TOMINGLEY
GOLD OPERATIONS PTY LTD
(A wholly owned subsidiary of Alkane Resources Ltd)
ABN 53 149 040 371

Tomingley Gold Extension Project

Groundwater Assessment

Part 6

Major Project Application No. PA 09_0155





Prepared by **Jacobs** *Jacobs Group (Australia) Pty Limited*

December 2021

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Tomingley Gold Extension Project Groundwater Assessment

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Specialist Consultant Studies Compendium

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Tomingley Gold Extension Project Groundwater Assessment

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Contents

Executive Summary

Tomingley Gold Operations Pty Ltd (the Applicant) owns and operates Tomingley Gold Operations (TGO), an active open cut and underground gold mine, located at Tomingley, approximately 50km southwest of Dubbo in central-western NSW.

The Applicant is proposing additional or modified TGO operations, plus extension of mining, both open cut and underground, at the San Antonio and Roswell Deposits (SAR) about 2 km south of TGO, hereafter referred to as SAR. Collectively, TGO and SAR are referred to as the Tomingley Gold Extension Project (TGEP).

Key proposed additional or modified TGO operations relevant to the groundwater assessment include waste rock emplacement/backfilling of two open cuts (Caloma 1 and 2) and an increase in elevation/capacity for a residue storage facility, Residue Storage Facility 2, from an approved maximum elevation of 272 mAHD to 286 mAHD.

Key proposed SAR features relevant to the groundwater assessment include an open cut, divided into three distinct but connected open cuts, plus an underground mine under the deepest portion of open cut.

Except for a relatively deep northern portion of open cut at SAR and an existing open cut (Wyoming 1) at TGO, the open cuts would be backfilled with waste rock in the final TGEP landform. The underground mining stopes would be stabilised/backfilled with pastefill, a tailings/residue/cement mixture.

A groundwater impact assessment was undertaken to assess potential impacts to groundwater due to the additional or modified TGO operations and SAR proposal, to support the environmental impact statement for the Project.

The groundwater impact assessment included:

- Review of relevant legislation, policy guidelines and licencing requirements.
- Review of the environmental setting, including development of a conceptual hydrogeological model.
- Calculation of groundwater inflows to the open cuts and underground mines and groundwater level drawdown using an industry standard numerical groundwater flow model, MODFLOW. In accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al.* 2012), the intended model confidence level classification is Class 2.
- Assessment of potential impacts to groundwater due to proposed additional or modified TGO operations and the SAR proposal.
- Development of groundwater related mitigation and management measures.

Interpretations and results from the groundwater flow model predictions are as follows:

- The maximum annual groundwater take due to mining is anticipated to occur in the year of 2026, with a predicted annual groundwater take of 767 ML. This volume is approximately 2.1 ML/d expressed as an average daily volume. The groundwater take is predicted to occur due to dewatering for open cut and underground mining.
- Perpetual groundwater take will occur after mining has ceased due to ongoing evaporative loss within the two open cuts where backfilling is not proposed. A pit lake is anticipated to form in these two voids. The predicted total post-mining groundwater take is about 118 ML/yr once pit lake water levels have recovered to equilibrium levels. Prior to pit lake equilibrium levels being achieved, the post-mining groundwater take would be higher than 118 ML/yr but less than that occurring during mining, and is anticipated to progressively decrease with time as the pit lake water levels increase with time. The bulk of pit lake development is estimated to take place within 80 years of mining ceasing, with final increases towards the equilibrium levels taking longer.

- The modelled groundwater inflow rates do not account for evaporation after the groundwater is removed from the model by the numerical boundary used to simulate dewatering. For this reason, due to evaporative losses, the groundwater inflow rate perceived onsite may be considerably lower than the model results.
- At the end of mining, the modelled 2 m groundwater level drawdown contour is contained within the TGO and SAR mine site boundaries except in the north, where the 2 m groundwater level drawdown contour is about 125 m north of the TGO mine site boundary.

  At the end of the 200 year post-mining period, the modelled 2 m groundwater level drawdown contour extends up to about 2.7 km from the SAR mine site boundary and up to about 1.7 km from the TGO mine site boundary.
- GDEs and baseflows to watercourses are not anticipated to be impacted by TGO/SAR. The fractured rock groundwater system, which hosts the regional water table, that mining is predicted to depressurise, is hydraulically disconnected from overlying alluvial groundwater systems. The alluvial groundwater systems are those most likely to act as a recharge source for the potential GDEs or baseflows to watercourses. This is supported by TGO/SAR groundwater monitoring data, which shows that Gundong Creek alluvium groundwater levels north of TGO mining are approximately 70 m above the regional groundwater level.
- Uncertainty analysis was undertaken to assess the effect of varying model input parameter values on model predictions. None of the uncertainty scenario results alter the base case assessment main findings.

Final void equilibrium water levels for TGO and SAR are predicted to be approximately 200 mAHD and 180 mAHD, respectively. Thus, a perpetual groundwater sink is predicted to form as these levels are about 20 – 25 m lower than the regional water table level.

Potential groundwater impacts due to TGO/SAR were assessed against the NSW Aquifer Interference Policy's Minimal Impact Considerations (NSW 2012). Aside from TGO monitoring bores, the modelled 2 m groundwater level drawdown contour propagates beneath 5 existing registered bores at the end of the 200 year post-mining period. All of these bores are reported as being used for monitoring and are located at a BP Truckstop about 800 m north of TGO. These bores monitor a shallow perched alluvial groundwater systems (bores range from 3.5 – 4.5 m deep) that is disconnected from the regional fractured rock groundwater system that the mine will draw down. As such, they are assessed as unlikely to be impacted by mining induced drawdown.

TGO/SAR is assessed as unlikely to lower the groundwater beneficial use category beyond a distance of 40 m from an activity, which is an AIP (DPI, 2012) Minimal Impact Consideration criterion. The groundwater salinity of the fractured rock groundwater system in the vicinity of TGO/SAR is typically saline and the beneficial use category of the groundwater is limited to industrial use.

Annual groundwater entitlement is required to cover TGO/SAR dewatering from the Lachlan Fold Belt MDB Groundwater Source of the Water Sharing Plan for the NSW MDB Fractured Rock Groundwater Sources 2020 (NSW Government, 2020). The maximum annualised groundwater take of 767 ML is anticipated to occur in the year 2026 and is taken to inform assessment of licensing implications. Thus, 477 ML of entitlement in addition to the existing Mine entitlement of 290 ML/year will be required (477 ML + 290 ML = 767 ML). It is recommended that the Applicant initially obtain entitlement to cover the predicted groundwater take in the year 2025, which is 427 ML, and obtain additional entitlement as required after re-running the groundwater model in the year 2024. The model re-run should take into account monitoring data collected in the intervening period and be re-calibrated if necessary.

Trading is common in the applicable groundwater source and about 70% of the groundwater in this water source is currently unassigned. Therefore, acquiring additional entitlement is considered feasible.

Annual groundwater entitlement will also be required to cover the perpetual groundwater take that will occur after mining has ceased.

Management and mitigation measures are outlined in the report, including recommendations for ongoing groundwater monitoring.

The Project is considered to constitute a low risk to the regional groundwater systems.

Important note about your report

The sole purpose of this report is to present the findings of a groundwater impact assessment, in connection with the proposed additional or modified TGO operations and proposed SAR, to enable key information to be drawn into the Project's EIS. The report was commissioned by Alkane Resources Ltd and was produced in accordance with, and is limited to the scope of services set out in, the proposal/contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

All reports and conclusions that deal with sub-surface conditions are based on interpretation and judgement and as a result have uncertainty attached to them. This report contains interpretations and conclusions which are uncertain, due to the nature of the investigations. No study can investigate every risk, and even a rigorous assessment and/or sampling programme may not detect all problem areas within a site.

This report is based on assumptions that the site conditions as revealed through sampling are indicative of conditions throughout the site. The findings are the result of standard assessment techniques used in accordance with normal practices and standards, and (to the best of Jacobs knowledge) they represent a reasonable interpretation of the current conditions on the site. Sampling techniques, by definition, cannot determine the conditions between the sample points and so this report cannot be taken to be a full representation of the sub-surface conditions. This report only provides an indication of the likely sub surface conditions.

Conditions encountered during mining may be different from those inferred in this report, for the reasons explained in this limitation statement. If site conditions encountered during mining are different from those encountered during the Jacobs and others' site investigations, Jacobs reserves the right to revise any of the findings, observations and conclusions expressed in this report.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the Project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

Except as specifically stated in this report, Jacobs makes no statement or representation of any kind concerning the suitability of the site for any purpose or the permissibility of any use.

1. Introduction

1.1 Background

Tomingley Gold Operations Pty Ltd (the Applicant) owns and operates Tomingley Gold Operations (TGO), an active gold mine, located at Tomingley, approximately 50 km southwest of Dubbo in central-western NSW (**Figure 1.1**). TGO (**Figure 1.2**) comprises both open cut and underground mining operations at the Wyoming 1 and Caloma 1 and 2 Deposits.

The Applicant is proposing additional or modified TGO operations, plus extension of open cut and underground mining, at the San Antonio and Roswell Deposits (SAR) about 2 km south of TGO, hereafter referred to as SAR (**Figure 1.3**). Collectively, TGO and SAR are referred to as the Tomingley Gold Extension Project (TGEP).

The Project has been classified as a “State Significant Development” under Schedule 1 (7(a)) of the State Environmental Planning Policy (State and Regional Development) 2011.

This report documents a groundwater impact assessment undertaken to support the environmental impact statement (EIS) for the Project.

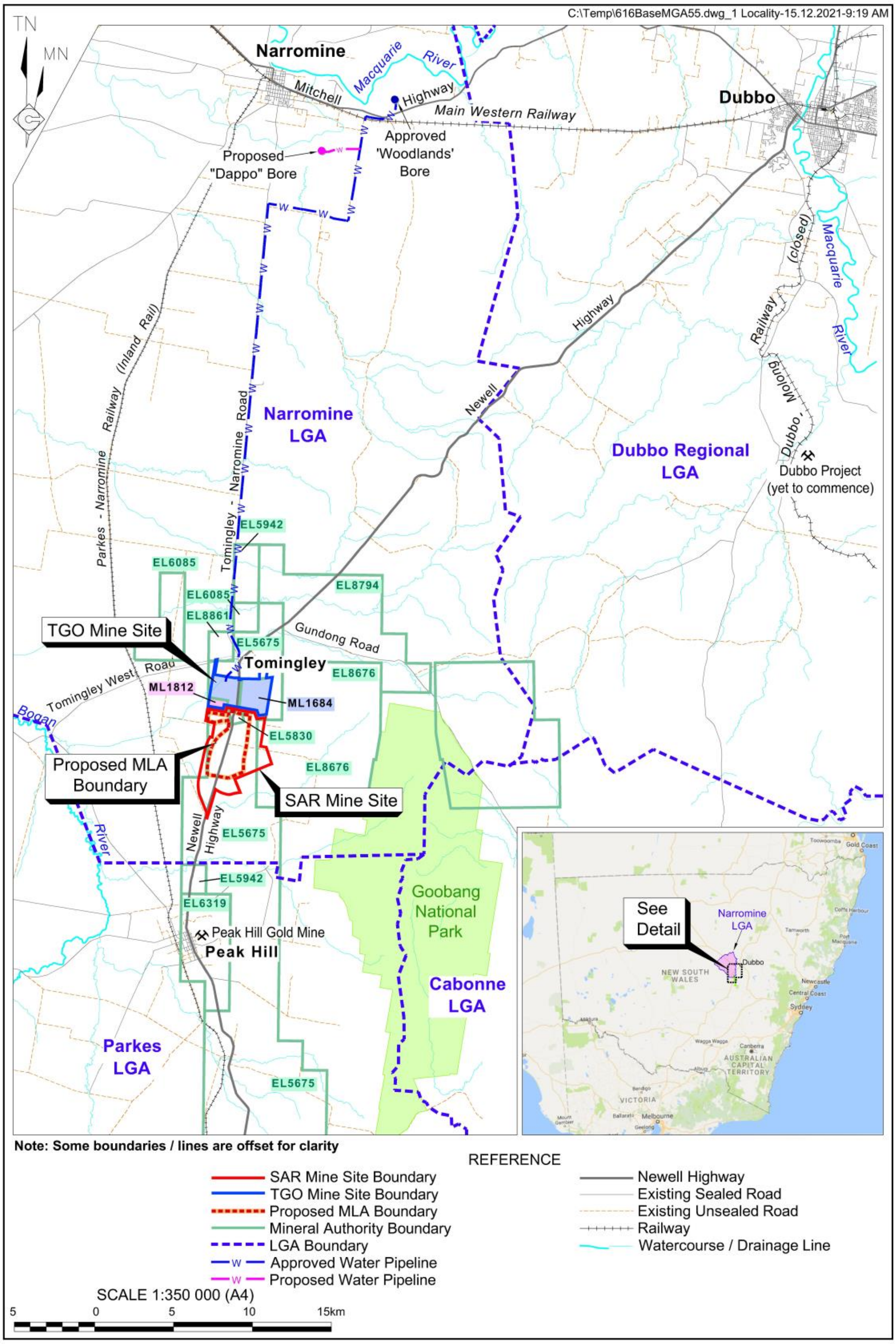


Figure 1.1: Locality plan and mineral authorities (source: RW Corkery & Co, 2021)

1.2 Report objective and layout

The purpose of this report is to document an assessment of potential impacts to groundwater due to the TGEP, including proposed additional or modified TGO operations, to support the EIS for the Project.

Key requirements of the groundwater assessment are identified in the Secretary's Environmental Assessment Requirements (SEARs – **Section 1.5.2**) and also requirements identified through early consultation with DPIE-Water and the NSW Natural Resources Access Regulator (NRAR – **Section 1.5.1**).

The report is divided into the following sections:

- **Section 1 –** Introduction, introduces and describes the Project and outlines the objectives of the report.
- **Section 2 –** Legislative and policy context.
- **Section 3 –** Existing environment, describes elements of the existing environment relevant to groundwater. The section content is based on review of site-specific data and data/mapping available in the public domain.
- **Section 4 –** Groundwater Investigations, summarises groundwater site investigations and subsequent data analysis specifically undertaken to inform the Project's groundwater assessment
- **Section 5 –** Conceptualisation, conceptualises hydrogeology relevant to the Project.
- **Section 6 –** Numerical groundwater flow modelling, describes the development, calibration and results of numerical groundwater flow modelling undertaken for the Project.
- **Section 7 –** Groundwater impact assessment, summarises the results of the groundwater impact assessment completed for the Project.
- **Section 8 –** Management and mitigation measures, outlines groundwater related management and mitigation measures for the Project.
- **Section 9 –** Conclusion, provides a summary of assessment findings.

1.3 Project description

1.3.1 Project overview

The Project comprises two components as follows.

- Approved TGO mining operations (**Figure 1.2**). These activities are undertaken in accordance with development consent MP 09_0155. The approved activities would continue under any new development consent, with MP 09_0155 to be surrendered following receipt of the new development consent and all required approvals for the Project. The approved activities include the following.
  - Extraction of ore and waste rock from four open cuts, with underground mining beneath three of those open cuts.
  - Construction of three out-of-pit waste rock emplacements and one in-pit emplacement.
  - Construction and use of various haul roads, a run-of-mine (ROM) pad and associated stockpiles.
  - Construction and use of a Processing Plant to process up to 1.5 million tonnes per annum (Mtpa).
  - Construction and use of two residue storage facilities comprising Residue Storage Facility 1 (to Stage 9 or a maximum elevation of 286.5m AHD) and Residue Storage Facility 2 (to Stage 2 or a maximum elevation of 272m AHD).
  - Construction and use of ancillary infrastructure.

- The proposed SAR operations and additional or modified TGO operations, including the following (**Figure 1.2**, **Figure 1.3** and **Figure 1.4**).
  - Realigned Newell Highway and Kyalite Road and associated intersections with Back Tomingley West Road and McNivens Lane and Kyalite Road overpass.
  - The SAR Open Cut and Underground Mine.
  - Construction of two waste rock emplacements, namely the Caloma and SAR Waste Rock Emplacement and backfilling of the associated open cuts.
  - The SAR Amenity Bund, Haul Road and Services Road between the SAR Open Cut and the Caloma 2 Open Cut.
  - Processing of ore from the SAR deposits using the approved Processing Plant at a maximum rate of 1.75Mtpa.
  - Increased capacity for Residue Storage Facility 2, from Stage 2 to Stage 9, with a maximum elevation of 286m AHD.
  - Associated surface and underground activities and infrastructure.

In addition, the Project would include an extension of the approved mine life, likely from 31 December 2025 to 31 December 2032.

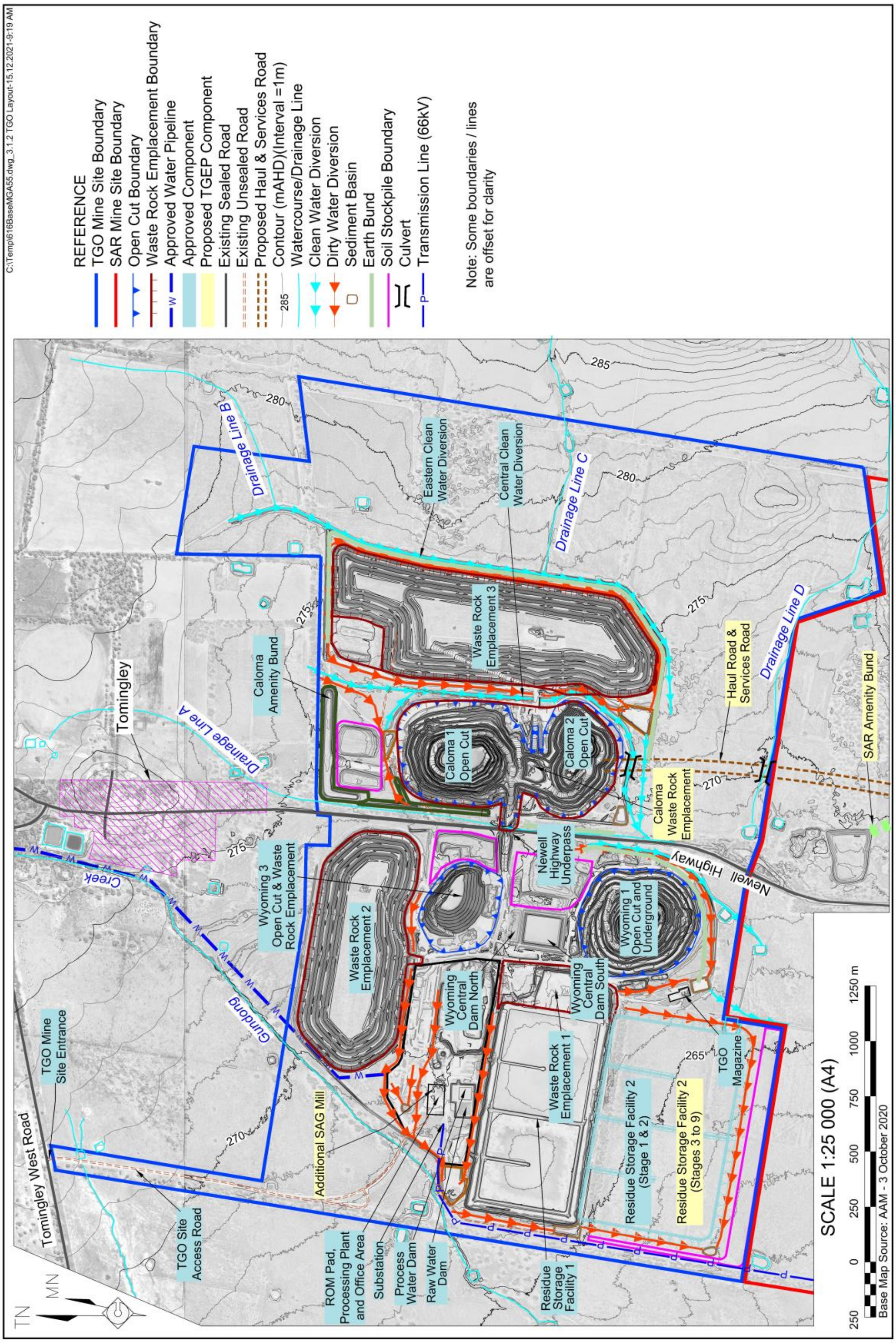


Figure 1.2: TGO mine site layout (source: RW Corkery & Co, 2021)

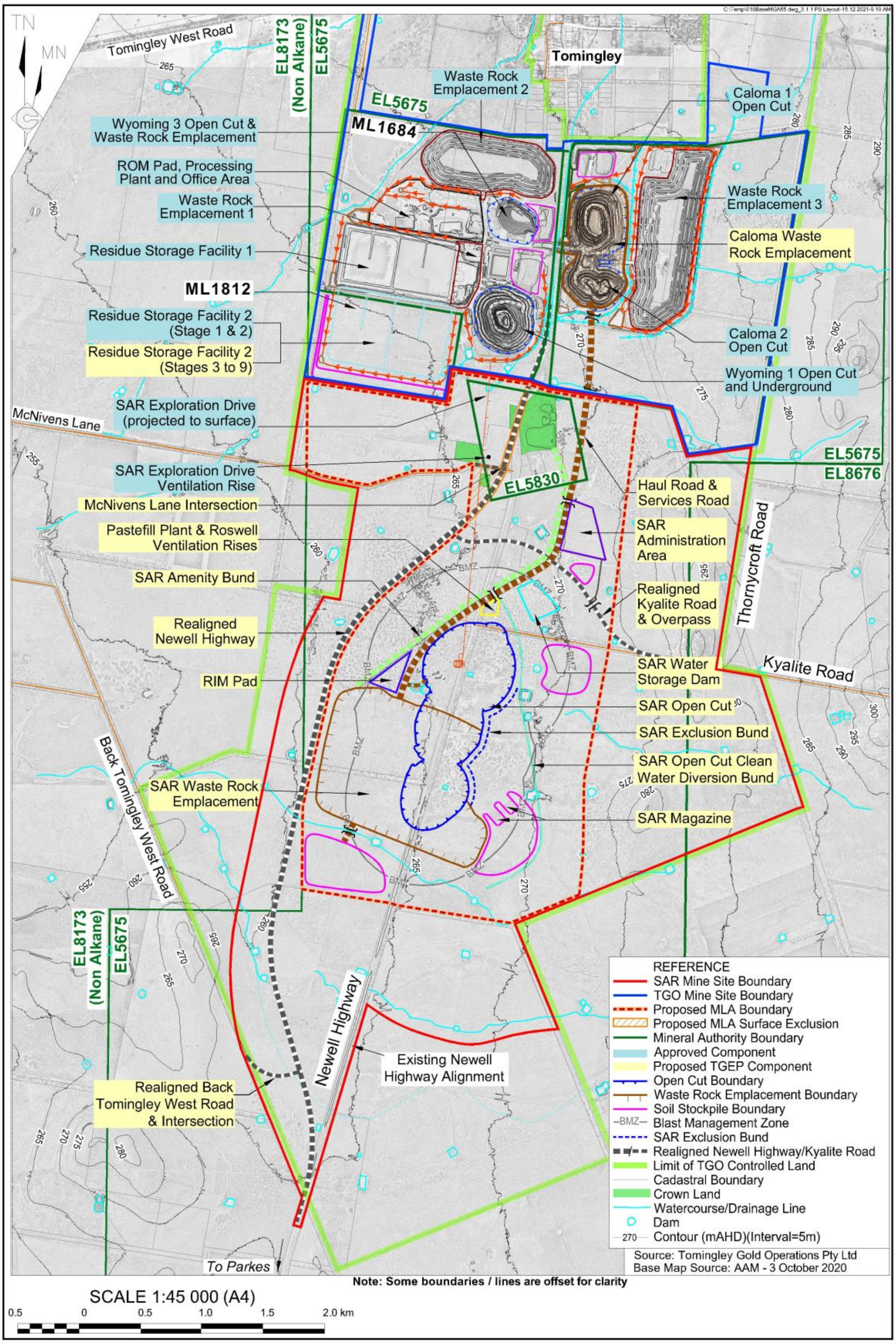


Figure 1.3: Project site layout (source: RW Corkery & Co, 2021)

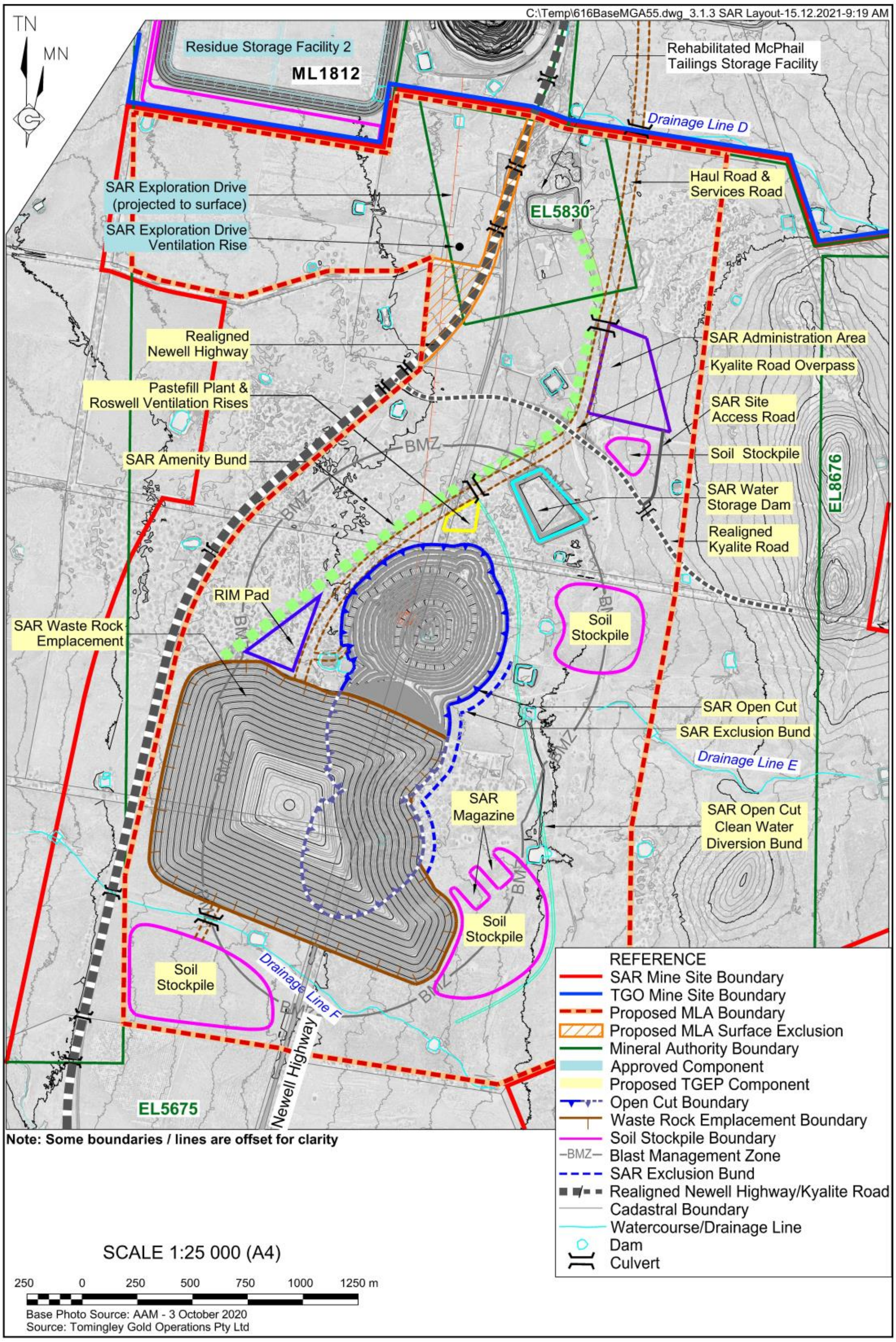


Figure 1.4: SAR layout (source: RW Corkery & Co, 2021)

1.3.2 SAR orebody overview

The orebodies at SAR typically consist of sheeted quartz vein systems hosted within andesite and monzodiorite at Roswell and within two andesite units at San Antonio. The San Antonio deposit also has additional shear hosted orebodies. The orebodies comprise both oxide and sulphide ore zones beneath 20 m to 60 m of Cenozoic alluvial deposits. The resources at Roswell and San Antonio are open to depths of approximately 400 m below ground level (bgl) and 250 mbgl respectively.

SAR would principally comprise an extended open cut mine over both the Roswell and San Antonio deposits, apportioned into three separate but connected open cuts to depths of about 165 mbgl to 300 mbgl, with underground mining continuing at depth beneath the open cuts.

1.3.3 Mining operations

1.3.3.1 Open cut mining

Open cut mining operations would commence in the southern section of the SAR Open Cut. Mining of the near surface material would be undertaken using conventional free dig, load and haul techniques. Once competent rock is exposed, it would be extracted using conventional drill, blast, load and haul techniques. Open cut ore would be transported to the TGO Mine Site via the proposed Haul Road. Alternatively, ore may be stockpiled within the Run-in-Mine (RIM Pad) from where it would be transported to the TGO Mine Site via the proposed Haul Road.

Waste rock would be placed into the SAR or Caloma Waste Rock Emplacements (WREs).

Table 1.1 presents the indicative mining sequence for the Project. Further details such as the production schedule and material movements are provided in the EIS.

Table 1.1: Mining sequence

	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33
Mining Sequence												
Caloma 1 Open Cut Cutback	■	■										
TGO Underground	■	■	■	■		Projected						
SAR Underground		■	■	■	■	■			Projected			
South Pit			■	■								
Central Pit			■	■	■							
North Pit				■	■	■	■	■	■	■		
Waste Rock Placement Sequence												
SAR WRE			■	■			■	■	■	■		
Caloma 1 and Caloma 2 Open Cuts			■	■								
SAR Open Cut South Pit				■	■							
SAR Open Cut Central Pit						■	■					

Note : Mining is proposed to cease by 31 December 2032

1.3.3.2 Underground Mining

Underground mining operations would be undertaken using the SAR Exploration Drive (**Figure 1.3**). The drive would permit access from the Wyoming 1 underground workings to the SAR deposits. The drive and a single ventilation rise were approved under the Mining Act 1992 as exploration-related activities by the Resources Regulator on 7 May 2020. That approval permits exploration drilling from underground and extraction of a bulk sample.

Following receipt of development consent, the drive would be converted from an exploration drive to a production drive. Development of additional drives for production purposes would be undertaken using traditional jumbo-based drill, blast, load and haul techniques. Stoping operations would indicatively rely upon long hole open stoping or similar methods. No surface subsidence, with the possible exception of breakthrough into the base of the open cuts, would occur.

At this stage, the Applicant has only designed underground mining operations within the Roswell deposit. Underground mining within the San Antonio deposit would also be undertaken. In addition, mineralisation within the SAR deposits remains open at depth. As a result, it is very likely that additional underground ore will be identified.

Ore would initially be transported to the TGO Mine Site via the underground drive and Wyoming 1 Portal. Ore transported via the Wyoming 1 Portal would be directly transferred to the ROM Pad using underground haul trucks. An additional portal may be established within the SAR Open Cut and ore may be bought to the surface via the SAR Portal and stockpiled within the RIM Pad from where it would be transported to the TGO Mine Site.

Waste rock is intended to be used to backfill completed stopes or transported to surface via the Wyoming 1 or SAR Portals and placed within surface Waste Rock Emplacements.

Underground mining operations (**Figure 1.5**) would be supported by the following surface infrastructure:

- The approved SAR Exploration Drive Ventilation Rise
- Proposed Roswell Ventilation Rises.
- A Pastefill Plant.

Pastefill is tailings/residue mixed with a binding agent such as cement and is used to backfill and stabilise completed underground stopes. Dewatered tailings/residue would be transported to the Pastefill Plant from the TGO Mine Site via the Services Road before being mixed with the binding agent and pumped underground. Once cured, the pastefill would have a consistency similar to cement and would enable extraction of ore that would otherwise be unable to be extracted.

The indicative underground mining sequence is included in **Table 1.1** in **Section 1.3.3.1**.

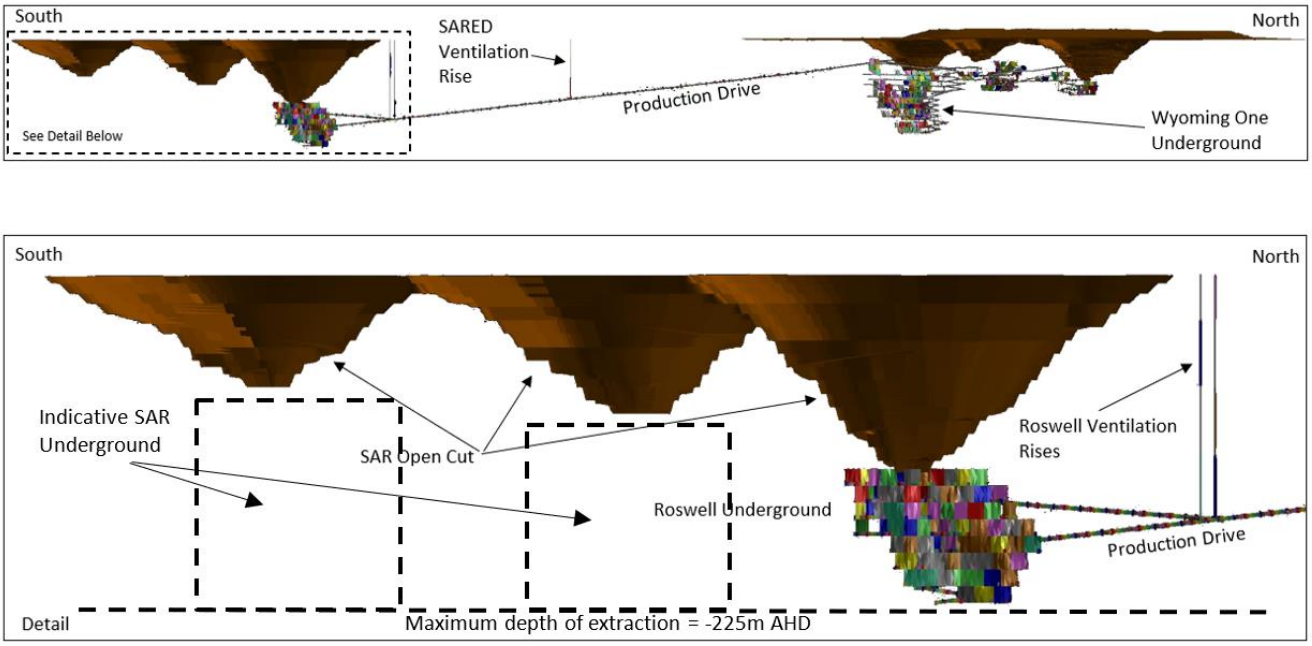


Figure 1.5: Proposed underground mining operations

1.3.4 Waste rock management

Waste rock from the SAR Open Cut would initially be used for site establishment operations, including construction of the SAR Amenity Bund. Subsequently, waste rock would be transported to the TGO Mine Site via the Haul Road and placed into the Caloma and Caloma 2 Open Cuts which would be completely backfilled, with a small hill constructed over the backfilled open cuts. Once complete, waste rock would be placed into the SAR Waste Rock Emplacement, initially in an out-of-pit location, with in-pit placement of waste rock commencing following completion of the southern and central sections of the SAR Open Cut. The southern and central sections of the SAR Open Cut would also be completely backfilled to form an integrated SAR Waste Rock Emplacement.

During waste rock placement operations in the SAR Waste Rock Emplacement, the Applicant would construct, shape and rehabilitate the outer sections of the Waste Rock Emplacement to minimise noise emissions and ensure that operations are, to the extent practicable, not visible from locations to the west of the Project Site.

The SAR and Caloma Waste Rock Emplacements would be designed as geomorphic landforms, with side slopes substantially less steep than the existing Waste Rock Emplacements within the TGO Mine Site. The proposed Waste Rock Emplacements would also, to the extent practicable, be designed without benches, steps or a large, flat upper surface. The intention of the design of the Waste Rock Emplacement would be to replicate a natural landform that would be less visually intrusive than "traditional" Waste Rock Emplacement designs. Design principles are presented in the EIS.

1.3.5 Processing operations and residue management

Ore will be processed using the existing Processing Plant. The Applicant would add a second (primary) ball mill between the existing crushing circuit and the existing (secondary) ball mill. This would permit the Processing Plant to achieve the approved production rate of 1.5 Mtpa when processing hard rock. However, the SAR deposits include a substantial proportion of oxide ore. As a result, production rates when processing this softer material may increase to 1.75 Mtpa.

The Project would require additional capacity to store residue/tailings. RSF2 was approved to Stage 2 or a maximum elevation of 272 mAHD. Development consent would be sought to increase the height of RSF2 to incorporate Stage 9 of RSF2, with a maximum elevation of 286 mAHD. This would result in RSF2 having approximately the same final elevation as the approved RSF1.

1.3.6 Water management

The Project Site and surrounding areas generally slope gently from east to west, with occasional low rises. Surface water flows are typically limited to small, indistinct watercourses. Surface water primarily flows east to west as sheet flow, with water pooling on the eastern side of the current Newell Highway. In extreme rainfall events, the Highway floods, typically once every 3 to 4 years.

Surface water diversion structures would be constructed during the initial site establishment phase of the Project. The surface water diversions would be designed to convey water at non-erosive velocities. An Inundation Bund would be constructed to the east of the SAR Open Cut to provide protection from extreme rainfall events.

Culverts would be installed under the relocated Newell Highway, Haul Road and Services Road and gaps would be left in the SAR Amenity Bund. Where existing culverts under the section of the Newell Highway to be decommissioned are inadequate, sections of the road would be removed. Potentially sediment-laden or dirty water would be retained within the disturbed section of the Mine Site and would be used for mining-related purposes. Dirty water would be prevented from being discharged from site.

Water that seeps into the underground workings would be pumped to a surface storage facility and would be used for mining-related purposes. Mine water would be prevented from being discharged from site.

The current water supply for TGO is drawn from the Woodlands Borefield located approximately 35 km north of the TGO Mine Site in the Lower Macquarie alluvial aquifer. Groundwater extraction from the borefield for the purpose of mineral ore processing is permitted under WAL20270 with an annual extraction limit of 1,000 ML.

The Applicant proposes to replace an existing dilapidated bore1 on the “Dappo” property (Lot 235, DP 755131). The replacement bore would:

- extract water from the same groundwater source and the same depth as the existing bore;
- be within 20m of the existing bore; and
- have an internal diameter the same as the existing bore.

In accordance with Clause 44 of the Water Sharing Plan for the Macquarie-Castlereagh Groundwater Sources Order 2020, the proposed bore would be classified as a “replacement bore” and no additional hydrogeological impact assessment is required.

The existing “Dappo” bore has an existing water allocation of 716MLpa under WAL11692. The Applicant proposes to subdivide WAL11692 and acquire a part of that licence to permit extraction of up to 400MLpa from the replacement bore. As the existing bore and associated WAL are already licenced and approved, the Applicant contends that a change of purpose from “irrigation” to “mining” is the only approval required and that no further groundwater assessment is required.

1.3.7 Final landform, land use, rehabilitation and mine closure

The approved and proposed final landform would include the following:

- Two bunded and fenced final voids, namely the approved and existing Wyoming 1 Open Cut and a proposed void within the northern section of the SAR Open Cut.

[1] Water Supply Works Authority 80CA703364.

- Three fully backfilled open cuts, namely the approved Wyoming 3 and proposed Caloma 1 and Caloma 2 Open Cuts.
- Four shaped and rehabilitated Waste Rock Emplacements, namely the approved and existing WRE2 and WRE3 and the proposed Caloma and SAR Waste Rock Emplacement.
- A capped, shaped and revegetated RSF1 and RSF2.
- Water management structures.
- The realigned Newell Highway and Kyalite Road would be retained. The Haul Road overpass on Kyalite Road would be removed or retained in consultation with Narromine Shire Council.

All infrastructure not required for the final land use would be removed or reduced in size, indicatively including the following:

- The Amenity Bund and Haul Road would be removed. The Services Road would be reduced in size to facilitate ongoing management of the land post-mining.
- The SAR Administration Area would be largely removed, with those structures suitable for the final land use retained. This may include sheds and limited hardstand areas.
- The Processing Plant TGO Administration building and associated infrastructure would be removed.
- The magazines, RIM Pad, Pastefill Plant and other infrastructure would all be removed.
- All entrances to the underground workings would be sealed.

The final land use would comprise a mixture of agriculture and nature conservation.

Rehabilitation would be undertaken progressively, with the outer face of the SAR Waste Rock Emplacement rehabilitated as each lift is established, on an indicatively annual cycle throughout the life of the Project. Rehabilitation of other sections of the Project Site would be undertaken at the end of mine life. A Rehabilitation Management Plan describing the proposed rehabilitation operations and providing detailed completion criteria would be prepared in accordance with the guidelines relevant at that time.

Following completion of all rehabilitation operations and confirmation that the relevant completion criteria have been achieved, the Applicant would relinquish the Mining Lease.

1.4 Study area

A specific groundwater 'study area' was not adopted for the groundwater assessment. However, data review was generally concentrated to within an area of between 5 km and 10 km from the Project Site. Data for the broad scale standing water level contouring was collected from a larger data review area, which was about 55 km by 55 km and centred around the Project Site. These contours demonstrate the dominant regional groundwater flow directions.

1.5 Consultation

1.5.1 DPIE Water and NRAR consultation

Early consultation regarding a preliminary scope of works for the Project's groundwater assessment was undertaken with DPIE Water in September 2020. DPIE (2020) concluded that the proposed scope was generally satisfactory but recommended some amendments and provided comment on the preliminary scope. These comments were considered in finalising the Project's groundwater assessment scope.

The DPIE (2020) comments and a response/reference to relevant report sections are summarised in **Table 1.2**.

Table 1.2: Coverage of DPIE (2020) comments relating to groundwater

DPIE (2020) comment relating to groundwater	Response/coverage in report
General	
Reference should be made to Department terminology including water sharing plan, groundwater source name, bore numbering conventions and existing water access licences.	Reference has been made to Water Sharing Plan (WSP), groundwater source name, state bore I.D. numbers and existing water access licences throughout various report sections, most notably in **Section 2.2** (for water policy/legislation elements) and **Section 3.4** and **7.1** (state bore I.D.s).
Groundwater Testing and Analysis	
We recommend that the proponent reconsiders the use of airlifting as a methodology to test aquifer parameters and collect water quality samples. *There are a range of limitations in using airlifting to determine yield, aquifer parameters and water quality of an aquifer:* • *airlifting does not provide a constant pumping rate from which to satisfactorily interpret aquifer parameters from* • *airlifting can over-estimate yields* • *airlifting will alter the pH of water through addition of carbon dioxide making the samples no longer representative of the site* • *airlifting is generally used in the development of bores. Please do not try to do these separate tasks at the same time as the results will not be representative and will be rendered unusable.* • *whilst airlifting can be used to undertake aquifer parameter testing and collection of water samples the confidence in the results will be low given the above limitations.*	<u>Water quality sampling</u> Only a single water quality sample from one SAR monitoring bore was collected during airlifting and subsequently tested. Aside from this single sample, SAR water quality samples were collected using hydrasleeves, to ensure representative water quality samples were collected. <u>Aquifer parameters</u> A multi-faceted approach has been applied to investigate groundwater system hydraulic characteristics. Whilst airlifting yields have been considered, other approaches were used, such as water level recovery after airlifting, packer testing, and groundwater inflow rate observations from the existing open cuts and underground mine. Groundwater quality and hydraulic testing is covered in **Sections 4.3** and **4.4**, respectively.
Can you please: • *pay attention to the recording of the recovery test results as its analysis is likely to be more indicative of the aquifer parameters.* • *survey monitoring bores so that groundwater levels can be measured in metres Australian Height Datum and compared to one another.* • *include Form As or any bore construction information relating to the monitoring bores in the report so assessment of whether the monitoring bores have been appropriately designed for their intended purpose can be made.* • *carefully consider the methodology for groundwater quality sampling so as not to introduce further errors into the water quality results.*	Water level recovery after airlifting was recorded and is covered in **Section 4.4.3**. Ground level or top of casing level has been surveyed at the monitoring bores. Groundwater levels are compared in the datum of mAHD. SAR/TGO monitoring bore construction details are summarised in **Section 4.2**. Form As for the recently constructed SAR monitoring bores are provided in Appendix F. As outlined above, SAR groundwater quality samples were typically collected using hydrasleeves, to ensure representative sample collection.

Groundwater Modelling and Monitoring	
Can you please: • *Include a site water balance.* • *provide evidence so that the Department has confidence in your chosen model classification. This is particularly true on the range of model parameters.* • *ensure the conceptual groundwater model includes site cross sections.* • *include a groundwater monitoring plan with a proposal to include a trigger action and response plan in order to manage potential impacts if they arise.*	A combined surface water and groundwater water balance is outside of the groundwater assessment scope and is provided in the Project's EIS. Groundwater model water balance volumes are included in **Section 6.8.1.4** and **6.8.2.4** and predicted groundwater inflow rates are discussed in **Section 6.10.1**. A final void water balance is documented in Appendix E. Groundwater model classification is justified in **Section 6.4**.

1.5.2 Secretary's Environmental Assessment Requirements

An EIS must be prepared in response to requirements set out by the Secretary of the NSW Department of Planning, Industry and Environment (DPIE). These requirements are known as the Secretary's Environmental Assessment Requirements (SEARs).

Key issues relating to groundwater, as identified in the SEARs (NSW DPIE, 2021a), are provided in **Table 1.3**. **Table 1.3** also includes direction to the relevant section(s) within this report where each issue has been addressed. Additionally, **Table 1.4** outlines coverage of issues identified by other government agencies for consideration.

Table 1.3: Coverage of SEARs relating to groundwater

Summarised or Paraphrased Relevant Requirement	**Coverage in report**
The EIS must address the following specific issues with the level of assessment of likely impacts proportionate to the significance of, or degree, of impact on, the issue, within the context of the project location and the surrounding environment and having regard to applicable NSW Government policies and guidelines, including: ▪ an assessment of the likely impacts of the development on the quantity and quality of surface, and groundwater resources, having regard to the NSW Aquifer Interference Policy;	Surface water elements covered in Project's surface water assessment. Groundwater elements covered in **Section 7**.
▪ an assessment of the hydrological characteristics of the site and downstream;	Covered in Project's surface water assessment.
▪ an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure and systems and other water users, including impacts to water supply from dams, and riparian and licensed water users;	Surface water elements covered in Project's surface water assessment. Groundwater elements covered in **Section 7**.

Summarised or Paraphrased Relevant Requirement	Coverage in report
▪ a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply and transfer infrastructure and water storage structures, and measures to minimise water use;	Covered in Project's EIS.
▪ demonstration that water for the construction and operation of the development, for the life of the project, can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP), and include an assessment of the current market depth where water entitlement is required to be purchased;	Coverage of groundwater take is addressed in **Section 7.4**
▪ a description of the measures proposed, including monitoring activities and methodologies, to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Demonstration that the Project can operate in accordance with the relevant WSP is covered in **Sections 2.1**, **2.2** and **7.4**.
▪ a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;	Management and mitigation measures, including a preliminary groundwater monitoring program are outlined in **Section 8**.
▪ a description of construction erosion and sediment controls, how the impacts of the development on areas of erosion, salinity or acid-sulphate risk, steep gradient land or erodible soils types would be managed and any contingency requirements to address residual impacts; and	Covered in Project's EIS.
▪ an assessment of the potential flooding impacts of the project;	Covered in Project's surface water assessment.

Table 1.4: Coverage of issues identified by other government agencies for consideration

Agency / Organisation	Summary or Paraphrased Relevant Requirement	Relevant Section(s)
Biodiversity, Conservation and Science Directorate 06/07/2021	The EIS must map the following features relevant to water and soils including: d. Groundwater	**Section 3.4**
	e. Groundwater dependent ecosystems;	**Section 3.5**
	The EIS must describe background conditions for any water resource likely to be affected by the development, including: a. Existing surface and groundwater;	Background groundwater conditions are described in **Section 4.2** and **4.3**
	c. Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters;	The groundwater Water Quality Objective is outlined in **Section 2.5**
	d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government;	Trigger values are covered in the preliminary monitoring program, **Section 8.3**
	The EIS must assess the impacts of the development on water quality, including: a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction;	Impacts to groundwater quality are assessed in **Section 7.5**, **7.6** and **7.7**.
	b. Identification of proposed monitoring of water quality.	Groundwater monitoring covered in **Section 8.3**
	The EIS must assess the impact of the development on hydrology, including: a. Water balance including quantity, quality and source;	Covered in Project's EIS.
	b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas;	Covered in Project's surface water assessment.

Agency / Organisation	Summary or Paraphrased Relevant Requirement	Relevant Section(s)
	c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems;	Assessment of potential impacts to groundwater dependent ecosystems is covered in **Section 7.2**.
	d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches);	Covered in Project's EIS.
	e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water;	**Section 7.4**
	f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options;	Covered in Project's surface water assessment.
	g. Identification of proposed monitoring of hydrological attributes.	Covered in Project's surface water assessment.
DPIE Water and Natural Resources Access Regulator 29/06/2021	The identification of an adequate and secure water supply for the life of the project. This includes confirmation that water can be sourced from an appropriately authorised and reliable supply. This is also to include an assessment of the current market depth where water entitlement is required to be purchased.	**Section 2.1**, **2.2** and **7.4**
	A detailed and consolidated site water balance.	Covered in Project's EIS.
	Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	Groundwater related elements are assessed in **Section 7** and management/mitigation measures are covered in **Section 8**.
	Proposed surface and groundwater monitoring activities and methodologies.	Groundwater monitoring is covered in **Section 8.3**.
	Consideration of relevant legislation, policies and guidelines, including the NSW Aquifer Interference Policy (2012), the Guidelines for Controlled Activities on Waterfront Land (2018) and the relevant Water Sharing Plans (available at https://www.industry.nsw.gov.au/water).	**Section 2**, **7.4** and **7.7**.

Agency / Organisation	Summary or Paraphrased Relevant Requirement	Relevant Section(s)
Narromine Shire Council 07/07/2021	The EIS shall consider the potential for groundwater contamination as well as the contamination of nearby watercourses. Contamination and mitigation measures shall be detailed in the EIS along with preventative measures to contain runoff and sediments from the proposed mine impacting on water resources.	**Section 7.5**
	Additionally, the proposal shall consider the impact of the proposed extraction methods on the soil profile and stability of the site along with erosion and sediment control measures, including surface water runoff management.	Covered in Project's EIS.
	A comprehensive assessment of the potential impacts on the intermittent watercourses and dams on neighbouring properties from stormwater flows including an assessment of potential water discharge quantities and qualities against receiving water shall be provided within the EIS.	Covered in Project's surface water assessment.
	An assessment of the impact of water diversions on public roads and realigned roads should be made.	Covered in Project's surface water assessment.

Agency / Organisation	Summary or Paraphrased Relevant Requirement	Relevant Section(s)
NSW Resource Regulator	▪ Where a void, is proposed to remain as part of the final landform, include: - a constraints and opportunities analysis of final void options, including backfilling, to justify that the proposed design is the most feasible and environmentally sustainable option to minimise the sterilisation of land post-mining; - a geotechnical assessment to identify the likely long-term stability risks associated with the proposed remaining high wall(s) and low wall(s) along with associated measures that will be required to minimise potential risks to public safety; and - an assessment of the long-term erosional stability of pit walls that will remain as part of the final rehabilitated landform; - outcomes of the surface and groundwater assessments in relation to the likely final water level in the void. This should include an assessment of the potential for fill and spill along with measures required be implemented to minimise associated impacts to the environment and downstream water users. ▪ Where the mine includes underground workings: - determine (with reference to the groundwater assessment) the likelihood and associated impacts of groundwater accumulating and subsequently discharging (e.g. acid or neutral mine drainage) from the underground workings post cessation of mining; and - consideration of the likely controls required to either prevent or mitigate against these risks as part of the closure plan for the site.	Assessment of final void water levels and quality is covered in **Section 7.6**. A perpetual groundwater sink is predicted to form in the post-mining period. This is anticipated to minimise the potential for migration of potentially poor quality water.

1.5.3 Gateway Application

On 16 August 2021, the Applicant applied for a Gateway Certificate (GA- 15823373) for the project. The Gateway Application was referred to the Commonwealth Independent Expert Scientific Committee (IESC) and DPIE, who both made comment in relation to a final draft version of the groundwater impact assessment (Jacobs, 2021) for the project. The IESC and DPIE comments were considered in a Conditional Gateway Certificate Report, (NSW IPC, 2021), which outlined requests for further information, some of which pertained to groundwater.

Groundwater related requests for further information in the Conditional Gateway Certificate Report (NSW IPC, 2021) have been addressed in this report, as summarised in Table 1.5.

Table 1.5: Coverage of issues identified at Gateway stage

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
Gateway Certificate	
Groundwater	
The Gateway Panel recommends the EIS address the duration of any impact identified below and to detail any proposed avoidance, mitigation, offset or rehabilitation measures in respect of any impact.	**Section 7** and **8**
The Gateway Panel recommends additional data gathering and analysis to be prepared as part of the EIS to confirm the conceptual groundwater model premise of a hydraulic disconnect locally between the shallow alluvial aquifer units associated with drainage lines, the transported colluvium overlying the saprolite, and the regional fractured rock groundwater system.	The Applicant has committed to the additional data gathering outlined in **Section 5.3** and **8.3.2**.
Improved details are also required on any future groundwater modelling and uncertainty analysis that is to be used in an EIS, to confirm and justify the preliminary findings, including on the final void water balance and water quality and the duration of the impacts.	Additional uncertainty (and sensitivity) analysis has been undertaken and is covered in Appendix D.
NSW Minister for Water	
Groundwater	
The EIS documents should confirm the disconnect locally through some additional data gathering, analysis, and improved conceptual model. This would resolve the potential risk of impacts to the shallow groundwater system.	The Applicant has committed to the additional data gathering outlined in **Section 5.3** and **8.3.2**. Additionally, the first water strike encountered during drilling is presented in a long section and cross sections at the end of **Section 3.3**, which support the disconnect.
Improvements to the numerical modelling are required to confirm the level of impact to surface water features and enable informed decision making and conditioning by the proponents, government agencies, and other stakeholders.	Additional uncertainty (and sensitivity) analysis has been undertaken and is covered in Appendix D. The model is commensurate with the low level of risk. Additional data gathering is proposed (**Section 5.3** and **8.3.2)** to support the conceptualised disconnect between shallow features and the regional fractured rock groundwater system.
Licensing and entitlement	
a) Clarify that the proponent has appropriately considered and addressed any risks associated with acquiring entitlement through trade to account for the predicted maximum take. Options include seeking to acquire permanent shares (entitlement) or taking advantage of controlled allocations.	**Section 7.4**

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
b) Outline the intended method to dewater the underground mining activities.	Inflows to the underground will be directed towards underground sumps from where the water will either be re-used or pumped to surface.
c) Discussing the hydraulic gradient difference between the Wyoming monitoring bores and the San Antonio and Roswell monitoring bores as this flow direction towards the south is perpendicular to the current flow direction maps. Also, identify the aquifer that the flow direction maps represent.	**Section 4.2.3** and **3.4.2**
Update the monitoring network and analysis of the groundwater level trends by:	
a) Installing additional bores to the monitoring network for the San Antonio and Roswell deposits to compensate for the three out of four monitoring bores being dry.	As outlined in **Section 4.2.2**, only one of the four SAR monitoring bores is dry, RWWB004. Whilst RWWB004 is dry, the monitoring location is valuable for confirmation of the hydraulic separation of the shallow alluvial aquifer and the deeper regional water table.
b) Discussing the errors associated with the water levels recorded. For example, RWWB003 is potentially recording water levels just above the sump.	The observed groundwater levels at RWWB003 are within the screened interval and are representative of the formation.
c) Discussing the hydraulic gradient difference between the Wyoming monitoring bores and the San Antonio and Roswell monitoring bores as this flow direction towards the south is perpendicular to the current flow direction maps. Also, identify the aquifer that the flow direction maps represent.	**Section 4.2.3**
Update the groundwater model in respect to:	
a) Improving the identification of neighbouring bores by putting the existing information into a table. The predicted drawdown results at the relevant neighbouring bores should also be presented in a table and/or drawdown contour map.	Identification of neighbouring bores has been improved by labelling bores on figures showing drawdown in **Section 6.10.3** and Appendix D. Registered bores are tabulated in Appendix A.
b) Conceptualisation The conceptual model states that there is a possibility for preferential flow paths but then disregards them as a major controlling factor on groundwater flow direction. The justification to disregard faults as a control on flow direction is of concern for the following reasons:	Faults are discussed in **Section 6.6**. The method used to create the groundwater contours in **Section 3.4.2** is outlined in that section. Additional groundwater contour maps are in **Section 4.2.3**, where the method used to generate the contours is outlined.

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
▪ The flow direction maps do not describe which aquifer they relate to	
▪ There is only one effective SAR monitoring bore	As outlined in **Section 4.2.2**, only one of the four SAR monitoring bores is dry, RWWB004. Therefore, there are three effective SAR monitoring bores.
▪ Two of the older monitoring bores show responses to the historic mine workings	The locations of WYMB01 and WYMB06 are prone to inundation during even relatively modest (10% AEP) rainfall events. The historic workings are known to be linked to the surface, and anecdotally surface water flows have been observed disappearing into the workings during heavy rainfall. It is therefore considered likely that the observed water level responses are the result of surface water ingress to the old buried workings.
▪ The higher hydraulic conductivity of WYMB006 which has been identified as being close to the historic mine workings	The hydraulic conductivity of WYMB006 has been considered in the application of model parameters, along with all available hydraulic conductivity data.
The proponent should improve its conceptualisation by: i. providing further evidence prior to eliminating the possibility of preferential flow paths in the conceptual model.	Potential flow paths associated with faulting are discussed in **Section 6.6**.
ii. referencing the layer of which the groundwater flow direction maps are being created.	The method used to create the groundwater contours in **Section 3.4.2** is outlined in that section. Additional groundwater contour maps are in **Section 4.2.3**, where the method used to generate the contours is outlined.
iii. discussing the hydraulic gradient between the monitoring bores as a product of the different geologies they are constructed into.	**Section 4.2.3**
iv. discussing the hydraulic conductivity differences between the different methods used to obtain aquifer parameter information.	**Section 4.4.6**

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
v. discussing the sources of uncertainty within the conceptual model such as the logger within RWWB003 recording a water level in the base of the screen.	The observed groundwater levels at RWWB003 are within the screened interval and are representative of the formation. Equilibrium groundwater elevations are similar at all three bores and the bores are interpreted to be monitoring the regional fractured rock groundwater system groundwater level.
vi. comparing the EIS water balance to the conceptual model to provide an indicative test.	EIS water balance incorporated groundwater model results. Groundwater model results accord with the conceptualisation.
vii. identifying the source of evapotranspiration data and the methodology used to obtain the data.	**Section 6.5.5**
c) Numerical modelling must be undertaken and demonstrated to be in accordance with the Australian groundwater modelling guidelines 2012 and the IESC uncertainty analysis guidance 2018. To limit assumptions could the proponent please clarify a number of elements of the model set-up: i. provide a simple justification of the choice of model.	Groundwater modelling has been undertaken in accordance with the Australian groundwater modelling guidelines 2012 and the IESC uncertainty analysis guidance 2018. These guidelines are references in relevant report sections. Model choice is justified in **Section 6.2**.
ii. clarify whether the same boundary conditions have been applied across all 6 layers of the numerical model as it is possible they apply only to Layer 1 which has different consequences on the interpretation of the results.	Clarified in **Section 6.5.1**.
iii. describe how the layers and hydraulic conductivity zones relate to the conceptual model.	**Section 6.5.3** and **6.8.1.2**.
iv. identify the confinement of each layer in the numerical model.	**Section 6.5.4**
v. justify the applied vertical conductivity is required.	**Section 6.8.1.2**
vi. identify the model run-times to help us understand to what extent calibration is limited by model-run time lengths.	**Section 6.9.2**
vii. clarify the initial conditions for the transient model.	**Section 6.9.2**
viii. clarify whether the model is sensitive to changes in vertical conductivity.	Appendix D

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
Summarised or Paraphrased Relevant Requirement	Relevant EIS Section(s)
ix. clarify the number of time-steps used in the prediction of impact and justify.	**Section 6.9.2**
x. define the baseline scenario for the model.	**Section 6.9.1**
d) Predicted results The calculation of uncertainty is described in Appendix D but it is difficult to see how it has been applied to the results. Understanding this aspect will allow DPIE Water to have greater confidence in the calculated volume accounted for under a Water Access Licence. It is unclear how uncertainty in the model has been applied when calculating drawdown at neighbouring bores and how the overestimation of the hydraulic head across most of the model when compared to the observed will impact the neighbours through an underestimation of drawdown. Could the proponent please: a. clarify how the mining activity phases align with the model results. It is unclear whether the maximum mining take occurs in 2031 as shown in Figure 7.1 or 2026 as described in the text.	Base case results used to calculate drawdown and groundwater take. Maximum groundwater take anticipated in the year 2026.
b. present the prediction results for drawdown on the neighbours more clearly such as a table, map or water budget changes over time.	Identification of neighbouring bores has been improved by labelling bores on figures showing drawdown in **Section 6.10.3** and Appendix D.
c. clarify the units in Table 6.9. It is unclear whether the recharge rate as a % of rainfall adopted in the model is 0.036 % or 3.6%.	Clarified in **Section 6.8.4**
d. clarify how the estimation of uncertainty have been applied to the maximum take volume and the predicted impacts to neighbours.	Base case results used to calculate drawdown and groundwater take.
e. discuss how the overestimated water level in the computed water levels is likely to underestimate drawdown in neighbouring bores and the consequences for this calibration.	Discussed in **Section 6.8.2.4**
f. relate the model results back to the target model confidence level classification.	**Section 6.10.1**
g. describe how the uncertainty analysis has been considered in the results.	Base case results used to calculate drawdown and groundwater take. Uncertainty results discussed in **Section 6.10.4** and Appendix D.

Summarised or Paraphrased Relevant Requirement	Relevant Section(s)
Groundwater quality analysis and monitoring The piper diagram shows that the RWWB002 monitoring bore appears to have a different ionic composition to the other bores that can't be as easily explained as the shallow alluvial monitoring bore GDCMB01. RWWB002 is also the only monitoring bore to have a significant decline in water levels as it is adjacent to the Wyoming open-cut and underground. It is not discussed whether the water quality difference and decline in water level are related or whether paste-backfilling of stopes has influenced the water quality. Therefore, it is requested that the proponent please: a) Discuss the groundwater quality impacts of backfilling stopes with paste.	WYMB02 is also the only monitoring bore to have a significant decline in water levels, not RWWB002. There has been no mining to date near RWWB002. Therefore, water quality differences are due to natural causes.
b) Include a timeseries analysis of groundwater quality changes at WYMB002 and the implications for groundwater quality changes at the San Antonio and Roswell activities.	Refer to above comment.
The Preliminary Groundwater Management Plan Neighbouring bores have been identified within the model domain and although most are associated with the perched aquifer and therefore conceptualised to be disconnected, there still appears to be some bores that are a bit deeper. Although, the project is not deemed to be high-risk, the suggestion to remove triggers and only enact make-good provisions upon complaint cannot be accepted. Could the proponent please: a) Extend the monitoring network to include mid-point bores between the mining activity and neighbouring water supply bores.	**Section 8.3**
b) Consider alternative options to bore deepening given the yield of the aquifer.	Deepening option has been removed.
c) Include timeframes for actions in the proposed triggers.	**Section 8.3**
d) Be explicit about proposed actions and avoid vague commitments.	**Section 8.3**
Independent Expert Scientific Committee	
Groundwater	
• Further information is required to confirm the site's groundwater conceptualisation. Field data are particularly required to establish the extent of the perched alluvial aquifers, their degree of hydraulic connection with the Bogan River and Gundong and Bulldog creeks and verify the claim that there is no connection between the perched alluvial aquifers and the deeper regional fractured rock aquifer in the vicinity of the mapped GDEs. Based on this assessment, further groundwater modelling may be required to fully understand the magnitude and extent of drawdown and associated impacts.	The Applicant has committed to the additional data gathering outlined in **Section 5.3** and **8.3.2**
• The order-of-magnitude uncertainties of aquifer hydraulic parameters should be addressed by the model uncertainty analysis to capture plausible ranges of these parameters in the project area. Drawdown impacts may extend further than presently predicted.	Appendix D

2. Legislative and policy context

The legislative and policy context relevant to groundwater is summarised in the following sections.

2.1 Water Act 1912 and Water Management Act 2000

Water resources in NSW are administered under the Water Act 1912 and the Water Management Act 2000 (WM Act) by the DPIE-Water. In general, the WM Act governs the issue of water access licences (WALs) and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where WSPs have commenced. The WSPs for the Project have commenced and water management for the Project is therefore generally governed under the WM Act. The WSPs relevant to the Project are outlined in **Section 2.2**.

Ordinarily, if an activity leads to a take from a groundwater or surface water source covered by a WSP, then an approval and / or licence is required. In general, the WM Act requires:

- a WAL to take water;
- a water supply works approval to construct a work; and
- a water use approval to use the water.

Where an activity leads to a take from a groundwater or surface water source not covered by a WSP or consists of an activity not specifically addressed by the WM Act, then the activity is managed through the Water Act 1912. In such cases, the Water Act 1912 requires:

- a licence to extract groundwater or surface water using any type of work; and
- a water supply work approval to construct a work.

It is noted that, as the Project is considered to be a State Significant Development, under Section 4.41 (1g) of the EP&A Act 1979, the authorisation provided by a water use approval under Section 89 of the WM Act, a water management work approval under Section 90 of the WM Act or an activity approval under Section 91 WM Act are not required. Rather, this authorisation is provided by a development consent.

Thus, if the Project's groundwater / surface water extraction is assessed and approved as part of the State Significant Development proposal, only a WAL would be required. A WAL is required for dewatering and other taking of water from any water source which is covered by a WSP under the WM Act. A WAL authorises the taking of a share of water from a specified water source in accordance with the volumetric entitlement in the WAL. That entitlement is measured by the number of units assigned to the WAL and the annual volumetric value of a unit for that water source as determined by the Minister administering the WM Act. Units can be transferred from one WAL to another. A WAL is held personally and may be transferred and otherwise dealt with in accordance with the WM Act.

The Applicant currently holds the WALs shown in **Table 2.1** and six groundwater works approvals under the Water Act 1912 as summarised in **Table 2.2**. Background information on WAL20270 is provided in **Section 1.3.6**.

Table 2.1: WALs held by the mine

Water Access License number	Extraction limit (ML/year)	Water Sharing Plan	Water Sharing Plan Water Source	Description
	Surface water			
WAL 35321	22	Macquarie Bogan Unregulated and Alluvial Water Sources 2012	Upper Bogan River Water Source	Water Supply Works and Water Use
	Groundwater			
WAL 20270	1,000	Macquarie-Castlereagh Groundwater Sources 2020	Lower Macquarie Zone 6 Groundwater Source	Aquifer (Woodlands Borefield)
WAL 28643	220	NSW Murray Darling Basin (MDB) Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source	Dewatering (work approval number 80MW724171)
WAL29266	70	NSW MDB Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source	Dewatering (work approval number 80MW724171)

Table 2.2: Water Act 1912 licenses held by the Mine

License number	Issue date	Expiry date	Purpose
80BL245428	23 September 2009	Perpetuity	Groundwater monitoring
80BL245429			
80BL245430			
80BL24531			
80BL245432			
80BL620426	27 October 2014		

2.2 Water Sharing Plans

The Project resides in the Lachlan Fold Belt MDB Groundwater Source of the Water Sharing Plan for the NSW MDB Fractured Rock Groundwater Sources 2020 (NSW Government, 2020). The Lachlan Fold Belt MDB Groundwater Source is subdivided into management zones and the Project resides in the 'Lachlan Fold Belt MDB (Other) Management Zone'.

It is noted that alluvial material overlies fractured rock in the vicinity of the Project. The alluvium is not covered by any alluvial WSP and is therefore covered by the Lachlan Fold Belt MDB Groundwater Source of the Water Sharing Plan for the NSW MDB Fractured Rock Groundwater Sources 2020 (NSW Government, 2020).

As at March 2021, the NSW Water Register (Water NSW, 2021a) indicates the groundwater source has 1,098 WALs and a total share component of 75,819 units(ML). The WSP (NSW Government 2020) indicates the groundwater source has a long-term average annual extraction limit (LTAEL) of 253,788 ML/year. Thus, about 70% of the groundwater in this water source is currently unassigned. Trading in this water source is common, and in the 2020/2021 water/financial year there were 52 records of transfer trading (Water NSW, 2021a).

Surface water WSPs are potentially relevant to the groundwater assessment if the Project causes baseflow reductions to nearby watercourses due to groundwater level drawdown. With regards to surface water, the Project resides in the Upper Bogan River Water Source of the Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012. In relation to the Upper Bogan River Water Source, the NSW Water Register (Water NSW, 2021a) indicates this surface water source has 27 WALs and a total share component of 1,849 units/ML. The register indicates that the volume of water made available to all the WALs is 1,849 ML.

As outlined in **Section 1.3.6**, the Mine water supply is extracted from groundwater from an off-site source; that is, the Lower Macquarie Zone 6 Groundwater Source of the Water Sharing Plan for the Macquarie-Castlereagh Groundwater Sources 2020 (NSW Government, 2020a). The borefield and groundwater source are located approximately 35 km to the north of TGO. The water is used for processing and other mine related purposes.

2.3 NSW Aquifer Interference Policy (2012)

The NSW Aquifer Interference Policy (AIP) (DPI, 2012) outlines 'Minimal Impact Considerations' for the assessment of aquifer interference activities, such as those proposed for the Project.

Different 'Minimal Impact Considerations' from DPI (2012) are applicable to different groundwater source types. In the context of the AIP, the Project is characterised to reside in the 'porous and fractured rock water sources' sub-category of the 'less productive groundwater sources' category. This characterisation is made on the basis that groundwater systems in the vicinity of TGEP do not simultaneously have existing bores that can yield greater than 5 L/s and a total dissolved solids concentration of <1,500 mg/L, which is the NSW DPI (2012) criteria used distinguish a 'highly productive' groundwater source from a 'less productive groundwater source'.

Small perched discrete alluvial groundwater systems associated with watercourses exist within the vicinity of the Project Site. These groundwater systems are not recognised as being part of a distinct alluvial water source in the WSP. Therefore, potential impacts to these alluvial groundwater systems have been assessed against the criterium applicable for the 'less productive' 'porous and fractured rock water sources' category.

In accordance with the AIP (DPI, 2012), the Minimal Impact Considerations outlined in **Table 2.3** apply.

With respect to groundwater-dependent high priority culturally significant sites, no such sites are identified in the WSP for the NSW MDB Fractured Rock Groundwater Sources 2020 (NSW Government, 2020). Furthermore, OzArk Environment & Heritage Management Pty Ltd who prepared the Aboriginal Heritage Assessment for the Project advise that the Registered Aboriginal Parties have not identified any culturally significant groundwater-related locations in the vicinity of the Project Site. Similarly, OzArk state that they are not aware of any such sites in the vicinity of the Project Site based on over 20 years of experience in the area.

Table 2.3: AIP (DPI, 2012) Minimal Impact Considerations - Less Productive Groundwater Sources

Water Source	***Water Table***	***Water Pressure***	***Water Quality***
Porous and fractured rock groundwater sources	*1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any:* *(a) high priority GDE; or* *(b) high priority culturally significant site;* *listed in the schedule of the relevant water sharing plan.* *A maximum of a 2m decline cumulatively at any water supply work.* *2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any:* *(a) high priority GDE; or* *(b) high priority culturally significant site;* *listed in the schedule of the relevant water sharing plan then appropriate studies would be required to demonstrate to the Minister's satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site.* *If more than 2m decline cumulatively at any water supply work, then make good provisions should apply.*	*1. A cumulative pressure head decline of not more than a 2m decline, at any water supply work.* *2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.*	*1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.* *2. If condition 1 is not met then appropriate studies would be required to demonstrate to the Minister's satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.*

2.4 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) (Australian Government, 2018) is the adopted national approach to protecting and improving water quality in Australia. It consists of several guideline documents, of which certain documents relate to protection of surface water resources and others relate to the protection of groundwater resources.

The primary document relevant to the assessment of groundwater risks for the proposal is the Guidelines for Groundwater Quality Protection in Australia (Australian Government, 2013). This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called 'environmental values'), including aquatic ecosystems, primary industries (including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods), recreational and aesthetic values (e.g. swimming, boating and aesthetic appeal of water bodies), drinking water, industrial water and cultural values.

For the purpose of the groundwater assessment, the industrial water 'environmental value' is considered potentially applicable in the vicinity of the Project Site. The other 'environmental values' are not applicable due to the high salinity of the groundwater.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (ANZG, 2018) provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters and list a range of environmental values assigned to that waterbody. The ANZG (2018) recommended guideline values have been considered in the assessment of existing groundwater quality.

2.5 Groundwater quality objective

The adopted groundwater quality objective for the Project is to ensure construction and operation of the Project has a neutral or beneficial effect to groundwater quality.

For the purpose of this assessment, a neutral or beneficial effect to groundwater quality is defined as an effect that does not lower the beneficial use category of the groundwater system beyond 40 m from a Project activity, or an effect that raises the beneficial use category of the groundwater system. The adopted groundwater quality objective to not lower the beneficial use category of the groundwater system beyond 40 m from a Project activity aligns with the water quality 'Minimal Impact Consideration' from the NSW AIP (DPI, 2012).

3. Existing environment

3.1 Climate

For the purpose of this assessment, climate data has been obtained from both the onsite Automatic Weather Station (TGO AWS) and from Queensland Government's online SILO database of Australian climate data. The onsite AWS climatic record which commenced in October 2013 is considered relatively short for the purposes of analysing long term climatic trends and as such, is supplemented with the use of the SILO dataset. The long-term statistics for the onsite AWS are presented alongside the SILO dataset which has a significantly longer historical record, with data commencing from 1889.

SILO data can be acquired for individual weather station points, or as point or gridded dataset with a resolution of approximately 5 km x 5 km. The SILO data used in this report is a point dataset from January 1970 and consists of interpolated daily data. The SILO data was extracted for the now closed Tomingley weather station (Bureau of Meteorology station # 050091) point Latitude -32.60 degrees north and Longitude 148.20 degrees east.

Key rainfall and evaporation statistics are provided in **Table 3.1**.

The climate statistical trends between the SILO and the TGO AWS dataset are in general agreeance except for the months of February and March which can be attributed to the relatively short dataset of TGO AWS. Mean monthly pan evaporation exceeds mean monthly rainfall for all months in both datasets. Mean monthly FAO56 Penman-Monteith evaporation (SILO) exceeds mean monthly rainfall for all months. The difference between evaporation and rainfall is most pronounced during summer months.

Table 3.1: Tomingley (Lat -32.60 N, Long 148.20 E) and Alkane AWS rainfall and evaporation summary (Source: SILO)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Mean monthly rainfall (mm) (TGO)[1]	65	35	85	46	37	40	44	37	42	46	61	65	603
Mean monthly rainfall (mm) (SILO)[2]	59	50	51	41	44	37	44	39	42	45	53	56	562
Mean monthly pan evaporation (mm) (TGO)[1]	244	207	165	118	81	53	69	95	127	171	204	229	1762
Mean monthly pan evaporation (mm) (SILO)[2]	278	221	189	120	73	48	53	77	114	172	218	272	1833
Mean monthly FAO56 evaporation (mm) (SILO)[2]	203	164	146	98	63	43	46	66	95	139	168	199	1432
Rainfall surplus (mm) (TGO)[3]	-179	-171	-80	-72	-45	-13	-24	-58	-85	-125	-143	-165	-1158
Rainfall surplus (mm) (SILO)[3]	-219	-171	-137	-79	-29	-11	-8	-38	-72	-127	-164	-216	-1271

Notes: [1] Based on record from Oct 2013 to end of Apr 2021. [2] Based on record from 1970 to Apr 2021. [3] Calculated by subtracting pan evaporation from rainfall.

3.2 Topography and drainage

Topography and watercourses in the region of TGO and SAR are shown in **Figure 3.1**.

The TGEP is situated on relatively gently sloping, rolling to flat terrain with dominant fall to the west. Typical topographic gradients are of the order of 1:250 (V:H). Surface elevations in the vicinity of the Project Site are typically of the order of 265 mAHD to 270 mAHD. The rolling terrain continues north and south of the Project Site. To the west towards the Bogan River, the gentle slopes flatten even further; whereas, to the east, slopes increase towards the foothills of the Herveys Range that in places is in excess of 500 mAHD.

The Project Site is situated in the Bogan River catchment between the ephemeral Gundong and Bulldog Creeks which both drain west to the Bogan River, approximately 10 km to 12 km to the south and southwest of the Project Site. In this locality, the Bogan River itself is also ephemeral, flowing only after large or sustained rainfall events. Both Gundong Creek and Bulldog Creek rise on the western flanks of the Herveys Range and are third order drainages as they cross the Newell Highway. Water courses rising on the east of the Herveys Range ultimately drain east to the Macquarie River.

A number of ephemeral and poorly defined drainage channels also exist in the area, typically draining to the west or south-west, with numerous small dams established along the drainage lines.

More detail on local surface water and catchments is provided in the Project's surface water assessment.

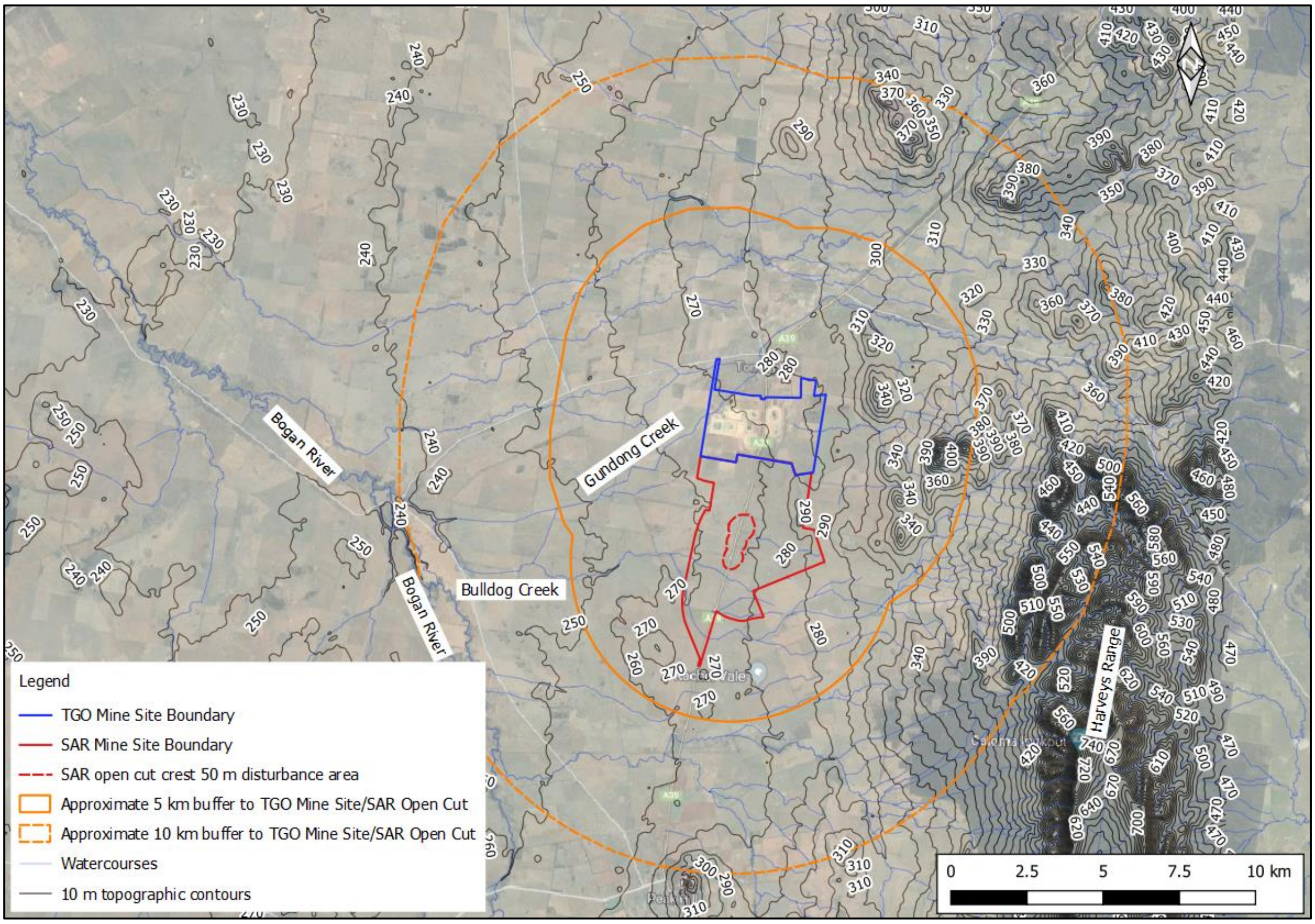


Figure 3.1: Topography and drainage

3.3 Geology

Regionally the Project Site is located in the eastern zone of the Lachlan Foldbelt in an area known as the Macquarie Arc. The Macquarie Arc consists of igneous and fore arc accretionary deposits of Ordovician and Silurian age.

The Impax Group (2011) indicates that '*within the Macquarie Arc, several individual belts of mafic to intermediate volcanic, intrusive, volcaniclastic and turbiditic rocks have been identified. These sequences are segmented by a number of generally north–south to north-northwest trending arc-parallel structures, many of which are thought to be thrust faults or major strike-slip faults. The volcanic belts comprise Ordovician to early Silurian rocks with predominantly mafic to andesitic composition and display a spectrum of rock types including lavas, breccias, volcaniclastic sandstone and siltstone, and the monzonitic to dacitic intrusions'*.

The Impax Group (2011) indicates the Project Site is '*located near the eastern margin of the Junee-Narromine volcanic belt, just east of the interpreted Parkes Thrust. This structure separates the flat lying Goonumbla volcanic complex from a thin slice of north-south trending andesitic volcanics (Mingelo volcanics) (The Impax Group, 2011). The late Ordovician Mingelo volcanics are overlain by meta-sediments thought to be equivalents of the early Silurian Cotton formation'*.

The Impax Group (2011) indicates the '*deformation of the Lachlan Fold Belt is complex and reflects multiple events. The Ordovician rocks west of the Parkes thrust are weakly deformed, with broad open folds and sub-greenschist metamorphic assemblages. In contrast, the Ordovician-Silurian sequences east of the fault, including the rocks hosting the deposits at TGO and SAR, exhibit tight to isoclinal folding, strong axial planar cleavage with greenschist metamorphic assemblages. Northwest trending transverse structures are also evident in regional magnetic and gravity data, and rarely as faults mappable in outcrop. These structures appear to be long lived fundamental crustal breaks that were irregularly reactivated throughout the geological development of the Macquarie Arc. They also show a relationship to intrusive centres and mineralisation where the structures intersect and occasionally offset the arc parallel structures. The TGEP deposits themselves are interpreted as orogenic gold systems positioned within a major structural zone'*.

The Parkes Special 1:100,000 Geological Sheet (Krynen *et al.*,1990) indicates that the majority of the Project Site is covered by Cainozoic alluvial and colluvial deposits with occasional outcrops of Ordovician Mingelo volcanics and Silurian siltstones of the Cotton and Mumbidgle Formations (**Figure 3.2**). Geological mapping in the Narromine 1:250,000 Geological Sheet (Sherwin,1997) (**Figure 3.3**) and Narromine 1:250,000 Metallogenic Series Sheet (Bowman et.al, 1980) (**Figure 3.4**) is generally similar to Parkes Geological Sheet, however there are some differences.

The Cainozoic deposits typically comprise alluvial clays to sandy clays with thicknesses ranging from 20 m to 60 m. At the historic Myalls United gold mine, located between the TGO and SAR Deposits, the basement rocks (Cotton Formation) outcrop on a low rise. There is potential for minor sandy alluvial deposits within the main drainage channels with a minor alluvial aquifer associated with Gundong Creek.

The geotechnical report for the TGEP (WSP, 2021) describes five geotechnical horizons, and differentiates the Cainozoic alluvium into Quaternary and Tertiary alluvial deposits, although the characteristics are very similar.

The WSP (2021) geotechnical horizons are as follows:

1. Quaternary Alluvium (QA) of brown sandy clays, sandy silty clays and minor sands and gravels.

2. Tertiary Alluvium (TA) of grey mottled red orange sandy clays and silty clays and sands. The total thickness of alluvium, including the Tertiary Alluvium, is typically in the order of 25 m to 60 m based on cross sections within WSP (2021).

3. Saprolite defined as extremely weathered rock with soil consistency and relict geological structure and referred to operationally as saprock. The thickness of this material is anticipated to vary between 10 m and 15 m (WSP, 2021).

4. Weathered Rock (WR) oxidised and highly to moderately weathered rock. The thickness of this material is anticipated to vary between 20 m and 50 m (WSP, 2021).

5. Slightly Weathered and Fresh Rock (SW/FR).

The alluvial deposits are characterised from ten samples (WSP, 2021). Average grain size analysis results from all ten samples indicate a composition of approximately 12% sand, 86% fines (silt and clay), and 2% gravel. Particle size distribution testing did not separate the silt and clay fractions. The samples are generally represented as silty clay with sand and trace gravel and are of moderate to high plasticity indicating a dominance of clay.

The regolith profile at TGEP is generally well developed with weathering and oxidation extending to around 70 mbgl.

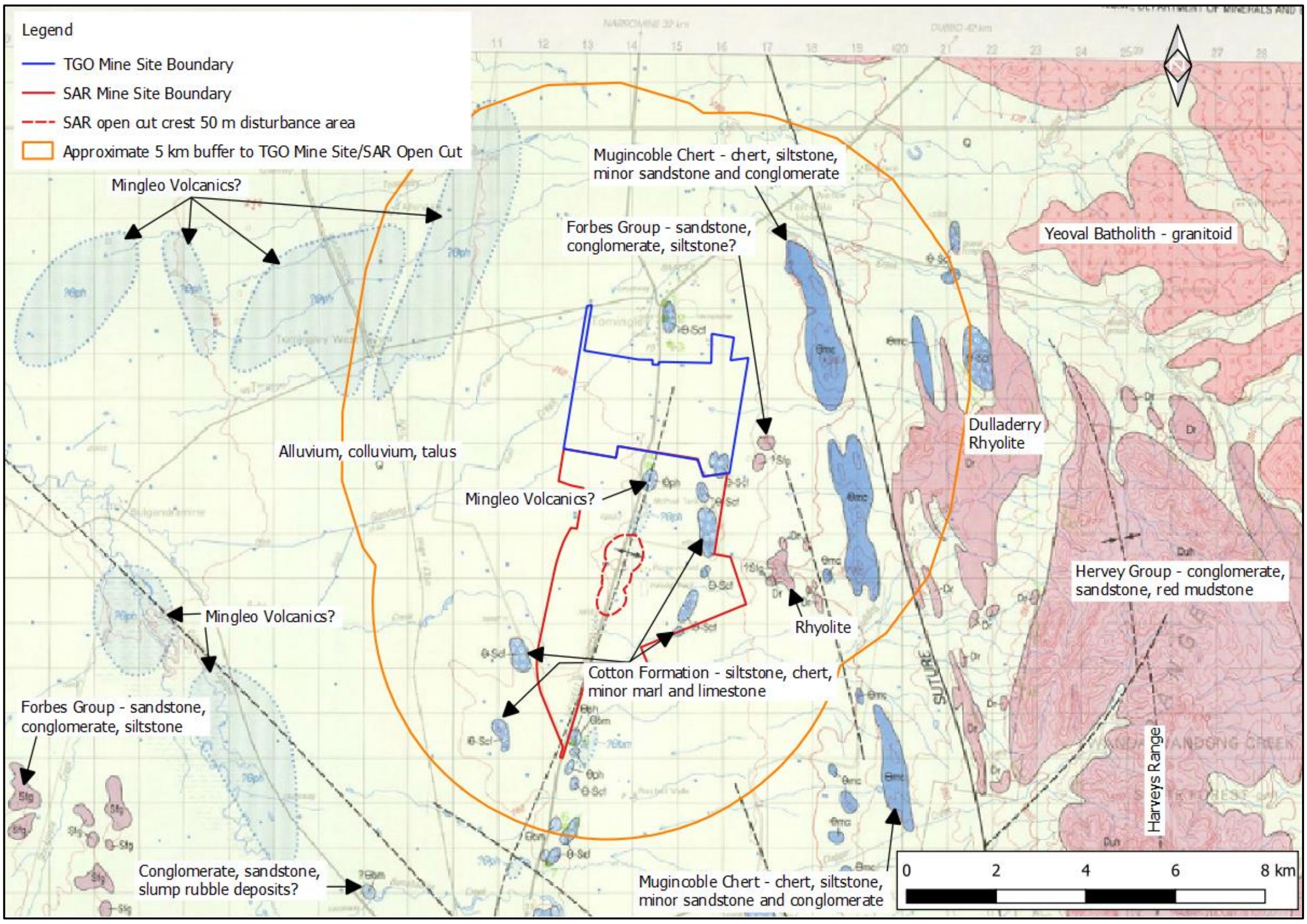
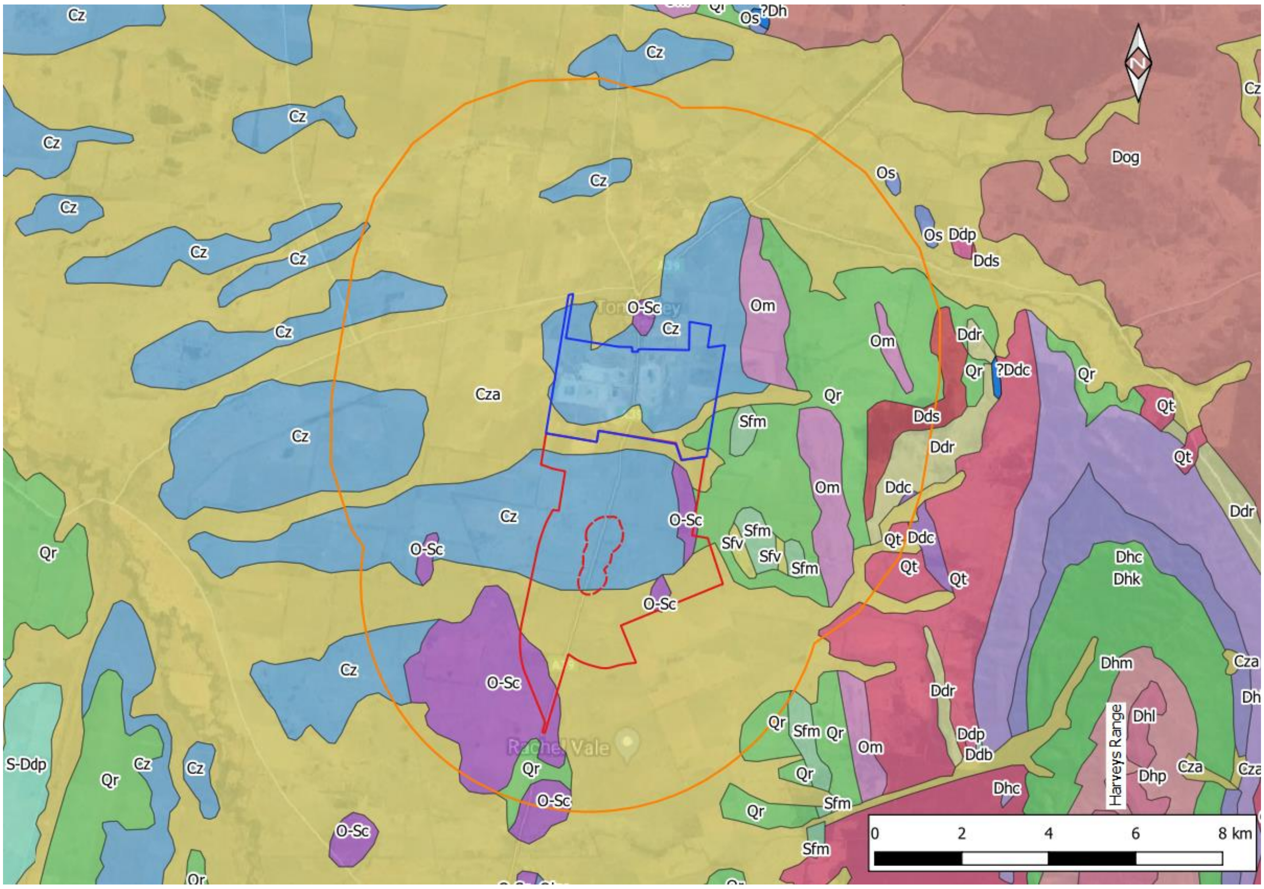


Figure 3.2: Regional Geology, extract from Parkes Special 1:100,000 Geology Sheet (Krynen et.al, 1990)



Legend

- TGO Mine Site Boundary
- SAR Mine Site Boundary
- SAR open cut crest 50 m disturbance area
- Approximate 5 km buffer to TGO Mine Site/SAR Open Cut

Narromine250RockUnit_MGAz55

- Cz - Alluvium but without any obvious meanders
- Cza - Alluvium, dominantly red silt with some pebble bands and quartz grit; includes relict meanders but currently is being eroded
- Ddb - Basaltic members
- Ddc - Lithic conglomerate
- Ddp - Quartz feldspar porphyry
- Ddr - Massive and flow banded rhyolite
- Dds - Lithic conglomerate to fine siliceous sediments
- Dhc - Interbedded fine to medium reddish sandstone and reddish-purple mudstone with locally developed quartz pebble conglomerate
- Dhk - Reddish siltstone with some thick sandstone beds
- Dhl - Medium grained quartzose, flaggy laminate to thickly massive or crossbedded sandstone
- Dhm - Coarse to medium grained reddish sandstone
- Dhp - Thick to flaggy bedded, cross bedded medium grained sandstone
- Dog - Medium to coarse grained pink granite
- Obv - Andesitic lavas and volcanogenic sandstone and conglomerate
- Om - Probable silicified fine sediment lacking clear sedimentary structures
- Os - Undifferentiated siltstone, phyllite and shale
- O-Sc - Siltstone and minor chert
- Qr - Residual deposits
- Qt - Scree and talus deposits
- S-Ddp - Shale, siltstone and fine grained sandstone
- Sfm - Fine grained sandstone, siltstone and mudstone
- Sfv - Siliceous volcanics

Figure 3.3: Regional Geology, extract from Narromine 1:250,000 Geological Sheet (Sherwin, 1997)

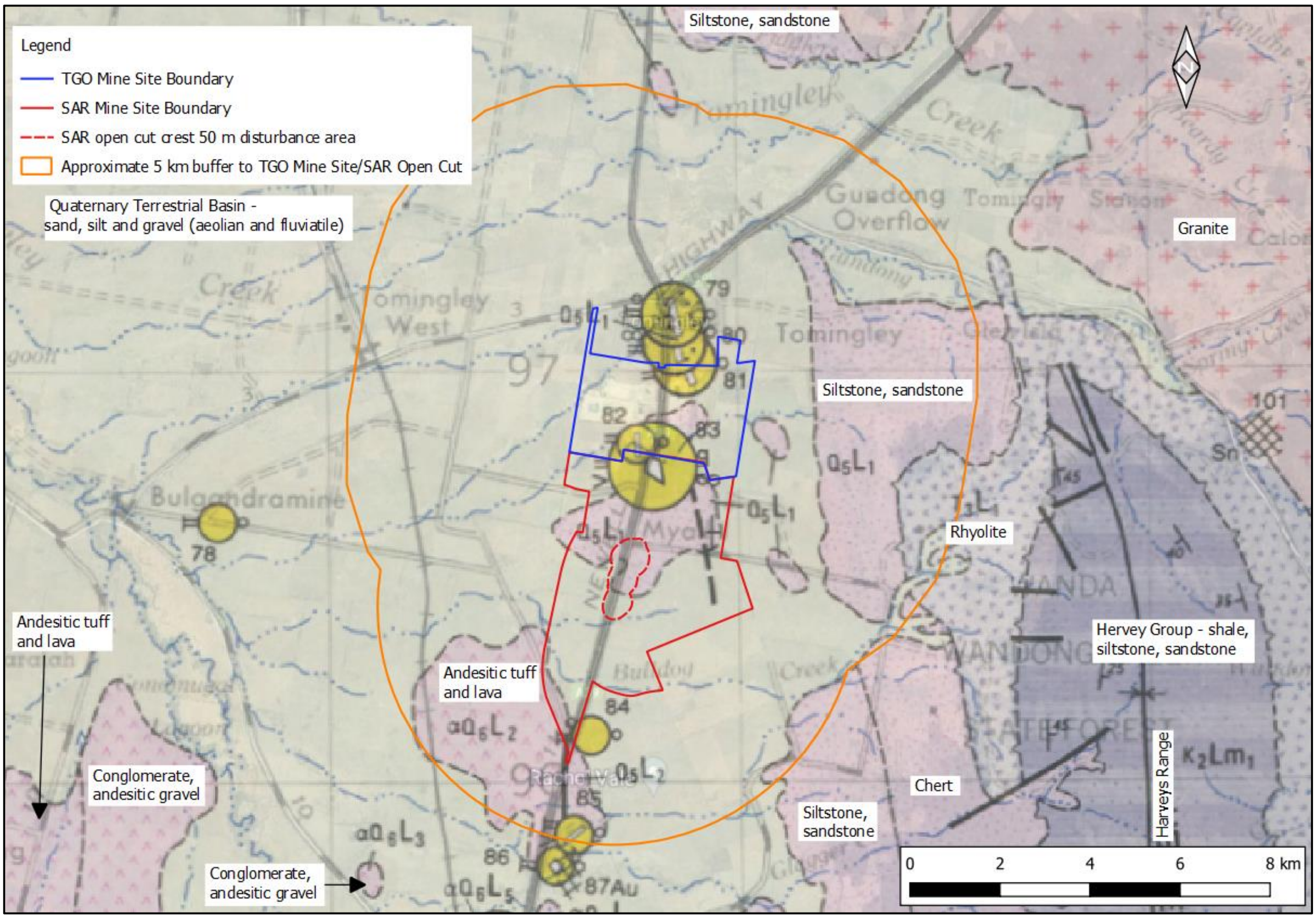


Figure 3.4: Regional Geology, extract from Narromine 1:250,000 Metallogenic Series Sheet (Bowman et.al, 1980)

The sedimentary/metamorphic units are thick and extend to levels far below sea level, as is shown by the partial extract of the regional geological cross section (**Figure 3.5**) from Bowman et.al (1980).

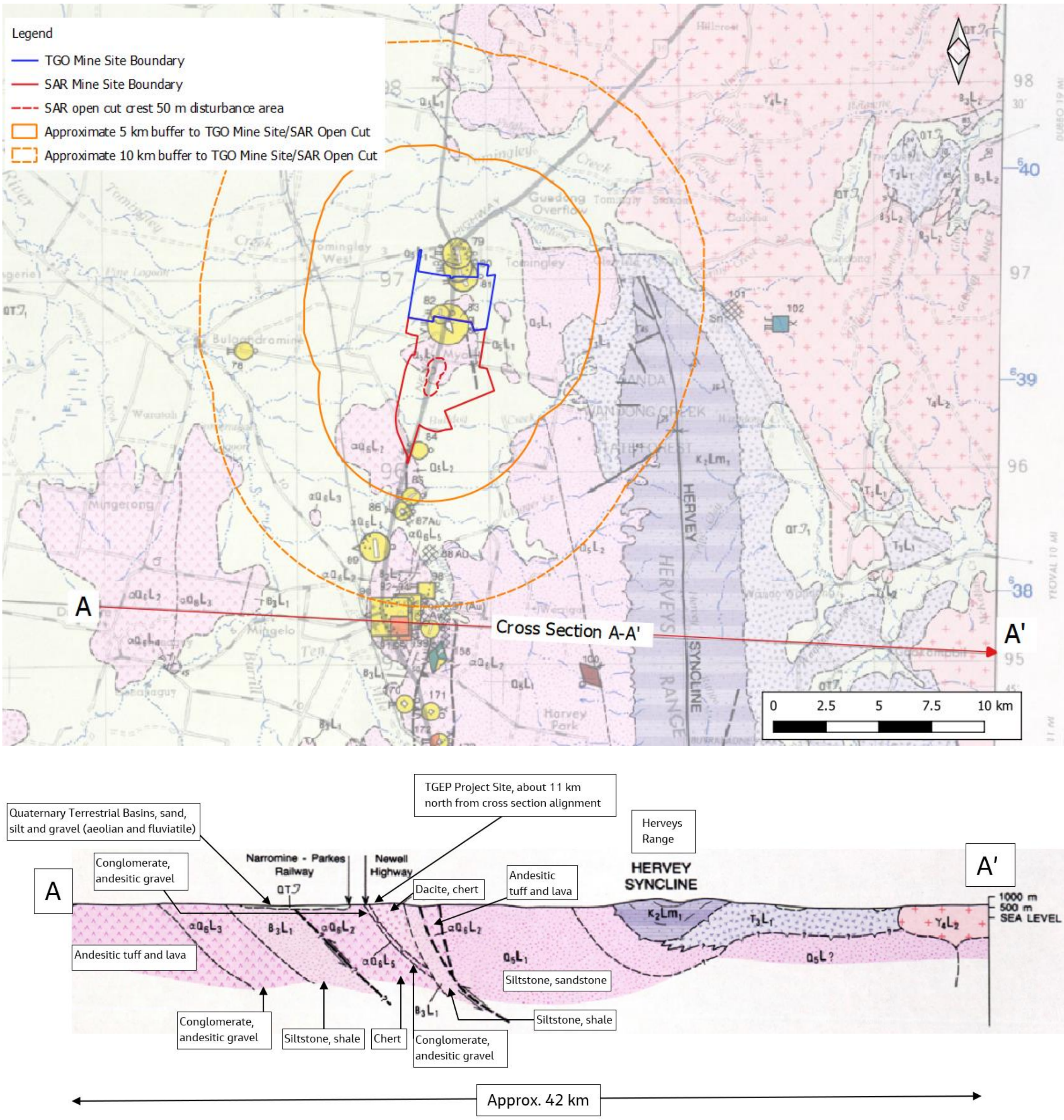


Figure 3.5: Partial regional geological cross section extract from Narromine 1:250,000 Metallogenic Series Sheet (Bowman et.al, 1980).

The applicant has prepared a geological long section and two geological cross sections. The section locations are shown in **Figure 3.6**, long section provided in **Figure 3.6**, and cross sections through Roswell and San Antonio provided in **Figure 3.7** and **Figure 3.8**, respectively. The sections show the level of the first water strike encountered during drilling.

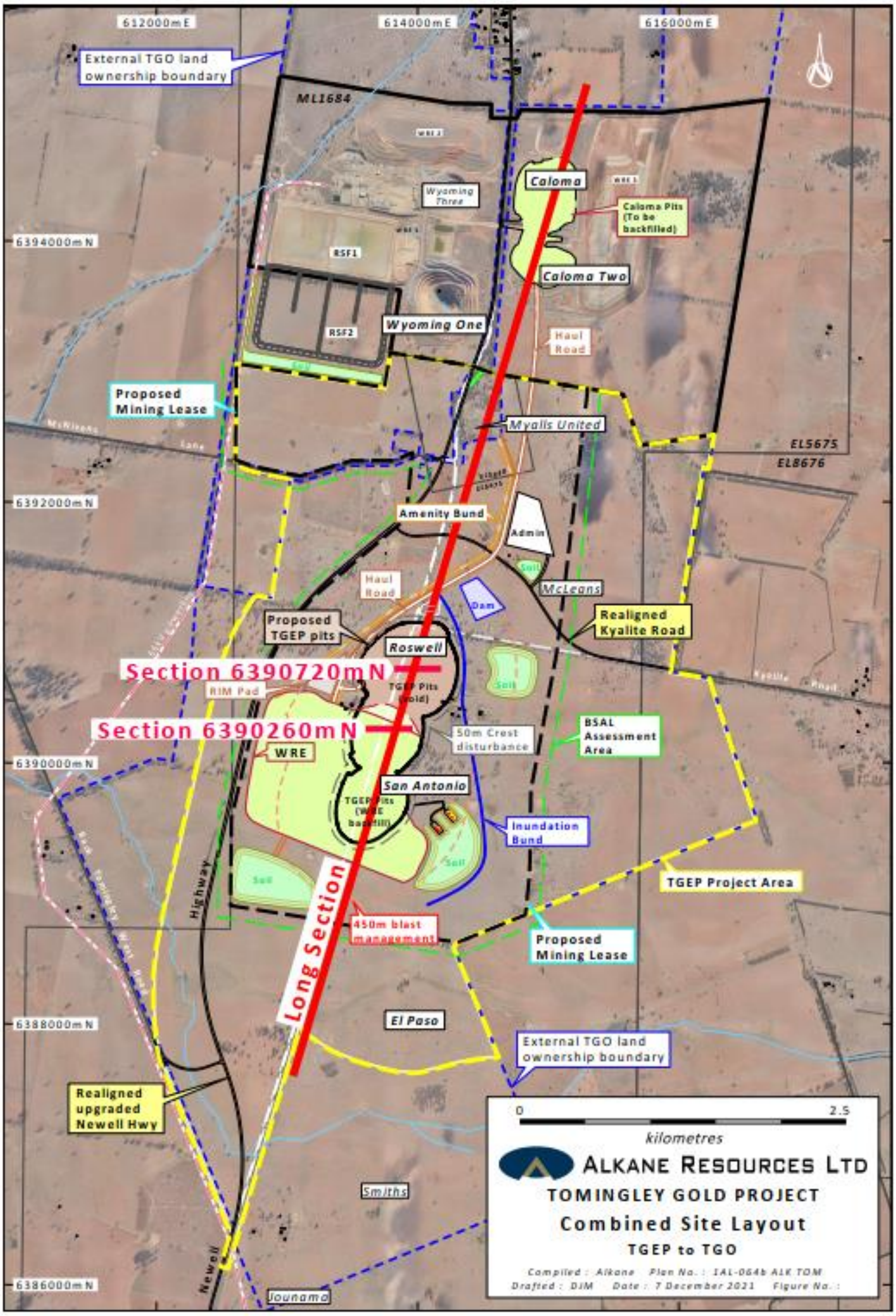


Figure 3.6: Long section and cross section locations

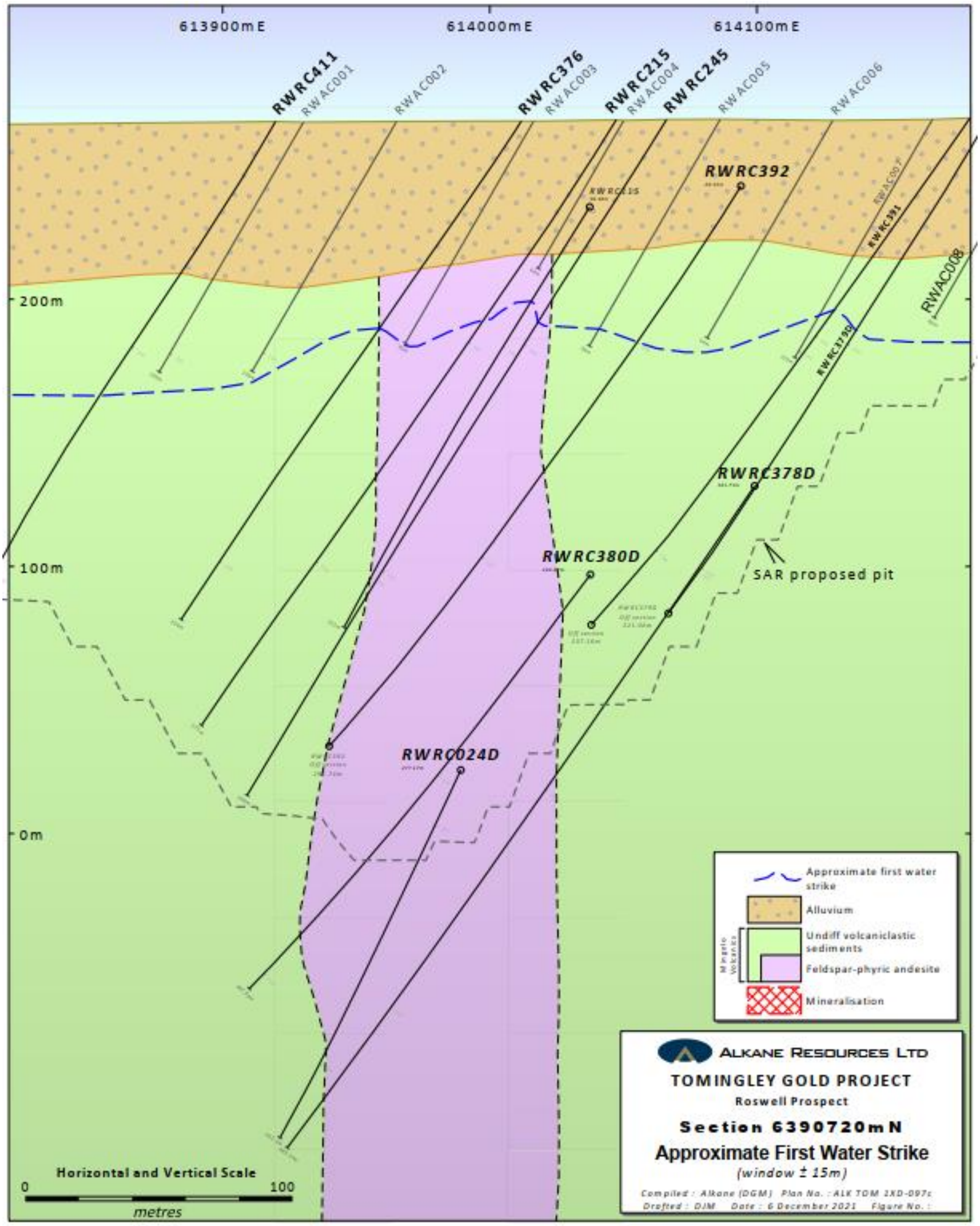


Figure 3.7: Cross section, 6390720N

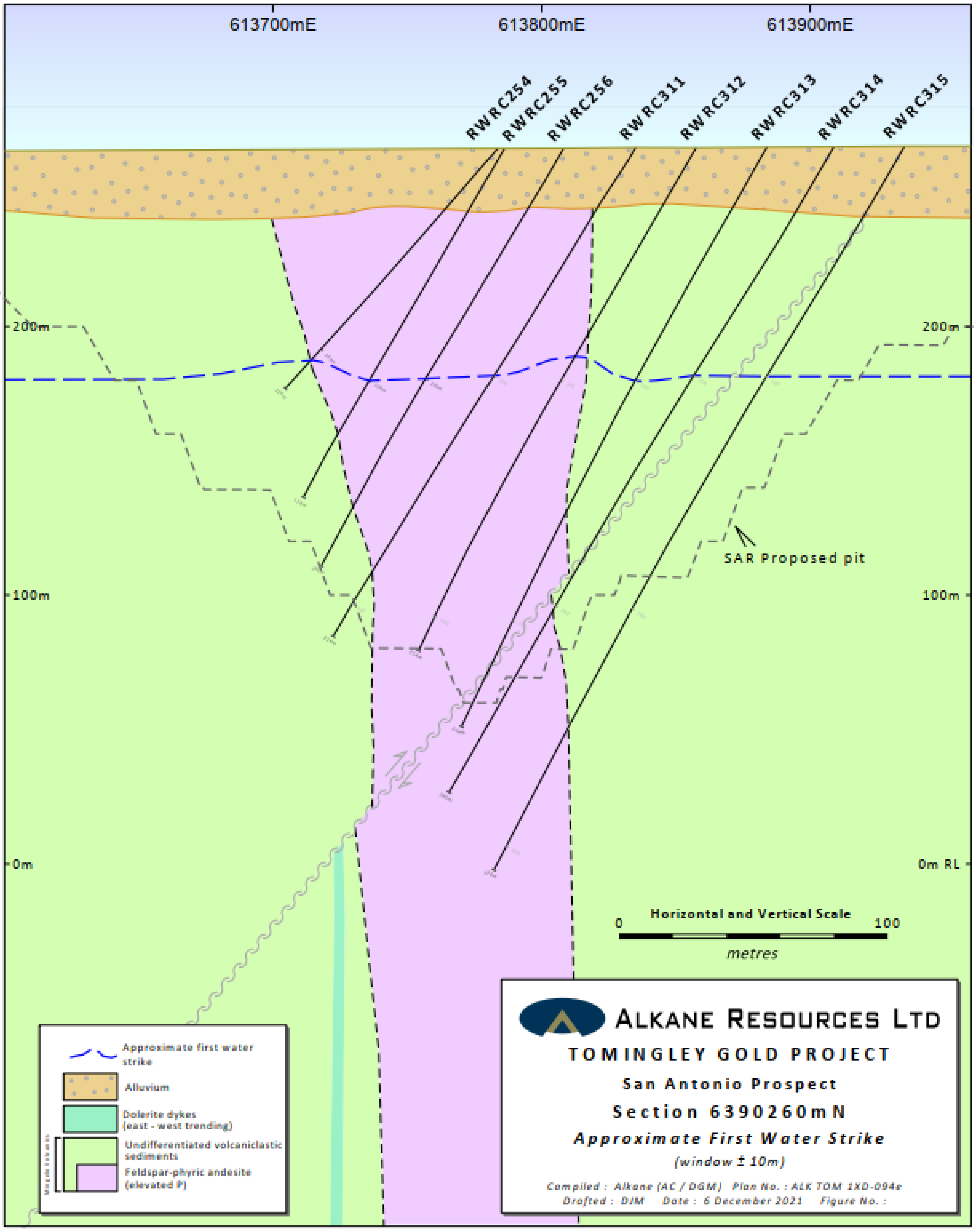


Figure 3.8: Cross section, 6390260N

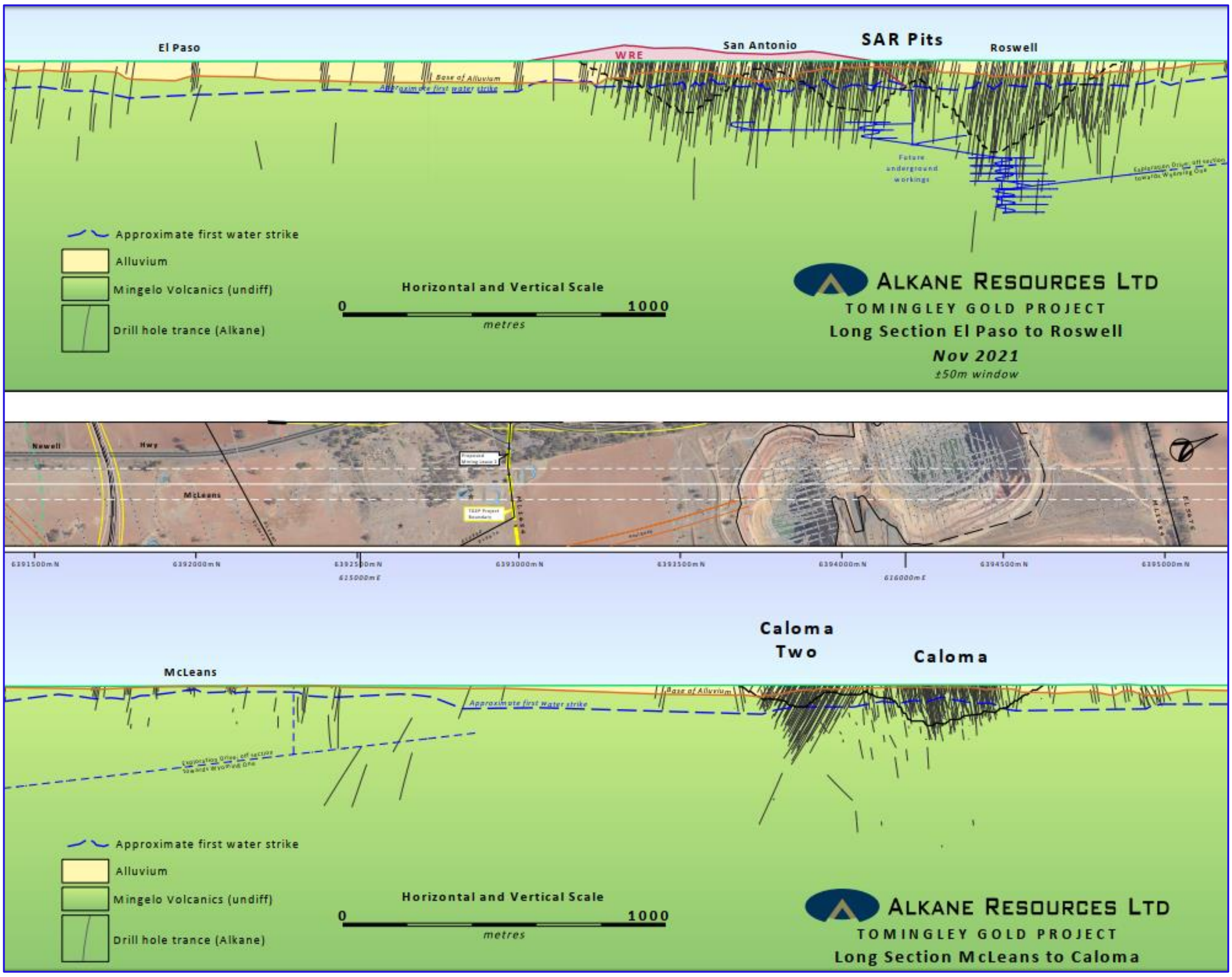


Figure 3.9: Long section

3.4 Groundwater Users

Registered bores within the Australian Groundwater Explorer (BoM, 2021a) and Water NSW (2021b) online bore databases were reviewed to identify groundwater users and assess groundwater levels/flow directions in the region of the TGP. The review also informed calibration of the numerical groundwater flow model (refer **Section 5.3**).

3.4.1 Groundwater users within 10km of TGEP

The Australian Groundwater Explorer (BoM, 2021a) identifies 34 groundwater works within a 10 km buffer to the TGO mine site and SAR open cut. These registered groundwater works are shown on **Figure 3.10** and are summarised in Appendix A.

Of the 34 registered groundwater works within 10km:

- 13 bores are recorded as being used for general water supply purposes, including water supply, stock, household use, irrigation and commercial and industrial use. The depth of the 13 bores used for general water supply purposes ranges from 1.8 m to 121.9 m.

Of the 13 bores, seven bores (GW045137, GW045134, GW037395, GW803148, GW045135, GW045136 and GW034897) are located within a combined 5 km buffer to TGO mine site boundary/SAR open cut. However, all of the seven bores are greater than 5 km from the proposed SAR open cut.

The depths of the seven bores are 1.8 m, 3.7 m, 4.5 m, 5.2 m, 5.8 m, 12.2 m and 18.3 m. The relatively shallow depths and locations of these bores suggests they are likely to be associated with perched groundwater in the Gundong Creek alluvial aquifer (or in the case of GW034897 a perched aquifer associated with Tomingley Creek) and not connected to the regional water table.

- The remaining 21 bores have a purpose of either monitoring (20 bores) or exploration (1 bore).
- None of the bores within 10 km have available water level data available within the BoM (2021a) database. However, eight of the bores have water level data in the WaterNSW (2021b) database. Standing water level depths range from 0.9 mbgl to 44 mbgl (**Figure 3.11**). Standing water levels are discussed further in **Section 3.4.2**.

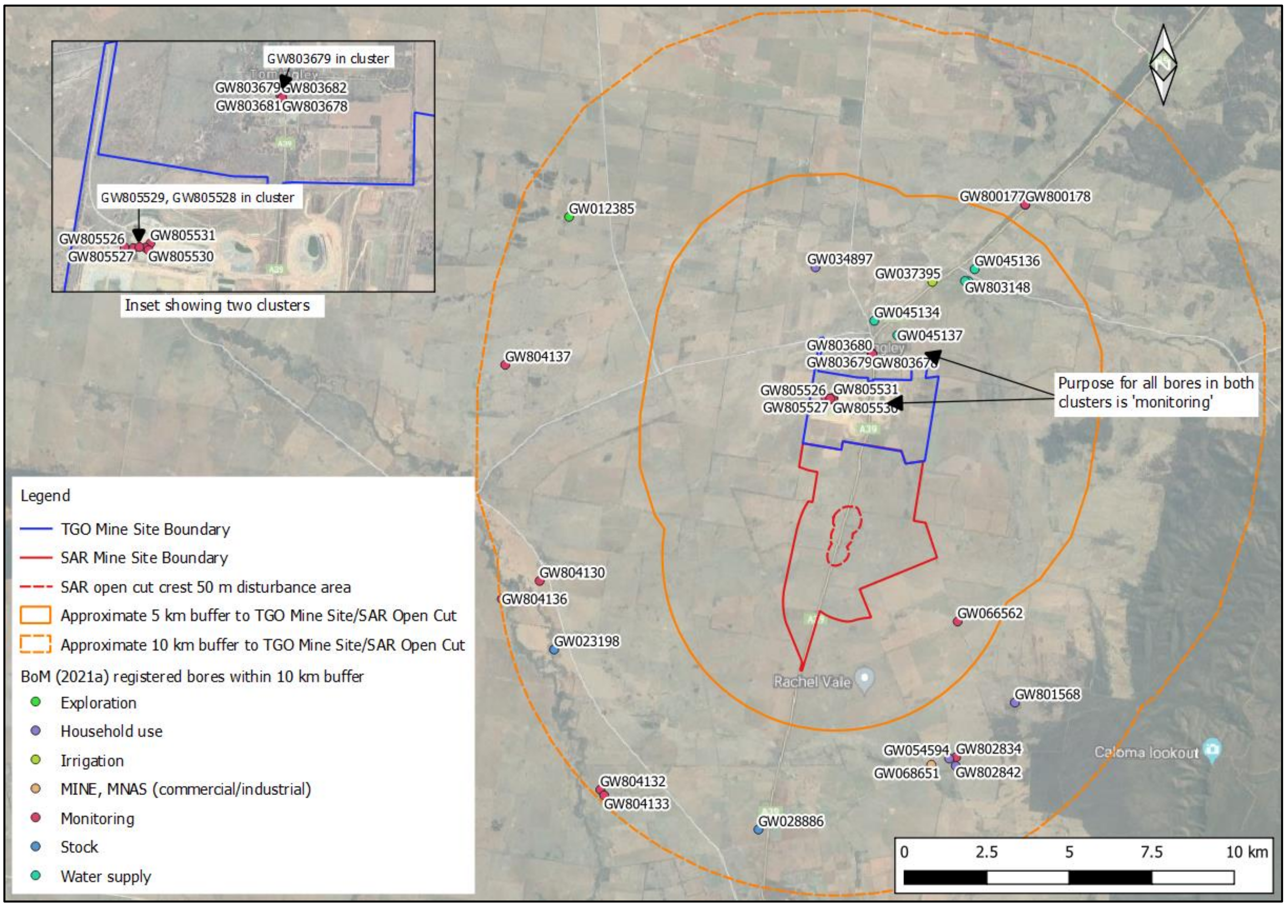


Figure 3.10: BoM (2021a) registered bores within 10 km buffer to TGO mine site boundary / SAR open cut

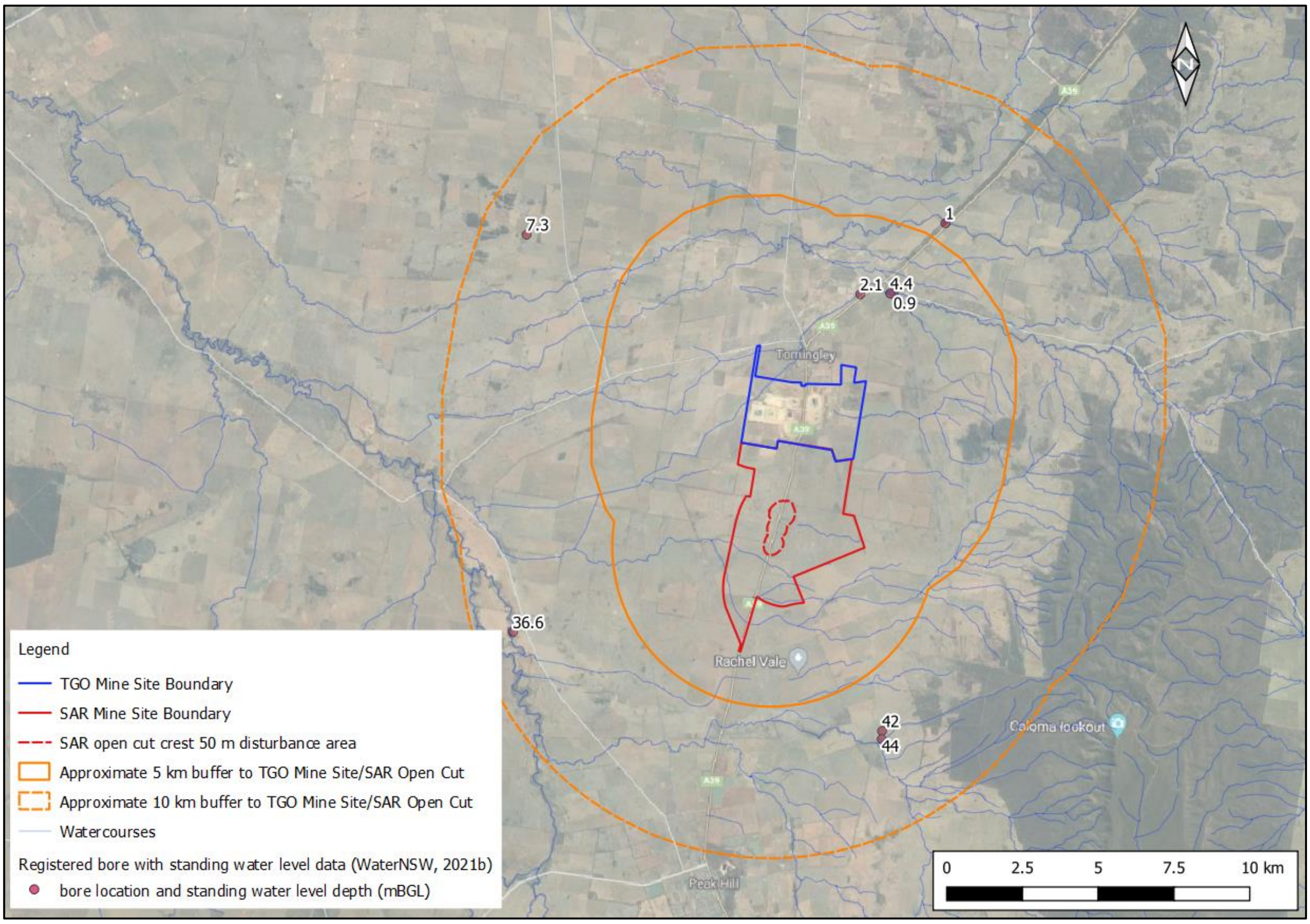


Figure 3.11: Standing water level depth for registered bores within 10 km buffer to TGO mine site boundary /SAR open cut (WaterNSW, 2021b)

3.4.2 Regional groundwater flow

Groundwater level/depth contouring was undertaken to investigate regional groundwater flow directions, broad groundwater levels/depth trends and to inform assessment of whether groundwater is likely to be providing significant baseflow to watercourses in the vicinity of the Project Site.

For the contouring exercise, the analysis extent was increased from that used to assess registered bores in the vicinity of TGO/SAR (**Section 3.4.1**) to an approximate 55 km by 55 km area centred over the Project Site.

Groundwater level/depth contours derived from registered bore standing water level data (WaterNSW, 2021b) and site groundwater levels (discussed in **Section 4.2**) are presented in the datums of mAHD and mbgl in **Figure** 3.12 and **Figure 3.13**, respectively.

Water levels from registered bores are typically recorded at bore construction and so represent a broad temporal spread. Also, the water level data comprises a mixture of water levels from different depths and potentially different groundwater systems. No attempt has been made to isolate the water level data into separate groundwater system types or depth zones. Hence, the contouring is influenced by groundwater levels associated with a range of groundwater systems (e.g. perched alluvial, regional alluvial and regional fractured rock). In spite of these limitations, the contouring is considered suitable for assessment of regional groundwater flow directions, broad groundwater level/depth trends, and to inform assessment of whether groundwater is likely to be providing significant baseflow to watercourses in the vicinity of TGEP.

The composite groundwater level contours (**Figure 3.12**) generally indicate that groundwater flows from areas of relatively high elevation towards areas of relatively low elevation. Groundwater flow directions are down-gradient orthogonal to the contour lines and are generally consistent with the surface water drainage directions. In the vicinity of the Project Site groundwater flow is indicated to the west, with flow then to the northwest consistent with Bogan River drainage system. West from the Herveys Range and foothills, hydraulic gradient are relatively steep but flatten just to the east of the Project Site.

Although not apparent in the contours, it is noted that preferential flow, coincident with the dominant structural orientation may occur; however, the regional flow direction indicated on **Figure 3.12,** is generally orthogonal to the major structural orientations (sub north-south).

It is noted that the groundwater flow direction is interpreted to be falsely indicated in some areas of Herveys Range, where a groundwater flow divide is interpreted to exist in reality. Due to contour point distribution, except for the southern portion of Herveys Range, the interpreted groundwater flow divide is not shown by the contours. In the southern area of the range, where contour point distribution is considered reasonable, the groundwater flow divide is represented by the contours. In reality, this groundwater flow divide is interpreted as likely to extend along the entirety of Herveys Range. The location of the interpreted groundwater flow divide is shown later in the report, in **Section 5.1**, **Figure 5.1**.

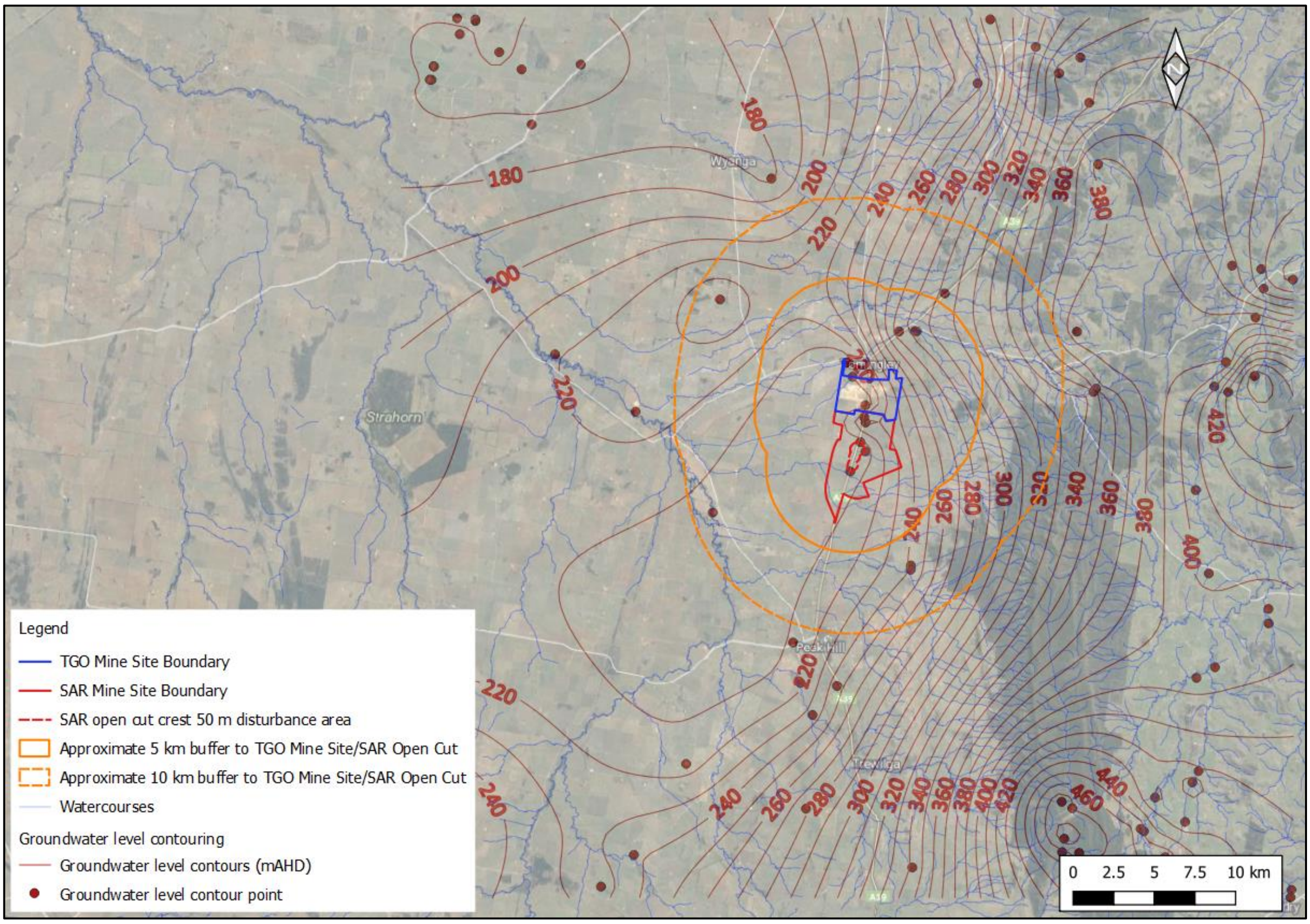


Figure 3.12: Groundwater level (mAHD) contours

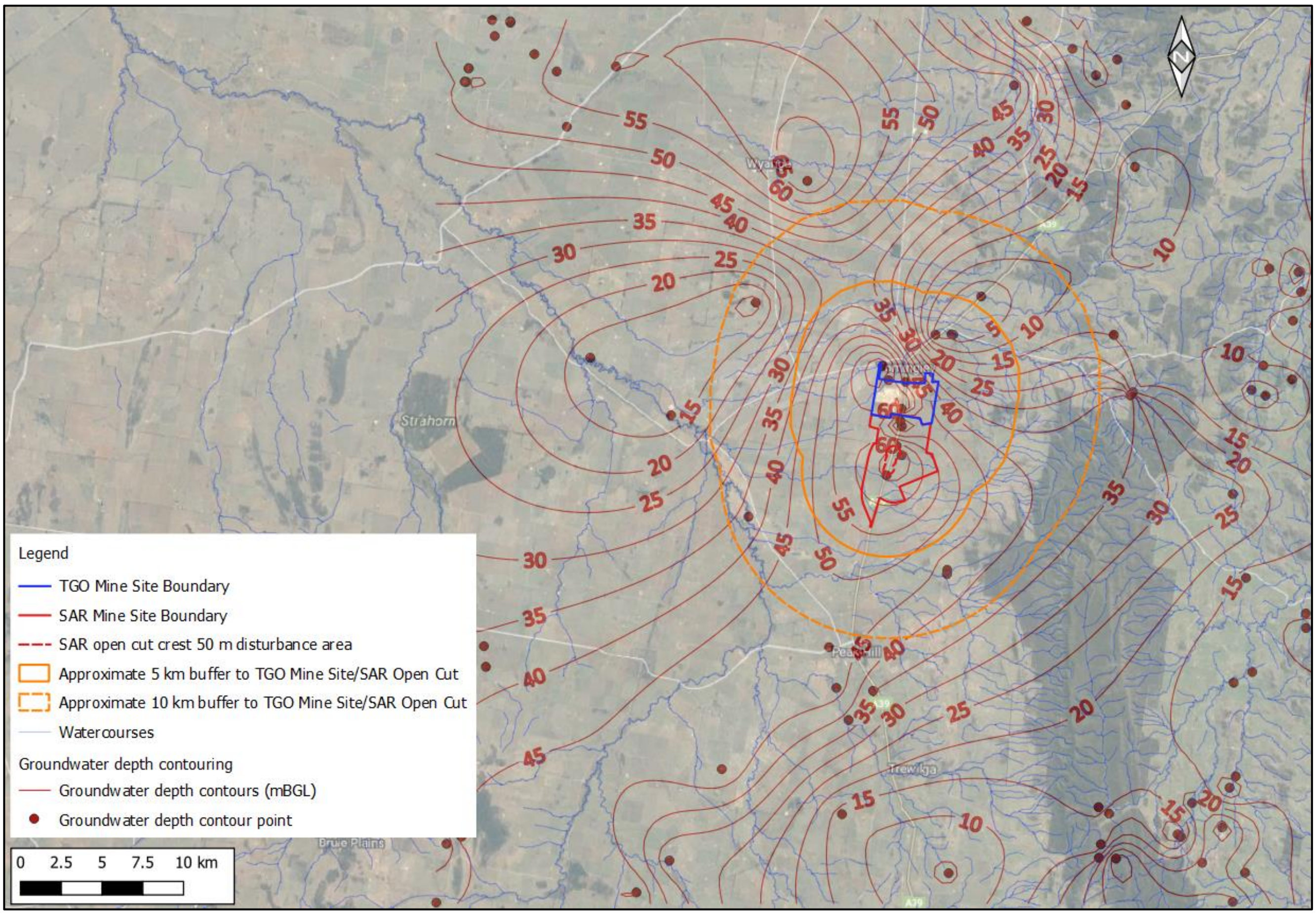


Figure 3.13: Groundwater depth (mbgl) contours

The groundwater depth contours indicate groundwater depths in the area of the Project Site of about 60 mbgl. The contoured groundwater depths are generally far below ground levels in the vicinity of major rivers and creeks, which suggests baseflow to watercourses is not regionally significant. Shallow groundwater depths, of the order of 5 mbgl) are indicated to the northeast of the Project Site in the vicinity of the Gundong Creek alluvial aquifer. Contouring indicates a very steep gradient towards the Project Site, however water levels in the Gundong Creek alluvial aquifer are considered to be perched above the regional water table with no direct hydraulic connection.

3.5 Groundwater Dependent Ecosystems

The potential for GDEs in the vicinity of the Project Site was assessed through review of the BoM's GDE Atlas (BOM, 2021b and High Priority GDE mapping in the WSP (NSW Government, 2020). GIS files of the High Priority GDE areas were obtained from NSW DPIE by email (Dabovic, 2020).

3.5.1 BoM (2021b) Terrestrial GDEs

There are several isolated tracts of high potential terrestrial GDE plotted in the vicinity of the Project Site based on regional studies (**Figure 3.14**). These areas are associated with Gundong Creek and Bulldog Creek and are located greater than 800 m from current/proposed mining. The potential GDEs contain a variety of trees, shrubs and sedges including:

- *Eucalyptus sideroxylon , Eucalyptus macrocarpa, Eucalyptus macrocarpa, Eucalyptus camaldulensis subsp. Camaldulensis*
- *Acacia deanei subsp. Deanei, Acacia hakeoides, Acacia stenophylla , Acacia salicina*
- *Dodonaea viscosa subsp. Spatulata*
- *Callitris endlicheri*
- *Muehlenbeckia florulenta*
- *Eleocharis*
- *Paspalidium jubiflorum*

It is noted that none of the trees noted above are obligatre phreatophytes (deep rooted plants that only inhabit areas where they can access groundwater, via the capillary fringe, to satisfy at least some proportion of their environmental water requirement), while *Muehlenbeckia florulenta* (tangled lignum) and *Eleocharis* (sedges) are typically associated with wetland environments.

There are several isolated tracts of low potential terrestrial GDE plotted (based on regional studies) in the vicinity of TGO and SAR (**Figure 3.14**).

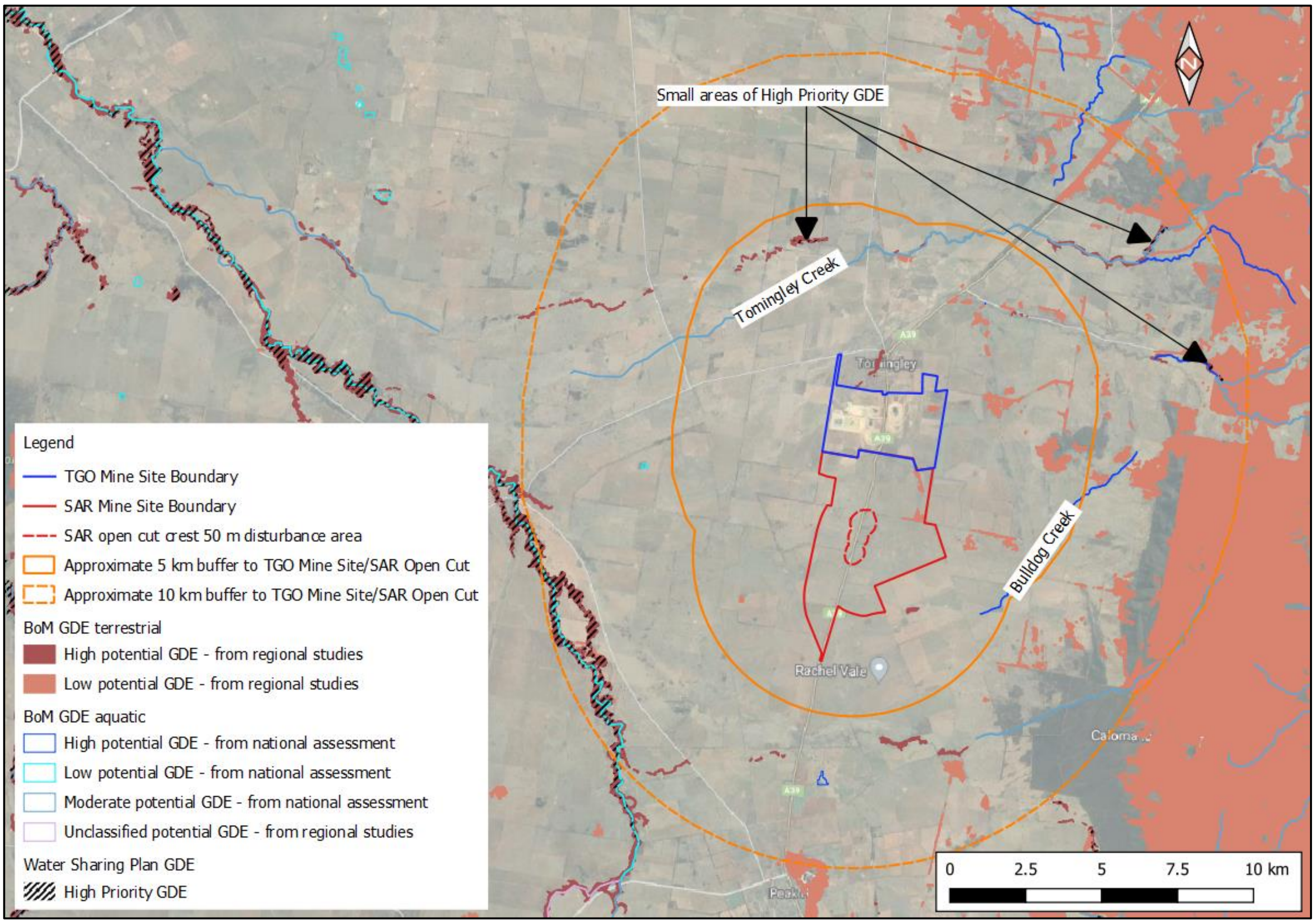


Figure 3.14: BoM (2021b) potential GDEs and WSP (NSW Government, 2020) High Priority GDEs

3.5.2 BoM (2021b) Aquatic GDEs

Potential aquatic GDEs plotted in the vicinity of the Project Site, based on national assessment and in the case of one watercourse located outside of the 10 km buffer, regional studies, are shown in **Figure 3.14.** Within a combined 5 km buffer to TGO Mine Site and the SAR open cut disturbance area, plotted potential aquatic GDEs comprise Tomingley Creek, a portion of Bulldog Creek and a very small (30 m long by 20 m wide) portion of Gundong Creek located about 2.9 km northeast of the TGO Mine Site. These plotted potential aquatic GDEs are located greater than 4 km from existing and proposed mining.

3.5.3 WSP High Priority GDEs

High Priority GDEs plotted in the vicinity of the Project Site are shown in **Figure 3.14**. There are no High Priority GDEs close to TGO or SAR. The largest area of mapped High Priority GDEs are located about 8.5 km southwest of the Project Site, in the vicinity of the Bogan River. Additional relatively small tracts of High Priority GDEs are located north, northeast and east of the Project Site, with the closest located about 5.8 km north north-west of TGO.

3.6 Recharge estimation via chloride mass balance

Due to relatively thick unsaturated clayey alluvial deposits which overlie the fractured rock, and low rainfall and high evaporation, groundwater recharge in the area of the SAR and TGO is anticipated to occur at a low rate. To substantiate this notion, a chloride mass balance was undertaken.

A chloride mass balance can be undertaken to estimate groundwater recharge. The approach assumes that the chloride ion is conservative in precipitation, evapotranspiration, recharge and runoff; and that all the chloride is from rainfall rather than the formation, for example from halite saturation or dissolution processes.

The recharge rate (mm/yr) can be estimated using the following formula:

Recharge (mm/yr) = annual rainfall chloride concentration (mg/L) x average annual rainfall / groundwater chloride concentration (mg/L)

Previously, Wolfgang (2000) used a rainfall chloride concentration of 3.25 mg/L for nearby town, Dubbo. Average annual rainfall at Tomingley is 562 mm (**Section 3.1**). The median monitored chloride concentration at the SAR monitoring bores is 6,155 mg/L.

Based on the chloride mass balance equation and the above input values, the calculate recharge rate is 0.30 mm/year. As a proportion of mean annual rainfall, this is a percentage of 0.05%.

The chloride mass balance result suggests a very low groundwater recharge rate to the regional water table is applicable for the area of the mine, and is consistent with the hydrogeological setting.

4. Groundwater investigations

4.1 Resource drilling

Water strike data from resource drilling was reviewed as an initial assessment of groundwater level and potential for any high yielding zones or structures warranting further, more detailed, investigation.

Water strike data are collected by the Applicant's geologists during reverse circulation (RC) drilling and include observations of water strike depths and a qualitative assessment of water strike strength. Indicators of water strike strength are as follows:

- Strength 0 - water not observed;
- Strength 1 - water table, a trickle of water, samples might be damp;
- Strength 2 - weak, water at end of rod, first sample can be wet;
- Strength 3 - medium, flowing whilst drilling; and
- Strength 4 - strong, driller could not hold water back, samples very wet, hole terminated.

Water strike data are presented in plan view and section view for SAR on **Figure 4.1** and **Figure 4.2**.

Key observations from **Figure 4.1** and **Figure 4.2** are noted as follows:

- Water strike strengths of 4, requiring termination of the drill-hole are relatively infrequent.
- Water strike strengths of 3 appear to be more frequent in the northern Roswell deposit compared to those at San Antonio. This may be indicative of more frequent, or more open, fracturing. However, there is also the possibility that the increased concentration is the result of increased drilling frequency in the area. The strike 3 strengths occur in the range of about 80 mbgl to 220 mbgl, with the majority occurring between about 120 mbgl and 220 mbgl.
- In all cases the first water strike is below the base of the alluvium (**Figure 4.2**), suggesting that the alluvial deposits are likely to be predominantly unsaturated.
- First water strike depths appear to be relatively uniform at depths of the order of 60 mbgl to 100 mbgl. This depth is inferred to be associated with the transition from saprolite (predominantly clay material, derived from weathered rock) to saprock with relic structures and enhanced permeability.
- The upper most water strike strength is typically water strike strength 1. However, whilst the vast majority of water strikes with a strength of 1 occur at relatively shallow depths (i.e. typically of the order of 60 mbgl to 100 mbgl), there are instances where water strikes with a strength of 1 occur at depths greater than approximately 150 mbgl.

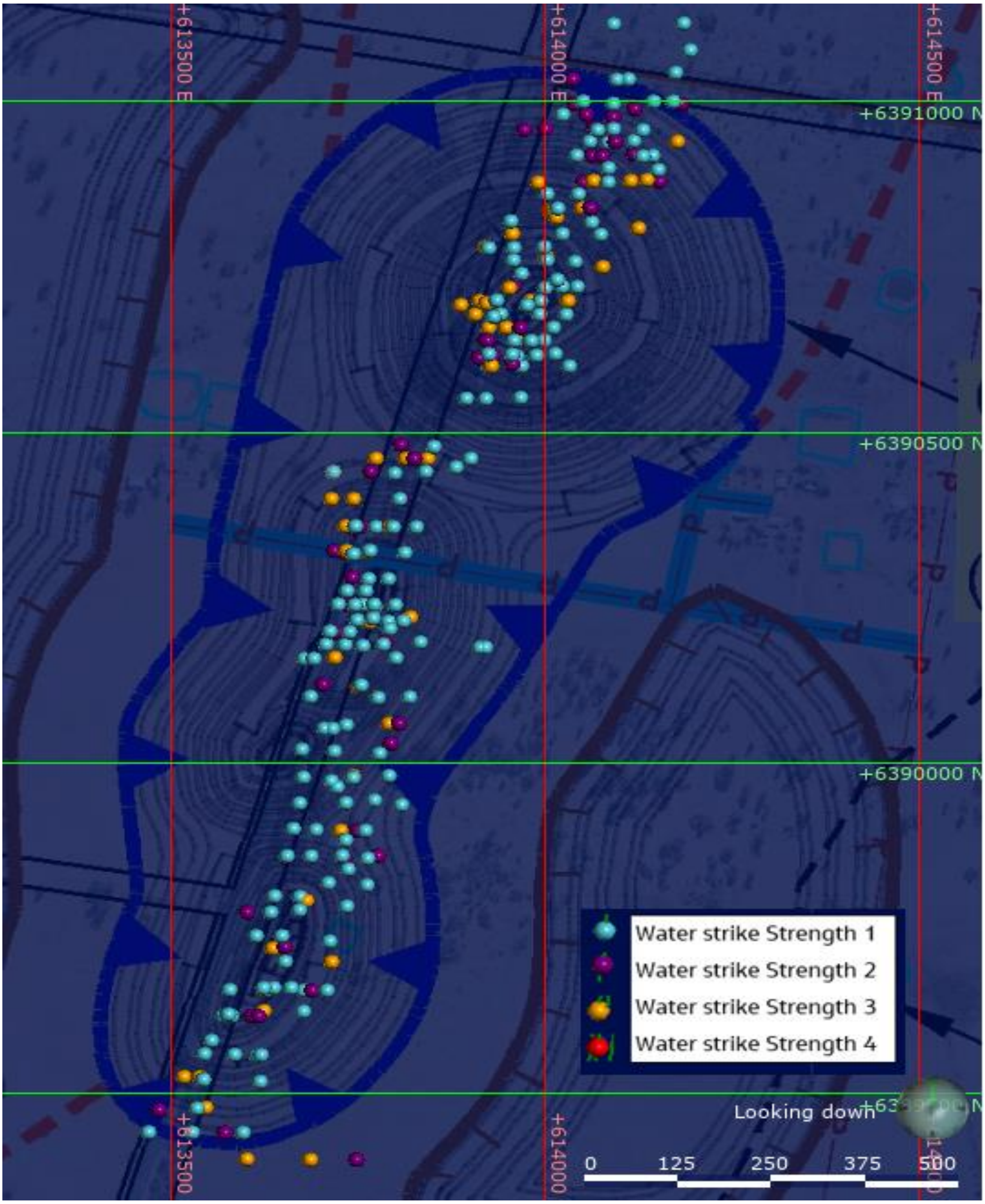


Figure 4.1: SAR Water Strike Data - Plan View

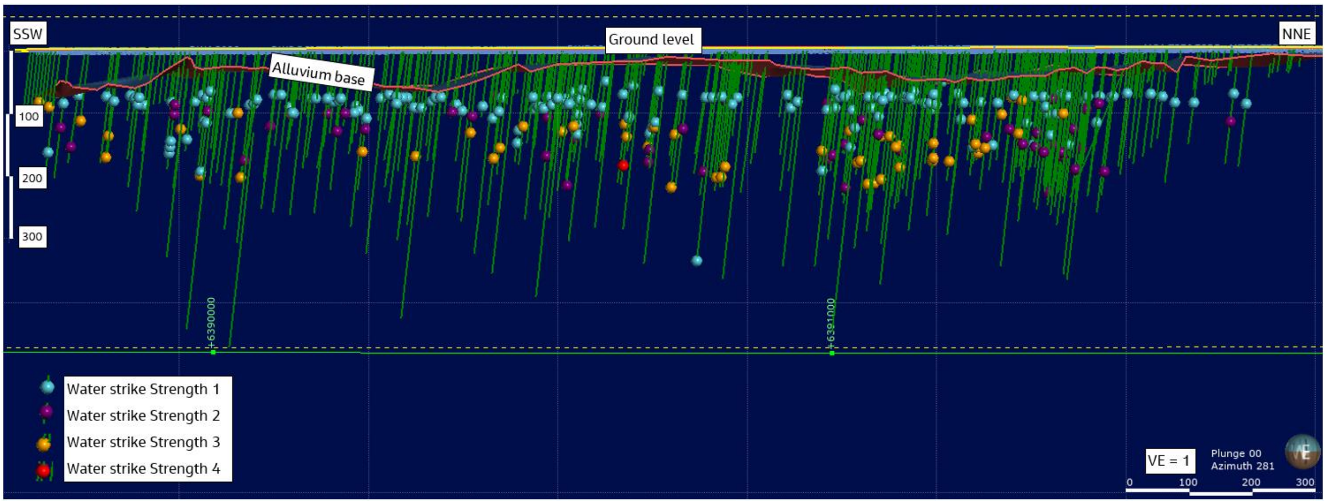


Figure 4.2: SAR Water Strike Data - Section View

The first water strike encountered during drilling is included on the Applicants geological long section and cross sections, provided at the end of **Section 3.3**. The level of the first water strikes indicates that the regional water table is located within the fractured rock near the mine, and that non-perched alluvial aquifers are unlikely to be present near the mine.

4.2 Groundwater levels

With the exception of shallow bores that monitor groundwater in the vicinity of RSF1, the Applicant operates a network of seven monitoring bores at TGO and have recently installed four monitoring bores at SAR. Details of the groundwater monitoring bores are summarised in **Table 4.1** with locations shown on **Figure 4.3**. Form-As for the recently constructed SAR monitoring bores are provided in Appendix F.

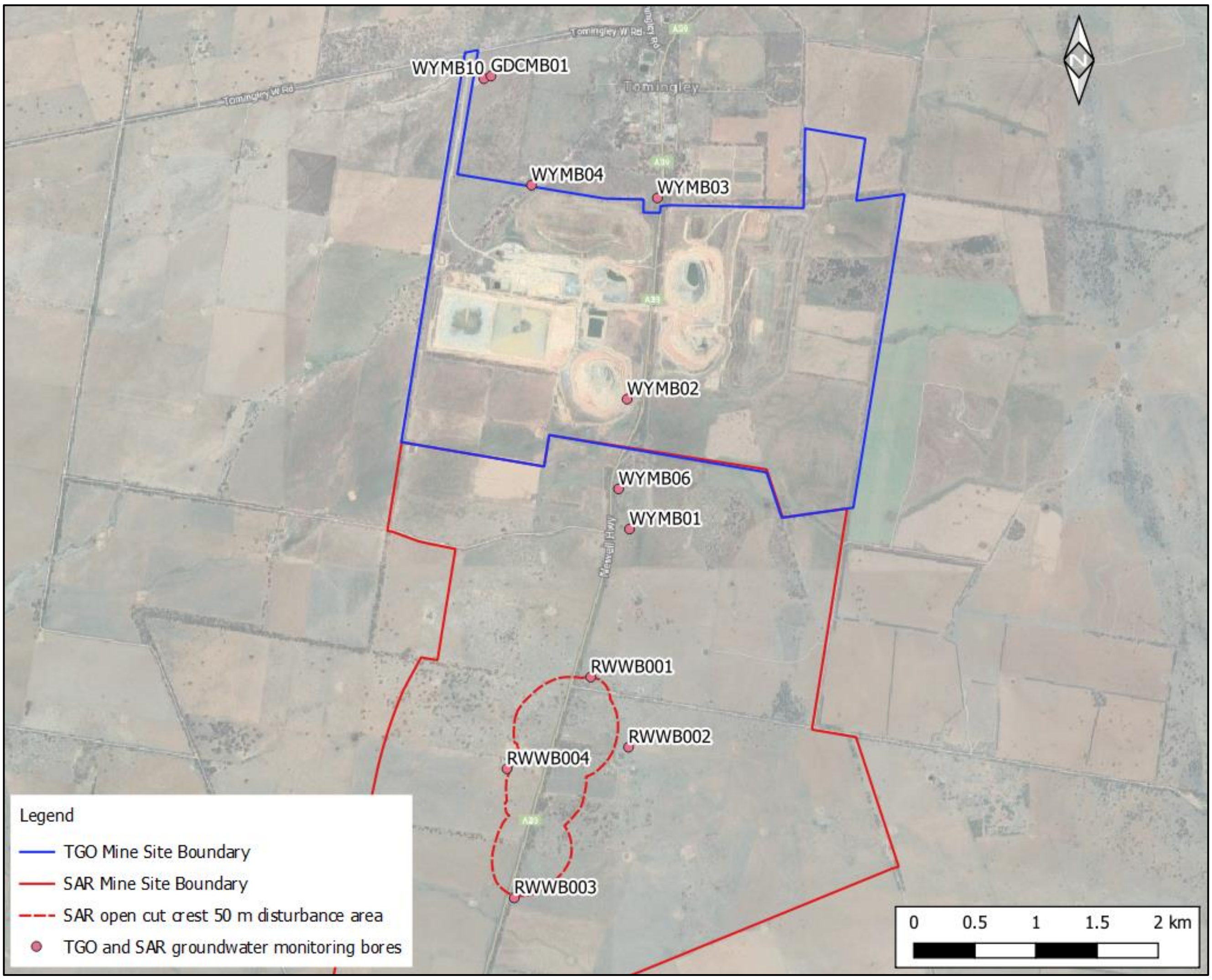


Figure 4.3: TGO/SAR groundwater monitoring bores

Table 4.1: Monitoring bore details

Monitoring bore	Easting	Northing	Ground level (mAHD)	Top of casing (mAHD)	Screen interval (mBGL)	Gravel pack interval (mBGL)	Screened Lithology	Depth to base of alluvium (mBGL)
SAR groundwater monitoring bores								
RWWB001	614132	6391126	269	269.57	120 – 150	110 – 150	Monzodiorite, fresh, unoxidised, grey and blue, fine grained, feldspathic	39
RWWB002	614441	6390553	274	274.58	120.2 – 150.2	110 – 150.2	Volcaniclastic sandstone, fresh, unoxidised, grey and green, coarse grained, poorly sorted	31
RWWB003	613506	6389321	272	272.55	40.5 – 70.5	40.5 – 70.5	Alluvium, clay, red brown to 56 m. Large (40 mm – 80 mm) gravels from somewhere within alluvium caused hole collapse during drilling. Saprolite from 56 to 70 m; quartz, completely oxidised, brown-orange, clayey. At 70 m the saprolite clay transitions to saprolite rock.	56
RWWB004	613446	6390376	271	271.69	28 – 52	20 – 52	Alluvium, clay and sand layers, poorly sorted, some pebbly layers, variable colour. Transitions to saprolite clay at 40 m.	40
TGO groundwater monitoring bores								
WYMB01	614449	6392336		270.42	78 – 81 and 84 – 90	60 – 90	Feldspar phyric volcanic, fresh, fine grained, brown to green	5
WYMB02	614429	6393398		268.52	96 – 99, 102 – 105, 108 – 114	71.2 – 114	Sandstone, siltstone and tuff, variably weathered (completely oxidised to fresh), volcaniclastic, foliated	13
WYMB03	614678	6395043		275.47	60 – 63, 69 – 72,	42 – 84	Siltstone and sandstone, slightly weathered to fresh, brown to grey, foliated	4

Monitoring bore	Easting	Northing	Ground level (mAHD)	Top of casing (mAHD)	Screen interval (mBGL)	Gravel pack interval (mBGL)	Screened Lithology	Depth to base of alluvium (mBGL)
					78 – 84			
WYMB04	613647	6395148		272.07	72 – 78	30 – 78	Saprolite, quartz and sandstone, volcaniclastic, variably weathered (completely weathered to fresh) green, brown, grey,	23
WYMB06	614360	6392664		268.43	75 – 81, 84 – 90	60 – 90	Quartz, feldspar porphyry, generally fresh, white, khaki, grey, green, brown	3
WYMB10	613258	6396018		272.62	Bore construction details unknown. Bore inferred to be screened in fractured rock. Total hole depth was 150 m.			10.5
GDCMB01	613316	6396040		273.44	Bore construction details unknown. Bore screened in Gundong Creek Alluvium. Total hole depth was 3.5 m.			3.5

4.2.1 TGO groundwater levels

Quarterly groundwater monitoring is undertaken at deep hard rock monitoring bores (WYMB01, WYMB02, WYMB03, WYMB04, WYMB06 and WYMB10) and the shallow alluvial bore (GDCMP01). Regular monitoring data is available from October 2012; however, data prior to this date is less frequent.

Water level hydrographs from the TGO monitoring bores are plotted on **Figure 4.4** and **Figure 4.5**. A number of distinct trends are apparent from the hydrographs:

- Shallow groundwater levels in Gundong Creek alluvium are relatively stable, with long-term fluctuations of the order of one metre in response to long-term climatic trends. The GDCMB01 hydrograph shows a very close correlation with the CRD curve.
- Hard rock monitoring bores WYMB03, WYMB04 and WYMB10 display relatively stable to slightly increasing trends over the period. These bores are located more than 700 m from mining operations at TGO.
  - WYMB03 shows a gradual and steadily increasing water level from 2008 to 2016, presumably in response to the general rainfall surplus over the period. Since 2017, water levels have been relatively stable.
  - WYMB04 has two spurious data points in late 2007 and early 2008 that are considered likely to be erroneous. Other than these two points water levels are relatively stable.
- Water levels at WYMB02, located adjacent to the Wyoming 1 pit, show a distinct declining trend and response to mining since mid-2016. Prior to 2016 water level were very stable.
- Hard rock monitoring bores WYMB01 and WYMB06 display different responses to the other hard rock monitoring bores, with both monitoring bores responding to a significantly wet period in mid- to late-2016. It is noted that both WYMB01 and WYMB06 are located adjacent to historical workings at the Myalls United gold mine and are screened over depths similar to the old workings. It is also noted, as outlined in the Surface Water Specialist Study, that the locations of WYMB01 and WYMB06 are prone to inundation during even relatively modest (10% AEP) rainfall events due to runoff being impounded behind the Newell Highway.

  The historic workings are known to be linked to the surface, and anecdotally surface water flows have been observed disappearing into the workings during heavy rainfall. It is therefore considered likely that the observed water level responses are the result of surface water ingress to the old buried workings.

  An apparent drawdown and recovery response observed at WYMB01 in 2012 and 2013 may also be associated with extraction of water from the underground workings.
- The difference in groundwater levels at adjacent monitoring bores GDCMB01 and WYMB010 is of the order of 70 m and demonstrates the hydraulic separation of the shallow alluvial aquifer (GDCMB01) and the regional water table (WYMB010).

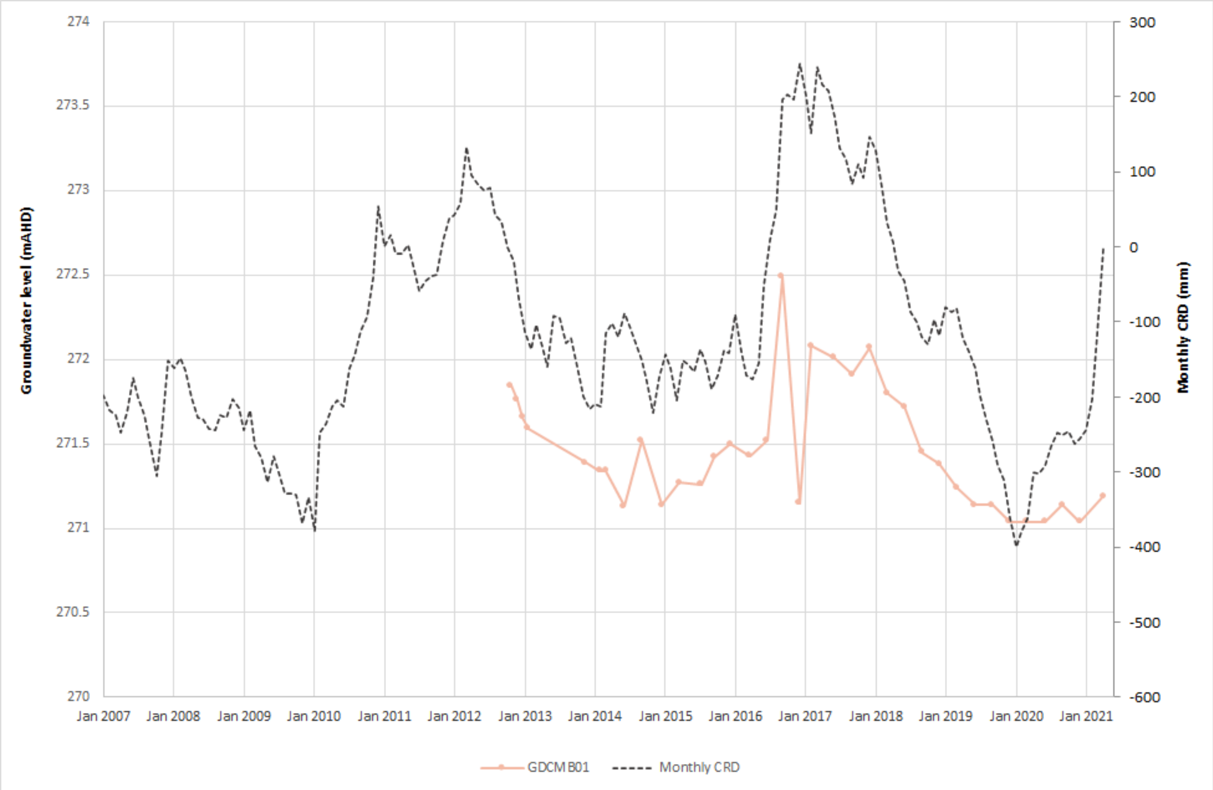


Figure 4.4: TGO alluvial monitoring bore (GDCMB01) hydrograph

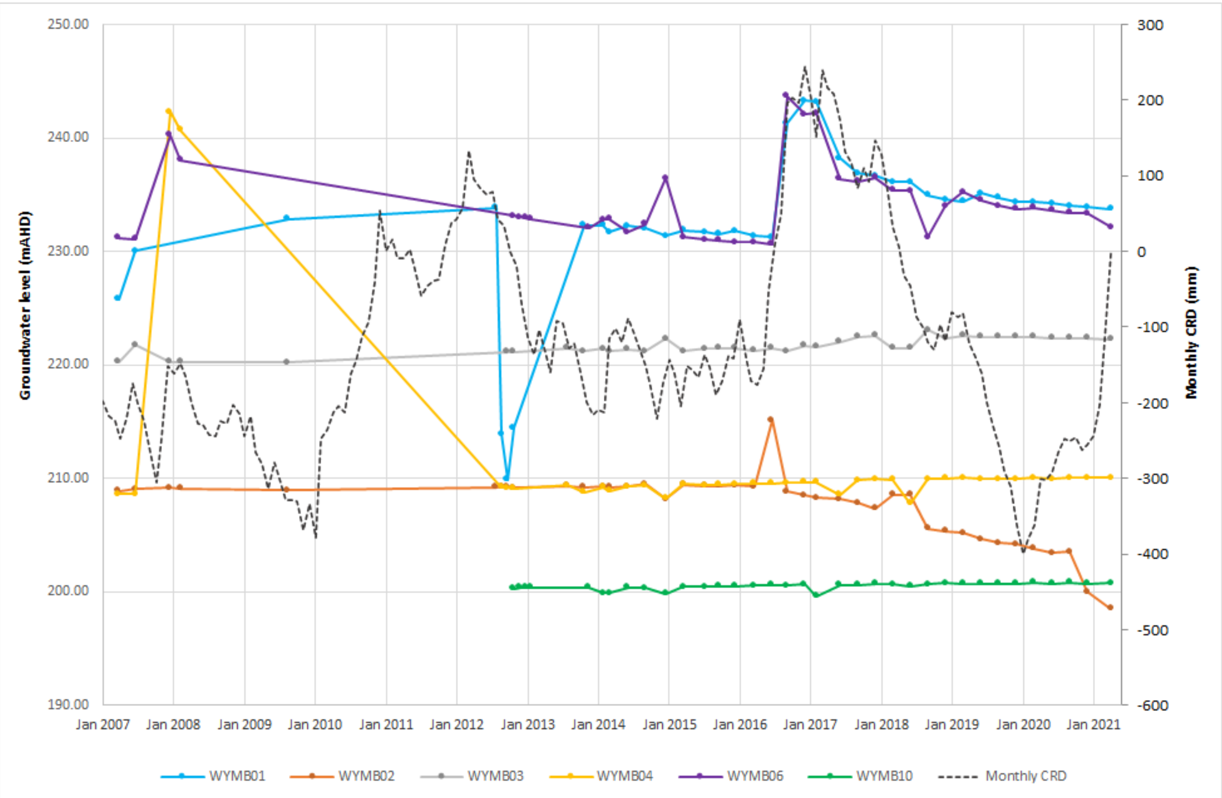


Figure 4.5: TGO hard rock monitoring bore hydrographs

4.2.2 SAR groundwater levels

As part of recent investigations, the Applicant installed four new monitoring bores at SAR, RWWB001, RWWB002, RWWB003 and RWB004. The locations of the monitoring bores are included on **Figure 4.3** and bore details are summarised in **Table 4.1**.

Three out of the four new monitoring bores at SAR effectively monitor groundwater level.

After equilibrium of groundwater levels following bore construction, in late March 2021, RWWB001, RWWB002 and RWWB003 had groundwater levels approximately 86 m, 82 m and 3.3 m, respectively, above the base of the bore. Equilibrium groundwater elevations are similar at all three bores and the bores are interpreted to be monitoring the regional fractured rock groundwater system groundwater level.

RWWB004 is screened to a depth of 52 mbgl and is dry, and as such, no water level data is available. Whilst RWWB004 is dry, the monitoring location is valuable for confirmation of the hydraulic separation of the shallow alluvial aquifer and the deeper regional water table. RWWB004 is screened across the interface between the Cainozoic alluvium and underlying weathered bedrock and therefore demonstrates a lack of saturation overlying bedrock at this location. It is noted however, that this does not preclude the potential presence of saturated alluvium within deeper palaeochannels that may exist below the regional water table at other locations.

The SAR monitoring bores are equipped with water level data loggers and available water levels from November 2020 through to March 2021 are presented on **Figure 4.6**. It is noted that RWWB004, screened to a depth of 52 m below ground level is dry and, as such, no water level data is available. For the duration presented on **Figure 4.6**, the monthly CRD does not provide any relevant correlation and instead, daily rainfall is presented.

From **Figure 4.6**, the following observations are made:

- Groundwater level trends at RWWB001 and RWWB003 over the period of observation are relatively stable.

  In mid-March 2021, RWWB003 displayed a minor response following a large rainfall event with a lag of approximately 6 days. Over the same duration, RWWB001 showed erratic fluctuations that are attributed to interference from nearby resource drilling operations.

- Groundwater level trends at RWWB002 demonstrate a very slow recovery following drilling and bore construction. RWWB002 was drilled dry with no indication of groundwater. The prolonged recovery, over a period of approximately 130 days is indicative of the very tight and low permeability of the formation at that location.

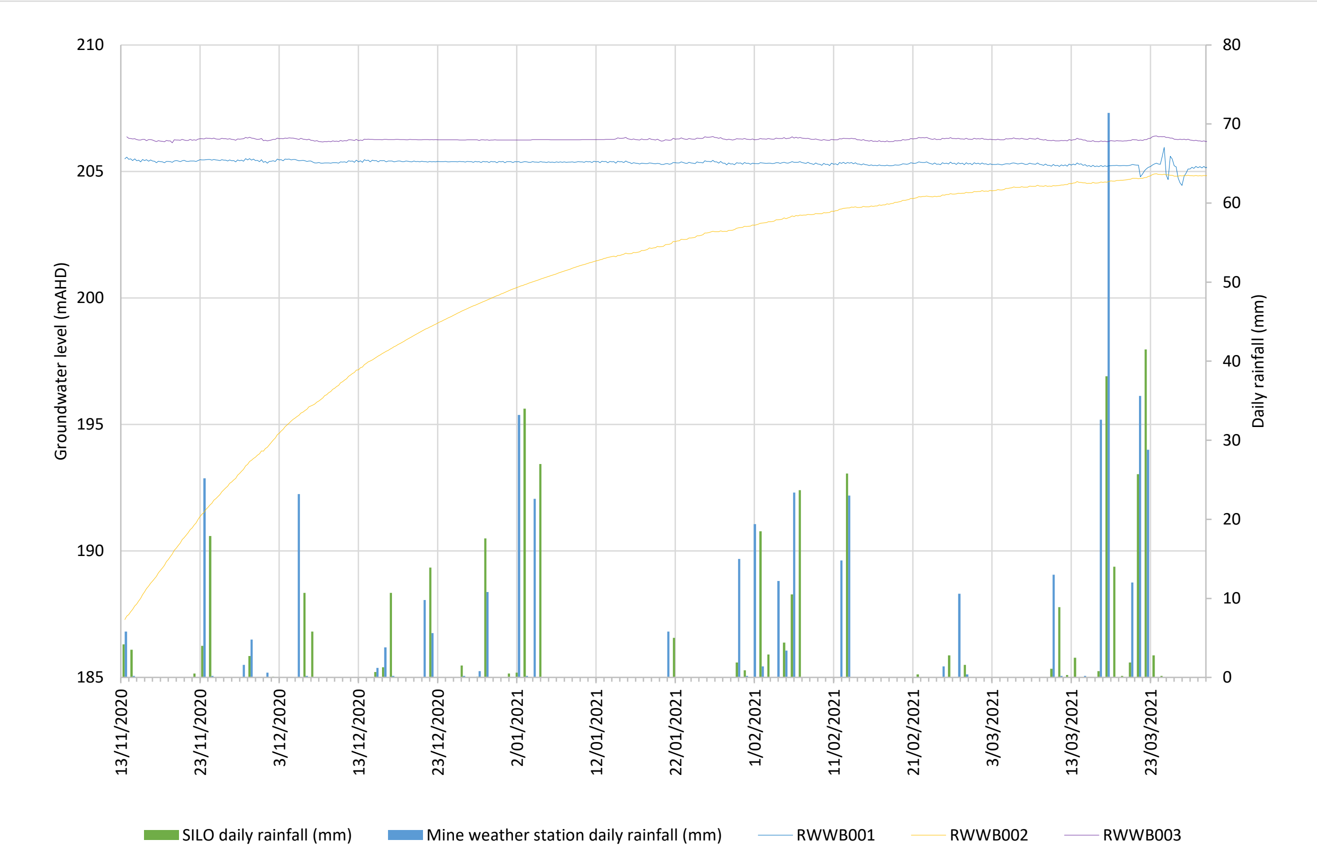


Figure 4.6: SAR Monitoring bore hydrographs

4.2.3 Near site fractured rock hydraulic gradients

Hydraulic gradients of the fractured rock groundwater system have been reviewed in the vicinity of TGO and SAR based on contouring representative groundwater levels. Two sets of contours were developed:

- Contours that included the current groundwater level from WYMB02, the only location interpreted to be currently subjected to mining induced groundwater level drawdown, and
- Contours that included a nominal pre-mining influence groundwater level from WYMB02, determined from the WYMB02 hydrograph. These contours were developed so that gradients and flow directions could be examined for groundwater levels applicable prior to the influence of mining.

For both contour sets, the contour points comprised all current TGO/SAR fractured rock groundwater monitoring bores aside from RWWB004 (dry monitoring bore), and WYMB01 and WYMB06. As outlined in **Section 4.2.1** bores WYMB01 and WYMB06 display different responses to the other hard rock monitoring bores and are inferred to be influenced by surface water ingress to old buried workings. Therefore, water levels in these bores are not considered to be representative.

Groundwater level contours developed with the current WYMB02 groundwater level and pre-mining WYMB02 groundwater level are provided in **Figure 4.7** and **Figure 4.8**, respectively.

The current predominant flow directions, as demonstrated by **Figure 4.7**, are to the west or northwest, and towards the existing Wyoming 1 open cut, which functions as a sink. The current hydraulic gradient between WYMB03 and WYMB04 is approximately 0.012 m/m. The current hydraulic gradient in the vicinity of the SAR open cut crest 50 m disturbance area is low and difficult to discern due to RWWB004 being dry.

Predominant flow direction with the influence of mining removed, as demonstrated by **Figure 4.8**, is generally to the west in the vicinity of TGO, where the contour point distribution is reasonable. There is relatively poor contour point distribution between TGO and SAR, and at SAR due to RWWB004 being dry. Therefore, the flow direction indicated by the contours in these areas is considered unreliable. The hydraulic gradient between WYMB03 and WYMB04 with the influence of mining removed is 0.012 m/m, the same as the contour case which included the current WYMB02 groundwater level.

Based on the contoured representative groundwater levels from the TGO and SAR fractured rock monitoring bores, the dominant flow direction of the fractured rock groundwater system is inferred to generally be to the west, but with potential variance between southwest and northwest. This is in-keeping with the regional groundwater flow direction, which is discussed in **Section 3.4.2**.

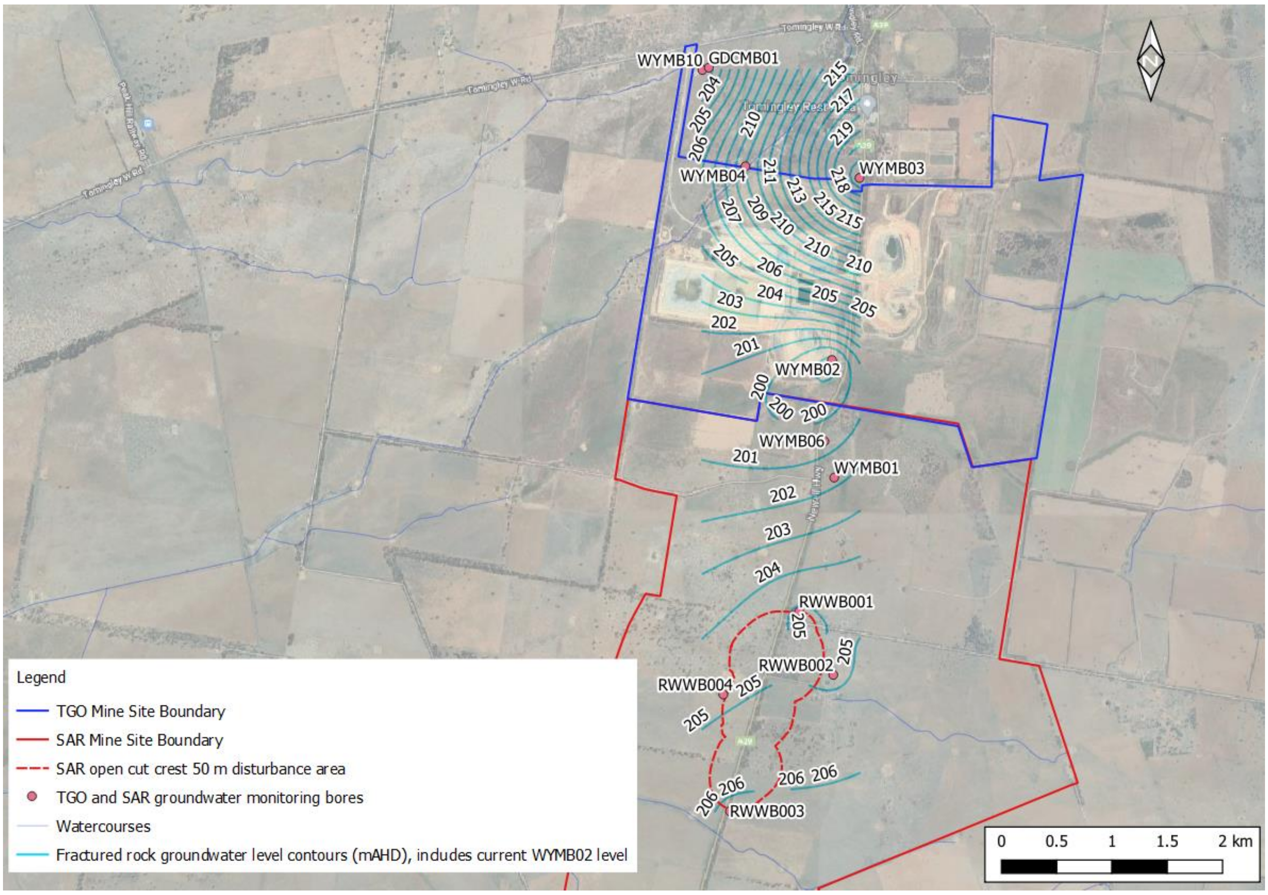


Figure 4.7: Fractured rock groundwater level contours based on site monitoring bores, includes current groundwater level from WYMB02

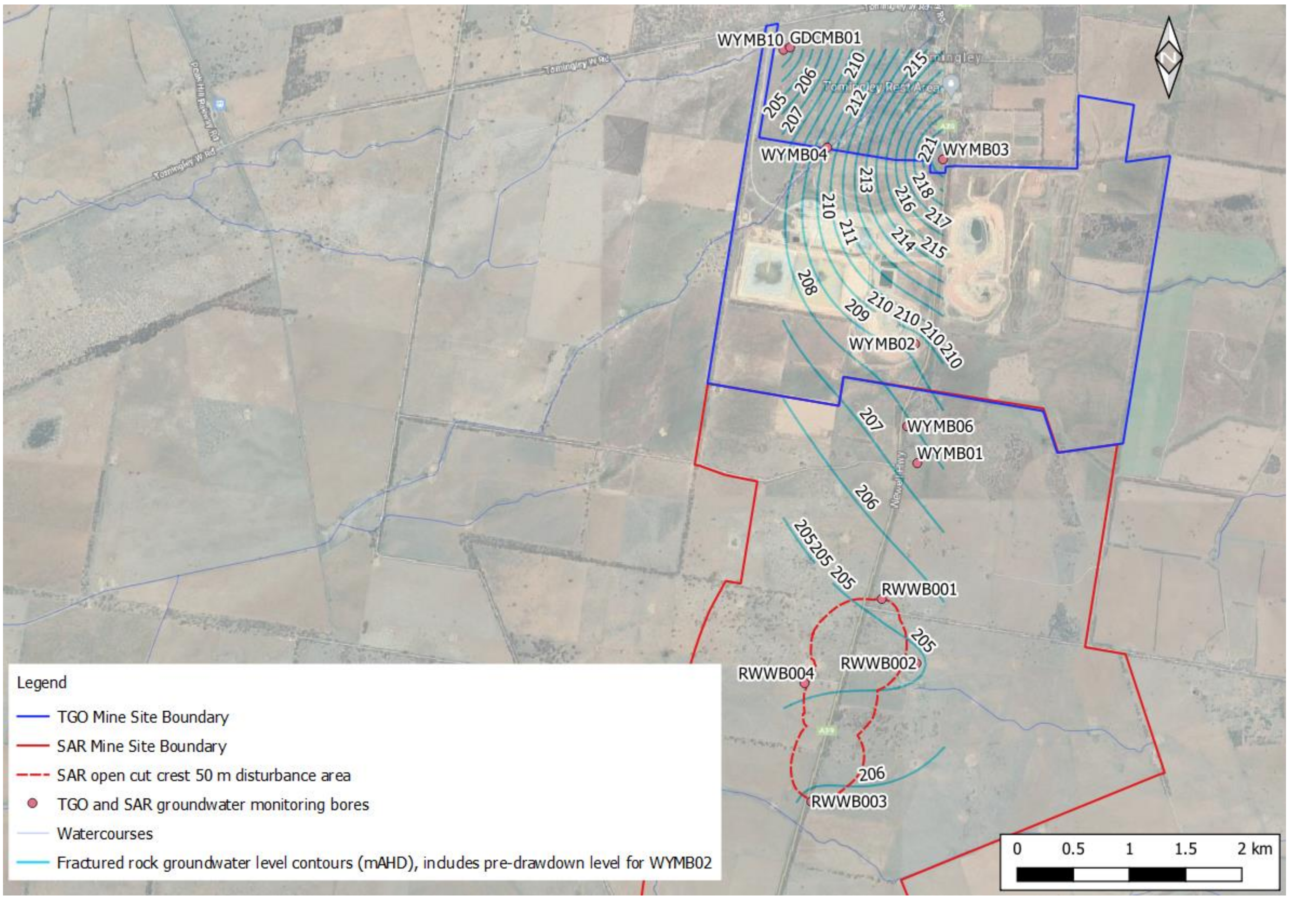


Figure 4.8: Fractured rock groundwater level contours based on site monitoring bores, includes pre-mining induced drawdown groundwater level from WYMB02

4.2.4 Surface water – groundwater interaction

The degree and type of interaction between groundwater and surface water is largely dependent on topography, watercourse geomorphology and the underlying groundwater systems, particularly the depth of groundwater levels relative to watercourse levels.

Surface water – groundwater interaction within the groundwater study area is characterised as follows:

Perched localised alluvial groundwater systems

At a local scale, small perched and discrete alluvial groundwater systems can be expected in the vicinity of some of the larger current or ancient watercourses near TGO/SAR. As these water courses are predominantly ephemeral, groundwater interaction is likely to be dominated by groundwater recharge occurring during times of surface flow, with the watercourses behaving as 'losing' streams.

Registered bores GW037395, GW803148 and GW045135 are located within Gundong Creek alluvium about 3.5 km to 4 km northeast of TGO. Bore depths range from 3.7 mbgl to 5.8 mbgl and have reported standing water levels ranging from 0.9 mbgl to 4.4 mbgl. Additionally, project groundwater monitoring bore, GDCMB01, also installed within Gundong Creek alluvium, is about 3.5 m deep and has standing water levels less than 3.5 mbgl.

Despite not being the dominant recharge process, there may be short periods of time along isolated reaches of these ephemeral water courses when the local water table exceeds the stream bed elevation resulting in groundwater baseflow contribution to surface flow.

The localised discrete alluvial groundwater systems are characterised to be physically and hydraulically disconnected from underlying regional groundwater systems. As discussed in **Section 4.2.1**, the water levels observed in the perched Gundong Creek alluvium at GDCMB01, are approximately 70 m above the regional groundwater level at WYMB010.

Regional alluvial and fractured rock groundwater systems

The depth to the water table associated with the regional groundwater system is generally relatively deep compared to the watercourse bed levels near the project. Groundwater depth contours (**Section 3.4.2**) indicate groundwater depths of about 40 mBGL to 60 mBGL in the vicinity of watercourses near the Project. Therefore, unless localised discrete perched alluvium groundwater systems are present, regional scale surface water – groundwater interaction in the vicinity of TGO/SAR is conceptualised to be generally limited and characterised by 'disconnected losing streams'. 'Disconnected losing watercourses' are defined as having watercourse water levels that are above and disconnected from underlying groundwater systems. Indirectly, losing watercourses can interact with the underlying groundwater systems by providing recharge via leakage from the watercourse to the groundwater system.

This characterisation is supported by project drilling and groundwater monitoring bore data (**Sections 4.1**, **4.2.1** and **4.2.2**), which indicates that the alluvium in the vicinity of the project is generally unsaturated. Furthermore, the most significant watercourse in the region of TGO/SAR, the Bogan River, only has three registered bores near it: GW036833, GW802483 and GW023198. These bores have reported groundwater depths ranging from 12 mbgl to 36.6 mbgl and reported water bearing zones commencing from 25 mbgl to 51 mbgl, one of which is within weathered rock and not alluvium. The low quantity and distribution of registered bores in the groundwater study area also supports the characterisation that regionally significant alluvial aquifers are not present or are uncommon within the groundwater study area.

4.3 Groundwater quality

Comprehensive groundwater quality sampling has been undertaken on TGO monitoring bores on a quarterly basis, since 2008. Additionally, SAR monitoring bores RWWB002 and RWWB003 have been sampled on three occasions since late 2020, and RWWB001 sampled on four occasions.

Comprehensive laboratory results for TGO/SAR monitoring bores are summarised in Appendix B.

Summary statistics for field measured physical parameters, pH and electrical conductivity, and total dissolved solids (TDS), for all monitoring bores are provided in **Table 4.2**.

Table 4.2: Summary of groundwater quality physical parameters, pH and EC, and TDS

Monitoring bore	pH[1]			EC (µS/cm)[1]			TDS (mg/L)[1]		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
RWWB001	6.67	6.58	6.77	28,567	25,600	32,700	19,375	18,700	19,800
RWWB002	6.74	6.63	6.87	20,040	18,400	22,320	15,400	14,300	16,400
RWWB003	6.92	6.86	6.97	19,307	17,800	22,320	12,200	11,700	12,500
WYMB01	7.50	7.08	8.00	11,393	1,241	12,350	7,627	6,400	8,400
WYMB02	7.41	6.80	8.33	20,626	1,877	25,610	14,627	12,800	16,400
WYMB03	7.38	6.70	8.12	19,062	1,817	22,100	13,845	11,500	14,900
WYMB04	7.32	6.89	8.05	24,512	2,124	29,180	18,250	15,800	20,400
WYMB06	7.45	6.83	8.21	12,172	1,174	15,480	8,627	6,830	10,000
WYMB10	7.28	6.72	7.86	25,217	1,967	51,700	16,831	2,190	20,000
GDCMB01	7.19	6.80	8.01	629	345	1,137	552	280	1,000

Note: [1] - SAR data range 2020-2021, 3-4 measurements. TGO data range 2013-2018, 16-20 measurements.

The key points relating to groundwater quality are:

- Average pH for all monitoring bores is typically near neutral, ranging from 6.7 to 7.5.
- Average EC of the regional water table is typically saline, ranging from about 11,393 µS/cm to 28,567 µS/cm.
- RWWB003 is the shallowest of the SAR monitoring bores and has lower salinity (as both EC and TDS) than RWWB001 and RWWB002. Mean TDS at RWWB003 is 11,700 mg/L and is 7,000 mg/L and 2,600 mg/L lower than at RWWB001 and RWWB002, respectively.
- RWWB002 and RWWB003 are screened at similar depths, but RWWB001 is considerably more saline.
- WYMB01 and WYMB06 have the lowest average salinity of the hardrock monitoring bores. WYMB01 and WYMB06 are located adjacent to historical workings at the Myalls United gold mine and are screened over depths similar to the old workings. The reduced salinity is inferred to be related to the enhanced recharge to the underground workings and dilution of ambient groundwater.
- EC of the Gundong Creek alluvial aquifer (GDCMB01) is generally fresh (maximum measured EC of 1,137 µS/cm) and is as expected for a shallow ephemeral alluvial aquifer. The moderately elevated salinity is likely the result of evaporative concentration via evapotranspiration, and evaporation of pooled surface water prior to recharge.

4.3.1 Major Ions

The relative concentrations of the major ions in groundwater samples from all monitoring bores is provided on the Piper Diagram on **Figure 4.9**. Most of the TGO and SAR hardrock monitoring bores show similar composition and plot as a group as sodium chloride type groundwater. Key differences from this trend are as follows:

- RWWB002 is transitional between sodium chloride type and having no dominant cation, with increased importance of calcium. This is likely the result of reverse ion exchange and/or dissolution of calcium from the formation.
- WYMB06 plots in the sodium-chloride field but is transitional toward having no dominant anion and has elevated sulphate with respect to chloride. This is potentially related to the proximity to the historic underground workings of the Myalls United gold mine and potential oxidation of sulphide minerals. However, the same trend is not observed at WYMB04, also in proximity to the Myalls United gold mine and of similarly reduced salinity. This indicates that the sulphate influence at WYMB06 may be due to localised formation conditions.
- GDCMB01 is associated with the Gundong Creek alluvial aquifer and plots as a sodium dominant water type with significant bicarbonate.

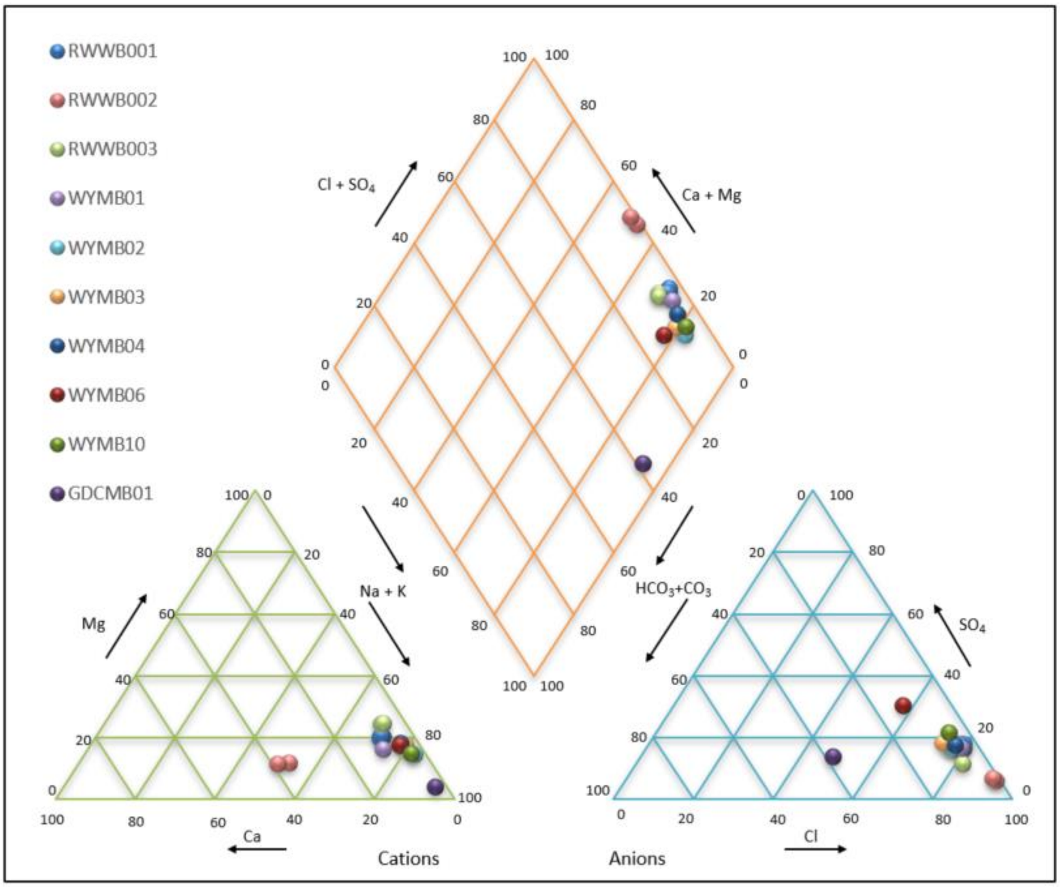


Figure 4.9: Piper plot of major anions and cations

4.4 Hydraulic testing

Formation hydraulic conductivity values have been derived for the TGO and SAR based on:

- Rising head data from groundwater monitoring bores
- Rising head data from airlifted resource drillholes
- Packer testing within diamond drillholes.

Additionally, airlift yield testing was undertaken at project boreholes to provide a basis to qualitatively assess indicative formation yield and the potential extent of groundwater inflows which may occur to the mine.

4.4.1 Monitoring bores

Indicative values for formation hydraulic conductivity were calculated at SAR groundwater monitoring bores by Jacobs as part of the current assessment and at TGO groundwater monitoring bores by AGE (2011) and Coffey (2007).

Hydraulic conductivity at the SAR groundwater monitoring bores RWWB001 and RWWB002 was calculated using water level recovery following airlifting and using delayed water level recovery data following bore construction for RWWB002. RWWB002 displayed no signs of saturation in the monitored zone during drilling or significant water level recovery following bore construction. However, slow water level recovery was observed in this bore in the months after bore construction (**Section 4.2.2** and **Figure 4.6**). Water level recovery data was analysed in the program AQTESOLV (HydroSOLVE, 2007) using the Theis recovery straight line solution (RWWB001) and Hvorslev solution (RWWB002). For both RWWB001 and RWWB002, aquifer thickness was approximated as the saturated formation thickness from the base of hole.

It is noted that RWWB003 was unable to be tested due to jammed equipment in the hole, and RWWB004 was dry.

Hydraulic conductivity at TGO groundwater monitoring bores was calculated by AGE (2011) using airlift water level recovery data from WYMB001, WYMB002 and WYMB003, which was analysed with the Hvorslev solution. Coffey (2007) calculated hydraulic conductivity at WYMB004 and WYMB006 via slug testing. Further details regarding the Coffey (2007) testing are not known. The Coffey (2007) results were taken from a table within GHD (2015) not the original document.

Calculated hydraulic conductivity at the SAR and TGO groundwater monitoring bores is summarised in **Table 4.3**. Hydraulic conductivity of the fractured rock at SAR and TGO groundwater monitoring bores ranged from 2.9×10^{-6} m/d (RWWB002) to 0.11 m/d (WYMB006). The arithmetic and geometric means are approximately 2.7×10^{-2} m/d and 2.1×10^{-3} m/d, respectively. It is noted that bore WYMB006, where the maximum value occurred, is located in close proximity to historical underground workings of the Myalls United mine. It is unclear if the elevated value is related to the workings or associated with structural or weathering influences.

When considering WYMB006 as an outlier, the arithmetic and geometric means are approximately 1.4×10^{-2} m/d and 1.1×10^{-3} m/d, respectively.

Statistics for calculated hydraulic conductivity are summarised in **Section 4.4.5** alongside the results obtained via airlift recovery analysis at open boreholes and packer testing. A qualitative summary of the hydraulic conductivity test values is also provided in **Section 4.4.5**.

Table 4.3: SAR/TGO hydraulic conductivity results

Monitoring bore	Gravel pack lithology	Hydraulic conductivity (m/d)
SAR groundwater monitoring bore		
RWWB001	Monzodiorite, fresh, unoxidised, grey and blue, fine grained, feldspathic	1.1×10^{-3}
RWWB002	Volcaniclastic sandstone, fresh, unoxidised, grey and green, coarse grained, poorly sorted	2.9×10^{-6}
RWWB003	Alluvium, clay, red brown to 56 m. Large (40 mm – 80 mm) gravels from somewhere within alluvium caused hole collapse during drilling. Saprolite from 56 to 70 m; quartz, completely oxidised, brown orange, clayey. At 70 m the saprolite clay transitions to saprolite rock.	testing not completed [+]
RWWB004	Alluvium, clay and sand layers, poorly sorted, some pebbly layers, variable colour. Transitions to saprolite clay at 40 m.	dry bore
TGO groundwater monitoring bore		
WYMB001	Feldspar phyric volcanic, fresh, fine grained, brown to green	1.0×10^{-4} [#]
WYMB002	Sandstone, siltstone and tuff, variably weathered (completely oxidised to fresh), volcaniclastic, foliated	9.5×10^{-3} [#]
WYMB003	Siltstone and sandstone, slightly weathered to fresh, brown to grey, foliated	6.1×10^{-2} [#]
WYMB004	Saprolite, quartz and sandstone, volcaniclastic, variably weathered (completely weathered to fresh) green, brown, grey,	9.5×10^{-3} [*]
WYMB005	Bore construction details unknown. Bore inferred to be screened in weathered or fractured rock because total hole depth was 84 m.	No test data/result available
WYMB006	Quartz, feldspar porphyry, generally fresh, white, khaki, grey, green, brown	0.11 [*]
WYMB007	Bore construction details unknown. Bore noted to be monitoring fractured rock groundwater system. Total hole depth was 150 m.	No test data/result available
WYMB008	Bore construction details unknown. Bore noted to be monitoring a localised perched alluvial groundwater system. Total hole depth was 9 m.	No test data/result available
WYMB10	Bore construction details unknown. Bore inferred to be screened in fractured rock. Total hole depth was 150 m.	No test data/result available

Notes: [#] Calculated by AGE (2011), as documented in Appendix 6 of The Impax Group (2011). [*] Calculated by Coffey, 2007, as documented in GHD (2015).
[+] Not estimated – volume displacement slug got jammed in bore and could not be lowered to water table. Hydraulic conductivity in monitored zone inferred to be very low to low as during drilling and immediately following bore construction, the monitored zone did not display signs of saturation.

4.4.2 Airlift yield testing

Airlift yield testing was completed on 13 RC drill holes and one diamond drill hole.

Airlifting was undertaken via the drill string and typically undertaken for a period of up to 120 minutes. Yields were measured using a timed bucket, with a yield estimation undertaken every 10 minutes.

Details of the airlift yield tested boreholes and the average yield determined from testing are summarised in **Table 4.4**.

The yield values are generally low; however, four locations had relatively elevated yields. RWD048 and RWRC397 recorded average yields of approximately 3 L/s, RWRC399 recorded an average yield of 1.1 L/s, and RWRC422 and RWRC428 recorded average yields of 0.7 L/s and 0.8 L/s. The median and average yield values overall were of the order of 0.2 L/s and 0.7 L/s, respectively. Based on only three out of 13 locations having a yield above 1 L/s, which represents 23% of the test locations, the hydraulic conductivity of the rock mass is inferred to typically be generally low, with some isolated locations where the hydraulic conductivity is low to moderate.

It is noted that only holes with airlift yields below the median value of 0.2 L/s had successful airlift recovery tests completed (**Table 4.5**).

Table 4.4: Summary of airlift yield tested boreholes and airlift yield results

Borehole	Easting	Northing	Ground level (mAHD)	Dip °	Total depth (m)	Total vertical depth (m)	Average yield (L/s)
RWRC387	613758	6389682	266.35	60	264	228.63	0.05
RWRC401	613799	6390284	266.37	58	154	130.60	0.19
RWRC403	613911	6390264	267.07	60	232	200.92	0.11
RWRC418	613739	6389743	265.65	58	190	161.13	0.1
RWD048	614188	6390808	267.89	60	200	173.21	3.32
RWRC389	613811	6390140	266.33	60	232	200.92	0.29
RWRC397	614187	6390850	268.12	58	129	109.40	3.09
RWRC399	614158	6390744	267.74	58	328	278.16	1.13
RWRC405	613732	6390049	266.05	60	210	181.87	0.04
RWRC417	613737	6389811	266.18	58	154	130.60	0.23
RWRC422	613865	6390401	266.78	58	172	145.86	0.7
RWRC427	613863	6389920	267.24	60	172	148.96	0.25
RWRC428	613806	6389782	266.61	60	280	242.49	0.84
RWRC433	613814	6390058	266.34	60	226	195.72	0.09

4.4.3 Airlift recovery testing

Hydraulic conductivity was estimated at four out of a total of the 14 airlifted boreholes (RWRC387, RWRC401, RWRC403 and RWRC418) using airlift water level recovery data. Hydraulic conductivity was only able to be estimated at these four locations due to lack of water level recovery data at the remaining locations. This was generally due to the dip meter either snagging within the angled holes or falsely signalling on clays within the inner tube.

The testing and analysis method that was employed is summarised as follows:

- Pre-test groundwater level measured by dip meter. In cases where a measurement was not available, the groundwater level was estimated based on available site data
- Airlifting via drill string, typically undertaken for a period of up to120 minutes
- Yield estimation via a timed bucket and stopwatch, with a yield estimation undertaken every 10 minutes
- Water level recovery measurement via dip meter lowered down drill rods. It is noted that difficulty was encountered measuring the water level recovery due to the dip meter falsely signalling due to mud, and due to difficulties encountered lowering the dip meter in the angled boreholes. This led to recovery measurements for only four of the 14 tests
- Angled down-hole measurements were converted to equivalent vertical depths
- Water level recovery data was analysed in the program AQTESOLV (HydroSOLVE, 2007), using the Theis straight line recovery solution or Theis/Hantush type curve recovery solution. Aquifer thickness was estimated using the saturated thickness in the borehole.
- It is noted that given the testing methodology and application in angled drillholes, the resulting hydraulic conductivity values should be indicative or order of magnitude only.

Calculated hydraulic conductivity at the airlifted boreholes is summarised in **Table 4.5** and test locations and yields are shown in **Figure 4.10**. The calculated hydraulic conductivity values range from 4.8×10^{-5} m/d to 1.6×10^{-3} m/d.

Airlift recovery curves and analyses are provided in Appendix C.

As indicated in **Section 4.4.3**, the airlift recovery tests were only able to be successfully undertaken on boreholes that had below median yields (0.2 L/s) and as such the results are not necessarily fully representative of the range of airlift yields observed. In particular the five boreholes with yields of 0.7 L/s or greater would be expected to return relatively elevated hydraulic conductivity values compared to those outlined in **Table 4.5**.

Table 4.5: Hydraulic conductivity calculated based on airlift water level recovery

Borehole	Easting	Northing	Ground level (mAHD)	Dip °	Total depth (m)	Total vertical depth (m)	Average yield (L/s)	Hydraulic conductivity estimate (m/d)
RWRC387	613758	6389682	266.35	60	264	228.63	0.05	1.1×10^{-4} (based on only four data points)
RWRC401	613799	6390284	266.37	58	154	130.60	0.19	1.6×10^{-3}
RWRC403	613911	6390264	267.07	60	232	200.92	0.11	4.8×10^{-5}
RWRC418	613739	6389743	265.65	58	190	161.13	0.1	5.1×10^{-5}

Statistics for calculated hydraulic conductivity are summarised in **Section 4.4.5** alongside the results obtained from SAR/TGO groundwater monitoring bores and packer testing. A qualitative summary of the hydraulic conductivity test values is also provided in **Section 4.4.5**.

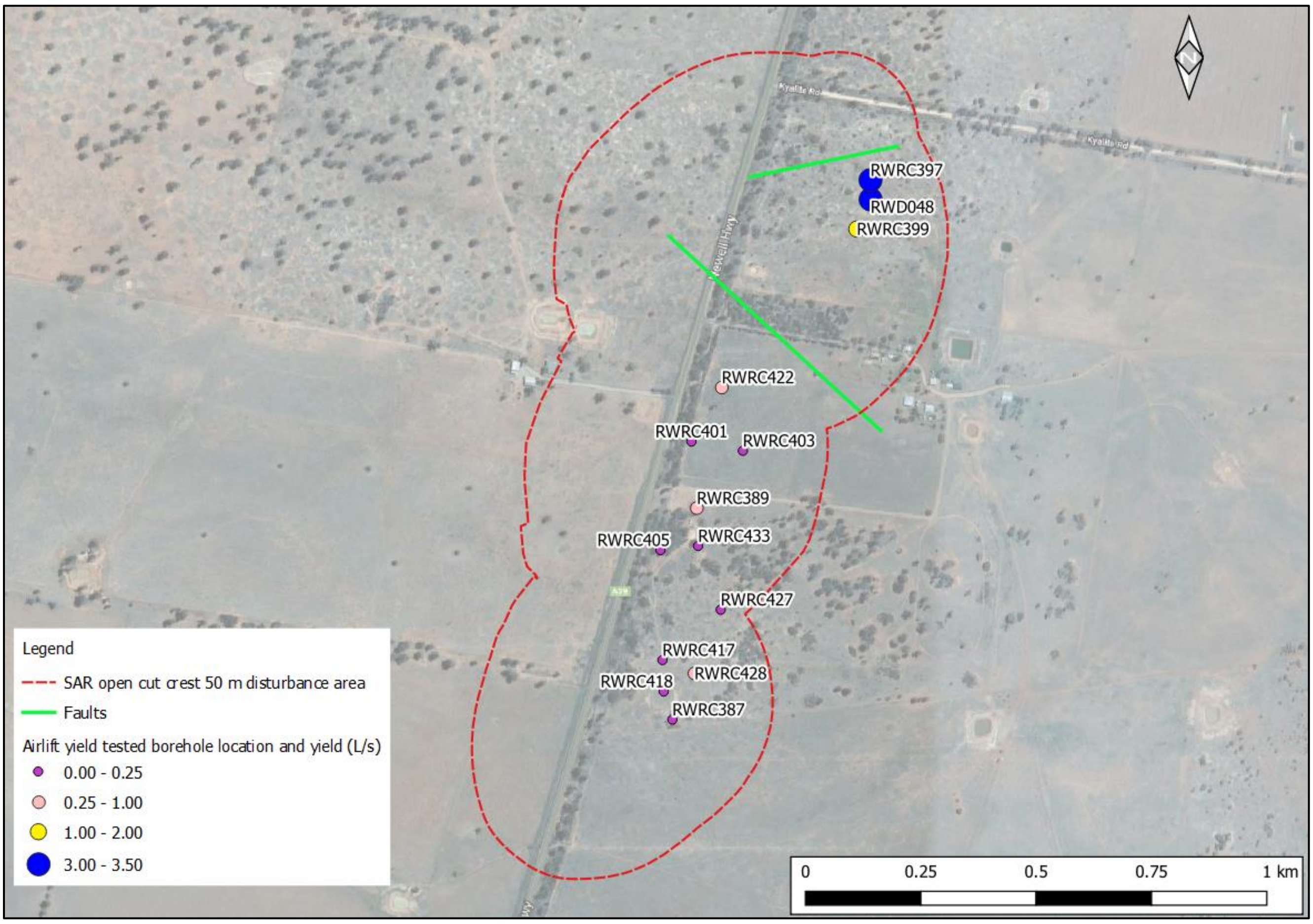


Figure 4.10: Airlift yield test locations and results

4.4.4 Packer testing

Lugeon, or packer injection testing, was completed on four diamond drill holes in the area of SAR, RWRC352D, RWDO42, RWD048 and RWMET01.

In general, the field testing and data analysis was completed as follows:

- Pre-test groundwater level measured by dip meter. In cases where a measurement was not available, the groundwater level was estimated based on available site data. Angled measurements were converted to vertical measurements
- Single stage packer testing was undertaken. The testing length interval increasing cumulatively upward by approximately 50 m per test (i.e. minimum test interval occurred near borehole base and then testing intervals increased cumulatively towards ground surface as the packer assembly was gradually withdrawn from the borehole)
- Each test interval typically comprised three five-minute flow intervals at seven pressure stages (i.e. four stages with pressure increasing cumulatively and three stages with pressure decreasing cumulatively)
- Data was analysed in spreadsheet, with consideration given to pressure and flow trends. A lugeon value was calculated for each pressure stage and then a representative lugeon value selected based on Houlsby (1976) and Quinones-Rozo (2010). The representative lugeon value was converted to derive a representative formation hydraulic conductivity value.
- Qualitative classification and description of rock mass discontinuities in accordance with Quinones-Rozo (2010).

Details of the packer tested boreholes and intervals, and test results are summarised in **Table 4.6**. Test analysis summaries are provided in Appendix C. The results are generally indicative of very low to low hydraulic conductivity and a very tight to tight rock mass with respect to discontinuities. Estimates of formation hydraulic conductivity ranged from 4.7×10^{-4} m/d to 6.5×10^{-2} m/d and had a geometric mean and median value of 5.7×10^{-3} m/d and 7.3×10^{-3} m/d, respectively.

There was one test interval result, the maximum of all test results, which occurred at RWD048, where the hydraulic conductivity is classified as 'moderate' and the rock mass classified to have 'a few partly open discontinuities' in accordance with Quinones-Rozo (2010). It is noted that although the hydraulic conductivity is classified as 'moderate' under Quinones-Rozo (2010), the maximum hydraulic conductivity test value of 6.5×10^{-2} m/d is considered relatively low.

It is noted that test results generally show a trend of fracture filling. Fracture filling can result from fractures of limited extent becoming fully pressurised accepting less flow at consecutive steps, or it can also result from the holes not being flushed adequately and drill cuttings physically clogging up the fractures. Notwithstanding, the results are generally indicative of a very tight to tight rock mass.

Statistics for calculated hydraulic conductivity are summarised in **Section 4.4.5** alongside the results obtained from SAR/TGO groundwater monitoring bores and borehole airlift recovery testing. A qualitative summary of the hydraulic conductivity test values is also provided in **Section 4.4.5**.

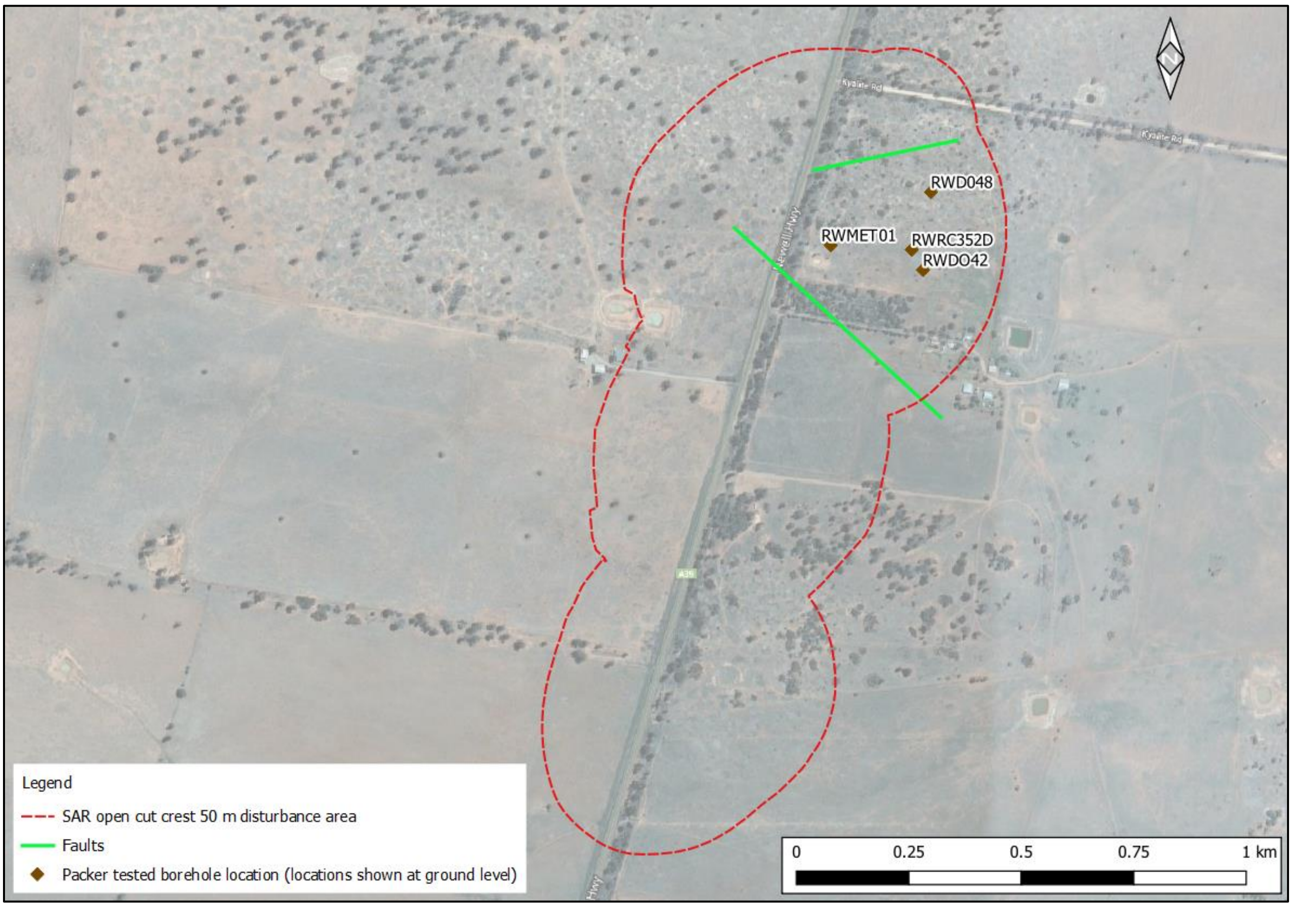


Figure 4.11: Packer tested borehole locations

Table 4.6: Packer testing results summary

Borehole (and dip/azimuth)	Ground level (mAHD)	Tested declined interval (m)	Tested vertical interval (mBGL)	Tested vertical interval (mAHD)	Lugeon	Hydraulic conductivity, K (m/d)	Qualitative assessment of hydraulic conductivity and rock mass discontinuities	Comment
RWRC352D (dip 60°, azimuth 270°	268.04[1]	400-519	346-449	-78 to -181	0.87	1.09×10^{-2}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates filling of fractures ▪ Average lugeon of pressure Stages 1 to 3 used to calculate K
		451-519	391-449	-123 to -181	NA – no flow conditions	NA – no flow conditions	Very low hydraulic conductivity, very tight rock mass	▪ Negligible to no flow for all pressure stages
		499-519	432-449	-164 to -181	0.04	4.69×10^{-4}	Very low hydraulic conductivity, very tight rock mass	▪ Inconsistent data ▪ Average lugeon value of all pressure stages used to calculate K
RWD042 (dip 60°, azimuth 270°	268.13[1]	150-478	130-414	138 to -146	1.14	1.43×10^{-2}	Low hydraulic conductivity, tight rock mass	▪ Unable to increase pressure beyond 200 kPa. Therefore, only first pressure stage was completed. As such, result is indicative only.
		221-478	191-414	77 to -146	0.27	3.43×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates filling of fractures, possible hydraulic fracturing, or packer bypass at Stage 4 ▪ Average lugeon of pressure Stages 1 to 3 used to calculate K

Borehole (and dip/azimuth)	Ground level (mAHD)	Tested declined interval (m)	Tested vertical interval (mBGL)	Tested vertical interval (mAHD)	Lugeon	Hydraulic conductivity, K (m/d)	Qualitative assessment of hydraulic conductivity and rock mass discontinuities	Comment
		252-478	218-414	50 to -146	1.04	1.30×10^{-2}	Low hydraulic conductivity, tight rock mass	▪ Highest lugeon (Stage 6) used to calculate K
		300-478	260-414	8 to -146	0.66	8.24×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates filling of fractures ▪ Average lugeon of Stages 1 - 4 used to calculate K
		350-478	303-414	-35 to -146	1.11	1.39×10^{-2}	Low hydraulic conductivity, tight rock mass	▪ Test curve indicates filling of fractures ▪ Average lugeon of Stages 1 – 4 used to calculate K
		400-478	346-414	-78 to -146	2.02	2.53×10^{-2}	Low hydraulic conductivity, tight rock mass	▪ Test curve indicates filling of fractures ▪ Average lugeon of Stages 1 - 3 used to calculate K
		450-478	390-414	-122 to -146	0.73	9.20×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates filling of fractures, partial recovery at Stage 7 ▪ Average lugeon of Stages 1 - 4 used to calculate K
RWD048 (dip 60°,	267.89[2]	200-455	173-394	95 to -126	0.10	1.30×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Average lugeon of Stage 1 - 6 used to calculate K

Borehole (and dip/azimuth)	Ground level (mAHD)	Tested declined interval (m)	Tested vertical interval (mBGL)	Tested vertical interval (mAHD)	Lugeon	Hydraulic conductivity, K (m/d)	Qualitative assessment of hydraulic conductivity and rock mass discontinuities	Comment
azimuth 270°		245-455	212-394	56 to -126	0.12	1.46×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates possible filling of fractures ▪ Lugeon of highest pressure stage used to calculate K
		257-455	223-394	46 to -126	0.16	2.00×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Average lugeon of Stage 1 and 2 (only stages completed) used to calculate K
		300-455	260-394	8 to -126	0.13	1.63×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates possible filling of fractures ▪ Average lugeon of Stage 2 - 3 used to calculate K
		350-455	303-394	-35 to -126	0.32	3.96×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Inconsistent flows ▪ Average lugeon of all stages used to calculate K
		400-455	346-394	-78 to -126	0.54	6.74×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Test curve indicates possible filling of fractures ▪ Average lugeon of Stages 1 - 3 used to calculate K
		446-455	386-394	-118 to -126	5.07	6.35×10^{-2}	Moderate hydraulic conductivity, few partly open rock mass discontinuities	▪ Only 3 stages completed ▪ Average lugeon of Stages 1 – 3 used to calculate K. Test was

Borehole (and dip/azimuth)	Ground level (mAHD)	Tested declined interval (m)	Tested vertical interval (mBGL)	Tested vertical interval (mAHD)	Lugeon	Hydraulic conductivity, K (m/d)	Qualitative assessment of hydraulic conductivity and rock mass discontinuities	Comment
								terminated after 5 minutes into Stage 3.
RWMET01 (vertical)	267.03[1]	96-196	96-196	171 to 71	0.51	6.36×10^{-3}	Very low hydraulic conductivity, very tight rock mass	▪ Lowest lugeon value of stages used to calculate K
		144-196	144-196	123 to 71	0.85	1.07×10^{-2}	Very low hydraulic conductivity, very tight rock mass	Possible flushing Highest lugeon value of stages used to calculate K

Notes: [1] Based on borehole collar coordinate projected onto a 5 m LIDAR digital elevation model (Geoscience Australia, 2020). [2] Differential GPS.

4.4.5 Spatial data trends

Derived values of hydraulic conductivity at groundwater monitoring bores, airlifted boreholes and packer test locations (maximum value shown for packer test locations) are shown in **Figure 4.12**.

It is noted that, except for the groundwater monitoring bores (WYMB and RWWB series bores) and RWMET, the test locations typically have 58 to 60 degree dips and an azimuth of approximately 270 degrees. The borehole locations presented in **Figure 4.12** are the collar locations at ground level.

The maximum hydraulic conductivity test values are relatively elevated in a cluster comprising locations RWD048, RWMET01, RWRC352D and RWD042. This cluster is located between the location of two fault lines that have been mapped by The Applicant. Airlift yields were also relatively elevated in this area with the two highest airlift yields of 3.09 and 3.32 L/s recorded in the vicinity of the northern most fault in the Roswell deposit. There is the possibility that hydraulic conductivity may be relatively enhanced in the Roswell deposit in association with proximity to the two fault lines. However, it is noted that although relatively elevated compared to surrounding tests, the packer test derived hydraulic conductivity values for tests between the two fault lines were generally very low to low, with only a single result considered representative of moderate hydraulic conductivity, the maximum test value of 6.53×10^{-2} m/d.

It is likely that the mineralisation targeted by mining would have a relatively higher hydraulic conductivity than the surrounding siltstone and shale; however, whilst this is considered reasonably likely, the current data is not considered sufficient to validate this notion.

Packer test interval mid-point depths (mbgl) and calculated hydraulic conductivity for the packer tests are graphed in **Figure 4.13**. It is noted that ground surface elevation variation between the packer tested boreholes is only about 1 m. Thus, whilst **Figure 4.13** displays the data with respect to mbgl, due to the negligible ground surface level variation between the boreholes, the graph is also reflective of hydraulic conductivity trends with respect to relative levels.

Based on **Figure 4.13**, there is no apparent correlation between hydraulic conductivity and test depth or elevation.

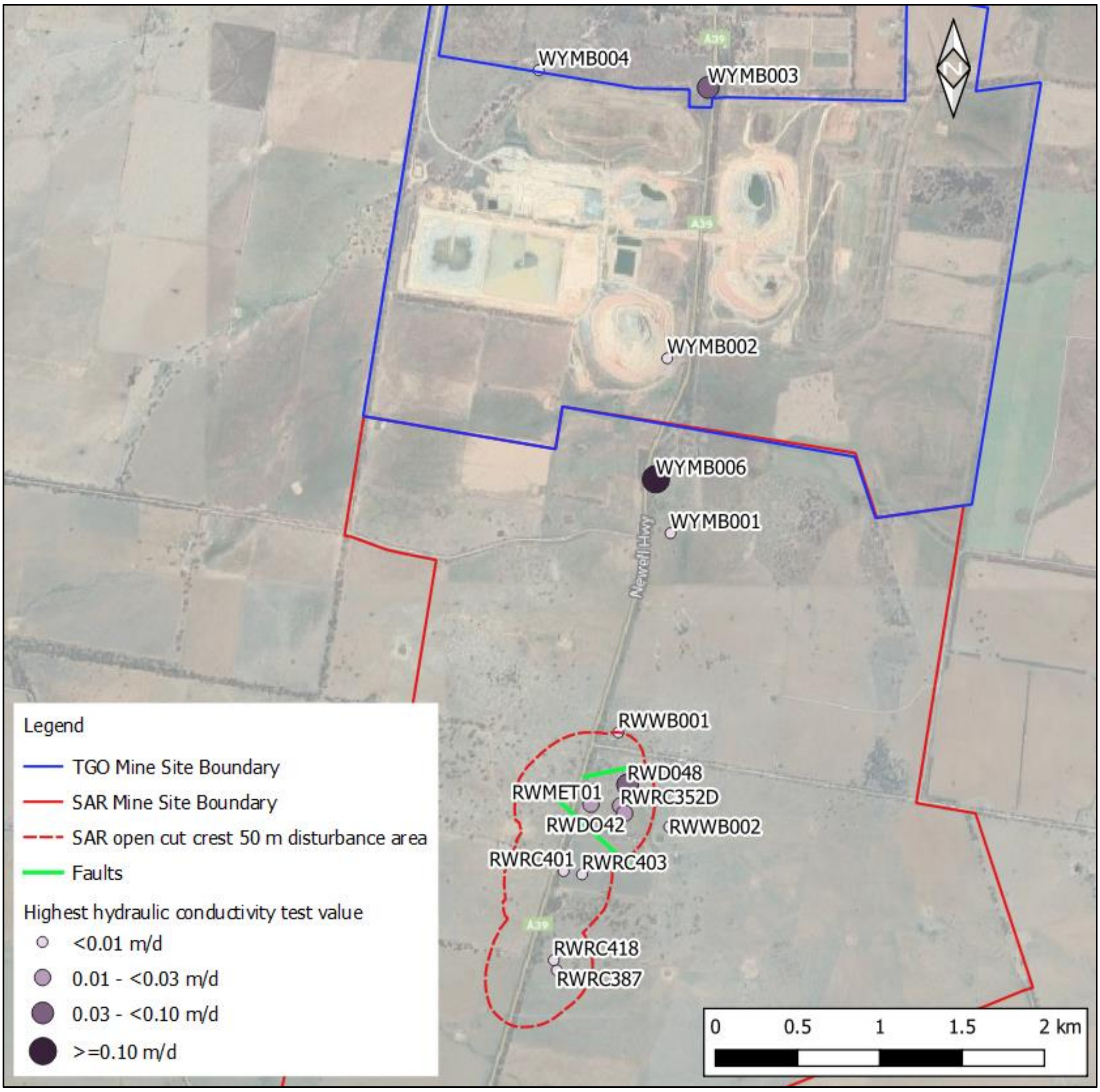


Figure 4.12: Distribution of hydraulic conductivity

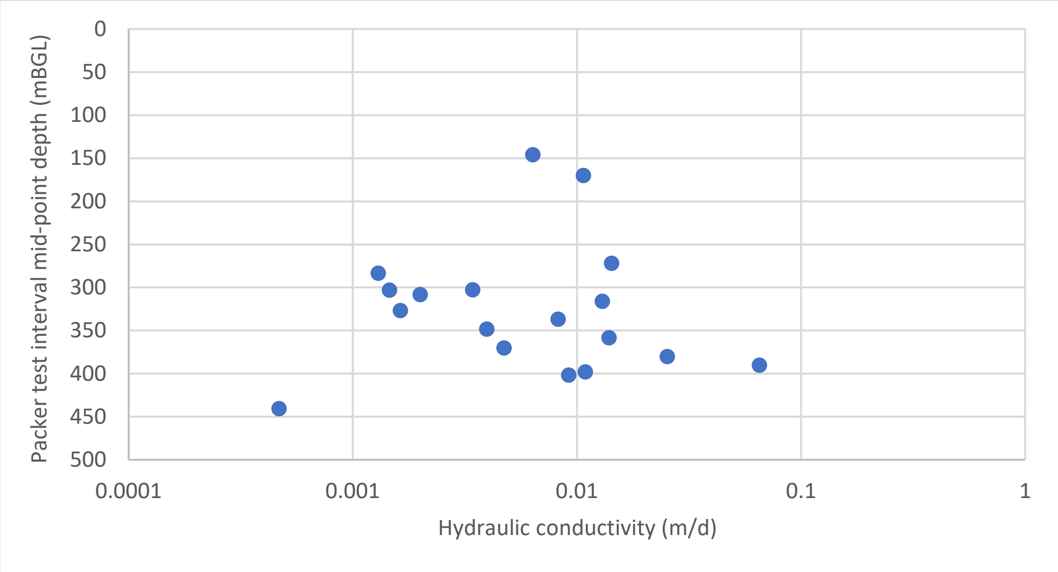


Figure 4.13: Packer test interval mid-point depth (mBGL) and hydraulic conductivity (m/d)

4.4.6 Hydraulic conductivity – statistical summary

A statistical summary of all hydraulic conductivity test results is provided in **Table 4.7**. Out of a total of 29 test values, the minimum and maximum values were 2.90×10^{-6} m/d and 0.11 m/d, respectively.

Generally speaking, hydraulic conductivity of aquifer materials varies over many orders of magnitude in nature and has most often been found to be log-normally distributed (Sanchez et al. 1996). Thus, the geometric mean of hydraulic conductivity data is often used to obtain a representative hydraulic conductivity value for a groundwater system (Prudic, 1991).

The geometric mean of all the hydraulic conductivity testing results was 2.71×10^{-3} m/d. This value is classified by Quiñones-Rozo (2010) to be 'very low' and indicative of a 'very tight' rock mass with respect to discontinuities.

The maximum value of all hydraulic conductivity test results of 0.11 m/d is classified by Quiñones-Rozo (2010) to be 'moderate' and indicative of a rock mass with a 'few partly open discontinuities'. It is noted that although the maximum hydraulic conductivity value is classified as 'moderate' under Quiñones-Rozo (2010), the maximum hydraulic conductivity test value of 0.11 m/d is considered relatively low. The qualitative Quiñones-Rozo (2010) classifications were developed for packer test interpretation and are applicable to rock. Thus, under more broad classifications which consider a wider range of aquifer materials (e.g. sands and gravels), the maximum hydraulic conductivity test value of 0.11 m/d is considered relatively low.

The arithmetic mean, geometric mean, median and maximum hydraulic conductivity results derived from the monitoring bore testing and packer testing were in the same order of magnitude for a given statistic. The hydraulic conductivity estimates derived from airlift recovery data were one to two orders of magnitude lower than those derived from monitoring bore and packer tests. The packer test results are considered likely to be most representative compared to the other test types. This is because the packer test sample quantity is significantly higher, the tested intervals included long test lengths, which maximises the potential to intercept fractures, the stress exerted onto the groundwater system is relatively large and the test method is more methodical than that of airlift recovery testing and the rising head testing in the monitoring bores.

Table 4.7: Statistical summary of all hydraulic conductivity testing results

Hydraulic conductivity test type	Hydraulic conductivity (m/d) summary statistics				
	Minimum	Arithmetic Mean	Geometric mean	Median	Maximum
SAR/TGO Groundwater monitoring bores (n=7)	2.90×10^{-6}	2.73×10^{-2}	2.12×10^{-3}	9.50×10^{-3}	0.11
Airlifted boreholes (n=4)	4.80×10^{-5}	4.52×10^{-4}	1.44×10^{-4}	8.05×10^{-5}	1.60×10^{-3}
Packer tested boreholes (n=18)	4.69×10^{-4}	1.09×10^{-2}	5.73×10^{-3}	7.30×10^{-3}	6.53×10^{-2}
All testing types and packer intervals (n=29)	2.90×10^{-6}	1.34×10^{-2}	2.71×10^{-3}	4.73×10^{-3}	0.11

4.5 Storage (groundwater system)

Groundwater system storage properties are physical properties that characterise the capacity of a groundwater system to release groundwater. For water table groundwater systems, storage is discussed in terms of specific yield (Sy), which is also known as drainable porosity. Specific yield, quoted as a ratio, is generally less than or equal to the effective porosity (total connected pore space). Additionally, specific storage (Ss) is the amount of water that a portion of an aquifer releases from storage, per unit mass or volume of aquifer, per unit change in hydraulic head, while remaining fully saturated. Specific storage is a function of the compressibility of the formation and the compressibility of water. Specific storage is also known as elastic storage.

In the vicinity of TGO and SAR, the Cainozoic deposits are considered to be unconfined, although it is noted that they are also largely unsaturated. The total porosity of these deposits is likely to be relatively large due to the clay and silt content, although the specific yield is likely to be reduced. Indicative values for porosity and specific yield for silty and clayey alluvial deposits is of the order of 5% (Johnson, 1967).

Groundwater system storage within the vicinity TGO/SAR is inferred to be low for the basement lithologies (volcanics and meta-sediments). Specific yield, where unconfined, is inferred to be in the range of 1 % to 10 %. This specific yield value range aligns with representative specific yield values for fractured igneous and metamorphic rock (1%), shale (2.5%), sandstone (6%) and siltstone (12%) in Bair and Lahm (2006). Specific yield is expected to be at the lower end of the range based on the very tight nature of the rock mass and lack of any significant primary porosity.

An assessment of specific storage has been undertaken based on geotechnical rock strength data. Specific storage is related to formation compressibility, that can be derived from rock strength coefficients of Youngs Modulus and Poissons Ratio, and the compressibility of water. For available project data from five valid strength tests (WSP, 2021) the geometric mean value for specific storage has been estimated at 1.3×10^{-7}, whereas Younger (1993) suggests that typical values of specific storage range from the order of 1×10^{-6} for moderately fractured rock to 7×10^{-7} for unfractured rock.

5. Conceptualisation

A conceptual hydrogeological model is a descriptive representation of a groundwater system that incorporates an interpretation of the geological and hydrological conditions. A conceptual model consolidates the current understanding of the key processes of the groundwater system, including the influence of stresses, and assists in the understanding of possible future changes.

5.1 Conceptual hydrogeological model

The conceptual hydrogeological model for the Project Site is summarised as follows:

- There are three broad groundwater systems apparent in the vicinity of the Project Site:
  - Perched aquifer: A shallow and localised perched water table system associated with the larger drainages, particularly Gundong Creek and possibly the Bogan River. These systems are not located close to the TGEP. Also, in the vicinity of the Project Site, this unit has been shown to be hydraulically disconnected from the lower fractured rock groundwater system (system discussed below). As such, the project is anticipated to have no significant interaction from a groundwater perspective with this unit.
  - Cainzoic alluvial groundwater system: The Cainzoic alluvial system comprises a relatively thick layer of generally low permeability fluvial sediments. In the vicinity of the Project Site this unit has been shown to be unsaturated and does not locally represent an aquifer. On a regional scale there is potential for saturation, particularly in more deeply incised palaeochannels.
  - Fractured rock groundwater system: Locally, in the vicinity of the Project Site, the regional water table is expressed within the basement lithologies. The primary permeability of these basement lithologies is likely to be very low, however there is potential for enhanced permeability associated with structural deformation and discontinuities, zones of mineralisation, and chemical weathering within the transition zone from completely oxidised saprolite to moderately weathered formation.
- Given the depth to groundwater in the vicinity of the Project Site, the primary groundwater system of interest with respect to potential groundwater inflows and associated impacts is the fractured rock groundwater system.
- There is potential for preferential groundwater flow along the dominant direction of structural orientation; however, there is no indication of this and the regional groundwater flow direction is typically orthogonal to the structural orientation in the vicinity of the TGEP, to the west in the vicinity of the Project Site.
- Hydraulic conductivity of the fractured rock groundwater system will typically be very low to low and generally of the order of 1×10^{-3} to 1×10^{-2} m/d. Some localised elevated hydraulic conductivity may be anticipated due to local fracture conditions; however, any such fractures are unlikely to be extensive or interconnected and any associated inflows would be short lived.
- Observed groundwater inflows at TGO open cuts and the underground mine are very low and do not present any issues or require active dewatering. A basic water balance prepared by RW Corkery & Co (2020) for the Wyoming underground at TGO indicated that inflows to the underground could be as much as 1.5 L/s; however, the majority (estimated 75%) of this is inferred by the Applicant to be seepage or water recycling from the Wyoming One pit sump to the underground (unplugged boreholes from the open cut to the underground provide a flow path).
- Rainfall recharge is the dominant recharge process but given the large thickness of unsaturated Cainozoic alluvial deposits, is likely to be relatively very low to low. The chloride mass balance (**Section 3.6**) supports the conceptualisation that recharge is likely very low to low. Rainfall recharge is likely to be more significant along the Herveys Range, contributing to the groundwater throughflow beneath the Project Site.

- Given the large depth to groundwater and ephemeral nature of local water courses there is not anticipated to be a significant groundwater - surface water interaction in the vicinity of the Project Site. During times of surface water flow, there may be a component of surface water loss to groundwater (recharge) particularly in the perched groundwater systems. This interaction will not be affected by mine dewatering.
- Within the Project Site, the dominant mechanism for groundwater discharge is likely to be inflows to mine workings and evaporation from pit walls and sumps. Evapotranspiration may be significant for perched groundwater systems, but due to depth, the regional groundwater system will be beyond the influence of evapotranspiration. Groundwater extraction by existing registered bores in the vicinity of the Project Site is considered to be negligible.
- Based on observations from the current extraction areas, groundwater inflows for the Project are anticipated to be low.

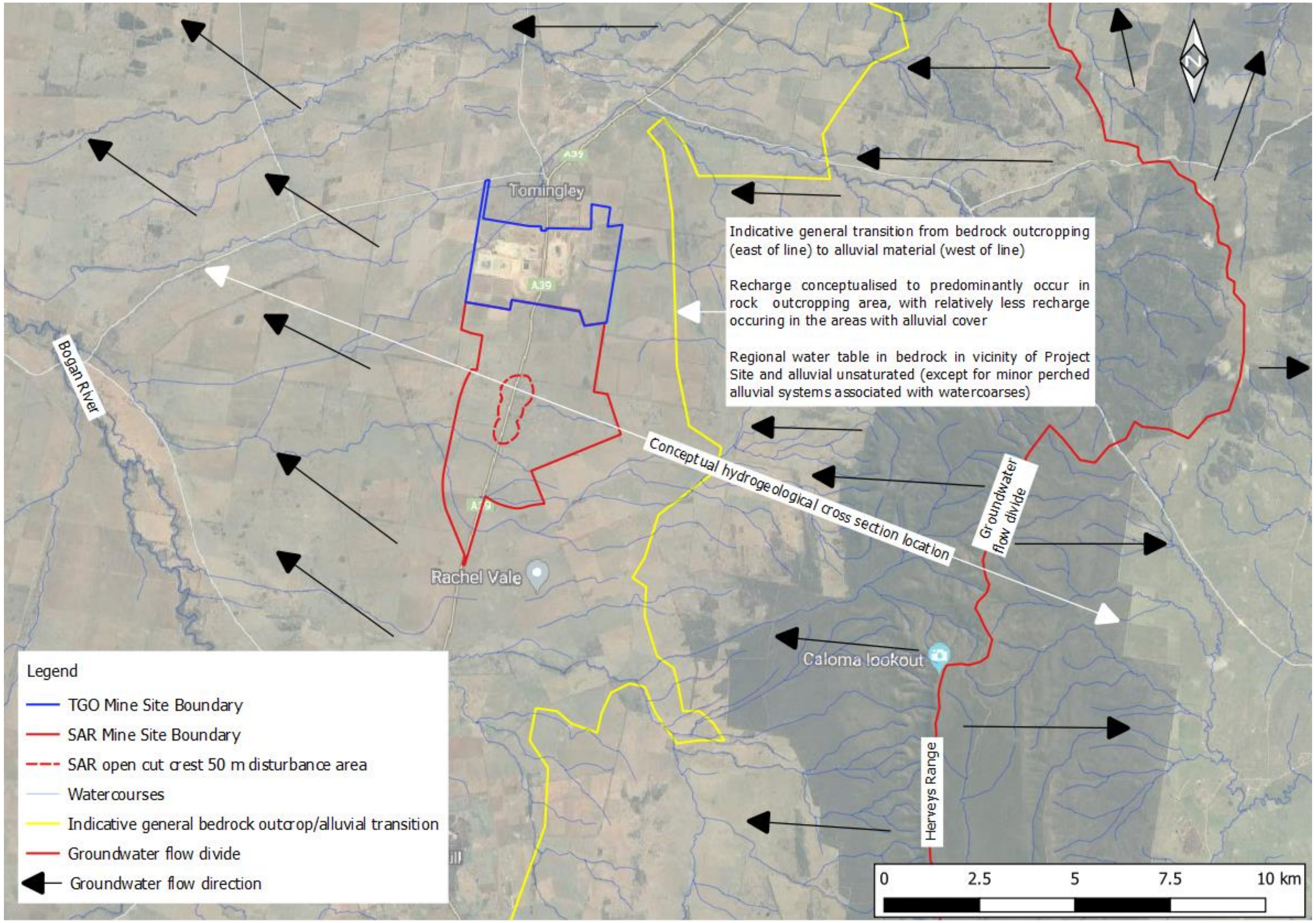


Figure 5.1: Conceptual hydrogeological plan, showing conceptual hydrogeological cross section location

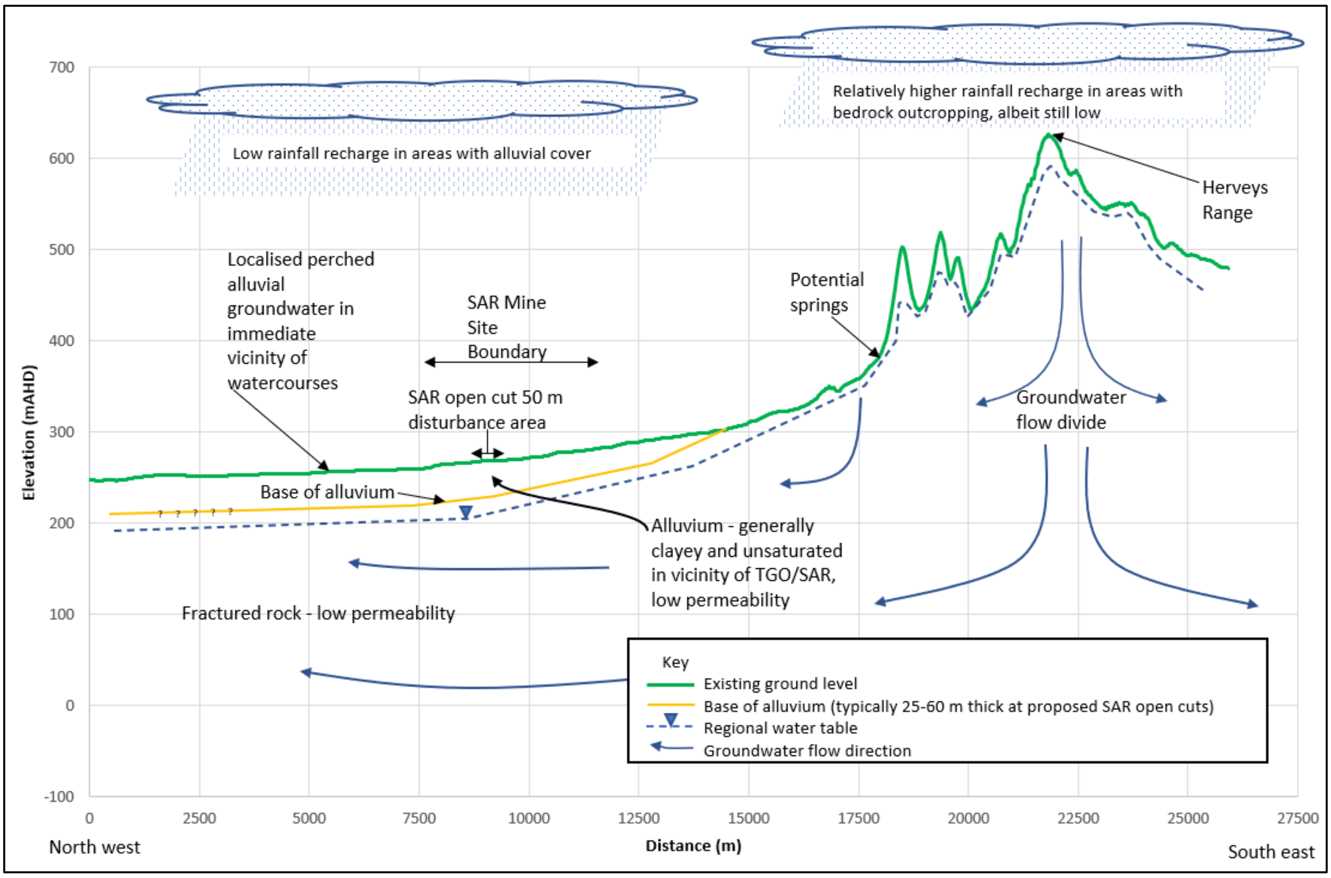


Figure 5.2: Conceptual hydrogeological cross section

5.2 Conceptual hydrogeological slice

A conceptual hydrogeological slice, along the main structural corridor at TGO and SAR is shown in **Figure 5.3**. The slice view is looking towards the northwest.

The slice was developed in geological modelling software, Leapfrog, by importing existing and proposed mine designs, a base of alluvium surface from site drilling data, SAR monitoring bores and a derived water table surface for existing conditions.

It is noted that in the southwest of the slice, the base of alluvium surface is deeper than in reality and has not been updated for drilling results at RWWB003. Groundwater level monitoring at RWWB003 shows that the alluvium in this location is shallower and unsaturated and that the water table is located within the fractured rock beneath the alluvium. Notwithstanding this, the slice is considered suitable for demonstrating conceptual hydrogeology and mine development.

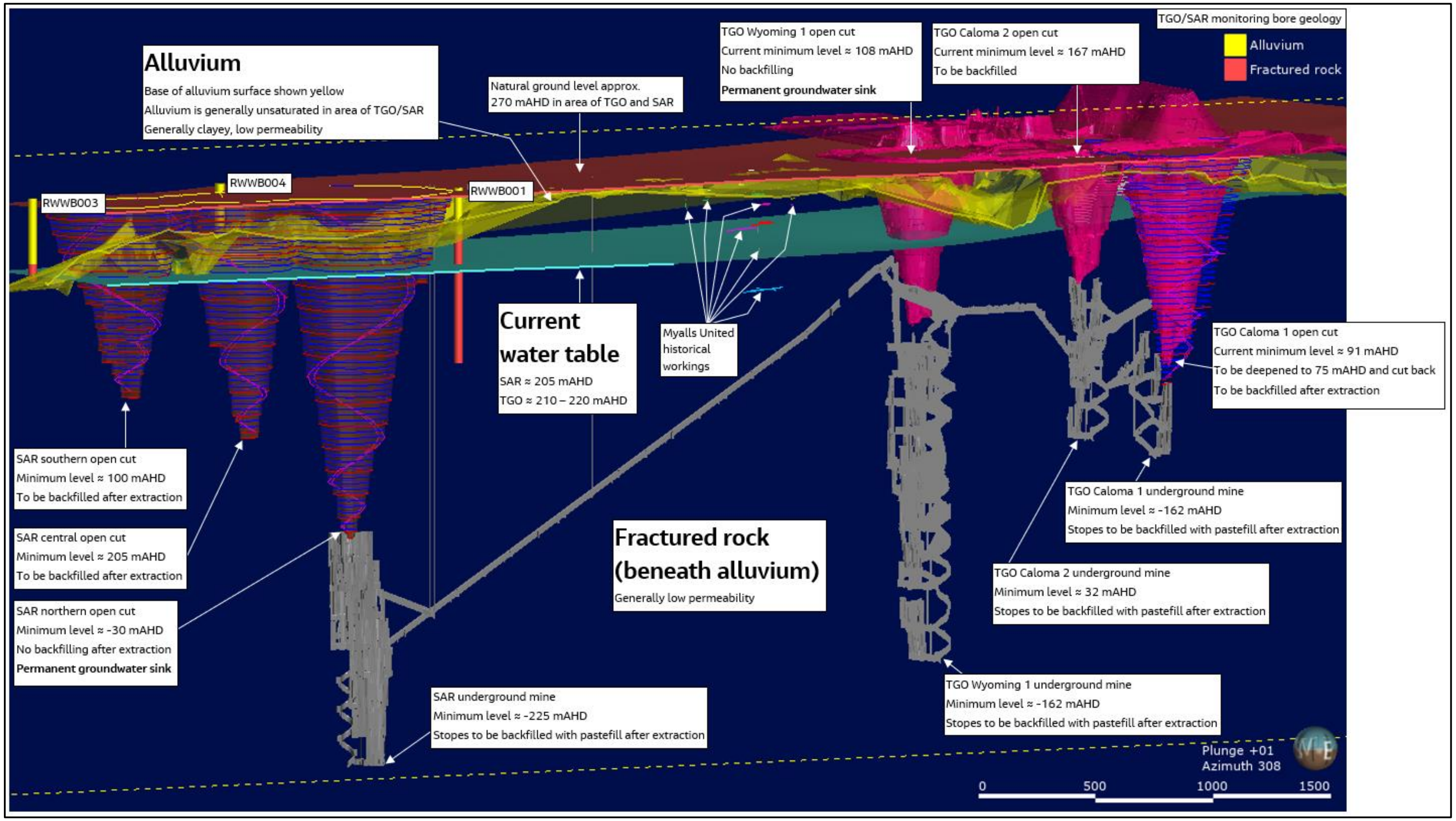


Figure 5.3: Conceptual hydrogeological slice

5.3 Conceptualisation verification

In response to Conditional Gateway Certificate Report (NSW IPC, 2021) requests for further information (**Section 1.5.3**) pertaining to the hydraulic separation between the shallow alluvium and fractured rock groundwater systems, to further demonstrate and verify the conceptualisation, the Applicant has committed to installing additional monitoring bores in late 2021 or early 2022.

The proposed locations of the additional monitoring bores are shown in **Figure 5.4,** with their specific purpose described as follows:

- Northern additional monitoring bore – a bore monitoring the fractured rock groundwater system is proposed in the vicinity of existing bore GW045137 or GW045134. These two bores are the closest bores with a purpose of 'water supply' to the TGO and SAR Mine Site Boundaries and are indicated to be installed within alluvium based on their shallow depths of 12.2 m (GW045137) and 18.3 m (GW045134), and the Work Summary drillers log for GW045134 (drillers log not available for GW045137).

  It is noted that groundwater levels are not reported in the drillers log for either GW045137 or GW045134. However, water bearing zones for GW045134 are noted from 7.3 mBGL to 8.5 mBGL and from 16.8 mBGL to 18.3 mBG, both within sandy clay.

  The ground surface elevation at GW045137 and GW045134 is approximately 280 mAHD. A screen base level of approximately 180 mAHD (100 mbgl) is proposed for the additional monitoring bore, with a screen length of approximately 12 m to 24 m, subject to drilling observations and the screen remaining wholly with fractured rock. The screen base level aligns with being slightly lower than the approximate minimum monitored groundwater level (200 mAHD) at the existing TGO monitoring bores, which occurred at WYMB10, and has been chosen to minimise the chance of the additional bore being dry as a result of being screened above the fractured rock groundwater level.

  Out of the two potential locations (i.e. GW045137 or GW045134), GW045134 is considered preferable due to it being deeper and having water bearing zones reported. Therefore, there is considered to be more potential for this bore to be saturated and less potential to be unsaturated. Also, GW045134 is closer to Gundong Creek, and closer to an area plotted (BoM, 2021b) as high potential terrestrial GDE.

  The intent is to demonstrate that the groundwater levels within the fractured rock are significantly different to those in the alluvium, to further support the conceptualisation that the alluvium and fractured rock groundwater systems are disconnected in the area of the existing shallow bores with a purpose of 'water supply' and in the area of Gundong Creek. To facilitate this, in addition to groundwater level monitoring in the additional monitoring bore, groundwater level monitoring would be required in bore GW045134. If this is not agreeable by the bore owner, installing the additional monitoring bore in the vicinity of GW045137 may be preferable. If monitoring of either of the existing water supply bores is not practicable, then a new shallow groundwater monitoring bore will be installed into the alluvium.

- Southern additional monitoring bores – an additional paired site is proposed in the vicinity of Bulldog Creek within the SAR mine site boundary. The paired site would comprise a fractured rock monitoring bore with accompanying shallow alluvial monitoring bore. The purpose of the paired site is to demonstrate either lack of a shallow alluvium groundwater system at this location, or a disconnect between a shallow alluvium groundwater system, if present, and the underlying fractured rock groundwater system.

  A depth of 10 m is proposed for the shallow alluvial monitoring bore, with a nominal depth of 90 m is for the deeper fractured rock monitoring bore. The fractured rock monitoring bore would screened wholly within fractured rock. A depth of 90 m equates to an elevation of approximatyely 170 mAHD. This is well below fractured rock groundwater system groundwater level of about 206 mAHD in existing monitoring bore RWWB003, thereby reducing the risk of a dry bore.

It is noted that **Figure 5.4** also includes indicative intended RSF2 shallow monitoring bores, which are not relevant to substantiating the conceptualisation but are shown for completeness, to give an overview of the future groundwater monitoring network. Also, it is noted that shallow RSF1 monitoring bores are shown as BoM registered bores in **Figure 5.4**.

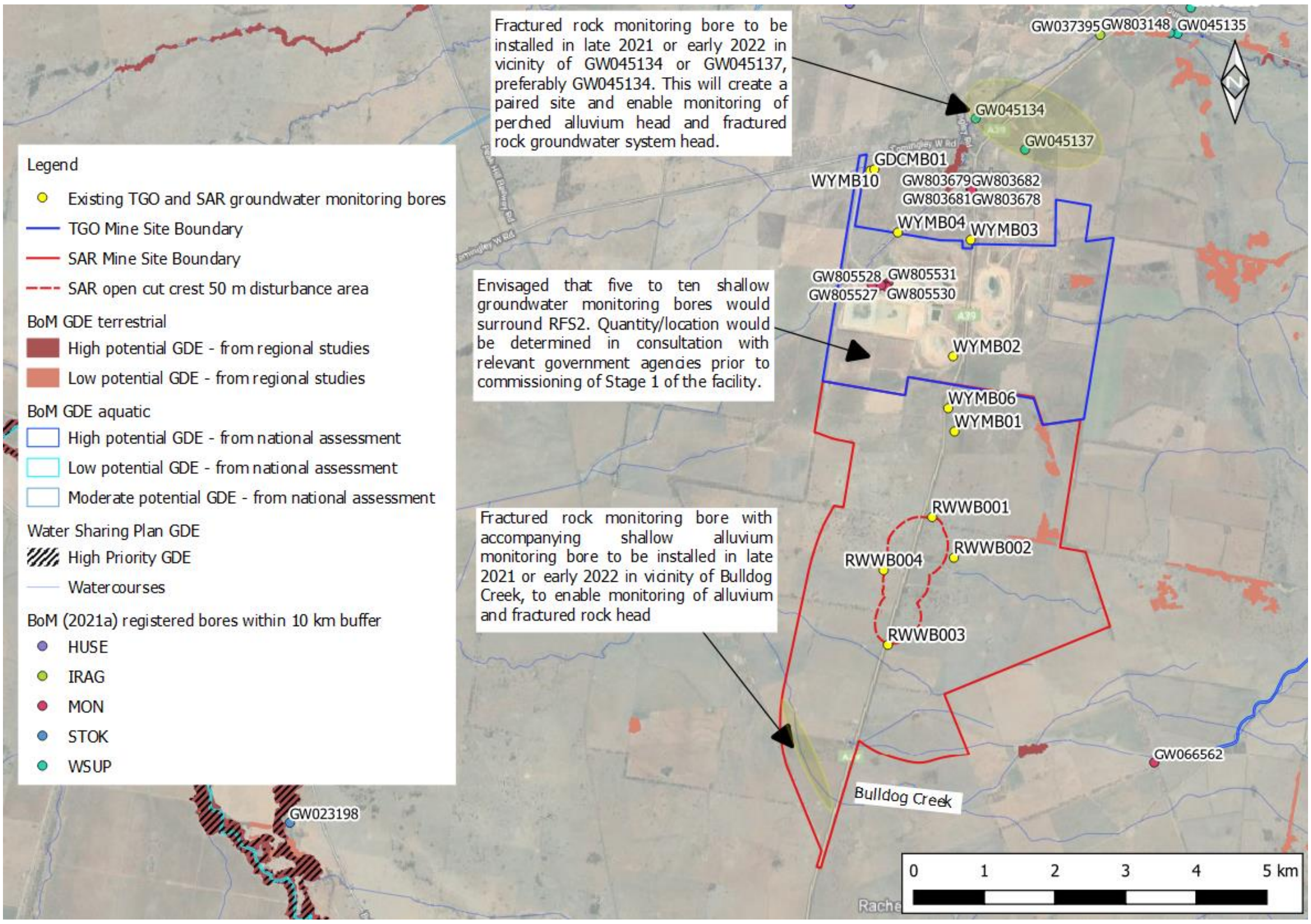


Figure 5.4: Proposed locations of additional monitoring bores to substantiate conceptualised perched alluvium - fractured rock groundwater system disconnect, and indicative intended RSF2 shallow monitoring bores

6. Numerical groundwater flow modelling

6.1 Model objectives

A numerical groundwater flow model (GFM) has been developed for the TGEP to inform the groundwater impact assessment. The modelling objectives were as follows:

- Predict future groundwater take due to mining operations, to inform assessment of water licensing entitlement requirements
- Predict associated propagation of groundwater level drawdown, to inform assessment of potential impacts to existing registered bores.

  It is noted that the model does not intend to predict drawdown at potential GDEs or High Priority GDEs. The fractured rock groundwater system that the model represents is conceptualised to not be associated with such GDEs. Therefore, whilst GDE mapping is included in model outputs for transparency/completeness, impacts to GDEs are assessed qualitatively, outside of the GFM. Also, potential impacts to baseflow to watercourses are assessed in this manner for the same core reasons.

The model was developed in accordance with the principles of the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), with uncertainty analysis undertaken in accordance with the principles of the IESC Uncertainty analysis guidance (Middlemis and Peeters, 2018).

6.2 Numerical code

The model has been developed using MODFLOW-USG, which was executed in the saturated flow mode. The input and output MODFLOW files were processed using the Groundwater Vistas Graphical User Interface Version 7.15 Build 8.

This type of model was elected because it is able to simulate three dimensional time-varying saturated flow through porous media and it is the industry standard code for groundwater flow modelling. Although the MODFLOW model was intended for porous media, an Equivalent Porous Media (EPM) approach can be taken to simulate groundwater flow in a fractured rock or dual porosity groundwater system. The EPM approach approximates a fractured rock or dual porosity groundwater system with a conceptualised, equivalent continuous medium. An EPM approach was adopted for the model.

6.3 Model assumptions and limitations

The TGEP GFM is a groundwater flow model developed to estimate groundwater take associated with mining operations and the resulting groundwater level drawdown.

The TGEP GFM includes the following assumptions and limitations:

- Modelling the subsurface in the model domain as an equivalent porous medium is valid.
- Modelling groundwater in the vicinity of the TGEP as a single-density fluid is valid.
- Conceptual errors associated with no-flow assumptions across no-flow boundaries along the northern, eastern and southern model exterior are negligible.
- The TGEP GFM does not simulate surface water processes, and as such, it does not address issues of surface-water routing and conveyance, or baseflows to watercourses.
- There exists the possibility that specific subsurface features that act as barriers or conduits to groundwater flow have not been explicitly represented in the TGEP GFM.

- All model elevations related to model layering and boundary conditions were referenced to the Australian Height Datum (AHD).
- Open cuts and underground mines are represented coarsely, spatially and temporally. Additionally, the model is a simplification of the complex natural system. Therefore, whilst the model is considered suitable to achieve the objectives, there is an inherent degree of uncertainty with results.
- Backfilled open cuts are not represented with altered hydraulic properties. Groundwater level recovery at backfilled open cuts is facilitated by deactivating drain (DRN) boundaries.
- Caloma 1 and 2 open cut water storage is represented by raising the DRN boundary level in each void to the average water storage level.

Additional limitations pertaining to model confidence level classification indicators are discussed in **Section 6.4**.

6.4 Model Class

In accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al.* 2012), the intended model confidence level classification is Class 2.

Table 6.1 presents a comparison between the characteristics of the model and quantitative indicators for that of a confidence Class 2 model, following the recommendation of Middlemis and Peters (2018). From **Table 6.1**, it can be seen that the TGEP GFM meets or exceeds the majority of Class 1 and Class 2 criterion.

Deficiencies in the model, as highlighted by the partially or non-met Class 1 and Class 2 criterion in **Table 6.1** are summarised as follows:

- 'Not much / sparse data coverage' – spatial and temporal head data and hydraulic conductivity data is considered reasonable in the vicinity of TGEP, and broader surrounding spatial head data is also considered reasonable. However, it is noted that there is no hydraulic conductivity information for areas within the model domain located further away from TGEP. There is also no continuous groundwater level monitoring data for areas located further away from the TGEP. Available data for the distal areas consists of individual groundwater level measurements obtained immediately following bore drilling.
- 'Long stress periods' – whilst the calibration and transient prediction model stress period length is one month and is not considered 'long', it is noted that the DRN boundaries in the model used to represent mining generally progress at intervals larger than one month. For predictive modelling, the drains used to represent open cuts progress on a six monthly basis. For underground mining, the drains levels progress at coarser intervals, generally ranging from six months to 30 months.
- 'Poor aquifer geometry' – it is noted that the model does not represent specific 'aquifer geometry'. However, this is because aside from shallow perched alluvium, the available data indicates the alluvium in the vicinity of TGEP is generally unsaturated. Also, the TGEP data does not support the presence of multiple groundwater systems with varying hydraulic properties (i.e. aquifers separated by confining units).
- 'Basic/initial conceptualisation' – the basic conceptualisation adopted is considered to be suitable based on the available data, problem and level of risk.
- 'Validation' – the model has not been validated.
- 'Some high resolution topography &/or some aquifer geometry' – as outlined above, specific aquifer geometry is not represented in the model. Given that topographic variation in the area is minimal, the use of high resolution topographic data is not considered essential for developing the conceptual and numerical groundwater models.
- 'Some coarse discretisation in key areas (grid or time)' – whilst the grid discretisation is considered adequate and not too coarse in key areas, as outlined above, the DRN boundary progression used to simulate mining is considered somewhat coarse. However, this does not hamper model objectives.

Table 6.1: Model confidence level classification characteristics and indicators

Class	Data	Calibration	Prediction	Quantitative Indicators
1 Simple	Not much / Sparse coverage	Not possible	Timeframe >> Calibration	Model predictive timeframe >10x transient calibration period
	No metered usage	Large error statistic	Long stress periods.	Stresses in predictions >5x higher than calibration
	Low resolution topography	Inadequate data spread	Poor / no validation.	Mass balance error > 1% (or one-off >5%)
	Poor aquifer geometry.	Targets incompatible with model purpose.	Targets incompatible with model purpose.	Properties <> range from expected field values
	Basic / Initial conceptualisation.			No review by Hydrogeologist / Modeller.
2 Impact assessment	Some data / adequate coverage.	Weak seasonal match.	Timeframe > Calibration	Predictive timeframe = 3 to 10x calibration (exceeded for life of mine predictions)
	Some usage data/low volumes.	Long-term trends not replicated in entire model domain.	Long stress periods.	Stresses = 2 to 5 greater than calibration
	Baseflow estimates. Some hydraulic conductivity and storage measurements	Partial performance (e.g. some statistics / part record / model-measure offsets).	Validation. (no validation undertaken at this stage)	Mass balance error< 1%
	Some high resolution topography &/or some aquifer geometry.	Head & Flux targets used to constrain calibration.	Calibration & prediction consistent (transient or steady-state)	Some properties <> range from expected field values.
				Review by Hydrogeologist
	Sound conceptualisation, reviewed & stress-tested.	Non-uniqueness and qualitative uncertainty partially addressed.	Significant new stresses not in calibration.	Some coarse discretisation in key areas (grid or time).
3 Complex simulator	Significant data, good coverage.	Good performance statistics.	Timeframe ~ Calibration	Predictive timeframe = < 3x calibration period (with exception of post mining period)
	Good metered usage information.	Most long term trends matched.	Similar stress periods.	Stresses < 2x
	Local climate data.	Most seasonal matches OK.	Good validation. (no validation although calibration constrained by past mine inflows)	Mass balance error < 0.5%

Class	Data	Calibration	Prediction	Quantitative Indicators
	Aquifer testing data (Kh, Kv & Sy) measurements from range of tests.	Present day head / flux targets, with good model validation.	Transient calibration and prediction.	Properties ~ field measurements.
	High resolution topography in all areas with good aquifer geometry.	Non-uniqueness minimised, qualitative uncertainty justified.	Similar stresses to those in calibration.	No coarse discretisation in key areas (grid or time).
	Detailed conceptualisation.			Review by experienced Modeller.
Legend	Criterion exceeded	Criterion met	Criterion partially met	Criterion not met

6.5 Model set up

6.5.1 Model domain and boundaries

Figure 6.1 presents the extent of the active model domain, which has maximum extents of approximately 37 km east to west by 27 km north to south. The active model boundary locations are associated with a groundwater flow divide, inferred groundwater flow directions and a down gradient boundary to allow groundwater to exit the model. The boundaries are located at a distance from the Project Site such that the assessment of mine inflows and resulting drawdown will have negligible influence from any boundary conditions.

External model boundaries adopted for the GFM, include:

- General head boundary
  - The General-Head Boundary package (GHB) is used to simulate head-dependent flux boundaries. The GHB allows flow to enter or leave the model domain based on calculated heads within the model domain, specified heads at a distance outside the model domain and a hydraulic conductance term.
- Specified flux (no flow) boundaries
  - No flow boundaries are specified flux boundaries with flux set at zero.

The areal extent of the active model domain is included in **Figure 6.1** and is defined as follows:

- The northwestern model boundary is a GHB set orthogonal to the dominant groundwater flow direction. The GHB was assigned uniformly to all model layers. The head at the boundary was assigned a level of 171 mAHD and the conductance was assigned a value of 4,250 m^2/d. The conductance value was calculated by Groundwater Vistas based on assigned saturated cell thickness of 85 m, width of GHB cell of 500 m, hydraulic conductivity of 0.1 m/d, distance to GHB head of 1 m, and the following formula:

  Conductance (m^2) = Hydraulic conductivity (m/d) * saturated cell thickness (m) * width of GHB cell (m) / distance to GHB head (m)

  The adopted head at the boundary of 171 mAHD and conductance value of 4,250 m^2/d were determined during calibration via an iterative step-wise process using manual adjustment of input parameters. Ground surface elevation along this boundary is in the range of about 230 mAHD to 240 mAHD. Therefore, the assumed fractured rock groundwater level of 171 mAHD is about 59 mBGL to 69 mBGL, which is in keeping with pre-mining fractured rock groundwater system groundwater level depths at TGO and SAR.
- Herveys Range is a no flow boundary and is applied to represent a groundwater flow divide conceptualised to occur along the range.

- The northern, southern and eastern extremities are assigned as no flow, with the boundaries set parallel to the dominant groundwater flow direction.

The closest boundary to SAR and TGO is the northern boundary at approximately 9.9 km and 6.5 km, respectively.

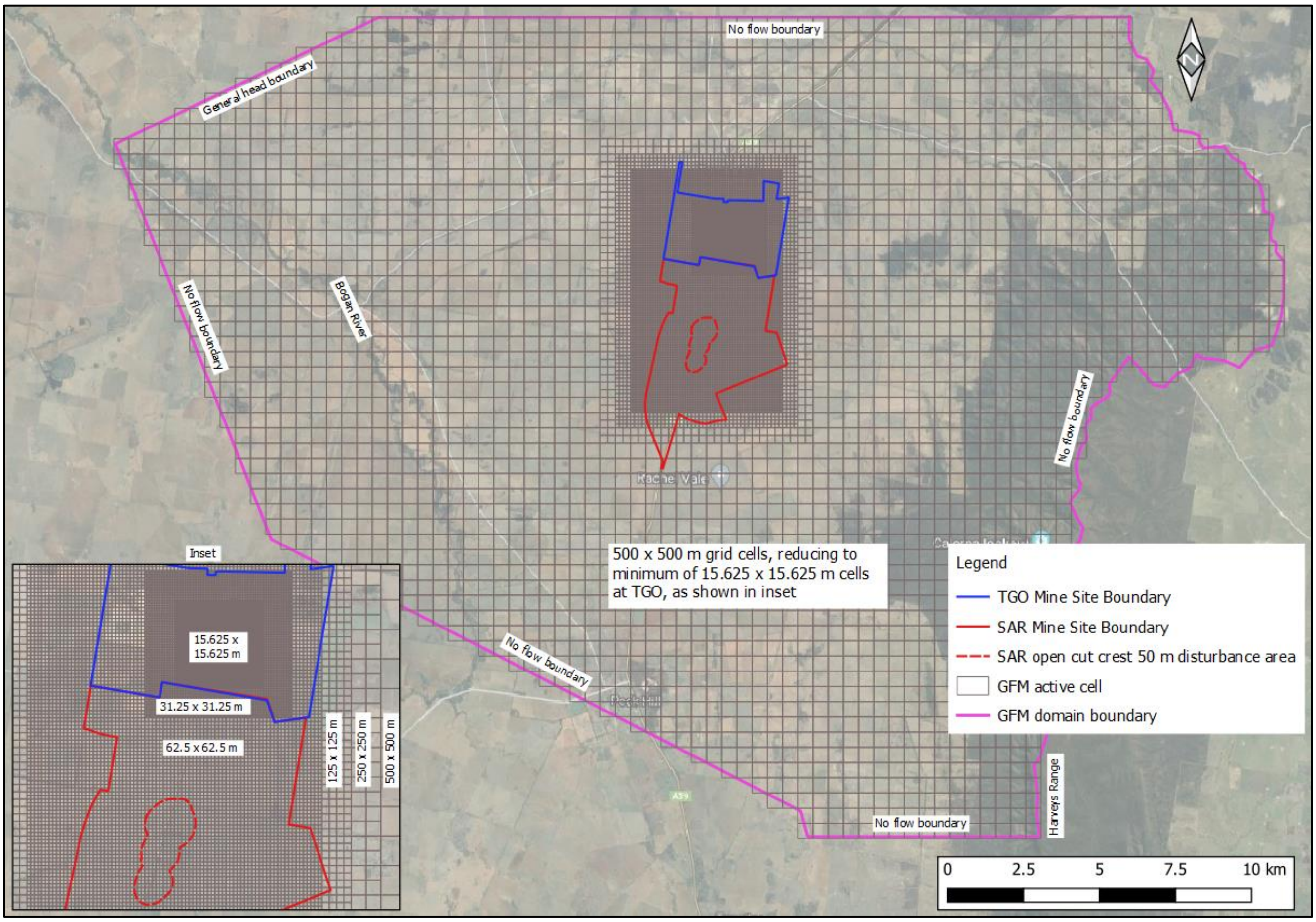


Figure 6.1: GFM active domain boundary and cells

6.5.2 Model grid

The model grid incorporates quadtree refinement to allow more detail in key areas of interest. The model grid comprises cell sizes ranging from 15.625 m to 500 m, with the 15.625 m grid cells used in the vicinity of mining operations at TGO and 62.5 m cells used at SAR (**Figure 6.1**). The origin point (0, 0) for the entire model grid (i.e. including inactive cells) is easting 592,000 m and northing 6,374,000 m (Map Grid of Australia 1994, Zone 55). The model grid is not rotated.

The total number of cells, across 6 model layers (vertical) is 93,240, of which 83,634 cells are within the active model domain.

6.5.3 Model layers

All of the applied model layers represent the fractured rock groundwater system and do not represent conceptualised different groundwater system layers within the fractured rock groundwater system. Instead, model layer elevations were assigned based on topography (top of Layer 1) and existing and proposed mining levels, so that various DRN boundaries within model different layers could adequately represent mining. The bottom model layer was established to enable interaction of mining with the groundwater system below the extent of mining.

Model layer elevations were as follows:

- Layer 1 (top): derived using the hydrologically enforced digital elevation model (1 second SRTM data) (Galant *et al.*, 2011).
- Layer 1 (bottom): 170 mAHD, uniform.
- Layer 2 (bottom): 70 mAHD, uniform.
- Layer 3 (bottom): -35 mAHD, uniform.
- Layer 4 (bottom): -100 mAHD, uniform.
- Layer 5 (bottom): -180 mAHD, uniform.
- Layer 6 (bottom): -300 mAHD, uniform.

The bottom of Layer 6 (-300 mAHD) is about 75 m below the minimum level of proposed mining (i.e. about -225 mAHD for SAR underground mine). Such a layer thickness is considered adequate to represent interaction of mining with the underlying groundwater system.

As discussed in the calibration section, **Section 6.8**, hydraulic parameter zonation is uniform for all model layers. The uniform model layer elevations and uniform hydraulic parameter zonation for the model layers is considered appropriate and is in keeping with the hydrogeological conceptualisation.

The adopted model layering relates to the hydrogeological conceptualisation in the following ways:

- In the vicinity of the project, the shallow perched alluvium groundwater system has been shown to be hydraulically disconnected from the lower fractured rock groundwater system that the project will directly interact with. The project is conceptualised as likely to have no significant interaction from a groundwater perspective with this unit. As such, this unit is not represented in the groundwater model, either through layering or hydraulic parameter zonation.
- In the vicinity of the project, the Cainzoic alluvial groundwater system has been shown to be unsaturated and does not locally represent an aquifer. As this system is unsaturated in the vicinity of the project, interaction of the project with this unit from a groundwater perspective is conceptualised to be insignificant. As such, this unit is not explicitly represented in the groundwater model, but can be considered to be incorporated within Layer 1.
- Distinct separate and significant hydrogeological layers are not conceptualised within the fractured rock groundwater system in the vicinity of the project. Instead, the available data indicates that the rock mass in the vicinity of the Project Site is generally 'tight' with relatively low hydraulic conductivity, and with limited distinct 'aquifers'. Some localised elevated hydraulic conductivity may be anticipated due to local fracture conditions; however, any such fractures are unlikely to be extensive or interconnected and any associated inflows would be short lived. As a result, the uniform model layer elevations and uniform hydraulic parameter zonation for the model layers is appropriate and in keeping with the conceptualisation.

South to north and west to east cross sections through the GFM are shown in **Figure 6.2**.

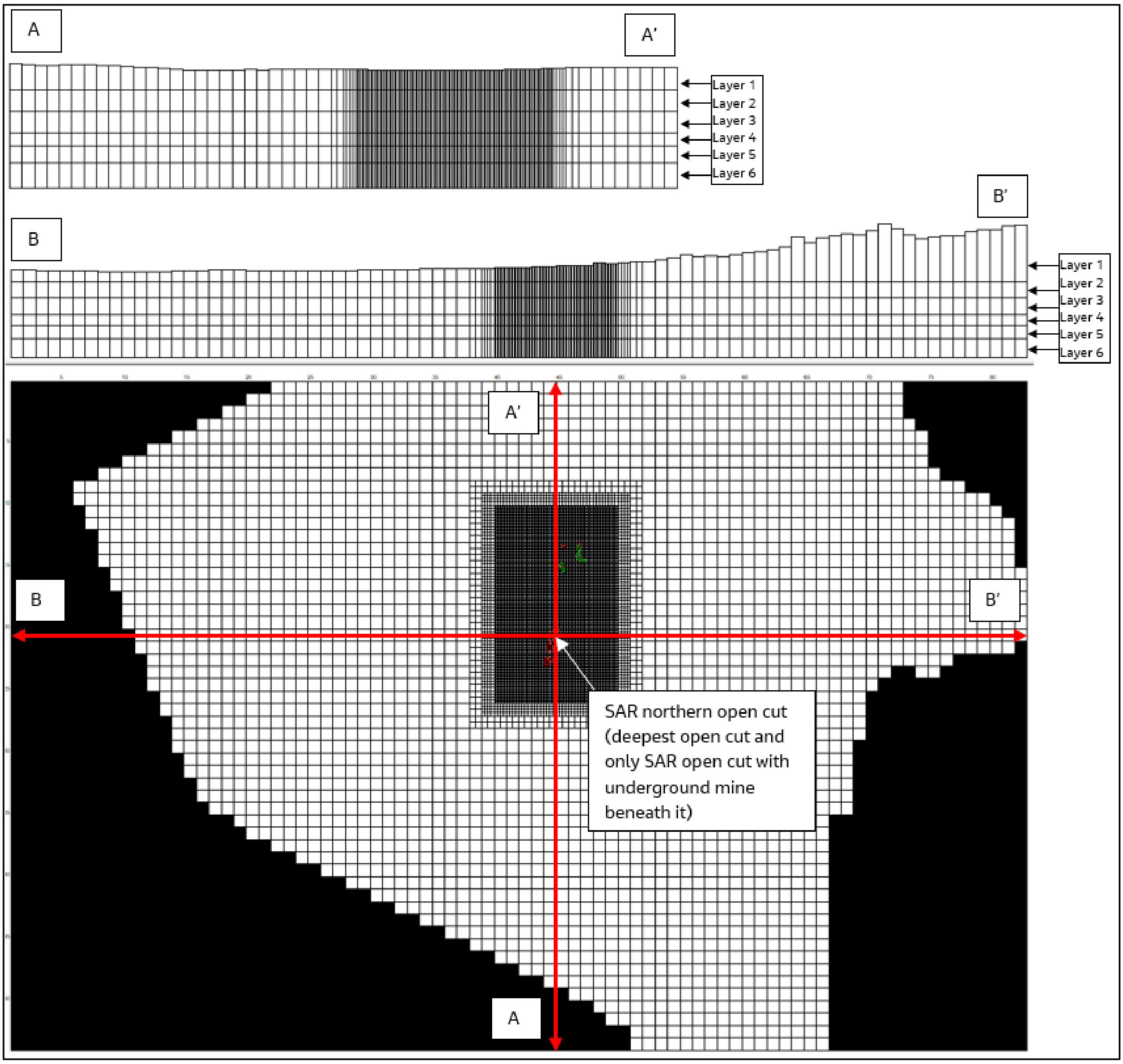


Figure 6.2: Cross sections through GFM

6.5.4 Model layer type

Layers 1 to Layer 5 were assigned a layer type of USG Upstream Water Table and Layer 6 was assigned a Layer type of confined. The confined layer was introduced to achieve model stability, as without it, solution convergence was difficult.

6.5.5 Internal boundary conditions

Drains

The DRN boundary condition is a head dependant flux boundary that is suitable for simulating mine dewatering.

The volume of water removed by a cell with a DRN boundary applied to it is dependent on the DRN cell conductance value and the difference between the specified DRN level and the groundwater level calculated by the model for the DRN cell. The DRN boundary has potential to remove groundwater from the model but cannot add groundwater to the model. If the calculated head in the model cell is below the specified DRN level, no groundwater is removed and the DRN boundary condition is essentially dormant. Conversely, if the head in the model cell is above the specified DRN level, the DRN boundary removes groundwater from the model.

DRN boundaries are used in the model to simulate dewatering associated with open cut and underground mining.

DRN cells on areas of open cut were assigned a conductance based on full cell width and length (62.5 m x 62.5 m at SAR and 15.625 m x 15.625 m at TGO), drain thickness of 1 m and vertical drain hydraulic conductivity of 100 m/d. The computed uniform conductance rate was 390,625 m^2/d for SAR and 24,414 m^2/d for TGO, which effectively results in the model efficiently removing groundwater from the cells if the groundwater head is higher than the DRN stage. DRN stages were set based on minimum mining levels.

DRN cells were applied to encompass areas of underground mining and the DRN conductance was determined during calibration, through manual trial and error, by approximately matching modelled DRN flows to a water balance based estimate of Wyoming 1 underground mine inflows (RW Corkery & Co, 2020). DRN stages in underground mining areas were also set based on minimum mining levels.

The applied DRN boundary conductance values and DRN levels have implications for the estimated groundwater inflow rates and groundwater levels (and groundwater level drawdown) in areas influenced by the DRN cells

Recharge

Rainfall recharge to the model was represented using the Recharge (RCH) boundary condition. This recharge was informed by rainfall data obtained from the SILO climatic database.

Recharge zones were defined based on the geological information from the Narromine 1:250,000 Metallogenic Series Sheet (Bowman et.al, 1980). The following two recharge zones shown in **Figure 6.3** were defined based on the most eastern transition from outcropping bedrock to alluvium:

- Zone 1 – floodplain and lower slopes
- Zone 2 – foothills and upper slopes

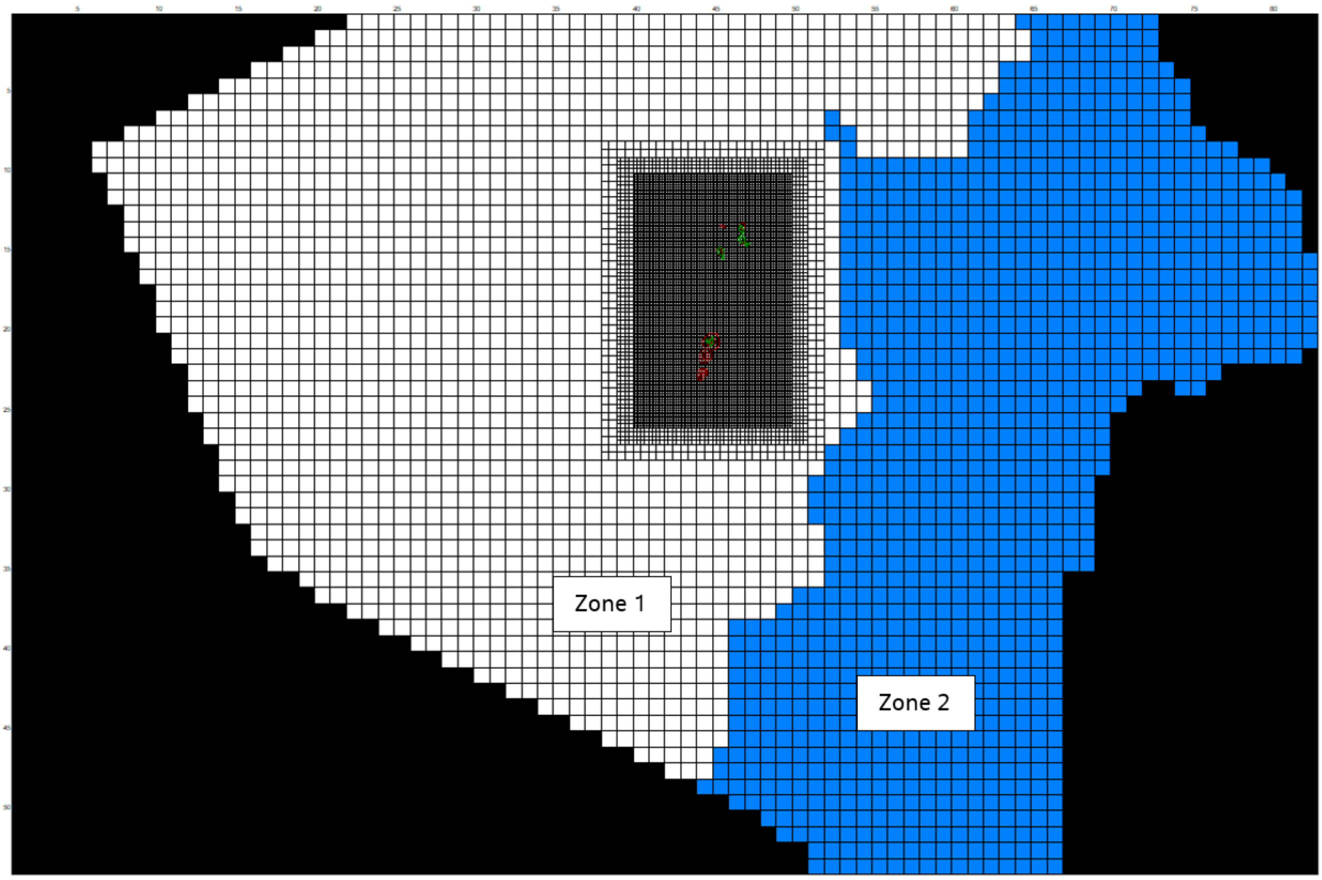


Figure 6.3: GFM recharge zones

Evapotranspiration

Losses from the model via evapotranspiration (ET) were represented using the Evapotranspiration (EVT) boundary condition. One EVT zone was assigned over the entire model domain to represent ET. The maximum (applicable when water table at or above model ground surface level) ET rate applied for all stress periods was 3.93 mm/d and was based on the FAO56 average daily evaporation rate from 01/01/1970 to 05/04/2021 from SILO data extracted for the now closed Tomingley weather station (Bureau of Meteorology station # 050091), point Latitude -32.60 degrees north and Longitude 148.20 degrees east.

The EVT extinction depth was set at a uniform value of 2.0 m. The EVT extinction depth is the depth at which ET approaches zero, and beyond which the EVT boundary cannot remove water from the model.

The use of a single EVT boundary zone and constant EVT rate for the model is a simple approach and is considered appropriate because losses via the EVT boundary condition do not occur in the vicinity of the mine due to the depth of the regional water table being far below the EVT extinction depth. Therefore, ET is not an important process to model at a high level of detail in order to achieve model objectives.

6.6 Fault representation

Faults are not represented in the groundwater model. The faults that have been identified by the Applicant (**Section 4.4.5**) pre-date the Cainozoic alluvium and therefore would not provide enhanced connectivity between surface water features and the fractured rock groundwater system. Also, due to the lack of existing fractured rock production bores surrounding the project, there is limited potential for enhanced drawdown to impact at an existing fractured rock production bore due to the influence of faulting on groundwater flow.

There is a potential for the faults identified by the Applicant to influence groundwater inflow rates to the project. However, this is not distinctly indicated by the currently available hydraulic testing data and has little relevance to groundwater impacts for the reasons outlined above. General potential for elevated hydraulic conductivity is assessed in the uncertainty analysis.

6.7 Cumulative impacts consideration

Cumulative impacts are not relevant to the model and groundwater impact assessment. Except for the historic Myalls United gold mine, located between the TGO and SAR Deposits, and Peak Hill mine located about 10 km south of the Project Site, there are no existing mines in the region of the mine.

As shown in **Figure 5.3**, the historic Myalls United gold mine workings are very small in extent and are separated from the project's existing and proposed mining. Also, the workings are anticipated to be flooded and surrounding groundwater levels recovered from potential historic mining induced drawdown. Potential historic mining induced drawdown is anticipated to have recovered relatively quickly because the Applicant indicates that shafts to these workings are subjected to flow from surface flooding, and the workings have been previously intentionally flooded during feasibility testing associated with assessing their potential to be used as a water storage.

Peak Hill mine open cut water levels are discussed in **Section 7.6**, where it is concluded that the water level in the main Peak Hill open cut is interpreted to have come to an equilibrium level that is considerably higher than the minimum open cut level and likely to a level slightly below the regional water table level, due to evaporative loss. Due to the main Peak Hill open cut interpreted water levels being slightly below the regional water table level, given Peak Hill mine is located about 10 km south of the Project Site, cumulative impacts associated with Peak Hill mine interacting with the project are considered highly unlikely.

In light of above, the historic Myalls United gold mine and Peak Hill mine are not incorporated into the model.

6.8 Calibration

The TGEP GFM was calibrated to observed groundwater conditions to ensure the model's ability to replicate the behaviour of the natural groundwater system.

The calibration was performed for both steady state and transient groundwater conditions.

Initial model parameter values, prior to calibration, are shown in **Table 6.2**.

Table 6.2: Initial model parameter values, prior to calibration

Parameter	Initial pre-calibrated base case model value
Horizontal hydraulic conductivity (m/d) [1]	All zones: 0.00271 (geomean of all site testing)
Recharge rate as % of mean annual rainfall	Zone 1 and 2: 1%
Evaporation rate (mm/d)	3.93
Storage	Specific storage = 1.3×10^{-7} Specific yield = 0.05
DRN conductance for open cuts (m^2/d)	Variable, depending on cell area, but calculated based on cell area, DRN thickness of 1 m and vertical drain hydraulic conductivity of 100 m/d 390,625 m^2/d for 62.5 m x 62.5 m cells 24,414 m^2/d for 15.625 m x 15.625 m cells
DRN conductance for Wyoming 1 (m^2/d)	0.05

Note: [1] Applied vertical hydraulic conductivity = 1/10 x horizontal hydraulic conductivity.

6.8.1 Steady state calibration parameters and results

6.8.1.1 Approach

The steady state model was calibrated to the first available (20/03/2007) standing water level measurements at TGO groundwater monitoring bores, WYMB002, WYMB003 and WYMB004, and with a few exceptions, standing water levels at registered bores interpreted to be associated with the fractured rock groundwater system. This resulted in registered bores GW804561, GW802832, GW802834, GW802842 and GW801299 being included as calibration targets. The registered bore standing water level measurements occur in various years, 1993 (one bore), 1997 (three bores) and 2001 (one bore).

Standing water level measurements were available on 20/03/2007 at WYMB001 and WYMB006. However, these locations were not assigned as calibration targets due to water level analysis (**Section 4.2.1**) indicating these bores are likely in hydraulic connection with historical underground workings and at times record markedly different water levels compared to the other TGO bores.

The following registered bores interpreted to be associated with the fractured rock groundwater system were excluded as calibration targets:

- GW027631 – excluded as a calibration target because this bore is very close to GW804561 and there is considerable head difference between the standing water levels (about 28 m). Bore GW804561 was used as a target instead of GW027631 or both GW027631 and GW804561. Bore GW804561 was selected because it had the shallowest standing water level.
- GW802483 – excluded as the relatively shallow standing water level depth (12 m) does not align with the relatively deep water bearing zone depth (centre about 51 m) and there is no aquifer at 12 m depth based on the lithology log. Thus, the reported standing water level is thought to represent perched water table conditions. Furthermore, the reported standing water level in the datum of mAHD is about 225 mAHD and upgradient bore, GW802842, has a standing water level of about 212 mAHD. This is a disparity and not consistent with the demonstrated regional flow direction.

Equal weighting was assigned to observed heads from the registered bores and the TGO monitoring bores.

Calibration was undertaken via an iterative step-wise process using manual adjustment of input parameters (hydraulic conductivity and recharge) within realistic ranges to achieve an acceptable match between simulated and observed heads (groundwater levels). Calibration success was gauged by qualitatively assessing the match between modelled and observed heads as well as assessing statistical calibration measures. Calibration was considered complete when a reasonably good match between observed and simulated heads was obtained.

6.8.1.2 Calibrated hydraulic conductivity zones and values

Initially, the simplest zonation possible of hydraulic conductivity was trialled, a single zone over the entire model. Justification for this initial simplistic approach is provided in **Section 6.5.3**. However, this approach resulted in unfavourable calibration, primarily due to the model not appropriately representing steeper hydraulic gradients in the foothills/upper slopes east of the mine. To address this, firstly, a total of seven hydraulic conductivity zones (**Figure 6.4**) were introduced into the model, largely based on the Narromine 1:250,000 Metallogenic Series Sheet (Bowman et.al, 1980):

- Zone 1 – fractured rock west of Zone 2
- Zone 2 – siltstone and shale
- Zone 3 – fractured rock in area of mine
- Zone 4 – siltstone and sandstone
- Zone 5 – granite
- Zone 6 – Dulladerry Rhyolite
- Zone 7 – Hervey Group (shale, siltstone and sandstone)

Although a total of seven hydraulic conductivity zones were initially incorporated into the model, a successful attempt was made to limit the number of zone values, which effectively resulted in three zones of differing hydraulic conductivity (**Figure 6.5**). This approach was taken to limit unnecessary model complexity. The applied horizontal hydraulic conductivity values were as follows:

- Zone 1 – 0.05 m/d
- Zone 2 and 3 – 0.01 m/d
- Zone 4, 5, 6 and 7 – 0.001 m/d

Of the applied three zones (**Figure 6.5**), the hydraulic conductivity for the zone enveloping the mine of 0.01 m/d is similar to the arithmetic mean of packer test values and all test type values. This value aligns with the conceptualisation that that the rock mass in the vicinity of the Project Site is generally 'tight' and relatively low hydraulic conductivity, with limited distinct 'aquifers'. The hydraulic conductivity values for the zones west and east of the enveloped zone of 0.05 m/d and 0.001 m/d, respectively, are also in keeping with the conceptualisation that the rock mass is of relatively low hydraulic conductivity and were arrived at through trial and error calibration.

Vertical hydraulic conductivity was assigned a value one tenth of horizontal hydraulic conductivity for all zones. This anisotropy was adopted as it allowed for model calibration with reasonably conservative hydraulic parameters and in particular allowed matching to the magnitude of observed mining related drawdown at WYMB002 (**Section 6.8.2.4**). However, it is noted that isotropic hydraulic conductivity (i.e. vertical hydraulic conductivity equivalent to horizontal hydraulic conductivity) was assessed as an uncertainty analysis scenario (**Appendix D**).

The zonation is uniform for all model layers and aligns with the conceptualisation. Justification for this approach is provided in **Section 6.5.3**.

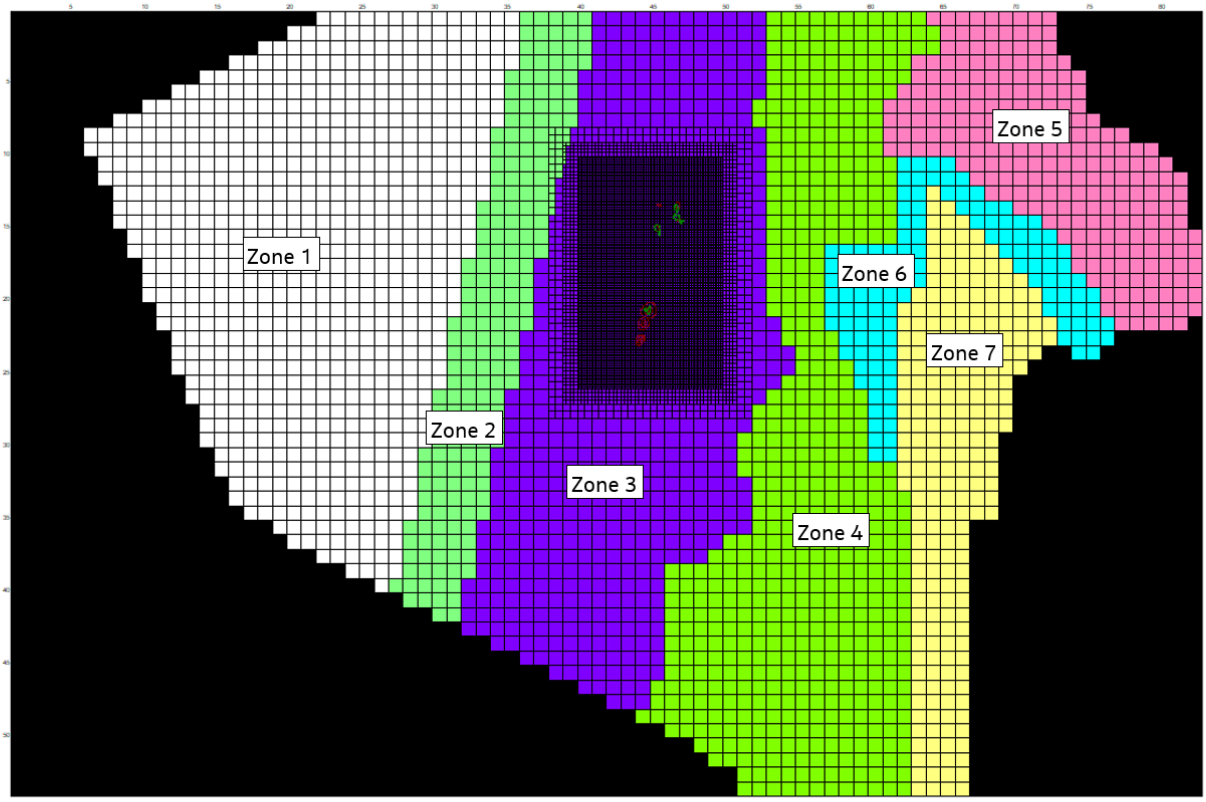


Figure 6.4: Hydraulic conductivity zones (prior to simplification)

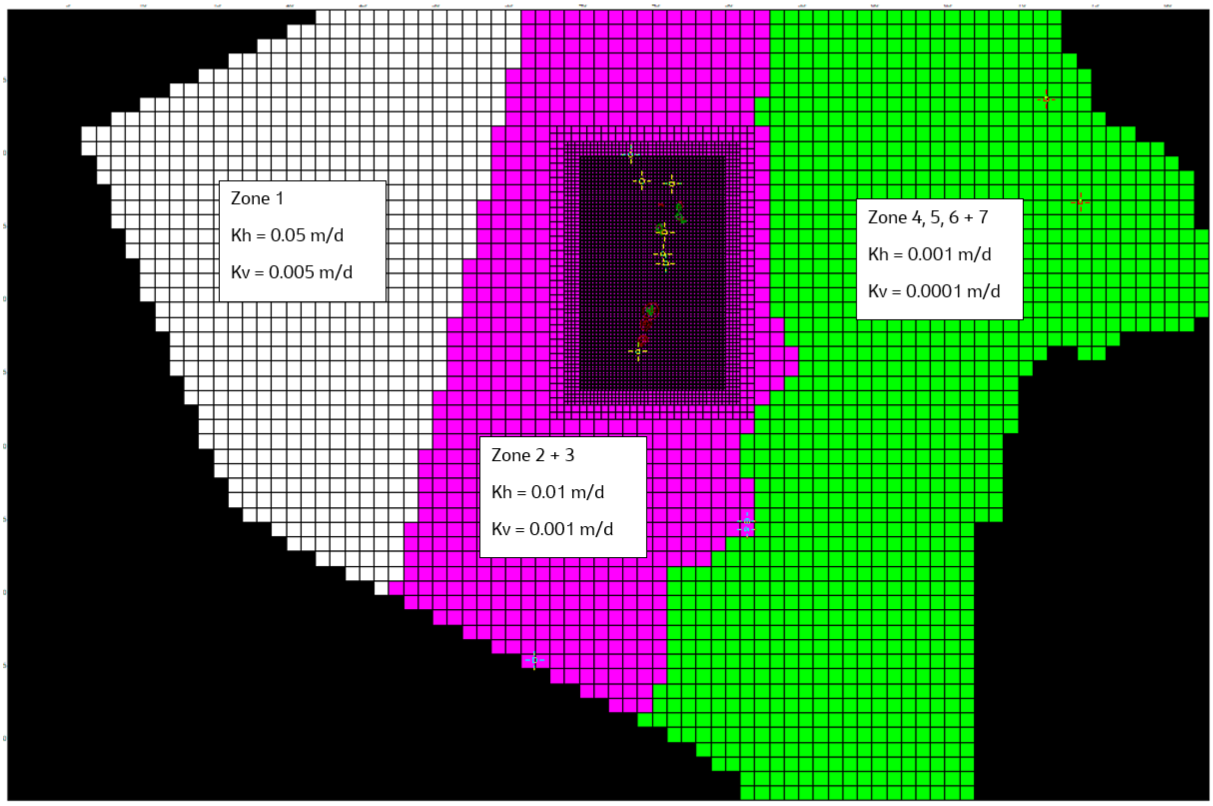


Figure 6.5: Effective and simplified hydraulic conductivity zones and values

6.8.1.3 Calibrated recharge rates

Recharge rates of 0.2 mm/year and 1 mm/year were assigned to recharge Zone 1 and 2, respectively (**Figure 6.5**). The recharge rates were determined through trial and error calibration, whilst constraining hydraulic conductivity values for the hydraulic conductivity zone enveloping TGP (representing Zone 2 and 3), to be similar to the arithmetic mean of TGEP test values.

The applied recharge rate for both recharge zones is considered low but aligns with the conceptualisation. Chloride mass balance recharge estimation supports a low recharge rate. Relatively higher recharge is expected in the elevated portions of the model where rock outcropping occurs. Relatively lower recharge occurs in areas with thick clayey alluvium cover.

The mean annual rainfall at TGEP is about 562 mm/year (**Section 3.1**). Thus, the maximum applied recharge rate of 1 mm/year for Zone 2 is about 0.18 % of average annual rainfall. The relatively low recharge rates as a percentage of average annual rainfall are considered plausible given the hydraulic conductivity values in the area of the mine have been constrained to be similar to the arithmetic mean of test values, and because literature supports low recharge in the area of the model, as does the geology and recharge estimation via chloride mass balance (**Section 3.6**).

CSIRO (2011) broad scale mapping indicates recharge in the area of the GFM is of the order of 1 mm to 5 mm per year. The applied rate for Zone 2 is within this range. The applied rate for Zone 1 is below this range. However, a relatively lower recharge rate is conceivable given the thick clayey alluvium cover. Significantly less recharge is expected to be able to migrate through thick alluvium compared to areas where bedrock is outcropping or subcropping.

6.8.1.4 Evapotranspiration

The EVT zonation and rate was not altered during calibration and was kept as described in **Section 6.5.4**.

6.8.1.5 Calibration results

A comparison of modelled groundwater levels and observed groundwater levels is provided in **Figure 6.6** and **Table 6.3**. Steady state calibration statistics are provided in **Table 6.4**.

Figure 6.6 shows the match between simulated steady state heads and observed heads for all calibration targets. Qualitative assessment of the degree of calibration can be determined by the match between modelled and observed heads that are shown on **Figure 6.6**. This is determined according to how close the plotted points are to the diagonal line from the origin (i.e. along the line y=x that represents perfect calibration). As shown on **Figure 6.6,** there is a good correlation between simulated and observed heads (groundwater levels).

The scaled root mean square (scaled RMS) is one of the statistics often used to quantitatively assess the goodness-of-fit between simulated groundwater levels and actual observed groundwater levels. A scaled RMS error less than ten percent can, depending on the circumstances, is usually a good indicator of a reasonable degree of calibration. The scaled RMS error of 5.5% obtained in the calibrated steady state model indicates the model is reasonably well calibrated to measured heads.

Given the good match between simulated and observed heads in **Figure 6.6** and the acceptable calibration statistics (**Table 6.4**), it was concluded that the steady state model simulates average groundwater levels (heads) with reasonable accuracy.

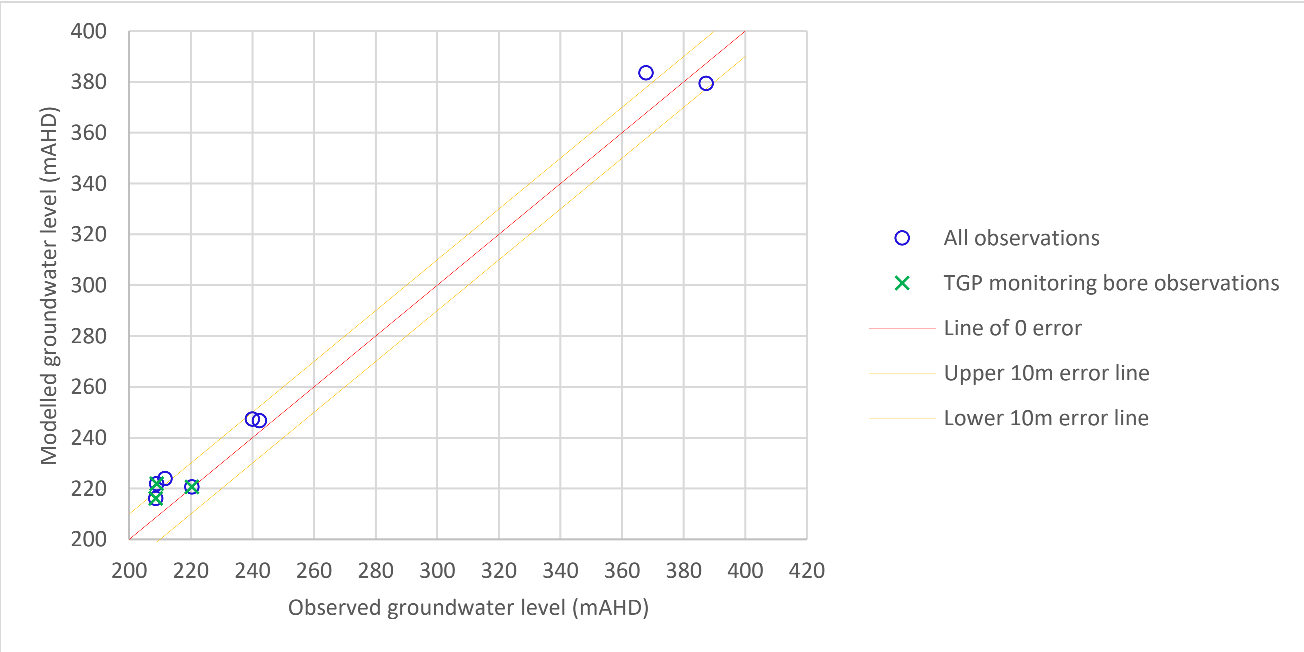


Figure 6.6: Steady state calibration plot

Table 6.3: Steady state calibration summary

Observation point	Observed groundwater level (mAHD)	Modelled groundwater level (mAHD)	Residual (m)
GW804561	367.71	383.63	-15.92
GW802832	211.55	223.95	-12.40
GW802834	242.16	246.78	-4.62
GW802842	239.89	247.34	-7.45
GW801299	387.25	379.51	7.74
WYMB002	208.90	221.96	-13.06
WYMB003	220.27	220.70	-0.43
WYMB004	208.59	216.16	-7.57

Table 6.4: Steady state calibration statistics

Statistical Parameters	Value
Residual Mean	-6.71
Residual Standard Deviation	7.17
Absolute Residual Mean	8.65
Residual Sum of Squares	771.97
RMS Error	9.82
Minimum Residual	-15.92
Maximum Residual	7.74
Range of Observation	178.66
Scaled Residual Standard Deviation	0.04
Scaled Absolute Residual Mean	0.05
Scaled RMS	5.50%
Number of Observations	8

Calibrated groundwater level contours from the model are shown in **Figure 6.7,** which shows that groundwater levels are elevated in areas of relatively higher topography and decrease in areas with lower elevations, flow is to the west then northwest and the hydraulic gradient is steeper in the foot slopes and upper slopes. This aligns with the conceptual model and regional interpolated groundwater level contours (**Figure 3.12**).

The water balance for the steady state model is shown in **Table 6.5**.

Table 6.5: Steady state water balance

Element	Inflow (kL/d)	Outflow (kL/d)
General head	0	680
Recharge	988	-
ET	-	308
Total	988	988
Percent error	0.02	

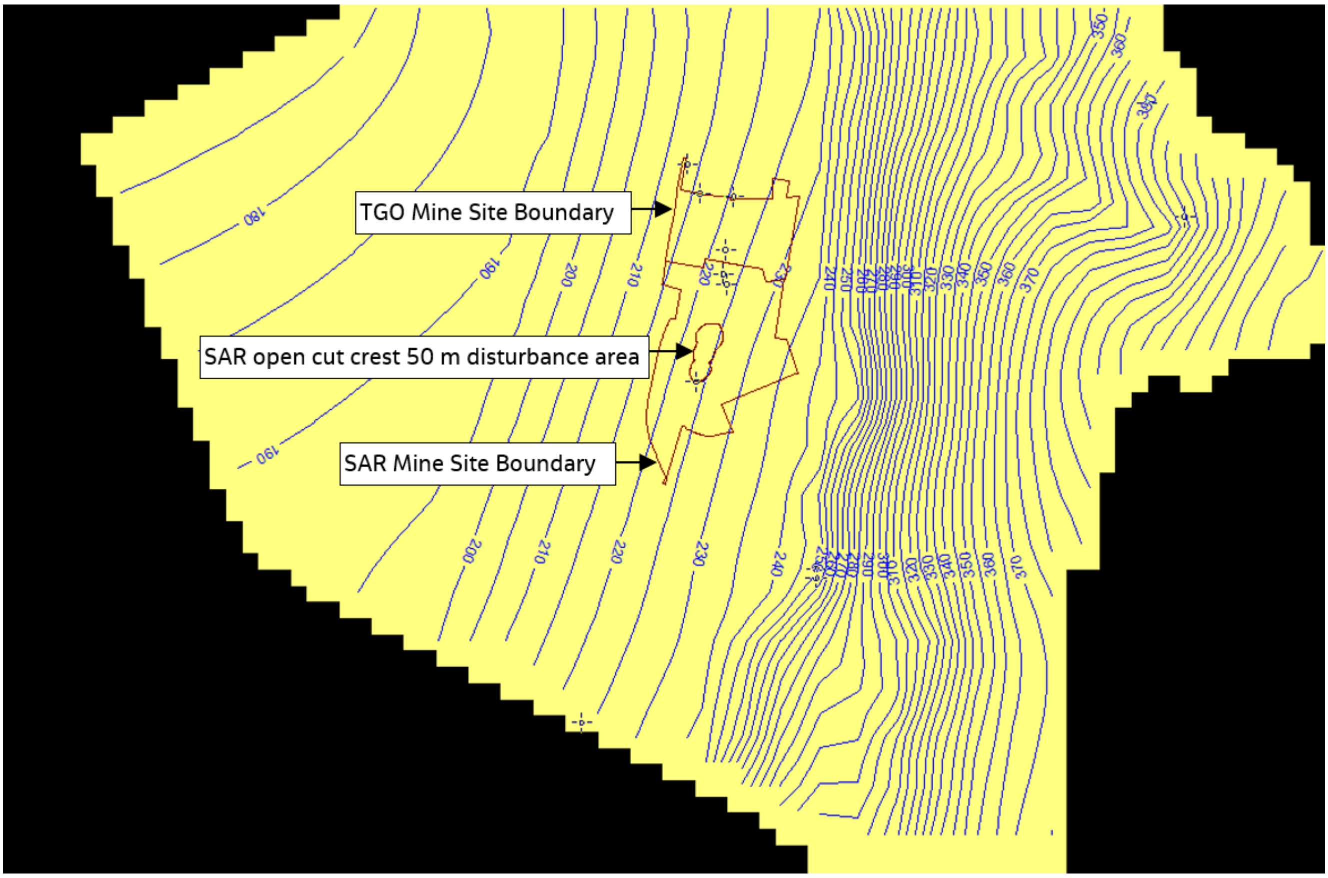


Figure 6.7: Steady state groundwater level contours (5 m interval)

6.8.2 Transient calibration

6.8.2.1 Approach

The transient calibration period comprised 170 monthly stress periods, commencing 01/03/2007 and ending 30/04/2021, with the first period configured as per the steady state model and run in steady state mode. Thus, the calibration period comprises an approximate 6.7 year period prior to commencement of mining and then an approximate 7.5 year period of TGO mining (pre strip at TGO commenced November 2013). The period of TGO mining includes open cut and underground mining.

Aside from the first steady state period, the monthly stress periods were assigned four timesteps.

The recharge rate applied to the first stress period of the transient model was the same as the rate applied to the steady state model. For the rest of the transient model stress periods, the percentages of daily rainfall assigned as recharge for the zones in the calibrated transient model were the same as applied to the calibrated steady state model. Recharge rates were assigned based on SILO database rainfall.

The EVT zonation and rate applied in the steady state model were maintained in the transient calibration model.

Hydraulic conductivity zones and values applied in the steady state model were maintained in the transient model.

Storage parameters (specific yield and specific storage) were incorporated into the transient model and calibrated via an iterative step-wise process using manual adjustment within realistic ranges to achieve an acceptable match between simulated and observed heads.

DRN boundaries were introduced into the model to represent open cut and underground mining occurring at TGO during the calibration period.

Calibration target locations were as per the steady state model with the addition of:

- TGO monitoring bore, WYMB010 (no measurement is available for this location at the time of steady state model calibration), and SAR monitoring bores, RWWB001, RWWB002 and RWB003. Groundwater level observations for these TGO/SAR monitoring bores are included in **Figure 4.5** and **Figure 4.6**. It is noted that for RWB003, only the later groundwater levels were included as targets as groundwater levels measured shortly after bore construction were assumed to be still recovering.
- Groundwater inflow rate targets set as upper limits for the TGO open cuts and a water balance derived groundwater inflow rate for Wyoming 1 underground. The details of these inflow rate targets are discussed alongside results in **Section 6.8.2.4**.

6.8.2.2 Calibrated storage parameters

Specific yield and specific storage values of 7.5% and 1.3×10^{-7} m^{-1}, respectively, were applied to all model cells in the calibrated model.

The adopted specific storage value is the geometric mean of values estimated from rock strength data (**Section 4.5**). This value also aligns with literature values for 'tight' rock (**Section 4.5**).

The adopted specific yield value was largely derived by matching the mining induced drawdown trend at WYMB002, whilst ensuring minimal or no drawdown at other TGP monitoring bores, as WYMB002 is the only bore during the calibration period that is interpreted to be subjected to mining induced drawdown. The adopted value broadly accords with literature (Bair and Lahm, 2006) representative values for sandstone (6%) and siltstone (12%) but is somewhat higher than literature representative values for metamorphic rock (1%) and shale (2.5%). Trial model runs with a lower specific yield value resulted in overstated drawdown and therefore poor calibration.

6.8.2.3 DRN boundaries

A summary of the levels of the DRN boundaries used to simulate open cut and underground TGO mining is provided in **Figure 6.8**. The open cut DRN boundaries were assigned to have three areas for each open cut, an upper area, intermediate area and lower area. This was done to represent the open cuts tapering inwards with depth.

The underground (Wyoming 1) DRN boundary was applied to envelope the area of underground mining.

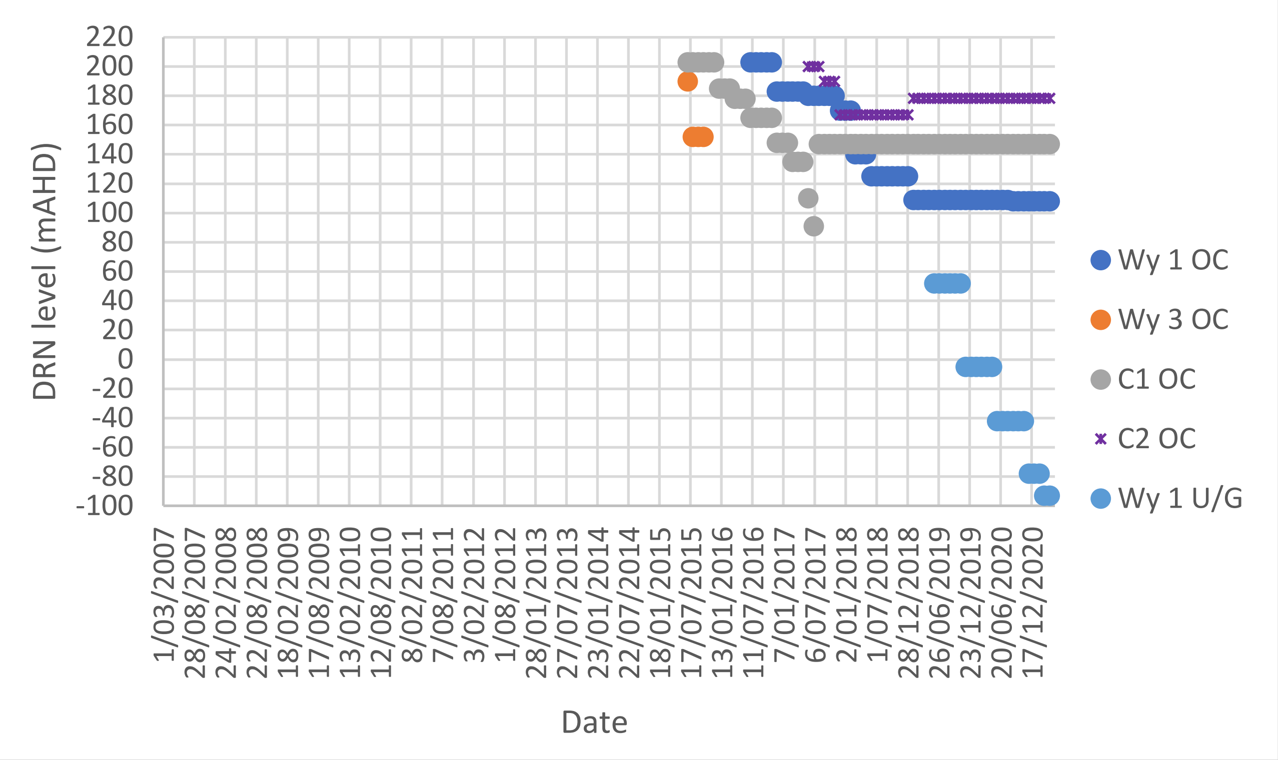


Figure 6.8: Calibration period DRN levels

6.8.2.4 Calibration results

Hydrographs – history matching

Hydrographs comparing observed and modelled heads for TGO and SAR monitoring bores are shown in **Figure 6.9** and **Figure 6.10**, respectively. Modelled head trends match observed head trends reasonably well and the following is noted:

- The model simulates the mining induced drawdown trend at WYMB002 reasonably well.
- The model hydrographs do not show significant mining induced drawdown at bores other than WYMB002, which corresponds with observed conditions.
- Excepting two non-representative outliers at WYMB004 which are deemed to be likely erroneous data, aside from WYMB002, the model hydrographs show little temporal head variation. This model characteristic corresponds with observed conditions.

The model is generally over predicting heads. Excepting two non-representative outliers at WYMB004 (likely erroneous data points), at TGO bores the maximum error is 13.79 m, which occurs at WYMB002. At SAR bores the error is larger and an average of about 17.90 m. The overestimation of head is conservative with regards to prediction of groundwater take.

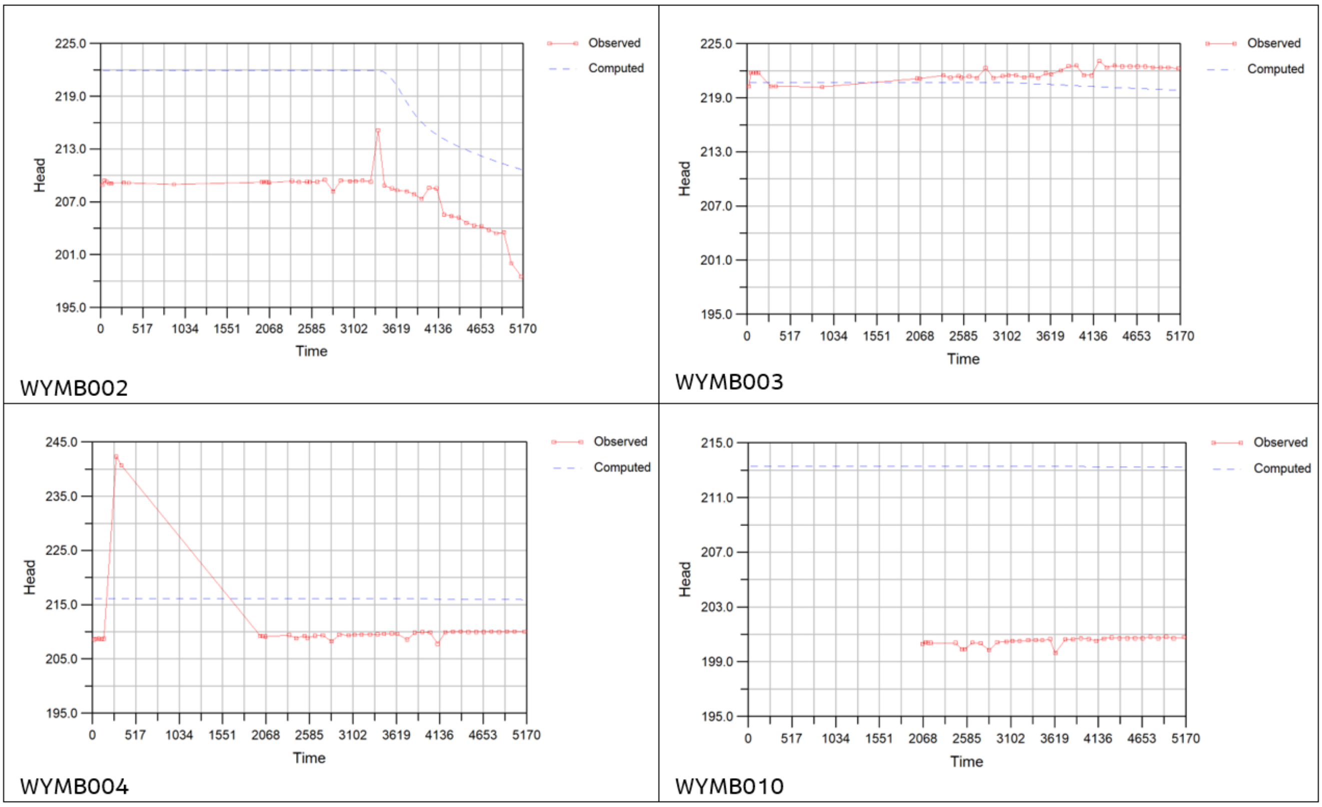


Figure 6.9: Calibration period hydrographs for TGO bores

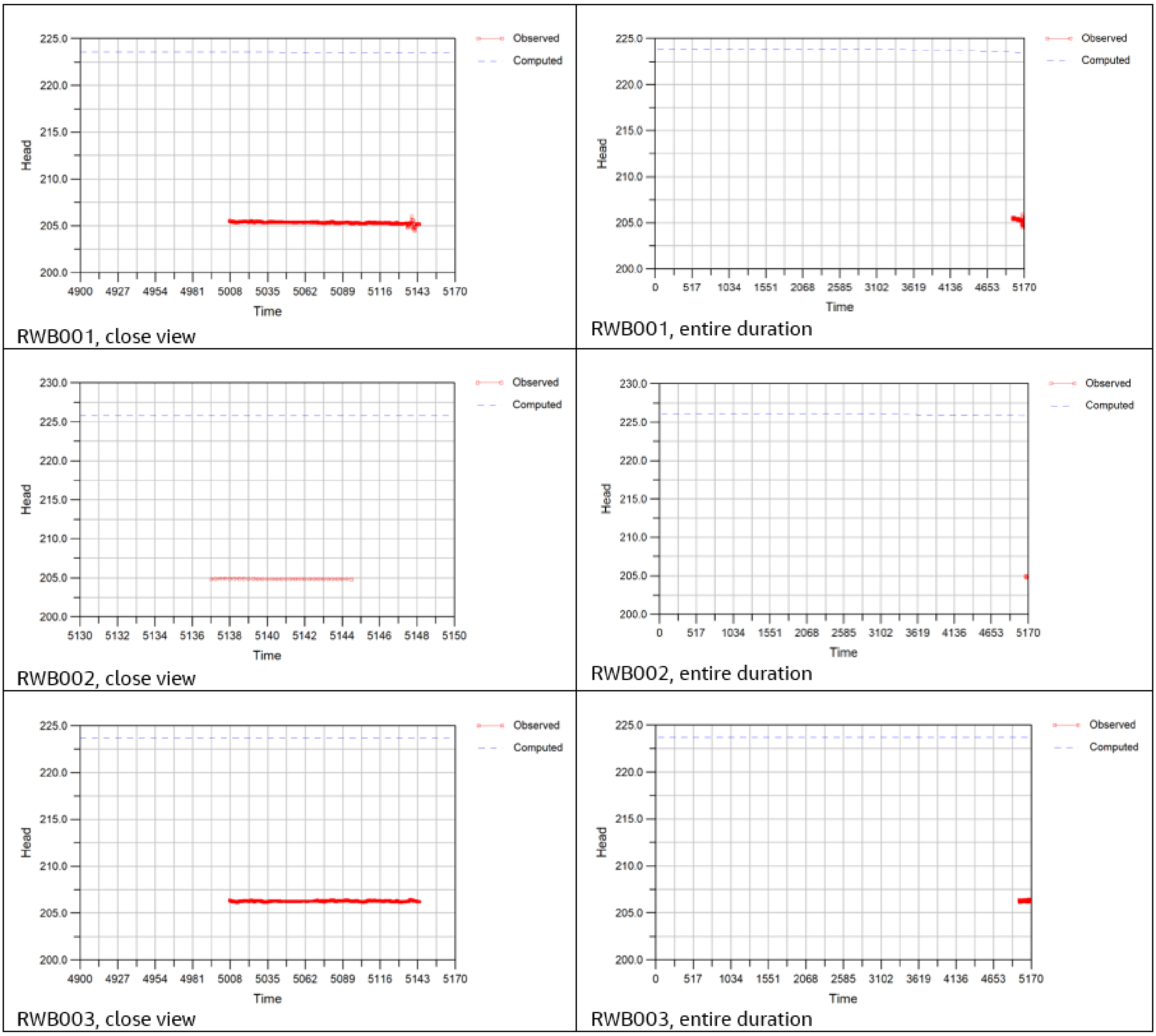


Figure 6.10: Calibration period hydrographs for SAR bores

Mine Inflows – history matching

Historical inflows to mining operations have been insignificant for both open cuts and underground mining. No active dewatering of groundwater inflows from open cut operations has been undertaken and inflows have not been enough to be of nuisance or interrupt mining. Target inflow rates for calibration are therefore set as an upper limit, with total inflows not to exceed the potential areal evaporation from the pit. The potential areal evaporation was roughly approximated as the pit surface area multiplied by the local annual pan evaporation. As there is no pit lake to account for cooling, and the stilling effect and increased humidity in the pit would likely be countered by the heating of the pit walls, no pan factor was applied. It is noted that the assessment of potential evaporation assumes diffuse seepage over entire area below water table with no focussed inflows. Potential evaporation also assumes saturation at surface and, as such, is likely to be significantly higher than actual evaporation.

The Bureau of Meteorology website indicate that the average annual pan evaporation near TGEP is of the order of 1800 mm, or approximately 4.9 mm/day.

A simple water balance undertaken for the Wyoming 1 open cut pit and underground (RW Corkery & Co, 2020) for the period 12 November 2019 to 4 February 2020, indicates that maximum potential inflows to the Wyoming 1 underground mine were of the order of 47 ML/yr (128.8 kL/day or 1.5 L/s). However, it was noted that the bulk of these inflows (Applicant estimates 75%) were thought to be due to recirculation from the Wyoming 1 open cut pit sump, located above the underground workings, with inflow noted to increase after rainfall. The Wyoming 1 open cut sump was included during the calibration period and the target upper inflow rate for Wyoming 1 underground mine was 0.38 L/s (25% × 1.5 L/s = 0.38 L/s).

Groundwater inflow rate upper limits/targets and modelled groundwater inflows during transient calibration are presented in **Table 6.6.** From **Table 6.6** it is apparent that modelled groundwater take over the transient calibration period for all cases are within the target criteria.

Table 6.6: Transient calibration - groundwater inflow targets (upper limit) vs modelled inflow

Pit / Underground	Surface area below water table[1] (m^2)	Potential Areal Evaporation[2,3] (L/s)	Water balance – seepage plus inflow (L/s)	Modelled inflow (L/s)
Wyoming 1	120,100	6.8	-	3.0 [5]
Wyoming 3	42,700	2.4	-	2.1 [6]
Caloma 1	127,600	7.2	-	2.9 [7]
Caloma 2	52,700	3.0	-	1.3 [8]
Wyoming 1 U/G		-	1.5 (of this, 0.38 L/s in late 2019/early 2020 is thought to be from underground inflows, with the remaining being seepage from the open cut via non-backfilled boreholes). The inflow of 0.38 L/s was the calibration target.	0.38 [4], 1.47 [5]

Note: [1] – approximated at 220 mAHD
[2] – based on average daily pan evaporation of 4.9 mm.
[3] – Assumes diffuse seepage over entire surface area below water table with no focussed inflows. Potential evaporation also assumes saturation at surface and, as such, is likely to be higher than actual evaporation.
[4] – At end of stress period 153 (end of November, 2019).
[5] – At end of stress period 170, end of calibration period.
[6] – At end of stress period 104, last period before Wyoming 3 open cut DRN is made inactive to simulate recovery.
[7] – At end of stress period 125, last period before Caloma 1 open cut DRN raised to average water storage level.
[8] – At end of stress period 143, last period before Caloma 2 open cut DRN raised to average water storage level.

Statistics, mass balance and groundwater levels

A comparison of modelled groundwater levels and observed groundwater levels for all observations and only TGO/SAR monitoring bores is provided in **Figure 6.11** and **Figure 6.12**, respectively. Calibration statistics are provided in **Table 6.7** The figures and calibration statistics indicate the model is reasonably well calibrated to observed heads, particularly at WYMB004 and WYMB003. However, it is noted that the model is generally over predicting head. Excepting two non-representative outliers at WYMB004 (likely erroneous data points), at TGO bores the maximum error is 13.79 m, which occurs at WYMB002, and the average error is 6.75 m. At SAR monitoring bores, the error is larger and an average of about 17.90 m.

The scaled RMS error is 9%, indicating the model is reasonably well calibrated to measured heads.

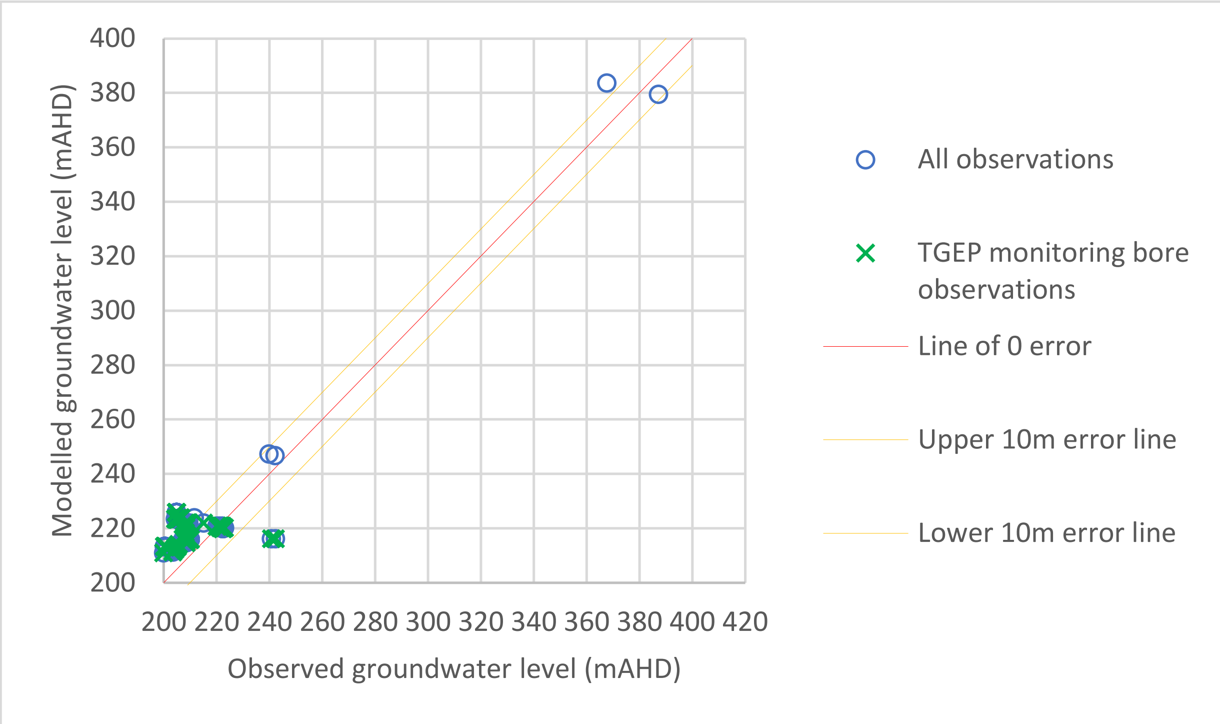


Figure 6.11: Transient calibration plot (all observations)

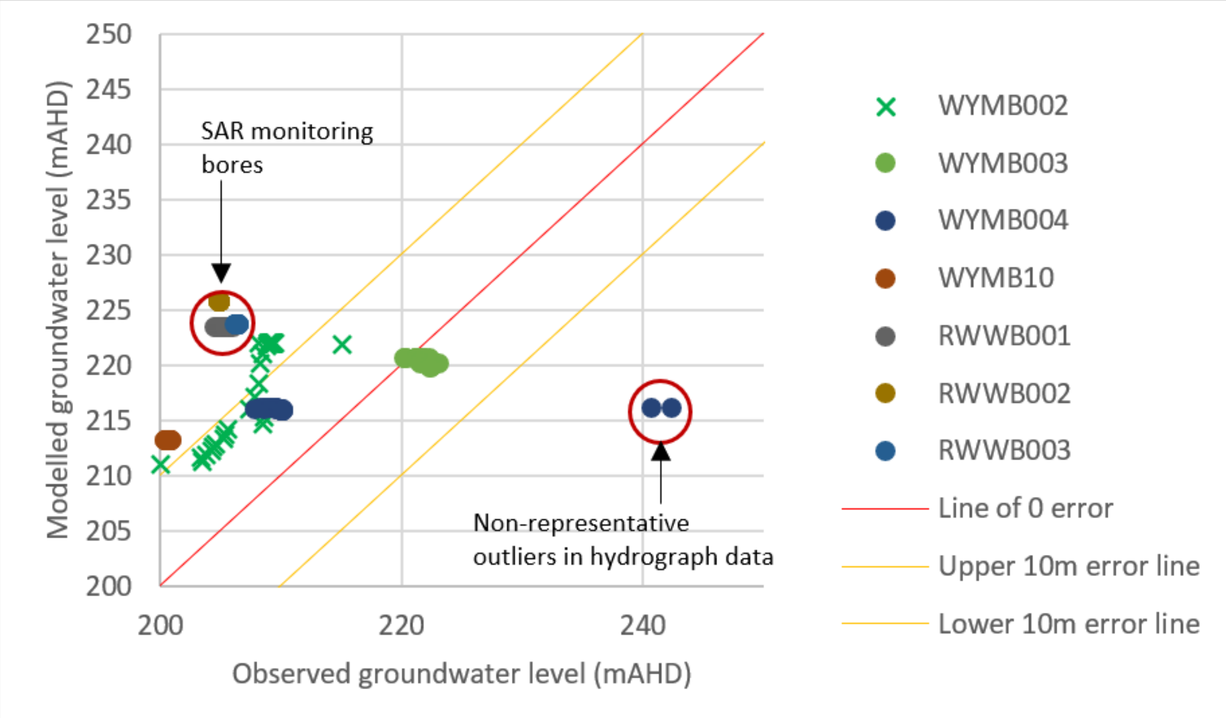


Figure 6.12: Transient calibration plot (TGO/SAR monitoring bore observations)

Table 6.7: Transient calibration statistics

Statistical Parameters	Value
Residual Mean	-16.45
Residual Standard Deviation	4.49
Absolute Residual Mean	16.62
Residual Sum of Squares	376125
RMS Error	17.05
Minimum Residual	-21.04
Maximum Residual	26.16
Range of Observation	188.73
Scaled Residual Standard Deviation	0.02
Scaled Absolute Residual Mean	0.09
Scaled RMS	9.0%
Number of Observations	1294

The average water balance for the transient calibration model is shown in **Table 6.8** and was calculated based on the cumulative water balance divided by the number of days in the transient calibration period.

Groundwater level contours at the end of the transient calibration period are shown in **Figure 6.13**. The contours show mining induced groundwater level reduction, generally constrained to slightly beyond TGO. It is noted that the contours in **Figure 6.13** appropriately convey the groundwater level reduction areal extent at a broad scale but do not accurately convey the detailed groundwater level reduction in the vicinity of mining. This is due to the way the modelling software's contouring function works and its inability to represent closely spaced contours at zoomed out model views. A more detailed view of the groundwater level contours in the vicinity of TGO is shown in **Figure 6.14**, which better shows the groundwater level reduction in the vicinity of mining. As shown in **Figure 6.14**, the model predicts minimum groundwater levels at TGO to be 147 mAHD (Caloma 1), 108 mAHD (Wyoming 1), 178.25 mAHD (Caloma 2) and about 212 mAHD (Wyoming 3). Except for Wyoming 3, the minimum levels accord with the DRN boundary levels applied over the open cuts. Prior to the end of the calibration period, Wyoming 3 DRN is made inactive to represent backfilling and allow groundwater levels to recover at this open cut.

Table 6.8: Transient calibration model average water balance

Element	Inflow (kL/d)	Outflow (kL/d)
Storage	781	397
General head	0	681
Recharge	1,015	-
ET	-	310
Drain	-	408
Total	1,796	1,795
Percent error	0.02	

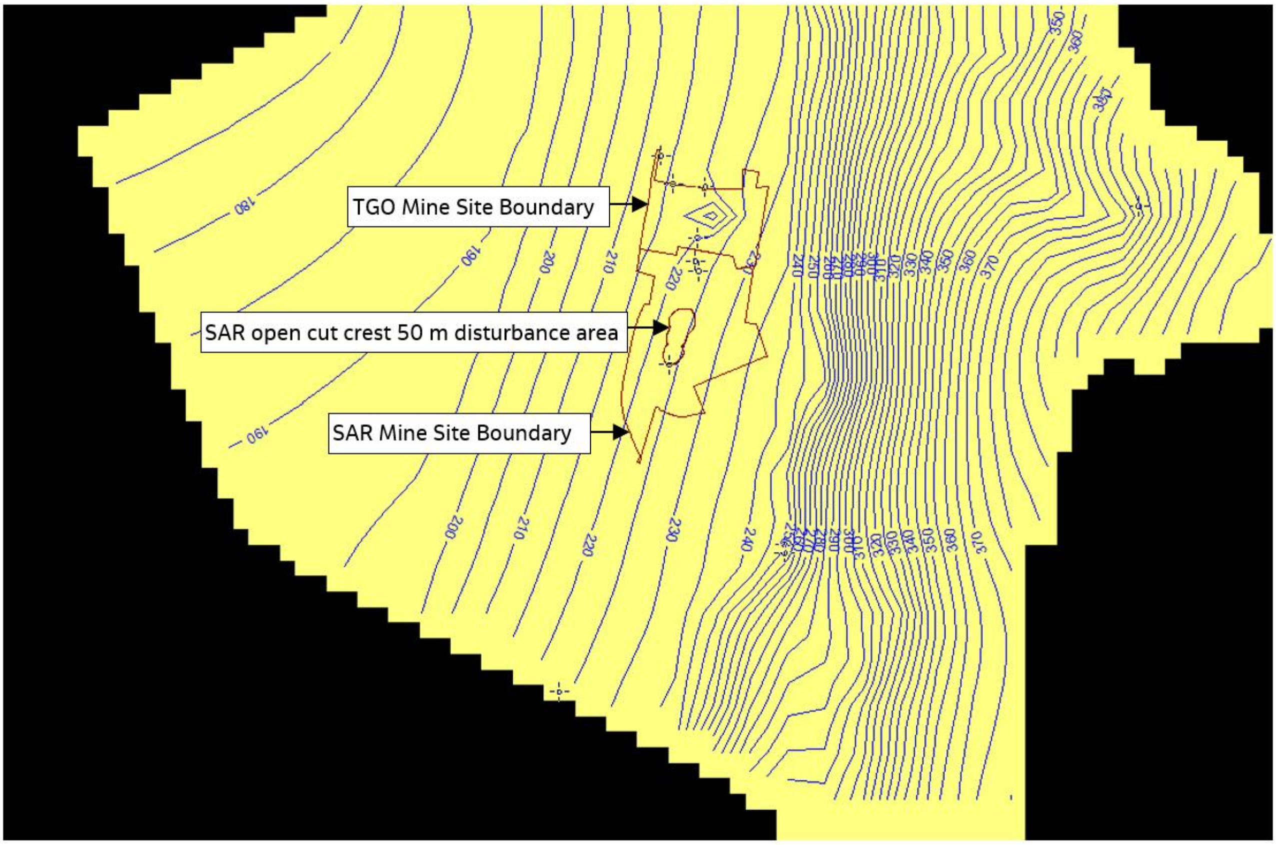


Figure 6.13: Groundwater level contours (5 m interval) at end of transient calibration period (note: closely spaced groundwater levels in vicinity of mining are not represented in the figure)

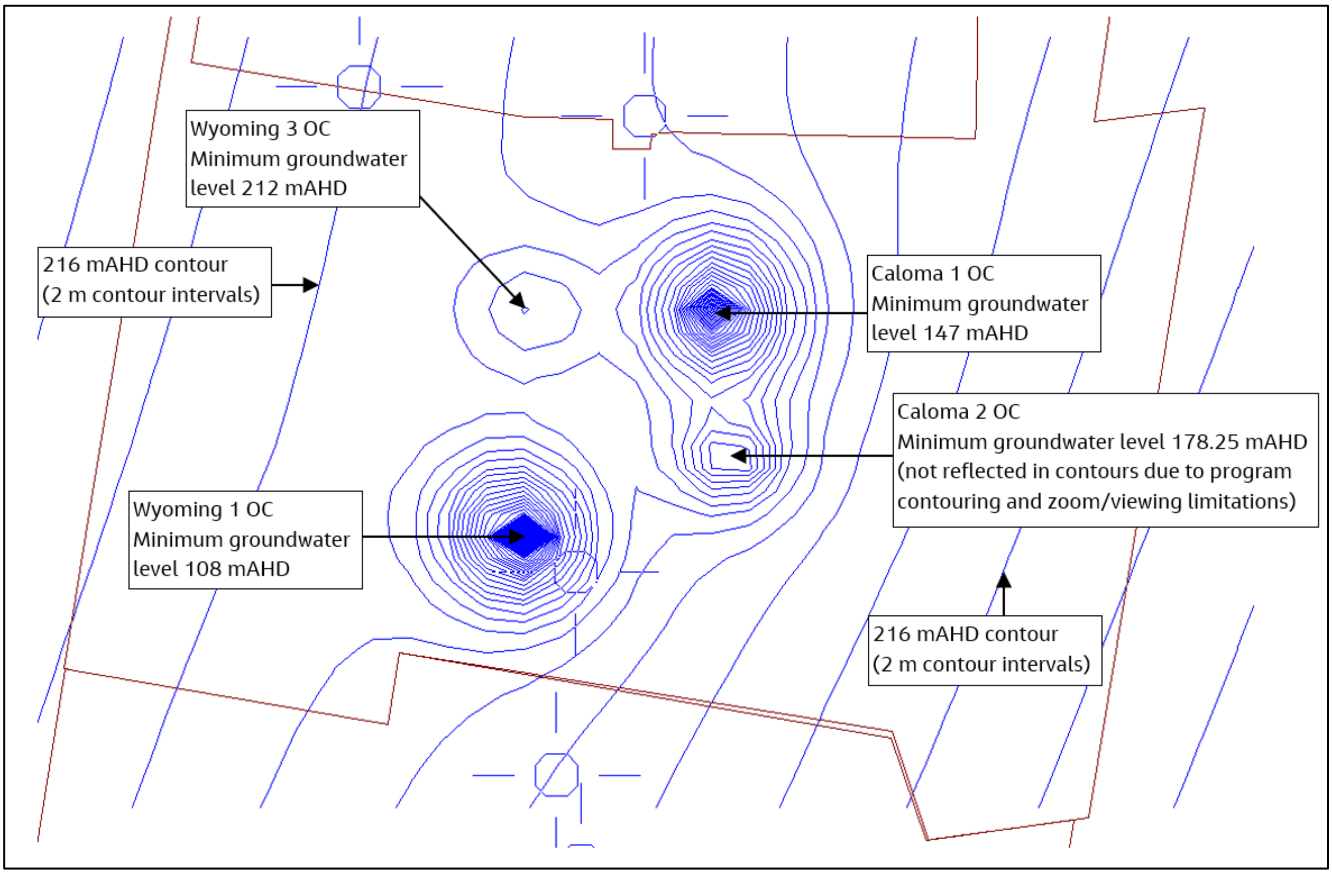


Figure 6.14: Detailed view of groundwater level contours (2 m interval) in vicinity of TGO at end of transient calibration period

Conclusion

Notwithstanding the model generally over predicting heads, on balance, the model is considered sufficiently calibrated to achieve model objectives. This is because the model appropriately represents the regional flow direction, hydraulic conductivity of the model accords with site testing data, modelled DRN flows meet the calibration criteria, modelled mining induced drawdown generally accords with site observations and the depth of mining is large relative to the over prediction of head.

With the exception of two non-representative outliers at WYMB004 (likely erroneous data points), at TGO bores the maximum error is 13.79 m, which occurs at WYMB002, and the average error is 6.75 m. At SAR bores the error is larger and an average of about 17.90 m. The overestimation of head is small relative to the magnitude of depressurisation in the vicinity of open cut and underground mining. For instance, Wyoming 1 open cut has a current minimum level of approximately 108 mAHD, which is greater than 100 m below the pre-mining water table level. A drawdown magnitude of over 100 m at Wyoming 1 open cut is relatively large compared to the average overprediction of head at TGO of about 6.75 m. Similarly, the deepest SAR open cut has a minimum level of -30 mAHD, which is about 235 m below the inferred pre-mining water table. Again, this is relatively large compared to the average overprediction of head at SAR of 17.90 m. Accordingly, the general overprediction of head is not considered to hinder the model achieving its objectives.

With respect to prediction of groundwater inflow rates and drawdown, the model's tendency to over predict head is conservative or neutral, for impact assessment. The higher head causes relatively higher groundwater inflow rates, which is conservative. With respect to groundwater level drawdown, the higher head results in over estimation of drawdown over the drain cells. Further afield, the over predicted head is either conservative or neutral for drawdown prediction. This is because a null case model run is used to compute the drawdown. The over prediction of head is also present in the null case model run. Therefore, the model is assessing relative change. It is noted that the over predicted head could have non-conservative implications for assessment of baseflow impacts to surface water features. However, mining is not anticipated to have any interaction with surface water and such processes are not represented in the model, as the conceptualisation indicates they are not relevant. Accordingly, the over prediction of head does not detract from the model's ability to be used for impact assessment.

6.8.3 Sensitivity analysis

Sensitivity analysis is documented in Appendix D and indicates the model is relatively sensitive to hydraulic conductivity and recharge. The other parameters tested in the sensitivity analysis, EVT, specific storage, specific yield and Wyoming 1 underground DRN conductance were significantly less sensitive.

6.8.4 Final adopted parameters summary

Key final adopted model parameters are summarised in **Table 6.9**.

Table 6.9: Key final adopted model parameter values

Parameter	Final adopted base case model value
Horizontal hydraulic conductivity (m/d) [1]	▪ Zone 1 – fractured rock west of Zone 2, 0.05 m/d ▪ Zone 2 – siltstone and shale, 0.01 m/d ▪ Zone 3 – fractured rock in area of mine, 0.01 m/d ▪ Zone 4 – siltstone and sandstone, 0.001 m/d ▪ Zone 5 – granite, 0.001 m/d ▪ Zone 6 – Dulladerry Rhyolite, 0.001 m/d ▪ Zone 7 – Hervey Group (shale, siltstone and sandstone), 0.001 m/d
Recharge rate as % of mean annual rainfall	Zone 1: 0.036 [2] Zone 2: 0.177 [2]
Evaporation rate (mm/d)	3.93
Storage	Specific storage = 1.3×10^{-7} Specific yield = 0.075
DRN conductance for open cuts (m^2/d)	390,625 for 62.5 x 62.5 m cells and 24,414 for 15.625 x 15.625 m cells
DRN conductance for Wyoming 1 (m^2/d)	0.00065 for 15.625 x 15.625 m cells and 0.0104 for 62.5 x 62.5 m cells

Note: [1] Applied vertical hydraulic conductivity = 1/10 x horizontal hydraulic conductivity. [2] Number is already expressed as a percentage – do not multiply by 100 to derive percent value. Values are 0.036% and 0.177%.

6.9 Prediction model configuration

6.9.1 Scenario description

Existing and proposed open cut and underground mining up until early in the year 2031 is represented in the model, with a 200 year post-mining recovery period.

The prediction model's prediction period simulates the following open cut and underground mines:

- Wyoming 1, Caloma 1 and Caloma 2 open cuts at TGO
- Wyoming 1, Caloma 1 and Caloma 2 underground at TGO
- Proposed open cut and underground at SAR.

The small Wyoming 3 open cut is not simulated during the prediction period as it is already backfilled to above the water table and simulation of this feature ceases during the calibration period.

The conceptual hydrogeological slice shown in **Figure 5.3** shows the open cut and underground mines represented in the model. Representation of these features using DRN boundaries is covered in **Section 6.9.4**, including the levels applied.

6.9.2 Approach, time discretisation and model run-time

The prediction model was created from doing a 'save as' of the transient calibration model. The model was then extended beyond the transient calibration period and extended to the end of February 2031, to simulate future mining, then had a final 200 year post-mining period.

The initial head was the same as that of the transient calibration model, with the first period configured as per the steady state model and run in steady state mode.

Aside from the 200 year post-mining period, time discretisation characteristics were maintained from the transient calibration period (i.e. monthly stress periods, four time steps, time step multiplier of 1.2).

The 200 year post-mining period was represented as a single stress period with four time steps, time step multiplier of 1.2.

The stress period length and number of time steps are suitable to achieve the model's objectives. Monthly stress periods result in the prediction period during mining being broken into 118 stress periods, distributed between early 2021 and early 2031, which allows mining to be represented appropriately. The single 200 year post-mining period being represented as a single stress period is appropriate as mining no longer occurs in this period and the purpose of the final period is to allow for recovery of groundwater levels. Four time steps per stress period is sufficient to capture early groundwater system responses to stresses changing in the model, and these groundwater system responses abating with time.

The 200 year post-mining period is considered a suitably long planning horizon.

The model run-time was approximately 15 minutes, with export of the detailed mass balance taking considerable time, typically overnight.

6.9.3 Recharge and ET

The recharge rates from the transient calibration period were maintained but applied to long-term monthly average rainfall for the mining simulation period. For the post-mining period, the recharge rate was applied to average long term rainfall.

The ET zonation and rate from the transient calibration period was maintained.

Potentially increased recharge associated with waste rock backfilling of the open cuts was not represented in the prediction model. This additional complexity is not considered necessary to achieve the model's objectives. At SAR, the conceptual hydrogeological slice (**Figure 5.3**) shows that from below the current water table, there will not be a direct pathway through backfilled waste rock between the central open cut and non-backfilled northern open cut. At TGO, there will not be a direct pathway through backfilled waste rock between backfilled open cuts and the non-backfilled Wyoming 1 open cut.

6.9.4 DRN boundaries

Additional DRN boundaries were incorporated into the model to represent the deepening of Caloma 1 open cut and Wyoming 1 underground mine, underground mining at Caloma 1 and 2 and open cut/underground mining at SAR.

Except for DRN boundaries associated with the northern portion of the SAR open cut and the Wyoming 1 open cut, open cut DRN boundaries were made inactive from scheduled backfilling commencement dates provided by The Applicant, to simulate potential groundwater level recovery. Underground DRN boundaries were made inactive at the end of scheduled mining for the given underground mines, to simulate potential groundwater level recovery.

DRN boundaries were left active for the northern portion of the SAR open cut and Wyoming 1 open cut for the post-mining period, as these open cuts will not be backfilled. The levels during the post-mining period for these DRNs were assigned based on equilibrium post-mining water levels determined using a spreadsheet water balance model which is documented in Appendix E. The SAR open cut and Wyoming 1 open cut were assigned DRN levels in the post-mining period of 180 mAHD and 200 mAHD, respectively.

DRN boundary levels are shown for TGO and SAR in **Figure 6.15** and **Figure 6.16**, respectively.

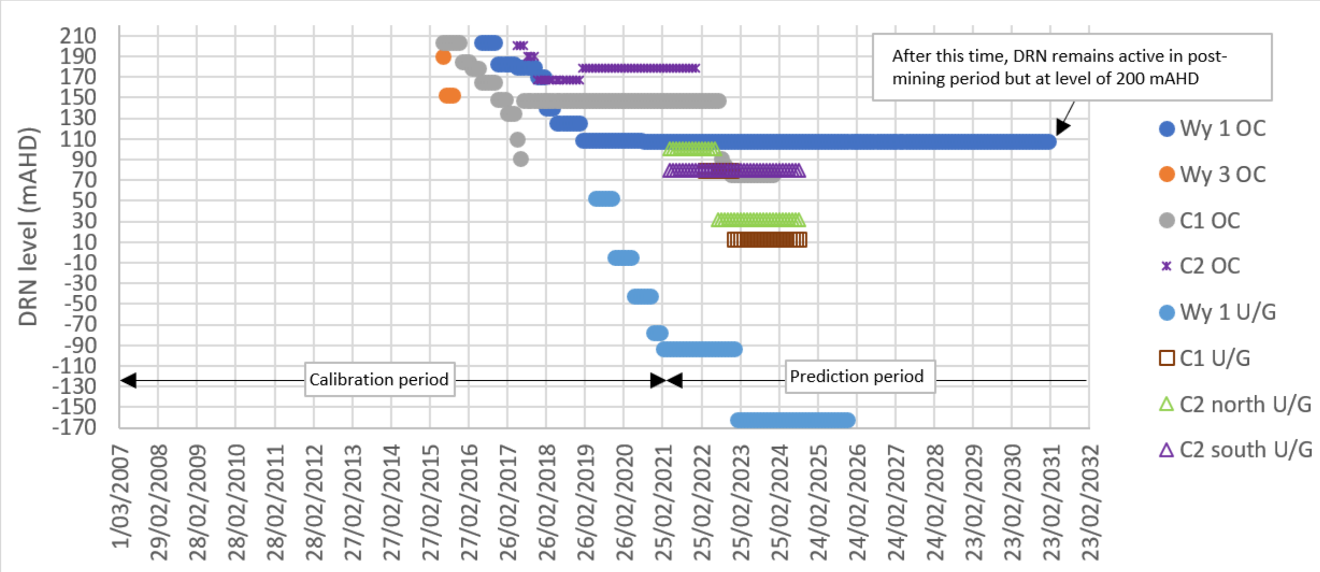


Figure 6.15: TGO DRN boundary levels

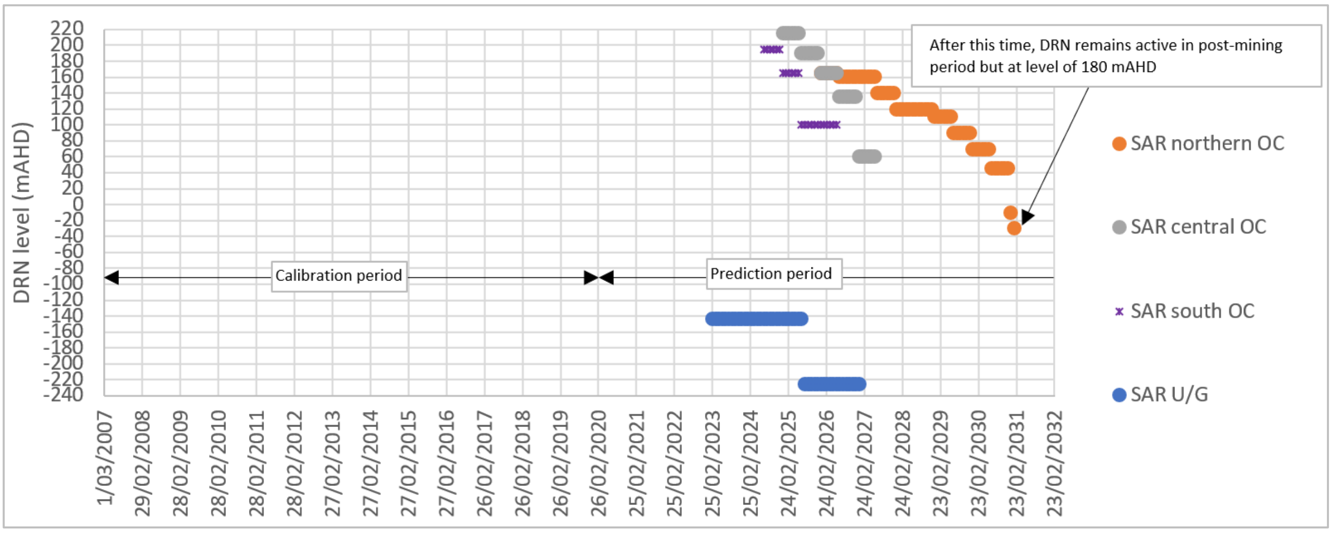


Figure 6.16: SAR DRN boundary levels

6.10 Results

6.10.1 Results relative to intended Model Class

As outlined in **Section 6.4**, the intended model confidence level classification is Class 2. Model results and the model as a whole are related back to the target confidence level classification in **Section 6.4**.

In general, the model results are considered commensurate with that of a Class 2 model.

6.10.2 Base case inflows

The total drain flow rate at the end of each period for all the open cuts and underground drains is shown in **Figure 6.17** for the mining period. The post-mining total drain flow is not included in **Figure 6.17**. The predicted total post-mining groundwater take is about 118 ML/yr once pit lake water levels have recovered to equilibrium levels. Prior to pit lake equilibrium levels being achieved, the post-mining groundwater take would be higher than 118 ML/yr but less than that occurring during mining, and is anticipated to progressively decrease with time as the pit lake water levels increase with time.

The total DRN flow rate during mining is typically in the range of 0.5 ML/d to 2.5 ML/d, with a maximum rate of about 3.04 ML/d occurring in January 2027.

The individual DRN flow rates for TGO open cuts, TGO underground mines and SAR open cut/underground are shown in **Figure 6.18**, **Figure 6.19** and **Figure 6.20**, respectively.

As shown in **Figure 6.20**, for proposed SAR mining, the central open cut and the northern open cut have the highest DRN flow rates, with maximum rates of about 2 ML/d to 2.1 ML/d. Flow rates for the southern open cut and the underground mine are significantly less.

Maximum inflow rates for a given DRN level taper off quickly. For example, in the case of the SAR central open cut, the maximum inflow rate of about 2 ML/d tapers to about 1.4 ML/d within six months.

Groundwater take which occurs in reality are expected to be less than modelled as mining progression would be smoother than modelled. The sudden decreases in DRN levels causes an accompanying sudden increase in DRN flow rates.

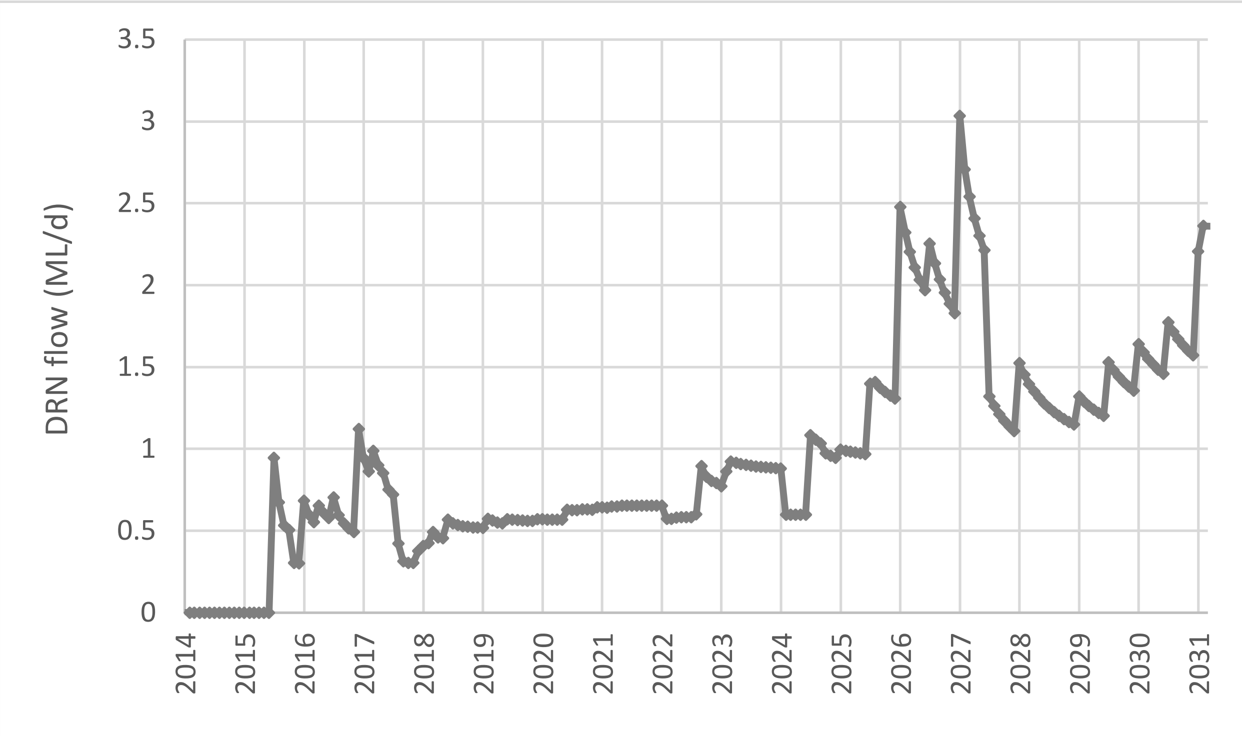


Figure 6.17: Total DRN flow rate (ML/d) during mining

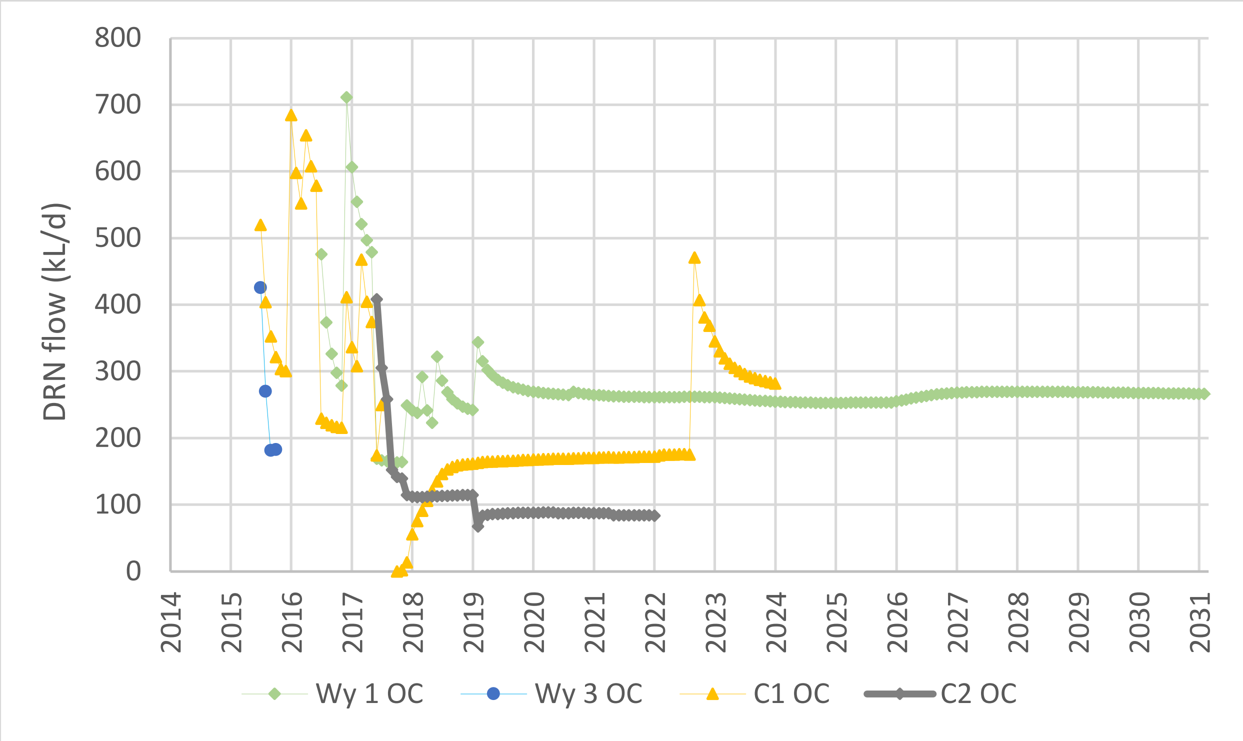


Figure 6.18: DRN flow rate (kL/d) during mining for TGO open cuts

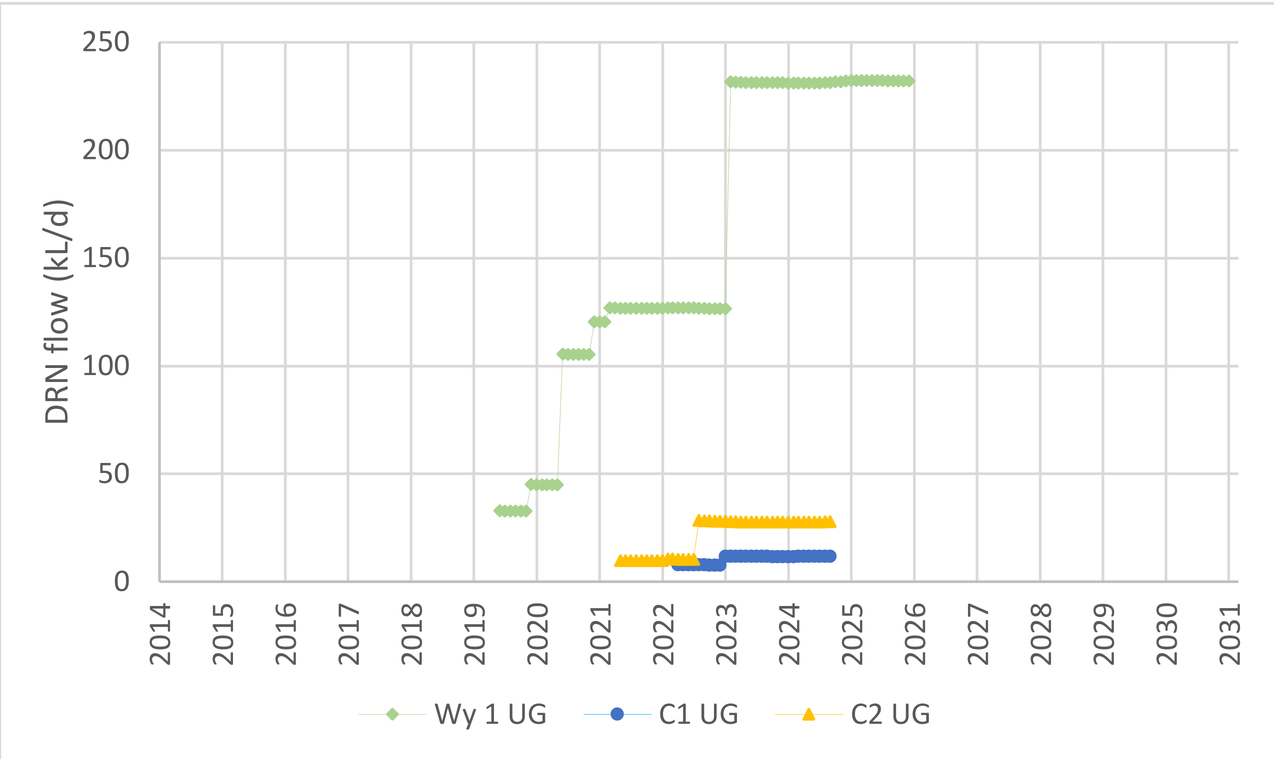


Figure 6.19: DRN flow rate (kL/d) during mining for TGO underground mines

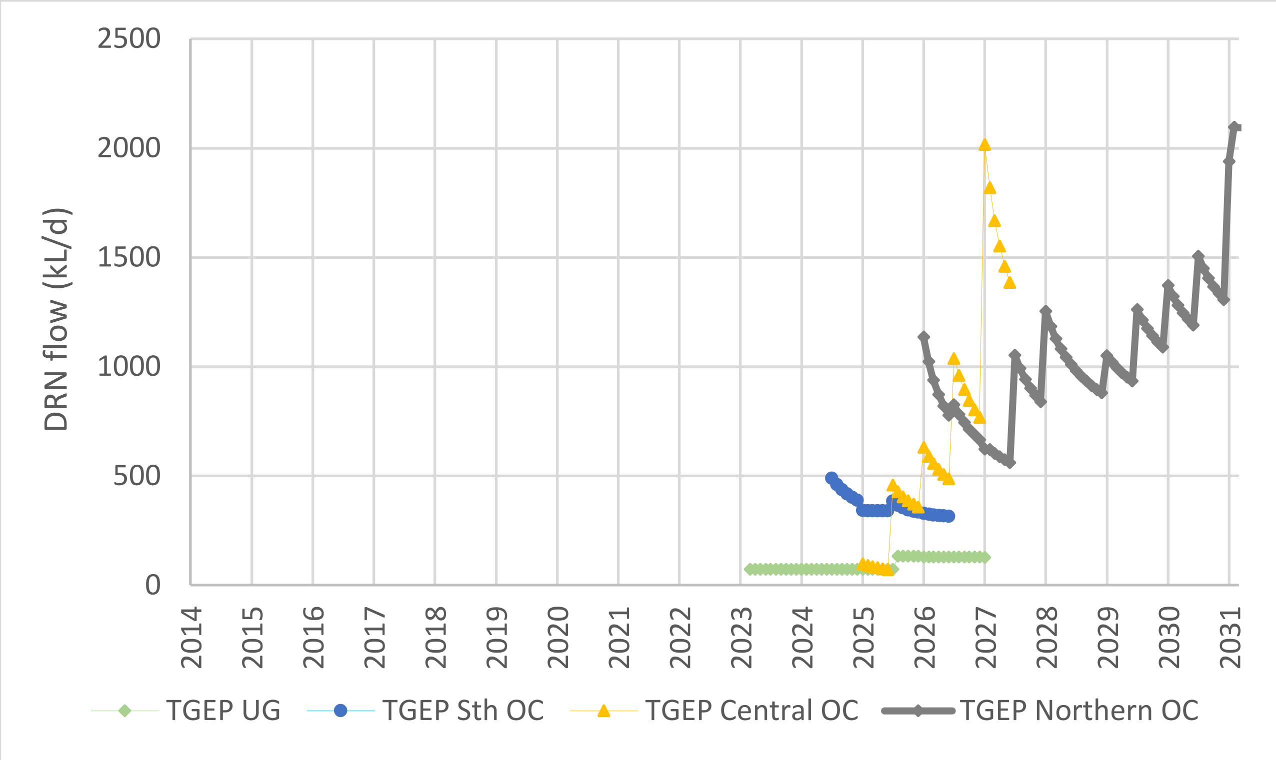


Figure 6.20: DRN flow rate (kL/d) during mining for SAR open cuts and underground mine

6.10.3 Base case groundwater level drawdown

Drawdown at end of mining

Base case drawdown at the end of mining is shown in **Figure 6.21**.

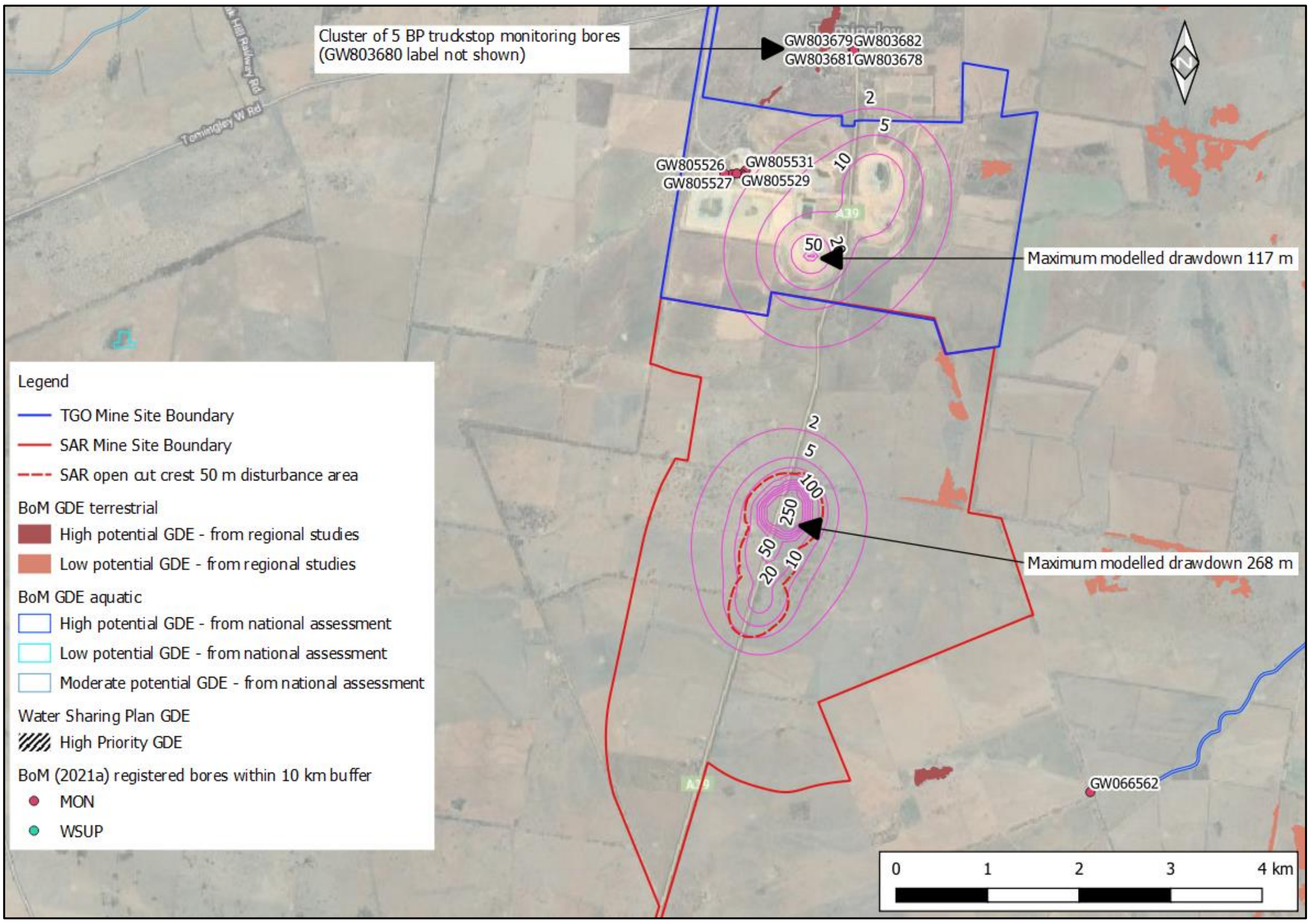


Figure 6.21: Base case drawdown contours (non-uniform and in metres) at end of mining

Post-mining period drawdown

Base case groundwater level drawdown approximately 200 years after end of mining is shown in **Figure 6.22.**

Wyoming 1 open cut and the northern portion of the SAR open cut function as perpetual groundwater sinks because these pits are not proposed to be backfilled and post-mining water level recovery modelling (Appendix E) indicates equilibrium levels about 20 m to 25 m below the pre-mining regional water table level.

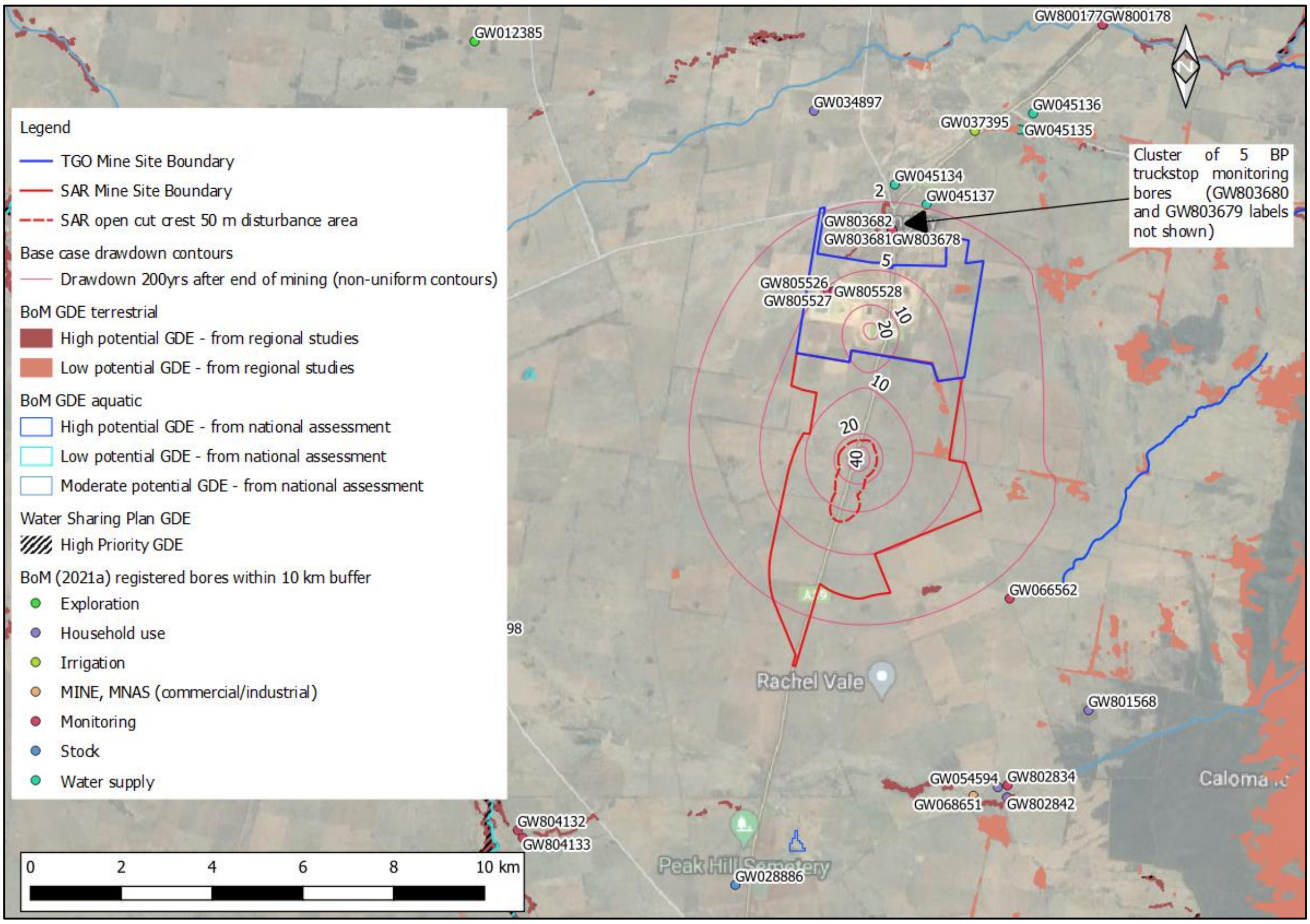


Figure 6.22: Base case drawdown contours (non-uniform and in metres) approximately 200 years after end of mining

6.10.4 Uncertainty Analysis

Uncertainty analysis was undertaken to assess the effect of varying model input parameter values on model predictions and is documented in Appendix D.

At the end of mining, the extent of the 2 m drawdown contour increases under uncertainty scenarios of increased hydraulic conductivity and recharge, decreased storage, increased hydraulic conductivity and no anisotropy. Approximately 200 years after the end of mining, the extent of the 2 m drawdown contour increases under uncertainty scenarios of increased recharge and no anisotropy. None of the uncertainty scenario results significantly alter the primary base case assessment findings relating to groundwater level drawdown impacts.

Groundwater take increases under uncertainty scenarios of increased hydraulic conductivity and recharge, increased storage, increased hydraulic conductivity, no anisotropy and increased recharge. None of the uncertainty scenario results alter the primary base case assessment finding relating to groundwater take, which is that acquiring entitlement to cover the groundwater take is considered feasible due to the extent of predicted groundwater take, trading frequency in the applicable water source and percentage of unallocated water in the water source.

7. Groundwater impact assessment

7.1 Groundwater level drawdown – registered bores

During mining and at the end of mining, the modelled base case 2 m drawdown contour does not encroach on any existing registered groundwater bores except for a cluster of TGO monitoring bores.

Approximately 200 years after the end of mining, the base case 2 m drawdown contour encroaches on the following bores in addition to the cluster of TGO monitoring bores:

- A cluster of five shallow (11 m to 12 m depth) bores, north of TGO (GW803680, GW803679, GW803682, GW803681 and GW803678), where about 4.5 m of drawdown is predicted. These bores are located at the BP Truckstop about 800 m north of TGO and are identified as being piezometers for the purpose of 'monitoring', likely associated with the underground fuel storage tanks.

The viability of the five BP Truckstop monitoring bores located inside the 2 m drawdown contour from the worst case drawdown scenario, drawdown 200 years after mining has ceased, is not anticipated to be impacted by mining. These shallow BP Truckstop monitoring bores tap shallow perched alluvial groundwater systems disconnected from the fractured rock groundwater system that the mine will drawdown. As such, they are assessed as unlikely to be subjected to drawdown. Furthermore, the bores are only used for monitoring.

As outlined in the uncertainty analyses (Appendix D), none of the uncertainty scenarios are considered to significantly alter the primary base case assessment findings relating to groundwater level drawdown impacts. This is because there are no existing fractured rock production bores within the 2 m drawdown contour for any uncertainty scenario, and because the alluvium has been shown to be hydraulically disconnected from the fractured rock groundwater system that the mine will depressurise.

7.2 Groundwater level drawdown – GDEs

Despite modelled drawdown contours propagating beneath areas mapped as potential GDE, GDEs are assessed as unlikely to be impacted by mining. These mapped potential GDEs, if actually associated with groundwater, are likely to be associated with shallow perched alluvial groundwater systems that are disconnected from the fractured rock groundwater system that the mine will drawdown. As such, they are assessed as unlikely to be subjected to drawdown associated with mining.

7.3 Baseflow reduction

Mining is assessed as unlikely to cause material reductions in baseflow to watercourses. The regional water table in the vicinity of TGO/SAR is within fractured rock and relatively deep compared to watercourse bed levels. Mining induced groundwater level drawdown is not anticipated to affect groundwater levels in perched alluvial groundwater systems, which could at times provide baseflow to watercourses.

7.4 Water licensing

Annual groundwater entitlement is required from the Lachlan Fold Belt MDB Groundwater Source of the Water Sharing Plan for the NSW MDB Fractured Rock Groundwater Sources Order 2020 (NSW Government, 2020) to cover TGO/SAR dewatering.

Annualised groundwater take was used to inform assessment of licensing implications and is shown in **Figure 7.1**.

The predicted maximum annual groundwater take of 767 ML in the year 2026 is taken to inform assessment of licensing implications. Thus, 477 ML of entitlement in addition to the existing Mine entitlement of 290 ML/year will be required (477 ML + 290 ML = 767 ML) during the mining period. It is noted that a recommendation is made (**Section 9.1**) that the Applicant initially obtain entitlement to cover the predicted groundwater take in the year 2025, which is 427 ML, and obtain additional entitlement as required after re-running the groundwater model in the year 2024. The model re-run should take into account monitoring data collected in the intervening period and be re-calibrated if necessary.

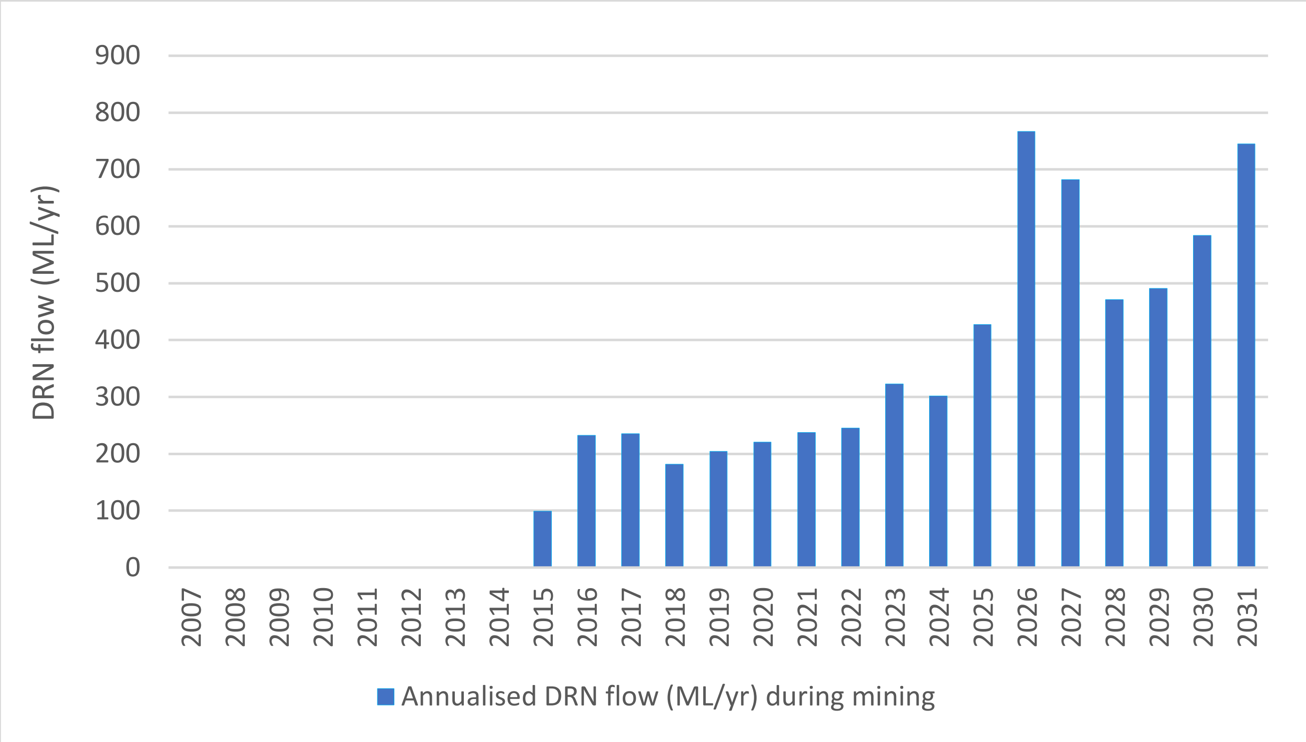


Figure 7.1: Annualised groundwater take during mining

Trading and controlled allocations are common in the applicable groundwater source and about 70% of the groundwater in this water source is currently unassigned. Therefore, acquiring additional entitlement is considered feasible.

Annual groundwater entitlement will also be required to cover the perpetual groundwater take that will occur after mining has ceased. The predicted total post-mining groundwater take is about 118 ML/yr once pit lake water levels have recovered to equilibrium levels. Prior to pit lake equilibrium levels being achieved, the post-mining groundwater take would be higher than 118 ML/yr but less than that occurring during mining, and is anticipated to progressively decrease with time as the pit lake water levels increase with time.

Groundwater inflow rate observations, water balance modelling and groundwater modelling could be undertaken at the end of mining, during mining or in the very early stages of the post-mining period to estimate the progressively decreasing required entitlement to cover the groundwater take in the early post-mining period prior to equilibrium conditions occurring.

Based on the predicted post-mining groundwater take of 118 ML/yr, the Applicant currently holds sufficient entitlement to cover licensing requirements after mining has ceased.

It is noted that whilst the model results are considered suitable to inform assessment of licensing implications and feasibility, there is uncertainty with the model results. Therefore, ongoing assessments during mining, including water balance assessments and/or groundwater modelling at a higher resolution with additional inflow rate calibration targets or successful verification of the current groundwater model, could be undertaken to attempt to reduce uncertainty and increase accuracy of required entitlement volumes.

None of the uncertainty scenario results (Appendix D) alter the primary base case assessment finding relating to groundwater take, which is that acquiring entitlement to cover the groundwater take is considered feasible due to the extent of predicted groundwater take, trading frequency in the applicable water source and percentage of unallocated water in the water source.

7.5 Groundwater quality

The Project is assessed as unlikely to lower the groundwater beneficial use category beyond a distance of 40 m of the Project Area, which is an AIP (DPI, 2012) Minimal Impact Consideration criterion.

Although considered low risk, groundwater could become contaminated if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during extraction.

To date, the Applicant has indicated the existing RSF is performing satisfactorily. There is a potential that increasing the approved RSF 2 capacity by increasing the elevation, will increase seepage. Groundwater quality could be reduced in the vicinity of the residue storage facilities due to seepage of poor quality water.

Potential contamination impacts are assessed as low risk and would be mitigated as discussed in **Section 8.1**.

Groundwater quality in relation to the final void and final void water quality is discussed in **Section 7.6**.

7.6 Final void

The two final voids are expected to behave as sinks, where evaporative loss from the voids exceed surface water and groundwater inflow. The spreadsheet water balance modelling (Appendix E) developed to simulate water level recovery in the two final voids indicates equilibrium water levels for the SAR open cut and Wyoming 1 open cut at approximately180 mAHD and 200 mAHD, respectively.

The majority of water level recovery occurs by 37 years for the Wyoming 1 open cut and by 80 years for the SAR open cut, with final water level increases approaching the equilibrium level taking longer.

The final void equilibrium water levels for the SAR open cut and Wyoming 1 open cut are approximately 25 m and 20 m below the pre-mining regional water table level and the final voids will act as terminal groundwater sinks.

As a groundwater sink, the final void water chemistry will gradually degrade, with concentration of salts increasing due to ongoing evaporative loss from the void. Due to the low hydraulic conductivity of the rock mass and the water level in the open cut remaining lower than the regional fractured rock groundwater system water table level, poor quality water will remain within the vicinity of the void and is unlikely to migrate a significant distance from the voids.

The spreadsheet water balance modelling (Appendix E) developed to simulate water level recovery also predicts evaporative salt concentrations. Salt concentration predictions are as follows:

- SAR
  - 80 years after end of mining – 15,980 mg/L
  - 200 years after end of mining – 22,640 mg/L
  - 300 years after end of mining – 31,385 mg/L
  - 500 years after end of mining – 48,875 mg/L
- Wyoming 1
  - 100 years after end of mining – 17,790 mg/L

- 200 years after end of mining – 32,178 mg/L
- 300 years after end of mining – 46,567 mg/L
- 500 years after end of mining – 75,345 mg/L

There is potential for final void water quality parameters in addition to salinity to alter from that applicable under pre-mining conditions, such as, but not limited to, pH, metals, metalloids and major ions. However, as stated above, poor quality water is anticipated to remain within the vicinity of the voids and is unlikely to migrate a significant distance from the voids.

The potentially poor groundwater quality is unlikely to lower the groundwater beneficial use category (industrial) beyond a distance of 40 m from the mining lease, the activity boundary, which is an AIP (DPI, 2012) Minimal Impact Consideration criterion.

The viability of existing registered bores is assessed as unlikely to be impacted under this scenario due to significant separation distances from the open cuts. The nearest registered bores are located greater than 2 km from Wyoming 1 and greater than 4 km from the SAR Open Cut. Water quality at these bores is unlikely to be impacted by mining.

Potential reduced water quality in the vicinity of the voids is assessed as unlikely to impact GDEs as the regional water table within the fractured rock groundwater system is disconnected from overlying perched alluvial groundwater systems in the vicinity of mining.

7.7 Cumulative impacts

DPIE (2021b) indicates cumulative impacts are a result of incremental, sustained and combined effects of human action and natural variations over time and can be both positive and negative. They can be caused by the compounding effects of a single project or multiple projects in an area, and by the accumulation of effects from past, current and future activities as they arise.

Cumulative impacts to groundwater as a result of the project are assessed as unlikely to occur. Although the historic Myalls United gold mine and Peak Hill mine are located in the region of the project, cumulative impacts as a result of these mines interacting with the project are not likely. This is because groundwater level drawdown associated with these mines is assessed as unlikely to combine with that of the project. This is discussed in further detail in **Section 6.7**.

7.8 NSW AIP Minimal Impact Considerations summary

Model predicted groundwater level reductions include some instances where the AIP (DPI, 2012) Minimal Impact Considerations (see **Section 2.3**) are exceeded. However, interpretation of the model results is such that the AIP (DPI, 2012) Minimal Impact Considerations are assessed as being unlikely to be exceeded.

Excluding TGO monitoring bores, a total of five existing registered bores (GW803680, GW803679, GW803682, GW803681 and GW803678) are within the modelled 2 m drawdown contour at the end of the 200 year post-mining period, the worst case drawdown scenario. However, none of these bores are assessed as relevant to the modelled drawdown results.

The viability of all non-TGO monitoring bores inside the 2 m drawdown contour from the worst case scenario, drawdown 200 years after mining has ceased, are not anticipated to be impacted by mining. This is because all of the bores within the 2 m drawdown contour are shallow bores (3.5 – 4.5 m deep) used for monitoring. These bores tap shallow perched alluvial groundwater systems disconnected from the fractured rock groundwater system that the mine will drawdown. As such, they are assessed as unlikely to be subjected to mining induced drawdown.

TGO/SAR is assessed as unlikely to lower the groundwater beneficial use category beyond a distance of 40 m from an activity, which is an AIP (DPI, 2012) Minimal Impact Consideration criterion.

8. Management and mitigation measures

Management and mitigation measures applicable to groundwater are outlined below in **Sections 8.1**, **8.2** and **8.3**.

8.1 Potential contamination

If accidental spills or leaks occur, potential impacts would be minimised through the implementation of The Applicant's spill response procedures. These include training and standard practices for the control, containment, and clean-up of any hydrocarbon or chemical spill.

The Project's groundwater monitoring program (**Section 8.3**) would also be used to identify contamination attributable to mining.

8.2 Impacts at existing registered bores

Although not predicted, if unforeseen drawdown impacts occur at an existing registered bore due to mining, in accordance with the AIP (DPI, 2012) Minimal Impact Considerations, then make good previsions would apply. Under these conditions, the impacted bore could potentially be replaced with a bore in a new position.

8.3 Preliminary groundwater monitoring program

8.3.1 Overview

It is recommended that ongoing groundwater monitoring is completed during mining at the TGO and SAR monitoring bores, and that requirements for monitoring after mining has ceased are determined based on assessment of conditions at the end of mining. Also, it is recommended that an up to date groundwater monitoring program is developed and approved following Project approval but prior to commencement of mining at SAR. The current groundwater management plan (GHD, 2017) is provided in Appendix G and does not include proposed mining at SAR, nor does it consider the results of the numerical groundwater modelling documented in this report.

8.3.2 Commitment to extend monitoring network

In response to Conditional Gateway Certificate Report (NSW IPC, 2021) requests for further information (**Section 1.5.3**) pertaining to the conceptualised disconnect between the alluvium and fractured rock groundwater systems, to increase confidence in the conceptualisation, the Applicant has committed to installing additional monitoring bores in late 2021 or early 2022. The intended locations are shown in **Figure 8.1** and include a fractured rock monitoring bore to the north of the mine, near the two existing closest water supply bores to the mine, and a paired site within the SAR mine site boundary in the vicinity of Bulldog Creek, comprising a fractured rock monitoring bore with accompanying alluvial monitoring bore.

Monitoring is also proposed at either GW045134 or GW045137, the existing shallow alluvial water supply bores closest to the proposed northern additional fractured rock monitoring bore. Ultimately, proximity of GW045134 or GW045137 to the proposed northern additional fractured rock monitoring bore would dictate which is monitored, with the closest likely to be monitored.

Additional rationalisation and key preliminary details for the extended monitoring network are provided in **Section 5.3**.

In addition, the future groundwater monitoring network will incorporate a suitable number of shallow groundwater monitoring bores around RFS2, to enable monitoring of potential seepage from this facility. The quantity and location of these shallow groundwater monitoring bores would be determined in consultation with relevant government agencies prior to commissioning of Stage 1 of the facility. However, at this stage it is envisaged that five to ten shallow groundwater monitoring bores would surround RFS2.

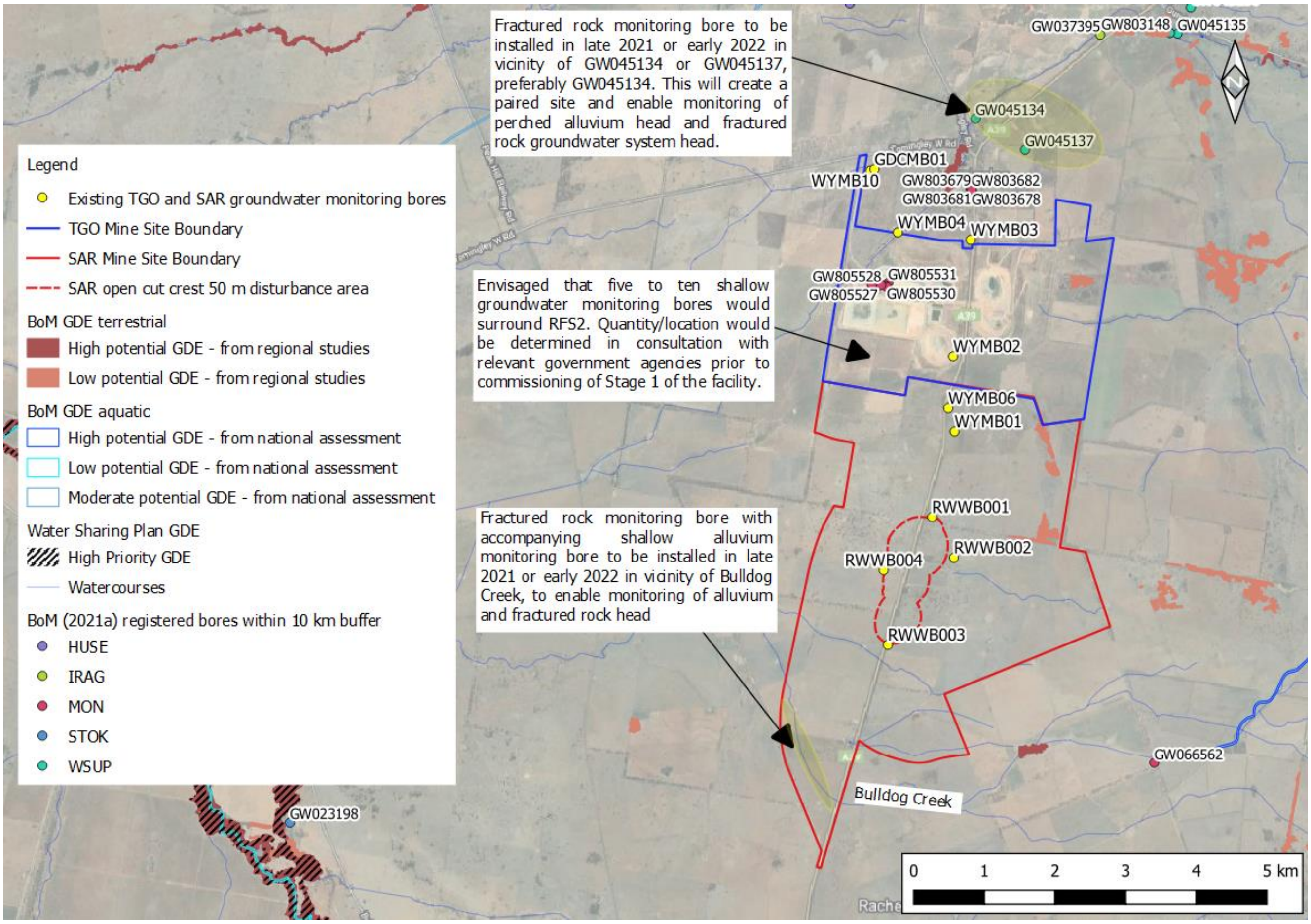


Figure 8.1: Groundwater monitoring network intended expansion sites (note: existing RSF1 shallow monitoring bores shown as BoM bores)

8.3.3 Future updated monitoring program

As the monitoring network is due for expansion soon (i.e. late 2021 to early 2022) and therefore data is not currently available for these expansion locations, it is recommended that an up to date groundwater monitoring program is developed and approved following Project approval but prior to commencement of mining at SAR.

The current groundwater management plan (GHD, 2017) is considered generally appropriate to form a basis by which to update the groundwater monitoring program, for ongoing application at TGO and implementation at SAR, with the following changes:

- Groundwater level monitoring should be expanded to include SAR monitoring bores, RWWB001, RWWB002, RWWB003 and RWB004, and the proposed monitoring network expansion sites. Aside from the shallow RSF bores, groundwater level monitoring should be undertaken at these bores via data logger at a daily frequency. A dedicated barometric logger should be installed in one of the bores and used to enable barometric compensation of the data. If RWWB004 continues to remain dry, then a data logger is not required in this bore. However, groundwater level at RWB004 should still be monitored manually quarterly, to verify the bore is remaining dry on an ongoing basis.

- Groundwater quality monitoring should be expanded to include SAR monitoring bores, RWWB001, RWWB002, RWWB003 and RWB004 (if not dry at time of sampling). The analysis suite should be the same as that specified in groundwater management plan (GHD, 2017) for the TGO fractured rock monitoring bores.
- The GHD (2017) GDCMB01 groundwater level trigger level should be updated to be a groundwater depth of 2.4 m below top of casing or greater for two consecutive quarterly monitoring events. The GHD (2017) trigger levels of 269.64 mAHD ('Stage 1 Trigger') and 268.64 mAHD ('Stage 2 Trigger') are well below the minimum GDCMB01 hydrograph level (271.04 mAHD) shown in **Figure 4.4**.

  The recommended revised trigger of 2.4 m below top of casing corresponds to a level of 271.04 mAHD and represents the minimum level observed in the hydrograph record, which occurs on four occasions.

  The disparity between the GHD (2017) GDCMB01 trigger levels and the hydrograph levels shown in **Figure 4.4** may be because GHD (2017) report that the bores were not surveyed at the time of trigger level development.
- Monitoring of the shallow RSF1 bores should be reviewed and carried over to the new monitoring program if appropriate, or adjusted as required.
- Monitoring requirements for the proposed shallow RSF2 bores should be determined.
- Trigger levels within GHD (2017) should be reviewed and carried over to the new monitoring program if appropriate, or if review finds these triggers are no longer appropriate, updated trigger levels should be developed for application in the up to date monitoring program.
- Trigger levels for monitoring bores that have been installed after GHD (2017) should be developed.
- Trigger levels for should be developed for GW045134 or GW045137, the closest existing shallow alluvial water supply bores to the mine. The trigger levels should be developed based on monitoring data.
- Trigger responses and timeframes within GHD (2017) should be reviewed and updated as required.
- An assessment comparing the observed groundwater level drawdown at TGO/SAR fractured rock monitoring bores to the drawdown predicted during and at the end of mining should be made on an annual basis. At this time, comparisons should also be made between observed groundwater inflow rates (with consideration of evaporation) and modelled groundwater take rates. If the observed drawdowns or groundwater take rates deviate significantly from the model predictions, then an investigation should take place.

9. Conclusion and recommendations

9.1 Recommendations

The following is recommended:

- TGO initially obtain WAL allocation to cover the predicted 2025 groundwater take of 427 ML.
- TGO collects water inflow and outflow data from the SAR Exploration Drive, the TGO UG and SAR Open Cuts, as well as continued monitoring of bores.
- The groundwater model is re-run in 2024 taking into account the monitoring data collected in the intervening period, and re-calibrated if necessary.
- TGO obtain additional groundwater allocation if required based on that updated modelling.

9.2 Conclusion

A groundwater impact assessment has been undertaken to assess potential impacts to groundwater due to proposed additional or modified TGO operations, and SAR mining.

The groundwater impact assessment included:

- Review of relevant legislation, policy, guidelines and licencing requirements.
- Review of the TGO/SAR environmental setting, including development of a conceptual hydrogeological model.
- Calculation of groundwater take for existing, approved and proposed open cuts and underground mines, and calculation of groundwater level drawdown, using an industry standard numerical groundwater flow model package - MODFLOW.
- Assessment of potential impacts to groundwater due to TGO/SAR.
- Development of groundwater related mitigation and management measures.

Interpretation of the groundwater flow model predictions are as follows:

- For TGO and SAR combined, the maximum annual groundwater take due to mining is anticipated to occur in the year of 2026, with a predicted annual groundwater take of 767 ML. This volume is approximately 2.1 ML/d expressed as an average daily volume. The groundwater take is predicted to occur due to dewatering for open cut and underground mining.
- Perpetual groundwater take will occur after mining has ceased due to ongoing evaporative loss within two open cuts where backfilling is not proposed. A pit lake is anticipated to form in these two voids. The predicted total post-mining groundwater take is about 118 ML/yr once pit lake water levels have recovered to equilibrium levels. Prior to pit lake equilibrium levels being achieved, the post-mining groundwater take would be higher than 118 ML/yr but less than that occurring during mining, and is anticipated to progressively decrease with time as the pit lake water levels increase with time. The bulk of pit lake development is estimated to take place within 80 years of mining ceasing, with final increases towards the equilibrium levels taking longer.
- The modelled groundwater inflow rates do not account for evaporation after the groundwater is removed from the model by the model's numerical boundary used to simulate dewatering. For this reason, due to evaporation, the groundwater inflow rate perceived onsite may be considerably lower than the model results.

- At the end of mining, the modelled 2 m groundwater level drawdown contour is contained within the TGO and SAR mine site boundaries except in the north, where the 2 m groundwater level drawdown contour is about 125 m north of the TGO mine site boundary.

  At the end of the 200 year post-mining period, the modelled 2 m groundwater level drawdown contour extends up to about 2.7 km from the SAR mine site boundary and up to about 1.7 km from the TGO mine site boundary.
- GDEs are not anticipated to be impacted by TGO/SAR.
- Baseflows to watercourses are not anticipated to be impacted by TGO/SAR.
- Uncertainty analysis was undertaken to assess the effect of varying model input parameter values on model predictions.
  - None of the uncertainty scenario results significantly alter the primary base case assessment findings relating to groundwater level drawdown impacts.
  - None of the uncertainty scenario results alter the primary base case assessment finding relating to groundwater inflow rates, which is that acquiring entitlement to cover the groundwater take is considered feasible due to the extent of predicted groundwater inflow rates, trading frequency in the applicable water source and percentage of unallocated water in the water source.

Conclusions pertaining to groundwater quality are as follows:

- Groundwater quality is assessed as unlikely to degrade to such point that the groundwater beneficial use category is lowered beyond a distance of 40 m from a TGO/SAR activity. The salinity of the fractured rock groundwater system water in the vicinity of TGO/SAR is high and the beneficial use category of the groundwater is limited to industrial use.
- Final void equilibrium water levels for SAR and TGO are predicted to be 180 mAHD and 200 mAHD, respectively. Thus, a perpetual groundwater sink is predicted to form.
- The final void water chemistry is anticipated to gradually degrade, with concentration of salts increasing due to ongoing evaporative loss from the void. Poor quality water is anticipated to remain within the vicinity of the voids and is unlikely to migrate a significant distance from the voids.
- To date, the Applicant has indicated the existing RSF is performing satisfactorily. There is a potential that increasing the approved RSF 2 capacity by increasing the elevation, will increase seepage. Groundwater quality could be reduced in the vicinity of the residue storage facilities due to seepage of poor quality water.
- Due to considerable horizontal and vertical separation distances, potential water quality reductions are assessed as unlikely to impact the viability of existing registered bores or potential GDEs.

Potential groundwater impacts due to TGO/SAR were assessed against the NSW Aquifer Interference Policy's Minimal Impact Considerations. Aside from TGO monitoring bores, the modelled 2 m groundwater level drawdown contour encroaches on five existing registered bores at the end of the 200 year post-mining period. However, the purpose of all of these bores is monitoring and none of these bores are assessed as relevant to the modelled drawdown results. These bores are located at a BP truckstop and tap shallow perched alluvial groundwater systems disconnected from the fractured rock groundwater system that the mine will drawdown. As such, they are assessed as unlikely to be subjected to mining induced drawdown.

TGO/SAR is assessed as unlikely to lower the groundwater beneficial use category beyond a distance of 40 m from an activity, which is an AIP (DPI, 2012) Minimal Impact Consideration criterion.

Annual groundwater entitlement is required from the Lachlan Fold Belt MDB Groundwater Source of the Water Sharing Plan for the NSW MDB Fractured Rock Groundwater Sources 2020 (NSW Government, 2020) to cover TGO/SAR dewatering.

The predicted maximum annualised groundwater take of 767 ML in the year 2026 is taken to inform assessment of licensing implications. Thus, 477 ML of entitlement in addition to the existing Mine entitlement of 290 ML/year will be required (477 ML + 290 ML = 767 ML) during the mining period. Trading is common in the applicable groundwater source and about 70% of the groundwater in this water source is currently unassigned. Therefore, acquiring additional entitlement is considered feasible. Annual groundwater entitlement will also be required to cover the perpetual groundwater take that will occur after mining has ceased.

Management and mitigation measures are outlined in the report, including recommendations for ongoing groundwater monitoring.

The Project is considered to constitute a low risk to groundwater systems.

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Appendix A. Registered groundwater works

Table A.1: Registered groundwater works within 10 km buffer to TGO mine site boundary and SAR open cut 50 m disturbance area (source: BoM (2021a), and WaterNSW (2021b) for standing water level data)

Bore ID	Bore depth (m)	Drilled date	Purpose	Status	Standing water level depth (m)	Latitude	Longitude
GW012385	44.1	1/10/1959	Exploration	Unknown	7.3	-32.5332	148.1234
GW023198	48.8	1/01/1965	Stock and Domestic	Unknown	36.6	-32.6515	148.1201
GW028886	121.9	1/09/1967	Stock and Domestic	Unknown		-32.7001	148.1867
GW034897	1.8		Water Supply	Unknown		-32.5462	148.2031
GW037395	4.5		Irrigation	Unknown	2.1	-32.5498	148.2409
GW045134	18.3	1/06/1975	Water Supply	Proposed		-32.5607	148.2223
GW045135	3.7	1/06/1975	Water Supply	Proposed	0.9	-32.5496	148.2526
GW045136	5.2	1/06/1975	Water Supply	Proposed		-32.5462	148.2545
GW045137	12.2	1/06/1975	Water Supply	Proposed		-32.5646	148.2298
GW054594	61.6		Water Supply	Functioning		-32.6801	148.2481
GW066562	73	28/04/1990	Monitoring	Proposed		-32.6426	148.2504
GW068651	97	27/04/1990	Commercial and	Proposed		-32.6818	148.2424
GW800177	113.88	18/10/1995	Monitoring	Removed	1	-32.5284	148.2706
GW800178	80	19/10/1995	Monitoring	Removed		-32.5284	148.2706
GW801568	81	30/03/2002	Water Supply	Removed		-32.6646	148.2692
GW802834	77	25/05/1997	Monitoring	Proposed	42	-32.6797	148.2504
GW802842	83	7/08/1997	Water Supply	Functioning	44	-32.6821	148.2503
GW803148	5.8	31/05/2005	Water Supply	Functioning	4.4	-32.5495	148.2514
GW803678	4	12/07/2008	Monitoring	Functioning		-32.5698	148.2219
GW803679	4	12/07/2008	Monitoring	Functioning		-32.5697	148.2217
GW803680	4.5	12/07/2008	Monitoring	Functioning		-32.5696	148.2217
GW803681	3.5	14/07/2008	Monitoring	Functioning		-32.5698	148.2218

GW803682	3.5	14/07/2008	Monitoring	Functioning		-32.5697	148.2218
GW804130	69	28/05/1998	Monitoring	Abandoned		-32.6328	148.1151
GW804132	61	26/05/1998	Monitoring	Abandoned		-32.6897	148.1355
GW804133	81	26/05/1998	Monitoring	Abandoned		-32.6912	148.1367
GW804136	84	29/05/1998	Monitoring	Abandoned		-32.6378	148.103
GW804137	64	11/06/1998	Monitoring	Removed		-32.5738	148.1033
GW805526	11	29/06/2015	Monitoring	Functioning		-32.5821	148.2069
GW805527	11	29/06/2015	Monitoring	Functioning		-32.5821	148.2078
GW805528	11	30/06/2015	Monitoring	Functioning		-32.582	148.2084
GW805529	12	30/06/2015	Monitoring	Functioning		-32.5821	148.2089
GW805530	11	29/06/2015	Monitoring	Functioning		-32.5823	148.2092
GW805531	11	30/06/2015	Monitoring	Functioning		-32.5817	148.2094

Notes: [1.] Monitoring bore at TGO.

Appendix B. Groundwater quality results summary

		Reactive Phosphate	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Magnesium (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	Soluble Carbonate as CaCO3*	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Bicarbonate Alkalinity as CaCO3	Calcium (Filtered)	Cations Total	Chloride	Electrical conductivity (lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)
			Metals											Inorganics																
		mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	meq/L	mg/L	mg/L	meq/L	mg/L	uS/cm	mg/L	%	mg/L	mg/L	mg/L	mg/L	mg/L
EQL		0.01	1	0.1	1	1	0.05	1	1	1	0.1	1	5	1	1	1	0.01	0.01	1	1	0.01	1	1	0.1	0.01	0.1	0.01	0.01	0.01	0.1
ADWG 2018 Health			10	2		2000		10		500	1	20												1.5				11.29[#1]	0.91[#2]	
ADWG 2018 Aesthetic						1000	0.3			100			3000									250								
ANZG (2018) Freshwater 95% toxicant DGVs				0.2[#3]		1.4[#3]		3.4[#4]		1900[#5]	0.6[#6]	11[#6]	8[#7]				0.9[#8]													
NEPM 2013 Table 1C GILs, Fresh Waters				0.2[#9]		1.4[#9]		3.4[#9]		1900[#10]	0.06[#11]	11[#9]	8[#9]																	[#12]
ANZECC 2000 Irrigation Long-Term			100	10	100	200	0.2	2000		200	2	200	2000											1						5
Location_Code	Sampled_Date_Time																													
RWWB001	12/10/2020	-	13	<0.1	<1	<1	0.06	<1	669	813	<0.1	19	<5	<1	<1	600	0.2	308	600	483	278	8590	27,900	-	5.11	<0.5	0.09	0.09	<0.01	<0.5
RWWB001	13/11/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB001	13/11/2020	-	6	<0.1	<1	<1	2.74	<1	699	3590	<0.1	20	8	<1	<1	707	0.36	300	707	450	287	8420	28,100	0.3	2.1	<0.5	0.02	0.02	<0.01	<0.5
RWWB001	30/03/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB001	30/03/2021	<0.01	2	<0.1	<1	<1	0.24	<1	743	3160	<0.1	5	<5	<1	<1	754	0.09	285	754	486	302	7810	27,200	0.3	2.98	<0.5	0.02	0.02	<0.01	<0.5
RWWB001	21/05/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB001	21/05/2021	-	10	<0.1	<1	<1	5.26	<1	719	1590	<0.1	10	10	<1	<1	645	0.25	282	645	451	296	7620	26,300	0.3	2.36	0.7	0.04	0.04	<0.01	0.7
RWWB002	13/11/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB002	13/11/2020	-	<1	<0.1	<1	4	0.73	<1	266	968	<0.1	2	32	<1	<1	130	0.32	192	130	1370	192	6340	19,800	0.6	0.09	0.5	0.01	0.01	<0.01	0.5
RWWB002	30/03/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB002	30/03/2021	<0.01	<1	<0.1	<1	<1	<0.05	<1	297	1190	<0.1	8	19	<1	<1	158	0.23	183	158	1680	217	5970	19,300	0.5	8.45	<0.5	<0.01	<0.01	<0.01	<0.5
RWWB002	21/05/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB002	21/05/2021	-	<1	<0.1	<1	<1	0.29	<1	280	1100	<0.1	4	8	<1	<1	151	0.16	183	151	1300	194	5900	18,500	0.5	2.99	<0.2	<0.01	<0.01	<0.01	<0.2
RWWB003	13/11/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB003	13/11/2020	-	<1	<0.1	<1	6	<0.05	<1	530	18	<0.1	6	23	<1	<1	724	<0.1	179	724	224	181	5140	18,400	0.9	0.53	1.3	0.05	0.05	<0.01	1.4
RWWB003	30/03/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB003	30/03/2021	0.18	<1	<0.1	<1	1	<0.05	<1	572	51	<0.1	78	<5	<1	<1	776	0.02	178	776	210	193	4760	17,100	0.9	3.83	<0.5	0.07	0.07	<0.01	<0.5
RWWB003	21/05/2021	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RWWB003	21/05/2021	-	<1	0.1	1	6	<0.05	<1	547	62	<0.1	92	11	<1	<1	759	<0.01	188	759	199	184	5070	17,200	0.8	1.06	1.4	0.05	0.05	<0.01	1.4

Statistical Summary

Statistic	Reactive Phosphate	Arsenic (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Magnesium (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	Soluble Carbonate as CaCO3*	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Bicarbonate Alkalinity as CaCO3	Calcium (Filtered)	Cations Total	Chloride	Electrical conductivity (lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)
Number of Results	3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10
Number of Detects	1	4	1	1	4	6	0	10	10	0	10	7	0	0	10	8	10	10	10	10	10	10	9	10	4	8	8	0	4
Minimum Concentration	<0.01	<1	<0.1	<1	<1	<0.05	<1	266	18	<0.1	2	<5	<1	<1	130	<0.01	178	130	199	181	4760	17100	0.3	0.09	<0.2	<0.01	<0.01	<0.01	<0.2
Minimum Detect	0.18	2	0.1	1	1	0.06	ND	266	18	ND	2	8	ND	ND	130	0.02	178	130	199	181	4760	17100	0.3	0.09	0.5	0.01	0.01	ND	0.5
Maximum Concentration	0.18	13	0.1	1	6	5.26	<1	743	3590	<0.1	92	32	<1	<1	776	0.36	308	776	1680	302	8590	28100	0.9	8.45	1.4	0.09	0.09	<0.01	1.4
Maximum Detect	0.18	13	0.1	1	6	5.26	ND	743	3590	ND	92	32	ND	ND	776	0.36	308	776	1680	302	8590	28100	0.9	8.45	1.4	0.09	0.09	ND	1.4
Average Concentration	0.063	3.4	0.055	0.55	2	0.94	0.5	532	1254	0.05	24	12	0.5	0.5	540	0.17	228	540	685	232	6562	21980	0.57	3	0.53	0.036	0.036	0.005	0.54
Median Concentration	0.005	0.5	0.05	0.5	0.5	0.15	0.5	559.5	1034	0.05	9	9	0.5	0.5	676	0.18	190	676	467	205.5	6155	19550	0.5	2.67	0.25	0.03	0.03	0.005	0.25
Standard Deviation	0.1	4.7	0.016	0.16	2.4	1.7	0	188	1243	0	33	9.9	0	0	277	0.12	57	277	548	51	1437	4737	0.25	2.5	0.47	0.029	0.029	0	0.49
Number of Guideline Exceedances	0	2	0	0	3	5	0	0	7	10	4	7	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Dete	0	2	0	0	3	5	0	0	7	0	4	7	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0

Env Stds Comments
#1:Converted from Nitrate as NO3 (50 mg/L)
#2:Converted from Nitrite as NO2 (3 mg/L)
#3:Very high reliability
#4:Moderate reliability
#5:Moderate reliability. DGV may not protect key test species from chronic toxicity (this refers to experimental chronic values or geometric mean for species). Check toxicant DGV technical brief for spread of data and its significance.
#6:Low reliability
#7:High reliability
#8:High reliability. Ammonia as total ammonia, measured as [NH3-N] at pH 8. DGV may not protect key test species from chronic toxicity (this refers to experimental chronic values or geometric mean for species).
#9:Values calculated using hardness of 30 mg/L CaCO3. Refer ANZECC & ARMCANZ (2000) for site specific hardness guidance
#10:Figure may not protect key species from chronic toxicity, refer to ANZECC & ARMCANZ (2000) for further guidance.
#11:Chemical for which possible bioaccumulation and secondary poisoning effects should be considered, refer to ANZECC & ARMCANZ (2000) for further guidance.
#12:refer to guideline

Environmental Standards
NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

								Field Parameters						Physiochemical parameters
		Potassium (Filtered)	Reactive Phosphorus as P	Sodium (Filtered)	Sulfate as SO4 - Turbidimetric (Filtered)	Total Dissolved Solids	TSS	DO (Field)	DO % (Field)	EC (field)	pH (Field)	Redox (Field)	Temp (Field)	pH (Lab)
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	uS/cm	pH Units	mV	oC	pH Units
EQL		1	0.01	1	1	10	5							0.01
ADWG 2018 Health														
ADWG 2018 Aesthetic				180		600					6.5-8.5|6.5-8.5			
ANZG (2018) Freshwater 95% toxicant D														
NEPM 2013 Table 1C GILs, Fresh Waters														
ANZECC 2000 Irrigation Long-Term														
Location_Code	Sampled_Date_Time													
RWWB001	12/10/2020	14	-	4560	2570	19,800	114	-	-	-	-	-	-	7.85
RWWB001	13/11/2020	-	-	-	-	-	-	2.79	35.4	25,600	6.58	24	27.7	-
RWWB001	13/11/2020	14	-	4760	2310	19,400	1710	-	-	-	-	-	-	6.85
RWWB001	30/03/2021	-	-	-	-	-	-	1.58	19.1	27,400	6.77	-104	27.7	-
RWWB001	30/03/2021	15	<0.01	4980	2380	18,700	26	-	-	-	-	-	-	7.02
RWWB001	21/05/2021	-	-	-	-	-	-	2.23	25.2	32,700	6.67	-29	22.6	-
RWWB001	21/05/2021	14	-	4910	2600	19,600	930	-	-	-	-	-	-	6.9
RWWB002	13/11/2020	-	-	-	-	-	-	2.31	28.4	18,400	6.72	159	26.3	-
RWWB002	13/11/2020	11	-	2330	518	16,400	71	-	-	-	-	-	-	6.96
RWWB002	30/03/2021	-	-	-	-	-	-	2.96	34.7	19,400	6.87	-92	27	-
RWWB002	30/03/2021	12	<0.01	2500	571	15,500	114	-	-	-	-	-	-	7.05
RWWB002	21/05/2021	-	-	-	-	-	-	1.91	22	22,320	6.63	-132	22.2	-
RWWB002	21/05/2021	10	-	2430	632	14,300	86	-	-	-	-	-	-	6.93
RWWB003	13/11/2020	-	-	-	-	-	-	5.66	69.3	17,800	6.97	184	25.8	-
RWWB003	13/11/2020	14	-	2890	937	12,400	4090	-	-	-	-	-	-	7.24
RWWB003	30/03/2021	-	-	-	-	-	-	5.23	64	17,800	6.94	176	26	-
RWWB003	30/03/2021	13	0.06	3100	1380	12,500	11,400	-	-	-	-	-	-	7.26
RWWB003	21/05/2021	-	-	-	-	-	-	4.77	55.1	22,320	6.86	123	22.2	-
RWWB003	21/05/2021	13	-	2950	1410	11,700	4610	-	-	-	-	-	-	7.13

Statistical Summary

Number of Results	10	3	10	10	10	10	9	9	9	9	9	9	10
Number of Detects	10	1	10	10	10	10	9	9	9	9	9	9	10
Minimum Concentration	10	<0.01	2330	518	11700	26	1.58	19.1	17800	6.58	-132	22.2	6.85
Minimum Detect	10	0.06	2330	518	11700	26	1.58	19.1	17800	6.58	ND	22.2	6.85
Maximum Concentration	15	0.06	4980	2600	19800	11400	5.66	69.3	32700	6.97	184	27.7	7.85
Maximum Detect	15	0.06	4980	2600	19800	11400	5.66	69.3	32700	6.97	184	27.7	7.85
Average Concentration	13	0.023	3541	1531	16030	2315	3.3	39	22638	6.8	34	25	7.1
Median Concentration	13.5	0.005	3025	1395	15950	522	2.79	34.7	22320	6.77	24	26	7.035
Standard Deviation	1.6	0.032	1117	863	3219	3624	1.5	19	5101	0.14	129	2.3	0.29
Number of Guideline Exceedances	0	0	10	0	10	0	9	0	0	0	0	9	10
Number of Guideline Exceedances(Dete	0	0	10	0	10	0	9	0	0	0	0	9	10

Env Stds Comments

#1:Converted from Nitrate as NO3 (50 m
#2:Converted from Nitrite as NO2 (3 mg
#3:Very high reliability
#4:Moderate reliability
#5:Moderate reliability. DGV may not pr
#6:Low reliability
#7:High reliability
#8:High reliability. Ammonia as total am
#9:Values calculated using hardness of 3
#10:Figure may not protect key species f
#11:Chemical for which possible bioaccu
#12:refer to guideline

Environmental Standards

NHMRC, NRMMC, August 2018, ADWG
NHMRC, NRMMC, August 2018, ADWG
ANZECC, October 2000, ANZECC 2000 Ir
NEPM, April 2013, NEPM 2013 Table 1C

			NA									
			Reactive Phosphate	Weak Acid Dissociable Cyanide	Arsenic	Arsenic (filtered)	Barium (filtered)	Beryllium (filtered)	Boron (filtered)	Cadmium	Cadmium (filtered)	Chromium (III+VI)
			mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL			**0.01**	**0.004**	**1**	**1**	**1**	**1**	**50**	**0.1**	**0.1**	**1**
ADWG 2018 Health					10	10	2,000	60	4,000	2	2	
ADWG 2018 Aesthetic												
ANZECC 2000 Irrigation Long-Term					100	100		100	500	10	10	100
NEPM 2013 Table 1C GILs, Fresh Waters									370#4	0.2#5	0.2#5	
6.5 < pH (Field) (pH Units)												
6.5 < pH (Lab) (pH Units)												
ANZG (2018) Freshwater 95% toxicant DGVs									370#9	0.2#10	0.2#10	
6.5 < pH (Lab) (pH Units)												
Field ID	**Date**	**Lab Report Number**										
SP1	14/10/2019	ES1934009	-	<0.004	-	**8**	**138**	<1	**170**	-	<0.1	-
WCDP3	26/11/2020	ES2042144	-	<0.004	-	**1**	**25**	<1	630	-	<0.1	-
WCDP03	22/02/2021	ES2106358	-	<0.004	-	**3**	**33**	<1	800	-	<0.1	-
WCDP03	26/03/2021	ES2111408	-	<0.004	-	**2**	**30**	<1	670	-	<0.1	-
WCDP04	22/02/2021	ES2106358	-	<0.004	-	**3**	**22**	<1	890	-	<0.1	-
WCDP04	26/03/2021	ES2111408	-	<0.004	-	**3**	**20**	<1	700	-	<0.1	-
WYMB01(EPA9)	27/06/2019	ES1920314	<0.01	<0.004	**6**	-	-	-	-	**0.2**	-	<1
WYMB02(EPA10)	27/06/2019	ES1920314	**0.55**	<0.004	**2**	-	-	-	-	**0.1**	-	**3**
WYMB03(EPA11)	27/06/2019	ES1920314	**0.13**	<0.004	**2**	-	-	-	-	<0.1	-	**1**
WYMB04(EPA12)	27/06/2019	ES1920314	**0.09**	<0.004	**1**	-	-	-	-	<0.1	-	**5**
WYMB06(EPA13)	27/06/2019	ES1920314	**0.44**	**0.019**	**71**	-	-	-	-	**0.1**	-	**3**
WYMB10(EPA14)	27/06/2019	ES1920314	**0.42**	<0.004	<10#16	-	-	-	-	<1.0#16	-	<10#16

Comments

#1 Converted from Nitrate as NO3 (50 mg/L)
#2 Converted from Nitrite as NO2 (3 mg/L)
#3 pH>6.5
#4 Figure may not protect key species from chronic toxicity, refer to ANZECC & ARMCANZ (2000) for further guidance.
#5 Values calculated using hardness of 30 mg/L CaCO3. Refer ANZECC & ARMCANZ (2000) for site specific hardness guidance
#6 Chemical for which possible bioaccumulation and secondary poisoning effects should be considered, refer to ANZECC & ARMCANZ (2000) for further guidance.
#7 refer to guideline
#8 Moderate reliability
#9 High reliability. DGV may not protect key test species from chronic toxicity (this refers to experimental chronic values or geometric mean for species). Check toxicant DGV technical brief for spread of data and its signifi
#10 Very high reliability
#11 Moderate reliability. DGV may not protect key test species from chronic toxicity (this refers to experimental chronic values or geometric mean for species). Check toxicant DGV technical brief for spread of data and its
#12 Low reliability
#13 High reliability
#14 High reliability. Ammonia as total ammonia, measured as [NH3-N] at pH 8. DGV may not protect key test species from chronic toxicity (this refers to experimental chronic values or geometric mean for species).
#15 Result value is an approximate.
#16 Reported Analyte LOR is higher than Requested Analyte LOR

Environmental Standards

NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

			Metals									
			Chromium (III+VI) (filtered)	Cobalt (filtered)	Copper	Copper (filtered)	Iron	Lead	Lead (filtered)	Magnesium (filtered)	Manganese (filtered)	Mercury
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
EQL			**1**	**1**	**1**	**1**	**50**	**1**	**1**	**1**	**1**	**0.1**
ADWG 2018 Health					2,000	2,000		10	10		500	1
ADWG 2018 Aesthetic					1,000	1,000	300				100	
ANZECC 2000 Irrigation Long-Term			100	50	200	200	200	2,000	2,000		200	2
NEPM 2013 Table 1C GILs, Fresh Waters					1.4[#5]	1.4[#5]		3.4[#5]	3.4[#5]		1,900[#4]	0.06[#6]
6.5 < pH (Field) (pH Units)												
6.5 < pH (Lab) (pH Units)												
ANZG (2018) Freshwater 95% toxicant DGVs					1.4[#10]	1.4[#10]		3.4[#8]	3.4[#8]		1,900[#11]	0.6[#12]
6.5 < pH (Lab) (pH Units)												
Field ID	**Date**	**Lab Report Number**										
SP1	14/10/2019	ES1934009	<1	**2**	-	4	-	-	<1	**78**	**181**	-
WCDP3	26/11/2020	ES2042144	**22**	**2**	-	5	-	-	<1	**45**	**1**	-
WCDP03	22/02/2021	ES2106358	**16**	**2**	-	6	-	-	<1	**53**	**2**	-
WCDP03	26/03/2021	ES2111408	**14**	**2**	-	<1	-	-	<1	**57**	**2**	-
WCDP04	22/02/2021	ES2106358	**5**	**2**	-	6	-	-	<1	**64**	**2**	-
WCDP04	26/03/2021	ES2111408	**5**	**2**	-	2	-	-	<1	**63**	<1	-
WYMB01(EPA9)	27/06/2019	ES1920314	-	-	6	-	**1,020**	6	-	**257**	-	<0.1
WYMB02(EPA10)	27/06/2019	ES1920314	-	-	5	-	**750**	6	-	**464**	-	**0.2**
WYMB03(EPA11)	27/06/2019	ES1920314	-	-	6	-	**120**	10	-	**577**	-	<0.1
WYMB04(EPA12)	27/06/2019	ES1920314	-	-	19	-	**4,820**	4	-	**709**	-	<0.1
WYMB06(EPA13)	27/06/2019	ES1920314	-	-	14	-	**540**	13	-	**266**	-	<0.1
WYMB10(EPA14)	27/06/2019	ES1920314	-	-	<10[#16]	-	**830**	<10[#16]	-	**650**	-	<0.1

Comments

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#15 Result value is an approximate.
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Environmental Standards

NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

			Mercury (filtered)	Nickel	Nickel (filtered)	Selenium (filtered)	Vanadium (filtered)	Zinc	Zinc (filtered)	Soluble Carbonate as CaCO3*	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L
EQL			**0.1**	**1**	**1**	**10**	**10**	**5**	**5**	**1**	**1**	**1**
ADWG 2018 Health			1	20	20	10						
ADWG 2018 Aesthetic								3,000	3,000			
ANZECC 2000 Irrigation Long-Term			2	200	200	20	100	2,000	2,000			
NEPM 2013 Table 1C GILs, Fresh Waters			0.06#6	11#5	11#5	5#6		8#5	8#5			
6.5 < pH (Field) (pH Units)												
6.5 < pH (Lab) (pH Units)												
ANZG (2018) Freshwater 95% toxicant DGVs			0.6#12	11#12	11#12	11#12		8#13	8#13			
6.5 < pH (Lab) (pH Units)												
Field ID	**Date**	**Lab Report Number**										
SP1	14/10/2019	ES1934009	<0.1	-	**3**	<10	<10	-	<5	<1	<1	**188**
WCDP3	26/11/2020	ES2042144	<0.1	-	<1	**20**	<10	-	**25**	<1	<1	**770**
WCDP03	22/02/2021	ES2106358	<0.1	-	**1**	**40**	<10	-	**14**	<1	<1	**714**
WCDP03	26/03/2021	ES2111408	<0.1	-	<1	**30**	<10	-	<5	<1	<1	**595**
WCDP04	22/02/2021	ES2106358	<0.1	-	**1**	**30**	**20**	-	**21**	<1	<1	**773**
WCDP04	26/03/2021	ES2111408	<0.1	-	<1	**30**	**20**	-	<5	<1	<1	**684**
WYMB01(EPA9)	27/06/2019	ES1920314	-	**3**	-	-	-	**32**	-	<1	<1	**333**
WYMB02(EPA10)	27/06/2019	ES1920314	-	**3**	-	-	-	**10**	-	<1	<1	**982**
WYMB03(EPA11)	27/06/2019	ES1920314	-	**3**	-	-	-	**19**	-	<1	<1	**1,120**
WYMB04(EPA12)	27/06/2019	ES1920314	-	**7**	-	-	-	**62**	-	<1	<1	**942**
WYMB06(EPA13)	27/06/2019	ES1920314	-	**20**	-	-	-	**111**	-	<1	<1	**1,070**
WYMB10(EPA14)	27/06/2019	ES1920314	-	<10#16	-	-	-	<52#16	-	<1	<1	**900**

Comments
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Environmental Standards
NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

Field ID	Date	Lab Report Number	Ammonia as N	Anions Total	Bicarbonate Alkalinity as CaCO3	Calcium (filtered)	Cations Total	Chloride	Cyanide (Free)	Cyanide Total	Electrical conductivity (lab)	Fluoride
			mg/L	meq/L	mg/L	mg/L	meq/L	mg/L	mg/L	mg/L	uS/cm	mg/L
EQL			**0.01**	**0.01**	**1**	**1**	**0.01**	**1**	**0.004**	**0.004**	**1**	**0.1**
ADWG 2018 Health										0.08		1.5
ADWG 2018 Aesthetic								250				
ANZECC 2000 Irrigation Long-Term												1
NEPM 2013 Table 1C GILs, Fresh Waters										0.007		
6.5 < pH (Field) (pH Units)												
6.5 < pH (Lab) (pH Units)												
ANZG (2018) Freshwater 95% toxicant DGVs			0.9[#14]									
6.5 < pH (Lab) (pH Units)												
SP1	14/10/2019	ES1934009	**0.07**	**26.7**	**188**	**60**	**26.6**	**660**	<0.004	<0.004	**2,880**	**0.6**
WCDP3	26/11/2020	ES2042144	**0.02**	**58.7**	**770**	**12**	**54.1**	**1,200**	<0.004	<0.004	**5,850**	**1.0**
WCDP03	22/02/2021	ES2106358	<0.01	**59.1**	**714**	**14**	**60.2**	**1,140**	<0.004	<0.004	**5,920**	**1.3**
WCDP03	26/03/2021	ES2111408	**0.06**	**59.0**	**595**	**14**	**66.6**	**1,250**	<0.004	<0.004	**6,240**	**0.9**
WCDP04	22/02/2021	ES2106358	<0.01	**65.4**	**773**	**22**	**66.7**	**1,080**	<0.004	<0.004	**6,320**	**0.8**
WCDP04	26/03/2021	ES2111408	**0.01**	**60.8**	**684**	**23**	**70.6**	**1,120**	<0.004	<0.004	**6,410**	**0.8**
WYMB01(EPA9)	27/06/2019	ES1920314	**0.19**	**119**	**333**	**265**	**128**	**3,310**	<0.004	**0.012**	**12,900**	**0.2**
WYMB02(EPA10)	27/06/2019	ES1920314	<0.01	**230**	**982**	**148**	**253**	**5,820**	<0.004	<0.004	**22,600**	**0.6**
WYMB03(EPA11)	27/06/2019	ES1920314	**0.01**	**231**	**1,120**	**195**	**251**	**5,660**	<0.004	<0.004	**21,900**	**0.6**
WYMB04(EPA12)	27/06/2019	ES1920314	<0.01	**282**	**942**	**291**	**319**	**7,240**	<0.004	<0.004	**27,300**	**1.8**
WYMB06(EPA13)	27/06/2019	ES1920314	<0.01	**111**	**1,070**	**125**	**133**	**1,700**	**0.018**	**0.150**	**11,900**	**0.6**
WYMB10(EPA14)	27/06/2019	ES1920314	<0.01	**290**	**900**	**232**	**330**	**7,320**	<0.004	<0.004	**28,400**	**0.8**

Comments

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Environmental Standards

NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

			Inorganics									
			Ionic Balance	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphorus	Potassium (filtered)	Reactive Phosphorus as P	Sodium (filtered)
			%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL			**0.01**	**0.1**	**0.01**	**0.01**	**0.01**	**0.1**	**0.01**	**1**	**0.01**	**1**
ADWG 2018 Health						11.29#1	0.91#2					
ADWG 2018 Aesthetic												180
ANZECC 2000 Irrigation Long-Term								5	0.05			
NEPM 2013 Table 1C GILs, Fresh Waters								#7	#7			
6.5 < pH (Field) (pH Units)												
6.5 < pH (Lab) (pH Units)												
ANZG (2018) Freshwater 95% toxicant DGVs												
6.5 < pH (Lab) (pH Units)												
Field ID	**Date**	**Lab Report Number**										
SP1	14/10/2019	ES1934009	**0.07**	**0.9**	**0.04**	**0.04**	<0.01	**0.9**	**0.10**	**8**	<0.01	**391**
WCDP3	26/11/2020	ES2042144	**4.10**	**2.2**	**9.82**	**9.81**	**0.01**	**12.0**	**0.06**	**9**	<0.01	**1,140**
WCDP03	22/02/2021	ES2106358	**0.90**	**2.2**	**13.4**	**13.4**	<0.01	**15.6**	**0.14**	**12**	**0.02**	**1,260**
WCDP03	26/03/2021	ES2111408	**6.05**	**2.0**	**13.5**	**13.5**	<0.01	**15.5**	**0.02**	**11**	<0.01	**1,400**
WCDP04	22/02/2021	ES2106358	**0.93**	**3.0**	**19.5**	**19.5**	<0.01	**22.5**	**0.08**	**11**	**0.04**	**1,380**
WCDP04	26/03/2021	ES2111408	**7.40**	**2.8**	**18.9**	**18.9**	**0.01**	**21.7**	**0.04**	**11**	<0.01	**1,470**
WYMB01(EPA9)	27/06/2019	ES1920314	**3.32**	-	<0.01	<0.01	<0.01	-	-	**6**	<0.01	**2,140**
WYMB02(EPA10)	27/06/2019	ES1920314	**4.82**	-	**0.62**	**0.62**	<0.01	-	-	**9**	**0.18**	**4,760**
WYMB03(EPA11)	27/06/2019	ES1920314	**4.15**	-	**0.37**	**0.37**	<0.01	-	-	**16**	**0.04**	**4,450**
WYMB04(EPA12)	27/06/2019	ES1920314	**6.11**	-	**0.08**	**0.08**	<0.01	-	-	**18**	**0.03**	**5,640**
WYMB06(EPA13)	27/06/2019	ES1920314	**8.72**	-	**0.54**	**0.54**	<0.01	-	-	**6**	**0.14**	**2,400**
WYMB10(EPA14)	27/06/2019	ES1920314	**6.49**	-	**0.43**	**0.43**	<0.01	-	-	**21**	**0.14**	**6,080**

Comments
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Environmental Standards
NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

								Physiochemical parameters
			Sodium Absorption Ratio (filtered)	Sulfate as SO4 - Turbidimetric (filtered)	Total Dissolved Solids	Hardness as CaCO3 (filtered)	TSS	pH (Lab)
			-	mg/L	mg/L	mg/L	mg/L	pH Units
EQL			**0.01**	**1**	**10**	**1**	**5**	**0.01**
ADWG 2018 Health								
ADWG 2018 Aesthetic					600	200		
ANZECC 2000 Irrigation Long-Term								
NEPM 2013 Table 1C GILs, Fresh Waters								
6.5 < pH (Field) (pH Units)								
6.5 < pH (Lab) (pH Units)								
ANZG (2018) Freshwater 95% toxicant DGVs								
6.5 < pH (Lab) (pH Units)								
Field ID	**Date**	**Lab Report Number**						
SP1	14/10/2019	ES1934009	**7.84**	**206**	**1,660**	**471**	**100**	**8.09**
WCDP3	26/11/2020	ES2042144	**33.8**	**457**	**3,420**	**215**	**105**	**8.07**
WCDP03	22/02/2021	ES2106358	**34.4**	**609**	**3,730**	**253**	**100**	**7.95**
WCDP03	26/03/2021	ES2111408	**37.1**	**568**	**3,870**	**270**	**54**	**8.09**
WCDP04	22/02/2021	ES2106358	**33.6**	**938**	**4,140**	**318**	**85**	**7.85**
WCDP04	26/03/2021	ES2111408	**35.9**	**748**	**4,140**	**317**	**58**	**8.04**
WYMB01(EPA9)	27/06/2019	ES1920314	-	**931**	**6,480**	**1,720**	**7**	**7.47**
WYMB02(EPA10)	27/06/2019	ES1920314	-	**2,200**	**14,500**	**2,280**	**33**	**7.51**
WYMB03(EPA11)	27/06/2019	ES1920314	-	**2,360**	**14,600**	**2,860**	<5	**7.41**
WYMB04(EPA12)	27/06/2019	ES1920314	-	**2,830**	**19,300**	**3,650**	**497**	**7.49**
WYMB06(EPA13)	27/06/2019	ES1920314	-	**2,020**	**6,620**	**1,410**	**25**	**7.85**
WYMB10(EPA14)	27/06/2019	ES1920314	-	**3,140**	**19,500**	**3,260**	**23**	**7.47**

Comments
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#14 High reliability. Ammonia as total ammonia, measured as [NH3-N] at pH 8. DGV
#15 Result value is an approximate.
#16 Reported Analyte LOR is higher than Requested Analyte LOR

Environmental Standards
NHMRC, NRMMC, August 2018, ADWG 2018 Health
NHMRC, NRMMC, August 2018, ADWG 2018 Aesthetic
ANZECC, October 2000, ANZECC 2000 Irrigation Long-Term
NEPM, April 2013, NEPM 2013 Table 1C GILs, Fresh Waters

Appendix C. Hydraulic testing

Packer test analysis sheets (19 sheets)

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWRC352D	**Test No:**		Date:	21-Sep-20	Operator:	
Collar RL:	268.04	Location:	Easting (m) / Northing (m)	614145 / 6390680		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	400	Drill rod depth + 1.03 m
j		-vertical	346.4	h.sin a
k	Length of test section(m)		119	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		6267	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		2739	(j-d).10
q	Maximum allowable total test pressure (KPa)		5014	0.8n
r	Maximum allowable gauge test pressure (KPa)		4279	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5061	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		6750	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	19574	19710	19850	19980		
	Flow (L)	0	136	140	130		
	Average Test Flow (L/min)	135.3		**Test Flow (L/min/m)**		1.14	

Stage							
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	20150	20310	20460	20610		
	Flow (L)		160	150	150		
	Average Test Flow (L/min)	153.3		**Test Flow (L/min/m)**		1.29	

Stage							
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	20810	20970	21145	21320		
	Flow (L)	0	160	175	175		
	Average Test Flow (L/min)	170.0		**Test Flow (L/min/m)**		1.43	

Stage							
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	21650	21735	21920	22130		
	Flow (L)	0	85	185	210		
	Average Test Flow (L/min)	160.0		**Test Flow (L/min/m)**		1.34	

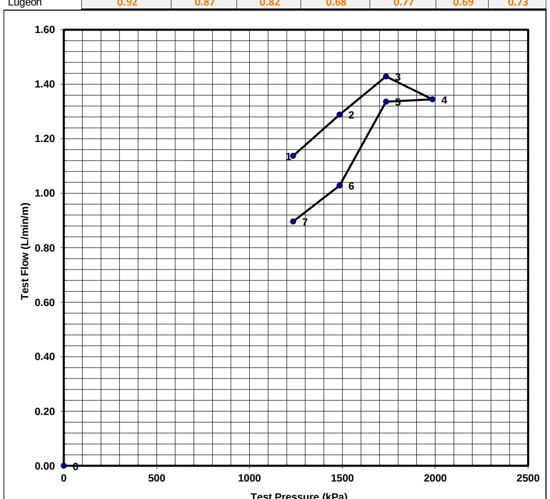
Stage							
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	22330	22492	22652	22807		
	Flow (L)	0	162	160	155		
	Average Test Flow (L/min)	159.0		**Test Flow (L/min/m)**		1.34	

Stage							
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	22970	23107	23245	23337		
	Flow (L)	0	137	138	92		
	Average Test Flow (L/min)	122.3		**Test Flow (L/min/m)**		1.03	

Stage							
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	23500	23600	23710	23820		
	Flow (L)	0	100	110	110		
	Average Test Flow (L/min)	106.7		**Test Flow (L/min/m)**		0.90	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	1.14	1.29	1.43	1.34	1.34	1.03	0.90
Lugeon	0.92	0.87	0.82	0.68	0.77	0.69	0.73



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.87 (average of Stage 1 - 3)
Permeability (m/day) = 1.09E-02
Permeability (m/s) = 1.26E-07

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWRC352D	**Test No:**		Date:	21-Sep-20	Operator:	
Collar RL:	268.04	Location:	Easting (m) Northing (m)	614145 6390680		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	451	Drill rod depth + 1.03 m
j		-vertical	390.6	h.sin a
k	Length of test section(m)		68	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		6974	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		3181	(j-d).10
q	Maximum allowable total test pressure (KPa)		5579	0.8n
r	Maximum allowable gauge test pressure (KPa)		4844	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5503	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		6250	

1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10			
	Meter reading (L)	18150	18160	18161			
	Flow (L)	0	10	1			
	Average Test Flow (L/min)	5.5		**Test Flow (L/min/m)**		0.08	

2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	18161	18162	18162	18162		
	Flow (L)		1	0	0		
	Average Test Flow (L/min)	0.3		**Test Flow (L/min/m)**		0.005	

3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	18162	18162	18162	18162		
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	18162	18163	18163	18163		
	Flow (L)	0	1	0	0		
	Average Test Flow (L/min)	0.3		**Test Flow (L/min/m)**		0.005	

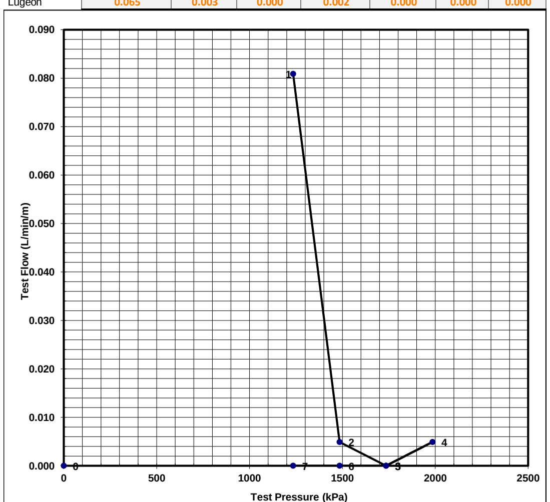
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	18163	18163	18163	18163		
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	18163	18163	18163	18163		
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	18163	18163	18163	18163		
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.081	0.005	0.000	0.005	0.000	0.000	0.000
Lugeon	0.065	0.003	0.000	0.002	0.000	0.000	0.000



Lugeon units = Test Flow (L/min/m) at 1000kPa =
Permeability (m/day) =
Permeability (m/s) =

No flow conditions. Lugeon and permeability not reported.

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP	
Hole No:	RWRC352D	**Test No:**		Date:	21-Sep-20	Operator:
Collar RL:	268.04	Location:	Easting (m) Northing (m)	614145 6390680	Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	499	Drill rod depth + 1.03 m
j		-vertical	432.1	h.sin a
k	Length of test section(m)		20	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		7639	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		3597	(j-d).10
q	Maximum allowable total test pressure (KPa)		6111	0.8n
r	Maximum allowable gauge test pressure (KPa)		5377	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5918	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		6750	

1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10			
	Meter reading (L)	1784	1785	1786			
	Flow (L)	0	1	1			
	Average Test Flow (L/min)	1.0		**Test Flow (L/min/m)**		0.05	

2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	1786	1788	1789	1791		
	Flow (L)		2	1	2		
	Average Test Flow (L/min)	1.7		**Test Flow (L/min/m)**		0.08	

3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	1791	1792	1793	1794		
	Flow (L)	0	1	1	1		
	Average Test Flow (L/min)	1.0		**Test Flow (L/min/m)**		0.05	

4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	1794	1795	1796	1798		
	Flow (L)	0	1	1	2		
	Average Test Flow (L/min)	1.3		**Test Flow (L/min/m)**		0.07	

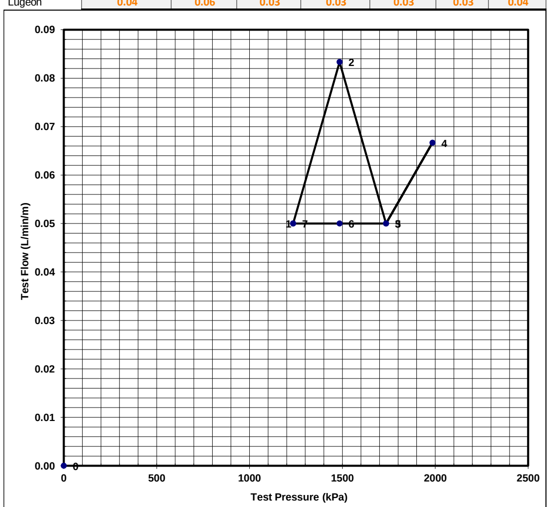
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	1798	1799	1800	1801		
	Flow (L)	0	1	1	1		
	Average Test Flow (L/min)	1.0		**Test Flow (L/min/m)**		0.05	

6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	1801	1802	1803	1804		
	Flow (L)	0	1	1	1		
	Average Test Flow (L/min)	1.0		**Test Flow (L/min/m)**		0.05	

7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	1804	1805	1806	1807		
	Flow (L)	0	1	1	1		
	Average Test Flow (L/min)	1.0		**Test Flow (L/min/m)**		0.05	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.05	0.08	0.05	0.07	0.05	0.05	0.05
Lugeon	0.04	0.06	0.03	0.03	0.03	0.03	0.04



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.04 (average lugeon for stages)

Permeability (m/day) = 4.69E-04

Permeability (m/s) = 5.43E-09

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD042	**Test No:**		Date:	26-Sep-20	Operator:	
Collar RL:	268.13	Location:	Easting (m) / Northing (m)	614175 / 6390630		Azimuth:	270

a	Declination (^{0}):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	97.4	Dipper level.
d		-vertical	84.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		85.4	d+e
g	Gauge height pressure (Kpa)		854	10f
h	Depth to top of test section (m)	-declined	150	Drill rod depth + 1.03 m
j		-vertical	129.9	h.sin a
k	Length of test section(m)		328	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		2922	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		456	(j-d).10
q	Maximum allowable total test pressure (KPa)		2338	0.8n
r	Maximum allowable gauge test pressure (KPa)		1484	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2054	s+g
u	Target inflation pressure at packer (KPa)		2464	1.2t
v	**Target packer inflation gauge pressure (KPa)**		2920	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		3250	

Stage							
1	Gauge Pressure (KPa):	200		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1054					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	41658	42045	42442	42843		
	Flow (L)	0	387	397	401		
	Average Test Flow (L/min)	395.0		**Test Flow (L/min/m)**		1.20	

Stage							
2	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)		0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Stage							
3	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Stage							
4	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

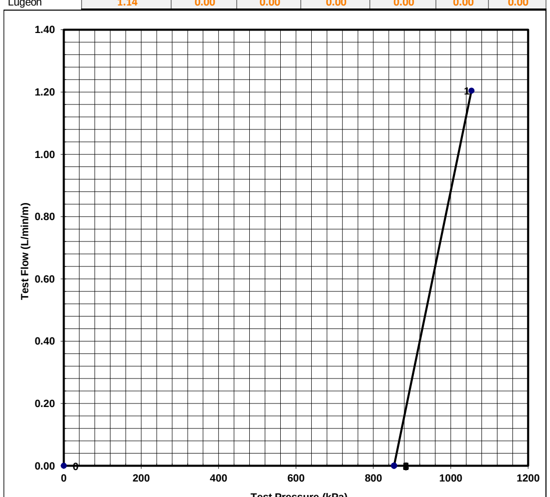
Stage							
5	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Stage							
6	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Stage							
7	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	854					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Summary

Test Pressure (Kpa)	1054	854	854	854	854	854	854
Flow Rate (L/min/m)	1.20	0.00	0.00	0.00	0.00	0.00	0.00
Lugeon	1.14	0.00	0.00	0.00	0.00	0.00	0.00



Lugeon units = Test Flow (L/min/m) at 1000kPa = 1.14 (Stage 1)

Permeability (m/day) = 1.43E-02

Permeability (m/s) = 1.65E-07

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Packer Test Data Sheet

Project: Tomingley				**Project No.:** TGEP		
Hole No:	RWD042	**Test No:**	1	Date: 16-Sep-20	Operator:	
Collar RL:	268.13	Location:	Easting (m) / Northing (m)	614175 / 6390630	Azimuth:	270

a	Declination (^{o}):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	94.0	Dipper level.
d		-vertical	81.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		82.4	d+e
g	Gauge height pressure (Kpa)		824	10f
h	Depth to top of test section (m)	-declined	221	Drill rod depth + 1.03 m
j		-vertical	191.4	h.sin a
k	Length of test section(m)		257	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		3876	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1100	(j-d).10
q	Maximum allowable total test pressure (KPa)		3101	0.8n
r	Maximum allowable gauge test pressure (KPa)		2277	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2024	s+g
u	Target inflation pressure at packer (KPa)		2429	1.2t
v	**Target packer inflation gauge pressure (Kpa)**		3529	u+p Press. applied = kPa

1

Gauge Pressure (KPa):	400		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1224					
Time (min)	0	5	10	15	20	25
Meter reading (L)	490	600	710	810	910	1000
Flow (L)	0	110	110	100	100	90
Average Test Flow (L/min)	102.0		**Test Flow (L/min/m)**		0.40	

2

Gauge Pressure (KPa):	600		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1424					
Time (min)	0	5	10	15	20	25
Meter reading (L)	1130	1230	1330	1420	1510	1600
Flow (L)		100	100	90	90	90
Average Test Flow (L/min)	94.0		**Test Flow (L/min/m)**		0.37	

3

Gauge Pressure (KPa):	800		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1624					
Time (min)	0	5	10	15	20	25
Meter reading (L)	1750	1860	1960	2060	2160	2250
Flow (L)	0	110	100	100	100	90
Average Test Flow (L/min)	100.0		**Test Flow (L/min/m)**		0.39	

4

Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1824					
Time (min)	0	5	10	15	20	25
Meter reading (L)	2310	2460	2610	2740	2890	3020
Flow (L)	0	150	150	130	150	130
Average Test Flow (L/min)	142.0		**Test Flow (L/min/m)**		0.55	

5

Gauge Pressure (KPa):	800		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1624					
Time (min)	0	5	10	15	20	25
Meter reading (L)	3110	3190	3270	3350	3430	3510
Flow (L)	0	80	80	80	80	80
Average Test Flow (L/min)	80.0		**Test Flow (L/min/m)**		0.31	

6

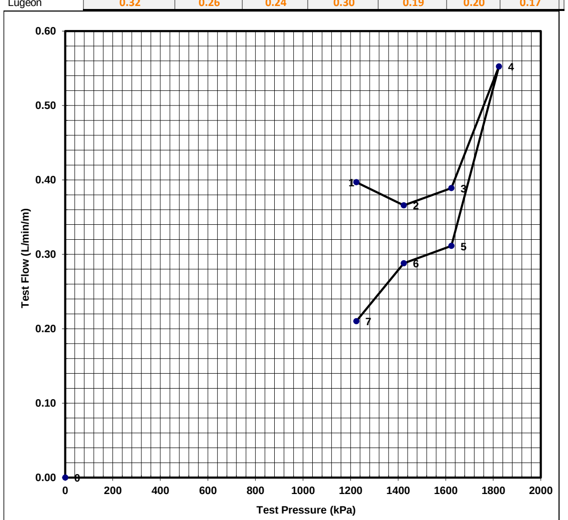
Gauge Pressure (KPa):	600		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1424					
Time (min)	0	5	10	15	20	25
Meter reading (L)	3580	3650	3720	3790	3870	3950
Flow (L)	0	70	70	70	80	80
Average Test Flow (L/min)	74.0		**Test Flow (L/min/m)**		0.29	

7

Gauge Pressure (KPa):	400		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1224					
Time (min)	0	5	10	15	20	25
Meter reading (L)	3980	4010	4070	4130	4190	4250
Flow (L)	0	30	60	60	60	60
Average Test Flow (L/min)	54.0		**Test Flow (L/min/m)**		0.21	

Summary

Test Pressure	1224	1424	1624	1824	1624	1424	1224
Flow Rate (L/min/m)	0.40	0.37	0.39	0.55	0.31	0.29	0.21
Lugeon	0.32	0.26	0.24	0.30	0.19	0.20	0.17



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.27 (average of Stage 1 - 3)

Permeability (m/day) = 3.43E-03

Permeability (m/s) = 3.97E-08

\\Jacobs.com\ANZ\IE\Projects\05_Northern\IH191000\06_Technical\Groundwater\Packer testing\[Packer Test_RWD042.xls]221-478m

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD042	**Test No:**	2	Date:	17-Sep-20	Operator:	
Collar RL:	268.3	Location:	Easting (m) / Northing (m)	614175 / 6390630		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	94.0	Dipper level.
d		-vertical	81.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		82.4	d+e
g	Gauge height pressure (Kpa)		824	10f
h	Depth to top of test section (m)	-declined	252	Drill rod depth + 1.03 m
j		-vertical	218.2	h.sin a
k	Length of test section(m)		226	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		4306	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1368	(j-d).10
q	Maximum allowable total test pressure (KPa)		3445	0.8n
r	Maximum allowable gauge test pressure (KPa)		2621	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2024	s+g
u	Target inflation pressure at packer (KPa)		2429	1.2t
v	**Target packer inflation gauge pressure (KPa)**		3797	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4000	

1						
Gauge Pressure (KPa):	400		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1224					
Time (min)	0	5	10	15	20	25
Meter reading (L)	6300	6480	6680	6870	7030	7210
Flow (L)	0	180	200	190	160	180
Average Test Flow (L/min)	182.0		**Test Flow (L/min/m)**		0.81	

2						
Gauge Pressure (KPa):	600		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1424					
Time (min)	0	5	10	15	20	25
Meter reading (L)	7450	7650	7850	8040	8220	8420
Flow (L)		200	200	190	180	200
Average Test Flow (L/min)	194.0		**Test Flow (L/min/m)**		0.86	

3						
Gauge Pressure (KPa):	800		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1624					
Time (min)	0	5	10	15	20	25
Meter reading (L)	8640	8880	9120	9360	9590	9840
Flow (L)	0	240	240	240	230	250
Average Test Flow (L/min)	240.0		**Test Flow (L/min/m)**		1.06	

4						
Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1824					
Time (min)	0	5	10	15	20	25
Meter reading (L)	10200	10510	10830	11150	11490	11860
Flow (L)	0	310	320	320	340	370
Average Test Flow (L/min)	332.0		**Test Flow (L/min/m)**		1.47	

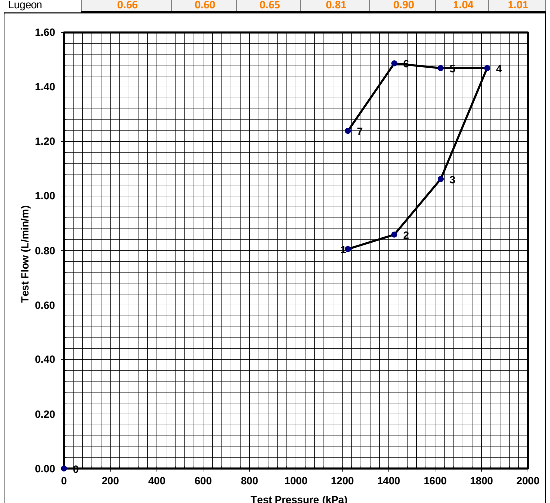
5						
Gauge Pressure (KPa):	800		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1624					
Time (min)	0	5	10	15	20	25
Meter reading (L)	12140	12480	12780	13080	13400	13800
Flow (L)	0	340	300	300	320	400
Average Test Flow (L/min)	332.0		**Test Flow (L/min/m)**		1.47	

6						
Gauge Pressure (KPa):	600		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1424					
Time (min)	0	5	10	15	20	25
Meter reading (L)	14100	14440	14780	15120	15440	15780
Flow (L)	0	340	340	340	320	340
Average Test Flow (L/min)	336.0		**Test Flow (L/min/m)**		1.49	

7						
Gauge Pressure (KPa):	400		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	824					
Total Test Pressure (Kpa):	1224					
Time (min)	0	5	10	15	20	25
Meter reading (L)	16040	16320	16610	16900	17170	17440
Flow (L)	0	280	290	290	270	270
Average Test Flow (L/min)	280.0		**Test Flow (L/min/m)**		1.24	

Summary

Test Pressure (Kpa)	1224	1424	1624	1824	1624	1424	1224
Flow Rate (L/min/m)	0.81	0.86	1.06	1.47	1.47	1.49	1.24
Lugeon	0.66	0.60	0.65	0.81	0.90	1.04	1.01



Lugeon units = Test Flow (L/min/m) at 1000kPa = 1.04 (Stage 6)

Permeability (m/day) = 1.30E-02

Permeability (m/s) = 1.51E-07

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD042	**Test No:**		Date:	26-Sep-20	Operator:	
Collar RL:	268.13	Location:	Easting (m) Northing (m)	614175 6390630		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	97.4	Dipper level.
d		-vertical	84.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		85.4	d+e
g	Gauge height pressure (Kpa)		854	10f
h	Depth to top of test section (m)	-declined	300	Drill rod depth + 1.03 m
j		-vertical	259.8	h.sin a
k	Length of test section(m)		178	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		5000	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1755	(j-d).10
q	Maximum allowable total test pressure (KPa)		4000	0.8n
r	Maximum allowable gauge test pressure (KPa)		3147	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2054	s+g
u	Target inflation pressure at packer (KPa)		2464	1.2t
v	**Target packer inflation gauge pressure (KPa)**		4219	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4750	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	35920	36131	36298	36445		
	Flow (L)	0	211	167	147		
	Average Test Flow (L/min)	175.0		**Test Flow (L/min/m)**		0.98	

Stage							
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	36497	36712	36884	37042		
	Flow (L)		215	172	158		
	Average Test Flow (L/min)	181.7		**Test Flow (L/min/m)**		1.02	

Stage							
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	37090	37325	37522	37706		
	Flow (L)	0	235	197	184		
	Average Test Flow (L/min)	205.3		**Test Flow (L/min/m)**		1.15	

Stage							
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	2104					
	Time (min)	0	5	10	15		
	Meter reading (L)	37745	38025	38247	38470		
	Flow (L)	0	280	222	223		
	Average Test Flow (L/min)	241.7		**Test Flow (L/min/m)**		1.36	

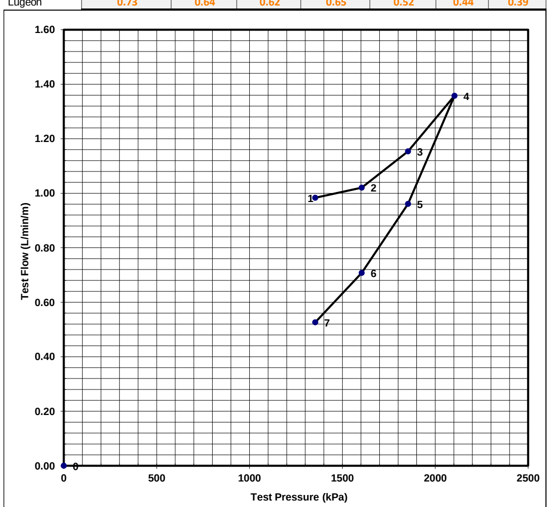
Stage							
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	38484	38664	38825	38997		
	Flow (L)	0	180	161	172		
	Average Test Flow (L/min)	171.0		**Test Flow (L/min/m)**		0.96	

Stage							
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	39000	39111	39242	39378		
	Flow (L)	0	111	131	136		
	Average Test Flow (L/min)	126.0		**Test Flow (L/min/m)**		0.71	

Stage							
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	39380	39460	39554	39661		
	Flow (L)	0	80	94	107		
	Average Test Flow (L/min)	93.7		**Test Flow (L/min/m)**		0.53	

Summary

Test Pressure (Kpa)	1354	1604	1854	2104	1854	1604	1354
Flow Rate (L/min/m)	0.98	1.02	1.15	1.36	0.96	0.71	0.53
Lugeon	0.73	0.64	0.62	0.65	0.52	0.44	0.39



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.66 (average Stage 1 - 4)

Permeability (m/day) = 8.24E-03

Permeability (m/s) = 9.54E-08

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Packer Test Data Sheet

Project: Tomingley				**Project No.:** TGEP		
Hole No:	RWD042	**Test No:**		Date:	26-Sep-20	Operator:
Collar RL:	268.13	Location:	Easting (m) / Northing (m)	614175 / 6390630	Azimuth:	270

	Parameter		Value	Notes
a	Declination (^{o}):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	97.4	Dipper level.
d		-vertical	84.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		85.4	d+e
g	Gauge height pressure (Kpa)		854	10f
h	Depth to top of test section (m)	-declined	350	Drill rod depth + 1.03 m
j		-vertical	303.1	h.sin a
k	Length of test section(m)		128	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		5693	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		2188	(j-d).10
q	Maximum allowable total test pressure (KPa)		4555	0.8n
r	Maximum allowable gauge test pressure (KPa)		3701	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2054	s+g
u	Target inflation pressure at packer (KPa)		2464	1.2t
v	**Target packer inflation gauge pressure (KPa)**		4652	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		5250	

1

Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1354					
Time (min)	0	5	10	15		
Meter reading (L)	30940	31117	31340	31507		
Flow (L)	0	177	223	167		
Average Test Flow (L/min)	189.0		**Test Flow (L/min/m)**		1.48	

2

Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1604					
Time (min)	0	5	10	15		
Meter reading (L)	31512	31872	32071	32234		
Flow (L)		360	199	163		
Average Test Flow (L/min)	240.7		**Test Flow (L/min/m)**		1.88	

3

Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1854					
Time (min)	0	5	10	15		
Meter reading (L)	32289	32562	32783	33021		
Flow (L)	0	273	221	238		
Average Test Flow (L/min)	244.0		**Test Flow (L/min/m)**		1.91	

4

Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	2104					
Time (min)	0	5	10	15		
Meter reading (L)	33069	33440	33729	33983		
Flow (L)	0	371	289	254		
Average Test Flow (L/min)	304.7		**Test Flow (L/min/m)**		2.38	

5

Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1854					
Time (min)	0	5	10	15		
Meter reading (L)	34009	34186	34374	34570		
Flow (L)	0	177	188	196		
Average Test Flow (L/min)	187.0		**Test Flow (L/min/m)**		1.46	

6

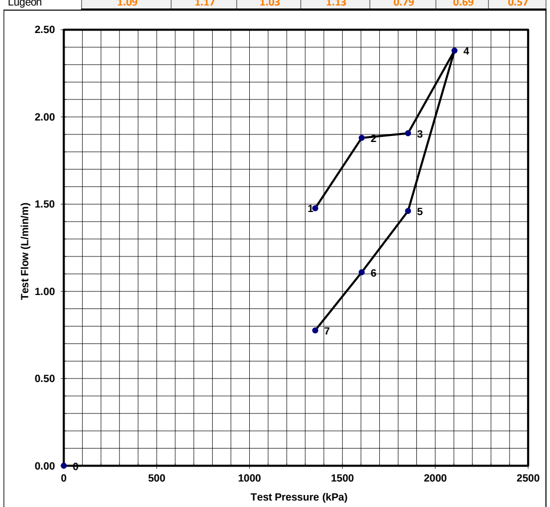
Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1604					
Time (min)	0	5	10	15		
Meter reading (L)	34578	34708	34856	35004		
Flow (L)	0	130	148	148		
Average Test Flow (L/min)	142.0		**Test Flow (L/min/m)**		1.11	

7

Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	854					
Total Test Pressure (Kpa):	1354					
Time (min)	0	5	10	15		
Meter reading (L)	35008	35097	35198	35306		
Flow (L)	0	89	101	108		
Average Test Flow (L/min)	99.3		**Test Flow (L/min/m)**		0.78	

Summary

Test Pressure (Kpa)	1354	1604	1854	2104	1854	1604	1354
Flow Rate (L/min/m)	1.48	1.88	1.91	2.38	1.46	1.11	0.78
Lugeon	1.09	1.17	1.03	1.13	0.79	0.69	0.57



Lugeon units = Test Flow (L/min/m) at 1000kPa = 1.11 (average Stage 1 - 4)

Permeability (m/day) = 1.39E-02

Permeability (m/s) = 1.60E-07

\\Jacobs.com\ANZ\IE\Projects\05_Northern\IH191000\06_Technical\Groundwater\Packer testing\[Packer Test_RWD042.xls]350-478m

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD042	**Test No:**		Date:	25-Sep-20	Operator:	
Collar RL:	268.13	Location:	Easting (m) Northing (m)	614175 6390630		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	97.4	Dipper level.
d		-vertical	84.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		85.4	d+e
g	Gauge height pressure (Kpa)		854	10f
h	Depth to top of test section (m)	-declined	400	Drill rod depth + 1.03 m
j		-vertical	346.4	h.sin a
k	Length of test section(m)		78	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		6386	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		2621	(j-d).10
q	Maximum allowable total test pressure (KPa)		5109	0.8n
r	Maximum allowable gauge test pressure (KPa)		4255	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2054	s+g
u	Target inflation pressure at packer (KPa)		2464	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5085	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		5750	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	25158	25458	25655	25846		
	Flow (L)	0	300	197	191		
	Average Test Flow (L/min)	229.3		**Test Flow (L/min/m)**		2.94	

Stage							
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	25897	26156	26379	26613		
	Flow (L)		259	223	234		
	Average Test Flow (L/min)	238.7		**Test Flow (L/min/m)**		3.06	

Stage							
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	26643	26982	27260	27504		
	Flow (L)	0	339	278	244		
	Average Test Flow (L/min)	287.0		**Test Flow (L/min/m)**		3.68	

Stage							
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	2104					
	Time (min)	0	5	10	15		
	Meter reading (L)	27541	27844	28124	28404		
	Flow (L)	0	303	280	280		
	Average Test Flow (L/min)	287.7		**Test Flow (L/min/m)**		3.69	

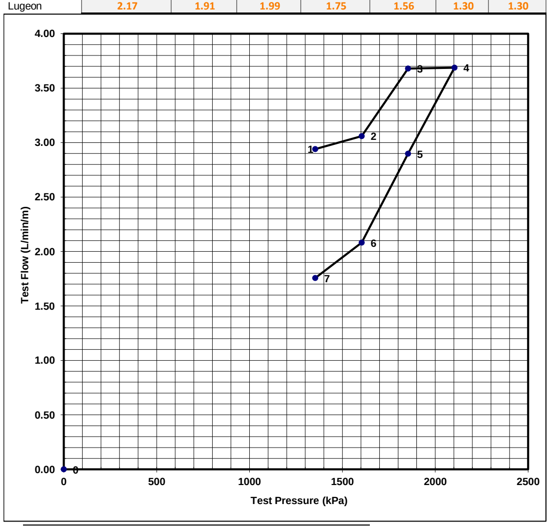
Stage							
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	28436	28650	28894	29114		
	Flow (L)	0	214	244	220		
	Average Test Flow (L/min)	226.0		**Test Flow (L/min/m)**		2.90	

Stage							
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	29138	29262	29450	29625		
	Flow (L)	0	124	188	175		
	Average Test Flow (L/min)	162.3		**Test Flow (L/min/m)**		2.08	

Stage							
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	29641	29794	29906	30052		
	Flow (L)	0	153	112	146		
	Average Test Flow (L/min)	137.0		**Test Flow (L/min/m)**		1.76	

Summary

Test Pressure (Kpa)	1354	1604	1854	2104	1854	1604	1354
Flow Rate (L/min/m)	2.94	3.06	3.68	3.69	2.90	2.08	1.76
Lugeon	2.17	1.91	1.99	1.75	1.56	1.30	1.30



Lugeon units = Test Flow (L/min/m) at 1000kPa =	2.02	(average Stage 1 - 3)
Permeability (m/day) =	**2.53E-02**	
Permeability (m/s) =	**2.93E-07**	

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Packer Test Data Sheet

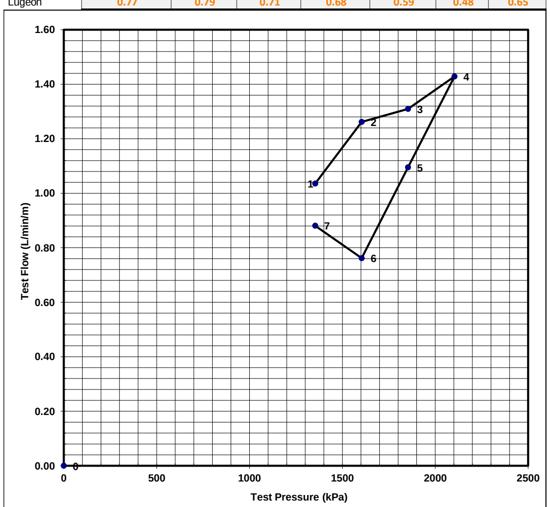
Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD042	**Test No:**		Date:	25-Sep-20	Operator:	
Collar RL:	268.13	Location:	Easting (m) / Northing (m)	614175 / 6390630		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	97.4	Dipper level.
d		-vertical	84.4	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		85.4	d+e
g	Gauge height pressure (Kpa)		854	10f
h	Depth to top of test section (m)	-declined	450	Drill rod depth + 1.03 m
j		-vertical	389.7	h.sin a
k	Length of test section(m)		28	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		7079	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		3054	(j-d).10
q	Maximum allowable total test pressure (KPa)		5663	0.8n
r	Maximum allowable gauge test pressure (KPa)		4810	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		2054	s+g
u	Target inflation pressure at packer (KPa)		2464	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5518	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		6250	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	24145	24175	24203	24232		
	Flow (L)	0	30	28	29		
	Average Test Flow (L/min)	29.0		**Test Flow (L/min/m)**		1.04	
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	24237	24274	24307	24343		
	Flow (L)		37	33	36		
	Average Test Flow (L/min)	35.3		**Test Flow (L/min/m)**		1.26	
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	24347	24385	24441	24457		
	Flow (L)	0	38	56	16		
	Average Test Flow (L/min)	36.7		**Test Flow (L/min/m)**		1.31	
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	2104					
	Time (min)	0	5	10	15		
	Meter reading (L)	24463	24502	24538	24583		
	Flow (L)	0	39	36	45		
	Average Test Flow (L/min)	40.0		**Test Flow (L/min/m)**		1.43	
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1854					
	Time (min)	0	5	10	15		
	Meter reading (L)	24587	24621	24649	24679		
	Flow (L)	0	34	28	30		
	Average Test Flow (L/min)	30.7		**Test Flow (L/min/m)**		1.10	
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1604					
	Time (min)	0	5	10	15		
	Meter reading (L)	24682	24713	24741	24746		
	Flow (L)	0	31	28	5		
	Average Test Flow (L/min)	21.3		**Test Flow (L/min/m)**		0.76	
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	854					
	Total Test Pressure (Kpa):	1354					
	Time (min)	0	5	10	15		
	Meter reading (L)	24746	24772	24796	24820		
	Flow (L)	0	26	24	24		
	Average Test Flow (L/min)	24.7		**Test Flow (L/min/m)**		0.88	

Summary

Test Pressure (Kpa)	1354	1604	1854	2104	1854	1604	1354
Flow Rate (L/min/m)	1.04	1.26	1.31	1.43	1.10	0.76	0.88
Lugeon	0.77	0.79	0.71	0.68	0.59	0.48	0.65



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.73 (average Stage 1 - 4)
Permeability (m/day) = 9.20E-03
Permeability (m/s) = 1.07E-07

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Packer Test Data Sheet

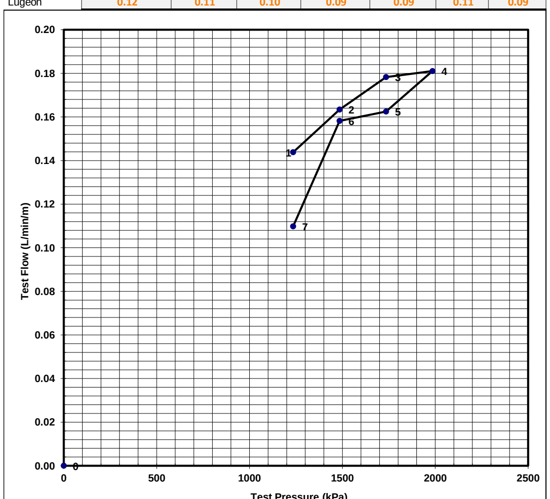
Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	29-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) / Northing (m)	614188 / 6390808		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	200	Drill rod depth + 1.03 m
j		-vertical	173.2	h.sin a
k	Length of test section(m)		255	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		3496	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1007	(j-d).10
q	Maximum allowable total test pressure (KPa)		2797	0.8n
r	Maximum allowable gauge test pressure (KPa)		2062	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		3329	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4000	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	51991	52029	52066	52101		
	Flow (L)	0	38	37	35		
	Average Test Flow (L/min)	36.7		**Test Flow (L/min/m)**		0.14	
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	52155	52199	52241	52280		
	Flow (L)		44	42	39		
	Average Test Flow (L/min)	41.7		**Test Flow (L/min/m)**		0.16	
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			3.2
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	52349	52400	52446	52495		
	Flow (L)	0	51	46	49		
	Average Test Flow (L/min)	45.5		**Test Flow (L/min/m)**		0.18	
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			3.5
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	52579	52627	52677	52728		
	Flow (L)	0	48	50	51		
	Average Test Flow (L/min)	46.2		**Test Flow (L/min/m)**		0.18	
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			2.9
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	52798	52842	52887	52931		
	Flow (L)	0	44	45	44		
	Average Test Flow (L/min)	41.4		**Test Flow (L/min/m)**		0.16	
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	52978	53016	53052	53099		
	Flow (L)	0	38	36	47		
	Average Test Flow (L/min)	40.3		**Test Flow (L/min/m)**		0.16	
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	53120	53149	53178	53204		
	Flow (L)	0	29	29	26		
	Average Test Flow (L/min)	28.0		**Test Flow (L/min/m)**		0.11	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.14	0.16	0.18	0.18	0.16	0.16	0.11
Lugeon	0.12	0.11	0.10	0.09	0.09	0.11	0.09



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.10 (average Stage 1 - 6)

Permeability (m/day) = 1.30E-03

Permeability (m/s) = 1.50E-08

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Packer Test Data Sheet

Project:	Tomingley		**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	29-Sep-20	Operator:
Collar RL:	267.89	Location:	Easting (m) / Northing (m)	614188 / 6390808	Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	245	Drill rod depth + 1.03 m
j		-vertical	212.2	h.sin a
k	Length of test section(m)		210	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		4120	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1397	(j-d).10
q	Maximum allowable total test pressure (KPa)		3296	0.8n
r	Maximum allowable gauge test pressure (KPa)		2561	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (Kpa)**		3719	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4200	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	50601	50641	50678	50712		
	Flow (L)	0	40	37	34		
	Average Test Flow (L/min)	37.0		**Test Flow (L/min/m)**		0.18	

Stage							
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0.5
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	50717	50757	50794	50831		
	Flow (L)		40	37	37		
	Average Test Flow (L/min)	37.5		**Test Flow (L/min/m)**		0.18	

Stage							
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			1.3
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	50838	50880	50919	50959		
	Flow (L)	0	42	39	40		
	Average Test Flow (L/min)	39.0		**Test Flow (L/min/m)**		0.19	

Stage							
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			1.4
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	50962	51005	51046	51087		
	Flow (L)	0	43	41	41		
	Average Test Flow (L/min)	40.3		**Test Flow (L/min/m)**		0.19	

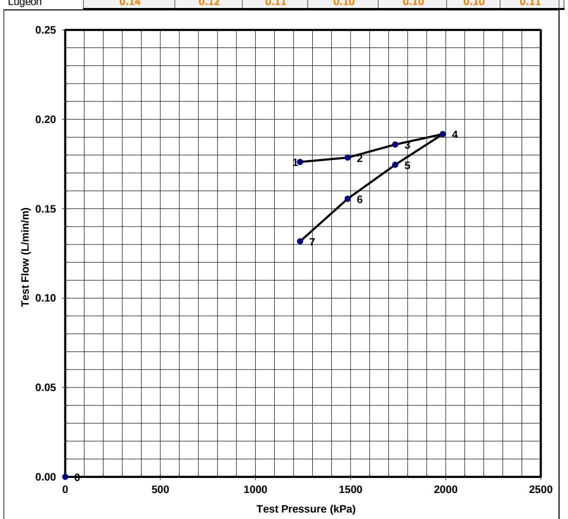
Stage							
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	51090	51127	51164	51200		
	Flow (L)	0	37	37	36		
	Average Test Flow (L/min)	36.7		**Test Flow (L/min/m)**		0.17	

Stage							
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	51203	51235	51268	51301		
	Flow (L)	0	32	33	33		
	Average Test Flow (L/min)	32.7		**Test Flow (L/min/m)**		0.16	

Stage							
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	51303	51331	51358	51386		
	Flow (L)	0	28	27	28		
	Average Test Flow (L/min)	27.7		**Test Flow (L/min/m)**		0.13	

Summary

Test Pressure	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.18	0.18	0.19	0.19	0.17	0.16	0.13
Lugeon	0.14	0.12	0.11	0.10	0.10	0.10	0.11



Lugeon units = Test Flow (L/min/m) at 1000kPa =	0.12	(average Stage 1 - 4)
Permeability (m/day) =	**1.46E-03**	
Permeability (m/s) =	**1.69E-08**	

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	29-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) Northing (m)	614188 6390808		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	257	Drill rod depth + 1.03 m
j		-vertical	222.6	h.sin a
k	Length of test section(m)		198	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		4286	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1501	(j-d).10
q	Maximum allowable total test pressure (KPa)		3429	0.8n
r	Maximum allowable gauge test pressure (KPa)		2694	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		3823	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4320	

1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			3.25
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	49999	50044	50085	50126		
	Flow (L)	0	45	41	41		
	Average Test Flow (L/min)	39.1		**Test Flow (L/min/m)**		0.20	

2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)	50132	50179				
	Flow (L)		47				
	Average Test Flow (L/min)	47.0		**Test Flow (L/min/m)**		0.24	

3	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

4	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

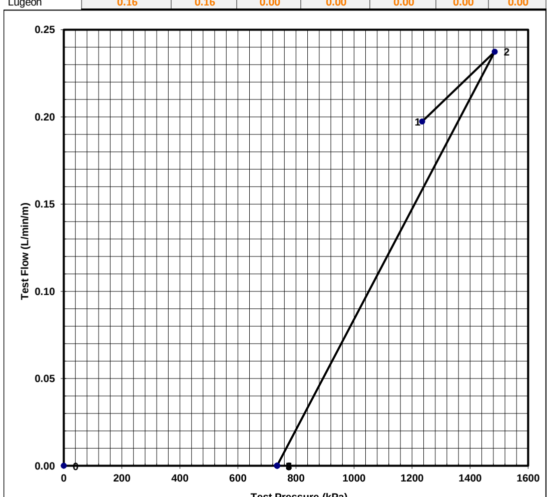
5	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

6	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

7	Gauge Pressure (KPa):			Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	735					
	Time (min)	0	5	10	15	20	25
	Meter reading (L)						
	Flow (L)	0	0	0	0	0	0
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Summary

Test Pressure (Kpa)	1235	1485	735	735	735	735	735
Flow Rate (L/min/m)	0.20	0.24	0.00	0.00	0.00	0.00	0.00
Lugeon	0.16	0.16	0.00	0.00	0.00	0.00	0.00



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.16 (average of Stage 1 and 2)
Permeability (m/day) = 2.00E-03
Permeability (m/s) = 2.32E-08

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	29-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) Northing (m)	614188 6390808		Azimuth:	270

a	Declination (^{o}):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	300	Drill rod depth + 1.03 m
j		-vertical	259.8	h.sin a
k	Length of test section(m)		155	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		4882	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		1873	(j-d).10
q	Maximum allowable total test pressure (KPa)		3905	0.8n
r	Maximum allowable gauge test pressure (KPa)		3171	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		4195	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		4750	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			3.25
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	48634	48673	48707	48740		
	Flow (L)	0	39	34	33		
	Average Test Flow (L/min)	32.1		**Test Flow (L/min/m)**	0.21		

Stage							
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			3.25
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	48746	48783	48817	48849		
	Flow (L)		37	34	32		
	Average Test Flow (L/min)	31.1		**Test Flow (L/min/m)**	0.20		

Stage							
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	48854	48889	48922	48955		
	Flow (L)	0	35	33	33		
	Average Test Flow (L/min)	33.7		**Test Flow (L/min/m)**	0.22		

Stage							
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	48958	48991	49025	49056		
	Flow (L)	0	33	34	31		
	Average Test Flow (L/min)	32.7		**Test Flow (L/min/m)**	0.21		

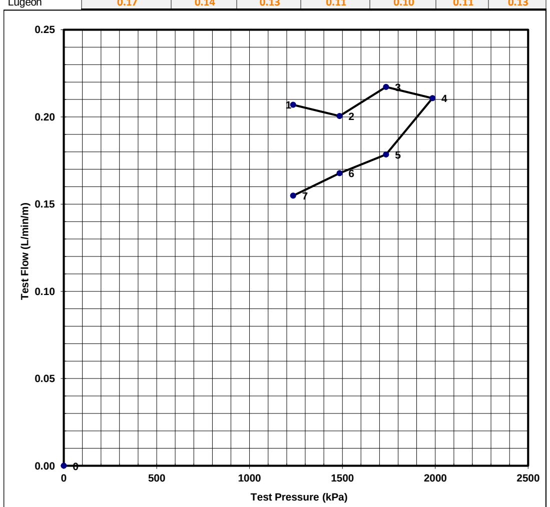
Stage							
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	49059	49087	49114	49142		
	Flow (L)	0	28	27	28		
	Average Test Flow (L/min)	27.7		**Test Flow (L/min/m)**	0.18		

Stage							
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	49144	49170	49196	49222		
	Flow (L)	0	26	26	26		
	Average Test Flow (L/min)	26.0		**Test Flow (L/min/m)**	0.17		

Stage							
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	49226	49250	49274	49298		
	Flow (L)	0	24	24	24		
	Average Test Flow (L/min)	24.0		**Test Flow (L/min/m)**	0.15		

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.21	0.20	0.22	0.21	0.18	0.17	0.15
Lugeon	0.17	0.14	0.13	0.11	0.10	0.11	0.13



Lugeon units = Test Flow (L/min/m) at 1000kPa = 0.13 (average Stage 2 - 3)

Permeability (m/day) = 1.63E-03

Permeability (m/s) = 1.89E-08

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	28-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) Northing (m)	614188 6390808		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	350	Drill rod depth + 1.03 m
j		-vertical	303.1	h.sin a
k	Length of test section(m)		105	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		5575 0	[(j-d).(m-1.0)+(d-b).m].10 [b</=d] (j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		2306	(j-d).10
q	Maximum allowable total test pressure (KPa)		4460	0.8n
r	Maximum allowable gauge test pressure (KPa)		3725	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		4628	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)			

1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	46370	46431	46491	46550		
	Flow (L)	0	61	60	59		
	Average Test Flow (L/min)	60.0		**Test Flow (L/min/m)**		0.57	

2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	46630	46663	46691	46716		
	Flow (L)		33	28	25		
	Average Test Flow (L/min)	28.7		**Test Flow (L/min/m)**		0.27	

3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	46767	46813	46838	46910		
	Flow (L)	0	46	25	72		
	Average Test Flow (L/min)	47.7		**Test Flow (L/min/m)**		0.45	

4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	47005	47089	47176	47251		
	Flow (L)	0	84	87	75		
	Average Test Flow (L/min)	82.0		**Test Flow (L/min/m)**		0.78	

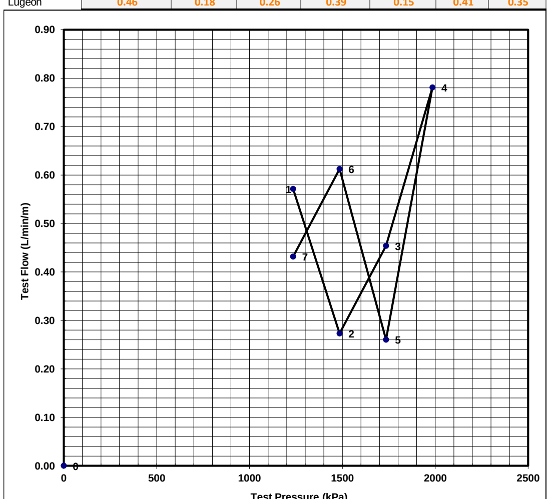
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	47341	47390	47401	47423		
	Flow (L)	0	49	11	22		
	Average Test Flow (L/min)	27.3		**Test Flow (L/min/m)**		0.26	

6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	47501	47568	47631	47694		
	Flow (L)	0	67	63	63		
	Average Test Flow (L/min)	64.3		**Test Flow (L/min/m)**		0.61	

7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	47748	47789	47838	47884		
	Flow (L)	0	41	49	46		
	Average Test Flow (L/min)	45.3		**Test Flow (L/min/m)**		0.43	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.57	0.27	0.45	0.78	0.26	0.61	0.43
Lugeon	0.46	0.18	0.26	0.39	0.15	0.41	0.35



Lugeon units = Test Flow (L/min/m) at 1000kPa =	0.32	(average of all stages)
Permeability (m/day) =	**3.96E-03**	
Permeability (m/s) =	**4.59E-08**	

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Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	28-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) / Northing (m)	614188 / 6390808		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	400	Drill rod depth + 1.03 m
j		-vertical	346.4	h.sin a
k	Length of test section(m)		55	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		6267	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		2739	(j-d).10
q	Maximum allowable total test pressure (KPa)		5014	0.8n
r	Maximum allowable gauge test pressure (KPa)		4279	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5061	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)			

1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			3.25
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	44908	44953	44990	45038		
	Flow (L)	0	45	37	48		
	Average Test Flow (L/min)	40.1		**Test Flow (L/min/m)**		0.73	

2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	45098	45144	45189	45234		
	Flow (L)		46	45	45		
	Average Test Flow (L/min)	45.3		**Test Flow (L/min/m)**		0.82	

3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	45300	45346	45391	45434		
	Flow (L)	0	46	45	43		
	Average Test Flow (L/min)	44.7		**Test Flow (L/min/m)**		0.81	

4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)	45491	45537	45579	45619		
	Flow (L)	0	46	42	40		
	Average Test Flow (L/min)	42.7		**Test Flow (L/min/m)**		0.78	

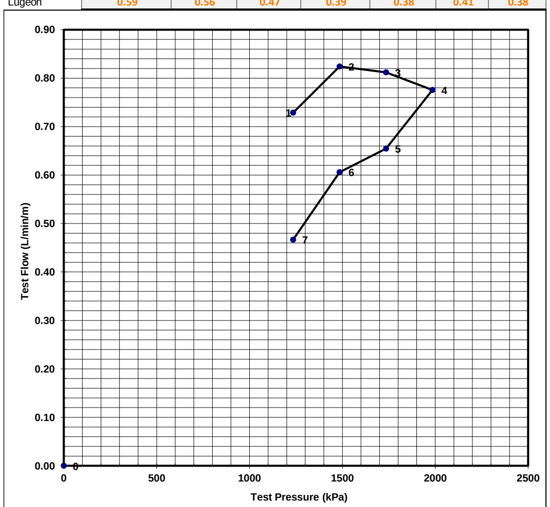
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	45660	45697	45732	45768		
	Flow (L)	0	37	35	36		
	Average Test Flow (L/min)	36.0		**Test Flow (L/min/m)**		0.65	

6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	45803	45837	45871	45903		
	Flow (L)	0	34	34	32		
	Average Test Flow (L/min)	33.3		**Test Flow (L/min/m)**		0.61	

7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	45932	45958	45983	46009		
	Flow (L)	0	26	25	26		
	Average Test Flow (L/min)	25.7		**Test Flow (L/min/m)**		0.47	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	0.73	0.82	0.81	0.78	0.65	0.61	0.47
Lugeon	0.59	0.56	0.47	0.39	0.38	0.41	0.38



Lugeon units = Test Flow (L/min/m) at 1000kPa =	0.54	(average Stage 1 - 3)
Permeability (m/day) =	**6.74E-03**	
Permeability (m/s) =	**7.80E-08**	

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Packer Test Data Sheet

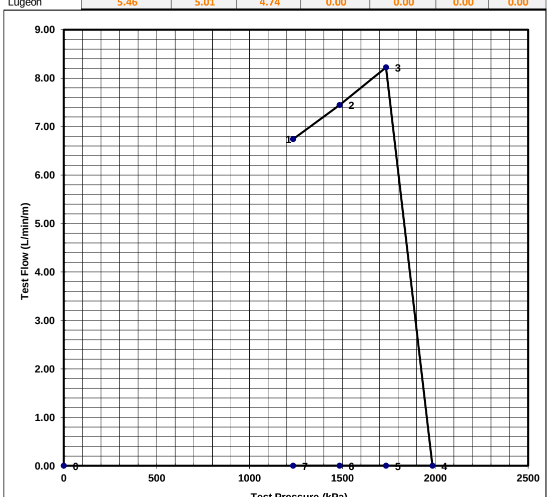
Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWD048	**Test No:**		Date:	28-Sep-20	Operator:	
Collar RL:	267.89	Location:	Easting (m) / Northing (m)	614188 / 6390808		Azimuth:	270

a	Declination (°):		60	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	83.7	Dipper level.
d		-vertical	72.5	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		73.5	d+e
g	Gauge height pressure (Kpa)		735	10f
h	Depth to top of test section (m)	-declined	446	Drill rod depth + 1.03 m
j		-vertical	386.2	h.sin a
k	Length of test section(m)		9	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		6905	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		3138	(j-d).10
q	Maximum allowable total test pressure (KPa)		5524	0.8n
r	Maximum allowable gauge test pressure (KPa)		4789	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1935	s+g
u	Target inflation pressure at packer (KPa)		2322	1.2t
v	**Target packer inflation gauge pressure (KPa)**		5459	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)		6250	

Stage							
1	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)	43796	43861	43920	43978		
	Flow (L)	0	65	59	58		
	Average Test Flow (L/min)	60.7		**Test Flow (L/min/m)**		6.74	
2	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)	43986	44054	44121	44187		
	Flow (L)		68	67	66		
	Average Test Flow (L/min)	67.0		**Test Flow (L/min/m)**		7.44	
3	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)	44192	44266				
	Flow (L)	0	74				
	Average Test Flow (L/min)	74.0		**Test Flow (L/min/m)**		8.22	
4	Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1985					
	Time (min)	0	5	10	15		
	Meter reading (L)						
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	
5	Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1735					
	Time (min)	0	5	10	15		
	Meter reading (L)						
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	
6	Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1485					
	Time (min)	0	5	10	15		
	Meter reading (L)						
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	
7	Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
	Gauge Height Pressure (Kpa):	735					
	Total Test Pressure (Kpa):	1235					
	Time (min)	0	5	10	15		
	Meter reading (L)						
	Flow (L)	0	0	0	0		
	Average Test Flow (L/min)	0.0		**Test Flow (L/min/m)**		0.00	

Summary

Test Pressure (Kpa)	1235	1485	1735	1985	1735	1485	1235
Flow Rate (L/min/m)	6.74	7.44	8.22	0.00	0.00	0.00	0.00
Lugeon	5.46	5.01	4.74	0.00	0.00	0.00	0.00



Lugeon units = Test Flow (L/min/m) at 1000kPa =	5.07	(average Stage 1 - 3)
Permeability (m/day) =	**6.35E-02**	
Permeability (m/s) =	**7.35E-07**	

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Packer Test Data Sheet

Project: Tomingley				**Project No.:** TGEP		
Hole No:	RWMET01	**Test No:**		Date:	29-Sep-20	Operator:
Collar RL:	267.03	Location:	Easting (m) / Northing (m)	613965 / 6390690	Azimuth:	

			Value	Notes
a	Declination (°):		90	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	75.0	Dipper level.
d		-vertical	75.0	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		76.0	d+e
g	Gauge height pressure (Kpa)		760	10f
h	Depth to top of test section (m)	-declined	96	Drill rod depth + 1.03 m
j		-vertical	96.0	h.sin a
k	Length of test section(m)		100	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		2286	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		210	(j-d).10
q	Maximum allowable total test pressure (KPa)		1829	0.8n
r	Maximum allowable gauge test pressure (KPa)		1069	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1960	s+g
u	Target inflation pressure at packer (KPa)		2352	1.2t
v	**Target packer inflation gauge pressure (KPa)**		2562	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)			

1

Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1260					
Time (min)	0	5	10	15	20	25
Meter reading (L)	3380	3443	3507	3572		
Flow (L)	0	63	64	65		
Average Test Flow (L/min)	64.0		**Test Flow (L/min/m)**		0.64	

2

Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1510					
Time (min)	0	5	10	15	20	25
Meter reading (L)	3664	3745	3832	3914		
Flow (L)		81	87	82		
Average Test Flow (L/min)	83.3		**Test Flow (L/min/m)**		0.83	

3

Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1760					
Time (min)	0	5	10	15	20	25
Meter reading (L)	4037	4148	4257	4366		
Flow (L)	0	111	109	109		
Average Test Flow (L/min)	109.7		**Test Flow (L/min/m)**		1.10	

4

Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	2010					
Time (min)	0	5	10	15	20	25
Meter reading (L)	4508	4648	4771	4900		
Flow (L)	0	140	123	129		
Average Test Flow (L/min)	130.7		**Test Flow (L/min/m)**		1.31	

5

Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1760					
Time (min)	0	5	10	15	20	25
Meter reading (L)	5041	5148	5253	5366		
Flow (L)	0	107	105	113		
Average Test Flow (L/min)	108.3		**Test Flow (L/min/m)**		1.08	

6

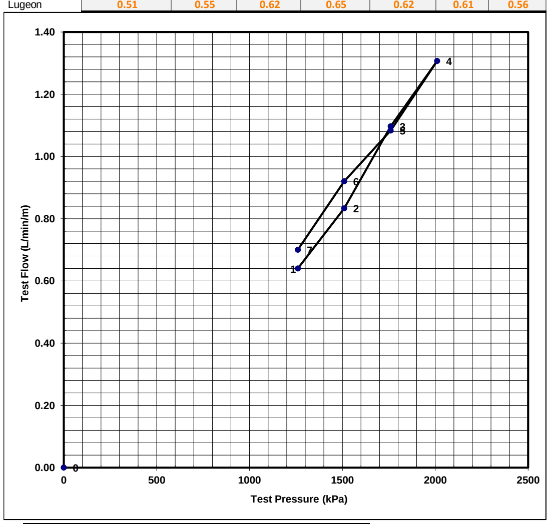
Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1510					
Time (min)	0	5	10	15	20	25
Meter reading (L)	5480	5578	5675	5756		
Flow (L)	0	98	97	81		
Average Test Flow (L/min)	92.0		**Test Flow (L/min/m)**		0.92	

7

Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1260					
Time (min)	0	5	10	15	20	25
Meter reading (L)	5842	5913	5984	6052		
Flow (L)	0	71	71	68		
Average Test Flow (L/min)	70.0		**Test Flow (L/min/m)**		0.70	

Summary

Test Pressure (Kpa)	1260	1510	1760	2010	1760	1510	1260
Flow Rate (L/min/m)	0.64	0.83	1.10	1.31	1.08	0.92	0.70
Lugeon	0.51	0.55	0.62	0.65	0.62	0.61	0.56



Lugeon units =	Test Flow (L/min/m) at 1000kPa =	0.51	(Stage 1, lowest lugeon for a stage)
Permeability (m/day) =		**6.36E-03**	
Permeability (m/s) =		**7.37E-08**	

\\Jacobs.com\ANZ\IE\Projects\05_Northern\IH191000\06_Technical\Groundwater\Packer testing\[Packer Test_RWMET01.xls]96-196

k m/s	6.60317E-08	7.1744E-08	8.1004E-08	8.45108E-08	8.0019E-08	7.92E-08	7.222E-08
k m/d	0.005705143	0.00619868	0.00699873	0.007301731	0.00691364	0.006843	0.00624

Packer Test Data Sheet

Project:	Tomingley			**Project No.:**	TGEP		
Hole No:	RWMET01	**Test No:**		Date:	29-Sep-20	Operator:	
Collar RL:	267.03	Location:	Easting (m) Northing (m)	613965 6390690		Azimuth:	

a	Declination (°):		90	
b	Depth pit base below hole collar (m)		0	For use when test sections are below pit. (Default = 0).
c	Depth to water below datum (m)	-declined	75.0	Dipper level.
d		-vertical	75.0	c.sin a
e	Height of gauge above datum (m)		1.0	
f	Depth to water below gauge (m)		76.0	d+e
g	Gauge height pressure (Kpa)		760	10f
h	Depth to top of test section (m)	-declined	144	Drill rod depth + 1.03 m
j		-vertical	144.0	h.sin a
k	Length of test section(m)		52	
m	Adopted rock density (specific gravity)		2.6	
n	Geostatic pressure on test section (KPa)		3054	[(j-d).(m-1.0)+(d-b).m].10 [b</=d]
			0	(j-b).(m-1.0).10 [For when b>d only]
p	Hydrostatic pressure on test section (Kpa)		690	(j-d).10
q	Maximum allowable total test pressure (KPa)		2443	0.8n
r	Maximum allowable gauge test pressure (KPa)		1683	q-g
s	**Target maximum gauge test pressure (KPa)**		**1200**	should be </=1500
t	Target maximum test pressure (KPa)		1960	s+g
u	Target inflation pressure at packer (KPa)		2352	1.2t
v	**Target packer inflation gauge pressure (KPa)**		3042	u+p Press. applied = kPa
	Applied packer inflation gauge pressure (KPa)			

1						
Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1260					
Time (min)	0	5	10	15		
Meter reading (L)	1173	1200	1231	1259		
Flow (L)	0	27	31	28		
Average Test Flow (L/min)	28.7		**Test Flow (L/min/m)**		0.55	

2						
Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1510					
Time (min)	0	5	10	15		
Meter reading (L)	1328	1362	1403	1446		
Flow (L)		34	41	43		
Average Test Flow (L/min)	39.3		**Test Flow (L/min/m)**		0.76	

3						
Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1760					
Time (min)	0	5	10	15		
Meter reading (L)	1521	1569	1617	1668		
Flow (L)	0	48	48	51		
Average Test Flow (L/min)	49.0		**Test Flow (L/min/m)**		0.94	

4						
Gauge Pressure (KPa):	1250		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	2010					
Time (min)	0	5	10	15		
Meter reading (L)	1733	1789	1843	1904		
Flow (L)	0	56	54	61		
Average Test Flow (L/min)	57.0		**Test Flow (L/min/m)**		1.10	

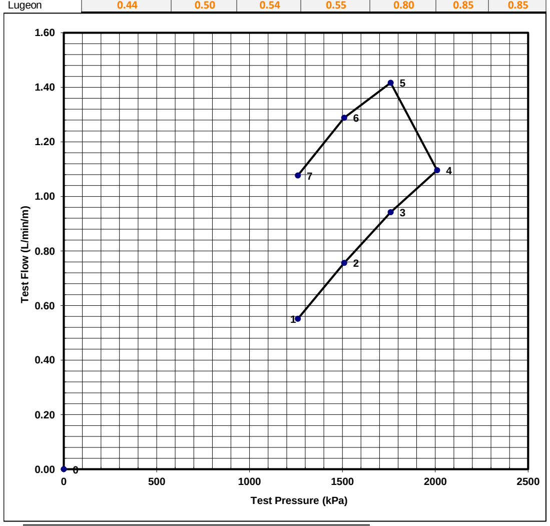
5						
Gauge Pressure (KPa):	1000		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1760					
Time (min)	0	5	10	15		
Meter reading (L)	1989	2058	2132	2210		
Flow (L)	0	69	74	78		
Average Test Flow (L/min)	73.7		**Test Flow (L/min/m)**		1.42	

6						
Gauge Pressure (KPa):	750		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1510					
Time (min)	0	5	10	15		
Meter reading (L)	2300	2362	2435	2501		
Flow (L)	0	62	73	66		
Average Test Flow (L/min)	67.0		**Test Flow (L/min/m)**		1.29	

7						
Gauge Pressure (KPa):	500		Gland packer leakage (L/min)			0
Gauge Height Pressure (Kpa):	760					
Total Test Pressure (Kpa):	1260					
Time (min)	0	5	10	15		
Meter reading (L)	2574	2631	2684	2742		
Flow (L)	0	57	53	58		
Average Test Flow (L/min)	56.0		**Test Flow (L/min/m)**		1.08	

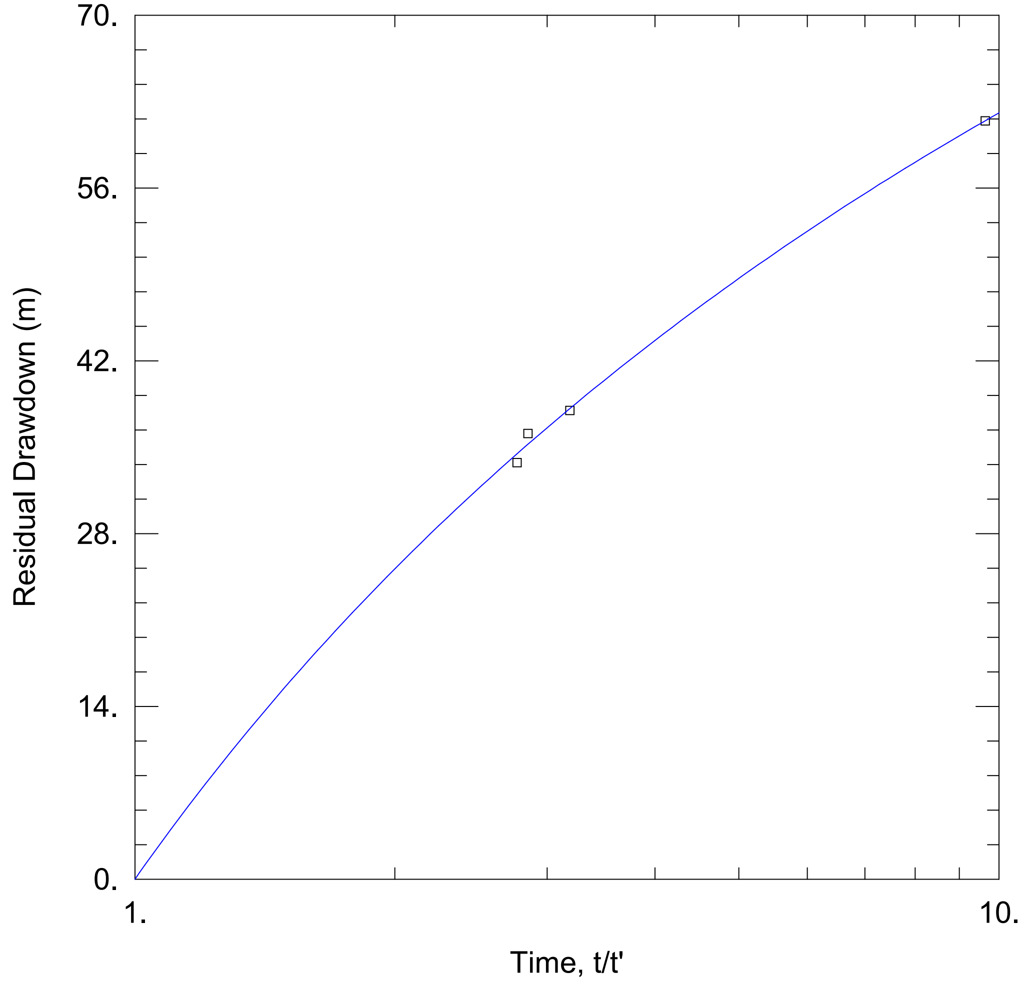
Summary

Test Pressure (Kpa)	1260	1510	1760	2010	1760	1510	1260
Flow Rate (L/min/m)	0.55	0.76	0.94	1.10	1.42	1.29	1.08
Lugeon	0.44	0.50	0.54	0.55	0.80	0.85	0.85



Lugeon units = Test Flow (L/min/m) at 1000kPa =	0.85	(Stage 7)
Permeability (m/day) =	**1.07E-02**	
Permeability (m/s) =	**1.24E-07**	

Airlift yield recovery analysis sheets (4 sheets)



RWRC387 AIRLIFT RECOVERY

Data Set: \...\RWRC387.aqt
Date: 01/15/21 Time: 13:01:54

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWRC387

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
RWRC387	613760	613760

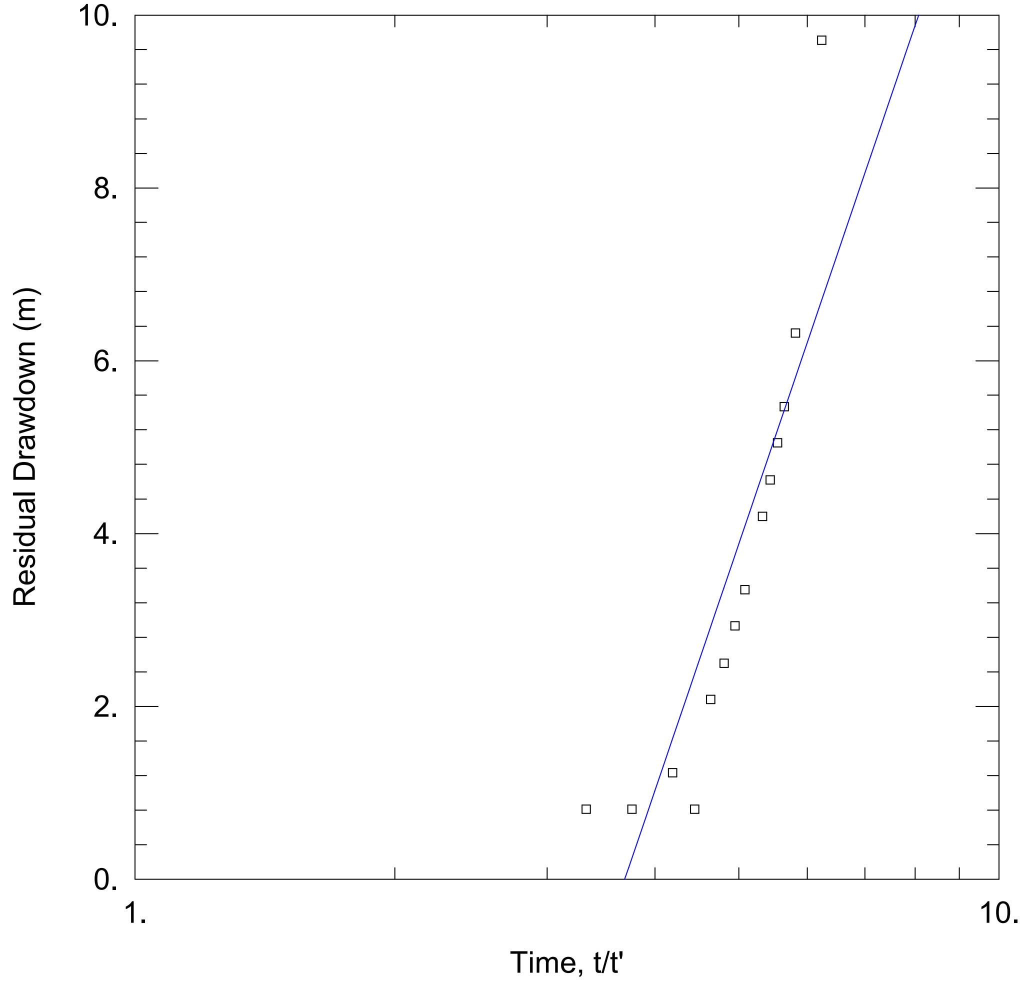
Observation Wells

Well Name	X (m)	Y (m

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 0.01786 m^2/day
S = 0.02217
Kz/Kr = 1.
b = 161. m



RWRC401 AIRLIFT RECOVERY

Data Set:
Date: 01/15/21 Time: 14:21:21

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWRC401

AQUIFER DATA

Saturated Thickness: 65. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
RWRC401	613805	6390290

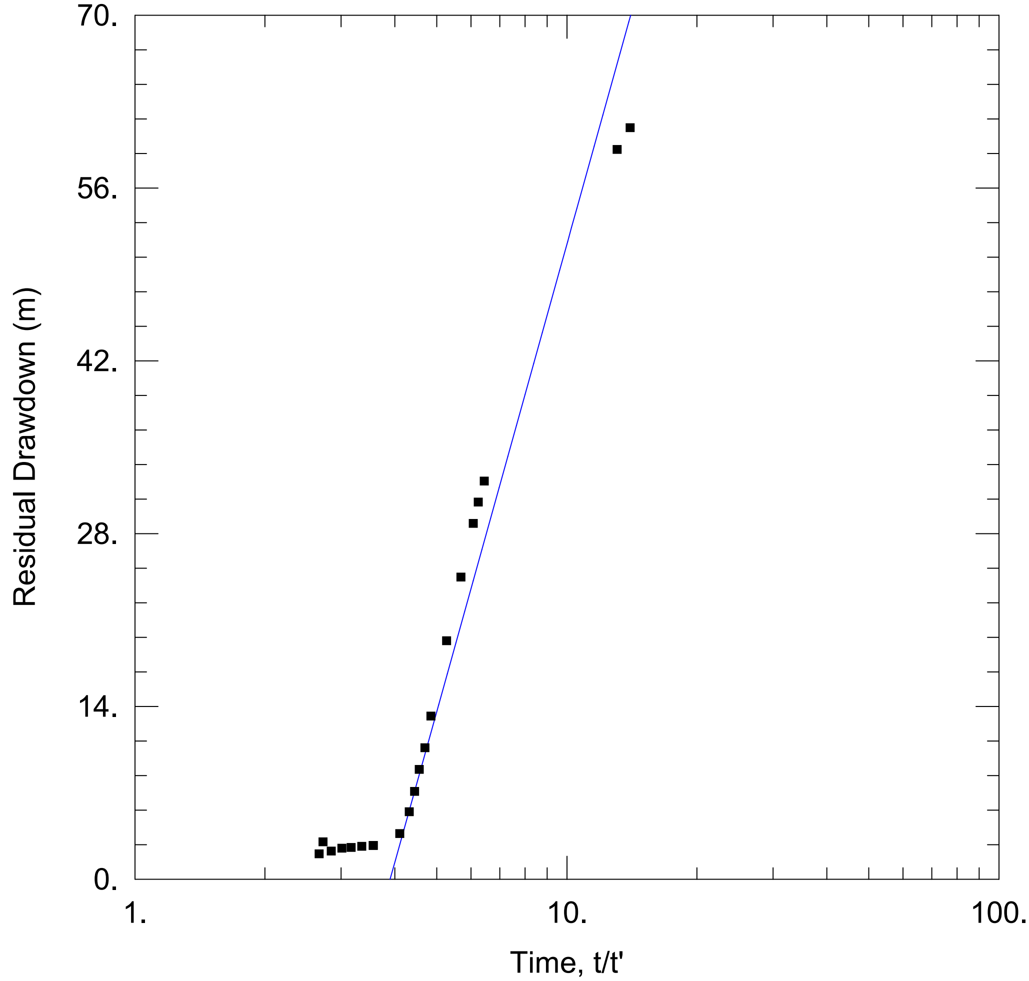
Observation Wells

Well Name	X (m)	Y (m)

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1058 m^2/day S/S' = 3.69



RWRC403

Data Set: \...\RWRC403.aqt
Date: 01/15/21 Time: 15:12:24

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWRC401

AQUIFER DATA

Saturated Thickness: 131. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
RWRC403	613811	6390140

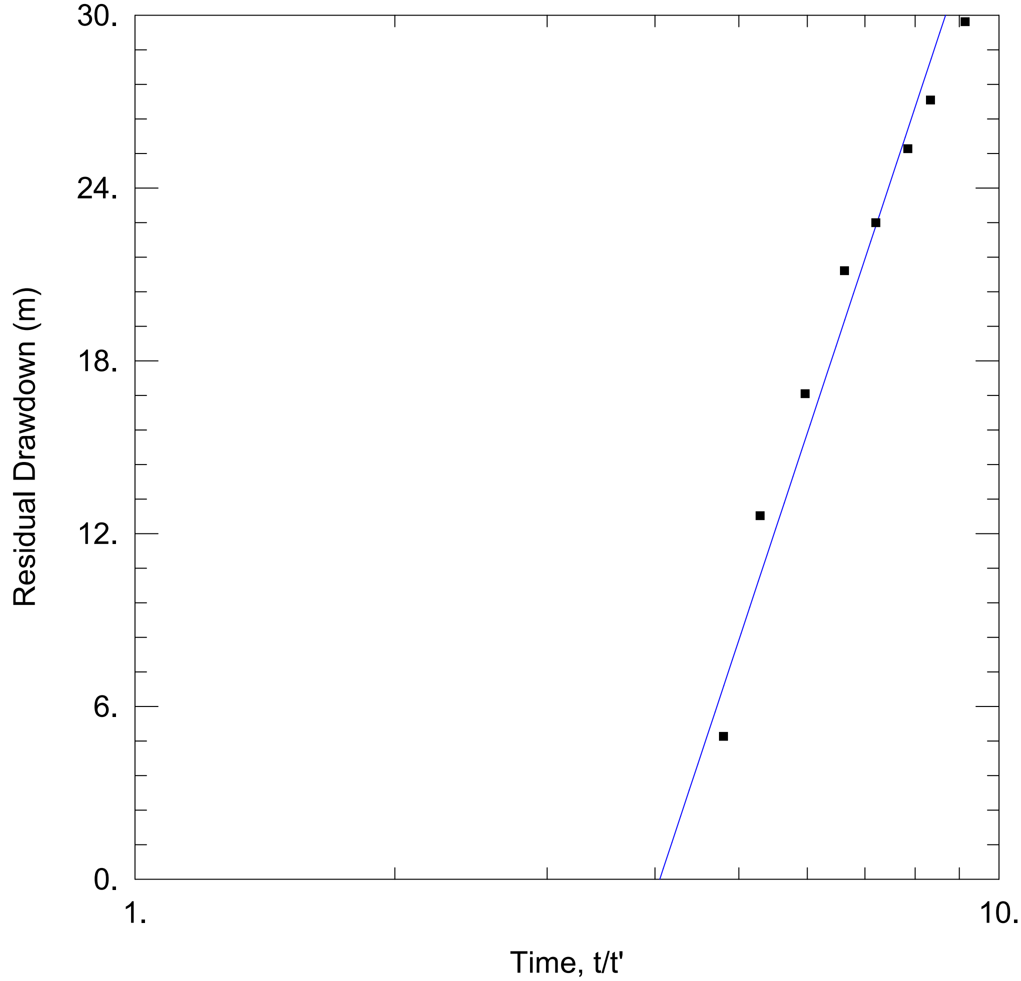
Observation Wells

Well Name	X (m)	Y (m)

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.006325 m^2/day S/S' = 3.898



RWRC418 AIRLIFT RECOVERY

Data Set: \...\RWRC418.aqt
Date: 01/15/21 Time: 16:30:47

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWRC418

AQUIFER DATA

Saturated Thickness: 94. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
RWRC418	613738	6389812

Observation Wells

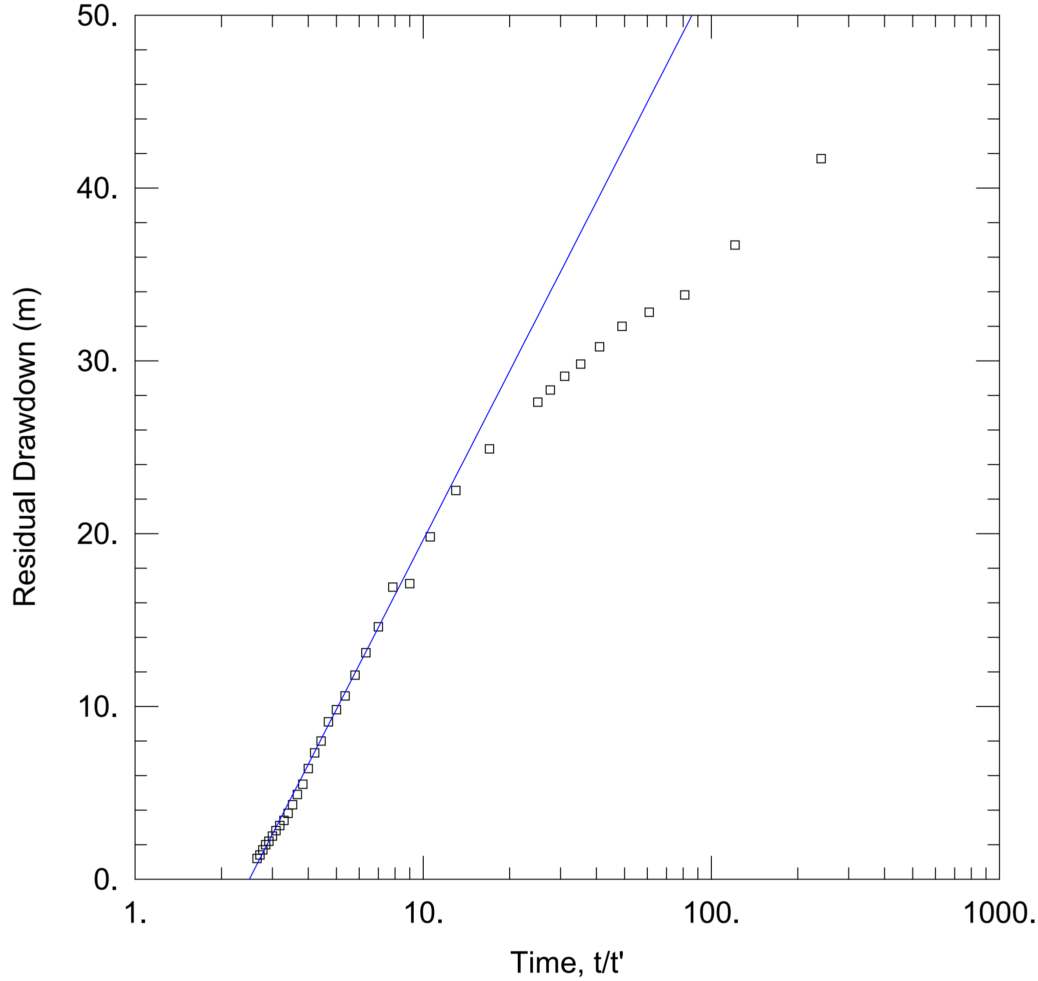
Well Name	X (m)	Y (m)

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.004765 m^2/day S/S' = 4.051

SAR groundwater monitoring bore hydraulic test analysis sheets (2 sheets)



RWWB001 AIRLIFT RECOVERY TEST

Data Set: \...\RWWB001.aqt
Date: 01/18/21 Time: 11:20:14

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWWB001
Test Date: 12.10.2020

AQUIFER DATA

Saturated Thickness: 86. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
RWWB001	614132	6391126

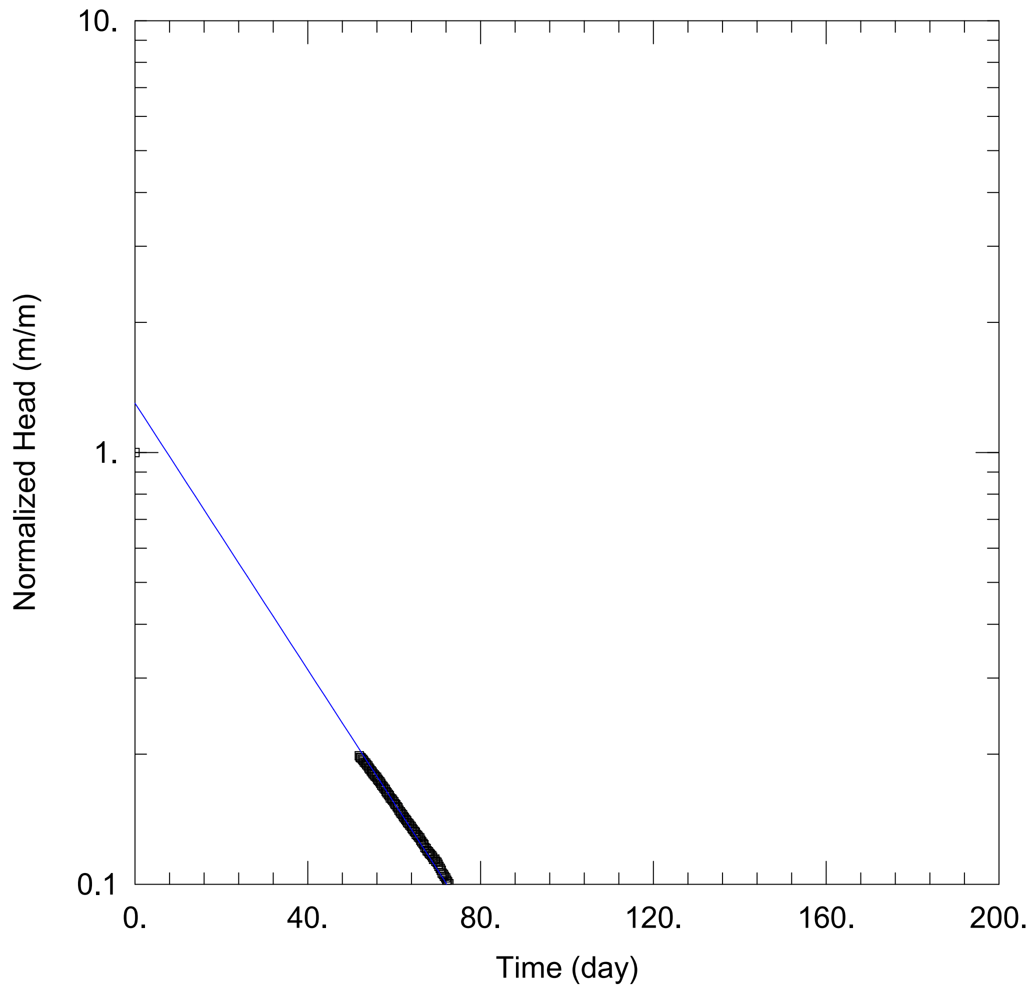
Observation Wells

Well Name	X (m)	Y (m)
□ RWWB001	614132	6391126

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.09729 m^2/day S/S' = 2.496



RWWB002 POST-DRILLING WATER LEVEL RECOVERY

Data Set: \...\RWWB002_slug test solution.aqt
Date: 01/19/21 Time: 12:24:09

PROJECT INFORMATION

Company: Jacobs
Client: R.W Corkery & Co
Project: IH191000
Location: TGEP
Test Well: RWWB002

AQUIFER DATA

Saturated Thickness: 79.2 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (RWWB002)

Initial Displacement: 79.2 m Static Water Column Height: 79.2 m
Total Well Penetration Depth: 150.2 m Screen Length: 30. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev
K = 2.881E-6 m/day y0 = 103. m

Appendix D. GFM sensitivity and uncertainty analysis

Sensitivity analysis

A sensitivity analysis was conducted on the transient calibration model for the following parameters:

- Horizontal hydraulic conductivity
- Vertical hydraulic conductivity
- Recharge
- ET
- Specific storage
- Specific yield
- DRN conductance for Wyoming 1 U/G
- GHB conductance
- GHB head

With the exception of vertical hydraulic conductivity and GHB head, the adopted final calibrated parameter values were subjected to multipliers of 0.75 and 1.25 to generate revised model parameters. Vertical hydraulic conductivity was subjected to a multiplier of 10, to generate a revised hydraulic conductivity scenario, where the vertical hydraulic conductivity was equivalent to the horizontal hydraulic conductivity. GHB head was subjected to multipliers of 0.05 and 1.05 to generate revised boundary head values. The model was then run separately for each revised parameter value. The multipliers and parameter values are shown in **Table D.1**.

The results are shown in **Table D.2**, which tabulates the sum of squared residuals (of the head targets) for each model run. The results indicate that the model is relatively sensitive to changes to horizontal hydraulic conductivity, recharge and GHB head. The other parameters tested in the sensitivity analysis, vertical hydraulic conductivity, EVT, specific storage, specific yield, Wyoming 1 underground DRN conductance and the GHB conductance were significantly less sensitive.

Table D.1: Transient calibration period sensitivity analysis parameter multipliers and values

Parameter	Base value parameter multiplier			
	0.75	**1 (i.e. base value)**	**1.25**	**10**
Horizontal hydraulic conductivity (m/d) [1]	Zone 1: 0.0375 Zone 2 and 3: 0.0075 Zone 4 -7: 0.0008	Zone 1: 0.05 Zone 2 and 3: 0.01 Zone 4 -7: 0.001	Zone 1: 0.0625 Zone 2 and 3: 0.0125 Zone 4 -7: 0.0013	
Vertical hydraulic conductivity (m/d) [2]		Zone 1: 0.005 Zone 2 and 3: 0.001 Zone 4 -7: 0.0001		Zone 1: 0.05 Zone 2 and 3: 0.01 Zone 4 -7: 0.001
Recharge rate as % of mean annual rainfall	Zone 1: 0.1334 Zone 2: 0.0267	Zone 1: 0.1779 Zone 2: 0.0356	Zone 1: 0.2224 Zone 2: 0.0445	
ET (mm/d)	2.95	3.93	4.91	
Specific storage	9.8×10^{-8}	1.3×10^{-7}	1.6×10^{-7}	
Specific yield (%)	5.6	7.5	9.4	
DRN conductance for Wyoming 1 U/G (m^2/d)	0.019	0.00065	0.031	
GHB conductance (m^2/d)	3187.5	4250	5312.5	
	GHB head base value multiplier			
	0.95	**1 (i.e. base value)**	**1.05**	
GHB head (mAHD)	162.45	171	179.55	

Notes: [1] Applied vertical hydraulic conductivity = 1/10 x horizontal hydraulic conductivity. [2] Applied horizontal hydraulic conductivity unchanged from base case, only vertical hydraulic conductivity changed.

Table D.2: Transient calibration period sensitivity analysis results

Parameter	Base value parameter multiplier			
	0.75	**1 (i.e. base value)**	**1.25**	**10**
	Sum of squared residuals [% deviation from base]			
Horizontal hydraulic conductivity	6.58×10^5 [75]	3.76×10^5	2.00×10^5 [-47]	
Vertical hydraulic conductivity		3.76×10^5		3.75×10^5 [-0.27]
Recharge	1.61×10^5 [-57]	3.76×10^5	5.83×10^5 [55]	
ET	3.77×10^5 [0.27]	3.76×10^5	3.77×10^5 [0.27]	
Specific storage	3.76×10^5 [0]	3.76×10^5	3.76×10^5 [0]	
Specific yield	3.75×10^5 [-0.27]	3.76×10^5	3.77×10^5 [0.27]	
DRN conductance for Wyoming 1 U/G	3.77×10^5 [0.27]	3.76×10^5	3.76×10^5 [0]	
GHB conductance	3.77×10^5 [0.27]	3.76×10^5	3.76×10^5 [0]	
	GHB head base value multiplier			
	0.95	**1 (i.e. base value)**	**1.05**	
GHB head	1.60×10^5 [-57]	3.76×10^5	6.88×10^5 [83]	

Uncertainty analysis

An uncertainty analysis was conducted on the groundwater model in accordance with the general principles outlined in Middlemis and Peeters (2018). The chosen uncertainty analysis method was deterministic scenario analysis with subjective probability assessment. This type of uncertainty analysis involves running the model with a limited number of different plausible parameter combinations and is the most straightforward to implement and communicate of the various uncertainty analysis methods.

Middlemis and Peeters (2018) indicate that the adopted uncertainty analysis method of deterministic scenario analysis with subjective probability assessment is appropriate for low risk projects. The project is considered low risk because the fractured rock groundwater system that the mine will interact directly with is conceptualised to be disconnected from shallow perched alluvial groundwater systems applicable to existing shallow perched alluvial water supply bores, GDEs and drainage lines. Additionally, the density of production bores in the fractured rock groundwater system in the vicinity of the mine is very low, and the background water quality of the fractured rock groundwater system is poor due to high salinity.

The uncertainty analysis was conducted using nine variations of the base case transient prediction model, with each variant representing a specific uncertainty scenario. The modelled uncertainty scenarios were as follows:

a) Increased hydraulic conductivity and recharge – base case values increased by 1.5 multiplier

b) Decreased hydraulic conductivity and recharge – base case values decreased by 0.5 multiplier

c) Increased storage – base case specific storage and specific yield values increased by one order of magnitude and 1.5 multiplier, respectively.

d) Decreased storage – base case specific storage and specific yield values decreased by one order of magnitude and 0.5 multiplier, respectively.

e) Increased hydraulic conductivity – base case increased by one order of magnitude

f) Decreased hydraulic conductivity – base case decreased by one order of magnitude

g) Isotropic hydraulic conductivity – base case vertical hydraulic conductivity increased by an order of magnitude, to equal values of horizontal hydraulic conductivity

h) Increased recharge rate – base case recharge rate increased by 50%. The 50% increase was arrived at based on the chloride mass balance estimate of 0.3 mm/year (**Section 3.6**), which represents a 50% increase from the calibrated steady state recharge rate of 0.2 mm/year.

i) Decreased recharge rate – base case recharge rate decreased by 50%. The 50% decrease was adopted to be consistent with the increased recharge rate scenario.

Scenarios a) to d) were completed using model variants that had some differences to the the base case transient prediction model. The main differences were cell resolution at TGO and DRNs at TGO being represented as a single area compared to being represented as three areas, decreasing with depth in the final transient calibration model. The differences are such that key findings from the uncertainty analysis scenarios are considered generally applicable to the final transient prediction model. In contrast to Scenarios a) to d), Scenarios e) to f) were completed by making parameter value changes to the base case prediction model.

Total DRN flow rate at the end of mining and the 2 m drawdown contour at the end of mining were compared to assess the results. Additionally, for Scenarios e) to i) the 2 m drawdown contours 200 years after end of mining were compared. Drawdown for each of the uncertainty scenarios was calculated using results from a corresponding null case model run for which all the DRNs were deleted.

The base case and uncertainty scenario individual parameter values are shown in **Table D.3**.

Table D.3: Uncertainty analyses: base case and uncertainty scenario individual parameter values

Uncertainty scenario I.D.	Uncertainty scenario	Base case value [2]	Uncertainty analyses scenario value
a)	Increased hydraulic conductivity and recharge	Hydraulic conductivity (m/d) Zone 1: 0.05 Zone 2 and 3: 0.01 Zone 4 -7: 0.001 Recharge Zone 1: 0.1779 Zone 2: 0.0356	Hydraulic conductivity (m/d) – values increased by 50% Zone 1: 0.075 Zone 2 and 3: 0.015 Zone 4 -7: 0.0015 Recharge values increased by 50%
b)	Decreased hydraulic conductivity and recharge		Hydraulic conductivity (m/d) – values decreased by 50% Zone 1: 0.025 Zone 2 and 3: 0.005 Zone 4 -7: 0.0005 Recharge values decreased by 50%
c)	Increased storage	Specific storage – 1.3×10^{-7} m^{-1} Specific yield – 7.5%	Specific storage – 1.3×10^{-6} m^{-1} Specific yield – 11.25%
d)	Decreased storage		Specific storage – 1.3×10^{-8} m^{-1} Specific yield – 3.75%
e)	Increased hydraulic conductivity	Hydraulic conductivity (m/d) Zone 1: 0.05 Zone 2 and 3: 0.01 Zone 4 -7: 0.001	Zone 1: 0.5 Zone 2 and 3: 0.1 Zone 4 -7: 0.01
f)	Decreased hydraulic conductivity		Zone 1: 0.005 Zone 2 and 3: 0.001 Zone 4 -7: 0.0001
g)	No anisotropy (i.e. Kv = Kh) [1]	Kv one order of magnitude less than Kh	Kv = Kh
h)	Increased recharge (expressed as a % of mean annual rainfall)	Zone 1: 0.1779 Zone 2: 0.0356	Recharge values increased by 50%
i)	Decreased recharge (expressed as a % of mean annual rainfall)		Recharge values decreased by 50%

Notes: [1] Hydraulic conductivity shown in table is horizontal. Except for Scenario g) applied vertical hydraulic conductivity = 1/10 x horizontal hydraulic conductivity. [2] Recharge rate in table expressed as % of mean annual rainfall.

Total DRN flow rates at the end of mining for the uncertainty scenarios are presented in **Table D.4**.

The 2 m drawdown contour at the end of mining is shown for Scenarios a) to d) in **Figure D.1,** and for Scenarios e) to i) in **Figure D.2**. The 2 m drawdown contour approximately 200 years after end of mining is shown for Scenarios e) to i) in **Figure D.3.** It is noted that drawdown for Scenario e) is not shown in **Figure D.3** because the hydraulic conductivity increase causes the head to be below the post-mining period DRN levels.

Table D.4: Uncertainty analyses: base case and uncertainty scenario total DRN flow rate at end of mining

Uncertainty scenario I.D.	Uncertainty scenario	Total DRN flow rate at end of mining (kL/d) [% increase from base case]
	Base case	2,496
a)	Increased hydraulic conductivity and recharge (×1.5)	3,328 [33]
b)	Decreased hydraulic conductivity and recharge (×0.5)	1,569 [-37]
c)	Increased storage (×10)	2,854 [14]
d)	Decreased storage (×0.1)	2,048 [-18]
	Base case	**2,361**
e)	Increased hydraulic conductivity (×10)	9,976 [+423]
f)	Decreased hydraulic conductivity (×0.1)	691 [-71]
g)	No anisotropy (i.e. Kv = Kh) [1]	4,367 [+185]
h)	Increased recharge (×1.5)	2,483 +[5]
i)	Decreased recharge (×0.5)	2,159 [-9]

Notes: [1] Kv = vertical hydraulic conductivity. Kh = horizontal hydraulic conductivity.

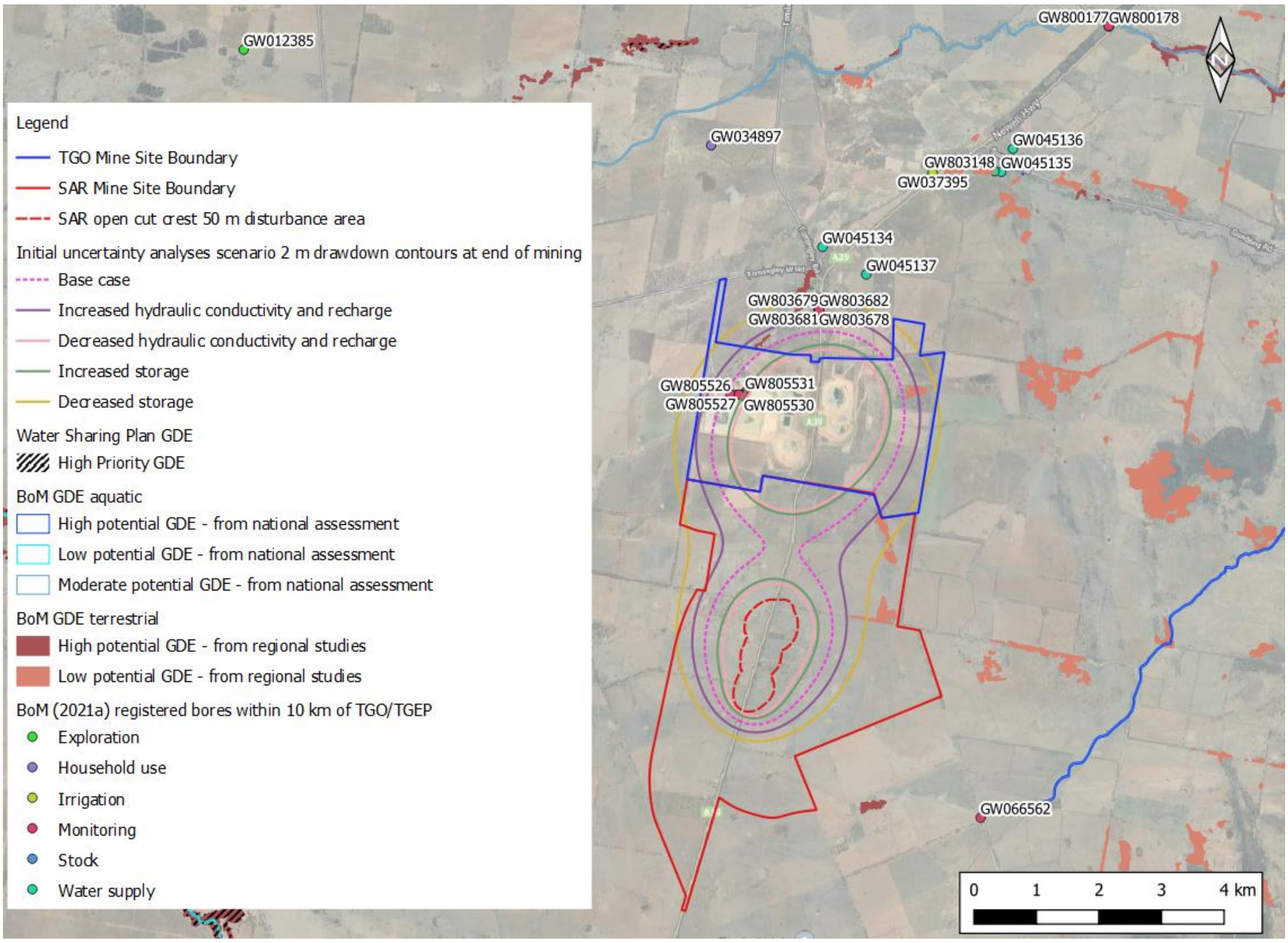


Figure D.1: Uncertainty analyses Scenarios a) to d) 2 m drawdown contours at end of mining

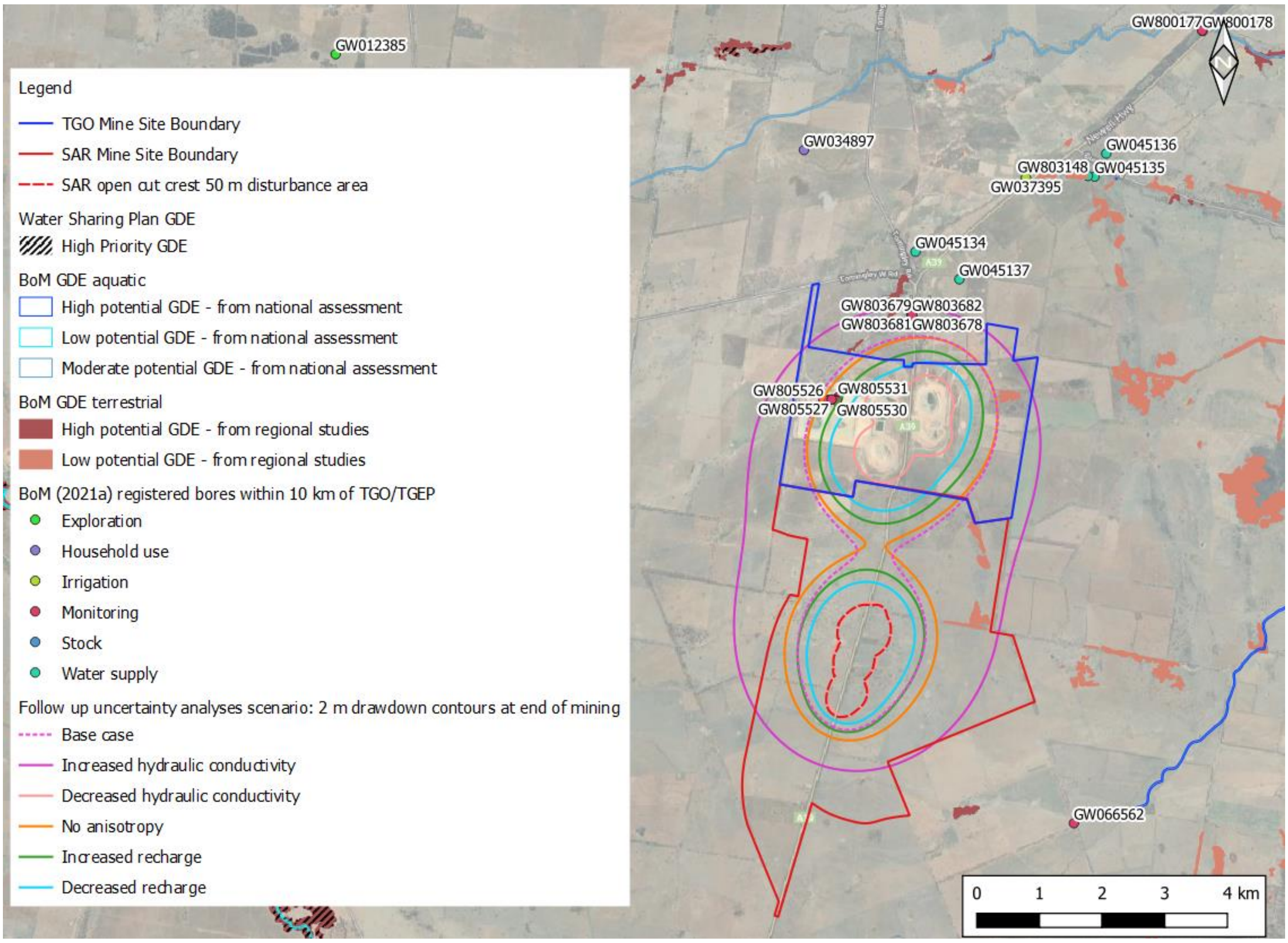


Figure D.2: Uncertainty analyses Scenarios e) to i) 2 m drawdown contours at end of mining

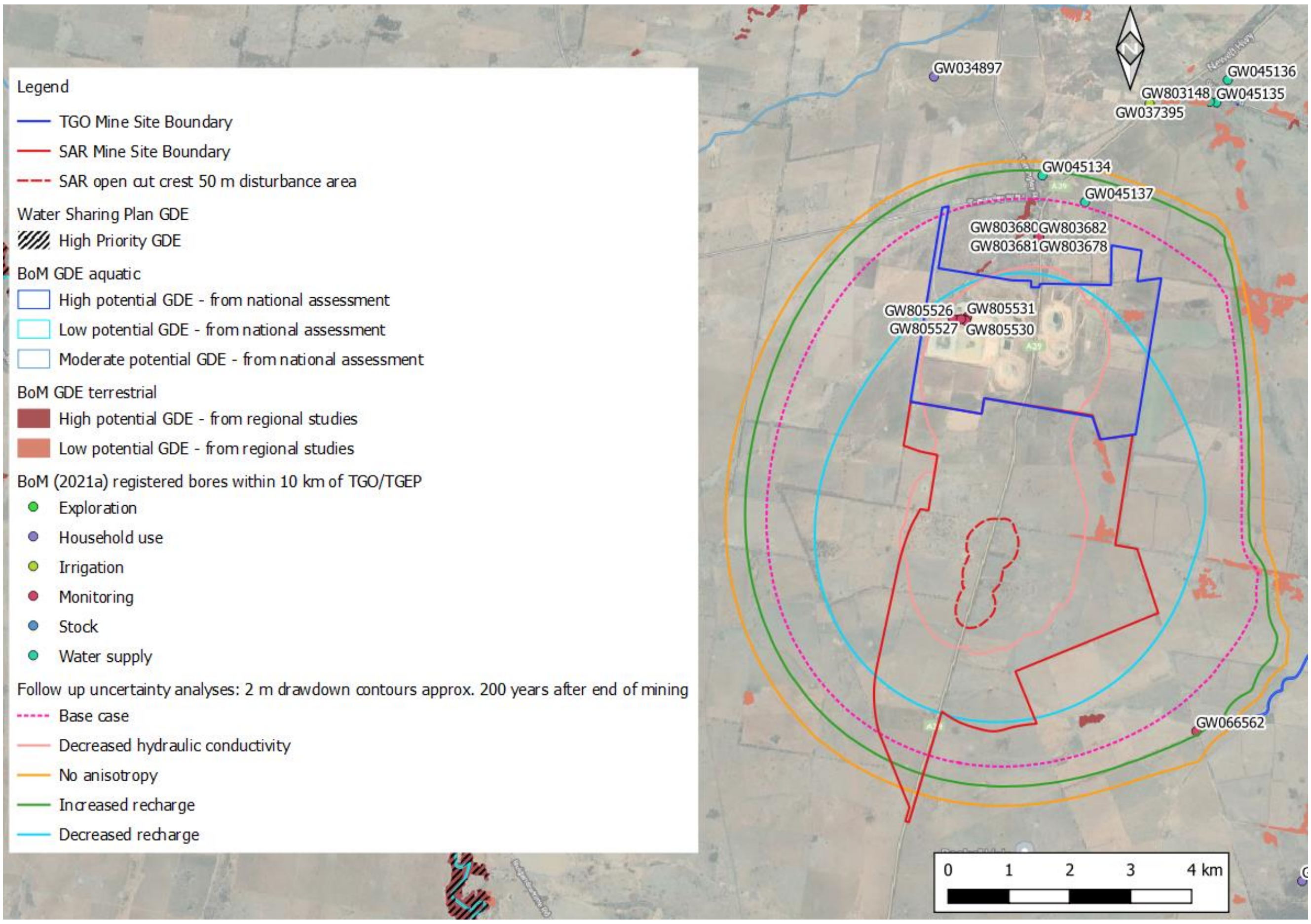


Figure D.3: Uncertainty analyses Scenarios e) to i) 2 m drawdown contours 200 years after end of mining

<u>Uncertainty analysis conclusion</u>

Based on all the uncertainty scenario 2 m drawdown contours at the end of mining and also approximately 200 years after end of mining, none of the uncertainty scenarios are considered to significantly alter the primary base case assessment findings relating to groundwater level drawdown impacts. The isotropic (i.e. Kv = Kh) scenario, Scenario g), and the increased recharge scenario, Scenario h), have the 2 m drawdown contours at approximately 200 years after end of mining extending the furthest from the mine. In spite of this, the increased drawdown extent is not assessed to manifest in increased drawdown impacts. This is because the drawdown extent only encroaches on bore GW066562, which has a purpose of 'monitoring', the five BP truckstop shallow monitoring bores and two shallow bores with a purpose of 'water supply', GW045134 and GW045137. GW045134 and GW045137 are alluvial bores and are not associated with the fractured rock groundwater system that the mine will drawdown. Monitoring data shows the alluvial groundwater system is disconnected from the underlying fractured rock groundwater system. As outlined in **Section 8.3**, the proponent has committed to installing a fractured rock monitoring bore near existing bores GW045134 and GW045137 to demonstrate the conceptualised hydraulic disconnection between perched alluvium and the fractured rock groundwater system. Increased drawdown extent associated with some of the uncertainty scenarios has no implications for potential GDEs for the same reasons.

With respect to the DRN flow rates of Scenarios a) to d), the largest increase (33%) from the base case flow rate occurs under the increased hydraulic conductivity and recharge scenario, Scenario a). The largest decrease (-

37%) from the base case flow rate occurs under the decreased hydraulic conductivity and recharge scenario, Scenario b).

For Scenarios e) to i), the largest increase (423%) from the base case flow rate occurs under the increased hydraulic conductivity scenario, Scenario e). The largest decrease (-71%) from the base case flow rate occurs under the decreased hydraulic conductivity scenario, Scenario f).

Scenario e) is considered highly unlikely and not realistic. Whilst some localised fracturing could lead to potential short term increased inflows, a universal increase to hydraulic conductivity of a full order of magnitude is unrealistic based on the testing completed and the available data and the hydrogeological environment. The other scenarios are considered plausible.

Based on all the uncertainty scenario DRN flow rate results, none of the uncertainty scenarios alter the primary base case assessment finding, which is that acquiring entitlement to cover the groundwater take is considered feasible due to the extent of predicted groundwater inflow rates, trading frequency in the water source and percentage of unallocated water in the water source.

Appendix E. Final void water level recovery modelling

Purpose

Water balance models were developed to simulate post-mining water level recovery in the two voids which will not be backfilled, the northern portion of the SAR open cut and the Wyoming 1 open cut at TGO. The objectives were to:

- Determine approximate equilibrium water levels, to inform groundwater modelling of the post-mining period, and to inform impact assessment, and
- Determine salt concentrations of the void water.

Methodology

Simple spreadsheet-based water balance models were developed to simulate post-mining water level recovery in the northern portion of the SAR open cut and the Wyoming 1 open cut at TGO.

Given their relatively uniform shapes, void volumes for SAR and Wyoming 1 were approximated using formula for conical and truncated conical volumes that closely approximated the final void geometry.

The models apportioned the total void volume into multiple slices based on elevation at increments of about 10 m to 15 m. Starting from a dry pit, the time for each void slice to fill was calculated. Inflow sources comprised direct rainfall, runoff from the dry area of the void and groundwater inflow. Run off from external catchment area was not considered as the external catchment area is negligible. Outflow was limited to evaporation.

Pit lake equilibrium level is determined to be the pit lake water level applicable for the void slice which has a net flux closest to zero.

Groundwater inflow rates were determined using the GFM by completing multiple model runs, each with different DRN level heights, to enable creation of pit lake level and groundwater inflow graphs. A pit lake elevation against inflow relationship was then developed to allow interpolation of inflow rate for the different pit lake water level elevations.

Rainfall and runoff were applied daily based on long-term mean daily rainfall from SILO, with a runoff coefficient of 0.45 applied for in-pit runoff. A runoff coefficient of 1 was used for direct rainfall. Groundwater inflow was applied daily. For levels above the pre-mining water table, groundwater inflow rate was zero. Evaporation was applied daily based on long-term mean daily evaporation from SILO and a pan factor of 0.70. The SILO climate data is summarised in Section 3.1 of the main report.

Groundwater salinity was assigned based on monitoring bore data. Runoff and direct rainfall were assigned a salinity of 30 mg/L and 10 mg/L, respectively.

Further insight into the model parameters and structure is covered in the results section below.

Results

<u>SAR</u>

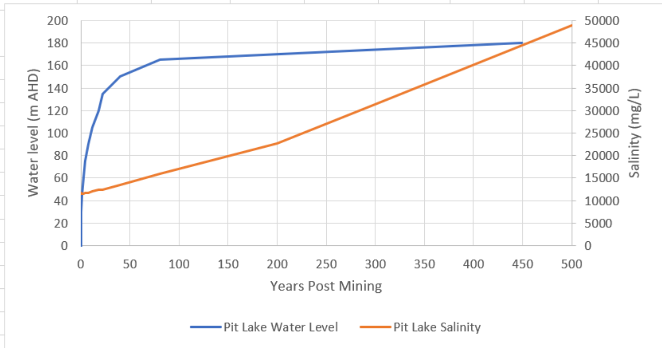
SAR water balance inputs and results are shown in Figure E.1. Net flux approaches zero for the slice which has a pit lake level of 180 mAHD (row highlighted green), meaning pit lake water level equilibrium occurs at approximately 180 mAHD.

Long-term pit lake salinity is 15,980 mg/L, 22,640 mg/L, 31,385 mg/L and 48,875 mg/L for 80 years, 200 years, 300 years and 500 years after end of mining, respectively.

TGEP Mine Void - Water and Salt Balance

Mean Daily Rainfall	1.54	mm/d	In Pit runoff coeff.	0.45	Groundwater salinity	15400	mg/L (Mean of RWWB002 monitoring bore)
Mean Daily Evaporation	5.02	mm/d	Ex Pit runoff coeff	0.35	Surface water salinity	30	mg/L
Minimum pit level (mAHD)	-27	mAHD	Pan Factor	0.70	Rainfall salinity	10	mg/L
Upstream Catchment	0	m2					

Row	Pit Lake Water Depth (m)	Pit Lake Water Level Elevation (mAHD)	Dry Pit Area (m2)	Pit Lake Surface Area (m2)	Pit Lake Surface Area Radius (m)	Pit Lake Volume (m3)	Pit Lake Slice Volume (m3)	Direct Rainfall - IN (m3/d)	In Pit Runoff - IN (m3/d)	Ex Pit runoff - IN (m3/d)	GW Inflow - IN (m3/d)	Pit Lake Evap - OUT (m3/d)	Net Flux (m3/d)	Time to fill (days)	Cumulative Time (days)	Cumulative Time (Years)	Salt Flux (kg/d)	Incremental Salt Load (kg)	Cumulative Salt Load (kg)	Pit Lake Salinity (mg/L)
10	0	-27	435,916	0	0	0														
11	12	-15	434,840	1,075	18.50	4,301	4,301	1.7	301.3	0	945.557	3.8	1244.8	3	3	0.01	14565	50,322	50,322	11701
12	27	0	431,498	4,418	37.50	39,761	35,460	6.8	299.0	0	887.33	15.5	1177.6	30	34	0.09	13668	411,557	461,879	11616
13	42	15	427,018	8,898	53.22	124,567	84,806	13.7	295.9	0	829.103	31.3	1107.5	77	110	0.30	12771	977,984	1,439,863	11559
14	57	30	420,725	15,191	69.54	288,631	164,064	23.4	291.6	0	770.876	53.4	1032.5	159	269	0.74	11875	1,886,967	3,326,830	11526
15	72	45	412,756	23,160	85.86	555,828	267,197	35.7	286.0	0	712.649	81.4	953.0	280	549	1.51	10978	3,078,050	6,404,880	11523
16	87	60	403,113	32,803	102.18	951,283	395,455	50.5	279.4	0	654.422	115.3	869.0	455	1,004	2.75	10081	4,587,592	10,992,471	11555
17	102	75	391,794	44,121	118.51	1,500,120	548,837	67.9	271.5	0	596.195	155.0	780.6	703	1,708	4.68	9185	6,457,682	17,450,153	11633
18	117	90	378,801	57,114	134.83	2,227,462	727,342	88.0	262.5	0	537.968	200.7	687.7	1,058	2,765	7.58	8288	8,765,560	26,215,714	11769
19	132	105	364,133	71,783	151.16	3,158,435	930,973	110.5	252.3	0	479.741	252.2	590.4	1,577	4,342	11.90	7392	11,655,782	37,871,495	11991
20	147	120	347,790	88,126	167.49	4,318,161	1,159,727	135.7	241.0	0	421.514	309.7	488.6	2,374	6,716	18.40	6495	15,417,418	53,288,913	12341
21	162	135	344,715	91,201	170.38	4,924,836	606,675	140.4	238.9	0	363.287	320.5	422.1	1,437	8,153	22.34	5598	8,045,627	61,334,541	12454
22	177	150	319,471	116,445	192.52	6,870,232	1,945,396	179.3	221.4	0	305.06	409.2	296.6	6,559	14,712	40.31	4702	30,840,770	92,175,311	13417
23	192	165	291,215	144,700	214.61	9,260,817	2,390,585	222.8	201.8	0	246.833	508.5	163.0	14,666	29,378	80.49	3805	55,809,360	147,984,671	15980
24	207	180	259,948	175,968	236.67	12,141,767	2,880,950	271.0	180.1	0	188.606	618.4	21.4	134,688	164,065	449.49	2909	391,812,901	539,797,572	44458
25	222	195	225,669	210,247	258.70	15,558,258	3,416,491	323.8	156.4	0	130.379	738.8	-128.3	-26637.3	137,428	377	2,013	-53611310.7	486,186,261	31,249
26	231	204	203,656	232,260	271.90	17,884,005	2,325,747	357.7	141.1	0	95.4428	816.2	-221.9	-10480.8	126,947	348	1,475	-15457223.4	470,729,038	26,321
27	232	205	201,143	234,773	273.37	18,155,750	271,745	361.5	139.4	0	0	825.0	-324.0	-838.6	126,109	346	5	-4200.9	470,724,837	25,927
28	237	210	188,378	247,538	280.70	19,555,465	1,399,715	381.2	130.5	0	0	869.8	-358.1	-3908.8	122,200	335	5	-20003.4	470,704,833	24,070
29	252	225	148,076	287,840	302.69	24,178,564	4,623,099	443.3	102.6	0	0	1011.5	-465.6	-9929.8	112,270	308	5	-54205.6	470,650,628	19,466
30	267	240	104,761	331,154	324.67	29,472,731	5,294,167	510.0	72.6	0	0	1163.7	-581.1	-9110.6	103,160	283	6	-53076.3	470,597,551	15,967
31	282	255	58,435	377,480	346.63	35,483,141	6,010,410	581.3	40.5	0	0	1326.5	-704.7	-8529.6	94,630	259	6	-53038.6	470,544,513	13,261
32	292	265	0	435,916	372.50	42,429,120	6,945,979	671.3	0.0	0	0	1531.8	-860.5	-8072.1	86,558	237	7	-54188.5	470,490,324	11,089



Longterm Salinity Years	Cumulative Salt Load kg	Pit Lake Salinity mg/L
200	274,884,137	22,640
300	381,064,233	31,385
500	593,424,426	48,875

Figure E.1: SAR water balance inputs and results

Wyoming 1

Wyoming 1 water balance inputs and results are shown in Figure E.2. Net flux approaches zero for the slice which has a pit lake level of 200 mAHD (row highlighted green), meaning pit lake water level equilibrium occurs at approximately 200 mAHD.

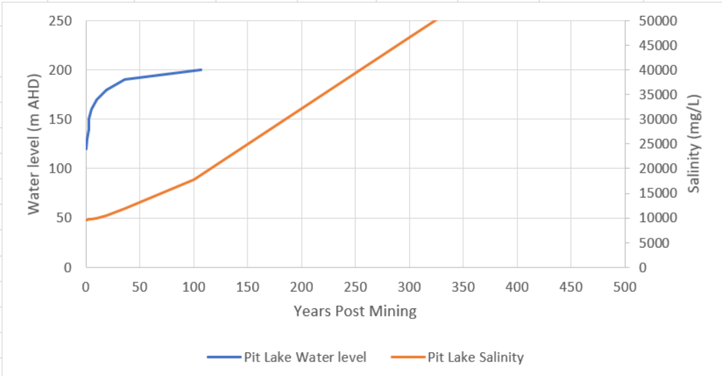
Long-term pit lake salinity is 17,790 mg/L, 32,178 mg/L, 46,567 mg/L and 75,345 mg/L for 100 years, 200 years, 300 years and 500 years after end of mining, respectively.

TGO Wyoming 1 Mine Void - Water and Salt Balance

Mean Daily Rainfall	1.54	mm/d	In Pit runoff coeff.	0.45	Groundwater salinity	14627	mg/L	Mean of WYMB02 monitoring bore
Mean Daily Evaporation	5.02	mm/d	Ex Pit runoff coeff	0.35	Surface water salinity	30	mg/L	
Minimum pit level (mAHD)	109	mAHD	Pan Factor	0.70	Rainfall salinity	10	mg/L	
Upstream Catchment	0	m2						

Pit Lake Water Depth (m)	Pit Lake Water Level Elevation (mAHD)	Dry Pit Area (m2)	Pit Lake Surface Area (m2)	Pit Lake Surface Area Radius (m)	Pit Lake Volume (m3)	Pit Lake Slice Volume (m3)	Direct Rainfall - IN (m3/d)	In Pit Runoff - IN (m3/d)	Ex Pit runoff - IN (m3/d)	GW Inflow - IN (m3/d)	Pit Lake Evap - OUT (m3/d)
0	109	193,032	3,318	32.5	0						
11	120	191,572	4,778	39.00	44,288	44,288	7.4	132.8	0	238.618	16.8
21	130	189,988	6,362	45.00	99,922	55,634	9.8	131.7	0	217.437	22.4
31	140	179,608	16,742	73.00	284,304	184,382	25.8	124.5	0	196.256	58.8
41	150	183,256	13,094	64.56	314,392	30,088	20.2	127.0	0	175.075	46.0
51	160	175,911	20,439	80.66	543,887	229,495	31.5	121.9	0	153.894	71.8
61	170	166,889	29,461	96.84	867,565	323,678	45.4	115.7	0	132.713	103.5
71	180	156,190	40,160	113.06	1,302,192	434,627	61.8	108.2	0	111.532	141.1
81	190	143,815	52,535	129.32	1,864,532	562,341	80.9	99.7	0	90.351	184.6
91	200	129,763	66,587	145.59	2,571,354	706,821	102.5	89.9	0	69.17	234.0
101	210	114,034	82,316	161.87	3,439,421	868,068	126.8	79.0	0	47.989	289.3
111	220	96,629	99,721	178.16	4,485,502	1,046,081	153.6	67.0	0	0	350.4
121	230	77,547	118,803	194.46	5,726,363	1,240,860	183.0	53.7	0	0	417.5
131	240	56,789	139,561	210.77	7,178,769	1,452,407	214.9	39.4	0	0	490.4
141	250	34,354	161,996	227.08	8,859,488	1,680,719	249.5	23.8	0	0	569.3
151	260	10,242	186,108	243.39	10,785,287	1,925,798	286.6	7.1	0	0	654.0
161	270	0	196,350	250.00	12,085,399	1,300,113	302.4	0.0	0	0	690.0

Pit Lake Water Depth (m)	Net Flux (m3/d)	Time to fill (days)	Cumulative Time (days)	Cumulative Time (Years)	Salt Flux (kg/d)	Incremental Salt Load (kg)	Cumulative Salt Load (kg)	Pit Lake Salinity (mg/L)
0								
11	361.9	122	122	0.34	3492	427,248	427,248	9647
21	336.5	165	288	0.79	3182	525,998	953,246	9540
31	287.7	641	929	2.54	2872	1,840,849	2,794,095	9828
41	276.2	109	1,038	2.84	2562	279,100	3,073,195	9775
51	235.5	975	2,012	5.51	2253	2,195,549	5,268,744	9687
61	190.2	1,702	3,714	10.18	1943	3,306,045	8,574,789	9884
71	140.5	3,094	6,807	18.65	1633	5,051,955	13,626,744	10464
81	86.3	6515.3	13322.8	36.5	1323	8622195.6	22248939.5	11932.7
91	27.7	25560.4	38883.1	106.5	1014	25909878.9	48158818.4	18729.0
101	-35.5	-24469.2	14413.9	39.5	704	-17226131.3	30932687.2	8993.6
111	-129.9	-8053.9	6360.0	17.4	2	-17761.6	30914925.5	6892.2
121	-180.8	-6864.1	-504.1	-1.4	2	-16247.0	30898678.5	5395.9
131	-236.1	-6150.6	-6654.7	-18.2	3	-15639.8	30883038.7	4302.0
141	-296.0	-5678.6	-12333.3	-33.8	3	-15518.6	30867520.1	3484.1
151	-360.3	-5345.3	-17678.6	-48.4	3	-15699.3	30851820.8	2860.5
161	-387.6	-3354.3	-21032.9	-57.6	3	-10142.7	30841678.1	2552.0



Longterm Salinity Years	Cumulative Salt Load kg	Pit Lake Salinity mg/L
100	45,743,104	17,790
200	82,742,216	32,178
300	119,741,327	46,567
500	193,739,550	75,345

Figure E.2: Wyoming 1 water balance inputs and results

Appendix F. Recent SAR monitoring bore Form As

Form A Particulars of completed work

WaterNSW

		1
Driller's Licence No:	DL2472	
Class of Licence:	Class 5	
Driller's Name:	Luke Barber	
Assistant Driller:	D. Nelson, A. MacInstosh	
Contractor:	The Impax Group	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	
Final Depth	150 m		

		2
Work Licence No:		
Name of Licensee:	Alkane Resources	
Intended Use:	Monitoring Bore	
Completion Date:	17.9.20	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	5.8	330	9
5.8	150	150	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)
70	72	2										
124	132	8	70	1	0.2	1	A					

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	225	10.7	0	5.8	1
6	60.3	3.4	0	150	1

Casing support method (See Code 5): 4

Type of casing bottom (See Code 5): 1

Centralisers installed {Yes/No}	Yes	(indicate on sketch)				
Sump installed {Yes/No}	No	From		m To		m
Pressure cemented {Yes/No}	No	From		m To		m
Casing Protector cemented in place						

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
6	60.3	3.4	120	150	5	1	2			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m^3
Rounded	X	Graded		3	5	110	150		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)			Yes			0	110		

Method of placement of Gravel Pack (See Code 7): 1

For Departmental use only: G W

Form A Particulars of completed work

BORE DEVELOPMENT 8						
Chemical used for breaking down drilling mud (Yes/No) No			Name:			
Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:
Duration	hrs	hrs	hrs	hrs	hrs	hrs

DISINFECTION ON COMPLETION 9		
Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10										
Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery		
								Water level (m)	Time taken (hrs)	(mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11					
Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) From m To m

Site chosen by: Hydrogeologist Geologist Driller Diviner Client X Other 12

13

Lot No 43 DP No 755093

Work Location Co ordinates Easting Northing Zone

GPS: (Yes/No) >> AMG/AGD or MGA/GDA (See explanation)

Longitude Latitude

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

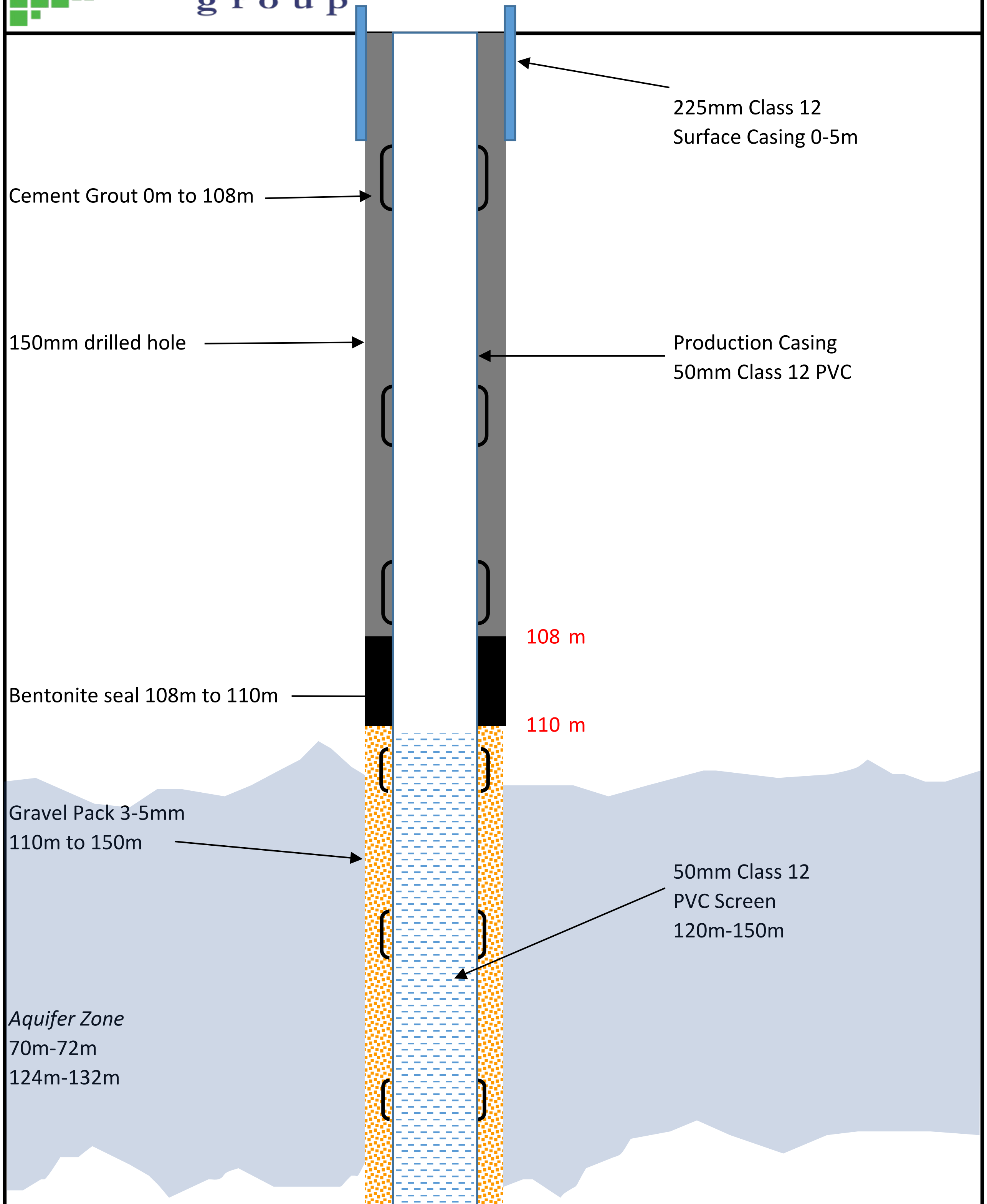
Driller: Luke Barber **Licensee:**

Date: 23.9.20 **Date:**

Bore Log
Alkane Resources
Monitoring Hole 1 - RWWB001

From(M)	To (M)	Thickness(M)	Description	Comment
0	1	1	Topsoil	
1	35	34	Clay,Brown/Red	
35	40	5	Quartz	
40	57	17	Sand,Red	
57	75	18	Sand, Yellow	
75	78	3	Sandstone,White	
78	90	12	Sand,Yellow	
90	150	60	Bedrock/Basalt,Grey/Black,Hard	

Bore Construction - Schematic Diagram
Alkane Resources
Tomingly - Monitoring Bore RWWB-001



Total Depth: 150m

Not to scale

Form A Particulars of completed work

WaterNSW

Driller's Licence No:	DL2472	1
Class of Licence:	Class 5	
Driller's Name:	Luke Barber	
Assistant Driller:	D. Nelson, A. MacInstosh	
Contractor:	The Impax Group	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	
Final Depth	150 m		

Work Licence No:		2
Name of Licensee:	Alkane Resources	
Intended Use:	Monitoring Bore	
Completion Date:	24.9.20	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	5.7	330	9
5.7	150	150	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity TDS (mg/L)

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	225	10.7	0	5.7	
6	60.3	3.5	0	150	

Casing support method	See Code 5	4			
Type of casing bottom	See Code 5	1			
Centralisers installed {Yes/No}	Yes	(indicate on sketch)			
Sump installed {Yes/No}	No	From	m	To	m
Pressure cemented {Yes/No}	No	From	m	To	m
Casing Protector cemented in place					

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Slot Details Width (mm)	Slot Details Alignment See Code 6
6	60.3	3.4	120	150	5	1	2			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	X	Graded		3	5	110	150		
Crushed		Ungraded							
Bentonite/Grout seal (Yes/No)		Yes				0	110		
Method of placement of Gravel Pack		See Code 7		1					

For Departmental use only: G W

Form A Particulars of completed work

BORE DEVELOPMENT							8
Chemical used for breaking down drilling mud (Yes/No)	No	Name:					
Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:	
Duration	hrs	hrs	hrs	hrs	hrs	hrs	

DISINFECTION ON COMPLETION		9
Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION										10
Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	(mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED						11
Original depth of work: m			Is work partly backfilled: (Yes/No)			
Is work abandoned: (Yes/No)		Method of abandonment:	Backfilled	Plugged	Capped	
Has any casing been left in the work (Yes/No)			From m	To m		
Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	

Site chosen by:	Hydrogeologist	Geologist	Driller	Diviner	Client	Other	12
					X		

						13
Lot No	43	DP No	755093			
Work Location Co ordinates		Easting		Northing		Zone
GPS: (Yes/No)		>>	AMG/AGD	or MGA/GDA		(See explanation)
		Longitude		Latitude		

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

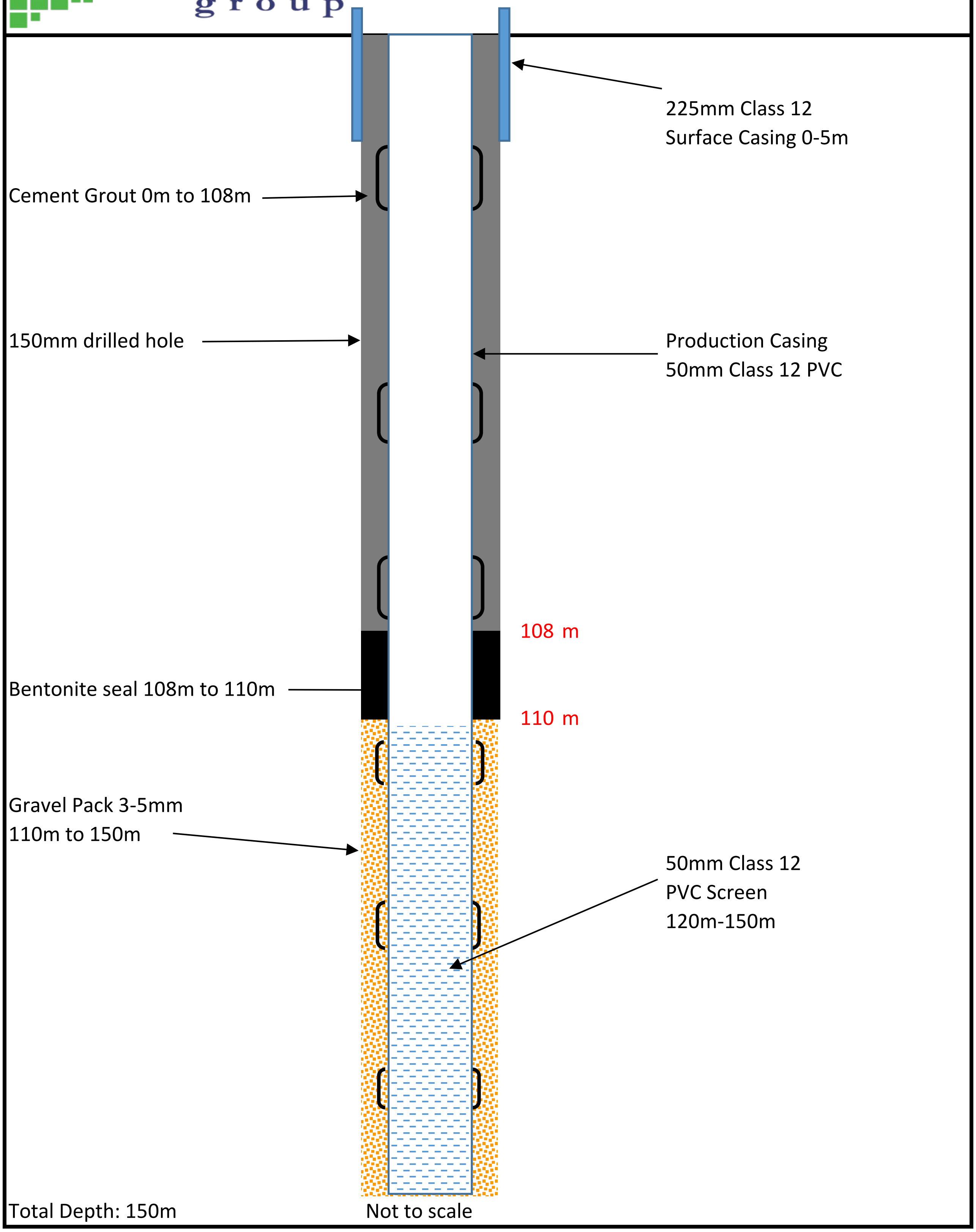
Driller: **Luke Barber** **Licensee:**

Date: **25.9.20** **Date:**

Bore Log
Alkane Resources
Monitoring Hole 2 - RWWB002

From(M)	To (M)	Thickness(M)	Description	Comment
0	1	1	Topsoil	
1	4	3	Clay,Brown	
4	7	3	Clay/Quartz	
7	35	28	Clay,Red/Brown	
35	47	12	Sand, Yellow	
47	48	1	Quartz	
48	53	5	Clay,Brown	
53	65	12	Sand,White	
65	78	13	Clay,Sandy	
78	140	62	Bedrock,Black/Grey,Hard	
140	142	2	Quartz	
144	150	6	Bedrock	

Bore Construction - Schematic Diagram
Alkane Resources
Tomingly - Monitoring Bore RWWB-002



Form A Particulars of completed work

WaterNSW

Driller's Licence No:	DL1576	1
Class of Licence:	Class 6	
Driller's Name:	Luke Barber	
Assistant Driller:	A.McIntosh,D.Nelson	
Contractor:	The Impax Group	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	
Final Depth	72 m		

Work Licence No:		2
Name of Licensee:	Alkane Resources	
Intended Use:	Monitoring Bore	
Completion Date:	29.9.20	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	5.8	330	9
5.8	72	150	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	60.8	10.7	0	5.8	1

Casing support method See Code 5:

Type of casing bottom See Code 5: 1

Centralisers installed {Yes/No} (indicate on sketch)

Sump installed {Yes/No} From m To m

Pressure cemented {Yes/No} From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN 6

General: Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details: Length (mm)	Width (mm)	Alignment See Code 6

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m³
Rounded		Graded							
Crushed		Ungraded							

Bentonite/Grout seal (Yes/No)

Method of placement of Gravel Pack See Code 7

For Departmental use only: G W

Form A Particulars of completed work

BORE DEVELOPMENT (8)

Chemical used for breaking down drilling mud (Yes/No)		Name:										
Method	Bailing/Surging		Jetting		Airlifting		Backwashing		Pumping		Other:	
Duration		hrs		hrs		hrs		hrs		hrs		hrs

DISINFECTION ON COMPLETION (9)

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION (10)

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ___ m   Test Method ___ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED (11)

Original depth of work: 72 m   Is work partly backfilled: (Yes/No) No

Is work abandoned: (Yes/No) Yes   Method of abandonment: Backfilled ___ Plugged ___ Capped X

Has any casing been left in the work (Yes/No) Yes   From 0 m To 5.8 40.5

Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)

(12)

Site chosen by: Hydrogeologist ___ Geologist ___ Driller ___ Diviner ___ Client X Other ___

(13)

Lot No 43   DP No 755093

Work Location Co ordinates   Easting ___   Northing ___   Zone 54

GPS: (Yes/No) ___ >> AMG/AGD ___ or MGA/GDA ___ (See explanation)

Longitude ___   Latitude ___

Please mark the work site with "X" on the CLID provided map.

Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: **Luke Barber**   **Licensee:**

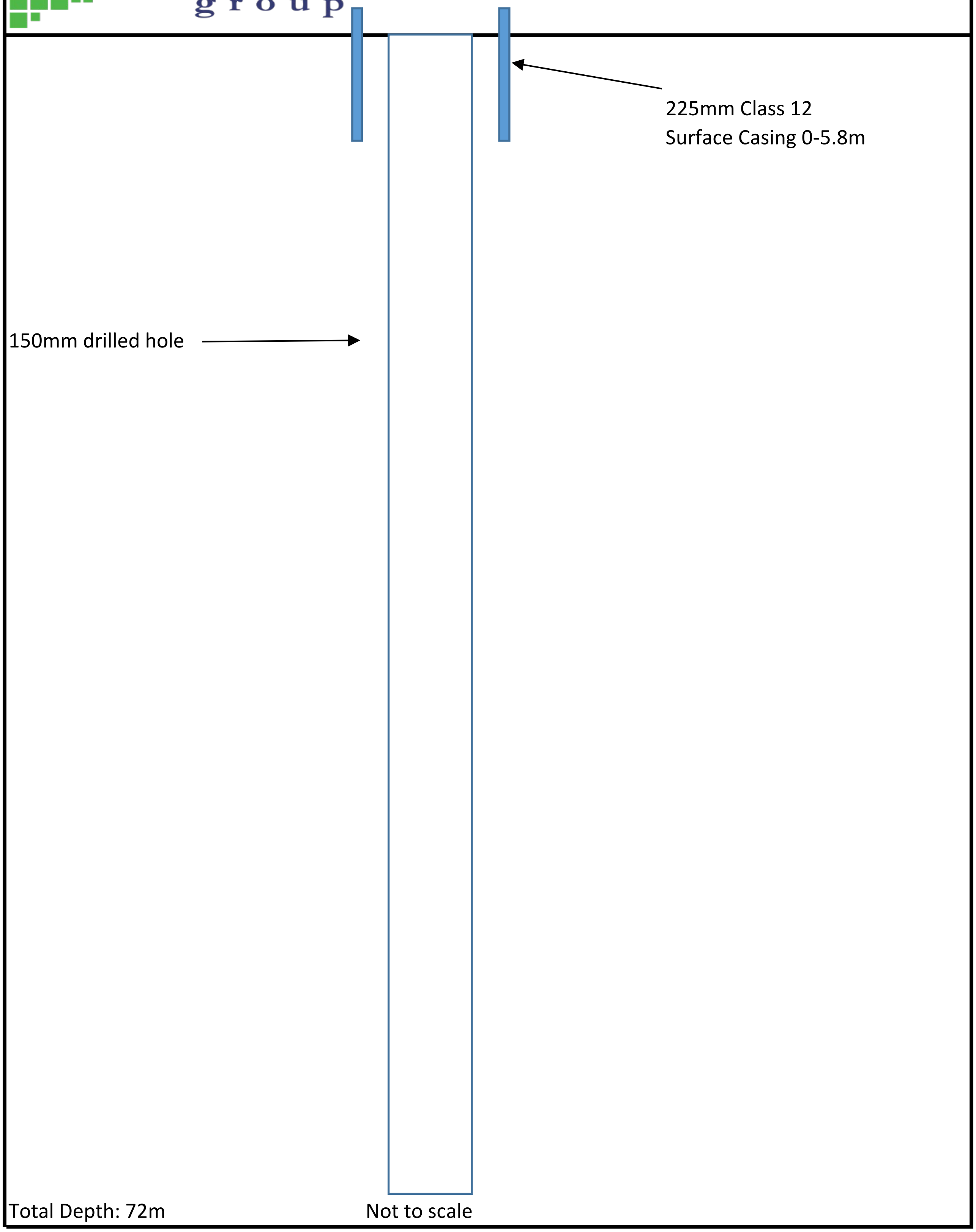
Date: **29.9.20**   **Date:**

Please submit forms to groundwater@waternsw.com.au or send to WaterNSW, PO Box 398, Parramatta 2124

Bore Log
Alkane Resources
Monitoring Hole 3-1 - RWWB003-1

From(M)	To (M)	Thickness(M)	Description	Comment
0	2	2	Topsoil	
2	6	4	Quartz/Clay	
6	35	29	Clay,Brown/Red	
35	60	25	Sand,Yellow	
60	65	5	Sand,Red	
65	70	5	Gravel,Fine/Clay	
70	78	8	Gravel,Large	

Bore Construction - Schematic Diagram
Alkane Resources
Tomingly - Monitoring Bore RWWB-003/1



Form A Particulars of completed work

Driller's Licence No:	DL2472	1
Class of Licence:	Class 5	
Driller's Name:	Luke Barber	
Assistant Driller:	D. Nelson, A. MacInstosh	
Contractor:	The Impax Group	

New bore	X	Replacement bore	
Deepened		Enlarged	
Reconditioned		Other (specify)	
Final Depth	70.5 m		

Work Licence No:		2
Name of Licensee:	Alkane Resources	
Intended Use:	Monitoring Bore	
Completion Date:	1.10.2020	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	5.8	330	9
5.8	138	150	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	225	10.7	0	5.8	1
6	60.8	3.4	0	40	1

Casing support method See Code 5: 2

Type of casing bottom See Code 5: 1

Centralisers installed	(Yes/No)	Yes	(indicate on sketch)				
Sump installed	(Yes/No)	No	From		m	To	m
Pressure cemented	(Yes/No)	No	From		m	To	m
Casing Protector cemented in place							

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
6	60.8	3.4	40	70	5	1	2			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m^3
Rounded	X	Graded		3	5	35	70.5		
Crushed		Ungraded							
Bentonite/Grout seal	(Yes/No)	Yes				0	35		

Method of placement of Gravel Pack See Code 7: 1

For Departmental use only: G W

Form A Particulars of completed work

BORE DEVELOPMENT							8
Chemical used for breaking down drilling mud (Yes/No)	No	Name:					
Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:	
Duration	hrs	hrs	hrs	hrs	hrs	hrs	

DISINFECTION ON COMPLETION		9
Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION								Recovery		10
Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Water level (m)	Time taken (hrs)	Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED						11
Original depth of work:	138 m		Is work partly backfilled: (Yes/No)	Yes		
Is work abandoned: (Yes/No)	No	Method of abandonment:	Backfilled	Plugged	Capped	
Has any casing been left in the work (Yes/No)	Yes		From 0 m	To 70.5 m		
Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	Sealing / fill type (See Code 11)	From depth (m)	To depth (m)	
4	70.5	138				

							12
Site chosen by:	Hydrogeologist	Geologist	Driller	Diviner	Client X	Other	

						13
Lot No	45	DP No	755093			
Work Location Co ordinates		Easting		Northing		Zone
GPS: (Yes/No)		>>	AMG/AGD	or	MGA/GDA	(See explanation)
		Longitude		Latitude		

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: Luke Barber **Licensee:**

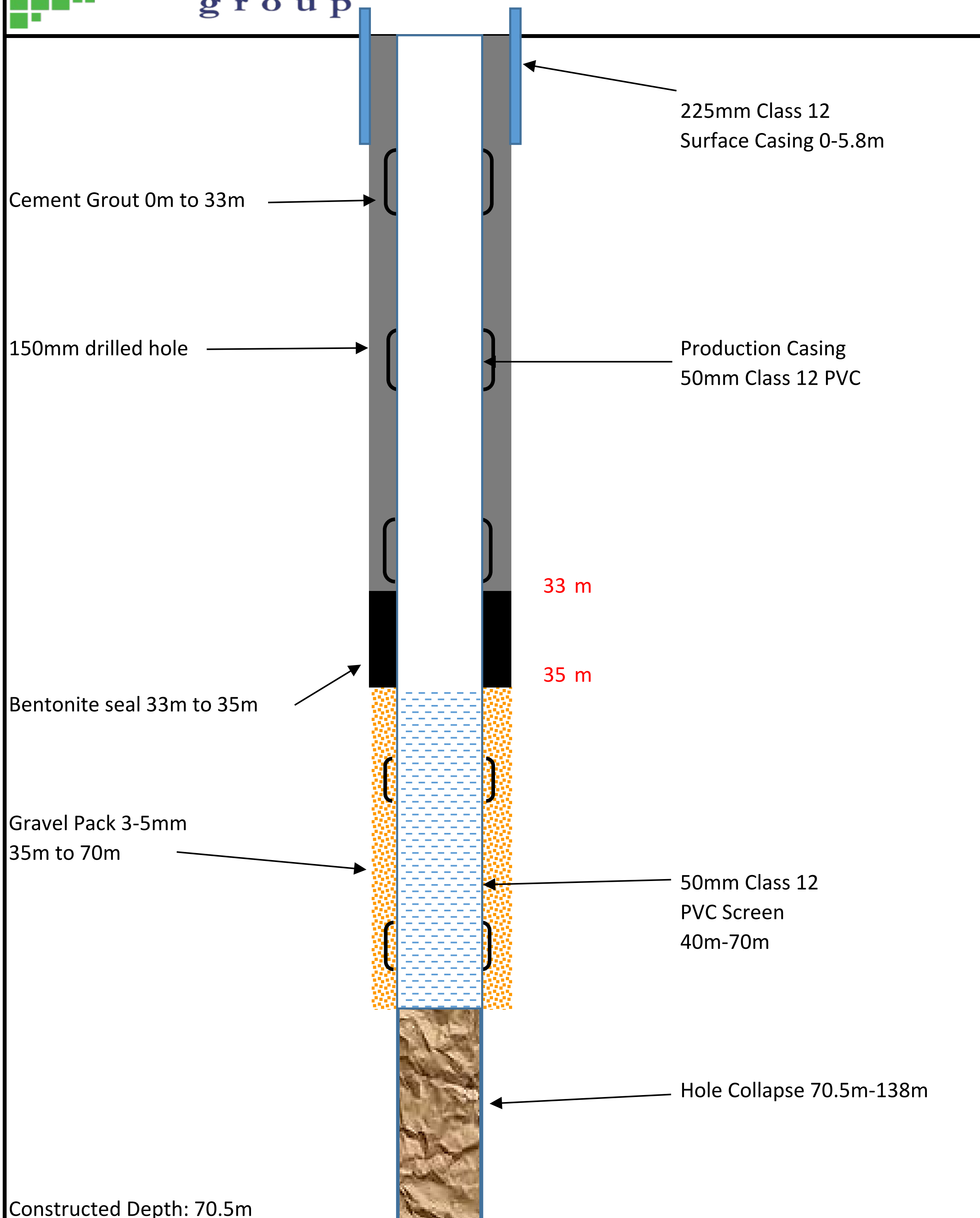
Date: 30.9.20 **Date:**

Please submit forms to groundwater@waternsw.com.au or send to WaterNSW, PO Box 398, Parramatta 2124

Bore Log
Alkane Resources
Monitoring Hole 3 - RWWB003

From(M)	To (M)	Thickness(M)	Description	Comment
0	2	2	Topsoil	
2	6	4	Quartz/Clay	
6	35	29	Clay,Brown/Red	
35	60	25	Sand,Yellow	
60	65	5	Sand,Red	
65	70	5	Gravel,Fine/Clay	
70	78	8	Gravel,Large	

Bore Construction - Schematic Diagram
Alkane Resources
Tomingly - Monitoring Bore RWWB-003/2



Constructed Depth: 70.5m
Total Depth: 138m

Not to scale

Form A Particulars of completed work

Driller's Licence No:	DL2472	1
Class of Licence:	Class 5	
Driller's Name:	Luke Barber	
Assistant Driller:	D. Nelson, A. MacInstosh	
Contractor:	The Impax Group	
New bore	X	
Deepened		
Reconditioned		
Replacement bore		
Enlarged		
Other (specify)		
Final Depth	52 m	

Work Licence No:		2
Name of Licensee:	Alkane Resources	
Intended Use:	Monitoring Bore	
Completion Date:	9.10.20	

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	5.8	330	9
5.8	144	150	9

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	min	Salinity (Conductivity or TDS) Cond (µS/cm)	TDS (mg/L)

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	225	10.7	0	5.8	1
6	60.8	3.4	0	28	

Casing support method — See Code 5: 2

Type of casing bottom — See Code 5: 1

Centralisers installed {Yes/No} Yes (indicate on sketch)

Sump installed {Yes/No} No From m To m

Pressure cemented {Yes/No} No From m To m

Casing Protector cemented in place

WATER ENTRY DESIGN 6

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
6	60.8	3.4	28	52	5	1	2			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	To	Depth (m) From	To	Quantity Litres	m^3
Rounded	X	Graded		3	5	25	52		
Crushed		Ungraded							

Bentonite/Grout seal (Yes/No) Yes — Depth From 0 To 25

Method of placement of Gravel Pack See Code 7: 1

For Departmental use only: G W

Form A Particulars of completed work

BORE DEVELOPMENT							8
Chemical used for breaking down drilling mud (Yes/No) No			Name:				
Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:	
Duration	hrs	hrs	hrs	hrs	hrs	hrs	

DISINFECTION ON COMPLETION		9
Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION **10**

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED **11**

Original depth of work: 144 m Is work partly backfilled: (Yes/No) Yes

Is work abandoned: (Yes/No) No Method of abandonment: Backfilled Plugged Capped

Has any casing been left in the work (Yes/No) Yes From 0 m To 52 m

Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)
4	52	144			

Site chosen by: Hydrogeologist Geologist Driller Diviner Client X Other **12**

13

Lot No 5 DP No 1213503

Work Location Co ordinates Easting Northing Zone

GPS: (Yes/No) >> AMG/AGD or MGA/GDA (See explanation)

Longitude Latitude

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: **Luke Barber** **Licensee:**

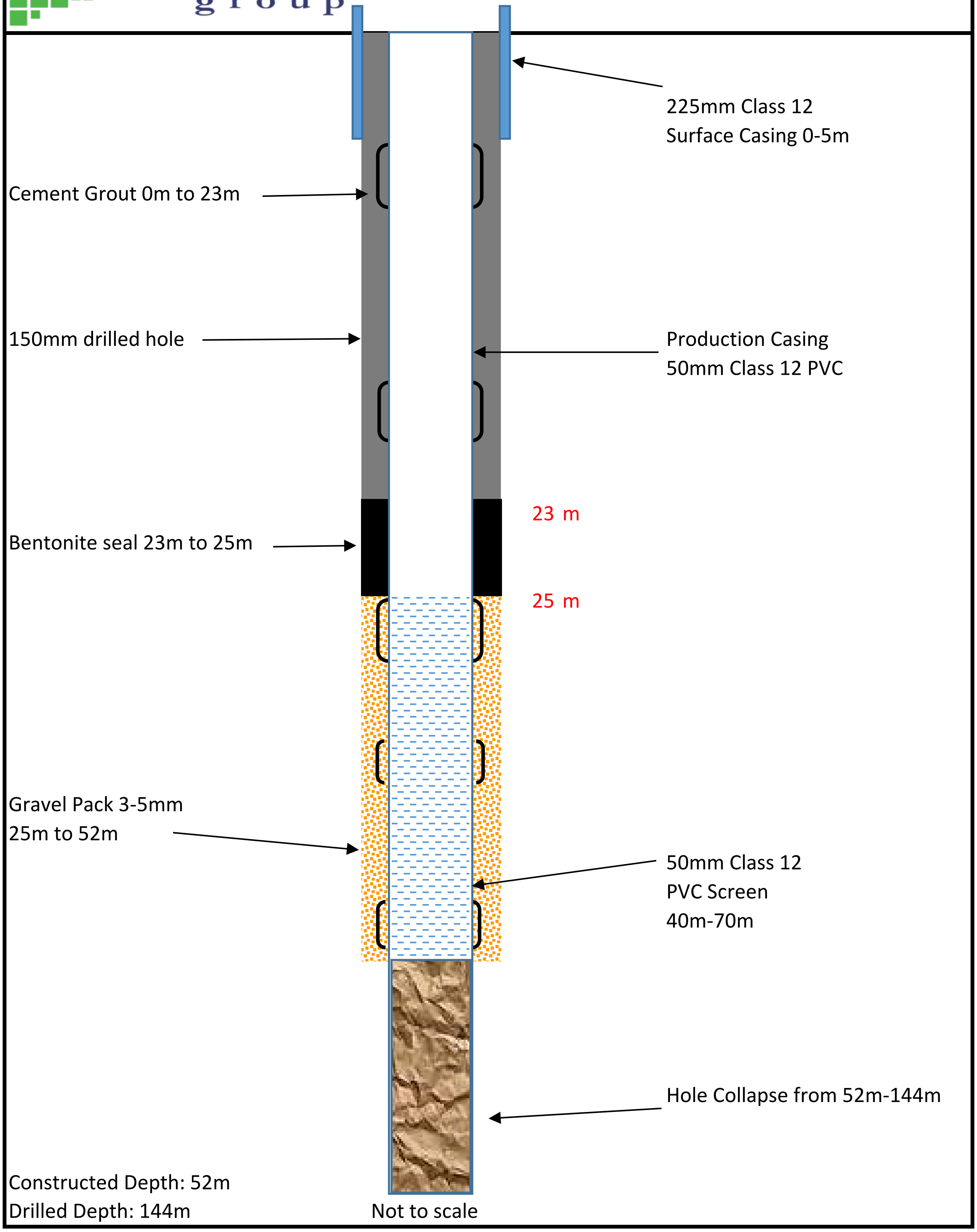
Date: **30.9.20** **Date:**

Please submit forms to groundwater@waternsw.com.au or send to WaterNSW, PO Box 398, Parramatta 2124

Bore Log
Alkane Resources
Monitoring Hole 4 - RWWB004

From(M)	To (M)	Thickness(M)	Description	Comment
0	2	2	Topsoil/Rock Hard	
2	48	46	Clay,Brown/Red	
48	90	42	Sand,Yellow	
90	120	30	Bedrock,Black/Grey/Hard	

Bore Construction - Schematic Diagram
Alkane Resources
Tomingly - Monitoring Bore RWWB-004



Appendix G. GHD (2017) Groundwater management plan

Alkane Resources Pty Ltd

Tomingley Gold Operations
Groundwater management plan

November 2017

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Figure index

Appendices

1. Introduction

1.1 Overview

Tomingley Gold Mine is owned and operated by Tomingley Gold Operations Pty Ltd (TGO), a wholly owned subsidiary of Alkane Resources Ltd. TGO is a medium-sized gold project with approximately 921,000 ounces of gold in the current defined resource, with an aim to produce approximately 50,000 to 60,000 ounces of gold per year. TGO is located at Tomingley in central western NSW, south of Dubbo and north of Peak Hill (refer to Figure 1-1).

Project approval was granted in July 2012 with the mining lease issued in February 2013. Mining commenced in January 2014 with three open cut mines (Wyoming One, Wyoming Three and Caloma One). The project includes a processing plant with associated residue storage facility (RSF). The original approval has been modified three times. A summary of the site history at TGO is included in Table 1-1.

Table 1-1 Site history

Year	Month	Activity
2012	July	Project approval.
2013	February	Mining lease granted.
		Construction of key processing infrastructure complete including RSF, additional surface water management features constructed and in use.
	November	Mining of overburden commenced only necessary surface water management features constructed.
		Modification 1 approved.
2014	May	Water Management Plan Revision 1 prepared.
2015	April	Modification 2 approved.
	July	Additional Groundwater Bores installed around Raw Water and Process Water Dam.
	October	Commencement of Wyoming One Pit.
		Modifications to surface water management system around Caloma One Pit.
	December	Expansion of Sediment Basin 5 capacity.
2016	February	Water Management Plan Revision 2 prepared.
	May	Modification 3 approved.
	July	Commencement of Caloma Two Pit.
2017	March	Expansion of Sediment Basin 4 and alteration of clean water diversion.
	November	Water Management Plan Revision 3 prepared.

TGO is currently operating the mine in accordance with the following approvals:

- Project Approval 09_0155 (as modified).
- Environment Protection Licence (EPL) 20169 (licence version date 20 March 2017).
- Mining Lease (ML) 1684.

This water management plan (WMP) covers all operations at TGO and includes the approved mining operations and associated infrastructure within the site boundary (refer to Figure 1-2).

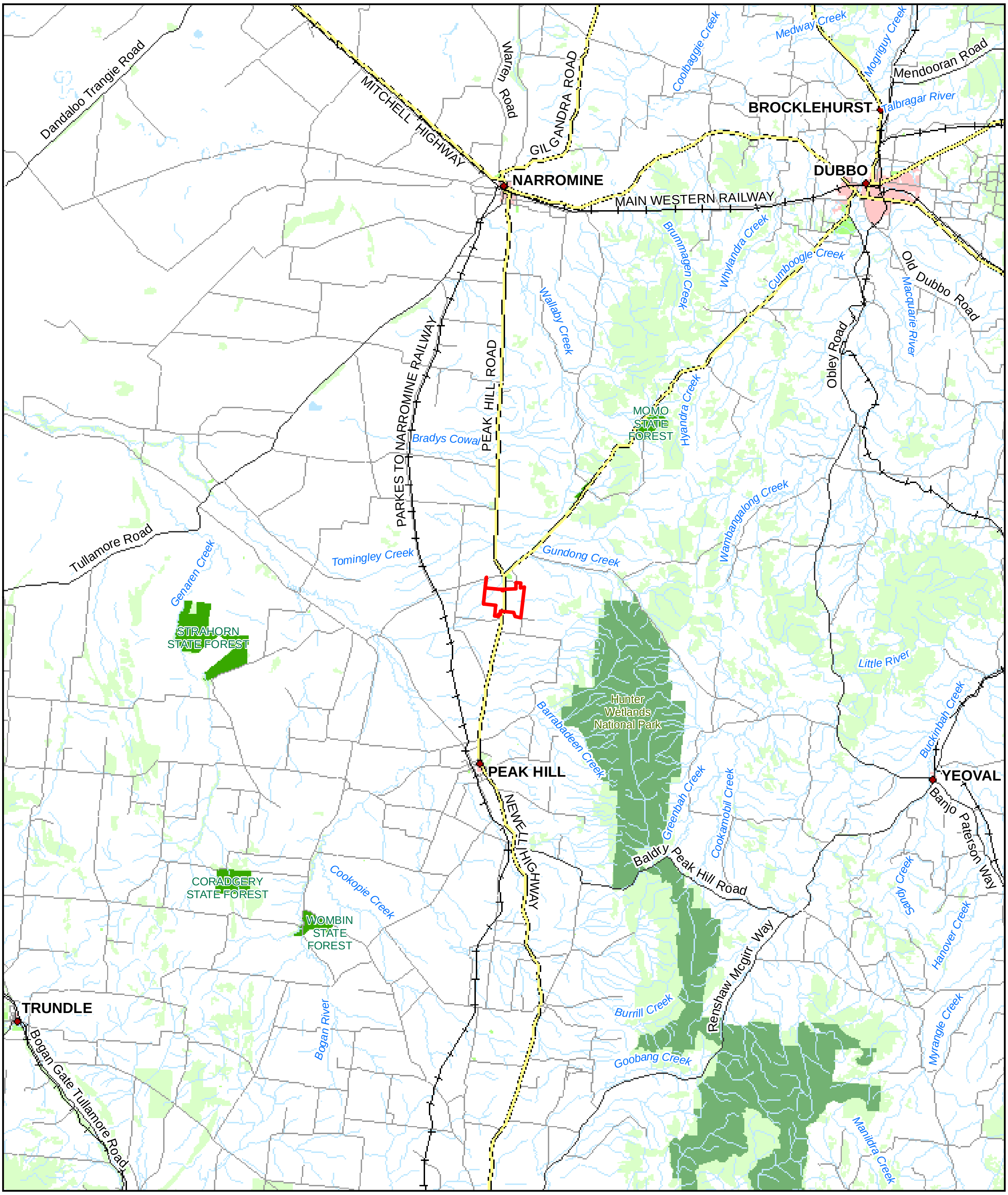
Land use within and surrounding TGO includes:

- Residential and rural residential.

- Agriculture.
- Transportation infrastructure (Newell Highway).
- Commercial (Tomingley Township).
- Recreation and community facilities.
- Former mining operations, north of Tomingley (Myalls United Gold Mine).

1.2 Purpose

This groundwater management plan (GWMP) addresses the specific water components of the conditions of the Project Approval 09_0155 and outstanding statement of commitments as part of the Project.



LEGEND

Site boundary	Minor Road	National Park
Railway	Watercourse	State Forest
Principal Road	Built Up Area	Forest Or Shrub
Secondary Road	Recreation Area	

Paper Size A4

0 1.5 3 6 9 12 15

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Tomingley Gold Operations
Groundwater Management Plan

Job Number	21-26505
Revision	0
Date	13 Nov 2017

Locality plan

Figure 1-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

\\ghdnet\ghd\AU\Newcastle\Projects\21\26505\GIS\Maps\Deliverables\GWMP\2126505_GWMP005_Locality_0.mxd

Data source: Geoscience Australia: 250k Topographic Series 3, 2006; LPI: DTDB, 2012. Created by: gmcdiarmid

Paper Size A4

0 90 180 360 540 720 900

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site boundary
- Tomingley Gold Operations Pty Ltd
- Alkane Resoursces Ltd
- Water storages
- Existing Open Cut
- Approved Open Cut
- Watercourse

GHD

ALKANE RESOURCES LTD

Tomingley Gold Operations
Groundwater Management Plan

Job Number	21-26505
Revision	0
Date	15 Nov 2017

Site layout and mineral titles

Figure 1-2

G:\21\26505\GIS\Maps\Deliverables\GWMP\2126505_GWMP006_SiteLayout_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: NSW DT&I R&E: Mine titles; Tomingley Gold Operations: Imagery, 2015. LPI: DTDB, 2012; LPI, imagery, 2017. Created by: gmcdiarmid

2. Data

2.1 Climate

2.1.1 Rainfall

Daily rainfall data was obtained as SILO Patched Point Data from the Queensland Climate Change Centre of Excellence. SILO Patched Point Data is based on historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations. For this assessment, SILO data was obtained for the Peak Hill Post Office Station (station number 50031), which is located approximately 14 km south of the site. This station was chosen based on the length and quality of the data record and proximity to the mine site.

The period of rainfall data used for this assessment extended from January 1900 to July 2015 and is summarised as annual totals in Figure 2-1. The statistics for this rainfall data set are:

- Minimum annual rainfall – 233 mm in 1944.
- Average annual rainfall – 561 mm.
- Median annual rainfall – 545 mm.
- Maximum annual rainfall – 1217 mm in 1950.

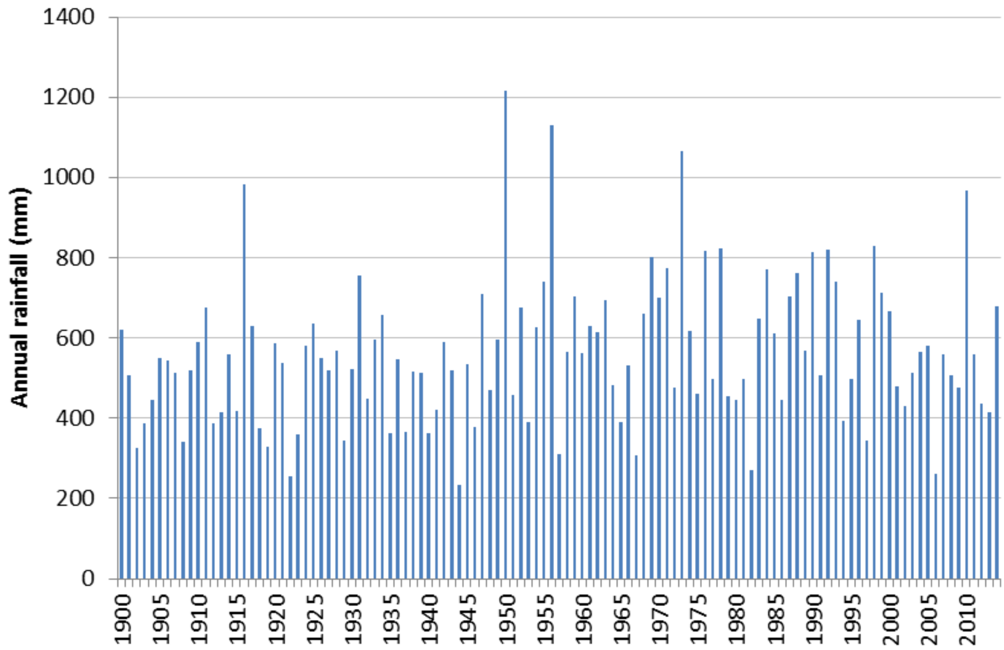


Figure 2-1 Annual rainfall recorded at Peak Hill Post Office station

The SILO dataset was used to generate a Cumulative Rainfall Departure (CRD) curve. CRD is the monthly accumulation of the difference between the observed monthly rainfall and the long-term average monthly rainfall.

The CRD over the period 1900 to 2015 is shown in Figure 2-2. Any increase in the CRD reflects above average rainfall while a decrease in CRD reflects below average rainfall. The CRD curve only deviates from zero due to atypical (above and below average) rainfall.

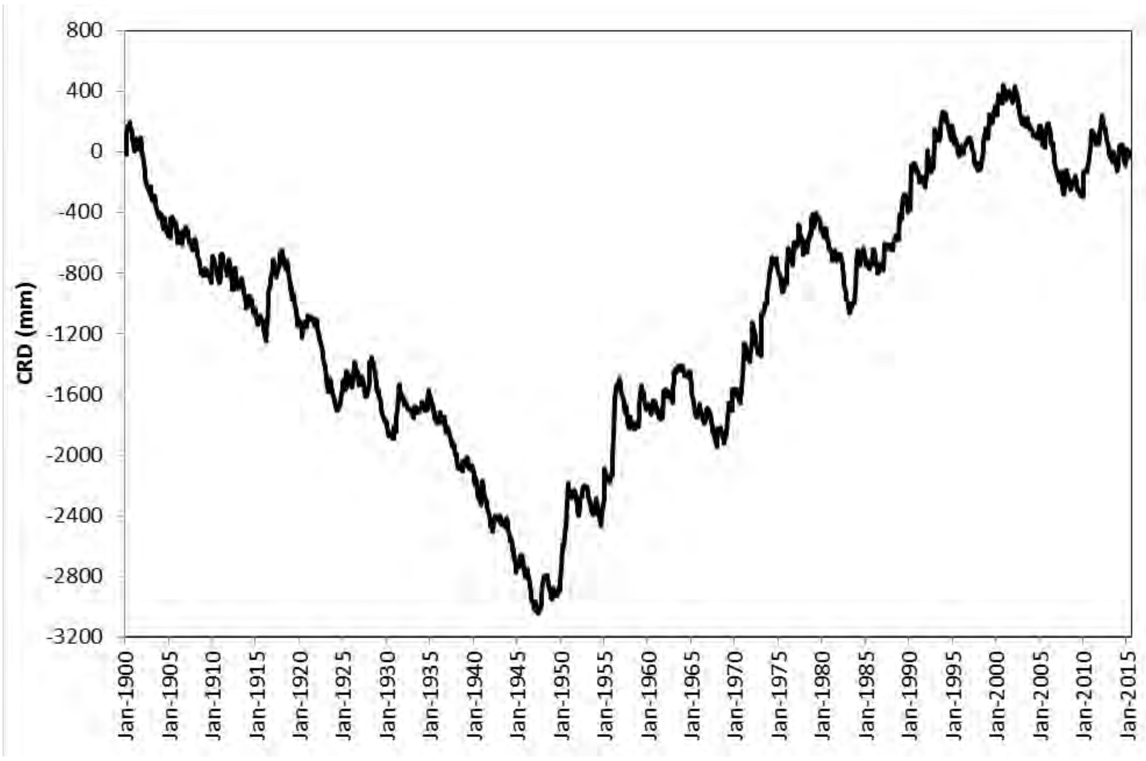


Figure 2-2 CRD curve for Peak Hill Post Office station

As shown in Figure 2-2, the CRD curve indicates that in recent years average rainfall has had periods both below average (2005 to 2010) and above average (2010 to 2014).

2.2 Geology and soils

Tomingley is located on the Junee-Narromine volcanic belt, part of the Palaeozoic Lachlan Orogen composition of sedimentary, volcanic and intrusive rock formations of early Cambrian to early Devonian age. The Ordo-Silurian sequences that comprise the Wyoming/Caloma deposits, are tight to isoclinal folding, strong axial planar cleavage with green schist metamorphic assemblages.

The area is dominated by alluvial sequences of clays, sands and gravel of Quaternary to Tertiary age, up to 50 m thick. The alluvial material dissipates to the south and north with basement outcropping. There is a well-developed weathering profile which can extend down to 70 m below ground level (The Impax Group, 2011).

Soil erodibility values (K factors) for the site are moderate to high at 0.04 to 0.05 (SEEC, 2011). Typically, the worst soils are located to the east of the Newell Highway in the sodic Gilgaied Dermosol soils (SEEC; 2011).

As part of the site Mining Operations Plan (MOP), topsoils are approximately 30 cm below natural surface with the most ideal for stripping and stockpiling being the red Dermasol. Subsoils were defined from 30 cm to 70 cm below natural surface with sodic tendencies. The typical emersion value for the subsoil material has been reported to be Class 1.

2.3 Hydrogeology

There are three distinct groundwater systems within the vicinity of TGO's mining leases, as identified by The Impax Group (2011):

- Shallow alluvium – discrete, shallow alluvium (less than 10-20 m deep) dissects the plains surrounding the mine site along creek flow paths. These aquifers are believed to be recharged from rainfall infiltration. Groundwater within these systems is of relatively good quality; however, yields are relatively low and dependent on rainfall.

- Deep alluvium – up to 100 m deep and located approximately 10 km to the northwest and west of TGO. Groundwater yields are believed to be low and of poor quality. These systems may have some interaction with underlying bedrock however are believed to be primarily recharged from rainfall.
- Fractured rock – the area surrounding Tomingley is typically underlain by shale, siltstone and chert with several fractured rock aquifers in the vicinity of the mine. Groundwater yields range from 0-3 L/s, generally less than 1.5 L/s, and water quality is poor with high salinity.

Perched groundwater occurs within the shallow alluvium; however, it is generally not continuous across the mine site. Shallow groundwater appears to be more permanent along Gundong Creek to the northeast of the Wyoming 3 pit.

The hydraulic conductivity of the shallow alluvial clay is generally low to very low. Falling head tests on clayey strata between 1.55 and 42.5 m bgl at the RSF area (to the southwest of the Wyoming 3 pit) indicate hydraulic conductivities of 0.0002 to 0.002 m/d or 2.3×10^{-8} to 10^{-9} m/s (DE Cooper & Associates, 2011). In addition, overburden clay from the Wyoming 1 pit was tested for its potential use in the RSF embankment and found to have a compacted hydraulic conductivity of less than 10^{-10} m/s (8.6×10^{-6} m/day) (DE Cooper & Associates, 2011).

A deeper confined groundwater system occurs within the fractured sandstone and siltstone. The water bearing zone most likely occurs at a depth of greater than 100 m bgl in the vicinity of the Wyoming 3 pit, as indicated by the lack of groundwater inflow into the pit. During exploration drilling at the Wyoming 3 pit site, there was no record of water flows into the drill hole at less than 50 m bgl. At 50 to 100 m depth there was some water recorded during rod changes but no flow during drilling. At greater than 100 m depth, some weak flow during drilling was recorded. Therefore, the Wyoming 3 pit is predominantly within the unsaturated zone above the confined water bearing zone. Based on the information available there is no mention of potential hydraulic connectivity from the Wyoming 3 pit to the proposed underground mine 500 m to the south of the pit.

Based on groundwater monitoring data, the hydraulic gradient of the deep groundwater system is approximately 0.01 to the north. Adopting a hydraulic conductivity of 0.07 m/day, the deep groundwater moves to the north at a rate of approximately 0.0007 m/day or 0.3 m/year.

2.3.1 Groundwater bore search

A search of the NSW Groundwater Bore Database (DPIW, 2015) was undertaken to identify registered bores within a 10 km radius of TGO and within a 5 km radius of the production borefield. The search identified 22 bores within a 10 km radius of TGO. Licences for a number of these 22 bores were reported as cancelled, lapsed or abandoned. Of the 22 bores the majority (11) were licensed as a test bore or monitoring bore. Of the remaining bores; four were intended for public/municipal water supply, three were registered as stock and domestic, and one bore was registered as groundwater exploration, mining, irrigation and town water supply.

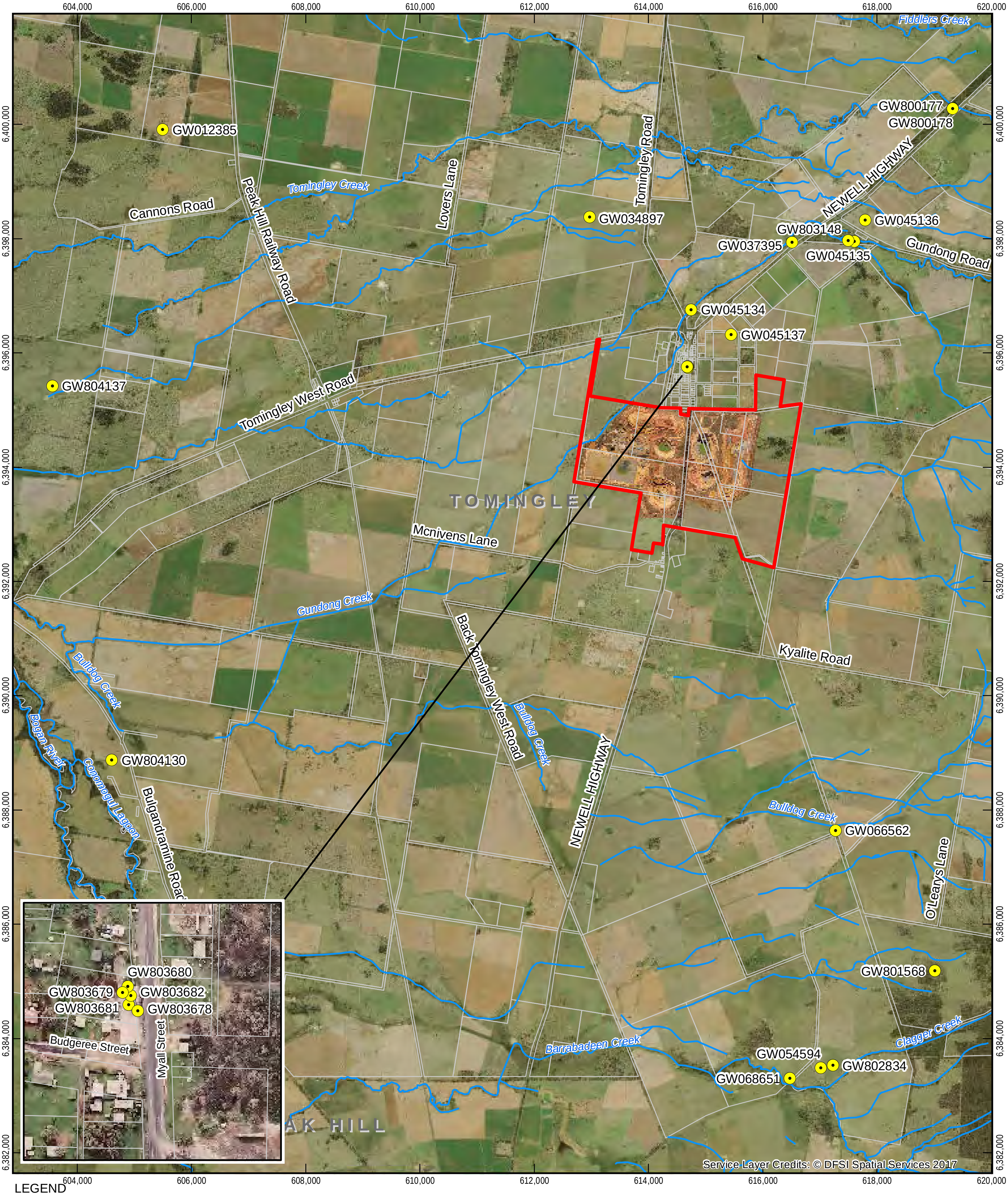
The search of the NSW Groundwater Bore Database identified 67 bores within a 5 km radius of the production borefield. A number of the identified bores were reported as cancelled or lapsed. Of the 67 bores identified the majority (48) were licensed for stock, domestic or irrigation use. Of the remaining bores; 10 were licensed as monitoring bores, three as groundwater exploration, two as industrial, two as test bores and two bores had an unknown licensed purpose.

Licensed groundwater bores in the vicinity of TGO are shown in Figure 2-3 and licensed bores in the vicinity of the production bore are shown in Figure 2-4. Details regarding licensed groundwater bores are summarised in Appendix A.

2.3.1 Groundwater dependant ecosystems

The closest high priority GDEs listed in the NSW Murray Darling Fractured Rock Groundwater Sources WSP are Dilladerry Spring located approximately 18.5 km east of TGO and Hyandra Hill Spring located approximately 28 km north east of TGO. Various tributaries of the Bogan River that lie to the north of the site are potential GDEs. The piper plot in Appendix B and the discussion of water quality in Section 3.2.5 indicates that the groundwater of the deeper fractured rock aquifer is saline and of sodium chloride type while the groundwater of the Gundong Creek alluvial aquifer is fresh to brackish and of sodium-chloride/bicarbonate type. The differing water chemistry indicates a low degree of connectivity between the alluvial and fractured rock aquifers. Therefore, it is likely that groundwater drawdown in the fractured rock aquifer will have negligible impact on the alluvial aquifer of Gundong Creek or of the various watercourses near TGO.

Near the extraction bore potential GDEs include isolated areas of eucalyptus forest and the Macquarie River. It is considered that as with areas of vegetation near TGO, these areas of eucalyptus forest are unlikely to be solely dependent on groundwater.



LEGEND

- Site boundary
- Cadastre
- Groundwater bore
- Watercourse

Paper Size A4

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

ALKANE RESOURCES LTD

Tomingley Gold Operations
Groundwater Management Plan

Job Number	21-26505
Revision	0
Date	13 Nov 2017

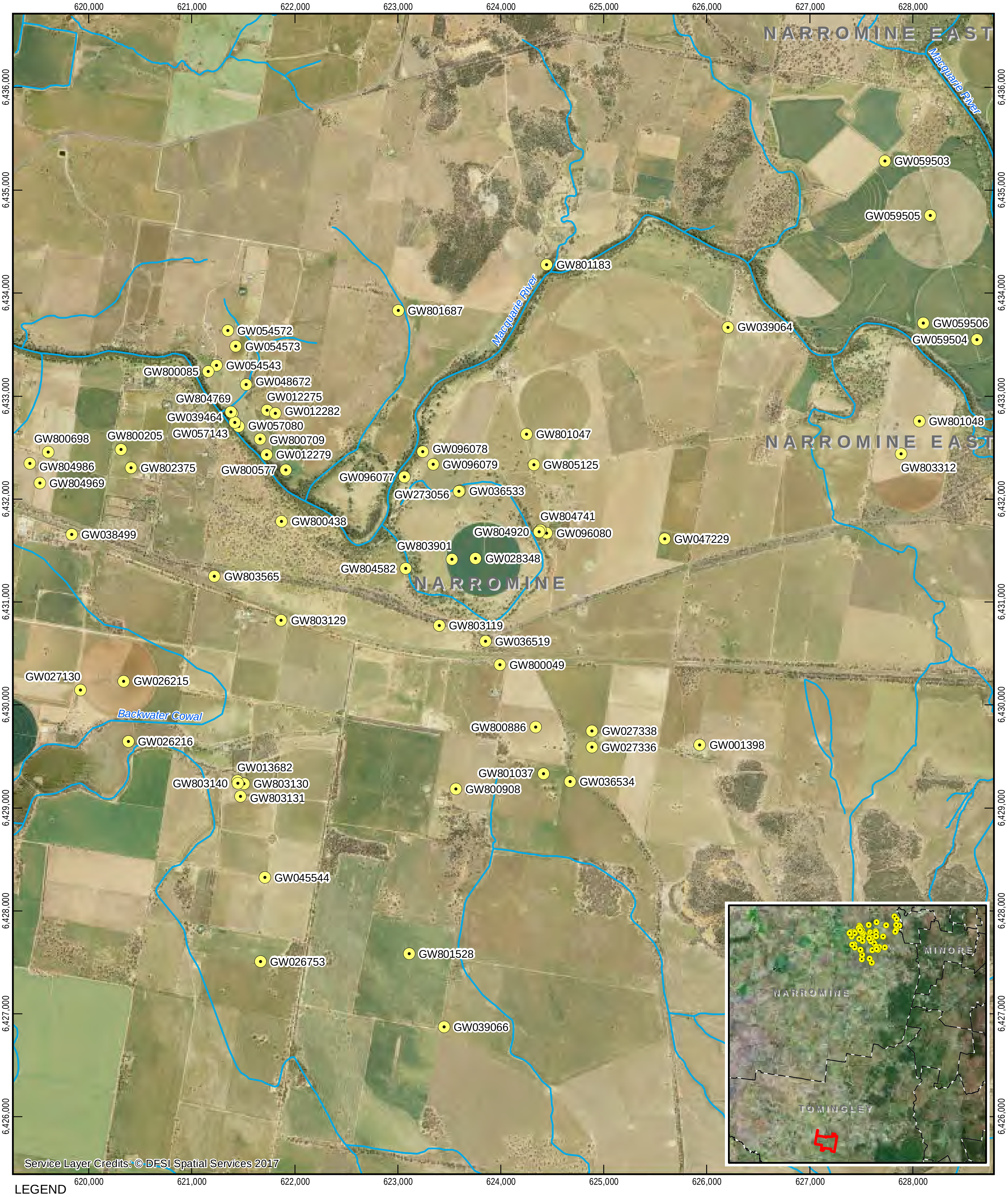
NSW groundwater
bore search - TGO

Figure 2-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

\\ghdnet\ghd\AU\Newcastle\Projects\21\26505\GIS\Maps\Deliverables\GWMP\2126505_GWMP001_BoreSearchTGO_0.mxd

Data source: LPI: DTDB\DCDB, 2012. LPI: Imagery, 2015: DPI: Groundwater Bores, 2015. Created by: gmcdiarmid



LEGEND

- Site boundary
- Groundwater bore
- Roads
- Watercourse

Paper Size A4

0 200 400 800 1,200 1,600 2,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

ALKANE RESOURCES LTD

Tomingley Gold Operations
Groundwater Management Plan

Job Number	21-26505
Revision	0
Date	13 Nov 2017

NSW groundwater bore search - production borefield

Figure 2-4

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

\\ghdnet\ghd\AU\Newcastle\Projects\21\26505\GIS\Maps\Deliverables\GWMP\2126505_GWMP002_BoreSearchProduction_0.mxd

Data source: LPI: DTDB\DCDB, 2012. LPI: Imagery, 2015; DPI: Groundwater Bores, 2015. Created by: gmcdiarmid

3. Groundwater management

3.1 Groundwater monitoring network

The existing groundwater monitoring network has been progressively established at TGO since 2006. TGO undertakes quarterly groundwater monitoring of deep bores (WYMB01, WYMB02, WYMB03, WYMB04 and WYMB06) and shallow alluvial bore GDCMP01 in accordance with EPL 20169. In addition, TGO undertakes monthly monitoring of shallow bores in the vicinity of the RSF (RSFMP01, RSFMP02, RSFMP03, RSFMP04, RSFMP05, RSFMP06, RSFMP07, RSFMP08, RSFMP09, RSFMP10 and RSFMP11), PWD (PWMP01 and PWMP02) and WCD – South (WCD-P1, WCD-P2, WCD-P3, WCD-P4, WCD-P5, WCD-P6, WCD-P7, WCD-P8). Six additional shallow monitoring bores were installed to monitor potential impact from the PWD and associated process water pipelines (PWMP03, PWMP04, PWMP05, PWMP06, PWMP07 and PWMP08).

Details of groundwater bores are summarised in Table 3-1. Monitoring bore locations are shown in Figure 3-1.

Table 3-1 Groundwater monitoring bore details

Bore	Depth (m)	Top of Casing (TOC) Elevation (m AHD)	Monitoring Period	Lithology
WYMB001	90	270.424[(a)]	April 2007 – present	Unknown
WYMB002	114	268.515[(a)]	April 2007 – present	Unknown
WYMB003	84	275.472[(a)]	April 2007 – present	Unknown
WYMB004	78	272.07[(a)]	April 2007 – present	Unknown
WYMB006	90	268.43[(a)]	April 2007 – present	Unknown
WYMB10	150	272.62[(b)]	November 2012 – present	Unknown
GDCMB01	3.5	273.44[(b)]	November 2012 – present	Gundong Creek Alluvium
RSFMP01	10.95	268.9[(c)]	March 2014 – present (dry since installation)	Shallow strata
RSFMP02	10.58	268.3[(c)]	March 2014 – present (dry since installation)	Shallow strata
RSFMP03	11.88	267.25[(c)]	March 2014 – present	Shallow strata
RSFMP04	5.28	266.1[(c)]	March 2014 – present	Shallow strata
RSFMP05	13	265.8[(c)]	March 2014 – present	Shallow strata
RSFMP06	4.08	264.85[(c)]	March 2014 – present	Shallow strata
RSFMP07	5.5	265.15[(c)]	March 2014 – present	Shallow strata
RSFMP08	4.43	265.9[(c)]	March 2014 – present (dry since installation)	Shallow strata
RSFMP09	5	266.65[(c)]	March 2014 – present (dry since May 2014)	Shallow strata
RSFMP10	5.5	267.75[(c)]	March 2014 – present (dry since August 2014)	Shallow strata
RSFMP11	5.74	269[(c)]	March 2014 – present (dry since installation)	Shallow strata
PWMP01	11.49	267.85[(c)]	January 2015 – present	Shallow strata
PWMP02	12	267.95[(c)]	January 2015 – present	Shallow Strata
PWMP03	12	To be surveyed	July 2015 – present	Shallow Strata
PWMP04	11.56	To be surveyed	July 2015 – present	Shallow Strata
PWMP05	11.59	To be surveyed	July 2015 – present	Shallow Strata
PWMP06	12.91	To be surveyed	July 2015 – present	Shallow Strata

Bore	Depth (m)	Top of Casing (TOC) Elevation (m AHD)	Monitoring Period	Lithology
PWMP07	11.82	To be surveyed	July 2015 – present	Shallow Strata
PWMP08	9.56	To be surveyed	July 2015 – present	Shallow Strata
WCD-P1	TBC	TBC	Following upgrade of WCD - South	Shallow Strata
WCD-P2	TBC	TBC		Shallow Strata
WCD-P3	TBC	TBC		Shallow Strata
WCD-P4	TBC	TBC		Shallow Strata
WCD-P5	TBC	TBC		Shallow Strata
WCD-P6	TBC	TBC		Shallow Strata
WCD-P7	TBC	TBC		Shallow Strata

(a) Casing surveyed.
(b) Casing elevation estimated using natural surface survey and measuring stand up of casing.
(c) Level estimated using natural surface survey.

3.1.1 Background groundwater levels

Fractured rock monitoring bores

Hydrographs of all fractured rock groundwater monitoring bores have been plotted and compared with the CRD and are shown in Figure 2-2.

The groundwater hydrographs presented in Appendix C show that pre-mining groundwater levels at WYMB001 were generally rising over the period of monitoring while levels at WYMB002 and WYMB003 were generally constant. The observed variation of pre-mining groundwater levels at WYMB002 and WYMB003 is likely due to natural variation in groundwater levels.

The groundwater hydrographs in Appendix C for WYMB004 and WYMB006 indicate that groundwater levels at these monitoring locations are generally constant with the exception of a spike in groundwater levels in early 2008. Coffey (2008) found this observed rise in groundwater levels at WYMB004 and WYMB006 followed a significant month of above average rainfall of approximately 150 mm in December 2007. WYMB004 and WYMB006 are located near McPhail's historical workings and Coffey (2008) concluded that the response in groundwater levels following rainfall might be related to filling of McPhail's historical workings.

Groundwater hydrographs for WYMB004 and WYMB006 in Appendix C indicate that the rise in groundwater levels in early 2008 does follow a period of heavy rainfall. However, there is no similarly strong response in groundwater levels at WYMB004 following wet periods in early 2014 and December 2014. Similarly, the response in groundwater levels at WYMB006 to wet periods in early 2014 and December 2014 is not as strong as the response to rainfall observed in early 2008.

Baseline and operational groundwater levels are summarised in Table 3-2.

Table 3-2 Groundwater level summary

Location	Baseline (pre-January 2014) groundwater level (m AHD)		Operational groundwater level (m AHD)	
	Minimum	Maximum	Minimum	Maximum
WYMB001	209.97	233.82	230.79	232.25
WYMB002	208.91	209.37	208.17	209.49
WYMB003	220.19	221.74	221.20	222.29

Location	Baseline (pre-January 2014) groundwater level (m AHD)		Operational groundwater level (m AHD)	
	Minimum	Maximum	Minimum	Maximum
WYMB004	208.62	242.32	208.23	209.48
WYMB006	231.13	240.31	231.06	236.42
WYMB10	200.30	200.42	196.85	200.47

During the operational phase at TGO groundwater levels have typically remained within pre-mining minimum and maximum groundwater levels. The hydrographs for WYMB002, WYMB003, WYMB006 and WYMB010 shown in Appendix C indicate some variation in groundwater levels for the December 2014 monitoring round; however groundwater levels returned to typical levels by the following March 2015 monitoring round.

Shallow bores

There is limited background data for shallow groundwater monitoring bores. As outlined in Table 3-1 monitoring commenced at GDCMB01 in November 2011. Monitoring of bores associated with the RSF and the processing area did not begin until after commencement of operations at TGO.

Of the RSF monitoring locations, RSFMP01, RSFMP02, RSFMP08 and RSFMP11 have been dry since installation; RSFMP09 has been dry since May 2014 and RSFMP10 has been dry since August 2014. Of the PWD monitoring locations PWMP03 to PWMP08 were only recently installed and therefore typically water level has been gauged only once at these locations.

At alluvial monitoring locations where sufficient groundwater level data exists, groundwater level have been plotted and compared to the CRD curve. These hydrographs are shown in Appendix C. The recorded groundwater elevations (m AHD) for each alluvial monitoring bore are shown in black. It should be noted that groundwater levels at TGO have been manually recorded and that the limit of reading of the measuring tape is considered to be 10 mm. When considering the accuracy achievable by the field technician, the limit of accuracy of an individual measurement may be up to ± 50 mm. Therefore, groundwater monitoring is unlikely to detect changes in groundwater level of less than 10 mm at a particular bore from one monthly monitoring round to the next. Further, groundwater bore top of casing (TOC) elevations have not been surveyed for shallow groundwater monitoring locations and groundwater elevations have been estimated using natural surface survey and measuring the height of the top of casing above the natural surface.

HARTT (Hydrograph Analysis: Rainfall and Time Trends) analysis has been undertaken for each dataset to establish the relationship between groundwater levels and rainfall to determine underlying trends in groundwater level that are independent of rainfall. The best fit HARTT regression line is shown in red in each hydrograph. The HARTT statistical output for each alluvial hydrograph is shown in Table 3-3.

Table 3-3 HARTT analysis results for monitoring bores

Bore	R^2	Rainfall Coeff. *a* (m/mm)	P rain	Time Coeff. *b* (m/mth)	P Time	*c* (m)
RSFMP03	0.661	0.008	0.454	0.327	0.000	257.77
RSFMP04	0.406	0	0.221	0.008	0.068	260.72
RSFMP05	0.759	0.007	0.010	0.100	0.000	257.60
RSFMP06	0.265	0.005	0.059	0.026	0.095	261.60
RSFMP07	0.873	0	0.666	0.071	0.002	259.75
RSFMP10	0.148	0.007	0.731	-0.049	0.564	263.53

Bore	R^2	Rainfall Coeff. *a* (m/mm)	P rain	Time Coeff. *b* (m/mth)	P Time	*c* (m)
PWMP01	0.957	0.004	0.355	0.224	0.004	257.09
PWMP02	0.315	0.056	0.329	0.073	0.888	263.97
GDCMB01	0.566	0	0.859	-0.022	0.012	271.747

The R^2 value of the HARTT regression line gives a measure of the quality of fit of the non-linear regression line to the observed hydrograph. This value was greater than 50% for five of the nine alluvial hydrographs analysed, indicating that over half of the hydrographs can be reasonably modelled by the HARTT variables (CRD and linear time trends) alone. A lower R^2 value indicates that the bore is situated at a location where the hydrograph cannot be adequately modelled by the HARTT variables and that other factors are affecting groundwater levels.

The p-value for the rainfall variable *a* is less than 0.05 for RSFMP05 only indicating that there is a strong relationship between groundwater level and CRD at this location. The p-value for the time variable is less than 0.05 for RSFMP03, RSFMP05, RSFMP07, PWMP01 and GDCMB01 indicating statistically significant linear time trends (independent of rainfall) in groundwater levels at these locations. Where the p-value is greater than 0.05, time trends are statistically insignificant and the time coefficient *b* cannot be relied upon to describe historical trends or predict future groundwater levels.

All the monitoring locations that identified a statistically significant rising time trend in groundwater level (RSFMP03, RSFMP05, RSFMP07 and PWMP01) are located near the western end of the RSF. The rising trend in groundwater levels at these monitoring locations may be due to recovery in shallow groundwater levels following the completion of construction of the surface facilities area and/or seepage to groundwater from a process water pipeline in the vicinity of PWMP02 (GHD, 2015). Monitoring bores PWMP03, PWMP04, PWMP05, PWMP06, PWMP07 and PWMP08 were installed to monitor this rising trend in groundwater.

WCD – South was enlarge and upgraded to a process water storage in later 2017. Monitoring of bores around the storage will commence when the upgrade is completed.

Production borefield

There are a number of DPIW monitoring bores located in the vicinity of the production borefield. The DPIW monitoring bores are located in the Macquarie River Alluvium; the same aquifer that the production borefield is extracting from. Monitoring data from the DPIW bores GW096079-1 and GW096080-2 is publically available and has been analysed using HARTT Analysis. Hydrographs for these DPIW monitoring bores are shown in Appendix C and the HARTT statistical output for these bores is shown in Table 3-4.

Table 3-4 HARTT analysis results for DPIW monitoring bores

Bore	R^2	Rainfall Coeff. *a* (m/mm)	P rain	Time Coeff. *b* (m/mth)	P Time
GW096079-1	0.514	0.008	0.000	-0.022	0.000
GW096080-2	0.606	0.006	0.074	-0.116	0.000

The R^2 value of the HARTT regression line gives a measure of the quality of fit of the non-linear regression line to the observed hydrograph. This value was greater than 50% for both the alluvial hydrographs analysed, indicating that both hydrographs can be reasonably modelled by the HARTT variables (CRD and linear time trends) alone.

The p-value for the rainfall variable *a* is less than 0.05 for GW096079-1 only indicating that there is a strong relationship between groundwater level and CRD at this location. At GW096079-1 groundwater levels respond by approximately 8 mm per mm of CRD (or atypical rainfall). Where the p-value is greater than 0.05, CRD trends are statistically insignificant and the rainfall coefficient *a* cannot be relied upon to describe historical trends or predict future groundwater levels.

The p-value for the time variable is less than 0.05 for both hydrographs analysed indicating statistically significant linear time trends (independent of rainfall) in groundwater levels at these locations. Both monitoring locations indicate a statistically significant falling time trend in groundwater levels (independent of rainfall). The falling time trend in groundwater level may be attributable to groundwater extraction from the alluvial aquifer.

3.2 Monitoring

The purpose of this Groundwater Monitoring Program is to provide a framework for monitoring and management of groundwater quality and levels. The aim of groundwater monitoring is to ensure groundwater drawdown is within the predictions of the groundwater modelling undertaken as part of the EIS for the Project (Impax Group, 2008), monitoring for any leachate from the RSF and to detect any potential impact on surrounding groundwater users and to ensure that requirements of the NSW Aquifer Interference Policy are met. The Groundwater Monitoring Program outlines the locations, parameter, frequency and methodology of monitoring.

3.2.1 Monitoring methodology

As specified by DIPNR (2003) (to be adopted as a minimum standard), groundwater monitoring should be undertaken in general accordance with 'A Practical Guide to Groundwater Sampling' (Jiwan and Gates, 1992). It is recommended that low flow sampling techniques be used for purging and sampling (rather than bailers or submersible pumps) to minimise aquifer disturbance and reduce the volume of groundwater extracted during sampling.

In general, the groundwater monitoring methodology should include the following:

- Gauging of groundwater levels prior to purging.
- Purging of monitoring bores using a low flow peristaltic pump. To limit the disturbance of possible sediments in the base of each bore, the sample tubing at each bore should be lowered to approximately the middle of the screened interval for purging and sample collection.
- Measurement of groundwater field parameters (pH, EC) using a calibrated water quality meter and a flow cell during purging. The pH and EC readings should be recorded in the field once they have stabilised.
- If groundwater samples are to be collected, they are to be transferred into suitably preserved laboratory supplied sample containers once field parameters have stabilised. Samples to be analysed for dissolved metals are to be filtered in the field using 0.45 μm filters. All sample containers are to be clearly labelled with sample number, sample location, sample depth and sample date. The sample containers are to be transferred to a chilled esky for sample preservation prior to and during shipment to the testing laboratory. A Chain-of-Custody form should be forwarded with the samples to the testing laboratory.
- Decontamination of all non-dedicated sampling equipment between monitoring locations.

Where contractor specific sampling protocols exist, the adoption of the more stringent monitoring methodologies should be considered.

3.2.2 Groundwater monitoring network

The TGO groundwater monitoring network is shown in Figure 3-1. Details regarding monitoring bores are provided in Table 3-1.

3.2.3 Groundwater transfer metering

To monitor and assess groundwater make at TGO, dewatering volumes from all open cut pits require to be metered. Volumetric metering must continue as long as dewatering continues.

Once dewatering from each open cut pit has ceased monitoring of water level in each pit is required. Monitoring of water levels should continue until water levels stabilise and equilibrium of groundwater levels has occurred.

Water quality samples from each of the open cut pits and underground workings should be collected on a monthly basis when water is present.

3.2.4 Monitoring parameters and frequency

The monitoring of groundwater levels and quality and dewatering volumes is to continue as part of the Project. The frequency and parameters to be monitored have been provided in Table 3-5.

It is also recommended that groundwater level data at DPIW monitoring bores GW096079-1 and GW096080-2 is reviewed on an annual basis. This data is publically available from DPIW website; http://www.water.nsw.gov.au/realtime-data/groundwater.

Table 3-5 Groundwater monitoring parameters and frequency

Location	Frequency	Parameter
WYMB01, WYMB02, WYMB03, WYMB04, WYMB06, WYMB10, GDCMB01	Quarterly	Water Level
WYMB01, WYMB02, WYMB03, WYMB04, WYMB06, WYMB10, GDCMB01	Quarterly	Alkalinity (as calcium carbonate), ammonia, arsenic, bicarbonate, cadmium, calcium (dissolved), carbonate, chloride, chromium, copper, cyanide (free), cyanide (total), cyanide (weak acid dissociable), EC, hardness (as calcium carbonate), lead, magnesium (dissolved), mercury, nickel, nitrate, pH, phosphate, potassium (dissolved), sodium (dissolved), sulphate, TDS, iron (total), TSS, zinc.
RSFMP01, RSFMP02, RSFMP03, RSFMP04, RSFMP05, RSFMP06, RSFMP07, RSFMP08, RSFMP09, RSFMP10, RSFMP11, PWMP01, PWMP02, PWMP03, PWMP04, PWMP05, PWMP06	Monthly	Water Level
RSFMP01, RSFMP02 RSFMP03, RSFMP04 RSFMP05, RSFMP06 RSFMP07, RSFMP08 RSFMP09, RSFMP10 RSFMP11, PWMP01 PWMP02, PWMP03 PWMP04, PWMP05 PWMP06	Monthly	pH, EC, TDS, TSS, alkalinity, ammonia, nitrate, sulphate, chloride, calcium (dissolved), magnesium (dissolved), sodium (dissolved), potassium (dissolved), aluminium, arsenic, cadmium, chromium, copper, nickel, lead, selenium, zinc, iron, mercury, cyanide (free), cyanide (total), cyanide (weak acid dissociable).

Location	Frequency	Parameter
WCD-P1, WCD-P2, WCD-P3, WCD-P4, WCD-P5, WCD-P6, WCD-P7, WCD-P8	Monthly	Water level
Open cut pits and underground workings	Daily	Dewatering volumes
Open cut pits and underground workings	Monthly when water is present	pH, EC, arsenic, copper, nickel, zinc, cyanide and ammonia, calcium, magnesium, sodium, potassium.
Open cut pits	Monthly once extraction is complete	Water level

3.2.5 Groundwater quality

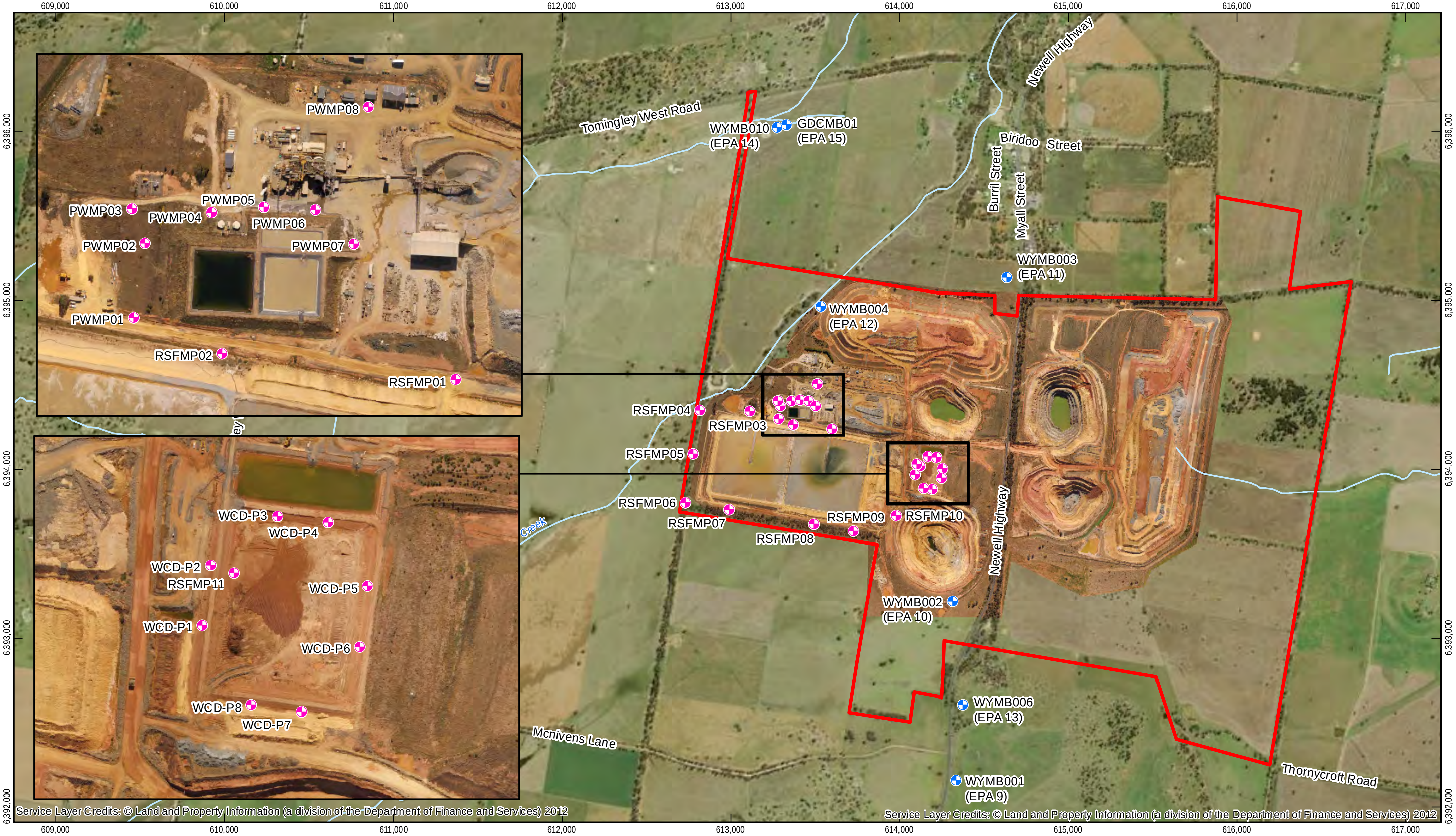
Background water quality data is available at deeper bores WYMB01, WYMB02, WYMB03, WYMB04, WYMB06 and WYMB10; and at alluvial monitoring bore GDCMB01. Groundwater quality plots are presented in Appendix D.

Background groundwater quality indicates that pH was generally between 7 and 8.5 for all sites indicating that all sites are slightly basic. Background Electrical Conductivity (EC) at WYMB02, WYMB03, WYMB04 and WYMB10 was over 20,000 µS/cm indicating very saline water. Background EC at WYMB01 and WYMB06 was lower however still very saline at typically 12,000 to 13,000 µS/cm.

Piper diagram has been developed for all groundwater monitoring locations and is shown in Appendix B. The piper diagram allows comparison of water chemistry between monitoring locations. The piper diagram indicates that the groundwater at all deeper monitoring locations within the fractured and porous rock aquifer is of similar chemistry of sodium chloride type. The groundwater at the Wyoming three sump and the Caloma one sump is of similar chemistry to the fractured and porous groundwater monitoring locations indicating that the open cut pits are intercepting groundwater from the fractured and porous rock aquifer.

The piper diagram indicates that groundwater in the Gundong Creek alluvial aquifer is of differing chemistry to the deeper fractured and porous aquifer. The differing chemistry indicates a low degree of connectivity between the alluvial aquifer and the fractured and porous rock aquifer.

Water quality parameters at GDCMB01 have been compared to Default Trigger Values (DTVs) for 95% species protection recommended by ANZECC and ARMCANZ (2000a) due to its location within the alluvium. Water quality at GDCMB01 has been plotted against DTVs with quality graphs shown in Appendix D. Water quality at GDCMB01 is below DTVs for arsenic, cadmium, mercury, and ammonia. EC at GDCMB01 is typically just above the DTV. GDCMB01 has also exceeded DTVs for pH, TSS, chromium, copper, lead, nickel, zinc and dissolved iron on one or more occasions.



Paper Size A4

0 200 400 600 800 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site boundary
- EPL 20169
- Groundwater monitoring bore
- Watercourse

Tomingley Gold Operations
Groundwater Management Plan

Job Number	21-26505
Revision	0
Date	15 Nov 2017

Groundwater monitoring points **Figure 3-1**

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: Tomingley Gold Operations: Imagery, 2015; LPI: DTDB\Imagery, 2012, 2015. Created by: gmcdiarmid

3.3 Groundwater trigger values

The NSW Aquifer Interference Policy requires that potential impacts on groundwater sources, including users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The Level 1 minimal impact considerations for Less Productive Fractured Groundwater Sources have been adopted for the TGO pit top. The Level 1 minimal impact considerations for Highly Productive Alluvial Groundwater Sources have been adopted for the production borefield. The Level 1 minimal impact considerations are as follows:

- A cumulative pressure head decline of not more than a 2 m, at any water supply work.
- If the predicted pressure head decline is greater than the requirement above, then appropriate studies are required to demonstrate that the decline will not prevent the long-term viability of the affected water source unless make good provisions apply.
- If the above condition is not met then appropriate studies will need to demonstrate that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

3.3.1 Groundwater levels

The majority of shallow bores have been located to provide early detection of leaks from the RSF and processing areas. Therefore, trigger values for shallow monitoring bores are recommended to be based on a rise in groundwater level. For all shallow monitoring bores (except GDCMBP01) a Stage 1 trigger would be exceeded if groundwater levels rise over three consecutive months. A Stage 1 trigger would result in an investigation to determine if the rise in groundwater level is attributable to mining related activities.

The stage 1 investigation will include an analysis of groundwater quality monitoring data to identify whether the increases in groundwater levels are attributable to mining related activities. If it is likely that the rise in groundwater levels is the result of mining related activities, temporary modifications to the responsible mining activities will be made until groundwater levels return to normal levels. The modifications may include reduction in the placement of tailings and process water within the RSFs.

A Stage 2 trigger would be exceeded if groundwater levels rise over six consecutive months. The subsequent investigation will also include an analysis of groundwater quality monitoring data to determine whether the increases are the result of mining related activities. If mining related activities are likely to be responsible for the changes to shallow groundwater levels, longer term changes to water management on site will be implemented. These changes may include cessation of tailings placement and process water storage within the RSFs.

Groundwater level triggers for deeper groundwater monitoring bores have been developed to monitor drawdown in the fractured rock aquifer. All deeper groundwater monitoring bores are within the radius of groundwater drawdown predicted by the Impax Group (2011) as discussed in Section 4.1. Due to the lack of a numerical groundwater model, the extent of drawdown at each of the monitoring bores has not been predicted. It is recommended that groundwater level drawdown triggers are based on historical groundwater levels and from any complaints from a surrounding land holder.

The proposed groundwater level Stage 1 trigger is a drop in groundwater level more than 2 m below minimum pre-mining groundwater level or a complaint from a surrounding landholder. The proposed groundwater level Stage 2 trigger is a drop in groundwater level more than 4 m below the pre-mining groundwater level or two complaints from surrounding landholders within a three-month period.

Similar to groundwater monitoring bores in the fractured rock, the groundwater level trigger for GDCMP01 is recommended to be based upon historical groundwater levels. The stage 1 trigger value for groundwater level at GDCMP01 is proposed to be a groundwater level of 1 m below minimum historical groundwater level. The stage 2 trigger value for groundwater level at GDCMP01 is proposed to be a groundwater level of 2 m below minimum historical groundwater level.

Groundwater monitoring bores WYMB001 and WYMB006 are located outside of the modelled drawdown area. The potential impact to groundwater levels at these locations due to mining operations at TGO is therefore expected to be negligible.

Groundwater level trigger values are summarised in Table 3-6.

If the deeper groundwater levels are drawn down to either the stage 1 and stage 2 trigger level, an investigation will be undertaken to ascertain whether the falling groundwater levels are the result of mining related activities, and the result of external factors (eg over-use of the groundwater source by other licensed water users or extended period of drought). If the investigation identifies that the fall in groundwater levels is the result of mining related activities, compensatory water supplies will be provided to the affected landowners.

Table 3-6 Groundwater level trigger values

Bore	Stage 1 Trigger (m AHD)	Stage 2 Trigger (m AHD)
WYMB001	207.97	205.97
WYMB002	206.91	204.91
WYMB003	218.19	216.19
WYMB004	206.62	204.62
WYMB006	229.13	227.13
WYMB10	198.30	196.30
GDCMB01	269.64	268.64

Production borefield

Triggers for the production borefield have been defined in order to identify potential drawdown in the Macquarie River alluvium. Groundwater level trigger values are based on groundwater levels at DPIW monitoring bores, since these have been largest historical dataset. Trigger values are also based on complaints from adjacent landholders regarding groundwater level or quality.

Trigger values have been defined for the DPIW monitoring bores in order to identify drawdown occurring at surrounding landholder's groundwater extraction locations. The two closest surrounding landholder's stock and domestic groundwater extraction bores are GW805125 and GW028348 located approximately 650 m to the north and 700 m to the east south-east from the production bore respectively as shown in Figure 2-4.

DPIW monitoring bores within the vicinity of the production borefield include GW096080 located within 100 m of the production bore and GW273056 located 900 m to the north west of the production bore. GW273056 is also located at least 600 m from all other extraction bores.

Trigger levels are proposed to indicate a potential exceedance of Level 1 minimal impact considerations defined by the NSW AIP (i.e a fall in groundwater level of more than 2 m at any water supply work). The Stage 1 trigger for the production borefield is defined as a fall below the minimum groundwater level at GW273056-2 shown in Table 3-7; or a complaint from a surrounding landholder regarding groundwater level or quality. The Stage 2 trigger is defined as a fall in groundwater level of more than 2 m below minimum groundwater level at GW273056-2, shown in Table 3-7. It is recommended that TGO monitors groundwater levels at GW096080-2.

GW096080-2 is located within 100 m of the production bore and groundwater levels at this bore can be used to verify that extraction from the production bore is impacting on the Macquarie River alluvial aquifer. DPIW monitoring bore data is available from http://www.water.nsw.gov.au/realtime-data/groundwater.

Exceedance of trigger values at DPIW monitoring bores may not be directly attributable to extraction from the production borefield as there are a number of other bores extracting from the Macquarie River alluvium. Any exceedance of triggers at the production borefield is recommended to trigger further investigation into the cause of the fall in groundwater levels.

Table 3-7 Trigger values – DPIW monitoring bores

Bore	Minimum groundwater elevation (m AHD)	Stage 1 trigger (m AHD)	Stage 2 trigger (m AHD)
GW273056-2	220.01	220.01	218.01
GW096080-2	217.42	-	-

3.3.2 Groundwater quality triggers

The NSW Aquifer Interference Policy the impact on groundwater quality from TGO operations should not reduce the beneficial use category beyond 40 m from the activity.

The review of historical groundwater quality data indicates that EC at deeper groundwater monitoring bores is typically of a value around 20,000 µS/cm at WYMB02, WYMB03, WYMB04 and WYMB10. Background EC is approximately 12,000 to 13,000 µS/cm for WYMB01 and WYMB06. The very high EC at these locations limits the usefulness of deep groundwater within the porous and fractured groundwater source to industrial use only. The search for registered groundwater works indicates that there are only two monitoring bores registered as stock or domestic within 10 km of TGO. Both of these bores are over 8 km from TGO.

Considering the lack of nearby registered groundwater bores, high groundwater EC, and uneconomically low water yield, it is recommended that the trigger for groundwater quality for deep monitoring bores are based on complaints from surrounding landholders. It is recommended that a Stage 1 trigger for groundwater quality for the deep groundwater aquifer is a complaint from a surrounding landholder regarding groundwater quality.

It is recommended that groundwater quality triggers for deep groundwater monitoring bores are considered for revision in a revised WMP following approval of the in pit waste rock disposal.

Analysis of water quality data at GDCMP01 compared groundwater quality to DTVs. Groundwater quality at GDCMP01 exceeds DTVs for a number of water quality parameters. Recommended trigger values at GDCMP01 are recommended to be a combination of DTVs and historical water quality. It is proposed that the trigger value is proposed to be the DTV except where historical data exceeds the DTV. Where historical data exceeds the DTV then the trigger value is proposed to be the maximum historical concentration. Recommended trigger values are shown in Table 3-8.

Table 3-8 Recommended trigger values GDCMB01 (EPA 5)

Parameter	Trigger Value	Units	Source
pH	6.0 – 8.5	pH units	DTV
EC	706	µS/cm	Max. historical concentration
Arsenic	0.024	mg/L	DTV
Cadmium	0.0002	mg/L	DTV
Chromium	0.025	mg/L	Max. historical concentration

Parameter	Trigger Value	Units	Source
Copper	0.002	mg/L	Max. historical concentration
Lead	0.015	mg/L	Max. historical concentration
Mercury	0.0006	mg/L	DTV
Nickel	0.015	mg/L	Max. historical concentration
Zinc	0.071	mg/L	Max. historical concentration
Iron (dissolved)	2.5	mg/L	Max. historical concentration
Iron (total)	21.1	mg/L	Max. historical concentration
Cyanide (Total, Free and WAD)	0.004	mg/L	Max. historical concentration
Ammonia	0.9	mg/L	DTV

Limited groundwater quality data is available at shallow groundwater monitoring locations associated with the RSF and the PWD. This lack of data is due to a number of these locations being dry or almost dry for the majority of monitoring periods. The lack of water quality data is also due to these monitoring bores only being installed in the last two years.

In order to identify any impacts from the RSF or the PWD; it is proposed that the water quality trigger triggers for GDCMB01 are adopted for shallow groundwater monitoring locations associated with the RSF and the processing plant. The exception to this is RSFMP03 which appears to be influenced by the deeper porous and fractured rock aquifer as indicated by the piper plot shown in Appendix B.

The stage 1 trigger for all shallow groundwater monitoring locations (except RSFMP03) is proposed to be an exceedance of a trigger value for any water quality parameter listed in Table 3-8. The stage 1 trigger for all shallow groundwater monitoring bores is also proposed to be a continuous upward trend in any of the parameters listed in Table 3-8 for three consecutive months. The stage 2 trigger value is proposed to be an exceedance of a trigger value listed in Table 3-8 for three consecutive months for any water quality parameter. The stage 2 trigger for all shallow groundwater monitoring bores is also proposed to be a continuous upward trend in any of the parameters listed in Table 3-8 for six consecutive months.

4. Potential risks

A number of mining related activities have the potential to impact groundwater levels and quality. Open cut mining pits, waste rock dumps and reject storage facilities all have the ability to affect groundwater levels and quality.

4.1 Open cut and underground mining

Open cut and underground mining may result in groundwater level drawdown as mining intercepts aquifers that are pumped out of the workings. Any open cut or underground mining in Caloma Open Cut, Wyoming One, Wyoming One Underground Extension and Wyoming Three pits will potentially result in groundwater drawdown in the vicinity of the workings. Drawdown will continue as long as open cut areas continue to be dewatered. As dewatering ceases it is anticipated groundwater levels will slowly re-stabilise.

Observed groundwater make is approximately 0.2 ML/day for each pit.

Groundwater drawdown for each of the open cut pits and the underground workings was estimated by the Impax Group (2011) using the analytical equations and approach developed by Marinelli and Niccoli (2000). The analytical equations developed by Marinelli and Niccoli (2000) provide a method of estimating steady state or long term average inflows into a mine pit. The analysis was updated as part of the assessment process for Modification 3 (GHD 2015). The updated radius of drawdown was generally less than initially estimated by Impax Group (2011), which is consistent with groundwater observations. The updated radius of drawdown for each of the open cut pits and areas of underground mining is summarised in Table 4-1.

Table 4-1 Predicted radius of drawdown (GHD 2015)

Mining Area	Radius of Drawdown (m)
Caloma Open Cut	2,130
Wyoming One	2,130
Wyoming One Underground Extension	2,500
Wyoming Three	660
Caloma Two	810
Caloma Two Underground	2,400

The Marinelli and Niccoli (2000) method considers each area of mining individually and not the cumulative effect of all mining areas being mined either concurrently or consecutively.

4.2 Residue storage facilities

RSF decant water is saline and moderately alkaline, with elevated concentrations of arsenic, copper, nickel, cyanide and ammonia. The infiltration of RSF water into the local groundwater (or overflow into the surrounding surface water environment) therefore has the potential to result in the contamination of the local groundwater supply.

In accordance with the Statement of Commitments the RSF has been constructed over naturally occurring clays that have a permeability of less than 1 x 10^{-9} m/s of depth 900 mm or greater. The very low permeability, combined with adequate progressive dewatering of tailings, is intended to minimise the potential interaction of water from the RSF with the local groundwater resource.

4.3 Water supply borefield

The Woodlands Borefield consists of a number of water supply bores that extract from the Lower Macquarie River alluvium. Drilling of bores within the water Woodlands Borefield indicates that the alluvial material extends to a depth of at least 45 m bgl (Impax Group, 2008). The Woodlands Borefield is potentially extracting from the deeper alluvial sediments of the Macquarie River paleochannel.

GW801047 safe pumping yield is reported to be between 23.5 L/s and 30.8 L/s (or 741 ML/year to 971 ML/year) and Test bore 4 safe pumping yield is reported to be between 28.9 L/s and 39.7 L/s (or 911 ML/year to 1251 ML/year) (Impax Group, 2008).

4.4 Final void management

There will be four final voids (Caloma One, Caloma Two, Wyoming One Pit and the partially filled Wyoming Three) as part of the post-mining landscape. The rehabilitation objectives for the mine are identified in the Mining Operations Plan (MOP). Rehabilitation of the voids would include the following activities:

- 12 months prior to mining completion of a pit, an assessment of geotechnical stability will be undertaken.
- Where possible, the upper benches of Caloma One Pit will be laid back to encourage revegetation.
- No revegetation of the lower benches will be undertaken on any of the Pits.
- Access to each pit will be prevented through construction of berms and security fencing.

The final voids will be allowed to fill because of the post-mining landscape and this WMP will be updated to reflect the work completed as part of site rehabilitation.

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