VHM Limited and as part of the EES process and the Inquiry and Advisory Committee

Goschen Project EES - Groundwater

30 October 2023

CDM Smith
listen. think. deliver.

Table of Contents

Figures

Tables

Appendices

1. Introduction

CDM Smith Australia Pty Ltd (CDM Smith) was engaged by VHM Limited (VHM) to complete the reporting for the Goschen Project Environment Effects Statement (EES) Groundwater study. The objective of the groundwater study is to:

- Review of relevant reports and information describing the results of work that has previously been undertaken.
- Describe and characterise the key hydrogeological features.
- Identify and describe the processes that control or influence the movement and storage of groundwater and solutes in the hydrogeological system.
- Conceptualisation of the physical processes and resulting heads and flows of groundwater.
- Represent these in the numerical model domain and flow model.
- Consider Contaminants of Concern (COC) that have been linked to the project in relation to the groundwater at the site.
- Pathways and mechanisms for potential CoC release from the mine pits into local groundwater systems.
- Develop a particle tracking model to assess the fate of potential CoCs in groundwater.
- Identify and assess potential impacts from the development to the surrounding environment, groundwater users and groundwater dependent ecosystems.
- Evaluation of potential impacts to groundwater resources based on conceptual and model outcomes via a risk assessment approach.
- Recommend mitigation, monitoring and contingency measures in response to identified impacts, as considered necessary.

The scoping requirements (May 2019) for the Goschen Mineral Sands and Rare Earths Project Environment Effects Statement are detailed in Section 3.

1.1 Requirement for an EES

The Project was referred to the Minister for Planning to seek advice on the need for an EES under the Environment Effects Act 1978 (Vic) (EE Act).

On 10 October 2018, the Minister for Planning decided that an EES was required on the basis that the Project has the potential for a range of significant environmental effects.

On 19 December 2018 under delegated authority from the Minister for the Environment, the Department of the Environment and Energy (now referred to as the Department for Climate Change, Energy, the Environment and Water (DCCEEW) made a decision that the Project is a controlled action under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and would require assessment and a decision about whether approval should be given under the EPBC Act. DCCEEW also confirmed the Victorian Government's advice that the Project will be assessed under a bilateral agreement under the EE Act.

The EES allows stakeholders at both the state and federal level to understand the likely environmental impacts of the Project and how they are proposed to be managed. The State and Federal Minister's assessment of the EES will also inform statutory decisions that need to be made on the Project. The EES for this project was developed in consultation with the community and stakeholders.

2. Project Description

2.1 Project Overview

The Goschen Project is a rare earth and mineral sands mine and processing facility, with an operational life of approximately 20-years. VHM has been developing the Project in the context of a rapidly growing global demand for rare earths. One of the world's largest, highest-grade zircon, rutile and rare earth mineral deposits is in the Loddon Mallee region of Victoria in Australia. VHM intends to establish the Project to mine these deposits and process to produce and market a range of rare earth products to national and international consumers.

The mine footprint has been restricted to avoid intersection with groundwater and significant areas of remnant native vegetation. VHM will implement a staged development approach. Initially developing Phase 1 consisting of a mining unit plant (MUP), wet concentrator plant (WCP), rare earth mineral concentrate (REMC) flotation plant and a hydrometallurgical plant (AREM) that will further refine the REMC that is produced at Goschen.

The product suite for Phase 1 consists of a zircon/titania heavy mineral concentrate (HMC) and mixed rare earth carbonate (MREC). Phase 2 will commence approximately 2 years post-production and consist of an additional mineral separation plant (MSP) and, subject to prevailing market circumstances at that time, hot acid leach (HAL) and chrome removal circuit, that will produce additional products such as premium zircon, zircon concentrate, HiTi rutile, HiTi leucoxene, LoTi leucoxene, low chromium ilmenite.

Goschen Project is located approximately 4 hours' drive (275 kilometres) from Melbourne and 30 minutes (35 km) south of Swan Hill within Gannawarra Shire (Figure 2-1).

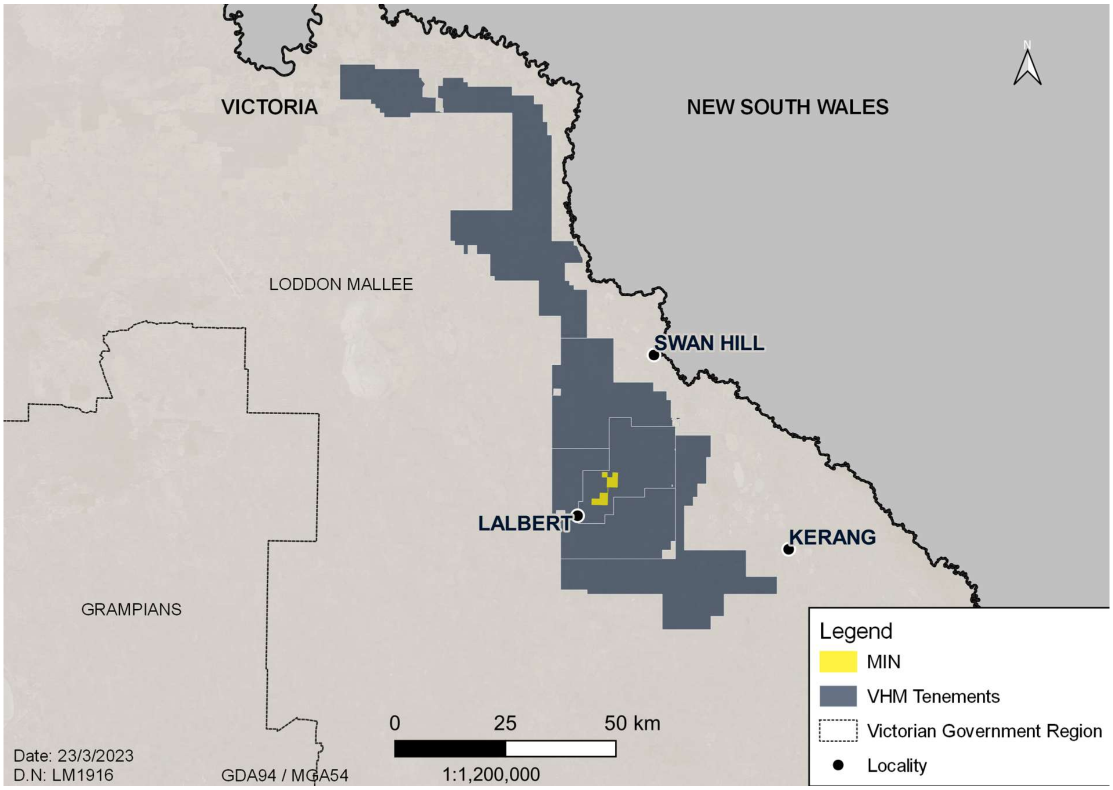


Figure 2-1 Goschen Project Location

2.2 Project Development

The Goschen project team have recognised that there are opportunities to avoid and minimise environmental impacts during the many stages of project development. During project inception and early design development stages of the project, decisions on the location of the project, its design and construction techniques have enabled potential environmental impacts to be avoided and/or minimised in accordance with the hierarchy presented in Figure 2-2.

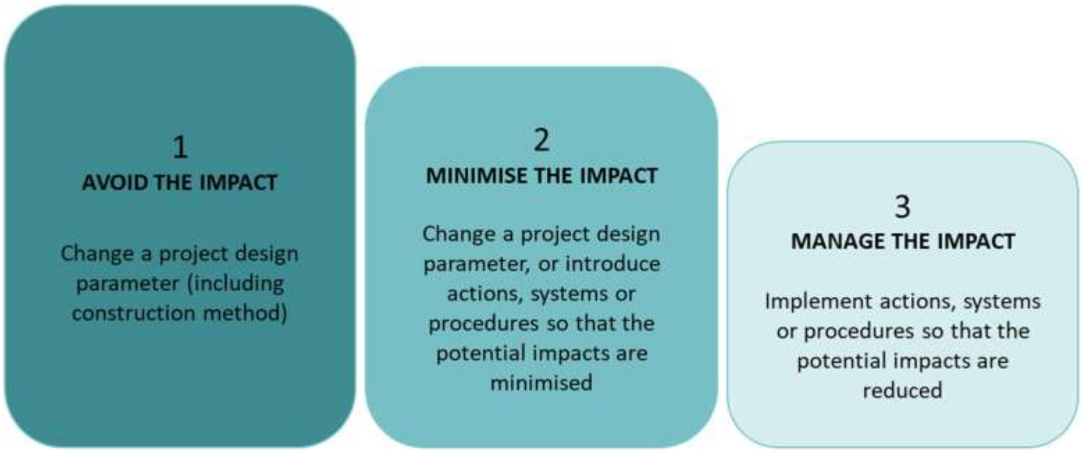


Figure 2-2 Goschen Project Mitigation Hierarchy

Avoidance and minimisation of social and environmental impacts is central to the project's decision making and as such, the project will continue to be refined in response to technical requirements and potential environmental and social impacts identified during the development phase.

Social and environmental impacts were also considered in the preparation of a project description, which can be found in Section 2 below.

After opportunities to avoid impact were incorporated into the project, minimisation and rehabilitation measures were developed. These are described in the impact assessment sections below.

2.3 Key Project Components

The Project site consists of a heavy mineral sand mining and processing operation that will produce several heavy mineral concentrates (HMC) and a range of critical rare earth minerals across two defined mining areas known as Area 1 and Area 3 (Figure 2-3 and Figure 2-4).

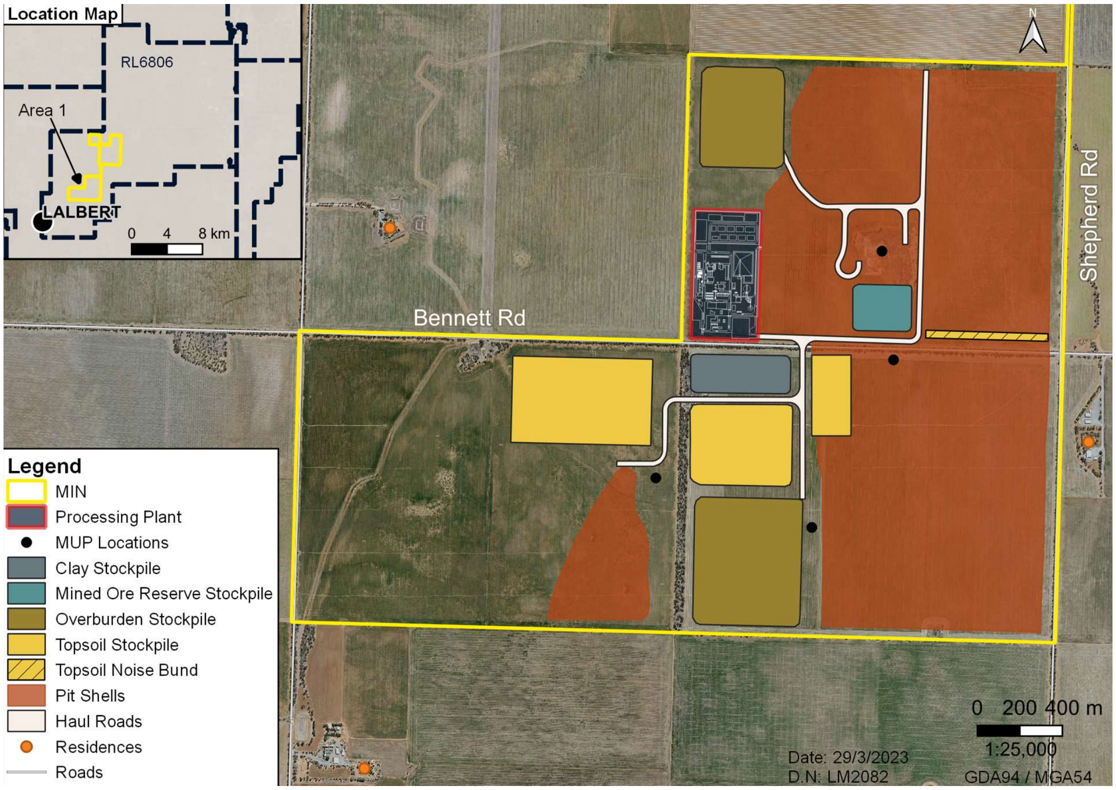


Figure 2-3 Area 1 Goschen Project

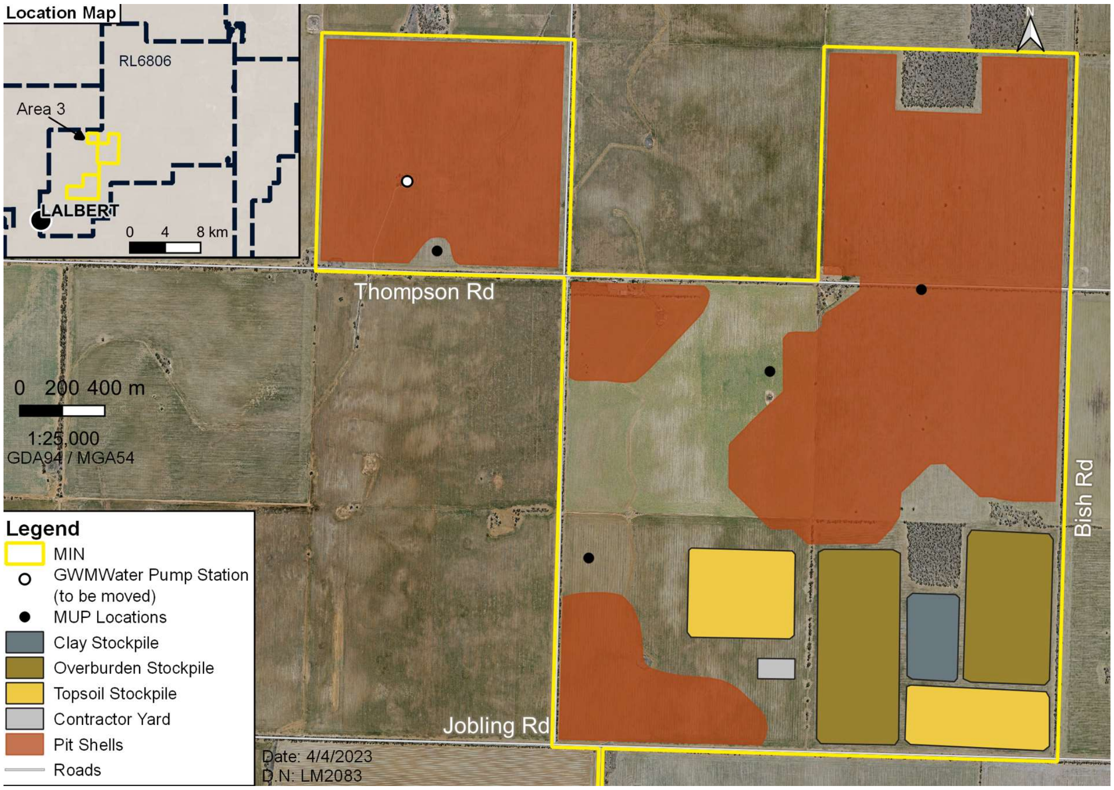


Figure 2-4 Area 3 Goschen Project

The key components that make up the project are described below:

- Mining – Mining will take approximately 20-25 years at 5M tonnes of ore produced per year, across approximately 1,479 hectares of farmland using conventional open cut mining methods of excavation, load, and haul.
- Processing – Heavy mineral sands and rare earths ore will be separated via an on-site WCP and MSP to generate a Rare Earth Mineral Concentrate (REMC). Refining of the REMC on-site is limited to hydrometallurgical extraction to produce a mixed rare earth carbonate. Tailings from the various mineral processes will be homogenised and placed back into the ore zone earlier mined.
- Rehabilitation – The mined areas will be progressively backfilled in a staged manner, with tailings dewatered in-pit to allow overburden and topsoil placement in a profile that reinstates the background soil structure. This will result in the ability for a return to the current agricultural land uses within 3 years.
- Power – Electrical power needed for mining and processing will be produced on-site from dual fuel diesel/LNG fired power generators, with a gradual evolution over the life of mine to renewables, hydrogen and/or battery as technologies and commercial viability increase. Heat energy for the on-site gas fired appliances shall be provided from an extension of the distribution network from the main LNG storage and regasification system.
- Transport – Final products shall be containerised in 20ft sealed sea containers on site and exported via Melbourne Port using road and/or rail-based land logistics solutions. Ultima will provide intermodal rail solution, to reach the shipping export ports.
- Water - Water will be required for construction earthworks, processing, dust suppression and rehabilitation. Up to 4.5 GL a year will be needed for the start-up of the Project. Water will be sourced from Goulburn Murray Water (GMW) from a new pumpstation at Kangaroo Lake via the open water market. A 38 km underground pipeline is proposed beneath existing local road easements as shown in Figure 2-5.
- Tailings - Tailings water will be continually collected from the inpit decant and pumped back into the process water circuit. The tailings water content is estimated at 50 % saturated, however future testing will be completed to optimise this value. Tailings will only be generated once sufficient in-pit void is generated with the embankment constructed.
- Tailings Management – four (4) key mitigation measures to seepage (recover water):
  - thickener at process plant
  - decant on tailings to recover water
  - solar drying before backfilling
  - an underdrain along the embankment (not under entire tailings cell)
- Surface Water- All surface water run-off generated from a 1:20 year rainfall event on stockpiles will be captured and diverted for use. Surface water run-off from a rainfall event greater than 1:20 will be diverted in-pit.

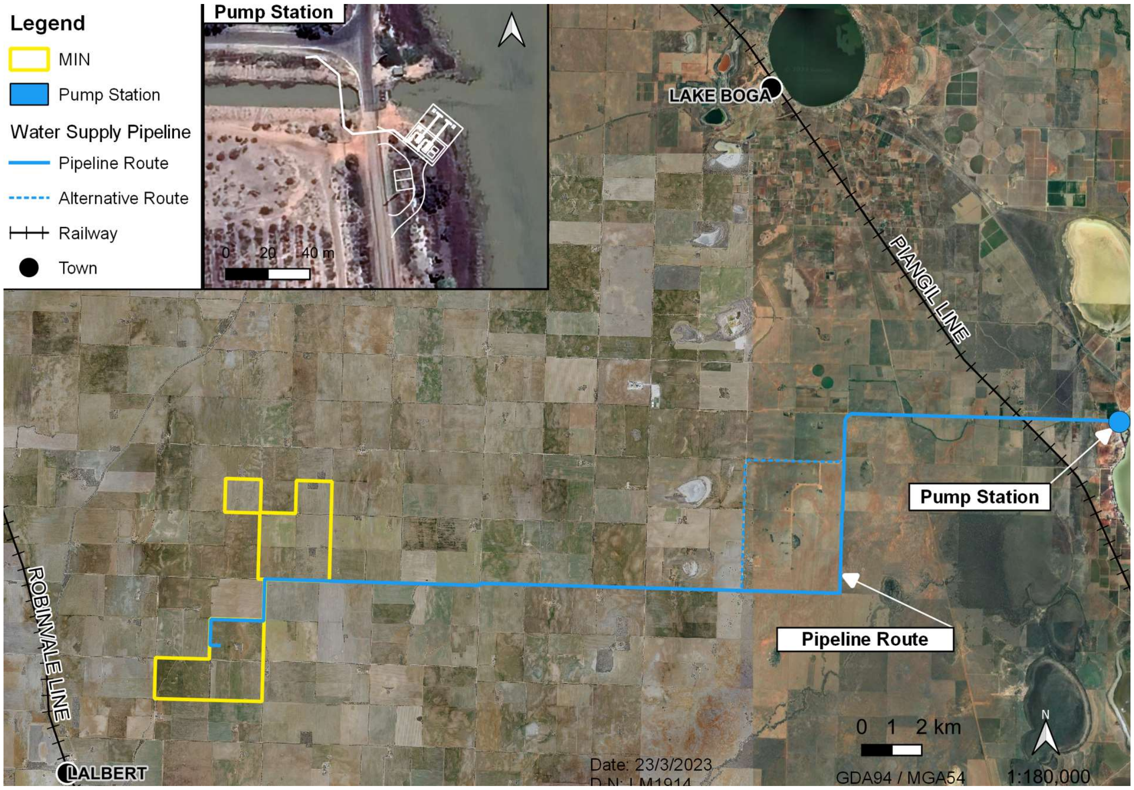


Figure 2-5 Proposed Water Supply Pipeline Route

3. Scope of Work

3.1 EES Evaluation Objectives and Scoping Requirements

The scoping requirements for the Goschen Mineral Sands and Rare Earths Project Environment Effects Statement ('scoping requirements') by the Minister for Planning, set out the specific environmental matters the project must address in order to satisfy the Victorian assessment and approval requirements (DELWP, 2019).

The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project in accordance with the Ministerial guidelines for assessment of environmental effects under the EE Act.

The following sub-sections lists the objective, key issues, existing environment, likely effects, design and mitigation, and performance objectives and management identified in Section 4.3 of the document *Scoping requirements for Goschen Mineral Sands and Rare Earths Project Environment Effects Statement* (DELWP, 2019).

3.1.1 Objective

The following evaluation objective is considered relevant to this groundwater study (DELWP, 2019):

- To minimise effects on water resources and on beneficial and licensed uses of groundwater and related catchment values (including the Kerang Wetlands Ramsar site) over the short and long-term.
- Development of mitigation measures, monitoring programs and management of groundwater resources.

3.1.2 Key Issues

The following key issues associated with this evaluation are considered relevant to this groundwater study (DELWP, 2019):

- The potential for adverse effects on the functions and environmental values of groundwater due to the project's activities, including water extraction, interception or diversion of flows, discharges or seepage from mining areas and other operational areas or saline water intrusion.
- The potential for adverse effects on the functions, values, beneficial and licensed uses of groundwater due to the project's activities, including water extraction, interception or diversion of flows, discharges or seepage from operational areas or saline water intrusion.
- The potential for adverse effects on nearby and downstream water environments (including the Murray and Avoca Rivers and Kerang Wetlands Ramsar site) due to changed water quality, flow regimes, groundwater mounding during construction, operations, rehabilitation, decommissioning and post-closure.
- Ore, product, overburden, tailings and mining by-products management, in the context of potential water quality impacts including those arising from sedimentation, release of radionuclides, other contaminants and pollutants, acid sulphate soils, acid/metalliferous drainage formation, and salinity.

3.1.3 Existing Environment

The following existing environment elements are considered relevant to this Groundwater study (DELWP, 2019):

- Identify and characterise the relevant groundwater environments, including the Kerang Wetlands Ramsar site, in terms of their protected environmental values, existing drainage functions and behaviours and catchments.
- Identify existing groundwater users and allocations in the broader area, including downstream of the site.
- Characterise the interaction between surface water and groundwater within the project site and the broader area.

- Provide a hydrogeological characterisation (e.g., a model) of the current allocations, extractions and uses of groundwater (e.g., irrigation use, stock and domestic use and environmental flows) in the broader area, including downstream of the site.
- Characterise the physical and chemical properties of the project area soils/mine geological materials including the potential environmental risks (e.g., salinity and acidification).

3.1.4 Likely Effects

The following likely effects are considered relevant to this groundwater study (DELWP, 2019):

- Use appropriate methods, including modelling, to identify and evaluate effects of the project and feasible alternatives on groundwater environments, including:
  - the likely extent, magnitude and duration of groundwater level drawdown in the vicinity of the mine and water supply bores during construction and operation, and the expected timing and scale of recovery of groundwater levels post-closure (spatial and temporal groundwater modelling).
  - the potential for mounding and migration of groundwater from the backfilled tailings material along the mine-path during operations, decommissioning and post-closure (including predicted volume, timing and water characteristics).
  - changes to groundwater quality at all project phases, including effects from drawdown and rebound of groundwater levels in the vicinity of the mine-path and water supply bores, present contaminants (including radionuclides), as well as downstream and upstream effects on ecological values (e.g., groundwater dependent ecosystems and the Kerang Wetlands Ramsar site).
  - changes to availability of and groundwater for environmental values (e.g., licenced users and/or ecosystems) as a result of the project (e.g., as a result of predicted extraction groundwater for operational use), accounting for climate risks and the potential effects of climate change.
  - risks associated with potential acid forming materials (soil and rock) which may be disturbed or exposed by mining activities.

3.1.5 Design and Mitigation

The following design and mitigation elements are considered relevant to the Groundwater study (DELWP, 2019):

- Describe proposed design options and measures which could avoid or minimise significant effects on environmental values of surface water, groundwater and downstream water environments, accounting for climate risks and the potential effects of climate change, during the project construction, operations, decommissioning and post-closure phases.

3.1.6 Performance Objectives and Management

The following performance objectives and management are considered relevant to the Groundwater study (DELWP, 2019):

- Describe monitoring programs to be implemented to ensure prompt detection of and groundwater effects associated with the project.
- Identify possible contingency actions to respond to foreseeable changes that may be identified through the monitoring program.

4. Evaluation Framework

The assessment will consider legislation, policy and standards relevant to groundwater assessment along with specific assessment criteria that have been derived for the purposes of the study.

4.1 Legislation, Policy, Guidelines and Standards

The legislation, policy, guidelines and standards relevant to this assessment are summarised in Table 4-1.

Table 4-1 Legislation, Policy, Guidelines and Standards Relevant to the Assessment

Document Title	Summary	Relevance to the Project
Commonwealth Government		
Environment Effects Act, 1978	The procedures and requirements applying to the EES process under section 8B (5) of the Environment Effects Act 1978	The procedures and requirements applying to the EES process, in accordance with both section 8B(5) and the Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978 (Ministerial Guidelines) An inquiry will be appointed under the Environment Effects Act 1978 to consider and report on the environmental effects of the proposal.
Environment Protection and Biodiversity Conservation Act, 1999	The delegate for the commonwealth minister for the Environment determined on 19 December 2018 that the project is a controlled action5, as it is likely to have a significant effect on matters of national environmental significance (MNES), which are protected under Part 3 of the EPBC Act.	The following matters of national environmental significance (MNES), which are protected under Part 3 of the EPBC Act: Ramsar wetlands (sections 16 and 17B); listed threatened species and communities (sections 18 & 18A); and Protection of the environment from nuclear actions (sections 21 and 22A).
Water Act, 2007	The Water Act 2007 (Water Act) establishes a range of mechanisms which support sustainable management of water resources, particularly in the Murray-Darling Basin.	The conservation of declared Ramsar wetlands.
Victorian Government		
Environment Protection Act, 2017	The Act defines how the Environment Protection Authority Victoria (EPA) works with community and industry to minimise risks to human health and the environment from pollution and waste.	The Environment Protection Act is the overarching environmental protection legislation in Victoria.
Environment Reference Standard (ERS) 2021	Guide water quality management in Victoria and improve protection of waterways, bays and coastal waters. The ERS is not a compliance standard. Its primary function is to provide an environmental assessment and reporting benchmark.	Environmental value is the term used to describe the values and uses of water environments Victorians want to protect and is the key instrument in shaping protection of water resources in the environment under the guidance.

Document Title	Summary	Relevance to the Project
Water Act, 1989	The Water Act 1989 governs entitlements to water issued by the Minister for Water	Regarding environmental entitlements and water licences.
Guidelines		
Australian Groundwater Modelling Guidelines	The objective of the Australian groundwater modelling guidelines is to promote a consistent and sound approach to the development of groundwater flow and solute transport models in Australia.	Numerical groundwater model simulations for groundwater mounding and particle tracking.
Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria	Climate change may affect rates of recharge and the future availability of groundwater. These guidelines provide advice only on how the recharge rates should be estimated to consider climate change projections.	Climate risks and the potential effects of climate change.
EPA Victoria Publication 668 Hydrogeological Assessment (groundwater quality) guidelines. EPA Victoria Publication 669 Groundwater sampling guidelines.	Detailed overview of the requirements for a hydrogeological assessment. Methods used for drilling, installation or development of groundwater bores, or collection of groundwater samples	The EPA Victoria Hydrogeological assessment (water quality) guidelines, publication 668 and the EPA Victoria. Groundwater sampling guidelines, publication 669 were referred to for the hydrogeological assessment.

4.2 Assessment Criteria

The assessment criteria relevant to this study are contained in the Environment Protection Act 2017 Environment Reference Standard which defines the environmental values of water type by the background level of Total Dissolved Solids (TDS) in the groundwater.

For the purposes of this the risk assessment has been undertaken based on the Preparation of Work Plans and Work Plan Variations Guideline for Mining Projects December 2020 (version 1.3).

5. Methodology

5.1 Overview of Method

The environmental assessments were undertaken according to the following steps:

- Establishment of a study area and characterisation of existing environment.
- Review of the project description, comprising the key project components (including locations and form), proposed construction and operation activities (in the context of existing environment) and decommissioning activities to determine the location, type, timing, intensity, duration and spatial distribution of potential project interactions with sensitive receptors.
- A risk-based analysis to evaluate the potential effects of proposed project activities and their likelihood of occurring (considering initial mitigation measures) to determine the relative importance of environmental impacts associated with the project and therefore prioritise issues for attention in the subsequent assessment of impacts.
- An assessment of potential groundwater impacts and the sensitivity of the receptors.
- Evaluation of predicted outcomes against criteria provided such as those described in relevant legislation.
- Evaluation of the potential for cumulative impacts (where relevant) caused by impacts of the project in combination with impacts of other existing and proposed projects that may have an overall significant impact on the same environmental asset.
- Identification of additional mitigation measures where necessary to address potentially significant environmental impacts.
- Evaluation and reporting of the residual environmental impacts including magnitude, duration and extent, taking into account the proposed mitigation measures and their likely effectiveness.

The specific methods adopted during the key steps in relation to the groundwater assessment element of the environmental assessments are described in the sections below.

6. Study Area

The Goschen Project is located near Lalbert in the Murray Basin, Victoria. The Goshen Project resides within the Avoca River Basin, which itself resides in the much larger Murray geological basin. The northern limit of the proposed mined area is approximately 27 km south of the township of Swan Hill (Figure 6-1). The Avoca River is located just outside the southeast boundary, while the Kerang Lakes (including Lake Boga, Lake Tutchewop, Kangaroo Lake, Lake Charm, Lake Cullen) scatter the landscape to the east and northeast of the Goshen Project.

The project layout is shown in Figure 6-1. The ore within the project area is planned to be mined as two separate sites called Area 1 and Area 3. The mining schedule for Area 1 will be mined in year 1 to year 8 (8 years in total) and Area 3 will be mined in year 9 to year 20 (12 years in total). The two mined areas are divided into mining blocks with 36 mining blocks in Area 1 and 38 mining blocks in Area 3. Groundwater will not be a source of water for mining and water for operations will be sourced from Kangaroo Lake and harvesting incident rainfall within the active mine footprint.

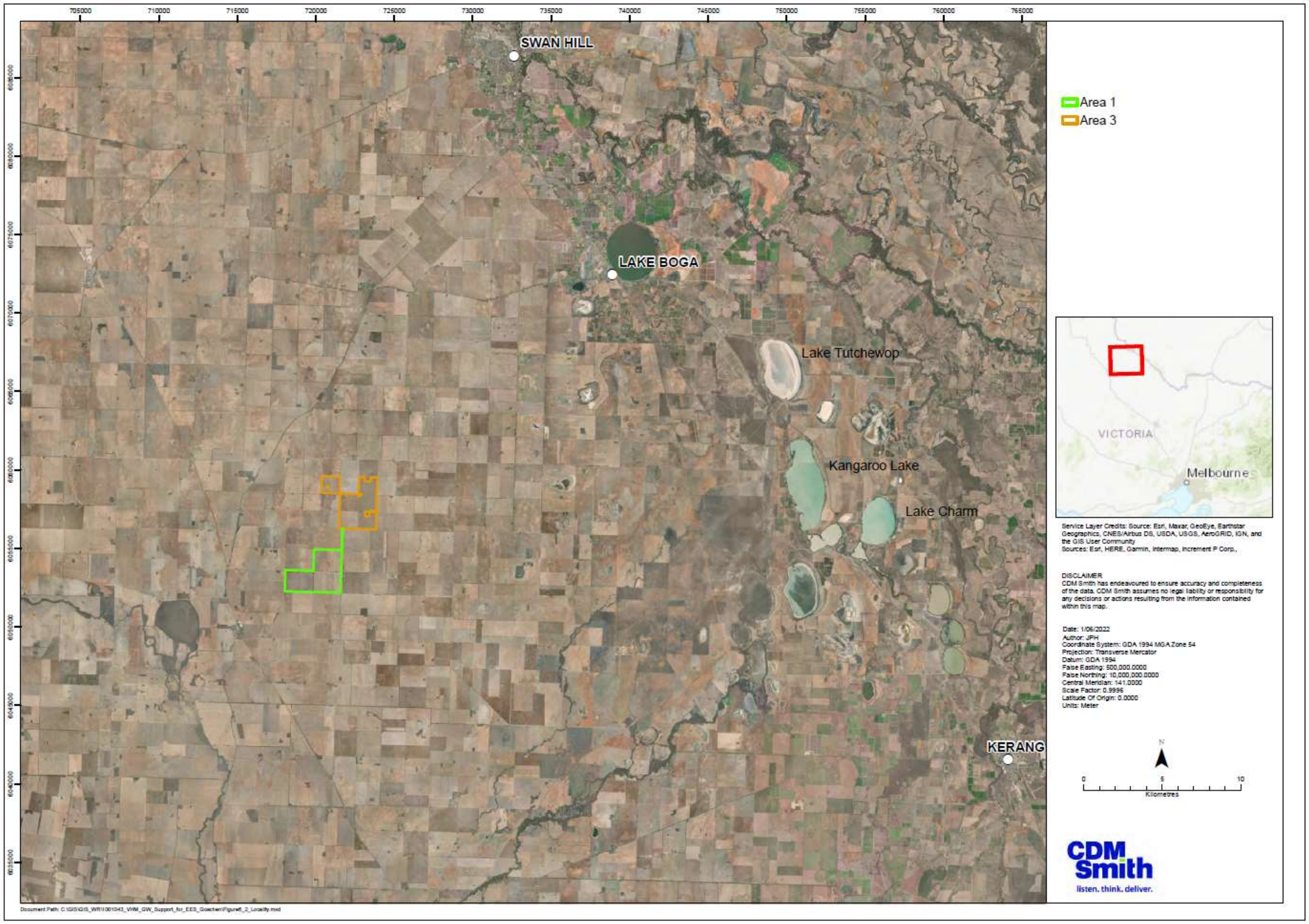


Figure 6-1 Locality Plan

7. Project Limitations, Uncertainties and Assumptions

The following limitations, uncertainties and assumptions apply to this assessment:

- Groundwater monitoring is scheduled at a frequency of bi-annual for a period of two years prior to mining to develop a baseline groundwater level and quality database against which changes can be monitored to the groundwater regime due to mining. There have been two groundwater monitoring events undertaken in August/September 2021 and April 2022. Considering, the regions low recharge rates, and little to no evidence of any considerable seasonal recharge events within existing data, the available groundwater monitoring baseline datasets, and proposed ongoing monitoring is considered to be adequate at this time.
- There is limited data available in the government Water Measurement Information System (WMIS) for groundwater level data for 10 monitoring bores identified.
- Construction environmental risks have not been identified or assessed at the mine pit locations. Construction activities are reported by VHM to be above the water table and will not intersect the water table. No construction activities intercept groundwater and construction activities are assumed to include the following:
  - Mine site: construction of process plant.
  - Pipeline: Underground pipeline from Kangaroo Lake to the mine site.
  - Road upgrades: Widening and intersections.
- The tailings composition presented herein is based on a limited number of samples but assumed to be representative of the material derived from the ore sourced across the entire mine site.
- There is also limited data on the aquifer matrix other than the general information presented.
- The assessment assumes the likely geochemical process which could occur within the aquifer during mining and changes to groundwater quality from interaction with tailings and their leachates following their interment in the pit at closure.
- There is no abstraction of groundwater for the mine operation proposed, including groundwater for construction, operations and closure activities.
- Not all physical processes have been represented or "captured" in the model (e.g., unsaturated flow is not represented).
- Field groundwater level data and any associated survey elevation data used in this assessment have not been assessed for errors and have been assumed to be correct.
- Approximations have been made in the formulation and application of model boundaries and initial conditions where required.
- The model excludes any design or features that may reduce groundwater mounding, for example tailings management.
- Model assumes a tailings specific yield to be 0.15.
- The modelling excludes groundwater mounding associated with stockpiles or process storage facilities.
- The modelling approach assumes that the unsaturated zone will transfer rainfall recharge and tailings seepage to the water table and ignore the possibility of perched conditions to form within the unsaturated zone. If such conditions were to occur due to very low vertical hydraulic conductivity in the Loxton Parilla Sands, the mounding of the water table would be even lower, but the perched conditions could potentially generate seepage of groundwater near the base of tailings or the active pit cell.

- The modelling approach adopted in this assessment is considered conservative as it does not take into account all the attenuation processes that reduce the concentration of COCs along the groundwater flow path.
- Dispersion and diffusion are processes that tend to reduce the concentration of solutes and the forward particle tracking offers a reasonable approximation of the zone of potential contamination. A conservative approach does not aim at making exact predictions, but aims at overestimating the potential impact related to the predictions.
- The modelling approach adopted in this assessment is conservative. A conservative approach does not aim at making exact predictions but aims at overestimating the potential impact related to the predictions. The overestimation of impacts offers a safety buffer that allows a robust and reliable risk assessment, as the response of the real system (mounding of the water table aquifer in this case) to the mining operations will be contained within the envelope provided by the conservative approach proposed in this study.
- The Australian groundwater modelling guidelines (Barnett et al., 2012) provide guiding principles and minimum standards of numerical groundwater models. The guidelines recommend that the overall reliability, complexity and confidence level of the model should be assessed and agreed prior to construction of the model, and if possible, re-assessed at a later stage in the modelling project. The confidence level classification comprises three classes: class 1, class 2 and class 3, in order of increasing confidence level. The level of confidence typically depends on the available data, calibration procedures, consistency between the calibration conditions and predictive analysis scenario, and the level or severity of stresses being simulated. The numerical model developed for this assessment has the characteristics of a class 1 model and is appropriate for the impact assessment framework.

8. Existing Environment

8.1 Geographical Setting

8.1.1 Climate

Daily rainfall and pan evaporation data is available from the Bureau of Meteorology (BoM) Station ID 77021 at Lake Boga (Kunat), located approximately 10 km northeast of the Project area. Mean minimum and maximum temperatures range between 9.7 and 23 °C. Average annual rainfall and evaporation in the area is around 320 and 1620 mm, respectively. The area experiences a relatively dry climate where average monthly rates of rainfall are exceeded by evaporation in all months of the year (Figure 8-1).

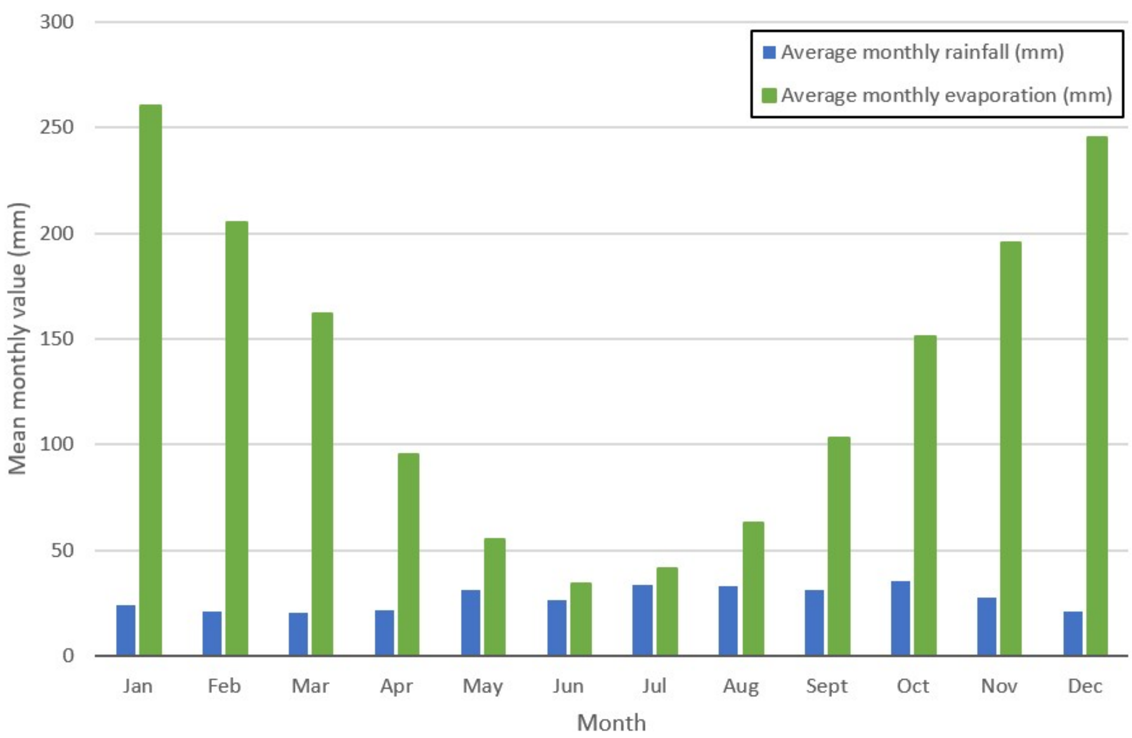


Figure 8-1 Weather Station 77021 Average Monthly Rainfall and Evaporation Data

8.1.2 Topography

The topography in the study area ranges from approximately 75 to 125 metres Australian Height Datum (AHD). The topography is characterised by a north-south orientated ridge elevated around 100 to 125 mAHD that can be seen transecting the proposed pit areas as shown in Figure 8-2.

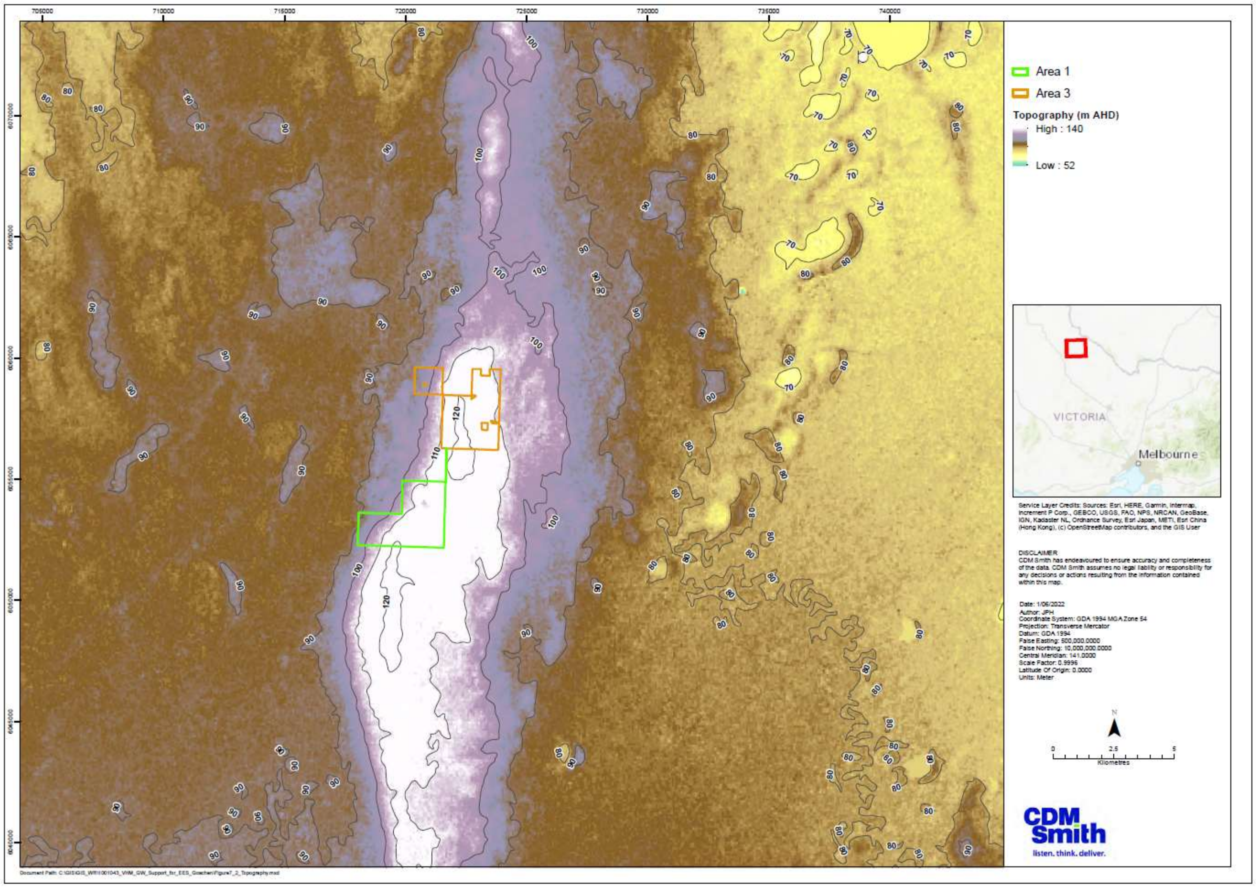


Figure 8-2 Topography (Source: VHM Supplied Lidar Data)

8.2 Geology and Hydrogeology

8.2.1 Geology

The outcropping geology at the Project site is comprised of a thin quaternary cover of sandy clay, and ranges in thickness from approximately 5 to 10 metres below ground level (mbgl). The quaternary material overlays the Loxton Parilla Sands, which hosts the target mineralisation zone. The Loxton Parilla Sands has an average thickness of 50 m across the basin, and consists of an unconsolidated to weakly cemented yellow-brown fine to coarse well-sorted quartz sand, sandstone, interstitial white kaolinitic or gibbsite clay matrix towards top; composite sand sheet deposited in strand plain and fluvial environments (GeoScience Australia, 2022).

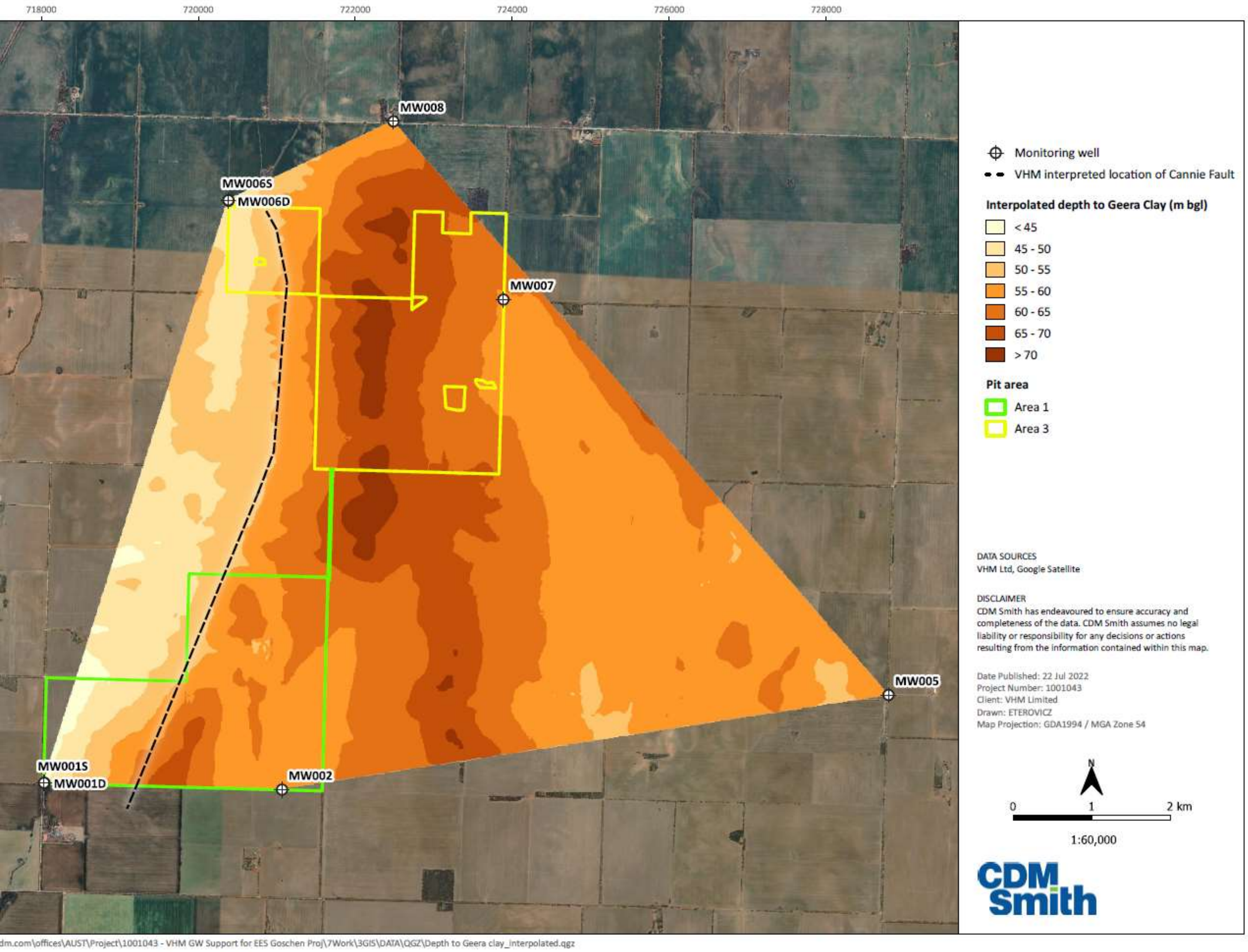
In the broader General Study Area, the Loxton Parilla Sands overlays the Geera Clay, which separates the Loxton Parilla Sands from the Renmark Group. The Geera Clay is comprised of carbonaceous silts and minor carbonates; massive clays with minor sand and silt layers (GeoScience Australia, 2022). Drilling investigations undertaken by CDM Smith (2021) identified the Geera Clay to be prominent across the site with a thickness ranging from 32 to 46 m. Field observations are typically consistent with VHM drillhole data, with encountered depths ranging from 43 to 56 m below ground level (bgl) This suggests that the Loxton Parilla Sands is thinner in the vicinity of the Project site location than regional mapping indicates, and that the Geera Clay is more extensive than regional mapping shows.

The Renmark Group consists of fluvio-lacustrine sediments comprising of gravels, sand, silt and clay and is divided into the upper Olney Formation and the lower Warina Sand.

- The Olney Formation consist of poorly consolidated, thinly bedded, dark brown, grey, black, carbonaceous sand, silt, clay, brown coal, peat; commonly micaceous, pyritic, ferruginised; intercalated poorly sorted fine-medium quartz sand and polymictic sand (GeoScience Australia, 2022). No brown coal or peat beds were identified during drilling investigations completed by CDM Smith.
- The Warina Sand is also typically poorly consolidated and comprises of carbonaceous sand, clay and silt sequences (GeoScience Australia, 2022). CDM Smith drilling investigations identified several bands of green laminated shale at depths of 110 to 120 mbgl.

The Victorian Aquifer Framework (VAF) indicates that the Renmark Group is 33 m thick at the site. In the general study area, the Renmark Group rests unconformably on sedimentary basement rocks and granitic plutons. The Project site is located on a basement high, with the VAF indicating a basement elevation of 6 mAHD at the Project site location. The basement high is likely due to a granitic intrusion in the basement rocks (Lake Boga Granite). The site stratigraphy is presented in Table 8-1.

VHM geologists have interpreted a basement fault which has experienced movement during and after deposition of the Geera Clay and Loxton Parilla Sands, resulting in a step change in thickness and elevation of these units. Figure 8-3 shows the interpreted location of the fault, as well as the interpolated depths to the top of the Geera Clay gathered from drilling investigations. The fault forms the western edge of the Cannie Ridge and coincides with the interpreted edge of the Lake Boga Granite pluton. The elevation of the top of the Geera Clay is 10 to 15 m lower on the western side of the fault. The depth of the interpreted basement fault is not inferred to behave as a barrier to flow in the groundwater system. The interpreted basement fault resulted step change in thickness and elevation of the units, which behaves differently to a barrier fault which will likely influence the flow through it.



Depth to Geera Clay and VHM interpreted location of Cannie Fault

Table 8-1 Stratigraphic Unit Geology Details

Age	Stratigraphic Unit	Description
Quaternary		Clay, sand, sandy clay
Pliocene	Loxton-Parilla Sands	Unconsolidated to weakly cemented yellow-brown fine to coarse well-sorted quartz sand, sandstone, interstitial white kaolinitic or gibbsite clay matrix towards top; composite sand sheet deposited in strand plain and fluvial environments.
Miocene	Geera Clay	Carbonaceous silts and minor carbonates; massive clays with minor sand and silt layers.
Late Eocene to Miocene	Olney Formation	Unconsolidated to poorly consolidated, thinly-bedded, dark brown, grey, black, carbonaceous sand, silt, clay, brown coal, peat; commonly micaceous, pyritic, ferruginised; intercalated poorly-sorted fine-medium quartz sand and polymictic sand.
Eocene	Warina Sand	Poorly consolidated carbonaceous sand, clay and silt

8.3 Hydrogeology

Drilling and groundwater investigations undertaken by CDM Smith in the region have identified the four main hydrogeological units. The units are classified in Table 8-2 into three aquifers and one aquitard.

Table 8-2 Stratigraphic Unit Hydrogeology Details

Stratigraphic Unit	Hydrogeology
Loxton-Parilla Sands	Aquifer
Geera Clay	Aquitard
Olney Formation	Aquifer
Warina Sand	Aquifer

8.3.1 Loxton Parilla Sands

The Loxton-Parilla Sands forms the main aquifer in the study area. The Loxton Parilla Sands aquifer is unconfined and hosts the regional aquifer. Loxton Parilla Sands consists of a coarse grained to gravelly, well sorted, quartz rich sand with interbeds of finer sand and clay. Interbedded high strength, iron-stained sand (ironstone) is prominent near the base of the aquifer across the project area. The Loxton Parilla Sands aquifer thickness ranges from 35 to 55 m.

8.3.2 Geera Clay

The Geera Clay forms a significant aquitard and consists of a dark grey to black clay of low plasticity with a sticky/slimy texture. The unit serves as an aquitard in the region, separating the Loxton-Parilla Sands and the underlying Renmark Group aquifer. Regional mapping may indicate there is no Geera Clay in the region however investigations have identified the Geera Clay to be prominent across the site. The Geera Clay aquitard thickness ranges from 32 to 46 m.

8.3.3 Renmark Group

The Olney Formation forms an aquifer underlying the Geera Clay and consists of a dark grey to black silty clay of medium to low plasticity with a slimy/sticky texture. The unit becomes increasingly coarser grained/gravelly with depth and the thickness ranges from 13 to 25 m.

The Warina Sand forms an aquifer underlying the Olney Formation and consists of a poorly consolidated coarse-grained sand, with clayey interbeds, minor quartz and laminated shale. The unit is encountered at depths of approximately 105 mbgl.

8.4 Groundwater Levels and Hydraulic Properties

8.4.1 Groundwater Monitoring Network

Eight dedicated groundwater monitoring bores were installed in July 2021 and were screened across the Loxton-Parilla Sands aquifer or the Renmark Group (Appendix A Monitoring Bore Logs). The locations details for the monitoring bore details are listed in Table 8-3 and shown in Figure 8-4. The general construction details for the monitoring bore details are listed in Table 8-4. Airlift yields measured during the development of the monitoring bores are variable, ranging from 0.1 to 2 L/Sec. Bore MW007 is dry, and this bore is screened above the water table in the Loxton-Parilla Sands and no airlift yield data is available.

Table 8-3 VHM Groundwater Monitoring Bore Location Details

Bore ID	Easting	Northing	Completed date	Screened Aquifer
MW001S	718035	6052278	July 2021	Loxton Parilla Sands
MW001D	718040	6052278	July 2021	Renmark Group
MW002	721066	6052192	July 2021	Loxton Parilla Sands
MW005	728795	6053398	July 2021	Loxton Parilla Sands
MW006S	720384	6059699	July 2021	Loxton Parilla Sands
MW006D	720384	6059691	July 2021	Renmark Group
MW007	723888	6058434	July 2021	Loxton Parilla Sands
MW008	722487	6060703	July 2021	Loxton Parilla Sands

Table 8-4 VHM Groundwater Monitoring Bore Construction Details

Bore ID	Ground Elevation (mAHD)	Screened from (mAHD)	Screened to (mAHD)	Screened from (mbgl)	Screened to (mbgl)	Drilled Total Depth (mbgl)	Airlift Yield (L/Sec)
MW001S	93.0	58.0	52.0	35	41	45	< 0.25
MW001D	93.0	-12.0	-24.0	105	117	118	< 0.25
MW002	111.7	64.7	58.7	47	53	75	< 0.1
MW005	85.9	43.9	31.9	42	54	58	1 – 2
MW006S	88.8	48.8	42.8	40	46	49	0.25 – 0.5
MW006D	88.8	-18.2	-30.2	107	119	120	> 0.5
MW007	108.4	70.4	64.4	38	44	78	-
MW008	103.0	55.0	49.0	48	54	58	0.25 – 0.5

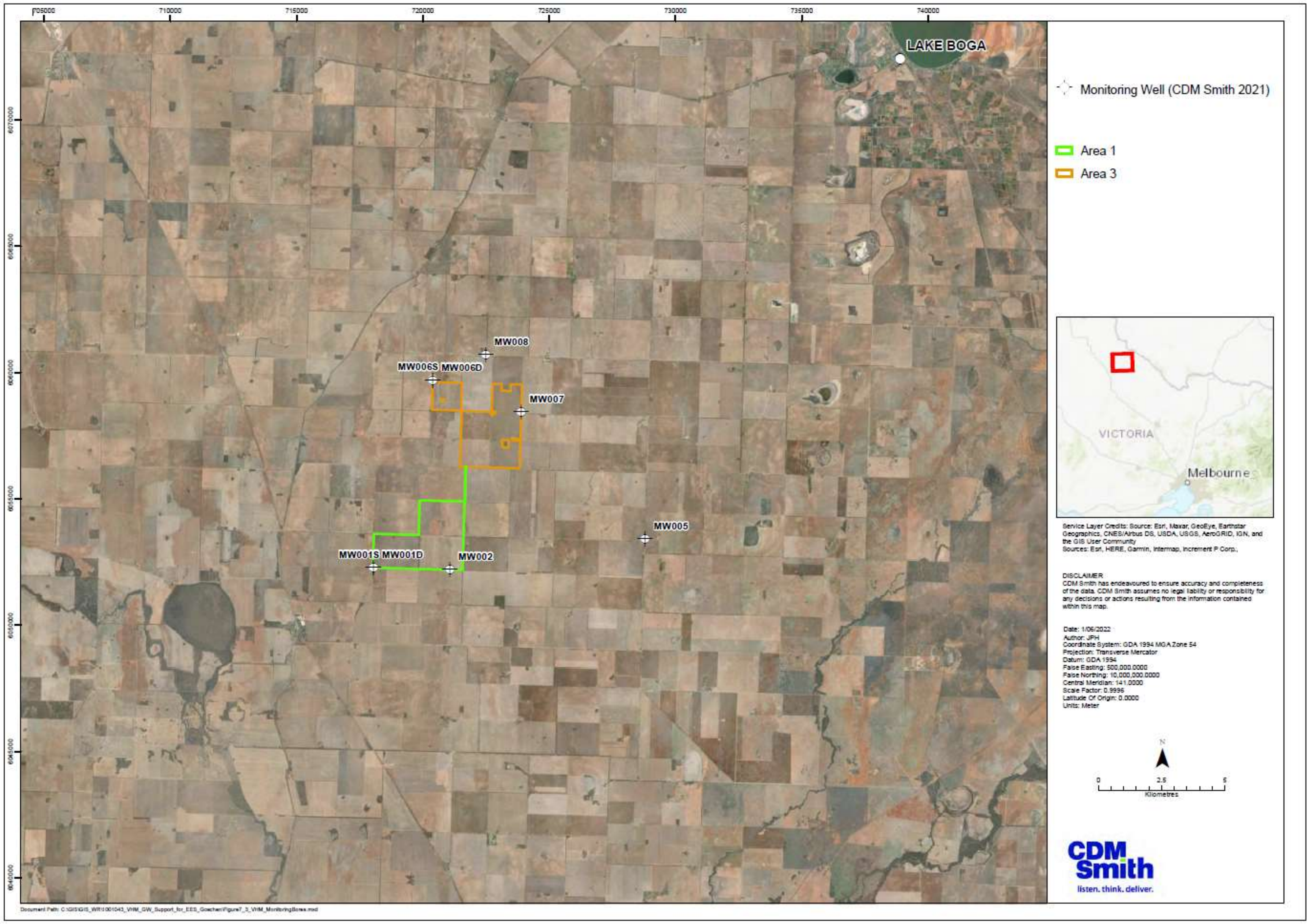


Figure 8-4 VHM Monitoring Bore Locations

8.4.2 Water Measurement Information System Groundwater Bores

A search of the Water Measurement Information System (WMIS) identified 18 monitoring bores within 10 kilometres of the Project area, details of which are listed in Table 8-5 and shown in Figure 8-5. The existing groundwater bores have a listed use of monitoring / observation purposes or non-groundwater / unknown. No bores are listed with the use of domestic / stock bores or licensed bores within 10 kilometres of the Project area. The WMIS does not provide sufficient detail to determine the aquifer details or bore depths for all bores listed.

Table 8-5 WMIS Groundwater Database Details

Bore ID	Easting	Northing	Top of casing (mAHD)	Total depth (mbgl)	Completed date	WMIS Aquifer Description	WMIS Bore Use Description
116769	710735	6056276	85.561	54	April 1988	Loxton Parilla Sands	Monitoring / Observation
307686	719284	6054629	96.15	120	July 1981	Renmark Group	Non-Groundwater
311182	729063	6062066	87.72	128	July 1981	Renmark Group	Non-Groundwater
311682	712282	6050895	82.95	176	October 1981	-	Non-Groundwater
327740	715455	6049422	84.91	9.44	December 1965	-	Non-Groundwater
327741	715443	6049423	84.91	6.09	December 1965	-	Non-Groundwater
327742	728637	6049039	83.22	148	July 1981	-	Non-Groundwater
6096	730904	6063706	86.1	23	January 1977	Loxton Parilla Sands	Monitoring / Observation
6097	727122	6063877	90.27	33	December 1976	Loxton Parilla Sands	Monitoring / Observation
6098	720921	6063977	89.33	7	December 1976	-	Monitoring / Observation
6103	718821	6064077	87.94	31	December 1976	Loxton Parilla Sands	Monitoring / Observation
74015	710521	6056277	87.51	54	April 1988	Loxton Parilla Sands	Unknown
92807	728589	6048997	83.01	134.7	September 1988	-	Monitoring / Observation
WRK957735	712699	6048541	85.3	-	March 2001	-	Monitoring / Observation
40662	715621	6067327	86.57	27	February 1976	Loxton Parilla Sands	Monitoring / Observation
40663	718806	6065621	88.662	30	January 1976	Loxton Parilla Sands	Monitoring / Observation
6822	732762	6062127	81.94	26	March 1982	Loxton Parilla Sands	Monitoring / Observation
6823	732762	6062127	82.05	7.16	March 1982	Loxton Parilla Sands	Monitoring / Observation

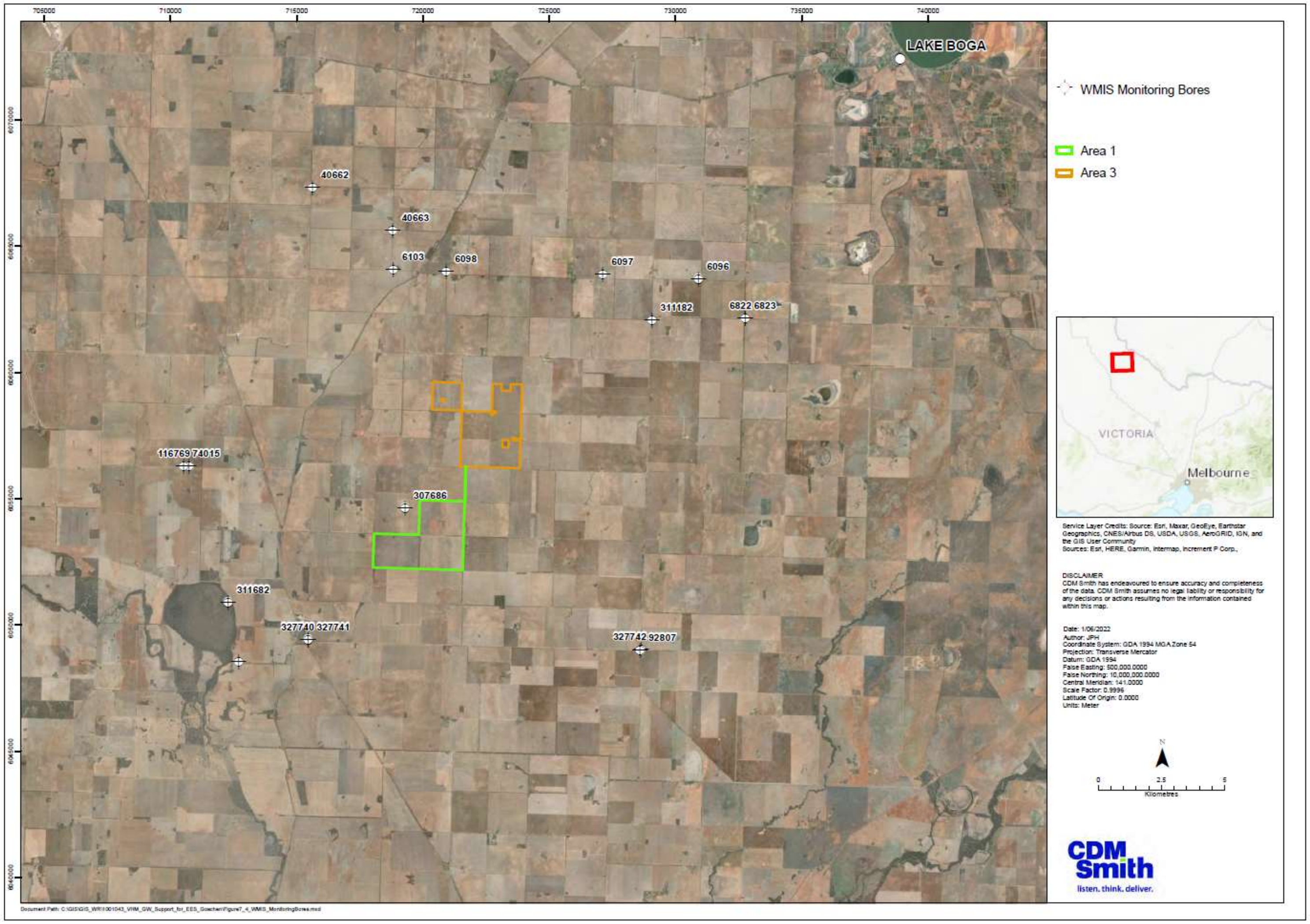


Figure 8-5 WMIS Bore Locations

8.4.3 Groundwater Levels

8.4.3.1 Monitoring Bore Groundwater Levels

Groundwater levels for the monitoring bores were collected on two occasions during the first GME in August 2021 the second GME in April 2022 with results reported in Table 8-6.

Groundwater level loggers were installed at four locations (MW005, MW006s, MW006d and MW008) in early September 2021, and are set to record hourly groundwater level readings. Time series groundwater level data for the project monitoring bores is shown as depth to groundwater in Figure 8-6 and as groundwater elevation in Figure 8-7.

Table 8-6 VHM Monitoring Bore Groundwater Levels

Bore ID	Measurement date	Aquifer	Standing Water Level (metres below ground level)	Standing Water Level (metres Australian Height Datum)
MW001S	August 2021	Loxton Parilla Sands	30.5	62.5
MW001D	August 2021	Renmark Group	29.0	63.8
MW002	August 2021	Loxton Parilla Sands	47.1	64.6
MW005	August 2021	Loxton Parilla Sands	18.8	67.1
MW006S	August 2021	Loxton Parilla Sands	25.7	63.1
MW006D	August 2021	Renmark Group	25.5	63.9
MW007	August 2021	Loxton Parilla Sands	Bore dry*	Bore dry*
MW008	August 2021	Loxton Parilla Sands	40.4	63.2
MW001S	April 2022	Loxton Parilla Sands	29.20	62.54
MW001D	April 2022	Renmark Group	30.45	63.82
MW002	April 2022	Loxton Parilla Sands	47.04	64.64
MW005	April 2022	Loxton Parilla Sands	18.81	67.05
MW006S	April 2022	Loxton Parilla Sands	24.93	63.04
MW006D	April 2022	Renmark Group	25.72	63.88
MW007	April 2022	Loxton Parilla Sands	Bore dry*	Bore dry*
MW008	April 2022	Loxton Parilla Sands	39.89	63.15

**The depth of the base of screen at MW007 is 44 mbgl and therefore the depth to groundwater is >44 mbgl (<64 mAHD).*

Standing water level (SWL): Measurements from the reference point on the bore to the groundwater level. Positive values are below the reference point and negative values are above the reference point.

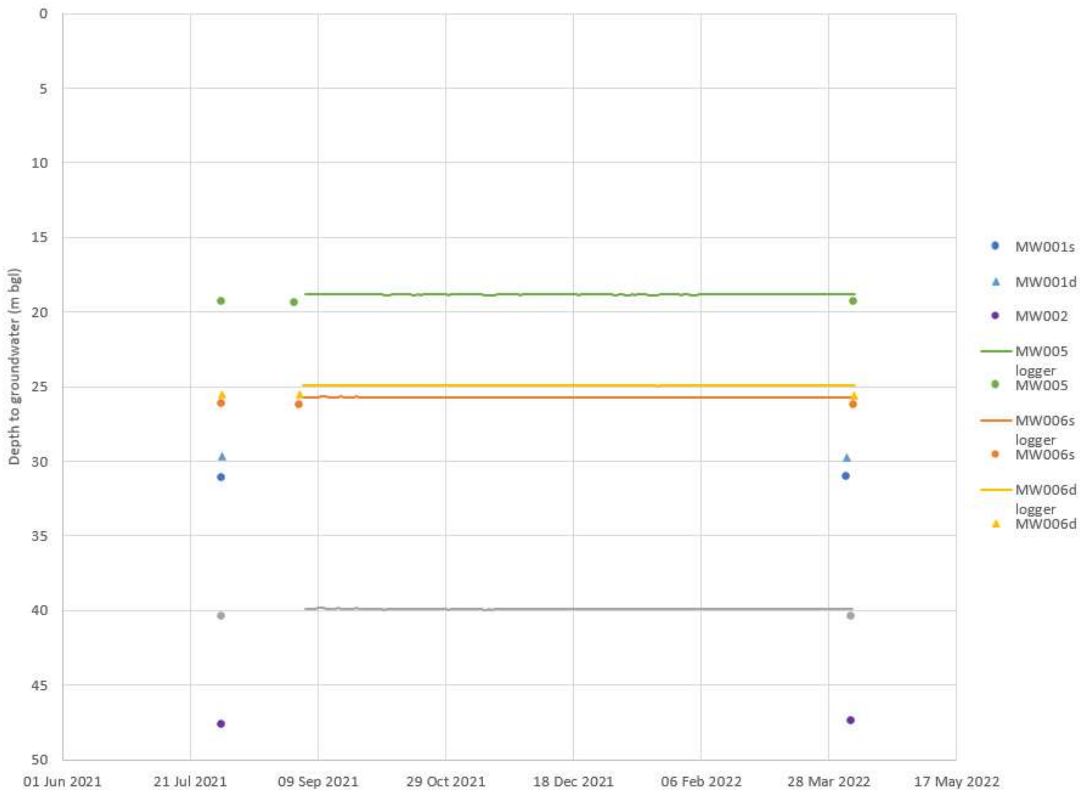


Figure 8-6 VHM Monitoring Bores (Depth To Groundwater)

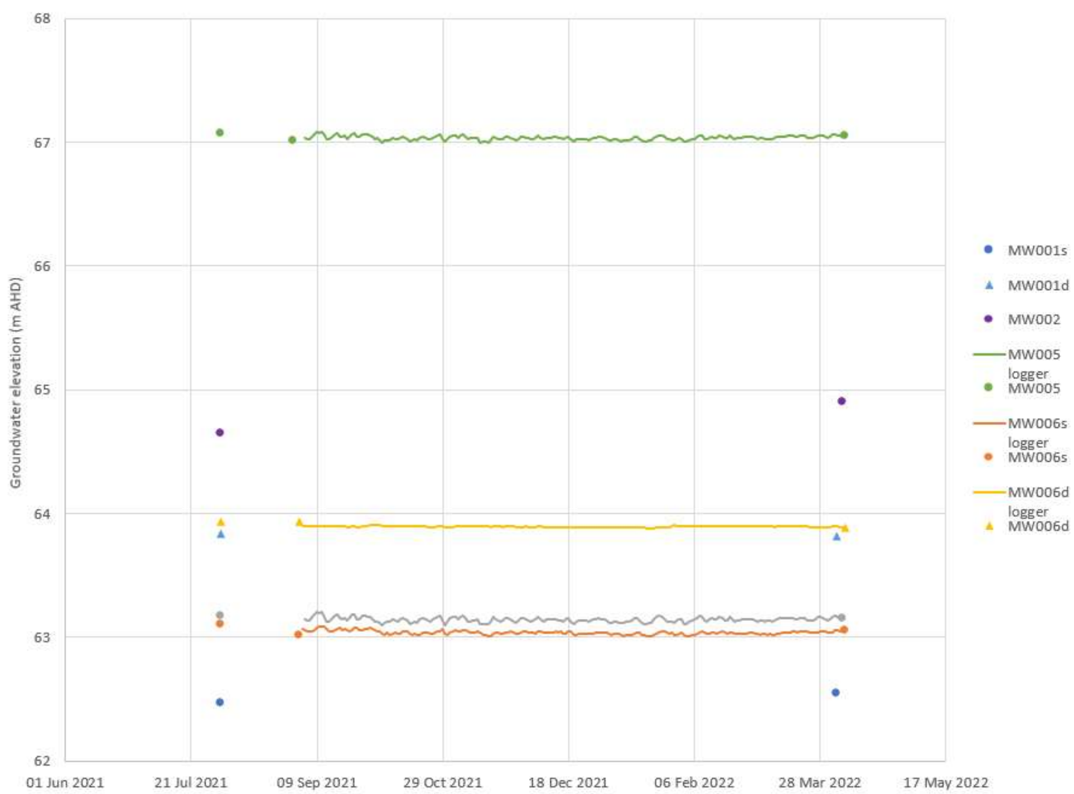


Figure 8-7 VHM Monitoring Bores (Groundwater Elevation)

Groundwater level data is also available from 8 of the 18 monitoring bores identified through WMIS (Table 8-7). Time series groundwater level data for three WMIS monitoring bores is shown in Figure 8-8 reported as groundwater elevation (mAHD).

Table 8-7 WMIS Bore Groundwater Levels

Bore ID	Measurement date	Type	Aquifer	SWL (metres Australian Height Datum)
6096	May 2016	Monitoring bore	Loxton Parilla Sands	65.87
6097	November 1991	Monitoring bore	Loxton Parilla Sands	63.28
6103	September 1991	Monitoring bore	Loxton Parilla Sands	60.39
6822	June 1986	Monitoring bore	Loxton Parilla Sands	66.25
40662	November 1991	Monitoring bore	Loxton Parilla Sands	59.31
40663	August 2021	Monitoring bore	Loxton Parilla Sands	60.68
92807	February 2010	Monitoring bore	Renmark Group	69.57
116769	January 2017	Monitoring bore	Loxton Parilla Sands	60.53

Standing water level (SWL): Measurements from the reference point on the bore to the groundwater level. Positive values are below the reference point and negative values are above the reference point.

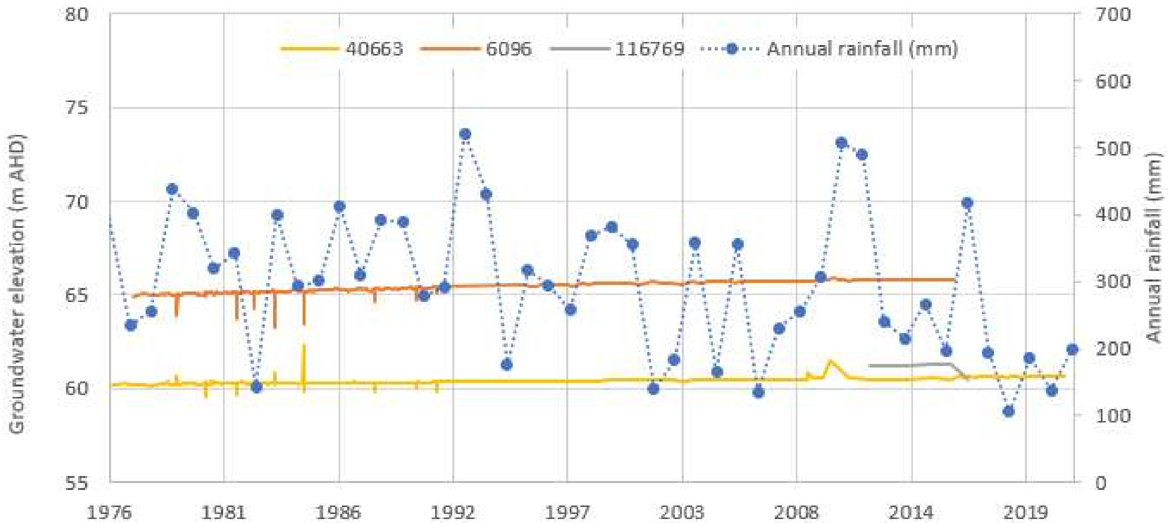


Figure 8-8 WMIS Monitoring Bores (Groundwater Elevation) and Annual Rainfall

There is limited time series groundwater level data available in the Project area due to monitoring bores only being installed in 2021. However, the long term hydrographs from WMIS data show that groundwater level fluctuations appear relatively low across all seasons. This time series data indicates very stable groundwater levels and no clear response to rainfall events as shown in the cumulative departure from mean monthly rainfall (CDFM) shown on Figure 8-9.

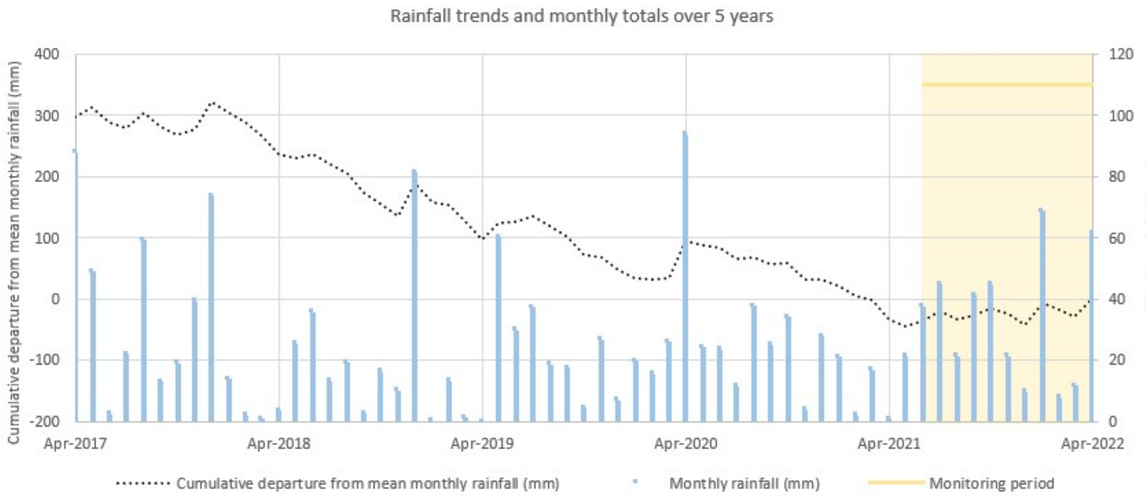


Figure 8-9 Rainfall and Cumulative Departure From The Mean Rainfall

8.4.4 Water Table Depth

Groundwater level contours have been developed for the Loxton Parilla Sands aquifer using groundwater levels from VHM and WMIS monitoring bores and are presented in Figure 8-10. To broaden the extent of the groundwater contours, groundwater levels from existing bores from the Victorian Water Management Information System (WMIS) were included. It should be noted that the groundwater elevations recorded for the WMIS bores are from a variety of dates. However, given the relatively static condition of groundwater levels over time, these levels are considered to be representative. There is no evidence to show a perched aquifer exists in the area based on the available drilling bore logs, water level observations and as shown in MW007, which is screened above the water table, is dry.

The observed groundwater heads and interpreted head contours based on monitoring bore data for the project area. Shown inferred contour lines are drawn by hand without sophisticated software. The contours for the water table indicate that groundwater in the Loxton Parilla Sands aquifer flows to the northwest. The interpolated depth to water for the study area, shows the depth to water table is largely negatively aligned with topography, i.e., water table depth is greatest beneath higher ground elevations and least beneath lower ground elevations. Beneath the north-south orientated ridge / strandline within the mine area, the depth to water table is greater than 50 mbgl. The shallower depths are encountered on the border of the western most proposed pit in Area 1, where depth to water ranges from 30 to 35 mbgl.

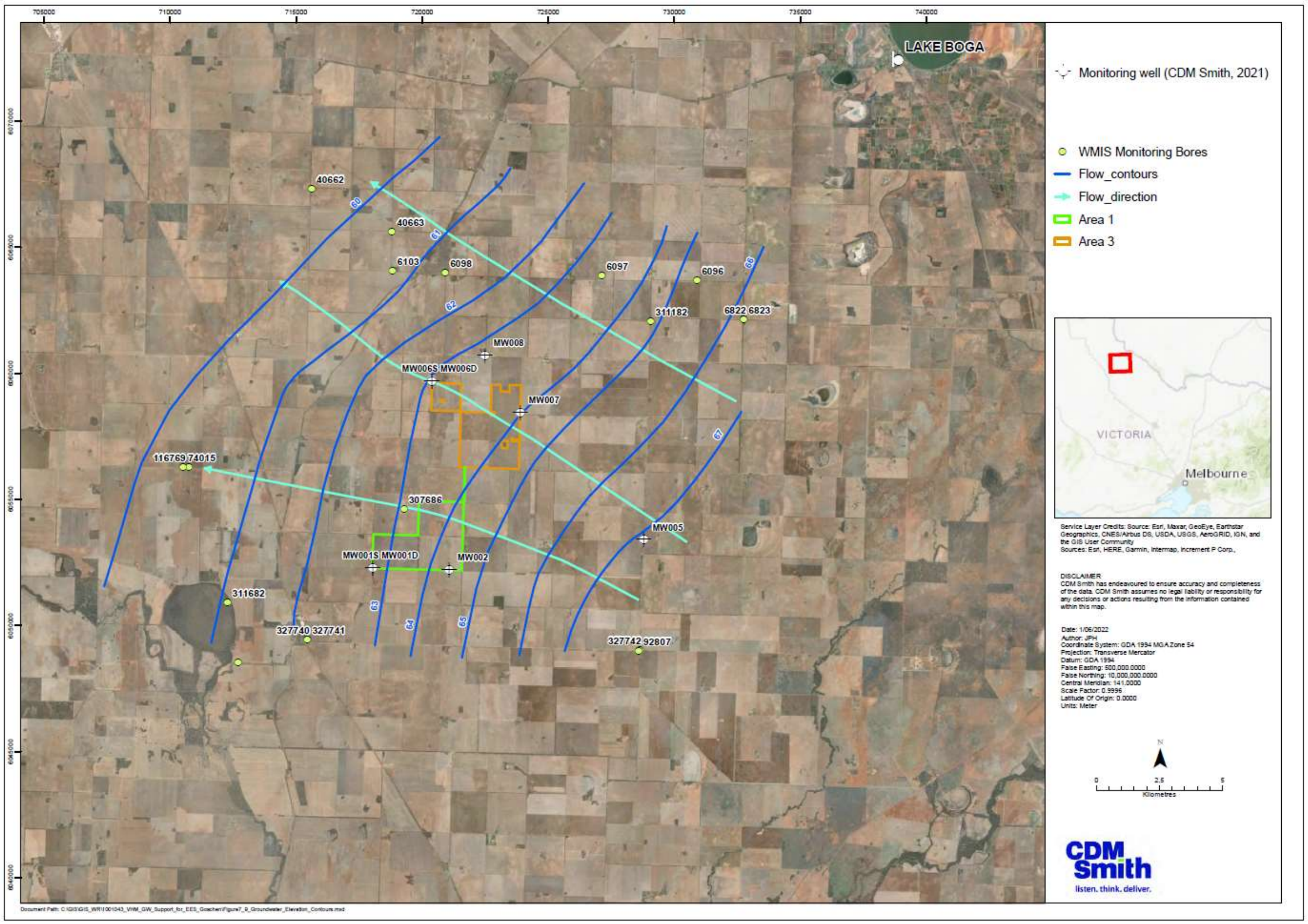


Figure 8-10 Loxton-Parilla Sands Groundwater Contours

8.4.5 Hydraulic Gradients

8.4.5.1 Horizontal Gradient

Groundwater levels range from a high of 67.1 mAHD at monitoring bore MW005 in the east to a low of 59.31 mAHD north of the Project area. The data presented in Figure 8-10 shows a steady groundwater elevation decline to the northwest at an average gradient of 0.0004, which equates to 7 m vertically and 17 km horizontally. The low hydraulic gradient suggests low recharge to the underlying Loxton Parilla Sands aquifer as also indicated by a lack of mounding.

8.4.5.2 Vertical Gradient

Nested bores are installed at locations MW001 and MW006 where groundwater levels from both aquifers are simultaneously monitored. The results of the groundwater level data indicate an upward vertical pressure gradient between the Renmark Group and the Loxton Parilla Sands of between 0.8 and 1.3. The results are shown in Table 8-8. The upward gradient identified indicates a low potential of leakage to the underlying Renmark Group aquifer from the Loxton-Parilla Sands in the area. No other nested data is available within 10 km of the Project area.

Table 8-8 Vertical Gradients

Bore ID	Screened Formation	Screen midpoint (mbgl)	Groundwater elevation (mAHD) April 2022	Difference in groundwater elevation (m)	Vertical pressure gradient	Direction of gradient
MW001S	Loxton Parilla Sands	38	62.54	1.28	0.018	Upward
MW001D	Renmark Group	111	63.82			
MW006S	Loxton Parilla Sands	43	63.04	0.84	0.012	Upward
MW006D	Renmark Group	113	63.88			

8.5 Hydraulic Properties

A slug testing program completed in August - September 2021 comprised of conventional rising and falling head (slug) tests. The slug testing methodology and results are available in Appendix B. The slug test results were analysed using the industry standard aquifer testing analysis software AQTESOLV to provide estimates of hydraulic conductivity. The Bouwer and Rice method was used for the analysis in AQTESOLV. Slug test and analysis on the groundwater monitoring bores as shown in Table 8-9. Results of the slug testing data analysis show that the Loxton Parilla Sands generally has the highest hydraulic conductivities of the tested hydro stratigraphic units, with estimates ranging from 0.02 to 0.65 m/day, and an overall mean value (all tests) of 0.35 m/day. The Renmark Group had estimates ranging from 0.006 to 0.15 m/day with an overall mean value (all tests) of 0.08 m/day.

Table 8-9 Slug Test Results

Bore ID	Aquifer	Slug Test Results (m/day)	Aquifer
MW001S	Loxton Parilla Sands	0.15	Unconfined
MW002	Loxton Parilla Sands	0.02	Unconfined
MW005	Loxton Parilla Sands	0.65	Unconfined
MW006S	Loxton Parilla Sands	0.65	Unconfined
MW008	Loxton Parilla Sands	0.3	Unconfined
MW001d	Renmark Group	0.006	Confined
MW006d	Renmark Group	0.15	Confined

8.6 Groundwater Recharge and Discharge

8.6.1 Groundwater Recharge

The groundwater recharge mechanism in this area is via rainfall infiltration. Due to this rainfall mechanism the recharge rate is likely to be low due to a reported depth to groundwater of 31 mbgl on average.

Two datasets are available to inform the potential rate of groundwater recharge:

- Crosbie et al. (2009) used the 1-D model called WAVES to model diffuse groundwater recharge, deriving an estimate of average annual recharge in this area of between 6 to 37 mm.
- Cook et al 2001 reported deep drainage rates at Euston and Balranald between 3.5 – 9.5 mmyr and 4-10 mmyr respectively. We have assumed a rate of 7.5 mmyr. An assumed rate of 7.5 mm / year was adopted based on the study. The value is within the referenced range estimated by Crosbie et al. (2009) i.e. average annual recharge in this area of between 6 to 37 mm.

Assuming a recharge rate of 7.5 mm/year, this corresponds to an annual recharge rate of approximately 5,700 kL/year over the tenement areas.

8.6.2 Groundwater Discharge

The discharge mechanism is related to groundwater throughflow to the northwest of the project area. Groundwater discharge is likely to outfall at the Murray River floodplain, with localised areas of discharge restricted to areas where the water table occurs at elevations that intersect the ground surface. Lake Tyrell, Lake Wahpool and Lake Tiboram located 55 km to the northwest are known groundwater discharge features in the area (CDM Smith, 2018).

There are no known permanent surface expressions of groundwater for example springs or seeps within 10 km of the proposed Project area. Major watercourses in the area called Lambert and Tyrell Creeks, and Avoca River are typically disconnected from the regional water table (CDM Smith, 2018).

8.7 Groundwater Chemistry

A summary of the groundwater field water quality results for the monitoring bores are detailed in Table 8-10. Field monitoring data indicates groundwater salinity (as total dissolved solids) to range from 13,394 to 29,565 mg/L across the Project area in the Loxton Parilla Sands aquifer. Groundwater salinity is slightly less in the Renmark Group aquifer, as indicated by a TDS of 13,432 and 13,394 mg/L in MW001D and MW006D, respectively.

The field parameters and results of major ion analysis indicate the following:

- The salinity of the groundwater is high with electrical conductivity readings of 19,991 to 29,400 µS/cm across the project area and 44,127 µS/cm at MW005 to the east of the project area.
- The pH indicates a neutral to slightly acidic groundwater (5.05 to 8.19).
- The distribution of major ions shown on the piper plot (Figure 8-11) indicates a sodium-chloride dominant water type typical of “end product” water (groundwater that has a long residence time in the aquifer with limited groundwater recharge).
- There is no consistent distinction between the Loxton-Parilla Sands and the Renmark Group groundwater general water quality.

Table 8-10 Groundwater Field Water Quality Results

Bore ID	Measurement date	Aquifer	EC (uS/cm	TDS (mg/L)	Temperature (°C)	pH
MW001S	August 2021	Loxton Parilla Sands	24,021	16,094	16.4	8.15
MW001D	August 2021	Renmark Group	20,048	13,432	22.3	8.14
MW002	August 2021	Loxton Parilla Sands	23,160	15,517	19.7	8.19
MW005	August 2021	Loxton Parilla Sands	44,127	29,565	18.3	7.7
MW006S	August 2021	Loxton Parilla Sands	23,761	15,920	16.5	7.83
MW006D	August 2021	Renmark Group	19,991	13,394	19.7	7.69
MW008	August 2021	Loxton Parilla Sands	23,045	15,440	18	7.9
MW001S	April 2022	Loxton Parilla Sands	22,690	15,202	19.4	6.89
MW001D	April 2022	Renmark Group	29,151	19,531	22.1	6.52
MW002	April 2022	Loxton Parilla Sands	29,400	19,698	20.4	6.41
MW005	April 2022	Loxton Parilla Sands	42,917	28,754	22.3	5.51
MW006S	April 2022	Loxton Parilla Sands	28,116	18,838	19.7	6.49
MW006D	April 2022	Renmark Group	21,523	14,420	18.1	6.30
MW008	April 2022	Loxton Parilla Sands	28,533	19,117	20.5	5.05

Note: TDS estimated through an approximate conversion of EC to TDS EC (µS/cm) x 0.67 = TDS (mg/L).

Proportional abundances of major cations and anions are shown on the piper diagram presented as Figure 8-11 for monitoring bores across the site. Piper Plots explain the classification type of water facies on the basis of its interaction with rock and soil minerals. The diamond plot at the centre is a blend of two trilinear plots on the two sides of the diamond. Different quadrants of the diamond show the different type of water on the basis of ion concentration dominance. Groundwater with sodium as the dominant cation and chloride the dominant anion is typically consistent across the site. Currently there is insufficient data to assess trends in groundwater quality over time and therefore timeseries plots have not been presented.

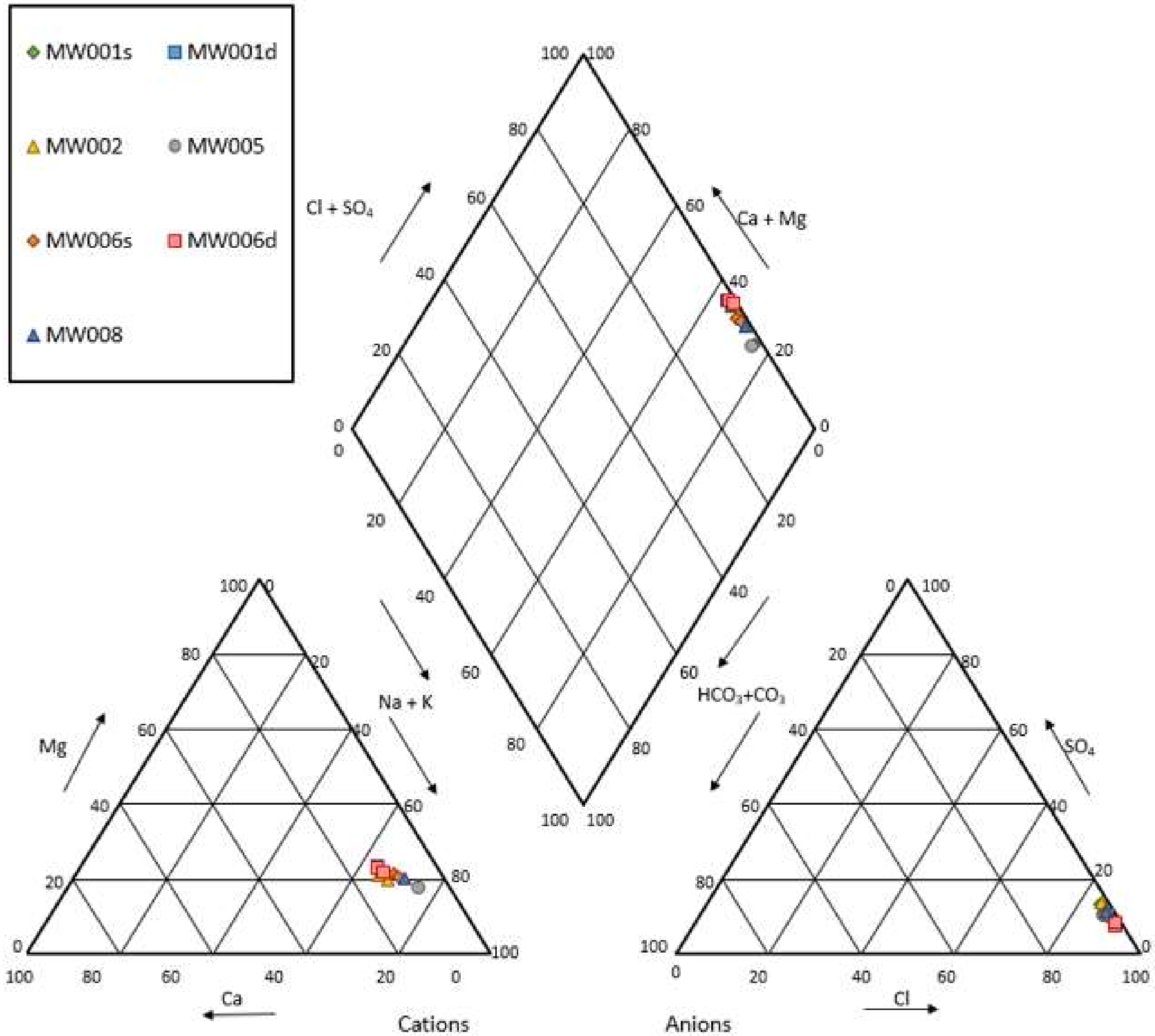


Figure 8-11 Piper Plot (Major Anions and Cations)

The laboratory results have been compiled and are presented in Table 8-11 to Table 8-14, with the following key points:

- The pH of the groundwater within the aquifer is lower than expected for a saline bicarbonate rich water. This is likely due to hydrolysis of the kaolinite and gibbsite within the aquifer releasing hydrogen ions and aluminium into solution. In addition, dissolved Iron and Manganese will also likely contribute to the acidity within the aquifer.
- It is noted that Aluminium was below Limit of Reporting (LOR) in the dissolved fraction. At a pH of 6, it is possible the Aluminium is present as a colloidal phase given this pH is outside the stability for solid phase Aluminium species.
- Given dissolved oxygen levels in the aquifer are generally below 1 mg/L this aquifer is considered dysaerobic to anaerobic. These conditions are suitable for the presence of anaerobic bacteria communities containing species within the sulfate reducing bacteria and or iron oxidising bacteria class.
- The presence of sulfides in the aquifer is attributed to bacterial sulfate reduction (BSR). The presence of clays can impede water flow to a point where chemically reducing (low dissolved oxygen) conditions can form.

Table 8-11 Laboratory results – general water quality

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
pH Value	pH unit	0.01	-	7.55	6.98	-	7.23	8.53	-
Sodium adsorption ratio	-	0.01	-	21.6	27.0	-	28.4	21.2	-
Electrical Conductivity @ 25°C	µS/cm	1	-	24,500	32,700	-	28,900	21,000	-
Total Dissolved Solids @180°C	mg/L	10	-	12,800	17,600	-	16,900	12,500	-
Total Dissolved Solids (Calc.)	mg/L	1	-	15,900	21,200	-	18,800	13,600	-
Turbidity	NTU	0.1	-	56.1	16.0	-	27.2	53.4	-
Total Hardness as CaCO3	mg/L	1	-	3,910	5,200	-	4,560	3,620	-
Hydroxide Alkalinity as CaCO3	mg/L	1	-	<1	<1	-	<1	<1	-
Carbonate Alkalinity as CaCO3	mg/L	1	-	<1	<1	-	<1	<1	-
Bicarbonate Alkalinity as CaCO3	mg/L	1	-	170	205	-	287	150	-
Total Alkalinity as CaCO3	mg/L	1	-	170	205	-	287	150	-
Silicon	mg/L	*0.1,* 0.05	*8.4*	*4.6*	*7.7*	*11*	*9.2*	5.7	*11*
Sulfate as SO4 – turbimetric	mg/L	1	*2,000*	1,110	1,990	*3,800*	1,480	824	*3,200*
Chloride	mg/L	1	*9,300*	6,820	9,140	*15,000*	9,600	7,100	*9,800*
Fluoride	mg/L	0.1	*0.1*	0.2	0.4	*<0.1*	0.3	0.5	*<0.1*
Calcium	mg/L	*0.01,* 1	*430*	555	818	*650*	568	518	*490*
Magnesium	mg/L	*0.01,* 1	*660*	612	766	*1,000*	764	564	*750*
Sodium	mg/L	*0.01,* 1	*5,600*	3,110	4,480	*8,600*	4,410	2,930	*5,400*
Potassium	mg/L	*0.01,* 1	*94*	82	75	*100*	114	68	*86*
Ammonia as N	mg/L	0.01	-	0.65	0.17	-	0.10	0.61	-
Ammonium as N	mg/L	0.01	-	0.64	0.17	-	0.10	0.60	-
Nitrite as N	mg/L	0.01	-	<0.01	0.01	-	<0.01	<0.01	-
Nitrate as N	mg/L	0.01	-	0.02	0.01	-	0.01	0.02	-
Nitrite and nitrate as N	mg/L	0.01	-	0.02	0.02	-	0.01	0.02	-
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	1.2	<0.5	-	0.6	1.2	-
Total Nitrogen as N	mg/L	0.1	-	1.2	<0.5	-	0.6	1.2	-
Total Phosphorous as P	mg/L	0.01	*<0.01*	0.10	0.14	*<0.01*	<0.01	0.10	*0.11*
Reactive Phosphorous as P	mg/L	0.01	-	<0.01	<0.01	-	<0.01	<0.01	-

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
Escherichia coli (Colilert)	orgs/100mL	1	-	<10	<10	-	<10	<10	-
Total Coliforms (Colilert)	orgs/100mL	1	-	<10	<10	-	<10	<10	-
Enterococci	orgs/100mL	1	-	<10	<10	-	<10	<10	-

Table 8-12 Laboratory results – metals

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
Aluminium	mg/L	0.001	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Antimony	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	mg/L	0.0005	0.029	0.0053	0.12	0.013	0.070	0.027	0.015
Barium	mg/L	0.001	0.039	0.056	0.053	0.045	0.051	0.17	0.035
Beryllium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/L	0.001	1.8	0.50	0.45	1.4	0.91	0.38	0.98
Cadmium	mg/L	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cerium	mg/L	0.0005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	mg/L	0.0002	0.0046	<0.002	<0.002	<0.002	0.0024	<0.002	<0.002
Copper	mg/L	0.001	0.018	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dysprosium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gallium	mg/L	0.01	<0.01	0.01	0.01	<0.01	0.01	0.04	<0.01
Hafnium	mg/L	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron	mg/L	0.001	4.7	3.7	14	8.1	7.6	5.1	14
Lanthanum	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	mg/L	0.0002	0.15	<0.002	<0.002	<0.002	<0.002	0.0063	<0.002
Lithium	mg/L	0.001	0.23	0.13	0.27	0.33	0.24	0.28	0.34
Manganese	mg/L	0.0005	0.16	0.084	0.19	0.19	0.18	0.11	0.44
Mercury	mg/L	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Neodymium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	mg/L	0.0005	0.0050	<0.005	0.0070	<0.005	<0.005	<0.005	<0.005
Praseodymium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rubidium	mg/L	0.01	0.07	0.09	0.06	0.16	0.08	0.08	0.09
Scandium	mg/L	0.001	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
Silver	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.001	8.4	7.9	10	13	8.7	8.9	9.2
Terbium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Titanium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tungsten	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ytterbium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Yttrium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.001	0.12	0.013	0.20	0.078	0.071	<0.01	0.10
Zirconium	mg/L	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 8-13 Laboratory results – radiology

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
Gross alpha activity	Bq/L	0	0.762	0.303	0.314	0.238	0.300	0.902	0.254
Gross beta activity (excluding K-40)	Bq/L	0	0.641	1.11	0.437	0.479	0.613	0.899	0.352
Radium-226	Bq/L	0	0.635	0.304	0.161	0.249	0.249	0.335	0.098
Radium-228	Bq/L	0	0.594	1.16	0.317	0.443	0.561	0.875	0.261
Lead-210	Bq/L	0	0.103	<0.12	<0.19	<0.17	<0.14	<0.16	<0.2

Table 8-14 Laboratory results – organics

Analyte	Unit	LOR	MW001s	MW001d	MW002	MW005	MW006s	MW006d	MW008
C6 - C10 Fraction	µg/L	20	-	200	40	-	70	50	-
C6 - C10 Fraction minus BTEX (F1)	µg/L	20	-	200	40	-	70	50	-
>C10 - C16 Fraction	µg/L	100	-	<100	<100	-	<100	<100	-
>C16 - C34 Fraction	µg/L	100	-	<100	<100	-	<100	<100	-
>C34 - C40 Fraction	µg/L	100	-	<100	<100	-	<100	<100	-
>C10 - C40 Fraction (sum)	µg/L	100	-	<100	<100	-	<100	<100	-
>C10 - C16 Fraction minus Naphthalene (F2)	µg/L	100	-	<100	<100	-	<100	<100	-
Benzene	µg/L	1	-	<1	<1	-	<1	<1	-
Toluene	µg/L	2	-	<2	<2	-	<2	<2	-
Ethylbenzene	µg/L	2	-	<2	<2	-	<2	<2	-
Meta- & para-Xylene	µg/L	2	-	<2	<2	-	<2	<2	-
Ortho-Xylene	µg/L	2	-	<2	<2	-	<2	<2	-
Total Xylenes	µg/L	2	-	<2	<2	-	<2	<2	-
Sum of BTEX	µg/L	1	-	<1	<1	-	<1	<1	-
Naphthalene	µg/L	5	-	<5	<5	-	<5	<5	-

Note – all analysis for Organochlorine Pesticides (OCs), Organophosphorus Pesticides (OPs) and Phenoxyacetic Acid Herbicides were below detection limits

There is limited water quality data available from the Water Measurement Information System (WMIS). Of the identified 18 monitoring bores within 10 kilometres of the Project area, only 7 bores have water quality data ranging from 1979 to 2017. Details of which are listed in Table 8-15.

Table 8-15 Water Measurement Information System Water Quality

Details	Unit	116769	6096		6097	6103	92807	40662	40663				
Measurement date		April 2015	Sept 1990	Sept 1991	March 1979	March 1979	May 1989	March 1979	March 1979	April 2011	May 2012	February 2014	April 2015
Bicarbonate, as HCO3	mg/L				168	397	609.756	632	289				
Boron	mg/L						0.85						
Bromide	mg/L						36						
Calcium	mg/L				694	670	460	113	553				
Carbonate	mg/L				15			54					
Chloride	mg/L				20140	13425	10000	1675	13500				
Conductivity	(µS/cm)				54200	37500	30000	6500	38500				
DME Silicate, as SIO3	mg/L				59	31		23	25				
EC (Field)	(uS/cm)		49000	50000									
Hardness, as CaCO3	mg/L						3977.42						
Hardness, as CaCO3	mg/L				8492	6571		715	6238				
Iodide	mg/L						0.79						
Iron total	mg/L						12						
Lithium	mg/L						0.17						
Magnesium	mg/L				1642	1190	680	105	1180				
Nitate + Nitrite as N	mg/L						0.42						
Nitrate as N	mg/L				0.677			3.16	0.677				
pH		6.1								6.97	7.3	6.8	6.7
Potassium	mg/L				141	113	71	25	127				
Silica total	mg/L						14						
Sodium	mg/L				11020	6780	5900	1162	7136				
Strontium	mg/L						7.2						
Suplhate	mg/L				3483	2140	1400	265	2647				
Total Alkalinity	mg/L						500						
Total Dissolved Solids	mg/L						17722.86						
Total Soluble Salts	mg/L				37437	24785		4076	25507				

8.8 Conceptual Model Summary

Figure 8-12 presents a pre mining hydrogeological simplified conceptual cross section that has been developed for the Project area, based on available hydrogeological information and assessment works completed to date.

For the purpose of this impact assessment the depth of mining has been assumed to be consistent between Area 1 and Area 3, with the more conservative scenario used of a pit depth of approximately 40 m below ground level and pit floor in the order of 3 m above the water table. It is understood that the mine plan for Area 1 is for the pit floor to be at least 20m (elevation of 85 mAHD) above the groundwater table.

The other key features of the hydrogeological conceptualisation are as follows.

- Drilling and groundwater investigations in the region have identified the four main hydrogeological units. The Loxton-Parilla Sands forms the main aquifer in the study area. The Loxton Parilla Sands aquifer is unconfined and hosts the regional aquifer. The Geera Clay forms a significant aquitard separating the Olney Formation and Warina Sand which forms an aquifer underlying the Geera Clay.
- The aquifer at site is predominantly unsaturated, the groundwater table is approximately 45 metres below the current ground surface. The pit will remove the majority of the unsaturated profile, with the base of the pit terminating about 10 metres above current groundwater level. Groundwater levels at the site are stable and therefore the unsaturated aquifer is considered to be undisturbed and will likely hold salts and stored acidity.
- Results of the slug testing data analysis show that the Loxton Parilla Sands hydraulic conductivity ranges from 0.02 to 0.65 m/day and an overall mean value (all tests) of 0.35 m/day. The Renmark Group had estimates ranging from 0.006 to 0.15 m/day and an overall mean value (all tests) of 0.08 m/day.
- The water table contours indicate that groundwater in the Loxton Parilla Sands aquifer flows to the northwest. The interpolated depth to water for the study area, shows the depth to water table is largely negatively aligned with topography.
- The recharge mechanism in this area is the infiltration of rainfall. The discharge mechanism is throughflow to the north and northwest.
- The results of the groundwater level data indicate an upward vertical pressure gradient between the Renmark Group and the Loxton Parilla Sands. The upward gradient identified indicates a low potential of leakage to the underlying Renmark Group aquifer from the Loxton-Parilla Sands in the area. No other nested data is available within 10 km of the Project area.
- Geochemistry indicates that groundwater with sodium is the dominant cation and chloride the dominant anion is typically consistent across the site. The salinity of the groundwater is high (saline) and pH indicates a neutral to slightly acidic groundwater. There is no consistent distinction between the Loxton-Parilla Sands and the Renmark Group groundwater in relation to water quality.
- Groundwater is neutral to slightly acidic, saline and dysaerobic (low dissolved oxygen) to aneroboic. It is likely that there are a number of solid mineral phases within the aquifer that can attenuate dissolved constituents in groundwater to reduce their transport away from the point of entry to the system. Further it is also likely that the aquifer hosts an active microbial community which can sequester dissolved constituents from groundwater to create solid minerals, which will further reduce concentrations of dissolved constituents in groundwater.

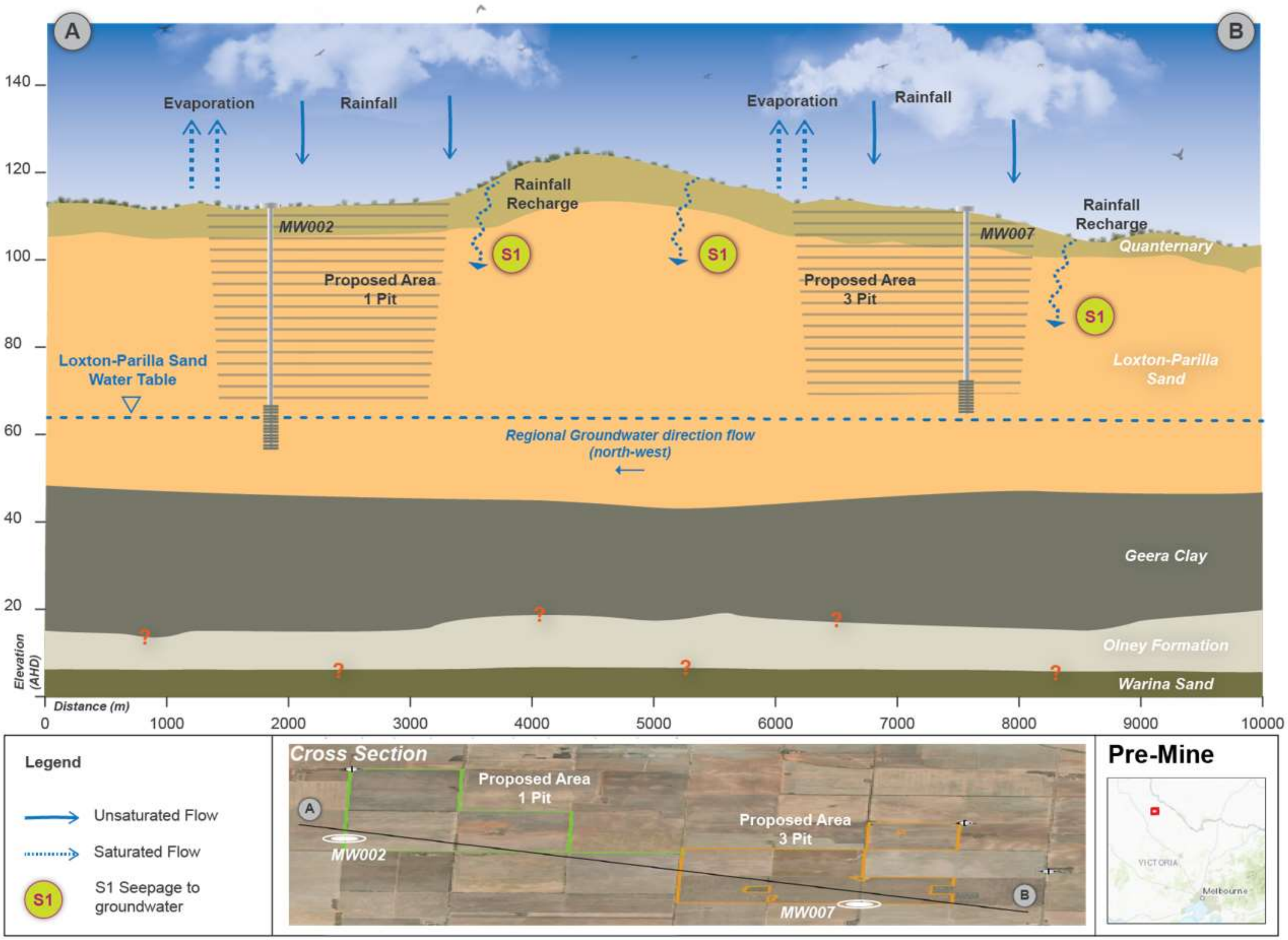


Figure 8-12 Pre-Mining Hydrogeological Conceptual Model

9. Numerical Model

Following the conceptual hydrogeological model development this project involves the development of a numerical groundwater model for the prediction of groundwater system response to mine operations and cessation of mining, and to assist in understanding the potential fate of CoCs during and after groundwater recovery. Based on the conceptual model detailed in section 6, a 3D numerical model was constructed. The numerical modelling was carried out using Feflow version 7 (Feflow). The model domain is 40 kilometres (East to West) by 35 kilometres (North to South) with a variable model grid cell size ranging from about 30 m at the mine site up to 500 m near the edge of the model domain. The model domain is shown in Figure 9-1.

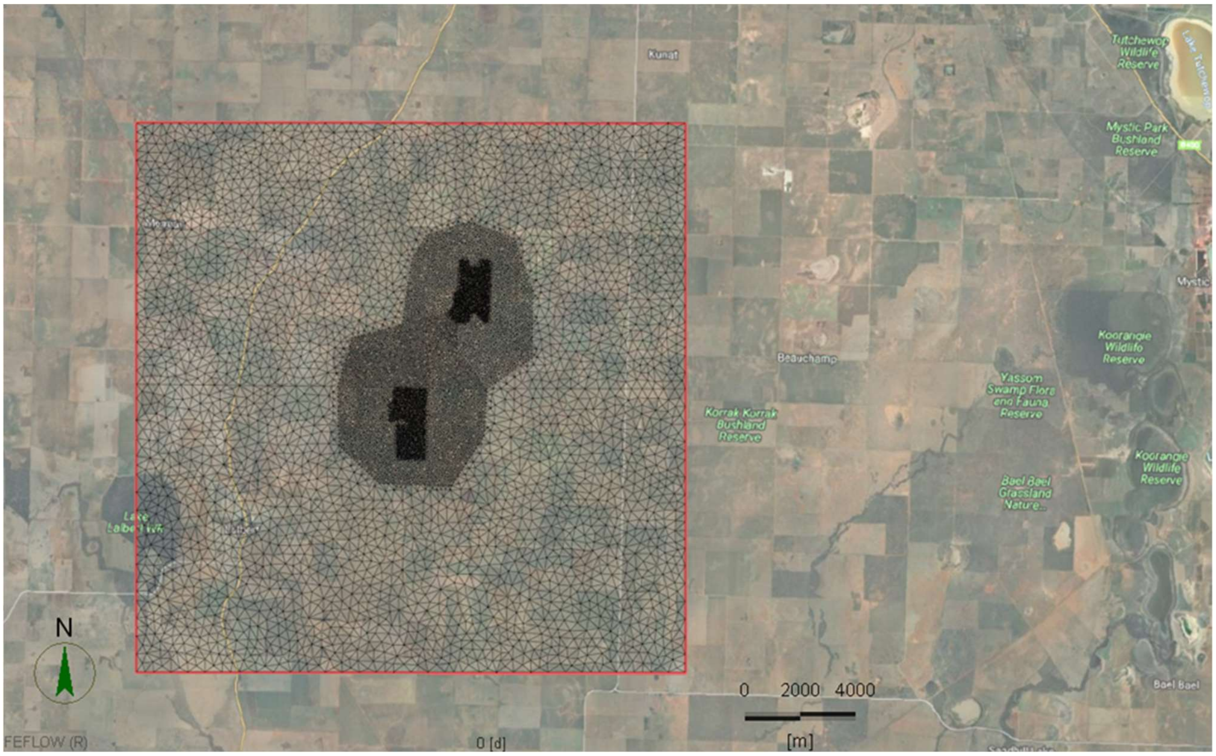


Figure 9-1 Model Domain (Red Square) and Model Grid (Black Mesh)

The Australian groundwater modelling guidelines (Barnett et al., 2012) provide guiding principles and minimum standards of numerical groundwater models. The guidelines recommend that the overall reliability, complexity and confidence level of the model should be assessed and agreed prior to construction of the model, and if possible, re-assessed at a later stage in the modelling project. The confidence level classification comprises three classes: class 1, class 2 and class 3, in order of increasing confidence level. The level of confidence typically depends on the available data, calibration procedures, consistency between the calibration conditions and predictive analysis scenario, and the level or severity of stresses being simulated. The numerical model developed for this assessment has the characteristics of a class 1 model and is appropriate for the impact assessment framework.

The modelling approach adopted in this assessment is conservative. A conservative approach does not aim at making exact predictions but aims at overestimating the potential impact related to the predictions. The overestimation of impacts offers a safety buffer that allows a robust and reliable risk assessment, as the response of the real system (mounding of the water table aquifer in this case) to the mining operations will be contained within the envelope provided by the conservative approach proposed in this study.

9.1 Model Assumptions

The groundwater flow model simulates a simplified version of the geological and hydrogeological system. This simplification is based on a regionalisation of the sit conditions for example the aquifer thickness, and properties are assumed homogeneous and uniform. Further, the model assumptions are considered conservative in respect to the scale of the seepage rates and rise in groundwater levels (mounding) that are predicted. Any model refinement will likely result in the mounding results to be reduced. The model excludes any design or features that may reduce groundwater mounding, for example tailings management.

9.1.1 Conservative Assumptions and Conceptual Uncertainty

The conservative assumptions that were made to overestimate the potential mounding are summarised in Table 9-1. Those assumptions are contributing to the overestimation of the water table mounding and of related potential impacts. However, it should be noted that the modelling approach assumes that the unsaturated zone will transfer rainfall recharge and tailing seepage to the water table and ignore the possibility of perched conditions to form within the unsaturated zone. If such conditions were to occur due to very low vertical hydraulic conductivity in the Loxton Parilla Sands, the mounding of the water table would be even lower, but the perched conditions could potentially generate seepage of groundwater near the base of tailings or the active pit cell. Further consideration such as engineering or operational controls may need to be assessed to manage this potential scenario.

The modelling approach adopted in this assessment is considered conservative. A conservative approach does not aim at making exact predictions, but aims at overestimating the potential impact related to the predictions. Conservative approaches are often adopted within impact assessments as it keeps the predictive uncertainty on the side of overestimation. Therefore, whenever the overestimated impacts remain within acceptable bounds, as in, environmental values are unlikely to be affected by the project, the results can be considered reliable and do not require more detailed analyses.

Table 9-1 Modelling Approach Conservative Assumptions

Parameter	Assumption	Why This Is Conservative
Rainfall recharge	The model assumes 350 mm/year of rainfall recharge from the open pit during the two years of mining. 350mm/year corresponds to the average rainfall at the site location.	The soil moisture deficit occurring during dry period would capture a portion of rainfall and prevent it from infiltrating. Small rainfall events can even potentially be fully captured by the soil moisture deficit and then evaporated before generating any infiltration. Assuming 100% of mean yearly rainfall is therefore likely an overestimation of potential infiltration.
Tailing water content	The model assumes that the tailings are 50% saturated and that the total water content of the drainable water (Sy) is contributing to the water table recharge.	It will be in the interest of VHM to recirculate as much water content as possible from the tailings. The portion of water therefore available for infiltration will likely be a smaller portion of the initial tailing water content.
Tailing specific yield	The tailing specific yield is assumed to be 0.15.	The specific yield will be function of the particle grain size. Smaller grain size would tend to have lower Sy than coarser one. The adopted tailing Sy corresponds to a silt material.
Tailing disposal	The infiltration is modelled over the whole area 1 and area 3 of the site.	The tailings cells are not covering the whole mine site area. By overestimating the tailings disposal area, the infiltration is also overestimated.

Parameter	Assumption	Why This Is Conservative
Unsaturated zone modelling	The model assumes that the infiltration generated by the tailings and by rainfall reports directly to the water table.	In the natural system, the infiltration will be delayed by the flow through the unsaturated zone.
Mine schedule	The mining schedule is simplified and consistent for Area 1 and Area 3. Recharge is occurring beneath the whole portions from the start of mining.	The mining will progress through small mining blocks and therefore at the start of operation, the mining pit and related infiltration will only cover a small portion of the site (smaller than modelled). Similarly at any given time and until the end of operation, only a smaller portion of the mined area will be open.

9.1.2 Assumed Mining Schedule and Recharge

The mining schedule for both Area 1 and Area 3 was simplified from the planned mining approach for this modelling scope, with 36 mining blocks in Area 1 and 38 mining blocks in Area 3 utilised in the model construct.

The following model assumptions were made in relation to proposed mining activity:

- The mining scheduled is simplified for both mined areas. The mining blocks (36 blocks for Area 1 and 38 blocks for Area 3) are grouped into four equal portions for Area 1 and six equal portions for Area 3. This assumption does not affect the total estimated volume of tailing seepage and is conservative as it assumes a larger backfilled area at any time compared to the proposed mining approach.
- Area 1 will be mined in year 1 to year 8 (8 years in total) and Area 3 will be mined in year 9 to year 20 (12 years in total). Each equal area is assumed to be mined consecutively at two years each.
- Tailings at 50% saturation when deposited. The mine pit depth is assumed to be 67 mAHD for both Area 1 and Area 3. Wet tailing assumed to be set at 92 mRL WL (base of overburden) – 67 mRL (base of mine) = 25m tailing thickness. Tailings assumed not go higher than ore zone (dry overburden). The land surface elevation is assumed at 112 mAHD and initial heads based on the groundwater elevation contours Figure 8-10.
- Each of the mined portions is then backfilled with tailings. For each of the portion, the backfilling is assumed to occur during a five-year period at an average rate of 12.5 m of tailings per year (for a total of 25 m tailings thickness). The seepage associated with the tailing deposition correspond to the amount of water contained within a fully saturated tailings assuming a specific yield of 0.15 (25m * 0.15 * 0.5 = 1875 mm of recharge). The model assumes that the tailings are 50% saturated. The representative value of specific yield was adopted from Morris and Johnson 1967.
- When a portion is mined (i.e., 2 years each) rainfall recharge is 100% of rainfall (350 mm/year) and during the three years following mining operation recharge is 50% of rainfall (175 mm/year).
- Zero infiltration to groundwater from diversion of storm events into the pit voids. The reasoning being that any stormwater that collects within the pits will be extracted and used within days or weeks and infiltration will be negligible and not sensitive to other recharge mechanisms.
- At the end of backfilling, the assumption is that recharge is equal to pre-mining conditions.

The schedule of mining for each portion is summarised in Table 9-2 and the corresponding applied recharge in relation to the mine plan is summarised in Table 9-3. For both Area 1 and Area 3 mining is assumed to be completed by year 20 and post mining from year 21 onwards.

Total seepage recharge through the tailings is assumed to be the annual rainfall plus seepage derived from the rate of tailings deposition. The total annual recharge is estimated at 1287.5 mm/year during the 2 years of mining and 175 mm/year for the following three post-mining year. Over a period of five years each portion assumes a recharge of 2950mm (Table 9-3). Figure 9-2 shows a simplified cross section of the system.

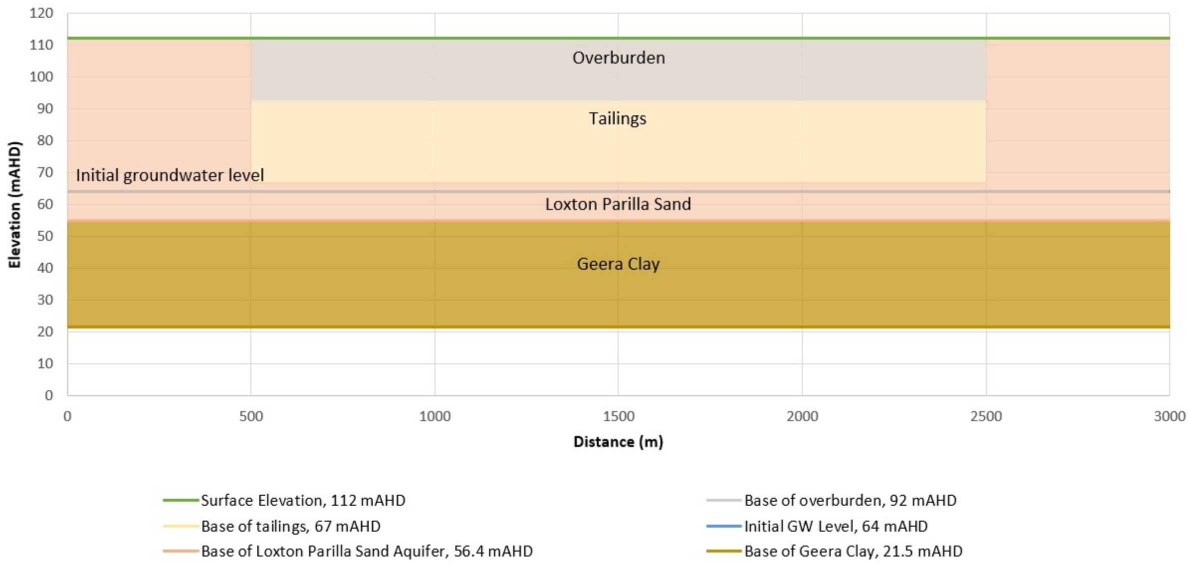


Figure 9-2 Simplified Cross Section

Table 9-2 Schedule Of Mining

Area	(1/4 of mining Area 1)	(1/4 of mining area 1)	(1/4 of mining area 1)	(1/4 of mining area 1)	(1/6 of mining area 3)	(1/6 of mining area 3)	(1/6 of mining area 3)	(1/6 of mining area 3)	(1/6 of mining area 3)	(1/6 of mining area 3)
Year 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 4	Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 5	Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 6		Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 7		Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 8			Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 9			Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 10				Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 11				Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 12					Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining	Pre-mining
Year 13					Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining	Pre-mining
Year 14						Post-mining 2	Mining 2 year	Pre-mining	Pre-mining	Pre-mining
Year 15						Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining	Pre-mining
Year 16							Post-mining 2	Mining 2 year	Pre-mining	Pre-mining
Year 17							Post-mining 3	Post-mining 1	Mining 1 year	Pre-mining
Year 18								Post-mining 2	Mining 2 year	Pre-mining
Year 19								Post-mining 3	Post-mining 1	Mining 1 year
Year 20									Post-mining 2	Mining 2 year
Year 21									Post-mining 3	Post-mining 1
Year 22										Post-mining 2
Year 23										Post-mining 3
Year 23 to 1000										

Table 9-3 Applied Recharge

Description	Tailings Recharge (mm/year)	Rainfall Recharge (mm/year)	Total Recharge (mm/year)
Mining 1 Year	937.5	350	1287.5
Mining 2 Year	937.5	350	1287.5
Post-mining 1	0	175	175
Post-mining 2	0	175	175
Post-mining 3	0	175	175

9.1.3 Assumed Mine Void and Tailings

The mining void and tailings for both Area 1 and Area 3 was simplified from the planned mining approach and does not include a number of inherent (engineered) controls to reduce the volume and rate of seepage entering the groundwater system, such as:

- Underdrain constructed as part of the in-pit embankment
- Solar drying of tailings prior to backfill of overburden
- Interception of mounded groundwater in adjacent pits, which is collected and returned to the mine water circuit.

In summary, the following assumptions were made within the model:

- The mined void and tailings are unlined.
- The mining void infilled tailings and fines waste are assumed saturated and unconfined.
- The mining void infilled tailings and fines waste are assumed to be of uniform thickness, isotropic and homogeneous.
- The hydraulic conductivity values of the tailings and fines waste is assumed to be constant and do not change with time, i.e., as the tailings material consolidates the permeability would likely reduce and lessen actual seepage rates.

9.1.4 Groundwater System

The groundwater system was simplified, and the following assumptions were made:

- The model assumes a singular layer, representing the water table aquifer (Loxton Parilla Sands) as the receiving environment for the seepage.
- The receiving aquifer is assumed to be of uniform thickness, isotropic, homogeneous and unconfined.
- The initial water table has a regional gradient of about 0.36 metres by kilometres (Figure 9-3) and steady state conditions have been reached.

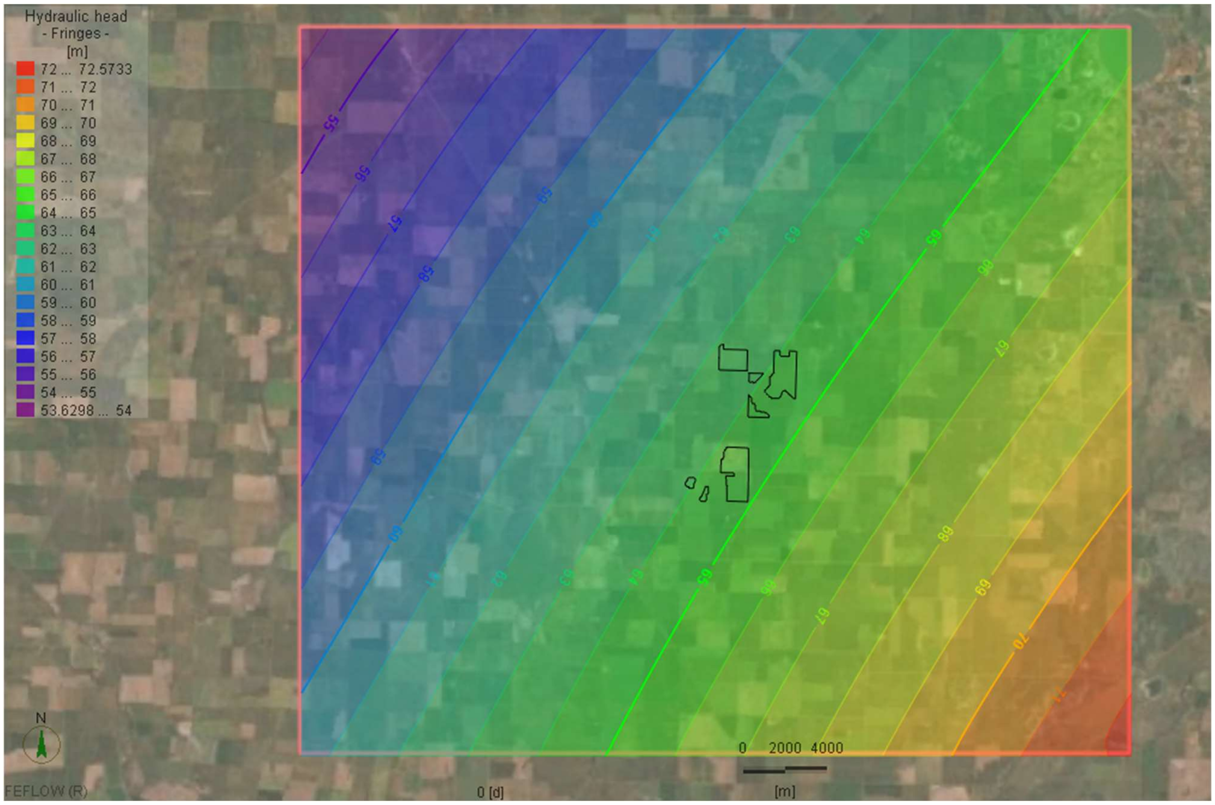


Figure 9-3 Initial Water Table

9.1.5 Mining and Sensitivity Simulations

The aquifer is heterogeneous, and the appropriate regionally representative hydraulic parameters are uncertain. Table 9-4 shows a range of representative values of hydraulic conductivity and specific yield for various geologic materials (Domenico and Schwartz, 1990 and Morris and Johnson, 1967) as applied to the sensitivity simulations. To evaluate the magnitude of the mounding uncertainty related to the aquifer hydraulic parameter uncertainty, five sensitivity scenarios were developed and are presented in Table 9-5. Sensitivity simulations were completed varying the adopted hydraulic conductivity and specific yield of the Loxton-Parilla Sands aquifer.

Table 9-4 Representative Values of Hydraulic Conductivity and Specific Yield

Material	Hydraulic Conductivity (m/day)	Specific Yield
Gravel, coarse	26	0.21
Gravel, medium	0.1	0.24
Silt	0.0001	0.20
Clay	0.000001	0.06

Table 9-5 Sensitivity Simulations

Scenario	Hydraulic Conductivity (m/day)	Specific Yield
Base	0.20	0.15
Scenario 1	0.02	0.15
Scenario 2	0.65	0.15
Scenario 3	0.20	0.10
Scenario 4	0.20	0.25
Scenario 5	0.02	0.10

9.2 Model Results

9.2.1 Area 1 and Area 3

Figure 9-4 shows the maximum seepage rate and resultant mounding observed at any point within the model domain during mining operations and for the following 100 years post operations.

The modelling results shows that the maximum seepage rate and mounding is reached at year 8 and remains high for the following three years (until the end of the backfilling period at year 20). From year 20 the maximum year modelled seepage and mounding declines, but the mounding continues to spread laterally and dissipates within the aquifer.

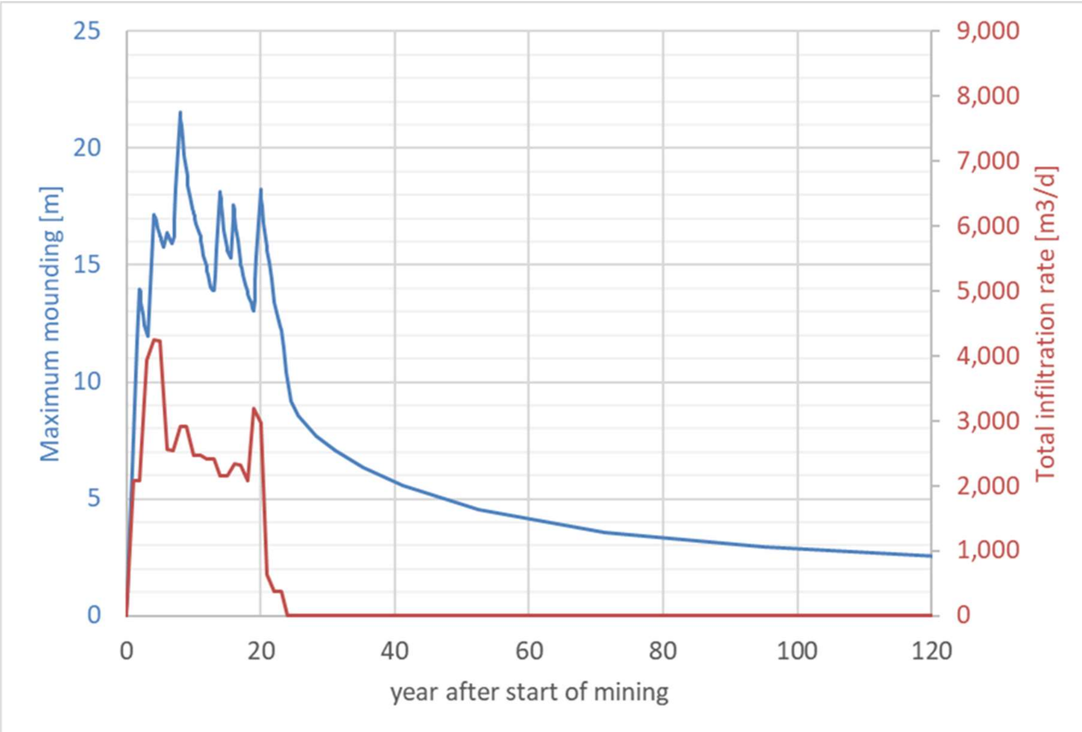


Figure 9-4 Maximum Mounding and Seepage rate During and After Operation

The change in the rate of seepage from the in-pit tailings deposition in the model generates a predicted extent of mounding at the end of operations in year 20; and in 100 and 1000 years post-operation and is illustrated respectively in Figure 9-5 to Figure 9-7.

At the end of operations, the 0.1 m drawdown contours extend no further than 2.0 km from the mined areas. At 100 years post mining, the 0.1 m contour has migrated to a distance comprised within 4.0 km from the mined areas. At 1000 years post-mining the 0.1 m mounding contour is extending about 10 km from the mined areas while the residual mounding beneath the mined area is about 0.5 m. The 0.1 m of mounding is an arbitrary limit that is close to the smallest meaningful noticeable effect on the water table elevation and is within the numerical accuracy of the model. The maximum groundwater mounding shows there is no potential expression of groundwater to ground surface.

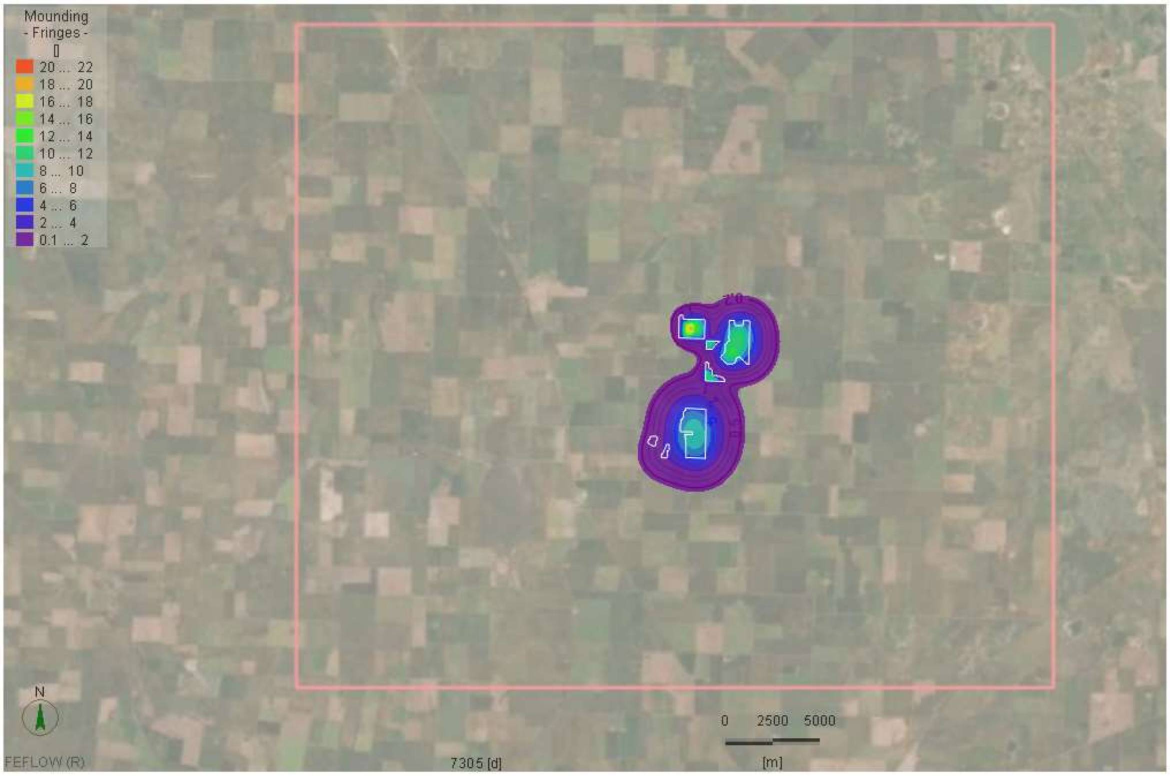


Figure 9-5 Mounding at Year 20 (End of Operations)

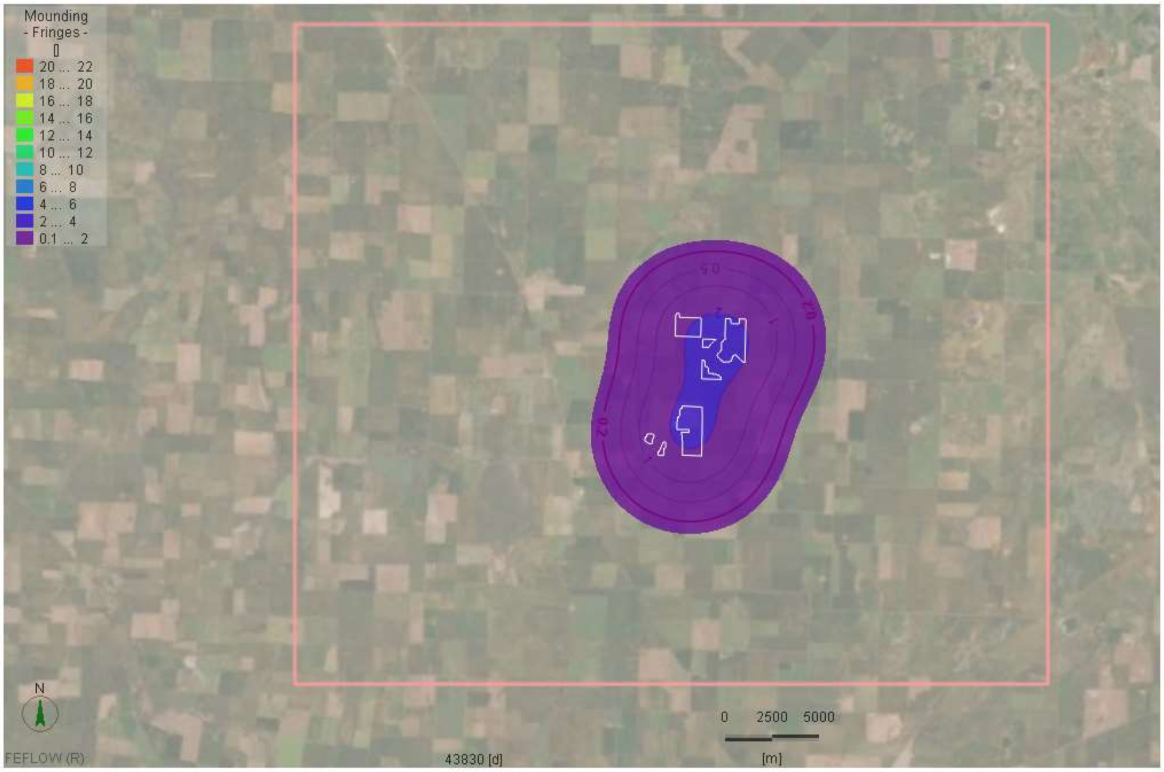


Figure 9-6 Maximum at 100 Years (After End of Operations)

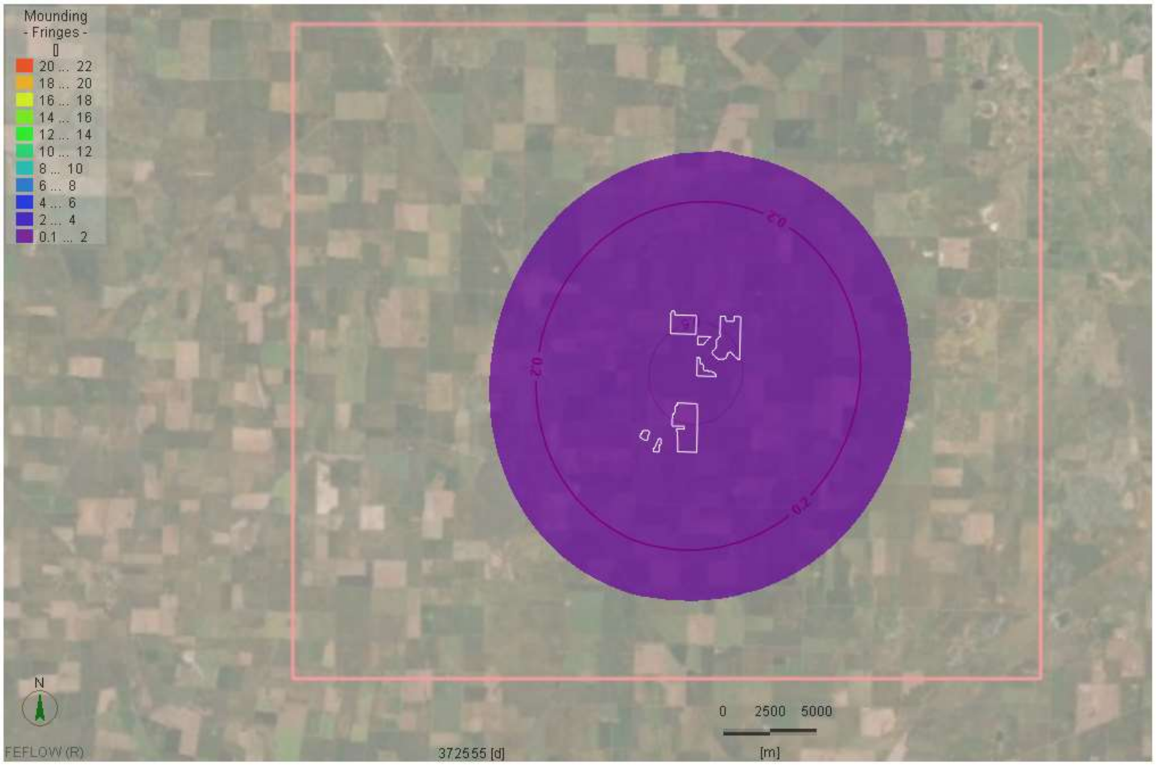


Figure 9-7 Mounding at 1000 Years (After End of Operations)

9.3 Sensitivity Analysis

The sensitivity analysis explores the level of constraint of the model prediction and involves changing a model parameter (one at the time) to establish how the mounding is affected by that change. Sensitive parameters generate a significant change while insensitive parameters generate little predictive change. The sensitivity analysis allows identification of which parameters are most controlling the mounding, and which would therefore require the most scrutiny to reduce predictive uncertainty. Insensitive parameters indicate that parameter error is of limited consequence.

Figure 9-8 illustrates the maximum mounding at any point within the model domain and for a period extending to 100 years post mining for all the sensitivity scenarios. The results shows that if either the representative regional hydraulic conductivity or the specific yield of the aquifer is higher than adopted best estimates (Kh = 0.2 m/d and Sy=0.15) then the maximum mounding will be lower.

At a hydraulic conductivity of 0.65 m/d the maximum mounding is 15.7 m and with a specific yield of 0.25 the maximum mounding reaches 12.5m. If the hydraulic conductivity is one order of magnitude less than the reference case (0.02 m/d) the mounding reaches 22.5 m while with a specific yield of 0.1 the mounding reaches 27.9 m. Combining a lower hydraulic conductivity and lower specific yield (scenario 5) generates a 32.7 m mounding.

The conservative assumptions that were adopted to overestimate the potential mounding for example pit depth, mine schedule, saturation of tailing is intended to overestimate the potential mounding. Changes to the assumptions for the pit depth, mine schedule, saturation of the tailings may result in alternative model outputs. For example, pit depth is not a sensitive input as long as the pit does not intercept the water table. The mine schedule and saturation of tailings is based on a conservative assumption therefore any sensitivity conducted would result in less mounding.

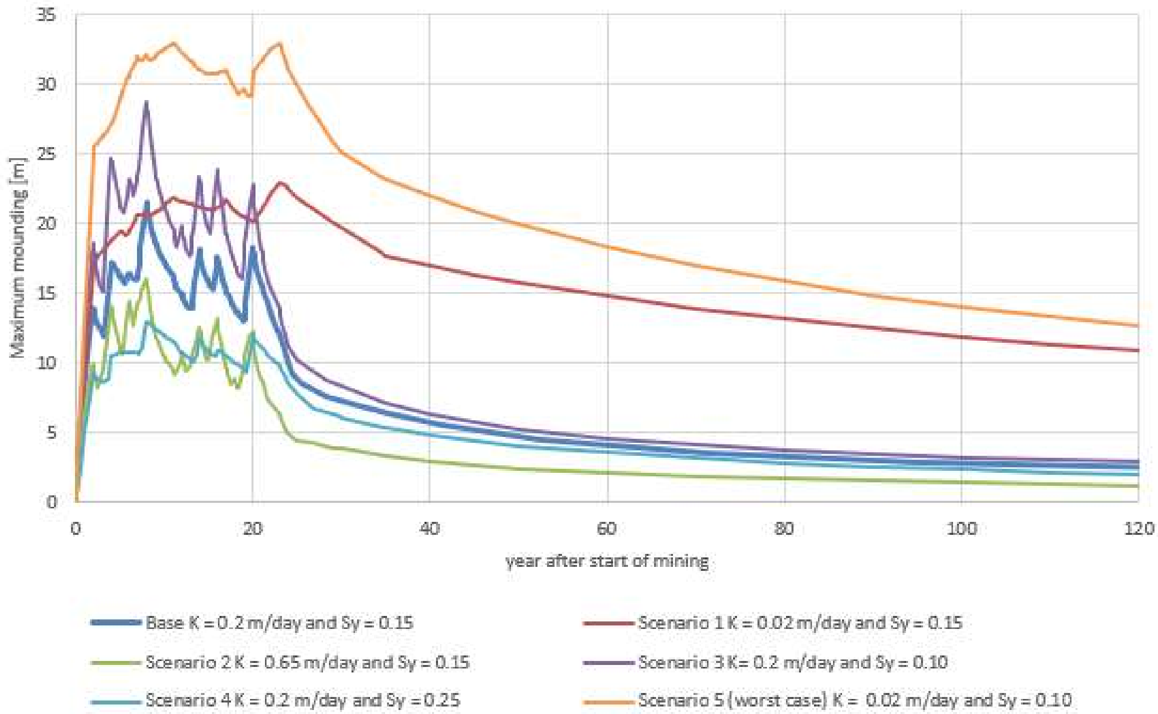


Figure 9-8 Sensitivity Analysis

9.4 Forward Particle Tracking

Forward particle tracking was completed using the numerical model created in Feflow Version 7. Forward particle tracking simulates the advective transport of solutes and is determined by releasing particles from seeding points, in this case the nodes beneath the mined Areas 1 and 3, into the groundwater flow field. For a pre-defined period of 10,000 years, the particles move along the groundwater hydraulic gradient, unless the particles exit the model boundary before the travel time end point. Forward particle tracking assists in visualising the fate of potential solutes leaching into the groundwater system and travelling with the groundwater flow from the mined Areas 1 and 3.

The modelling approach adopted in this assessment is considered conservative as it does not take into account all the attenuation processes that reduce the concentration of COCs along the groundwater flow path. Forward particle tracking only accounts for advection and the dispersion and diffusion of solutes are neglected. Dispersion and diffusion are processes that tend to reduce the concentration of solutes and the forward particle tracking offers a reasonable approximation of the zone of potential contamination. As described in Section 9.1.1 a conservative approach does not aim at making exact predictions, but aims at overestimating the potential impact related to the predictions. Conservative approaches are often adopted within impact assessments as it keeps the predictive uncertainty on the side of overestimation. Therefore, whenever the overestimated impacts remain within acceptable bounds, as in, environmental values are unlikely to be affected by the project, the results can be considered reliable and do not require more detailed analyses.

The forward particle tracking for the model is shown in Figure 9-9. Results show particle tracking travels to a distance of 2 km for 10,000 years with the view of the mounding at 1,000 years post mining. The figure shows that in the aquifer it is the groundwater hydraulic gradient or pressure that drives the travel distance / direction. The particles are migrating in the direction of the groundwater hydraulic gradient from the mined areas and driven by the gradient generated from the groundwater mounding. Over time the groundwater mounding related to the mining operation reduces and the solutes are then driven by the groundwater gradient, as defined in the pre-mining conditions.

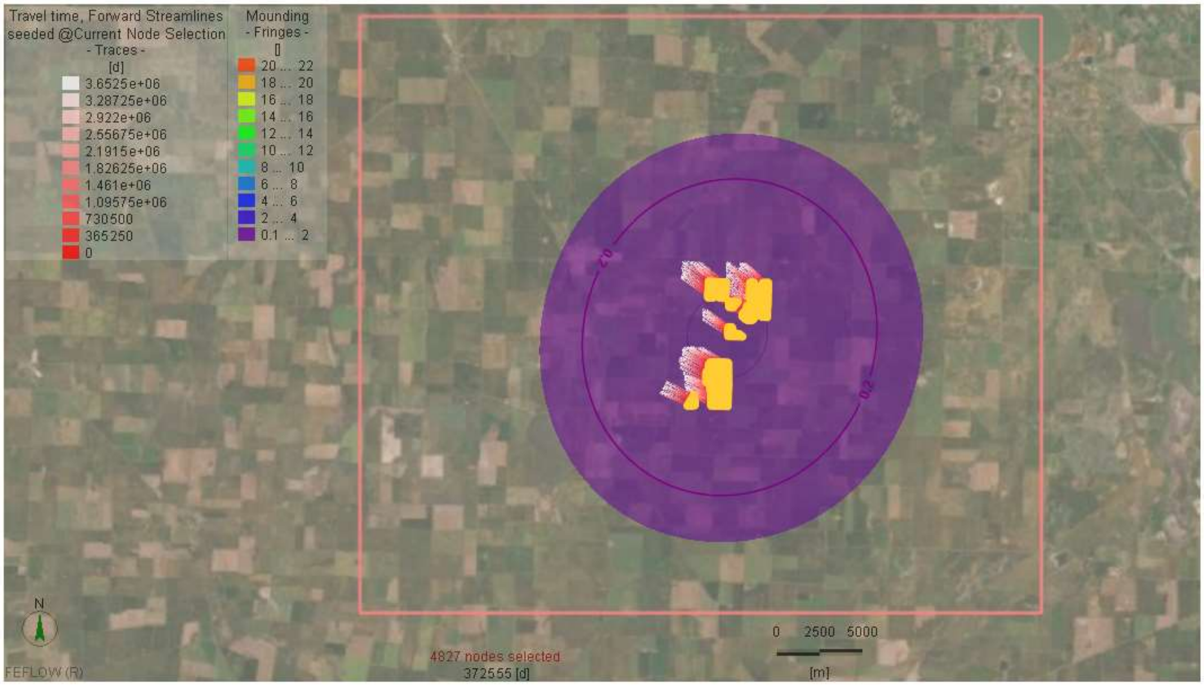


Figure 9-9 Particle Tracking for 10,000 years and Residual Mounding at 1,000 Years Post Mining

Figure 9-10 presents a post mining hydrogeological simplified conceptual cross section that has been developed for the Project area, based on available hydrogeological information, numerical model results and assessment works completed above. Key features of the post mining hydrogeological conceptualisation are as follows.

- The recharge mechanism in this area is the infiltration of rainfall. The discharge mechanism is throughflow to the northwest.
- At the end of operations groundwater mounding is present in the rehabilitated mine pits and at 100 years post mining the 0.1 m contour will migrated to a distance comprised within 4.0 km from the mined areas.
- The forward particle tracking shows particle tracking travels for at a distance of 2 km for 10,000 years post mining. The particles show COCs from seepage at the mine pits are calculated to migrate in the direction of the groundwater hydraulic gradient from the mined areas and driven by the gradient generated from the groundwater mounding.
- There is no evidence to show a perched aquifer exists in the area based on the available drilling bore logs, water level observations and as shown in MW007, which is screened above the water table, is dry. If such conditions were to occur due to very low vertical hydraulic conductivity in the Loxton Parilla Sands, the mounding of the water table would be lower.
- Over time the groundwater mounding related to the mining operation reduces and the COCs are then driven by the groundwater gradient, as defined in the pre-mining conditions.

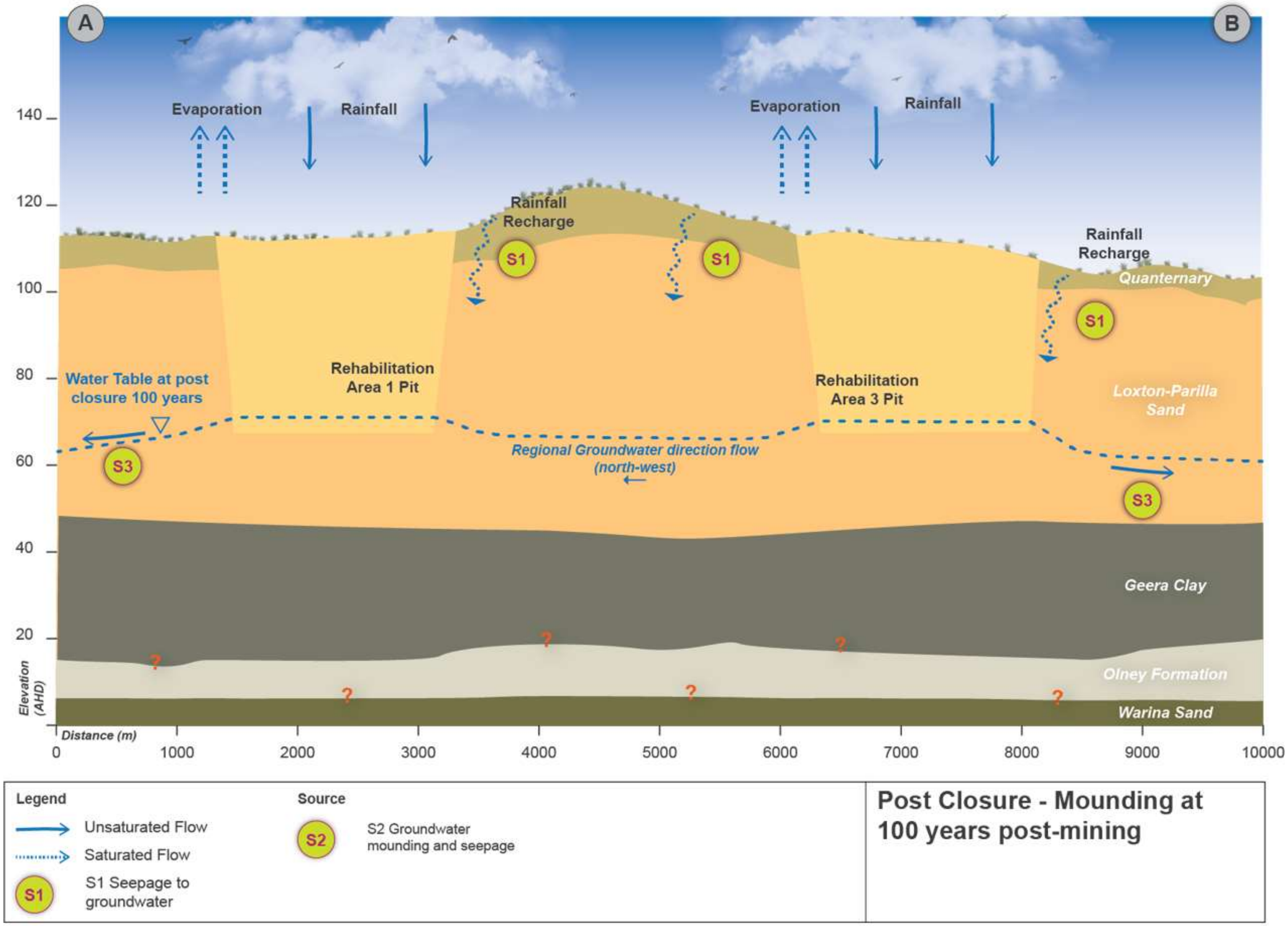


Figure 9-10 Post Closure Hydrogeological Conceptual Model

10. Environmental Values and Contaminants of Concern

10.1 Environmental Values

Environmental value is the term used to describe the values of water environments Victorians want to protect and is the key instrument in shaping protection of water resources in the environment under the guidance Environment Protection Act, 2017 (EPA Victoria, 2017). The Environment Protection Act 2017 is the overarching environmental protection legislation in Victoria. The Environment Reference Standard amended to the Act specifies suitable uses of groundwater based on the TDS of the groundwater. Table 10-1 presents a summary of this framework.

Table 10-1 Groundwater of Victoria Environmental Values Segments (mg/L for Total Dissolved Solids)

Environmental Values	Segment (mg/L TDS)						
	A1 (0 -600)	A2 (601 – 1200)	B (1201 – 3100)	C (3101 - 5400	D (5401 – 7100)	E (7101 – 10000)	F (> 10001)
Water dependent ecosystems and species	✔	✔	✔	✔	✔	✔	✔
Potable water supply – desirable	✔						
Potable water supply – acceptable	✔	✔					
Potable mineral water supply	✔	✔	✔	✔			
Agriculture and irrigation – irrigation	✔	✔	✔				
Agriculture and irrigation – stock watering	✔	✔	✔	✔	✔	✔	
Industrial and commercial	✔	✔	✔	✔	✔		
Water based recreation – primary contact recreation	✔	✔	✔	✔	✔	✔	✔
Buildings and structures	✔	✔	✔	✔	✔	✔	✔
Geothermal properties	✔	✔	✔	✔	✔	✔	✔
Traditional owner cultural values	✔	✔	✔	✔	✔	✔	✔

The groundwater salinity data summarised in Table 8-10 indicates that salinity in the Loxton-Parilla Sands ranges from 13,394 to 29,565 mg/L TDS in the Project Area, suggesting a F segment environmental values. The Environmental Values category indicated by the regional mapping is Segment F (>10,001 mg/L TDS), in alignment with site data collected to date. This segment includes the protection of the following:

- Water dependent ecosystems and species
- Water based recreation (primary contact)
- Traditional owner cultural values
- Buildings & Structures
- Geothermal properties

10.1.1 Water Dependant Ecosystems and Species

A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no high potential GDE types within 10 km of the Project area. The GDE Atlas was released in 2012 and was produced by conducting a national-scale assessment using remote sensing and GIS rules-based analysis, which mapped the potential for groundwater/ecosystem interaction. The Atlas indicates there are no baseflow dependant streams in the area. There are listed unnamed wetlands to the northeast and east of the site that are classified as GDEs as shown in Figure 10-1.

CDM Smith (2019) completed an assessment of the likely reliance on groundwater of these wetland features with findings summarised accordingly below.

Smaller wetland features exist between the site and Lake Lalbert located approximately 5 km to the west and between the site and the Avoca Marshes at approximately 10 km to the east. These are located in areas where the water table is likely to be greater than 10 m deep and highly saline, ranging from 13,000 to >35,000 mg/L TDS. It is therefore unlikely that they receive groundwater, or that groundwater would provide any ecological benefit to the wetlands.

Lake Lalbert and Lalbert Creek are DIWA listed wetlands and are approximately 8 km west of the Project area. The lake has been dry since 1998. The water table is deep at 20 to 50 m below ground level, highly saline and groundwater is not expected to contribute the water in the lake, or the wetlands associated with Lalbert Creek. It is unlikely for groundwater flow from the mine site to impact or contribute to Lake Lalbert and Lalbert Creek as the model results show at the end of operations groundwater mounding at 100 years post mining the 0.1 m contour will migrate to a distance comprised within 4.0 km from the mined areas.

The Kerang Wetlands that are listed as DIWA and RAMSAR status. The closest to the site being the Avoca Marshes: Third Marsh (26 km east), Second Marsh (26 km east), First Marsh (27 km east) and Lake Bael Bael (27 km east). The Avoca River flows directly into Lake Bael Bael, which fills and spills into First Marsh, Second Marsh and Third Marsh sequentially, each wetland receiving water via overflow from the preceding marsh. In their natural state, depth to water under the Avoca Marshes varies between 5 to 10 m, however modifications to the watercourse and irrigation in the area has resulted in a rising water table which has in turn had a detrimental impact on wetland health due to the highly saline nature of the groundwater. Elevated groundwater poses a significant risk to the wetlands and therefore they are not reliant on groundwater (CDM, 2019). It is unlikely for groundwater flow from the mine site to impact the wetlands as the flow direction is to the northwest and therefore, away from the direction of the wetlands.

Groundwater is relatively deep throughout the Project area on average 31 mbgl, and there are no known permanent surface expressions of groundwater that interact with groundwater within 10 km of the proposed Project area. As the groundwater level is deeper than the proposed pit depths, there is no expected impact/s on groundwater and GDEs from extraction of the ore as part of mining operations.

Groundwater fauna are found in aquifers across Australia, predominantly in aquifers with large pore spaces, especially alluvial, karstic and some fractured rock aquifers (CSIRO, 2015). The size of the pore spaces is a key determinant of the suitability of an aquifer as stygofauna habitat and are rarely found more than 100 m below ground level (CSIRO, 2015). Stygofauna are found across a range of water quality conditions (from fresh to saline), but most common in fresh and brackish water (electrical conductivity (EC) less than 5000 µS/cm) (CSIRO, 2015). Stygofauna are poorly recorded in the Victorian context (GHD, 2022). The likelihood of stygofauna occurrence is considered to be low to very low in the system based upon the conceptualisation from available bore monitoring data, and no reported occurrence within the region.

At the project site the thin quaternary alluvial cover of sandy clay is dry and ranges in thickness from approximately 5 to 10 mbgl. The Loxton Parilla Sands forms the main aquifer in the study area and consists of unconsolidated to weakly cemented yellow-brown fine to coarse well-sorted quartz sand, sandstone. The bore logs indicate that the screened sandstone is typically fine to coarse grained and well cemented with ironstone. Based on the drilling log descriptions the screened material below the water table does not possess large pore spaces typically found with alluvial, karstic and fractured rock systems. The permeability results estimated are low ranging from 0.02 to 0.65 m/day, and an overall mean value (all tests) of 0.35 m/day. The aquifer at depth has small or limited pore space and combined with the high groundwater salinity, electrical conductivity readings of 19,991 to 29,400 µS/cm, shows that the aquifer environment is highly unlikely suitable for groundwater fauna.

10.1.2 Building and Structures

No building and structure values have been identified for groundwater in the project area, likely related to aquifer permeability, water table depth and water quality. The Loxton Parilla Sands aquifer has low permeability at depth, the water table is deep at 20 to 50 m and highly saline. Future use for building and structures is unlikely from the Loxton Parilla Sands aquifer.

10.1.3 Water Based Recreation – Primary Contact Recreation

No water based recreation have been identified for groundwater in the project area likely due to the aquifer permeability, water table depth and water quality. The Loxton Parilla Sands aquifer has low permeability at depth, the water table is deep at 20 to 50 m and highly saline. The electrical conductivity readings of 19,991 to 29,400 µS/cm, shows that the aquifer environment is unlikely suitable for water based recreation. The water table is deep at 20 to 50 m and highly saline and groundwater does not at the site contribute water naturally to surface water features i.e. lakes or wetlands. Future use for water based recreation – primary contact recreation is unlikely from the Loxton Parilla Sands aquifer.

10.1.4 Geothermal Properties

No geothermal values have been identified for groundwater in the project area likely due to the absence of geothermal activity in the area as well as site groundwater temperature, aquifer permeability and water quality. Groundwater field water quality results show that the groundwater temperature is less than 25° and combined with the aquifer properties has very limited / low potential geothermal value. Future use for geothermal properties is unlikely from the Loxton Parilla Sands aquifer.

10.1.5 Cultural and Spiritual Values

Cultural and spiritual values may include custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities. No specific cultural and spiritual values have been identified for groundwater in the project area. For further details on engagement with Traditional Owners refer to the VHM study, Ecological Australia, 2022. Cultural Heritage Impact Assessment. September, 2022.

10.2 Groundwater Use

Groundwater in the area is unsuitable for human consumption due to elevated electrical conductivity. Due to the depth of the water table, aquifer permeability, and water salinity concentrations it is unlikely any potential groundwater users in the area are reliant on the groundwater sourced from the Loxton Parilla Sands. This is supported by the state-wide database of registered groundwater users which indicates there are no registered domestic or stock bores within 10 km of the Project site. There are six registered domestic or stock bores within 30 km of the Project as described below and shown in Figure 10-1. All registered bores identified are located up-gradient of the regional groundwater flow.

- WRK959015 (11 km northeast of Area 3) – completed on 21/06/2005 to 7 m depth (screen 3 to 7 m in brown/grey sand), listed as Domestic and Stock.
- 50294 (18 km northeast of Area 3) – completed on 31/12/1967 to 36.57 m depth (no construction details), listed as Domestic and Stock.
- 50295 (18.5 km northeast of Area 3) – completed on 31/12/1967 to 36.57 m depth (no construction details), listed as Domestic and Stock.
- 50293 (20 km northeast of Area 3) – completed on 31/12/1967 to 30.48 m depth (no construction details), listed as Domestic and Stock.
- 50331 (24 km northeast of Area 3) – completed on 1/07/1976 to 5.97 m (no construction details), listed as Domestic and Stock.
- 50330 (24 km northeast of Area 3) – completed on 4/10/1974 to 24.9 m (screen 13.1 to 15.4 m), listed as Domestic and Stock.

Based on the available information groundwater is not used for human consumption, stock watering, irrigation or industrial purposes within 10 km of the Project area.

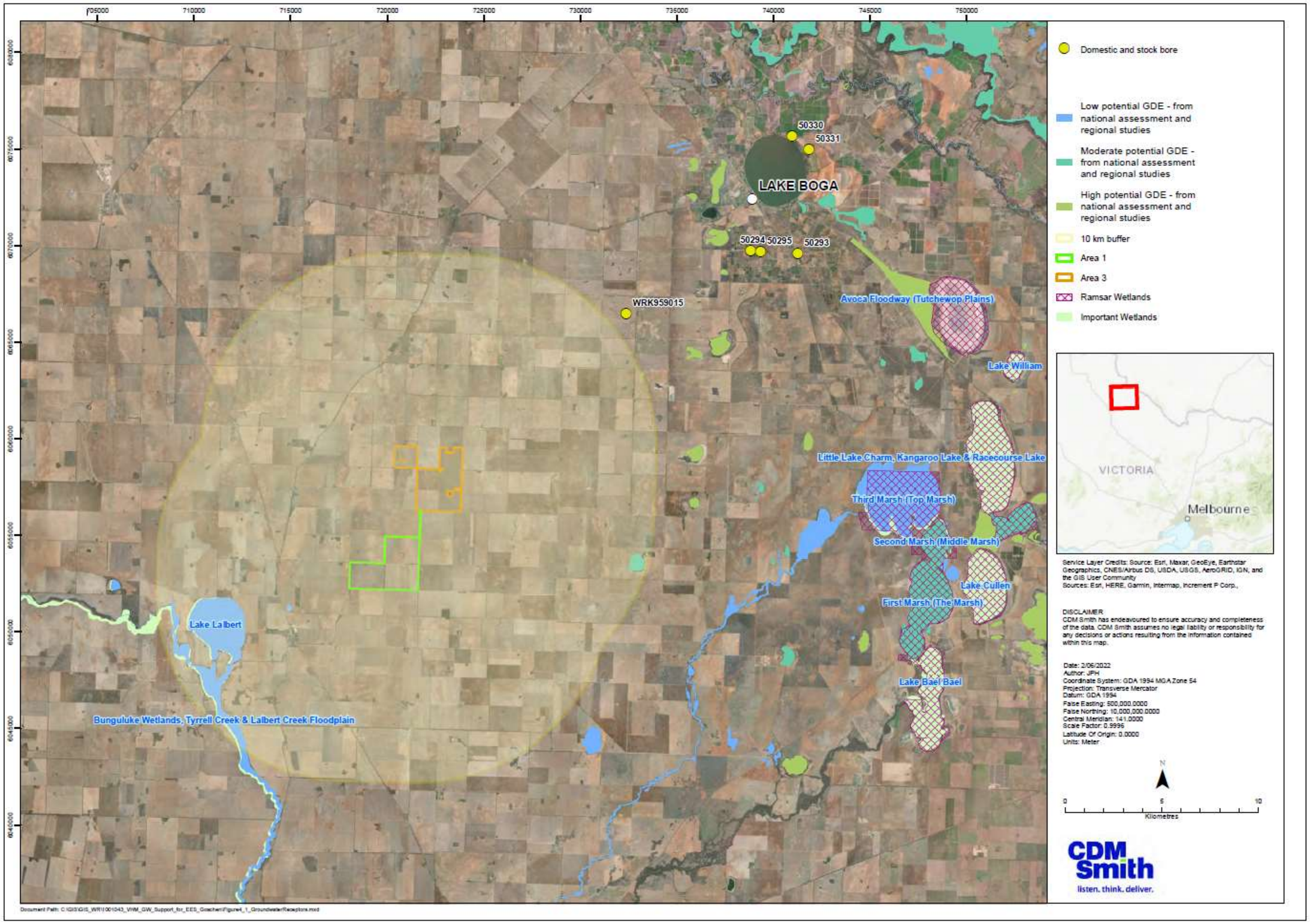


Figure 10-1 Potential Groundwater Receptors

10.3 Contaminants of Concern and Water Quality

10.3.1 Mine Pits

The following outlines the key assumptions and characterisation of the tailings and tailings leachate relevant to the assessment of impacts:

- The regional water table is below the pit floor, but seepage from the tailings will raise the water table and create a groundwater mound that intersects the pits. Dewatering of the pit will lower the mounded water table, however, the effect of this dewatering has not been modelled.
- The Geera Clay unit is likely to contain sulfides. Should oxygen be delivered to this geological unit, either by lowering the water table below the pre-mining level and or aquifer re-injection oxidation of these sulfides may affect groundwater quality. Neither of these activities are needed or planned as part of the Goschen Project, thus this risk is avoided.
- At the end of mining, dewatering of the mounded water table will cease and the groundwater table will rise, mounding is expected to result in a groundwater table at least 5m above baseline. It is therefore likely that the final interred tailings will sit below the water table following closure.
- Tailings contain leachable content, once interred in the pit, seepage will initially percolate through the unsaturated zone to the rising water table, and then eventually a proportion of the tailings will sit below the water table.
- The seepage through the tailings has been assessed to be of low salinity and will unlikely be acidic, as the tailings are non-acid forming, but will likely contain elements at concentrations higher than in groundwater, thus groundwater quality will evolve through the input of tailings seepage.
- The fresh water supply that is provided by Kangaroo Lake and used in the process circuit and the source of water to slurry the tailings to in-pit deposition, has a salinity of less than 500 mg/L. The recycling of this water through what is collected as part of the tailings management will slowly increase over time. However, the constant input from Kangaroo Lake and the relatively minor inputs from tailings leachate and processing means this concentration over the life of operations will be significantly less than background groundwater levels, and thus assumed not to be material in terms of impact.

10.3.2 Tailings and Tailings Leachate

In 2021, VHM characterised the tailings streams for the Heavy Mineral Concentrate (HMC) in terms of their acid generation potential and leachability. This characterisation was compiled and reported by Right Solutions in 2022 (Appendix C). The following provides a summary of the characterisation work completed and likely geochemical processes as follows:

- Tailings contain leachable content, once interred in the pit, seepage will initially percolate through the unsaturated zone to the rising water table, and then eventually a proportion of the tailings will sit below the mounded water table for a period of time.
- Seepage from the tailings will be of low salinity and will unlikely be acidic, as the tailings are non acid forming, but will likely contain elements at concentrations higher than in groundwater, thus groundwater quality will change through the input of tailings leachate.
- The contaminants of potential concern (COPC) in seepage from the tailings which leach at concentrations above those measured in groundwater are: aluminium, arsenic, cerium, chromium, hexavalent chromium, fluoride, phosphorus (as reactive phosphorus), nickel, titanium and vanadium.
- COPC which leach but could not be fully assessed with due to limits of reporting in groundwater being too high or the element was not included in the initial background analytical groundwater suite are: selenium, tin, thorium,

thallium, uranium, yittrium, and zircon. Although the limit of reporting was not sufficiently low to detect trace levels of these parameters in background groundwater and thus compare with the conservative leachate concentration, it is considered for the purpose of the impact assessment that these elements would have the potential change groundwater quality, and thus considered a COPC.

- The geochemical processes in the Loxton Parilla Sands aquifer will potentially mitigate long term impacts to groundwater quality from the seepage, such as:
  - The dissolved aluminium in the tailings seepage may precipitate in the reducing waters of the Loxton Parilla Sands aquifer, but the presence of fluoride complicates the calculations (Hem, 1985) and any hexavalent chromium from the leachate will likely reduce to its less toxic tri valent form.
  - The presence of vanadium in the seepage may lead to precipitation of uranium.
  - The released rare earth elements (REE) such as cerium, lanthanum and yittrium may sorb to the in situ clays or other mineral phases such as iron oxides or may complex with phosphate.
  - The element most likely to attenuate onto iron oxide phases is nickel. Arsenic and selenium may also sorb onto iron oxides. Thus, there is a likelihood based on the receiving groundwater environment that some of the solutes (COPC) introduced through seepage will attenuate in the aquifer over time.
  - The Loxton Parilla Sands aquifer is unlikely to contain sulfides, but it will contain stored salts, and retained acidity. Thus, increases in the water table (mounding) will release these salts and stored acidity altering groundwater quality.
  - The tailings leachate will dilute groundwater in terms of salinity, however the effect of increases in salinity from saturation of previously unsaturated aquifer are likely to far outweigh any input from the tailings. Furthermore, given that salinity levels in groundwater led to higher laboratory detection limits, the effect from the tailings may not be significant enough to be measurable, it will very much depend on the volume of seepage likely to be generated by the tailings whether any change will be noted.

In summary, given the leachate chemistry from the tailings and likely attenuation processes once it enters the aquifer, the activity most likely to alter groundwater quality at the site is the mobilisation of salts as a result of generation of mounding beneath the pit. The introduction of tailings to the pit, will introduce additional solutes, primarily aluminium to the aquifer and may also lead to ion exchange reactions with the clays which will in turn alter water chemistry and potentially reduce hydraulic conductivity of the aquifer. The ion exchange reactions will possibly not alter the groundwater chemistry within the measurable range.

11. Risk Assessment

The identified risk of harm and associated residual risk ratings are listed in Table 11-1, and based on the Earth Resource Regulation risk framework[1].

Construction environmental risk of harm have not been identified or assessed at the mine pit locations. Construction activities are reported by VHM to be above the water table and unlikely to intersect the water table based on current construction plans available at the time of report preparation. The depth to water table at the proposed mine pit location is approximately 48 mbgl, and combined with the permeability the water table is unlikely to receive any environmental risks from surface construction activities.

The main risk of harm to the receiving environment is from seepage of the tailings pore water to the localised groundwater system and groundwater mounding from mine operations related to pit backfilling with tailings. The following are potential risks to the receiving environment associated within the mine pit tailing facility at Area 1 and Area 3 development:

- Changes to the flow system related to different groundwater levels (mounding) and fluxes.
- Changes to recharge and discharge mechanisms due to mounding, and the potential of this to influence groundwater levels and fluxes flowing through the aquifer.
- Changes to the groundwater geochemistry, including:
  - Operations and closure: acid generation seepage of contaminated water to underlying groundwater from the mine pits / tailings.
  - Operations and closure: salinity generated may lead to seepage of contaminated water to underlying groundwater from the mine pits / tailings.
  - Operations and closure: COPC and metal leaching seepage of contaminated water to underlying groundwater from the mine pits / tailings.

Table 11-1 summarises the identified groundwater residual risk of harm due to the planned operational and decommissioning activities that have been considered, and the potential environment effect due to the presence / proximity of environmental receptors and defined environmental values.

The project is not considered to have significant impacts on groundwater users and receptors at this time for the following reasons:

- A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no high potential GDE types within 10 km of the Project area. The GDE Atlas indicates there are no baseflow dependant streams in the area.
- The numerical model results show there is unlikely to be an impact at wetlands to the northeast and east of the site that are classified as GDEs or the Kerang Wetland that are listed as DIWA and RAMSAR status.
- It is unlikely for groundwater flow from the mine site to impact the wetlands as the flow direction is to the northwest and therefore, away from the direction of the wetlands / groundwater users.

The likelihood and consequence classifications based on ERR Risk Framework linking the risk to the receptor, are as follows:

- Groundwater mounding and changes in groundwater recharge

[1] Appendix A of Preparation of Work Plans – Guideline for Mining Projects - https://earthresources.vic.gov.au/legislation-and-regulations/guidelines-and-codes-of-practice/work-plan-guidelines-for-mining-licences

- Likelihood = Rare, as the groundwater modelling has shown a conservative estimate of mounding will not reach any users or receptors of groundwater, and recharge will return to pre mining level post closure.
- Consequence = Minor, as even if several centimetres of mounding does reach a receptor the consequence is unmeasurable, and changes in recharge post mining do not occur.

- Groundwater salinity changes
  - Likelihood = Rare, as the mining operations are likely not to change the groundwater salinity negatively, as in will not increase the groundwater salinity as fresh water will be imported into mine operations.
  - Consequence = Minor, as no receptor will be impacted by a decrease in salinity, even if that was to occur.
- Groundwater acidity change, seepage of contaminated water
  - Likelihood = Unlikely, if changes in acidity or increase in contaminates due to mining operations occurs, the travel distance and time to the receptor (>1000years) would lead to significant dilution and natural attenuation through the Parilla Sand aquifer and effectively become unmeasurable.
  - Consequence = Minor, as the dilution would result in only minor impacts to the water requirements of the quality and water requirements of the receptor as dilution and natural attenuation through the Parilla Sand aquifer would significantly reduce any contaminate concentration.

Table 11-1 Summary of Groundwater Risks

Risk ID	Potential threat to identified environmental receptors and defined environmental values	Residual risk rating to identified environmental receptors and defined environmental values – based on ERR Risk Framework (refer above)
Operations / Closure (Decommissioning)		
Changes to the flow system	Groundwater mounding threat to GDE	Low
Changes to the flow system	Groundwater mounding threat to Groundwater Use	Low
Changes to recharge and discharge mechanisms	Groundwater change in recharge and discharge mechanisms threat to GDE	Low
Changes to recharge and discharge mechanisms	Groundwater change in recharge and discharge mechanisms threat to Groundwater Use	Low
Changes to the groundwater acidity	Groundwater acidity change threat to GDE	Low
Changes to the groundwater acidity	Groundwater acidity change threat to Groundwater Use	Low
Changes to the groundwater salinity	Groundwater salinity change threat to GDE	Low
Changes to the groundwater salinity	Groundwater salinity change threat to Groundwater Use	Low
Changes to the groundwater from tailings leaching	Groundwater COCs and tailings metalliferous drainage COCs threat to GDE	Low
Changes to the groundwater from tailings leaching	Groundwater COCs and tailings metalliferous drainage COCs threat to Groundwater Use	Low

In terms of risk to uses of groundwater, given there are no known users of groundwater, the increase in concentration of all measured components in groundwater from the interment of tailings at the site, whether from seepage or mounding may not affect the current use of the aquifer, but it may affect future users.

No groundwater receptors have been identified to date in the course of this study, with no known or identified registered water supply stock or domestic bores within 10 kilometres of the project site. Given the sites location and considering that use of groundwater at the site is considered unlikely at this time. If required, any future users will be managed via Administrative Control that aims to make sure any future user is made aware of groundwater chemistry changes within a certain area.

The risk rating provided for the changes to the groundwater chemistry from tailings leaching to groundwater is due to the hydrogeological controls on groundwater movement such that the consequence to environmental values is low.

12. Operation Impact Assessment

This section discusses the potential groundwater impacts of the project through operation and rehabilitation of the project. The mined pits are planned to be progressively backfilled in a staged manner, with tailings to be primarily dewatered in-pit, with overburden and topsoil placement to occur in a profile that reinstates the background soil structure. Mine tailings management and tailing in pit dewatering is necessary to effectively manage tailings in pit water content, and manage groundwater mounding entering the mine pit base or sides. The general configuration and sequencing of mining through the project lifecycle is shown in Figure 12-1.

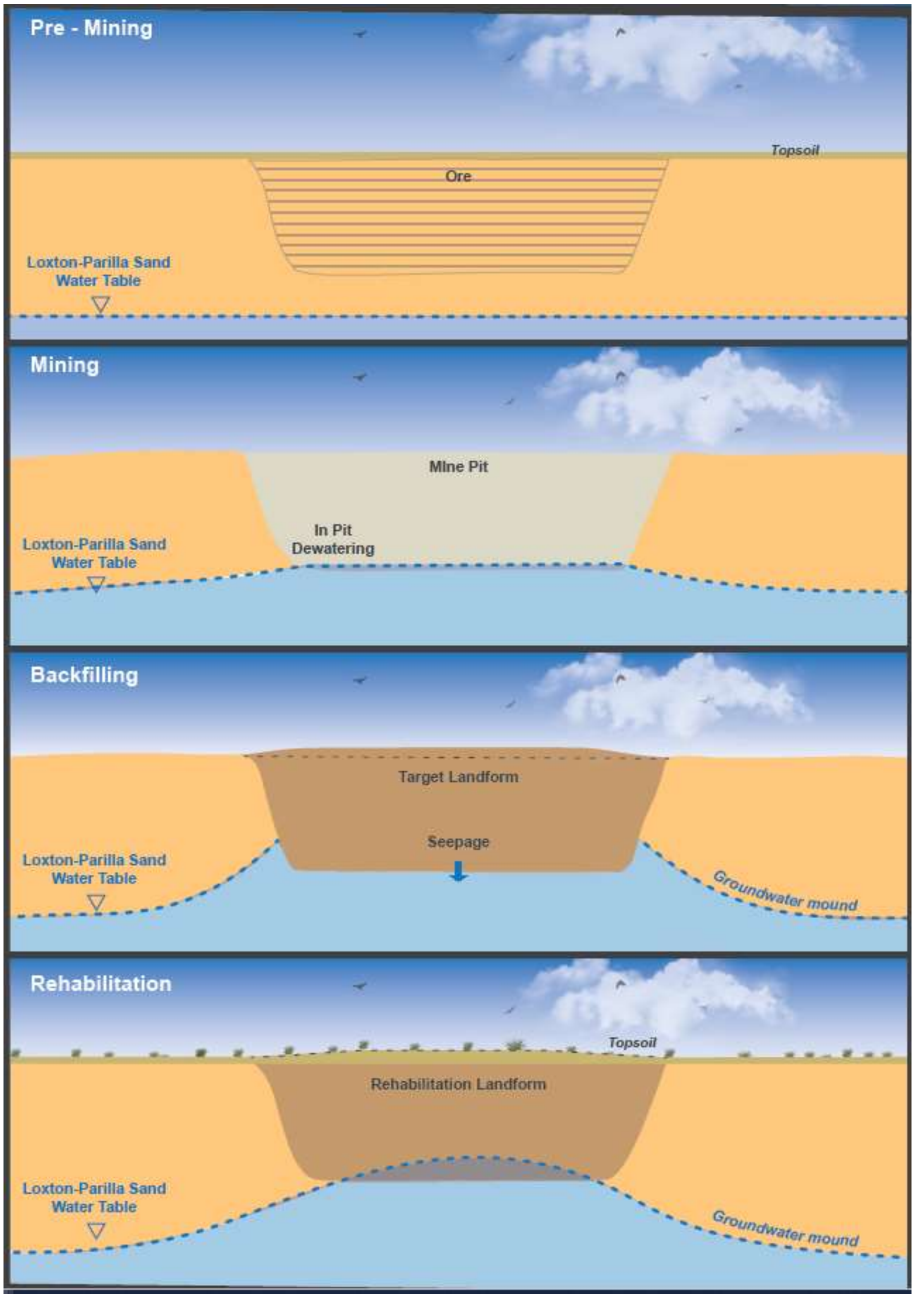


Figure 12-1 Configuration of Mining

The figure shows in a simplified form the water table response to pre-mining, mining, backfilling and rehabilitation phases, with the mounding identified during numerical modelling clearly present in the pit backfill phase. This is crucial as during this phase it is expected that the groundwater will be in direct hydraulic connection within pit tailings materials, with the tailings dewatering contributing directly to the aquifer, both in volume and quality.

12.1 Dewatering

The mining approach proposed is conventional open pit mining, where equipment will be used for a strip-mining operation above Loxton Parilla Sands aquifer pre-mining initial groundwater table. However, it should be noted that elevated groundwater levels though mounding may occur, leading to potential groundwater connection with mine pits during mining/backfilling operations. It has been indicated that the groundwater entering the pits through the sides or base will be managed through a collection network of sumps which will then be pumped out with water proposed to enter the return water circuit together with the decanted water from the tailings.

The potential for a change to groundwater levels to decline due to dewatering activities is technically reduced due to groundwater mounding. Mine dewatering systems such as groundwater dewatering bores are planned to be used and there is a system to reduce water levels beneath the pit floor. A take and use of groundwater license will be required from GWMWater for capture of mound within and beneath the pit floor. The Project design in regards water recovery of tailings management includes the use of homogenisation of the tailings and flocculants. The geotechnical impact assessment (Pit & Sherry, 2023) documented a conceptual level engineering on dewatering systems to manage mounding and ensure pit floor is dry, with the groundwater mound level reduced to 1 metre below pit floor.

It should be noted that perched water may be encountered within the shallower sequences of the Loxton Parilla Sands if low permeability layers are encountered. However, dewatering of perched water would not be expected to result in drawdown in the Loxton Parilla Sands aquifer due to the nature of these local groundwater lenses.

12.2 Mounding (from mine tailings seepage)

As noted above mined areas are planned to be progressively backfilled in a staged manner, with tailings emplaced and dewatered in-pit. Mine tailings management and tailing in pit dewatering will be necessary to effectively manage tailings in pit water content and address groundwater mounding entering the mine pit base or sides.

Based on the numerical modelling results the calculated groundwater mounding at the end of operations shows that the 0.1m drawdown contours extends no further than 2 km from the mine. This shows that the conservative modelling approach adopted in the assessment calculates the mounding extent from Area 1 and Area 3 to be spatially limited to this distance, and indicates that groundwater mounding impact is localised around the mining pits.

The groundwater mounding lateral extent maybe reduced through the use of engineering design features that limit the groundwater mounding extent for example extraction bores or interceptor drains.

The groundwater vertical maximum mounding observed at any point within the model domain during mining operations is 21.4 m. The elevated groundwater levels are calculated to results in a groundwater connection with the base / sides of the mine pits during mining/backfilling operations.

12.3 Groundwater Quality and CoC

A baseline groundwater quality profile for the site is being developed. Groundwater monitoring is currently scheduled at a frequency of bi-annual for a period of two years total to develop a pre-mining baseline groundwater level and quality database against which changes can be monitored to the groundwater regime due to mining. There have been two groundwater monitoring events completed to date, undertaken in August/September 2021 and April 2022. Ongoing groundwater monitoring is planned at a frequency of bi-annual for a period of two years to develop a baseline groundwater level and quality database against which changes can be monitored to the groundwater regime. Further detail in relation to monitoring is presented in Section 14 below.

The water affecting activity most likely to alter groundwater quality at the site is the generation of mounding beneath the pit. The introduction of tailings to the pit, will introduce additional solutes, primarily aluminium to the aquifer and may also lead to ion exchange reactions with the clays which will in turn alter water chemistry and potentially reduce hydraulic conductivity of the aquifer. The ion exchange reactions will possibly not alter the chemistry within the measurable range.

The travel distance of COCs maybe reduced through the use of engineering design features that limit the groundwater mounding extent such as extraction bores or interceptor drains.

12.4 Groundwater and Surface Water

Groundwater and connected surface water impacts are considered unlikely considering the current site conditions and proposed mining approaches. Groundwater discharge to surface occurs wherever groundwater flow intercepts the land surface. The Loxton Parilla Sands aquifer does not discharge to any known wetlands, lakes or surface water features in the study area. Groundwater is relatively deep throughout the Project area on average 31 mbgl, and there are no known permanent surface expressions of groundwater that interact with groundwater within 10 km of the proposed Project area.

Surface water will be prevented from flowing into the mine pit via bunding installed above the existing water table. Surface water that flows into the pit will be recycled or pumped out to keep the workings dry during mining operations. The reduction in recharge to the aquifer overall due to removal of surface water will be proportionate to the size of the site. It is not expected that the reduction in recharge will have any effect on the regional Loxton Parilla Sands aquifer water table at this time considering the hydrogeological setting. The mine site surface water management for surface water diversion and bunding is outlined in the report from Pitt & Sherry, 2023.

12.5 Groundwater Users

Potentially sensitive groundwater receptors identified in the Project area include private users of groundwater and the environment. VHM have reportedly consulted landholders within the immediate area of the project and no unregistered bores have been reported. The key conclusions drawn from the environmental impact assessment are:

A search of the state-wide database of groundwater users indicates:

- No registered domestic or stock bores within 10 km of the Project area.
- Six registered domestic or stock bores within 30 km of the Project area.
- Based on the available information groundwater is not used for human consumption, stock watering, irrigation or industrial purposes within 10 km of the Project area.
- A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no GDE types within 10 km of the Project area. The Atlas indicates there are no baseflow dependent surface water features in the area. There are known features existing between the site and Lake Lalbert but it is unlikely that they receive groundwater from the Loxton Parilla Sands aquifer or that groundwater would provide any ecological benefit to the wetlands.

Groundwater impacts to EVs or groundwater users related to mining operations are considered unlikely at this time. EVs (stock watering or ecological) have not been identified within the predicted model mounding or particle tracking plume extent.

12.6 Climate Change

Climate change may affect rates of recharge and the future availability of groundwater. To assess climate change impact the DELWP guideline for Assessing the Impact of Climate Change on Water Availability in Victoria was reviewed (DELWP, 2020). The guidelines list the requirements to determine the aquifers sensitivity to climate change as follows:

- The aquifer sedimentary and unconfined with a depth to water table less than 20m.
- The aquifer highly responsive to rainfall and/or changes in stream flows.

To assess the groundwater resource availability a conceptual model of the system is shown in Figure 8-12, as well as an understanding of how the system is recharged as described in Section 8.6.1.

Based on the available data the Loxton Parilla Sands aquifer in the vicinity of the tenements area is unlikely to be sensitive to climate change. The data shows a shallow water table greater than 20 m below the ground level with the water table at the site on average is 31 mbgl. Long term hydrographs for three WMIS monitoring bores is shown in as depth to groundwater Figure 8-8 as groundwater elevation. The groundwater table does not respond to rainfall events and indicates very stable groundwater levels with no clear response to rainfall events as shown in the cumulative departure from mean monthly rainfall (CDFM) shown on Figure 8-9. Due to the depth of water table and the aquifer subdued response to rainfall events the aquifer is considered not sensitive to climate change impacts.

13. Closure and Rehabilitation Impact Assessment

This section discusses the potential groundwater impacts of the project as a result of decommissioning activities, including rehabilitation and closure. It also details any associated mitigation measures proposed that aim to reduce impacts to groundwater to as low a level as possible.

13.1 Dewatering

No dewatering impacts are considered likely for the mine pit closure and rehabilitation assessment at this time. Mine dewatering systems such as groundwater dewatering bores are planned to be used, and the system will be used to reduce water levels beneath the pit floor until the area is backfilled. The mined areas will be progressively backfilled in a staged manner with the intent to return the site to the current agricultural land uses within 3 years following rehabilitation.

13.2 Mounding (from mine tailings seepage)

Based on the numerical modelling results the 0.1 m drawdown contours extend no further than 2.0 km from the mined areas. At 100 years post mining, the 0.1 m contour has migrated to a distance comprised within 4.0 km from the mined areas. At 1000 years post-mining the 0.1 m mounding contour is extending about 10 km from the mined areas while the residual mounding beneath the mined area is about 0.5 m. This shows that the conservative modelling approach adopted in the assessment calculates the mounding extent from Area 1 and Area 3 for mine closure / rehabilitation to be limited, and indicates that groundwater mounding impact is generally localised around the mining pits.

13.3 Groundwater Quality

Particle tracking modelling has been used to show the likely pathway of possible contaminates and zone of potential contamination. Forward particle tracking shows that for a pre-defined period of 10,000 years the approximate zone of potential contamination travels at a distance of 2 km.

Tailings contain leachable content, once interred in the pit, seepage will initially percolate through the unsaturated zone to the rising water table, and then eventually a proportion of the tailings will sit below the water table. This seepage will be of low salinity and will unlikely be acidic, as the tailings are non acid forming, but will likely contain elements at concentrations higher than in groundwater, thus groundwater quality will evolve through the input of tailings seepage. Groundwater quality will also evolve with increasing input from the unsaturated Loxton Parilla Sands aquifer.

13.4 Groundwater and Surface Water

Groundwater and connected surface water impacts are considered unlikely for the mine pit closure and rehabilitation assessment. The final landform will lead to a return to the current agricultural land uses, and there is no planned groundwater - surface water interactions at the site post closure.

13.5 Groundwater Users

Groundwater impacts to EVs or groundwater users are considered unlikely in relation to the mine pit closure and rehabilitation assessment. EVs (stock watering or ecological) have not been identified within the predicted model mounding or particle tracking plume extent post closure and considering current users it is unlikely these EVs will change post closure.

13.6 Climate Change

Groundwater impacts due to climate change are considered unlikely in relation to this mine pit closure and rehabilitation assessment. Due to the depth of water table and the aquifer subdued response to rainfall events the aquifer is considered not sensitive to climate change impacts over the long term.

13.7 Potential Exposure Pathways from COC Sources to Receptors

A potential exposure pathway is the route along which a COC might move through the environment from its source to a receptor. Potential pathways considered for the site post closure are presented in Table 13-1.

In summary, two pathways are considered relevant post closure with respect to connection of the source (groundwater mounding and seepage from the mine pits).

Table 13-1 Identified Post Closure Pathways

Pathways (P)	Description
P1	Groundwater mounding and contact of water with mine tailings.
P2	Vertical or lateral migration of solutes from the mine pits to the external groundwater.
P3	Seepage of tailings metalliferous drainage to underlying groundwater.

The development of the source-pathway-receptor assessment included assessment of the following elements:

- Sources of contamination or site activities that can cause contamination.
- Pathways by which contaminants can or may infiltrate to the local water table and then migrate via groundwater flow pathways.
- Receptor of the pollution who or what could be affected due to operations and closure.

The current source-pathway-receptor assessment incorporating the sources, pathways and receptors identified post closure have been summarised and is presented in Table 13-2.

Table 13-2 Source, Pathway and Groundwater Receptor Summary – Post Closure

Source	Pathways (P)	Receptor
Mine Pits	P1 At the end of operations groundwater mounding is present in the rehabilitated mine pits and at 100 years post mining the 0.1 m contour will migrated to a distance comprised within 4.0 km from the mined areas. The groundwater vertical maximum mounding observed at any point within the model domain during mining operations is 21.4 m. The elevated groundwater levels are calculated to results in a groundwater connection with the base / sides of the mine pits during mining/backfilling operations.	The groundwater receptor is related to Groundwater Dependant Ecosystems and Species. A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no potential GDE types within 10 km of the Project area. There are no known permanent surface expressions of groundwater for example springs or seeps within 10 km of the proposed Project area. Major watercourses in the area called Lambert and Tyrell Creeks, and Avoca River are typically disconnected from the regional water table (CDM Smith, 2018). Groundwater mounding based on the numerical model results shows no potential expression of groundwater to ground surface.
Mine Pits	P2 and P3 Forward particle tracking for the model shows particle tracking travels at a distance of 2 km for 10,000 years.	The groundwater receptor is related to Groundwater Dependant Ecosystems and Species. A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no potential GDE types within 10 km of the Project area. There are no known permanent surface expressions of groundwater for example springs or seeps within 10 km of the proposed Project area. Major watercourses in the area called Lambert and Tyrell Creeks, and Avoca River are typically disconnected from the regional water table (CDM Smith, 2018).

There is a potential exposure pathway if a source is connected to a pathway which leads to a receptor. The likelihood of potential exposure pathway is considered low given the current understanding of pathways identified and modelling results, namely:

- No human groundwater use receptors have been identified within 10 km likely due to the natural total dissolved solids concentration. The groundwater is naturally, highly saline and is not suitable for drinking or stock watering purposes.
- The modelling results show that there is potential movement of COCs offsite however due to the travel distance there is an unlikely pathway to groundwater receptors. While COCs may exist in the tailings pore water the forward particle tracking for the model shows particle tracking travels at a distance of 2 km for 10,000 years.
- At the end of operations groundwater mounding is present in the rehabilitated mine pits and at 100 years post mining the 0.1 m contour will migrated to a distance comprised within 4.0 km from the mined areas. The modelling results show that there is potential groundwater mounding offsite however due to the mounding extent there is an unlikely pathway to groundwater receptors.

Once groundwater studies are concluded and results evaluated then any applicable post closure impact mitigation actions will be considered. This will include design and mitigation elements which could avoid or minimise significant effects on groundwater and downstream water environments. Once mitigations measures have been considered an evaluation and reporting of the residual environmental impacts will be considered.

14. Summary of Monitoring and Contingency Measures

The monitoring and contingency measures that are proposed to assess groundwater study impacts associated with the project are summarised in Table 14-1. Details associated with the proposed monitoring program attached to this project are presented in the Groundwater Monitoring Program developed for the project (CDM Smith, 2022).

As part of the Goschen Project Mitigation Hierarchy (refer to Figure 2-2) the assessment is able to conclude the following:

Avoid Impact

Impacts to groundwater have been avoided through the following:

- Design of the 60ML process water pond (PWP) will include lining with HDPE, or equivalent system, to engineer no or negligible leakage to sub-surface.
- Mining operations (pits) will not extend to intersect the pre-mining groundwater table. This is discussed in EES Chapter 3 Project Description and EES Chapter 4 Project alternatives and specifically aim to avoid any potential drawdown effect on the regional aquifer system.
- The area of mining, and thus tailings deposition, is significantly reduced (Area 1 and 3) from that presented in the 2018 Referral, and now greater than 10km from any sensitive groundwater receptors.

Minimise the Impact

To minimise tailings seepage to groundwater tailings water recover would be optimised as much as practicable and would be managed as part of a Tailings Management Plan. The tailings management strategy for the Project to minimise seepage is as follows:

1. homogenising (mixing) and thickening (partially dewatering) the various tailings streams at the process plant prior to being hydraulically transported to open pits for deposition.

2. ‘dewatering’ in-pit underdrain

3. progressively backfilling on top of the tailings as soon as practicable with overburden and topsoil to aid consolidation of tailings and allow re-vegetation and re-profile to the pre-existing landform.

The aim of the addition of flocculant to the tailings is to coagulate (clump) suspended solids from the standing water and allow water to be recovered for reuse in ore processing. Polyacrylamide based flocculants are planned to be used and are commonly used in the mineral sands industry and have been for many years. These polyacrylamide flocculant products can contain impurities that result from the manufacturing process, including acrylamide. Acrylamide has been identified as toxic to humans but degrade relatively rapidly through microbially facilitated biodegradation processes. The half-life of acrylamide has been estimated in the order of hours with complete degradation occurring within a range of days to a few weeks. Therefore, the long-term presence of acrylamide in the project area is not anticipated.

It is estimated (as a conservative assumption) that as a minimum of 35% of the entrained water deposited in-pit will be able to be directly recovered, which is the basis for the groundwater impact assessment. Once interred in the pit, seepage will initially percolate through the unsaturated zone to the rising water table, and then eventually a proportion of the tailings in cells located in Area 3 will sit below the water table.

The interception of seepage would add to the tailings water recovery and be in addition to the 35% recovery assumed in the impact assessment and include the following:

- embankment underdrain

- pit interception/dewatering of mounded groundwater

The quality of the tailings water has been geochemically characterised based on the various tailings streams to be homogenised, which includes any residual breakdown products from the various reagents used in the mineral processing. The conclusion is that the initial quality of the seepage (leachate) water will be of low salinity (brackish), neutral pH as the tailings are non-acid forming, but will contain a number of elements at concentrations higher than in groundwater. The consequence is that what seepage does enter the groundwater environment will be initially of a quality of the leachate, but will immediately start to mix with the native groundwater and trend to be indistinguishable from that of background groundwater quality within that area of the groundwater mound and found to be elevated with:

- aluminium, arsenic, cerium, chromium, hexavalent chromium, fluoride, phosphorus (as reactive phosphorus), nickel, titanium and vanadium.

The following are also likely to be CoCs in seepage, but has uncertainty given the limits of reporting in groundwater were not sufficiently low:

- selenium, tin, thorium, thallium, uranium, yttrium, and zircon

Manage the Impact

Management of the risk of harm to groundwater is presented in Table 14-1.

Biannual groundwater monitoring would be undertaken during Project operation and rehabilitation and water level and water quality change is detected and unplanned impacts are revealed, a review of the groundwater model would be undertaken.

In summary the following groundwater monitoring measures are recommended:

- Ongoing groundwater monitoring (captured as part of a groundwater Management Plan) is recommended to develop a baseline groundwater level and quality database against which changes can be monitored to the groundwater regime due to construction, operations and closure activities.
- The combined group of COPC should be monitored in any water monitoring program to provide baseline conditions and throughout the life of the mine.
- Long term rehabilitation monitoring program will need to be developed to monitor the groundwater level and groundwater quality.

Table 14-1 Monitoring and contingency measures relevant to Groundwater study

Measure ID	Monitoring or contingency measure	Phase
Groundwater level and quality	Baseline and ongoing groundwater monitoring at a frequency of bi-annual for a period of two years total to develop a baseline groundwater level and quality database against which changes can be monitored to the groundwater regime due to mining.	Pre mining

Measure ID	Monitoring or contingency measure	Phase
Groundwater level and quality	Operations ongoing groundwater monitoring at a frequency of bi-annual. If water level or water quality change is detected reveals unplanned impacts undertake review of groundwater data and whether change in mining practices will result in reduced impact. Review modelling results with observed data to update and inform a revaluation of impact assessment.	Mining
Groundwater level and quality	Rehabilitation monitoring at a frequency of bi-annual. If water level or water quality change is detected reveals unplanned impacts undertake review of groundwater data and whether change in mining practices will result in reduced impact. Review modelling results with observed data to update and inform a revaluation of impact assessment.	Closure

15. Summary of Implications Under Relevant Legislation

This groundwater study in support of the VHM Goshen EES has assessed the impacts of construction and operation of the project on Groundwater assets (as far as practicable) with due consideration to environmental values to be protected. The significance of the groundwater impacts has been assessed in accordance with the evaluation framework, based on applicable legislation, policy and standards and the evaluation objectives and environmental significance guidelines arising from the government terms of reference established to guide the assessments.

The following sections summarise these identified impacts in relation to the relevant Commonwealth and Victorian legislation.

15.1 Commonwealth

In relation to the evaluation matters of national environmental significance (MNES), which are protected under Part 3 of the EPBC Act: Ramsar wetlands (sections 16 and 17B); listed threatened species and communities (sections 18 & 18A); and protection of the environment from nuclear actions (sections 21 and 22A). The project is considered not have significant impacts on groundwater at this time for the following reasons:

- A search of the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas shows no high potential GDE types within 10 km of the Project area. The GDE Atlas indicates there are no baseflow dependant streams in the area.
- The numerical model results show there is unlikely to be an impact at wetlands to the northeast and east of the site that are classified as GDEs or the Kerang Wetland that are listed as DIWA and RAMSAR status.
- It is unlikely for groundwater flow from the mine site to impact the wetlands as the flow direction is to the northwest and therefore, away from the direction of the wetlands.

15.2 Victorian

In relation to the evaluation objectives set out in the EES Scoping Requirements, points to consider in the evaluation and a summary of the assessed project impacts on groundwater are as follows:

- The modelling approach adopted in this assessment is considered conservative. A conservative approach does not aim at making exact and reliable predictions but aims at overestimating the potential impact related to the predictions. The overestimation of impacts offers a safety buffer that allows a robust and reliable risk assessment, as the response of the real system (mounding of the water table aquifer in this case) to the mining operations will be contained within the envelope provided by the conservative approach proposed in this study.
- The extent of mounding at the end of operations, the 0.1 m drawdown contours extend no further than 2.0 km from the mined areas. At 100 years post mining, the 0.1 m contour has migrated to a distance comprised within 4.0 km from the mined areas. At 1000 years post-mining the 0.1 m mounding contour is extending about 10 km from the mined areas while the residual mounding beneath the mined area is about 0.5 m.
- The groundwater vertical maximum mounding observed at any point within the model domain during mining operations is 21.4 m. The elevated groundwater levels are calculated to results in a groundwater connection with the base / sides of the mine pits during mining/backfilling operations.
- The forward particle tracking for the model shows particle tracking travels at a distance of 2 km for 10,000 years with the view of the mounding at 1,000 years post mining. Or at an approximate distance of 20 metres for 100 years post mining. The particles move very slowly through the aquifer and do not travel for a great distance from the mine pits.
- EVs (stock watering or ecological) have not been identified within the predicted model mounding or particle tracking plume extent.

- Due to the depth of water table and the aquifer subdued response to rainfall events the aquifer is considered not sensitive to climate change impacts.
- No groundwater receptors have been identified to date in the course of this study, with no known or identified registered water supply stock or domestic bores within 10 kilometres of the project site. Given the sites location and considering the points above future use of groundwater at the site is considered unlikely at this time. If required, any future users will be managed via Administrative Control that aims to make sure any future user is made aware of groundwater chemistry changes within a certain area. The administration controls are reported by VHM to be:
  - Define the area of changed groundwater quality as compared to background, which is provided to the Water Authority in the form of a shapefile and technical document outline the basis or justification for the area.
- Considering the pathways to receptors exist, the hydrogeological controls of COPC from the sources is such that the likelihood of that pathway being realised is low. Therefore, the potential likelihood of impact to groundwater receptors is considered to be low. From a construction, operation and closure perspective, and considering the rehabilitation plan for the site, it is expected that environmental value exposure to potential COPCs will also be low.
- Given the likely geochemical conditions in the Loxton Parilla Sands aquifer there is unlikely to be any long term measurable change to groundwater quality at the site from the deposition of tailings. The greatest water quality impacts are likely to come from wetting up the unsaturated zone. The risk of harm with respect to groundwater has been minimised as far as reasonably practicable through tailings water recovery, groundwater dewatering reducing seepage and surface water diversions.
- The proposed activities will trigger an A18 permit which is required for activities involving releasing of waste into an aquifer. An A18 application will need to be made through the EPA Victoria for permission and approval. The application will need to include a summary of the proposal, characteristics of the waste discharge, characteristics of the aquifer and consideration of risk of harm to human health or the environment.

16. Disclaimer

This document has been prepared for VHM Limited to satisfy the Minister for Planning's Scoping Requirements for the Goschen Mineral Sands Project (the Project) dated May 2019 under the Environment Effects Act 1978. (Sub-consultant Company Name) accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party. Any third party using and/or relying upon this document accepts sole responsibility and all risk for using and/or relying on this document for any purpose. This document is based on the information available, and the assumptions made, as at the date of the document. This document is to be read in full. No excerpts are to be taken as representative of the findings without appropriate context.

If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

17. References

ANZECC and ARMCANZ, 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand. October 2000.

Barnett et al., 2012. Australian groundwater modelling guidelines, Waterlines report, National. Water Commission, Canberra.

Bureau of Meteorology, 2012. National Groundwater Dependent Ecosystems (GDE) Atlas. Bioregional Assessment Source Dataset. Viewed 22 October 2021.

CDM Smith 2018, Goschen Hydrogeological Assessment, 31 May 2018.

CDM Smith 2021, Goschen Detailed Feasibility Study Hydrogeological Assessment, November 2021.

CDM Smith 2022, Goschen Groundwater Monitoring Program, August 2022.

Crosbie RS, McCallum JL & Walker GR., 2009. Dryland diffuse groundwater recharge modelling across the Murray-Darling Basin.

CSIRO, 2015. Stygofauna in Australian Groundwater Systems: Extent of knowledge.

Cook et al 2001. Cook PG, Leaney FW and Jolly ID. 2001. Groundwater recharge in the Mallee Region, and salinity implications for the Murray River – A review. CSIRO: Land and Water Technical Report 45/01, November 2001.

DELWP, 2019. Scoping requirements for Goschen Mineral Sands and Rare Earths Project Environmental Effects Statement.

DELWP, 2020. Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria.

Domenico, P.A. and F.W. Schwartz., 1990. Physical and Chemical Hydrogeology, John Wiley & Sons, New York, 824 p.

EPA Victoria Environment Protection Act 2017.

EPA Victoria Publication 668: Hydrogeological Assessment (groundwater quality) guidelines. 2006.

EPA Victoria Publication 669 Groundwater sampling guidelines. 2022.

Feflow version 7. https://www.mikepoweredbydhi.com/products/feflow.

Geoscience Australia and Australian Stratigraphy Commission, 2017. Australian stratigraphic units database.

GHD, 2022. Avonbank Mineral Sands Project, Environment Effects Statement, Groundwater Impact Assessment Report. December 2022.

Hem, J. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water, Third Edition.

Howe P, 2011. Framework for assessing potential local and cumulative effects of mining on groundwater resources. Prepared for The National Water Commission. Waterlines Report Series No. 59. Canberra, ACT.

Morris, D.A. and A.I. Johnson., 1967. Summary of hydrologic and physical properties of rock and soil materials as analysed by the Hydrologic Laboratory of the U.S. Geological Survey, U.S. Geological Survey 1839-D, 42p.

Pitt & Sherry, 2023. Mine Site Surface Water Impact Assessment. May 2023.

Right Solutions, 2022. Process Material Characterisation Report. November 2022.

Appendix A Monitoring Bore Logs

WELL LOG MW001D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718040 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.02
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.51
DRILLING DATE 11/07/2021 - 13/07/2021	**TOTAL DEPTH** 118 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126431	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Lithological Description	Formation	Field comments	Well Description	Elevation (m AHD)
0 - 1	AIR (8" Drag Bit)		Silty Sand LOAM: Brown/red, slightly weathered, moderately sorted, minor clay (< 15%), trace organic matter	Quat	Pre-collar with air rotary to 3 m bgl	0 - 3 m PN12 PVC DN177mm surface casing	93 - 92
1 - 5	MUD (6" Chevron Drag Bit) (from 3 m)		Sandy CLAY: Red/brown, highly weathered, glossy texture, sand increasing with depth		Switch to mud rotary	0 - 105 m PN18 PVC DN50mm production casing	92 - 88
5 - 7			As above, with increasing quartz rich sand (> 20%)	trans.			88 - 86
7 - 20		0.82 (12 m); 1.12 (18 m)	SAND: Yellow/grey, very coarse grained to gravelly, quartz rich, well sorted, sub-rounded, with interbedded clay (< 20%)	Loxton Parilla Sand		0 - 100 m Bentonite grout	86 - 73

Depth (m): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

Elevation (m AHD): 93, 92, 91, 90, 89, 88, 87, 86, 85, 84, 83, 82, 81, 80, 79, 78, 77, 76, 75, 74

Disclaimer This bore log is intended for environmental not geotechnical purposes.

produced by ESlog.ESdat.net on 05 Aug 2021

WELL LOG MW001D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718040 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.02
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.51
DRILLING DATE 11/07/2021 - 13/07/2021	**TOTAL DEPTH** 118 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126431	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21									72
22									71
23									70
24		1.34		Clayey SAND: Yellow/grey/white, fine to medium grained with minor gravelly sub-rounded quartz (< 5%)					69
25									68
26									67
27									66
28									65
29									64
30	MUD (6" Chevron Drag Bit)	0.97			Loxton Parilla Sand				63
31									62
32									61
33				SAND: Brown/grey/yellow, poorly sorted, well cemented medium to coarse grained sand with high strength, sub-angular ironstone (< 20%) and minor clay (< 10%)					60
34									59
35									58
36		0.73							57
37									56
38									55
39									54

WELL LOG MW001D

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 11/07/2021 - 13/07/2021
LICENCE NO. WRK126431

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 118 m
DIAMETER 6" - 8"

COORDINATES E718040 N6052278
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 93.02
WELL TOC 93.51
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN18 PVC DN50mm
SCREEN PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
41					Loxton Parilla Sand				52
42		0.58		Sandy CLAY: Dark grey/black/yellow, low plasticity, with fine grained sand (< 20 %)	trans.				51
43									50
44				CLAY: Black/dark grey, low to medium plasticity, soft texture, trace silts (< 2%)	Geera Clay				49
45									48
46									47
47									46
48		0.53							45
49									44
50	MUD (6" Chevron Drag Bit)								43
51									42
52									41
53									40
54		0.53							39
55									38
56									37
57									36
58									35
59		0.54							34

WELL LOG MW001D

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 11/07/2021 - 13/07/2021
LICENCE NO. WRK126431

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 118 m
DIAMETER 6" - 8"

COORDINATES E718040 N6052278
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 93.02
WELL TOC 93.51
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN18 PVC DN50mm
SCREEN PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
61									32
62									31
63									30
64									29
65									28
66		0.74							27
67									26
68									25
69									24
70	MUD (6" Chevron Drag Bit)				Geera Clay				23
71									22
72		0.64							21
73									20
74									19
75									18
76									17
77									16
78		0.59							15
79									14

produced by ESlog.ESdat.net on 05 Aug 2021

CDM Smith

WELL LOG MW001D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718040 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.02
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.51
DRILLING DATE 11/07/2021 - 13/07/2021	**TOTAL DEPTH** 118 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126431	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
81					Geera Clay				12
82									11
83									10
84		0.64							9
85									8
86									7
87									6
88									5
89	MUD (6" Chevron Drag Bit)								4
90		0.64		Silty CLAY: Black/dark grey, low plasticity, slimy texture, with silts and fine grained sand (> 10%)	Olney				3
91									2
92									1
93									0
94									-1
95									-2
96									-3
97									-4
98									-5
99				Sandy CLAY: Black/dark grey, low plasticity with coarse grained, sub-rounded sand	trans.				-6

WELL LOG MW001D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718040 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.02
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.51
DRILLING DATE 11/07/2021 - 13/07/2021	**TOTAL DEPTH** 118 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126431	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
	MUD (6" Chevron Drag Bit)				trans.				-7
101								100 - 103 m Bentonite seal (Bentonite pellets)	-8
102		0.55							-9
103				SAND: Black/grey/blue, coarse to very coarse grained, sub-rounded, moderately sorted with minor fine grained laminated shale (< 5%), interbedded clay (< 10%) and silt (> 10%)	Warina Sand				-10
104								103 - 118 m Gravel fill	-11
105								105 - 117 m PN18 PVC DN50mm production casing (slotted)	-12
106									-13
107									-14
108		0.65							-15
109									-16
110									-17
111									-18
112									-19
113									-20
114									-21
115									-22
116								117 - 118 m PN18 PVC DN50mm production casing (sump)	-23
117									-24
118								EOH at 118 m	-25
119									-26
120									-27

produced by ESlog.ESdat.net on 05 Aug 2021

WELL LOG MW001S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718034.6 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.00
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.63
DRILLING DATE 10/07/2021 - 11/07/2021	**TOTAL DEPTH** 45 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126433	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0 - 2	AIR (8" Drag Bit)			Silty Sand LOAM: Brown/red, slightly weathered, well sorted, trace organic matter, clay increasing with depth	Quat	Pre-collar with air rotary to 3 m bgl		0 - 3 m PN12 PVC DN177mm surface casing	
2 - 3				Clayey SAND: Red/brown, highly weathered, moderately sorted				0 - 35 m PN12 PVC DN50mm production casing	
3 - 5	MUD (6" Chevron Drag Bit)			Sandy CLAY: Red/brown, medium plasticity, minor gravels (< 5%)		Switch to mud rotary			
5 - 7				As above, with increasing quartz rich sand (> 30%)	trans.				
7 - 20		0.82 (12 m); 1.09 (18 m)		SAND: Yellow/grey, coarse grained to gravelly, quartz rich, well sorted, well rounded, minor interbedded clay (< 5%)	Loxton Parilla Sand			0 - 31 m Bentonite grout (10 m)	

Depth scale: 1 to 19 m; Elevation scale: 92 to 74 m AHD.

WELL LOG MW001S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718034.6 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.00
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.63
DRILLING DATE 10/07/2021 - 11/07/2021	**TOTAL DEPTH** 45 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126433	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Lithological Description	Formation	Field comments	Well Description	Elevation (m AHD)
21							72
22							71
23							70
24		1.31	Clayey SAND: Yellow/white/grey, fine to medium grained, minor quartz (< 10%)				69
25							68
26							67
27							66
28							65
29							64
30	MUD (6" Chevron Drag Bit)	0.86		Loxton Parilla Sand			63
31						31 - 33 m Bentonite seal (Bentonite pellets)	62
32							61
33			SAND: Brown/grey/yellow, moderately sorted, coarse grained to gravelly sub-rounded quartz (< 10 %), with high strength, sub-angular, coarse grained ironstone			33 - 45 m Gravel fill	60
34							59
35						35 - 41 m PN12 PVC DN50mm production casing (slotted)	58
36		0.64					57
37							56
38							55
39							54
40							53

WELL LOG MW001S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E718034.6 N6052278
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 93.00
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 93.63
DRILLING DATE 10/07/2021 - 11/07/2021	**TOTAL DEPTH** 45 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126433	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
41	MUD (6" Chevron Drag Bit)				Loxton Parilla Sand			41 - 45 m PN12 PVC DN50mm production casing (sump)	52
42		0.58		Clayey SAND: Dark grey/yellow, fine grained, interbedded clay (< 20%), some iron staining present	trans.				51
43									50
44				CLAY: Dark grey/black, slimy texture, low plasticity, with minor sand (< 5%)	Geera Clay				49
45								EOH at 45 m	48
46									47
47									46
48									45
49									44
50									43
51									42
52									41
53									40
54									39
55									38
56									37
57									36
58									35
59									34
60									33

WELL LOG MW002

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E721066.4 N6052192
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 111.68
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 112.32
DRILLING DATE 5/07/2021 - 7/07/2021	**TOTAL DEPTH** 75 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126432	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0–3	AIR (8" Drag Bit)			Sandy CLAY: Red/brown/yellow, very fine grained sand, slightly calcareous	Quat	Pre-collar with air rotary to 3 m bgl		0 - 3 m PN12 PVC DN177mm surface casing	
3–5	MUD (6" Chevron Drag Bit)			As above, with increasing quartz rich sand (> 10%)	trans.	Switch to mud rotary		0 - 47 m PN12 PVC DN50mm production casing	
5–		1.20 (12 m); 0.99 (18 m)		SAND: Grey/yellow, very coarse grained to gravelly, quartz rich, well sorted, sub-rounded to rounded	Loxton Parilla Sand			0 - 43 m Bentonite grout (at 10 m)	

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

Elevation scale: 111, 110, 109, 108, 107, 106, 105, 104, 103, 102, 101, 100, 99, 98, 97, 96, 95, 94, 93, 92

WELL LOG MW002

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E721066.4 N6052192
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 111.68
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 112.32
DRILLING DATE 5/07/2021 - 7/07/2021	**TOTAL DEPTH** 75 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126432	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21–25	MUD (6" Chevron Drag Bit)	0.97 (24)		SAND: Grey/yellow, fine to medium grained with minor interbedded clay (< 10%) and gravelly quartz (< 5%)	Loxton Parilla Sand				91–87
25–40		1.19 (30); 1.00 (36)		Clayey SAND: Red/yellow/grey, very fine grained, clay interbeds (< 15%)					86–72

Depth scale: 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

Elevation scale: 91, 90, 89, 88, 87, 86, 85, 84, 83, 82, 81, 80, 79, 78, 77, 76, 75, 74, 73, 72

WELL LOG MW002

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E721066.4 N6052192
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 111.68
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 112.32
DRILLING DATE 5/07/2021 - 7/07/2021	**TOTAL DEPTH** 75 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126432	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Lithological Description	Formation	Field comments	Well Description
40 - 54	MUD (6" Chevron Drag Bit)	1.09 (at 42); 0.14 (at 48)	SAND: Grey/yellow, very coarse grained to gravelly, moderately sorted, with interbedded high strength, well cemented coarse grained ironstone and minor quartz (< 10%), iron staining prominent at 44 and 46 m bgl	Loxton Parilla Sand	Iron staining in samples Hard ground at 44 and 46 m bgl (high strength ironstone). Slow ROP	43 - 45m Bentonite seal (Bentonite pellets) 45 - 55 m Gravel fill 47 - 53 m PN12 PVC DN50mm production casing (slotted) 53 - 55 m PN12 PVC DN50mm production casing (sump)
54 - 57		0.72 (at 54)	Sandy CLAY: Dark grey/yellow, slimy texture, medium plasticity, with minor gravels (< 5%)	trans.		55 - 60 m Bentonite seal (Bentonite pellets)
57 - 60		0.43 (at 59.5)	CLAY: Black/dark grey, low plasticity, sticky/slimy texture	Geera Clay		

Depth (m): 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60

Elevation (m AHD): 71, 70, 69, 68, 67, 66, 65, 64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52

produced by ESlog.ESdat.net on 05 Aug 2021

WELL LOG MW002

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E721066.4 N6052192
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 111.68
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 112.32
DRILLING DATE 5/07/2021 - 7/07/2021	**TOTAL DEPTH** 75 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126432	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
60 - 75	MUD (6" Chevron Drag Bit)				Geera Clay			60 - 75 m Blue Steel gravel backfill	
66		0.80							
72		0.65							
75		0.86						EOH at 75 m	

CDM Smith

WELL LOG MW005

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E728794.6 N6053398
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 85.86
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 86.40
DRILLING DATE 9/07/2021 - 10/07/2021	**TOTAL DEPTH** 58 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126436	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
	AIR (8" Drag Bit)			LOAM: Brown, medium grained clayey sand, trace organic matter	Quat	Pre-collar with air rotary to 3 m bgl		0 - 3 m PN12 PVC DN177mm surface casing	
1				Sandy CLAY: Brown/red, high plasticity, slightly calcareous, with fine to medium grained sand and trace quartz (< 2%)					85
2								0 - 42 m PN12 PVC DN50mm production casing	84
3	MUD (6" Chevron Drag Bit)					Switch to mud rotary			83
4									82
5									81
6									80
7				SAND: Yellow/grey, coarse grained, quartz rich sand, well sorted, well rounded, with minor interbedded clay (< 5%)	Loxton Parilla Sand				79
8									78
9									77
10								0 - 38 m Bentonite grout	76
11									75
12		0.60							74
13									73
14									72
15									71
16									70
17									69
18		0.83							68
19									67
				Clayey SAND: Yellow/grey, fine grained, poorly sorted with sub-rounded gravelly quartz					66

WELL LOG MW005

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E728794.6 N6053398
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 85.86
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 86.40
DRILLING DATE 9/07/2021 - 10/07/2021	**TOTAL DEPTH** 58 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126436	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21									65
22									64
23									63
24		0.98							62
25				SAND: Yellow/grey, coarse grained, poorly sorted well cemented sands, quartz (< 10%)					61
26									60
27									59
28									58
29									57
30	MUD (6" Chevron Drag Bit)	1.08			Loxton Parilla Sand				56
31									55
32									54
33									53
34									52
35									51
36		1.17							50
37									49
38								38 - 40 m Bentonite seal (Bentonite pellets)	48
39									47
40									46

WELL LOG MW005

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E728794.6 N6053398
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 85.86
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 86.40
DRILLING DATE 9/07/2021 - 10/07/2021	**TOTAL DEPTH** 58 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126436	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Lithological Description	Formation	Field comments	Well Description
40 - 42	MUD (6" Chevron Drag Bit)	0.55		Loxton Parilla Sand	Hard ground at 42 m bgl, iron staining present. Slow ROP	40 - 58 m Gravel fill
42 - 52		0.72	SAND: Yellow/grey/black, coarse grained, well sorted, with very coarse grained to gravelly sub-angular quartz and high strength, brown/red ironstone (> 20 %)			42 - 54 m PN12 PVC DN50mm production casing (slotted)
52 - 55		1.09	SAND: Yellow, fine grained, minor clay (< 10%)			54 - 58 m PN12 PVC DN50mm production casing (sump)
55 - 56			Sandy CLAY: Dark grey/yellow, low plasticity, fine grained sand	trans.		
56 - 58			CLAY: Dark grey/black, soft/sticky texture, low plasticity, with minor fine grained yellow sand (< 5%)	Geera Clay		EOH at 58 m

Depth (m): 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60

Elevation (m AHD): 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26

WELL LOG MW006D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.6 N6059691
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.81
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.43
DRILLING DATE 29/06/2021 - 4/07/2021	**TOTAL DEPTH** 120 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126439	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0	AIR (8" Drag Bit)			Clayey SAND: Red/brown, fine to medium grained, moderately sorted, slightly calcareous, highly weathered	Quat	Pre-collar with air rotary to 3 m bgl		0 - 3 m PN12 PVC DN177mm surface casing	88
1				Sandy CLAY: Brown, fine to medium grained sand, firm texture, slightly calcareous, sand increasing with depth					87
2								0 - 107 m PN18 PVC DN50mm production casing	86
3	MUD (6" Chevron Drag Bit)					Switch to mud rotary			85
4									84
5									83
6									82
7									81
8									80
9				SAND: Light grey/yellow, coarse to very coarse grained quartz rich sand, well rounded, well sorted with minor interbedded clay (< 5%)	Loxton Parilla Sand				79
10									78
11									77
12		0.54							76
13									75
14									74
15								0 - 101 m Bentonite grout	73
16									72
17									71
18		0.58							70
19									69

WELL LOG MW006D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.6 N6059691
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.81
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.43
DRILLING DATE 29/06/2021 - 4/07/2021	**TOTAL DEPTH** 120 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126439	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21									68
22									67
23									66
24		0.58							65
25									64
26									63
27									62
28				SAND: Yellow/grey, coarse grained, well cemented sands, poorly sorted, with sub-angular gravels, iron staining more prominent with depth, trace quartz (< 2%)					61
29									60
30	MUD (6" Chevron Drag Bit)	0.54			Loxton Parilla Sand				59
31									58
32									57
33									56
34									55
35									54
36									53
37									52
38									51
39									50
40									49

WELL LOG MW006D

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 29/06/2021 - 4/07/2021
LICENCE NO. WRK126439

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 120 m
DIAMETER 6" - 8"

COORDINATES E720383.6 N6059691
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 88.81
WELL TOC 89.43
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN18 PVC DN50mm
SCREEN PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
41					Loxton Parilla Sand				48
42		0.66							47
43									46
44									45
45									44
46				As above, with increased dark grey/black clay (> 20%), low plasticity	trans.				43
47									42
48		0.65		CLAY: Black/dark grey, sticky/soft texture, low to medium plasticity, with minor mottled yellow fine grained sand (< 5%)	Geera Clay				41
49	MUD (6" Chevron Drag Bit)								40
50									39
51									38
52									37
53									36
54		0.46							35
55									34
56									33
57									32
58									31
59		0.48							30
60									29

WELL LOG MW006D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.6 N6059691
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.81
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.43
DRILLING DATE 29/06/2021 - 4/07/2021	**TOTAL DEPTH** 120 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126439	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
61									28
62									27
63									26
64									25
65									24
66		0.50							23
67									22
68									21
69									20
70	MUD (6" Chevron Drag Bit)				Geera Clay				19
71									18
72									17
73									16
74									15
75									14
76									13
77									12
78		0.50							11
79									10
80									9

CDM Smith

WELL LOG MW006D

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 29/06/2021 - 4/07/2021
LICENCE NO. WRK126439

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 120 m
DIAMETER 6" - 8"

COORDINATES E720383.6 N6059691
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 88.81
WELL TOC 89.43
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN18 PVC DN50mm
SCREEN PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
81				Silty CLAY: Dark grey/black, soft/slimy texture, low plasticity, moist, with fine grained sand (< 10%) and sub-angular gravels increasing with depth					8
82									7
83									6
84		0.50							5
85									4
86						Hard ground at 86 m bgl, slow ROP, swelling clays			3
87									2
88									1
89									0
90	MUD (6" Chevron Drag Bit)	0.39			Olney				-1
91									-2
92									-3
93									-4
94									-5
95									-6
96									-7
97									-8
98									-9
99									-10
100									-11

WELL LOG MW006D

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.6 N6059691
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.81
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.43
DRILLING DATE 29/06/2021 - 4/07/2021	**TOTAL DEPTH** 120 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126439	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN18 PVC DN50mm	**SCREEN** PN18 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
101					Olney			101 - 104 m Bentonite seal (Bentonite pellets)	-12
102									-13
103				As above, with increased gravelly sand (> 20 %)	trans.				-14
104								104 - 120 m Gravel fill	-15
105				SAND: Dark grey/blue/green, very coarse grained to gravelly, moderately sorted, with interbedded clay and silt (< 10%), quartz (< 10%) and sequences of green/grey, fine grained laminated shale	Warina Sand				-16
106									-17
107								107 - 119 m PN18 PVC DN50mm production casing (slotted)	-18
108									-19
109	MUD (6" Chevron Drag Bit)								-20
110									-21
111									-22
112									-23
113									-24
114									-25
115									-26
116									-27
117									-28
118								119 - 120 m PN18 PVC DN50mm production casing (sump)	-29
119								EOH at 120 m	-30
120									-31

WELL LOG MW006S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.9 N6059699
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.76
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.29
DRILLING DATE 1/07/2021 - 2/07/2021	**TOTAL DEPTH** 49 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126440	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0 - 1	AIR (8" Drag Bit)			Clayey SAND: Red/brown, fine to medium grained, moderately sorted, trace organic matter	Quat	Pre-collar with air rotary to 3 m bgl		0 - 3 m PN12 PVC DN177mm surface casing	88
1 - 7				Sandy CLAY: Red/brown, firm texture, slightly calcareous with fine to medium grained sand					87, 86, 85, 84, 83, 82
3	MUD (6" Chevron Drag Bit)					Switch to mud rotary		0 - 40 m PN12 PVC DN50mm production casing	
7 - 19		0.93 (12 m); 0.96 (18 m)		SAND: Yellow/grey, very coarse grained to gravelly quartz rich sand, well rounded, well sorted, unconsolidated with minor interbedded clay (< 5%)	Loxton Parilla Sand			0 - 34 m Bentonite grout	81, 80, 79, 78, 77, 76, 75, 74, 73, 72, 71, 70, 69

WELL LOG MW006S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.9 N6059699
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.76
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.29
DRILLING DATE 1/07/2021 - 2/07/2021	**TOTAL DEPTH** 49 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126440	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21									68
22									67
23									66
24		0.94							65
25									64
26									63
27									62
28									61
29	MUD (6" Chevron Drag Bit)								60
30		1.00			Loxton Parilla Sand				59
31									58
32				SAND: Grey/yellow/red, medium grained, interbedded clay (< 10%), iron staining more prominent with depth					57
33									56
34									55
35								34 - 37 m Bentonite seal (Bentonite pellets)	54
36		1.10							53
37									52
38								37 - 49 m Gravel fill	51
39									50
40									49

WELL LOG MW006S

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E720383.9 N6059699
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 88.76
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 89.29
DRILLING DATE 1/07/2021 - 2/07/2021	**TOTAL DEPTH** 49 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126440	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
40–47	MUD (6" Chevron Drag Bit)	1.12			Loxton Parilla Sand			40 - 46 m PN12 PVC DN50mm production casing (slotted)	
47–48		0.98		Clayey SAND: Red/grey/yellow, fine grained, with minor sub-angular high strength ironstone and clay (< 20%)	trans.			46 - 49 m PN12 PVC DN50mm production casing (sump)	
48–49				Sandy CLAY: Black/grey, medium plasticity, with minor fine grained sand (< 10%)	Geera Clay			EOH at 49 m	

Depth scale (m): 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60

Elevation scale (m AHD): 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29

WELL LOG MW007

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E723887.8 N6058434
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 108.40
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 108.95
DRILLING DATE 7/07/2021 - 9/07/2021	**TOTAL DEPTH** 78 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126437	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0 – 3	AIR (8" Drag Bit)			Sandy CLAY: Brown/grey, fine to medium grained sand, sticky texture, medium plasticity, sand increasing with depth	Quat	Pre-collar with air rotary to 3 m bgl		0 - 5 m PN12 PVC DN177mm surface casing	108 – 105
3 – 8	MUD (6" Chevron Drag Bit)					Switch to mud rotary		0 - 38 m PN12 PVC DN50mm production casing	105 – 100
8 – 10				Clayey SAND: Yellow/grey, fine to medium grained, minor quartz (< 5%)	trans.				100 – 98
10 – 20		0.63 (at 18 m)		SAND: Grey/red/yellow, coarse to very coarse grained quartz rich sand, well rounded, well sorted	Loxton Parilla Sand	No water/cuttings returns. Clay swelling and blocking hole. Condition hole		0 - 33 m Bentonite grout	98 – 88

WELL LOG MW007

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E723887.8 N6058434
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 108.40
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 108.95
DRILLING DATE 7/07/2021 - 9/07/2021	**TOTAL DEPTH** 78 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126437	**DIAMETER** 6" - 8"	**CHECKED BY**

COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21									88
22				SAND: Yellow/grey, very coarse to gravelly quartz rich sand, sub-rounded, moderately sorted, minor interbedded clay (< 5%)					87
23									86
24		0.83							85
25									84
26						Mud seeping to surface, pull of out hole. Remove pre-collar, add 5 m of surface casing			83
27									82
28									81
29	MUD (6" Chevron Drag Bit)				Loxton Parilla Sand				80
30		0.98		SAND: Yellow/grey, fine grained, minor clay (< 10%), unconsolidated, weakly cemented					79
31									78
32									77
33								33 - 36 m Bentonite seal (Bentonite pellets)	76
34									75
35									74
36		0.99						36 - 54 m Gravel fill	73
37									72
38								38 - 44 m PN12 PVC DN50mm production casing (slotted)	71
39									70
40									69

CDM Smith

WELL LOG MW007

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 7/07/2021 - 9/07/2021
LICENCE NO. WRK126437

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 78 m
DIAMETER 6" - 8"

COORDINATES E723887.8 N6058434
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 108.40
WELL TOC 108.95
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN12 PVC DN50mm
SCREEN PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
41–44	MUD (6" Chevron Drag Bit)	1.10		SAND: Yellow/grey, very coarse grained, moderately cemented sands, moderately sorted with minor gravelly angular ironstone and quartz (< 5%)	Loxton Parilla Sand				68–65
44–49		0.81		Clayey SAND: Yellow/grey, very fine grained, interbedded clay (< 15%)		Slow ROP. Iron staining present, hard band of ironstone at 49 m bgl.		44 - 52 m PN12 PVC DN50mm production casing (sump)	64–60
49–52				SAND: Grey/yellow, coarse grained with high strength, very coarse to gravelly angular ironstone					59–57
52–59		0.26		Sandy CLAY: Black/grey/yellow, low plasticity, very fine grained sand	trans.			52 - 58 m Bentonite seal (Bentonite pellets)	56–50
59–60		0.72		CLAY: Dark grey/black, low plasticity, moist, sticky/slimy texture	Geera Clay			58 - 78 m Blue Steel gravel backfill	49

WELL LOG MW007

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E723887.8 N6058434
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 108.40
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 108.95
DRILLING DATE 7/07/2021 - 9/07/2021	**TOTAL DEPTH** 78 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126437	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
	MUD (6" Chevron Drag Bit)				Geera Clay				48
61									47
62									46
63									45
64									44
65									43
66									42
67									41
68									40
69									39
70									38
71									37
72		1.08							36
73									35
74									34
75									33
76									32
77									31
78								EOH at 78 m	30
79									29
80									

WELL LOG MW008

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 4/07/2021 - 5/07/2021
LICENCE NO. WRK126438

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 58 m
DIAMETER 6" - 8"

COORDINATES E722486.5 N6060703
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 103.04
WELL TOC 103.57
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN12 PVC DN50mm
SCREEN PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
0–3	AIR (8" Drag Bit)			Sandy CLAY: Red/brown, slightly calcareous, with minor fine to medium grained sand	Quat	Pre-collar with air rotary to 3 m bgl Switch to mud rotary		0 - 3 m PN12 PVC DN177mm surface casing 0 - 48 m PN12 PVC DN50mm production casing	103–100
3–5	MUD (6" Chevron Drag Bit)			Sandy CLAY: Red/brown/yellow, increasing fine grained sand (> 15%)	trans.				100–98
5–15		0.93		SAND: Yellow/grey, medium to coarse grained well cemented sands, poor sorted, sub-angular grains, trace quartz (< 2%)	Loxton Parilla Sand			0 - 44 m Bentonite grout	98–88
15–20		0.72		SAND: Light grey/yellow, coarse to very coarse grained quartz rich sand, moderately sorted, sub-rounded grains, minor interbedded clay (< 10%)					88–83

WELL LOG MW008

PROJECT NUMBER 10001043
PROJECT NAME Goschen Drilling Program
LOCATION Goschen, VIC
CLIENT VHM Limited
DRILLING DATE 4/07/2021 - 5/07/2021
LICENCE NO. WRK126438

DRILLING COMPANY Watson Drilling
DRILLER Ken Adams
DRILL RIG L700THD
DRILLING METHOD Mud Rotary
TOTAL DEPTH 58 m
DIAMETER 6" - 8"

COORDINATES E722486.5 N6060703
COORD SYS GDA94 MGA Zone 54
SURFACE ELEVATION 103.04
WELL TOC 103.57
LOGGED BY Zlatko Eterovic
CHECKED BY

COMPLETION
CASING PN12 PVC DN50mm
SCREEN PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
21–24	MUD (6" Chevron Drag Bit)	0.75 (at 24)			Loxton Parilla Sand				82–79
24–36		0.59 (at 30)		Silty SAND: Red/grey/yellow, fine grained with minor interbedded clay (< 5%)					79–67
36–40		0.70 (at 36)		SAND: Yellow/grey, coarse grained well cemented sands, moderately sorted, with gravelly to pebble sized high strength ironstone					67–63

WELL LOG MW008

PROJECT NUMBER 10001043	**DRILLING COMPANY** Watson Drilling	**COORDINATES** E722486.5 N6060703
PROJECT NAME Goschen Drilling Program	**DRILLER** Ken Adams	**COORD SYS** GDA94 MGA Zone 54
LOCATION Goschen, VIC	**DRILL RIG** L700THD	**SURFACE ELEVATION** 103.04
CLIENT VHM Limited	**DRILLING METHOD** Mud Rotary	**WELL TOC** 103.57
DRILLING DATE 4/07/2021 - 5/07/2021	**TOTAL DEPTH** 58 m	**LOGGED BY** Zlatko Eterovic
LICENCE NO. WRK126438	**DIAMETER** 6" - 8"	**CHECKED BY**
COMPLETION	**CASING** PN12 PVC DN50mm	**SCREEN** PN12 PVC DN50mm Slotted

COMMENTS

Depth (m)	Drilling Method	Penetration Rate (m/min)	Graphic Log	Lithological Description	Formation	Field comments	Well Installation	Well Description	Elevation (m AHD)
41	MUD (6" Chevron Drag Bit)				Loxton Parilla Sand				62
42		0.39				Hard ground at 42 m bgl, iron staining present. Slow ROP			61
43									60
44									59
45								44 - 46 m Bentonite seal (Bentonite pellets)	58
46									57
47				Clayey SAND: Red/grey, fine grained, some iron staining present (< 2%)				46 - 58 m Gravel fill	56
48		0.63						48 - 54 m PN12 PVC DN50mm production casing (slotted)	55
49				SAND: Grey/brown/yellow, coarse grained well cemented sands, moderately sorted, with high strength ironstrone and minor quartz (< 5%)					54
50									53
51									52
52									51
53									50
54		0.60		Sandy CLAY: Dark grey/yellow, low plasticity, fine grained sand (< 20%)	trans.				49
55								54 - 58 m PN12 PVC DN50mm production casing (sump)	48
56									47
57				CLAY: Black/dark grey, soft/sticky texture, low plasticity, minor mottled fine grained sand (< 5%)	Geera Clay				46
58		0.67						EOH at 58 m	45
59									44

Appendix B Slug Test Methods and Results

Procedure Summary

Table 1 Aquifer Hydraulic Testing (Slug Test) Procedure – General Requirements

Theme	Details
Guidelines	Slug tests will be undertaken in accordance with: ▪ Australian Standard AS 2368-1990 Test pumping of water wells, Section 6. This procedure is based on the Australian Standard and further details are provided in the publication.
Equipment and Instrumentation	▪ Dip meter. ▪ Solid "slug" of appropriate (and known) diameter and length – for a 50 mm well a 40 mm slug is appropriate ▪ Data logger to record high frequency water level data
Calibration	Equipment should be calibrated at intervals set by the manufacturer prior by the equipment supplier. Calibration records should be maintained.
Record Keeping	▪ Daily Field Record and health and safety documentation (HASP, JSA). ▪ Calibration records (from equipment supplier). ▪ Slug test field record (including data logger details).

General Information

- A slug test is conducted by instantaneously removing or introducing a known volume of water into a well.
- The resulting recovery, either rise or fall, of the water level in the well is then monitored, and the data analysed by one of several methods to determine the hydraulic conductivity.
- Slug tests will give an order of magnitude of aquifer hydraulic conductivity.
- A solid object that displaces a known volume of water should be used as best practice, rather than actually dealing with a volume of water. This solid object or slug, may be steel casing or sand filled PVC casing or solid acetate (PFAS free).
- Using a solid slug both falling-head and rising-head tests can be completed.
- The thickness of the tested water bearing zone, bore construction details and whether a well is fully or partially penetrating should be known.
- There is a need to consider problems encountered with wells in which the well screen crosses the water table – this can be accounted for during analysis.
- The slug must be of sufficient size to create at least 300mm of drawdown or recovery as the slug displacement device is added to or removed from the well.

Slug Testing

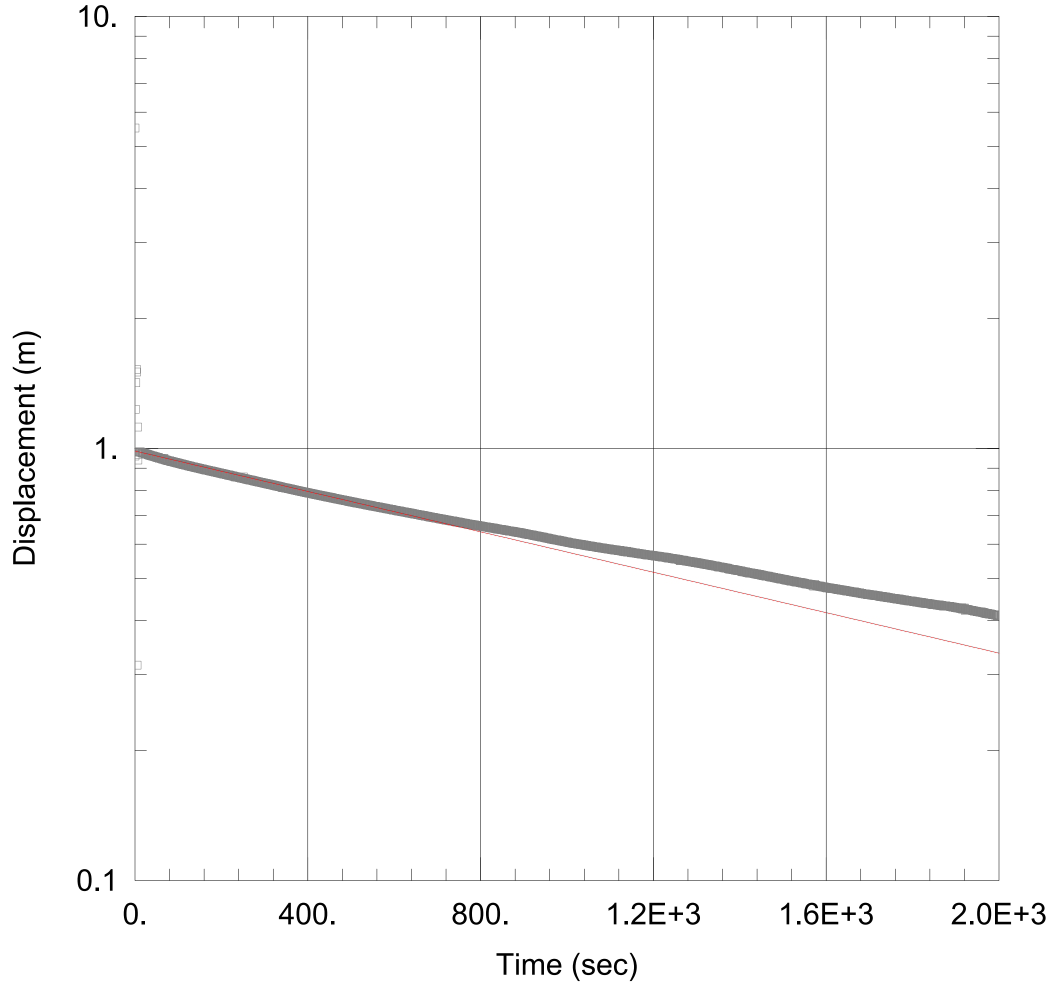
Slug test data will be undertaken in accordance with the following methodology:

- Measure static water level prior to adding the slug and transducer, measure base of bore and check against construction records.

- Draw a diagram to show ideal placement of transducer and slug (to ensure slug is fully submerged below the water in the well).
- Set the transducer to record every second, add the transducer to the well and allow water levels to recover.
- Measure out the wire for the slug and secure loose end at the desired length to ensure when dropped the slug does not hit the transducer.
- Lower the slug displacement device into the well (completely submerging the device) and measure water levels as water level recovers to standing water level – this is the Falling Head Test (FHT).
- Once static water level has been achieved, remove the slug displacement device as quickly as possible and measure water levels as water level recovers to standing water level – this is the Rising Head Test (RHT).
- Water levels should recover to 100% after the FHT before beginning an RHT. If recovery from a FHT takes longer than 1 hour, the FHT can be terminated and no RHT undertaken.
- Sometimes the logger wire will get tangled in the slug wire and be displaced during a Rising Head Test – untangle the wire as quickly as possible and replace transducer into well.
- Decontaminate all down well equipment by washing in tap water with Decon (or Liquinox where sampling for PFAS) and rinsing in potable water followed by deionised water.
- Be sure to note the slug displacement device dimensions.

Analysis

- Data output should be as elapsed time and displacement.
- Analysis should be undertaken by a suitably experienced person (e.g. a hydrogeologist).



WELL TEST ANALYSIS

Data Set: \...\MW001d FHT.aqt
Date: 02/08/22 Time: 16:05:02

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

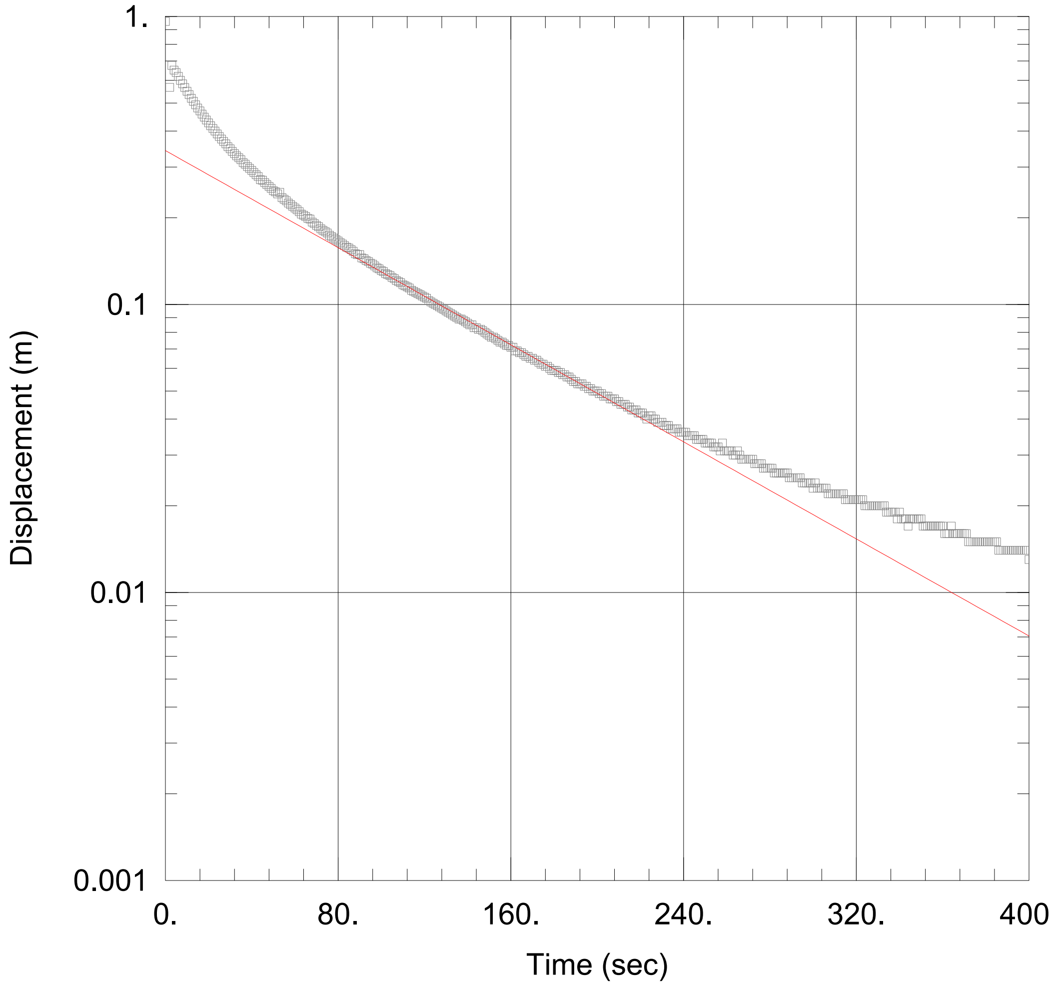
WELL DATA (MW001d)

Initial Displacement: 0.96 m Static Water Column Height: 88.33 m
Total Well Penetration Depth: 87.33 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.006251 m/day y0 = 0.9867 m



WELL TEST ANALYSIS

Data Set: \...\MW001s FHT.aqt
Date: 02/08/22 Time: 16:05:08

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

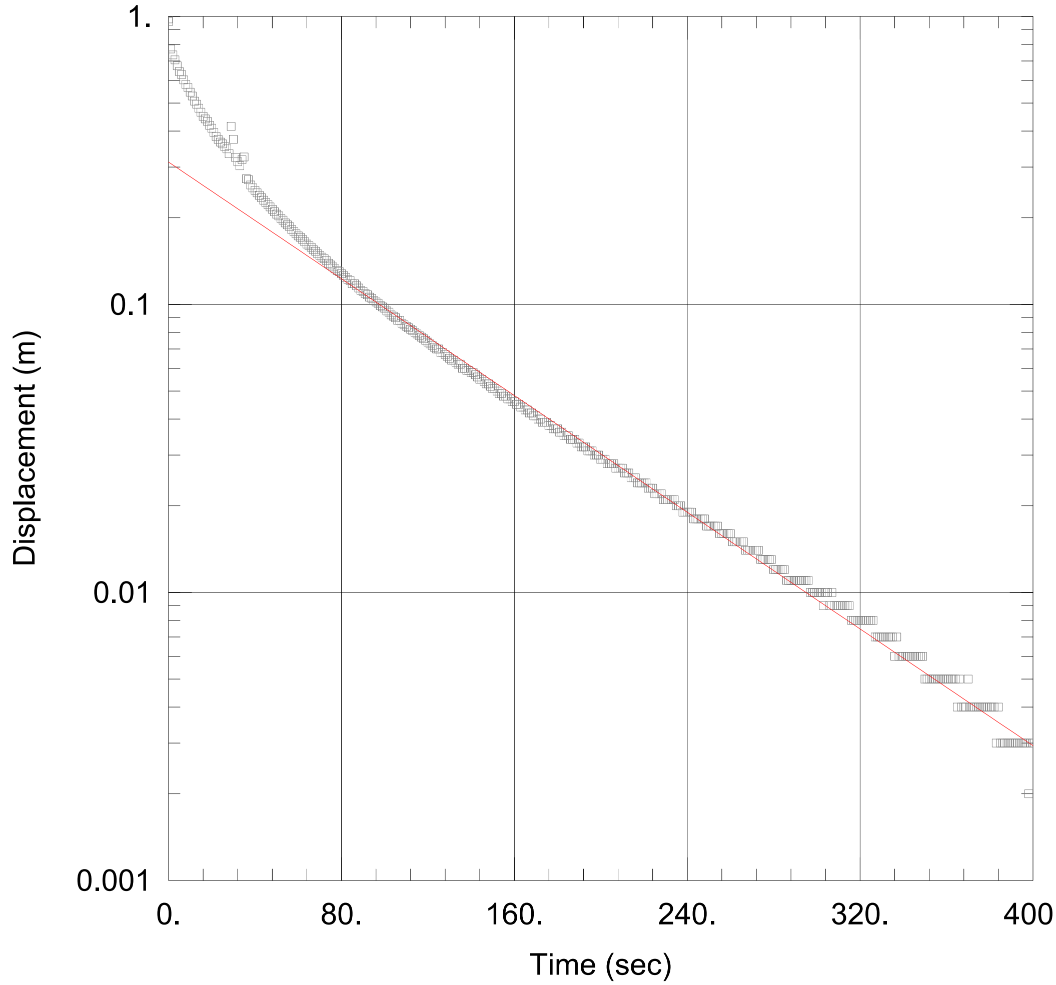
Saturated Thickness: 12.85 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW001s)

Initial Displacement: 0.96 m Static Water Column Height: 13.85 m
Total Well Penetration Depth: 9.845 m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 0.1432 m/day y0 = 0.3421 m



WELL TEST ANALYSIS

Data Set: \...\MW001s RHT.aqt
Date: 02/08/22
Time: 16:05:13

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

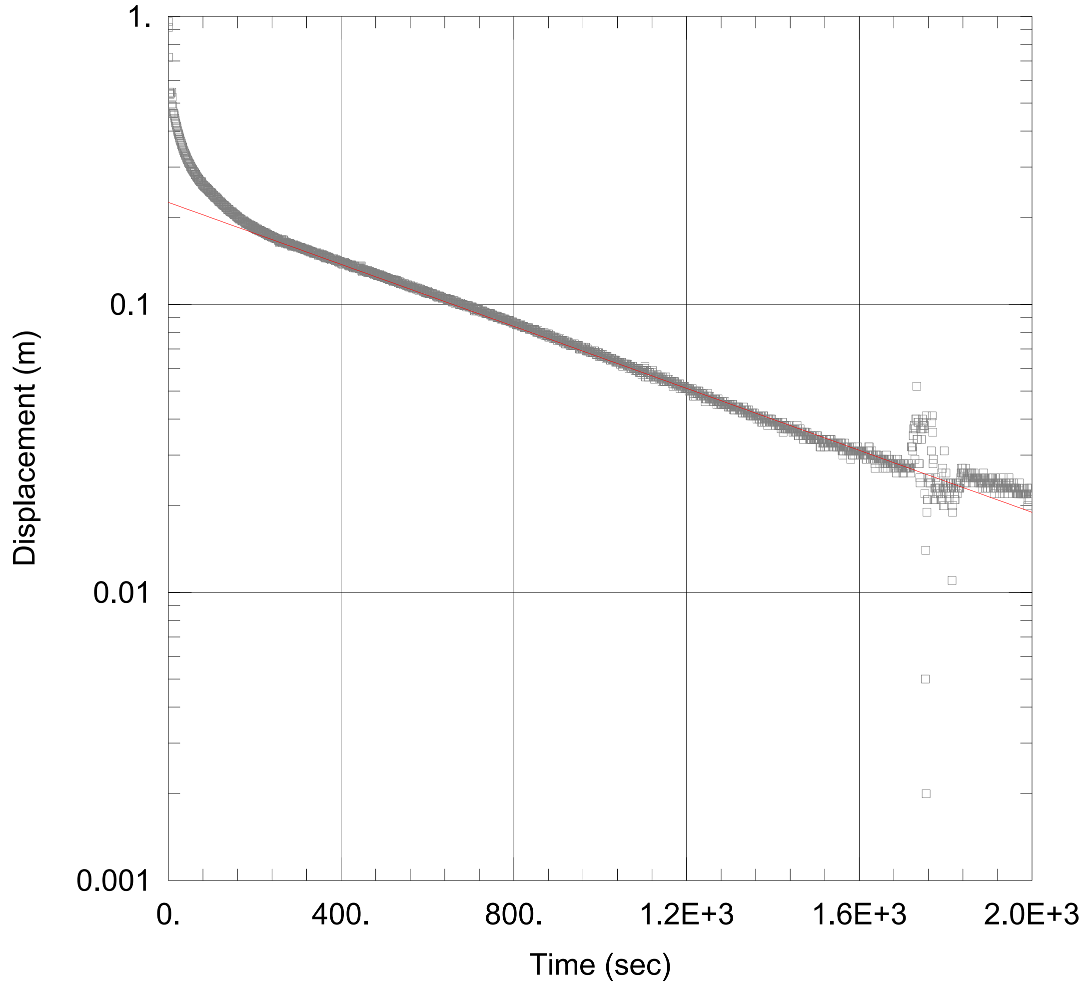
Saturated Thickness: 12.85 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW001s)

Initial Displacement: 0.96 m
Static Water Column Height: 13.85 m
Total Well Penetration Depth: 9.845 m
Screen Length: 6. m
Casing Radius: 0.025 m
Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.1722 m/day
y0 = 0.312 m



WELL TEST ANALYSIS

Data Set: \...\MW002 FHT.aqt
Date: 02/08/22 Time: 16:05:19

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 6.32 m Anisotropy Ratio (Kz/Kr): 1.

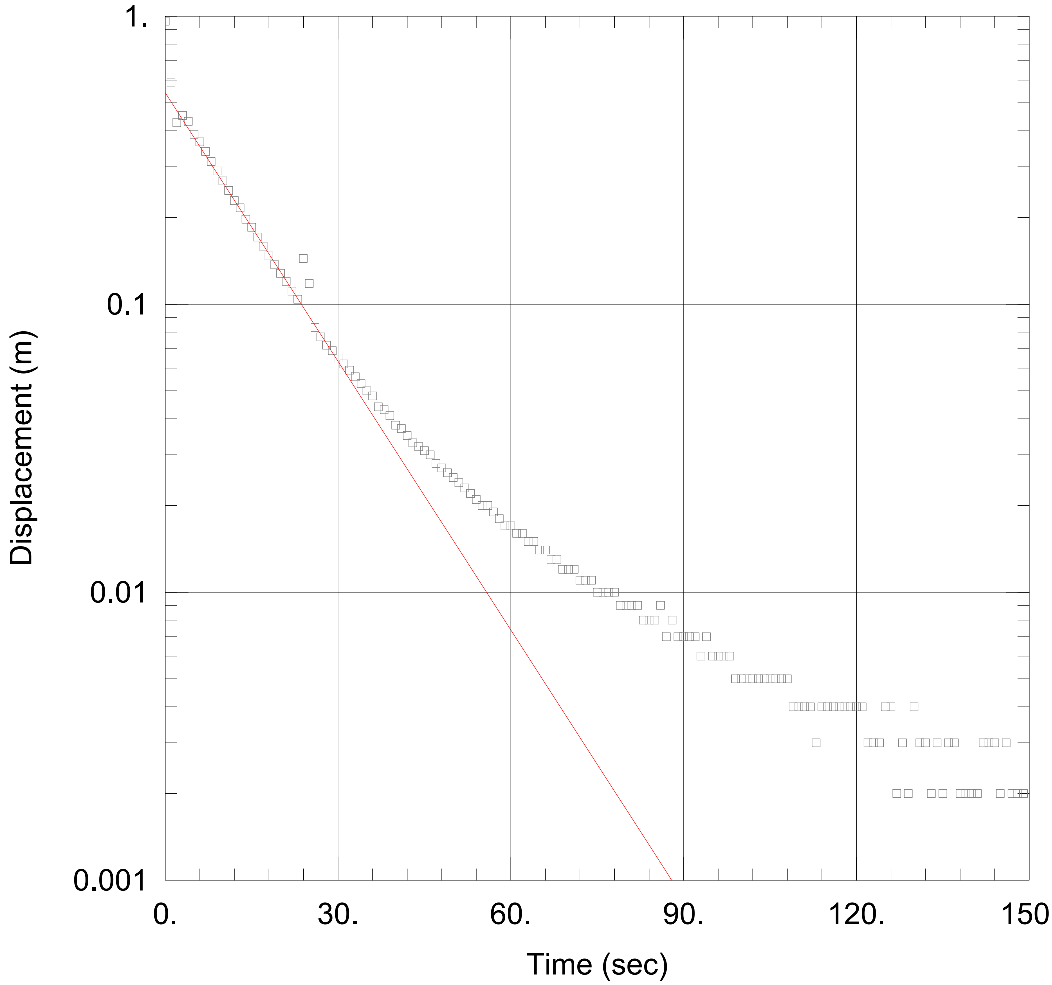
WELL DATA (MW002)

Initial Displacement: 0.96 m Static Water Column Height: 7.32 m
Total Well Penetration Depth: 5.32 m Screen Length: 5.32 m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.01888 m/day y0 = 0.226 m



WELL TEST ANALYSIS

Data Set: \...\MW005 FHT.aqt
Date: 02/08/22 Time: 16:05:23

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 36.62 m Anisotropy Ratio (Kz/Kr): 1.

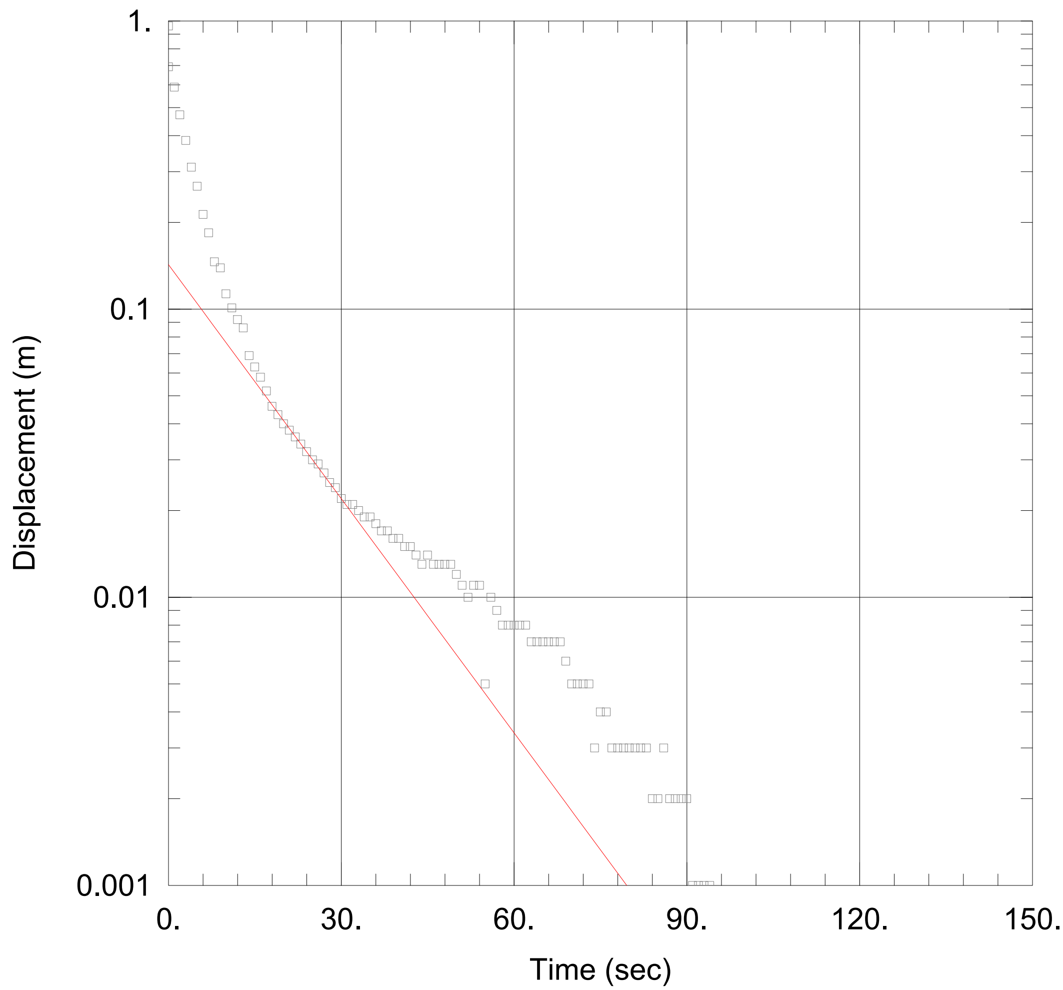
WELL DATA (MW005)

Initial Displacement: 0.96 m Static Water Column Height: 38.62 m
Total Well Penetration Depth: 34.62 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.6854 m/day y0 = 0.5422 m



WELL TEST ANALYSIS

Data Set: \...\MW005 RHT.aqt
Date: 02/08/22 Time: 16:05:34

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 36.62 m Anisotropy Ratio (Kz/Kr): 1.

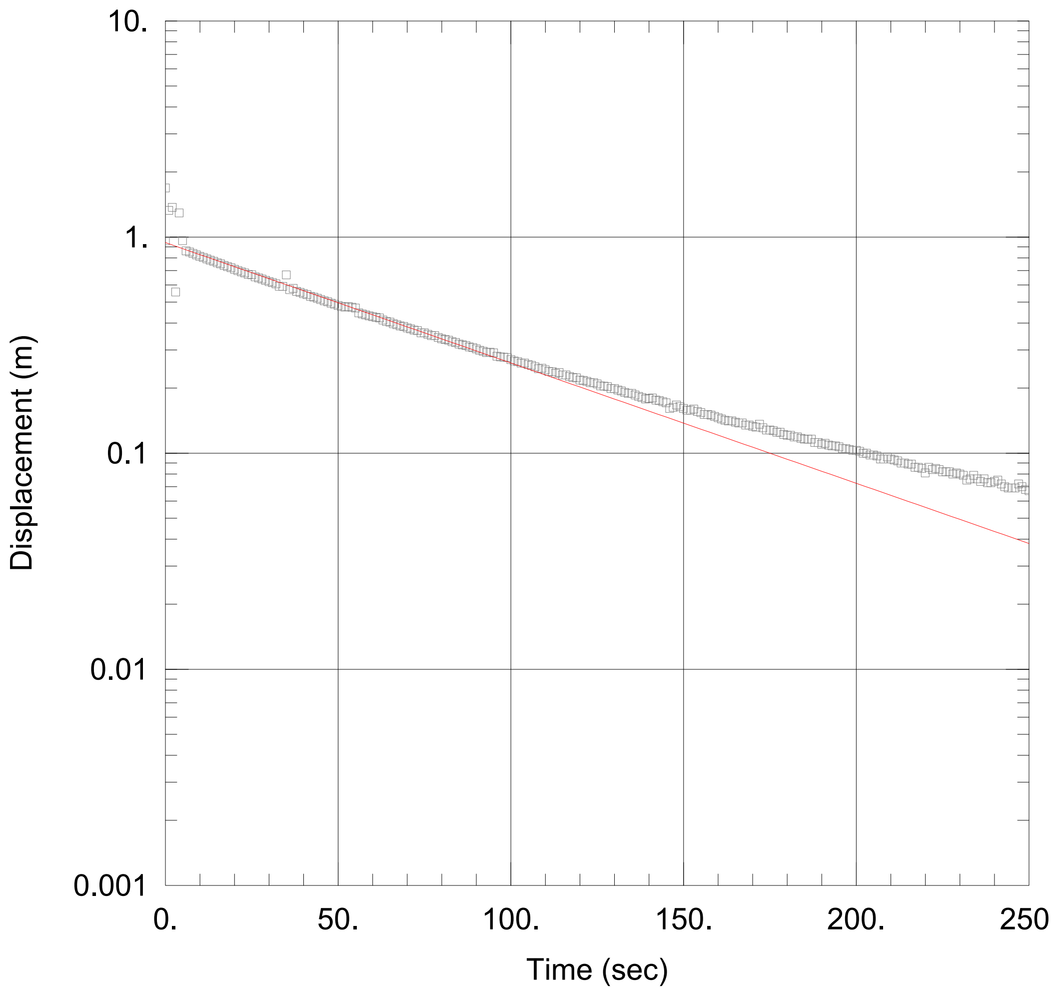
WELL DATA (MW005)

Initial Displacement: 0.96 m Static Water Column Height: 38.62 m
Total Well Penetration Depth: 34.62 m Screen Length: 12. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.597 m/day y0 = 0.1426 m



WELL TEST ANALYSIS

Data Set: \...\MW006d FHT.aqt
Date: 02/08/22 Time: 16:05:39

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

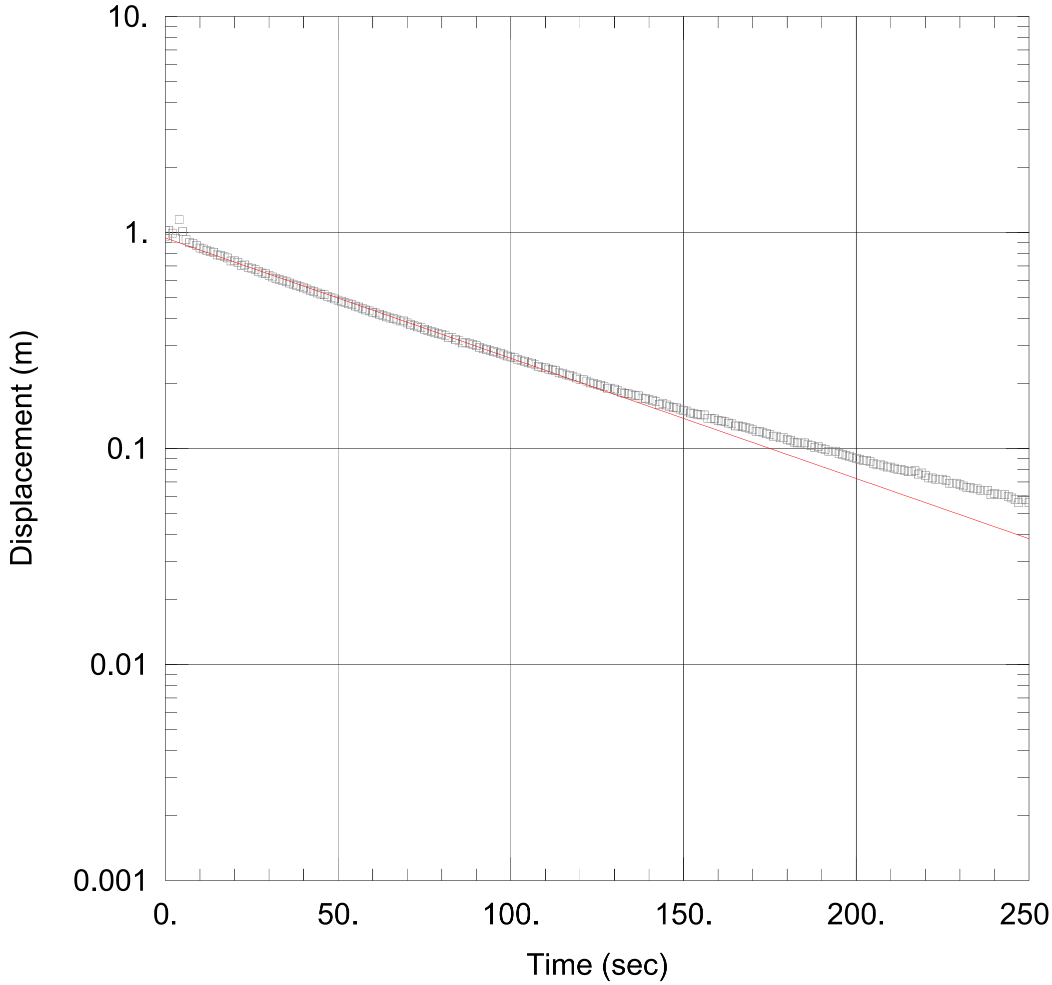
WELL DATA (MW006d)

Initial Displacement: 0.96 m
Total Well Penetration Depth: 93.5 m
Casing Radius: 0.025 m
Static Water Column Height: 94.5 m
Screen Length: 12. m
Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.15 m/day y0 = 0.9423 m



WELL TEST ANALYSIS

Data Set: \...\MW006d RHT.aqt
Date: 02/08/22 Time: 16:05:45

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

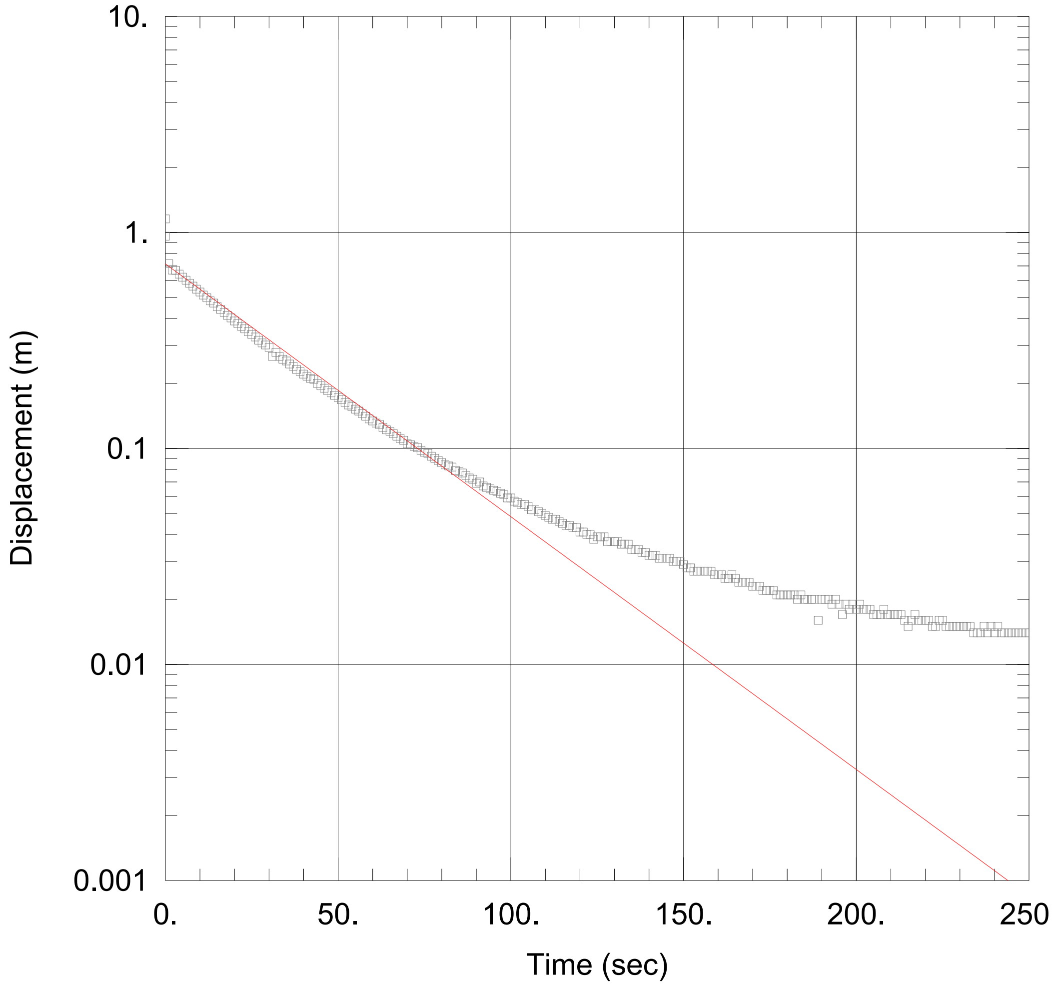
Saturated Thickness: 15. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW006d)

Initial Displacement: 0.96 m
Total Well Penetration Depth: 93.5 m
Casing Radius: 0.025 m
Static Water Column Height: 94.5 m
Screen Length: 12. m
Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.15 m/day y0 = 0.9423 m



WELL TEST ANALYSIS

Data Set: \...\MW006s FHT.aqt
Date: 02/08/22 Time: 16:06:40

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

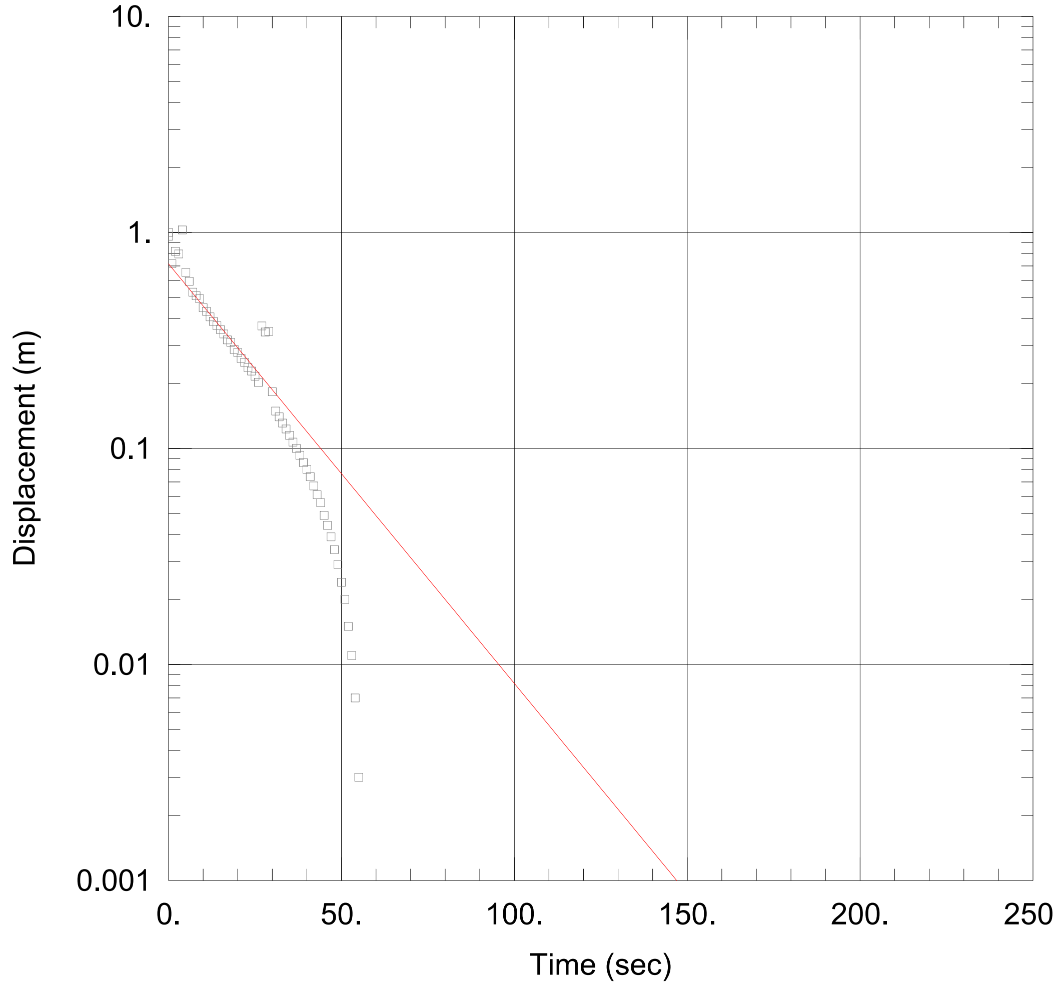
Saturated Thickness: 20.79 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW006s)

Initial Displacement: 0.96 m Static Water Column Height: 22.79 m
Total Well Penetration Depth: 19.79 m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 0.4529 m/day y0 = 0.7148 m



WELL TEST ANALYSIS

Data Set: \...\MW006s RHT.aqt
Date: 02/08/22 Time: 16:06:46

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 20.79 m Anisotropy Ratio (Kz/Kr): 1.

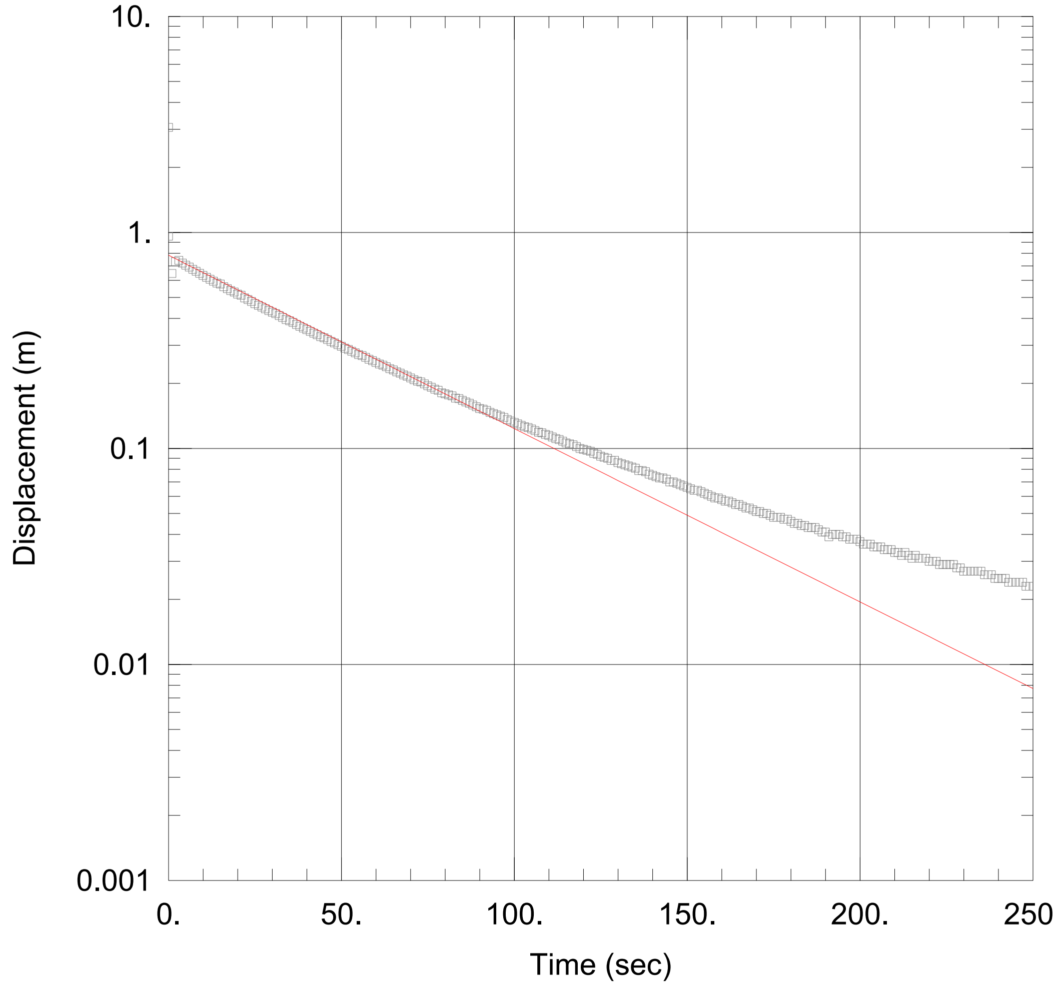
WELL DATA (MW006s)

Initial Displacement: 0.96 m
Total Well Penetration Depth: 19.79 m
Casing Radius: 0.025 m
Static Water Column Height: 22.79 m
Screen Length: 6. m
Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.7516 m/day y0 = 0.7148 m



WELL TEST ANALYSIS

Data Set: \...\MW008 FHT.aqt
Date: 02/08/22 Time: 16:06:56

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 16.54 m Anisotropy Ratio (Kz/Kr): 1.

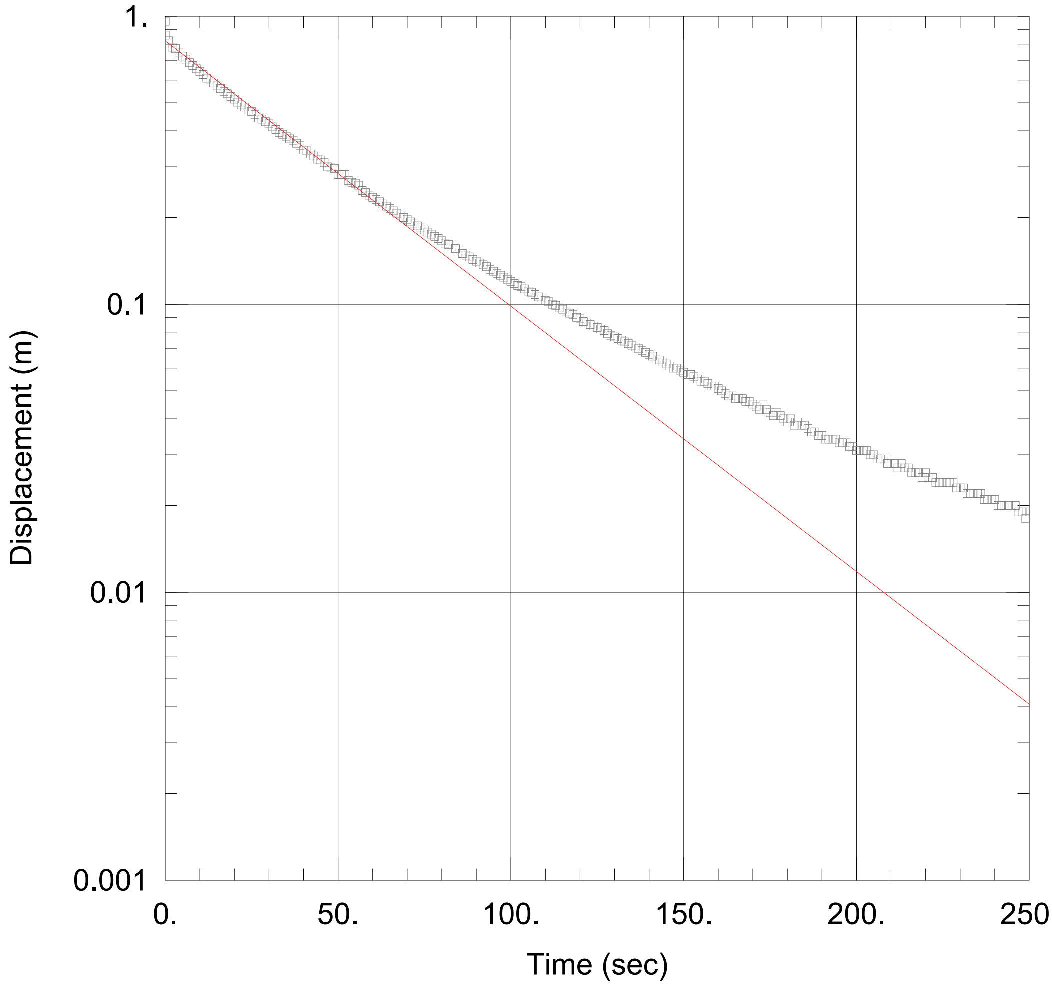
WELL DATA (MW008)

Initial Displacement: 0.96 m Static Water Column Height: 17.54 m
Total Well Penetration Depth: 13.54 m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.2857 m/day y0 = 0.7837 m



WELL TEST ANALYSIS

Data Set: \...\MW008 RHT.aqt
Date: 02/08/22 Time: 16:07:04

PROJECT INFORMATION

Company: CDM Smith
Project: 1001043

AQUIFER DATA

Saturated Thickness: 16.54 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW008)

Initial Displacement: 0.96 m Static Water Column Height: 17.54 m
Total Well Penetration Depth: 13.54 m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.0762 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.3281 m/day y0 = 0.8207 m

Appendix C RightSolutions Process Material Characterisation

VHM Ltd - Goschen Mineral Sands and Rare Earth Elements Project

Process Material Characterisation

25 November 2022

EXECUTIVE SUMMARY

This investigation determines the geochemical characteristics of process material to constitute a Source of potential contamination which is vital to understand impacts to the environment. If there is potential that mining waste may contain elevated concentrations of elements or ions that exceed natural concentrations, then the material may be considered a potential Source of contamination. Tailings streams from metallurgical testwork conducted on ore from Areas 1 and 3 were assessed for acid generating, salinity and metal leaching potential.

Acid generation:

Tailings streams are slightly acidic largely after being subjected to oxidation as a result of very little carbonate material being present and very minor amounts of sulfide minerals but no significant or long-term acid drainage is likely to occur from tailings material. Tailings is not considered to be a potential source for acid drainage.

Saline potential:

Salinity in various ratios of solid to water leachates were relatively low, particularly when compared to groundwater. Tailings is not considered to be a potential source of saline drainage.

Metal leaching:

The tailings material tested show the potential to be a source of aluminium, arsenic, hexavalent chromium and vanadium.

Differences in Mining Areas

There appears to be a marked difference in total elements between the two mining Areas with Area 3 containing considerably higher total concentrations than the tailings from Area 1. However, this difference does not appear to be reflected as a significant difference in the leachability of the tailings.

TABLE OF CONTENTS

List of tables

List of figures

List of abbreviations and acronyms

95% of ANZG SLP	95% of Species limit of protection
ABA	Acid-base accounting
AC	Acid consuming
ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
AMD	Acid and/or metalliferous drainage
AMIRA	Australian Mineral Industries Research Association
ANC	Acid neutralising capacity
ANZECC	Australian and New Zealand Environmental and Conservation Council
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
AS	Australian standard
ASLP	Australian Standard Leaching Procedure
BC	Blanchetown Clay
BoM	Bureau of Meteorology
$CaCO_3$	Calcite
$CaTiSiO_5$	Sphene
Ce, La, Nd, Th, Sm, Eu, Gd, U-PO_4	Monazite
CF	Coonambidgal Formation
FeS_2	Pyrite
$FeTiO_3$	Ilmenite
g/cm³	grams per cubic centimetre (density)
GAI	Geochemical abundance index
GARD	Global acid rock drainage
GC	Geera Clay
HMTV	Hardness Modified Trigger Values
ICP-AES	Inductively coupled plasma atomic emission spectrometry
ICP-MS	Inductively coupled plasma mass spectrometry
INAP	International Network for Acid Prevention
ka	kilo annum (thousands of years)
LOR	Limit of reporting
LPS	Loxton-Parilla Sand
Ma	Mega annum (millions of years)
Mbgl	Metres below ground level
MPA	Maximum potential acidity
MRSD Act	Mineral Resources (Sustainable Development) Act 1990
Mtpa	Million tonnes per annum
NAF	Non-acid forming
NAG	Net acid generating

NAPP .... Net acid producing potential (MPA minus ANC)
NATA .... National Association of Testing Authorities (Australia)
NPR .... Neutralisation potential ratio (ANC divided by MPA)
OF-LPS .... Offshore facies of the Loxton-Parilla Sand
OPF .... Ore processing facilities
PAF .... Potentially acid forming
PAF-HC .... Potential acid forming – high capacity
PAF-LC .... Potentially acid forming – low capacity
QA .... Quaternary Alluvium
QA/QC .... Quality assurance / quality control
ROM .... Run of mine
RPD .... Relative per cent difference
SF .... Shepparton Formation
SiO_2 .... Silica/ quartz
SZ-LPS .... Surf-Zone of the Loxton-Parilla Sand
TDS .... Total dissolved solids
TiO_2 .... Rutile/ Anatase / Leucoxene
TRG .... Technical Reference Group
TSF .... Tailings storage facility
UCL/U .... Uncertain-likely/ unlikely
WOO .... Woorinen Formation
WRL .... Waste rock landform
YPO_4 .... Xenotime
$ZrSiO_4$ .... Zircon

1. INTRODUCTION

Victoria's Murray Basin contains several world-class heavy mineral sands deposits. The Goschen Mineral Sands and Rare Earth Project (Goschen Project) is located near the towns of Lalbert and Goschen in the Loddon Mallee Region in the north-west of Victoria in the Shire of Gannawarra. This document presents a brief summary of the physical conditions of the site and the preliminary characterisation of waste material.

This report outlines the geochemical understanding of the project material tested and summarises related data including geological characteristics, and regional hydrogeology.

1.1 Objective

The main aim of any geochemical characterisation programme is to identify material that, if disturbed, could result in environmental impact. Materials that could pose a risk include overburden, tailings, stockpiled/ low-grade ore or *in situ*, exposed mine void surfaces. Environmental harm could occur if any of these materials or potential “sources” contained minerals at risk of oxidation, such as pyrite (FeS_2) which is acid generating, or other minerals that may not generate acid but would release unacceptable concentrations of potentially toxic elements into the environment. Post-closure impacts from acid and/or metalliferous drainage (AMD) have been identified as the dominant primary potential environmental impact, and cost, of mine rehabilitation.

This Process Material Characterisation geochemistry study outlines the testing conducted to determine whether material constitutes a potential source and the risk that mine wastes may pose.

1.2 Background

Mineral sands deposits host materials that have a specific gravity that is greater than that of quartz (SiO_2 - 2.65 g/cm^3). These heavy minerals are eroded from sources such as granites and metamorphic rocks. The sediments are deposited and then concentrated in place usually by fluvial or marine action, which, over time, washes out the lighter silica minerals and serves to concentrate the heavy minerals where they would otherwise occur at low concentrations.

Mineral sands are chiefly mined as a source of titanium feedstocks in the form of **rutile**, **anatase** (TiO_2), ilmenite ($FeTiO_3$) and their alteration product **leucoxene**. These TiO_2 minerals are frequently found with **zircon** ($ZrSiO_4$) and are also often a valuable source of rare earth elements such as yttrium in the associated heavy mineral **xenotime** (YPO_4), and also of cerium, lanthanum, neodymium, thorium, samarium, europium, gadolinium and uranium in the mineral **monazite** (Ce, La, Nd, Th, Sm, Eu, Gd, U-PO_4). Other non-economic heavy minerals, such as tourmaline or garnet, can also be present and as such the mineralogy of a deposit is important in determining grade.

Deposits of mineral sands can contain levels of Naturally Occurring Radioactive Material (NORM) and their decay products and, as a result of radioactivity, must be assessed for human and environmental safety.

2. PHYSICAL DESCRIPTION

The deposit is expected to generate a total of 56 million tonnes of ore (Mt) and up to 89 Mt of overburden and tailings. Development of the resource will proceed from surface by strip mining. The volume of material mined as ore and waste is important in determining the sampling strategy and numbers of required samples to define material.

The project site is situated approximately 30 km southwest of Swan Hill the nearest major town and 4 km northeast of the small rural town of Lalbert in the Shire of Gannawarra. The Mallee Region is a part of the larger Murray River basin in Victoria, which refers to the geological depositional environment and not the Murray River Catchment. The relatively low rainfall of this region results in significant use of irrigation for crops. Lalbert is supplied with untreated, piped water, directly from the northern Murray River via the Northern Mallee Pipeline with pumping stations at Swan Hill.

2.1 Geology

The Murray Basin is a 600 m thick, Cenozoic Era (66 Ma to present), sedimentary deposit. The basin depositional and erosional environment has been driven by cyclical changes in sea levels and rivers eroding from the Great Dividing Range deposited between 56-15 Ma during the Eocene to Miocene Epochs (timescale shown in Figure 1). Generally, the Group encompasses the marine mud, clay and limestone sediments between the Renmark and Wunghnu Groups.

The lithological units present in the project area are given in Table 1 and discussed further in the text.

Table 1: Stratigraphy of the mining area

Code	Description	Age
CF	Coonambidgal Formation -Quaternary alluvium	24-25 ka
SF	Shepparton Formation – channel sands & floodplain clays	31-21 ka
WOO	Woorinen Formation	0.7-0.4 Ma
BC	Blanchetown Clay	2.4-1.2 Ma
LPS	Upper shoreface and dunes of the Loxton-Parilla Sand	7.2-4.5 Ma
SZ	Surf-Zone of the Loxton-Parilla Sand	
OFS	Offshore facies of the Loxton-Parilla Sand	
GC	Geera Clay	25-15 Ma

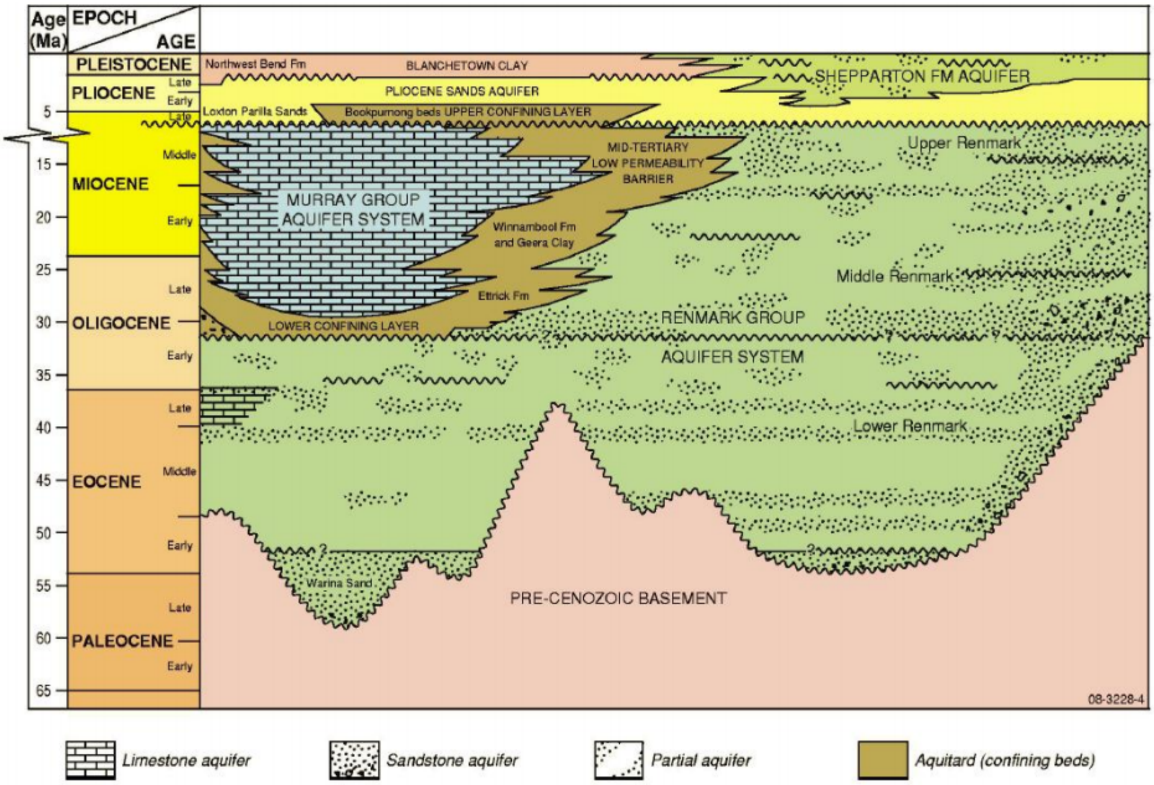


Figure 1: Schematic cross-section stratigraphy of the Murray Basin during the Cenozoic Era (Evans, 2013)

The upper-Oligocene to middle Miocene sequence contains shallow-marine clays and marls known as the Murray Group which includes marginal-marine clays and marls of the Geera Clay and Winnambool Formation. The marginal marine Geera Clay is a major, low-permeability barrier to groundwater flow in the Murray Basin and represents the maximum extent of the Oligocene-Miocene marine transgression into the basin. Progradation (growth of the river delta) of the Geera Clay over platform carbonates of the Murray Group, is widely assumed to reflect marine regression during the Miocene. The Geera clay at the project site is found at the base of the deposit and consists of dark greenish-grey to black, silty muds, silts, clays and minor dark sands, accumulated under complex paralic (interfingered) conditions. Goethitic and glauconitic faecal pellets and pyritic tubules may be frequent, locally (Evans, 2013).

The Loxton-Parilla Sands (LPS) were deposited by a marine intrusion into the Murray Basin, as a sand sheet comprised of layers of sand, silt and clay that has consolidated and in places ferruginised, as an iron cemented sandstone between 20 and 70 m thick. Where the upper surface of the LPS was previously exposed it has undergone extensive weathering and alteration to kaolinite clay (Evans, 2013). Strandlines were deposited in approximately 20 ka phases related to the Milankovitch cycles of glaciation, superimposed on a more gradual marine regression.

The palaeo-Lake Bungunnia was formed during the Pliocene (approximately 3.2 Ma) by the uplifting of the Pinnaroo Block, which began to dam the Murray River and inundated an area around 68,000 km² of the Murray Valley. Deposition into this fluvial and lacustrine environment formed the Blanchetown Clay unit: a mottled silty to sandy clay with quartz sand and gravel beds. The recession of Lake Bungunnia, around 0.5 Ma (Middle Pleistocene), marks the end of a relatively wet phase. Drying of the lake was accompanied by aeolian (wind-driven) processes that generated an extensive system of dunes and lunette features in the Mallee. Lunettes are crescent-shaped, fixed dunes along the edges of playas and river valleys in arid and semi-arid landscapes. Since this time, the climate has undergone a series of oscillating wet to dry, dune-building conditions. During these periods of episodic aeolian processes, the LPS and Blanchetown Clay sediments were blown from the surface of the lake floor and re-worked into the Woorinen Formation, a unit of orange-brown sand and silty clay forming linear dunes (Evans, 2013).

The Pliocene to Recent age Shepparton Formation overlies the Pliocene sand deposits and comprises fluvio-lacustrine sediments that are mainly mottled, variegated clay and silt, with subordinate shoestring lenses of coarse to fine mixed material sand and gravel. These sands and gravels represent channel deposits within the dominant finer grained floodplain. The sequence has been extensively modified by pedogenesis and fluctuating watertables, and numerous palaeosol surfaces are present (Brodie & Tucker, 1993).

The Coonambidgal Formation contains unconsolidated silt, silty clay, sand and gravel units, and is around five metres thick. The Coonambidgal Formation is thought to act as an aquitard on top of lower river terraces (Evans, 2013).

The source of the heavy minerals that form the deposit sands in the Murray Basin is likely to be the weathered and eroded Palaeozoic and older rocks surrounding the basin. The heavy mineral sand (HMS) deposits in the Murray Basin formed within the LPS during a Late Miocene-Pliocene regression. HMS accumulated in the near-shore environment of the Murray Basin sea, as strandline deposits becoming concentrated in the near-shore, low energy zone (Olshina & Miranda, 2011). Sheet deposits of HMS are also present in the area and represent deep basin deposition of fine-grained material. The presence of both strandline and sheet-like deposits indicate the fluctuating position of the coastline.

The pre-Cenozoic basement rocks unconformably underlying the project area are comprised of the Devonian (362-389 Ma) Lake Boga Granite. The Lake Boga Granite, covered almost entirely by thin Murray Basin sediments, is one of the largest plutons in the western Lachlan Fold Belt.

2.2 Surface water

The project area is situated in a part of the Avoca basin 8 (DSE, 2005). Regional surface water flow direction is to the north and northwest but no surface watercourses are present at the project site. The nearest creek to the project site occurs at a distance of 5 km.

Regional surface water quality results ranges from good to moderate. In the Mallee basin the majority of stream length was in poor condition (64%) or very poor condition (32%) with high levels of turbidity and phosphorus. The stream conditions are similar in the Avoca basin (ISC, 2013).

2.3 Groundwater

The majority of the deposit occurs above the water table, which is estimated to be at >40 mbgl (below ground level) and potentially between 68-70 m AHD with no mine voids expected to require dewatering (CDM Smith, 2018).

Much of the Murray Basin contains saline groundwater with total dissolved solids (TDS) concentrations commonly >14,000 mg/L and locally up to 300,000 mg/L. Aquifer thicknesses and groundwater salinity both increase westwards in the Murray Basin with short residence times of < 30 ka. High salt concentrations result from recycling of solutes in low lying terminal saline lakes and playas or repeated cycles of evapotranspiration in the unsaturated zone (Cartwright, et al., 2017).

Salinity of groundwater within the LPS in areas away from the Murray River ranges between 14,000 and 35,000 µS/cm. In recent times, irrigation of the surface has caused 'freshening' in the upper section of the Parilla Sand aquifer, reducing concentrations (Aquaterra, 2009).

As a result of this high salinity, there are few groundwater users in the vicinity of the project, with one stock bore located a distance of 6 km away. Locally in the project area groundwater flow direction is expected to be to the north-east, but regionally groundwater flow direction is to the north-west.

2.4 Geochemistry

The distribution of heavy minerals indicate that depositional process varied over time and area. The mineral source regions indicate that the majority of the sediment originated in the Adelaide Fold Belt, Lachlan Fold Belt, Grampians, Coleraine Volcanics, New England Fold Belt and the Whitsunday Volcanic Province. The major controls on geochemistry are the detrital minerals themselves and post-depositional weathering and reworking. There is a secondary accumulation of goethite, hematite, silica, clays and carbonate and sulfate minerals. The decomposition of clays and the subsequent inclusion of aluminium of in the structure of iron minerals, mobilisation of silica and the precipitation of barite ($BaSO_4$) indicate a hydromorphic soil-forming process with ferrolysis and the formation of acid sulfate soils. The distribution of trace elements in the LPS are widely heterogenous and indicate a complex history of wet and dry conditions accompanied by changes in acidity and reducing and oxygenated conditions (McLennan, 2016).

2.5 Goschen Process Material

As a result of the nature of a mineral sands deposit, the vast majority (>97%) of mined material is considered gangue (non-economic) and is separated onsite mostly in physical concentration process before being returned to the mine void as backfill. The mineral processing involves various separation processes including particle size screening, gravity spirals for density fractionation, floatation, electrostatic and magnetic separation to reject the non-economic minerals from the valuable heavy minerals. During the course of separating out the various product minerals from the ore several tailings streams will be generated. As a result of this, the management of tailings material is an important part of mining progression.

Project development will follow a phased progression with Phase 1a and Phase 2 starting approximately 18 months after Phase 1. The tailings streams originating from the process are shown in Figure 2 with the mass of tailings produced from each concentration step given in Table 2. For an assumed run-of-mine (ROM) ore feed of 5 million tonnes per annum (Mtpa) approximately 4.8 Mtpa of tailings will be produced. The majority of the tailings will comprise of the coarse, gravity separated light fraction from the wet concentrator plant. This material is largely expected to consist of quartz sand and fine clay, which is likely to be largely inert and fairly resistant to weathering considering the reworking process under which the material was deposited. However, to practice precaution all material should be tested prior to mining.

Mining and mineral processing at the Goschen project is expected to produce ten different tailings streams described in Table 2. The tailings streams are given in approximate order of production, with the T1 Oversize and T2 Fines tailings being produced in the Feed Preparation Plant (FPP) which processes the Run-of-Mine (ROM) material, and stream T3 the Sand tails being produced in the Wet Concentrator Plant (WCP).

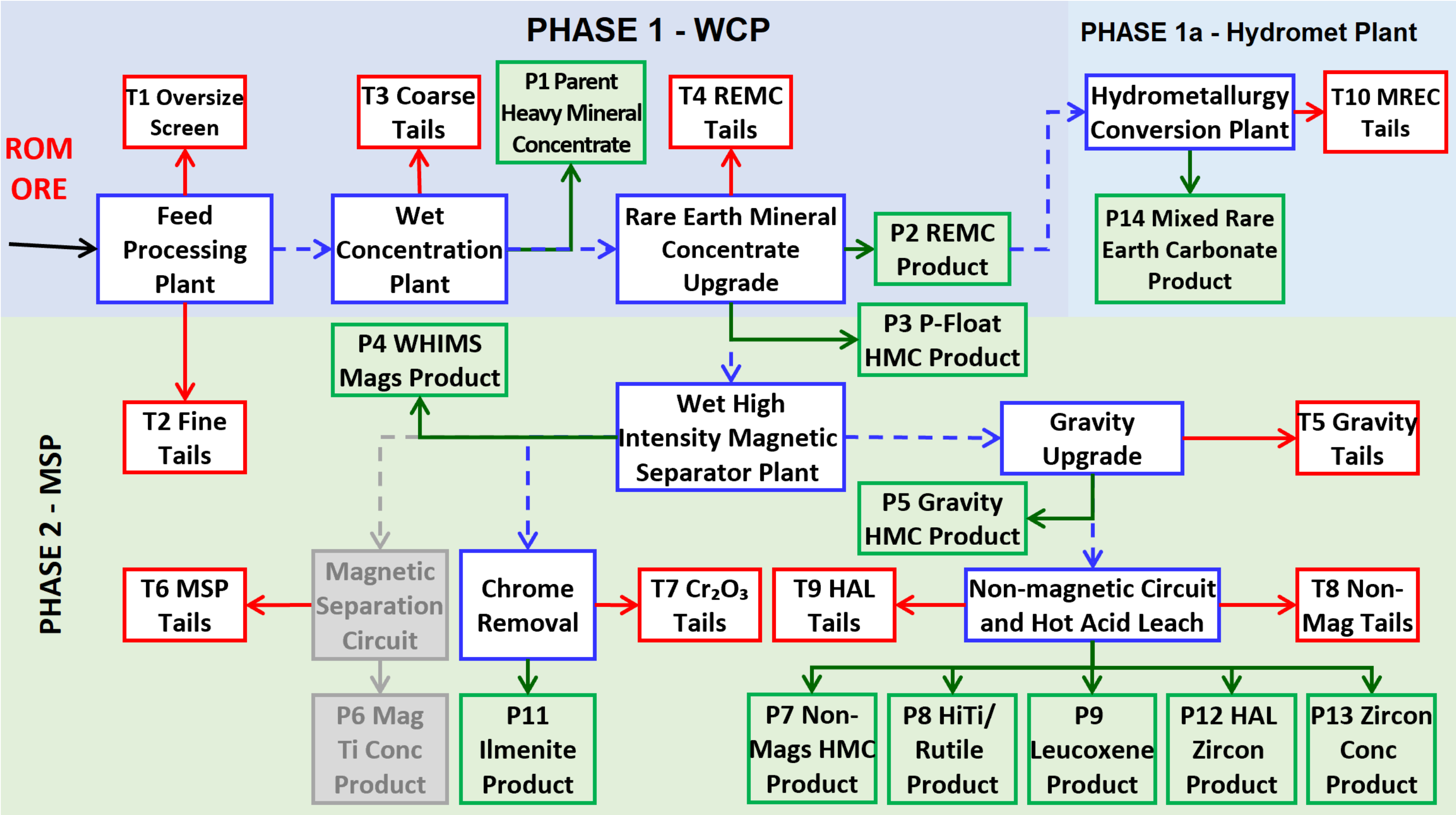


Figure 2: Goschen mineral sands process circuit

Table 2: Tailings streams and mass flow rates

Stream	Process	Size	Mass (ktpa)	%
T1	Feed Process Plant (FPP) - Oversize Tails	>2mm	90	2
T2	Feed Process Plant (FPP) - Fines Tails	< 20 µm	800	16
T3	Wet Concentrator Plant (WCP) – Coarse Tails	20 µm – 2mm	3,900	80
T4	Rare Earth Mineral Concentrate (REMC) Tails		1.1	<0.05
T5	Non-magnetic Gravity Upgrade (N/M-GT) Tails		40	0.8
T6	Magnetic Separation Plant (MSP) – "Mags" Tails		-	-
T7	Cr_2O_3 Removal (CrFloat) Tails		15	0.3
T8	Non-Magnetic Zr/HiTi (N/M-MSP) Tails		<5	<0.5
T9	Hot acid leach (HAL) Tails		<1	<0.05
T10	Mixed Rare Earth Carbonate (MREC) Tails		40	0.8

The Oversize tails are generated by a simple 2mm screen, and as such have the moisture content of natural ground which is estimated to be ~5%. The Oversize Tails are functionally dry and can be easily mechanically handled with a truck and loader with no dewatering required. This screened material is then slurried and pumped through a hydrocyclone which separates the <20 µm fraction out of the ROM feed to produce a stream of Fine Tails that are 3-4% solids initially which are thickened to ~25% solids after passing through a thickener using flocculant to recover process water.

The majority of the mass of tailings (80%) produced in the processing plant in a year, is stream T3 - Coarse tails, generated through gravity separation of valuable heavy minerals from the low-density particles. The nature of the deposit comprising mineral sands means that this lighter, silt to sand size-fraction comprises approximately 80% quartz and 15% clay minerals (See Section 4.3) with the remainder comprising minor amounts of rutile, zircon, and ilmenite. The tailings are homogenised and pumped as a slurry back to the mine and used to fill the pit. As such all material except the >2mm oversize will be effectively mixed into one stream to be backfilled into the pit.

3. ANALYTICAL METHODS

A geochemical assessment involves a range of material testing in order to estimate how waste material will behave when excavated. Individually, each of the geochemical test methods has limitations, but when a strategic combination of analyses is applied and selected according to the nature of the deposit, the complexity of the geology, the reactivity of sulfides or the degree of weathering, the reliability of AMD classification is greatly enhanced. Static test results are used to evaluate the potential for acid formation and short-term release of elements. The following analytical tests were conducted:

- Acid-base Accounting (ABA);
- Total element analysis (whole rock) by acid digestion;
- Dissolved parameters by leach testing; and
- Mineralogy by x-ray diffraction (XRD).

3.1 Acid-base accounting

Acid-base accounting (ABA) estimates the capacity of material to produce or neutralise acid. ABA methods compare the **maximum potential acidity (MPA)** with the **acid neutralisation capacity (ANC)** for a given material, using either the total sulfur (AMIRA, 2002) or sulfide content (Price, 2009) to calculate MPA. MPA is merely the %S of a sample expressed as kg H_2SO_4/t that could be generated from waste.

The total sulfur of a solid sample is determined by high temperature combustion and mass change. Using total sulfur as a measure of MPA is conservative and commonly overestimates the acid generation as total sulfur comprises both sulfide and sulfate, which is not acid generating. As a consequence, sulfate concentration is also determined by HCl extraction, and the total sulfide concentration is calculated by the difference as total sulfur minus sulfate.

The ANC is determined by the modified Sobek method (Sobek, et al., 1978) where a known amount of standardised hydrochloric acid (HCl) is added to an accurately weighed sample, allowing the sample time to react, then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCl. The amount of acid consumed by reaction with the sample is then calculated. The determinations of MPA and ANC are then expressed in the same units of kilograms of sulfuric acid per tonne (kg H_2SO_4/t) for ease of comparison.

The **Net Acid Generating (NAG)** capacity of the material is determined by reacting the sample with peroxide with heat to oxidise all reactive minerals both acidic and neutralising. The NAGpH is used to classify material and the NAG liquor may be analysed to provide an indication of metal release.

Total carbon (**%C**) is determined by combustion and provides an indication how much of the ANC is a result of carbonate material (**Total Inorganic Carbon - %TIC**) and whether any organic material (**Total Organic Carbon - %TOC**) is present. ABA results are used to determine the **Neutralisation Potential Ratio** where **NPR** = ANC/MPA and the **Net Acid Production Potential** where **NAPP** = MPA-ANC. The NAPP in conjunction with the NAGpH are used to categorise material into potentially acid forming high-capacity (**PAF-HC**), potentially acid forming low-capacity (**PAF-LC**), non-acid forming (**NAF**), acid consuming (**AC**), uncertain-likely (**UCL**) or uncertain-unlikely (**UCU**). Table 3 gives the criteria for the classification of material according to AMIRA (2002). Material classified as having uncertain acid-forming potential may be recommended to undergo additional testing to assess the dissolution rates of acid-forming (e.g. pyrite) and acid-neutralising (e.g. calcite) minerals via kinetic tests. The NAPP used to classify material as potentially acid forming is given as greater than 5 kg H_2SO_4/t.

3.2 Total element analysis

Multi-element analysis of a whole rock, acid (strong HCl) digested sample provides the near-total elemental composition and gives an indication of the maximum potential load of constituents to the environment should extreme weathering conditions and dissolution occur. The total element concentration is then used to determine a **geochemical abundance index (GAI)** calculated by utilising the median concentration for that particular element in the most relevant media (e.g. crustal abundance). The method for calculating GAI is given on the INAP (2009) website and typical distributions for element concentrations for sedimentary rocks are given in Bowen (1979). The recent study of the LPS by McLennan (2016) is also referenced as a more regionally applicable measure of average minor and trace metal concentrations. The calculated GAI provides an indication of whether any elemental enrichment exists. The GAI is expressed as an integer where a 0 indicates the element is present at similar concentrations to the median concentration used and a value of 3 indicates a concentration 12-times that of the median value, which is considered to be significant enrichment and may be of concern should leaching take place into a pathway leading to an environmental receptor.

3.3 Dissolved concentrations

Water extract leaching tests are conducted to determine the potential for release of water soluble elements as a result of precipitation and runoff in compliance with the Australian standard leaching procedure (ASLP) AS 4439.2 (Standards Australia, 1997a) and AS4439.3 (Standards Australia, 1997b)). The procedure utilises 500 mL of deionised water and 25 g of sample to give a water to solid ratio of 20:1. The samples are shaken for 18 hours, with the pH periodically measured and buffered at a value of approximately 5 (with nitric acid), before being filtered and the extract analysed for dissolved elements. To better simulate low rainfall or infiltration scenarios lower ratios of liquid to solid are also conducted i.e. 1:5.

3.4 Standards

In order to evaluate analytical data, calculations and concentrations are required to be compared to standards and references. The acid-base accounting analyses are evaluated using the Australian Mineral Industry Research Association (AMIRA) *Acid Rock Drainage Test Handbook* (AMIRA, 2002). The additional division of the Uncertain classification into Likely and Unlikely is according to the G*lobal Acid Rock Drainage (GARD) Guide* developed by the International Network for Acid Prevention (INAP, 2009).

The simpler Price (2009) classification system uses only acid potential and neutralising potential to calculate NPR =ANC/ MPA is also shown in Table 3 and does not use the NAG test. Price (2009) only defines three categories (PAF, Uncertain and NAF) and is intended to be used as a first estimate of potentially deleterious material. These methods of classification are intended as a guideline to determine the site specific acid potential of the material being characterised. Site specific classification criteria are discussed further in the characterisation sections of this document.

Table 3: Acid-base accounting classification criteria according to AMIRA (2002) and Price (2009)

Material classification	AMIRA (2002)		Price (2009)
	NAPP (kg H_2SO_4/t)	NAG pH	NPR
Potentially acid forming (PAF)	> 10	< 4.5	<1
Potentially acid forming – low capacity (PAF-LC)	5 - 10	< 4.5	
Uncertain – Likely (UCL)	< 0	< 4.5	1 ≤ 2
Uncertain – Unlikely (UCU)	> 0	≥ 4.5	
Non-acid forming (NAF)	< 0	≥ 4.5	> 2
Acid consuming (ACM)	< -100	≥ 4.5	

In the absence of site-specific reference/baseline trigger values, dissolved concentrations are compared to the ANZ *Guidelines for Fresh and Marine Water Quality* at the 95% of Species Limit of Protection (SLP) for a Slightly to Moderately Disturbed System, hereafter referred to simply as “ANZG” (ANZECC & ARMCANZ, 2000a). As the regional area has been utilised as farmland for some time it is likely that ecosystems are already impacted. Where applicable (hardness greater than 30 mg $CaCO_3$/L), the SLP limits will be modified for the relative hardness of the water (Table 4).

The results for total whole rock elemental analyses are used to calculate a geochemical abundance index (GAI) according to the GARD guide (INAP, 2009).The total element concentration of an acid digested sample of solid tailings material, is compared to the average crustal abundance given in Table 4 in order to determine whether any particular element is significantly enriched.

Low reliability limits (indicated by “§” symbol) in Table 4 are sourced from Volume 2 of the ANZG (2000b) and are somewhat uncertain because of a low number of toxicity data points. The guideline limits, additionally noted as “<LOR”, are theoretical guideline limits that are lower than the laboratory capability of detection, as a result all analyses for these elements (silver (Ag), beryllium (Be), cobalt (Co), lanthanum (La) and thallium (Tl)) will, by default, occur above this limit, even if they are below the achievable limit of reporting. For cobalt, the guideline value of 0.0028 mg/L, which has not had the safety factor of 2 applied, has been used to avoid this. For elements where speciation has not been conducted, i.e. arsenate (As V), arsenite (As III), chromate (Cr III) and hexavalent chromium (Cr VI), the lowest guideline limit is chosen for evaluation. For calculation of hardness modified trigger values (HMTV) the Cr VI low reliability value of 0.0033 mg/L is used as stated in the method in ANZG (2000a). The elements: cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn); with trigger values that may be modified for high hardness, are indicated with a “*”.

Table 4: Water quality (mg/L) and total element reference standards for solid material (mg/kg)

Parameter	ANZG 95% of SLP	Average crustal abundance (mg/kg) (Bowen, 1979)
pH	6.5-8.5	-
EC (µS/cm)	-	-
Alkalinity as $CaCO_3$	-	-
Ag – silver	0.00005<LOR	0.070
Al – aluminium	pH>6.5 - 0.055; pH<6.5 – 0.0008	82,000
As – arsenic	As V = 0.013	1.5
B – boron	0.37	950
Ba – barium	-	500
Be – beryllium	0.00013§<LOR	2.6
Bi – bismuth	0.00070 §	0.048
Ca – calcium	-	41,000
Cd – cadmium	0.00020 *	0.11
Ce – cerium	-	68
Cl – chloride	-	130
Co – cobalt	0.0014 §<LOR (0.0028 § used)	20
Cr – chromium	Cr VI = 0.0010 * HMTV Cr III = 0.0033 §	100
Cs – caesium	-	3.0
Cu – copper	0.0014*	50
F – fluoride	-	950
Fe – iron	0.30 §	41,000
HCO_3 – bicarbonate	-	-
Hg – mercury	0.00060	0.050
K – potassium	-	21,000
La – lanthanum	0.00004 §<LOR	32
Li – lithium	-	20
Mg – magnesium	-	23,000
Mn – manganese	1.9	950
Mo molybdenum	0.034§	1.5
Na – sodium	-	23,000
Ni - nickel	0.011*	80
P – phosphorous	-	1,000
Pb – lead	0.0034*	14
Rb – rubidium	-	90
SO_4 – sulfate	-	-
Sb – antimony	0.0090 §	0.20
Sc – scandium	-	16
Se – selenium	0.011	0.050
Sn – tin	0.0030 §	2.2
Sr strontium	-	370
Th – thorium	-	12
Ti – titanium	-	5,600
Tl – thallium	0.000030 §<LOR	0.60
U – uranium	0.00050 §	2.4
V – vanadium	0.0060 §	160

Parameter	ANZG 95% of SLP	Average crustal abundance (mg/kg) (Bowen, 1979)
W – tungsten	-	161
Zn - zinc	0.0080	75
Notes	<LOR – indicates guideline below limit of reporting i.e. all analyses will occur above ANZECC 95% of SLP	
	§–Low reliability limit	*–HMTV

3.5 Qualitative assessment criteria

The geochemical characterisation of a material to constitute a Source of potential contamination to the environment is assessed based on the following:

- How often a particular element or ion is detected in samples for all of the five leach tests is the Likelihood of Occurrence;
- The solubility and consequent ecotoxicology of a particular element or ion in a natural system i.e. a highly soluble parameter, such as sodium is less toxic in an environment that has evolved to tolerate it, while a sparingly soluble parameter is naturally more toxic (except in an environment which has locally, naturally, high concentrations). Solubility can depend on the environmental and weathering conditions and can be changed by mineral processing; while ecotoxicology is dependent on the sensitivity of the receptor. For example, in a highly saline environment additional salinity is unlikely to have a significant effect on biota, while in a pristine, sensitive glacial environment additional salinity could be toxic. Elements like arsenic or mercury would ordinarily be deemed to be highly toxic except in environments where they occur naturally, and the local biota have evolved a tolerance;
- Further determinants of whether a material constitutes a potential Source takesinto account specific, quantitative, legislative limits, also based on ecotoxicology, and local site-specific trigger values (if available) based on the groundwater quality of the likely receptor. Additionally the relative volumes of material are also taken into account.

A high potential impact would occur when the ecotoxicology of the parameter given in the ANZ Guidelines is high and the relative solubility of that species in local groundwater, as based on site specific concentrations, is very low, or “trace”; the concentration that the element occurs at exceeds the site-specific trigger values *and* the occurrence of that element is possible to certain. Elements that are not detected are not considered to be of concern.

If there is potential that mining waste may contain elevated concentrations of elements or ions that exceed natural concentrations, then the material may be considered a potential Source of contamination. The environmental risk is then determined with a conceptual site model where the potential pathways for contamination to travel into the ecosystem are assessed as well as the occurrence of any sensitive receptors.

3.6 Sampling

Each of the tailings streams of significant volume were characterised from material produced from processing samples from Areas 1 and 3 of the mine site. Table 5 details the number of samples analysed for each test. Samples for tailings material T8 and T9 were not included as the volumes generated are too small and no material was available for testing. Fines from Area 1 could not be analysed as planned as sample material was destroyed by weather. REMC from Area 3 could not be analysed as insufficient material remained after metallurgical testing. Very small amounts (less than 100 g) of T7 were available for testwork and so only a water leach and acid digest were conducted. The MSP Upgrade and Chrome removal Roast Process circuits are no longer included in the circuit – this is indicated by grey text in the below table.

Table 5: Number of tailings samples analysed and tests conducted

No	Process	Area	NAG pH	Full ABA	pH & EC 1:2	TC, TOC TIC	NAG Liquor	ASLP	Water Leach 1:5	Water Leach 1:20	Slurry Decant	Acid extract	XRD
T1	Oversize	1	2	1	1	1	1	1	1	1	-	1	-
		3	2	1	1	1	1	1	1	1	-	1	-
T2	Fines	3	4	2	2	1	2	2	4	4	8	4	2
T3	Sand	1	6	2	2	2	4	1	2	2	-	2	1
		3	6	2	2	2	4	1	2	2	-	2	1
T4	REMC Float	1	2	1	1	-	1	1	-	-	-	1	-
T5	N/M Gravity Upgrade	1	2	1	1	-	1	1	1	1	-	1	-
T6	MSP Upgrade	1	2	1	1	1	1	1	1	1	-	1	-
		3	2	1	1	-	1		1	1	-	1	-
T7	Cr_2O_3 Removal – Roast	1	-	-	-	-	-	-	-	1	-	1	-
	Cr_2O_3 Removal – Float		-	-	-	-	-	-	-	1	-	1	-
T8	N/M (Zr/HiTi)	1	1	1	1	1	1	1	1	1	-	1	-
		3	1	1	1	-	1	-	1	1	-	1	-

Tailings samples were named according to number (T1-T8), process step (FPP, WCP, REMC, N/M-GT, Mags etc.), area and then sample number so that: “T2-FPP-FT_A3-11” is tailings number 2 - feed processing plant fine tails from Area 3 sample number 11.

4. RESULTS

The purpose of the Process Material Characterisation assessment is to describe the chemical composition of material in order to maintain the inland water quality so that environmental values are protected.

The risk of pollution that exposed and excavated ore or process waste may pose is assessed by analysing the likely discharge from various sources and comparing them to the existing water quality.

4.1 Acid/ Alkaline Potential

The test results for the acid-base accounting of tailings material are given in Table 6. All tailings material is classified as Non-Acid Forming (NAF). Figure 3 displays the classification of material by the Australian and international classification methods. Sediments are slightly acidic largely after being subjected to oxidation as a result of very little carbonate material being present and very minor amounts of sulfide material. This minor amount of acidity would not be generated long-term and would likely be neutralised by alkalinity in natural waters.

Coarse tails (CT) have no detectable sulfide material or carbonate alkalinity, and net acid generation is below the detection limit but the NAG pH is consistently below 5, indicating a mineral source of very minor acidity.

Table 6: Acid-base accounting results

Tails Sample	pH (1:2)	EC (1:2)	pH (NAG)	Tot S	SO_4	S	C	TOC	TIC	ANC	NAG
		µS/cm		%						kg H_2SO_4/t	
T1-FPP-OS_A1-1	5.7	170	4.5	<0.01	0.010	0.010	<0.05	<0.05	<0.05	1.7	0.90
T1-FPP-OS_A1-2	-	-	4.6	-	-	-	-	-	-	-	-
T1-FPP-OS_A3-3	7.6	400	6.1	0.020	0.030	0.050	0.12	0.090	<0.05	3.4	<0.5
T1-FPP-OS_A3-4	-	-	5.4	-	-	-	-	-	-	-	-
T2-FPP-FT_A3-9	7.2	410	5.4	0.010	0.030	0.040	0.17	0.16	<0.05	2.6	0.60
T2-FPP-FT_A3-10	-	-	5.4	-	-	-	-	-	-	-	-
T2-FPP-FT_A3-11	6.7	340	5.6	0.010	0.030	0.040	-	-	-	2.8	0.60
T2-FPP-FT_A3-12	-	-	5.3	-	-	-	-	-	-	-	-
T3-WCP-CT_A1-13	6.7	30	4.6	0.010	<0.01	0.010	<0.05	<0.05	<0.05	1.9	<0.5
T3-WCP-CT_A1-14	-	-	4.7	-	-	-	-	-	-	-	-
T3-WCP-CT_A1-15	-	-	4.6	-	-	-	-	-	-	-	-
T3-WCP-CT_A1-16	6.9	30	4.5	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	1.2	<0.5
T3-WCP-CT_A1-17	-	-	4.7	-	-	-	-	-	-	-	-
T3-WCP-CT_A1-18	-	-	4.6	-	-	-	-	-	-	-	-
T3-WCP-CT_A3-19	7.4	30	4.7	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	1.7	<0.5
T3-WCP-CT_A3-20	-	-	4.7	-	-	-	-	-	-	-	-
T3-WCP-CT_A3-21	-	-	4.8	-	-	-	-	-	-	-	-
T3-WCP-CT_A3-22	7.5	30	4.8	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	1.8	<0.5
T3-WCP-CT_A3-23	-	-	4.8	-	-	-	-	-	-	-	-

T3-WCP-CT_A3-24	-	-	4.8	-	-	-	-	-	-	-	-	-
T4-REMC-GT_A1-25	-	-	4.6	0.010	<0.01	0.010	-	-	-	2.2	<0.5	
T4-REMC-GT_A1-26	7.6	50	-	-	-	-	-	-	-	-	-	
T5-N/M-GT_A1-29	7.3	40	5.2	<0.01	<0.01	<0.01	-	-	-	2.2	<0.5	
T5-N/M-GT_A1-30	-	-	5.3	-	-	-	-	-	-	-	-	
T6-Mags_A1-31	7.5	70	5.2	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	1.2	<0.5	
T6-Mags_A1-32	-	-	5.2	-	-	-	-	-	-	-	-	
T6-Mags_A3-33	7.3	70	5.3	0.010	<0.01	0.010	-	-	-	1.9	<0.5	
T6-Mags_A3-34	-	-	5.3	-	-	-	-	-	-	-	-	
T8-N/M-MSP_A1-37	7.1	50	5.5	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	1.6	<0.5	
T8-N/M-MSP_A1-38	-	-	5.4	-	-	-	-	-	-	-	-	
T8-N/M-MSP_A3-39	7.2	70	5.1	<0.01	<0.01	<0.01	-	-	-	0.90	<0.5	

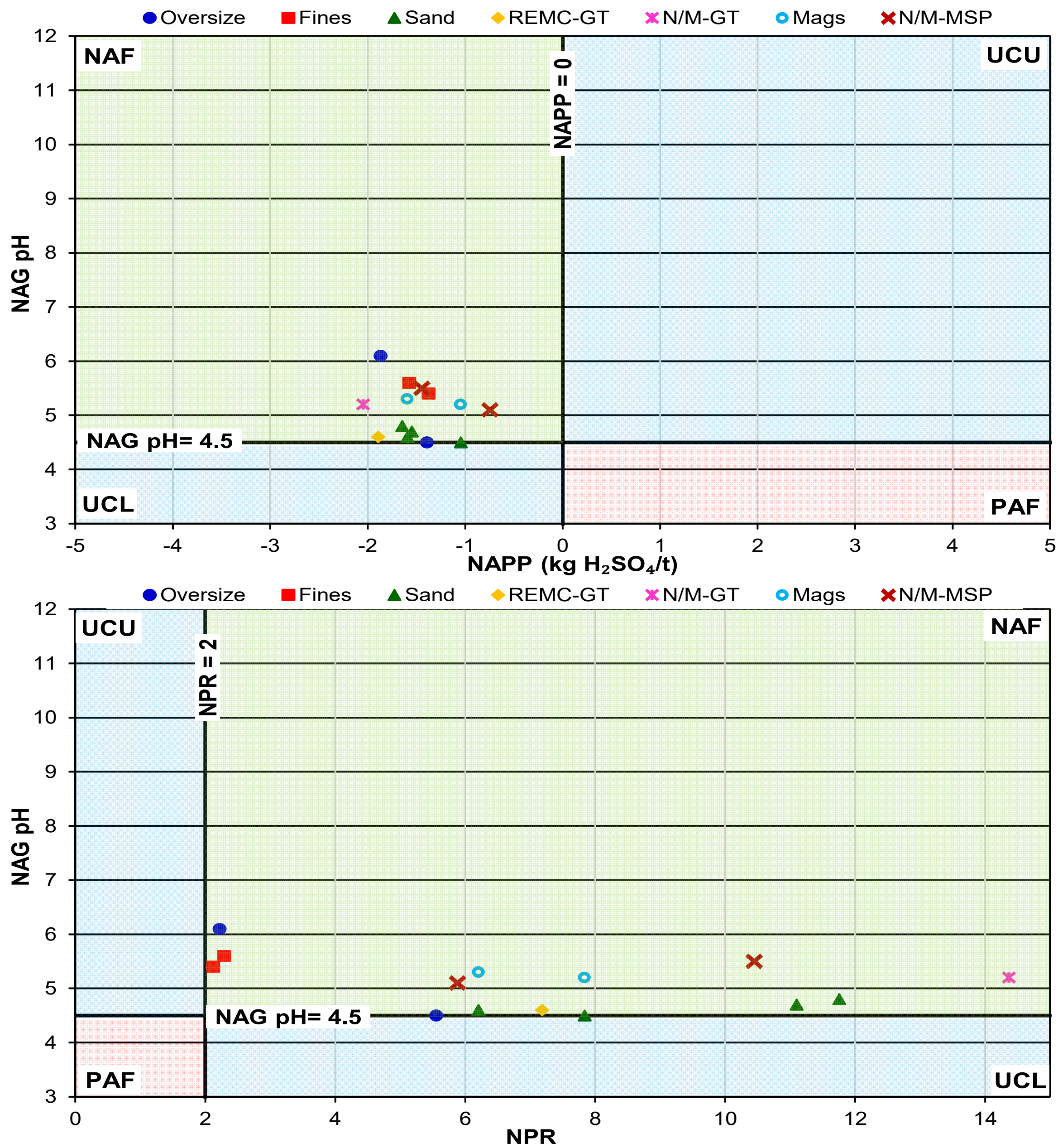


Figure 3: Classification of acid potential for tailings material

4.2 Total element concentration

The acid extract results are provided in Table 8 and the calculated geochemical abundance index (GAI) is provided in Table 9. There is a significant difference in total element concentrations between the Feed Process Plant (FPP) oversize (OS) and fine tails (FT). The higher aluminium concentrations in the Fine Tails indicates that the majority of clay minerals have been separated into this fraction which is the goal of this process. Similarly the major soluble ions are also highest in the fines tails as they are associated with clay minerals.

The Wet Concentrator Plant (WCP) Coarse Tails (CT), which comprises the largest volume generally has the lowest concentrations of all metals.

The Rare Earth Mineral Concentrate (REMC) Gravity Tails (GT) have elevated concentrations of minor metals such as barium, cerium, gallium, lanthanum, selenium, and yttrium. The flotation process is designed to separate the rare earth heavy minerals and so minor concentrations of the heavy minerals are expected in the gravity upgrade tails.

There appears to be higher metal concentrations in the Area 3 tailings than Area 1. This may indicate slightly higher potential for leaching from these tails.

The GAI indicates the tailings material is generally elevated, relative to average crustal abundance, in arsenic and bismuth. The REMC gravity tails and the MSP magnetic tails from Area 3 have several minor elements that are elevated relative to the average crustal abundance.

4.3 Mineralogy

The mineralogy of four select samples are given in Table 7. The amorphous content may contain some of the more poorly crystalline clay phases and conversely the clay phase content may contain some poorly crystalline or amorphous material. Where there is a significant presence of clay material, the distinction between poorly crystalline material and amorphous content can be imprecise. For confirmation of the expanding clay mineralogy, further separation would be required. The mixed layer clay is usually a mixture of poorly ordered transitional minerals and may be characterised, for example, as an Illite/smectite and/or chlorite/smectite.

Table 7: Mineralogy of Fine and Coarse Tails (wt.%)

Sample name	Amorphous Content	Anatase	Expanding clay	Goethite	Hematite	Illite/ Muscovite	Kaolin	Mixed Layer Clay	Quartz	Rutile
T2-FPP-FT_A3-9	20	<0.5	1	9	<0.5	11	35		24	<0.5
T2-FPP-FT_A3-11	23	<0.5	6	8	<0.5	6	31	2	23	<0.5
T3-WCP-CT_A1-13	15				<0.5	1	4		79	
T3-WCP-CT_A3-19	15					<0.5			84	

Table 8: Total element concentrations (mg/kg)

Tails Sample	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Fe	Ga	Hg	K	La	Li	Mg	Mn
T1-FPP-OS_A1-1	<0.05	6,090	110	<5	65	0.44	0.09	24	<0.05	260	1.8	85	3.5	19,000	11	<0.02	370	110	3.5	210	14
T1-FPP-OS_A3-3	<0.05	6,530	240	<5	55	2.5	0.13	400	<0.05	59	18	93	8.5	170,000	5.0	<0.02	450	24	3.0	490	210
T2-FPP-FT_A3-9	<0.05	26,100	120	14	82	2.3	0.62	440	<0.05	130	14	94	10	86,000	11	0.02	1,300	56	20	1,400	160
T2-FPP-FT_A3-10	<0.05	24,000	130	12	73	2.1	0.59	450	<0.05	120	14	90	11	84,000	10	0.02	1,200	50	15	1,300	160
T2-FPP-FT_A3-11	<0.05	26,600	130	14	86	2.3	0.62	440	<0.05	130	14	96	10	83,000	12	0.02	1,400	58	22	1,400	160
T2-FPP-FT_A3-12	<0.05	24,100	130	13	80	2.2	0.62	440	<0.05	130	14	93	11	79,000	11	0.02	1,300	56	19	1,400	160
T3-WCP-CT_A1-13	<0.05	768	5.6	<5	8.8	<0.05	<0.05	<10	<0.05	27	<0.5	6.4	<0.5	1,100	1.5	<0.02	140	14	0.50	54	4.8
T3-WCP-CT_A1-16	<0.05	770	5.6	<5	9.2	<0.05	<0.05	<10	<0.05	28	<0.5	6.3	<0.5	1,100	1.5	<0.02	100	15	0.40	53	4.7
T3-WCP-CT_A3-19	<0.05	944	13	<5	7.7	0.18	<0.05	27	<0.05	26	1.4	6.8	<0.5	8,500	1.5	<0.02	190	12	0.70	63	19
T3-WCP-CT_A3-22	<0.05	603	12	<5	5.8	0.18	<0.05	21	<0.05	22	1.3	6.0	<0.5	8,200	1.2	<0.02	140	10	0.40	53	16
T4-REMC-GT_A1-25	<0.05	157	35	<5	**230**	0.070	0.83	320	<0.05	**3,500**	<0.5	7.9	2.6	540	**100**	<0.02	26	**1,600**	0.30	22	5.1
T5-N/M-GT_A1-29	<0.05	200	4.3	<5	5.6	<0.05	0.08	36	<0.05	12	<0.5	8.8	1.6	890	0.99	<0.02	68	6.4	<0.2	27	6.6
T6-Mags_A1-31	0.08	615	12	<5	35	0.34	0.92	130	<0.05	140	1.8	94	15	11,000	8.6	<0.02	51	65	0.20	80	110
T6-Mags_A3-33	0.07	1,520	48	<5	46	0.99	0.71	210	<0.05	1,500	7.5	56	23	55,000	45	<0.02	96	600	0.80	130	130
T7-CrFloat_A1-35	0.06	690	7.2	<5	21	0.18	0.73	30	<0.05	57	1.8	80	5.4	9,400	4.3	<0.02	16	28	0.20	94	140
T7-CrRoast_A1-36	<0.05	1,970	6.5	12	53	0.19	1.2	540	<0.05	100	18	**110**	14	59,000	10	<0.02	92	49	1.8	**1,700**	**2,300**
T8-N/M-MSP_A1-37	<0.05	337	11	<5	13	0.20	0.69	150	<0.05	80	0.5	26	49	3,400	4.5	<0.02	60	35	<0.2	47	27
T8-N/M-MSP_A3-39	<0.05	644	14	<5	77	0.41	0.68	150	<0.05	450	1.6	16	13	10,000	13	<0.02	86	180	0.60	63	36

Tails Sample	Mo	Na	Ni	Pb	Rb	S	Sb	Sc	Se	Sn	Sr	Th	Ti	Tl	U	V	W	Y	Yb	Zn	Zr
T1-FPP-OS_A1-1	2.8	150	6.5	9.2	3.1	130	1.0	5.1	0.35	1.1	5.3	54	220	<0.05	3.9	290	<0.5	17	0.68	27	10
T1-FPP-OS_A3-3	2.8	280	22	9.0	6.2	380	1.1	14	0.52	1.2	11	21	210	0.26	2.5	360	<0.5	16	1.5	170	17
T2-FPP-FT_A3-9	2.8	430	32	19	25	300	0.51	14	0.45	4.9	28	32	290	0.32	2.7	320	<0.5	17	1.4	170	29
T2-FPP-FT_A3-10	2.9	420	29	17	23	280	0.56	13	0.43	4.7	26	32	280	0.29	2.5	320	<0.5	17	1.3	170	31
T2-FPP-FT_A3-11	2.8	430	33	19	26	300	0.52	14	0.43	5.1	29	34	300	0.33	2.7	330	<0.5	18	1.4	170	33
T2-FPP-FT_A3-12	2.9	430	32	19	24	280	0.61	14	0.43	5.4	28	33	300	0.31	2.7	320	<0.5	17	1.4	170	34
T3-WCP-CT_A1-13	0.20	28	1.3	2.8	1.1	7.0	0.12	0.71	<0.05	<0.5	2.0	7.0	140	<0.05	0.44	13	<0.5	2.1	0.13	3.8	5.0
T3-WCP-CT_A1-16	0.19	28	1.2	2.6	1.1	7.0	0.12	0.67	<0.05	<0.5	2.2	7.0	130	<0.05	0.42	13	<0.5	2.1	0.12	3.5	4.1
T3-WCP-CT_A3-19	0.18	28	2.3	2.3	1.8	41	0.13	1.2	<0.05	<0.5	3.3	6.5	120	<0.05	0.52	27	<0.5	3.3	0.23	17	4.3
T3-WCP-CT_A3-22	0.17	24	2.1	1.7	1.4	25	0.12	1.1	<0.05	<0.5	2.3	6.2	75	<0.05	0.49	25	<0.5	2.9	0.20	16	4.0
T4-REMC-GT_A1-25	0.46	94	3.6	**48**	0.47	56	0.19	1.5	**1.8**	0.60	32	**380**	120	0.11	39	9.9	<0.5	**220**	7.7	20	7.1
T5-N/M-GT_A1-29	0.30	16	3.5	5.0	0.57	<5	0.21	1.1	<0.05	0.80	1.4	9.1	210	0.08	0.90	16	<0.5	3.3	0.42	7.2	10
T6-Mags_A1-31	1.1	140	19	43	0.34	26	1.3	9.5	0.13	12	4.9	100	1,600	0.48	5.6	130	<0.5	29	3.5	34	43
T6-Mags_A3-33	0.72	120	72	39	1.4	100	0.98	9.3	0.98	6.5	13	200	440	0.64	21	160	<0.5	140	8.0	100	13
T7-CrFloat_A1-35	0.85	32	11	32	0.10	27	1.1	4.6	0.050	9.8	2.6	57	1,800	2.5	2.3	94	<0.5	8.6	0.93	31	27
T7-CrRoast_A1-36	0.17	72	26	45	0.51	270	0.83	11	0.060	6.0	6.4	50	**2,600**	0.54	1.9	66	<0.5	9.5	0.92	94	9.7
T8-N/M-MSP_A1-37	0.77	31	11	14	0.71	8.0	0.66	12	0.12	3.5	3.6	67	330	0.66	7.0	59	<0.5	42	6.2	38	57
T8-N/M-MSP_A3-39	0.33	69	4.4	22	1.1	38	0.48	12	0.32	2.9	12	130	260	0.42	8.2	60	<0.5	93	9.6	39	34

Table 9: Geochemical abundance index (>3 indicates enrichment relative to average crustal abundance)

Tails Sample	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cu	Fe	Ga	Hg	K	La	Li	Mg	Mn
T1-FPP-OS_A1-1	-2	-4	**6**	-9	-4	-3	0	-11	-3	1	-4	-1	-4	-2	-1	-3	-6	1	-3	-7	-7
T1-FPP-OS_A3-3	-2	-4	**7**	-9	-4	-1	1	-7	-3	-1	-1	-1	-3	1	-2	-3	-6	-1	-3	-6	-3
T2-FPP-FT_A3-9	-2	-2	**6**	-7	-3	-1	**3**	-7	-3	0	-1	-1	-3	0	-1	-2	-5	0	-1	-5	-3
T2-FPP-FT_A3-10	-2	-2	**6**	-7	-3	-1	**3**	-7	-3	0	-1	-1	-3	0	-1	-2	-5	0	-1	-5	-3
T2-FPP-FT_A3-11	-2	-2	**6**	-7	-3	-1	**3**	-7	-3	0	-1	-1	-3	0	-1	-2	-4	0	0	-5	-3
T2-FPP-FT_A3-12	-2	-2	**6**	-7	-3	-1	**3**	-7	-3	0	-1	-1	-3	0	-1	-2	-5	0	-1	-5	-3
T3-WCP-CT_A1-13	-2	-7	1	-9	-6	-7	-2	-14	-3	-2	-7	-5	-8	-6	-4	-3	-8	-2	-6	-9	-8
T3-WCP-CT_A1-16	-2	-7	1	-9	-6	-7	-2	-14	-3	-2	-7	-5	-8	-6	-4	-3	-8	-2	-6	-9	-8
T3-WCP-CT_A3-19	-2	-7	3	-9	-7	-4	-2	-11	-3	-2	-4	-4	-8	-3	-4	-3	-7	-2	-5	-9	-6
T3-WCP-CT_A3-22	-2	-8	2	-9	-7	-4	-2	-12	-3	-2	-5	-5	-8	-3	-4	-3	-8	-2	-6	-9	-6
T4-REMC-GT_A1-25	-2	-10	**4**	-9	-2	-6	**4**	-8	-3	**5**	-7	-4	-5	-7	2	-3	-10	**5**	-7	-11	-8
T5-N/M-GT_A1-29	-2	-9	1	-9	-7	-7	0	-11	-3	-3	-7	-4	-6	-6	-5	-3	-9	-3	-8	-10	-8
T6-Mags_A1-31	0	-8	2	-9	-4	-4	**4**	-9	-3	0	-4	-1	-2	-2	-2	-3	-9	0	-7	-9	-4
T6-Mags_A3-33	-1	-6	**4**	-9	-4	-2	**3**	-8	-3	**4**	-2	-1	-2	0	1	-3	-8	**4**	-5	-8	-3
T7-CrFloat_A1-35	-1	-7	2	-9	-5	-4	**3**	-11	-3	-1	-4	-1	-4	-3	-3	-3	-11	-1	-7	-9	-3
T7-CrRoast_A1-36	-2	-6	2	-7	-4	-4	**4**	-7	-3	0	-1	0	-2	0	-1	-3	-8	0	-4	-4	1
T8-N/M-MSP_A1-37	-2	-9	2	-9	-6	-4	**3**	-9	-3	0	-6	-3	-1	-4	-3	-3	-9	0	-8	-10	-6
T8-N/M-MSP_A3-39	-2	-8	3	-9	-3	-3	**3**	-9	-3	2	-4	-3	-3	-3	-1	-3	-9	2	-6	-9	-5
Tails Sample	**Mo**	**Na**	**Ni**	**Pb**	**Rb**	**S**	**Sb**	**Sc**	**Se**	**Sn**	**Sr**	**Th**	**Ti**	**Tl**	**U**	**V**	**W**	**Y**	**Yb**	**Zn**	**Zr**
T1-FPP-OS_A1-1	0	-8	-4	-1	-5	-2	-7	-2	2	-2	-7	2	-5	-5	0	0	-10	-1	-3	-2	-5
T1-FPP-OS_A3-3	0	-7	-2	-1	-4	0	-7	-1	3	-1	-6	0	-5	-2	-1	1	-10	-1	-2	1	-4
T2-FPP-FT_A3-9	0	-6	-2	0	-2	0	-8	-1	3	1	-4	1	-5	-1	0	0	-10	-1	-2	1	-3
T2-FPP-FT_A3-10	0	-6	-2	0	-3	0	-8	-1	3	1	-4	1	-5	-2	-1	0	-10	-1	-2	1	-3
T2-FPP-FT_A3-11	0	-6	-2	0	-2	0	-8	-1	3	1	-4	1	-5	-1	0	0	-10	-1	-2	1	-3
T2-FPP-FT_A3-12	0	-6	-2	0	-2	0	-8	-1	3	1	-4	1	-5	-2	0	0	-10	-1	-2	1	-3
T3-WCP-CT_A1-13	-3	-10	-7	-3	-7	-6	-10	-5	-2	-4	-8	-1	-6	-5	-3	-4	-10	-4	-5	-5	-6
T3-WCP-CT_A1-16	-4	-10	-7	-3	-7	-6	-10	-5	-2	-4	-8	-1	-6	-5	-3	-4	-10	-4	-5	-5	-6
T3-WCP-CT_A3-19	-4	-10	-6	-3	-6	-3	-10	-4	-2	-4	-7	-1	-6	-5	-3	-3	-10	-4	-4	-3	-6
T3-WCP-CT_A3-22	-4	-10	-6	-4	-7	-4	-10	-4	-2	-4	-8	-2	-7	-5	-3	-3	-10	-4	-5	-3	-6
T4-REMC-GT_A1-25	-2	-9	-5	1	-8	-3	-9	-4	**5**	-2	-4	**4**	-6	-3	**3**	-5	-10	2	1	-2	-5
T5-N/M-GT_A1-29	-3	-11	-5	-2	-8	-7	-9	-4	-2	-2	-9	-1	-5	-3	-2	-4	-10	-4	-4	-4	-5
T6-Mags_A1-31	-1	-8	-3	1	-9	-4	-7	-1	1	2	-7	2	-2	-1	1	-1	-10	-1	-1	-2	-3
T6-Mags_A3-33	-2	-8	-1	1	-7	-2	-7	-1	**4**	1	-5	**3**	-4	0	3	-1	-10	2	1	0	-4
T7-CrFloat_A1-35	-1	-10	-3	1	-10	-4	-7	-2	-1	2	-8	2	-2	1	-1	-1	-10	-2	-2	-2	-3
T7-CrRoast_A1-36	-4	-9	-2	1	-8	-1	-7	-1	0	1	-6	1	-2	-1	-1	-2	-10	-2	-2	0	-5
T8-N/M-MSP_A1-37	-2	-10	-3	-1	-8	-6	-8	-1	1	0	-7	2	-5	0	1	-2	-10	0	0	-2	-2
T8-N/M-MSP_A3-39	-3	-9	-5	0	-7	-3	-8	-1	2	0	-6	3	-5	-1	1	-2	-10	1	1	-2	-3

4.4 Saline potential

The pH and salinity of three water leach solutions at different solid to liquid ratios is given in Table 10. As expected, the Fine Tails (T2) stream produces the highest salinity leachates but the amount of dissolved solids is low compared to the regional groundwater concentrations. Area 3 has higher soluble concentrations than Area 1.

Table 10: Comparison of pH and EC for different water leach ratios

Tails Sample	pH 1:2	pH 1:5	pH 1:20	EC 1:2	EC 1:5	EC 1:20
				µS/cm		
T1-FPP-OS_A1-2	5.7	5.9	5.3	170	86	29
T1-FPP-OS_A3-4	7.6	6.5	6.1	400	168	44
T2-FPP-FT_A3-9	7.2	6.2	6.2	410	147	42
T2-FPP-FT_A3-10	6.7	6.3	6.1	340	139	42
T2-FPP-FT_A3-11	-	6.2	6.3	-	141	41
T2-FPP-FT_A3-12	-	6.2	-	-	135	-
T3-WCP-CT_A1-14	6.7	6.0	6.1	30	14	6.0
T3-WCP-CT_A1-17	6.9	6.1	6.1	30	13	5.0
T3-WCP-CT_A3-20	7.4	6.6	6.3	30	14	5.0
T3-WCP-CT_A3-24	7.5	6.6	6.1	30	14	5.0
T4-REMC-GT_A1-25	7.6		6.4	50	-	9.0
T5-N/M-GT_A1-30	7.3	6.4	6.2	40	15	5.0
T6-Mags_A1-32	7.5	6.7	6.5	70	31	10
T6-Mags_A3-34	7.3	6.6	6.4	70	33	11
T7-CrFloat_A1-35	-	-	5.7	-	-	12
T7-CrRoast_A1-36	-	-	8.5	-	-	158
T8-N/M-MSP_A1-38	7.1	6.6	6.4	50	26	9.0
T8-N/M-MSP_A3-40	7.2	6.7	6.4	70	33	11

4.5 Leach testing

Several different types of leach solutions were tested to determine under what conditions metal leaching may occur. Table 11 details the results of water leaching at a 1:20 solid to water ratio. Table 12 details the results of water leaching at a 1:5 solid to water ratio. Table 13 details the results of analysis of the NAG liquor after complete oxidation of all reactive minerals. Table 14 details the results of the ASLP leach which is buffered at a pH of 5 with nitric acid. Table 15 details the results of analysis of the decant water from the Fine Tails (T2) slurry.

The two leaching ratios represent different water regimes such as rainfall or contact with groundwater The NAG and ASLP leach tests represent aggressive weathering conditions that would only occur over a long period of time or under mild acid generating conditions. The decant fluid represents an aged leach at a realistic slurry ratio.

Green bold values in the tables indicate greater than ANZG while blue bold values indicate values exceeding the ANZG hardness modified trigger values.

4.5.1 Metalliferous Leaching Potential

The following summarises the results of the four leach tests conducted on tailings material:

- Elements that appear to show no potential for leaching include silver, bismuth and selenium based on a below detection limit in all leach solutions, even the more aggressive ASLP.
- Elements that appear to have rare potential for leaching based on detectable concentrations in only the ASLP test include beryllium, cadmium, ytterbium, while tungsten is only detected in the NAG liquor
- Elements that appear to show an unlikely potential (i.e. seldom detected in water leach) for leaching include mercury, scandium and tin. Both Hg and Sn occur at low concentrations, below the ANZG, while Sc does not have an ANZG.
- Elements with a possible chance of leaching: boron, cerium, cobalt, copper, iron, gallium, lanthanum, molybdenum, nickel, lead, antimony, thorium, thallium, uranium, yttrium and zircon. Of these all, or the majority, of solutions with detectable boron, gallium, molybdenum, lead and antimony occur below ANZG and are not a concern. Cobalt and uranium are below the ANZG in all of the water leach solutions with only the ASLP and one NAG solution (cobalt) exceeding the ANZG. Cerium, thorium, yttrium and zircon do not have an ANZ guideline.
- Copper occurs at high concentrations in ASLP solutions but is below detectable limits in all NAG solutions. In the water leach solutions copper only exceeds the ANZG in tailings material that occurs further down the process stream (Mags and non-mags circuit) and is at low concentrations in solutions of oversize, coarse and fine tails.
- Iron occurs above the ANZG in 16% of solutions the majority of which are in the 1:5 water leach solutions, and low or below detectable concentrations in the ASLP and NAG solutions.
- The detection limit for lanthanum is above the ANZG and is not achievable by conventional laboratories thus any concentrations below the detection limit are considered to be below the ANZG. Lanthanum occurs in monazite and is present in the majority of solutions except NAG liquor from oversize, fine and coarse tails. Significantly, lanthanum is not detected in the fines supernatant. This indicates that while highly soluble in water and slightly acidic solutions - over time, these concentrations may be ameliorated by exchange onto clay surfaces as the supernatant solutions are aged.
- Nickel occurs above the ANZG in 16% of solutions. The majority of these are ASLP leaches and the water and NAG solutions have low to non-detectable concentrations.
- The detection limit for thallium is above the very low ANZG and is not achievable by conventional laboratories thus any concentrations below the detection limit are considered to be below the ANZG. Thallium is not readily soluble in the water leach

solutions or the NAG liquor and main leaches out in the ASLP solutions and from the downstream process tails, particularly the non-mags MSP tails.

- Elements which appear to have a high potential for leaching include aluminium, arsenic, chromium, copper, manganese, vanadium and zinc. Manganese does not occur above ANZG in any solutions.
- Soluble and non-toxic elements that are detected in all leach solutions include barium, lithium, rubidium, silica, strontium and titanium, and thus it should be assumed are almost certain to occur in any tailings leachates but as these elements are of low ecotoxicity there are unlikely to be adverse consequences.
- Of the elements with a moderate to high potential to occur in leach test solutions, aluminium, chromium, lanthanum and vanadium frequently occur above the ANZG in the water leach solutions, while copper, thallium and zinc occasionally occur above ANZG in water leach solutions.
- As a result of the elevated soluble chromium concentrations, speciation was conducted on the water leach and ASLP solutions. Hexavalent chromium was detected in 68% of these solutions, with 49% occurring above the ANZG.
- The REMC tails has the highest concentrations of cerium, gallium, lanthanum, lead, uranium, yttrium, ytterbium, due to the nature of the separation process.

Table 11: Water leach testing 1:20 (mg/L)

Tails Sample	pH	EC	TDS	HCO_3	CO_3	Al	As	B	Ba	Ca	Ce	Cl	Co	Cr	Cr^{3+}	Cr^{6+}	Cu	F	Fe	Ga	Hg	K	La
ANZG	5.5-8.3	-	-	-	-	0.0008	0.013	0.94	-	-	-	-	0.028	0.001	0.0033	0.001	0.0014	-	0.3	0.018	0.006	-	0.00004
T1-FPP-OS_A1-1	5.3	29	16	<1	<1	0.035	<0.001	0.011	0.019	<0.1	<0.0005	2.0	0.0001	<0.0005	-	-	<0.0001	<0.05	0.0080	<0.0001	<0.0001	0.80	<0.0001
T2-FPP-FT_A3-9	6.1	44	24	<1	<1	0.41	0.0020	0.046	0.0009	0.1	<0.0005	5.0	0.0001	0.0013	0.001	<0.001	0.0004	0.53	0.30	0.00010	<0.0001	0.90	0.00020
T2-FPP-FT_A3-10	6.2	42	23	<1	<1	0.43	0.0020	0.048	0.0018	0.2	0.00070	5.0	0.0002	0.0018	0.001	<0.001	0.0004	0.55	0.34	0.00020	<0.0001	0.80	0.00040
T2-FPP-FT_A3-11	6.1	42	23	<1	<1	0.46	0.0030	0.048	0.0011	0.1	0.00080	5.0	0.0002	0.0022	0.001	0.001	0.0010	0.54	0.33	0.00020	<0.0001	0.80	0.00040
T2-FPP-FT_A3-12	6.3	41	22	<1	<1	0.33	0.0030	0.049	0.0038	0.2	<0.0005	4.0	<0.0001	0.0011	0.001	<0.001	0.0005	0.57	0.26	0.00010	<0.0001	0.70	0.00020
T3-WCP-CT_A1-13	6.1	6.0	<5	1.0	<1	0.19	0.0010	<0.005	0.0007	<0.1	<0.0005	<1	<0.0001	0.0036	<0.001	0.003	<0.0001	0.090	0.047	<0.0001	<0.0001	0.20	<0.0001
T3-WCP-CT_A1-16	6.1	5.0	<5	<1	<1	0.15	0.0010	<0.005	0.0005	<0.1	<0.0005	<1	<0.0001	0.0033	0.001	0.002	<0.0001	0.090	0.038	<0.0001	<0.0001	0.20	<0.0001
T3-WCP-CT_A3-19	6.3	5.0	<5	<1	<1	0.089	0.0060	<0.005	0.0011	<0.1	<0.0005	<1	<0.0001	0.0030	<0.001	0.003	0.0001	<0.05	0.22	<0.0001	<0.0001	0.20	0.00010
T3-WCP-CT_A3-22	6.1	5.0	<5	<1	<1	0.089	0.0060	<0.005	0.0014	0.1	<0.0005	<1	<0.0001	0.0030	<0.001	0.003	0.0002	<0.05	0.21	<0.0001	<0.0001	0.20	<0.0001
T4-REMC-GT_A1-25	6.4	9.0	5.0	<1	<1	0.031	<0.001	<0.005	0.13	0.7	0.014	<1	<0.0001	0.0008	-	-	0.0007	<0.05	<0.005	0.00050	<0.0001	<0.1	0.0063
T5-N/M-GT_A1-29	6.2	5.0	<5	<1	<1	0.011	0.0030	<0.005	0.0057	0.3	<0.0005	<1	<0.0001	0.0013	<0.001	0.001	0.0003	<0.05	<0.005	<0.0001	<0.0001	<0.1	<0.0001
T6-Mags_A1-31	6.5	10	6.0	<1	<1	0.044	0.021	<0.005	0.0007	<0.1	0.0026	<1	<0.0001	0.011	<0.001	0.010	0.0028	0.19	0.043	0.00020	<0.0001	<0.1	0.0010
T6-Mags_A3-33	6.4	11	6.0	<1	<1	0.041	0.0090	0.0080	0.0021	<0.1	<0.0005	<1	<0.0001	0.0072	<0.001	0.007	0.0044	0.27	0.051	<0.0001	<0.0001	0.20	0.00010
T7-CrFloat_A1-35	5.7	12	7.0	<1	<1	0.11	<0.001	<0.005	0.011	0.5	<0.0005	<1	<0.0001	<0.0005	<0.001	<0.001	0.0012	0.61	<0.005	<0.0001	<0.0001	0.20	<0.0001
T7-CrRoast_A1-36	8.5	158	87	1.0	6.0	0.40	0.23	0.0060	0.051	21	<0.0005	1.0	<0.0001	<0.0005	<0.001	<0.001	0.0077	0.08	<0.005	0.0023	0.00070	0.10	<0.0001
T8-N/M-MSP_A1-37	6.4	9.0	5.0	<1	<1	0.011	0.0040	<0.005	0.0012	0.5	<0.0005	<1	<0.0001	0.0085	<0.001	0.008	0.0071	0.26	<0.005	<0.0001	0.00010	0.20	0.0001
T8-N/M-MSP_A3-39	6.4	11	6.0	<1	<1	0.035	0.0030	0.006	0.0018	0.5	<0.0005	<1	<0.0001	0.0087	<0.001	0.008	0.0045	0.31	0.030	<0.0001	<0.0001	0.30	<0.0001

Tails Sample	Li	Mg	Mn	Mo	Na	Ni	P_SR	Pb	Rb	S	Sb	Si	Se	Sn	Sr	Th	Ti	Tl	U	V	Y	Zn	Zr
ANZG	-	-	1.9	0.034	-	0.011	-	0.0034	-	-	0.009	-	0.011	0.003	-	-	-	0.00003	0.0005	0.006	-	0.008	-
T1-FPP-OS_A1-1	0.0032	0.10	0.0020	<0.001	3.8	<0.001	<0.01	<0.0001	0.001	2.3	<0.0001	1.6	<0.001	<0.0001	0.0016	<0.0001	<0.0005	<0.0001	<0.0001	<0.0001	<0.0002	0.0070	<0.0001
T2-FPP-FT_A3-9	0.0022	0.20	0.0009	0.0020	6.9	<0.001	<0.01	0.0001	0.0008	2.8	0.00010	5.6	<0.001	<0.0001	0.0019	0.00010	0.016	<0.0001	<0.0001	0.0041	<0.0002	0.0030	0.0017
T2-FPP-FT_A3-10	0.0022	0.20	0.0012	0.0020	6.6	<0.001	<0.01	0.0002	0.0007	2.6	0.00010	5.7	<0.001	<0.0001	0.0022	0.00020	0.023	<0.0001	<0.0001	0.0056	<0.0002	0.0030	0.0021
T2-FPP-FT_A3-11	0.0022	0.10	0.0014	0.0020	6.5	<0.001	0.01	0.0006	0.0008	2.4	0.00010	5.5	<0.001	0.00010	0.0022	0.00020	0.026	<0.0001	<0.0001	0.0062	<0.0002	0.0040	0.0022
T2-FPP-FT_A3-12	0.0020	0.10	0.0008	0.0020	6.4	<0.001	<0.01	0.0001	0.0007	2.4	0.00010	5.6	<0.001	<0.0001	0.0016	0.00010	0.015	<0.0001	<0.0001	0.0059	<0.0002	0.0020	0.0013
T3-WCP-CT_A1-13	0.0008	<0.1	<0.0001	<0.001	0.70	<0.001	<0.01	<0.0001	0.0003	0.20	<0.0001	0.68	<0.001	<0.0001	<0.0001	<0.0001	0.0070	<0.0001	<0.0001	0.0015	<0.0002	<0.001	0.00050
T3-WCP-CT_A1-16	0.0007	<0.1	<0.0001	<0.001	0.70	<0.001	<0.01	<0.0001	0.0002	0.20	<0.0001	0.60	<0.001	<0.0001	<0.0001	<0.0001	0.0059	<0.0001	<0.0001	0.0016	<0.0002	<0.001	0.00040
T3-WCP-CT_A3-19	0.0006	<0.1	0.0006	<0.001	0.60	<0.001	0.02	<0.0001	0.0002	<0.1	<0.0001	0.59	<0.001	<0.0001	0.0008	<0.0001	0.011	<0.0001	<0.0001	0.0055	<0.0002	0.0010	0.00070
T3-WCP-CT_A3-22	0.0006	<0.1	0.0006	<0.001	0.60	<0.001	0.02	<0.0001	0.0002	<0.1	<0.0001	0.60	<0.001	<0.0001	0.0009	<0.0001	0.010	<0.0001	<0.0001	0.0053	<0.0002	0.0010	0.00070
T4-REMC-GT_A1-25	0.0002	0.20	0.0004	<0.001	0.50	<0.001	<0.01	0.0002	0.0003	0.20	<0.0001	0.16	<0.001	0.00030	0.011	0.0018	0.0026	<0.0001	0.00030	0.0001	0.0020	<0.001	0.00050
T5-N/M-GT_A1-29	0.0001	<0.1	0.0001	<0.001	0.40	<0.001	<0.01	<0.0001	0.0002	<0.1	<0.0001	0.28	<0.001	<0.0001	0.0014	0.00010	0.0057	<0.0001	<0.0001	0.0031	<0.0002	<0.001	0.0015
T6-Mags_A1-31	0.0003	<0.1	0.0012	0.0020	1.8	0.0010	0.030	0.0003	0.0001	0.30	<0.0001	0.81	<0.001	0.00010	0.0001	0.00080	0.047	<0.0001	0.00010	0.027	0.0008	0.0030	0.0070
T6-Mags_A3-33	0.0018	<0.1	0.0004	0.0010	1.8	0.010	0.010	<0.0001	0.0003	0.20	<0.0001	1.0	<0.001	<0.0001	0.0004	0.00020	0.013	<0.0001	<0.0001	0.0079	0.0002	0.0020	0.0020
T7-CrFloat_A1-35	0.0004	0.10	0.0021	<0.001	0.80	0.0060	<0.01	<0.0001	0.0003	0.30	<0.0001	0.35	<0.001	0.00010	0.0036	<0.0001	<0.0005	0.0019	<0.0001	0.0004	<0.0002	0.012	0.00070
T7-CrRoast_A1-36	0.0049	1.3	0.0007	0.0070	0.30	<0.001	0.12	<0.0001	0.0003	16	0.0024	1.9	<0.001	0.00030	0.066	<0.0001	<0.0005	0.00020	<0.0001	0.64	<0.0002	<0.001	0.00010
T8-N/M-MSP_A1-37	0.0004	0.20	0.0002	0.0010	0.70	0.0020	<0.01	<0.0001	0.0005	0.20	<0.0001	0.71	<0.001	<0.0001	0.0017	0.00020	0.014	0.00010	<0.0001	0.0066	0.0003	0.0020	0.0052
T8-N/M-MSP_A3-39	0.0020	0.10	0.0001	<0.001	1.3	<0.001	<0.01	<0.0001	0.0006	0.30	<0.0001	0.93	<0.001	0.00010	0.0025	<0.0001	0.0056	0.00010	<0.0001	0.0034	<0.0002	0.0020	0.0016

Parameters analysed for but not shown, as all concentrations below limit of reporting: Ag <0.0001, Be <0.0001, Bi <0.0001, Cd <0.0001, Sc <0.0005, W <0.002, Yb <0.0005

Table 12: Water leach testing 1:5 (mg/L)

Tails Sample	pH	EC	TDS	HCO_3	CO_3	Al	As	B	Ba	Ca	Cd	Ce	Cl	Co	Cr	Cr^{3+}	Cr^{6+}	Cu	F	Fe	Ga	Hg	K
ANZG	5.5-8.3	-	-	-	-	0.0008	0.013	0.94	-	-		-	-	0.028	0.001	0.0033	0.001	0.0014	-	0.3	0.018	0.006	-
T1-FPP-OS_A1-2	5.9	86	47	<1	<1	0.015	<0.001	0.037	0.10	0.9	<0.0001	<0.0005	7.0	0.0010	<0.0005	-	-	<0.0001	<0.05	0.095	<0.0001	<0.0001	2.4
T1-FPP-OS_A1-4	6.5	168	92	<1	<1	0.011	<0.001	0.080	0.050	1.2	<0.0001	<0.0005	21	0.0001	0.0027	0.0030	<0.001	0.0001	0.46	0.0080	<0.0001	0.00010	2.5
T2-FPP-FT_A3-9	6.2	147	81	<1	<1	0.093	<0.001	0.13	0.0046	0.9	<0.0001	<0.0005	19	<0.0001	0.0006	-	-	0.0004	0.48	0.10	<0.0001	<0.0001	2.3
T2-FPP-FT_A3-10	6.3	139	76	<1	<1	0.19	<0.001	0.13	0.0046	0.9	<0.0001	<0.0005	19	0.0001	0.0009	-	-	0.0004	0.51	0.21	<0.0001	<0.0001	2.1
T2-FPP-FT_A3-11	6.2	141	77	<1	<1	0.41	0.0010	0.13	0.0042	0.9	<0.0001	<0.0005	20	0.0001	0.0012	0.0010	<0.001	0.0004	0.48	0.44	<0.0001	<0.0001	2.1
T2-FPP-FT_A3-12	6.2	135	74	<1	<1	0.72	0.0010	0.13	0.0045	0.8	<0.0001	<0.0005	18	0.0002	0.0025	0.0030	<0.001	0.0008	0.51	0.70	<0.0001	<0.0001	2.1
T3-WCP-CT_A1-14	6.0	14	8	<1	<1	1.9	0.0030	0.015	0.0029	<0.1	<0.0001	0.00090	<1	0.0001	0.014	0.0040	0.011	0.0003	0.30	0.53	0.00030	<0.0001	0.40
T3-WCP-CT_A1-17	6.1	13	7	<1	<1	0.84	0.0020	0.013	0.0016	<0.1	<0.0001	0.00050	<1	<0.0001	0.012	0.0020	0.011	0.0002	0.29	0.23	0.00020	<0.0001	0.40
T3-WCP-CT_A3-20	6.6	14	8	2	<1	0.87	0.014	0.0090	0.0041	0.3	0.00010	0.0017	<1	0.0003	0.010	0.0060	0.010	0.0009	0.12	2.8	0.00010	<0.0001	0.60
T3-WCP-CT_A3-24	6.6	14	8	2	<1	0.79	0.014	0.0080	0.0035	0.2	<0.0001	0.0016	<1	0.0002	0.0099	0.0070	0.0080	0.0008	0.11	2.6	0.00010	<0.0001	0.50
T5-N/M-GT_A1-30	6.4	15	8	<1	<1	0.032	0.0080	<0.005	0.0007	0.7	<0.0001	0.00090	2.0	<0.0001	0.0049	<0.001	0.0040	0.0009	0.15	0.050	0.00010	<0.0001	0.20
T6-Mags_A1-32	6.7	31	17	2	<1	0.094	0.051	0.013	0.0008	<0.1	<0.0001	0.013	2.0	<0.0001	0.039	0.0070	0.035	0.011	0.70	0.23	0.00060	<0.0001	0.20
T6-Mags_A3-34	6.6	33	18	2	<1	0.250	0.012	0.025	0.0007	0.2	<0.0001	0.0026	3.0	<0.0001	0.025	0.0010	0.025	0.024	0.82	0.51	0.00020	<0.0001	0.40
T8-N/M-MSP_A1-38	6.6	26	14	2	<1	0.027	0.0040	0.013	0.0013	1.2	<0.0001	0.0020	1.0	<0.0001	0.026	0.0040	0.024	0.026	0.68	0.043	0.00010	<0.0001	0.50
T8-N/M-MSP_A3-40	6.7	33	18	2	<1	0.24	0.0030	0.021	0.0023	0.8	<0.0001	0.0012	2.0	<0.0001	0.030	<0.001	0.031	0.013	0.76	0.37	0.00010	<0.0001	0.70

Tails Sample	La	Li	Mg	Mn	Na	Mo	Ni	P_SR	Pb	S	Rb	Sb	Si	Sn	Sr	Th	Ti	Tl	U	V	Y	Zn	Zr
ANZG	0.00004	-	-	1.9	-	0.034	0.011	-	0.0034	-	-	0.009	-	0.003	-	-	-	0.00003	0.0005	0.006	-	0.008	-
T1-FPP-OS_A1-2	<0.0001	0.011	0.90	0.019	11	<0.001	0.0040	<0.01	<0.0001	7.2	0.003	<0.0001	4.3	<0.0001	0.014	<0.0001	<0.0005	<0.0001	<0.0001	0.0002	<0.0002	0.035	<0.0001
T1-FPP-OS_A1-4	<0.0001	0.024	1.3	0.0018	25	<0.001	<0.001	<0.01	<0.0001	10	0.003	<0.0001	5.5	<0.0001	0.025	<0.0001	<0.0005	0.0002	<0.0001	0.0005	<0.0002	0.0030	0.00030
T2-FPP-FT_A3-9	<0.0001	0.0054	1.1	0.0034	21	<0.001	<0.001	0.010	<0.0001	10	0.0016	0.0001	9.8	<0.0001	0.013	<0.0001	0.0055	<0.0001	<0.0001	0.0017	<0.0002	0.0020	0.00060
T2-FPP-FT_A3-10	0.0001	0.0050	1.1	0.0035	20	<0.001	<0.001	<0.01	<0.0001	9.7	0.0014	0.0001	10	<0.0001	0.013	<0.0001	0.0100	<0.0001	<0.0001	0.0027	<0.0002	0.0020	0.00090
T2-FPP-FT_A3-11	0.0002	0.0053	1.0	0.0036	21	<0.001	<0.001	<0.01	0.00010	9.3	0.0014	0.0002	11	<0.0001	0.012	0.0002	0.0170	<0.0001	<0.0001	0.0036	<0.0002	0.0020	0.0013
T2-FPP-FT_A3-12	0.0002	0.0051	0.90	0.0062	20	<0.001	0.0010	0.020	0.00070	9.0	0.0016	0.0001	11	<0.0001	0.012	0.0001	0.0150	<0.0001	<0.0001	0.0034	<0.0002	0.0020	0.0012
T3-WCP-CT_A1-14	0.0005	0.0023	<0.1	0.0005	2.2	0.0010	<0.001	<0.01	0.00020	0.80	0.0007	<0.0001	4.2	0.0001	0.0008	0.0003	0.0470	<0.0001	<0.0001	0.0060	0.0003	0.0030	0.0033
T3-WCP-CT_A1-17	0.0003	0.0020	<0.1	0.0003	2.0	0.0010	<0.001	<0.01	0.00010	0.70	0.0005	<0.0001	2.6	<0.0001	0.0004	0.0002	0.0270	<0.0001	<0.0001	0.0042	<0.0002	0.0020	0.0020
T3-WCP-CT_A3-20	0.0007	0.0017	0.10	0.0022	2.1	<0.001	0.0010	0.060	0.00040	0.30	0.0004	<0.0001	2.8	<0.0001	0.0021	0.0004	0.0230	<0.0001	0.0001	0.015	0.0007	0.0080	0.0019
T3-WCP-CT_A3-24	0.0006	0.0014	0.10	0.0019	2.1	<0.001	<0.001	0.050	0.00040	0.30	0.0004	<0.0001	2.7	0.0001	0.0021	0.0004	0.0190	<0.0001	0.0001	0.015	0.0006	0.0060	0.0017
T5-N/M-GT_A1-30	0.0004	0.0004	0.20	0.0006	1.3	0.0010	<0.001	<0.01	0.00050	0.40	0.0005	<0.0001	0.88	0.0002	0.0026	0.0006	0.0350	<0.0001	<0.0001	0.0062	0.0007	0.0030	0.011
T6-Mags_A1-32	0.0052	0.0009	<0.1	0.0041	5.8	0.0090	0.0040	0.070	0.0011	1.0	0.0003	0.0001	2.0	0.0005	0.0003	0.0050	0.1500	<0.0001	0.0005	0.030	0.0038	0.0040	0.040
T6-Mags_A3-34	0.0012	0.0053	<0.1	0.0018	6.0	0.0040	0.080	0.020	0.00040	0.70	0.0007	<0.0001	2.7	0.0003	0.0011	0.0015	0.0540	<0.0001	0.0001	0.011	0.0017	0.011	0.014
T8-N/M-MSP_A1-38	0.0008	0.0013	0.50	0.0010	2.2	0.0040	0.011	<0.01	0.00040	0.60	0.0011	<0.0001	2.0	0.0005	0.004	0.0016	0.0370	0.0002	0.0003	0.0042	0.0017	0.0090	0.035
T8-N/M-MSP_A3-40	0.0005	0.0065	0.30	0.0011	4.4	0.0010	0.0020	<0.01	0.00040	1.3	0.0015	<0.0001	2.5	0.0005	0.0043	0.0011	0.0470	0.0002	0.0001	0.0048	0.0011	0.0060	0.015

Parameters analysed for but not shown as all concentrations below limit of reporting: Ag <0.0001, Be <0.0001, Bi <0.0001, Sc <0.0005, Se <0.011, W <0.002, Yb <0.0005 mg/L

Table 13: NAG Liquor (mg/L)

Tails Sample	Al	As	B	Ba	Ca	Ce	Cl	Co	Cr	Fe	Ga	K	La	Li	Mg	Mn	Mo
ANZG	0.0008	0.013	0.94	-	-	-	-	0.028	0.001	0.3	0.018	-	0.00004	-	-	1.9	0.034
T1-FPP-OS_A1-1	**0.0080**	0.0060	<0.005	0.049	<0.1	<0.0005	<5.0	0.00030	**0.037**	<0.005	<0.0001	<0.1	<0.0001	0.0010	0.20	0.0045	<0.001
T1-FPP-OS_A3-3	<0.005	0.0050	<0.005	0.025	1.1	<0.0005	<5.0	<0.0001	**0.035**	<0.005	<0.0001	<0.1	<0.0001	0.0027	1.0	0.010	0.0010
T2-FPP-FT_A3-9	**0.045**	0.0040	<0.005	0.0079	0.50	<0.0005	<5.0	0.00050	**0.022**	0.021	<0.0001	<0.1	<0.0001	0.0028	0.70	0.036	0.0050
T2-FPP-FT_A3-11	<0.005	0.0040	<0.005	0.0064	0.40	<0.0005	<5.0	0.00050	**0.016**	<0.005	<0.0001	<0.1	<0.0001	0.0027	0.60	0.032	0.0050
T3-WCP-CT_A1-13	**0.024**	0.0040	<0.005	0.018	<0.1	<0.0005	<5.0	0.00020	**0.0065**	<0.005	<0.0001	0.40	<0.0001	0.00050	<0.1	0.0060	<0.001
T3-WCP-CT_A1-14	**0.0080**	0.0040	<0.005	0.037	0.10	<0.0005	<5.0	0.00020	**0.0066**	<0.005	<0.0001	<0.1	<0.0001	0.00060	<0.1	0.0020	<0.001
T3-WCP-CT_A1-16	**0.0080**	0.0050	<0.005	0.015	0.10	<0.0005	<5.0	**0.00430**	**0.0067**	<0.005	<0.0001	<0.1	<0.0001	0.00070	<0.1	0.0035	<0.001
T3-WCP-CT_A1-18	<0.005	0.0030	<0.005	0.016	<0.1	<0.0005	<5.0	0.00040	**0.010**	<0.005	<0.0001	0.30	<0.0001	0.00070	<0.1	0.0012	<0.001
T3-WCP-CT_A3-19	<0.005	0.0030	0.010	0.017	0.20	<0.0005	<5.0	0.00040	**0.0080**	<0.005	<0.0001	0.30	<0.0001	0.00050	<0.1	0.0048	<0.001
T3-WCP-CT_A3-20	**0.0060**	0.0040	0.010	0.017	0.20	<0.0005	<5.0	0.00040	**0.0075**	0.026	<0.0001	1.3	<0.0001	0.00050	<0.1	0.0052	<0.001
T3-WCP-CT_A3-22	<0.005	0.0050	<0.005	0.017	0.20	<0.0005	<5.0	0.00090	**0.0058**	0.017	<0.0001	0.30	<0.0001	0.00050	<0.1	0.012	<0.001
T3-WCP-CT_A3-23	**0.0050**	0.0040	<0.005	0.015	0.20	<0.0005	<5.0	0.00040	**0.0049**	0.0050	<0.0001	0.90	<0.0001	0.00040	<0.1	0.0053	<0.001
T4-REMC-GT_A1-25	<0.005	0.0060	<0.005	0.062	0.20	0.0027	<5.0	0.00040	**0.011**	<0.005	0.00010	<0.1	**0.0013**	0.00010	<0.1	0.0076	<0.001
T5-N/M-GT_A1-29	**0.0060**	0.0070	0.040	0.0040	0.20	0.00070	<5.0	0.00020	**0.016**	<0.005	<0.0001	1.5	**0.00020**	0.00020	<0.1	0.049	<0.001
T6-Mags_A1-31	<0.005	**0.020**	<0.005	0.0003	0.20	0.0020	<5.0	0.00030	**0.098**	0.013	<0.0001	0.20	**0.00050**	0.00040	0.10	0.012	0.0030
T6-Mags_A3-33	<0.005	0.011	0.010	<0.0001	0.40	<0.0005	<5.0	0.00020	**0.032**	0.035	<0.0001	<0.1	**0.00020**	0.0010	0.20	0.012	<0.001
T8-N/M-MSP_A1-37	<0.005	**0.017**	<0.005	0.0004	0.40	0.0010	<5.0	0.00030	**0.037**	<0.005	<0.0001	<0.1	**0.00030**	0.00030	0.10	0.030	0.0010
T8-N/M-MSP_A3-39	<0.005	0.013	0.020	0.0025	0.40	<0.0005	<5.0	0.00040	**0.018**	0.0080	<0.0001	<0.1	<0.0001	0.0010	0.10	0.029	<0.001

Tails Sample	Na	Ni	Pb	Rb	S	Sb	Si	Sr	Th	Ti	Tl	U	V	W	Y	Zn	Zr
ANZG	-	0.011	0.0034	-	-	0.009	-	-	-	-	0.00003	0.0005	0.006		-	0.008	-
T1-FPP-OS_A1-1	0.20	<0.001	<0.0001	0.00040	0.60	<0.0001	0.59	0.0025	<0.0001	0.0070	<0.0001	<0.0001	**0.084**	<0.002	<0.0002	0.0080	<0.0001
T1-FPP-OS_A3-3	0.40	<0.001	<0.0001	0.0010	0.40	<0.0001	2.0	0.014	<0.0001	0.0086	**0.00020**	<0.0001	**0.17**	<0.002	<0.0002	<0.001	<0.0001
T2-FPP-FT_A3-9	0.60	<0.001	<0.0001	0.00060	0.40	0.00010	2.7	0.0088	<0.0001	0.015	<0.0001	0.00010	**0.24**	0.011	<0.0002	<0.001	<0.0001
T2-FPP-FT_A3-11	0.50	<0.001	<0.0001	0.00030	0.40	0.00020	2.6	0.0086	<0.0001	0.012	<0.0001	0.00010	**0.24**	0.010	<0.0002	<0.001	0.00080
T3-WCP-CT_A1-13	<0.1	<0.001	<0.0001	0.00030	<0.1	<0.0001	0.25	0.0016	<0.0001	0.027	<0.0001	0.00010	**0.013**	<0.002	<0.0002	0.0070	<0.0001
T3-WCP-CT_A1-14	<0.1	<0.001	<0.0001	0.00030	<0.1	<0.0001	0.24	0.0025	<0.0001	0.033	<0.0001	<0.0001	**0.012**	<0.002	<0.0002	<0.001	<0.0001
T3-WCP-CT_A1-16	<0.1	<0.001	<0.0001	0.00030	<0.1	<0.0001	0.24	0.0019	<0.0001	0.032	<0.0001	0.00010	**0.013**	<0.002	<0.0002	0.0050	<0.0001
T3-WCP-CT_A1-18	<0.1	<0.001	<0.0001	0.00010	<0.1	<0.0001	0.38	0.0017	<0.0001	0.014	<0.0001	<0.0001	**0.013**	<0.002	<0.0002	<0.001	<0.0001
T3-WCP-CT_A3-19	<0.1	<0.001	<0.0001	0.00010	<0.1	<0.0001	0.43	0.0033	<0.0001	0.012	<0.0001	<0.0001	**0.017**	<0.002	<0.0002	<0.001	<0.0001
T3-WCP-CT_A3-20	<0.1	0.0030	<0.0001	<0.0001	<0.1	<0.0001	0.44	0.0031	<0.0001	0.020	<0.0001	0.00010	**0.017**	<0.002	<0.0002	<0.001	<0.0001
T3-WCP-CT_A3-22	<0.1	<0.001	<0.0001	0.00010	<0.1	<0.0001	0.34	0.0031	<0.0001	0.023	<0.0001	0.00010	**0.017**	<0.002	<0.0002	<0.001	<0.0001
T3-WCP-CT_A3-23	<0.1	<0.001	<0.0001	0.00030	<0.1	<0.0001	0.32	0.0031	<0.0001	0.019	<0.0001	0.00010	**0.016**	<0.002	<0.0002	<0.001	<0.0001
T4-REMC-GT_A1-25	<0.1	0.0060	0.00020	<0.0001	0.30	0.00010	0.11	0.0058	0.00060	0.0078	**0.00030**	**0.0018**	**0.0098**	<0.002	0.00070	**0.038**	<0.0001
T5-N/M-GT_A1-29	<0.1	0.0040	<0.0001	0.00010	<0.1	0.00020	0.29	0.0025	0.00030	0.18	<0.0001	**0.0017**	**0.034**	<0.002	0.00040	**0.010**	0.0038
T6-Mags_A1-31	0.10	0.0090	<0.0001	0.00030	<0.1	0.00040	1.1	0.0021	0.00060	0.30	<0.0001	**0.0020**	**0.23**	0.0040	0.00070	<0.001	0.0060
T6-Mags_A3-33	<0.1	**0.019**	<0.0001	0.00040	<0.1	0.00020	1.3	0.0059	0.00020	0.18	**0.00020**	**0.0010**	**0.21**	0.0050	0.00060	<0.001	0.0016
T8-N/M-MSP_A1-37	<0.1	0.0080	<0.0001	<0.0001	<0.1	0.00030	1.0	0.0024	0.00070	0.24	**0.00040**	**0.0028**	**0.11**	0.0020	0.00090	**0.017**	0.013
T8-N/M-MSP_A3-39	<0.1	0.0020	<0.0001	0.00030	0.10	0.00020	1.2	0.0055	0.00030	0.20	**0.00020**	**0.0015**	**0.16**	0.0040	0.00040	0.0060	0.0051

Parameters analysed for but not shown as all concentrations below limit of reporting: Ag <0.0001, Be <0.0001, Bi <0.0001, Cd <0.0001, Cu <0.0001, Hg <0.0001 Sc <0.0005, Se <0.001, Sn <0.0001, Yb <0.0005

Table 14: ASLP test (mg/L)

Tails Sample	Al	As	B	Ba	Be	Ca	Cd	Ce	Cl	Co	Cr	Cr III	Cr VI	Cu	F	Fe	Ga	K	La	Li
ANZG	0.0008	0.013	0.94	-	0.00013	-	0.0002	-	-	0.028	0.001	0.0033	0.001	0.0014	-	0.3	0.018	-	0.00004	-
T1-FPP-OS_A1-2	**0.61**	<0.001	0.014	0.93	**0.0009**	2.9	<0.0001	0.030	2.0	**0.0039**	**0.081**	**0.072**	<0.001	**0.0034**	0.080	**0.77**	0.0013	1.9	**0.012**	0.0051
T1-FPP-OS_A3-4	**0.48**	<0.001	0.038	0.99	**0.0025**	6.2	<0.0001	0.0059	6.0	**0.024**	**0.061**	**0.055**	<0.001	**0.0038**	0.12	0.059	0.00040	2.9	**0.0027**	0.013
T2-FPP-FT_A3-9	**0.53**	<0.001	0.070	0.30	**0.0024**	19.4	**0.00030**	0.0091	5.0	**0.0066**	**0.0015**	0.0010	<0.001	**0.0053**	0.21	<0.005	0.00040	5.6	**0.0025**	0.013
T2-FPP-FT_A3-12	**0.29**	0.0010	0.090	0.31	**0.0019**	20.2	**0.00030**	0.0084	5.0	**0.0062**	0.0010	<0.001	<0.001	**0.0056**	0.17	<0.005	0.00040	5.6	**0.0023**	0.013
T3-WCP-CT_A1-15	**0.065**	<0.001	0.033	0.15	**0.0002**	1.8	<0.0001	0.0090	<1	0.0003	**0.0042**	**0.0020**	**0.002**	**0.0073**	<0.05	<0.005	0.00040	1.0	**0.0044**	0.0012
T3-WCP-CT_A3-21	**0.070**	0.0010	0.032	0.097	**0.0005**	2.5	<0.0001	0.0031	<1	0.0014	**0.0039**	**0.0020**	**0.002**	**0.0041**	<0.05	<0.005	0.00010	0.80	**0.0014**	0.0011
T4-REMC-GT_A1-26	**0.045**	0.010	0.036	2.2	**0.0002**	3.1	**0.00030**	0.45	<1	0.0011	**0.0083**	**0.0060**	0.001	**0.051**	<0.05	<0.005	**0.021**	0.30	**0.31**	0.0004
T5-N/M-GT_A1-30	**0.048**	0.0030	0.029	0.064	**0.0002**	2.8	**0.00030**	0.022	<1	0.0004	**0.0033**	**0.0020**	0.001	**0.030**	<0.05	<0.005	0.0010	0.40	**0.016**	0.0003
T6-Mags_A1-32	**0.052**	0.0040	0.032	0.097	**0.0004**	4.7	<0.0001	0.0460	<1	0.0019	**0.0066**	**0.0030**	**0.003**	**0.18**	<0.05	<0.005	0.0021	1.4	**0.038**	0.0011
T8-N/M-MSP_A1-38	**0.052**	0.0030	0.036	0.12	**0.0004**	6.9	0.00020	0.032	<1	0.0012	**0.0051**	**0.0040**	<0.001	**1.0**	<0.05	<0.005	0.0015	0.80	**0.024**	0.0007

Tails Sample	Mg	Mn	Na	Ni	P	Pb	Rb	S	Sc	Si	Sn	Sr	Th	Tl	U	V	Y	Yb	Zn	Zr
ANZG	-	1.9	-	0.011	-	0.0034	-	-	-	-	0.003	-	-	0.00003	0.0005	0.006	-	-	0.008	-
T1-FPP-OS_A1-2	2.2	0.057	<0.1	**0.013**	<0.01	0.0006	0.0061	2.9	0.0006	1.6	<0.0001	0.051	0.0001	<0.0001	**0.0025**	0.0001	0.012	0.0008	**0.18**	<0.0001
T1-FPP-OS_A3-4	4.9	0.500	<0.1	**0.022**	<0.01	0.0002	0.008	2.8	<0.0005	4.8	<0.0001	0.14	<0.0001	**0.0013**	**0.0065**	0.0002	0.011	0.0006	**0.029**	<0.0001
T2-FPP-FT_A3-9	19	0.28	<0.1	**0.016**	<0.01	0.0002	0.0077	2.7	<0.0005	8.7	<0.0001	0.27	<0.0001	**0.0003**	**0.0049**	0.0006	0.0071	<0.0005	**0.10**	0.00020
T2-FPP-FT_A3-12	19	0.27	46	**0.017**	<0.01	0.0002	0.008	2.3	<0.0005	8.3	<0.0001	0.28	<0.0001	**0.0003**	**0.0046**	0.0007	0.0068	<0.0005	**0.094**	<0.0001
T3-WCP-CT_A1-15	1.1	0.0074	120	0.004	<0.01	<0.0001	0.0042	0.20	<0.0005	0.47	<0.0001	0.023	<0.0001	**0.0001**	**0.0007**	0.0003	0.0045	<0.0005	**0.038**	<0.0001
T3-WCP-CT_A3-21	0.70	0.014	98	0.005	<0.01	<0.0001	0.0025	0.10	<0.0005	0.66	<0.0001	0.034	<0.0001	**0.0001**	**0.0013**	0.0005	0.0035	<0.0005	**0.034**	<0.0001
T4-REMC-GT_A1-26	0.70	0.016	148	**0.038**	0.080	0.0019	0.0017	0.70	<0.0005	0.49	0.0002	0.075	0.0007	**0.0020**	**0.0220**	0.0002	0.2200	0.019	**0.29**	0.00020
T5-N/M-GT_A1-30	0.40	0.020	91	**0.023**	<0.01	0.0003	0.0031	0.20	<0.0005	0.59	<0.0001	0.025	<0.0001	**0.0008**	**0.0033**	0.0005	0.022	0.0022	**0.15**	0.00020
T6-Mags_A1-32	0.80	0.028	159	**0.090**	<0.01	<0.0001	0.0036	0.30	<0.0005	1.6	<0.0001	0.043	<0.0001	**0.0014**	**0.0053**	0.0008	0.040	0.0024	**0.20**	<0.0001
T8-N/M-MSP_A1-38	1.0	0.036	129	**0.080**	<0.01	0.0001	0.0040	0.20	<0.0005	1.8	<0.0001	0.049	<0.0001	**0.0033**	**0.0052**	0.0006	0.029	0.0022	**0.79**	0.00020

Parameters analysed for but not shown as all concentrations below limit of reporting: Ag <0.0001, Be <0.0001, Bi <0.0001, Cd <0.0001, Cu <0.0001, Hg <0.0001 Sc <0.0005, Se <0.001, Sn <0.0001, Yb <0.0005

Table 15: Decant liquid from Fine Tails (mg/L)

Decant Sample	Al	B	Ba	Ca	Co	Cu	K	Li	Mg	Mn
ANZG	0.0008	0.94	-	-	0.028	0.0014	-	-	-	1.9
T2-FPP-FT_A3-9	<0.005	0.31	0.035	8.6	0.0002	**0.0016**	4.2	0.0047	9.1	0.037
T2-FPP-FT_A3-10	<0.005	0.31	0.036	8.6	0.0002	0.0009	4.1	0.0046	9.0	0.040
T2-FPP-FT_A3-11	<0.005	0.31	0.035	8.6	0.0002	0.0008	4.2	0.0046	9.1	0.040
T2-FPP-FT_A3-12	<0.005	0.30	0.036	8.5	0.0002	0.0006	4.1	0.0047	9.1	0.034
Tails Sample	**Mo**	**Na**	**Rb**	**S**	**Si**	**Sr**	**Tl**	**V**	**Zn**	**Zr**
ANZG	0.034	-	-	-	-	-	0.00003	0.006	0.008	-
T2-FPP-FT_A3-9	0.0010	88	0.0015	26	12	0.088	**0.0001**	0.0017	0.0040	0.00020
T2-FPP-FT_A3-10	0.0010	87	0.0014	25	12	0.091	**0.0001**	0.0018	0.0030	0.00010
T2-FPP-FT_A3-11	<0.001	87	0.0014	25	12	0.087	**0.0001**	0.0016	0.0030	<0.0001
T2-FPP-FT_A3-12	<0.001	87	0.0016	25	11	0.092	**0.0001**	0.0014	0.0040	<0.0001

Parameters analysed for but not shown as all concentrations below limit of reporting: Ag <0.0001, Al <0.005, As < 0.001, Be <0.0001, Bi <0.0001, Cd <0.0001, Ce <0.0005, Cr <0.0005, Fe <0.005, Ga <0.0001, Hg <0.0001, La <0.0001, Ni <0.001, Pb <0.0001, Sb <0.0001, Sc <0.0005, Se <0.001, Sn <0.0001, Th <0.0001, Ti <0.0005, U <0.0001, W <0.002, Y <0.0002, Yb <0.0005

5. TAILINGS AS A POTENTIAL SOURCE OF CONTAMINATION

An assessment of the geochemical characterisation of tailings as a potential Source of contamination is given in Table 16 according to the Qualitative Assessment Criteria detailed in 3.5. The frequency of occurrence is based, not just on how often each metal occurs in leach solutions, but also whether it only occurs in the most aggressive leachate or whether it is readily soluble in water.

The significance of concentrations rating is based on the relative toxicity of the element, (e.g. the significance of high concentrations of a non-toxic element such as strontium leaching out would be negligible as it has low toxicity), and the magnitude of the element concentrations (i.e. how often guideline values are exceeded).

The Magnitude of material assesses from which tailings stream the element leaches. For example: even if a highly toxic element is occurring in a leachate from, for example, REMC tails, the volume of this stream is <0.05% of the total tailings volume, which when diluted with the other tailings streams will result in a low potential to be a source. Similarly, if a highly toxic element is found to occur frequently in a high-volume tailings stream but at low concentrations that do not exceed guideline values, then the consequence of these occurrences would also be low.

In general, tailings appear to show no potential for acid or saline drainage and a slight to moderate potential for metalliferous drainage. There is a moderate to high risk that tailings may constitute a Source of aluminium, arsenic, hexavalent chromium and vanadium. It is well-known that ilmenite concentrates produced from Murray Basin deposits contain high levels of chromium due to the presence of chrome spinel minerals (Pownceby, et al., 2019).

Table 16: Geochemical Assessment of Tailings as a Source of Metalliferous Drainage

Risk Parameter	Frequency of occurrence	Significance of Concentration	Magnitude of Material Volume	Source Potential
Acidity	Unlikely	Negligible	Comprehensive	**Insignificant**
Salinity	Rare	Negligible	Comprehensive	**Insignificant**
Element Leaching: Ba, Li, Rb, Si, Sr, Zr, Ti	Almost Certain	None	Comprehensive	**None**
Element Leaching: Ag, Bi, Ce, P, Se, Sc, W, Y, Yb	None to Unlikely	None	Small - Comprehensive	**None**
Element Leaching: Be Cd, Ga, Hg, Mo, Pb, Sb, Sn	Rare to Possible	Negligible – Minor	Small - Comprehensive	**Insignificant**
Element Leaching: B, Co, Fe, Ni, Th, Tl, U	Unlikely to Likely	Negligible – Moderate	Comprehensive	**Slight**
Element Leaching: Cu, La, Mn, Zn	Possible to Almost Certain	Negligible – Moderate	Comprehensive	**Intermediate**
Element Leaching: Al, As, Cr^{6+}, V	Likely to Almost Certain	Moderate	Comprehensive	**Moderate**
Element Leaching: Cr	Almost Certain	Major	Comprehensive	**High**

6. REFERENCES

1. AMIRA, 2002. *Acid Rock Drainage Test Handbook: Project P387A Prediction and Kinetic Control of Acid Mine Drainage.,* Pp. 42: Australian Mineral Industries Research Association.

2. ANZECC & ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1: The Guidelines; Chapters 1-7,* National Water Quality Management Strategy (NWQMS): Document 4; Australian and New Zealand Environment and Conservation Council and Agriculture and Resources Management Council of Australia and New Zealand: Pp. 314.

3. ANZECC & ARMCANZ, 2000b. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 2: Aquatic Ecosystems – Rationale and Background Information; Chapter 8 ,* National Water Quality Management Strategy (NWQMS): Document. 4; Australian and New Zealand Environment and Conservation Council and Agriculture and Resources Management Council of Australia and New Zealand: Pp. 678.

4. Aquaterra, 2009. *Mallee Zone 5-Year Rolling Salinity Review – B-Register 'Legacy of History' Assessments – Eastern Mallee Model Version 1.2 (EM1.2),* Murray Darling Basin Authority: July 2009.

5. Bowen, H., 1979. *Environmental Chemistry of the Elements,* London: Academic Press.

6. Brodie, R. & Tucker, A., 1993. *Estimation of Leakage Rates Through the Shepparton Formation Aquifer, Deniliquin, New South Wales, Record 1993/88, Australian Geological Survey Organisation,* Environmental Geoscience and Groundwater Program: s.n.

7. Cartwright, I., Hofmann, H., Currell, M. J. & Fifield, L. K., 2017. Decoupling of solutes and water in regional groundwater systems: The Murray Basin, Australia. *Chemical Geology,* pp. Volume 466, 5 September 2017, Pp 466-478.

8. CDM Smith, 2018. *VHM Exploration: Goschen Hydrogeological Assessment,* CDM Smith Australia Pty Ltd, VHM-1000035-GW-RPT-001-V2: 31 May 2018, Pp. 34 .

9. DSE, 2005. *Murray REALM Model User Guide,* s.l.: Department of Sustainability and Environment..

10. Evans, R., 2013. *Geology and hydrogeology,* Mallee Catchment Management Authority, Mallee Salinity Workshop; Sinclair Knight Merz (SKM): Project Number: 1525-2-103: 30 May 30 2012; Pp 30..

11. INAP, 2009. *International Network for Acid Prevention: Global Acid Rock Drainage (GARD) Guide,* Available at: www.gardguide.com/ [Accessed: 1 January 2014].

12. ISC, 2013. *The Third Benchmark of Victorian River Condition,* Part 5, Mallee River Basins: Index of Stream Conditions.

13. McLennan, S. M., 2016. *Sedimentation and Geochemistry of the Loxton-Parilla Sands in the Murray Basin, southeastern Australia.* February 2016 ed. Department of Geology and Geophysics: University of Adelaide.

14. Olshina, A. & Miranda, J., 2011. *Heavy Mineral Sands in Victoria,* GeoScience Victoria Unpublished Report 2011/2.: Department of Primary Industries.

15. Pownceby, M. I., Bruckard, W. J. & Sparrow, G. J., 2019. *Technological developments in processing Australian mineral sand deposits.* The Eleventh International Heavy Minerals Conference, 5–6 August 2019, The Vineyard, Cape Town, South Africa, The Southern African Insitute of Mining and Metallurgy; Pg 105-112.

16. Price, W. A., 2009. *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials,* Mine Environment Neutral Drainage Report 1.20.1; Natural Resources Canada;: Pp. 579.

17. Sobek, A. A., Schuller, W. A., Freeman, J. R. & Smith, R. M., 1978. *Field and Laboratory Methods Applicable to Overburdens and Minesoils,* Report Ref. EPA-600/2-78-054, United States Environmental Protection Agency (USEPA): Pp. 47-50.

18. Standards Australia, 1997a. *AS 4439.2-1997: Wastes, Sediments and Contaminated Soils, Part 2: Preparation of Leachates-Zero Headspace Procedure,* Homebush, Australia: Pp. 7.

19. Standards Australia, 1997b. *AS 4439.3-1997: Wastes, Sediments and Contaminated Soils, Part 3: Preparation of Leachates-Bottle Leaching Procedure,* Homebush, Australia: Pp. 7.

Appendix A: Laboratory Certificates

Up Date Version 2055156/001-034

Level 1, Sample Receivals, Resources & Chemistry Precinct
Cnr Manning Road & Townsing Drive, (Delivery Entrance off Conlon St) BENTLEY WA 6102
T: +61 8 9422 9966

Chem Centre

Level 2 Suite 9, 389 Oxford Street, Mount Hawthorn, 6016
T:+61 08 6216 9228 M: +61 417 986 865
E: colleen.burgers@vhmltd.com.au

VHM Limited

Decants D 35-38

No	Quote 2103045B Label	Mass sample	NAG pH	Full ABA	pH & EC 1:2	Carbon (TC, TOC, TIC)	NAG Liquor [2+3]	ASLP [2+3]	Water Leach# 1:5 [1+2+3]	Water Leach 1:20 [1+2+3]	Decant Analysis [1+2+3]	Acid extract Metals[2]	Mineralogy
1	T1-FPP-OS_A1-1	500 g	1	1	1	1	1			1		1	
2	T1-FPP-OS_A1-2	500 g	1					1	1				
3	T1-FPP-OS_A3-3	500 g	1	1	1	1	1					1	
4	T1-FPP-OS_A3-4	500 g	1					1	1				
5	T2-FPP-FT_A3-9	250 mL	1	1	1	1	1	1	1	1	2§	1	1
6	T2-FPP-FT_A3-10	250 mL	1						1	1	2§	1	
7	T2-FPP-FT_A3-11	250 mL	1	1	1		1		1	1	2§	1	1
8	T2-FPP-FT_A3-12	250 mL	1					1	1	1	2§	1	
9	T3-WCP-CT_A1-13	1 kg	1	1	1	1	1			1		1	1
10	T3-WCP-CT_A1-14	1 kg	1				1		1				
11	T3-WCP-CT_A1-15	1 kg	1					1					
12	T3-WCP-CT_A1-16	1 kg	1	1	1	1	1			1		1	
13	T3-WCP-CT_A1-17	1 kg	1						1				
14	T3-WCP-CT_A1-18	1 kg	1				1						
15	T3-WCP-CT_A3-19	1 kg	1	1	1	1	1			1		1	1
16	T3-WCP-CT_A3-20	1 kg	1				1		1				
17	T3-WCP-CT_A3-21	1 kg	1					1					
18	T3-WCP-CT_A3-22	1 kg	1	1	1	1	1			1		1	
19	T3-WCP-CT_A3-23	1 kg	1				1						
20	T3-WCP-CT_A3-24	1 kg	1						1				
21	T4-REMC-GT_A1-25	40 g	1	1			1			1		1	
22	T4-REMC-GT_A1-26	40 g			1			1					
23	T5-N/M-GT_A1-29	500 g	1	1	1		1			1		1	
24	T5-N/M-GT_A1-30	500 g	1					1	1				
25	T6-Mags_A1-31	500 g	1	1	1	1	1			1[4]		1	
26	T6-Mags_A1-32	500 g	1					1	1[4]				
27	T6-Mags_A3-33	150 g	1	1	1		1			1[4]		1	
28	T6-Mags_A3-34	150 g	1						1[4]				
29	T7-CrFloat_A1-35	50 g								1[4]		1	
30	T7-CrRoast_A1-36	30 g								1[4]		1	
31	T8-N/M-MSP_A1-37	250 g	1	1	1	1	1			1		1	
32	T8-N/M-MSP_A1-38	250 g	1					1	1				
33	T8-N/M-MSP_A3-39	100 g	1	1	1		1			1		1	
34	T8-N/M-MSP_A3-40	100 g							1				
	Total		30	14	14	9	18	10	15	17	4	18	4

Notes: *If sufficient sample #Please conduct 1:5 leach overnight § S:L production ratio is 25% so additional liquid can be added if insufficient decant water

List 1: pH, EC, TDS, HCO_3, CO_3

List 2: **Ag**, **Al**, **As**, **B**, Ba, **Be**, **Bi**, Ca, **Cd**, Ce, **Co**, **Total Cr**, **Cu**, **Fe**, **Ga**, **Hg**, K, **La**, Li, Mg, **Mn**, **Mo**, Na, **Ni**, **Pb**, Rb, S, **Sb**, Sc, **Se**, Si, **Sn**, Sr, **Th**, Ti, **Tl**, **U**, **V**, W, Y, Yb, **Zn**, Zr

List 3 Anions: Cl, F, PO_4

List 4: Hexavalent chromium, Trivalent chromium Conduct speciation for samples 31-36

a. Please report the mass of sample remaining with results

b. Limits of Reporting ANZ Toxicant Default Guideline Values (TDGV) for Aquatic Ecosystems 2018 for bolded elements.

c. Preparation It is required that leachate testing and decant fluids be **"run clear"** and only dissolved metals and metalloids be analysed for – i.e. ALL suspended, particulate clay matter (>0.2 µm) causing cloudiness must be completely filtered out of solution and no suspended particles remain when solution is

From **TZ Minerals International**
Level 1, 11 Kitchener Avenue
Burswood WA 6100
Australia

Name Dispatcher
Gavin Williams
gwilliams@tzmi.com
T: +61 8 9359 6000

T Z M I

Date Dispatched ____________________ **Signature** ____________________

1-4	1 x bucket **Area 3** FPP T100 Slimes 4 x 250 mL	T2-FPP-FT_A3-9 to 12
3	1 x bucket **Area 1** Coarse Sand Tails 6 x 1 kg 1372520	T3-WCP-CT_A1-13 to 18
4	1 x bucket **Area 3** Coarse Sand Tails 6 x 1 kg 1334711	T3-WCP-CT_A3-19 to 24
5	1 x bucket **Area 1** & **Area 3** Small Samples	FPP, WCP, REMC, MSP
6	4 x buckets **Area 3** 60 Litres 1248923 T100 Bulk Slimes	NOT for Geochem analysis. Retain please for collection (~1 week)
7	1 x bucket **Area 1** Coarse Sand Tails Bulk 10 kg 1372520	NOT for Geochem analysis. Retain please for collection (~1 week)
8	1 x bucket **Area 3** Coarse Sand Tails Bulk 10 kg 1334711	NOT for Geochem analysis. Retain please for collection (~1 week)
9	1 x bucket Area 1 1372520 Bulk Headsample 10 kg	NOT for Geochem analysis. Retain please for collection (~1 week)

ChemCentre
Scientific Services Division
Report of Examination

Resources and Chemistry Precinct
Cnr Manning Road and Towning Drive
Bentley
WA 6102
T +61 8 9422 9800
F +61 8 9422 9801
www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: 0388
ChemCentre Reference: 20S5156 R0

VHM Limited
Level 2, Suite 9, 389 Oxford Street
MOUNT HAWTHORN WA 6016

Attention: Colleen Burgers

Report on: 33 samples received on 23/06/2021, 4 samples received on 01/07/2021

LAB ID	Material	Client ID and Description
20S5156 / 001	solid	T1-FPP-OS_A1-1
20S5156 / 002	solid	T1-FPP-OS_A1-2
20S5156 / 003	solid	T1-FPP-OS_A3-3
20S5156 / 004	solid	T1-FPP-OS_A3-4
20S5156 / 005	solid	T2-FPP-FT_A3-9
20S5156 / 006	solid	T2-FPP-FT_A3-10
20S5156 / 007	solid	T2-FPP-FT_A3-11
20S5156 / 008	solid	T2-FPP-FT_A3-12
20S5156 / 009	solid	T3-WCP-CT_A1-13
20S5156 / 010	solid	T3-WCP-CT_A1-14
20S5156 / 011	solid	T3-WCP-CT_A1-15
20S5156 / 012	solid	T3-WCP-CT_A1-16
20S5156 / 013	solid	T3-WCP-CT_A1-17
20S5156 / 014	solid	T3-WCP-CT_A1-18
20S5156 / 015	solid	T3-WCP-CT_A3-19
20S5156 / 016	solid	T3-WCP-CT_A3-20
20S5156 / 017	solid	T3-WCP-CT_A3-21
20S5156 / 018	solid	T3-WCP-CT_A3-22
20S5156 / 019	solid	T3-WCP-CT_A3-23
20S5156 / 020	solid	T3-WCP-CT_A3-24
20S5156 / 021	solid	T4-REMC-GT_A1-25
20S5156 / 022	solid	T4-REMC-GT_A1-26
20S5156 / 023	solid	T5-N/M-GT_A1-29
20S5156 / 024	solid	T5-N/M-GT_A1-30
20S5156 / 025	solid	T6-Mags_A1-31
20S5156 / 026	solid	T6-Mags_A1-32
20S5156 / 027	solid	T6-Mags_A3-33
20S5156 / 028	solid	T6-Mags_A3-34
20S5156 / 029	solid	T7-CrFloat_A1-35
20S5156 / 030	solid	T7-CrRoast_A1-36
20S5156 / 031	solid	T8-N/M-MSP_A1-37
20S5156 / 032	solid	T8-N/M-MSP_A1-38
20S5156 / 033	solid	T8-N/M-MSP_A3-39
20S5156 / 035	decant	T2-FPP-FT_A3-9 (dec) Decant of sample 005
20S5156 / 036	decant	T2-FPP-FT_A3-10 (dec) Decant of sample 006
20S5156 / 037	decant	T2-FPP-FT_A3-11 (dec) Decant of sample 007
20S5156 / 038	decant	T2-FPP-FT_A3-12 (dec) Decant of sample 008

LAB ID			001	002	003	004
Client ID			T1-FPP-OS_A1-1	T1-FPP-OS_A1-2	T1-FPP-OS_A3-3	T1-FPP-OS_A3-4
Sampled						
Analyte	**Method**	**Unit**				
NAG pH	ARD		4.5	4.6	6.1	5.4

LAB ID			001	002	003	004
Client ID			T1-FPP-OS_A1-1	T1-FPP-OS_A1-2	T1-FPP-OS_A3-3	T1-FPP-OS_A3-4
Sampled						
Analyte	**Method**	**Unit**				
NAG (Net Acid Generation)	ARD	kg H2SO4/	0.9		<0.5	
Total oxidisable sulfur	TOS (ARD)	%	<0.01		0.02	
Sulfur present as SO4	SO4 S (ARD)	%	0.01		0.03	
Sulfur	(combs)	%	0.01		0.05	
Acid Neutralising Capacity	ARD	kg H2SO4/	1.7		3.4	
pH, 1:2 soil:water	ARD		5.7		7.6	
EC 1 soil 2 water paste	ARD	mS/m	17		40	
Carbon	(combs)	%	<0.05		0.12	
Total Organic Carbon	(combs)	%	<0.05		0.09	
Total Inorganic Carbon	(combs)	%	<0.05		<0.05	
Aluminium	iMET2SAICP	mg/kg	6090		6530	
Antimony	iMET2SAMS	mg/kg	1.0		1.1	
Arsenic	iMET2SAICP	mg/kg			240	
Arsenic	iMET2SAMS	mg/kg	110			
Barium	iMET2SAICP	mg/kg	65		55	
Beryllium	iMET2SAMS	mg/kg	0.44		2.5	
Bismuth	iMET2SAMS	mg/kg	0.09		0.13	
Boron	iMET2SAICP	mg/kg	<5		<5	
Cadmium	iMET2SAMS	mg/kg	<0.05		<0.05	
Calcium	iMET2SAICP	mg/kg	24		400	
Cerium	iMET2SAMS	mg/kg	260		59	
Chromium	iMET2SAICP	mg/kg	85		93	
Cobalt	iMET2SAMS	mg/kg	1.8		18	
Copper	iMET2SAMS	mg/kg	3.5		8.5	
Gallium	iMET2SAMS	mg/kg	11		5.0	
Iron	iMET2SAICP	mg/kg	19000		170000	
Lanthanum	iMET2SAICP	mg/kg	110		24	
Lead	iMET2SAMS	mg/kg	9.2		9.0	
Lithium	iMET2SAICP	mg/kg	3.5		3.0	
Magnesium	iMET2SAICP	mg/kg	210		490	
Manganese	iMET2SAICP	mg/kg	14		210	
Mercury	iMET2SAMS	mg/kg	<0.02		<0.02	
Molybdenum	iMET2SAMS	mg/kg	2.8		2.8	
Nickel	iMET2SAMS	mg/kg	6.5		22	
Potassium	iMET2SAICP	mg/kg	370		450	
Rubidium	iMET2SAMS	mg/kg	3.1		6.2	
Scandium	iMET2SAMS	mg/kg	5.1		14	
Selenium	iMET2SAMS	mg/kg	0.35		0.52	
Silicon	iMET2SAICP	mg/kg	260		260	
Silver	iMET2SAMS	mg/kg	<0.05		<0.05	
Sodium	iMET2SAICP	mg/kg	150		280	
Strontium	iMET2SAICP	mg/kg	5.3		11	
Sulfur	iMET2SAICP	mg/kg	130		380	
Thallium	iMET2SAMS	mg/kg	<0.05		0.26	
Thorium	iMET2SAMS	mg/kg	54		21	
Tin	iMET2SAMS	mg/kg	1.1		1.2	
Titanium	iMET2SAICP	mg/kg	220		210	
Tungsten	iMET2SAMS	mg/kg	<0.5		<0.5	
Uranium	iMET2SAMS	mg/kg	3.9		2.5	

LAB ID			001	002	003	004
Client ID			T1-FPP-OS_A1-1	T1-FPP-OS_A1-2	T1-FPP-OS_A3-3	T1-FPP-OS_A3-4
Sampled						
Analyte	**Method**	**Unit**				
Vanadium	iMET2SAICP	mg/kg	290		360	
Ytterbium	iMET2SAMS	mg/kg	0.68		1.5	
Yttrium	iMET2SAMS	mg/kg	17		16	
Zinc	iMET2SAICP	mg/kg			170	
Zirconium	iMET2SAMS	mg/kg	10		17	
Zinc	iMET2SAMS	mg/kg	27			
pH	iPH1WASE		5.3			
Electrical Conductivity	iEC1WZSE	mS/m	2.9			
TDS (calculated)	iSOL1WDCA	mg/L	16			
Bicarbonate	iALK1WATI	mg/L	<1			
Carbonate	iALK1WATI	mg/L	<1			
Aluminium	iMET1WCICP	mg/L	0.035			
Antimony	iMET1WCMS	mg/L	<0.0001			
Arsenic	iMET1WCMS	mg/L	<0.001			
Barium	iMET1WCMS	mg/L	0.019			
Beryllium	iMET1WCMS	mg/L	<0.0001			
Bismuth	iMET1WCMS	mg/L	<0.0001			
Boron	iMET1WCMS	mg/L	0.011			
Cadmium	iMET1WCMS	mg/L	<0.0001			
Calcium	iMET1WCICP	mg/L	<0.1			
Cerium	iMET1WCMS	mg/L	<0.0005			
Chromium	iMET1WCMS	mg/L	<0.0005			
Cobalt	iMET1WCMS	mg/L	0.0001			
Copper	iMET1WCMS	mg/L	<0.0001			
Gallium	iMET1WCMS	mg/L	<0.0001			
Iron	iMET1WCICP	mg/L	0.008			
Lanthanum	iMET1WCMS	mg/L	<0.0001			
Lead	iMET1WCMS	mg/L	<0.0001			
Lithium	iMET1WCMS	mg/L	0.0032			
Magnesium	iMET1WCICP	mg/L	0.1			
Manganese	iMET1WCMS	mg/L	0.0020			
Mercury	iMET1WCMS	mg/L	<0.0001			
Molybdenum	iMET1WCMS	mg/L	<0.001			
Nickel	iMET1WCMS	mg/L	<0.001			
Potassium	iMET1WCICP	mg/L	0.8			
Rubidium	iMET1WCMS	mg/L	0.0010			
Scandium	iMET1WCMS	mg/L	<0.0005			
Selenium	iMET1WCMS	mg/L	<0.001			
Silicon	iMET1WCICP	mg/L	1.6			
Silver	iMET1WCMS	mg/L	<0.0001			
Sodium	iMET1WCICP	mg/L	3.8			
Strontium	iMET1WCMS	mg/L	0.0016			
Sulfur	iMET1WCICP	mg/L	2.3			
Thallium	iMET1WCMS	mg/L	<0.0001			
Thorium	iMET1WCMS	mg/L	<0.0001			
Tin	iMET1WCMS	mg/L	<0.0001			
Titanium	iMET1WCMS	mg/L	<0.0005			
Tungsten	iMET1WCMS	mg/L	<0.002			
Uranium	iMET1WCMS	mg/L	<0.0001			
Vanadium	iMET1WCMS	mg/L	<0.0001			

LAB ID			001	002	003	004
Client ID			T1-FPP-OS_A1-1	T1-FPP-OS_A1-2	T1-FPP-OS_A3-3	T1-FPP-OS_A3-4
Sampled						
Analyte	**Method**	**Unit**				
Ytterbium	iMET1WCMS	mg/L	<0.0005			
Yttrium	iMET1WCMS	mg/L	<0.0002			
Zinc	iMET1WCMS	mg/L	0.007			
Zirconium	iMET1WCMS	mg/L	<0.0001			
Chloride	iCO1WCDA	mg/L	2			
Fluoride	iF1WASE	mg/L	<0.05			
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01			

LAB ID			005	006	007	008
Client ID			T2-FPP-FT_A3-9	T2-FPP-FT_A3-10	T2-FPP-FT_A3-11	T2-FPP-FT_A3-12
Sampled						
Analyte	**Method**	**Unit**				
NAG pH	ARD		5.4	5.4	5.6	5.3
NAG (Net Acid Generation)	ARD	kg H2SO4/	0.6		0.6	
Total oxidisable sulfur	TOS (ARD)	%	0.01		0.01	
Sulfur present as SO4	SO4 S (ARD)	%	0.03		0.03	
Sulfur	(combs)	%	0.04		0.04	
Acid Neutralising Capacity	ARD	kg H2SO4/	2.6		2.8	
pH, 1:2 soil:water	ARD		7.2		6.7	
EC 1 soil 2 water paste	ARD	mS/m	41		34	
Carbon	(combs)	%	0.17			
Total Organic Carbon	(combs)	%	0.16			
Total Inorganic Carbon	(combs)	%	<0.05			
Outsourced to Intertek	SUPP		1		1	
Aluminium	iMET2SAICP	mg/kg	26100	24000	26600	24100
Antimony	iMET2SAMS	mg/kg	0.51	0.56	0.52	0.61
Arsenic	iMET2SAICP	mg/kg	120			
Arsenic	iMET2SAMS	mg/kg		130	130	130
Barium	iMET2SAICP	mg/kg	82	73	86	80
Beryllium	iMET2SAMS	mg/kg	2.3	2.1	2.3	2.2
Bismuth	iMET2SAMS	mg/kg	0.62	0.59	0.62	0.62
Boron	iMET2SAICP	mg/kg	14	12	14	13
Cadmium	iMET2SAMS	mg/kg	<0.05	<0.05	<0.05	<0.05
Calcium	iMET2SAICP	mg/kg	440	450	440	440
Cerium	iMET2SAMS	mg/kg	130	120	130	130
Chromium	iMET2SAICP	mg/kg	94	90	96	93
Cobalt	iMET2SAMS	mg/kg	14	14	14	14
Copper	iMET2SAMS	mg/kg	10	11	10	11
Gallium	iMET2SAMS	mg/kg	11	10	12	11
Iron	iMET2SAICP	mg/kg	86000	84000	83000	79000
Lanthanum	iMET2SAICP	mg/kg	56	50	58	56
Lead	iMET2SAMS	mg/kg	19	17	19	19
Lithium	iMET2SAICP	mg/kg	20	15	22	19
Magnesium	iMET2SAICP	mg/kg	1400	1300	1400	1400
Manganese	iMET2SAICP	mg/kg	160	160	160	160
Mercury	iMET2SAMS	mg/kg	0.02	0.02	0.02	0.02
Molybdenum	iMET2SAMS	mg/kg	2.8	2.9	2.8	2.9

LAB ID			005	006	007	008
Client ID			T2-FPP-FT_A3-9	T2-FPP-FT_A3-10	T2-FPP-FT_A3-11	T2-FPP-FT_A3-12
Sampled						
Analyte	**Method**	**Unit**				
Nickel	iMET2SAMS	mg/kg	32	29	33	32
Potassium	iMET2SAICP	mg/kg	1300	1200	1400	1300
Rubidium	iMET2SAMS	mg/kg	25	23	26	24
Scandium	iMET2SAMS	mg/kg	14	13	14	14
Selenium	iMET2SAMS	mg/kg	0.45	0.43	0.43	0.43
Silicon	iMET2SAICP	mg/kg	120	130	110	130
Silver	iMET2SAMS	mg/kg	<0.05	<0.05	<0.05	<0.05
Sodium	iMET2SAICP	mg/kg	430	420	430	430
Strontium	iMET2SAICP	mg/kg	28	26	29	28
Sulfur	iMET2SAICP	mg/kg	300	280	300	280
Thallium	iMET2SAMS	mg/kg	0.32	0.29	0.33	0.31
Thorium	iMET2SAMS	mg/kg	32	32	34	33
Tin	iMET2SAMS	mg/kg	4.9	4.7	5.1	5.4
Titanium	iMET2SAICP	mg/kg	290	280	300	300
Tungsten	iMET2SAMS	mg/kg	<0.5	<0.5	<0.5	<0.5
Uranium	iMET2SAMS	mg/kg	2.7	2.5	2.7	2.7
Vanadium	iMET2SAICP	mg/kg	320	320	330	320
Ytterbium	iMET2SAMS	mg/kg	1.4	1.3	1.4	1.4
Yttrium	iMET2SAMS	mg/kg	17	17	18	17
Zinc	iMET2SAICP	mg/kg	170	170	170	170
Zirconium	iMET2SAMS	mg/kg	29	31	33	34
pH	iPH1WASE		6.1	6.2	6.1	6.3
Electrical Conductivity	iEC1WZSE	mS/m	4.4	4.2	4.2	4.1
TDS (calculated)	iSOL1WDCA	mg/L	24	23	23	22
Bicarbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Carbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Aluminium	iMET1WCICP	mg/L	0.41	0.43	0.46	0.33
Antimony	iMET1WCMS	mg/L	0.0001	0.0001	0.0001	0.0001
Arsenic	iMET1WCMS	mg/L	0.002	0.002	0.003	0.003
Barium	iMET1WCMS	mg/L	0.0009	0.0018	0.0011	0.0038
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.046	0.048	0.048	0.049
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.1	0.2	0.1	0.2
Cerium	iMET1WCMS	mg/L	<0.0005	0.0007	0.0008	<0.0005
Chromium	iMET1WCMS	mg/L	0.0013	0.0018	0.0022	0.0011
Cobalt	iMET1WCMS	mg/L	0.0001	0.0002	0.0002	<0.0001
Copper	iMET1WCMS	mg/L	0.0004	0.0004	0.0010	0.0005
Gallium	iMET1WCMS	mg/L	0.0001	0.0002	0.0002	0.0001
Iron	iMET1WCICP	mg/L	0.30	0.34	0.33	0.26
Lanthanum	iMET1WCMS	mg/L	0.0002	0.0004	0.0004	0.0002
Lead	iMET1WCMS	mg/L	0.0001	0.0002	0.0006	0.0001
Lithium	iMET1WCMS	mg/L	0.0022	0.0022	0.0022	0.0020
Magnesium	iMET1WCICP	mg/L	0.2	0.2	0.1	0.1
Manganese	iMET1WCMS	mg/L	0.0009	0.0012	0.0014	0.0008
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	0.002	0.002	0.002	0.002
Nickel	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	0.9	0.8	0.8	0.7

LAB ID			005	006	007	008
Client ID			T2-FPP-FT_A3-9	T2-FPP-FT_A3-10	T2-FPP-FT_A3-11	T2-FPP-FT_A3-12
Sampled						
Analyte	Method	Unit				
Rubidium	iMET1WCMS	mg/L	0.0008	0.0007	0.0008	0.0007
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	5.6	5.7	5.5	5.6
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	6.9	6.6	6.5	6.4
Strontium	iMET1WCMS	mg/L	0.0019	0.0022	0.0022	0.0016
Sulfur	iMET1WCICP	mg/L	2.8	2.6	2.4	2.4
Thallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	0.0001	0.0002	0.0002	0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.016	0.023	0.026	0.015
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	iMET1WCMS	mg/L	0.0041	0.0056	0.0062	0.0059
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	0.003	0.003	0.004	0.002
Zirconium	iMET1WCMS	mg/L	0.0017	0.0021	0.0022	0.0013
Chloride	iCO1WCDA	mg/L	5	5	5	4
Fluoride	iF1WASE	mg/L	0.53	0.55	0.54	0.57
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	<0.01	0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.001	0.001	0.001	0.001
Chromium(VI)	iCO1WCDAL	mg/L	<0.001	<0.001	0.001	<0.001

LAB ID			009	010	011	012
Client ID			T3-WCP-CT_A1-13	T3-WCP-CT_A1-14	T3-WCP-CT_A1-15	T3-WCP-CT_A1-16
Sampled						
Analyte	Method	Unit				
NAG pH	ARD		4.6	4.7	4.6	4.5
NAG (Net Acid Generation)	ARD	kg H2SO4/	<0.5			<0.5
Total oxidisable sulfur	TOS (ARD)	%	0.01			<0.01
Sulfur present as SO4	SO4 S (ARD)	%	<0.01			<0.01
Sulfur	(combs)	%	0.01			<0.01
Acid Neutralising Capacity	ARD	kg H2SO4/	1.9			1.2
pH, 1:2 soil:water	ARD		6.7			6.9
EC 1 soil 2 water paste	ARD	mS/m	3			3
Carbon	(combs)	%	<0.05			<0.05
Total Organic Carbon	(combs)	%	<0.05			<0.05
Total Inorganic Carbon	(combs)	%	<0.05			<0.05
Outsourced to Intertek	SUPP		1			
Aluminium	iMET2SAICP	mg/kg	768			770
Antimony	iMET2SAMS	mg/kg	0.12			0.12
Arsenic	iMET2SAMS	mg/kg	5.6			5.6
Barium	iMET2SAICP	mg/kg	8.8			9.2
Beryllium	iMET2SAMS	mg/kg	<0.05			<0.05
Bismuth	iMET2SAMS	mg/kg	<0.05			<0.05

LAB ID			009	010	011	012
Client ID			T3-WCP-CT_A 1-13	T3-WCP-CT_A 1-14	T3-WCP-CT_A 1-15	T3-WCP-CT_A1-16
Sampled						
Analyte	Method	Unit				
Boron	iMET2SAICP	mg/kg	<5			<5
Cadmium	iMET2SAMS	mg/kg	<0.05			<0.05
Calcium	iMET2SAICP	mg/kg	<10			<10
Cerium	iMET2SAMS	mg/kg	27			28
Chromium	iMET2SAICP	mg/kg	6.4			6.3
Cobalt	iMET2SAMS	mg/kg	<0.5			<0.5
Copper	iMET2SAMS	mg/kg	<0.5			<0.5
Gallium	iMET2SAMS	mg/kg	1.5			1.5
Iron	iMET2SAICP	mg/kg	1100			1100
Lanthanum	iMET2SAICP	mg/kg	14			15
Lead	iMET2SAMS	mg/kg	2.8			2.6
Lithium	iMET2SAICP	mg/kg	0.5			0.4
Magnesium	iMET2SAICP	mg/kg	54			53
Manganese	iMET2SAICP	mg/kg	4.8			4.7
Mercury	iMET2SAMS	mg/kg	<0.02			<0.02
Molybdenum	iMET2SAMS	mg/kg	0.20			0.19
Nickel	iMET2SAMS	mg/kg	1.3			1.2
Potassium	iMET2SAICP	mg/kg	140			100
Rubidium	iMET2SAMS	mg/kg	1.1			1.1
Scandium	iMET2SAMS	mg/kg	0.71			0.67
Selenium	iMET2SAMS	mg/kg	<0.05			<0.05
Silicon	iMET2SAICP	mg/kg	370			370
Silver	iMET2SAMS	mg/kg	<0.05			<0.05
Sodium	iMET2SAICP	mg/kg	28			28
Strontium	iMET2SAICP	mg/kg	2.0			2.2
Sulfur	iMET2SAICP	mg/kg	7			7
Thallium	iMET2SAMS	mg/kg	<0.05			<0.05
Thorium	iMET2SAMS	mg/kg	7.0			7.0
Tin	iMET2SAMS	mg/kg	<0.5			<0.5
Titanium	iMET2SAICP	mg/kg	140			130
Tungsten	iMET2SAMS	mg/kg	<0.5			<0.5
Uranium	iMET2SAMS	mg/kg	0.44			0.42
Vanadium	iMET2SAICP	mg/kg	13			13
Ytterbium	iMET2SAMS	mg/kg	0.13			0.12
Yttrium	iMET2SAMS	mg/kg	2.1			2.1
Zirconium	iMET2SAMS	mg/kg	5.0			4.1
Zinc	iMET2SAMS	mg/kg	3.8			3.5
pH	iPH1WASE		6.1			6.1
Electrical Conductivity	iEC1WZSE	mS/m	0.6			0.5
TDS (calculated)	iSOL1WDCA	mg/L	<5			<5
Bicarbonate	iALK1WATI	mg/L	1			<1
Carbonate	iALK1WATI	mg/L	<1			<1
Aluminium	iMET1WCICP	mg/L	0.19			0.15
Antimony	iMET1WCMS	mg/L	<0.0001			<0.0001
Arsenic	iMET1WCMS	mg/L	0.001			0.001
Barium	iMET1WCMS	mg/L	0.0007			0.0005
Beryllium	iMET1WCMS	mg/L	<0.0001			<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001			<0.0001
Boron	iMET1WCMS	mg/L	<0.005			<0.005
Cadmium	iMET1WCMS	mg/L	<0.0001			<0.0001

LAB ID			009	010	011	012
Client ID			T3-WCP-CT_A 1-13	T3-WCP-CT_A 1-14	T3-WCP-CT_A 1-15	T3-WCP-CT_A1-16
Sampled						
Analyte	Method	Unit				
Calcium	iMET1WCICP	mg/L	<0.1			<0.1
Cerium	iMET1WCMS	mg/L	<0.0005			<0.0005
Chromium	iMET1WCMS	mg/L	0.0036			0.0033
Cobalt	iMET1WCMS	mg/L	<0.0001			<0.0001
Copper	iMET1WCMS	mg/L	<0.0001			<0.0001
Gallium	iMET1WCMS	mg/L	<0.0001			<0.0001
Iron	iMET1WCICP	mg/L	0.047			0.038
Lanthanum	iMET1WCMS	mg/L	<0.0001			<0.0001
Lead	iMET1WCMS	mg/L	<0.0001			<0.0001
Lithium	iMET1WCMS	mg/L	0.0008			0.0007
Magnesium	iMET1WCICP	mg/L	<0.1			<0.1
Manganese	iMET1WCMS	mg/L	<0.0001			<0.0001
Mercury	iMET1WCMS	mg/L	<0.0001			<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001			<0.001
Nickel	iMET1WCMS	mg/L	<0.001			<0.001
Potassium	iMET1WCICP	mg/L	0.2			0.2
Rubidium	iMET1WCMS	mg/L	0.0003			0.0002
Scandium	iMET1WCMS	mg/L	<0.0005			<0.0005
Selenium	iMET1WCMS	mg/L	<0.001			<0.001
Silicon	iMET1WCICP	mg/L	0.68			0.60
Silver	iMET1WCMS	mg/L	<0.0001			<0.0001
Sodium	iMET1WCICP	mg/L	0.7			0.7
Strontium	iMET1WCMS	mg/L	<0.0001			<0.0001
Sulfur	iMET1WCICP	mg/L	0.2			0.2
Thallium	iMET1WCMS	mg/L	<0.0001			<0.0001
Thorium	iMET1WCMS	mg/L	<0.0001			<0.0001
Tin	iMET1WCMS	mg/L	<0.0001			<0.0001
Titanium	iMET1WCMS	mg/L	0.0070			0.0059
Tungsten	iMET1WCMS	mg/L	<0.002			<0.002
Uranium	iMET1WCMS	mg/L	<0.0001			<0.0001
Vanadium	iMET1WCMS	mg/L	0.0015			0.0016
Ytterbium	iMET1WCMS	mg/L	<0.0005			<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002			<0.0002
Zinc	iMET1WCMS	mg/L	<0.001			<0.001
Zirconium	iMET1WCMS	mg/L	0.0005			0.0004
Chloride	iCO1WCDA	mg/L	<1			<1
Fluoride	iF1WASE	mg/L	0.09			0.09
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01			<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	<0.001			0.001
Chromium(VI)	iCO1WCDAL	mg/L	0.003			0.002

LAB ID			013	014	015	016
Client ID			T3-WCP-CT_A 1-17	T3-WCP-CT_A 1-18	T3-WCP-CT_A 3-19	T3-WCP-CT_A3-20
Sampled						
Analyte	Method	Unit				
NAG pH	ARD		4.7	4.6	4.7	4.7
NAG (Net Acid Generation)	ARD	kg H2SO4/			<0.5	

LAB ID			013	014	015	016
Client ID			T3-WCP-CT_A1-17	T3-WCP-CT_A1-18	T3-WCP-CT_A3-19	T3-WCP-CT_A3-20
Sampled						
Analyte	Method	Unit				
Total oxidisable sulfur	TOS (ARD)	%			<0.01	
Sulfur present as SO4	SO4 S (ARD)	%			<0.01	
Sulfur	(combs)	%			<0.01	
Acid Neutralising Capacity	ARD	kg H2SO4/			1.7	
pH, 1:2 soil:water	ARD				7.4	
EC 1 soil 2 water paste	ARD	mS/m			3	
Carbon	(combs)	%			<0.05	
Total Organic Carbon	(combs)	%			<0.05	
Total Inorganic Carbon	(combs)	%			<0.05	
Outsourced to Intertek	SUPP				1	
Aluminium	iMET2SAICP	mg/kg			944	
Antimony	iMET2SAMS	mg/kg			0.13	
Arsenic	iMET2SAMS	mg/kg			13	
Barium	iMET2SAICP	mg/kg			7.7	
Beryllium	iMET2SAMS	mg/kg			0.18	
Bismuth	iMET2SAMS	mg/kg			<0.05	
Boron	iMET2SAICP	mg/kg			<5	
Cadmium	iMET2SAMS	mg/kg			<0.05	
Calcium	iMET2SAICP	mg/kg			27	
Cerium	iMET2SAMS	mg/kg			26	
Chromium	iMET2SAICP	mg/kg			6.8	
Cobalt	iMET2SAMS	mg/kg			1.4	
Copper	iMET2SAMS	mg/kg			<0.5	
Gallium	iMET2SAMS	mg/kg			1.5	
Iron	iMET2SAICP	mg/kg			8500	
Lanthanum	iMET2SAICP	mg/kg			12	
Lead	iMET2SAMS	mg/kg			2.3	
Lithium	iMET2SAICP	mg/kg			0.7	
Magnesium	iMET2SAICP	mg/kg			63	
Manganese	iMET2SAICP	mg/kg			19	
Mercury	iMET2SAMS	mg/kg			<0.02	
Molybdenum	iMET2SAMS	mg/kg			0.18	
Nickel	iMET2SAMS	mg/kg			2.3	
Potassium	iMET2SAICP	mg/kg			190	
Rubidium	iMET2SAMS	mg/kg			1.8	
Scandium	iMET2SAMS	mg/kg			1.2	
Selenium	iMET2SAMS	mg/kg			<0.05	
Silicon	iMET2SAICP	mg/kg			420	
Silver	iMET2SAMS	mg/kg			<0.05	
Sodium	iMET2SAICP	mg/kg			28	
Strontium	iMET2SAICP	mg/kg			3.3	
Sulfur	iMET2SAICP	mg/kg			41	
Thallium	iMET2SAMS	mg/kg			<0.05	
Thorium	iMET2SAMS	mg/kg			6.5	
Tin	iMET2SAMS	mg/kg			<0.5	
Titanium	iMET2SAICP	mg/kg			120	
Tungsten	iMET2SAMS	mg/kg			<0.5	
Uranium	iMET2SAMS	mg/kg			0.52	
Vanadium	iMET2SAICP	mg/kg			27	

LAB ID			013	014	015	016
Client ID			T3-WCP-CT_A1-17	T3-WCP-CT_A1-18	T3-WCP-CT_A3-19	T3-WCP-CT_A3-20
Sampled						
Analyte	Method	Unit				
Ytterbium	iMET2SAMS	mg/kg			0.23	
Yttrium	iMET2SAMS	mg/kg			3.3	
Zirconium	iMET2SAMS	mg/kg			4.3	
Zinc	iMET2SAMS	mg/kg			17	
pH	iPH1WASE				6.3	
Electrical Conductivity	iEC1WZSE	mS/m			0.5	
TDS (calculated)	iSOL1WDCA	mg/L			<5	
Bicarbonate	iALK1WATI	mg/L			<1	
Carbonate	iALK1WATI	mg/L			<1	
Aluminium	iMET1WCICP	mg/L			0.089	
Antimony	iMET1WCMS	mg/L			<0.0001	
Arsenic	iMET1WCMS	mg/L			0.006	
Barium	iMET1WCMS	mg/L			0.0011	
Beryllium	iMET1WCMS	mg/L			<0.0001	
Bismuth	iMET1WCMS	mg/L			<0.0001	
Boron	iMET1WCMS	mg/L			<0.005	
Cadmium	iMET1WCMS	mg/L			<0.0001	
Calcium	iMET1WCICP	mg/L			<0.1	
Cerium	iMET1WCMS	mg/L			<0.0005	
Chromium	iMET1WCMS	mg/L			0.0030	
Cobalt	iMET1WCMS	mg/L			<0.0001	
Copper	iMET1WCMS	mg/L			0.0001	
Gallium	iMET1WCMS	mg/L			<0.0001	
Iron	iMET1WCICP	mg/L			0.22	
Lanthanum	iMET1WCMS	mg/L			0.0001	
Lead	iMET1WCMS	mg/L			<0.0001	
Lithium	iMET1WCMS	mg/L			0.0006	
Magnesium	iMET1WCICP	mg/L			<0.1	
Manganese	iMET1WCMS	mg/L			0.0006	
Mercury	iMET1WCMS	mg/L			<0.0001	
Molybdenum	iMET1WCMS	mg/L			<0.001	
Nickel	iMET1WCMS	mg/L			<0.001	
Potassium	iMET1WCICP	mg/L			0.2	
Rubidium	iMET1WCMS	mg/L			0.0002	
Scandium	iMET1WCMS	mg/L			<0.0005	
Selenium	iMET1WCMS	mg/L			<0.001	
Silicon	iMET1WCICP	mg/L			0.59	
Silver	iMET1WCMS	mg/L			<0.0001	
Sodium	iMET1WCICP	mg/L			0.6	
Strontium	iMET1WCMS	mg/L			0.0008	
Sulfur	iMET1WCICP	mg/L			<0.1	
Thallium	iMET1WCMS	mg/L			<0.0001	
Thorium	iMET1WCMS	mg/L			<0.0001	
Tin	iMET1WCMS	mg/L			<0.0001	
Titanium	iMET1WCMS	mg/L			0.011	
Tungsten	iMET1WCMS	mg/L			<0.002	
Uranium	iMET1WCMS	mg/L			<0.0001	
Vanadium	iMET1WCMS	mg/L			0.0055	
Ytterbium	iMET1WCMS	mg/L			<0.0005	
Yttrium	iMET1WCMS	mg/L			<0.0002	

LAB ID			013	014	015	016
Client ID			T3-WCP-CT_A 1-17	T3-WCP-CT_A 1-18	T3-WCP-CT_A 3-19	T3-WCP-CT_A3-20
Sampled						
Analyte	**Method**	**Unit**				
Zinc	iMET1WCMS	mg/L			0.001	
Zirconium	iMET1WCMS	mg/L			0.0007	
Chloride	iCO1WCDA	mg/L			<1	
Fluoride	iF1WASE	mg/L			<0.05	
Phosphorus, sol. reactive	iP1WTFIA	mg/L			0.02	
Chromium(III)	iCR3+1WCCAL	mg/L			<0.001	
Chromium(VI)	iCO1WCDAL	mg/L			0.003	

LAB ID			017	018	019	020
Client ID			T3-WCP-CT_A 3-21	T3-WCP-CT_A 3-22	T3-WCP-CT_A 3-23	T3-WCP-CT_A3-24
Sampled						
Analyte	**Method**	**Unit**				
NAG pH	ARD		4.8	4.8	4.8	4.8
NAG (Net Acid Generation)	ARD	kg H2SO4/		<0.5		
Total oxidisable sulfur	TOS (ARD)	%		<0.01		
Sulfur present as SO4	SO4 S (ARD)	%		<0.01		
Sulfur	(combs)	%		<0.01		
Acid Neutralising Capacity	ARD	kg H2SO4/		1.8		
pH, 1:2 soil:water	ARD			7.5		
EC 1 soil 2 water paste	ARD	mS/m		3		
Carbon	(combs)	%		<0.05		
Total Organic Carbon	(combs)	%		<0.05		
Total Inorganic Carbon	(combs)	%		<0.05		
Aluminium	iMET2SAICP	mg/kg		603		
Antimony	iMET2SAMS	mg/kg		0.12		
Arsenic	iMET2SAMS	mg/kg		12		
Barium	iMET2SAICP	mg/kg		5.8		
Beryllium	iMET2SAMS	mg/kg		0.18		
Bismuth	iMET2SAMS	mg/kg		<0.05		
Boron	iMET2SAICP	mg/kg		<5		
Cadmium	iMET2SAMS	mg/kg		<0.05		
Calcium	iMET2SAICP	mg/kg		21		
Cerium	iMET2SAMS	mg/kg		22		
Chromium	iMET2SAICP	mg/kg		6.0		
Cobalt	iMET2SAMS	mg/kg		1.3		
Copper	iMET2SAMS	mg/kg		<0.5		
Gallium	iMET2SAMS	mg/kg		1.2		
Iron	iMET2SAICP	mg/kg		8200		
Lanthanum	iMET2SAICP	mg/kg		10		
Lead	iMET2SAMS	mg/kg		1.7		
Lithium	iMET2SAICP	mg/kg		0.4		
Magnesium	iMET2SAICP	mg/kg		53		
Manganese	iMET2SAICP	mg/kg		16		
Mercury	iMET2SAMS	mg/kg		<0.02		
Molybdenum	iMET2SAMS	mg/kg		0.17		
Nickel	iMET2SAMS	mg/kg		2.1		
Potassium	iMET2SAICP	mg/kg		140		

LAB ID			017	018	019	020
Client ID			T3-WCP-CT_A3-21	T3-WCP-CT_A3-22	T3-WCP-CT_A3-23	T3-WCP-CT_A3-24
Sampled						
Analyte	**Method**	**Unit**				
Rubidium	iMET2SAMS	mg/kg		1.4		
Scandium	iMET2SAMS	mg/kg		1.1		
Selenium	iMET2SAMS	mg/kg		<0.05		
Silicon	iMET2SAICP	mg/kg		320		
Silver	iMET2SAMS	mg/kg		<0.05		
Sodium	iMET2SAICP	mg/kg		24		
Strontium	iMET2SAICP	mg/kg		2.3		
Sulfur	iMET2SAICP	mg/kg		25		
Thallium	iMET2SAMS	mg/kg		<0.05		
Thorium	iMET2SAMS	mg/kg		6.2		
Tin	iMET2SAMS	mg/kg		<0.5		
Titanium	iMET2SAICP	mg/kg		75		
Tungsten	iMET2SAMS	mg/kg		<0.5		
Uranium	iMET2SAMS	mg/kg		0.49		
Vanadium	iMET2SAICP	mg/kg		25		
Ytterbium	iMET2SAMS	mg/kg		0.20		
Yttrium	iMET2SAMS	mg/kg		2.9		
Zirconium	iMET2SAMS	mg/kg		4.0		
Zinc	iMET2SAMS	mg/kg		16		
pH	iPH1WASE			6.1		
Electrical Conductivity	iEC1WZSE	mS/m		0.5		
TDS (calculated)	iSOL1WDCA	mg/L		<5		
Bicarbonate	iALK1WATI	mg/L		<1		
Carbonate	iALK1WATI	mg/L		<1		
Aluminium	iMET1WCICP	mg/L		0.089		
Antimony	iMET1WCMS	mg/L		<0.0001		
Arsenic	iMET1WCMS	mg/L		0.006		
Barium	iMET1WCMS	mg/L		0.0014		
Beryllium	iMET1WCMS	mg/L		<0.0001		
Bismuth	iMET1WCMS	mg/L		<0.0001		
Boron	iMET1WCMS	mg/L		<0.005		
Cadmium	iMET1WCMS	mg/L		<0.0001		
Calcium	iMET1WCICP	mg/L		0.1		
Cerium	iMET1WCMS	mg/L		<0.0005		
Chromium	iMET1WCMS	mg/L		0.0030		
Cobalt	iMET1WCMS	mg/L		<0.0001		
Copper	iMET1WCMS	mg/L		0.0002		
Gallium	iMET1WCMS	mg/L		<0.0001		
Iron	iMET1WCICP	mg/L		0.21		
Lanthanum	iMET1WCMS	mg/L		<0.0001		
Lead	iMET1WCMS	mg/L		<0.0001		
Lithium	iMET1WCMS	mg/L		0.0006		
Magnesium	iMET1WCICP	mg/L		<0.1		
Manganese	iMET1WCMS	mg/L		0.0006		
Mercury	iMET1WCMS	mg/L		<0.0001		
Molybdenum	iMET1WCMS	mg/L		<0.001		
Nickel	iMET1WCMS	mg/L		<0.001		
Potassium	iMET1WCICP	mg/L		0.2		
Rubidium	iMET1WCMS	mg/L		0.0002		
Scandium	iMET1WCMS	mg/L		<0.0005		

LAB ID			017	018	019	020
Client ID			T3-WCP-CT_A3-21	T3-WCP-CT_A3-22	T3-WCP-CT_A3-23	T3-WCP-CT_A3-24
Sampled						
Analyte	**Method**	**Unit**				
Selenium	iMET1WCMS	mg/L		<0.001		
Silicon	iMET1WCICP	mg/L		0.60		
Silver	iMET1WCMS	mg/L		<0.0001		
Sodium	iMET1WCICP	mg/L		0.6		
Strontium	iMET1WCMS	mg/L		0.0009		
Sulfur	iMET1WCICP	mg/L		<0.1		
Thallium	iMET1WCMS	mg/L		<0.0001		
Thorium	iMET1WCMS	mg/L		<0.0001		
Tin	iMET1WCMS	mg/L		<0.0001		
Titanium	iMET1WCMS	mg/L		0.010		
Tungsten	iMET1WCMS	mg/L		<0.002		
Uranium	iMET1WCMS	mg/L		<0.0001		
Vanadium	iMET1WCMS	mg/L		0.0053		
Ytterbium	iMET1WCMS	mg/L		<0.0005		
Yttrium	iMET1WCMS	mg/L		<0.0002		
Zinc	iMET1WCMS	mg/L		0.001		
Zirconium	iMET1WCMS	mg/L		0.0007		
Chloride	iCO1WCDA	mg/L		<1		
Fluoride	iF1WASE	mg/L		<0.05		
Phosphorus, sol. reactive	iP1WTFIA	mg/L		0.02		
Chromium(III)	iCR3+1WCCAL	mg/L		<0.001		
Chromium(VI)	iCO1WCDAL	mg/L		0.003		

LAB ID			021	022	023	024
Client ID			T4-REMC-GT_A1-25	T4-REMC-GT_A1-26	T5-N/M-GT_A1-29	T5-N/M-GT_A1-30
Sampled						
Analyte	**Method**	**Unit**				
NAG pH	ARD		4.6		5.2	5.3
NAG (Net Acid Generation)	ARD	kg H2SO4/	<0.5		<0.5	
Total oxidisable sulfur	TOS (ARD)	%	0.01		<0.01	
Sulfur present as SO4	SO4 S (ARD)	%	<0.01		<0.01	
Sulfur	(combs)	%	0.01		<0.01	
Acid Neutralising Capacity	ARD	kg H2SO4/	2.2		2.2	
pH, 1:2 soil:water	ARD			7.6	7.3	
EC 1 soil 2 water paste	ARD	mS/m		5	4	
Aluminium	iMET2SAICP	mg/kg	157		200	
Antimony	iMET2SAMS	mg/kg	0.19		0.21	
Arsenic	iMET2SAMS	mg/kg	35		4.3	
Barium	iMET2SAICP	mg/kg	230		5.6	
Beryllium	iMET2SAMS	mg/kg	0.07		<0.05	
Bismuth	iMET2SAMS	mg/kg	0.83		0.08	
Boron	iMET2SAICP	mg/kg	<5		<5	
Cadmium	iMET2SAMS	mg/kg	<0.05		<0.05	
Calcium	iMET2SAICP	mg/kg	320		36	
Cerium	iMET2SAMS	mg/kg	3500		12	
Chromium	iMET2SAICP	mg/kg	7.9		8.8	
Cobalt	iMET2SAMS	mg/kg	<0.5		<0.5	

LAB ID Client ID Sampled Analyte	Method	Unit	021 T4-REMC-GT_A1-25	022 T4-REMC-GT_A1-26	023 T5-N/M-GT_A1-29	024 T5-N/M-GT_A1-30
Copper	iMET2SAMS	mg/kg	2.6		1.6	
Gallium	iMET2SAMS	mg/kg	100		0.99	
Iron	iMET2SAICP	mg/kg	540		890	
Lanthanum	iMET2SAICP	mg/kg	1600		6.4	
Lead	iMET2SAMS	mg/kg	48		5.0	
Lithium	iMET2SAICP	mg/kg	0.3		<0.2	
Magnesium	iMET2SAICP	mg/kg	22		27	
Manganese	iMET2SAICP	mg/kg	5.1		6.6	
Mercury	iMET2SAMS	mg/kg	<0.02		<0.02	
Molybdenum	iMET2SAMS	mg/kg	0.46		0.30	
Nickel	iMET2SAMS	mg/kg	3.6		3.5	
Potassium	iMET2SAICP	mg/kg	26		68	
Rubidium	iMET2SAMS	mg/kg	0.47		0.57	
Scandium	iMET2SAMS	mg/kg	1.5		1.1	
Selenium	iMET2SAMS	mg/kg	1.8		<0.05	
Silicon	iMET2SAICP	mg/kg	190		230	
Silver	iMET2SAMS	mg/kg	<0.05		<0.05	
Sodium	iMET2SAICP	mg/kg	94		16	
Strontium	iMET2SAICP	mg/kg	32		1.4	
Sulfur	iMET2SAICP	mg/kg	56		<5	
Thallium	iMET2SAMS	mg/kg	0.11		0.08	
Thorium	iMET2SAMS	mg/kg	380		9.1	
Tin	iMET2SAMS	mg/kg	0.6		0.8	
Titanium	iMET2SAICP	mg/kg	120		210	
Tungsten	iMET2SAMS	mg/kg	<0.5		<0.5	
Uranium	iMET2SAMS	mg/kg	39		0.90	
Vanadium	iMET2SAICP	mg/kg	9.9		16	
Ytterbium	iMET2SAMS	mg/kg	7.7		0.42	
Yttrium	iMET2SAMS	mg/kg	220		3.3	
Zirconium	iMET2SAMS	mg/kg	7.1		10	
Zinc	iMET2SAMS	mg/kg	20		7.2	
pH	iPH1WASE		6.4		6.2	
Electrical Conductivity	iEC1WZSE	mS/m	0.9		0.5	
TDS (calculated)	iSOL1WDCA	mg/L	5		<5	
Bicarbonate	iALK1WATI	mg/L	<1		<1	
Carbonate	iALK1WATI	mg/L	<1		<1	
Aluminium	iMET1WCICP	mg/L	0.031		0.011	
Antimony	iMET1WCMS	mg/L	<0.0001		<0.0001	
Arsenic	iMET1WCMS	mg/L	<0.001		0.003	
Barium	iMET1WCMS	mg/L	0.13		0.0057	
Beryllium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Bismuth	iMET1WCMS	mg/L	<0.0001		<0.0001	
Boron	iMET1WCMS	mg/L	<0.005		<0.005	
Cadmium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Calcium	iMET1WCICP	mg/L	0.7		0.3	
Cerium	iMET1WCMS	mg/L	0.014		<0.0005	
Chromium	iMET1WCMS	mg/L	0.0008		0.0013	
Cobalt	iMET1WCMS	mg/L	<0.0001		<0.0001	
Copper	iMET1WCMS	mg/L	0.0007		0.0003	
Gallium	iMET1WCMS	mg/L	0.0005		<0.0001	

LAB ID Client ID Sampled Analyte	Method	Unit	021 T4-REMC-GT_A1-25	022 T4-REMC-GT_A1-26	023 T5-N/M-GT_A1-29	024 T5-N/M-GT_A1-30
Iron	iMET1WCICP	mg/L	<0.005		<0.005	
Lanthanum	iMET1WCMS	mg/L	0.0063		<0.0001	
Lead	iMET1WCMS	mg/L	0.0002		<0.0001	
Lithium	iMET1WCMS	mg/L	0.0002		0.0001	
Magnesium	iMET1WCICP	mg/L	0.2		<0.1	
Manganese	iMET1WCMS	mg/L	0.0004		0.0001	
Mercury	iMET1WCMS	mg/L	<0.0001		<0.0001	
Molybdenum	iMET1WCMS	mg/L	<0.001		<0.001	
Nickel	iMET1WCMS	mg/L	<0.001		<0.001	
Potassium	iMET1WCICP	mg/L	<0.1		<0.1	
Rubidium	iMET1WCMS	mg/L	0.0003		0.0002	
Scandium	iMET1WCMS	mg/L	<0.0005		<0.0005	
Selenium	iMET1WCMS	mg/L	<0.001		<0.001	
Silicon	iMET1WCICP	mg/L	0.16		0.28	
Silver	iMET1WCMS	mg/L	<0.0001		<0.0001	
Sodium	iMET1WCICP	mg/L	0.5		0.4	
Strontium	iMET1WCMS	mg/L	0.011		0.0014	
Sulfur	iMET1WCICP	mg/L	0.2		<0.1	
Thallium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Thorium	iMET1WCMS	mg/L	0.0018		0.0001	
Tin	iMET1WCMS	mg/L	0.0003		<0.0001	
Titanium	iMET1WCMS	mg/L	0.0026		0.0057	
Tungsten	iMET1WCMS	mg/L	<0.002		<0.002	
Uranium	iMET1WCMS	mg/L	0.0003		<0.0001	
Vanadium	iMET1WCMS	mg/L	0.0001		0.0031	
Ytterbium	iMET1WCMS	mg/L	<0.0005		<0.0005	
Yttrium	iMET1WCMS	mg/L	0.0020		<0.0002	
Zinc	iMET1WCMS	mg/L	<0.001		<0.001	
Zirconium	iMET1WCMS	mg/L	0.0005		0.0015	
Chloride	iCO1WCDA	mg/L	<1		<1	
Fluoride	iF1WASE	mg/L	<0.05		<0.05	
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01		<0.01	
Chromium(III)	iCR3+1WCCAL	mg/L			<0.001	
Chromium(VI)	iCO1WCDAL	mg/L			0.001	

LAB ID Client ID Sampled Analyte	Method	Unit	025 T6-Mags_A1-31	026 T6-Mags_A1-32	027 T6-Mags_A3-33	028 T6-Mags_A3-34
NAG pH	ARD		5.2	5.2	5.3	5.3
NAG (Net Acid Generation)	ARD	kg H2SO4/	<0.5		<0.5	
Total oxidisable sulfur	TOS (ARD)	%	<0.01		0.01	
Sulfur present as SO4	SO4 S (ARD)	%	<0.01		<0.01	
Sulfur	(combs)	%	<0.01		0.01	
Acid Neutralising Capacity	ARD	kg H2SO4/	1.2		1.9	
pH, 1:2 soil:water	ARD		7.5		7.3	
EC 1 soil 2 water paste	ARD	mS/m	7		7	

LAB ID			025	026	027	028
Client ID			T6-Mags_A1-31	T6-Mags_A1-32	T6-Mags_A3-33	T6-Mags_A3-34
Sampled						
Analyte	**Method**	**Unit**				
Carbon	(combs)	%	<0.05			
Total Organic Carbon	(combs)	%	<0.05			
Total Inorganic Carbon	(combs)	%	<0.05			
Aluminium	iMET2SAICP	mg/kg	615		1520	
Antimony	iMET2SAMS	mg/kg	1.3		0.98	
Arsenic	iMET2SAMS	mg/kg	12		48	
Barium	iMET2SAICP	mg/kg	35		46	
Beryllium	iMET2SAMS	mg/kg	0.34		0.99	
Bismuth	iMET2SAMS	mg/kg	0.92		0.71	
Boron	iMET2SAICP	mg/kg	<5		<5	
Cadmium	iMET2SAMS	mg/kg	<0.05		<0.05	
Calcium	iMET2SAICP	mg/kg	130		210	
Cerium	iMET2SAMS	mg/kg	140		1500	
Chromium	iMET2SAICP	mg/kg	94		56	
Cobalt	iMET2SAMS	mg/kg	1.8		7.5	
Copper	iMET2SAMS	mg/kg	15		23	
Gallium	iMET2SAMS	mg/kg	8.6		45	
Iron	iMET2SAICP	mg/kg	11000		55000	
Lanthanum	iMET2SAICP	mg/kg	65		600	
Lead	iMET2SAMS	mg/kg	43		39	
Lithium	iMET2SAICP	mg/kg	0.2		0.8	
Magnesium	iMET2SAICP	mg/kg	80		130	
Manganese	iMET2SAICP	mg/kg	110		130	
Mercury	iMET2SAMS	mg/kg	<0.02		<0.02	
Molybdenum	iMET2SAMS	mg/kg	1.1		0.72	
Nickel	iMET2SAMS	mg/kg	19		72	
Potassium	iMET2SAICP	mg/kg	51		96	
Rubidium	iMET2SAMS	mg/kg	0.34		1.4	
Scandium	iMET2SAMS	mg/kg	9.5		9.3	
Selenium	iMET2SAMS	mg/kg	0.13		0.98	
Silicon	iMET2SAICP	mg/kg	230		250	
Silver	iMET2SAMS	mg/kg	0.08		0.07	
Sodium	iMET2SAICP	mg/kg	140		120	
Strontium	iMET2SAICP	mg/kg	4.9		13	
Sulfur	iMET2SAICP	mg/kg	26		100	
Thallium	iMET2SAMS	mg/kg	0.48		0.64	
Thorium	iMET2SAMS	mg/kg	100		200	
Tin	iMET2SAMS	mg/kg	12		6.5	
Titanium	iMET2SAICP	mg/kg	1600		440	
Tungsten	iMET2SAMS	mg/kg	<0.5		<0.5	
Uranium	iMET2SAMS	mg/kg	5.6		21	
Vanadium	iMET2SAICP	mg/kg	130		160	
Ytterbium	iMET2SAMS	mg/kg	3.5		8.0	
Yttrium	iMET2SAMS	mg/kg	29		140	
Zirconium	iMET2SAMS	mg/kg	43		13	
Zinc	iMET2SAMS	mg/kg	34		100	
pH	iPH1WASE		6.5		6.4	
Electrical Conductivity	iEC1WZSE	mS/m	1.0		1.1	
TDS (calculated)	iSOL1WDCA	mg/L	6		6	
Bicarbonate	iALK1WATI	mg/L	<1		<1	

LAB ID			025	026	027	028
Client ID			T6-Mags_A1-31	T6-Mags_A1-32	T6-Mags_A3-33	T6-Mags_A3-34
Sampled						
Analyte	**Method**	**Unit**				
Carbonate	iALK1WATI	mg/L	<1		<1	
Aluminium	iMET1WCICP	mg/L	0.044		0.041	
Antimony	iMET1WCMS	mg/L	<0.0001		<0.0001	
Arsenic	iMET1WCMS	mg/L	0.021		0.009	
Barium	iMET1WCMS	mg/L	0.0007		0.0021	
Beryllium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Bismuth	iMET1WCMS	mg/L	<0.0001		<0.0001	
Boron	iMET1WCMS	mg/L	<0.005		0.008	
Cadmium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Calcium	iMET1WCICP	mg/L	<0.1		<0.1	
Cerium	iMET1WCMS	mg/L	0.0026		<0.0005	
Chromium	iMET1WCMS	mg/L	0.011		0.0072	
Cobalt	iMET1WCMS	mg/L	<0.0001		<0.0001	
Copper	iMET1WCMS	mg/L	0.0028		0.0044	
Gallium	iMET1WCMS	mg/L	0.0002		<0.0001	
Iron	iMET1WCICP	mg/L	0.043		0.051	
Lanthanum	iMET1WCMS	mg/L	0.0010		0.0001	
Lead	iMET1WCMS	mg/L	0.0003		<0.0001	
Lithium	iMET1WCMS	mg/L	0.0003		0.0018	
Magnesium	iMET1WCICP	mg/L	<0.1		<0.1	
Manganese	iMET1WCMS	mg/L	0.0012		0.0004	
Mercury	iMET1WCMS	mg/L	<0.0001		<0.0001	
Molybdenum	iMET1WCMS	mg/L	0.002		0.001	
Nickel	iMET1WCMS	mg/L	0.001		0.010	
Potassium	iMET1WCICP	mg/L	<0.1		0.2	
Rubidium	iMET1WCMS	mg/L	0.0001		0.0003	
Scandium	iMET1WCMS	mg/L	<0.0005		<0.0005	
Selenium	iMET1WCMS	mg/L	<0.001		<0.001	
Silicon	iMET1WCICP	mg/L	0.81		1.0	
Silver	iMET1WCMS	mg/L	<0.0001		<0.0001	
Sodium	iMET1WCICP	mg/L	1.8		1.8	
Strontium	iMET1WCMS	mg/L	0.0001		0.0004	
Sulfur	iMET1WCICP	mg/L	0.3		0.2	
Thallium	iMET1WCMS	mg/L	<0.0001		<0.0001	
Thorium	iMET1WCMS	mg/L	0.0008		0.0002	
Tin	iMET1WCMS	mg/L	0.0001		<0.0001	
Titanium	iMET1WCMS	mg/L	0.047		0.013	
Tungsten	iMET1WCMS	mg/L	<0.002		<0.002	
Uranium	iMET1WCMS	mg/L	0.0001		<0.0001	
Vanadium	iMET1WCMS	mg/L	0.027		0.0079	
Ytterbium	iMET1WCMS	mg/L	<0.0005		<0.0005	
Yttrium	iMET1WCMS	mg/L	0.0008		0.0002	
Zinc	iMET1WCMS	mg/L	0.003		0.002	
Zirconium	iMET1WCMS	mg/L	0.0070		0.0020	
Chloride	iCO1WCDA	mg/L	<1		<1	
Fluoride	iF1WASE	mg/L	0.19		0.27	
Phosphorus, sol. reactive	iP1WTFIA	mg/L	0.03		0.01	
Chromium(III)	iCR3+1WCCAL	mg/L	<0.001		<0.001	
Chromium(VI)	iCO1WCDAL	mg/L	0.010		0.007	

LAB ID			029	030	031	032
Client ID			T7-CrFloat_A1-35	T7-CrRoast_A1-36	T8-N/M-MSP_A1-37	T8-N/M-MSP_A1-38
Sampled						
Analyte	**Method**	**Unit**				
NAG pH	ARD				5.5	5.4
NAG (Net Acid Generation)	ARD	kg H2SO4/			<0.5	
Total oxidisable sulfur	TOS (ARD)	%			<0.01	
Sulfur present as SO4	SO4 S (ARD)	%			<0.01	
Sulfur	(combs)	%			<0.01	
Acid Neutralising Capacity	ARD	kg H2SO4/			1.6	
pH, 1:2 soil:water	ARD				7.1	
EC 1 soil 2 water paste	ARD	mS/m			5	
Carbon	(combs)	%			<0.05	
Total Organic Carbon	(combs)	%			<0.05	
Total Inorganic Carbon	(combs)	%			<0.05	
Aluminium	iMET2SAICP	mg/kg	690	1970	337	
Antimony	iMET2SAMS	mg/kg	1.1	0.83	0.66	
Arsenic	iMET2SAMS	mg/kg	7.2	6.5	11	
Barium	iMET2SAICP	mg/kg	21	53	13	
Beryllium	iMET2SAMS	mg/kg	0.18	0.19	0.20	
Bismuth	iMET2SAMS	mg/kg	0.73	1.2	0.69	
Boron	iMET2SAICP	mg/kg	<5	12	<5	
Cadmium	iMET2SAMS	mg/kg	<0.05	<0.05	<0.05	
Calcium	iMET2SAICP	mg/kg	30	540	150	
Cerium	iMET2SAMS	mg/kg	57	100	80	
Chromium	iMET2SAICP	mg/kg	80	110	26	
Cobalt	iMET2SAMS	mg/kg	1.8	18	0.5	
Copper	iMET2SAMS	mg/kg	5.4	14	49	
Gallium	iMET2SAMS	mg/kg	4.3	10	4.5	
Iron	iMET2SAICP	mg/kg	9400	59000	3400	
Lanthanum	iMET2SAICP	mg/kg	28	49	35	
Lead	iMET2SAMS	mg/kg	32	45	14	
Lithium	iMET2SAICP	mg/kg	0.2	1.8	<0.2	
Magnesium	iMET2SAICP	mg/kg	94	1700	47	
Manganese	iMET2SAICP	mg/kg	140	2300	27	
Mercury	iMET2SAMS	mg/kg	<0.02	<0.02	<0.02	
Molybdenum	iMET2SAMS	mg/kg	0.85	0.17	0.77	
Nickel	iMET2SAMS	mg/kg	11	26	11	
Potassium	iMET2SAICP	mg/kg	16	92	60	
Rubidium	iMET2SAMS	mg/kg	0.10	0.51	0.71	
Scandium	iMET2SAMS	mg/kg	4.6	11	12	
Selenium	iMET2SAMS	mg/kg	0.05	0.06	0.12	
Silicon	iMET2SAICP	mg/kg	240	160	240	
Silver	iMET2SAMS	mg/kg	0.06	<0.05	<0.05	
Sodium	iMET2SAICP	mg/kg	32	72	31	
Strontium	iMET2SAICP	mg/kg	2.6	6.4	3.6	
Sulfur	iMET2SAICP	mg/kg	27	270	8	
Thallium	iMET2SAMS	mg/kg	2.5	0.54	0.66	
Thorium	iMET2SAMS	mg/kg	57	50	67	
Tin	iMET2SAMS	mg/kg	9.8	6.0	3.5	
Titanium	iMET2SAICP	mg/kg	1800	2600	330	

LAB ID			029	030	031	032
Client ID			T7-CrFloat_A1-35	T7-CrRoast_A1-36	T8-N/M-MSP_A1-37	T8-N/M-MSP_A1-38
Sampled						
Analyte	**Method**	**Unit**				
Tungsten	iMET2SAMS	mg/kg	<0.5	<0.5	<0.5	
Uranium	iMET2SAMS	mg/kg	2.3	1.9	7.0	
Vanadium	iMET2SAICP	mg/kg	94	66	59	
Ytterbium	iMET2SAMS	mg/kg	0.93	0.92	6.2	
Yttrium	iMET2SAMS	mg/kg	8.6	9.5	42	
Zirconium	iMET2SAMS	mg/kg	27	9.7	57	
Zinc	iMET2SAMS	mg/kg	31	94	38	
pH	iPH1WASE		5.7	8.5	6.4	
Electrical Conductivity	iEC1WZSE	mS/m	1.2	15.8	0.9	
TDS (calculated)	iSOL1WDCA	mg/L	7	87	5	
Bicarbonate	iALK1WATI	mg/L	<1	1	<1	
Carbonate	iALK1WATI	mg/L	<1	6	<1	
Aluminium	iMET1WCICP	mg/L	0.11	0.40	0.011	
Antimony	iMET1WCMS	mg/L	<0.0001	0.0024	<0.0001	
Arsenic	iMET1WCMS	mg/L	<0.001	0.23	0.004	
Barium	iMET1WCMS	mg/L	0.011	0.051	0.0012	
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Boron	iMET1WCMS	mg/L	<0.005	0.006	<0.005	
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Calcium	iMET1WCICP	mg/L	0.5	20.5	0.5	
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	
Chromium	iMET1WCMS	mg/L	<0.0005	<0.0005	0.0085	
Cobalt	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Copper	iMET1WCMS	mg/L	0.0012	0.0077	0.0071	
Gallium	iMET1WCMS	mg/L	<0.0001	0.0023	<0.0001	
Iron	iMET1WCICP	mg/L	<0.005	<0.005	<0.005	
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Lithium	iMET1WCMS	mg/L	0.0004	0.0049	0.0004	
Magnesium	iMET1WCICP	mg/L	0.1	1.3	0.2	
Manganese	iMET1WCMS	mg/L	0.0021	0.0007	0.0002	
Mercury	iMET1WCMS	mg/L	<0.0001	0.0007	0.0001	
Molybdenum	iMET1WCMS	mg/L	<0.001	0.007	0.001	
Nickel	iMET1WCMS	mg/L	0.006	<0.001	0.002	
Potassium	iMET1WCICP	mg/L	0.2	0.1	0.2	
Rubidium	iMET1WCMS	mg/L	0.0003	0.0003	0.0005	
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	
Silicon	iMET1WCICP	mg/L	0.35	1.9	0.71	
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	
Sodium	iMET1WCICP	mg/L	0.8	0.3	0.7	
Strontium	iMET1WCMS	mg/L	0.0036	0.066	0.0017	
Sulfur	iMET1WCICP	mg/L	0.3	16	0.2	
Thallium	iMET1WCMS	mg/L	0.0019	0.0002	0.0001	
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0002	
Tin	iMET1WCMS	mg/L	0.0001	0.0003	<0.0001	
Titanium	iMET1WCMS	mg/L	<0.0005	<0.0005	0.014	
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	

LAB ID			029	030	031	032
Client ID			T7-CrFloat_A1-35	T7-CrRoast_A1-36	T8-N/M-MSP_A1-37	T8-N/M-MSP_A1-38
Sampled						
Analyte	Method	Unit				
Vanadium	iMET1WCMS	mg/L	0.0004	0.64	0.0066	
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	0.0003	
Zinc	iMET1WCMS	mg/L	0.012	<0.001	0.002	
Zirconium	iMET1WCMS	mg/L	0.0007	0.0001	0.0052	
Chloride	iCO1WCDA	mg/L	<1	1	<1	
Fluoride	iF1WASE	mg/L	0.61	0.08	0.26	
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	0.12	<0.01	
Chromium(III)	iCR3+1WCCAL	mg/L	<0.001	<0.001	<0.001	
Chromium(VI)	iCO1WCDAL	mg/L	<0.001	<0.001	0.008	

LAB ID			033	035	036	037
Client ID			T8-N/M-MSP_A3-39	T2-FPP-FT_A3-9 (dec)	T2-FPP-FT_A3-10 (dec)	T2-FPP-FT_A3-11 (dec)
Sampled						
Analyte	Method	Unit				
NAG pH	ARD		5.1			
NAG (Net Acid Generation)	ARD	kg H2SO4/	<0.5			
Total oxidisable sulfur	TOS (ARD)	%	<0.01			
Sulfur present as SO4	SO4 S (ARD)	%	<0.01			
Sulfur	(combs)	%	<0.01			
Acid Neutralising Capacity	ARD	kg H2SO4/	0.9			
pH, 1:2 soil:water	ARD		7.2			
EC 1 soil 2 water paste	ARD	mS/m	7			
Aluminium	iMET2SAICP	mg/kg	644			
Antimony	iMET2SAMS	mg/kg	0.48			
Arsenic	iMET2SAMS	mg/kg	14			
Barium	iMET2SAICP	mg/kg	77			
Beryllium	iMET2SAMS	mg/kg	0.41			
Bismuth	iMET2SAMS	mg/kg	0.68			
Boron	iMET2SAICP	mg/kg	<5			
Cadmium	iMET2SAMS	mg/kg	<0.05			
Calcium	iMET2SAICP	mg/kg	150			
Cerium	iMET2SAMS	mg/kg	450			
Chromium	iMET2SAICP	mg/kg	16			
Cobalt	iMET2SAMS	mg/kg	1.6			
Copper	iMET2SAMS	mg/kg	13			
Gallium	iMET2SAMS	mg/kg	13			
Iron	iMET2SAICP	mg/kg	10000			
Lanthanum	iMET2SAICP	mg/kg	180			
Lead	iMET2SAMS	mg/kg	22			
Lithium	iMET2SAICP	mg/kg	0.6			
Magnesium	iMET2SAICP	mg/kg	63			
Manganese	iMET2SAICP	mg/kg	36			
Mercury	iMET2SAMS	mg/kg	<0.02			
Molybdenum	iMET2SAMS	mg/kg	0.33			
Nickel	iMET2SAMS	mg/kg	4.4			
Potassium	iMET2SAICP	mg/kg	86			

LAB ID			033	035	036	037
Client ID			T8-N/M-MSP_A3-39	T2-FPP-FT_A3-9 (dec)	T2-FPP-FT_A3-10 (dec)	T2-FPP-FT_A3-11 (dec)
Sampled						
Analyte	**Method**	**Unit**				
Rubidium	iMET2SAMS	mg/kg	1.1			
Scandium	iMET2SAMS	mg/kg	12			
Selenium	iMET2SAMS	mg/kg	0.32			
Silicon	iMET2SAICP	mg/kg	270			
Silver	iMET2SAMS	mg/kg	<0.05			
Sodium	iMET2SAICP	mg/kg	69			
Strontium	iMET2SAICP	mg/kg	12			
Sulfur	iMET2SAICP	mg/kg	38			
Thallium	iMET2SAMS	mg/kg	0.42			
Thorium	iMET2SAMS	mg/kg	130			
Tin	iMET2SAMS	mg/kg	2.9			
Titanium	iMET2SAICP	mg/kg	260			
Tungsten	iMET2SAMS	mg/kg	<0.5			
Uranium	iMET2SAMS	mg/kg	8.2			
Vanadium	iMET2SAICP	mg/kg	60			
Ytterbium	iMET2SAMS	mg/kg	9.6			
Yttrium	iMET2SAMS	mg/kg	93			
Zirconium	iMET2SAMS	mg/kg	34			
Zinc	iMET2SAMS	mg/kg	39			
pH	iPH1WASE		6.4			
Electrical Conductivity	iEC1WZSE	mS/m	1.1			
TDS (calculated)	iSOL1WDCA	mg/L	6			
Bicarbonate	iALK1WATI	mg/L	<1			
Carbonate	iALK1WATI	mg/L	<1			
Chloride	iCO1WCDA	mg/L	<1			
Fluoride	iF1WASE	mg/L	0.31			
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01			
Chromium(III)	iCR3+1WCCAL	mg/L	<0.001			
Chromium(VI)	iCO1WCDAL	mg/L	0.008			
Aluminium	iMET1WCICP	mg/L	0.035	<0.005	<0.005	<0.005
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.003	<0.001	<0.001	<0.001
Barium	iMET1WCMS	mg/L	0.0018	0.035	0.036	0.035
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.006	0.31	0.31	0.31
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.5	8.6	8.6	8.6
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	iMET1WCMS	mg/L	0.0087	<0.0005	<0.0005	<0.0005
Cobalt	iMET1WCMS	mg/L	<0.0001	0.0002	0.0002	0.0002
Copper	iMET1WCMS	mg/L	0.0045	0.0016	0.0009	0.0008
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	0.030	<0.005	<0.005	<0.005
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0020	0.0047	0.0046	0.0046
Magnesium	iMET1WCICP	mg/L	0.1	9.1	9.0	9.1
Manganese	iMET1WCMS	mg/L	0.0001	0.037	0.040	0.040

LAB ID			033	035	036	037
Client ID			T8-N/M-MSP_A 3-39	T2-FPP-FT_A3- 9 (dec)	T2-FPP-FT_A3- 10 (dec)	T2-FPP-FT_A3-1 1 (dec)
Sampled						
Analyte	Method	Unit				
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	0.001	0.001	<0.001
Nickel	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	0.3	4.2	4.1	4.2
Rubidium	iMET1WCMS	mg/L	0.0006	0.0015	0.0014	0.0014
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.93	12	12	12
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	1.3	88.2	87.3	87.0
Strontium	iMET1WCMS	mg/L	0.0025	0.088	0.091	0.087
Sulfur	iMET1WCICP	mg/L	0.3	26	25	25
Thallium	iMET1WCMS	mg/L	0.0001	0.0001	0.0001	0.0001
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.0056	<0.0005	<0.0005	<0.0005
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	iMET1WCMS	mg/L	0.0034	0.0017	0.0018	0.0016
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	0.002	0.004	0.003	0.003
Zirconium	iMET1WCMS	mg/L	0.0016	0.0002	0.0001	<0.0001

LAB ID			038
Client ID			T2-FPP-FT_A3- 12 (dec)
Sampled			
Analyte	Method	Unit	
Aluminium	iMET1WCICP	mg/L	<0.005
Antimony	iMET1WCMS	mg/L	<0.0001
Arsenic	iMET1WCMS	mg/L	<0.001
Barium	iMET1WCMS	mg/L	0.036
Beryllium	iMET1WCMS	mg/L	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001
Boron	iMET1WCMS	mg/L	0.30
Cadmium	iMET1WCMS	mg/L	<0.0001
Calcium	iMET1WCICP	mg/L	8.5
Cerium	iMET1WCMS	mg/L	<0.0005
Chromium	iMET1WCMS	mg/L	<0.0005
Cobalt	iMET1WCMS	mg/L	0.0002
Copper	iMET1WCMS	mg/L	0.0006
Gallium	iMET1WCMS	mg/L	<0.0001
Iron	iMET1WCICP	mg/L	<0.005
Lanthanum	iMET1WCMS	mg/L	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001
Lithium	iMET1WCMS	mg/L	0.0047
Magnesium	iMET1WCICP	mg/L	9.1
Manganese	iMET1WCMS	mg/L	0.034

LAB ID			038
Client ID			T2-FPP-FT_A3-12 (dec)
Sampled			
Analyte	**Method**	**Unit**	
Mercury	iMET1WCMS	mg/L	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001
Nickel	iMET1WCMS	mg/L	<0.001
Potassium	iMET1WCICP	mg/L	4.1
Rubidium	iMET1WCMS	mg/L	0.0016
Scandium	iMET1WCMS	mg/L	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001
Silicon	iMET1WCICP	mg/L	11
Silver	iMET1WCMS	mg/L	<0.0001
Sodium	iMET1WCICP	mg/L	86.6
Strontium	iMET1WCMS	mg/L	0.092
Sulfur	iMET1WCICP	mg/L	25
Thallium	iMET1WCMS	mg/L	0.0001
Thorium	iMET1WCMS	mg/L	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001
Titanium	iMET1WCMS	mg/L	<0.0005
Tungsten	iMET1WCMS	mg/L	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001
Vanadium	iMET1WCMS	mg/L	0.0014
Ytterbium	iMET1WCMS	mg/L	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002
Zinc	iMET1WCMS	mg/L	0.004
Zirconium	iMET1WCMS	mg/L	<0.0001

Method	Method Description
(combs)	Total carbon, total organic carbon (acid pretreatment), total inorganic carbon (calculation) and Sulfur in soils by combustion, in-house method S57.
ARD	The acid generating and acid neutralising capacities of the sample are measured. These values are used in acid/base accounting (ABA) to determine if the sample will generate acid after prolonged exposure in the environment. The methods used are based on industry conventions. A Net Acid Generation (NAG) test is often used to confirm the predictions from ABA..
iALK1WATI	Alkalinity (as CaCO3) and constituents by acid titration.
iCO1WCDA	Colourimetric analysis by DA (Discrete Autoanalyser).
iCO1WCDAL	Colourimetric analysis by DA (Discrete Autoanalyser).
iCR3+1WCCAL	Chromium (III) species by calculation (Cr minus Cr(VI)).
iEC1WZSE	Electrical conductivity in water compensated to 25C.
iF1WASE	Fluoride in water by ion specific electrode (ISE).
iMET1WCICP	Total dissolved metals by ICPAES.
iMET1WCMS	Total dissolved metals by ICPMS.
iMET2SAICP	Acid digestable metals (dry wt basis) by digestion and ICPAES.
iMET2SAMS	Acid digestable metals (dry wt basis) by ICPMS.
iP1WTFIA	Phosphorus soluble reactive as P in water by FIA.
iPH1WASE	pH in water by pH meter.
iSOL1WDCA	Total Dissolved Solids (TDS) calculated (ECond * 5.5)
SO4 S (ARD)	Sulfur present as Sulfate (HCl ext.)
SUPP	Analysis outsourced to external laboratories
TOS (ARD)	Total oxidisable sulfur, the difference between total S and sulfate S

Selected samples from the range 20S5156/001-034 were extracted in accordance with AS 4439.3-1997 using DI water as the extractant.
Results reported for these samples under method codes iPH1WASE, iEC1WZSE, iALK1WATI, iMET1WCMS, iMET1WCICP, iCO1WCDA and iSOL1WDCA are concentrations found in the 1:20 extract.

Some samples were outsourced to Intertek Genalysis for quantative XRD. A copy of their report and results is attached.

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report.
This report may only be reproduced in full.

HMay

Hanna May
Team Leader
SSD Inorganic Chemistry
10-Aug-2021

B. Price

Barry Price
Snr Chemist & Research Officer

ChemCentre

Scientific Services Division

Report of Examination

Resources and Chemistry Precinct
Cnr Manning Road and Townsing Drive
Bentley
WA 6102
T +61 8 9422 9800
F +61 8 9422 9801
www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: 2103045B
ChemCentre Reference: 21S0017 R0

VHM Limited
Level 2, Suite 9, 389 Oxford Street
MOUNT HAWTHORN WA 6016

Attention: Colleen Burgers

Report on: 18 samples received on 01/07/2021

LAB ID	Material	Client ID and Description
21S0017 / 001	NAG Liquor	20S5156/001_NAG Liq T1-FPP-OS_A1-1
21S0017 / 002	NAG Liquor	20S5156/003_NAG Liq T1-FPP-OS_A3-3
21S0017 / 003	NAG Liquor	20S5156/005_NAG Liq T2-FPP-FT_A3-9
21S0017 / 004	NAG Liquor	20S5156/007_NAG Liq T2-FPP-FT_A3-11
21S0017 / 005	NAG Liquor	20S5156/009_NAG Liq T3-WCP-CT_A1-13
21S0017 / 006	NAG Liquor	20S5156/010_NAG Liq T3-WCP-CT_A1-14
21S0017 / 007	NAG Liquor	20S5156/012_NAG Liq T3-WCP-CT_A1-16
21S0017 / 008	NAG Liquor	20S5156/014_NAG Liq T3-WCP-CT_A1-18
21S0017 / 009	NAG Liquor	20S5156/015_NAG Liq T3-WCP-CT_A3-19
21S0017 / 010	NAG Liquor	20S5156/016_NAG Liq T3-WCP-CT_A3-20
21S0017 / 011	NAG Liquor	20S5156/018_NAG Liq T3-WCP-CT_A3-22
21S0017 / 012	NAG Liquor	20S5156/019_NAG Liq T3-WCP-CT_A3-23
21S0017 / 013	NAG Liquor	20S5156/021_NAG Liq T4-REMC-GT_A1-25
21S0017 / 014	NAG Liquor	20S5156/023_NAG Liq T5-N/M-GT_A1-29
21S0017 / 015	NAG Liquor	20S5156/025_NAG Liq T6-Mags_A1-31
21S0017 / 016	NAG Liquor	20S5156/027_NAG Liq T6-Mags_A3-33
21S0017 / 017	NAG Liquor	20S5156/031_NAG Liq T8-N/M-MSP_A1-37
21S0017 / 018	NAG Liquor	20S5156/033_NAG Liq T8-N/M-MSP_A3-39

LAB ID			001	002	003	004
Client ID			20S5156/001_NAG Liq	20S5156/003_NAG Liq	20S5156/005_NAG Liq	20S5156/007_NAG Liq
Sampled						
Analyte	**Method**	**Unit**				
Aluminium	iMET1WCICP	mg/L	0.008	<0.005	0.045	<0.005
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	0.0002
Arsenic	iMET1WCMS	mg/L	0.006	0.005	0.004	0.004
Barium	iMET1WCMS	mg/L	0.049	0.025	0.0079	0.0064
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	<0.005	<0.005	<0.005	<0.005
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	<0.1	1.1	0.5	0.4
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Chloride	iANIO1WAIC	mg/L	<5.0	<5.0	<5.0	<5.0
Chromium	iMET1WCMS	mg/L	0.037	0.035	0.022	0.016
Cobalt	iMET1WCMS	mg/L	0.0003	<0.0001	0.0005	0.0005
Copper	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	<0.005	<0.005	0.021	<0.005

LAB ID			001	002	003	004
Client ID			20S5156/001_NAG Liq	20S5156/003_NAG Liq	20S5156/005_NAG Liq	20S5156/007_NAG Liq
Sampled						
Analyte	**Method**	**Unit**				
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0010	0.0027	0.0028	0.0027
Magnesium	iMET1WCICP	mg/L	0.2	1.0	0.7	0.6
Manganese	iMET1WCMS	mg/L	0.0045	0.0097	0.036	0.032
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	0.001	0.005	0.005
Nickel	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Rubidium	iMET1WCMS	mg/L	0.0004	0.0010	0.0006	0.0003
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.59	2.0	2.7	2.6
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	0.2	0.4	0.6	0.5
Strontium	iMET1WCMS	mg/L	0.0025	0.014	0.0088	0.0086
Sulfur	iMET1WCICP	mg/L	0.6	0.4	0.4	0.4
Thallium	iMET1WCMS	mg/L	<0.0001	0.0002	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.0070	0.0086	0.015	0.012
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	0.011	0.010
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	0.0001
Vanadium	iMET1WCMS	mg/L	0.084	0.17	0.24	0.24
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	0.008	<0.001	<0.001	<0.001
Zirconium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	0.0008

LAB ID			005	006	007	008
Client ID			20S5156/009_NAG Liq	20S5156/010_NAG Liq	20S5156/012_NAG Liq	20S5156/014_NAG Liq
Sampled						
Analyte	**Method**	**Unit**				
Aluminium	iMET1WCICP	mg/L	0.024	0.008	0.008	<0.005
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.004	0.004	0.005	0.003
Barium	iMET1WCMS	mg/L	0.018	0.037	0.015	0.016
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	<0.005	<0.005	<0.005	<0.005
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	<0.1	0.1	0.1	<0.1
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Chloride	iANIO1WAIC	mg/L	<5.0	<5.0	<5.0	<5.0
Chromium	iMET1WCMS	mg/L	0.0065	0.0066	0.0067	0.010
Cobalt	iMET1WCMS	mg/L	0.0002	0.0002	0.0043	0.0004
Copper	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001

LAB ID Client ID Sampled			005 20S5156/009_NAG Liq	006 20S5156/010_NAG Liq	007 20S5156/012_NAG Liq	008 20S5156/014_NAG Liq
Analyte	**Method**	**Unit**				
Iron	iMET1WCICP	mg/L	<0.005	<0.005	<0.005	<0.005
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0005	0.0006	0.0007	0.0007
Magnesium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Manganese	iMET1WCMS	mg/L	0.0060	0.0020	0.0035	0.0012
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Nickel	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	0.4	<0.1	<0.1	0.3
Rubidium	iMET1WCMS	mg/L	0.0003	0.0003	0.0003	0.0001
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.25	0.24	0.24	0.38
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Strontium	iMET1WCMS	mg/L	0.0016	0.0025	0.0019	0.0017
Sulfur	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Thallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.027	0.033	0.032	0.014
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0001	<0.0001	0.0001	<0.0001
Vanadium	iMET1WCMS	mg/L	0.013	0.012	0.013	0.013
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	0.007	<0.001	0.005	<0.001
Zirconium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001

LAB ID Client ID Sampled			009 20S5156/015_NAG Liq	010 20S5156/016_NAG Liq	011 20S5156/018_NAG Liq	012 20S5156/019_NAG Liq
Analyte	**Method**	**Unit**				
Aluminium	iMET1WCICP	mg/L	<0.005	0.006	<0.005	0.005
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.003	0.004	0.005	0.004
Barium	iMET1WCMS	mg/L	0.017	0.017	0.017	0.015
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.010	0.010	<0.005	<0.005
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.2	0.2	0.2	0.2
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Chloride	iANIO1WAIC	mg/L	<5.0	<5.0	<5.0	<5.0
Chromium	iMET1WCMS	mg/L	0.0080	0.0075	0.0058	0.0049
Cobalt	iMET1WCMS	mg/L	0.0004	0.0004	0.0009	0.0004
Copper	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001

LAB ID			009	010	011	012
Client ID			20S5156/015_NAG Liq	20S5156/016_NAG Liq	20S5156/018_NAG Liq	20S5156/019_NAG Liq
Sampled						
Analyte	**Method**	**Unit**				
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	<0.005	0.026	0.017	0.005
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0005	0.0005	0.0005	0.0004
Magnesium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Manganese	iMET1WCMS	mg/L	0.0048	0.0052	0.012	0.0053
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Nickel	iMET1WCMS	mg/L	<0.001	0.003	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	0.3	1.3	0.3	0.9
Rubidium	iMET1WCMS	mg/L	0.0001	<0.0001	0.0001	0.0003
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.43	0.44	0.34	0.32
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Strontium	iMET1WCMS	mg/L	0.0033	0.0031	0.0031	0.0031
Sulfur	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	<0.1
Thallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.012	0.020	0.023	0.019
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001	0.0001	0.0001	0.0001
Vanadium	iMET1WCMS	mg/L	0.017	0.017	0.017	0.016
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Zirconium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001

LAB ID			013	014	015	016
Client ID			20S5156/021_NAG Liq	20S5156/023_NAG Liq	20S5156/025_NAG Liq	20S5156/027_NAG Liq
Sampled						
Analyte	**Method**	**Unit**				
Aluminium	iMET1WCICP	mg/L	<0.005	0.006	<0.005	<0.005
Antimony	iMET1WCMS	mg/L	0.0001	0.0002	0.0004	0.0002
Arsenic	iMET1WCMS	mg/L	0.006	0.007	0.020	0.011
Barium	iMET1WCMS	mg/L	0.062	0.0040	0.0003	<0.0001
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	<0.005	0.040	<0.005	0.010
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.2	0.2	0.2	0.4
Cerium	iMET1WCMS	mg/L	0.0027	0.0007	0.0020	<0.0005
Chloride	iANIO1WAIC	mg/L	<5.0	<5.0	<5.0	<5.0
Chromium	iMET1WCMS	mg/L	0.011	0.016	0.098	0.032
Cobalt	iMET1WCMS	mg/L	0.0004	0.0002	0.0003	0.0002

LAB ID			013	014	015	016
Client ID			20S5156/021_N AG Liq	20S5156/023_N AG Liq	20S5156/025_N AG Liq	20S5156/027_N AG Liq
Sampled						
Analyte	**Method**	**Unit**				
Copper	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Gallium	iMET1WCMS	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	<0.005	<0.005	0.013	0.035
Lanthanum	iMET1WCMS	mg/L	0.0013	0.0002	0.0005	0.0002
Lead	iMET1WCMS	mg/L	0.0002	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0001	0.0002	0.0004	0.0010
Magnesium	iMET1WCICP	mg/L	<0.1	<0.1	0.1	0.2
Manganese	iMET1WCMS	mg/L	0.0076	0.049	0.012	0.012
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	0.003	<0.001
Nickel	iMET1WCMS	mg/L	0.006	0.004	0.009	0.019
Potassium	iMET1WCICP	mg/L	<0.1	1.5	0.2	<0.1
Rubidium	iMET1WCMS	mg/L	<0.0001	0.0001	0.0003	0.0004
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.11	0.29	1.1	1.3
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	<0.1	<0.1	0.1	<0.1
Strontium	iMET1WCMS	mg/L	0.0058	0.0025	0.0021	0.0059
Sulfur	iMET1WCICP	mg/L	0.3	<0.1	<0.1	<0.1
Thallium	iMET1WCMS	mg/L	0.0003	<0.0001	<0.0001	0.0002
Thorium	iMET1WCMS	mg/L	0.0006	0.0003	0.0006	0.0002
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.0078	0.18	0.30	0.18
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	0.004	0.005
Uranium	iMET1WCMS	mg/L	0.0018	0.0017	0.0020	0.0010
Vanadium	iMET1WCMS	mg/L	0.0098	0.034	0.23	0.21
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	0.0007	0.0004	0.0007	0.0006
Zinc	iMET1WCMS	mg/L	0.038	0.010	<0.001	<0.001
Zirconium	iMET1WCMS	mg/L	<0.0001	0.0038	0.0060	0.0016

LAB ID			017	018
Client ID			20S5156/031_N AG Liq	20S5156/033_N AG Liq
Sampled				
Analyte	**Method**	**Unit**		
Aluminium	iMET1WCICP	mg/L	<0.005	<0.005
Antimony	iMET1WCMS	mg/L	0.0003	0.0002
Arsenic	iMET1WCMS	mg/L	0.017	0.013
Barium	iMET1WCMS	mg/L	0.0004	0.0025
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	<0.005	0.020
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.4	0.4
Cerium	iMET1WCMS	mg/L	0.0010	<0.0005
Chloride	iANIO1WAIC	mg/L	<5.0	<5.0
Chromium	iMET1WCMS	mg/L	0.037	0.018

LAB ID			017	018
Client ID			20S5156/031_N AG Liq	20S5156/033_N AG Liq
Sampled				
Analyte	**Method**	**Unit**		
Cobalt	iMET1WCMS	mg/L	0.0003	0.0004
Copper	iMET1WCMS	mg/L	<0.0001	<0.0001
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	<0.005	0.008
Lanthanum	iMET1WCMS	mg/L	0.0003	<0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.0003	0.0010
Magnesium	iMET1WCICP	mg/L	0.1	0.1
Manganese	iMET1WCMS	mg/L	0.030	0.029
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	0.001	<0.001
Nickel	iMET1WCMS	mg/L	0.008	0.002
Potassium	iMET1WCICP	mg/L	<0.1	<0.1
Rubidium	iMET1WCMS	mg/L	<0.0001	0.0003
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	1.0	1.2
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	<0.1	<0.1
Strontium	iMET1WCMS	mg/L	0.0024	0.0055
Sulfur	iMET1WCICP	mg/L	<0.1	0.1
Thallium	iMET1WCMS	mg/L	0.0004	0.0002
Thorium	iMET1WCMS	mg/L	0.0007	0.0003
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.24	0.20
Tungsten	iMET1WCMS	mg/L	0.002	0.004
Uranium	iMET1WCMS	mg/L	0.0028	0.0015
Vanadium	iMET1WCMS	mg/L	0.11	0.16
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	0.0009	0.0004
Zinc	iMET1WCMS	mg/L	0.017	0.006
Zirconium	iMET1WCMS	mg/L	0.013	0.0051

Method	Method Description
iANIO1WAIC	Anions in water by Ion Chromatography.
iMET1WCICP	Total dissolved metals by ICPAES.
iMET1WCMS	Total dissolved metals by ICPMS.

The results reported are analyses of the NAG liquor solutions generated.

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report.
This report may only be reproduced in full.

HMay

Hanna May
Team Leader
SSD Inorganic Chemistry
22-Jul-2021

ChemCentre

Scientific Services Division

Amended Report

Resources and Chemistry Precinct
Cnr Manning Road and Townsing Drive
Bentley
WA 6102
T +61 8 9422 9800
F +61 8 9422 9801
www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: 2103045B
ChemCentre Reference: 21S0018 R1

VHM Limited
Level 2, Suite 9, 389 Oxford Street
MOUNT HAWTHORN WA 6016

Attention: Colleen Burgers

Report on: 10 samples received on 01/07/2021

LAB ID	Material	Client ID and Description
21S0018 / 001	ASLP extract	20S5156/002_ASLP T1-FPP-OS_A1-2
21S0018 / 002	ASLP extract	20S5156/004_ASLP T1-FPP-OS_A3-4
21S0018 / 003	ASLP extract	20S5156/005_ASLP T2-FPP-FT_A3-9
21S0018 / 004	ASLP extract	20S5156/008_ASLP T2-FPP-FT_A3-12
21S0018 / 005	ASLP extract	20S5156/011_ASLP T3-WCP-CT_A1-15
21S0018 / 006	ASLP extract	20S5156/017_ASLP T3-WCP-CT_A3-21
21S0018 / 007	ASLP extract	20S5156/022_ASLP T4-REMC-GT_A1-26
21S0018 / 008	ASLP extract	20S5156/024_ASLP T5-N/M-GT_A1-30
21S0018 / 009	ASLP extract	20S5156/026_ASLP T6-Mags_A1-32
21S0018 / 010	ASLP extract	20S5156/032_ASLP T8-N/M-MSP_A1-38

LAB ID			001	002	003	004
Client ID			20S5156/002_ASLP	20S5156/004_ASLP	20S5156/005_ASLP	20S5156/008_ASLP
Sampled						
Analyte	**Method**	**Unit**				
pH ASLP extract	iLP		4.9	4.9	4.9	5.0
Aluminium	iMET1WCICP	mg/L	0.61	0.48	0.53	0.29
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	0.001
Barium	iMET1WCMS	mg/L	0.93	0.99	0.30	0.31
Beryllium	iMET1WCMS	mg/L	0.0009	0.0025	0.0024	0.0019
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCICP	mg/L			0.07	0.09
Boron	iMET1WCMS	mg/L	0.014	0.038		
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0003	0.0003
Calcium	iMET1WCICP	mg/L	2.9	6.2	19.4	20.2
Cerium	iMET1WCMS	mg/L	0.030	0.0059	0.0091	0.0084
Chromium	iMET1WCMS	mg/L	0.081	0.061	0.0015	0.0010
Cobalt	iMET1WCMS	mg/L	0.0039	0.024	0.0066	0.0062
Copper	iMET1WCMS	mg/L	0.0034	0.0038	0.0053	0.0056
Gallium	iMET1WCMS	mg/L	0.0013	0.0004	0.0004	0.0004
Iron	iMET1WCICP	mg/L	0.77	0.059	<0.005	<0.005
Lanthanum	iMET1WCMS	mg/L	0.012	0.0027	0.0025	0.0023
Lead	iMET1WCMS	mg/L	0.0006	0.0002	0.0002	0.0002
Lithium	iMET1WCMS	mg/L	0.0051	0.013	0.013	0.013
Magnesium	iMET1WCICP	mg/L	2.2	4.9	18.6	19.2
Manganese	iMET1WCMS	mg/L	0.057	0.50	0.28	0.27
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001

LAB ID			001	002	003	004
Client ID			20S5156/002_A SLP	20S5156/004_A SLP	20S5156/005_A SLP	20S5156/008_A SLP
Sampled						
Analyte	Method	Unit				
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Nickel	iMET1WCMS	mg/L	0.013	0.022	0.016	0.017
Potassium	iMET1WCICP	mg/L	1.9	2.9	5.6	5.6
Rubidium	iMET1WCMS	mg/L	0.0061	0.0080	0.0077	0.0080
Scandium	iMET1WCMS	mg/L	0.0006	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	1.6	4.8	8.7	8.3
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	<0.1	<0.1	<0.1	46.2
Strontium	iMET1WCMS	mg/L	0.051	0.14	0.27	0.28
Sulfur	iMET1WCICP	mg/L	2.9	2.8	2.7	2.3
Thallium	iMET1WCMS	mg/L	<0.0001	0.0013	0.0003	0.0003
Thorium	iMET1WCMS	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0025	0.0065	0.0049	0.0046
Vanadium	iMET1WCMS	mg/L	0.0001	0.0002	0.0006	0.0007
Ytterbium	iMET1WCMS	mg/L	0.0008	0.0006	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	0.012	0.011	0.0071	0.0068
Zinc	iMET1WCMS	mg/L	0.18	0.029	0.10	0.094
Zirconium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0002	<0.0001
Chloride	iCO1WCDA	mg/L	2	6	5	5
Fluoride	iF1WASE	mg/L	0.08	0.12	0.21	0.17
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	<0.01	<0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.072	0.055	0.001	<0.001
Chromium(VI)	iCO1WCDAL	mg/L	<0.001	<0.001	<0.001	<0.001

LAB ID			005	006	007	008
Client ID			20S5156/011_A SLP	20S5156/017_A SLP	20S5156/022_A SLP	20S5156/024_A SLP
Sampled						
Analyte	Method	Unit				
pH ASLP extract	iLP		5.0	5.0	5.0	5.0
Aluminium	iMET1WCICP	mg/L	0.065	0.070	0.045	0.048
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	<0.001	0.001	0.010	0.003
Barium	iMET1WCMS	mg/L	0.15	0.097	2.2	0.064
Beryllium	iMET1WCMS	mg/L	0.0002	0.0005	0.0002	0.0002
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.033	0.032	0.036	0.029
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0003	0.0003
Calcium	iMET1WCICP	mg/L	1.8	2.5	3.1	2.8
Cerium	iMET1WCMS	mg/L	0.0090	0.0031	0.45	0.022
Chromium	iMET1WCMS	mg/L	0.0042	0.0039	0.0083	0.0033
Cobalt	iMET1WCMS	mg/L	0.0003	0.0014	0.0011	0.0004
Copper	iMET1WCMS	mg/L	0.0073	0.0041	0.051	0.030
Gallium	iMET1WCMS	mg/L	0.0004	0.0001	0.021	0.0010
Iron	iMET1WCICP	mg/L	<0.005	<0.005	<0.005	<0.005

LAB ID			005	006	007	008
Client ID			20S5156/011_A SLP	20S5156/017_A SLP	20S5156/022_A SLP	20S5156/024_A SLP
Sampled						
Analyte	**Method**	**Unit**				
Lanthanum	iMET1WCMS	mg/L	0.0044	0.0014	0.31	0.016
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0019	0.0003
Lithium	iMET1WCMS	mg/L	0.0012	0.0011	0.0004	0.0003
Magnesium	iMET1WCICP	mg/L	1.1	0.7	0.7	0.4
Manganese	iMET1WCMS	mg/L	0.0074	0.014	0.016	0.020
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Nickel	iMET1WCMS	mg/L	0.004	0.005	0.038	0.023
Potassium	iMET1WCICP	mg/L	1.0	0.8	0.3	0.4
Rubidium	iMET1WCMS	mg/L	0.0042	0.0025	0.0017	0.0031
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	0.47	0.66	0.49	0.59
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	120	98.3	148	90.9
Strontium	iMET1WCMS	mg/L	0.023	0.034	0.075	0.025
Sulfur	iMET1WCICP	mg/L	0.2	0.1	0.7	0.2
Thallium	iMET1WCMS	mg/L	0.0001	0.0001	0.0020	0.0008
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0007	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0002	<0.0001
Titanium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0007	0.0013	0.022	0.0033
Vanadium	iMET1WCMS	mg/L	0.0003	0.0005	0.0002	0.0005
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	0.019	0.0022
Yttrium	iMET1WCMS	mg/L	0.0045	0.0035	0.22	0.022
Zinc	iMET1WCMS	mg/L	0.038	0.034	0.29	0.15
Zirconium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0002	0.0002
Chloride	iCO1WCDA	mg/L	<1	<1	<1	<1
Fluoride	iF1WASE	mg/L	<0.05	<0.05	<0.05	<0.05
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	<0.01	0.08	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.002	0.002	0.006	0.002
Chromium(VI)	iCO1WCDAL	mg/L	0.002	0.002	0.001	0.001

LAB ID			009	010
Client ID			20S5156/026_A SLP	20S5156/032_A SLP
Sampled				
Analyte	**Method**	**Unit**		
pH ASLP extract	iLP		5.0	5.0
Aluminium	iMET1WCICP	mg/L	0.052	0.052
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.004	0.003
Barium	iMET1WCMS	mg/L	0.097	0.12
Beryllium	iMET1WCMS	mg/L	0.0004	0.0004
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.032	0.036
Cadmium	iMET1WCMS	mg/L	<0.0001	0.0002
Calcium	iMET1WCICP	mg/L	4.7	6.9

LAB ID			009	010
Client ID			20S5156/026_A SLP	20S5156/032_A SLP
Sampled				
Analyte	**Method**	**Unit**		
Cerium	iMET1WCMS	mg/L	0.046	0.032
Chromium	iMET1WCMS	mg/L	0.0066	0.0051
Cobalt	iMET1WCMS	mg/L	0.0019	0.0012
Copper	iMET1WCICP	mg/L	0.18	1.0
Gallium	iMET1WCMS	mg/L	0.0021	0.0015
Iron	iMET1WCICP	mg/L	<0.005	<0.005
Lanthanum	iMET1WCMS	mg/L	0.038	0.024
Lead	iMET1WCMS	mg/L	<0.0001	0.0001
Lithium	iMET1WCMS	mg/L	0.0011	0.0007
Magnesium	iMET1WCICP	mg/L	0.8	1.0
Manganese	iMET1WCMS	mg/L	0.028	0.036
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001
Nickel	iMET1WCICP	mg/L	0.09	0.08
Potassium	iMET1WCICP	mg/L	1.4	0.8
Rubidium	iMET1WCMS	mg/L	0.0036	0.0040
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	1.6	1.8
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	159	129
Strontium	iMET1WCMS	mg/L	0.043	0.049
Sulfur	iMET1WCICP	mg/L	0.3	0.2
Thallium	iMET1WCMS	mg/L	0.0014	0.0033
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	<0.0005	<0.0005
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0053	0.0052
Vanadium	iMET1WCMS	mg/L	0.0008	0.0006
Ytterbium	iMET1WCMS	mg/L	0.0024	0.0022
Yttrium	iMET1WCMS	mg/L	0.040	0.029
Zinc	iMET1WCMS	mg/L	0.20	0.79
Zirconium	iMET1WCMS	mg/L	<0.0001	0.0002
Chloride	iCO1WCDA	mg/L	<1	<1
Fluoride	iF1WASE	mg/L	<0.05	<0.05
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.003	0.004
Chromium(VI)	iCO1WCDAL	mg/L	0.003	<0.001

Method	Method Description
iCO1WCDA	Colourimetric analysis by DA (Discrete Autoanalyser).
iCO1WCDAL	Colourimetric analysis by DA (Discrete Autoanalyser).
iCR3+1WCCAL	Chromium (III) species by calculation (Cr minus Cr(VI)).
iF1WASE	Fluoride in water by ion specific electrode (ISE).
iLP	1:20 leach extraction.
iMET1WCICP	Total dissolved metals by ICPAES.
iMET1WCMS	Total dissolved metals by ICPMS.
iP1WTFIA	Phosphorus soluble reactive as P in water by FIA.

Please note: This is an amended report that contains information that is different from the original report . The original report must be destroyed and replaced with this corrected version. Additional analysis was requested after issue of the original report.

The sample(s) were extracted in accordance with AS 4439.3-1997 using pH 5 buffer as the extractant - Final pH of extract reported above. Results reported are concentrations found in the 1:20 extract.

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report.
This report may only be reproduced in full.

Hanna May
Team Leader
SSD Inorganic Chemistry
9-Aug-2021

ChemCentre

Scientific Services Division

Amended Report

Resources and Chemistry Precinct
Cnr Manning Road and Townsing Drive
Bentley
WA 6102
T +61 8 9422 9800
F +61 8 9422 9801
www.chemcentre.wa.gov.au
ABN 40 991 885 705

Purchase Order: 2103045B
ChemCentre Reference: 21S0019 R1

VHM Limited
Level 2, Suite 9, 389 Oxford Street
MOUNT HAWTHORN WA 6016

Attention: Colleen Burgers

Report on: 15 samples received on 01/07/2021

LAB ID	Material	Client ID and Description
21S0019 / 001	water extract	20S5156/002_WE T1-FPP-OS_A1-2
21S0019 / 002	water extract	20S5156/004_WE T1-FPP-OS_A3-4
21S0019 / 003	water extract	20S5156/005_WE T2-FPP-FT_A3-9
21S0019 / 004	water extract	20S5156/006_WE T2-FPP-FT_A3-10
21S0019 / 005	water extract	20S5156/007_WE T2-FPP-FT_A3-11
21S0019 / 006	water extract	20S5156/008_WE T2-FPP-FT_A3-12
21S0019 / 007	water extract	20S5156/010_WE T3-WCP-CT_A1-14
21S0019 / 008	water extract	20S5156/013_WE T3-WCP-CT_A1-17
21S0019 / 009	water extract	20S5156/016_WE T3-WCP-CT_A3-20
21S0019 / 010	water extract	20S5156/020_WE T3-WCP-CT_A3-24
21S0019 / 011	water extract	20S5156/024_WE T5-N/M-GT_A1-30
21S0019 / 012	water extract	20S5156/026_WE T6-Mags_A1-32
21S0019 / 013	water extract	20S5156/028_WE T6-Mags_A3-34
21S0019 / 014	water extract	20S5156/032_WE T8-N/M-MSP_A1-38
21S0019 / 015	water extract	20S5156/034_WE T8-N/M-MSP_A3-40

LAB ID			001	002	003	004
Client ID			20S5156/002_WE	20S5156/004_WE	20S5156/005_WE	20S5156/006_WE
Sampled						
Analyte	**Method**	**Unit**				
pH	iPH1WASE		5.9	6.5	6.2	6.3
Electrical Conductivity	iEC1WZSE	mS/m	8.6	16.8	14.7	13.9
TDS (calculated)	iSOL1WDCA	mg/L	47	92	81	76
Bicarbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Carbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Aluminium	iMET1WCICP	mg/L	0.015	0.011	0.093	0.19
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	0.0001
Arsenic	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Barium	iMET1WCMS	mg/L	0.10	0.050	0.0046	0.0046
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCICP	mg/L		0.08	0.13	0.13
Boron	iMET1WCMS	mg/L	0.037			
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.9	1.2	0.9	0.9
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	iMET1WCMS	mg/L	<0.0005	0.0027	0.0006	0.0009
Cobalt	iMET1WCMS	mg/L	0.0010	0.0001	<0.0001	0.0001
Copper	iMET1WCMS	mg/L	<0.0001	0.0001	0.0004	0.0004

LAB ID Client ID Sampled			001 20S5156/002_ WE	002 20S5156/004_ WE	003 20S5156/005_ WE	004 20S5156/006_W E
Analyte	**Method**	**Unit**				
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Iron	iMET1WCICP	mg/L	0.095	0.008	0.10	0.21
Lanthanum	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Lead	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Lithium	iMET1WCMS	mg/L	0.011	0.024	0.0054	0.0050
Magnesium	iMET1WCICP	mg/L	0.9	1.3	1.1	1.1
Manganese	iMET1WCMS	mg/L	0.019	0.0018	0.0034	0.0035
Mercury	iMET1WCMS	mg/L	<0.0001	0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Nickel	iMET1WCMS	mg/L	0.004	<0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	2.4	2.5	2.3	2.1
Rubidium	iMET1WCMS	mg/L	0.0030	0.0030	0.0016	0.0014
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	4.3	5.5	9.8	10
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	11.4	24.6	20.9	20.4
Strontium	iMET1WCMS	mg/L	0.014	0.025	0.013	0.013
Sulfur	iMET1WCICP	mg/L	7.2	10	10	9.7
Thallium	iMET1WCMS	mg/L	<0.0001	0.0002	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	<0.0005	<0.0005	0.0055	0.010
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	iMET1WCMS	mg/L	0.0002	0.0005	0.0017	0.0027
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Zinc	iMET1WCMS	mg/L	0.035	0.003	0.002	0.002
Zirconium	iMET1WCMS	mg/L	<0.0001	0.0003	0.0006	0.0009
Chloride	iCO1WCDA	mg/L	7	21	19	19
Fluoride	iF1WASE	mg/L	<0.05	0.46	0.48	0.51
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	<0.01	0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L		0.003		
Chromium(VI)	iCO1WCDAL	mg/L		<0.001		

LAB ID Client ID Sampled			005 20S5156/007_ WE	006 20S5156/008_ WE	007 20S5156/010_ WE	008 20S5156/013_W E
Analyte	**Method**	**Unit**				
pH	iPH1WASE		6.2	6.2	6.0	6.1
Electrical Conductivity	iEC1WZSE	mS/m	14.1	13.5	1.4	1.3
TDS (calculated)	iSOL1WDCA	mg/L	77	74	8	7
Bicarbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Carbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Aluminium	iMET1WCICP	mg/L	0.41	0.72	1.9	0.84
Antimony	iMET1WCMS	mg/L	0.0002	0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.001	0.001	0.003	0.002

LAB ID			005	006	007	008
Client ID			20S5156/007_WE	20S5156/008_WE	20S5156/010_WE	20S5156/013_WE
Sampled						
Analyte	Method	Unit				
Barium	iMET1WCMS	mg/L	0.0042	0.0045	0.0029	0.0016
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCICP	mg/L	0.13	0.13		
Boron	iMET1WCMS	mg/L			0.015	0.013
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.9	0.8	<0.1	<0.1
Cerium	iMET1WCMS	mg/L	<0.0005	<0.0005	0.0009	0.0005
Chromium	iMET1WCMS	mg/L	0.0012	0.0025	0.014	0.012
Cobalt	iMET1WCMS	mg/L	0.0001	0.0002	0.0001	<0.0001
Copper	iMET1WCMS	mg/L	0.0004	0.0008	0.0003	0.0002
Gallium	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0003	0.0002
Iron	iMET1WCICP	mg/L	0.44	0.70	0.53	0.23
Lanthanum	iMET1WCMS	mg/L	0.0002	0.0002	0.0005	0.0003
Lead	iMET1WCMS	mg/L	0.0001	0.0007	0.0002	0.0001
Lithium	iMET1WCMS	mg/L	0.0053	0.0051	0.0023	0.0020
Magnesium	iMET1WCICP	mg/L	1.0	0.9	<0.1	<0.1
Manganese	iMET1WCMS	mg/L	0.0036	0.0062	0.0005	0.0003
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	0.001	0.001
Nickel	iMET1WCMS	mg/L	<0.001	0.001	<0.001	<0.001
Potassium	iMET1WCICP	mg/L	2.1	2.1	0.4	0.4
Rubidium	iMET1WCMS	mg/L	0.0014	0.0016	0.0007	0.0005
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	11	11	4.2	2.6
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	21.0	20.0	2.2	2.0
Strontium	iMET1WCMS	mg/L	0.012	0.012	0.0008	0.0004
Sulfur	iMET1WCICP	mg/L	9.3	9.0	0.8	0.7
Thallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	0.0002	0.0001	0.0003	0.0002
Tin	iMET1WCMS	mg/L	<0.0001	<0.0001	0.0001	<0.0001
Titanium	iMET1WCMS	mg/L	0.017	0.015	0.047	0.027
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	iMET1WCMS	mg/L	0.0036	0.0034	0.0060	0.0042
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	<0.0002	<0.0002	0.0003	<0.0002
Zinc	iMET1WCMS	mg/L	0.002	0.002	0.003	0.002
Zirconium	iMET1WCMS	mg/L	0.0013	0.0012	0.0033	0.0020
Chloride	iCO1WCDA	mg/L	20	18	<1	<1
Fluoride	iF1WASE	mg/L	0.48	0.51	0.30	0.29
Phosphorus, sol. reactive	iP1WTFIA	mg/L	<0.01	0.02	<0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.001	0.003	0.004	0.002
Chromium(VI)	iCO1WCDAL	mg/L	<0.001	<0.001	0.011	0.011

LAB ID			009	010	011	012
Client ID			20S5156/016_WE	20S5156/020_WE	20S5156/024_WE	20S5156/026_WE
Sampled						
Analyte	**Method**	**Unit**				
pH	iPH1WASE		6.6	6.6	6.4	6.7
Electrical Conductivity	iEC1WZSE	mS/m	1.4	1.4	1.5	3.1
TDS (calculated)	iSOL1WDCA	mg/L	8	8	8	17
Bicarbonate	iALK1WATI	mg/L	2	2	<1	2
Carbonate	iALK1WATI	mg/L	<1	<1	<1	<1
Aluminium	iMET1WCICP	mg/L	0.87	0.79	0.032	0.094
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Arsenic	iMET1WCMS	mg/L	0.014	0.014	0.008	0.051
Barium	iMET1WCMS	mg/L	0.0041	0.0035	0.0007	0.0008
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.009	0.008	<0.005	0.013
Cadmium	iMET1WCMS	mg/L	0.0001	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.3	0.2	0.7	<0.1
Cerium	iMET1WCMS	mg/L	0.0017	0.0016	0.0009	0.013
Chromium	iMET1WCMS	mg/L	0.010	0.0099	0.0049	0.039
Cobalt	iMET1WCMS	mg/L	0.0003	0.0002	<0.0001	<0.0001
Copper	iMET1WCMS	mg/L	0.0009	0.0008	0.0009	0.011
Gallium	iMET1WCMS	mg/L	0.0001	0.0001	0.0001	0.0006
Iron	iMET1WCICP	mg/L	2.8	2.6	0.050	0.23
Lanthanum	iMET1WCMS	mg/L	0.0007	0.0006	0.0004	0.0052
Lead	iMET1WCMS	mg/L	0.0004	0.0004	0.0005	0.0011
Lithium	iMET1WCMS	mg/L	0.0017	0.0014	0.0004	0.0009
Magnesium	iMET1WCICP	mg/L	0.1	0.1	0.2	<0.1
Manganese	iMET1WCMS	mg/L	0.0022	0.0019	0.0006	0.0041
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	<0.001	<0.001	0.001	0.009
Nickel	iMET1WCMS	mg/L	0.001	<0.001	<0.001	0.004
Potassium	iMET1WCICP	mg/L	0.6	0.5	0.2	0.2
Rubidium	iMET1WCMS	mg/L	0.0004	0.0004	0.0005	0.0003
Scandium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	0.0007
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	2.8	2.7	0.88	2.0
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	2.1	2.1	1.3	5.8
Strontium	iMET1WCMS	mg/L	0.0021	0.0021	0.0026	0.0003
Sulfur	iMET1WCICP	mg/L	0.3	0.3	0.4	1.0
Thallium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Thorium	iMET1WCMS	mg/L	0.0004	0.0004	0.0006	0.0050
Tin	iMET1WCMS	mg/L	<0.0001	0.0001	0.0002	0.0005
Titanium	iMET1WCMS	mg/L	0.023	0.019	0.035	0.15
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0001	0.0001	<0.0001	0.0005
Vanadium	iMET1WCMS	mg/L	0.015	0.015	0.0062	0.030
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Yttrium	iMET1WCMS	mg/L	0.0007	0.0006	0.0007	0.0038
Zinc	iMET1WCMS	mg/L	0.008	0.006	0.003	0.004
Zirconium	iMET1WCMS	mg/L	0.0019	0.0017	0.011	0.040
Chloride	iCO1WCDA	mg/L	<1	<1	2	2
Fluoride	iF1WASE	mg/L	0.12	0.11	0.15	0.70

LAB ID			009	010	011	012
Client ID			20S5156/016_WE	20S5156/020_WE	20S5156/024_WE	20S5156/026_WE
Sampled						
Analyte	**Method**	**Unit**				
Phosphorus, sol. reactive	iP1WTFIA	mg/L	0.06	0.05	<0.01	0.07
Chromium(III)	iCR3+1WCCAL	mg/L	0.006	0.007	<0.001	0.007
Chromium(VI)	iCO1WCDAL	mg/L	0.010	0.008	0.004	0.035

LAB ID			013	014	015
Client ID			20S5156/028_WE	20S5156/032_WE	20S5156/034_WE
Sampled					
Analyte	**Method**	**Unit**			
pH	iPH1WASE		6.6	6.6	6.7
Electrical Conductivity	iEC1WZSE	mS/m	3.3	2.6	3.3
TDS (calculated)	iSOL1WDCA	mg/L	18	14	18
Bicarbonate	iALK1WATI	mg/L	2	2	2
Carbonate	iALK1WATI	mg/L	<1	<1	<1
Aluminium	iMET1WCICP	mg/L	0.25	0.027	0.24
Antimony	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Arsenic	iMET1WCMS	mg/L	0.012	0.004	0.003
Barium	iMET1WCMS	mg/L	0.0007	0.0013	0.0023
Beryllium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Bismuth	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Boron	iMET1WCMS	mg/L	0.025	0.013	0.021
Cadmium	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Calcium	iMET1WCICP	mg/L	0.2	1.2	0.8
Cerium	iMET1WCMS	mg/L	0.0026	0.0020	0.0012
Chromium	iMET1WCMS	mg/L	0.025	0.026	0.030
Cobalt	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Copper	iMET1WCMS	mg/L	0.024	0.026	0.013
Gallium	iMET1WCMS	mg/L	0.0002	0.0001	0.0001
Iron	iMET1WCICP	mg/L	0.51	0.043	0.37
Lanthanum	iMET1WCMS	mg/L	0.0012	0.0008	0.0005
Lead	iMET1WCMS	mg/L	0.0004	0.0004	0.0004
Lithium	iMET1WCMS	mg/L	0.0053	0.0013	0.0065
Magnesium	iMET1WCICP	mg/L	<0.1	0.5	0.3
Manganese	iMET1WCMS	mg/L	0.0018	0.0010	0.0011
Mercury	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Molybdenum	iMET1WCMS	mg/L	0.004	0.004	0.001
Nickel	iMET1WCMS	mg/L	0.080	0.011	0.002
Potassium	iMET1WCICP	mg/L	0.4	0.5	0.7
Rubidium	iMET1WCMS	mg/L	0.0007	0.0011	0.0015
Scandium	iMET1WCMS	mg/L	<0.0005	0.0006	<0.0005
Selenium	iMET1WCMS	mg/L	<0.001	<0.001	<0.001
Silicon	iMET1WCICP	mg/L	2.7	2.0	2.5
Silver	iMET1WCMS	mg/L	<0.0001	<0.0001	<0.0001
Sodium	iMET1WCICP	mg/L	6.0	2.2	4.4
Strontium	iMET1WCMS	mg/L	0.0011	0.0040	0.0043
Sulfur	iMET1WCICP	mg/L	0.7	0.6	1.3
Thallium	iMET1WCMS	mg/L	<0.0001	0.0002	0.0002
Thorium	iMET1WCMS	mg/L	0.0015	0.0016	0.0011
Tin	iMET1WCMS	mg/L	0.0003	0.0005	0.0005

LAB ID			013	014	015
Client ID			20S5156/028_ WE	20S5156/032_ WE	20S5156/034_ WE
Sampled					
Analyte	**Method**	**Unit**			
Titanium	iMET1WCMS	mg/L	0.054	0.037	0.047
Tungsten	iMET1WCMS	mg/L	<0.002	<0.002	<0.002
Uranium	iMET1WCMS	mg/L	0.0001	0.0003	0.0001
Vanadium	iMET1WCMS	mg/L	0.011	0.0042	0.0048
Ytterbium	iMET1WCMS	mg/L	<0.0005	<0.0005	<0.0005
Yttrium	iMET1WCMS	mg/L	0.0017	0.0017	0.0011
Zinc	iMET1WCMS	mg/L	0.011	0.009	0.006
Zirconium	iMET1WCMS	mg/L	0.014	0.035	0.015
Chloride	iCO1WCDA	mg/L	3	1	2
Fluoride	iF1WASE	mg/L	0.82	0.68	0.76
Phosphorus, sol. reactive	iP1WTFIA	mg/L	0.02	<0.01	<0.01
Chromium(III)	iCR3+1WCCAL	mg/L	0.001	0.004	<0.001
Chromium(VI)	iCO1WCDAL	mg/L	0.025	0.024	0.031

Method	Method Description
iALK1WATI	Alkalinity (as CaCO3) and constituents by acid titration.
iCO1WCDA	Colourimetric analysis by DA (Discrete Autoanalyser).
iCO1WCDAL	Colourimetric analysis by DA (Discrete Autoanalyser).
iCR3+1WCCAL	Chromium (III) species by calculation (Cr minus Cr(VI)).
iEC1WZSE	Electrical conductivity in water compensated to 25C.
iF1WASE	Fluoride in water by ion specific electrode (ISE).
iMET1WCICP	Total dissolved metals by ICPAES.
iMET1WCMS	Total dissolved metals by ICPMS.
iP1WTFIA	Phosphorus soluble reactive as P in water by FIA.
iPH1WASE	pH in water by pH meter.
iSOL1WDCA	Total Dissolved Solids (TDS) calculated (ECond * 5.5)

Please note: This is an amended report that contains information that is different from the original report . The original report must be destroyed and replaced with this corrected version. Additional analysis was requested after issue of the original report.

The samples were extracted overnight, at a 1:5 ratio DI water as the extractant.
Results reported for these samples are concentrations found in the 1:5 extract.

These results apply only to the sample(s) as received. Unless arrangements are made to the contrary, these samples will be disposed of after 30 days of the issue of this report.
This report may only be reproduced in full.

HMay

Hanna May
Team Leader
SSD Inorganic Chemistry
9-Aug-2021

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

QUANTITATIVE X-RAY DIFFRACTION ANALYSIS

REPORT PREPARED FOR	CHEMISTRY CENTRE (WA) J. BROWN
CLIENT CODE	396.00
JOB CODE	2113104
No. of SAMPLES	4
CLIENT O/N	20S5156
SAMPLE SUBMISSION No.	
PROJECT	
STATE	PULPS
DATE RECEIVED	20/07/2021
DATE COMPLETED	9/08/2021
DATE WRITTEN	9/08/2021
WRITTEN BY	Dr Sharon Ness
ANALYSING LABORATORY	Perth

intertek genalysis

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

SAMPLE DETAILS

DISCLAIMER

This report relates specifically to the sample(s) that were drawn and/or provided by the client or their nominated third party. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment and only relate to the sample(s) as received and tested. This report is prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or laibility suffered by a third party as a result of any reliance upon or use of this report.

The results provided are not intended for commercial settlement purposes.

SIGNIFICANT FIGURES

The detection limit for most crystalline phases is approximately 0.5 wt%. However, this is dependent on instrument conditions, matrix, crystallinity and whether the pattern for the phase has been sufficiently deconvoluted in the presence of overlapping reflections.

Uncertainty in the analysis should reflect errors (absolute) of no greater than: +/-10% for phases 50-95%, +/- 5% for phases 10-50% and +/- 2% for phases 3-10%. Phases of < 3% are approaching detection limit and normally no refinements are made on these.

Please note that results are rounded off to integer values

LEGEND

ND	Not Detected
EMPTY CELL	Phase not included in refinement

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

JOB INFORMATION

PREPARATION

XRD16 (dry 50C, mill < 60um, micronised)

ANALYTICAL METHOD

XRDQUANT01 - Quantitative analysis, crystalline and amorphous content

SAMPLING

Sample(s) coned and quartered, then grab(s) taken

AMORPHOUS CONTENT DETERMINATION

Internal standard single scan

ADDITIONS

Internal standard ZnO (zincite)
20S5156/005
20S5156/007

Internal standard CaF2 (fluorite)
20S5156/009
20S5156/015

SAMPLE PRESENTATION

Sample(s) packed and presented as unoriented powder mount(s) of the total sample

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

JOB INFORMATION

INSTRUMENTATION AND PARAMETERS

INSTRUMENT:

PANalytical Cubix^3 XRD
Copper radiation (operating at 45 kV and 40 mA)
Graphite monochromator (diffracted beam)

PARAMETERS:

Parameter	Setting
Start angle (deg 2θ)	4
End angle (deg 2θ)	65
Step size (deg 2θ)	0.02
Time/active length (secs)	150
Active length (deg 2θ)	4.01

SOFTWARE:

Qualitative analysis: Bruker Diffrac.EVA 4.2 Search/Match
ICDD PDF-2 (2020) database

Quantitative analysis: SIROQUANT Version 4
ICSD (2021) database

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

RESULTS

The quantitative analysis of the crystalline and amorphous content of each sample is given in the file, **396.00_2113104 XRD RESULTS.xlsx**, attached to the report email.

Calculation of the phase abundances has been based on the Brindley contrast corrections using a particle diameter of 4 µm.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

NOTES

1

The amorphous content may contain some of the more poorly crystalline clay phases and conversely the clay phase content may contain some poorly crystalline or amorphous material. Where there is a significant presence of clay material, the distinction between poorly crystalline material and amorphous content can be imprecise.

2

For confirmation of the clay mineralogy, a clay separation followed by analysis of oriented clay mounts (glycol and heat treated) would be required.

3

The mixed layer clay is usually a mixture of poorly ordered transitional minerals and may be characterised, for example, as an illite/smectite and/or chlorite/smectite.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

QUALITY CONTROL

NIST STANDARD REFERENCE MATERIAL (SRM) 656

This standard is used for quality control on the instrument and software.

The standard reference material is a powder which consists of sub-micrometer, equi-axial, non-aggregated grains that do not display the effects of absorption contrast, extinction or preferred orientation.

An aliquot of this SRM, spiked with 10% Al_2O_3 (SRM 676a) for the amorphous content determination, was prepared as un-oriented powder mount of the total sample and the pattern analysed with SIROQUANT™

Sample ID **α 656 (High α Phase Powder)**

		2113104	method std dev	SRM certified	SRM uncert
Phase	**Formula**	**wt%**	**wt%**	**wt%**	**wt%**
Amorphous content		9.5	0.4	9.5	0.61
Si3N4, alpha	Si3N4	87.3	0.4	87.5	0.59
Si3N4, beta	Si3N4	3.2	0.1	3.0	0.05

Each interval defined by the certified value and its uncertainty is a 95% confidence interval for the true value of the mean in the absence of systematic error.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

METHOD DESCRIPTION

Quantification is determined from the chosen software package: this uses the full-profile Rietveld method of refining the profile of the calculated XRD pattern against the profile of the measured XRD pattern. The total calculated pattern is the sum of the calculated patterns of the individual phases.

Results are given as weight % of the total crystalline phases and amorphous content.

The amorphous content quantifies the amorphous material and unknown minerals or known minerals for which there is not a suitable crystal structure.

Corrections are incorporated into the process that allows for a more accurate description of the mineral's contribution to the measured pattern and to allow for variation due to atomic substitution, layer disordering, preferred orientation, and other factors that affect the acquisition of the XRD scan.

The limitations of qualitative XRD analysis are as follows:

There is a limit of detection of approximately 0.5 wt% on the crystalline phases.
The detection of a phase may be dependent on its crystallinity.
Where there exist multiple phases, overlap of diffracted reflections can occur, thus rendering some ambiguity into the interpretation.
Overlapping reflections of a major phase can mask the presence of minor or trace phases.

Some phases cannot be unambiguously identified as they are present in minor or trace amounts.

The limitations of quantitative XRD analysis by a full-profile Rietveld method are as follows:

The limitations for qualitative XRD analysis apply.
The method as described is standardless: it relies solely on the published crystallographic data available for each phase. Some data may not exactly describe the phases present.

Particle size is important with respect to the absorption of the X-rays by the sample. Micronising reduces the particle size to that more suitable for quantitative analysis.

The accuracy of the analysis is dependent on sampling and sample preparation in addition to the calculated profiles being exactly representative of the chemistry of the component phases and their crystallinity. Some preferred orientation effects and reflection overlaps may occur which cannot be adequately resolved.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

AMORPHOUS CONTENT

INTERNAL STANDARD METHOD

Single scan (SIROQUANT™ and TOPAS)

The amorphous content is determined from the addition of a known spike of a well-crystalline internal standard to each sample.

When amorphous material is present, the weight percentage of the spike found is larger than actually weighed out. The amount of amorphous material that causes the difference in the spike weight percentages is then calculated and all weight percentages are normalised to include the amorphous content.

Double scan (SIROQUANT only)

SIROQUANT™ also allows the choice of using the spiked pattern completely, or combining the run with a previous unspiked pattern result. This choice is given because the weight percentages from an unspiked pattern are more accurate since the intensities are not diluted by the spike addition. The percentages from the unspiked sample are normalised to the amorphous content calculated from the spiked sample pattern.

EXTERNAL STANDARD METHOD (SIROQUANT™ and TOPAS)

The amorphous content is determined from the external standard method[1].

The normalisation constant is determined from the external standard which allows the calculated weight fractions to be placed on an absolute scale.

Reference:

1. O'Connor, B.H., and Raven, M.D., "Application of the Rietveld refinement procedure in assaying powdered mixtures", Powder Diffraction 3(1), (1988), 2-6.

Modelling

A pattern representing a poorly crystalline form of silica is used in the SIROQUANT program.[2]

Reference:

2. Ward, C.R. and French, D., "Determination of glass content and estimation of glass composition in fly ash using quantitative X-ray diffractometry." Fuel 85 (2006), 2268-2277.

15 Davison Street, Maddington
Western Australia 6109
Telephone: +61 8 9263 0100

intertek.com
ABN: 32 008 787 237

XRD ANALYSIS STANDARD REPORT CONDITIONS

1. The work for and preparation of this report are governed by the Standard Report Conditions listed below and Intertek Minerals Terms and Conditions 2021, a copy of which is available online at www.intertek.com. The Standard Report Conditions also govern use and reproduction of this report and any extract of it. This endorsement highlights some of the Standard Report Conditions but does not override or vary them.

2. The analytical methods and procedures used in carrying out the work are summarised in the report. Any interpretations of data are also identified as such in the report. Intertek accepts no responsibility for any further or other interpretations. Any questions relating to the work or the report or about inferences to be drawn from them, should be referred to the author of the report.

3. The report must not be disseminated in any way which is likely to mislead or deceive any person, including by disseminating an extract of the report without including relevant qualifications contained in the report without limitation.

4. Subject to condition 17, the Client indemnifies Intertek against all Claims arising in any way of or in connection with:

a) the use, investigation, analysis, deterioration or destruction of the samples or other Client Property;
b) any breach of intellectual property rights of any person in any sample;
c) the use of any part of the Works or Report by any person other than the Client; and
d) any breach of any of these conditions by the client

5. Notwithstanding anything to the contrary, Intertek's liability for any Claim arising in any way out of or in connection with the Work or the Report, whether in contract, tort or otherwise is limited to, at the option of Intertek:

a) the supplying of services again; or
b) the cost of having those services supplied again.

6. The work and this report are subject to indemnity, exclusion and liability limiting provisions set out in the Intertek Terms and Conditions.

7. Every copy of this report which is made must include this Standard Report Conditions of XRD Analysis in a clearly legible form.