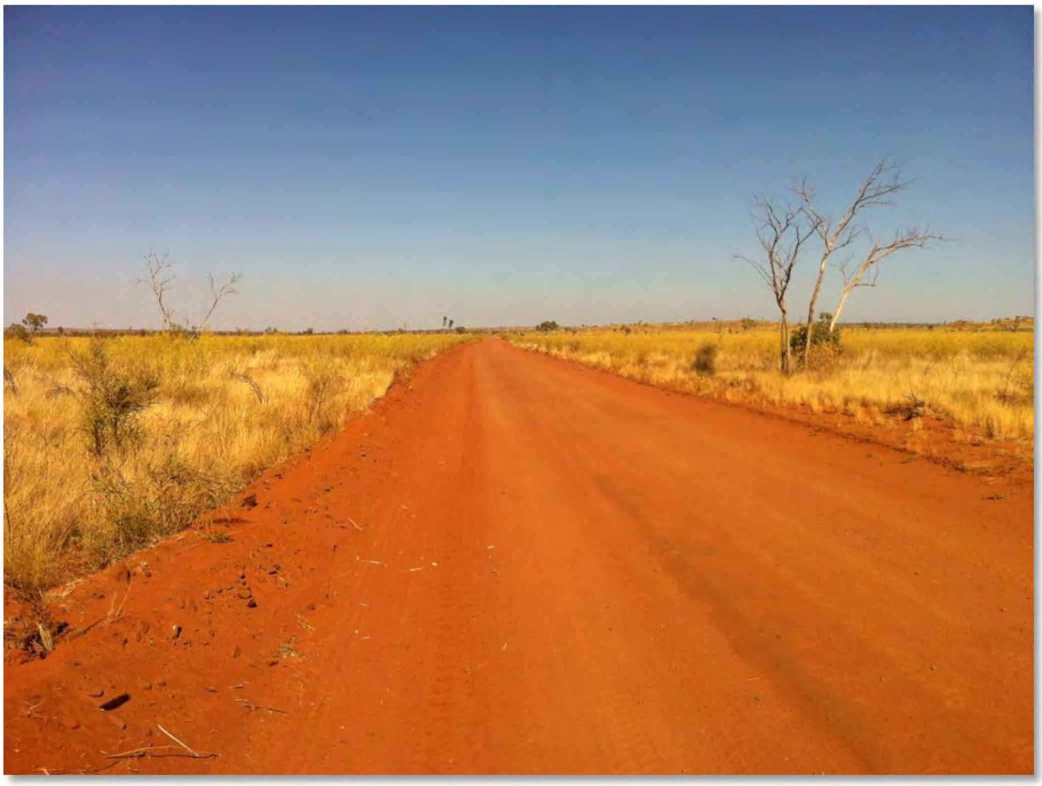
Northern Minerals Limited

Browns Range HREE Project



Stage 2 – Hydrogeological Test Drilling, Aquifer Testing and Assessment

June 2014
M09812A03

June 11, 2014

Northern Minerals Limited
Level 1, 675 Murray Street
West Perth, Western Australia
6005

Mr. Robin Jones
Project Manager

Dear Mr Jones:

Browns Range HREE Project
Stage 2 - Hydrogeological Test Drilling, Aquifer Testing and Assessment

Please find a copy of our Stage 2 Hydrogeological Test Drilling, Aquifer Testing and Assessment Report for the Browns Range Project.

If you have any queries or would like to discuss the report please contact the undersigned on (08) 9486 5400.

Yours truly,
KLOHN CRIPPEN BERGER LTD.

Pieter Boshoff
Project Hydrogeologist

Chris Strachotta
Associate & Manager – Western Australia

PB:CS

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EXECUTIVE SUMMARY

Klohn Crippen Berger Ltd has been engaged by Northern Minerals Limited to undertake a Hydrogeological Test Drilling, Aquifer Testing and a Hydrogeological Assessment at the Browns Range Rare Earth Element Project site.

The objectives of the hydrogeological assessment are to obtain groundwater information from site-specific hydrogeological investigations, to allow the technical assessment of:

- Baseline groundwater conditions (pre-mining environment);
- Preliminary groundwater resource potential; and,
- Potential impacts on the groundwater resources and receptors (if present) due to development of the Project.

This hydrogeological assessment also includes numerical assessments of the groundwater systems to identify:

- Water supply feasibility from the Gardiner Sandstone aquifer unit and associated potential impacts to the groundwater system and associated groundwater dependent environmental values as a result of the proposed long term abstraction activities; and,
- Potential dewatering activities and associated groundwater level drawdown extent for each proposed mining area.

Methodology

The adopted methodology comprised:

- Hydrogeological exploration drilling to identify groundwater resources associated with the proposed mining areas and potential water supply for the Project.
- Aquifer hydraulic testing in selected production and monitoring bores to assess aquifer hydraulic parameters / characteristics.
- Groundwater level and quality monitoring across the Project site to establish baseline conditions.
- Update of conceptual hydrogeological understanding for the Project site.
- Numerical modelling to undertake predictive simulations of dewatering activities to assess:
  - dewatering rates associated mine development and dewatering activities;
  - drawdown extent based on various Project periods; and,
  - preliminary dewatering infrastructure required.
- Numerical modelling of a water supply borefield to predict:
  - drawdown extent associated with long-term pumping from the Gardiner Sandstone aquifer;
  - evaluate the long-term sustainability of the Gardiner Sandstone as potential water supply option for the Project; and,
  - identify potential impacts on identified environmental values (e.g. Banana Springs).

Hydrogeological Conceptualisation

Based on NTU's exploration drilling database and data from the hydrogeological exploration drilling and testing program, it is evident that the key aquifer host media across the Project site can be generalised as follow:

- Fractured rock aquifers hosted within the Browns Range Metamorphics – classified as a thick sequence of metamorphosed sediments with generally very low to no primary porosity. As a result, groundwater movement is controlled by the occurrence of discrete, secondary porosity, geological structures (e.g. faults, shears, associated fracturing). Bore yields are generally low and water strikes were encountered between 352 mAHD and 413 mAHD. Discrete and localised variations in hydraulic parameter may occur and are likely to be a result of characteristics of the secondary porosity. Hydraulic conductivity values vary between ~7.2 x 10^{-3} m/d and 9.5 m/d with storativity values between 10^{-5} to 10^{-2}. The groundwater quality indicates a sodium-chloride-bicarbonate groundwater type with elevated boron, copper and zinc values.
- Fractured rock aquifers hosted within the Gardiner Sandstone – classified as a medium-grained bedded sublithic to lithic arenite and quartz arenite sandstone unit. The matrix of this sandstone unit has low primary porosity, therefore, groundwater storage and movement is predominantly confined and is associated with geological structures and associated fracturing throughout the unit. Water strikes with discrete fracture zones was encountered between 330 mAHD and 370 mAHD with high bore yields (>6 L/s). Hydraulic conductivity values vary between 4.8 m/d to 11.3 m/d and storativity between 10^{-5} to 10^{-3}. The groundwater quality indicates a sodium-chloride-bicarbonate groundwater type with elevated copper and zinc values.

Groundwater levels, measured across the Project site, when compared with available groundwater intersection data, indicates confined groundwater flow conditions within both fractured rock aquifers with an inferred groundwater flow towards the west (a subdued reflection of the surface topography).

Groundwater samples collected during the hydrogeological and groundwater baseline assessments provide baseline information and characterisation of the groundwater in the Project site area. The results indicate groundwater across the Project site is considered sodium-chloride-bicarbonate type which is representative of evolved groundwater.

Environmental Values

The identified environmental values of groundwater to be protected in the area include:

- Cultural values (e.g. Banana Springs); and,
- Ringer Soak water supply bore.

Both these environmental values are sites of significance to the Kudat Djaru community of Ringer Soak and are located approximately 34 km (Ringer Soak water supply bore) and 12 km (Banana Springs) west of the Project site, respectively. The groundwater at both of these sites is sourced from the Gardiner Sandstone aquifer.

Numerical Model Setup

The groundwater assessment associated with this investigation comprises two components; dewatering assessment for the proposed pits and water supply assessment for the Project water demand.

- Dewatering Assessment
  - Wolverine and Gambit deposits

    The cone of influence as a result of the proposed dewatering activities is considered localised in the vicinity of Wolverine and Gambit-West mining activities. From Month 23 of the Project schedule; inter-connection of the various localised dewatering cone of influences for each pit results in the development of a large elongated northeast-southwest cone of influence across the Wolverine and Gambit deposits. The drawdown distance extent, from the pit void perimeter, varies across the various mining areas as mining activities progress. The maximum distance of drawdown extent, from the pit void perimeter, with 1 m drawdown contour observed is approximately 600 m.

    Generally, pit inflow rates (up to 27L/s) increase gradually from the intersection of the water table to the final pit floor elevation and is considered the upper limit estimated inflow rates due to the model specific assumptions and limitations.
  - Area 5 deposit

    Although the cone of influence as a result of the proposed dewatering activities is considered localised in the vicinity of the Area 5 pit; the drawdown is most pronounced along strike of the northwest to southeast interpreted shear zone due to higher hydraulic conductivity associated with this zone in comparison to the adjacent country rock. The maximum distance of drawdown extent, from the pit void perimeter, with 1 m drawdown contour observed is approximately 220 m.

    Generally, pit inflow rates increase gradually from 2 L/s at the intersection of the water table to 13 L/s at the final pit floor elevation and is considered the upper limit estimated inflow rates. Groundwater is not anticipated to be encountered in the pit until mining of the 410 mAHD bench commences, which is scheduled for Month 51 of the Project schedule (6 months into the mining of Area 5 pit).
- Water supply assessment

  A steady-state model was developed and verified for hydraulic parameters, boundary conditions and recharge; and formed the basis of the transient simulations. Steady-state verified groundwater levels were used as the initial groundwater level for the predictive transient simulations. A transient simulation duration of 10 years was undertaken to assess the groundwater level drawdown extents as a result of long-term pumping from a proposed production bore network throughout the duration of the Project life, based on the following borefield scenarios:
  - Base Case – pumping from the installed test production bores (BRRWS007 and BRRWS010) pumping at a total cumulative rate of 21 L/s; and,
  - Scenario A – abstraction from seven production bores, with each bore pumping at 6 L/s.

The resulting predicted drawdowns provide a reasonable estimate for the anticipated Project water supply borefield development and operation. Based on these results the extent of drawdown from the borefield will likely have no discernible impact on Banana Spring and the Ringer Soak community water supply bores. The proposed production from the proposed borefield, at a pumping rate of 42 L/s over the Project life duration is considered sustainable.

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1 INTRODUCTION

Northern Minerals Limited (NTU) contracted Klohn Crippen Berger Ltd (KCB) to undertake Hydrogeological Test Drilling, Aquifer Testing and a Hydrogeological Assessment (Stage 2) at the Browns Range Rare Earth Element (REE) Project (the Project). Generally, this investigation comprised the assessment of:

- water supply potential from groundwater sources within the vicinity of the Project area; and,
- potential dewatering requirements for the proposed open pits to allow “dry” mining conditions.

The Project site is located in the Tanami Desert of Western Australia, approximately 150 km southeast of Halls Creek (Figure 1-1).

1.1 Project Description

At the time of undertaking this assessment, the Project consisted of four (4) granted exploration licences (E80/3547, E80/3548, E80/4393, and E80/4479) located along the western extent of the Browns Range Dome. This geological structure straddles the Western Australian and Northern Territory border, with all NTU’s exploration licences relevant to this assessment located within Western Australia.

NTU conducted extensive exploration drilling of these licence areas, comprising a total of 1,143 diamond core and reverse circulation (RC) holes to various depths (maximum: ~561 m bGL) and various inclinations (between ~48 and ~90 degrees). This exploration drilling program resulted in the identification of the following REE[1] deposits:

- Wolverine;
- Gambit (consisting of Gambit, Gambit-Central and Gambit-West); and,
- Area 5 (consisting of Area 5 and Area 5-North).

Preliminary pit optimisation and mine design conducted by NTU in 2013, proposed the extraction of ore and associated waste using a combination of conventional open pit (i.e. drilling, blasting, loading and hauling) and supported underground (i.e. cut and fill) mining techniques. Access to deeper ore tonnages at Wolverine and Gambit-West deposits is proposed through selective deposit-specific decline systems, originating from a portal within the open pit extent.

Although the metallurgical optimisation process is currently being undertaken by NTU, to produce a 20 percent (%) total rare earth oxides (TREO) concentrate with an overall circuit recovery of 82%, one of the following processing routes are in consideration by NTU (NTU, 2013):

- Whole of ore flotation; or,
- A combination of wet high gradient magnetic separation followed by flotation cleaning.

[1] Project specific REE mineralisation resulted from Hydrothermal xenotime mineralisation comprising Lanthanides (including yttrium, dysprosium, erbium, ytterbium, terbium, gadolinium, samarium, europium), and light rare earth elements (NTU, 2013)

Waste materials (e.g. waste rock, tailings generated from the beneficiation and hydrometallurgical processes) will be stored on-site via a combination of waste rock dumps (WRD's) and a single tailings storage facility (TSF), to be developed as an integrated waste landform using waste rock from the Gambit mine pits.

Following the cessation of the mining activities (estimated life of mine approximated at 10 years), the post-closure landform is proposed to comprise several open pit voids and rehabilitated waste landforms.

1.2 Objective & Scope of Service

The objectives of the Stage 2 hydrogeological assessment are to obtain groundwater information from site-specific hydrogeological investigations, to allow the technical assessments of:

- Baseline groundwater conditions (pre-mining environment)
- Preliminary groundwater resource potential to:
    - provide a sustainable Project water demand – approximately 1.32 GL/a (includes a 20% contingency); and,
    - dewatering requirements for the proposed open pits (assessment of dewatering from the underground workings is not captured in this scope of service).
- Potential impacts on the groundwater resources and groundwater dependent ecosystems (if present) due to development of the Project.

1.2.1 Scope of Service

To address the objectives for this assessment the following scope of service was initially proposed:

- Hydrogeological exploration drilling to identify groundwater resources associated with the proposed mining areas (to identify potential groundwater management requirements during operations) and potential water supply for the Project. These drilling locations were identified during a scoping study (KCB, 2012a) and refined based on a subsequent surface geophysics (electrical-resistivity and magnetic) survey campaign (KCB, 2012b).
- Aquifer hydraulic testing (pumping tests and permeability tests) in selected production and monitoring bores to assess aquifer hydraulic parameters/characteristics.
- Groundwater level and quality monitoring across the Project site to establish baseline conditions, commencing in August/September 2013.
- Update of conceptual hydrogeological understanding for the Project site.
- Analytical assessment of groundwater flow to identify:
    - potential groundwater inflow, dewatering requirements and groundwater level drawdown extent for the proposed pits; and,
    - potential preliminary impacts to the groundwater system, to groundwater dependent ecosystems (if present) and to other environmental values (including culturally significant sites) as a result of the development and operation of a groundwater supply borefield and pit dewatering requirements.

However, modifications to the scope of service were required during the undertaking of this assessment due to changes in the Project description, supplementary assessment required for parallel technical studies and Project approval requirements. Modifications to the service scope items included:

- Quarterly groundwater monitoring to assess seasonal variability in groundwater levels and quality.
- Numerical assessment of groundwater potential to identify:
  - water supply feasibility from the Gardiner Sandstone aquifer unit and associated potential impacts to the groundwater system and related environmental values as a result of proposed long term abstraction activities; and,
  - potential dewatering requirements and associated groundwater level drawdown extent for each proposed mining areas (i.e. Wolverine, Gambit and Area 5 deposits).

2 PREVIOUS INVESTIGATIONS & BACKGROUND DATA

Numerous regional and site-specific investigations / background data have been conducted / compiled across the Project site and generally comprise:

- General spatial data;
  - Cadastral data – i.e. road corridors, pastoral lease boundaries
  - Surface water courses
  - Aerial photography
  - Digital elevation model
- Surface geological maps;
- Airborne geophysical survey;
- Internal NTU geological reports;
- Meteorological data (source: Bureau of Meteorology (BoM);
- Geological data collected during exploration drilling program/s; and,
- Available public domain hydrogeological data.

Table 2-1 summarises the compiled background data.

Table 2-1: Summary of Project Background Data

Description	Data/Information	Source	NTU Reference
Physiographic Information	Regional Information	NTU (PNC Exploration Pty Ltd (The Granites-Tanami Project))	A32288 (D. Pearcey, 1991)
	Topographic Data – LiDAR Data	NTU	na
	Meteorological Information	NTU Weather Station records	na
		Halls Creek Weather Station records (ID: 002012)	na
Geological Information	Regional and site-specific	NTU (PNC Exploration (Pty) Ltd (The Granites-Tanami Project))	A25982 (Pearcey et al., 1988) A37491 (K. Fulwood, 1993)
		NTU (Internal Report)	K. Das, 2011
	Bore Logs – site-specific	NTU (PNC Exploration (Pty) Ltd (The Granites-Tanami Project))	A25984
	Browns Range – Regional		A30138 (Pearcey et al., 1990)
	Diamond Core Information – site-specific	NTU (Exploration Drilling Database)	na
	Exploration Drilling Database – site-specific	NTU (Exploration Drilling Database)	na

Description	Data/Information	Source	NTU Reference
Structural Geology Information	Interpretation – site-specific	NTU (Remote Sensing and Geological Services)	na
		NTU (Digirock Exploration Geologists)	na
Hydrogeological Information	Data for Production Camp Bore – EP1204323	NTU (Hydrogeological Database)	na
		NTU (Outback Ecology Services)	Outback Ecology Services, April 2012
	Scoping Level Hydrogeological Investigation	KCB, 2012	M09812A01 (KCB)
	Stage 1 Non-Intrusive Investigation	KCB, 2012	M09812A02 (KCB)
	Regional Groundwater Level Information	Department of Water	na

Note/s:

- site-specific - Data/information coverage based on prospect exploration only
- Regional - Data/information coverage on a Browns Range Dome scale.
- na - not applicable

A description of the background data sourced for this assessment, and preliminary hydrogeological investigations completed by KCB at the project site, is provided in the following sections.

2.1 Project Background Data

2.1.1 NTU Exploration Drilling Database

NTU's exploration drilling database (received on November 19, 2013) includes a total of 1,143 diamond core, RC and conventional drillholes totaling 101,845 m. The majority of these holes are located within the identified deposit areas (Figure 2–1). Key information obtained from this database comprised:

- lithological descriptions;
- geological structure;
- depth of weathering; and,
- encountered drilling conditions of relevance to the hydrogeological assessment (e.g. groundwater intersections, lost circulation, air-lift yields, anecdotal groundwater observations etc.).

2.1.2 Site-Specific Spatial Data

The following spatial data were obtained from NTU:

- aerial photography across the Project site;
- surface geological mapping;

- interpreted regional structural geology;
- airborne geophysical survey data;
- Project digital terrain model (LiDAR grid); and,
- proposed conceptual infrastructure layout.

Table 2-2 provides a summary of these spatial data.

2.1.3 Public Domain Data

The following public domain data were obtained and reviewed as part of this assessment:

- geological mapping (1:250,000 Geological Map series for Halls Creek);
- meteorological data (BoM data from Hall Creek station);
- Department of Water (DoW) groundwater database records, including bore locations and monitoring records (e.g. levels, quality, pumping rates etc), within a 35 km radius of the Project site; and,
- December 2012 groundwater quality records for the Ringer Soaks community bore (Department of Housing).

2.1.4 Site-Specific Climate Records

Site specific daily meteorological data were provided by NTU. These data comprise:

- temperature;
- relative humidity;
- precipitation;
- wind speed and direction; and,
- short-wave radiation.

Installation of the weather station was conducted by NTU, in conjunction with Compliance Monitoring Pty Ltd, in December 2012 and is located within the vicinity of the exploration camp, south of the Gambit deposits. Operation, maintenance and monitoring are completed by NTU on-site personnel.

Operational issues were encountered following the installation of the weather station resulting in several data gaps in the monitoring records. As a result, climate data from the Halls Creek weather station were adopted for this study.

Table 2-2: Spatial Data Sourced from NTU

Data	Description	File ID	Date Received
Remote Sensing	Aerial Photography	BR.geotiff	2012
Geological Data	Transported Materials – Alluvial and Colluvium	BR_Alluvium and BR_Colluvium_Subcrop	2012
	Gardiner Sandstone	BR_Gardiner_Sandstone (zone 1 to 4)	
	Browns Range Methamorphics	BR_Ferruginised_Metamorphics and BR_Metamorphics_Outcrop_Exported	
	Sands – Quaternary/Tertiary	BR_Quaternary_Lakeseds_exported, BR_Quaternary_Sand, BR_Tertiary_lime_soils and BR_Tertiary_Sands	
Surface Water Data	Catchments	Catchment1 and Catchment2	2012
	Stream	MineSiteStreams, Streams	
Surface Topography Information	Surface Topography Information	LiDAR	January 2014
NTU Database	Drill Database	NM_BR_DrillData	November 2013
Infrastructure Data	Site Constraints	BROW_SiteLayout_20131107 and BROW_ProjFtprnt_v3	November 2013
	Pit Constraints	Area5, Gambit-Central, Gambit, Gambit-West and Wolverine	November 2013
	Heritage Constraints	BR_Surveyed HeritageSites_Master	October 2013
Tenement Constraints	Tenement Constraints	BR_Tenement_all	2012

2.2 Regulatory Framework

The *Rights in Water and Irrigation Act 1994* (RIWI Act) established a legislative framework for managing and allocating water resources in Western Australia. Under the Act, administration of the right to the use, flow and/or control of surface water and/or groundwater is vested with the DoW (DoW, 2009). Water licence applications (e.g. RIWI 5C and RIWI 26D licences) for the Project are administered by DoW's regional office in Kununurra.

Establishment of the Project water supply from a groundwater source will require the approval of a water licence from DoW. Once the licence application has been submitted an initial assessment will be conducted by DoW. At the discretion of DoW (under Clause 4(2) of Schedule 1 of the Act), further information may be requested from NTU to support the application (i.e. hydrogeological assessment). Three levels of hydrogeological assessments may be requested by DoW as supporting documents to the application:

- Level H1 – a desktop hydrogeological assessment.
- Level H2 – a basic field hydrogeological assessment, including drilling and test pumping.
- Level H3 – a detailed field hydrogeological assessment, including drilling, test pumping and groundwater modelling.

Key aspects contributing to the hydrogeological assessment level criteria are listed below:

- The volume of groundwater and pumping rate requested.
- The level of use of the groundwater management area (not applicable for fractured rock aquifers).
- The potential impacts on other users.
- The potential impacts on groundwater dependent ecosystems.
- The existing salinity of the groundwater.

Table 2-3 summarises the hierarchy list of each contributing key level criterion for a water licence application and the associated level of hydrogeological assessment, respectively. Application of the DoW water licence application criteria to the proposed Browns Range Project water supply option is summarised in Section 9.2.2.

Currently, NTU holds a "Licence to Take Water" (GWL177452(2)) with a 12 ML/a entitlement for the purpose of dust suppression, mineral exploration activities, earthworks and construction and mining camp supply. This licence was approved on November 22, 2013 and is valid through to March 18, 2015.

Table 2-4 summarises the 26D (licence prior to construction) and 5C (licence to abstract water from the bore) submitted to date as part of the "Licence to Take Water" application.

Table 2-3: DoW Water Licence Application Hydrogeological Assessments Criteria (DoW, 2009)

Volume Requested (ML/a)	Level of Allocation (as %SY)	Potential for Unacceptable Impacts		Existing Salinity (mg/L)
		Other Users	Groundwater Dependent Ecosystems	
<10 (0 points)	0 to <30% (C1) (0 points)	Impacts unlikely (0 points) **(Refer to Section 8)**	Impacts unlikely (0 points)	Fresh <500 (4 points)
10-50 (2 points)	30 to <70% (C2) (1 point)	Impacts possible (2 points)	Impacts possible (2 points) **(Refer to Section 8)**	Marginal 500-1500 (3 points) **(Refer to Section 6.3)**
50-250 (4 points)	70 to <100% (C3) (3 points)	Impacts likely (5 points)	Impacts likely (5 points)	Brackish 1,501-5,000 (2 points)
250-500 (6 points)	100% and over (C4) (5 points)			Saline 5,001-50,000 (1 point)
500-1,000 (8 points)				Hypersaline >50,000 (0 points)
1,000-2,500 (15 points) **(Refer to Section 3.3)**				
>2,500 (20 points)				
DoW Grade Assignment Summary:				
0-7 points	*None (unless other knowledge of risks indicates that Level H1 assessment is warranted)*			
8-12 points	*Level H1 Assessment*			
13-18 points	*Level H2 Assessment*			
> 19 points	*Level H3 Assessment*			

Notes:
- SY - Sustainable Yield
- ML/a - Mega Liters per annum
- mg/L - milligrams per Liter

Table 2-4: Regulatory Licencing Summary

<table>
<tr><th rowspan="3">Bore ID</th><th rowspan="3">Purpose</th><th rowspan="3">Easting [m]</th><th rowspan="3">Northing [m]</th><th colspan="3">Licence</th></tr>
<tr><th rowspan="2">Mine</th><th colspan="2">26D Licence</th></tr>
<tr><th>Form 1</th><th>Form 2</th></tr>
<tr><td>BRRWS001</td><td>Exploration</td><td>489320</td><td>7905860</td><td>E80/3548</td><td>Yes</td><td>No</td></tr>
<tr><td>BRRWS002</td><td>Production</td><td>492985</td><td>7901350</td><td>E80/3548</td><td rowspan="2">Yes</td><td>Yes</td></tr>
<tr><td>BRRWS002M</td><td>Monitoring</td><td>493015</td><td>7901358</td><td>E80/3548</td><td>Yes</td></tr>
<tr><td>BRRWS003</td><td>Exploration</td><td>492775</td><td>7910990</td><td>E80/3547</td><td>No</td><td>No</td></tr>
<tr><td>BRRWS007</td><td>Production</td><td>486095</td><td>7905546</td><td>E80/3548</td><td rowspan="2">Yes</td><td>Yes</td></tr>
<tr><td>BRRWS007M</td><td>Monitoring</td><td>486096</td><td>7905551</td><td>E80/3548</td><td>Yes</td></tr>
<tr><td>BRRWS010</td><td>Production</td><td>485039</td><td>7907927</td><td>E80/4479</td><td rowspan="2">Yes</td><td>Yes</td></tr>
<tr><td>BRRWS010M</td><td>Monitoring</td><td>485053</td><td>7907930</td><td>E80/4479</td><td>Yes</td></tr>
<tr><td>BRRWS008</td><td>Monitoring</td><td>498192</td><td>7912769</td><td>E80/4393</td><td>Yes</td><td>Yes</td></tr>
<tr><td>BRRWS009</td><td>Exploration</td><td>485901</td><td>7916643</td><td>E80/4479</td><td>No</td><td>No</td></tr>
<tr><td>BRWWD002</td><td>Monitoring</td><td>493750</td><td>7914680</td><td>E80/3547</td><td>Yes</td><td>Yes</td></tr>
<tr><td>BRGWD003</td><td>Monitoring</td><td>493970</td><td>7913780</td><td>E80/3547</td><td>Yes</td><td>Yes</td></tr>
<tr><td>BRGWD007</td><td>Monitoring</td><td>492146</td><td>7910024</td><td>E80/3547</td><td>Yes</td><td>Yes</td></tr>
<tr><td>BRAWD006</td><td>Exploration</td><td>493598</td><td>7913661</td><td>E80/3547</td><td>No</td><td>No</td></tr>
<tr><td>BRAWD008</td><td>Monitoring</td><td>492214</td><td>7909949</td><td>E80/3547</td><td rowspan="2">Yes</td><td>Yes</td></tr>
<tr><td>BRAWD009</td><td>Production</td><td>492179</td><td>7909898</td><td>E80/3547</td><td>Yes</td></tr>
</table>

2.3 Preliminary Hydrogeological Investigations

2.3.1 Hydrogeological Scoping Level Assessment – KCB, 2012

KCB completed a scoping level hydrogeological assessment of the anticipated Project water supply and Project dewatering requirements (KCB, 2012a).

A total of 10 preliminary targets for further groundwater investigation were identified and prioritised based on the following criteria:

- Aquifer type and expected sustainable yield / recharge potential.

  The following two aquifer types were targeted:

  - Weathered Bedrock Aquifer – preferentially targeted adjacent to ephemeral water courses for increased recharge potential; and,
  - Deep Regional and Secondary Porosity Aquifer/s – structurally-controlled fractured Browns Range metamorphic and / or Gardiner sandstone aquifer/s.

- Proposed borefield infrastructure / logistics (e.g. distance from infrastructure, anticipated installation cost).

Based on the available hydrogeological information and the outcomes of the scoping level hydrogeological assessment, KCB proposed the following multi-staged approach for the assessment of baseline groundwater conditions, groundwater supply potential and preliminary pit dewatering requirements:

- Stage 1: Site Reconnaissance and Non-Intrusive Investigation (geophysical survey)
- Stage 2: Drilling and Test Pumping Program.
- Stage 3: Analytical Assessment and Numerical Modelling (if applicable).
- Stage 4: Borefield Design (Water Supply and Dewatering Network)

2.3.2 Stage 1 Non-Intrusive Assessment – KCB, 2012b

In October 2012, KCB completed a non-intrusive investigation to allow further characterisation of potential groundwater host media, recharge mechanisms for the targeted aquifer system/s; and, to more accurately identify test drilling locations.

Surface geophysical methods (magnetics and electrical resistivity) were used to characterise previously interpreted geological features (e.g. lithological changes, structure, weathering profile). A total of eight traverses totaling 6,050 m were conducted using the following methods / instruments:

- Electrical resistivity survey using a dipole-dipole array with 10 m electrode spacing, allowing for observation depths of approximately 80 m below ground level.
- Magnetic proton survey with a sensor height of 1.5 m and station spacing at 10 m.

A total of 11 targets were identified from the survey results. These targets were assessed against the targets identified / prioritised during the scoping study (KCB, 2012a) to confirm the test drilling locations for the Stage 2 field program.

In addition to the above, KCB provided drilling supervision for the drilling of one large diameter test production bore (BRR0036P), and an accompanying monitoring bore (BRR0036M) using conventional rotary air-hammer drilling techniques.

3 BROWNS RANGE PROJECT SUMMARY

3.1 Proposed Project Infrastructure

Based on background information provided by NTU, the proposed Project infrastructure is summarised below and presented in Figure 3–1:

- Mining – Open-Pit & Underground

  Mining is proposed to be undertaken using a combination of conventional open pit techniques (i.e. drilling, blasting, loading and hauling) and supported underground (i.e. cut and fill) mining techniques. Access to deeper ore at certain deposits (Wolverine and Gambit-West) is proposed through decline systems, originating from a portal within the open pit.

  Open-Pit Mining

  A total of five open-pits are proposed at Project site. Table 3-1 summarises key aspects of the pit design.

Table 3-1: Open-Pit Design Summary

Deposit	Pit Depth [m]	Surface Diameter [m]	Volume [m^3]
Wolverine	~152	~208	~6,764,063
Gambit	~80	~85	~502,910
Gambit-Central	~44	~66	~248,336
Gambit-West	~140	~155	~4,056,921
Area 5	~70	~99	~1,004,281

Note/s:
- Preliminary pit designs received from NTU on November 14, 2013.
- m – meters.
- m^3 – cubic meter.

Underground Mining

Underground mine designs are currently being undertaken by NTU. Preliminary designs provided by NTU are summarised in Table 3-2. Currently, underground mining is only proposed at the Wolverine and Gambit-West deposits.

Table 3-2: Underground Design Summary – Wolverine & Gambit-West Deposits

Deposit	Depth From [mAHD]	Depth To [mAHD]	No. of Stopes	Average Stope Height [m]
Wolverine	~290	~130	6	~24
Gambit-West	~310	~240	3	~25

Note/s:
- Preliminary underground mine designs received from NTU on January 10, 2014 (Gambit-West) and January 22, 2014 (Wolverine), respectively.
- m – meters.
- mAHD – meters Australian Height Datum.

- Tailings Storage Facility (TSF)

  A single TSF is proposed to store tailings produced from the Project process facility. The proposed TSF extent, as part of the integrated waste landform, is approximately 103 ha, comprising two cells. The two-cell TSF allows for tailings placement to occur in one cell while the other cell is raised; reducing operational difficulties and providing more favorable conditions for the tailings to consolidate (Knight Piesold, 2014).

- Waste Rock Dumps (WRD)

  Currently, three WRDs have been proposed for the storage / use of the waste rock material:

  - Wolverine WRD for the storage of waste rock sourced from the Wolverine deposit;
  - Area 5 WRD for the storage of waste rock sourced from the Area 5 deposit; and,
  - An Integrated waste landform (IWL), which includes the two-cell TSF, for waste rock sourced from the various Gambit deposits.

  However, the design of these facilities is currently still in development and details on final infrastructure configurations is unavailable.

  A stormwater diversion system, is proposed as part of the IWL infrastructure. A stormwater holding pond may be included within the footprint of the IWL, depending upon the amount of water that can be recycled from the TSF without compromising recovery of rare earth elements in the ore processing facility.

- Borrow Material

  Borrow material areas have been identified to source material required for Project construction. These borrow areas include:

  - A rock quarry located approximately 2 km east-southeast of the proposed TSF.
  - Various borrow pits totaling and area of up to about 27 ha along the alignment of the existing access road to Ringer Soak (materials required for proposed road upgrade)

- Roads and Airstrip Infrastructure

  The mine access road would be used during development / construction of the mining areas; personnel village and airstrip facilities; and, to transport equipment and operating supplies. Internal service roads will constructed on an as needs basis.

  The proposed airstrip is located approximately 3 km southeast of the TSF.

- Mine Camp / Village and Office / Administration Facilities

  An accommodation village for an approximate 250 persons mine workforce will be located south of the proposed airstrip.

  The Administration facilities are proposed to be located adjacent to the process plant, east of the TSF.

3.2 Mine Infrastructure & Schedule

Mining activities are scheduled to commence in 2015/2016 with an approximated 10 year Project duration (not including the time required for construction and for mine decommissioning / rehabilitation). A detailed underground mining development schedule was not available at the time of this investigation, therefore, Table 3–3 summarises the proposed schedule for mining activities of the Wolverine, Gambit and Area 5 deposits for the initial 5 years of mining. Figure 3-2 to Figure 3–6 presents the proposed open pit and underground mine layouts of the Wolverine, Gambit and Area 5 deposits.

Table 3-3: Mining Development Schedule Summary

Deposit		Duration		
		Start	End	Total
Wolverine	Open Pit	Month 1	Month 40	40 months
	Underground	~Month 20	TBA	TBA
Gambit	Open Pit	Month 21	Month 33	5 months
Gambit-Central	Open Pit	Month 17	Month 21	13 months
Gambit-West	Open Pit	Month 1	Month 20	20 months
	Underground	~Month 24	TBA	TBA
Area5	Open Pit	Month 45	Month 58	13 months

Note/s:
- TBA - To Be Announced
  Underground mine designs (including associated mining schedule) are currently being undertaken by NTU.

3.2.1 Wolverine Deposit

The proposed open pit and underground mine layouts for Wolverine are presented in Figure 3–2. NTU proposes a multi-stage development schedule for the Wolverine open pit to elevation ~290 mAHD, in a series of 10 m benches:

- Stage 1: Starter pit

  Mining is schedule to commence in Month 1 of the Project schedule with an anticipated completion in Month 10 (elevation 380 mAHD).

- Stage2a: Layback / Expansion

  In order to accommodate deeper mining (greater than elevation 380 mAHD), a layback / expansion of the starter pit will commence in Month 4 through to Month 13 (elevation 380 mAHD) to the final pit surface extent.

- Stage 2b: Pit Deepening

  Deepening of the pit is scheduled to commence in Month 13 through to Month 40 of the Project schedule (base elevation: 290 mAHD).

Access to deeper ore, beneath the proposed pit shell, is proposed through an exploration decline (approximately 6 m high and 6 m wide) to elevation ~130 mAHD which will originate from a portal in the pit wall located at elevation ~400 mAHD. However, a detailed underground mining development schedule was not available at the time of this assessment, therefore, the following key assumptions, based on feedback from NTU, were adopted for this assessment (Section 8.1):

- Decline development
  - A general development rate of 15 m per month (elevation development rate).
  - Assume commencement in Month 9 with continuous development through to Month 29 of the Project schedule.
- Stope development
  - Assume commencement in Month 21 through to Month 32 of the Project schedule.
  - Mining rates and progression are assumed at 2 months per stope level with continuous mining development (from elevation ~290 mAHD) to elevation ~130 mAHD.

3.2.2 Gambit Deposit

The proposed pit extent for Gambit is presented in Figure 3–3. The proposed pit will be mined in a single stage to a pit floor elevation of ~390 mAHD, in a series of 10 m benches. Mining of the Gambit pit is scheduled to commence in Month 21 of the Project schedule with an anticipated completion in Month 33 (13 months mining duration for Gambit).

3.2.3 Gambit-Central Deposit

The proposed pit extent for Gambit-Central is presented in Figure 3–4. The proposed pit will be mined in a single stage to a final pit floor elevation of ~410 mAHD, via a series of 10 m benches. Mining of the Gambit-Central pit is scheduled to commence in Month 17 of the Project schedule with an anticipated completion in Month 21 (5 months mining duration for Gambit-Central).

3.2.4 Gambit-West Deposit

The proposed pit extent for Gambit-West is presented in Figure 3–5. NTU propose a multi-stage development schedule for the Gambit-West pit to a pit floor elevation of ~320 mAHD, via a series of 10 m benches. These stages comprise:

- Stage 1: Starter pit

  Mining is scheduled to commence in Month 1 of the Project schedule with an anticipated completion in Month 8 (elevation 380 mAHD).
- Stage 2a: Layback / Expansion

  In order to accommodate deeper mining (greater than elevation 380 mAHD), a layback / expansion of the starter pit will commence in Month 2 through to Month 14 (elevation 380 mAHD) to the final pit surface extent.
- Stage 2b: Deepening

  Deepening of the pit is scheduled to commence in Month 15 through to Month 20 of the Project schedule (final pit floor elevation: ~320 mAHD).

Access to deeper ore, beneath the proposed pit shell, is proposed through an exploration decline (approximately 6 m high and 6 m wide) to elevation ~240 mAHD which will originate from a portal in the pit wall located at elevation ~330 mAHD. A detailed underground mining development schedule was not available at the time of this investigation and the following key assumptions were adopted for this assessment (Section 8.1):

- Decline development
  - A general development rate of 15 m per month (elevation development rate).
  - Assume commencement in Month 20 with continuous development through to Month 29 of the Project schedule.
- Stope development
  - Assume commencement in Month 20 through to Month 23 of the Project schedule.
  - Mining rates and progression are assumed at 2 months per stope level with continuous mining development (from elevation ~310 mAHD) to elevation ~240 mAHD.

3.2.5 Area 5 Deposit

The proposed pit extent for Area 5 is presented in Figure 3–6. The proposed pit will be mined in a single stage to an approximate depth of 370 mAHD (approximate pit depth of 70 m), in a series of 10 m benches. Mining of the Area 5 pit is scheduled to commence in Month 45 of the Project life, with an anticipated completion in Month 57 (12 month mining duration for Area 5 pit).

3.3 Anticipated Project Water Demand

NTU have indicated that a minimum water supply of ~1,040 ML/a will be required by for the Process Plant following commissioning and during full operation. In addition to this demand, water will also be required for dust suppression and the accommodation village and mine facilities (potable supply). Table 3-4 provides a summary of the water supply requirements for the Project.

Table 3-4: Project Water Supply Requirement Summary

Description	Assumption/s	Volume Requirements	
		[L/s]	[ML/a]
Process Plant	Minimum water supply requirement: 1,040 ML/a:	33	1,041
Accommodation Village	Maximum of 100 person camp Water supply estimate @ 200 L/d per person	0.2	6
Dust Suppression	Average water supply requirement: 300 m^3/d	3	95
	Total	***36.2***	***1,142***
	Contingency (15%)	***6***	***172***
	Total	***42***	***1,325***

Note/s:
- L/s – Liters per second
- ML/a – Mega Liters per annum

4 PROJECT SETTING

4.1 Climate

The Project site is located in northeast Western Australia, adjacent to the Western Australian – Northern Territory border, in the Tanami Desert. Climatic conditions at this location are classified as tropical semi-arid with hot-wet summers, observed from December to March, and cool-dry winters from May to October. Mean temperatures within this region vary from 12.6°C in winter to 38°C in summer (BoM Halls Creek weather station).

4.1.1 Rainfall & Evaporation

The closest active BoM weather station to the Project site is the Halls Creek station (Station ID: 002012), which is located approximately 150 km northwest of the Project site. The following summarises the available BoM data, while Table 4-1 provides a summary of the average monthly rainfall and evaporation.

- Rainfall

  Based on the rainfall records from 1944 to 2013, the mean annual rainfall is 565 mm. Approximately 81% of rainfall occurs between the months of December and March, with the majority of rainfall occurring as high-rainfall tropical storm events.

- Evaporation

  Evaporation has been recorded at the Halls Creek weather station from 2009 to 2013, with a mean annual evaporation of 2,172 mm (pan factor = 0.66). Mean monthly evaporation varies from 126 to 231 mm/month, with higher evaporation rates observed between the months of September and January. Mean evaporation exceeds mean rainfall in every month, including during the wet season.

Table 4-1: BoM Data Summary

Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall												
mm/month	150	143	82	21	13	5	6	2	5	18	37	82
Evaporation												
mm/month	197	164	163	169	146	126	143	170	209	230	231	224
Note/s:												
- mm/month – millimeters per month												

4.2 Physiography

4.2.1 Topography & Drainage

The Project site is located on the northern edge of the Tanami Desert and on the western extent of the Paleoproterozoic Browns Range dome structure. The geology is dominated by the Browns Range Metamorphics and the surrounding Gardiner Sandstone.

The topography across the Project site is relatively flat with a gentle gradient towards the west. Surface elevation ranges between approximately 460 mAHD in the east to 410 mAHD in the west with broad valleys superimposed on the relief (Figure 4–1). The Gardiner Sandstone forms the most prominent topographic features across the site, comprising shallow ridges and undulating terrain.

Surface water drainage across the Project site is ephemeral, with flows observed during the summer wet season (December to March). Surface water flows towards the west, as part of the Sturt Creek catchment. The main water course of Sturt Creek is located approximately 45 km west-northwest of the Project site and is also classified as an ephemeral system.

4.2.2 Natural Springs

A total of three natural springs (one perennial and two ephemeral) have been identified within the vicinity of the Project site. These include:

- Banana Springs (perennial); and,
- Two unnamed ephemeral gnamma holes.

Banana Springs is considered a site of cultural significance to the Kundat Djaru community and is located approximately 12 km to the west of the Project site.

Based on available data, the following provides background information on the perennial Banana Springs:

- The surface expression of the spring is represented by a localised, internal draining wetland;
- The majority of the spring flow is evaporated or used for stock watering;
- The groundwater feeding this spring is hosted by the Gardiner Sandstone (based on the 1:250,000 Gordon Downs Geological Series Map (Sheet SE 52-10)); and,
- Monitoring of the spring discharge (flow and/or quality) has not been previously undertaken.

The above spring characteristics were confirmed by KCB personnel during a visit to the spring in August 2013. No groundwater samples were collected during the Stage 2 field program due to:

- Being unable to identify a distinct groundwater discharge location; and,
- Collection of a water sample from a stagnant water body is unlikely to be representative of the spring discharge (e.g. evaporative signature, fouling from livestock).

Table 4-2 summarises the spring and gnamma hole locations, while Figure 4–2 presents their location with respect to surface geology and proposed Project infrastructure.

Table 4-2: Natural Spring Summary

Springs	Easting (m)	Northing (m)	Geology	Status (August 2013)	Culturally Significant
Banana Springs	478,606	7,911,352	Gardiner Sandstone	Flowing	Yes
Gnamma Hole #1	485,980	7,909,006	Gardiner Sandstone	Not Flowing Potential Seasonal flow only	Unknown
Gnamma Hole #2	493,956	7,914,613	Browns Range Metamorphics	Not Flowing Potential Seasonal flow only	Unknown

Note/s:
- m – meters
- Coordinate System – GDA94, Zone 52

4.3 Regional Geology

Regionally, the Browns Range dome encompasses the majority of the Project site with the general geology summarised by Das (2011): *The Browns Range Dome is a Paleoproterozoic dome formed by a granitic core intruding the Paleoproterozoic "Browns Range" Metamorphics (meta-arkoses, feldspathic meta-sandstones and schists); and, an Archaean orthogneiss and schist unit to the south. The dome, and the aureole of metamorphic units, is surrounded by the Mesopreoterozoic Gardiner Sandstone of the Birrindudu Group. Sandstone units (age uncertain) from the Eastern Canning Basin margin (Billiluna Shelf) have been interpreted to be overlying the Gardiner Sandstone to the southwest of the dome.*

However, a large portion of the Project site area is covered by transported material (e.g. alluvium) of various thickness, with transported material deposition predominantly occurring in areas of lower topography.

4.3.1 Structural Geology

Key regional structures across the Project site (Figure 4–2) comprise:

- A series of east to west trending faults / fracture zones;
- A series of east-northeast to west-southwest trending faults / fracture zones;
- A north to south trending fault / fracture zone west of the deposits; and,
- A north-northwest to south-southeast trending fault / fracture zone east of the deposits.

4.4 Local Geology

A summary of the local geology at each of the deposits is provided in following sections, and is based on Wolverine Total Resource Doubled in a Major Upgrade of Browns Range HRE Mineral Resource Estimate (NTU, 2014).

4.4.1 Wolverine Deposit

The geology of the Wolverine deposit consists of metamorphosed quartz-lithic and arkosic arenites and conglomerates with minor inter-bedded schists, which form part of the Browns Range Metamorphics. The host rocks in the mineralised zone are silicified and brecciated along structures trending between east-west and west-northwest to east-southeast, and dipping steeply to the north. Hematite and sericite alteration are associated with mineralisation. The style of mineralisation is xenotime hydrothermal breccia. Xenotime is associated with varying degrees of veining and brecciation; from 1 mm to 2 mm crackle vein selvages to matrix infill in 5 m wide zones of breccia.

4.4.2 Gambit Deposits

The geology of the Gambit deposits consists of fault breccias that occur within a meta-arenite unit of the Browns Range Metamorphics. The deposit is located within an east-west corridor, defined by increased structural deformation, the alteration signatures, variable silicification and increased fracturing. The main ‘pod’ of mineralisation is interpreted to be sub-vertical, striking east-west with a plunge towards the west. A number of mineralised ‘pods’ have been identified, and are partly associated with fault breccias, within the overall east-west corridor. Mineralisation is interpreted to be a result of hydrothermal xenotime.

4.4.3 Area 5 Deposit

The geology of Area 5 deposit consists of a highly altered quartz arenite and conglomerates which form part of the Browns Range Metamorphics. Intense bleaching and kaolinisation of the arenite unit is observed close to surface, and overlies ferruginous alteration. Foliation of the host rock indicates potential shearing along the contact. Bounding faults have been identified trending north-northwest to the east and west of the mineralisation, with the western fault appearing to cut the bleached arenite. To the east, it appears that the orientation of the alteration contact changes in the vicinity of the shear, trending in a southeast to northwest direction.

5 HYDROGEOLOGICAL FIELD PROGRAM

The hydrogeological field program was conducted between July 25, 2013 and November 6, 2013, and consisted of site reconnaissance and drill target identification; test drilling and bore installation; and, aquifer testing and groundwater sampling. A summary of the applied methodology for this field program is provided in the following sections.

5.1 Water Supply Target Identification

KCB identified 10 water supply targets, as part of the scoping assessment (KCB, 2012a), for further investigation. With limited site-specific hydrogeological information available and the estimated Project water demand (~1,325 ML/a), these targets were prioritised based on the following criteria:

- Aquifer type (e.g. Gardiner Sandstone aquifer, deep fractured-rock aquifer);
- Sustainable yield and associated recharge;
- Distance from proposed Project infrastructure;
- Groundwater quality; and,
- Borefield installation costs.

Table 5-1 summarises the water supply targets and justification for selection.

Table 5-1: Project Water Supply Target Summary

Hierarchy List	Target ID	Easting (m)	Northing (m)	Distance from Proposed Process Plant (m)	Decision Record
1	KCB 3	489,328	7,905,660	9,433	Targeting the Alluvial Aquifer and the Deeper Fracture Aquifer - associated east – west regional fault structure
2	KCB 6	486,095	7,905,546	11,800	Targeting the Gardiner Sandstone Aquifer - associated east northeast – west southwest trending regional fault structure
3	KCB 5	493,184	7,901,443	11,780	Targeting Deeper Fracture Aquifer – (Could be used as a back-up water supply bore for camp) - associated north – south localised structural feature
4	KCB 9	498,192	7,912,769	2,976	Targeting the Deeper Fracture Aquifer - associated east northeast – west southwest trending regional fault structure

Hierarchy List	Target ID	Easting (m)	Northing (m)	Distance from Proposed Process Plant (m)	Decision Record
5	KCB 8	485,901	7,916,643	10,010	Targeting the Gardiner Sandstone Aquifer - associated northeast – southwest and north – south trending fault structure intersection
6	KCB 1	485,039	7,907,927	11,380	Targeting the Gardiner Sandstone Aquifer - associated east northeast - west southwest trending regional fault structure
7	KCB 10	493,318	7,910,489	3,155	Targeting the Deeper Fracture Aquifer - associated east northeast – west southwest trending regional fault structure
8	KCB 2	489,883	7,915,705	5,988	Targeting the Deeper Fracture Aquifer - associated east – west trending regional fault structure
9	KCB 4	499,695	7,916,444	5,657	Targeting the Deeper Fracture Aquifer - associated east – west and southeast – northwest trending fault structure intersection
10	KCB 7	498,219	7,921,281	8,850	Targeting the Deeper Fracture Aquifer - associated east northeast – west southwest and southeast – northwest trending fault structure intersection

Note/s:
- Coordinates - GDA94, Zone 52
- m - meter

A limited surface geophysical survey (KCB, 2012b), consisting of magnetic and electrical-resistivity methods, was conducted in order to verify interpreted geological and/or structural features at the selected targets. However, at the request of NTU, the survey was restricted to water supply targets (at the time) within existing Permit of Work (POW) licence areas.

5.1.1 Water Supply Targets Selection

Following the completion of the geophysical investigation, NTU revised the final drilling and bore network installation scope to include all scoping study identified targets within the greater tenement area.

Based on the originally identified targets, and the results of the geophysical survey, the target locations for the hydrogeological test drilling were refined. Table 5-2 summarises the final 10 water supply drill targets and is represented in Figure 6–1.

Table 5-2: Proposed Water Supply Target Drill Location Details

Hierarch List	Target ID	Easting (m)	Northing (m)	Description
1	BRRWS001	489,320	7,905,860	Possible sub-vertical structure (superficial aquifer & deeper fracture aquifer) - Geology Information: Quaternary sands/alluvial overlying Browns Range Metamorphic - Structural Geological Information: East-west trending regional fault structure zone/s - Geophysical Information: High-low resistive zone, most probably associated with interpreted east-west regional structure
2	BRRWS002	492,985	7,901,350	Possible sub-vertical structure (deeper fracture aquifer) - Geology Information: Colluvium/Quaternary sands overlying Browns Range Metamorphic - Structural Geological Information: No interpreted structural zones - Geophysical Information: High-low resistive zone, interpreted as a sub vertical structural zone.
3	BRRWS003	492,775	7,910,990	Possible structure / contact zone (deeper fracture aquifer) - Geology Information: Browns Range Metamorphic - Structural Geological Information: Northeast-southwest structural zone - Geophysical Information: Sub horizontal, dipping towards the north at about 45 degrees, interpreted as possible structural zone.
4	BRRWS007	486,095	7,905,546	Gardiner Sandstone Aquifer - Geology Information: Sediments – Gardiner Sandstone - Structural Geological Information: East-west structural zone - Geophysical Information: No geophysical information available.
5	BRRWS010	485,039	7,907,927	Gardiner Sandstone Aquifer - Geology Information: Sediments – Gardiner Sandstone - Structural Geological Information: northeast-southwest and north-south structural zones (intersection) - Geophysical Information: No geophysical information available
6	BRRWS008	498192	7912769	Deeper Fracture Aquifer - Geology Information: Tertiary sands overlying Browns Range Metamorphic - Structural Geological Information: Northeast-southwest structural zone/s. - Geophysical Information: No geophysical information available
7	BRRWS009	485901	7916643	Gardiner Sandstone Aquifer - Geology Information: Tertiary/Quaternary sands overlying Sediments – Gardiner Sandstone - Structural Geological Information: north-south and east-west structural zones (intersection). - Geophysical Information: No geophysical information available

Hierarch List	Target ID	Easting (m)	Northing (m)	Description
8	BRRWS004	489,320	7,905,900	Possible sub-vertical structure (superficial aquifer & deeper fracture aquifer) - Geology Information: Quaternary sands/alluvial overlying Browns Range Metamorphic - Structural Geological Information: East-west trending regional fault structure zone/s - Geophysical Information: High-low resistive zone, most probably associated with interpreted east-west regional structure
9	BRRWS005	492,985	7,900,550	Possible sub-vertical structure (deeper fracture aquifer) - Geology Information: Colluvium/Quaternary sands overlying Browns Range Metamorphic - Structural Geological Information: No interpreted structural zones - Geophysical Information: High-low resistive zone, interpreted as a sub vertical structural zone.
10	BRRWS006	492,985	7,900,440	Possible sub-vertical structure (deeper fracture aquifer) - Geology Information: Colluvium/Quaternary sands overlying Browns Range Metamorphic - Structural Geological Information: No interpreted structural zones - Geophysical Information: High-low resistive zone, interpreted as a sub vertical structural zone.

Note/s:
Coordinates - GDA94, Zone 52

5.1.2 Pit Dewatering Assessment Target Selection

A total of four targets were selected to assess the groundwater conditions associated with selected deposits at the Project site and to undertake a preliminary assessment of pit dewatering requirements. The selected deposits comprised Wolverine, Gambit, Gambit-West and Area 5. Targets were identified based on:

- Available surface geophysical results; and,
- Preliminary pit locations / geometries.

Table 5-3 summarises the selected drill targets (refer to Figure 6–1).

Table 5-3: Proposed Dewatering Drill Targets

Hierarch List	Target ID	Easting (m)	Northing (m)	Description
1	Area 5	493,598	7,913,661	Anecdotal hydrogeological information obtained during exploration drilling
2	Wolverine	493,750	7,914,680	Possible HREE structure
3	Gambit	493,970	7,913,780	Possible HREE structure
4	Gambit-West	492,146	7,910,024	Possible HREE structure

Notes:
- m - meter
- Coordinates - GDA94, Zone 52

5.1.3 Drilling Target Selection Limitations (Water Supply & Dewatering)

The following limitations were encountered during the drill target selection.

- Geophysical survey configuration and restricted areas

  The position and arrangement of the geophysical traverses was influenced by the extent of the Project area under approved POWs. Only 3 of the 10 identified water supply targets were surveyed during the Stage 1 field program.

- Available datasets

  - Drill Database

    181 exploration holes have been drilled as part of the exploration and environmental programs. The majority of the exploration holes are located within the vicinity of the deposits, although some holes / bores occur outside the mineralised areas. However, the spatial distribution of these holes / bores is limited to the proposed mining infrastructure and with limited depth (~40 m).

  - Spatial Database

    POW areas have been extended to include potential drill locations originally excluded from the Stage 1 Non-Intrusive program (KCB, 2013a); and, drill targets in these locations were positioned based on regionally interpreted geology and/or airborne geophysical datasets.

- Due to the discrete nature of the fracture system (i.e. high transmissive zones) across the Project site, effective selection of bore locations that could provide a groundwater yield that warrants production bore installation is challenging. As a results additional remote sensing data from the spatial database was incorporated into the target selection process.
- Drilling & Bore Network Installation Program

5.1.4 Hydrogeological Test Drilling

The objective of the hydrogeological test drilling program was to:

- confirm the presence / absence of potential water-bearing structural features (e.g. faults / fractures) identified during the scoping study (KCB, 2012a) and Stage 1 non-intrusive investigation (KCB, 2012b);
- determine the presence and characteristics of the encountered groundwater system, specifically the depth of groundwater intersection and progressive air-lift yield; and,
- establish bore installation designs to allow hydraulic testing of the encountered aquifer and/or monitoring for baseline characterisation.

Welldrill were commissioned by NTU as the hydrogeological drilling contractor for this program. KCB provided on-site drilling supervision and contractor management including hydrogeological / geological logging and coordination of program logistics. The drilling method adopted for this program was conventional rotary-air percussion, using a Fraste FS 500 rig with the capacity to drill to depths of up to 200 m. This drilling technique was selected to aid hydrogeological characterisation of the encountered geology, as immediate identification of groundwater inflow intervals and associated air-lifts yield during drilling can be undertaken.

The following information was recorded, by a qualified hydrogeologist / geologist, during the drilling at each target site:

- Geological data
  - Lithology (1 m intervals);
  - Interpreted structure (anecdotal); and,
  - Weathering.
- Hydrogeological information
  - Depth of groundwater intersection/s; and,
  - Air-lift yields.
  - Physicochemical parameters – pH, electrical conductivity (EC) and temperature (temp), during development of the constructed production bores.

5.1.5 Production & Monitoring Bore Installation

The objective of the production and monitoring bore installation program was to:

- Establish a groundwater monitoring network across the Project site for baseline characterisation of the groundwater system (levels and quality); and,
- Allow hydraulic testing of the encountered aquifers for assessment of supply potential and/or dewatering requirements.

Following completion of the hydrogeological test hole, and based on the drilling results (i.e. depth of groundwater intersection, air-lift yields), the hole was:

- Enlarged/reamed-out to a larger diameter for test production bore construction and subsequent test pumping;
- Constructed as a monitoring bore; or,
- Decommissioned (i.e. backfilled, hole-collapse).

Following the installation of each monitoring and production bore, the bore was developed by continuous air-lifting. This process was conducted to promote hydraulic connection between the bore casing and the aquifer through the annulus, removing fines and drilling additives from the bore. The duration of the development was governed by the removal of drilling additives and fines from the bore; and, the stabilisation of the physico-chemical parameters (pH, EC and temp) and air-lift yield.

5.2 Aquifer Testing Program

Upon completion of the drilling and installation of test production bores, an aquifer testing program was undertaken to allow estimation of aquifer hydraulic parameters and interpretation of hydrogeological characteristics. These parameters/hydrogeological characteristics include:

- Tranmissivity: The transmissivity (T) of an aquifer is a measure of the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the saturated thickness of the aquifer. The unit of measurement is L^2/t ($Length^2/time$). Transmissivity (T) is defined as the product of the hydraulic conductivity (K) and the saturated aquifer thickness (D).

  $$T = KD$$

- Storativity: The storativity (S) of an aquifer is the volume of water released from storage per unit surface area per unit change in head. This parameter is a dimensionless quantity.
- Characterisation of hydraulic boundary conditions in the aquifer, which may comprise barrier or recharge boundaries (e.g. low K fault zones and zones of increased storage, respectively).
- Groundwater flow conditions during pumping – i.e. sustainable yield, storage depletion.
- Groundwater quality changes during long-term pumping to assess groundwater flow paths and connectivity.

The aquifer testing program was carried out between September 2013 and November 2013 and included:

- Multi-Rate Test (MRT);
- Constant Rate Test (CRT); and,
- Recovery Monitoring.

Multi-Rate Test – during the MRT the production bore is pumped at a constant rate for a duration of 60 or 120 minutes (depending on anticipated hydrogeological parameters), where after the step is repeated at a progressively higher discharge rate. During the MRT the drawdown of the groundwater level in the test production bore was recorded. These results were used to assess the bore / aquifer characteristics and to identify the optimal pumping rate for the subsequent 72 hour CRT, and to estimate the maximum potential yield from the bore.

Constant Rate Test – a CRT was performed on the test production bores for a duration of 24 to 72 hours. During the CRT the groundwater level drawdown was recorded in the production and adjacent monitoring bores. The pumping rate was also monitored throughout the duration of the test, and was varied if the rate differed from the initial constant rate. In addition to estimating the aquifer hydraulic parameters, the CRT was undertaken to identify:

- Potential aquifer boundary conditions;
- The rate of groundwater drawdown propagation away from the production bore; and,
- Preliminary aquifer sustainability characteristics.

Recovery Monitoring – at the cessation of the CRT, groundwater levels immediately recover (residual drawdown) within the production and monitoring bores. Measurement of the recovering groundwater level was conducted until groundwater levels were within 90% of pre-CRT levels.

Prior to the commencement of the test pumping program static groundwater levels were measured in the production and monitoring bores to allow drawdown calculations during test pumping. All groundwater level measurements were collected from a fixed reference point (e.g. top of casing) using a dip meter and data-loggers/pressure transducers.

Groundwater discharge from the production bores during testing was via lay-flat house connected to the bore headworks. The lay-flat hose was installed transfer the water greater than 150 m from the test production bore, to limit potential infiltration into the aquifer and production bore during the CRT. For groundwater with high salinity concentrations (e.g. BRR0036P), discharge during the pumping test was directed into a large sump to minimise potential impact on the surface environment.

5.2.1 Falling Head Test

Due to the low air-lift yields encountered during test drilling at the Wolverine and Gambit deposits a production bore was not installed, and therefore, test pumping was not undertaken. Monitoring bores were installed at these deposits and permeability testing was conducted using falling head test (FHT) methods. The FHT was performed by injecting water into the monitoring bore to displace the groundwater level, which was monitored as it recovered to steady state conditions.

5.3 Groundwater Monitoring

5.3.1 Groundwater Sampling

Groundwater sampling was conducted across the Project site to:

- Characterise baseline groundwater quality and identify aquifer types to assist with site-specific hydrogeological conceptualisation and seasonal variability; and,
- Assess potential changes in the hydrogeological regime as a result of long-term abstraction.

An industry standard methodology (e.g. Murray Darling Basin Groundwater Quality Sampling Guidelines (MDBC, 1997)) for groundwater sampling was adopted for the collection of groundwater samples from the project site. This methodology comprised:

- Prior to sampling, groundwater levels in the hole/bore were measured using a “depth to groundwater level” meter (dip meter). The total depth of the hole/bore was measured to allow calculation of volume of the water column and/or static water level in the hole/bore.
- Samples were collected as follow:
  - *Baseline groundwater monitoring program* – Groundwater samples were collected after a minimum of three (3) bore volumes of water had been purged (using a Grundfos MP1 submersible pump) and following stabilisation of physicochemical parameter (e.g. pH, Electrical Conductivity (EC), temperature).
  - *Test pumping program* – Groundwater samples were collected during the CRT at selected intervals. Samples were collected directly from the bore head.
- Samples to be analysed for metal parameters were field filtered to 0.45 microns and preserved using sulfuric acid.

Samples were placed in laboratory-prepared sample containers and stored in insulated boxes packed with ice-packs/bricks prior to transporting to the analytical laboratory (Australian Laboratory Services) under strict chain-of-custody (CoC) protocols. Collected groundwater samples were analysed for the following analytical parameters:

Field physicochemical parameters:

- pH, EC, Temperature

Laboratory analytical parameters:

- Physicochemical Parameters:
  - pH, EC
- Inorganic and Metals Parameters
  - Major ionic constituents: Calcium, Magnesium, Potassium, Sodium, Sulphate, Bicarbonate, Carbonate, Chloride,
  - Fluoride, Phosphorus
  - Metals / Metalloids constituents (total and dissolved): Aluminium, Antimony, Arsenic, Barium, Beryllium, Cadmium, Cobalt, Copper, Chromium, Manganese, Nickel, Lead, Vanadium, Zinc, Molybdenum, Selenium, Tin, Iron, Mercury
  - Nitrogen-species Parameters: Ammonia, Nitrite, Nitrate, Nitrite + Nitrate

Quality Assurance/Quality Control (QA/QC)

Samples were handled, stored and transported to the laboratory in accordance with established protocols using Chain of Custody (CoC) documentation for sample tracking and specification of the required analytical suites.

Exceedence of holding times for some parameter (e.g. pH, alkalinity, major ionic constituents) occurred due to the remote Project site location and the logistics of transporting the collected samples to the laboratory.

The following quality checks were implemented for the inorganic laboratory results (after Hounslow, 1995):

- Quality check 1 – the relative percent difference (RPD) of the parent and duplicate sample should be less than 20%[2];
- Quality check 2 – charge balance error calculation should be less than 5%; and,
- Quality check 3 – if carbonate is absent, the pH should be less than 8.

The objective of the quality assurance checks was to obtain an estimate of the accuracy of the data. Quality check 1 is summarised in Appendix C, while Quality checks 2 and 3 are discussed below and summarised in Table 5-4.

Quality check 2: Anion-Cation Balance

Charge balance error calculations provide an additional measure of QC for the major ions. All solutions should be electrochemically neutral (i.e. the sum of the cations in meq/L should be equal to the sum of the anions in meq/L (Hounslow, 1995)). The charge balance error is usually expressed as a percentage and is calculated by:

[2] Springer et al, Water Quality Assessment – Issues from a Laboratory Management Perspective.

$$Charge\ Balance = \frac{(sum\ of\ Cations - sum\ of\ Anions)}{(sum\ of\ Cations + sum\ of\ Anions)}\ x\ 100$$

A charge balance of less than ±5% is acceptable. A charge balance in excess of 5% indicates that some analytes may not be correctly analysed, or that there is an analyte that has not been tested. Charge balance errors of greater than 5% were recorded at water samples collected from BRRWS010 only.

Quality Check 3 – Alkalinity and pH

If carbonate is absent in the water sample, the pH should be less than 8 (Hounslow, 1995). All samples have pH values of less than 8 (Table 5–4).

Table 5-4: Quality checks for inorganic laboratory results

Sample ID	Quality Check 2	Quality Check 3
	CBE<5%	If carbonate is absent, then calc pH<8
BRRWS010-72h	Greater than 5%	pH value less than 8 – carbonate is absent
BRRWS007-72h	Below 5%	pH value less than 8 – carbonate is absent
BRAWD009-72h	Below 5%	pH value less than 8 – carbonate is absent
BRAR0030	Below 5%	pH value less than 8 – carbonate is absent
BRGWD003	Below 5%	pH value less than 8 – carbonate is absent
BRGR0016	Below 5%	pH value less than 8 – carbonate is absent
BRGWD007	Below 5%	pH value less than 8 – carbonate is absent
BRR0030	Below 5%	pH value less than 8 – carbonate is absent
BRR0036M	Below 5%	pH value less than 8 – carbonate is absent
BRR004	Below 5%	pH value less than 8 – carbonate is absent
BRR010	Below 5%	pH value less than 8 – carbonate is absent
BRRWS001	Below 5%	pH value less than 8 – carbonate is absent
BRRWS008	Below 5%	pH value less than 8 – carbonate is absent
BRRWS007M	Below 5%	pH value less than 8 – carbonate is absent
BRWWD002	Below 5%	pH value less than 8 – carbonate is absent
OLD CAMP	Below 5%	pH value less than 8 – carbonate is absent

5.3.2 Groundwater Level Monitoring

The objective of the groundwater level monitoring program was to establish baseline groundwater levels and determine groundwater variability relative to seasonal changes.

Monitoring bores BRWWD002 and BRRWS010M were equipped with a Solinst levelogger data loggers, programmed to record at six-hourly intervals. In addition, a barometric logger was deployed to allow correction of water level data relatively atmospheric pressure changes.

6 HYDROGEOLOGICAL FIELD PROGRAM RESULTS

6.1 Drilling & Bore Installation

6.1.1 Hydrogeological Exploration Drilling

A total of 13 hydrogeological test holes were drilled as part of the water supply (7 targets) and dewatering (6 targets) assessment. Drilling was completed to depths ranging from 84 to 200 m. Figure 6–1 presents the locations of these test holes.

Each hydrogeological test hole was drilled and constructed as follows:

- A pre-collar was installed at the top of the hole to mitigate hole collapse from the surficial unconsolidated and/or weathered geology. Drilling was conducted using a ~254 mm/10 inch nominal diameter (ND) drill bit to the base of the softer weathered material and equipped with solid steel casing of ~203 mm/8 inch inner diameter (ID);
- Following the pre-collar installation, the hole was advanced to the final depth at a diameter of ~152 mm/6 inch; and,
- Based on the encountered drilling results from the test hole, the hole was either reamed for test production bore installation (i.e. high groundwater yield encountered), constructed as a monitoring bore (i.e. groundwater yield encountered not sufficient for production bore installation but suitable for baseline monitoring purposes) or abandoned by extracting the steel pre-collar for site rehabilitation purposes.

Hydrogeological drilling and bore construction logs for each of the drilled test holes are provided in Appendix B, and summarised in Table 6-1.

6.1.1.1 Geology

A summary of the geology encountered during the hydrogeological test drilling program is provided as follows.

Surficial Unconsolidated Sediments

A large proportion of the Project area is covered with unconsolidated alluvium and colluvium deposits of Quaternary and Tertiary age. The thickness of these deposits varies across the Project site with thicker (<12 m) sequence observed in lower lying areas (e.g. water courses etc.).

Table 6-1: Summary of Drilling Results

Description				BRRWS003	BRRWS002	BRRWS001	BRRWS007	BRRWS010	BRRWS008	BRGWD003	BRWWD002	BRGWD007	BRAWD006	BRAWD008	BRAWD009	BRRWS009
Location & Dates	Coordinates	Easting		492,774	492,984	489,319	486,102	485,053	498,189	493,945.08	493,474.52	493,115.25	492,142.25	492,214.03	492,179.45	486,010
		Northing		7,911,000	7,901,351	7,905,860	7,905,543	7,907,930	7,91,2758	7,913,905.84	7,914,715.28	7,913,596.77	7,910,024.84	7,909,948.72	7,909,897.51	7,916,625
	Commenced Date			July 29, 2013	July 30, 2013	August 01, 2013	August 03, 2013	August 05, 2013	August 10, 2013	August 12, 2013	August 15, 2013	August 16, 2013	August 18, 2013	August 28, 2013	August 31, 2013	September 19, 2013
	Completion Date			July 30, 2013	August 01, 2013	August 03, 2013	August 05, 2013	August 09, 2013	August 11, 2013	August 14, 2013	August 16, 2013	August 17, 2013	August 19, 2013	August 30, 2013	September 01, 2013	September 19, 2013
Drilling Details	Depth Advanced	From (m bGL)		0	0	0	0	0	0	0	0	0	0	0	0	0
		To (m bGL)		150	150	150	99	84	150	200	200	200	200	200	200	150
Geology Details				BR-MM -Clay -Arenite	BR-MM -Clay -SStone -Quartz	BR-MM -SStone -MStone	G-SS -Cl -Arkose -Quartz -Conglo	G-SS -Clay -Arkose -Quartz	BR-MM -SStone -Schists -Granite	BR-MM -SStone -Arkose	BR-MM -SStone -Arkose -Schist	BR-MM -SStone -Arkose -Schist	BR-MM -SStone -Arenite	BR-MM -SStone -Quartz -Mudstone	BR-MM -SStone -Quartz -Arenite	BR-MM -MStone
Hydrogeological Details	Water strike	m bGL		52	54 66	66	86	18	80	53	35	None	47	69	60	66
	Cumulative Yield	L/s		Seepage	Seepage (@54m) 3.5 (@66m) 5.5 (@138m) 6.6 (@150m)	Seepage	8	6.2 (@36m) 6.2 (@48m) 8.5 (@66) 11 (@84)	~1 (@102m)	Seepage	Seepage	Not Applicable	Seepage (@47m) 0.5 (@119m) 0.5 (@143m) 1.25 (@191m) 1.8 (@200m)	1 (@69m) 1 (@118m) 1.2 (@138m) 1.8 (@200)	1 (@114m) 1.1 (@118m) 3(@162m) 3 (@180m) 3 (@200m)	Seepage
	Quality[1]	pH	pH Unit	Not Applicable	9.57	Not Applicable	7.73	7.74	10.17	Not Applicable	Not Applicable	Not Applicable	10.32	8.86	8.37	Not Applicable
		EC	µS/cm	Not Applicable	1908	Not Applicable	232	72	482	Not Applicable	Not Applicable	Not Applicable	1900	2344	3020	Not Applicable
		Temp	°C	Not Applicable	30	Not Applicable	29.3	30.2	27.7	Not Applicable	Not Applicable	Not Applicable	29.8	30.4	29.6	Not Applicable
Spatial Survey Information	GPS/Differential GPS (NTU)			GPS	GPS	GPS	GPS	GPS	GPS	Differential GPS (NTU)	Differential GPS (NTU)	Differential GPS (NTU)	Differential GPS (NTU)	Differential GPS (NTU)	Differential GPS (NTU)	GPS
	Date			September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 19, 2013
	KCB/NTU			KCB	KCB	KCB	KCB	KCB	KCB	NTU	NTU	NTU	NTU	NTU	NTU	KCB

Note/s:
- L/s - Litres per second
- µS/cm - microSiemens per centimeter
- B-MM - Browns Range Metamorphics
- SStone - Sandstone
- Conglo - Conglomerate
- m bGL - meters below Ground Level
- °C - degrees Celsius
- G-SS - Gardiner Sandstone
- MStone - Mudstone
- [1] groundwater quality may be influenced by additives used during drilling

Browns Range Metamorphics

A summary of results from the test drilling conducted across the Browns Range Metamorphics is provided as follows:

- The encountered lithology was generally similar in each test hole consisting of a thick package of arkose sandstone with quartzite, clay and mudstone inter-beds.
- No direct visual evidence of fractures was recorded (i.e. observation of fracture faces on drill chips) at the drill locations.

  However, indirect evidence of fracture / structural zones was occasionally identified by the presence of quartz chips and/or minor leaching (iron staining).
- A granitic unit was encountered at BRRWS008 at a depth of approximately 75 mbGL.

Gardiner Sandstone

Drilling of the targets in the Gardiner Sandstone generally encountered a stratigraphic sequence predominantly comprising quartz-rich sandstone with minor inter-beds of mudstone. The following key observations were also identified:

- Weathering of the sandstone unit is relatively shallow ranging from 18 (BRRWS007) to 24 mbGL (BRRWS010).
- Anecdotal drilling characteristics, including lost circulation and increased groundwater yields, were associated with the intersection of groundwater-bearing zones, although changes in the lithology (e.g. iron-staining) were limited.

The following issues were encountered during the test drilling of the Gardiner Sandstone:

- Slow penetration rate – a dramatic decrease in drilling rates occurred once competent lithology was encountered:
  - BRRWS007 – from approximately 84 mbGL; and,
  - BRRWS010 – from approximately 42 mbGL.
- Drill bit damage – due to the encountered competent lithology, drill bit wear increased. As a result, to limit the wear on the drill bit, the bits were regularly inter-changed (approximately every 6 to 12 m) to maintain constant wear on each of the bits.

6.1.1.2 Groundwater Strike & Air-Lift Yields

Across the Project site, groundwater was intersected at depths ranging from 18^{o}m to 162 m, with cumulative air-lift yields ranging from minor seepage (<0.5L/s) to 11 L/s. The majority of groundwater intersections were encountered between 40 and 90 mbGL with some secondary deeper intersections occurring at depths of 140 and 160 mbGL (BRAWD009).

6.1.2 Monitoring & Production Bore Construction

A total of four hydrogeological test holes were reamed and constructed as large diameter production bores with depth ranging between 84 and 174 m. A summary of test production bore construction is provided below, with hydrogeological logs provided in Appendix B.

- Installation of a pre-collar using a 311 mm ND drill bit to the base of the softer unconsolidated transported material (i.e. quaternary sands) and/or weathered bedrock and equipped with solid steel casing of 305 mm inner diameter (ID).
- Following the pre-collar installation, the hole was advanced to final depth using 304 mm ND drill bit. All production bores were constructed in accordance with the "Minimum Construction Requirements for Water Bores in Australia (2012)[3]", including:
  - Construction with 203 mm outer diameter (OD) Class 18 uPVC, bell jointed casing, with up to 30 m factory slotted, 0.5 mm aperture casing screens and 6 m stainless steel "Johnson" wire-wound screen across the highest yielding zone of groundwater inflow.
  - Annular completions with 3 to 6 mm gravel pack, with bentonite seals and grout completion at surface.

Following construction of the production bores, a monitoring bore was drilled and constructed approximately 15 to 20 m adjacent to the production bore. The purpose of this monitoring bore is to allow monitoring of groundwater levels during the test pumping program. Drilling for the monitoring bore was completed using the same procedure as the test hole. Following drilling the bore was constructed using 50 mm OD, class 18, bell-jointed, uPVC casing with factory slotted 0.5 mm aperture screens. The slotted screen was located adjacent to the highest inflow zone within the hole.

In addition to the above monitoring and production bore construction, the following hydrogeological test holes were constructed as monitoring bores for baseline characterisation and long-term monitoring:

- BRWWD002 (Wolverine Pit),
- BRGWD003 (Gambit Pit),
- BRGWD007 (Gambit-West Pit); and,
- BRRWS008 (regional – east of the proposed mining activity areas).

[3] National uniform Drillers Licensing Committee, 2012, Minimum Construction Requirements for Water Bores in Australia, Third Edition (ISBN 978-0-646-56917-8).

Table 6-2: Monitoring & Production Drilling Details

Description				BRRWS002	BRRWS002M	BRRWS007*	BRRWS007M	BRAWD009	BRWSD008	BRRWS010	BRRWS010M
Status & Dates	Status			Completed	Completed	Completed	Completed	Completed	Completed	Completed	Completed
	Commenced Date			August 20, 2013	August 25, 2013	August 26, 2013	September 10, 2013	September 01, 2013	August 28, 2013	September 12, 2013	September 15, 2013
	Completion Date			August 24, 2013	August 26, 2013	September 09, 2013	September 12, 2013	September 05, 2013	August 30, 2013	September 15, 2013	September 17, 2013
Bore/Hole Type	Monitoring/Production Bore			Production Bore	Monitoring Bore	Production Bore	Monitoring Bore	Production Bore	Monitoring Bore	Production Bore	Monitoring Bore
Drilling Details	Depth Advanced		From (m bGL)	0	0	0	0	0	0	0	0
			To (m bGL)	153	153	99	93	200	200	84	83
	Drill Bit Size	7” (pre-collar)	From (m bGL)	n/a	0	n/a	0	n/a	0	n/a	0
			To (m bGL)	n/a	6	n/a	6	n/a	6	n/a	6
		>7”	From (m bGL)	n/a	6	n/a	6	n/a	6	n/a	6
			To (m bGL)	n/a	153	n/a	93	n/a	200	n/a	83
		14” (pre-collar)	From (m bGL)	0	n/a	0	n/a	0	n/a	0	n/a
			To (m bGL)	12	n/a	12	n/a	9	n/a	6	n/a
		12”	From (m bGL)	12	n/a	12	n/a	9	n/a	6	n/a
			To (m bGL)	153	n/a	99	n/a	200	n/a	84	n/a
Hydrogeological Details	Water strike/		m bGL	54 66 138	n/a	86	82	60	69 138	36 66 84	18
	Cumulative Yield		L/s	11	n/a	15	n/a	4	1.8	11	4
	Quality	pH	pH Unit	n/a	n/a	6.26	n/a	8.37	8.86	7.14	7.07
		EC	µS/cm	n/a	n/a	179.8	n/a	3020	2344	62.6	75
		Temp	°C	n/a	n/a	30	n/a	29.6	30.4	30.3	30.4
Spatial Survey Information	GPS/Differential GPS (NTU)			GPS	GPS	GPS	GPS	Differential GPS (NTU)	Differential GPS (NTU)	GPS	GPS
	Date			September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013	September 06, 2013
	KCB/NTU			KCB	KCB	KCB	KCB	NTU	NTU	KCB	KCB

Note/s:

- n/a - not applicable
- L/s - Liters per second
- °C - degrees Celsius
- m bGL - meters below Ground Level
- µS/cm - micro Siemens per centimeter
- * - Drilling of BRRWS007 was conducted in stages due to the nature/composition of the Gardiner Sandstone sedimentary unit and associated risk of equipment damage (Refer to Section 6.1.1.1)

Table 6-3: Monitoring & Production Bore Construction Details

Description	Depth	BRRWS003	BRRWS002	BRRWS002M	BRRWS001	BRRWS007	BRRWS007M	BRRWS010	BRRWS010M	BRRWS008	BRRWS009	BRWWD002	BRGWD003	BRAWD006	BRGWD007	BRAWD009	BRAWD008 (BRAWD009M)
Casing – 6½" Steel (pre-collar)	From (m bGL):	Not Constructed	n/a	0	Not Constructed	n/a	0	n/a	0	0	Not Constructed	0	0	Not Constructed	0	n/a	0
	To (m bGL):		n/a	6		n/a	6	n/a	6	6		6	6		6	n/a	6
Casing – 2" uPVC Class 18 Solid (Monitoring Bore)	From (m bGL):		n/a	0		n/a	0	n/a	0	0 90		0 42	0 60		0 60	n/a	0
	To (m bGL):		n/a	126		n/a	69	n/a	53	78 120		30 120	48 120		48 120	n/a	144
Casing – 2" uPVC Class 18 Slotted (Monitoring Bore)	From (m bGL):		n/a	126		n/a	69	n/a	53	78 120		30 120	48 120		48 120	n/a	144
	To (m bGL):		n/a	150		n/a	93	n/a	84	90 150		42 150	60 150		60 150	n/a	174
Casing – 12" Steel (pre-collar) (Production Bore)	From (m bGL):		0	n/a		0	n/a	0	n/a	n/a		n/a	n/a		n/a	0	n/a
	To (m bGL):		12	n/a		12	n/a	6	n/a	n/a		n/a	n/a		n/a	6	n/a
Casing – 8" uPVC Class 18 Solid (Production Bore)	From (m bGL):		0	n/a		0	n/a	0	n/a	n/a		n/a	n/a		n/a	0	n/a
	To (m bGL):		126	n/a		69	n/a	54	n/a	n/a		n/a	n/a		n/a	138	n/a
Casing – 8" uPVC Class 18 Slotted (Production Bore)	From (m bGL):		126	n/a		69	n/a	54	n/a	n/a		n/a	n/a		n/a	138	n/a
	To (m bGL):		150	n/a		99	n/a	84	n/a	n/a		n/a	n/a		n/a	162	n/a
Casing – 8" Stainless Steel Wire-Wound Screen (Production Bore)	From (m bGL):		138	n/a		81	n/a	66	n/a	n/a		n/a	n/a		n/a	162	n/a
	To (m bGL):		144	n/a		87	n/a	72	n/a	n/a		n/a	n/a		n/a	168	n/a
Gravel Pack	From (m bGL):		6	6		6	6	6	6	75 110		25 110	40 110		40 110	6	6
	To (m bGL):		153	153		99	93	84	84	95 150		45 150	64 150		64 150	168	174
Bentonite Seal	From (m bGL):		5	5		4	5	5	5	4		4	4		4	5	5
	To (m bGL):		6	6		5	6	6	6	5		5	5		5	6	6
Grout Seal	From (m bGL):		0	0		0	0	0	0	0		0	0		0	0	0
	To (m bGL):		5	5		4	5	5	5	4		4	4		4	5	5

Note/s:
- n/a – not applicable
- m bGL – meters below Ground Level

The monitoring bores were constructed to address "gaps" identified in the groundwater monitoring network (KCB, 2013), including:

- Lack of permanent long-term monitoring locations in the vicinity of the proposed Wolverine and Gambit deposits; and,
- Spatial distribution of monitoring network, particularly to the east of the proposed Project infrastructure.

Field Water Quality Measurements

Table 6-4 provides a summary of field measured physicochemical parameters recorded during production bore development.

Table 6-4: Summary of Field Physicochemical Results

Bore ID	Date	Duration [min]	pH [pH Unit]	Electrical Conductivity [µS/cm]	Temperature [°C]
BRAWD009	August 05, 2013	60	8.32	2940.0	31
		180	8.32	2850.0	30
		360	8.32	2840.0	30
BRRWS007	August 09, 2013	30	7.05	68.5	29
		60	7.82	65.2	29
		90	7.43	63.1	33
		120	7.39	62.7	31
		180	7.24	63.5	30
		240	7.28	46.9	30
		300	7.14	62.6	30
BRRWS010	15 September 2013	60	7.51	196.9	31
		120	7.61	172.5	32
		180	7.45	178.1	30
		240	6.67	185.5	31
		300	6.46	177	31.
		360	6.62	183.1	30
		420	6.26	179.8	30

Note/s:

- min - Minutes
- µS/cm - micro Siemens per centimeter
- °C - degrees Celsius

6.2 Test Pumping

Following construction and development of the production bores, test pumping was undertaken. Welldrill were commissioned to conduct the test pumping program between September 2013 and November 2013.

Table 6-5 provides a summary of the test pumping program.

6.2.1 Key Observations

The drawdown response/s in each of the tested bores is characteristic of the following:

- the groundwater system at each test location did not reach steady-state conditions over the duration of CRT;
- approximately 30% to 40% of the available drawdowns at each test location were achieved over the period of the CRT;
- Late time increases in drawdown are indicative of a boundary condition within the aquifer. These boundary conditions reflect the heterogeneous aquifer parameters (i.e. hydraulic conductivity and specific storage), typical of secondary porosity aquifers.

The drawdown and recovery curves from the MRT's and CRT's are provided in Figure 6–2 to Figure 6–9. A summary of the hydraulic parameters estimated from the test pumping program results are provided in Table 6-5, with further discussion provided in the following section.

6.2.2 Data Analyses

6.2.2.1 Multi-Rate Test

Interpretation of MRT data was undertaken to establish a relationship between drawdown and pumping rate; and, to derive apparent bore efficiency values, aquifer equation coefficients and preliminary aquifer parameters.

The MRT data at each tested bore was analysed using the Lennox (1966) analytical method for MRT analysis (Hazel, 1975), and the modified Sternberg bore equation (Hazel, 1975). Based on these analyses, a theoretical sustainable constant discharge rate was estimated for a 72 hour CRT. The estimated rate for the CRT was selected to suitably stress the aquifer, over the proposed test duration, to allow assessment of yield sustainability.

The MRT drawdown response for each tested bore location is presented in Figure 6–2 to Figure 6-5.

6.2.2.2 Constant-Rate Test

Based on the results from the MRT analysis, a CRT was undertaken on the production bores for a duration of 24 to 72 hours at the pre-determined discharge rate (Table 6–5). Results from the CRT's are discussed below in terms of the groundwater level response to abstraction.

BRR0036P

The CRT for BRR0036P was conducted at 5 L/s for 72 hours, with groundwater levels measured in the:

- Production bore BRR0036P – a total of 13.14 m drawdown was recorded over this period; and,
- Monitoring bore BRR0036M (located approximately 20 m east of BRR0036P) – a total of 9.97 m drawdown was recorded over this period.

Table 6-5: Test Pumping Program Summary

Site ID	Production/ Monitoring Bore	Easting	Northing	Distance from Production Bore	Static Water Level		Pump System Details			MRT			Recovery		CRT			Recovery	
							Pump Details	Pump Inlet Depth	Electronic Flow Meter	Steps	Yields	Maximum Drawdown	Duration	Recovery Percentage	Duration	Yield	Maximum Drawdown	Duration	Recovery Percentage
		[m]	[m]	[m]	[m bGL]	[m AHD]		[m bGL]			[L/s]	[m]	[min]	[%]	[min]	[L/s]	[m]	[min]	[%]
Water Supply Assessment																			
BRRWS002	Production	492,984	7,901,351	n/a	27.05	426.95	Lowara 16GS75	108	Yes	3	Step1: 1L/s Step2: 1.5L/s Step3: 2L/s	48.06	180	> 95%	1440	1.5	32.11	270	> 95%
BRRWS002M	Monitoring	492,997	7,901,355	13.60	26.97	427.03	n/a	n/a	n/a	n/a	n/a	2.35	180	> 95%	1440	n/a	3.23	270	> 95%
BRRWS007	Production	486,102	7,905,543	n/a	4.09	412.90	Grundfos, SP46, 50Hzn iso2548	80	Yes	4	Step1: 10L/s Step2: 12L/s Step3: 14L/s Step4: 15L/s	20.02	420	> 95%	4320	15	24.1	1680	> 95%
BRRWS007M	Monitoring	486,093	7,905,560	19.20	4.01	412.98	n/a	n/a	n/a	n/a	n/a	11.13	420	> 95%	4320	n/a	14.72	1680	> 95%
BRRWS010	Production	485,053	7,907,930	n/a	9.32	397.67	Grundfos, SP46, 50Hzn iso2548	85	Yes	4	Step1: 5L/s Step2: 6L/s Step3: 7L/s Step4: 9L/s	69.53	400	> 95%	4320	6	16.86	360	> 95%
BRRWS010M	Monitoring	485,057	7,907,912	20	9.61	397.39	n/a	n/a	n/a	n/a	n/a	0.61	400	> 95%	4320	n/a	0.86	360	> 95%
Dewatering Assessment																			
BRAWD009	Production	492,179	7,909,897	n/a	31.34	414.77	Grundfos, SP46, 50Hzn iso2548	80	Yes	3	Step1: 5L/s Step2: 6L/s Step3: 7L/s	62.14	300	> 95%	4320	5	40.88	1680	> 95%
BRAWD008	Monitoring (BRAWD009)	492,214	7,909,948	61.80	31.99	414.92	n/a	n/a	n/a	n/a	n/a	1.34	300	> 95%	4320	n/a	2.75	1680	> 95%
Existing Production Bore																			
BRR0036P	Production	489,759	7,905,669	n/a	Pumping*	Pumping*	Lowara 16GS75	65	Yes	3	Step1: 4L/s Step2: 5L/s Step3: 6L/s	9.04	360	> 95%	4320	6	13.14	2880	> 95%
BRR0036M	Monitoring	489,774	7,905,661	17	8.58	420.67	n/a	n/a	n/a	n/a	n/a	4.27	360	> 95%	4320	n/a	9.969	2880	> 95%

Note/s:

- * - Bore is currently being in use by NTU.
- m bGL - meters below Ground Level
- m AHD - meters Australian Height Datum
- n/a - not applicable

From the drawdown curve (Figure 6–6), the following have been identified:

- Continuous drawdown of the groundwater level throughout the duration of the CRT indicates that the system did not reach steady state conditions.
- Approximately 30% of the available drawdown[4] was achieved over the duration of the CRT.
- A sudden drop in water levels was observed after 5 hours of the CRT, indicating a possible boundary condition.
- Drawdown-time curve is typical of a linear flow regime with negligible influences from well bore storages.

BRAWD009

The CRT for BRAWD009 was conducted at 5 L/s for 72 hours, with groundwater levels measured in the:

- Production bore BRAWD009 – a total drawdown of 40.88 m was recorded over this period; and,
- Monitoring bore BRAWD008 (located approximately 61 m northeast of BRAWD009) – a total drawdown of 2.75 m drawdown was recorded over this period.

From the drawdown curve (Figure 6–7), the following are apparent:

- Continuous drawdown of the groundwater level throughout the duration of the CRT indicates that the system did not reach steady state conditions.
- Approximately 35% of the available drawdown was achieved over the duration of the CRT.
- The rate of drawdown remains relatively constant for the first 32 hours of the test, after which the rate of drawdown sharply increases to the end of the CRT. This increase in drawdown may indicate a boundary condition as the pumping rate has not changed but the drawdown rate has increased.

The abrupt level changes in the drawdown curve at 4.5 hours (4.79 m) and 12 hours (1.95 m) is most likely due to measurement errors during groundwater level monitoring.

BRRWS007

The CRT for BRRWS007 was conducted at 15 L/s over a period of 72 hours with groundwater levels measured in:

- Production bore BRRWS007 – a total drawdown of 24.10 m was recorded over this period; and,
- Monitoring bore BRRWS007M (located approximately 19 m north of BRRWS007) – a total drawdown of 14.72 m was recorded over this period.

[4] Available drawdown is determined as the distance between the screen top interval and the static water level prior to commencement of the CRT.

From the drawdown-time curves (Figure 6–8), the following have been identified:

- Continuous drawdown of the groundwater level throughout the duration of the CRT, indicates that the system did not reach steady state conditions.
- Approximately 40% of available drawdown occurred over the duration of the CRT.
- The rate of drawdown remains relatively constant during the first 42 hours of the CRT, after which the rate of drawdown slightly increases for the remaining test duration. This increase in drawdown after 42 hours may indicate a no-flow boundary condition (e.g. low permeability fault, extent of fracture complex etc) as the pumping rate has not changed but the drawdown rate has increased.

BRRWS010

The CRT performed on BRRWS010 was conducted at 6 L/s over a period of 72 hours, with groundwater levels measured in:

- Production bore BRRWS010 – a total drawdown of 16.86 m was recorded over this period;
- Monitoring bore BRRWS010M (located approximately 20 m north of BRRWS010) – a total drawdown of 0.86 m was recorded over this period; and,
- Monitoring bore BRRWS007M (located approximately 2.6 km southeast of BRRWS010) – drawdown was not recorded during the CRT.

Based on the drawdown-time curves (Figure 6–9), the following have been apparent:

- Continuous drawdown of the groundwater level throughout the duration of the CRT indicates that the system did not reach steady state conditions.
- Approximately 70%of the available drawdown occurred over the duration of the CRT.
- The rate of drawdown remains relatively constant for the first 28 hours of the CRT, after which the rate of drawdown significantly increases for the remainder of the test duration. This increase in drawdown after the 28 hour indicates a no-flow boundary conditions likely to be a result of the applied pumping rate exceeding the aquifer storage.

6.2.3 Hydraulic Parameter Solution

The aquifer parameters were estimated from the test pumping results using the Cooper-Jacob Straight-Line method (Cooper and Jacob, 1946) as this solution is based on the flow to a bore in a confined and leaky aquifer that is homogenous, isotropic and uniform thickness (including constant temperature and viscosity) with infinite areal extent. Although the applied methodology for calculating analytical parameters are based on assumptions not applicable to actual site conditions (e.g. infinite areal extent, homogeneous system etc), the resulting hydraulic parameters from these calculations are representative of the tested aquifer system within the vicinity of the production bore. Based on the conceptualised hydrogeological setting, these hydraulic parameters may be interpreted to be representative of the aquifer system, particularly regional system with relatively uniform lithology (e.g. Gardiner Sandstone).

The following equations provide a summary of the Cooper-Jacob solution for the calculation of aquifer transmissivity and storativity:

$$T = \frac{2.3Q}{4\pi\Delta s}$$

$$S = \frac{2.25Tt}{{r_0}^2}$$

Where:

T - Transmissivity (m^2/d);

Q - Pumping rate (m^3/d);

Δs - Drawdown per log cycle (m);

t_0 - straight-line projection of time drawdown to zero drawdown axis

r - radial coordinate

S - Storativity (unitless)

Table 6-6: Calculated Hydraulic Parameter Summary

Location	Bore ID	Transmissivity [m^2/d]	Horizontal Hydraulic Conductivity [m/d]	Storativity [unit less]	Analytical Method
Browns Range Metamorphics	BRAWD009	18	0.19	$10^{-05} – 10^{-04}$	Cooper-Jacob (1946)
	BRR0036P	61	9.5	$10^{-03} – 10^{-02}$	Cooper-Jacob (1946)
Gardiner Sandstone	BRRWS007	84	4.8	$10^{-04} – 10^{-03}$	Cooper-Jacob (1946)
	BRRWS010	75	11.3	$10^{-05} – 10^{-03}$	Cooper-Jacob (1946)

Note/s:
- m/d - meters per day
- m^2/d - squared meters per day

6.3 Groundwater Monitoring

6.3.1 Groundwater Quality

Groundwater quality sampling was conducted to establish the baseline groundwater quality of the encountered aquifers across the Project site. In addition to baseline characterisation, these data can be used to assess potential connectivity between different groundwater bearing units (via comparisons of groundwater chemistry between bore locations), and to identify potential changes over time during long-term pumping events (e.g. CRT).

Groundwater samples were collected during the CRT at pre-determined intervals; and during two quarterly groundwater sampling rounds from designated monitoring bores and exploration holes (KCB, 2013a and KCB, 2013b). Additional groundwater sampling was undertaken in April 2014, which included ultra-trace analysis for Selenium. Australian Laboratory Services (ALS), a NATA certified testing laboratory, was commissioned to undertake the analytical testing for the collected groundwater samples. Summary tables for the groundwater quality results are presented in Appendix C along with the laboratory certificates of analysis.

Groundwater quality parameter concentrations have been compared against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) for livestock watering and freshwater ecosystems (95% protection). Summary results of the key water quality parameter groups are provided in the following bullet points.

- Physicochemical Parameters

  Electrical Conductivity (EC) of the groundwater ranges from 60 µS/cm to approximately 4,970 µS/cm, with the exception of groundwater sampled from BRR0036P – 32,800 µS/cm.

  pH varies across the Project site from 5.56 to 8.17 indicating slightly acidic to slightly alkaline conditions.

- Major ionic Constituents

  In general, the cations and anions reported from the different samples are below the relevant ANZECC (2000) water quality criteria for livestock watering and freshwater ecosystems (95% protection), except for nitrate and sulphate (concentrations from groundwater sourced from BRR036P (3,180 mg/L)).

- Metals/Metalloids

  Parameters exceeding ANZECC (2000) guidelines trigger values for freshwater ecosystems (95% protection):

  - Boron (0.37 mg/L);
  - Copper (0.0014 mg/L);
  - Zinc (0.008 mg/L).

  There are no apparent spatial patterns associated with these parameters and they are likely a result of the varying geological and structural conditions.

6.3.2 Groundwater Level

In-situ water level data loggers were installed within monitoring bores BRWWD002 and BRRWS010M to assess water level variability over time, particularly between dry and wet seasons. Groundwater level hydrographs for BRWWD002 and BRRWS010M are presented in Figure 6-10 and Figure 6-11, respectively; for the period December 2013 through to March 2014.

The general groundwater level trends over this period, which includes a significant rainfall event (~480 mm over 5 days) between January 15, 2014 and January 20, 2014, can be summarised as follows:

- BRWWD002 (Browns Range Metamorphics aquifer):
  - Change in groundwater – 1.72 m
  - Groundwater response – a period of rapid and instantaneous increase in groundwater levels, followed by a slight decrease in levels. No significant, similar increases were recorded associated several additional smaller rainfall events to March 18, 2014.

- BRRWS010M (Gardiner Sandstone aquifer):
  - Change in groundwater level – 1.67 m.
  - Groundwater response – A gradual increase in groundwater levels. Groundwater levels continue to gradually increase over time due to several additional smaller rainfall events and the recharge characteristics of a regional system.

7 HYDROGEOLOGICAL CONCEPTUALISATION

Generally, the hydrogeological system at the Project site comprises the Browns Range Metamorphics aquifer and the Gardiner Sandstone aquifer. Unconsolidated surface alluvium overlies both aquifers and periodically stores water resulting from rainfall infiltration. The storage of this water is likely to be temporary as this water is likely removed from this system via infiltration to the underlying bedrock aquifers and/or evapotranspiration. Due to the seasonal nature of groundwater storage in the surface alluvium, the surficial alluvial aquifer is not considered in detail as part of this hydrogeological conceptualisation. Further details on the Browns Range Metamorphics and Gardiner Sandstone aquifers are provided in the following sections.

7.1 Browns Range Metamorphics Aquifer

The Browns Range Metamorphics comprises a thick sequence of metamorphosed sediments ranging from arenites to conglomerates with minor variability. Although specific differences in the lithological units of this formation are observed (e.g. degree of weathering and alteration etc), the lithology of this formation can be considered similar across the formation. The primary porosity of this formation is low, with groundwater predominantly occurring in localised geological structures (e.g. faults, shear zones, fracture zones), within zones of secondary porosity.

Limited major structural features have been interpreted within the vicinity of the Wolverine and Gambit deposit areas (AMC, 2013), however, a discrete northwest to southeast striking shear zone has been identified at Area 5. Upon drilling the shear zone at Area 5 groundwater storage was encountered. Based on the results of drilling within the vicinity of the Area 5 shear zone, the shear zone is considered to be discrete (5-10 m wide), with groundwater storage away from the shear zone being limited. Although the majority of groundwater in the Browns Range Metamorphics is stored within the secondary porosity of geological structures, some drilling away from the structures has encountered limited groundwater inflow, Therefore, although the encountered groundwater yield away from the geological structures are not sufficient to justify bore installation, the presence of groundwater indicates the potential inter-connectivity across the formation.

The estimated extent of the Browns Range Metamorphics aquifer is presented in Figure 7-1 along with the regional piezometric surface. Cross-sections through the aquifer, including a general west to east section through the Gambit deposits; and, a general north to south section through the Wolverine, Gambit and Area 5 deposits are presented in Figures 7-2 and 7-3, respectively.

Hydrogeological testing at locations across the Browns Range Metamorphics Aquifer indicates that the hydraulic conductivity of the aquifer ranges from 7.2×10^{-3} m/d (competent bedrock) to 9.5 m/d (Area 5 shear zone). Storativity of the Area 5 shear zone ranges from 10^{-3} to 10^{-2}.

Groundwater levels recorded from various locations across the Browns Range Metamorphics aquifer are summarised as follows:

- Wolverine – ~444 mAHD
- Gambit – ~446 mAHD
- Gambit West – ~431 mAHD
- Gambit Central – ~441 mAHD
- Area 5 – ~414 mAHD

Based on the results of the groundwater level monitoring the groundwater gradient across the Browns Range Metamorphics aquifer is from east to west at approximately 0.001. This gradient is a subdued reflection of the surface topography.

Automated groundwater level monitoring of a monitoring bore adjacent to the Wolverine Deposit (BRWWD002) indicates variability in groundwater levels as a result of seasonal variability, with an increase in water levels observed during the wet season (December to March). Specifically, the monitoring records indicate that a 1.72 m increase in groundwater levels occurred between January 15, 2014 and January 20, 2014; where a total of 480 mm of rain was recorded. These records indicate that recharge to the aquifer system is a result of rainfall infiltration. The groundwater level response to the rainfall event can be divided into three response sections described as:

- Section 1 (rapid and instantaneous increase) – represents the direct recharge of faults and/or fractures (secondary porosity) of the aquifer through rainfall infiltration.
- Section 2 (slight decrease) – represents the transfer of water from the fault/fracture zones into the low permeability matrix (micro-pores) of the Browns Range Metamorphics unit.
- Section 3 (gradual increase) – this section likely represents the recharge of the aquifer as a result of additional rainfall following the initial rainfall event. The gradual rise of the water level likely indicates the pre-saturation of the micro-pores and the fault/fracture zones, resulting in the combined rise of the water level in both water-bearing zones. Indirect infiltration from overlying alluvium, saturated during the rainfall events, into the bedrock aquifer may also be contributing to the rise in the groundwater level.

The groundwater level response summarised in the above bullet points indicates that recharge to the system is localised and is typical of a fractured rock aquifer system (Healy and Cook, 2002).

Based on the groundwater level and rainfall records, the estimated groundwater recharge rate of 0.4% was calculated using the Water-Table Fluctuation (WTF) method (Healy and Cook, 2002) and is presented in Table 7-1.

Table 7-1: Browns Range Metamorphics Recharge Calculation

Description	Value
Change in Water Level (m)	1.72
Rainfall (15 Jan - 20 Jan) (m)	0.48
Storativity (S)	0.0001
Recharge (mm)	0.18
Recharge Percentage (%)	0.04

Groundwater quality results from the Browns Range Metamorphics aquifer is variable, ranging from fresh to very saline (typically slightly saline), and is characterised as a sodium-chloride-bicarbonate:

- Electrical Conductivity (EC) of the groundwater ranges from 60 µS/cm to approximately 4,970 µS/cm, with the exception of groundwater sampled from BRR0036P (32,800 µS/cm).
- pH varies from 5.9 to 8.2 indicating slightly acidic to slightly alkaline conditions, with alkalinity represented entirely as bicarbonate

When compared to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) for livestock watering and freshwater ecosystems (95% protection), the Browns Range Metamorphics aquifer is generally below trigger values. Summary results of the key water quality parameter groups are provided in the following bullet points.

- Major ionic Constituents

  In general, the cations and anions reported from the different samples are below the relevant ANZECC (2000) water quality criteria for livestock watering and freshwater ecosystems (95% protection), except for nitrate and sulphate (concentrations from groundwater sourced from BRR036P (3,180 mg/L)).

- Metals/Metalloids

  Parameters exceeding ANZECC (2000) guidelines trigger values for freshwater ecosystems (95% protection):

  - Boron (0.37 mg/L);
  - Copper (0.0014 mg/L);
  - Zinc (0.008 mg/L).

There are no apparent spatial patterns associated with these parameters and they are likely a result of the varying geological and structural conditions.

7.2 Gardiner Sandstone Aquifer

The Gardiner Sandstone comprises a medium-grained bedded arenite and quartz-arenite sandstone unit, which is estimated to be over 300 m thick (DME, 2000). This unit unconformably overlies the Browns Range Metamorphics, and outcrops approximately 10 km to the west of the Project site. Regional mapping of the Gardiner Sandstone has identified this unit to occur beyond Sturt Creek to the west of the Project site (over 35 km from the Project site).

Limited primary porosity is observed in the Gardiner Sandstone, with the majority of groundwater hosted in the secondary porosity relating to geological structures and associated fracturing. Although limited information is available on the hydrogeological characteristics of the Gardiner Sandstone aquifer, beyond the characterisation conducted as part of this assessment, this unit is considered to be a regionally extensive system due to the number of registered DoW groundwater bores installed in this formation, along with the widespread occurrence of surface expressions of groundwater (e.g. springs, seepages) associated with the Gardiner Sandstone.

Hydrogeological testing of the Gardiner Sandstone aquifer indicates that the hydraulic conductivity ranges from 4.8 m/d to 11.3 m/d, with a storativity of 10^{-5} to 10^{-4}. The estimated storativity values are indicative of a confined or semi-confined aquifer system, which is supported by the observed artesian conditions across the formation and the higher groundwater level relative to the groundwater inflow zone.

Limited groundwater level records from the Gardiner Sandstone aquifer is available beyond the monitoring conducted as part of this assessment. As a result, the elevation of Banana Springs (i.e. groundwater elevation at surface) was incorporated with the groundwater level records from the installed Gardiner Sandstone bores to allow interpretation of a groundwater flow gradient and flow direction. Based on observed groundwater levels, the groundwater flow in the Gardiner Sandstone aquifer is from east to west, with an estimated gradient of approximately 0.002. Recorded groundwater levels range from 413 mAHD (BRRWS007) and 398 mAHD (BRRWS010) to 390 mAHD (Banana Springs).

Automated groundwater level monitoring, established by KCB, in the Gardiner Sandstone between January and March 2014 indicate a rise in the groundwater level of the system as a result of rainfall infiltration (wet season). This rise in groundwater level is anticipated to be a seasonal occurrence as a result of the wet season / dry season variability. A rise of 1.67 m in the groundwater level was observed in monitoring bore BRRWS010M from January 15, 2014 to January 20, 2014. This increase in the groundwater level correlates with a 480 mm rainfall period between January 15 and January 20. Additional, smaller, rainfall events from January 20 to March occurred and resulted in the continual increase in groundwater levels over this period. The rate of groundwater level increase over the monitoring period is relatively constant, indicating continued recharge from subsequent rainfall events and the recharge signature of a regional aquifer system (rather than a system fed by local infiltration).

Based on these groundwater level and rainfall records, an estimated groundwater recharge rate of 1.3% was calculated using the Water-Table Fluctuation (WTF) method (Healy and Cook, 2002) and is presented in Table 7-2.

Table 7-2: Gardiner Sandstone Recharge Calculation

Description	Value
Change in Water Level (m)	1.67
Rainfall (10 Jan - 20 Jan) (m)	0.48
Storativity (S)	0.0037
Recharge (m)	0.0062
Recharge (mm)	6.18
Recharge Percentage (%)	1.27

Groundwater quality results indicate that the Gardiner Sandstone groundwater is fresh with a sodium-chloride-bicarbonate character:

- Electrical Conductivity (EC) of the groundwater ranges from 64 µS/cm to approximately 161 µS/cm.

- pH varies from 5.6 to 6.2 indicating slightly acidic conditions, with alkalinity represented entirely as bicarbonate

When compared to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) for livestock watering and freshwater ecosystems (95% protection), the groundwater quality in the Gardiner Sandstone generally complies with the ANZECC (2000) trigger values. Summary results of the key water quality parameter groups are provided in the following bullet points.

- Major ionic constituents

  In general, the cations and anions reported from these samples are below the relevant ANZECC (2000) water quality criteria for freshwater ecosystems (95% protection), except for nitrate concentrations from BRRWS010 (1.02 mg/L).

- Metals/Metalloids

  Parameters exceeding ANZECC (2000) guidelines trigger values for freshwater ecosystems (95% protection):

  - Copper (0.0014 mg/L);
  - Zinc (0.008 mg/L).

8 GROUNDWATER ASSESSMENTS

The groundwater assessment associated with this investigation comprises two components; dewatering assessment for the proposed pits and water supply assessment for the Project water demand. Using the preliminary hydrogeological conceptualisation of the Project and the proposed mine development and schedule, numerical assessments of the hydrogeological system relative to the proposed Project development were undertaken.

Numerical models are commonly used to develop hydrogeological management solutions that include the prediction of groundwater level change over time and the associated groundwater pumping rates, as a result of the proposed mining activities. However, the complexity of groundwater systems may be beyond the ability of conventional numerical models to define in detail. Therefore, it is necessary to make several simplifying assumptions to allow a reasonable estimation of anticipated hydrogeological conditions.

Visual MODFLOW (Version 2011.1) was used to simulate the groundwater flow across the Project site. MODFLOW is a modular three-dimension (3D) finite-difference groundwater model developed by the U.S Geological Survey (McDonald and Harbaugh, 1983). Dewatering and Water Supply Model reports are provided in Appendix D and summarised in the following sections.

8.1 Dewatering Assessment

Based on the test drilling at each of the deposits, limited groundwater resources were identified, with the exception of Area 5. Mining depths vary from 44 m (Gambit-Central) to 324 m (Wolverine – underground), resulting in a saturated thickness of 75% to 95% relative to the total mining depths and the associated groundwater level.

Specific objectives of the dewatering assessment include:

- Assessment of the groundwater drawdown extent away from the mine development as a result of dewatering activities;
- Estimation of dewatering rates associated with mine development;
- Assessment of the dewatering schedule associated with each deposit – i.e. commencement of dewatering activities, timing and distribution of dewatering activities relative to open pit mine development; and,
- Preliminary assessment of infrastructure required to conduct dewatering activities.

8.1.1 Model Approach & Limitations

Conceptualisation of the hydrogeological system/s within the vicinity of the deposits (Section 7) and available development schedule for the initial 5 years formed the basis for the groundwater model development, governing the model domain and model input parameters.

However, as a result of various limitations / data gaps in the available conceptualised hydrogeological system, several assumptions were adopted in the development of the model domain to adequately represent the system. These included the distribution of the aquifer hydraulic parameters (hydraulic conductivity, specific storage), recharge mechanisms and aquifer thickness.

Based on available geological (including structural geology) and hydrogeological data (refer to Section 7), the drawdown extent from dewatering associated with the Wolverine and Gambit deposits are unlikely to reach the Area 5 deposit, therefore, two numerical models were constructed to simulate the groundwater systems and pit/underground workings development associated with:

- the Wolverine and Gambit deposits; and,
- the Area 5 deposit.

Key limitations, assumptions and consequences of predictive simulation/s are presented and summarised in Table 8-1.

Table 8-1: Model Limitations, Assumptions & Consequences Summary

Data	Limitations	Assumptions	Consequences
Localised Structural Geology	Limited data pertaining to localised water-bearing structures	Homogeneous aquifer with no discrete water-bearing structures (with the exception of the Area 5 deposit)	Potential water-bearing zones not modelled (with the exception of the Area 5 deposit)
Aquifer Recharge	No accurate site-specific recharge data	Assigned generally accepted values for comparable system setting	Potentially inaccurate modelled water levels
Hydraulic Parameters	Insufficient data set across the model domain	Bulk hydraulic parameter values have been assigned on a "regional scale" from hydraulic testing programs	Potentially inaccurate modelled scenarios
Simplified Model Domain for Simulation of Underground Workings – Single Layer Model	Drain cells conservatively simulate decline or stope dewatering	Drain cell elevation based on proposed elevations of workings from mining schedule and assumes dewatering from surface to drain cell elevation	Conservative simulation of groundwater levels and inflow rates
Mine Plan and Schedule	Preliminary mine plans and schedule available for Month 1 to Month 40	Mining activities only for a total of 40 months	Variation in drawdown extents with increase in mining development schedule.

8.1.2 Model Setup

8.1.2.1 Model Domains

Each model domain was constructed to allow the assignment of boundary conditions along the edges of the domain such that potential drawdown extents resulting from pit dewatering did not approach the model edge or was not unrealistically influenced by the boundary conditions. The total area of the model domains are:

- Wolverine and Gambit model – ~68km^2; and,
- Area 5 model – ~36km^2.

Details of the model domains including aquifer parameter distribution, recharge, boundary conditions and dimensions are provided in Appendix D.

8.1.3 Model Simulations & Verifications

Steady-state models were developed and verified for hydraulic parameters, boundary conditions and recharge; and formed the basis of the transient simulations. Steady-state verified groundwater levels were used as the initial groundwater level for the predictive transient simulations.

8.1.4 Transient Simulations

Predictive transient simulations were undertaken to assess the groundwater level drawdown extents and groundwater inflow rates from dewatering of the various mine voids throughout the duration of the Project schedule.

Details of the boundary conditions, and the assumptions associated with these boundary conditions, are provided in Appendix D.

8.1.5 Model Simulation Sensitivity Analyses & Results

The predictive drawdown results provided reasonable estimates for the anticipated dewatering activities associated with the proposed mine void development. A summary of the numerical model results for each mine void is provided in the following sections.

8.1.5.1 Wolverine & Gambit Model Results

During the initial stages of the predictive simulation, the cone of influence as a result of the proposed dewatering activities is predicted to be localised to the Wolverine and Gambit-West mine voids. From Month 23 of the Project schedule; inter-connection of the drawdown associated with the various localised pit developments occurs, resulting in the development of an elongated northeast-southwest cone of influence across the Wolverine and Gambit deposits.

It is evident from these predictive simulations that the drawdown extent changes, from the pit void perimeter, across the various mining areas relatively to the mine development schedules (e.g. mining depth, rate and schedule). At the time of this assessment, a detailed underground mining development schedule was not available and drawdown extents associated with underground mining weren't assessed and should be investigated further.

Table 8-2 to Table 8-4 summarise the drawdown simulations results for Wolverine, Gambit-West and Gambit pits, respectively. Figure 8–1 to Figure 8–4 represents the drawdown extents, associated with selective stages of the Project schedule.

Table 8-2: Drawdown Extent Summary – Wolverine Deposit

Mining Duration	Direction	Drawdown from Pit Perimeter						
		0m	50m	100m	200m	300m	400m	>400m
Stage [months]			[m]	[m]	[m]	[m]	[m]	[m]
Stage 1 (month 21)	N	28	18	11	4	1	-	-
	E	27	17	9	3	1(@260m)	-	-
	S	71	47	31	11	3	1(@380m)	-
	W	48	37	29	13	5	1 (@410)	-
Stage 2 (month 29)	N	50	31	19	7	3	1(@380m)	-
	E	51	31	19	7	2	1(@370m)	-
	S	123	80	52	21	8	3	2(@450m)
	W	87	57	40	19	8	3	1(@500m)

Mining Duration	Direction	Drawdown from Pit Perimeter						
		0m	50m	100m	200m	300m	400m	>400m
Stage [months]			[m]	[m]	[m]	[m]	[m]	[m]
Stage 3 (month 33)	N	65	41	26	10	4	1(@420m)	-
	E	64	40	25	10	4	1(@410m)	-
	S	135	91	61	27	11	5	3(@500m)
	W	104	68	46	21	10	4	1(@500m)
Stage 4 (month 40)	N	87	58	39	16	7	3	1(@500m)
	E	82	55	36	16	6	3	1(@500m)
	S	147	104	74	36	17	8	6(@460m)
	W	122	84	58	28	13	6	1(@600m)

Table 8-3: Drawdown Extent Summary – Gambit-West Deposit

Mining Duration	Direction	Drawdown from Pit Perimeter						
		0m	50m	100m	200m	300m	400m	>400m
[months]			[m]	[m]	[m]	[m]	[m]	[m]
Stage 1 (month 21)	N	133	97	51	13	3	1(@380m)	-
	E	33	21	12	4	1(@300m)	-	-
	S	40	26	16	6	2	1(@450m)	-
	W	43	16	6	2	1(@350m)	-	-
Stage 2 (month 29)	N	193	152	93	33	11	3	2(@460m)
	E	57	39	25	10	4	1(@400m)	-
	S	51	33	22	10	4	1(@430m)	-
	W	65	40	25	10	4	1(@430m)	-
Stage 3 (month 33)	N	124	106	82	39	15	6	3(@500m)
	E	63	46	31	13	6	3	3(@500m)
	S	54	38	26	12	5	2	1(@460m)
	W	64	45	30	13	5	2	1(@460m)
Stage 4 (month 40)	N	82	74	63	39	20	10	6(@500m)
	E	55	45	35	18	9	5	4(@660m)
	S	48	38	28	15	7	3	1(@520m)
	W	54	43	33	17	8	3	1(@520m)

Table 8-4: Drawdown Extent Summary – Gambit Deposit

Mining Duration	Direction	Drawdown from Pit Perimeter						
		0m	50m	100m	200m	300m	400m	>400m
[months]			[m]	[m]	[m]	[m]	[m]	[m]
Stage 1 (month 21)	N	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-
	S	-	-	-	-	-	-	-
	W	-	-	-	-	-	-	-
Stage 2 (month 29)	N	10	4	1(@110m)	-	-	-	-
	E	4	1(@60m)	-	-	-	-	-
	S	8	3	1(@100m)	-	-	-	-
	W	7	3	3(@140m)	-	-	-	-
Stage 3 (month 33)	N	13	7	3	2	2(@300m)	-	-
	E	7	3	2	1(@120m)	-	-	-
	S	12	6	1(@170m)	1	-	-	-
	W	11	6	5	6(@200m)	-	-	-
Stage 4 (month 40)	N	7	6	5	3	4(@300m)	-	-
	E	6	4	3	1(@200m)	-	-	-
	S	7	6	4	2	1(@260m)	-	-
	W	8	7	7(@110m)	-	-	-	-

Due to the size and proposed mining schedule for the Gambit-Central deposit, the drawdown cone of influence is masked by dewatering activities at the Gambit-West deposit.

Pit Inflows

Groundwater inflows into the various pit voids were assessed and are considered conservative due to the model specific assumptions and limitations. The conservatism is largely influenced by the model setup (e.g. general head boundary), which results in a continuous groundwater contribution into the groundwater system (as opposed to finite groundwater sources stored in discrete geological structures). Realistically, this infinite source of groundwater is not expected and the predicted inflow rates are likely to be an upper limit estimate.

Generally, groundwater inflow rates increased gradually from the intersection of the water table to the final pit floor elevation:

- Wolverine pit – from ~8L/s to ~23L/s;
- Gambit pit – from ~6L/s to ~9/s;
- Gambit-Central pit – from ~6L/s to ~9/s; and,
- Gambit-West pit – from ~1L/s to ~27/s.

Sensitivity Analysis

Sensitivity analyses have been undertaken to assess how sensitive the model results are to changes in the model hydraulic parameters. These parameters have been selected for the sensitivity analysis due to the limitations in the data set across the model domain (e.g. parameter distribution). Variations in parameter values were evaluated by:

- Hydraulic conductivity – decreasing (K / 5) and increasing (K x 5) by half an order of magnitude; and,
- Storage – halving (S / 2) and doubling (S x 2).

The resulting drawdown extents (Figure 8–5 and Figure 8–6) associated with the modified hydraulic parameters indicates that changes in hydraulic conductivity is considered the most significant with the extent of the 1 m drawdown contour from the pit edge ranging from:

- Wolverine deposit – ~320 m (K / 5) to ~1,400 m (K x 5) with drawdowns between ~68 m and ~173 m at the pit void extent, respectively.
- Gambit deposit –~110 m (K / 5) to ~1,150 m (K x 5) with drawdowns between ~7 m and ~21 m at the pit void extent, respectively.
- Gambit-West deposit –~200 m (K / 5) to ~1,450 m (K x 5) with drawdowns between ~33 m and ~50 m at the pit void extent, respectively.

8.1.5.2 Area 5 Model

Although the drawdown extent as a result of the dewatering activities associated with Area 5 is considered localised in the vicinity of the Area 5 pit, drawdown is most pronounced along strike of the northwest to southeast interpreted water-bearing shear zone. This is due to relatively higher hydraulic conductivity associated within this zone in comparison to the low hydraulic conductivity country rock. The maximum distance of drawdown extent, from the pit void extent, with 1 m drawdown contour observed is approximately 220 m. Table 8-5 summarises the drawdown simulations results for Area 5 pit, while Figure 8–7 presents the drawdown extents at the cessation of Area 5 development.

Table 8-5 Drawdown Extent Summary – Area 5 Pit

Mining Duration	Direction	Drawdown from Pit Perimeter						
		0m	50m [m]	100m [m]	200m [m]	300m [m]	400m [m]	>400m [m]
Month 58*	NW	13	8	4	1(@220m)	-	-	-
	E	3	1(@30m)	-	-	-	-	-
	W	10	3	1(@75m)	-	-	-	-
	SE	10	5	3	1(@210m)	-	-	-

* Month 58 represents the cessation of mining activity in the Area 5 pit (final pit void).

Pit Inflows

Groundwater inflows into Area 5 pit were assessed and are considered conservative due to the model specific assumptions and limitations. The conservatism is largely influenced by the model setup (e.g. general head boundary), which results in a continuous groundwater contribution into the groundwater system (as opposed to finite groundwater sources stored in discrete geological structures). Realistically, this finite source of groundwater is not expected and the predicted inflow rates are likely to be an upper limit estimate.

Generally, pit inflow rates increased gradually from 2 L/s at the intersection of the water table around the 410 mAHD bench to 13 L/s at the final pit floor elevation (~370 mAHD).

Sensitivity Analysis

Sensitivity analyses have been undertaken to assess how sensitive the model results are to changes in the model hydraulic parameters. These parameters have been selected for the sensitivity analysis due to the limitations in the data set across the model domain (e.g. parameter distribution). Variations in parameter values were evaluated by:

- Hydraulic conductivity – decreasing (K / 5) and increasing (K x 5) by half an order of magnitude; and,
- Storage – halving (S / 2) and doubling (S x 2).

The resulting drawdown extents (Figure 8–8and Figure 8–9) associated with the modified hydraulic parameters indicates that model results are most sensitive to hydraulic conductivity with the extent of the 1 m drawdown contour away from the pit edge ranging from:

- North – ~85 m (K / 5) to ~480 m (K x 5) with drawdowns between ~7 m and ~16 m at the pit void extent, respectively.
- East – pit perimeter (K / 5) to ~150 m (K x 5) with drawdowns between ~1 m and ~8 m at the pit void extent, respectively.
- South – ~85 m (K / 5) to ~220 m (K x 5) with drawdowns between ~3 m and ~16 m at the pit void extent, respectively.

- West – ~85 m (K / 5) to ~460 m (K x 5) with drawdowns between ~6 m and ~16 m at the pit void extent, respectively.

8.2 Water Supply Assessment

During the hydrogeological scoping study (KCB, 2012), the Ringer Soak community water supply bores and Banana Springs (groundwater-fed wetlands), located approximately 34 km and 12 km to the west of the Project area, respectively, were identified as being sourced from the Gardiner Sandstone aquifer. Therefore, development and production from a borefield installed in this aquifer, for the Project water supply, may potentially impact these receptors. As a result, the specific objectives of the water supply assessment include:

- assess the extent of drawdown associated with long-term (10 year Project life) pumping from the Gardiner Sandstone aquifer;
- evaluate the long-term sustainability of the Gardiner Sandstone as a potential water supply option for the Project; and,
- identify potential impacts on Banana Springs and the Ringer Soak community water supply.

8.2.1 Model Approach & Limitations

The conceptual understanding of the Gardiner Sandstone aquifer, based on limited hydrogeological drilling, testing and monitoring, was the basis for the groundwater modelling. As a result, key assumptions were adopted in the construction of the model to adequately represent the system. These included the distribution of the aquifer hydraulic parameters (e.g. hydraulic conductivity, specific storage), recharge mechanisms and aquifer thickness/extents.

Key limitations, assumptions and consequences of predictive simulation/s are presented and summarised in Table 8-6.

Table 8-6: Model Limitations, Assumptions and Consequences Summary

Data/Area	Limitations	Assumptions	Consequences
Regional Groundwater Level	No regional water level data was available beyond the Project area (exploration licence area)	Regional water levels developed from steady-state calibration	Potentially inaccurate modelled water levels; limited data for model verification away from the Project site
		Regional water levels was generally a reflection topography	
Regional Structural Geology	No data pertaining to regional structures	Homogeneous aquifer with no structures	Variations in hydraulic parameters across the model domain not incorporated into the model
Pumping Rates	Sustainable yields based on 72 hour pumping test	Calculated sustainable yields assumed to be sustainable for Project duration (10 years)	Potential decline in proposed Project water supply borefield yields over time
Recharge	No accurate site-specific rainfall or recharge data	Assigned generally accepted values relative to comparable settings	Potentially inaccurate modelled water levels

Data/Area	Limitations	Assumptions	Consequences
Hydraulic Parameters	Insufficient regional data (spatial distribution)	Bulk hydraulic parameter values have been assigned on a regional scale using estimated data	Potentially inaccurate modelled scenarios, inaccurate water levels and verification
Scenario A Proposed Borefield Network	Drilling has not been conducted at proposed bore site; actual groundwater yield and aquifer characteristics may not be accurately represented in the model	Homogenous aquifer parameter based on hydraulic testing conducted to date	Potentially inaccurate groundwater level drawdown simulation from proposed borefield

8.2.2 Model Setup

8.2.2.1 Model Domain

The model domain was establish to incorporate the interpreted regional extent of the Gardiner Sandstone aquifer and associated boundary conditions (e.g. Sturt Creek). This resulted in a model domain area of ~5800 km^2.

Details on the construction of the model domain and the various model input parameters (e.g. hydraulic conductivity, specific storage, recharge, boundary conditions) are provided in Water Supply Modelling report (KCB, 2014a), provided in Appendix D.

8.2.2.2 Model Verification & Sensitivity Analysis

8.2.2.3 Model Verification

Steady-state models were developed and verified for hydraulic parameters, boundary conditions and recharge; and formed the basis of the transient simulations. A steady-state verified groundwater level was used as the initial groundwater level for the transient simulations.

8.2.3 Transient Simulations

Predictive transient simulations were undertaken to assess the groundwater level drawdown extents as a result of long-term pumping from a proposed production bore network throughout the duration of the Project life and to assess the sustainability of the Gardiner Sandstone aquifer based on the following borefield scenarios:

- Base Case – pumping from the installed test production bores (BRRWS007 and BRRWS010) pumping at a total cumulative rate of 21 L/s; and,
- Scenario A – abstraction from seven production bores, with each bore pumping at 6 L/s.

8.2.4 Model Simulation Results & Sensitivity Analyses

8.2.4.1 Simulation Results

The predictive simulation drawdown results provided reasonable estimates for the anticipated borefield production activities. Influences on the groundwater level on Banana Spring are considered negligible with seasonal groundwater fluctuations likely to “mask” the simulated drawdown at the spring.

Based on the two borefield scenarios, the maximum drawdown simulated within the vicinity of these proposed borefields were similar, with drawdowns varying between 0.65 m (Base Case) and 0.72 m (Scenario A)[5]. Figure 8–10 and Figure 8–11 presents the drawdown extents associated with the different water supply borefields.

8.2.4.2 Sensitivity Analysis

Sensitivity analyses have been undertaken to assess how sensitive the model results are to changing the hydraulic parameters in the model. These parameters have been selected for sensitivity analysis due to the limitations in the data set across the model domain (e.g. parameter distribution). Variations in parameter values were evaluated by:

- Hydraulic conductivity – decreasing (K/10) by half an order of magnitude; and,
- Recharge – halving (Re/2).

The resulting drawdowns and drawdown extents associated with the modified hydraulic parameters resulted in variations to the cone of influence (Figure 8–12) and is summarised in Table 8-7.

Table 8-7: Sensitivity Analysis Results - Hydraulic Conductivity & Recharge

Location	Verified K & Re – Drawdown [m]	K/10 - Drawdown [m]	Re/2 - Drawdown [m]
Banana Springs	no discernable impact	no discernable impact	no discernable impact
BRRWS007	0.72	3.22	0.84
BRRWS010	0.67	3.33	0.78

Notes:
- K - Hydraulic Conductivity
- Re - Recharge
- m - meters

8.2.5 Discussion

The resulting predicted drawdowns provide a reasonable estimate for the anticipated Project water supply borefield development and operation. Based on these results the extent of drawdown from the borefield will likely have no discernable impact on Banana Spring and the Ringer Soak community water supply bores. The proposed production from the proposed borefield, at a pumping rate of 42 L/s over the Project life duration (10 years) is considered sustainable.

Although sensitivity analyses were undertaken to conservatively estimate groundwater level drawdowns from the borefield, it is recommended that additional hydraulic testing and on going water level monitoring should be undertaken during the operational phase of the Project to assess the distribution of aquifer parameters across the Gardiner Sandstone aquifer; particularly in the vicinity of the proposed borefield and between the borefield and Banana Spring.

[5] These simulation results are based on a 100% bore efficiency (i.e. ideal connectivity between the constructed bore and the aquifer) for each of the bores in the proposed borefield.

9 INFRASTRUCTURE

9.1 Dewatering Network

In order to maintain dry and safe mining conditions, effective management of groundwater within the vicinity of the pits is necessary. Based on the predicted pit inflow rates (Section 8.1), the following dewatering options are available for consideration:

- In-pit sump pumping

  Groundwater inflow, incident rainfall and surface water run-off are pumped from the pit void (from the pit floor) as required. Dewatering of the aquifer commences when the pit floor intersects the groundwater table.

- Dewatering bores network

  Pit dewatering using pit-peripheral production bores is implemented when in-pit sump pumping is identified as not sufficient to maintain “dry” mining conditions. In fractured rock aquifer systems, dewatering bores are installed to target the water-bearing structures, with pumping commencing prior to the pit void intersecting the groundwater table.

9.1.1 Wolverine, Gambit, Gambit-Central & Gambit-West Deposits

Groundwater inflow into the proposed pits at the Wolverine and Gambit deposits are anticipated to be relatively low (less than 30 L/s), therefore requiring limited pit dewatering infrastructure. Management of groundwater inflow into the pits will be incorporated into the pit void water management strategy, which includes the management of incident rainfall and surface water runoff into the pit voids.

The management of water in the pit voids can be undertaken using:

- In pit sump pumping – during pit excavation, a sump will be established on the pit floor to allow the collection of in-pit water. Drainage within the pits, will be established to allow in-pit water to be diverted towards the sump (e.g. drains along the pit wall toe, gradual gradient on the pit floor to direct water toward the sump). The location of the sump on the pit floor will vary relative to the mine schedule, with the sump located away from the active mining area.
- Pit crest bunding – a bund wall should be place around the crest of the proposed pits to limit the ingress of surface water into the pits. This bund wall should be installed prior to the commencement of the wet season (December to March), as the majority of surface water runoff would occur during this period.

9.1.2 Area 5 Deposit

Estimated groundwater inflow into the proposed Area 5 pit (~13 L/s) is anticipated to be higher than pit inflows for the pits proposed for at the Wolverine and Gambit deposits. At a minimum, sump pumping will be required to manage water (groundwater, rainfall, surface water) within the pit. However, due to the uncertainty associated with the fractured rock aquifer at Area 5 (due to data limitations) a dewatering bore network may be required in addition to in pit sump pumping.

A production bore (BRAWD009) is currently installed in the proposed Area 5 pit shell. Prior to the commencement of pit void excavation, this bore can be used for Project water supply requirements (e.g. construction water requirements, dust suppression etc), which will reduce groundwater levels and aid in the depletion of aquifer storage within the system. This pre-mining pumping may reduce the requirement for the establishment of a dewatering bore network. However, should a bore network be required, the bores are to be located beyond the extent of the pit shell, targeting the water bearing structure.

The groundwater-bearing structure at Area 5 occurs at approximately 60 m below the ground surface, while the total pit depth is approximately 70 m below the ground surface. Therefore, management of groundwater inflow into the pit will unlikely be required until the pit floor reaches an excavation depth of 60 m below the ground surface.

It is recommended that further assessment of the hydrogeological system within the vicinity of Area 5 is conducted to confirm the requirement of a dewatering bore network. Additional work may comprise:

- Identification of the extent of the water-bearing geological structure within the Area 5 deposit, particularly beyond the extent of the proposed pit shell; and,
- Further hydraulic testing of the fractured rock aquifer to confirm aquifer parameter, particularly storage, away from the proposed pit shell.

9.2 Water Supply Network

Predictive simulations of the proposed water supply borefield have indicated that a sustainable water supply, to meet the Project demand, may be sourced from the Gardiner Sandstone aquifer for the duration of the Project life (10 years). The proposed water supply borefield network comprises seven production bores pumping at a rate of 6 L/s each (42 L/s total). The layout of the proposed borefield network is provided in Appendix D.

Although no discernible groundwater level drawdown at Banana Spring has been estimated to occur as a result of borefield operations, monitoring of the drawdown migration away from the borefield towards Banana Spring should be undertaken. Installation of a groundwater monitoring network between the borefield and Banana Spring, and the implementation of a monitoring program should be undertaken.

9.2.1 Assumptions & Limitations

The proposed infrastructure for the water supply borefield is based on the modelled results of the water supply borefield operations from the Gardiner Sandstone aquifer. These results are considered preliminary based on the following assumptions and limitations:

- Limited hydrogeological data have been collected from the Gardiner Sandstone aquifer, and as a result the adopted model aquifer parameters are based on aquifer testing performed on test production bores BRRWS007 and BRRWS010. Variations in the aquifer parameters for the Gardiner Sandstone are anticipated and further site investigations should be conducted to assess this variability. An update to the numerical model should be undertaken as additional hydraulic parameter data and borefield testing/production data becomes available.

- Specific aquifer recharge studies have not been conducted on the Gardiner Sandstone, therefore, recharge has been conservatively applied to the numerical model based on KCB's experience on projects in similar environmental settings.

9.2.2 Regulatory Requirements

Based on the Project's water demand requirements (~1,300 ML/a), potential impact on environmental values (e.g. Banana Springs) and the hydrogeological characterisation of the Gardiner Sandstone aquifer (e.g. groundwater quantity and quality) as potential water supply option, a Level H2 hydrogeological assessment, consisting of a hydrogeological assessment (including drilling and test pumping field programmes), has been prepared in accordance with the DoW guidelines. This assessment has taken the following into account:

- Groundwater resource assessment – test production bore and monitoring bores have been constructed to assess the hydrogeological conditions and groundwater availability.
- Groundwater sampling and test pumping have been completed to assess the hydrogeological conditions.
- Groundwater modelling has been completed to assess potential impacts associated with water supply borefield development/operation on identified environmental values.

As part of the water licence application, NTU will be required to obtain the necessary groundwater licences and permits to construct additional bores to the bore field under the *Rights in Water and Irrigation Act 1994* (Section 5C and 26D respectively).

9.2.3 Borefield Infrastructure

9.2.3.1 Pump Selection Criteria

KCB recommends that the borefield pumps are standardised to approximately two pump sizes, which should incorporate all calculated discharge rates, in order to effectively manage the pumping equipment (i.e. back-up pump). In addition to the above, protection should be considered to protect the pump motor against damage in the event of the groundwater level reaching the pump inlet depth.

The pump sizes selection criteria should take, as a minimum, the following into account:

- Aquifer intersection depth and sustainable yield;
- Static groundwater level;
- Internal casing diameter;
- Discharge elevation (total head); and,
- Frictional losses (transfer pipe diameter).

9.2.3.2 Pump control

Two types of pump control devices that regulate flow can be utilised:

- Manual operated valve system

  These systems can be used for choking most water abstraction pumps, requiring manual opening and closing of valves to adjust pumping rates. Although it is a robust method, it is an ineffective method of fine tuning pumping rates and is time consuming.

- Variable drives valve system

  These systems provide effective and efficient management of the pump motor performance and subsequently abstraction rates. Management of these systems can be conducted manually or remotely.

9.2.3.3 Construction, Bore Casing & Headworks

The type and configuration of the bore casing should be selected according to the encountered geology and air-lift yield during the drilling program. A nominal 30 to 50 m slotted/screened interval is proposed; however, additional slotted/screen casing may be required to allow groundwater inflow from adjacent zones.

The annulus from the bottom of the hole to 6 mbGL should be filled with gravel pack and sealed with cement grout. The head works of each production bore should be equipped to allow water quality sampling/monitoring.

9.2.3.4 Power Supply & Monitoring Equipment

Power supply to each bore will be specified by NTU, but will likely comprise a diesel generator at each site. At each bore, the power distribution, control box and monitoring equipment should be protected from environmental conditions and mining activities and should facilitate easy access during routine maintenance and repairs.

9.2.4 Water Level, Quality & Flow Monitoring

The monitoring and associated management of the groundwater level across the borefield network is critical for effective borefield production, therefore the following is proposed:

- Manual monitoring – collection of groundwater levels, groundwater samples and field physicochemical monitoring

- Automated monitoring

  Data loggers are a more effective and efficient in the periodic collection of groundwater level data. These loggers allow for instant access to the groundwater level data (remotely), and provide real time indicators of any water level drawdown issues and/or equipment failure.

9.2.5 Recommendations

9.2.5.1 Groundwater Level & Quality Monitoring

Based on the potential risks and impacts on the surrounding environment/s associated with the proposed mining activities (both dewatering and water supply), KCB propose the implementation of a groundwater management plan considering the following:

- Groundwater monitoring network optimisation;
- Ongoing groundwater quality and level monitoring; and,
- Management measures implemented to maintain continuous dry mining conditions and sustainable water supply.

The main objective of the groundwater management plan is to:

- Provide reliable data on the level and quality of the groundwater across the Project site; and,
- Provide ongoing and reliable data for design and control systems.

Network Optimisation

In order to establish the local groundwater conditions across the Project site, augmentation to the current baseline monitoring network is proposed:

- to address any gaps (if applicable) within the spatial distribution across the Project site; and,
- to include infrastructure specific monitoring bores (i.e. TSF, WRD).

Monitoring bores should be constructed using 50 mm/2 inch class 12 PVC with slotted PVC positioned adjacent to the groundwater inflow zone/s. The annulus should be gravel packed across groundwater inflow zone/s with a bentonite seal placed above the gravel pack to isolate the inflow zone/s.

The proposed monitoring bore construction details presented are in adherence with the Minimum Construction Requirements for Water Bores in Australia[6].

Groundwater Level Monitoring

Routine monitoring of groundwater levels in the vicinity of the active mining areas will be required both prior to and during operations. The data is essential to site operations to:

- Assess water supply borefield and pit dewatering performance;
- Allow water supply borefield optimisation;
- Assess compliance with statutory mine and water management licence conditions and potential impacts on the surrounding environment.

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[6] National uniform Drillers Licensing Committee, 2012, Minimum Construction Requirements for Water Bores in Australia, Third Edition (ISBN 978-0-646-56917-8).

Monitoring of groundwater levels for operational requirements (e.g. water supply borefield, pit dewatering) should be conducted using automated monitoring equipment (e.g. data-logger) to allow frequent (i.e. daily as a minimum) monitoring of groundwater levels. Groundwater level monitoring relating to baseline characterisation and impact assessment should be undertaken at a frequency as recommended as the regulatory authority, however, at a minimum, levels should be recorded at a quarterly frequency.

Groundwater Quality Monitoring

A summary of the proposed groundwater quality monitoring program is provided in the following bullet points.

- Groundwater sampling/monitoring should be conducted at a quarterly/annual frequency
- Filtered groundwater samples should be provided for analysis at a National Associated of Testing Authorities (NATA) accredited laboratory
- Water quality parameters to be analysed include:
    - Physiochemical parameters (quarterly) – pH, Electrical Conductivity, temperature
    - Inorganic and metal parameters (quarterly):
        - Major ionic constituents – sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), chloride (Cl), bicarbonate (HCO_3), carbonate (CO_3) and sulphate (SO_4)
        - Fluoride (F) and phosphorus (P)
        - Dissolved Metals – aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), boron (B) cadmium (Cd), chromium (Cr), cobalt (Co), Copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), Thorium (Th), tin (Sn), Uranium (U), , vanadium (V) and zinc (Zn)
        - Ultra-trace Metals – lead (Pb), mercury (Hg) and selenium (Se)
    - Nitrogen-Species (quarterly)
        - Ammonia as N (NH_3), nitrite as N (NO_2), nitrate N(NO_3) and nitrite + nitrate as N.
    - Elemental (quarterly)
        - Uranium and thorium.
    - Radionuclides (annually)
        - Thorium – Th^{227}, Th^{228} and Th^{230}
        - Lead – Pb^{210}
        - Polonium – Po^{210}
        - Radium – Ra^{226}, Ra^{228}

Abstraction Monitoring (Dewatering & Water Supply)

An understanding of dewatering abstraction volumes form the pit will be required to support on-going optimisation of dewatering. This information will also assist with identifying operations sufficiency and is crucial for future mine water balance, discharge quality monitoring, salt balance calculations and discharge licence requirements. Monitoring of abstraction from the water supply borefield should also be undertaken for regular assessment of borefield sustainability (in comparison with groundwater levels) and for applicable compliance reporting.

10 CONCLUSIONS

10.1 Hydrogeological Conceptualisation

- The hydrogeological system can be broadly categorised into three aquifers; fractured rock aquifer – Browns Range Metamorphics, fractured rock aquifer – Gardiner Sandstone and unconfined aquifer – alluvium.

  Fractured rock aquifer – Browns Range Metamorphics comprises a thick sequence of metamorphosed sediments with limited primary porosity. Secondary structures (e.g. faults, shears, joints) have resulted in the development of discrete zones of high hydraulic conductivity. An interpreted shear zone has been identified trending through Area 5 deposit.

  Fractured rock aquifer – Gardiner Sandstone is a medium to thick bedded sublithic to lithic arenite and quartz arenite sandstone unit. Although the sandstone is typically of medium grain size, groundwater storage and movement is similar to a fractured rock aquifer.

  Unconfined aquifer – Alluvium is considered to be present only during and immediately following the wet season. Currently, limited information is available on this aquifer.

- Groundwater levels, measured across the Project site, when compared with available groundwater intersection data, indicates confined or semi-confined groundwater flow conditions within both fractured rock aquifers with an inferred groundwater flow towards the west (a reflection of the surface topography).
- Limited to no evidence exists to indicate interconnection between the Browns Range Metamorphics and Gardiner Sandstone aquifers.

10.2 Numerical Groundwater Modelling

10.2.1 Pit dewatering

- Key results obtained from these predictive simulations include:
  - Wolverine and Gambit deposits

    Initially, the cone of influence as a result of the proposed dewatering activities is considered localised in the vicinity of Wolverine and Gambit-West mining activities. From Month 23 of the Project schedule; inter-connection of the various localised dewatering cone of influences for each pit occurs; resulting in the development of a large elongated northeast-southwest cone of influence across the Wolverine and Gambit deposits.

    The maximum distance of drawdown extent, form the pit void perimeter, varies across the various mining areas as mining activities progress:

    - Wolverine deposit – drawdown distance extents with the 1 m drawdown contour observed ranges between ~410 m (Stage 1) and ~600 m (Stage4) with drawdowns ranging between ~30 m and ~150 m at the pit void perimeter.

- Gambit deposit – drawdown distance extent ranges between ~60 m (Stage 2) and ~300 m (Stage 4) with drawdowns between ~5 m and ~10 m at the pit void perimeter.
- Gambit-West deposit – drawdown distance extent ranges between ~300 m (Stage1) and ~660 m (Stage 4) with drawdowns between ~30 m and ~200 m at the pit void perimeter.

Due to the size and proposed mining schedule for the Gambit-Central deposit, the drawdown cone of influence is masked by dewatering activities at the Gambit-West deposit.

Generally, pit inflow rates increase gradually from the intersection of the water table to the final pit floor elevation and is considered the upper limit estimated inflow rates due to the model specific assumptions and limitations:

- Wolverine pit

  Inflow rates ranging from ~8 L/s to ~23 L/s, with anticipated groundwater depth is at 440 mAHD bench and scheduled to be encountered during Month 1 of the Project schedule.

- Gambit pit

  Inflow rates ranging from ~6 L/s to ~9 L/s, with anticipated groundwater depth is at 450 mAHD bench and scheduled to be encountered during Month 22 of the Project schedule.

- Gambit-Central pit

  Inflow rates ranging from ~6 L/s to ~9 L/s with anticipated groundwater depth is at 450 mAHD bench and scheduled to be encountered during Month 17 of the Project schedule.

- Gambit-West pit

  Inflow rates ranging from ~1 L/s to ~27 L/s with anticipated groundwater depth is at 430 mAHD bench and scheduled to be encountered during Month 2 of the Project schedule.

- Area 5 deposit

  Although the cone of influence as a result of the proposed dewatering activities is considered localised in the vicinity of the Area 5 pit; the drawdown is most pronounced along strike of the northwest to southeast interpreted shear zone. This is due to higher hydraulic conductivity associated with this zone in comparison to the relatively low hydraulic conductivity country rock. The maximum distance of drawdown extent, from the pit void perimeter, with 1 m drawdown contour observed is approximately 220 m.

Generally, pit inflow rates increase gradually from 2 L/s at the intersection of the water table to 13 L/s at the final pit floor elevation and is considered the upper limit estimated inflow rates due to the model specific assumptions and limitations. Groundwater is not anticipated to be encountered in the pit until mining of the 410 mAHD bench commences, which is scheduled for Month 51 of the Project schedule (6 months into the mining of Area 5 pit).

10.2.2 Water supply assessment

- A 10 year duration transient simulation was undertaken to verify the groundwater model to current conditions based on 13 groundwater level monitoring locations records.
- Operational model simulations were undertaken to assess the groundwater level drawdown extents as a result of long-term pumping throughout the duration of the Project life and assess the sustainability of the Gardiner Sandstone based on the following borefield scenarios:
  - Base Case – abstraction from the two established test production bores (BRRWS007 and BRRWS010) pumping at a cumulative rate of 21 L/s; and,
  - Scenario A – abstraction from a seven bore water supply borefield, with each bore pumping at 6 L/s.

  Key results obtained from these predictive simulations include:
  - The extent of drawdown from the proposed borefield scenarios are unlikely to discernibly impact Banana Springs and the Ringer Soak community water supply bores.
  - Maximum drawdown of between 0.65 m and 0.72 m was simulated at the borefields.
  - Pumping from the Gardiner Sandstone aquifer unit is considered sustainable at a constant abstraction rate of 42 L/s over a period of 10 years.

11 CLOSING

KCB is pleased to provide this Stage 2 – Hydrogeological Test Drilling, Aquifer Testing and Assessment document. We trust this report meets your requirements, and if you have any queries regarding the content of this document, please contact the undersigned on (08) 9486 5400.

Report Disclaimer

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