GHD

FI Joint Venture Pty. Ltd.

Yogi - Magnetite Project - Environmental

Hydrogeological Investigation

June 2019

Executive summary

FI Joint Venture (FIJV) proposes to construct and operate a magnetite iron ore project (the Yogi Mine Project) located approximately 225 km east-northeast of Geraldton and 16 km northeast of Yalgoo in Mid West, Western Australia (WA).

The project is still in its preliminary phases, with feasibility studies underway at the time of writing this report confirming various environmental constraints, as well as infrastructure planning and services requirements. The project's description, while subject to change, nonetheless forms the basis for this assessment, and is based on the mine plan as of 25 October 2017.

The proposed Project will comprise:

- Mining of a magnetite iron ore through an open-pit truck and shovel operation;
- Processing of the ore to produce a magnetite concentrate; and
- Pumping of the magnetite slurry via pipeline to Geraldton Port.

Assessing the environmental impact of the groundwater dewatering and abstraction was identified as a key component of the environmental approvals given that the proposed mine would need a borefield/water supply option supplying process water and that the proposed pit would require dewatering. To address the assessment needs, a preliminary hydrogeological investigation was completed (this report), which targets addressing the key groundwater-related aspects for the project's environmental referral, more specifically Hydrological Processes and Inland Waters Environmental Quality factors as identified by the Environmental Protection Authority (EPA).

The hydrogeological investigation included:

- Hydrogeological exploration drilling at 24 sites within the FIJV tenements
- Installation of four (4) test production bores
- Installation of ten (10) monitoring bores
- Aquifer testing at four (4) new locations and limited testing of five (5) previously installed sites
- Groundwater quality sampling of tested production bores
- Installation of five (5) water levels loggers and water level monitoring (currently on-going)
- Development of a hydrogeological conceptual model
- Construction and calibration of a regional numerical groundwater flow model for impact assessment purposes
- Development of pit dewatering rates, delineation of drawdown from dewatering for impact assessment purposes
- Estimation of pit lake water level and salinity after mining ceases, including the residual drawdown extent maintained by terminal lake in the mine pit
- Groundwater impacts for environmental impact assessment

The regional data and groundwater drilling completed for this assessment demonstrated that the hydrogeology of the project area is dominated by greenstone basement of Archaean age, with various degrees of weathering and thickness of surficial cover. BIF mineralisation, present within the greenstone basement, combined with fractures, shearing and weathering, created

localised conditions for enhanced groundwater occurrence and flow of fresh quality (i.e. low salinity). Numerous structural features such as dolerite dykes and shear zones are present within the mining area, but their influence on groundwater flow has yet to be established. Surficial sediments in the area of the mining pit also attained sizeable thickness and hold groundwater. Depth to groundwater in the mining area is generally around 20 metres below ground level.

The eastern part of the tenement encompasses a tributary to a major palaeovalley that underlies the Salt River system. The palaeovalley hosts, at its base, a sand-dominated aquifer with saline groundwater (TDS in the order of 10,000 mg/L). Sand has undergone various levels of compaction and is interspersed with finer fraction sand, silts and clays.

Following completion of the drilling and testing a program a regional groundwater flow model with locally increased discretisation was developed for the project to estimate groundwater inflows during dewatering, understand the spatial extent of drawdown from dewatering, estimate rebound of water level post-mining and inform environmental impact assessment. Estimation of approximate groundwater system changes is possible with regional scale predictive flow models. The regional scale flow model used to simulate the groundwater system has limitations due to the simplifications necessary to represent complex natural systems.

The outcomes of the current hydrogeological investigation and numerical modelling for the Yogi Mine project are:

- There appears sufficient groundwater capacity and contingency to sustain an abstraction of up to 5 GL/yr, the significant part of which would come from pit dewatering. This would have to be further confirmed by additional hydrogeological investigation including additional hydrogeological drilling, long-term hydraulic testing and subsequent numerical model updates.

- Estimated drawdown at the completion of mining (after 21 years) will reach a maximum depth at 125 m AHD, i.e. approximately 225 m below the pre-mining water level. The one (1) metre contour representing the extent of impact detectable in relation to natural water level variability is expected to extend up to 16 km from the mining pit at its furthest.

- After the mining ceases, and assuming that the pit will not be refilled with waste rock material, a terminal lake will develop in the open pit which will coalesce from two initial sub-lakes in the northern and southern extremes of the pit. The water level in the pit will stabilise after approximately 150 years at a level of 285 to 306 m AHD depending on the efficiency of measures to limit surface water runoff into the open pit. The terminal lake will form a permanent groundwater sink in the region. Groundwater drawdown from the lake will decrease vertically during refilling but will flatten horizontally. It is estimated that drawdown from the stabilised lake will extend up to 17 km from the pit lake.

- There are no recognised GDEs within the cone of depression from dewatering. The flow regime in ephemeral creek lines within the mining area is likely to be dominated by seasonal rainfall rather than baseflow and consequently less affected by dewatering (and post closure) drawdowns notably so if their alluvia include clay layers. Further investigation and monitoring is recommended to confirm these findings in the next stage of the project and develop triggers and contingencies if required.

- There are several stock bores and licensed groundwater users (include Yalgoo Town Water Supply) which are within the estimated drawdown that exceeds 1 m. While the town water supply is considered to be resilient enough against predicted drawdown impacts additional investigation and monitoring is recommended downgradient from the mining pit. Triggers and contingencies may need to be developed if required. Several stock bores (if still in operation) may become defunct due to dewatering impacts.

- Overall impacts are manageable, but need to be confirmed with more extensive monitoring instrumentation and additional aquifer testing. Project is at early stage, with significant more work required, including resource drilling, which will provide a significant body of data needed to refine the resource understanding and develop the understanding of structures that may control groundwater flow.

This report is subject to, and must be read in conjunction with the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

FI Joint Venture (FIJV) proposes to construct and operate a magnetite iron ore project (the Yogi Mine Project) located approximately 225 km east-northeast of Geraldton and 16 km northeast of Yalgoo in Mid West, Western Australia (WA). The Project incorporates various tenements (M59/740-1, M59/637-1, P59/2133, L59/156 and E59/2227-1), with a focus on environmental approvals relating specifically to tenements M59/740-1 and L59/156 (Figure 10-1).

The Yogi Mine Project proposal includes the mine and associated infrastructure as well as a magnetite slurry pipeline and a water pipeline to Geraldton Port, and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline network. Assessing the environmental impact of the groundwater dewatering and abstraction was identified as a key component of the environmental approvals given that the proposed mine would need a borefield/water supply option supplying process water and that the proposed pit would require dewatering. A hydrogeological investigation was completed (this report), which addresses the key groundwater related aspects for the Projects environmental referral (see Section 1.3)

1.2 Purpose of this report

FIJV commissioned GHD to undertake a hydrogeological assessment for the Yogi Mine Project. The purpose of the assessment was to develop the hydrogeological understanding of the Project area to allow the groundwater related impacts to be quantified.

This report has been developed with specific reference to the groundwater related 'Key Environmental Factors' as identified by the Environmental Protection Authority (EPA) and summarised below in Section 1.3.

1.3 ESD Terms of Reference

On 19 December 2017 the Yogi Mine Project was referred to the EPA under section 38 of the EP Act. The EPA determined on 26 February 2018 that the Proposal requires a Public Environmental Review (PER) level of assessment with a six-week public review period. The EPA identified that the proponent is required to prepare an Environmental Scoping Document (ESD, this document), which is then to be peer reviewed.

The Preliminary Key Environmental Factors identified by the EPA at the referral stage are Flora and Vegetation, Subterranean Fauna, Terrestrial Environmental Quality, Terrestrial Fauna, Hydrological Processes, Inland Waters Environmental Quality, Air Quality and Social Surroundings. This report provides the groundwater related technical component that is needed for the project. This technical component largely falls within Hydrological Processes and Inland Waters Environmental Quality factors. However, there are various other interrelated factors that are also referred to.

The ESD specified the following "Potential impacts and risks" that relate specifically to groundwater:

- Alteration of the hydrology of the area from groundwater abstraction

- Impacts to inland wetland communities or groundwater dependent ecosystems as a result of groundwater drawdown

- Impacts to inland wetland communities or groundwater dependent ecosystems as a result of groundwater drawdown and changes to groundwater quality

The following table provides a summary of the 'Required work' specified I the ESD that will address the above impacts and risks. The table outlines in what section of this report those items are addressed.

Table 1-1 - Inland water – required work to address Project risks (as detailed in the ESD).

Required work*	Section of this report
66) The key hydrogeological features relevant to the development envelope will be characterised including: aquifer system, aquifer recharge, discharge, flow direction, hydraulic parameters, hydrochemistry, from regional and site specific perspectives.	Regional and local hydrogeology presented in Section 4
67) Hydrogeological field investigation will be conducted including groundwater monitoring and aquifer testing.	Field investigations, including drilling and testing presented in Section 5
68) An initial conceptual and numerical groundwater flow model and water balance will be developed for predictive purposes (dewatering rates and impact assessment).	Regional conceptual model presented in Section 4, with initial numerical model presented in Section 6
69) Potential impacts of the Proposal will be identified (for the borefield and mine dewatering) including changes to groundwater levels, flows and quality, including: a. Assessing potential impacts to creeks, springs/soaks, salt lake ecology, water flats, groundwater dependant ecosystems (GDEs), subterranean fauna and other users. b. Identifying appropriate management measures to mitigate the impacts of the Proposal. c. This will include noting whether these impacts are unknown, unpredictable or irreversible, or combination or contrary to that thereof.	Groundwater modelling results identifying potential impacts presented in Section 6. Management of impacts presented in Section 6.13.
70) The potential for the formation of mine pit lakes after mine closure will be assessed. The pit lake risk assessment will determine the potential impact to hydrological regimes and water quality.	Groundwater modelling results identifying pit lake formation presented in Section 6.
74) An environmental management plan will be prepared that describes the proposed management, and monitoring methods to be implemented to mitigate potential impacts to inland waters and the surrounding environment.	Management of impacts presented in Section 6.13 and Section 7.

Required work as detailed and numbered in the ESD. Only groundwater specific items included.

2. Project overview

2.1 Introduction

The Project is located approximately 225 km east-northeast of Geraldton and approximately 16 km east of the rural township of Yalgoo, as shown in Figure 10-1. The proposed development envelope consists of 8,230 ha and includes mining tenements M59/740, M59/637, P59/2133 and L59/156.

The Project is still in its preliminary phases, with numerous studies underway at the time of writing this report confirming various environmental constraints, as well as infrastructure planning and services requirements. As such, the project description provided herein is preliminary and may change. This description nonetheless forms the basis for this assessment, and is based on the mine plan as of 25 October 2017.

The proposed Project will comprise:

- Mining of a magnetite iron ore through an open-pit truck and shovel operation;
- Processing of the ore to produce a magnetite concentrate; and
- Pumping of the magnetite slurry via pipeline to Geraldton Port.

The proposal also includes a water pipeline to Geraldton Port, and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline. The pipeline corridors from the mining tenement do not form part of this assessment.

2.2 Key project components

The Yogi Project includes the following components within the mining tenement area, the provisional proposed locations of which are depicted in Figure 10-2. *The location of the key components shown on Figure 10-2 and listed below is aligned with the original mine plan. During progression of the various technical studies, the location of some of these components was/is likely to change. For example, in response to this hydrogeological assessment, the depicted location of the borefield is now expected to change.*

Key components are:

- Open cut mine;
- Waste rock facility (WRF);
- Run of mine pad (ROM) / Ore stockpile;
- Overburden facility;
- Processing plant;
- Crusher;
- Dry Processing Waste Facility(DPWF);
- Borefield and associated water pipeline;
- Concentrate pipeline;
- Drainage water pond;
- Access road between mine site;
- Gas fired power station;

- Administrative buildings, workshops, laboratory and warehouses;

- Explosives warehouse;

- Access road; and

- Guardhouse.

The town of Yalgoo is expected to be the location for administrative operations and accommodation for staff.

A natural gas pipeline in close proximity to the plant has sufficient capacity to supply a gas fired power station located on the plant site for an anticipated energy demand of approximately 25 MW for the site. Coal supplies are also being considered for the smelting process.

It is anticipated that the site water requirement will be up to 5 GL per annum. As summarised in Section 5, a desktop hydrogeological study identified there was insufficient site data to demonstrate this requirement can be met by on-site sources (GHD, 2018). A drilling, testing and numerical groundwater modelling program, summarised in Section 5 and Section 6 was completed to provide further information on the potential for water supply within the project envelope. However, further work is still required to define the actual water demand of the project, which depending on ore processing and slurry methodologies may be reduced significantly from the provisional estimate of 5 GL per annum.

Disposal of up to 800 million tonnes of overburden/waste rock and of up to 80 million m^3 of dry processing waste is expected over the life of the Project.

Aside from the above details and the proposed mine layout, further details relating to the mine plan, pit development, mining, processing, and construction processes have yet to be confirmed.

3. Climate

The climate of the mine site is classified as warm and temperate with an average annual rainfall of 258 mm recorded at the Bureau of Meteorology (BoM) Station 7091 in Yalgoo (BoM, 2018), which is located 15 km south west of the mine. Annual rainfall is highly variable, as depicted in Figure 3-1, and is also highly seasonal with the majority of rainfall occurring during the winter months (June to August).

Monthly rainfall statistics, temperature and evaporation data[1] at this station are illustrated in Figure 3-2. The mean monthly maximum (minimum) temperature ranges from 18.8°C (6°C) in July to 38°C (21°C) in January (July). Average annual evaporation for Yalgoo totals approximately 2,766 mm with average monthly evaporation generally exceeding rainfall year-round.

Rainfall data is further discussed with regards to groundwater recharge in the groundwater modelling section of this report (see Section 4.7 and Section 6).
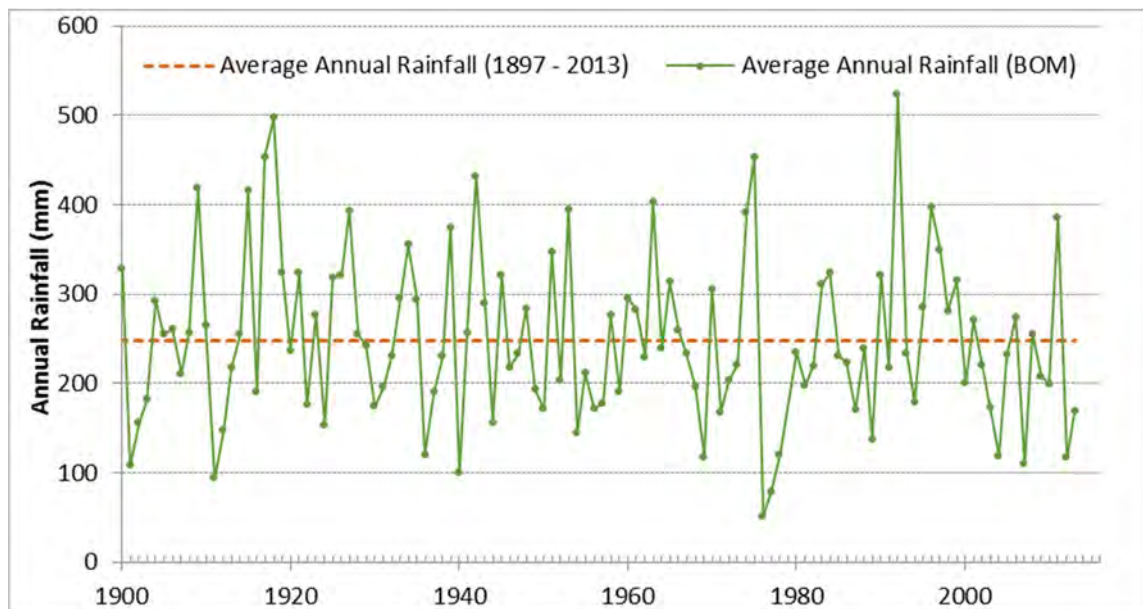
Figure 3-1 - Annual rainfall at Yalgoo Station 7091 (BoM, 2018)

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[1] Rainfall, temperature, and evaporation data sourced from the SILO data downloaded from https://legacy.longpaddock.qld.gov.au/silo/ppd/ on 2 October 2018. The SILO climate database (Queensland Department of Science, 2015) provides a continuous daily climatic record for a given point with gaps infilled based on interpolation of records from nearby weather stations.
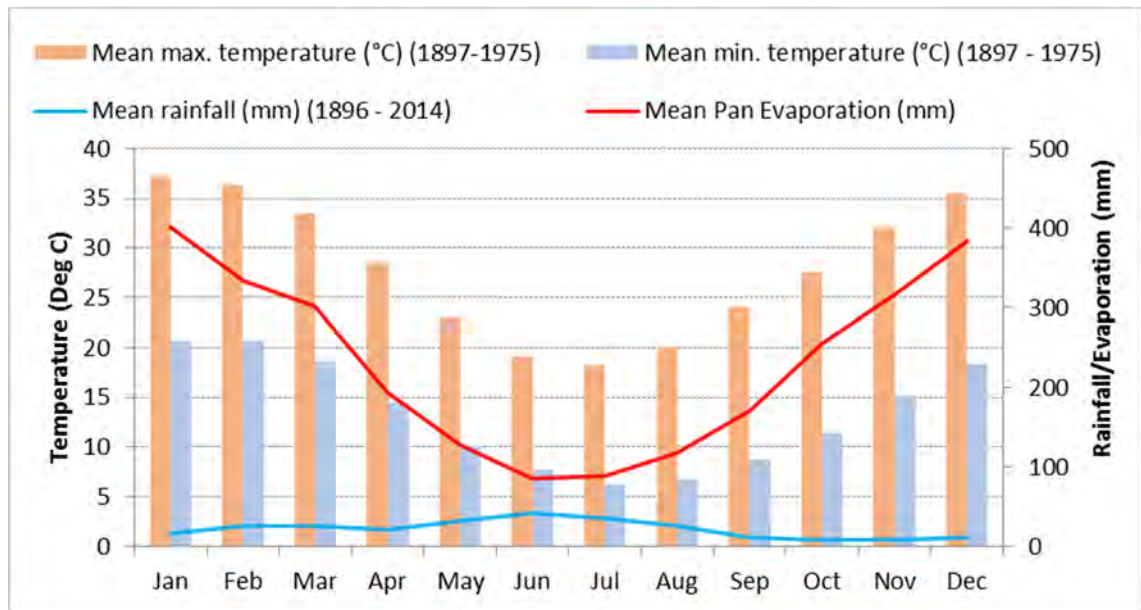
Figure 3-2 - Monthly climate statistics at Yalgoo Station 7091 (BoM, 2018)

4. Hydrogeological setting

The following sections provide a summary of the information used to develop the hydrogeological understanding of the site. This includes review and presentation of key existing data, including published geological and hydrogeological information. Further comment on the site specific hydrogeology is provided in subsequent sections, including discussion of field investigations (Section 5) and development of the site hydrogeological numerical model (Section 6).

4.1 Regional geology

The Project area is located within the Murchison Province, which is the westernmost of three granite-greenstone terranes in the Archaean Yilgarn Craton. The Archaean rocks of the Murchison Province comprise linear to arcuate, north to northwest-trending greenstone belts, which have been intruded by granitoid rocks (Watkins, 1990).

The greenstones occur beneath around 40% of the Murchison Province and contain metamorphosed and deformed sequence of mafic to ultramafic volcanic rocks, felsic volcanic rocks and metasedimentary rocks, including chert and banded iron-formations (BIF). Granitoids occur beneath the remaining 60% of the Murchison Province and comprise plutons of mainly equigranular to porphyritic adamellites with minor occurrences of granite, gneiss and migmatite (Johnson and Commander, 2006). The regional proportions of greenstone to granitoid basement geology is broadly consistent for the Project area, as highlighted by the simplified basement geology shown on Figure 10-4.

Most of the Archaean bedrock is largely obscured beneath a cover of Cainozoic deposits, which infilled the palaeodrainages during the early Tertiary. Within the general project area, topographical high areas tend to be where the Archaean bedrock is exposed. Within the Project tenements, this higher ground is largely a complex sequence forming the Luke Creek Group and Mount Farmer Group. The **Luke Creek Group** comprises laterally extensive (terrane-wide) lava flows, banded-iron formations (BIF) and associated rocks. The **Mount Farmer Group** comprises volcanic and epiclastic rocks. Just outside of the tenement, granitoid complexes are found exposed as the higher ground, for example Mooridarang Hill and Woonjedie Hill just to the east of the Project area.

4.2 Mine site geology

4.2.1 Project resource – Pit area

The magnetite resource of the Project area is located within tenement M5900740, forming the western area of the Project. The resource is found on the eastern slope of the ridgeline. This slope lies on the eastern limb of a regional scale synform locally known as the '**Bridge Well synform**'. Structural evidence, together with aeromagnetic data, suggests that this synform has been truncated by the **Mougooderra Shear Zone**, a north-south trending structure that can be traced southwards for approximately 100 kilometres (CSA, 2007).

As highlighted in Section 4.1, the rock units within the area form part of the Luke Creek Group, and belong predominantly to the Golconda Formation, which includes a sedimentary succession of thrust-thickened quartz–magnetite BIF and medium-grained epiclastics. These form a prominent north–south-trending ridge line that dominates the topography of the project area.

To the west of the tenements, the area is dominated by an intricately folded succession of schists interlayered with fine-grained basalts of the **Gabanintha Formation**. Due to the limited outcrops, the interpretation of the geometry of this succession is largely based on aeromagnetic data. A schematic conceptual cross section through this area is presented as Figure 10-6 and further discussed in the sections below.

The Yogi resource is a magnetite-rich BIF, which forms a steeply dipping, arcuate deposit. The magnetite-rich BIF is tight to isoclinally folded and trends north-south for approximately 27 km (i.e. some areas outside of the Project tenements). The strike of the orebody varies from approximately 24˚ in the south, 0˚ in the centre, to 335˚ in the north. Within the proposed pit area this is approximately 310˚.

The deposit is variably weathered, but is predominantly a banded haematite–magnetite–quartz rock with mafic amphiboles present at depth. The presence of the two iron oxides is interpreted as the result of progressive oxidation of a magnetite-rich proto-ore. Consequently, haematitic-rich BIF gives way to fresh magnetite-rich BIF at shallow depths (<40 m). The presence of iron-rich silicates indicates retrograde metamorphism of the BIF, and may represent slightly different chemical properties in the fresh BIF prior to weathering (CSA, 2007).

The relatively coarse grainsize of the haematite-magnetite is suggestive of recrystallization of the original iron-rich sedimentary (chemical) grains by a significant magmatic heat source.

Drilling data has shown that the orebody comprises three identifiable layers or zones (CSA, 2007):

1. An upper heavily oxidised zone (<10 to 40 meters thick), characterised as having very little or no remnant magnetism, most of the original magnetite having being oxidised to haematite. It is unlikely to contribute recoverable material;

2. A middle transitional zone where there is enough remnant magnetite to give a moderate to strong magnetic response. Although this zone is oxidised it is anticipated that there will be enough magnetite present to allow it to be processed as beneficiation feed;

3. A lower fresh zone where recoverable iron is 100% magnetite. This zone makes up the bulk of the mineral resource estimate.

4.2.2   Outside of pit area (within tenement)

To the east of the BIF dominated terrain of the Pit area, for example in Mining Lease 5900156, the topography is generally flatter, with the surface geology dominated by more recent sediments. These are generally mapped (GSWA, 1997) as sheetwash alluvial units that can include clay, silt and sand in extensive fans with local ferruginous gravel.

The depth of these sedimentary deposits is variable, with deepest deposits occurring in areas of thickening due to palaeodrainage features. The limb of a large palaeovalley feature has been mapped (Geoscience Australia, 2012) to occur within the eastern area of the Project. This feature is part of the Moore-Monger palaeovalley which is further discussed in Section 4.3, and was the target of investigatory drilling as presented in Section 5.

Within the Project area, the alluvial units in the east are generally underlain by granitoids such as the **Big Bell Suite** (metagranodiorite) and the **Walganna Suite** (monzogranite).

4.3   Regional hydrogeology

4.3.1   Overview of groundwater systems

It is acknowledged that that the groundwater resources of the region are poorly understood (Davis & Macaulay et al, 2016), largely a result of lack of development and lack of demand for

groundwater. In general terms, the regional area groundwater resources are described by four prevalent systems (Johnson, 2006) which are summarised below.

Alluvial aquifer(s)

Shallow alluvial aquifers form within drainage and palaeodrainage systems. Viable aquifers are found where there are significant deposits of sands and gravels, although these are usually associated with finer grained silts and clays which can limit their groundwater potential.

Within the project area, these shallow alluvial aquifers are often used for stock bores, and can have a variable salinity, dependant on their locations within the catchment.

Shallow alluvial aquifer appears to be a source of mine water for Dalgaranga Gold Mine (Gascoyne Resources), to the north-east of Yogi.

Calcrete aquifers

Calcrete aquifers can be found at the margins of present day salt lakes, and locally in some of the main sub-catchments in the palaeodrainages. Within the general Project area they are expected to occur only in the south-eastern area, and outside of the current tenements.

Due to the nature of the carbonate rock forming the calcrete, they are known to develop karstic features, which can add significant porosity (and potentially high yielding) zones. Calcrete is generally located in the lower reaches of the groundwater flow systems, and it usually hosts brackish groundwater with a salinity (as Total Dissolved Solids (TDS)) of between 2,000 to 6,000 mg/L.

Palaeochannel aquifers

The Tertiary sediments forming the palaeodrainage systems are poorly documented throughout the Mid-west region (Johnson, 2006). A broader understanding of Australia's palaeochannel systems was developed by Geoscience Australia in their study: *Palaeovalley Groundwater Resources in Arid and Semi-Arid Australia project* (Geoscience Australia, 2009). The study included assessment or large areas of arid Australia, mapping palaeovalleys using various techniques (largely interpretive). The study notes that although palaeovalleys are defunct fluvial systems now filled with early, middle and late Cenozoic sediments, they remain active groundwater systems which have further evolved during the alternate cool dry / warm-wet, glacial/interglacial climate cycles of the Quaternary.

Palaeovalley aquifers typically have a higher storage capacity and hydraulic conductivity than adjacent extensive weathered and fractured basement aquifers, and bores can yield relatively significant quantities of water.

A review of data highlighted that the upper limits of the Moore-Monger palaeovalley are mapped as coinciding with the southern limb of the Project tenement. The Moore-Monger palaeovalley is shown on Figure 10-4. The report (Johnson, 2006) notes that this palaeovalley has had limited investigation. A portion of the palaeovalley was investigated at Mount Gibson (150 km south of the site) where up to 100 metres of basal Eocene fluvial sand is confined by a lacustrine clay unit. These palaeovalley infilling sediments are overlain by up to 20 metres of slopewash alluvium and valley calcrete. The palaeochannel sands are a major confined sedimentary aquifer with large supplies of saline to hypersaline groundwater, and are used for ore processing at the Mount Gibson mine.

Following completion of the Geoscience Australia initial palaeovalley investigations, a regional scale airborne electromagnetic (AEM) survey was commissioned and flown in the Murchison extending over an area in excess of 106,000 km². This work was completed by WA Government Department of Water (now part of the Department of Water and Environmental Regulation) in association with CSIRO. The aim of the work was provide further definition and delineation of

the palaeovalleys. A review of this data was used to assist in identifying groundwater targets for the investigatory drilling program summarised in Section 5.

Fractured rock aquifers

The main fractured-rock aquifers relevant to the Project area are the granitoid and greenstone (metamorphic) rocks of the Murchison Province. Granitoid basement rocks are found in the east and outside of the Project area. Groundwater resources in granitoid areas are usually associated with the lower, more brittle section of the weathering profile, although low-yielding groundwater is also present in open joints and fractures. Groundwater yields in the weathered profile are generally quite low, but can increase in faulted areas. Larger groundwater supplies are difficult to locate because of the compact nature of granitoids and generally sparse fracturing.

The complex assemblage of rocks forming greenstones has variable properties, and variable weathering profiles which complicates assessing and interpreting their groundwater potential. Within the regional area, the basalts (for example **Mugs Luck Basalt**) have been targeted for groundwater supply, with Water Corporation operating several bores that supply Yalgoo's town water supply. These bores are known to be around 60 m deep and target the lower weathering profile (refer to Section 4.4 for further comment on the Yalgoo Town Water Supply).

4.3.2   Minesite hydrogeology

Prior to the site investigations completed for the Project, and discussed in Section 5, there had been no detailed hydrogeological assessment completed for the minesite (pit area). Whereas there had been resource drilling completed by previous tenement owners (i.e. RC and diamond cored holes completed by Ferrowest), no specific groundwater related assessment or investigation was completed.

A limited field program was completed by SRK in 2017 which included the measurement of groundwater levels within the Pit area, groundwater quality sampling and completion of several slug tests on selected exploration holes to obtain hydraulic conductivity values. Key findings of the study are summarised as:

- Groundwater levels were generally found to be around 20 metres below ground level (mbgl), occurring at a reported elevation of approximately 355 to 365 m AHD. Groundwater was inferred to occur within a fractured rock aquifer situated near and immediately below the base of weathering, typically 10 to 30 mbgl.

- Falling head tests completed on two open holes indicated an inferred hydraulic conductivity of 1.4 to 1.8 x 10^{-7} m/s (0.01 to 0.02 m/d).

- Groundwater quality results indicated some variability between the four bores tested, but generally fresh to brackish groundwater with an electrical conductivity of between 890 to 2,810 µS/cm.

4.4   Existing groundwater use

As highlighted by the above sections, due to the general sparsity of the region, and poor groundwater potential, there are relatively few existing users of groundwater within the Project area. However, an understanding of these existing groundwater users is required in order to protect them from potential mining impacts. The following sections summarise the key known groundwater users within the Project area.

4.4.1 Public water supply

The town of Yalgoo sources its water from a borefield operated by Water Corporation, located approximately 4.5 km north of town. The borefield represents one of the closest licensed groundwater uses to the project, being approximately 10 km from the proposed pit (Figure 10-6).

The borefield consists of three production bores (2/83, 1/84 and 3/83) and one unequipped bore (6/82) (DWER, 2010). The bores are located within the Yalgoo Water Reserve (Figure 10-4). It is understood that the extent of the reserve is conforms with the surface water catchment within which the bores are located.

The bores abstract groundwater from a fractured rock aquifer. They are screened between 24 and 60 m bgl and have a static water level generally within 13 to 21 m bgl (DWER, 2010). Based on their location and mapped geology, they are located within the **Mugs Luck Basalt Member**. However, the driller's geological log (obtained from DWER's Water Information Reporting) describes a weathered clay-rich profile to 39 m, underlain by dolerite to 60 m.

The unconfined nature of the aquifer or where overlying clay content is low makes the aquifer potentially vulnerable to contamination from surrounding land uses. Information presented by DWER (DWER, 2010) indicates that the fractured rock aquifer is recharged from direct infiltration of rainfall. Groundwater is inferred to flow to the south-west. The sustainable yield of the aquifer has been estimated as 92,500 kL per annum, with current licensed annual allocation of 75,000 kL.

4.4.2 Other licensed bore usage

Current licensed users of groundwater were reviewed as having active abstraction licences within 100 km of the Project area. The licence details are summarised below in Table 4-1, and shown on Figure 10-4. Key observations from the licence data indicate the following:

- All licenses are for the "Combined - Fractured Rock West - Fractured Rock" DWER defined aquifer with the exception of licence 163059 which is for the "Combined - Fractured Rock West – Alluvium" aquifer.

- Within the catchment area of the project (and the model boundary – see Section 6), there are two large abstraction licenses. Both these are for mining leases, with annual abstraction licensed at 3.5 GL for EMR at Golden Grove, located approximately 30 km south from the proposed pit, and 3.4 GL/annum at Gascoyne Resources, located approximately 60 km north east from the proposes pit.

- The Water Corporation Town Water Supply bores are approximately 10 km south west from the proposed Yogi open cut pit. Slightly closer, but licensed for a smaller rate is a private use (licence holder Holland, Craig) for 1,550 kL/a located approximately 8 km from the pit.

Table 4-1 - Groundwater licenses within 100 km of the Project

Licence Number	Area	Date	Allocation (kL/yr)	Holder
103574	Within catchment / model boundary	Jul-18-Aug-24	3,510,000	EMR Golden Grove
183561		Dec-17-Mar-27	3,400,000	Gascoyne Resources Limited
109408		Oct-18-Aug-26	75,000	Water Corporation
177990		Sep-13-Sep-23	24,000	Shire of Yalgoo
179358		Feb-16-Dec-20	9,000	Main Roads
179360		Feb-16-Dec-20	8,000	Main Roads
201926		Sep-18-Sep-28	5,000	Paul Church
168997		May-14-Mar-24	2,000	Arabian Gold
180498		May-15-Feb-25	1,550	Holland, Craig
180200		Dec-14-Dec-24	130	Addink, Johannes Peter
168757	Outside catchment / model boundary	Jun-18-Jun-28	4,700,000	Deflector Mining Limited
202380		Jan-19-Jan-29	3,500,000	Adaman Resources
169526		Dec-18-Dec-23	3,355,000	Minjar Gold
179363		Oct-15-Oct-25	950,000	Mount Gibson Mining Limited
98439		Oct-18-Jun-26	350,000	Water Corporation
159390		May-13-May-23	100,000	Wydgee Pastoral & Grazing Co
182868		May-17-Apr-20	38,200	Shire of Murchison
184167		Mar-17-Dec-19	36,000	Shire of Murchison
180911		May-15-May-25	25,000	Goldfields Technical Services
163059*		Jul-12-Jan-22	1,500	Foulkes - Taylor, Jano
201875		Aug-18-Aug-28	100	Buddadoo Metals

4.4.3   Stock bores

Whilst the groundwater users noted in Section 4.4.2 are licensed, groundwater abstracted for stock watering is exempt from licensing and therefore is not registered with the DWER. In order

to determine those locations were stock bores were present, data from the DWER WIR bore database was interrogated together with observations taken during field assessments. The location of the stock bores identified down-gradient of the Project bores are shown on Figure 10-5 and summarised in Table 4-2.

The majority of stock bore and well locations have been established early in the pastoral stations development. As such, some locations have since been re-drilled, or bores installed to replace old wells which were traditionally hand dug and relatively shallow. Due to the relatively low volumes of groundwater required at each location, bores tend to be relatively shallow and generally less than 40 m deep. Due to the widespread nature of these bores, they tend to target different units but predominately the fresher shallow groundwater often associated with alluvial sediments.

Most active stock bores are equipped with either a wind powered shaft drive positive displacement pump, or a solar powered electric submersible pump. In general, wind powered bores will pump continuously when there is sufficient wind, whereas solar pumps will fill a tank and only pump when levels in the tank drop below a specified level.

Due to the relatively shallow nature of stock bores, they have the potential to be impacted by reduction in groundwater levels, therefore consideration of impacts on these bores will be a key factor when assessing drawdown impacts from the Project.

Table 4-2 - Groundwater users immediately downstream of site (DWER, 2019)

Site Short Name	Site Reference	Easting	Northing	Site Comment
Cattle Well	61812067	481676	6879318	Colluvium. 1 tank, 1 trough.
Chookey Well	61812094	477354	6859979	1 Tank, 2 troughs. Colluvium.
Common Well	61812101	473394	6863198	1 tank, 1 trough; colluvium.
Lazy Well	61812068	488891	6867060	2 tanks 3 troughs.
Moongadaga Bby Well	61812092	479918	6852212	Colluvium. 1 tank, 1 trough
Mulloo Hill W	61812084	484018	6861440	2 tanks, 3 troughs. Laterite, weathered basics.
Mulloo Well (Ab)	61812097	486516	6859022	Colluvium
Ram Well	61812075	489269	6863854	1 tank, 2 troughs: colluvium.
Red Gate Well	61812080	478084	6874534	2 tanks. 3 troughs. Colluvium.
Six Mile Well	61812155	470890	6855287	1 tank 2 troughs. Colluvium.
Wadgingarra Well	61812081	482637	6873379	1 tank, 1 trough.
Wadgingarra Well	61812082	478970	6865476	Laterite - weathered basics.
Whelock Well	61812093	483724	6848560	Colluvium. 1 tank, 2 troughs.
Yalgoola Well	61812076	490800	6861594	2 tanks 3 troughs. Calcrete.

4.5 Groundwater Dependent Ecosystems (GDEs)

A review of the Threatened or Priority Ecological Communities (TECs or PECs) (see Flora and Vegetation Assessment, GHD, 2019) identified several ecosystems within the region that are categorised as having a low to high potential for groundwater interaction. These ecosystems are shown on Figure 10-4 and Figure 10-5.

Several areas of high potential for groundwater interaction situated in areas downgradient of the Project are largely calcrete groundwater assemblages that can be found within the palaeodrainage. Ecosystems present within the calcretes would potentially be sensitive to changes in the groundwater levels and groundwater quality.

4.6 Groundwater levels

Groundwater level data was collated from the DWER WIR dataset. A total of 541 bore records were identified that had some record of groundwater levels. For the majority of these (511 bores) only a single groundwater level measuring was available, likely to have been from when the bore was installed. In addition to the DWER bore data, groundwater level measurements were available from the investigations completed for this Project (See Section 5), which provided valid data for a further 15 locations.

The data indicates that in general, groundwater levels are generally found to be less than 20 m below ground level for approximately 90% of the data. Of the records with time-series data, all records were historic, with no consistent data available for dates later than 1989. The only site close to the Project with time series data was for bore '3-83' from the Yalgoo Town Water Supply, with a total of 22 measurements made between 1986 and 1989. Over this period, levels are seen to range by around 15 m, likely a response to pumping.

The data was used to generate a groundwater surface plot to show the inferred potentiometric surface for the catchment. This is presented as Figure 10-7. Data was presented for the average groundwater elevation for each site. Due to the sparsity of data, all dates used to generate the plot (i.e. water levels from various dates were used, not a snapshot).

The figure indicated that groundwater levels are broadly consistent with topography, and indicate a dominating groundwater high point coincident with the topographic high located approximately 40 km north east of the Pit area. Data for the Project area indicates that groundwater is generally flowing in the southern direction, discharging to the low ground present along the current drainage line of the Salt River. There is a groundwater divide, consistent with the catchment divide, located along the higher ground present to the immediate west of the Pit area.

4.7 Recharge

Rainfall is the primary source of groundwater recharge. The recharge rates are likely to be low due to the low overall annual rainfall and occurring mainly during sustained periods of rain, notably in the winter period. During this investigation rainfall experienced prior to aquifer testing in the pit area caused large scale ponding of water in a number of areas in the tenement.

Since groundwater is relatively deep, typically encountered between 10 to 30 m bgl, only limited rainfall-sourced water eventually percolates to the watertable. Direct percolation is considered more viable in outcrop areas with possibilities for water to enter vertical or sub-vertical fractures in the greenstone and granitoid terranes. Colluvium cover, especially with more abundant clay or fine fraction, may slow down this process subject to losses from evaporation and evapotranspiration and reduce the recharge amount.

Creek drainages represent areas for intermittent creek infiltration which would provide focused recharge to the aquifer if creek flows are sufficiently sustained following rains.

There are no direct measurements of groundwater recharge, nor groundwater hydrographs that would assist in elucidating the response of the aquifer system to rainfall, its potential seasonal effects and rates. Groundwater chloride values in the tested bores PB03 and PB04 are approximately 330 mg/L, while in the palaeochannel bores these concentrations are an order of magnitude higher. PB03 and PB04 chloride values suggest a low recharge rate of not exceeding approximately 1 mm/yr which in this magnitude is to be expected for this area. Chloride values from the rest of the catchment, in particular in outcrop areas, are not available (apart from Yalgoo public water supply the median chloride value of which is similar - 300 mg/L) to discuss the potential spatial variations.

4.8   Surface water and groundwater interactions

Given the alluvial nature of the region, the presence of ephemeral surface water drainage systems with floodout zones, and palaeodrainage channels, there is potential for surface water ground water interactions along the creeks and river courses. The site creeks are all ephemeral and will eventually drain to groundwater or lose water to evapotranspiration. The primary watercourses will contribute occasional recharge to aquifers when floodouts are activated.

The landforms within and surrounding the proposed mine site are strongly influenced by the geology. During rainfall events the alluvial aquifers predominantly in the south-eastern part of the development envelope will be recharged, followed by sheetflow once the soil is saturated.

5. Groundwater investigation

5.1 Overview of work complete

In order to develop the hydrogeological understanding of the site, and to assess its potential to meet the groundwater supply requirements for the Project, various stages of investigation have been completed:

- Desktop hydrogeological review

- Field reconnaissance - bore survey

- Preliminary aquifer testing on existing bores (total of 5 tests)

- Palaeovalley hydrogeological drilling investigation (10 locations drilled)

- Pit area hydrogeological drilling investigation (8 locations drilled)

- Aquifer testing (4 production bores tested)

A summary of the above stages is provided in the following sections, with tabulated data on bores constructed and tested presented as Table 5-1.

5.2 Desktop hydrogeological review

The desktop hydrogeology investigation for the Project (GHD, 2018) identified that there was insufficient data to characterise the site's hydrogeology. The general lack of site-specific data meant that there was considerable uncertainty that the potential groundwater impacts of the project could be assessed or that the Project water requirements could be met by onsite groundwater sources.

To address the uncertainty, a groundwater drilling and testing program was recommended to assess the feasibility for an onsite borefield and investigate the likely groundwater regime of the pit area to understand the dewatering requirements. The following sections provide a summary of the subsequent work completed.

5.3 Preliminary hydraulic testing – existing bores

5.3.1 Summary

A field reconnaissance visit undertaken by GHD hydrogeologists in October 2018 identified two existing bores close to the pit area (Geo Camp Bore and Drillers Bore) which were deemed suitable for testing. It is understood that both bores were installed during previous resource drilling programs undertaken in 2007. No installation or geological log data is available for either of these bores.

In addition, existing resource holes (reverse circulation and diamond core drilled holes) within the Pit area were also identified as potential holes for testing.

In light of the above, a field program for airlifting and pump testing of these bores was scheduled. The locations of the identified test sites are shown on Figure 10-10. The intention was that the testing would provide site-specific data on aquifer properties, thus informing the need and scope of subsequent drilling programs.

5.3.2 Pump tests: Existing bores

In February 2019 a testing program was completed on the two existing bores (Geo Camp Bore and Drillers Bore).

Geo Camp Bore

Geo Camp Bore is located 1.4 km north-west of the proposed Pit, and along the same strike as the resource. The depth of the bore was measured as 73 m. Whilst no existing log of the bore is available, geological mapping indicates that the bore is located within 'Olive Queen Gabbro', described as 'very coarse grained quartz gabbro with coarse spinifex-like granophyric texture with up to 10 cm crystals; metamorphosed' (GSWA, 1997). The site is close to the contact with mafic schist of the Norrie Group (to the east), which suggests that this unit may be present at depth.

Following completion of calibration tests and step tests, a constant rate test (CRT) was completed on the bore at a discharge rate of 0.5 Litres per second (L/s) for a period of 8 hours. During testing, groundwater levels were recorded in the pumping bore by manual dipped measurements and through the use of transducer data loggers. Groundwater levels were also measured at the nearest open resource hole (YORC084, 300 m to the north), but no measurable groundwater level response to pumping was observed.

Analysis of the CRT data was done using a combination of standard analytical methods using Aqtesolve software including Gringarten (vertical fractures) and Theis for unconfined aquifers. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data with both methods suggesting a hydraulic conductivity at a pumping bore location of around 0.2 m/d.

Drillers Bore

Drillers Bore is located 3 km north-west of the proposed Pit. The depth of the bore was measured as 69 m. Whilst no existing log of the bore is available, the geological mapping indicates that the bore is located within the Mugs Luck Basalt Member, described as a 'thick sequence of pyroxene spinifex-textured basalt flows; minor interlayered sedimentary and volcaniclastic rocks; metamorphosed to serpentinite' (GSWA, 1997).

Following completion of calibration tests and step tests, a CRT was completed on the bore at a rate of 1.9 L/s for a period of 5 hours. During testing, groundwater levels were recorded in the pumping bore by manual dipped measurements and through the use of a transducer data logger. Groundwater levels were also measured at the nearest bore (Geo Camp Bore 1,700 m to the east), but no measurable groundwater level response to pumping was observed.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software including Gringarten (vertical fractures) and Theis for unconfined aquifers. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data with methods suggesting a hydraulic conductivity of in the range of 0.5 to 0.6 m/d.

5.3.3   Resource holes testing

In February 2019 a testing program was completed on open resource holes within the proposed pit area. Following assessment of the resource holes, it was found that a large number of holes could not be tested because they were either:

- filled in/could not be located

- blocked at a relatively shallow depth

- too narrow to get pumping equipment down (newer diamond holes)

A total of three open holes were found that remained open to sufficient depth to get pumping equipment in. All three of these holes were inclined at 60º.

YORC079

YORC079 is located within the northern area of the proposed pit. The recorded depth of the RC hole is reported as 211 m, equivalent to 182 m vertically below ground level. The open depth of the hole was beyond the depth measurements of the field equipment (>100 m). The geological log from Ferrowest historical records describes basalt for 50 m, then BIF for most of the remaining depth. The upper 56 m is described as moderately to slightly weathered with fresh mafic BIF below this.

Following completion of calibration tests, a CRT was completed on the bore at a discharge rate of 1.8 L/s for a period of 4 hours. This was the maximum pumping rate available for the pump. During testing, groundwater levels were recorded in the pumping bore by manual dipped measurements and through the use of transducer data loggers. Maximum drawdown of only 1 m was recorded in the pumping bore, indicating that the bore could likely sustain a higher pumping rate.

Analysis of the pump test data was done using standard analytical methods using Aqtesolve. The Moench (slab shaped blocks) was found to provide the best fit for the considered conceptual model and test data. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a well aligned fit to the data, suggesting a hydraulic conductivity of the fracture/fault of 1.44 m/d and 0.65 m/d for the general rock mass.

YORC135

YORC135 is located within the northern area of the proposed pit, on the same drill-line and 75 m across strike from YORC079. The recorded depth of the RC hole is reported as 151 m, equivalent to 131 m vertically below ground level. The open depth of the hole was beyond the depth measurements of the field equipment (>100 m). The geological log from Ferrowest historical records describes interbedded basalt and BIF for 38 m, then BIF for most of the remaining depth. The upper 46 m is described as moderately to slightly weathered, with fresh Mafic BIF and Amphibolite below this.

Following completion of calibration tests, a CRT was completed on the bore at a rate of 0.55 L/s for a period of 4 hours. During testing, groundwater levels were recorded in the pumping bore by manual dipped measurements and through the use of transducer data loggers. During testing no observed drawdown was observed in YORC079.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software including Moench (with slab shaped block) and Barker for fractured rock aquifers. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data with methods suggesting a hydraulic conductivity of 0.02 m/d.

YORC081

YORC081 is located within the far northern area of the proposed pit. The recorded depth of the RC hole is reported as 182 m, equivalent to 162 m vertically below ground level. The open depth of the hole was beyond the depth measurements of the field equipment (>100 m). The geological log from Ferrowest historical records describes BIF for most of the depth, with the upper 42 m is described as moderately to slightly weathered, with fresh mafic BIF, gabbro and amphibolite below this.

Following completion of calibration tests, a CRT was completed on the bore at a rate of 0.3 L/s for a period of 4 hours. During testing, groundwater levels were recorded in the pumping bore by manual dipped measurements and through the use of transducer data loggers.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software including Barker for fractured rock aquifers and Hantush Jacob for porous aquifers. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data with methods suggesting a hydraulic conductivity in the range of 0.01 to 0.03 m/d.

5.3.4 Interpretation

As highlighted by the above, and the tabulated aquifer properties presented as Table 5-2, the hydraulic properties of the tested bores were found to be quite variable and required various different analytical solutions to provide a most appropriate match to the data. Of note is the significant difference between YORC079 and YORC135 that are located approximately 75 m apart. Both the resource holes have similar geology and weathering profiles, but show a different response to pumping.

Outside of the pit area, the data suggests a slightly higher hydraulic conductivity value for Driller Bore, located within Mugs Luck Basalt, with comparison to Geo Camp Bore located with the Olive Queen Gabbro.

The data suggest a complex relationship between locations, geology and aquifer properties. This is further discussed, with additional hydraulic interpretations made for the groundwater modelling assessment (Section 6).

5.4 Palaeovalley hydrogeological drilling investigation

5.4.1 Drilling approach

A palaeovalley system was identified within the Project area, hosting Tenement L5900156. The presence of a palaeovalley system suggests that a sedimentary aquifer with groundwater supply potential for the Project could be present. As such, an investigatory hydrogeological drilling program was undertaken that aimed to address the following:

- Identify if a suitable palaeovalley aquifer was present to offer groundwater supply potential
- Assist in delineating the extend of the aquifer to assist in groundwater model development

The proposed hydrogeological drilling program was completed in two stages, an initial investigatory drilling stage (aircore), followed by completion of test production bores and monitoring bores at the most productive groundwater sites.

5.4.2 Aircore drilling

For the investigatory drilling an aircore method was chosen as it provides a suitable approach to determine relative groundwater yield during drilling, and is suitable for drilling in sedimentary sequences.

The aircore investigatory drilling approach was to drill at accessible locations that were both within the tenement and broadly within or close to the mapped extent of the palaeovalley. In addition, locations were chosen to target any identified structural/topographical features and to align with the AEM flight lines completed by DWER/CSIRO (Davis and Macaulay, 2016).

The proposed number of drilling locations was limited to approximately 10 locations due to budgetary constraints. However a total of 19 sites were identified and pegged, allowing flexibility in which sites were drilled in accordance with field results.

5.4.3 Aircore drilling results

A total of ten aircore investigatory drilling locations were completed. A summary of the ten aircore sites is provided as Table 5-1 and are shown on Figure 10-8. Bore logs are presented as Appendix A.

All hydrogeological drilling was completed using a 100 mm diameter aircore method and continued until basement/weathered basement was intersected. As highlighted by Table 5-1, the depth to the basement (and the thickness of the sedimentary cover) varied between the drilled sites from 32 m at AC05 to 78 m at AC09. The shallow depth to basement at AC03 is interpreted as representing the thinning of the palaeovalley in its northern extent. Due to the reduced thickness of sedimentary cover in this area (and the poor groundwater yields), no drilling locations north of this were completed. The shallow depth to basement at AC05 (32 m) and AC07 (36 m) is interpreted as being a basement high. This is consistent with the AEM data which shows a variable response in these areas, possibly indicating various local basement high points.

In general, the sedimentary cover was found to be dominated by silty sands that were often weakly to well cement. The silty sands included various proportions of clays and minor coarser sands. Two locations (AC09 and AC10) were drilled beyond the western extent of the mapped palaeovalley (as defined by Geoscience Australia, 2012). Drilling was completed in the area based on the interpretation of the drilling data and assessment of the area, which suggested that palaeovalley sediments would be present beyond the previously mapped extents. The inferred updated palaeovalley extent is shown on Figure 10-8 and further discussed in the groundwater modelling section (Section 6).

Groundwater inflow was recorded during drilling, and was generally modest across the site, with inflow rates less than 1 L/s. Groundwater inflow was found to increase in zones where sands were dominant. Highest flows were found at AC04 and AC09, where the lower sand rich units provided flows of 1 to 1.5 L/s.

5.5 Palaeovalley test bores (drilling and testing)

Due to the relatively higher flows recorded at aircore sites AC04 and AC09, test production bores and monitoring bores were installed at these locations. At site AC04; test bore PB01 and monitoring bore MB AC04 were constructed. At site AC09; test bore PB02 and monitoring bore MB AC09 were constructed.

Test production bores and monitoring bores were drilled using mud-rotary techniques, with the completion depths and screen intervals determined from the interpretation of the aircore drill logs. The test bores were completed with 200 mm diameter PVC casing. The monitoring bores were completed at an approximate distance from the test production bores of 30 m, and completed with 50 mm PVC casing.

Following completion of the palaeovalley test bores and monitoring bores, and their subsequent development, both bores were tested in order to determine aquifer properties and sustainable pumping rates. The tests were completed in accordance with Australian Standards (AS 2368-1990, Test pumping of water wells). A summary of testing is provided in Table 5-2, Appendix C and the following sections.

5.5.1 PB01 testing summary

Calibrations and step rate tests indicated that PB01 could not sustain a constant pumping rate over 3.4 L/s. A CRT was completed at rate of 3 L/s for a period of 24 hrs. During the tests, pumping rates and groundwater levels were recorded in the pumping bore through use of flow meters and data loggers, and groundwater levels were recorded in the monitoring bore

(MB AC04, at a distance from the pumping bore of 36 m) through manual measurements and transducer data loggers. During the CRT, maximum drawdown in the pumping bore and monitoring bore was recorded as 45 m and 5 m respectively. An apparent bore efficiency of the test bore PB01 was calculated in the range of 34-44%.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software. Additionally, pump test analysis was also complemented by calibration of the numerical model, which is further discussed in Section 6. The most appropriate Aqtesolve solutions were found using the Theis and Copper-Jacob methods. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data. However there was a poor fit with early time data, possibly relating to bore inefficiencies and presence of drilling muds still present with the formation. Analysis indicated a hydraulic conductivity of around 0.4 m/d, consistent with reported values for a fine grained sand aquifer (Domenico and Schwartz, 1990).

5.5.2   PB02 testing summary

Calibrations and step rate tests demonstrated that PB02 could not sustain a constant pumping rate over 3 L/s. A constant rate test was completed at rate of 2.5 L/s for a period of 24 hrs. During the tests, pumping rates and groundwater levels were recorded in the pumping bore through use of flow meters and data loggers, and groundwater levels were recorded in the monitoring bore (MB AC09, at a distance from the pumping bore of 30 m) through manual measurements and transducer data loggers. During the constant rate test, maximum drawdown in the pumping bore and monitoring bore was recorded as 35 m and 0.6 m respectively. An apparent bore efficiency of the test bore PB02 was calculated in the range of 16-22%.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software. Additionally, pump test analysis was also complemented by transient calibration of the numerical model, which is further discussed in Section 6. The most appropriate Aqtesolve solutions were found using the Copper-Jacob and Tartakovsky-Neuman methods. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a good fit to the data with a calculated hydraulic conductivity in the range of 3.6 to 3.9 m/d, consistent with reported values for a fine grained sand aquifer (Domenico and Schwartz, 1990).

5.6   Pit area investigatory hydrogeological drilling - original program

Hydrogeological drilling was completed within the pit to determine aquifer properties, and to assist in making a preliminary assessment of groundwater inflow volumes and dewatering requirements.

In accordance with the Project drilling scope, a total of three investigation locations were proposed for the pit area, with one test production bore location to be chosen for the most productive site. The locations were chosen to provide a reasonable spatial distribution of drilling sites, and to represent the various areas and depths of the pit, which included:

• northern area of pit: (MB01) deepest area of the pit, up to 230 m deep,

• central area of pit: (MB02) pit up to 170 m deep; and

• southern area: (MB03) pit up to 180 m deep.

The following sections provide details of the hydrogeological drilling and bore completion for each location.

5.6.1 MB01 drilling summary

The location of MB01 was selected to represent the northern area of the pit (deepest proposed excavation) and located on a historic drillhole line that included record for four RC holes drilled to inclined depths up to 288 m.

The drilled lithology for MB01 broadly confirmed the geology detailed for the historic drillholes. A weathered profile, consisting of felsic volcanics was identified for the upper 40 m, which was recorded as dry. This was underlain by BIF, clay and amphibolite, with amphibolite becoming increasingly competent with depth.

Limited groundwater inflow rates were noted from around 85 m, with a maximum inflow rate recorded as 1 L/s. A high strength amphibolite unit was recorded from around 70 m to the base of the hole at 228 m. No fractures or increases in groundwater inflow were noted within this unit.

Due to the low groundwater inflow rates, no test production bore was chosen for this location. A monitoring bore was installed (50 mm casing) to a depth of 227 m (MB01). A slotted screen interval was installed between 167 and 227 m, with the bore annulus backfilled with graded gravel to a depth of 20 m (i.e. the whole of the potential groundwater inflow zone connected to the screen interval). The bore log for MB01 is presented in Appendix A.

5.6.2 MB02 drilling summary

The location of MB02 was selected to represent the central area of the pit and located on a historic drillhole line that included record for five RC holes drilled to inclined depths up to 263 m. The drilled lithology for MB02 broadly confirmed the geology detailed for the historic drillholes. A weathered profile, consisting of regolith and weathered BIF was identified for the upper 40 m. This was underlain by fresh BIF. Groundwater inflows were noted from around 45 m, with a maximum inflow rate recorded as 1 L/s. No fractures or increases in groundwater inflow were observed within the fresh BIF.

Due to the low groundwater inflow rates, no test production bore was chosen for this location. A monitoring bore was installed (50 mm casing) to a depth of 170 m (MB02). A slotted screen interval was installed between 110 and 170 m, with the bore annulus backfilled with graded gravel to a depth of 20 m (i.e. the whole of the potential groundwater inflow zone connected to the screen interval). The bore log for MB02 is presented in Appendix A.

5.6.3 MB03 / PB03 drilling summary

The location of MB03 was selected to represent the southern area of the pit and located on a historic drillhole line that included record for six RC holes drilled to inclined depths up to 239 m. The drilling of MB03 intersected regolith and weathered BIF for the upper 40 m, broadly consistent with MB01 and MB02, however the groundwater inflow was significantly greater, up to 15 L/s at 30 m. Groundwater inflow increased with depth as the geology became less weathered with fractured amphibolite and BIF identified as the flow zone. Groundwater inflow rates up to 20 L/s were recorded from around 40 m. The lithology log for MB03 broadly confirmed the geology detailed for the historic drillholes, however the weathering and fractured zones were not so readily identifiable on the historic drillhole logs.

Groundwater inflow did not increase beyond around 60 m where the BIF became fresh. A further minor groundwater increase was noted at around 135 m where a narrow band of fracturing was identified (fluorite and muscovite). Total groundwater inflow was up to 25 L/s at this depth (a combination of flow from this zone and above).

Based on the strike results this location was considered a suitable site for a test production bore. The initial pilot hole was reamed to allow for the installation of 200 mm PVC cased test bore casing (PB03). The test bore was installed to a depth of 70 m, with a screened interval of

34 to 64 m (6 m sump beneath the screens). The test bore PB03 was gravel packed from the base of the bore annulus to 20 m and backfilled with drill cuttings above this depth. Monitoring bore MB03 was then installed on the same pad, 9 m from PB03. The monitoring bore was constructed with 50 mm casing, to the same depth specifications as PB03. Bore logs for PB03 and MB03 are presented in Appendix A.

5.7 Pit area investigatory hydrogeological drilling - additional program

Following the encouraging groundwater flows found at PB03/MB03, the drilling program was extended to assess the groundwater supply potential of several locations outside of the pit footprint. The locations (EH holes) are shown on Figure 10-9, and were chosen based on the following reasoning:

- Targets identified by FIJV, along an existing east-west track, approximately 1.5 km south of the Pit (2 to 3 targets).

- Targets in the area of historic drillhole YORC089: This site was chosen as the log for YORC089 indicated a significant depth of weathered profile of up to 85 m (1 target).

- Target identified east of pit, relatively close to high yielding PB03, and coinciding with an existing stream channel (2 targets).

The following sections provide a summary of the drilling and bore completion for each location.

5.7.1 EH01 and EH02 drilling summary

For sites EH01 and EH02, located just east of the pit, the drilling identified significant weathered profiles, with a deep gravelly clay found for up to around 75 m, underlain by hard rock (possible mafic schist). However, despite the gravel-rich profile, the existing clay matrix limited groundwater flow, with yields generally not exceeding more than 4 L/s.

No test production bore was chosen for these locations. As the holes remained open at the end of the program, 50 mm casing was installed to offer opportunities to use the bores as monitoring bores. The bore logs for EH01 and EH02 are presented in Appendix A.

5.7.2 EH03 and EH04 drilling summary

For sites EH03 and EH04, located 1.8 km south pit, the drilling identified a very thin weathered profile. For EH04, regolith and alluvial gravels were found for the upper 10 m, whereas for EH03 only 2 m of regolith was found.

Beneath the weathered/alluvial profile, both sites found hard rock (described as schist), continuing until the cessation of drilling at 40 to 44 m. Drilling was ceased at these depths due to the lack of weathering profile and no indications of increasing groundwater inflow. Minor yields were recorded at EH03, not exceeding 0.3 L/s, whereas flows up to 6 L/s were recorded at EH04.

No test production bore was chosen for these locations. As the holes remained open at the end of the program, 50 mm casing was installed to offer opportunities to use the bores as monitoring bores. The bore logs for EH03 and EH04 are presented in Appendix A.

5.7.3 EH05 (PB04 / MB04) drilling summary

Drilling at site EH05 identified a significant weathered profile, consistent with the log for YORC089. The weathered profile consisted of gravelly clay, with gravel dominant and weathered/fractured BIF zones throughout, up to a depth of around 95 m. Groundwater inflow

was recorded from a depth of around 44 m, with yields generally increasing with depth, up to a maximum recorded yield of 12 L/s at the base of the bore.

Based on observed yields the site was selected for installation of a test production bore. The initial pilot hole (EH05) was reamed to allow the installation of 200 mm PVC cased test bore casing (PB04). The presence of gravel and fractured BIF nature of the lithology posed difficulties in maintaining an open hole to depth to allow casing installation. Fall-back within the bore limited the casing installation to a depth of 47 m, however still within the main groundwater inflow zone.

Monitoring bore MB04 was installed 60 m from PB04. The monitoring bore was constructed with 50 mm casing, to the same depth specifications as PB04. Bore logs for PB04 and MB04 are presented in Appendix A.

5.8   Pit area hydraulic testing

Following completion of the pit area test bores and monitoring bores, and their subsequent development, both bores were hydraulically tested in order to determine aquifer hydraulic properties and sustainable pumping rates. The tests were completed in accordance with Australian Standards (AS 2368-1990, Test pumping of water wells). A summary of testing is provided in Table 5-2, Appendix C and the following sections.

5.8.1   Testing at PB03

Calibration and step rate tests completed at PB03 demonstrated that the bore could nominally sustain a pumping rate of up to 30 L/s. A rate for the constant rate test was chosen at 25 L/s to allow an extended constant rate test for a proposed period of 72 hours. This duration was chosen to allow a more detailed assessment of aquifer response to pumping at this highest yielding site.

During the test, pumping rates and groundwater levels were recorded in the pumping bore through use of flow meters and data loggers. Groundwater levels were recorded in MB03, 9 m from the test bore, and also at the nearby monitoring bores MB04 (750 m), MB02 (814 m) and MB01 (1,590 m). Groundwater levels in these monitoring bores were recorded through use of transducer data loggers, calibrated by manually dipped measurements.

During the constant rate test, maximum drawdown in the pumping bore was recorded as 17.5 m. For monitoring bore MB03, maximum drawdown was around 8 m. For distant monitoring bores MB02 and MB01, drawdown at the end of the constant rate test was 0.75 m and 0.18 m respectively. An apparent bore efficiency of the test bore PB03 was calculated in the range of 59 to 74%.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software. Additionally, test analysis was also completed using the numerical model, which is further discussed in Section 6. The applied Aqtesolve solutions were based on the Theis, Moench and Neuman methods. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a good fit to the data with a calculated a hydraulic conductivity in the range of 1.7 to 3.5 m/d.

5.8.2   Testing at PB04

Calibrations and step rate tests demonstrated that PB04 could sustain a constant pumping rate of less than 12 L/s. A constant rate test was completed at rate of 5 L/s for a period of 24 hrs. During the tests, pumping rates and groundwater levels were recorded in the pumping bore through use of flow meters and data loggers, and groundwater levels were recorded in the monitoring bore (MB04 at a distance from the pumping bore of 60 m) through manual

measurements and transducer data loggers. During the constant rate test, maximum drawdown in the pumping bore and monitoring bore was recorded as 13 m and 3 m respectively. An apparent bore efficiency of the test bore PB04 was calculated in the range of 88-92%.

Analysis of the pump test data was done using a combination of standard analytical methods using Aqtesolve software. Additionally, test analysis was also aided using the numerical model, which is further discussed in Section 6. The Theis, Moench and Neuman methods were used for analysis. A summary of the interpreted aquifer properties is provided in Table 5-2 and Aqtesolve outputs presented as Appendix C. The analysis showed a reasonable fit to the data, albeit with poorly matched recovery data. The data indicated a calculated hydraulic conductivity in the range of 0.5 to 0.9 m/d.

Table 5-1 - Summary of drilling completed

Program	Bore ID	Type	Easting	Northing	Drilled depth(m bgl)	Screen interval (m bgl)	SWL* (m bgl)	Hydrogeological setting / comments
Palaeovalley - Aircore	AC01	Aircore*	488,360	6,867,459	61	NA	12.00	Palaeovalley – Minor groundwater potential, dominance of silts/clays
	AC02	Aircore	488,307	6,869,973	66	NA	13.50	Palaeovalley – Minor groundwater potential, dominance of silts/clays
	AC03	Aircore	488,306	6,872,219	36	NA	13.80	Palaeovalley – Minor groundwater potential, thin sequence of silts/clays over shallow basement (granite)
	AC04	Aircore	486,992	6,867,434	78	NA	11.80	Palaeovalley – minor groundwater potential, sands within silty profile (PB01 and MB AC04 constructed at this location)
	AC05	Aircore	489,148	6,865,772	32	NA	7.40	Palaeovalley – Minor groundwater potential, thin sequence of silts/clays over shallow basement (granite)
	AC06	Aircore	488,653	6,865,226	60	NA	7.40	Palaeovalley – Minor groundwater potential, dominance of silts/clays
	AC07	Aircore	486,607	6,864,804	36	NA	7.40	Palaeovalley – Minor groundwater potential, thin sequence of silts/clays over shallow basement (granite)
	AC08	Aircore	487,603	6,867,443	62	NA	7.80	Palaeovalley – Minor groundwater potential, dominance of silts/clays

Program	Bore ID	Type	Easting	Northing	Drilled depth(m bgl)	Screen interval (m bgl)	SWL* (m bgl)	Hydrogeological setting / comments
Palaeovalley - Bore install	AC09	Aircore	485,598	6,864,635	60	NA	7.80	Palaeovalley – Minor groundwater potential, sands within silty profile (PB02 and MB AC09 constructed at this location)
	AC10	Aircore	485,981	6,864,732	59	NA	7.60	Palaeovalley – Minor groundwater potential, sands within silty profile
	MB_AC04	Monitoring bore	486,983	6,867,438	76	55-73	13.70	Monitoring bore at site AC04, adjacent to PB01
	MB_AC09	Monitoring bore	485,586	6,864,636	55	35-42	8.10	Monitoring bore at site AC09, adjacent to PB02
	PB01	Production bore	486,988	6,867,409	73	52-70	13.10	Test production bore at site of AC04
	PB02	Production bore	485,597	6,864,634	62	34-52	8.30	Test production bore at site of AC09
In pit	MB01	Monitoring bore	479,556	6,878,274	228	167-227	25.50	Amphibolite dominant lithology, lack of fracturing/weathered profile, low groundwater inflow (1 L/s)
	MB02	Monitoring bore	480,117	6,877,732	170	110-170	25.50	Fresh BIF dominant lithology, lack of fracturing/weathered profile, low groundwater inflow (1 L/s)
	MB03	Monitoring bore	480,622	6,877,097	70	40-70	17.34	Monitoring bore adjacent to PB03
	PB03	Production bore	480,615	6,877,088	174	34-64	16.10	Weathered and fractured BIF/amphibolite lithology in upper 50 m, resulting high groundwater inflow (25 L/s). Fresh BIF beneath 50 m.
Pit area investigati	EH01	Monitoring bore	480,962	6,877,164	78	5-23	10.5	Significant weathered profile, clay dominant, groundwater inflow up to 4 L/s/

Program	Bore ID	Type	Easting	Northing	Drilled depth(m bgl)	Screen interval (m bgl)	SWL* (m bgl)	Hydrogeological setting / comments
	EH02	Monitoring bore	481,037	6,877,321	80	0-64.5	12.0	Significant weathered profile, clay dominant, groundwater inflow up to 3.5 L/s/
	EH03	Monitoring bore	481,826	6,875,419	40	20-38	16.00	Fresh rock (schist) dominant, low groundwater inflow (0.3 L/s)
	EH04	Monitoring bore	482,155	6,875,472	44	20-39	15.0	Fresh rock (schist) dominant, moderate groundwater inflow (6 L/s)
	MB04	Monitoring bore	480,976	6,876,431	54	32-44	12.50	Monitoring bore adjacent to PB04
	PB04	Production bore	481,040	6,876,439	100	23-47	11.90	Significant weathered profile, gravels and weathered/fractured BIF, moderate groundwater inflow (10 L/s)

Table 5-2 - Summary of hydraulic testing

Site	Tests completed	Geo setting	T (m²/d)	Ss (m⁻¹)	Ss' (m⁻¹)	S	Sy	K (m/d)	K' (m/d)	B (m)	Method
PB01	Calibration, SRT (2, 2.5, 3, 3.1). CRT 24 hr at 3 L/s.	In 'Palaeovalley'. Approx 74 metres of sediments. Mostly silty sand, clayey sand, and cemented (calcrete) fine grained sands. Screened sandier zone at depth.	24			0.0001		0.42		57	Theis unconfined
			19.76			0.0023		0.35		57	Cooper Jacob unconfined
PB02	Calibration, SRT (2, 2.5 & 3). CRT 24 hr at 2.5 L/s.	In 'Palaeovalley'. Approx 55 metres of sediments. Mostly silty sand, clayey sand, and cemented (calcrete) fine grained sands. Screened sandier zone at depth.	164			0.002		3.9		42	Cooper Jacob unconfined
			153			0.002	0.1	3.6		42	Tartakovsky Neuman
PB03	Calibration, SRT (15,20,25,30	In Pit. Most flow in fractured amphibolite (28-40m) and overlying	122			0.1210	0.1	3.1		39	Moench Unconfined
			66.3	0.0002	0.001	0.0000	0	1.7	1.44	39	Barker Fractured

Site	Tests completed	Geo setting	T (m²/d)	Ss (m⁻¹)	Ss' (m⁻¹)	S	Sy	K (m/d)	K' (m/d)	B (m)	Method
	L/s). CRT at 25 L/s for 72 hrs	regolith (2-28m). Underlying flow zone was very tight BIF. Minor flow zone at 134-136 m (not tested) in fluorite vein.	137			0.0188	0	3.5		39	Theis Unconfined
PB04	Calibration, SRT (6 and 10 L/s). CRT at 5 L/s for 24 hrs	South of Pit. Unusually weathered geological profile. Gravels, and gravelly clay of 0-96m (all BIF parent). Including rounded river like gravels present for full depth. Amphibolite at basement from 96 m. Test bore constructed at shallower depth due to collapse.	32.3			0.0014		0.9		35	Theis Unconfined w bound
			18.16			0.0008	0.1	0.5		35	Moench Unconfined
			19.6			0.00086	0.1	0.6		35	Neuman
	Calibration, SRT, CRT (8 hrs at	No log. 100 k simple geology shown	11			6^{-10}		0.2		55	Gringarten (Vertical)

Site	Tests completed	Geo setting	T (m²/d)	Ss (m⁻¹)	Ss' (m⁻¹)	S	Sy	K (m/d)	K' (m/d)	B (m)	Method
Geo Camp Bore	0.5 L.s), recovery	within Olive Queen Gabbro. BIF to east that may intersect bore.	10.53			2^{-16}		0.2		55	Theis unconfined with boundary
Drillers Bore	Calibration test, constant rate test (5 hrs at 1.9 L.s), recovery	No log. 100 k geology shown within Mugs Luck Basalt Member Complex sequence in area.	23.5			8^{-11}		0.5		47	Gringarten (vertical)
			29.6			5^{-9}		0.6		47	Theis unconfined with boundary
YORC081	Calibration test, constant rate test (4 hrs at 0.3 L.s), recovery	Geo for YORC081 shows Mafic BIF for most of depth. 100K simple geology shown within Olive Queen Gabbro	4.5	7^{-13}	0.00011			0.03	0.00002	150	Barker
			1.87			0.0484		0.01		150	Hantush Jacob
YORC079	Calibration test, constant rate test (4 hrs at 1.8 L.s), recovery	Geo for YORC079 shows upper basalt for 50m, then BIF for most of depth. Described as moderately to slightly weathered for upper 56 m. 100K geology shown within Olive Queen Gabbro	126	2^{-11}	0.001			0.7	1.44	180	Moench w/slab blocks

Site	Tests completed	Geo setting	T (m²/d)	Ss (m⁻¹)	Ss' (m⁻¹)	S	Sy	K (m/d)	K' (m/d)	B (m)	Method
YORC135	Calibration test, constant rate test (4 hrs at 0.55 L.s), recovery	Geo for YORC079 shows upper basalt for 50m, then BIF for most of depth. 100K geology shown within Olive Queen Gabbro	2.4	3^{-12}	0.001			0.02	1.44	120	Moench w/slab blocks
			2.4	3^{-12}	0.001			0.02	1.44	120	Barker

5.8.3   Interpretation of initial testing results

The first phase of aquifer testing was inevitably limited to the key areas of interest, the mining pit area and the palaeochannel aquifer. The aim of testing - an initial understanding of how these areas perform to the applied stresses which would also give indications of associated environmental effects, was followed during the program.

Yields of individual tested bores confirmed the heterogeneous nature of the aquifer system composed of fractured and weathered basement. Within the pita area up to 25 L/s was confirmed during the 3-day test. The drawdown during this test did not fully stabilise and it remains to be seen whether this rate would be sustainable over a long period of pumping.

The testing results also indicate the presence structural features that can locally obstruct or enhance groundwater flow. Hydraulic connectivity between PB03 cluster and MB01 and MB02 suggests a good degree of connectivity and possibly the presence of the connecting structural feature associated with BIF mineralisation. Connectivity between PB03 and PB04 clusters has not been established however this is due to absence of water level data during applied pumping stresses.

Across the strike the connectivity between the BIF structure and the neighbouring granitoid basement (to the east) is not apparent based on water level measurements in EH01 which stayed stable during testing on PB03 (and PB04).

Step discharge tests indicate small efficiency in production bores in the palaeochannel aquifer with up to 80-90% of head losses in the pumping bore attributable to well losses. This is indicative of the fact that these bores would require longer than usual development, to remove fine particles around bore and increase its yield. The tested yields in the palaeochannel aquifer are considered average for the region but adequate to the fact that these bores were installed on the palaeo-tributary rather than main palaeochannel. This limitation is due to current tenement area which does not extend into the main palaeovalley.

The testing results for the two palaeochannel production bores suggest different environments, with enhanced permeability around the PB02 cluster (an order of magnitude higher than around PB01 cluster). This may be due to the north-south structural feature (shear zone?) mapped in the basement in that area which may locally enhance groundwater flow.

The properties of greenstone basement and its weathered zone and/or alluvial and colluvial deposits overlaying it have not been tested and would need to be included in any subsequent hydrogeological investigation since they present the potential pathway between the minesite and the Town water supply. The basement is also known to be criss-crossed by a number of dolerite dykes the function of which from groundwater flow perspective is unknown. In some hydrogeological settings they are known to function as barriers to groundwater flow and contribute to its possible compartmentalisation. Longer-term groundwater level monitoring and targeted testing would be required whether compartmentalisation occurs in the area and has relevant effect on groundwater flow.

5.9   Groundwater quality

At the completion of the constant rate tests on the four test production bores, groundwater quality samples were taken for laboratory analysis. An analysis suite was selected to provide a baseline indication of groundwater quality. This included major ions, dissolved metals, nutrients and inorganics. The analytical results are presented in Appendix D, which includes comparison of the results to various assessment criteria, included primarily for comparative purposes only. Key observations from the results are detailed below:

- There is a significant difference between the groundwater quality results for the palaeovalley test bores (PB01 and PB02) and the pit area test bores (PB03 and PB04). A key difference between these two areas is the high salinity recorded in the palaeovalley test bores. These bores have a TDS around 10,000 mg/L, compared to just over 800 mg/L recorded in the pit area test bores. Groundwater with a salinity greater than 5,000 mg/L is considered unsuitable for stock watering.

- Consistent with the elevated salinity found in the palaeovalley test bores, major ion concentrations are all elevated in these bores.

- The relatively fresh groundwater (low salinity) found at the pit bores is indicative of those bores being close to a groundwater recharge area. Groundwater chloride values in these bores are approximately 330 mg/L – similar to Yalgoo production bore the median chloride value of which is 300 mg/L.

- All Yogi tenement samples reflect the sodium chloride dominated type present in the area (Figure 5-1). This suggests that atmospheric chloride, after undergoing various degrees of evapoconcentration is the main component of groundwaters in the area. In comparison to the palaeovalley samples, the pit samples have elevated proportions of magnesium indicating an input from mafic and ultramafic basement. The Yalgoo Water Supply sample, while also sodium-chloride dominated is transitional in its genesis in that magnesium proportion is yet higher than that of the pit area bores and it has higher alkalinity (bicarbonate) proportion suggesting additional dissolution of the mafic rock matrix by weak carbonic acid from locally recharging groundwater.

- Nitrogen concentrations vary between the palaeovalley and pit area bores. The pit area bores show higher nitrogen concentrations, predominately as nitrate nitrogen (up to 11 mg/L as N). This may be related to naturally occurring sources and/or surface water runoff (resulting in recharge) in areas that are grazed by cattle. The bores suppling the Yalgoo Town Water Supply have historically reported median nitrate concentrations of 18.5 mg/L, more than the maximum recorded for the four bores (11 mg/L in PB04). The nitrate concentrations of the palaeovalley bores (PB01 and PB02) are 4 to 6 mg/L as N due to the possibly less oxic conditions or limited availability of nitrate in the deeper-seated palaeo-alluvium.

- Metal concentrations were generally low for all test bores with no recorded exceedance of any assessment criteria. Of note was the lack of exceedance of arsenic concentrations as the bores suppling the Yalgoo Town Water Supply have historically reported elevated arsenic, with a median concentration of 0.009 mg/L (DWER, 2010). Bores PB01 and PB04 were the only bores to record concentration above the laboratory detection limits, with both recording arsenic concentrations of 0.001 mg/L.
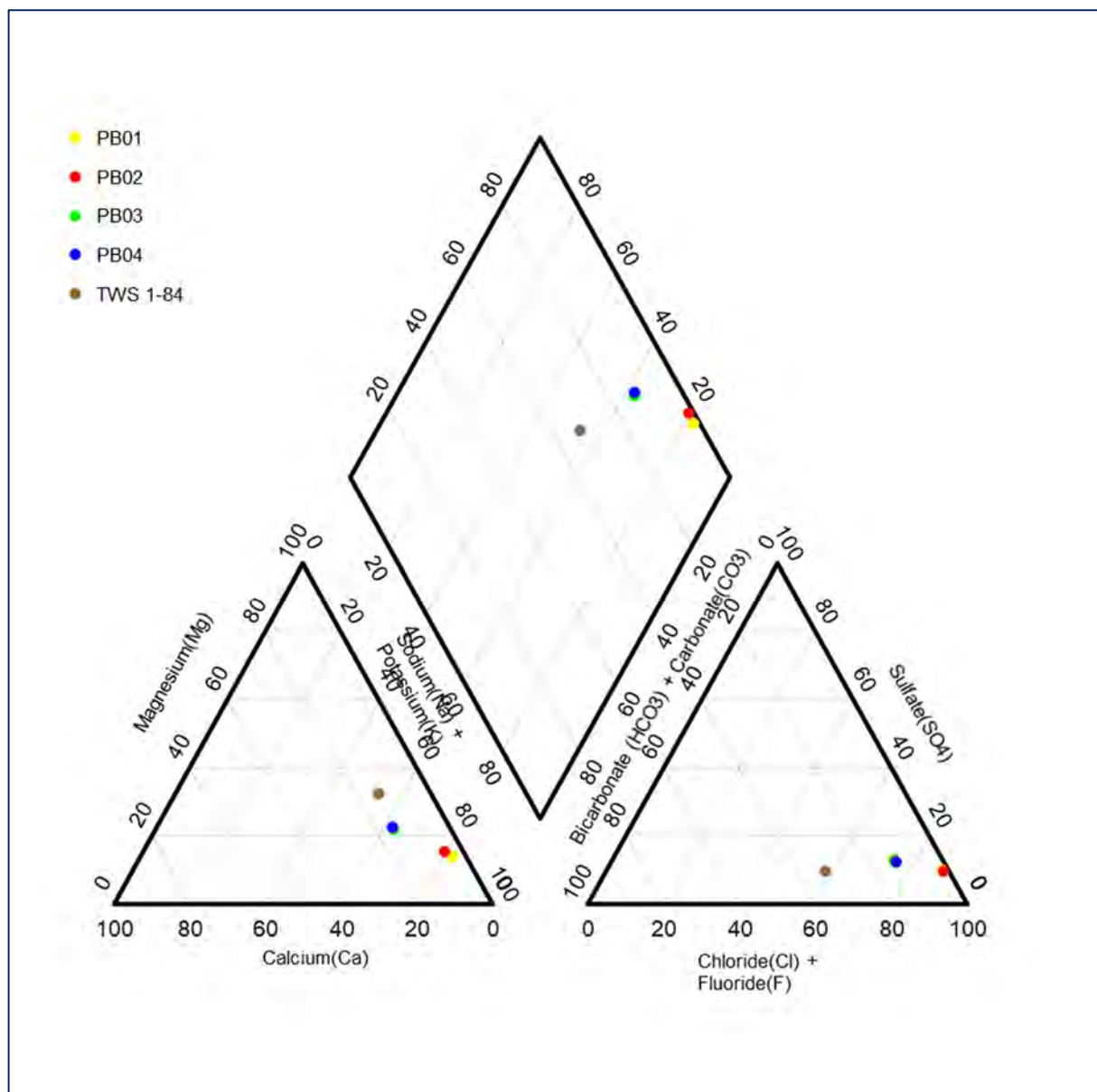
Figure 5-1 - Piper diagram of production bore samples (including Yalgoo Public Water Supply)

6. Numerical modelling

6.1 Objectives of numerical groundwater flow modelling

The purpose of numerical groundwater flow modelling is to assist in assessment of groundwater change for the LoM due to anticipated dewatering of the open cut pit and abstraction from the mine borefield. Assessment of the feasibility and related groundwater change for the mine operational footprint requires development of a suitable conceptual model for the regional groundwater system, and a numerical groundwater modelling system for quantitative analysis of the groundwater system response.

This section describes the following:

- Hydrogeological conceptualisation
- Development of the numerical model, modelling of dewatering and inflow rates and prediction of water level change during mining and post closure
- Proposed monitoring of mining impacts on groundwater and any additional work to reduce inherent prediction uncertainties

Specific objectives of the numerical modelling effort include estimated:

- Hydrogeological conditions prior to mining at Yogi (steady state), during mining and post mining
- Extent of groundwater level change associated with dewatering and production bore pumping (including town water supply)
- Rates of groundwater inflow into the pit during mining (dewatering) and post closure (groundwater level rebound)

Model results were used to assess potential impacts on groundwater dependent ecosystems and third party users in the study area.

Due to the nature, feasibility level and regional scale of this assessment, the evaluated LoM impacts will be evaluated from the regional rather than localised, operational scale. In terms of Australian Groundwater Modelling Guidelines (Barnett et al, 2012) the model is a Class 1-2, impact assessment model, primarily due to the lack of useful time-series data that can be used for calibration; and also due to insufficient stress applied on the aquifer before mining occurs. The dewatering rate required for mining is likely to be at least an order of magnitude higher than aquifer testing performed for this project.

The level of confidence is expected to increase in the future, once additional testing is undertaken around the area of groundwater impacts, with a monitoring dataset that will include at least one year's worth of monitoring and/or when mining starts and model validation can be undertaken.

6.2 Approach

Evaluation of potential groundwater impacts associated with mining at Yogi during development, operation and closure stages included:

- Collation of available hydrogeological data, including bore databases, geophysical data and geological mapping

- Construction of a simple hydrostratigraphical 3D model at a regional scale with major aquifer systems

- Refinement of a hydrogeological conceptual site model that considers regional-scale hydrogeological and site-specific information

- Construction and initial calibration of a regional-scale model with information refinement on the project tenement which simulates:

  o Pre-mining ('steady state') conditions

  o Transient conditions reflective of aquifer testing undertaken on site

  o Transient conditions as estimated during the vertical progression of the mining pit and operation of water supply bores

  o Transient conditions of post closure rebound and pit lake development in the open pit

6.3 Conceptual hydrogeological model

6.3.1 Model domain

The model domain is broadly consistent with the Salt River surface catchment area. It was delineated to represent the hydrogeological system at a regional scale and allowing having model boundaries sufficiently far from the Yogi to eliminate potential boundary effects. The model domain is also intended to provide opportunities for simulation of groundwater abstraction from the palaeochannel aquifer outside of the model tenement should it be required. The model domain covers an area of 9,145 km^2. Maps/Figures for the groundwater modelling are included as Appendix E. The model domain is shown on Figure E- 1.

The easternmost part of the Yarra Yarra Salt River catchment is not part of the model domain as it is not deemed material to this project.

6.3.2 Hydrogeological conceptual model

The hydrogeological conceptual model forms the basis of the numerical modelling and subsequent numerical predictions. The conceptual model is based on the following key flow processes:

- Topographically-driven groundwater flow oriented from the elevated areas (usually basement outcrops) towards the regional drainage lines, with two components of flow present, in the Cainozoic sediments, and the underlying weathered and fractured basement aquifers (greenstone and granitoid).

- Diffuse groundwater recharge is occasionally supplemented by short-term duration high-intensity flooding following cyclonic events.

- Groundwater removal (dewatering) associated with mining will commence in the near future and will take place for 21 years. This may be complemented, when necessary, with groundwater extraction from yet to be established borefields around the mining area and from palaeochannel aquifers.

- Groundwater discharge from dewatering and supplemented, if necessary, by production borefield(s) is planned to be used for processing and transport of ore. Average water demand for applied mining methods is estimated at up to 5 GL/yr (160 L/s).

- Under natural conditions the groundwater flow-paths terminate in or are redirected into the alluvia of major drainages (Salt River system).

- The study area is considered an effectively closed system in that fluxes between the study area and the surrounding areas are considered negligible and as a consequence would be considered zero-flux boundaries. An exception is a section at the south-western boundary where minor groundwater is expected to leave the catchment in the Salt River alluvium. This will be considered a specified head boundary.

The important features of hydrogeological conceptualisation are summarised in Table 6-1:

Table 6-1 - Summary of hydrogeological conceptual model

Element/feature	Description
Assessment domain	9,145 km^2 (larger part of the surface water catchment), deemed sufficiently extensive for regional impact assessment
Aquifer units	Surficial sediments – alluvium, colluvium, lake sediments Palaeochannel sand Weathered basement (greenstone, granitoid, metasediments) Fractured basement, including shear zones
Groundwater recharge	Basement outcrops (granitoids, greenstone) – on average up to 1 mm/yr Sandstone outcrops (west of the tenement) – on average up to 2 mm/yr Alluvia of major drainages – on average up to 1 mm/yr (may temporarily rise in response to major rainfall events) Colluvium – negligible recharge assumed under prevailing conditions, sheet-flow is common and has been observed in the area. No seasonal variations or medium to long-term trends considered at this level (due to lack of time series data), the rates are assumed to be 'steady state'.
Groundwater discharge	Evaporation and evapotranspiration in low-lying areas or areas with shallow groundwater. The rate of potential evapotranspiration can be applied at the ground surface, with linear decrease in rate with and up to extinction rates (up to 2 m below ground level)
Groundwater salinity	Groundwater salinity ranges between 800 mg/L in the greenstone bores to 10,000 mg/L in the palaeovalleys
Groundwater flow	Topographically driven groundwater flow with flow directions aligned with major drainage features in the area. Compartmentalisation or preferred flow-paths may be associated with numerous structural features such as dolerite dykes and shear zones. BIF mineralisation is likely to be associated with active groundwater flow.
Surface water groundwater interaction	In the majority of the study area groundwater depths are more than 5 m below ground and effectively removed from direct surface water groundwater interaction. Intermittent drainage network is considered to interact with groundwater both in a drainage and a recharge capacity. Alluvium along the Salt River receives groundwater from elevated areas which is subjected to evapotranspiration. Occasional, infrequent high volume rainfall events may temporarily refresh groundwater resources in major alluvial systems.
Groundwater abstraction/removal	Currently minor (stock bores, and town water supply 1 to 2 L/s). Dewatering during mining is considered to temporarily become a major groundwater abstraction component.

6.3.3   Conceptual water balance

The conceptual water balance represents broad average recharge and discharge conditions representative of a quasi-steady state, with negligible changes in aquifer storage.

Sheet-flow and creek flow events following cyclonic rainfall represent a significant but assumingly relatively short-term deviation from the study area's water balance.

The recharge from the basement outcrops is estimated to amount up to 9 GL/yr in greenstone and 12 GL/yr in granitoid terranes. The recharge occurring in various alluvia, including calcrete and lake deposits in the model domain is estimated to occur at a rate of 6 GL/yr. Recharge in sandplains, colluvium and durricrust is assumed to be negligible.

The overall average recharge to the model domain is estimated at 27 GL/yr.

Groundwater flow in the study area eventually terminates predominantly via the process of evaporation and evapotranspiration in alluvial and riparian zones and in other smaller areas where groundwater may be close to the ground surface. Based on the water level contour map derived from the domain-wide water level records and the 30 m DEM representing ground elevations, the area with shallow groundwater (less than 5 m BGL) is estimated to cover 3,690 km^2, or 2,246 km^2 (i.e. for areas with depth to water less than 3 m constituting 25% of the study area).

Areal actual evapotranspiration rate in the area is closer to 300 mm/yr (BOM, http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp). If applied over the shallow groundwater footprint (i.e. less than 5 or 3 m BGL) at this rate in the model domain during an average year, the evapotranspired volume is theoretically an order of magnitude higher than received recharge suggesting that all groundwater budget inputs are predominantly balanced by evapotranspiration.

6.3.4   Assumptions

The following assumptions are inherent in this modelling assessment:

- The presented conceptual model and its parameterisation is considered valid for the scale of assessment

- Mean annual rainfall and evaporation are considered representative for the modelled period (inter-annual variations are neglected); both rainfall and evapotranspiration are uniform within recharge and evapotranspiration zones (no intra-zonal variability)

- Large rainfall events do not have a lasting effect on the groundwater system

- The 30 m DEM is sufficient representation of ground surface for the regional-scale model

- Homogeneous bulk hydraulic properties are applied for the major aquifer units considered in this conceptual and numerical model (despite intricacies associated with fractured rock formations)

- Groundwater flow at a regional scale can be approximated with porous flow characteristics

- The mining plan is based on uniform progressive deepening of the mining pit over its pitshell footprint at a rate of 6 m per 6 months of mining, to maximum mining depth of 125 m AHD. The varying surface of the final pit base is honoured in this assessment (ranging between 125 to 200 m AHD).

6.4 Model set up

6.4.1 Numerical code selection

MODFLOW-USG was selected due to its unstructured grid capability which allowed simulation of site-scale features within the confines of a large regional model. The unstructured grid allows for efficient discretisation design that can address issues associated with varying resolution of geological and hydrogeological information.

6.4.2 Model discretisation

The regional model covers an area of over 9,000 km^2 (Figure E- 1). The selected model boundaries represent catchment boundaries except for the eastern boundary. An unstructured grid design is used to increase grid resolution in the pit area and areas of aquifer testing. Increased grid resolution is also applied in palaeochannels (Figure E- 2).

The model has 243,639 grid cells, out of which 226,787 are active. The dimension of grid cells varies from 15 to 1000 m.

Vertically, the model grid is discretised into three non-uniform layers derived from a Leapfrog 3D hydrostratigraphical model. Model layer 1 simulates predominantly surficial sediments and weathered basement outcrops; layer 2 represents weathered basement and palaeochannel sands, and layer 3 embodies fractured greenstone and granitoid basement.

Ground surface elevation, layer base elevations (layers 1 and 2) and (top of layer 1), as applied in the model grid, are presented in Figure E- 3, Figure E- 4 and Figure E- 5 respectively. Layer 1 base elevation is uniform, 80 m AHD.

6.4.3 Recharge specification

The model has the capability to provide recharge rates per individual key units: greenstone and granitoid basements, sedimentary units with greenstone basement and various surficial deposits. The spatial distribution of recharge zones based on key hydrostratigraphical units and land-systems is presented Figure E- 11. There is however insufficient information to differentiate the recharge rates for individual zones at this stage and a number of units have similar or identical recharge rates in the current model. These are broadly supported by estimates obtained from application of the chloride method and from experience with other similar areas:

- Alluvial and lake deposits – 7.3 mm/yr (2.8% of mean annual rainfall)
- Basement outcrops – 7.3 mm/yr (2.8% of mean annual rainfall)
- Sedimentary outcrops in greenstone basement – 20 mm/yr (7.8% of mean annual rainfall)
- Colluvium and other surficial cover – negligible

These rates of recharge generate a combined recharge volume of 27.6 GL/yr, which represents a bulk area average of 3 mm/yr (1.2% of mean annual rainfall).

Recharge rates are kept constant with time in current simulations.

6.4.4 Evapotranspiration

Evapotranspiration effects are important as they represent a major groundwater sink. Evapotranspiration is active in areas with shallow groundwater and phreatotype vegetation, notably in low-lying flat areas and along the drainage lines. The evapotranspiration rate applied in the model linearly reduces from maximum rate at the ground surface until it reaches depth at which evapotranspiration is negligible (extinction depth). Average daily surface

evapotranspiration rate implemented in the model is 5 mm/d, with extinction depth of 2 m. Extinction depth would be larger in areas with gumtrees and similar vegetation communities.

6.4.5   Boundary conditions

Since the model domain boundaries are consistent with surface water catchment boundaries, flux between the model domain and neighbouring areas is considered negligible and therefore assigned as no flux. There are the following exceptions:

- Outflow from the model through Salt River alluvium on the south-west boundary is simulated using a specified head boundary. The specified head is kept at a level of several metres below the ground surface consistent with shallow groundwater in alluvium. In this case the water level is maintained at 298 m RL (ground elevation is approximately 302 m RL, based on 30 m DEM). The width of this boundary is 1800 m.

- The eastern boundary of the model is drawn along a larger unnamed drainage line which would locally collect surface runoff and potentially some groundwater discharge. This is modelled using a DRAIN package with drain cell elevations set at 2 m below the ground elevation (to account for the incised nature of the drainage line). The length of the DRAIN boundary is approximately 20 km.

The two boundaries represent minor, almost negligible components of the overall water balance.

6.4.6   Hydraulic conductivity and storativity

The hydraulic parameter distribution is based on regional geology. Based on distribution of key geological units. The surface geology and basement geology are shown on Figure E- 6and Figure E- 7 respectively. The basic parameter zones include greenstone, granitoid, palaeochannel sands and surficial deposits. The basement units also differentiate between their upper weathered and lower fresh fractured parts.

During pumping test calibration it was also necessary to represent a discrete zone of higher permeability associated with BIF genesis in the pit area. The outline of that zone was estimated from geophysical data.

The parameter zone distribution in individual model layers is presented in Appendix E (Figure E- 8, Figure E- 9 and Figure E- 10 for layers 1, 2 and 3 respectively). There are no regionally available parameter values available from the model domain area. The only indication is available from hydraulic testing performed for this project and reported in Section 5. Parameter values used in the model are presented in Table 6-2.

Table 6-2 - Modelled hydraulic conductivity and storativity values

Parameter zone	Horizontal hydraulic conductivity (m/d)	Vertical hydraulic conductivity (m/d)	Specific storage (1/m); specific yield
Surficial cover	0.5	0.05	1×10^{-5}; 0.1
Weathered granite	0.06	0.006	1×10^{-6}; 0.004
Weathered greenstone	0.15	0.015	1×10^{-6}; 0.005
Palaeochannel sand	0.5	0.001	1×10^{-5}; 0.03
BIF zone	5	2.5	1×10^{-6}; 0.005
Shear zone	3	3	1×10^{-6}; 0.02
Greenstone basement	0.2	0.02	1×10^{-6}; 0.002
Granite basement	0.03	0.003	1×10^{-6}; 0.002

6.5   Model calibration

6.5.1   Approach

The calibration approach included iterative runs with perturbed parameters to obtain suitable match between observed and simulated water levels while preserving adequate water balance consistent with the conceptual model.

The match between observed and water levels was sought for (1) regional model, representative of 'steady state' hydrogeological conditions and for (2) simulation of drawdowns from a series of aquifer tests conducted for this project. The latter is the only hydraulic stress available for the area. No other time-series data is available for testing, e.g. seasonal effects or other longer-term effect on groundwater flow.

For steady state calibration a set of groundwater level records available from bores recorded on the DWER Water Information Reporting (WIR) database was used. The records contain non-concurrent measurements, with no specific time snapshot available. It is therefore assumed for the purposes of this study (and remains also one of its limitations) that these records are reasonably close to steady state. The degree of difference between measured and simulated water levels (the residual) is used as a measure of the model's accuracy. Reducing the water level residuals to within 5 to 10% is considered a good model fit.

6.5.2   Steady state calibration

Since there has been no known large-scale groundwater abstraction, the aquifer system can be assumed to be at steady state. Fifty five (55) bore records are used as steady state calibration targets. Computed water levels for steady state model and point observed measurements are presented as Figure E- 12 and Figure 6-2. The figures indicate a good fit for the regional model despite uncertainties with absolute water level measurements (observed locations do not usually have a record of surveyed collar elevation – area's DEM is used as proxy for these records).

The target residuals are generally low, showing a relatively narrow spread in Figure 6-1, conforming to 1:1 line. The calibration statistics also indicates a good fit. The scaled root mean squared error (SRMS) is below 5%, considered acceptable for the numerical model.

Most simulated bores are close to measured values given the uncertainties with their collar elevations. There are some exceptions, notably in the southern part of the Yogi tenement in which simulated water levels are higher than observed. While these could be partly attributed to uncertainties with collar elevations, there may be local uncharacterised geological complexity in this area, which would require additional hydrogeological investigation.

A summary of the steady state water balance for the model is presented in Table 6-3:

Table 6-3 - Steady state water balance

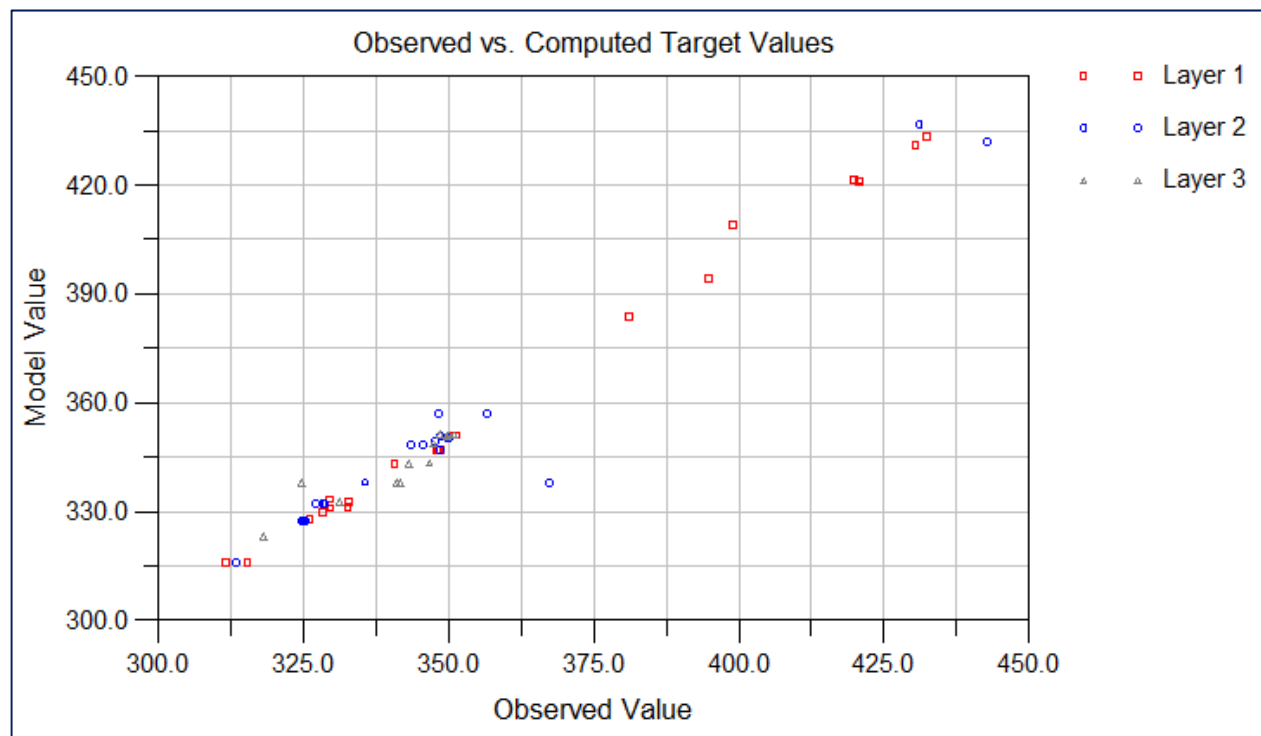| Component	Flux (m³/d)
Recharge (in)	75,501
Specified head (out) (outflow through Salt River alluvium)	332
Drain (out) (drainage line on eastern boundary)	432
Pumping (out) (town water supply	173
Evapotranspiration (out)	74,564

Figure 6-1 - Measured vs simulated water levels (steady state)

6.5.3   Transient calibration

Transient calibration is needed to adequately simulate groundwater storage changes over time. While it is common practice to estimate storativity parameters from hydraulic tests, the numerical model offers additional confirmation or refinement of storativity by including conditions

in the evaluation that are often beyond assumptions inherent in analytical techniques used for evaluation of aquifer tests.

Groundwater levels often respond to long-term pumping or changing climatic conditions. Long-term water level fluctuations have however not been recorded in the modelled domain, possibly due to the limited groundwater development in the model domain. The aquifer testing dataset generated during this investigation, in absence of other time-series data, is considered appropriate for transient calibration.

Hydraulic testing applied on PB01 to PB04 has been simulated with an objective to match observed water levels on observation bores associated with these production bores. Less emphasis is given to matching water levels in the production bores due to the presence of other than aquifer effects (e.g. well losses). During the transient calibration process the changes made in the transient model require edits to the steady state model so that the hydraulic parameters are consistent. The model is set up to automatically reflect parameter changes made in transient model into the steady state model.

Transient calibration achieved a reasonable fit for aquifer testing data with hydrograph information for both observed and simulated data presented in Figure 6-2. Overall transient calibration is considered adequate for the following reasons:

- Pumping and water level trends are well matched

- The magnitude of simulated drawdowns in observation bores matches observed data in all cases.

- Water levels in production bores (prefixed with PB) show only aquifer effects. Due to bore inefficiencies (well losses) the computed drawdown is smaller than observed. Bore efficiency calculated from the step-discharge tests is consistent with simulated results. For example, over 80% of drawdown in PB01 and PB02 is due to the well losses, meaning that aquifer component of drawdown is rather small – which is seen PB01 and PB02 hydrographs. Conversely in PB03 and PB04 the well loss component is smaller resulting in correctly larger component of aquifer losses.

- Computed water levels may need to be corrected once collar elevations are surveyed – this would cause potential slight movement along the vertical axis.
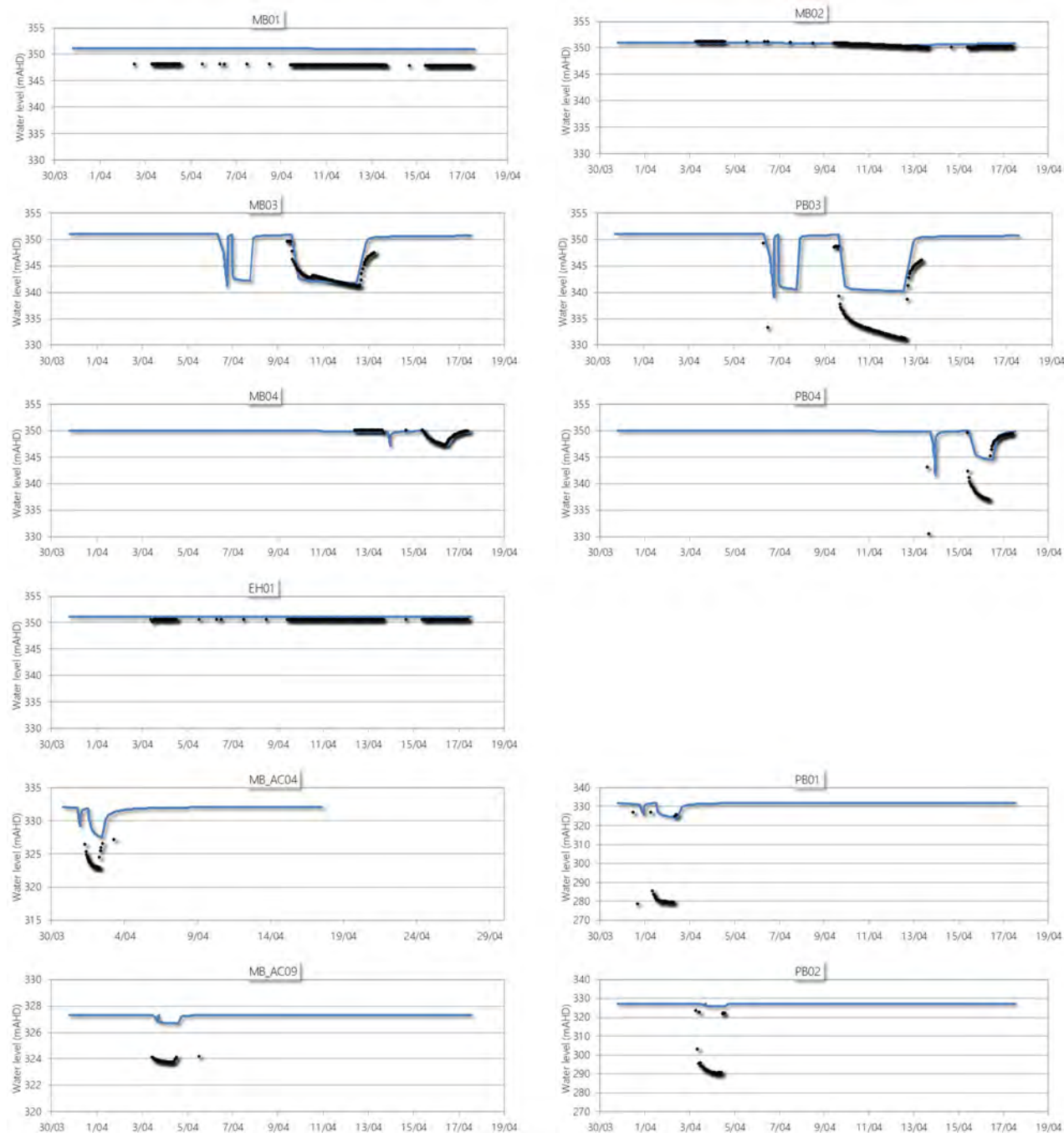
Figure 6-2 - Simulated and observed water levels during hydraulic testing (transient calibration)

6.5.4   Sensitivity analysis

Sensitivity of model response to changing parameter values has been examined and monitored during model calibration. The effect of parameter perturbations was examined against the magnitude and trend of water levels as well as on target residuals. These calibration-based sensitivity results are useful in understanding the regional model but also the specifics of the area to be mined. Some of the key outcomes and considerations are:

- As expected, hydraulic testing in the pit area is sensitive to hydraulic parameters of the surficial cover and greenstone formations, more specifically to applied hydraulic conductivity. Response of MB01 and MB02 to pumping in PB03 necessitated adjustment in

storativity. Higher values originally considered for specific yield of weathered greenstone in this areas would mask the muted response present in these two monitoring bores.

- Groundwater recharge is expected to be correlated with hydraulic conductivity and this relationship is relatively sensitive. The recharge rates were not varied extensively and were kept consistent with recharge estimates obtained using the chloride method. In the pit area increased recharge rate is considered for the outcropping metasediments which refines calibration of pumping test data in the pit area.

- Groundwater response in the palaeochannel aquifer is sensitive to values of vertical hydraulic conductivity. This is consistent with the layer's overall heterogeneity, in particular presence of low permeability layers in the sandy profile of this aquifer.

- Groundwater recharge in the palaeochannel area was minimised and eventually eliminated in order to reduce simulated water levels in this area. Elimination of recharge led to decrease in water levels however not sufficient enough. There must be other, potentially structural, rather than parameter based complexities having an effect on water levels in this area.

- Transient calibration is not particularly sensitive to storativity parameters of the greenstone basement. This is likely to the fact that there has been no monitoring point west of the tested bores, situated in the greenstone basement. Yalgoo Town's water supply is however situated in this direction.

Based on sensitivity analysis the scenarios based on varying storativity of the greenstone basement were selected as useful for understanding groundwater impacts to the west and southwest of the open pit. The scenarios were selected with reasonable upper and lower estimates of specific yield, to examine the likely range of groundwater effects.

6.6   Predictive simulations

Mine operation, in particular dewatering and production bore pumping was simulated following model calibration. The regional model was used to simulate the simultaneous response to dewatering and production bores both in the mining area and in the palaeochannel. Production bore pumping was simulated only within the existing Yogi tenement although the model was set up to simulate production pumping from areas external to the tenement.

The predictive simulation period for the mining phase is 21 years.

Post-mining effects are simulated using the pit lake refilling model. The pit lake refilling model is run for 500 years to confirm the predicted stabilisation and extent of cone of depression invoked and maintained by the pit lake.

6.7   Predictive simulation scenarios with parameter uncertainty

Due to the residual uncertainty around hydraulic parameters several simulations were performed to investigate the impact of water level change from dewatering. It has been established that the existing testing in the pit area did not demonstrate great influence of greenstone basement, in particular specific yield of the weathered part, however the unit is considered important when considering effects of much larger pumping associated with future dewatering potentially on Yalgoo's water supply which is situated in greenstone basement southwest of Yogi's mining pit.

For demonstration of weathered greenstone specific yield effect on drawdown from dewatering two simulations are presented which span the estimated parameter range (0.005 to 0.02).

6.7.1 Pit dewatering and borefield – assumed lower range of specific yield

Scenario 1 was completed with pit development over a period of 21 years. In the absence of detailed mine progression data, it was assumed that the pit base would progress vertically in a linear manner from year 1 until the end of mining in year 21. Final maximum pit base elevation was approximately 125 m AHD for the northern section of the pit (equivalent to a depth of approximately 230 m below ground level), and 140 m AHD for the southern section of the pit (equivalent to a depth of approximately 180 m below ground level).

For this scenario, dewatering was modelled to occur using the 'DRAIN' package. This simulates the pit base remaining dry as the mine depth progresses. It should be noted that in reality, depending on dewatering volumes, effective pit dewatering is more likely to occur through operation of pit dewatering bores in and/or around the pit. For this scenario, a specific yield of 0.005 was applied to the weathered part of greenstone basement.

In addition to pit dewatering, a conceptual borefield was simulated to provide additional groundwater supply. The simulated bores modelled were as follows:

* *Palaeovalley area*: Four bores were simulated to be operating within the southern portion of Project area (Tenement L59/156). Two of the bore locations were as per PB01 and PB02 (Project test bores as detailed in Section 5.5), and two were hypothetical bores located at a suitable distance from PB01 and PB02 to minimise interference effects. Each bore was modelled to be operating a continuous pumping rate of 3 L/s, consistent with the test pumping completed in this area.

* *Pit/BIF area*: Six bores were simulated to be operating within the formations north and south of the proposed pit. One of the bore locations was as per PB04 and one as per EH03 (Project test bores as detailed in Section 5.7). The remaining four bores are hypothetical and are located at a suitable distances along strike of the pit and to minimise interference effects. Each bore was modelled to be operating a continuous pumping rate of 5 L/s, consistent with the test pumping completed in this area.

Borefield and pit dewatering was simulated to occur over a period of 21 years.

6.7.2 Pit dewatering and borefield – assumed upper range of specific yield

A sensitivity/uncertainty scenario was completed using the same mine details as summarised above, however a specific yield of 0.02 for weathered greenstone as the upper limit in this environment.

6.8 Simulation results

Predicted drawdown is illustrated for year 5, year 10 and year 21 (end of mining) on Figure 10-11, Figure 10-12 and Figure 10-13 respectively. Drawdown for each of these time steps is also shown on the cross section presented as Figure 10-6. Predicted drawdown for the sensitivity scenario is presented for year 21 as Figure 10-14. The predicted drawdown at key receptors is summarised below as Table 6-4. The following observations from simulation results are noted:

* The predicted drawdown radiates out in all directions from the open pit as mining progresses. Drawdown extends further for the areas west of the pit compared to the east. This is due to the change in modelled units east of the pit where the greenstones are in contact the granitoid units.

* Drawdown impacts from the 6 bores located north and south of the pit is largely masked by the impact of drawdown from the pit. This highlights that such water supply bores within the

cone of influence of the pit may become unusable as the water level is lowered from combined pit and bore dewatering.

- The maximum extent of drawdown, as represented by the 1 m drawdown contour extends to a maximum distance of 16 km to the north of the pit, 17.5 km the south of the pit (including drawdown influence from the borefield), 5.5 km to the east of the pit and 17 km to the west of the pit. The area of drawdown in excess of 1 m at the end of mining (21 years) extends over an area of 587 km^2, equivalent to approximately 4% of the total catchment area.

- Of the existing licensed groundwater abstractors, a groundwater level impact is noted for GWL180498 (Craig Holland) at Year 5, with levels reducing by around 1 m increasing to 14.0 m at the end of mining. For the Yalgoo Town Water Supply (GWL109408), drawdown of around 1.5 m is predicted at the 10 year time step, increasing to 8 m at the end of mining.

- Dewatering of the pit is predicted to have an impact on existing pastoral bores/wells. For example at Cattle Well, the closest operational bore/well to the pit, drawdown of 2 m is predicted after 5 years of mining, increasing to 29.5 m by the end of mining. Greater drawdown is observed at Wadgingarra Well North, even though it is more distant from the pit. This is due to it being within the modelled greenstone belt that the mine will dewater. Drawdown of 21 m is predicted at 5 years, increasing to 73 m at the end of mining. The most distant pastoral bore/well to the pit that shows predicted groundwater level impact is Wadgingarra Well South, located around 13 km south of the pit. Drawdown of 0.5 m is predicted after 10 years of mining, increasing to 3 m by the end of mining.

- For the four bores simulated in the palaeovalley, drawdown is generally quite localised. The maximum extent of drawdown, as represented by the 1 m drawdown contour extends to around 2 km from each bore, combining with the pit dewatering affects in the north west of the borefield. Drawdown at stock bores near the southern borefield show minor drawdown impacts, with maximum drawdowns of between 1.5 and 2.0 m seen at Ram Well and Lazy Well respectively.

- The modelling predicts no drawdown in areas where the GDEs are located along the Salt River.

- The sensitivity scenario, with a modelled specific yield for the weathered greenstone of 0.02, shows a slightly less pronounced drawdown in the south west with comparison to the base-case scenario.

Table 6-4 - Drawdown at key receptors

Receptor	Drawdown (m) - Yr 5	Drawdown (m) - Yr 10	Drawdown (m) – End of mine (yr 21)	Drawdown (m) – End of mine (yr 21) Sensitivity run
GWL109408 (Yalgoo Town Water Supply)	0	1.5	8.0	4.0
GWL180498 (Craig Holland)	1.0	4.0	14.0	10.5
GWL180200 (Johannes Peter Addink)	1.0	3.0	10.0	8.5
Wadgingarra Well North	21.0	28.5	73.0	25.5
Cattle Well	2.0	10.0	29.5	29.0
Red Gate Well	4.0	23.5	52.5	49.0
Lazy Well	0.5	1.0	1.5	2.0
Ram Well	0.5	0.5	1.0	1.5
Wadgingarra Well South	0	0.5	3.0	1.0
Salt River GDEs	0	0	0	0

6.9   Mine inflow predictions

Estimated groundwater inflow rates during mining average between 135 to 140 L/s (over 4 GL/yr). The computed rates are based on DRAIN package approximation, in reality the dewatering effect may be achieved by a combination of in-pit and perimeter dewatering bores at slightly higher combined pumping rate.

The pumping rates may vary during the mine development and operation depending on the variations to the mine plan. It is possible that geological complexities, including faults, fractures, dolerite dykes that are not explicitly simulated in the numerical model may result in deviations from the predicted inflow rates. Data from aquifer testing in the pit area suggest the presence of structural controls that have not been fully characterised and therefore could not be replicated in the model. The structural influences were included to the degree they were expressed in the short-term pumping tests and steady state and transient targets. Some of the tested pumping rates were above average (e.g. 25 L/s in PB03), however it remains unclear whether this rate would be sustainable over the long-term. At the pit scale, fracturing and geological structures have an increasingly important role and the equivalent porous media assumption generally valid for the regional-scale model may be less appropriate and not account for potential high or low flows.

6.10 Pit lake development predictive simulation

6.10.1 Approach

Pit lake development was simulated using the LAK3 package which couples the lake water balance and the groundwater flow model. The inputs and outputs for the LAK3 package are:

- Rainfall onto the pit lake's surface

- Evaporation from the pit lake's surface

- Runoff into the pit (from walls within the pit and from the catchment area of the pit

- Conductance for LAK3 model cells which controls groundwater inflow into the pit

Due to the surface variations of the pit base, the middle part of the pit with base elevation of 200 m AHD was designated 'lake 1', the deeper southern part of the pit with minimum elevation of 140 m AHD was assigned 'lake 2' and the deepest northern section of the pit was assigned as 'lake 3'. The lake cell conductance was assigned sufficiently high to allow for fee release of water into the lake. Rainfall is estimated to be 258 mm/yr and pan evaporation is 2,766 mm/yr. A correction factor of 0.7 was applied to evaporation rate to account for reduction of the rate in the relatively narrow pit – the applied evaporation rate is 1,936 mm/yr.

The runoff component was neglected due the fact that the pit lake area is high up in the catchment and its area is assumed to be bunded post closure, eliminating or minimising any runoff from entering the pit. Pit wall runoff is considered to affect only short-term water level rise but the long-term equilibrium water level would not be noticeably affected.

The pit lakes can take decades or longer to reach their steady state ('equilibrium' water levels and water balance). A simulation period of 500 years was chosen for the post mining model. The climate inputs (rainfall, evaporation) in this simulation are constant with time.

6.10.2 Pit lake prediction

The simulation predicts that initially two independent pit lakes will form in the northern and southern sections of the open pit after dewatering ceases. The initial rebound will cause water levels in sub-lakes to rise rapidly. During gradual refilling over time the lakes will eventually coalesce forming a single pit lake which will continue to refill until evaporation matches inflows.

The model suggests that formation of a single lake will occur 12 to 13 years after cessation of dewatering. At this point the lake level will exceed 200 m AHD and will continue to rise as a single lake. The stage, inflows and outflows for the pit lake are predicted to approach steady state by approximately 160 years after mining. The lake stage at that point will be within 0.7 m of the stage achieved at the end of 500-year simulation. The steady state level in the pit is predicted to be 285 m AHD, approximately 65 below the pre-mining level which means that it will be a terminal lake.

Groundwater inflow into the lake during the steady state stabilises to approximately 4,800 kL/d (55 L/s). The surface area for the steady state lake is estimated to be just below 1 km^2. The volume of water in the steady state lake based on MODFLOW model will be approximately 73 million cubic metres.

The MODFLOW pit lake model neglects the potential effects of surface water runoff as well as short term variations in climate inputs (it uses average values). To examine the variable nature of climate parameters and surface runoff on predicted water level and water and salt balance in the pit a GOLDSIM model was set up.

A daily step SILO dataset over the last 100 years is replicated for 500 years post-mining to yield daily values of rainfall and pan evaporation. Groundwater inflow rates are taken from the

MODFLOW model. Catchment runoff is considered to be 1% of rainfall (to simulate imperfections in bunds and 5% within the pit walls. The resulting water level (Figure 6-3) in the pit varies slightly over the 500 year simulation period with only muted daily variability. This is due to dominance of groundwater inflow among the inflow components.
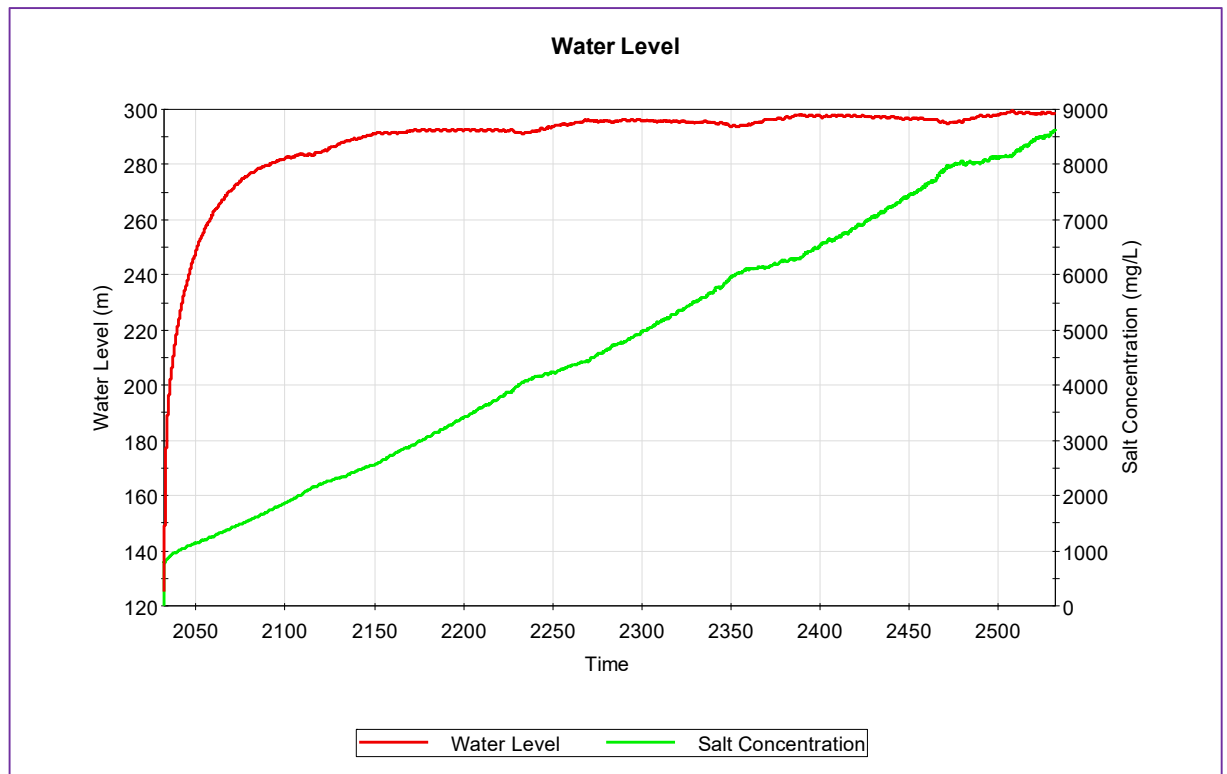

Figure 6-3 - Computed pit lake level, GOLDSIM simulation

The water level shown in Figure 6-3 may be over-predicted since the model assumes runoff being generated during any rainfall event while in fact runoff might be generated only after surpassing a certain threshold.

Using larger values of runoff coefficients (0.04 and 0.4 for catchment and in-pit runoff) – without threshold consideration, will raise the water level in the pit to 306 m RL. It is however very unlikely that catchment runoff will be present during any rainfall event and this result is therefore considered to be the upper limit of pit lake water level.

6.10.3   Residual drawdown from terminal lake

At this stage the pit lake rebound scenario assumes there would be no refilling of the lake with waste rock material. Under this scenario the cessation of dewatering will results in continuous rise of groundwater levels and rebound of water in the open pit fill with sourced water from rainfall and groundwater in-flow. This will continue until lake inflows are balanced by evaporation from the lake's surface.

The drawdown initially created by dewatering is going to reduce with rising water in the lake. Because the lake is predicted to be a groundwater sink (terminal lake) it will maintain its own cone of depression. The pit lake level will gradually rise and groundwater drawdown associated with the pit lake will become shallower but will expand laterally. The cone of depression is predicted to stabilise when the lake water balance will reach equilibrium – after about 150 years following cessation of dewatering.

Predicted drawdown distribution at 100 and 500 years after mining are illustrated on Figure 10-15 and Figure 10-16 respectively. The figures illustrate a relatively wide but shallow cone of groundwater level depression, with drawdown being more pronounced in the west of the area, due to the presence of the greenstone units. At 100 years, the extent of the 1 m drawdown is seen at a maximum distance of 16 km to the north and south west of the Pit. There is only a marginal difference between the 100 year and 500 year drawdown, with drawdown extending to the south west for the 500 year results, to a maximum distance of 17 km from the pit.

6.10.4 Pit lake salinity

The pit lake is predicted to become terminal, i.e. it will continue to be a groundwater sink. Due to evaporation effects the lake will be losing water but its dissolved solid content will reside in the lake and will continually concentrate over time.

The pit lake model allows for calculation of salinity based on assumed input concentrations (groundwater 800 mg/L, rainwater 50 mg/L). The model predicts a relatively linear increase in salinity in the lake. The predicted salinity (as TDS) for 10, 20, 50, 100 and 500 years after cessation of dewatering are 1,035 mg/L, 1170 mg/L, 1600 mg/L, 2355 mg/L and 8800 mg/L respectively.

6.11 Model limitations

Estimation of approximate groundwater system changes is possible with regional scale predictive flow models. The regional scale flow model used to simulate the groundwater system has limitations due to the simplifications necessary to represent complex natural systems. Small changes in water levels and groundwater flows are inherently difficult for a regional model to accurately simulate, but the predictions are useful for assessing the potential range of impacts as per requirements of this initial hydrogeological investigation.

The groundwater inflows to the open pit mine during mining and post-mining are quantified by simulating the mine dewatering operations. The effects of dewatering on the groundwater system are quantified by predicting the drawdowns, pit-lake development and changes in water balances. Some of these changes are small relative to the model scale.

Groundwater inflows to the open pit and post-mining pit lake(s) may differ from what was simulated. The necessary simplifying assumptions required to simulate the system as an equivalent porous media prevent simulation of the small-scale faults and fractures that could locally (in-pit) impact the groundwater inflows. Also, hydrogeological characterisation of the regional faults, shear zones, or other structural geologic features, is as yet unspecified (in that their hydraulic function with respect to groundwater flow is unknown) so their potential effect on pit and pit lake inflows (either as conduits or barriers) could not be accurately simulated.

The models are also constructed based on present-day conditions, but natural changes, such as changing climate, can be expected over the simulation period. No attempt has been made to simulate possible future changes that could alter the groundwater system. As simulations extend further in time, the error associated with the predictions increases. These factors limit the precision and accuracy of the model predictions. However, the results presented here represent best estimate of groundwater system changes associated with the Project at this stage.

6.12 Modelling conclusions

A regional groundwater flow model with locally increased discretisation was developed for the project to estimate groundwater inflows during dewatering, understand the spatial extent of drawdown from dewatering, estimate rebound of water level post-mining and inform environmental impact assessment. Steady-state and transient model calibrations were performed to simulate groundwater flow conditions and to estimate hydraulic parameters based

on average water levels and short term aquifer testing conducted at Yogi Project. The transient model was calibrated to short term (3 days or less in duration) constant rate tests conducted at four test production bores.

Dewatering will be necessary for the open-pit mining operations. Groundwater inflow to the open pit will begin when mining intersects the water table and will increase gradually as the pit is deepened. The predicted final inflows stabilize at about 12,000 m^3/day. Following cessation of mining, pit lakes are predicted to develop initially in the two deepest sections of the open pit, with steady-state water surface elevations of approximately 285 m AHD to 306 m AHD for the coalesced lake for the range of pit bunding efficiency to bypass surface runoff. The pit lake area will remain a terminal sink for regional groundwater flow.

Water balance for the pit lake indicates that groundwater inflow accounts for the majority of inflows into the pit lake. Groundwater inflow is predicted to stabilise at approximately 4,800 m^3/day. Water loss from the pit lake is exclusively by evaporation.

The mine dewatering activities and groundwater inflow to the post-mining pit lakes will result in lowering of the water table in the area around the mine. At the end of the mining period, drawdown of 1 metre or more extends to a maximum distance of 16 km to the north of the pit, 17.5 km the south of the pit (including drawdown influence from the borefield), 5.5 km to the east of the pit and 17 km to the west of the pit. The area of drawdown in excess of 1 m at the end of mining extends over an area of 587 km^2, equivalent to approximately 4% of the total catchment area.

After mining has ceased, groundwater inflow to the pit lakes will continue to keep the water table depressed until stabilisation due to achieving equilibrium conditions. The maximum distance predicted to experience drawdown of 1 metre or more extends to a maximum distance of 16 km to the north and south west of the Pit. The extent of drawdown does not change substantially beyond about 150 years after mining ends.

6.13 Assessment of potential impacts

The modelling has demonstrated that the proposed operation of the mine will have a localised impact on groundwater levels. The key environmental impacts are summarised in the below sections.

6.13.1 Pastoral bores/wells

As detailed in Section 6.6, a number of existing pastoral bores/wells are likely to be impacted by the drawdown in groundwater levels caused by dewatering and borefield abstraction.

Two wells within the current Project footprint (Wadgingarra Well and Cattle Well) are predicted to be impacted by groundwater level declines that would likely render these bores/wells inoperable due to the groundwater level reducing below their total depths. However, given their location within proposed operational areas of the mine, it is unlikely that these bores would be needed for stock watering as cattle would likely be excluded from the mine operational areas. This would require further discussion with the pastoralist. For example, alternative water supplies for livestock may still be required in this general area (albeit outside of the operational areas), and any new bores would need to consider the predicted decline in groundwater levels. Alternatively, water could be supplied from the mine site to the pastoralist.

Excluding Red Gate Well, for those bores located outside of the Project footprint, only minimal groundwater level change is predicted. For these bores (i.e. Lazy Well and Ram Well), existing bore pumps/infrastructure would be expected to cope with marginal water level declines (i.e. less than 3 m) which are typically within seasonal and historic ranges of groundwater level changes.

Red Gate Well is located outside of the Project footprint, but is modelled to be impacted by mine dewatering. Drawdown reaches a maximum of 52.5 m at the end of mining. Such a level of decline would likely result in this bore becoming inoperable. As such a make-good/compensation agreement would be needed to replace this water supply (if it is still operational).

6.13.2 Existing groundwater licences

Within the first ten years of mining, no significant groundwater level decline (i.e. <5 m) is predicted for licensed groundwater users within close proximity of the Project. Maximum groundwater level drawdown as a result of dewatering is predicted to be up to 10 to 14 m for the two closest licensed groundwater users (GWL180498 (Craig Holland) and GWL180200 (Johannes Peter Addink)). However, this is beyond the licence period for both operators therefore it is unclear if groundwater abstraction would still be required for these users.

For the licensed Yalgoo Town Water Supply bores, a maximum groundwater level drawdown of up to 8 m is predicted. This level of decline is possibly within the operational range for these bores. Drawdown impacts and bore management options should be discussed directly with Water Corporation to ensure that the Town water Supply is safeguarded.

6.13.3 Subterranean fauna

As outlined in Section 6.8 , the total area of groundwater level in excess of 1 m is predicted to be up to 587 km^2 (including drawdown impacts from the conceptual borefield in the palaeovalley). A baseline assessment of subterranean fauna has been completed as part of the Environmental Referrals for this project (Invertebrate Solutions, 2019).

The assessment identified that some permanent loss of potential subterranean fauna habitat will occur from mine construction and operations. However, subterranean fauna species are not restricted to the mine area and only a minor portion of the geological unit will be removed (96.5% remaining). Given the low level of impacts on subterranean fauna, it was concluded the Proposal will not have significant residual impacts, and no offsets are proposed.

7. Management approach

7.1 Additional hydrogeological investigations and modelling

Hydrogeological evaluation in this report draws on an initial hydrogeological investigation program which included limited groundwater exploration and aquifer testing in the pit area and the southern part of the tenement from the Tertiary palaeochannel.

The study identified that obtained groundwater information is limited and preliminary in nature. While this allowed the formulation of an initial hydrogeological conceptual and numerical model there are remaining areas of uncertainty, including:

- Investigations were limited to the immediate tenement.

- Two production bores were developed in the pit area with subsequent short-duration aquifer testing. Due to the geological complexity of the mining area additional test production locations are recommended.

- Short-term aquifer testing did not allow for assessment of sustainability of achieved flow rates, nor for assessment of hydraulic function of potential geological structural features.

- While the area has abundance of dolerite dykes and shear zones it is not readily understood whether they have an influence on groundwater and whether their configuration could result in compartmentalisation of the aquifer system. This could have implications on for example how fast the mining pit would be dewatered, the dewatering rates, the extent of the cone of depression and the availability of water for ore processing and transport

Additional groundwater investigations are recommended to address the areas of uncertainty which would include additional hydrogeological drilling, aquifer testing (including a long-term pumping test), groundwater sampling and water level monitoring. Further hydrogeological drilling should be completed taking into consideration data obtained during proposed resource and geotechnical drilling required for the Project. Data from these programs will assist in identifying potential features and variability in geological units that could control groundwater flow.

At least one year of groundwater level monitoring data is required for baseline assessment. Several water level loggers are now in monitoring bores installed during the investigation described in this report. The information recorded on loggers needs to be periodically downloaded and assessed.

The numerical groundwater model developed as part of this investigation should be updated, recalibrated, with predictive simulations rerun to refine the current estimates.

7.2 Groundwater abstraction licence

The Project will require groundwater abstraction licences (5C licences) in order to dewater the pit (fractured rock), and operate a borefield (possibly palaeovalley and fractured rock).

There are currently no environmental or social factors identified in this investigation program which would suggest cause not to grant a 5C licence to take approximately 4-5 GL/a of groundwater from the fractured rock aquifer. It is recommended that following refinement of the Projects water demands, 5C licence requirements are discussed with DWER.

7.3   Proposed monitoring program

Several potential receptors have the potential to be affected by changes in groundwater level and groundwater quality. A groundwater monitoring program should be developed to take into consideration these receptors allowing baseline data, and ongoing monitoring data to be collected to quantify any groundwater changes and to update and validate the groundwater model. Key receptors include:

- Groundwater dependent ecosystems

- Stock bores

- Licensed groundwater users (including Public Water Supply)

Monitoring of groundwater will be required to establish pre-mining baseline conditions relevant for those key receptors identified above. In addition, baseline conditions, and subsequent ongoing routine monitoring will be required for operational areas that have the potential to impact on groundwater levels and quality.

The monitoring network should therefore aim to provide baseline and ongoing monitoring for the following Project areas:

- Water supply and dewatering bores

- Waste Rock Facility

- Tailings Facilities

- Operational areas - general

- Site boundary

- Regional areas

With consideration of the key receptors and the areas listed above a conceptual groundwater monitoring network is proposed. The monitoring network is illustrated on Figure 10-17 and Figure 10-18 (operational areas and regional areas respectively) and summarised as Table 7-1.

Table 7-1 - Proposed monitoring bores

Bore ID	Area	Easting	Northing	RL	Comment
MB_PB01	Water supply bores	486,988	6,867,409	340.2	Monitoring for PB01
MB_PB02		485,597	6,864,634	332.9	Monitoring for PB02
MB_PB04		481,040	6,876,439	361.5	Monitoring for PB04
MB_PB05		481,761	6,875,408	364.2	Monitoring for PB05
MB_PB06		482,847	6,873,559	354.2	Monitoring for PB06
MB_PB07		479,153	6,878,650	369.4	Monitoring for PB07
MB_PB08		477,968	6,879,952	370.6	Monitoring for PB08
MB_PB09		487,546	6,864,786	332.6	Monitoring for PB09
MB_PB10		490,128	6,865,283	336.5	Monitoring for PB10
MB_PB11		477,820	6,881,761	373.3	Monitoring for PB11
MB_P01	Pit perimeter	479,635	6,878,706	367.2	Pit Perimeter
MB_P02		480,263	6,878,116	366.3	Pit Perimeter
MB_P03		479,112	6,878,094	373.9	Pit Perimeter
MB_P04		479,583	6,877,824	379.2	Pit Perimeter
MB_P05		480,679	6,877,651	363.9	Pit Perimeter
MB_P06		480,094	6,877,341	378.2	Pit Perimeter

Bore ID	Area	Easting	Northing	RL	Comment
MB_P07		481,002	6,877,194	361.5	Pit Perimeter
MB_P08		480,423	6,876,733	365.0	Pit Perimeter
MB_OP01	Operations	481,055	6,881,787	380.7	Operations North
MB_TS01	Tailings areas	485,151	6,880,808	383.4	Tailings Wet
MB_TS02		485,179	6,879,942	377.6	Tailings Wet
MB_TS03		485,167	6,878,927	374.0	Tailings Wet
MB_TS04		483,738	6,878,911	369.8	Tailings Wet
MB_TS05		483,737	6,879,872	372.5	Tailings Wet
MB_TS06		483,676	6,880,811	376.6	Tailings Wet
MB_TS07		486,799	6,878,496	389.0	Tailings Dry
MB_TS08		485,494	6,878,508	375.0	Tailings Dry
MB_TS09		485,482	6,877,073	366.8	Tailings Dry
MB_TS10		486,787	6,877,061	373.8	Tailings Dry
MB_W01	Waste Rock	481,518	6,879,932	370.8	Waste Rock facility NE
MB_W02		481,554	6,878,045	364.1	Waste Rock facility SE
MB_W03		480,216	6,878,522	365.7	Waste Rock facility SW
MB_W04		480,429	6,879,910	370.0	Waste Rock facility NW
MB_B01	Project Boundary	486,797	6,882,358	392.1	Boundary NE
MB_B02		480,486	6,883,246	386.2	Boundary N
MB_B03		478,819	6,877,572	380.0	Boundary W/Overburden
MB_B04		479,343	6,876,781	372.9	Boundary W/Overburden
MB_R01	Regional areas/receptors	477,235	6,884,450	379.8	Regional N
MB_R02		476,188	6,879,142	372.8	Regional W
MB_R03		478,001	6,875,757	375.4	Regional W (PDWSA)
MB_R04		479,369	6,873,581	381.6	Regional SW
MB_R05		488,442	6,873,320	357.7	Regional E
MB_R06		484,470	6,871,118	333.8	Regional S
MB_R07		490,909	6,862,924	329.6	Regional S
MB_R08		485,674	6,862,610	328.8	Regional S

8.   Conclusions and recommendations

The Yogi Mine Project proposal includes the mine and associated infrastructure as well as a magnetite slurry pipeline and a water pipeline to Geraldton Port, and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline network. Assessing the environmental impact of the groundwater dewatering and abstraction was identified as a key component of the environmental approvals given that the proposed mine would need a borefield/water supply option supplying process water and that the proposed pit would require dewatering.

A hydrogeological investigation was completed (this report), which addresses the key groundwater related aspects for the Projects environmental referral.

The current hydrogeological investigation included:

- Hydrogeological exploration drilling at 24 sites

- Installation of four test production bores

- Installation of 10 monitoring bores

- Aquifer testing at four new locations and limited testing of 5 previously installed sites

- Groundwater sampling of tested production bores

- Installation of water levels loggers

- Development of a hydrogeological conceptual model

- Construction and calibration of a regional numerical groundwater flow model for impact assessment purposes

- Development of pit dewatering rates, delineation of drawdown from dewatering for impact assessment purposes

- Estimation of pit lake water level and salinity after mining ceases, including the residual drawdown extent maintained by terminal lake in the mine pit

- Groundwater impacts for environmental impact assessment

The outcomes of the current hydrogeological investigation are:

- There appears sufficient groundwater capacity and contingency to sustain an abstraction of up to 5 GL/yr, the significant part of which would come from pit dewatering. This would have to be further confirmed by additional hydrogeological investigation including additional drilling, long-term pumping test and model development/updates.

- Estimated drawdown at the completion of mining (after 21 years) will reach a maximum depth at 125 m AHD, i.e. approximately 225 m below the pre-mining water level. The one (1) metre contour representing the extent of impact detectable in relation to natural water level variability is expected to extend up to 16 km from the mining pit at its furthest

- There are no recognised GDEs within the cone of depression from dewatering.

- There are several stock bores and licensed groundwater users (include Yalgoo Town Water Supply) which are within the estimated drawdown that exceeds 1 m. While the town water supply is considered to be resilient enough against predicted drawdown impacts additional investigation and monitoring is recommended downgradient from the mining pit. Triggers and contingencies may need to be developed if required. Several stock bores (if still in operation) may become defunct due to dewatering impacts.

- Several ephemeral creek lines are likely to be dominated by seasonal rainfall and unlikely to be affected by dewatering drawdowns. Further monitoring is recommended to confirm these findings in the next stage of the project and develop triggers and contingencies if required

- Overall impacts are manageable, but need to be confirmed with better instrumentation and additional aquifer testing.

- Project is at early stage, with significant more work required, including resource drilling, which will provide a significant body of data needed to refine the resource understanding and develop the understanding of structures that may control groundwater flow.

- Further work required to assess dewatering rates and methods i.e. drilling and testing program.

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