SIM): 2-Chlorophenol	95-57-8	5 µg/L	99.3	35	101
		EP075(SIM): 2-Nitrophenol	88-75-5	5 µg/L	118	39	121
		EP075(SIM): 4-Chloro-3-methylphenol	59-50-7	5 µg/L	112	32	130
		EP075(SIM): Pentachlorophenol	87-86-5	5 µg/L	81.3	11	147
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons (QCLot: 1617220)							
EM1807226-003	Anonymous	EP075(SIM): Acenaphthene	83-32-9	5 µg/L	106	42	122
		EP075(SIM): Pyrene	129-00-0	5 µg/L	89.6	40	136

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **EM1807311**	Page	: 1 of 5
Client	: **AECOM SERVICES PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MELINDA MORRIS	Telephone	: +61-3-8549 9600
Project	: 60565376	Date Samples Received	: 03-May-2018
Site	: NRWMF Site Characterisation	Issue Date	: 09-May-2018
Sampler	: JR	No. of samples received	: 2
Order number	: 60565376 4.0	No. of samples analysed	: 1

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **Laboratory Control outliers exist - please see following pages for full details.**
- **Matrix Spike outliers exist - please see following pages for full details.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

Outliers : Frequency of Quality Control Samples

- **Quality Control Sample Frequency Outliers exist - please see following pages for full details.**

Outliers : Quality Control Samples

Duplicates, Method Blanks, Laboratory Control Samples and Matrix Spikes

Matrix: **WATER**

Compound Group Name	Laboratory Sample ID	Client Sample ID	Analyte	CAS Number	Data	Limits	Comment
Laboratory Control Spike (LCS) Recoveries							
EP075(SIM)A: Phenolic Compounds	QC-1617220-001	----	**Pentachlorophenol**	87-86-5	30.6 %	48-130%	**Recovery less than lower control limit**
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons	QC-1617220-001	----	**Anthracene**	120-12-7	114 %	51-113%	**Recovery greater than upper control limit**
Matrix Spike (MS) Recoveries							
EP075(SIM)A: Phenolic Compounds	EM1807226--003	Anonymous	**Phenol**	108-95-2	49.1 %	15-49%	**Recovery greater than upper data quality objective**

Outliers : Analysis Holding Time Compliance

Matrix: **WATER**

Method	*Extraction / Preparation*			*Analysis*		
Container / Client Sample ID(s)	*Date extracted*	*Due for extraction*	***Days overdue***	*Date analysed*	*Due for analysis*	***Days overdue***
EP075(SIM)A: Phenolic Compounds						
Amber Glass Bottle - Unpreserved QC301_20180423	04-May-2018	30-Apr-2018	**4**	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons						
Amber Glass Bottle - Unpreserved QC301_20180423	04-May-2018	30-Apr-2018	**4**	----	----	----
EP080/071: Total Petroleum Hydrocarbons						
Amber Glass Bottle - Unpreserved QC301_20180423	04-May-2018	30-Apr-2018	**4**	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions						
Amber Glass Bottle - Unpreserved QC301_20180423	04-May-2018	30-Apr-2018	**4**	----	----	----

Outliers : Frequency of Quality Control Samples

Matrix: **WATER**

Quality Control Sample Type	Count		Rate (%)		Quality Control Specification
Method	QC	Regular	Actual	Expected	
Laboratory Duplicates (DUP)					
TRH - Semivolatile Fractions Only	0	1	0.00	10.00	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)					
TRH - Semivolatile Fractions Only	0	1	0.00	5.00	NEPM 2013 B3 & ALS QC Standard

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: ✘ = Holding time breach ; ✓ = Within holding time.

Method	Sample Date	Extraction / Preparation			Analysis		
Container / Client Sample ID(s)		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EG020T: Total Metals by ICP-MS							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EG020A-T)							
QC301_20180423	**23-Apr-2018**	**04-May-2018**	20-Oct-2018	✓	**07-May-2018**	20-Oct-2018	✓
EG035T: Total Recoverable Mercury by FIMS							
Clear Plastic Bottle - Unfiltered; Lab-acidified (EG035T)							
QC301_20180423	**23-Apr-2018**	**----**	----	----	**09-May-2018**	21-May-2018	✓
EP075(SIM)A: Phenolic Compounds							
Amber Glass Bottle - Unpreserved (EP075(SIM))							
QC301_20180423	**23-Apr-2018**	**04-May-2018**	30-Apr-2018	✘	**07-May-2018**	13-Jun-2018	✓
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons							
Amber Glass Bottle - Unpreserved (EP075(SIM))							
QC301_20180423	**23-Apr-2018**	**04-May-2018**	30-Apr-2018	✘	**07-May-2018**	13-Jun-2018	✓
EP080/071: Total Petroleum Hydrocarbons							
Amber Glass Bottle - Unpreserved (EP071-SV)							
QC301_20180423	**23-Apr-2018**	**04-May-2018**	30-Apr-2018	✘	**07-May-2018**	13-Jun-2018	✓
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions							
Amber Glass Bottle - Unpreserved (EP071-SV)							
QC301_20180423	**23-Apr-2018**	**04-May-2018**	30-Apr-2018	✘	**07-May-2018**	13-Jun-2018	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: ✘ = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	2	14	**14.29**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	2	20	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	2	19	**10.53**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH - Semivolatile Fractions Only	EP071-SV	0	1	**0.00**	**10.00**	✘	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	1	14	**7.14**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH - Semivolatile Fractions Only	EP071-SV	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	1	14	**7.14**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH - Semivolatile Fractions Only	EP071-SV	1	1	**100.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Matrix Spikes (MS)							
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	1	14	**7.14**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Mercury by FIMS	EG035T	1	20	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Total Metals by ICP-MS - Suite A	EG020A-T	1	19	**5.26**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
TRH - Semivolatile Fractions Only	EP071-SV	0	1	**0.00**	**5.00**	✘	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Total Metals by ICP-MS - Suite A	EG020A-T	WATER	In house: Referenced to APHA 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector.
Total Mercury by FIMS	EG035T	WATER	In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the unfiltered sample. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3)
TRH - Semivolatile Fractions Only	EP071-SV	WATER	In house: Referenced to USEPA SW 846 - 8015A The sample extract is analysed by Capillary GC/FID and quantification is by comparison against an established 5 point calibration curve of n-Alkane standards. This method is compliant with NEPM (2013) Schedule B(3)
PAH/Phenols (GC/MS - SIM)	EP075(SIM)	WATER	In house: Referenced to USEPA SW 846 - 8270D Sample extracts are analysed by Capillary GC/MS in SIM Mode and quantification is by comparison against an established 5 point calibration curve. This method is compliant with NEPM (2013) Schedule B(3)

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Digestion for Total Recoverable Metals	EN25	WATER	In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3)
Separatory Funnel Extraction of Liquids	ORG14	WATER	In house: Referenced to USEPA SW 846 - 3510B 100 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract. The resultant extracts are combined, dehydrated and concentrated for analysis. This method is compliant with NEPM (2013) Schedule B(3) . ALS default excludes sediment which may be resident in the container.

[Attn: Kieran Burns]
Note: Please forward all samples to ALS Melbourne with ice.

Environmental Division
Melbourne
Work Order Reference
EM1807311

Telephone : + 61-3-8549 9600

FREIGHT

Pg 1 of 1

AECOM PROJECT - CHAIN OF CUSTODY

CLIENT:	AECOM Services	LABORATORY:	ALS	All results to be provided in ESDAT format.	[redacted]
ADDRESS:	Level 28, 91 King William St Adelaide SA 5000	ADDRESS:	2-4 Westall Rd Springvale Vic, 3171	email address: adelaide@urscorp.com	
PHONE NO:	08 7100 6400	PHONE NO:	03 8549 9600	Quote Number:	
FAX NO:	08 7223 5499	FAX NO:			
PROJECT NAME:	NRWMF Site Characterisation	PROJECT MANAGER:	melinda.morris@aecom.com 0408 387 495	hayden.seear@aecom.com	
		SAMPLERS:	JR	SIGNED: J.	
PROJECT NO:	60565376.4.0				

COMMENTS: SPECIAL HANDLING/STORAGE
Please take extra sample volume from core splits if required.

ANALYSIS REQUIRED

[redacted]	SITE	LOCATION	MATRIX	SAMPLE TYPE	SAMPLE ID	Date	CONTAINER TYPE AND PRESERVATIVE	FIELD FILTERED?	TOTAL NUMBER OF CONTAINERS	Cation Exchange Capacity, Exchangeable Cations (Ca, Mg, Na, K) plus Exchangeable Sodium Percentage (ESP)	Metals – NEPM 15 (S-3), Total Fe & Mn	TRH/BTEXN/PAH/Phenols Suite (S-24)	OC/OPs Suite (S-12)	Triazine Pesticides (Atrazine and Simazine)	Carbonate & Total Organic Carbon	NEPM Screen for Soil Classification Suite (P-22)	Gross alpha and Gross beta (50 g bag)	Particle Size Distribution(500 g bag)	XRD with clay extraction (sub-sampled from 500 g bag)	HOLD
		*	Soil		W02D_[redacted]27-41.55	22.4.18	SP	–												X
		*	Soil		W02D_[redacted]-52.24	23.4.18	SP	–												X
		1	Soil		W02D_[redacted]4-52.32	"	J+2B	–												X
		2	Water		QC301 [redacted]0180423	23.4.18	P+A	–	A+P		X	X								
		*	Rock		W02D [redacted]9.25-49.51	22.4.18	SP	–												X

[redacted]	RELINQUISHED BY: J.R	CHECKED:	CONTAINER TYPE AND PRESERVATIVE CODES
	DATE: 26.4.18	TIME:	P = Natural Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar
	RECEIVED BY: Nisalat	CHECKED:	S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS Sulphuric Acid Preserved Glass Bottle;
	DATE: 03/5/18	TIME: 9.25 am	Z = Zinc acetate Preserved Bottle; E = EDTA Preserved Bottle; ST = Sterile Bottle; O = Other

SP = core split
B = bag J = glass jar

* These samples are at ALS Adelaide
- BN 4/5

Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax:(02) 9462 4710

Aggregate/Soil Test Report

Report No: SYD1801230
Issue No: 1
This report replaces all previous issues of report no 'SYD1801230'.

Client:
SMS Geotechnical Pty Ltd
Unit 9 / 21 Beafield Rd
Para Hills West SA 5096

Project: 2126797

Accredited for compliance with ISO / IEC 17025 - Testing

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 2/07/2018

Sample Details

GHD Sample No	SYD18-0241-01
Date Sampled	13/05/2018
Sampled By	Supplied by Client
Location	SMS1.G18135
BH / TP No.	WO2C
Depth (m)	36.9 - 37.3
Soil Description	CLAY: red brown

Test Results

Description	Method	Result	Limits
Coef of Permeability (m/sec)	AS 1289.6.7.3	6 e -11	
Mean Stress Level (kPa)		30	
Permeant Used		tap water	
Length (mm)		74.0	
Diameter (mm)		62.2	
Length/Diameter Ratio		1.20	
Laboratory Moisture Ratio (%)		0.0	
Laboratory Density Ratio (%)		0.0	
CompactiveEffort		n/a	
Method of Compaction		Undisturbed	
Surcharge Applied (Kg)		0.0	
Pressure Applied (Kpa)		10	
Oversize Sieve (mm)		6.3	
Percentage Oversize (%)		0.0	
Moisture Content (%)		21.6	
Date Tested		20/06/2018	

Comments

Moisture and Density Ratio's not applicable. Undisturbed sample.
Initial moisture content = 19.3% , initial dry density = 1.708 t/m³

GroundScience
A C N 105 704 078
13 Brock Street Thomastown VIC, P 03 9464 4617 F 03 9464 4618

PERMEABILITY - CONSTANT HEAD (Triaxial method) AS1289 6.7.3

client :	SMS GEOTECHNICAL (PARA HILLS WEST, SA)	job No.	GS4242/1
project:	GEOTECHNICAL TESTING	report No.	CM
location:	SUBMITTED SAMPLES	test date:	5/6/2018
		page:	1

Sample identification		**#55 (181002)**
Borehole / test pit		**WO2D @ 33.0 - 33.3 tube**
Depth, m		**-**
sample diameter	mm	62.76
sample height	mm	64.00
specimen wet density	t/m3	2.209
specimen dry density	t/m3	1.92
moisture content	%	15.0
cell pressure	kPa	500
inlet pressure	kPa	460
outlet pressure	kPa	440
mean effective stress	kPa	50
hydraulic head	kPa	20
saturation	%	96
PERMEABILITY	**m/sec**	**3.E-09**
water type		de-aired - filtered
specimen description		sandy CLAY, low plasticity, brown, fine to coarse sand, with silt
Notes:		undisturbed sample

Comments sample provided by client, tested "as received"

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

NATA Accredited Laboratory No. 15055
Accredited for compliance with ISO/IEC 17025 - Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/National Standards

Date of issue
7/06/2018

Jaquinde

Jean Aquinde
Approved Signatory

Ground Science
A C N 105 704 078
13 Brock Street Thomastown VIC, P 03 9464 4617 F 03 9464 4618

PERMEABILITY - CONSTANT HEAD (Triaxial method) AS1289 6.7.3

client :	SMS GEOTECHNICAL (PARA HILLS WEST, SA)	job No.	GS4242/1
project:	GEOTECHNICAL TESTING	report No.	CN
location:	SUBMITTED SAMPLES	test date:	25/6/2018
		page:	1

Sample identification		#56 (181003)
Borehole / test pit		WO2D 49.25 - 49.51 tube
Depth, m		-
sample diameter	mm	60.74
sample height	mm	59.22
specimen wet density	t/m3	2.55
specimen dry density	t/m3	2.47
moisture content	%	3.1
cell pressure	kPa	550
inlet pressure	kPa	510
outlet pressure	kPa	490
mean effective stress	kPa	50
hydraulic head	kPa	20
saturation	%	98
PERMEABILITY	**m/sec**	**4.E-11**
water type		de-aired - filtered
specimen description		conglomerate
Notes:		undisturbed sample

Comments sample provided by client, tested "as received"

NATA Accredited Laboratory No. 15055
Accredited for compliance with ISO/IEC 17025 - Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/National Standards

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Date of issue
3/07/2018

Jean Aquinde
Approved Signatory

Adelaide Laboratory

Coffey Services Australia Pty Ltd
ABN 55 139 460 521
33 Richmond Road
Keswick ADELAIDE SA 5035

Phone: +61 8 8375 4400
Fax: +61 8 8375 4499

coffey
A TETRA TECH COMPANY

Report No: ADEL18S-02170-1

Issue No: 2

This report replaces all previous issues of report no 'ADEL18S-02170-1'.

Material Test Report

Client:	AECOM Services Pty Ltd Level 8, 540 Wickham Street Fortitude Valley QLD 4006
Principal:	Department of Industry, Innovation & Science
Project No.:	754-ADEL00342AA
Project Name:	NRWMF#60565376
Lot No.:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing.

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Approved Signatory: Marie Edwards
(Geotechnician)
NATA Accredited Laboratory Number:431
Date of Issue: 5/06/2018

Sample Details

Sample ID:	ADEL18S-02170
Client Sample:	
Date Sampled:	
Source:	
Material:	
Specification:	No Specification
Sampling Method:	Submitted by client
Project Location:	South Australia
Sample Location:	W09, 0.60-0.80m

Other Test Results

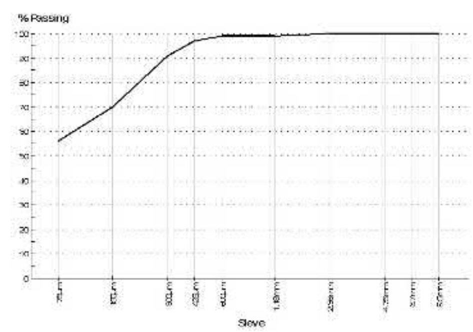
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	5.5	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	8.0	
Mould Length (mm)		254	
Liquid Limit (%)	AS 1289.3.1.1	29	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	15	
Plasticity Index (%)	AS 1289.3.3.1	14	
Date Tested		31/05/2018	
Emerson Class Number	AS 1289.3.8.1	4	
Soil Description		Sandy Clay, Orange /Brown	
Type of Water		Distilled	
Temperature of Water (°C)		18.0	
Date Tested		1/06/2018	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	29/06/2018
Note:	Sample Washed

Sieve Size	% Passing	Limits
9.5mm	100	
6.7mm	100	
4.75mm	100	
2.36mm	100	
1.18mm	99	
600µm	99	
425µm	97	
300µm	91	
150µm	70	
75µm	56	

Chart



Comments

N/A

Adelaide Laboratory

Coffey Services Australia Pty Ltd
ABN 55 139 460 521
33 Richmond Road
Keswick ADELAIDE SA 5035

Phone: +61 8 8375 4400
Fax: +61 8 8375 4499

coffey
A TETRA TECH COMPANY

Material Test Report

Report No: ADEL18S-02171-1
Issue No: 1

Client:	AECOM Services Pty Ltd Level 8, 540 Wickham Street Fortitude Valley QLD 4006
Principal:	Department of Industry, Innovation & Science
Project No.:	754-ADEL00342AA
Project Name:	NRWMF#60565376
Lot No.:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing.

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Approved Signatory: Marie Edwards (Geotechnician)
NATA Accredited Laboratory Number:431
Date of Issue: 1/06/2018

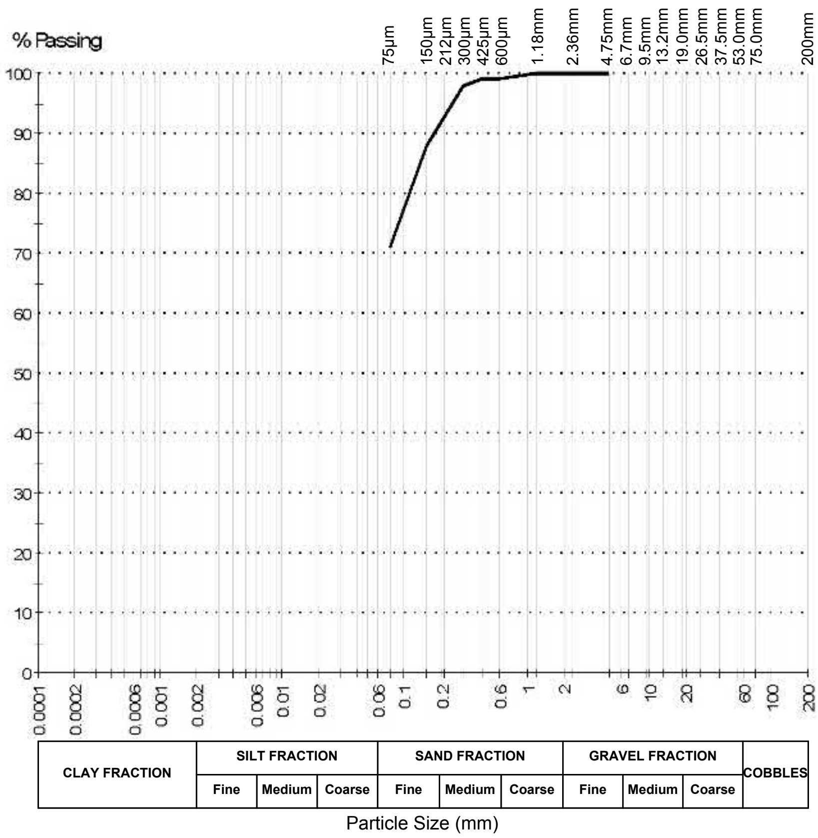
Sample Details

Sample ID:	ADEL18S-02171
Client Sample:	
Date Sampled:	
Source:	
Material:	
Specification:	No Specification
Sampling Method:	Submitted by client
Project Location:	South Australia
Sample Location:	W02D, 3.00-3.20m

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	6.6	
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	9.0	
Mould Length (mm)		254	
Liquid Limit (%)	AS 1289.3.1.1	31	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	16	
Plasticity Index (%)	AS 1289.3.3.1	15	
Date Tested		31/05/2018	

Particle Size Distribution



Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/05/2018

Note: Sample Washed

Sieve Size	% Passing	Limits
4.75mm	100	
2.36mm	100	
1.18mm	100	
600µm	99	
425µm	99	
300µm	98	
150µm	88	
75µm	71	

Comments

N/A

Adelaide Laboratory

Coffey Services Australia Pty Ltd
ABN 55 139 460 521
33 Richmond Road
Keswick ADELAIDE SA 5035

Phone: +61 8 8375 4400
Fax: +61 8 8375 4499

coffey
A TETRA TECH COMPANY

California Bearing Ratio Test Report

Report No: CBR:ADEL18S-02170
Issue No: 1

Client:	AECOM Services Pty Ltd Level 8, 540 Wickham Street Fortitude Valley QLD 4006
Principal:	Department of Industry, Innovation & Science
Project No.:	754-ADEL00342AA
Project Name:	NRWMF#60565376
Lot No.:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing.

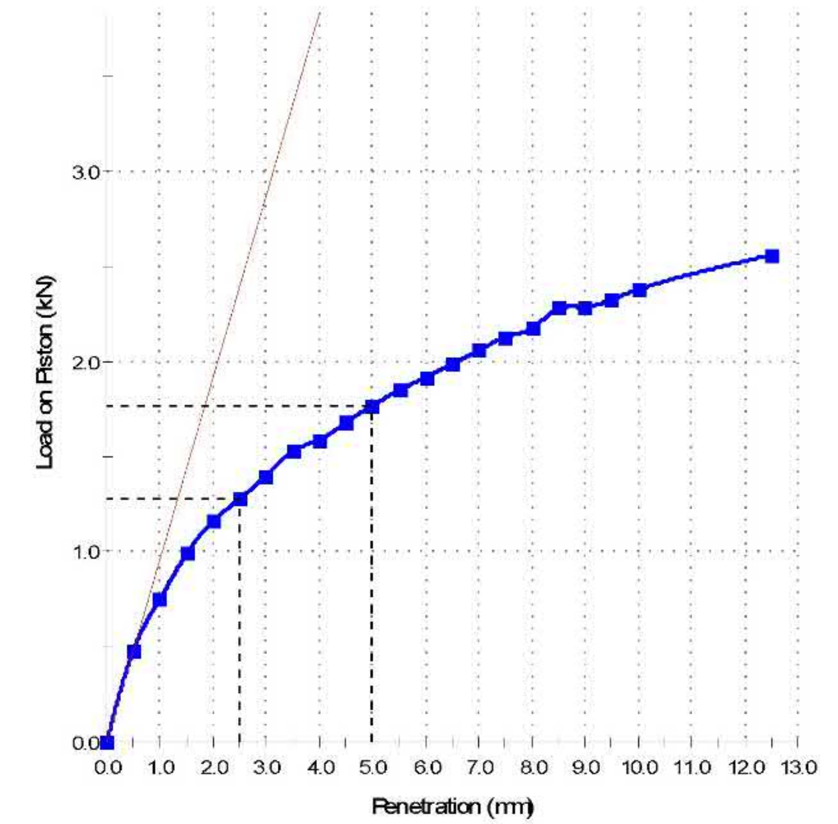
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Approved Signatory: Marie Edwards
(Geotechnician)
NATA Accredited Laboratory Number:431
Date of Issue: 5/06/2018

Sample Details

Sample ID:	ADEL18S-02170	**Sampling Method:**	Submitted by client
Date Sampled:		**Material:**	
Date Submitted:	28/05/2018	**Source:**	
Date Tested:	31/05/2018	**Specification:**	No Specification
Project Location:	South Australia		
Sample Location:	W09, 0.60-0.80m		

Load vs Penetration



Test Results

AS 1289.6.1.1

CBR At 2.5mm (%):	**10**
Maximum Dry Density (t/m³):	1.86
Optimum Moisture Content (%):	13.4
Dry Density before Soaking (t/m³):	1.82
Density Ratio before Soaking (%):	98
Moisture Content before Soaking (%):	13.5
Moisture Ratio before Soaking (%):	101
Dry Density after Soaking (t/m³):	1.82
Density Ratio after Soaking (%):	98
Swell (%):	0.0
Moisture Content of Top 30mm (%):	18.6
Moisture Content of Remaining Depth (%):	15.3
Compactive Effort:	Standard
Surcharge Mass (kg):	4.50
Period of Soaking (Days):	4
Oversize Material (%):	0.0

—— AS 1289.2.1.1 ——

Field Moisture Content (%):	5.5
Curing Time (Hrs):	12.0
Plasticity Level Method:	Linear Shrinkage

Comments

AECOM

AECOM Contact: Kylie Schmidt & Joseph Tan
Tel: 08 7223 5538 **Fax:** 08 7223 5499 email: kylie.schmidt@aecom.com joseph.tan@aecom.com
Level 28, 91 King William Street
Adelaide, SA 5000

Requisition for Testing - Soil Samples

Client: Department of Industry, Innovation and Science
Project: NRWMF
Number: 60565376
Date of Request:
Results Required By:

NOTES: 1. Retain sub-samples of all samples tested
2. Retain all samples until further notice
3. Supply PDF versions of lab certificates

Location	Depth (m)		Field Description	Sample Type e.g Bag [SPT, Spn], Tube [U63, U75], Core	Comments	Testing Required																										
						Moisture Content (AS1289 .2.1.1, 4133.4.2)	Atterberg limits (AS1289 .3.1.1, .3.2.1, .3.3.1, .3.4.1, .2.1.1)	Particle Size Distribution - 75mm to 75microns (AS1289 3.6.2)	Shrink/Swell Index (AS 1289.7.1.1)	Compaction (Standard - AS1289 5.1.1)	4 days soaked CBR @ 98%SMDD	Emerson Class																				
W08	3.00	3.20		Bag																												
W06	2.10	2.30		Bag																												
W10	0.30	0.50		Bag																												
W11	0.40	0.60		Bag																												
W09	0.60	0.80		Bag		1	1	1		1	1	1																				
W07	1.00	1.20		Bag																												
W02D	3.00	3.20		U63		1	1	1																								
Number of tests						2	2	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Dynamic Cone Penetrometer (9 kg) Test

AECOM

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W06

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**1**	1100	**11**	2100	**29**
200	**4**	1200	**16**	2200	**31**
300	**7**	1300	**18**	2300	**35**
400	**7**	1400	**25**	2400	**31**
500	**10**	1500	**15**	2500	**34**
600	**10**	1600	**17**	2600	**R**
700	**15**	1700	**19**	2700	
800	**17**	1800	**20**	2800	
900	**10**	1900	**23**	2900	
1000	**12**	2000	**20**	3000	

Test Procedure: AS 1289.6.3.2

Comments:

DCP refusal (bouncing and eight consecutive blows gave less than 20mm penetration) at depth 2.6m.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

Dynamic Cone Penetrometer (9 kg) Test

AECOM

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W07

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**5**	1100	**25**	2100	
200	**6**	1200	**18**	2200	
300	**12**	1300	**22**	2300	
400	**12**	1400	**25**	2400	
500	**12**	1500	**36**	2500	
600	**20**	1600	**37**	2600	
700	**18**	1700	**R**	2700	
800	**15**	1800		2800	
900	**17**	1900		2900	
1000	**22**	2000		3000	
Test Procedure: AS 1289.6.3.2					

Comments:

DCP refusal (bouncing and eight consecutive blows gave less than 20mm penetration) at depth 1.7m.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

Dynamic Cone Penetrometer (9 kg) Test

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W08

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**3**	1100		2100	
200	**5**	1200		2200	
300	**8**	1300		2300	
400	**12**	1400		2400	
500	**12**	1500		2500	
600	**14**	1600		2600	
700	**16**	1700		2700	
800	**16**	1800		2800	
900	**17**	1900		2900	
1000		2000		3000	
Test Procedure: AS 1289.6.3.2					

Comments:

DCP broken and terminated at depth 0.9 mbgl.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

Dynamic Cone Penetrometer (9 kg) Test

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W09

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**3**	1100	**25**	2100	
200	**5**	1200	**25**	2200	
300	**8**	1300	**33**	2300	
400	**11**	1400	**R**	2400	
500	**11**	1500		2500	
600	**12**	1600		2600	
700	**17**	1700		2700	
800	**20**	1800		2800	
900	**24**	1900		2900	
1000	**20**	2000		3000	
Test Procedure: AS 1289.6.3.2					

Comments:

DCP refusal (bouncing and eight consecutive blows gave less than 20mm penetration) at depth 1.4m.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

Dynamic Cone Penetrometer (9 kg) Test

AECOM

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W10

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**2**	1100	**22**	2100	**14**
200	**3**	1200	**14**	2200	**14**
300	**4**	1300	**11**	2300	**19**
400	**5**	1400	**9**	2400	**20**
500	**4**	1500	**7**	2500	**27**
600	**7**	1600	**6**	2600	**24**
700	**12**	1700	**5**	2700	**22**
800	**15**	1800	**4**	2800	**20**
900	**20**	1900	**6**	2900	**19**
1000	**21**	2000	**12**	3000	**15**
Test Procedure: AS 1289.6.3.2					

Comments:

DCP terminated at depth 3.0 mbgl.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

Dynamic Cone Penetrometer (9 kg) Test

AECOM

Project: NRWMF

Project Number: 60565376

Client: DIIS

Tested By: JT

Location: W11

Date: 1/05/2018

Results:

Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration	Penetration (mm)	Number of Blows per 100 mm Penetration
100	**2**	1100	**16**	2100	**22**
200	**3**	1200	**20**	2200	**R**
300	**7**	1300	**12**	2300	
400	**14**	1400	**18**	2400	
500	**10**	1500	**20**	2500	
600	**12**	1600	**21**	2600	
700	**22**	1700	**20**	2700	
800	**24**	1800	**24**	2800	
900	**16**	1900	**22**	2900	
1000	**16**	2000	**20**	3000	

Test Procedure: AS 1289.6.3.2

Comments:

DCP refusal (bouncing and eight consecutive blows gave less than 20mm penetration) at depth 2.2m.

Ground Moisture Condition: Dry

Testing Depth (mm): GL

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	5	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1808537				

Key Findings:

No major QA/QC issues were identified in the field or laboratory datasets that could have a material implication to decision-making on the project.

However, based on the DVAL below, the following should be considered during data interpretation:

- Potential under reporting should be taken into consideration when interpreting data for pH, as samples were extracted and analysed 6 days outside recommended holding time.
- The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- Elevated RPDs for TOC, iron, filtered silicon, filtered strontium and ionic balance should be taken into consideration when using the data quantitatively.

Quality Assurance/Quality Control Measures – AS 4482-1

Measurement	Soil	Water	Frequency	RPD (%)	Recovery (%)
Type of Quality Control Samples to be Prepared or Taken On-Site					
Rinsate Blanks	-	✓	1 per day per field piece of equipment	-	-
Trip Blanks (VOC analysis only)	-	✓	1 per esky or 1 per batch	-	-
Intra Laboratory Duplicates	✓	✓	1 in 20 samples collected or 1 per batch	30 - 50	-
Inter Laboratory Duplicates	✓	✓	1 in 20 samples collected or 1 per batch	30 - 50	-
Quality Control Samples to be Prepared by Laboratory					
Laboratory Blanks	✓	✓	1 per batch	-	-
Laboratory Duplicates	✓	✓	1 in 10 samples collected or 1 per batch (whichever is smaller)	30	-
Matrix Spike Recoveries	✓	✓	1 in 20 samples collected or 1 per batch	-	70 - 130
Spike Recoveries	✓	✓	1 in 20 samples collected or 1 per batch	-	70 - 130
Surrogates	✓	✓	Each analysis done by GC-MS (all organics except C10+ TPH)	-	70 - 130

Field Quality Assurance and Quality Control

Sampling Personnel	All sampling was conducted by Jody Elsworth on 23 May 2018.

Sampling Methodology	Grab samples were collected using a disposable bailer.
Chain of Custody (COC)	Chain of custody documents were completed by Jody Elsworth.
Analysis Request	Laboratory analysis request and sample receipt notification was reviewed and approved by Melinda Morris.
Field Blank	As concentrations were generally reported below (or close to) the limit of reporting (LOR) in the rinsate blank sample, the field blank sample was not analysed.
Rinsate Blank	Rinsate blank samples were analysed at a frequency of one per day per piece of equipment (one in total). One rinsate sample, collected from the interface probe, was analysed for the day of sampling. Manganese (1 ug/L), electrical conductivity (2 µS/cm), bicarbonate alkalinity as CaCO3 (1 mg/L), total alkalinity as CaCO3 (1 mg/L) and total anions (0.02 meq/L) were reported in the rinsate blank sample. However, through further investigation the manganese concentration is likely to be attributed to the rinsate water. The other analyte concentrations reported in the rinsate blank sample are two to four orders of magnitude below concentrations reported in primary samples; and are therefore not considered to materially affect the interpretation of results. Given that all sampling equipment was either dedicated, disposable or decontaminated with a solution of water and Decon 90 between sampling locations, the decontamination methods and field staff were consistent over the course of the sampling event, and concentrations were generally reported below the LOR in the rinsate sample analysed; the decontamination methods are assessed as acceptable and the potential for cross contamination via sampling methods is considered unlikely.
Trip Blank	NA
Frequency of Field QC	Inter- and intra-laboratory duplicate samples are collected at a rate of one per twenty primary samples in the Wallerberdina groundwater sampling program. No duplicates were collected in this batch. The precision of the data can be assessed based on the inter-laboratory duplicate RPDs analysed as part of the broader Wallerberdina sampling program and the laboratory duplicate RPDs, which were at or above the required frequency within control limits (Data Validation Report EM1809076, EM1809078, ES1816445 and ES1816499).
Handling and Preservation	Groundwater samples were received preserved and chilled at the laboratories. Sample receipt temperature (6.5°C) was marginally outside of the recommended range (≤6°C) in primary batch EM1808537. As the samples were received only marginally outside of the specified temperature range and were immediately cooled upon collection and during transit, the potential for under reporting is not considered to materially affect the interpretation of results. All samples were received at the laboratories in appropriate sample containers.
Laboratory QA/QC	
Tests Requested/Reported	Samples were analysed and reported as requested on the COC.
Holding Time Compliance	Samples were analysed outside recommended holding times for pH (6 days). There is the potential for this analyte to have degraded over time and not be truly representative of field conditions. This potential under reporting should be taken into consideration when interpreting data for pH.
Laboratory Accreditation	The laboratory analysis was conducted by ALS Environmental Pty Ltd (Melbourne) accredited by the National Association of Testing Authorities Australia (NATA) for the analyses undertaken.

Frequency of Laboratory QC	Matrix spikes were not reported at the required frequencies for silicon (ED040F) and sulphide as S2- (EK085F). The accuracy of the data can be assessed as acceptable based on method blanks and LCS (where reported), which were reported at the required frequencies and within control limits. Laboratory control spikes (LCS) were not reported for bromine, iodine and silicon. The accuracy of the data can be assessed as acceptable based on method blanks, which were reported at the required frequencies and within control limits.
Method Blank	Method blank concentrations were reported below the LOR for all analytes tested.
Laboratory Duplicate RPDs	Laboratory duplicate relative percentage differences (RPDs) were within control limits. The laboratory duplicate RPDs are presented in the laboratory Quality Control Report.
Laboratory Control Spike Recovery	Laboratory control spike (LCS) recoveries were within control limits.
Matrix Spike Recovery	Matrix spike (MS) recoveries (where reported) were within control limits. The following recoveries were not determined: Analyte: Sulphate as SO4- — Recovery (%): Not determined — Comment: MS recovery not determined, background level greater than or equal to 4x spike level This non-determination does not reflect method bias and does not affect data interpretation. The accuracy of the data can be assessed as acceptable based on method blanks and LCS, which were reported at or above the required frequencies and within control limits.
Surrogate Spike Recovery	NA
QA/QC Data Evaluation	
Comparison of Field Observations and Laboratory Results	No anomalous results between field observations and analysis results were noted.
Data Transcription	A random 10% check of the laboratory results identified no anomalies within the electronic data, the laboratory reports, and tables generated by AECOM.
Limits of Reporting	NA
Field Duplicate RPDs	NA
Field Triplicate RPDs	NA – based on results of the broader Wallerberdina sampling program elevated RPDs for TOC, iron, filtered silicon, filtered strontium and ionic balance should be taken into consideration when using the data quantitatively.
Other	
Ionic Balance	Acceptable
Sum Totals	Total alkalinity as CaCO3, ionic balance, total anions and total cations were laboratory reported.

Matrix spike recoveries not determined:

Analyte	Recovery (%)	Comment
Sulphate as SO4-	Not determined	MS recovery not determined, background level greater than or equal to 4x spike level

General Comments	ALS laboratory noted the following comments: - **EG020F**: RB01 dissolved manganese result has been confirmed by re-preparation and re-analysis - **EA010-P**: Electrical Conductivity @ 25°C was analysed by manual method (EA010). - **ED093F**:W02C has been confirmed for major cations by re-preparation and re-analysis. - **I**onic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium. - **ED045G**: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly. - Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

Key Findings:

No major QA/QC issues were identified in the field or laboratory datasets that could have a material implication to decision-making on the project.

However, based on the DVAL below, the following should be considered during data interpretation:

- Potential under reporting should be taken into consideration when interpreting data for pH and nitrite as N in laboratory batches EM1809076 and ES1816445 as samples were extracted and analysed outside recommended holding times.
- Elevated RPDs should be considered when using the data for TOC, iron, filtered silicon and ionic balance quantitatively.
- ES1816645: bromine and iodine quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.
- EM1809076: the presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.

Quality Assurance/Quality Control Measures – AS 4482-1

Measurement	Soil	Water	Frequency	RPD (%)	Recovery (%)
Type of Quality Control Samples to be Prepared or Taken On-Site					
Rinsate Blanks	-	✓	1 per day per field piece of equipment	-	-
Trip Blanks (VOC analysis only)	-	✓	1 per esky or 1 per batch	-	-
Intra Laboratory Duplicates	✓	✓	1 in 20 samples collected or 1 per batch	30 - 50	-
Inter Laboratory Duplicates	✓	✓	1 in 20 samples collected or 1 per batch	30 - 50	-
Quality Control Samples to be Prepared by Laboratory					
Laboratory Blanks	✓	✓	1 per batch	-	-
Laboratory Duplicates	✓	✓	1 in 10 samples collected or 1 per batch (whichever is smaller)	30	-
Matrix Spike Recoveries	✓	✓	1 in 20 samples collected or 1 per batch	-	70 - 130
Spike Recoveries	✓	✓	1 in 20 samples collected or 1 per batch	-	70 - 130
Surrogates	✓	✓	Each analysis done by GC-MS (all organics except C10+ TPH)	-	70 - 130

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

Field Quality Assurance and Quality Control

Sampling Personnel	All sampling was conducted by Steve Partridge on 1 June 2018.
Sampling Methodology	Samples were collected from air lift directly into appropriate laboratory supplied bottles.
Chain of Custody (COC)	Chain of custody documents were completed by Steve Partridge.
Analysis Request	Laboratory analysis request and sample receipt notification was reviewed and approved by Melinda Morris.
Field Blank	As per project specifications a field blank sample was not analysed.
Rinsate Blank	As per project specifications a rinsate blank samples was not analysed.
Trip Blank	NA
Frequency of Field QC	An inter-laboratory duplicate sample was collected at a frequency of one in twenty primary samples (one in total). As per project specifications an intra-laboratory duplicate sample was not collected. The precision of the data can be assessed as acceptable based on the available inter-laboratory duplicate RPDs and the laboratory duplicate RPDs which were reported at or above the required frequencies and generally within control limits.
Handling and Preservation	Groundwater samples were received preserved and chilled at the laboratories. Sample receipt temperatures for EM1809076 (5.8°C) and EM1809078 (5.8°C) and ES1816445 (5.9°C) and ES1816499 (5.9°C) were within the recommended range (≤6°C). All samples were received at the laboratories in appropriate sample containers.

Laboratory QA/QC

Tests Requested/Reported	Samples were analysed and reported as requested on the COC.
Holding Time Compliance	Samples were extracted and analysed outside recommended holding times for pH (5 days) and nitrite as N (3 days) in laboratory batches EM1809076 and ES1816445.There is the potential for these analytes to have degraded over time and not be truly representative of field conditions. This potential under reporting should be taken into consideration when interpreting data for these analytes.
Laboratory Accreditation	The primary laboratory analysis was conducted by ALS Environmental Pty Ltd (Melbourne). Gross alpha and gross beta analysis was subcontracted to ALS Fyshwick. Both laboratories are accredited by the National Association of Testing Authorities Australia (NATA) for the analyses undertaken. The triplicate sample was analysed at ALS (Sydney), which is NATA accredited for the analyses undertaken. Gross alpha and beta analysis was subcontracted to ALS (Canberra). All laboratories are accredited by the National Association of Testing Authorities Australia (NATA) for the analyses undertaken.

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

Frequency of Laboratory QC	Matrix spikes were not reported at the required frequencies for silicon (ED040F) and sulphide as S2- (EK085F). The accuracy of the data can be assessed as acceptable based on method blanks and LCS (where reported), which were reported at the required frequencies and within control limits. Laboratory control spikes (LCS) were not reported for bromine, iodine and silicon. The accuracy of the data can be assessed as acceptable based on method blanks, which were reported at the required frequencies and within control limits. Laboratory duplicate samples were not reported for gross beta. The precision of the data can be assessed as acceptable based on the inter-laboratory duplicate RPD, which was reported at the required frequency and within control limits.
Method Blank	Method blank concentrations were reported below the LOR for all analytes tested.
Laboratory Duplicate RPDs	Laboratory duplicate relative percentage differences (RPDs) were within control limits. The laboratory duplicate RPDs are presented in the laboratory Quality Control Report.
Laboratory Control Spike Recovery	Laboratory control spike (LCS) recoveries were within control limits.

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

Matrix Spike Recovery

The following recoveries were not determined:

Analyte	Recovery (%)	Comment
ES1816445 Sulfate as SO4-	Not determined	MS recovery not determined, background level greater than or equal to 4x spike level

This non-determination does not reflect method bias and does not affect data interpretation. This MS sample was an anonymous sample and is therefore not representative of the sample matrix within the laboratory batch. The accuracy of the data can be assessed as acceptable based on method blanks and LCS (which were reported at or above the required frequencies and within control limits).

Matrix spike (MS) recoveries (where reported) were within control limits, with the following exceptions:

Analyte	Recovery (%)	Range (%)	Comment
EM1809076 Mercury	55.2	70-120	Recovery less than lower data quality objective

This MS sample was an anonymous sample and is therefore not representative of the sample matrix within the laboratory batch.

Surrogate Spike Recovery: NA

QA/QC Data Evaluation

Comparison of Field Observations and Laboratory Results	No anomalous results between field observations and analysis results were noted.
Data Transcription	A random 10% check of the laboratory results identified no anomalies within the electronic data, the laboratory reports, and tables generated by AECOM.
Limits of Reporting	NA
Field Duplicate RPDs	NA

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

Field Triplicate RPDs

Field inter-laboratory duplicate RPDs were reported within control limits, with the exception of the following sample analysis (the samples with the higher reported concentration is in bold):

- W02D_20180601 and **Q01_20180601** for TOC (168%)
- **W02D_20180601** and Q01_20180601 for iron (35%)
- W02D_20180601 and **Q01_20180601** for strontium (162%)
- **W02D_20180601** and Q01_20180601 for filtered thorium (67%)
- W02D_20180601 and **Q01_20180601** for filtered silicon (181%)
- W02D_20180601 and **Q01_20180601** for ionic balance (33%)

As concentrations of filtered thorium are less than 10 x LOR, where precision is low and actual differences minor, the data is considered to be of an acceptable precision and these elevated RPDs are not considered to affect the interpretation of results.

As there are no adopted guideline values the elevated RPDs only need to be considered when using the data for TOC, iron, filtered silicon, filtered strontium and ionic balance quantitatively.

Other

Ionic Balance

Acceptable, with the exception of ES1816445 (ionic balance out of acceptable limits due to analytes not quantified in report ES1816445).

Sum Totals

Total alkalinity as CaCO3, ionic balance, total anions and total cations were laboratory reported.

General Comments

ALS laboratory noted the following comments:

- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

EM1809076:

- EK085F: W02D has been diluted prior to analysis due to matrix effect. LOR has been raised accordingly.
- **EA010-P**: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- **ED040F** W02D has been diluted prior to silicon analysis due to sample matrix. LOR has been raised accordingly.
- Ionic balances were calculated using: major anions - chloride, alkalinity

DATA VALIDATION REPORT

Project number:	60565376	**Validation by:**	Sylvia Bretherton	**Date:**	17/07/2018
Client:	Department of Industry, Innovation and Science				
Site:	Wallerberdina	**Data verified by:**	Jodie Castlehow	**Date:**	18/07/2018
Matrix type:	Water				
Primary samples:	2 (W02D and Q01)	**Project Manager:**	James Rusk	**Date:**	19/07/2018
Laboratory:	ALS				
Lab reference:	EM1809076 and EM1809078 (W02D) and ES1816445 and ES1816499 (Q01)				

and sulfate; and major cations - calcium, magnesium, potassium and sodium.

- This is a split batch of EM1809078 due to fast turnaround requested. gross alpha & gross beta analysis on a standard TAT.

EM1809078:

- LOR for gross alpha and beta in sample raised due to the high amount of solid and Potassium present.
- This is a split batch of EM1809076 due to fast turnaround requested. Gross alpha & gross beta analysis will be reported in this batch on a standard TAT.

ES1816445:

- **EK059G-EK058G**: LOR raised for NOx - nitrate on sample 1 due to sample matrix.
- **EG020**: bromine and iodine quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.
- Amendment (13/06/2018): this report has been amended to add silicon to sample Q01_20180601 as per the request received from Melinda Morris.

ES1816499:

- LOR for gross alpha and beta in sample raised due to the high amount of solid and Potassium present.

Wallerberdina Groundwater Rinsate Blank Sample Analysis

Lab Report	EM1808537
Field ID	RB01
Sample Date	23/05/2018
Sample Type	Rinsate blank

Reporting Group	Analyte	Units	LOR	
Physio-Chemical Parameters	pH (Lab)	pH Units	0.01	**6.01**
	Electrical conductivity (lab)	µS/cm	1	**2**
Radioactivity	Gross alpha	Bq/L	0.05	-
	Gross beta	Bq/L	0.1	-
Metals	Arsenic (Filtered)	ug/L	1	<1
	Barium (Filtered)	ug/L	1	<1
	Beryllium (Filtered)	ug/L	1	<1
	Boron (Filtered)	ug/L	50	<50
	Cadmium (Filtered)	ug/L	0.1	<0.1
	Chromium (Filtered)	ug/L	1	<1
	Cobalt (Filtered)	ug/L	1	<1
	Copper (Filtered)	ug/L	1	<1
	Iron	ug/L	50	-
	Lead (Filtered)	ug/L	1	<1
	Lithium (Filtered)	ug/L	1	<1
	Manganese	ug/L	1	-
	Manganese (Filtered)	ug/L	1	**1**
	Mercury (Filtered)	ug/L	0.1	<0.1
	Nickel (Filtered)	ug/L	1	<1
	Selenium (Filtered)	ug/L	10	<10
	Strontium (Filtered)	ug/L	1	<1
	Uranium (Filtered)	ug/L	1	<1
	Vanadium (Filtered)	ug/L	10	<10
	Zinc (Filtered)	ug/L	5	<5
	Thorium (Filtered)	ug/L	1	<1
Inorganics	Bromine (Filtered)	mg/L	0.1	<0.1
	Iodine (Filtered)	mg/L	0.1	<0.1
	Dissolved Organic Carbon	mg/L	1	-
Nutrients	Nitrate (as N)	mg/L	0.01	-
	Nitrite (as N)	mg/L	0.01	-
	Nitrate & Nitrite (as N)	mg/L	0.01	-
Alkalinity	Bicarbonate Alkalinity as CaCO3	mg/L	1	**1**
	Carbonate Alkalinity as CaCO3	mg/L	1	<1
	Hydroxide Alkalinity as CaCO3	mg/L	1	<1
	Total Alkalinity as CaCO3	mg/L	1	**1**
Major Ions	Silicon (Filtered)	mg/L	0.05	<0.05
	Chloride	mg/L	1	<1
	Calcium	mg/L	1	<1
	Fluoride	mg/L	0.1	<0.1
	Magnesium	mg/L	1	<1
	Potassium	mg/L	1	<1
	Sodium	mg/L	1	<1
	Sulphide (as S2-) (Filtered)	mg/L	0.1	-
	Total Anions	meq/L	0.01	**0.02**
	Total Cations	meq/L	0.01	<0.01
	Sulfate (as SO4-) (Filtered)	mg/L	1	<1
	Ionic Balance	%	0.01	-

Legend
LOR = limit of reporting
ug/L= micrograms per litre
mg/L = millograms per litre
µS/cm = microseimens per centimetre
meq/L = milliequivalents per litre
Bq/L = becquerel per litre

Wallerberdina Groundwater Field Duplicate Relative Percent Differences

		Lab Report	EM1809076 / EM1809078	ES1816445 / ES1816499	
		Field ID	W02D_20180601	Q01_20180601	RPD
		Sample Date	1/06/2018	1/06/2018	
Analyte	**Units**	**LOR**			
Physio-Chemical Parameters					
pH (Lab)	pH Units	0.01	7.14	7.52	5
Electrical conductivity (lab)	µS/cm	1	32700	34900	7
Radioactivity					
Gross alpha	Bq/L	0.05	<0.5	<0.5	0
Gross beta	Bq/L	0.1	<10	<10	0
Metals					
Arsenic (Filtered)	ug/L	1	<1	<1	0
Barium (Filtered)	ug/L	1	306	282	8
Beryllium (Filtered)	ug/L	1	<1	<1	0
Boron (Filtered)	ug/L	50	80	90	12
Cadmium (Filtered)	ug/L	0.1	<0.1	<0.1	0
Chromium (Filtered)	ug/L	1	<1	<1	0
Cobalt (Filtered)	ug/L	1	24	22	9
Copper (Filtered)	ug/L	1	27	28	4
Iron	ug/L	50	**308000**	**216000**	**35**
Lead (Filtered)	ug/L	1	<1	<1	0
Lithium (Filtered)	ug/L	1	132	138	4
Manganese	ug/L	1	7510	5800	26
Manganese (Filtered)	ug/L	1	3560	3430	4
Mercury (Filtered)	ug/L	0.1	<0.1	<0.1	0
Nickel (Filtered)	ug/L	1	504	503	0
Selenium (Filtered)	ug/L	10	<10	<10	0
Strontium (Filtered)	ug/L	1	**1140**	**10800**	**162**
Uranium (Filtered)	ug/L	1	<1	<1	0
Vanadium (Filtered)	ug/L	10	<10	<10	0
Zinc (Filtered)	ug/L	5	710	694	2
Thorium (Filtered)	ug/L	1	**2**	**<1**	**67**
Sulphide (as S2-) (Filtered)	mg/L	0.1	<2	<0.1	0
Total Organic Carbon	mg/L	1	**24**	**277**	**168**
Organic Matter		**Analyte**			
Ionic Balance	%	0.01	**1.9**	**2.64**	**33**
Inorganics					
Bromine (Filtered)	mg/L	0.1	32.8	38.9	17
Iodine (Filtered)	mg/L	0.1	<0.1	<0.1	0
Nutrients					
Nitrate (as N)	mg/L	0.01	0.12	<0.1	18
Nitrite (as N)	mg/L	0.01	<0.01	<0.01	0
Nitrate & Nitrite (as N)	mg/L	0.01	0.12	<0.1	18
Sulfate (as SO4-) (Filtered)		1	148	141	5
Alkalinity					
Bicarbonate Alkalinity as CaCO3	mg/L	1	108	125	15
Carbonate Alkalinity as CaCO3	mg/L	1	<1	<1	0
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	0
Total Alkalinity as CaCO3	mg/L	1	108	125	15
Silicon (Filtered)	mg/L	0.05	**1.66**	**33.8**	**181**
Chloride	mg/L	1	10700	10500	2
Calcium	mg/L	1	699	627	11
Fluoride	mg/L	0.1	0.5	0.4	22
Total Anions	meq/L	0.01	307	302	2
Total Cations	meq/L	0.01	319	286	11
Sulfate (as SO4-) (Filtered)	mg/L	1	148	141	5
Ionic Balance	%	0.01	**1.9**	**2.64**	**33**

High RPDs are in bold (Acceptable RPDs for each LOR multiplier range are: 30 (1-10 x LOR); 30 (10-20 x LOR); 30 (> 20 x LOR))
Interlab Duplicates are matched on a per compound basis as methods vary between laboratories.
Any methods in the row header relate to those used in the primary laboratory.

Legend
RPD = relative percent difference
LOR = limit of reporting
ug/L= micrograms per litre
mg/L = millograms per litre
µS/cm = microseimens per centimetre
meq/L = milliequivalents per litre
Bq/L = becquerel per litre

Wallerberdina Groundwater Frequency Table

Site Name	NRWMF
Project No.	60565376
Project Manager	Melinda Morris
Matrix	WATER
Laboratory	ALS
Batch File Number	EM1808537

NOTES:
(a) ✓ - holding times are within project guideline limits.
× - holding times exceed project guideline limits.
(b) ✓ - Limits of reporting (LORs) comply with project specifications.
× - LORs do not comply with project specifications.
NA - Not Applicable

Analytical Method	Analytical Parameter	Number of Tests Requested	Number of Tests Reported	Number of Primary Samples	Holding Times (a)	Limits of Reporting (b)	Field Blank (1 per day)		Rinsate Blank (1 per day per equipment)		Method Blank (1 per batch)		Intra-Laboratory Duplicate Sample (1 in 20)		Inter-Laboratory Duplicate Sample (1 in 20)		Lab Duplicate (1 in 10)		Matrix Spike (1 in 20)		LCS (1 per batch)		Surrogates (GC-MS organics)	
							Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Reported	OK
EA005P: pH by PC Titrator	pH (Lab)	6	6	5	×	✓	1	0	1	1	0	0	1	0	1	0	1	2	0	0	0	0	-	-
EA010P: Conductivity by PC Titrator	Electrical conductivity (lab)	6	6	5	✓	✓	1	0	1	1	1	2	1	0	1	0	1	4	0	0	1	2	-	-
EA250: Gross Alpha and Beta Activity	Gross alpha	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	0	0	1	1	-	-
	Gross beta	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	0	0	1	1	-	-
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	Sulfate (as SO4-)	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	1	1	2	-	-
EG020F: Dissolved Metals by ICP-MS	Arsenic	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	1	1	1	-	-
	Barium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Beryllium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Boron	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Cadmium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Chromium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Cobalt	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Copper	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Lead	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Lithium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Manganese	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Nickel	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Selenium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Strontium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Thorium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Uranium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Vanadium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Zinc	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		1	1	1	-	-
	Bromine	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	0	-	-
	Iodine	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	0	-	-
EG020T: Total Metals by ICP-MS	Manganese	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	1	1	1	1	-	-
	Iron	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2		0	1	1	-	-
EK057G: Nitrite as N by Discrete Analyser	Nitrite (as N)	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	1	1	1	1	-	-
EK058G: Nitrate as N by Discrete Analyser	Nitrate (as N)	5	5	5	✓	✓	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	-	-
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Anal	Nitrate & Nitrite (as N)	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	1	1	1	1	1	-	-
EK040P: Fluoride by PC Titrator	Fluoride	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	1	1	1	-	-
ED040F: Dissolved Major Anions	Silicon	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	0	1	0	-	-
EK085F: Dissolved Sulfide as S2-	Sulphide (as S2-)	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	1	0	1	1	-	-
ED037P: Alkalinity by PC Titrator	Hydroxide Alkalinity as CaCO3	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	1	2	0	0	0	0	-	-
	Carbonate Alkalinity as CaCO3	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	1	2		0	0	0	-	-
	Bicarbonate Alkalinity as CaCO	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	1	2		0	0	0	-	-
	Total Alkalinity as CaCO3	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	1	2		0	1	1	-	-
EP002: Dissolved Organic Carbon (DOC)	Dissolved Organic Carbon	5	5	5	✓	✓	1	0	1	0	1	1	1	0	1	0	1	2	1	1	1	1	-	-
EG035F: Dissolved Mercury by FIMS	Mercury	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	1	1	1	-	-
ED093F: Dissolved Major Cations	Calcium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	0	0	1	1	-	-
	Magnesium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Sodium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
	Potassium	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2		0	1	1	-	-
ED045G: Chloride by Discrete Analyser	Chloride	6	6	5	✓	✓	1	0	1	1	1	1	1	0	1	0	1	2	1	1	1	2	-	-
EN055: Ionic Balance	Total Anions	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	-	-
EM1809078 (W02D) and ES1816499 (Q01)	Total Cations	6	6	5	✓	✓	1	0	1	1	0	0	1	0	1	0	0	0		0	0	0	-	-
	Ionic Balance	5	5	5	✓	✓	1	0	1	0	0	0	1	0	1	0	0	0		0	0	0	-	-

Wallerberdina Groundwater Frequency Table

Site Name	NRWMF
Project No.	60565376
Project Manager	Melinda Morris
Matrix	WATER
Laboratory	ALS
Batch File Number	EM1809076 (W02D) and ES1816445 (Q01) EM1809078 (W02D) and ES1816499 (Q01)

NOTES:
(a) ✓ - holding times are within project guideline limits.
× - holding times exceed project guideline limits.
(b) ✓ - Limits of reporting (LORs) comply with project specifications.
× - LORs do not comply with project specifications.
NA - Not Applicable

Analytical Method	Analytical Parameter	Number of Tests Requested	Number of Tests Reported	Number of Primary Samples	Holding Times (a)	Limits of Reporting (b)	Field Blank (1 per day)		Rinsate Blank (1 per day)		Method Blank (1 per batch)		Intra-Laboratory Duplicate Sample (1 in 20)		Inter-Laboratory Duplicate Sample (1 in 20)		Lab Duplicate (1 in 10)		Matrix Spike (1 in 20)		LCS (1 per batch)		Surrogates (GC-MS organics)	
							Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Number Required	Number Reported	Reported	OK
EM1809076 (W02D) and ES1816445 (Q01)																								
EA005P: pH by PC Titrator	pH (Lab)	1	1	1	×	✓	1	0	1	0	0	0	1	0	1	1	1	2	0	0	0	0	-	-
EA010P: Conductivity by PC Titrator	Electrical conductivity (lab)	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	0	0	1	1	-	-
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA	Sulfate (as SO4-)	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	2	-	-
EG020F: Dissolved Metals by ICP-MS	Lead	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	-	-
	Arsenic	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Barium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Beryllium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Boron	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Cadmium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Chromium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Cobalt	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Copper	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Lithium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Manganese	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Nickel	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Selenium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Strontium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Thorium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Uranium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	1	-	-
	Vanadium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Zinc	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		1	1	1	-	-
	Bromine	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	0	-	-
	Iodine	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1		0	1	0	-	-
EG020T: Total Metals by ICP-MS	Manganese	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	-	-
	Iron	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2		0	1	1	-	-
EK057G: Nitrite as N by Discrete Analyser	Nitrite (as N)	1	1	1	×	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	-	-
EK058G: Nitrate as N by Discrete Analyser	Nitrate (as N)	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	-	-
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analy	Nitrate & Nitrite (as N)	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	-	-
ED045G: Chloride by Discrete Analyser	Chloride	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2	1	1	1	2	-	-
EK040P: Fluoride by PC Titrator	Fluoride	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	-	-
ED040F: Dissolved Major Anions	Silicon	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	0	1	0	-	-
EK085F: Dissolved Sulfide as S2-	Sulphide (as S2-)	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	1	0	1	1	-	-
ED037P: Alkalinity by PC Titrator	Hydroxide Alkalinity as CaCO3	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	1	1	0	0	0	0	-	-
	Carbonate Alkalinity as CaCO3	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	1	1		0	0	0	-	-
	Bicarbonate Alkalinity as CaCC	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	1	1		0	0	0	-	-
	Total Alkalinity as CaCO3	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	1	1		0	1	1	-	-
EP005: Total Organic Carbon (TOC)	Total Organic Carbon	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	0	0	1	1	-	-
EG035F: Dissolved Mercury by FIMS	Mercury	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2	1	1	1	1	-	-
ED093F: Dissolved Major Cations	Calcium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2	0	0	1	1	-	-
	Magnesium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2		0	1	1	-	-
	Sodium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2		0	1	1	-	-
	Potassium	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	2		0	1	1	-	-
EN055: Ionic Balance	Total Anions	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	-	-
	Total Cations	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	0	0		0	0	0	-	-
	Ionic Balance	1	1	1	✓	✓	1	0	1	0	0	0	1	0	1	1	0	0		0	0	0	-	-
EM1809078 (W02D) and ES1816499 (Q01)																								
EA250: Gross Alpha and Beta Activity	Gross alpha	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	1	0	0	1	1	-	-
	Gross beta	1	1	1	✓	✓	1	0	1	0	1	1	1	0	1	1	1	0	0	0	1	1	-	-

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