Jervois Base Metals Mine Groundwater Management Plan

version 2.1

May 2019

PREPARED FOR NITRO SOLUTIONS ON BEHALF OF KGL RESOURCES BY CLOUDGMS

CLOUDGMS PTY LTD
ABN 84 166 886 586

3 Wright Street
Edwardstown, SA 5039

Author

Anthony Knapton

CloudGMS Pty Ltd
ABN 84 166 886 586
3 Wright Street, Edwardstown
South Australia, 5039

Phone: 0428798665
Email: anthony.knapton@bigpond.com

Groundwater management plan summary

Groundwater Management Plan	
Environmental Value	Groundwater is to be managed to minimise environmental impacts.
Environmental Protection Objective	Groundwater will be managed to minimise the risk of impacts to the beneficial uses of groundwater resources and groundwater dependent environment.
Performance Indicator/Criteria	• Groundwater drawdown impacts greater than those forecast by numerical modelling. • Groundwater quality at baseline values
Management Actions	• Make-good measures at receptors to ensure water availability. For example, deepening bores / off-take from pipeline. • Pump and treat seepage from beneath the TSFs using interception bores for subsequent re-use in the process plant.
Monitoring	• Annual groundwater management procedure review. • Monitor groundwater levels. • Quantify, record and report monthly the volume of water extracted from groundwater resources.
Reporting	Annual reporting on any groundwater related incidents.

Table of Contents

Groundwater management plan summary 0
1 Overview 2
1.1. Current conditions 2
1.1.1. Hydrogeological setting 2
1.1.2. Environmental Values 3
1.1.3. Declaration of beneficial uses 3
1.2. Regulation 3
1.2.1. Water Allocation Plans 4
1.2.2. Water Extraction Licence 4
2 Groundwater management 4
2.1. Overview 4
2.2. Potential impacts 9
2.2.1. Water table drawdown from borefield pumping 9
2.2.2. Water table drawdown from dewatering during mining 9
2.2.3. Leachate seepage from waste rock dumps 10
2.2.4. Leachate seepage from tailings storage facility 10
2.2.5. Groundwater contamination from spills at the mine site 10
2.3. Monitoring and reporting 10
2.3.1. Monitoring network description 11
2.3.2. Implementation schedule 17
2.3.3. Monitoring suite and frequency 17
2.3.4. Monitoring program review and optimisation 17
2.4. Trigger levels and mitigation measures 17
2.4.1. Watertable drawdown from borefield pumping and mine dewatering. 17
2.4.2. Waste rock dump leachate seepage 18
2.4.3. Tailings storage facility leachate seepage 19
2.5. Model calibration and refinement 19
2.6. Contingency 19
3 Bibliography 21
4 Document history and version control 22

List of Figures

Figure 2-1 Overview of the locations of observation bores around the process water supply borefield and the Jervois mine site. 12
Figure 2-2 Locations of observation bores around the Jervois mine site. 14

List of Tables

Table 1-1 Groundwater management plan 2
Table 1-2 Groundwater Beneficial Use 3
Table 2-1 Groundwater Management and Monitoring Plan Overview 6
Table 2-2 Potential Groundwater Impacts 9
Table 2-3 Process water supply groundwater monitoring locations 15
Table 2-4 Third party groundwater monitoring locations 15
Table 2-5 Mine site groundwater monitoring locations 16
Table 2-6 Groundwater Monitoring Analytical Suite 17

Abbreviations and acronyms

DENR	Department of Environment and Natural Resources
GIS	geographical information system
GL	gigalitre (10^9 litres)
kL	kilolitre (10^3 litres)
km	kilometre
km^2	square kilometre
L/s	litres per second
m^2/d	metres squared per day
m^2/d	metres squared per day
m^3	cubic metre
m^3/d	cubic metres per day
m^3/s	cubic metres per second
ML	megalitre (10^6 litres)
ML/a	megalitre per year
mAHD	metres above Australian Height Datum
mBGL	metres Below Ground Level
mm	millimetre
mm/d	millimetre per day
pF	log scale for representing soil matric potential
RMS	root mean square
SRMS	scaled root mean square
SRTM	Shuttle Radar Topographic Mission
T	Transmissivity (metres squared per day)

1 Overview

Groundwater impacts are summarised in Table 1-1 below and the monitoring and management of impacts is described in the following sections.

Table 1-1 Groundwater management plan

Impact	Management	Monitoring	Reporting	Leading Indicator
Drawdown from wellfield pumping exceeds predicted values and reduces water availability for other users	Ongoing re-calibration of model to drawdown from borefield pumping	Pumped volumes (monthly) Water level drawdown at observation bores (minimum monthly) logged electronically	Annual Reporting of monitoring, model validation and refined prediction of water level drawdown.	Predicted drawdown impacts at Third Party users generated with the validated groundwater model
Drawdown from dewatering of mine features exceeds predicted values and reduces water availability for other users	Ongoing re-calibration of model to drawdown from mine dewatering	Dewatering volumes (monthly) Water level drawdown at observation bores (minimum monthly) logged electronically	Annual Reporting of monitoring, model validation and refined prediction of water level drawdown.	Predicted drawdown impacts at Third Party users generated with the validated groundwater model
Waste rock dump seepage	Per AMD Management Plan			
Tailing seepage	Per AMD Management Plan			
Spills	Appropriate material storage and handling. E.G. bunded storage, spill kits etc	None	Reporting of spill and clean-up	Compliance with material storage and handling standards

1.1. Current conditions

1.1.1. Hydrogeological setting

The hydrogeological setting is described in detail in the Project EIS, EIS Groundwater Impact Assessment (CloudGMS, 2018a) and Supplement to the Groundwater Impact Assessment . This WMP should be read in conjunction with those documents.

The mine site exhibits saturated orebodies, extending below the water table. The Fractured Rock groundwater system is very low yielding and hosts water generally suitable for pastoral and industrial use only.

The Project process water supply is extracted from the regionally extensive Georgina Basin Carbonate Aquifer via a planned borefield comprising at least 6 bores located about 20 km north of the mine site. Water in the Georgina Basin Carbonate aquifer at the borefield site is potable.

Regionally the groundwater system recharges via direct infiltration particularly where fractured rock aquifers are exposed, and through infiltration along creeks. Groundwater seeps to the highly transmissive Georgina Basin Carbonate aquifer and moves via the basin toward the east for eventual discharge many hundreds of kilometres from the Project site.

1.1.2. Environmental Values

There are no identified groundwater dependant ecosystems within 60 km of the proposal. The depth of the water table in proximity to the proposal is generally too deep to support groundwater dependent ecosystems. Riparian vegetation shown to be reliant on shallow groundwater may be accessing the regional groundwater, however, it is more likely that this vegetation is reliant on the water available in the alluvial sediments associated with the larger creeks, hence the very limited extent of vegetation beyond the river channels. The riparian vegetation along the sections of river channel that overlie the areas impacted by lowering of the regional groundwater are unlikely to be adversely affected.

A desktop review of stygofauna was undertaken and a survey of bores installed during the process water supply borefield investigation . This study encountered 1 count of a commonly found taxa and it was concluded that stygofauna are unlikely to be a factor for this Project due to the limited impact on a commonly found very extensive possible habitat.

1.1.3. Declaration of beneficial uses

The beneficial use of groundwater at the Project mine site is summarized in Table 1-2. Groundwater at the mine site is suitable for pastoral use and the Project process water supply borefield site.

Table 1-2 Groundwater Beneficial Use

Site	Aquifer	Groundwater Beneficial Use	Water Quality constraints
Mine	Fractured Rock	Pastoral / Industrial	TDS > 1000 mg/L, Fluoride and Iron exceeds drinking water guidelines
Process borefield	Georgina Basin Carbonate	Potable / Pastoral	Salinity sometimes exceeds aesthetic drinking water guidelines

Groundwater is currently used for:

- stock watering with the nearest stock bore located 15 km from the borefield,
- community water supply with the nearest bores at Orrtipa-Thurra community 18km from the mine site and 30 km from the proposed process water supply borefield, and
- pastoral stations with the nearest bore at Lucy Creek Station, approximately 15 km from the proposed Project process water supply borefield.

1.2. Regulation

The primary tool for managing and protecting the Territory’s water resources is the Northern Territory (NT) Water Act. The Water Act provide for the investigation, allocation, use, control, protection, management and administration of water resources.

Previously extraction and dewatering activities are governed under the MM Act, administered by the Department of Primary Industry and Resources (DPIR).

The Water Legislation Amendment Bill 2018 was recently passed on the Legislative Assembly on 28 November 2018. The amended Water Act is proposed for commencement on 31 December 2018.

These changes mean that the amended Water Act will apply to water use by mining activities and that a range of licence and permitting requirements will be required. The term ‘water use’ encompasses the following:

- Interfering with a waterway (e.g. diversions, dams, weirs etc.);
- Taking water from a waterway for other than stock and/or domestic purposes;
- Taking groundwater for other than stock and/or domestic purposes;
- Doing bore work (e.g. drilling, deepening, decommissioning, etc. water bores); and
- Recharging an aquifer.

Taking water for domestic use (drinking and household use) by a mining activity from a waterway or a bore on site will not require the grant of a water extraction licence under the Water Act.

These changes will also mean that:

- Water bore work for a mining activity must be undertaken by, or under the supervision of, a driller granted the relevant licence under the Water Act;
- Water bore work undertaken for a mining activity in a Water Control District will require a permit granted under the Water Act; and
- Taking water from a waterway or from a bore (including for dewatering) by a mining activity, for other than stock and/or domestic use, will require a licence granted under the Water Act.

The key requirements of the Water Act that will be applicable to the Project include:

- Water extraction licence for bores abstracting groundwater.

A water licence is usually granted for 10 years, but longer term licences can be approved in special circumstances.

1.2.1. Water Allocation Plans

The Project mine site is not located within or near any water control district (WCD).

1.2.2. Water Extraction Licence

A water extraction licence is required when extracting surface water or groundwater in a Water Control District or when extracting groundwater more than 15 L/s outside of a Water Control District. A water extraction licence would be required for the mine supply borefield.

All bores will have water meters comply with the Department of Environment and Natural Resources 'Non-Urban water metering policy' and 'Non-urban water metering code of practice for water extraction'.

Measures will be in place to quantify, record and report monthly the volume of water extracted from groundwater resources.

2 Groundwater management

2.1. Overview

The WAMP should:

- Includes a framework identifying the location, timing, methods and parameters for the collection of further groundwater information;
- Identification of natural recharge processes and extraction rates of other users; characterisation of flow and flow directions; and robustness of the water level baseline by capturing seasonal changes;
- Incorporate a program to monitor groundwater levels at nearby stock and community bores;

- Based on robust groundwater level baseline data capturing seasonal changes over at least 12 months at all proposed groundwater abstraction monitoring bores, including borefield and nearby stock and community bores;
- Zero reduction in water availability to other users from mining activities;
- Is developed in consultation with relevant stakeholders, including other groundwater users;
- Actively and continuously seeks to improve knowledge of aquifers and groundwater tables affected by the proposal and incorporates these into the model;
- Is independently peer reviewed by a suitably qualified independent professional;
- Is developed and implemented to the satisfaction of the relevant regulator;
- Is to be updated at least annually; and
- Reports all water monitoring data with an assessment of the impacts on groundwater hydrology in an annual Water Management Report.

Water will be managed at the Project in accordance with ANZECC/ARMCANZ (2013). Management of groundwater across the Project will be aligned with the six underlying principles:

1. **Protection of specified environmental value:** The current and future land use of the area is considered to be pastoral (cattle). Application of stock water ANZECC values will be used as groundwater trigger values.
2. **Polluter pays principle:** The site will be constructed, operated and rehabilitated in accordance with the Mining Management Act (MM Act). The MM Act requires the Proponent to report environmental data to assess and understand potential impacts from the Project to the Department of Mines and Energy (DME). In accordance with the MM Act, a security bond will be provided as part of the initial grant and maintaining Mine Authorisation. The security bond reinforces the polluter pays principle whereby the bond will be returned to the Proponent following successful rehabilitation or utilised by DME to complete rehabilitation (if the Proponent is not able to due to unforeseen circumstances).
3. **Intergenerational equity:** Currently the predominate use for groundwater in the immediate vicinity of the Project mine site and processing site is for pastoral use (i.e. stock drinking water). The development of the Project will be undertaken with consideration of current and potential future generations of pastoralists.
4. **Precautionary principle:** Hydrogeological modelling has been undertaken to assess the potential impact of the Project on surrounding groundwater resources. In accordance with the risk-based approach and implications of the polluter pays principle, the site will be operated under a precautionary principle.
5. **Ecologically sustainable development:** The Project will be managed in accordance with the above principles to promote ecologically sustainable development.

The Groundwater management plan comprising Monitoring, Trigger Levels and Mitigation measures for the risks identified in the EIS is summarised in Table 2-1. Details are provided in the sections that follow.

Table 2-1 Groundwater Management and Monitoring Plan Overview

Impact / Source	Pathway	Receptor	Probability / Risk	Monitoring	Triggers	Mitigation
Water table drawdown from borefield pumping over lifetime of mine followed by almost complete recovery.	Georgina Basin Carbonate Aquifer	Riparian vegetation along large creeks Other Groundwater users via: Stock bores Community bores Pastoral Station bores	Low. Species that may be affected are common throughout the study area. Modelled localised impact along drainage slightly greater than criteria adopted by DENR. Modelling predicts drawdown up to 3 m at other users. However, groundwater availability will not be reduced.	Monitor vegetation (Vegetation Management Plan) Monitoring of water levels and quality at a network of observation bores. Monitoring of volumes and water quality pumped.	Drawdown at observation bores exceeds drawdown predicted by modelling.	Re-calibration of model and re-assessment of predicted drawdown at receptors. Make-good measures at receptors to ensure water availability. For example, deepening bores / off-take from pipeline. Increased water efficiency to be studied and implemented if practicable. Modified pumping regimes. Revegetation of areas where impacts have resulted in vegetation mortality.
Water table drawdown from mine dewatering recovery of groundwater below initial levels.	Fractured Rock Aquifer, discharging to the southeast	Riparian vegetation along large creeks Other Groundwater users via: Stock bores Community bores Pastoral Station bores	Low. Water table initially >15 metres below ground and greater than the criteria adopted by DENR. Minimal drawdown of perched groundwater in alluvial sediments along drainage supporting riparian vegetation. Modelling predicts drawdown of less than 2 m at other users.	Monitor vegetation (Vegetation Management Plan) Monitoring of water levels and quality at a network of observation bores. Monitoring of volumes and water quality pumped.	Drawdown at observation bores exceeds drawdown predicted by modelling.	Re-calibration of model and re-assessment of predicted drawdown at receptors. Make-good measures at receptors to ensure water availability. For example, deepening bores / off-take from pipeline.

Impact / Source	Pathway	Receptor	Probability / Risk	Monitoring	Triggers	Mitigation
Waste rock dumps	Fractured Rock Aquifer, discharging to the southeast	Other Groundwater users via: Stock bores Community bores Pastoral Station bores	Low. Water table is at approximately 20-30m depth, surface expression of seepage very unlikely. WRD leachate quality is identified as being NAF. Seepage only occurs under high intensity rainfall events. Dilution down gradient will mitigate any impact even though there is no expected impact. Seepage ultimately captured by pit-lake sinks located down gradient of WRDs. The distance to down gradient receptors exceeds 20km.	Monitoring down gradient of WRDs for groundwater levels and quality.	Groundwater levels rise above baseline Groundwater quality changes from baseline to reduce beneficial use.	Risk assessment of seepage on receptors. Seepage management if required, for instance pump and treat, or pump and re-use.
Tailings leachate seepage from tailings storage facility.	Fractured Rock Aquifer, discharging to the southeast	Other Groundwater users via: Stock bores Community bores Pastoral Station bores	Moderate. Water table is at approximately 20-30m depth, surface expression of seepage very unlikely. TSF leachate quality is identified as being similar to the process water supply during operations although ultimately PAF.	Monitoring down gradient of TSF for groundwater levels and quality.	Groundwater levels rise above modelled values Groundwater quality changes from baseline that reduce beneficial use.	Risk assessment of seepage on receptors. Seepage management if required, for instance pump and treat, or pump and re-use.

Impact / Source	Pathway	Receptor	Probability / Risk	Monitoring	Triggers	Mitigation
			Underdrainage implemented to intercept seepage from TSF. Seepage ultimately captured by pit-lake sinks located down gradient of TSF. Dilution down gradient will mitigate any impact even though there is no expected impact. The distance to down gradient receptors exceeds 20km.			
Groundwater contamination from spills at the mine site and along the infrastructure corridor	Vertical Seepage via unsaturated zone, then lateral migration in aquifer.	Other Groundwater users: Stock Community Pastoral Stations	Low. Risk managed by appropriate transport and storage of hazardous materials	Detailed reporting of all spills and clean- up	Event based	Spills will be managed in accordance with the Emergency Response Management Plan (ERMP) including the Environmental Investigation Procedure.

2.2. Potential impacts

The project comprises three open pit mines, three underground mines with three waste rock dumps and a 2 cell tailings storage facility. The process water supply comprises a borefield pumping up to 2 GL/year. About 2 million tonnes of ore will be processed per annum to produce about 250,000 tonnes of contained copper during the life of the project. Ore production will decrease in the final year of the project as ore reserves are depleted.

A summary of the potential groundwater impacts are detailed in Table 2-2.

Table 2-2 Potential Groundwater Impacts

Groundwater Impact	
1	Water table drawdown from borefield pumping
2	Water table drawdown from dewatering of mine features
3	Groundwater contamination from waste rock dump leachate seepage
4	Groundwater contamination from tailings leachate seepage
5	Groundwater contamination from spills at the mine site

2.2.1. Water table drawdown from borefield pumping

Groundwater modelling was undertaken to predict impacts of groundwater pumping on receptors. Note that the groundwater use implemented in the groundwater modelling was assumed at the upper estimated required rate of 2 GL/yr.

The results from the drawdown analysis suggest that, for the 10 years scheduled life of mine, it is probable that a maximum drawdown of 2 – 3 metres can be expected at the closest pastoral bores (RN011102 & RN013274) and drawdown of less than 1 metre will be observed at the Lucy Creek homestead bore (RN013689), which has an available drawdown of 11 metres based on a total depth (TD) of 15 mBGL and standing water level (SWL) 4 mBGL at 29/07/1983. This level of drawdown is not expected to reduce the availability of water at these bores since the depth of the bores is greater than 1.0 m below the water table.

Drawdown at the end of mining is predicted to extend less than 40 km from the borefield to the 0.5m drawdown contour.

Groundwater levels are forecast to almost recover to pre-mining levels after about 10 – 20 years post closure.

There are no mapped Groundwater Dependant Ecosystems identified within the zone of drawdown. Riparian vegetation may be accessing the regional groundwater, however, it is more likely that this vegetation is reliant on the water available in the alluvial sediments associated with the larger creeks, hence the very limited extent of vegetation beyond the river channels. The riparian vegetation along the sections of river channel that overlie the areas impacted by lowering of the regional groundwater are unlikely to be adversely affected.

2.2.2. Water table drawdown from dewatering during mining

Groundwater modelling was undertaken to predict impacts of dewatering due to mining activities on the Fracture Rock groundwater system on receptors.

The results from the drawdown analysis suggest that, for the 10 years scheduled life of mine, it is probable that a maximum drawdown of 0.5 – 1.0 metres can be expected at a distance of less than 3 km from the tenement boundary.

200 year after the commencement of mining (990 years post closure), the extent of the 0.5 metre drawdown is less than 30 km and impacts of about 2 metres are observed at the closest pastoral bore (RN018078) and at the Orrtipa-Thurra community water supply (18 km).

2.2.3. Leachate seepage from waste rock dumps

WRD leachate quality is identified as being predominantly non-acid forming (NAF). Seepage only occurs under high intensity rainfall events and dilution effects are expected as the seepage mixes with the ambient groundwater as it migrates down gradient.

The fate of leachate downgradient of the waste rock dumps (WRDs) has been forecast using the flow field calculated by the numerical groundwater modelling and random walk particle tracking. The WRDs downgradient seepage is expected to be slow due to the low permeability of the Fractured Rock groundwater system and ultimately any WRD lseepage is expected to be captured by the local groundwater sinks formed at the Bellbird and Reward and Reward South pit-lake.

There are no receptors within this distance, and the beneficial use of the water will be unchanged.

2.2.4. Leachate seepage from tailings storage facility

TSF leachate quality is identified as being similar to the process water supply during operations, although potentially acid forming (PAF) post mining. Underdrainage implemented to intercept seepage from TSF and dilution effects are expected as the seepage mixes with the ambient groundwater as it migrates down gradient

The fate of leachate downgradient of the TSF has been forecast using the flow field calculated by the numerical groundwater modelling and random walk particle tracking. The TSF downgradient seepage is expected to be slow due to the low permeability of the Fractured Rock groundwater system and ultimately any TSF leachate is expected to be captured by the local groundwater sink form at the Reward and Reward South pit-lakes.

There are no receptors within this distance, and the beneficial use of the water will be unchanged.

2.2.5. Groundwater contamination from spills at the mine site

Groundwater contamination might occur through spills of hazardous material at the mine site or during transport. The risk will be managed through appropriate storage and transport of hazardous materials.

Accidental spills or will be managed in accordance with the Emergency Response Management Plan (ERMP) including the Environmental Investigation Procedure.

2.3. Monitoring and reporting

Groundwater monitoring will comprise:

1. Monitoring of drawdown in proximity to the process water supply borefield
2. Monitoring of drawdown between the process water supply borefield and third-party bores
3. Monitoring of drawdown in proximity to the mine excavations (pits and underground workings)
4. Monitoring of drawdown between the mine excavations (pits and underground workings) and third party bores
5. Monitoring of dewatering volumes from the pits and underground excavations
6. Monitoring at third-party bores

7. Monitoring adjacent to the TSF to assess mounding and groundwater quality changes due to any seepage.

Proposed monitoring locations around the Project mine site are presented in Figure 2-2. Monitoring details are presented below in Table 2-5.

Water levels should be recorded at a minimum monthly using automated data loggers and downloaded at nominally 12 monthly intervals to allow analysis of the data for annual reporting. Water quality should also be sampled and analysed annually at the borefield and in proximity to the mine pit. The volume of water pumped from each bore, and the borefield total should be monitored at least monthly, using totalizer flow meters at each bore head.

2.3.1. Monitoring network description

Process water supply borefield monitoring

Groundwater monitoring bores to measure the impact of Project process water supply borefield pumping is detailed in Table 2-3. The monitoring network was installed in 2018 (CloudGMS, 2018b) and comprises 7 observation bores (Figure 2-1): 2 adjacent to the production bores (Table 2-3) and 5 are located away from the borefield with 1 of these adjacent to the closest third party pastoral bores (Table 2-4).

Observation bores are located at a distance from pastoral bores to assess drawdown without being overly impacted by intermittent low rate pumping from the pastoral bore. The bore extraction rate/volumes from the pastoral bores will be estimated on an annual basis to assist with the interpretation of potential variations in water levels.

Additional observation bores will be installed beyond the current predicted zone of drawdown if measured drawdown exceeds predicted drawdown.

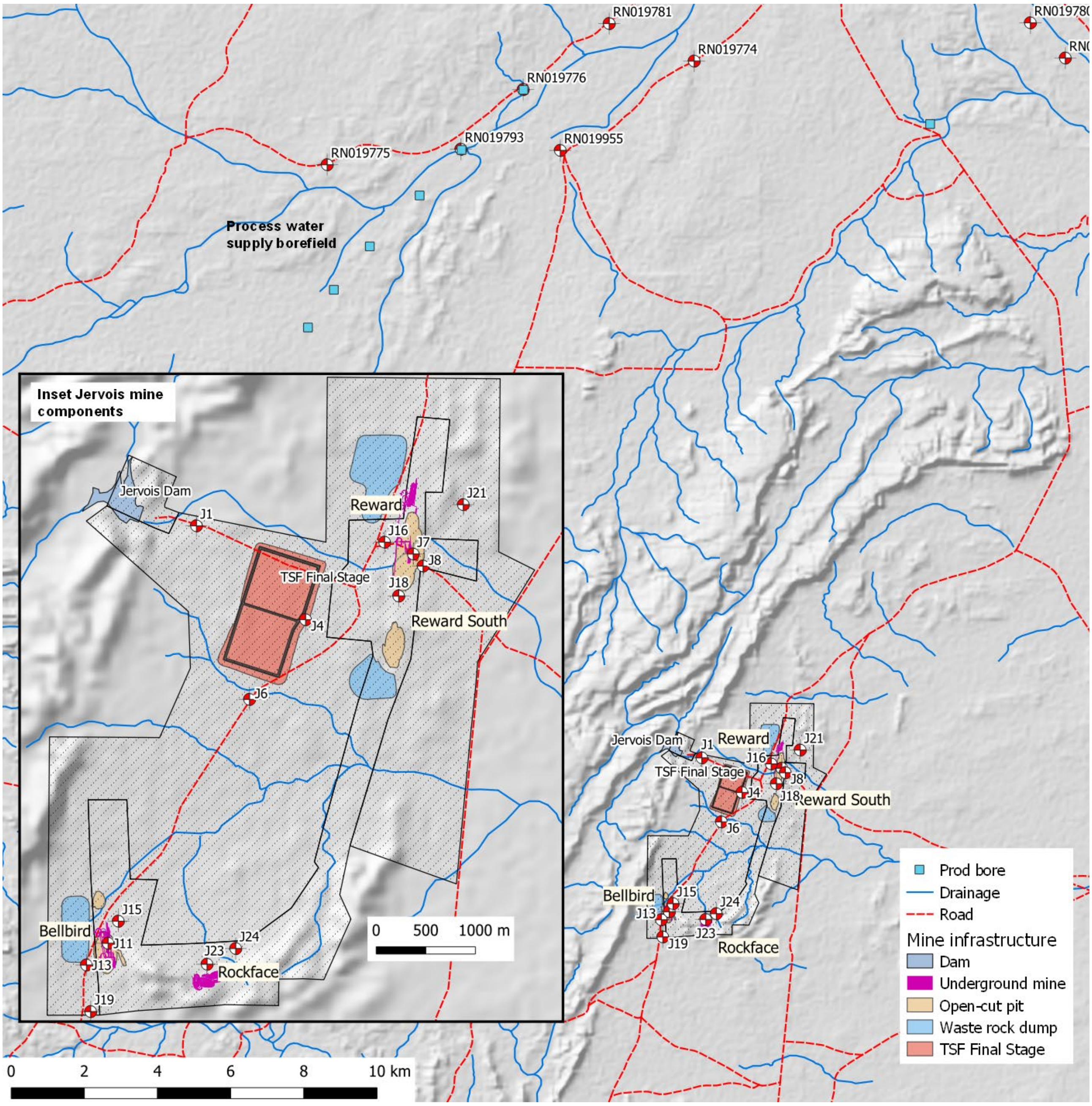

Figure 2-1 Overview of the locations of observation bores around the process water supply borefield and the Jervois mine site.

Mine dewatering monitoring

Groundwater monitoring to measure the impact of Project mining activities is detailed in Table 2-5. The monitoring network comprises 25 observation bores: 24 located within the mine tenement (Table 2-5) and 1 adjacent to the closest third party pastoral bores (Table 2-4).

Drilling to install these bores was undertaken in September – October 2018 (CloudGMS, 2019), and the results of this work will inform the final design of the mine site monitoring network.

Additional observation bores located adjacent to pastoral bores (RN018078) will be located approx. 200 m from the pastoral bore to assess drawdown without being overly impacted by intermittent low rate pumping from the pastoral bore. The bore extraction rate/volumes from the pastoral bores will be estimated on an annual basis to assist with the interpretation of potential variations in water levels.

Additional observation bores will be installed beyond the current predicted zone of drawdown if measured drawdown exceeds predicted drawdown.

Waste rock dumps

Groundwater Monitoring to measure the impact of possible WRDs seepage is detailed in Table 2-5 and Figure 2-2. Two bores are currently located down-gradient of the WRDs.

Tailings storage facility

Groundwater Monitoring to measure the impact of tailings seepage is detailed in Table 2-5 and Figure 2-2. One bore is located upgradient of the TSF, two bores are located down-gradient and adjacent to the TSF. Three bores are located to the east between the TSF and Reward pit.

Bore design

Bores will be constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia. The nominal bore design comprises 100mmDN Class18 UPVC Bore casing with slotted production zone. Bores will be drilled to approximately 30m below the first water yielding interval. The bore casing will be slotted against water producing intervals. The screen annulus will be gravel packed, and the casing annulus grout sealed to prevent surface water ingress. A steel lockable cover will be installed to protect the PVC from damage and to secure logging equipment.

All monitoring and production bores are surveyed to a common datum (mAHD) to ±0.1m vertical accuracy to allow for accurate characterisation of groundwater flow directions.

All bores will be registered with DENR and allocated an RN number.

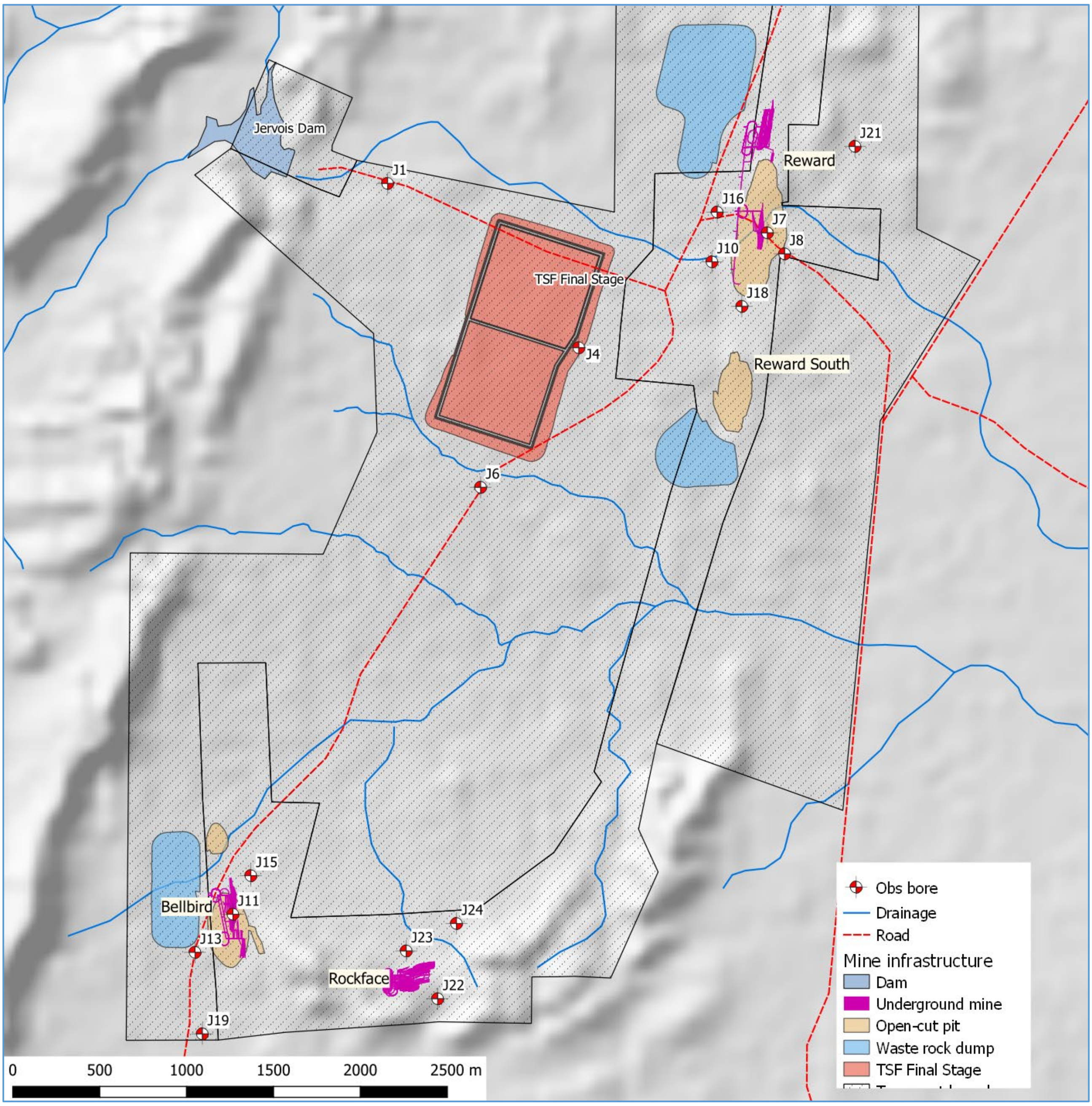

Figure 2-2 Locations of observation bores around the Jervois mine site.

Table 2-3 Process water supply groundwater monitoring locations

Site name	Easting	Northing	Purpose	Water Level Measurement	Monitoring Water Quality Analysis	Volume Pumped
Groundwater levels / quality						
RN019776 (Mon)	623311	7513279	Borefield Performance	Monthly	None	N/A
RN019793 (Mon)	621599	7511640	Borefield Performance	Monthly	None	N/A
RN019956 (Mon)	620453	7510399	Borefield Performance	Monthly	None	N/A
Production Bores Volumes						
RN019782 (Prod)	621622	7511636	Borefield Performance	Monthly	Quarterly	Weekly
RN019950 (Standby)	634423	7512336	Borefield Performance	Monthly	Quarterly	Weekly
RN019952 (Prod)	620478	7510390	Borefield Performance	Monthly	Quarterly	Weekly
RN019953 (Prod)	619135	7509029	Borefield Performance	Monthly	Quarterly	Weekly
RN019954 (Prod)	618131	7507838	Borefield Performance	Monthly	Quarterly	Weekly
RN019957 (Prod)	623308	7513239	Borefield Performance	Monthly	Quarterly	Weekly

Table 2-4 Third party groundwater monitoring locations

Site name	Easting	Northing	Purpose	Water Level Measurement	Monitoring Water Quality Analysis	Volume Pumped
RN019774	627979	7514063	Third Party Process Water Supply Impact Assessment	Monthly	None	N/A
RN019775	617946	7511234	Third Party Process Water Supply Impact Assessment	Monthly	None	N/A
RN019781	621907	7513363	Third Party Process Water Supply Impact Assessment	Monthly	None	N/A
RN019948	632857	7515290	Third Party Process Water Supply Impact Assessment	Monthly	None	N/A
RN019955	623994	7511520	Third Party Process Water Supply Impact Assessment	Monthly	None	N/A
RN018078 (200m offset)	623390	7488922	Third Party Mine Dewatering Impact Assessment	Monthly	None	N/A

Table 2-5 Mine site groundwater monitoring locations

Site name	Easting	Northing	Purpose	Water Level Measurement	Monitoring Water Quality Analysis	Volume Pumped
Groundwater levels / quality						
J1	628190	7495025	Tailings mounding and seepage assessment	Monthly	Quarterly	N/A
J4	629290	7494080	Tailings mounding and seepage assessment	Monthly	Quarterly	N/A
J6	628725	7493277	Tailings mounding and seepage assessment	Monthly	Quarterly	N/A
J7	630375	7494741	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J8	630474	7494620	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J10	630056	7494574	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J11	627300	7490821	Bellbird pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J13	627082	7490602	Bellbird pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J15	627403	7491043	Bellbird pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J16	630086	7494860	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J18	630228	7494318	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J19	627124	7490133	Bellbird pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J21	630879	7495238	Reward pit and underground mine excavation dewatering drawdown	Monthly	None	N/A
J22	628478	7490335	Rockface underground mine excavation dewatering drawdown	Monthly	None	N/A
J23	628297	7490610	Rockface underground mine excavation dewatering drawdown	Monthly	None	N/A
J24	628586	7490768	Rockface underground mine excavation dewatering drawdown	Monthly	None	N/A
RN006910	630803	7494755	Reward pit and underground mine dewatering drawdown Unca Ck	Monthly	Quarterly	N/A
Groundwater volumes						
Bellbird pit			Bellbird pit and underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly
Bellbird underground			Bellbird pit and underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly
Reward pit			Reward pit and underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly
Reward underground			Reward pit and underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly
Reward South pit			Reward South pit and underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly
Rockface underground			Rockface underground mine excavation dewatering drawdown	N/A	Quarterly	Weekly

2.3.2. Implementation schedule

Observation bores at the mine site and the process water supply were installed during September - October 2018. Monitoring of these bores will commence following installation in order to provide an ongoing baseline data set.

The remaining observation bores will be installed at the beginning of the construction phase. This will enable collection of one year of pre-mining baseline data.

Additional observation bores will be installed beyond the current predicted zone of drawdown if measured drawdown exceeds predicted drawdown. The timing of these bores will be dependent on monitoring results.

2.3.3. Monitoring suite and frequency

Water levels at all bores will be measured monthly typically by local environmental monitoring staff.

Water quality will be monitored annually at all observation bores, and quarterly at pumping bores, WRD and TSF seepage monitoring bores. A full suite of analytes per Table 2-6 will be analyses at all bores. The monitoring suite and frequency will be reviewed and optimised following two years data collection. Water quality sampling and analysis and QA/QC will be undertaken in accordance with guidelines (GA, 2009).

Volumes pumped will be recorded monthly for the Project process water supply production bores. Flow meters will comply with DENR Requirements.

Table 2-6 Groundwater Monitoring Analytical Suite

pH Value	Aluminium	Manganese
Electrical Conductivity	Antimony	Molybdenum
Total Dissolved Solids	Arsenic	Selenium
Total Alkalinity as CaCO3	Beryllium	Silver
Sulfate as SO4 -	Barium	Vanadium
Chloride	Cadmium	Tin
Calcium	Chromium	Uranium
Magnesium	Cobalt	Boron
Sodium	Copper	Iron
Potassium	Nickel	
Silicate	Lead	
Fluoride	Zinc	
Nitrate as N	Mercury	

2.3.4. Monitoring program review and optimisation

The monitoring suite and frequency will be reviewed and optimised following two years data collection and every two years thereafter. If stated purpose of the monitoring is not met then additional bores will be installed.

2.4. Trigger levels and mitigation measures

2.4.1. Watertable drawdown from borefield pumping and mine dewatering.

Water table drawdown from the process water supply borefield pumping and mine dewatering will be measured at observation bores as described above.

The groundwater model will be run annually to estimate drawdown at each of these observation bores using the groundwater pumping data recorded at the process water supply borefield and mine dewatering.

A trigger value is defined as: measured drawdown at observation bores exceeds the range of drawdown predicted by modelling.

Mitigation measures will be implemented sequentially as follows:

Stage 1 Development of a Class 2 Groundwater flow model will be undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Volumes pumped from the Project process water supply borefield and mine dewatering rates will be used to define hydraulic stress for the model. Water level drawdown measured at the monitoring bores will be used to provide a calibration data set. Aquifer parameters applied in the model will be adjusted such that the model drawdown matches the measured drawdown.

The recalibrated model will be run to predict drawdown impacts on other users. If these impacts will reduce water availability to other users, then subsequent mitigation will be implemented.

The model set-up may require modification to better meet the model objective which is to predict the aquifer response to Project process water supply borefield pumping and borefield closure and mine dewatering. Possible changes include: redefinition of parameter zones to simulate varied geology within current zonation and modification of boundary conditions.

Future models will be assessed as part of ongoing authorisation under the MM Act.
A recalibrated model will be delivered within one year of the trigger value being exceeded.

Stage 2 Make-good measures at other users to ensure water availability. For example, deepening bores and upgrading pumps.

Stage 3 Increased process water efficiency to be studied and implemented if practicable.

Stage 4 Modified pumping regimes to be implemented if significant impacts associated with groundwater drawdown are identified.

2.4.2. Waste rock dump leachate seepage

Waste rock is anticipated to be deposited to WRDs dry, however, seepage may result during significant rainfall events. It is unlikely that these events will result in groundwater level rises, although deterioration of water quality may occur. Groundwater quality downgradient of waste rock dumps will be monitored at the current observation bores to detect for the impacts of seepage if it occurs.

Trigger Levels comprise:

- Water level rise beyond seasonal variation.
- Water quality deteriorating from baseline.

Mitigation measures will be implemented sequentially as follows:

Stage 1 Assess the impact of water table rise. Water level rise can impact the environment if water levels rise to the root zones of plants, nominally higher than 15m below ground surface. Or if water tables rise to ground surface and cause soil waterlogging and/or salinisation.

Assess the impact of water quality decline. The current beneficial use of groundwater beneath the mine is pastoral use. The impact of tailings leachate seepage if detected should be assessed to determine if the beneficial use category of groundwater will change.

Stage 2 If seepage from the WRDs causes unacceptable impacts (change in beneficial use) then design and implement seepage management measures:

- Pump and treat seepage from beneath the TSFs using interception bores for subsequent re-use in the process plant.

2.4.3. Tailings storage facility leachate seepage

Groundwater levels and water quality downgradient of tailing storage will be monitored at 5 observation bores to detect for the impacts of seepage if it occurs.

Trigger Levels comprise:

- Water level rise beyond seasonal variation.
- Water quality deteriorating from baseline.

Mitigation measures will be implemented sequentially as follows:

Stage 1 Assess the impact of water table rise. Water level rise beyond the TSF footprint can impact the environment if water levels rise to the root zones of plants, nominally higher than 15m below ground surface. Or if water tables rise to ground surface and cause soil waterlogging and/or salinization.

Assess the impact of water quality decline. The current beneficial use of groundwater beneath the mine is pastoral use. The impact of tailings leachate seepage if detected should be assessed to determine if the beneficial use category of groundwater will change.

Stage 2 If tailing seepage causes unacceptable impacts (Water table rise to near surface beyond the TSF footprint or change in beneficial use) then design and implement seepage management measures:

- Pump and treat seepage from beneath the TSFs using interception bores for subsequent re-use in the process plant.

2.5. Model calibration and refinement

Development of a Class 2 Groundwater flow model will be undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Volumes pumped from the process water supply borefield and Lucy Creek Station water supply will be used to define hydraulic stress for the model. Water level drawdown measured at the monitoring bores will be used to provide a calibration data set. Aquifer parameters applied in the model will be adjusted such that the model drawdown matches the measured drawdown.

The model set-up may require modification to better meet the model objective which is to predict the aquifer response to borefield pumping and borefield closure.

Model revision and re-calibration will be undertaken annually if required. Drawdown predictions will be repeated for the life of mine and post closure period using the re-calibrated model.

2.6. Contingency

It is possible that groundwater impacts (water level drawdown and reduced groundwater availability to other users) exceeds the magnitude predicted in the impact assessment.

Prediction of drawdown using the calibrated groundwater flow model will be a leading indicator of impact and monitoring of water level at the receptors will be used to confirm impacts. If impacts are greater than predicted, the following contingency measures will be implemented

1. Impact assessment – the revised magnitude of the impact will be assessed for the full project duration from mining to mine closure and aquifer recovery.

2. Make-good measures will be assessed and implemented if required, for instance deepening of existing users bores to ensure ongoing water availability.
3. Additional water recycling methods will be explored, for example enhanced water recovery from tailings.
4. Alternative water sources will be explored, for instance extending / relocating the borefield further from receptors into deeper parts of the Georgina Basin might be considered – though this is likely to be cost prohibitive.

3 Bibliography

Barnett, B. et al., 2012. Australian groundwater modelling guidelines., Waterlines report 82: National Water Commision, Canberra.

CloudGMS, 2018a. Jervois Base Metals Mine EIS Groundwater Impact Assessment, Adelaide: Unpublished.

CloudGMS, 2018b. Jervois Base Metals Project Lucy Creek Water Supply Investigation, Adelaide: Unpublished.

CloudGMS, 2019. Jervois Mine Site Groundwater Investigation Field Report, Adelaide: Unpublished.

GA, 2009. Groundwater Sampling and Analysis – A Field Guide. Geoscience Australia, Record 2009/27, s.l.: s.n.

4 Document history and version control

Version	Date released	Approved by	Brief description
0.1	21/09/2018	AK	Draft
1.0	02/10/2018	AK	Comments from NT (Nitro Solutions)
2.0	04/07/2019	AK	Updated for EIS supplement
2.1	09/07/2019	AK	Comments from PR (KGL)