Dual Phase Survey for Subterranean Fauna for the Yogi Magnetite Project, Yalgoo, Western Australia.

Report by Invertebrate Solutions for FIJV Pty Ltd on behalf of GHD Pty Ltd

March 2020

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Invertebrate Solutions. (2020). Dual Phase Survey for Subterranean Fauna for the Yogi Magnetite Project, Yalgoo, Western Australia, March 2020.

Report Number 2018ISJ0702_F01_20200304

Prepared for: FIJV Ltd, on behalf of GHD Pty Ltd

Frontispiece: View of the Yogi magnetite project area from the south.

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Executive Summary

FI Joint Venture Pty Ltd (FIJV) is proposing to construct and operate a magnetite iron ore project (the Project), with mining, processing and associated infrastructure. The proposed mine is located approximately 225 kilometres (km) east-northeast of Geraldton and 15 km northeast of Yalgoo within the Shire of Yalgoo. The proposal includes a magnetite slurry pipeline and a water pipeline to Geraldton Port and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline network. Mining of the magnetite will occur below groundwater and will include a simple open cut operation with clearing and topsoil stockpiling, overburden drilling and blasting followed by conventional removal with truck.

No previous records of stygofauna or troglofauna are present in the databases of the Western Australian Museum from within the Desktop Study area. Suitable habitat for stygofauna and troglofauna is highly likely to occur in calcrete areas to the south of the Geraldton Mt Magnet Rd. Five stygofauna communities, all listed as Priority 1 Ecological Communities are known to occur in the calcrete areas in the region. All these calcretes were listed due to the presence of stygobiont Dytiscid diving beetles that occur in virtually every calcrete in the Mid West.

The dual phase stygofauna survey recorded six species and 172 individuals of stygofauna from six of the 45 bores sampled. Whilst Phase 1 sampling was entirely within the alluvial aquifer, Phase 2 sampling included the fractured rock aquifer within the mining pit and the palaeochannel aquifer to the south east of the Project area, with no stygofauna recorded except from the laterally extensive alluvial aquifer. No significant impacts to stygofauna are anticipated from the mine development as the modelled drawdown is minimal at 1 – 2 m where the copepod *Schizopera yalgoo* n. sp. was recorded. This level of drawdown, even over an extended period is not likely to significantly impact upon the available habitat for this species

The dual phase troglofauna survey within the mine pit recorded three subterranean isopod species from five different bores. Two of the three troglomorphic isopod species have been recorded at multiple locations indicating that there is connectivity throughout the sampled area for troglofauna, that likely extends well beyond the proposed mining area. The species' have been described as having a restricted distribution as they have only thus far been recorded from within the proposed mine pit where all sampling has occurred to date. This is not to say that their distributions do not extend more widely, especially in the same geological units that have provided habitat for these species (Figure 3). The potential habitat for these species extends far beyond the proposed mine pit and the entire project area to the north and south of the sampled area and these two species are highly likely to occur throughout these geological units where they have previously been found to occur.

In addition due to the relatively shallow depths at which the troglofauna traps have been placed in the Yogi project area (often <10m) due to the water table and blockages or collapses in the holes the species may be utilising the "Mesovoid Shallow Substratum" (MSS – refer to Ortuño 2013), the interconnected network of voids and cavities within the overlaying colluvium and alluvium to increase their potential habitat far beyond the area sampled thus far for troglofauna. It is therefore likely that both these troglobiont isopods (Paraplatyarthridae: *Paraplatyarthrus*? sp. indet.

and Armadillidae: *Troglarmadillo* sp. indet.) have potential habitat and distributions within the local region far exceeding the currently identified occurrences. The potential troglofauna habitat to be removed by the proposed mine pit is only 3.5% of the total volume of these geological units with 96.5% remaining as troglofauna habitat in the local area (GHD 2019, section 6.13.3). It is for these reasons that is it reasonable to conclude that no significant impacts to either of these species is likely from the development of the project.

Due to the absence of vertical bores within the mining pit void no troglofauna scrape sampling was able to be undertaken.

The impacts to subterranean fauna are considered to be low in the context of the Yogi Project due to the relatively small size of the development compared with the size of remaining subterranean fauna habitat outside of the Project area, with no significant impacts anticipated.

1. Introduction

FI Joint Venture Pty Ltd (FIJV) is proposing to construct and operate a magnetite iron ore project (the Project), with mining, processing and associated infrastructure. The proposed mine is located approximately 225 kilometres (km) east-northeast of Geraldton and 15 km northeast of Yalgoo within the Shire of Yalgoo. The proposal includes a magnetite slurry pipeline and a water pipeline to Geraldton Port and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline network.

Mining of the magnetite will occur below groundwater and will include a simple open cut operation with clearing and topsoil stockpiling, overburden drilling and blasting followed by conventional removal with truck.

The proposal includes the following key components:

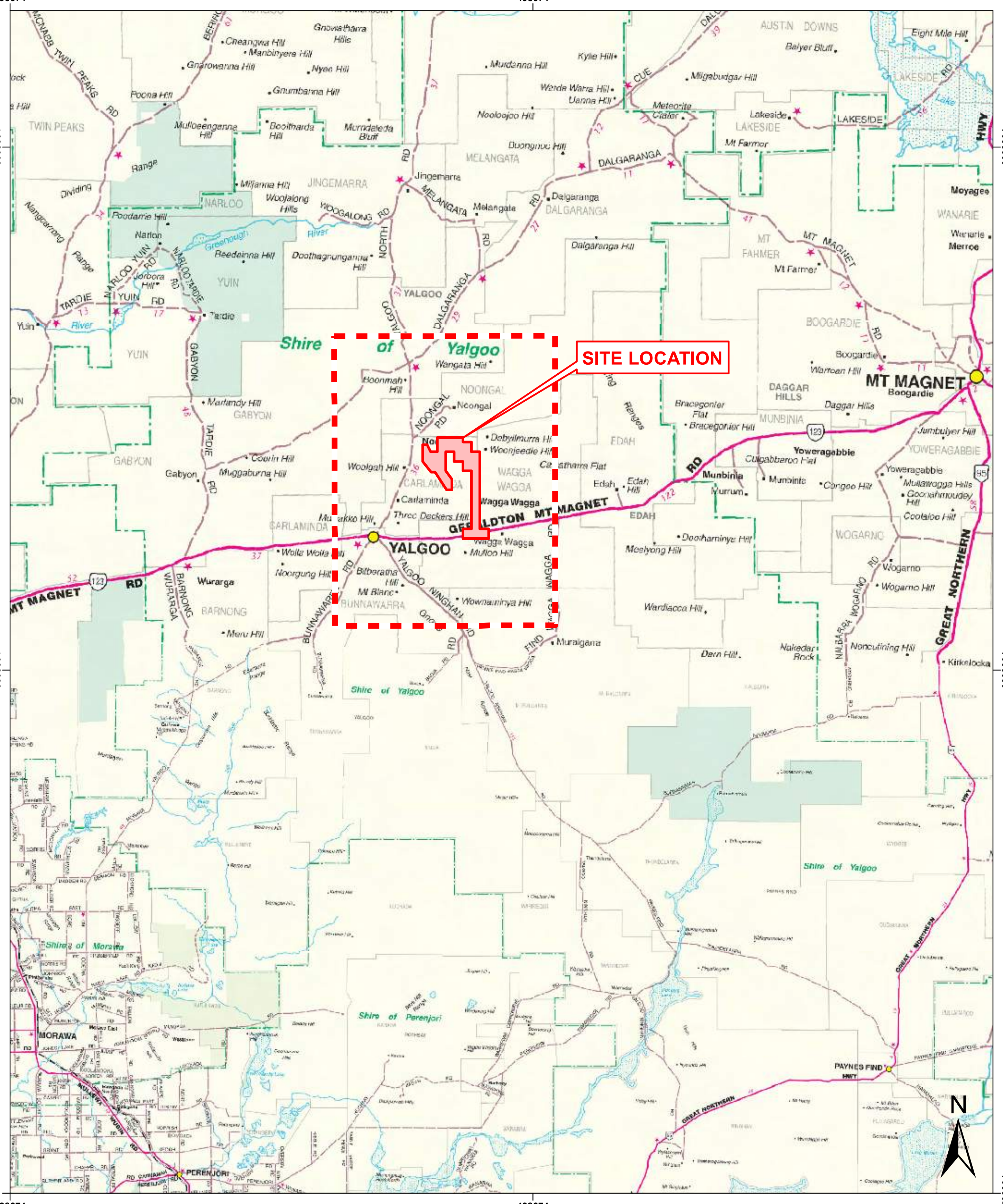
- Mine pit (clearing of no more than 200 ha);
- Mining overburden and waste facilities (clearing of no more than 400 ha);
- Processing waste containment facilities (clearing of no more than 500 ha);
- Mine and processing support infrastructure (clearing of no more than 2000 ha); and
- Magnetite slurry pipeline, water pipeline and gas pipeline (clearing of no more than 1500 ha).

Invertebrate Solutions has been requested by GHD Pty Ltd (GHD) on behalf of FIJV to undertake a dual phase field survey for stygofauna and troglofauna for the Yogi Magnetite Project. The Project is located adjacent to five separate calcrete Priority Ecological Communities that each contain unique and endemic stygofauna species. Banded Iron Formation (BIF) ridges in the Mid West also are known to contain troglofauna and hence a survey for subterranean fauna is required for the Yogi Magnetite Project.

1.1 Purpose of this Report

GHD has requested Invertebrate Solutions to undertake the following scope of works for the Yogi Magnetite Project area, Yalgoo, Western Australia:

- Undertake a dual phase assessment for stygofauna and troglofauna in the mine pit and waste storage facility and associated area.
- Identify any stygofauna or troglofauna collected to the lowest practical taxonomic level.
- Provide recommendations to minimise potential impacts and any suggested requirements for further work to comply with relevant legislation; and
- Provide a written report containing the above items.



Legend

- Desktop Study Area
- Site Boundary

0 10 20 40
km
Scale: 1:1,000,000 @ A4

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

LOCALITY MAP

SOURCE: TRAVELLER'S ATLAS

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PROJECT ID	DATE
YOGI MAGNETITE MINE	18/12/2018

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
ENVIRONMAPS	TM	TM	0

Subterranean Fauna Survey, Yogi Magnetite Project, Yalgoo, WA

Figure 1
Site Location

1.2 Project Area

The proposed mine is located approximately 225 kilometres (km) east-northeast of Geraldton and 15 km northeast of Yalgoo within the Shire of Yalgoo and is shown in Figure 1. The proposal includes a magnetite slurry pipeline and a water pipeline to Geraldton Port and a gas supply pipeline from the Dampier to Bunbury Natural Gas Pipeline network.

1.3 Survey Effort and Timing

Invertebrate Solutions completed the phase 1 survey for stygofauna in the mining tenements and regionally in August 2018. A total of 22 samples were collected from bores within the broader Project area (Appendix 1, Table 1). Phase 2 sampling was undertaken in November 2019 sampling a mixture of previously sampled bores and bores drilled for water exploration purposes in April 2019. Phase 2 sampled 23 bores for stygofauna (Appendix 1, Table 1). A map showing the locations of the bores sampled for stygofauna is shown in Figure 2. A total of 45 stygofauna samples undertaken in two different seasons has exceeded the EPA guidance of a minimum of 40 samples (EPA 2016b)

Table 1 Stygofauna sampling effort

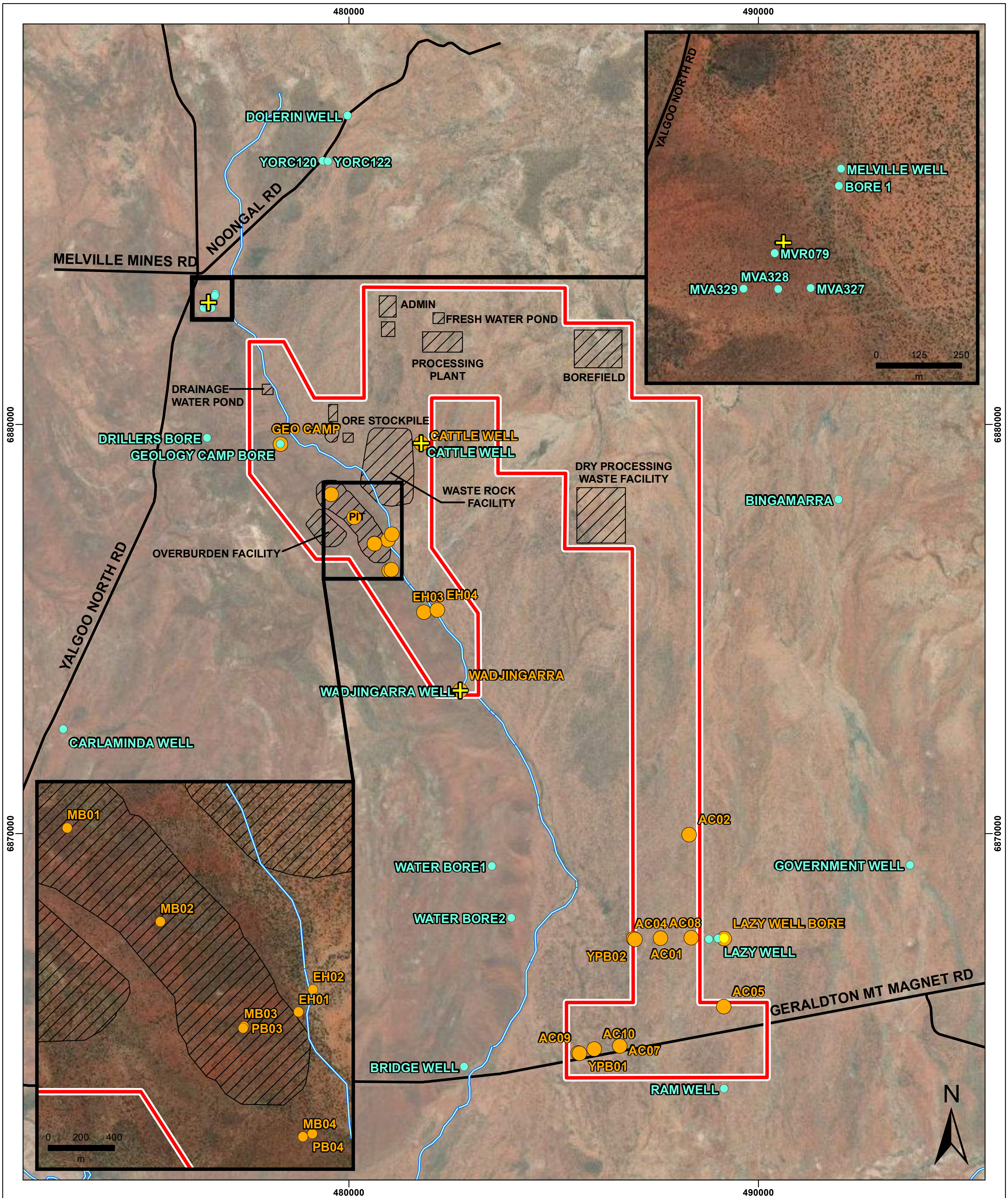
Sampling Phase	Bores Sampled	Date
Phase 1	**22**	August 2018
Phase 2	**23**	November 2019
Total	**45**	

The dual phase troglofauna survey retrieved 28 troglofauna leaf litter traps placed in 20 different bores in Phase 1 between August 2018 and October 2018 (Appendix 2, Table 2). The phase 2 troglofauna survey retrieved 26 traps from 18 bores previously sampled in Phase 1. The phase 2 troglofauna sampling was undertaken between October 2018 and November 2019. The survey has retrieved 54 traps of the 62 deployed over the two phases, with 8 traps irretrievable (Table 2). The sampling effort of 54 traps exceeds the effort for a pilot survey but is slightly less than the sampling effort for a level 2 troglofauna survey in accordance with Technical Guidance – Subterranean Fauna Survey (EPA 2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA 2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

Table 2 Troglofauna sampling effort

Sampling Phase	Troglofauna traps deployed	Troglofauna traps retrieved	Date deployed	Date retrieved
Phase 1	**30**	**28**	7 August 2018	13-14 October 2018
Phase 2	**32**	**26**	13-14 October 2018	18 November 2019
Total	**62**	**54**		

A map showing the locations of the bores sampled for troglofauna is shown in Figure 3.



Legend

- Site Boundary
- Watercourse
- Phase 1 stygofauna Sample Location
- Phase 2 stygofauna Sample Location

Recorded Stygofauna Location

- Copepoda: *Schizopera yalgoo n. sp.* (x1)
- Ostracoda: *Sarscypridopsis ochracea* (x3)

SOURCE: World Imagery

0 1.25 2.5 5
km
Scale: 1:125,000 @ A4

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

LOCALITY MAP

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PROJECT ID	DATE
YOGI MAGNETITE MINE	4/03/2020

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
ENVIRONMAPS	TM	TM	0

Subterranean Fauna Survey, Yogi Magnetite Project, Yalgoo, WA

Figure 2

Stygofauna Sampling Locations and Species Distributions

ENVIRONMAPS Environmental Mapping Solutions t: 0406 590 006 www.environmaps.com.au

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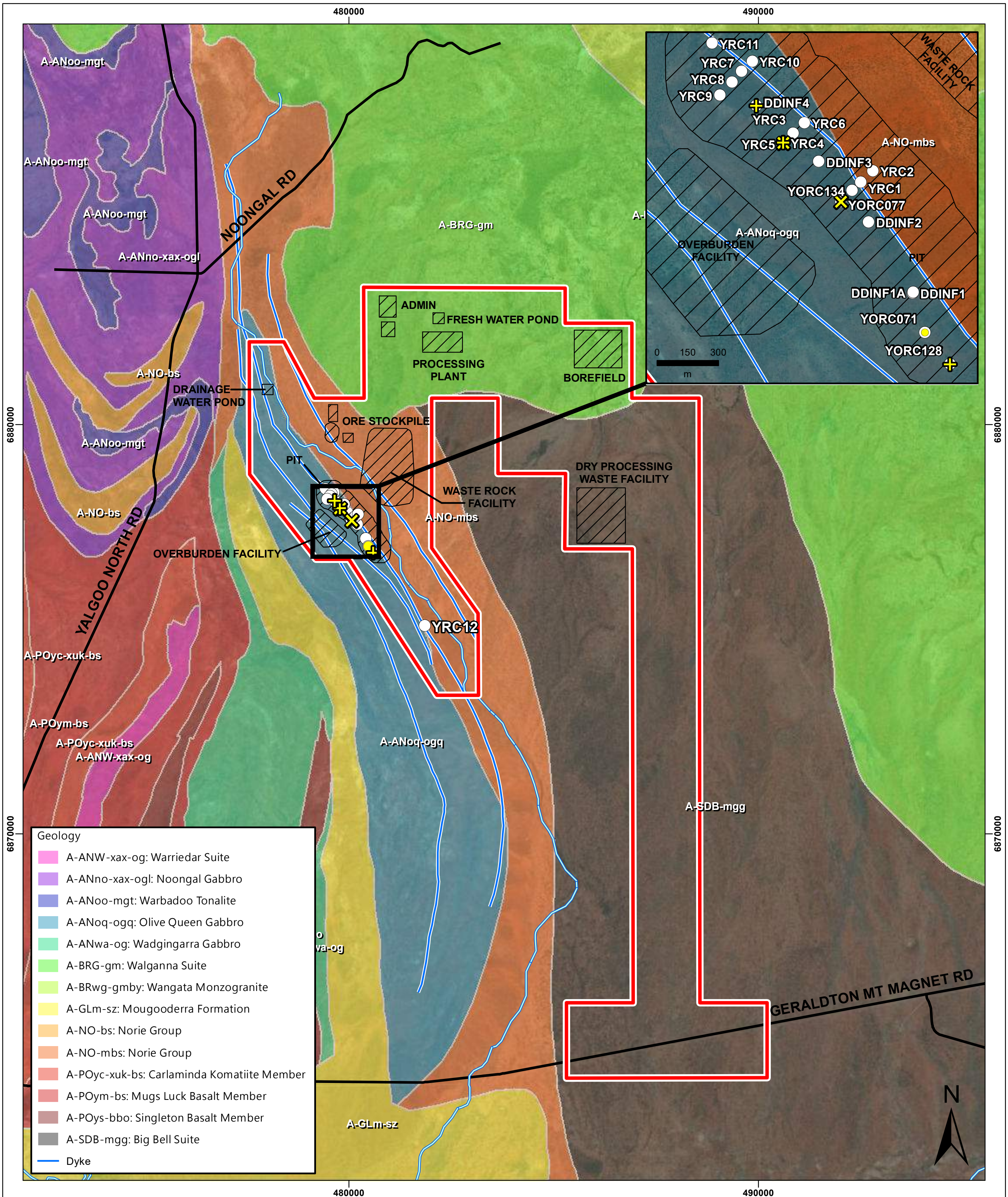

Legend

- Site Boundary
- Watercourse
- Troglofauna Sample Location

Recorded Troglofauna Location

- *Troglarmadillo sp. indet* (x1)
- *Paraplatyarthridae sp. indet.* (x2)
- *Philosciidae sp. 'yalgoo'* (x3)

0 1.25 2.5 5
km
Scale: 1:125,000 @ A4

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

LOCALITY MAP

SOURCE: World Imagery

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PROJECT ID	DATE
YOGI MAGNETITE MINE	5/03/2020

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
ENVIRONMAPS	TM	TM	0

Subterranean Fauna Survey, Yogi Magnetite Project, Yalgoo, WA

Figure 3
Troglofauna Sampling Locations and Species Distributions

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1.4 Introduction to Subterranean Fauna

Subterranean fauna are comprised of stygofauna (aquatic subterranean dependent species) and troglofauna (air breathing subterranean dependent species) which are known to be relatively diverse on a worldwide scale in Western Australia. Stygofauna and troglofauna are known to occur widely in the Pilbara, Yilgarn and Ngalia basins. Many species of subterranean fauna have highly restricted ranges due to habitat connectivity issues and evolutionary history.

The high degrees of local endemism and lack of habitat connectivity makes subterranean fauna susceptible to high levels of impact from sometimes localised projects, with species' extinction a real possibility if they are not adequately considered during project planning phases.

An extensive amount of jargon is associated with subterranean fauna and multiple forms of classification have been used historically. The most commonly accepted and used terms divide troglofauna into categories that describe a particular species' degree of dependence upon the subterranean environment. Due to the reliance upon ecological information to determine if a species is a troglobite, the concept of troglomorphy (Christiansen 1962) - specific morphological adaptations to the subterranean environment - is used to define obligate subterranean species. The term troglomorphy, initially confined to morphology, has since been used to describe both morphological or behavioural adaptations (Howarth 1973). This combination provides a practical system, easily applied in the field and with a minimum of detailed ecological study required. The level of subterranean dependency for different ecological groupings is described below:

- Troglobiont: animals that are obligate subterranean species and mostly show morphological adaptation to subterranean habitats (troglomorphisms) including depigmentation, loss or reduction of eyes, elongation of appendages, absent or reduced wings and extra sensory hairs;
- Troglophiles: animals that can complete their entire lifecycle within a cave but possess no specific adaptations to the cave environment. These species are capable of living outside caves in suitably dark and moist epigean habitats; and
- Trogloxenes: animals that use the subterranean environment but require surface environments to complete part of their lifecycle (generally either feeding or breeding). Common trogloxenes are cave dwelling bats, cave swiftlets and cave crickets that leave subterranean habitats to feed.

The aforementioned terms refer to stygofauna when the prefix is altered to stygo (Humphreys 2000).

Species which inhabit the deep soil habitat (Edaphophiles) often exhibit convergent morphological adaptations to those animals found exclusively within caves, such as reduced or absent eyes, body flattening, loss of pigmentation, etc. Soil dwelling species commonly do not show highly restricted distributions as they are less easily isolated in evolutionary timeframes, thus only true troglobitic animals are the focus of surveys for subterranean fauna. Taxa discussed in this study were assessed on their combination of loss/reduction of eyes, reduction in pigmentation and wing development, and elongation of appendages to assess if a taxa was an edaphophile or truly reliant upon the subterranean habitat (troglobiont).

1.5 Conservation Legislation and Guidance Statements

Subterranean fauna are protected under state legislation via the newly enacted Biodiversity Conservation (BC) Act (2016) which came into force on 1st January 2019, replacing the outdated Wildlife Conservation (WC) Act (1950). The new BC Act is aligned with the federal Environment Protection and Biodiversity Conservation (EPBC) Act (1999). The assessment of subterranean fauna for environmental impact assessment (EIA) is undertaken in Western Australia with regard to the Technical Guidance – Subterranean Fauna Survey (EPA2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

At the State level, the BC Act provides a list of species that have special protection as species listed under Part 2 of Biodiversity Conservation Act, 2016. This notice is updated periodically by the Department of Biodiversity, Conservation and Attractions (DBCA) (formerly the Department of Parks and Wildlife (DPaW) and the current list (November 2018) includes numerous subterranean species mainly from the Cape Range and Pilbara regions. Included in the list are crustaceans, arachnids and myriapods that are considered to be "rare or likely to become extinct, as critically endangered fauna, or are declared to be fauna that is in need of special protection" (DPaW 2015). In addition to the specially protected fauna, DBCA also maintains a list of Priority fauna that are considered to be of conservation significance but do not meet the criteria for formal listing under the BC Act. The Priority fauna list is irregularly updated by DBCA and, although it offers no formal legislative protection, these species are generally considered in the EIA process.

The Biodiversity Conservation Act now provides the ability for the state government of Western Australia to formally list Threatened Ecological Communities (TECs), along with threatening processes. Several subterranean ecological communities are recognised as Threatened including the Bundera Cenote Anchialine community on Cape Range, Cameron's Cave near the townsite of Exmouth on Cape Range, stygal root mat communities in both the Yanchep and Margaret River regions and stygobionts in the Ethel Gorge aquifer in the Pilbara.

The federal EPBC Act protects both species and ecological communities. The most relevant listings for subterranean fauna include the Bundera Cenote on the western side of the Cape Range which contains a unique anchialine ecosystem including the stygal Cape Range Remipede *Kumonga exleyi* that is listed as Vulnerable. The Cape Range gudgeon *Milyeringa veritas* and the Cape Range blind eel *Ophisternon candidum* are also listed as Vulnerable species from subterranean habitats on the Cape Range.

1.6 Survey Staff Qualifications

Field sampling for invertebrates was undertaken by experienced ecologists and comprised of:

- Dr Timothy Moulds BSc (Hons) Geol., PhD. Invert. Ecol.
- Grace Formentin BSc. (GHD)

Invertebrate extraction and sorting was completed by Dr Timothy Moulds.

Survey work was undertaken under the collection licences issued by the Department of Biodiversity, Conservation and Attractions:

- 08-002590-1; Licensee Dr Tim Moulds; Valid 3/08/2018 – 2/08/2019.
- BA27000170; Licensee Dr Tim Moulds; Valid 18/11/2019 – 17/11/2020.

1.7 Report Limitations and Exclusions

This study was limited to the written scope provided to GHD Pty Ltd by Invertebrate Solutions (24th July 2018) and in Section 1.1. This study was limited to the extent of information made available to Invertebrate Solutions at the time of undertaking the work. Information not made available to this study, or which subsequently becomes available, may alter the conclusions made herein. Assessment of potential impacts to subterranean fauna was based on proposed infrastructure plans provided by FIJV Ltd.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. Invertebrate Solutions has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by Invertebrate Solutions described in this report (this section and throughout this report). Invertebrate Solutions disclaims liability arising from any of the assumptions being incorrect.

Invertebrate Solutions has prepared this report on the basis of information provided by GHD for FIJV Ltd and others (including Government authorities), which Invertebrate Solutions has not independently verified or checked beyond the agreed scope of work. Invertebrate Solutions does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Site conditions may change after the date of this report. Invertebrate Solutions does not accept responsibility arising from, or in connection with, any change to the site conditions. Invertebrate Solutions is also not responsible for updating this report if the site conditions change.

Species were identified to the lowest practical taxonomic level, taking into consideration that the taxonomic framework of many invertebrate groups is incomplete and often in need of substantial revision to enable accurate identification. Insufficient information exists for many invertebrate species due to specimens being juvenile, the wrong sex to allow identification, damaged, or inadequate taxonomic frameworks, precluding identification.

Field surveys for subterranean fauna require multiple seasonal surveys to fully record all species that may be present in an area and additional surveys at different times of the year may record additional species.

1.7.1 Limitations

The following specific limitation to the current survey are noted below:

- No systematic core photos of the site were available for examination to assist in the determination of subterranean fauna habitat presence and/or extent.
- Due to the absence of vertical bores within the mining pit void no troglofauna scrape sampling was able to be undertaken.

2. Methods

Invertebrate Solutions undertook the following tasks for the phase 1 subterranean fauna survey of the Yogi Magnetite Project area:

- Desktop subterranean fauna assessment;
- Stygofauna Phase 1 field survey of the mining pit area;
- Troglofauna Phase 1 survey of the mining pit area.

The survey program was undertaken with regard to the Technical Guidance – Subterranean Fauna Survey (EPA2016a), Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b) and the Environmental Factor Guideline – Subterranean Fauna (EPA 2016c).

2.1 Subterranean Fauna Desktop Methodology

The likelihood of stygofauna and troglofauna species occurring in the Study Area was assessed using a combination of regional information, geological, hydrogeological and database searches including:

- Analysis of published and unpublished reports concerning subterranean fauna from the region;
- Available geological maps;
- Geological, geotechnical and hydrogeological information available for the Study area;
- Records of fauna held by the Western Australian Museum.

Based on the analysis of all available information, the study area was assigned a level of likelihood to support subterranean fauna of either 'Indeterminate', 'Low', 'Moderate', 'High', or 'Definite'.

2.2 Stygofauna Sampling Methods

Stygofauna was sampled using modified plankton nets in accordance with the Environmental Protection Authority (EPA) Technical Guidance – Subterranean Fauna Survey (EPA2016a) and EPA Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b). Bores were sampled for stygofauna using a plankton net of suitable diameter (32 mm to 90 mm) to match the bore/well. The net (either 125 µm or 50 µm mesh), with a weighted vial attached, was lowered into the bore and then hauled up through the water column (Plate 1).

The net was dropped to the base of the bore then agitated up and down (±1 m) several times to disturb the bottom sediment and any stygofauna contained within. Six hauls of the entire water column were undertaken at each bore. Depths to the water table and the bottom of bores were calculated using the number of rotations of the fishing reel. Three hauls were undertaken with both the 125 µm and the 50 µm mesh nets. Each net haul sample was transferred to a labelled polycarbonate container and preserved in 100% alcohol. Samples with large quantities of sediment were elutriated prior to preservation. To minimise the possibility of stygofauna cross contamination, the nets were treated with a decontamination solution and thoroughly rinsed in water and air-dried.

2.3 Troglofauna sampling methods

2.3.1 Leaf litter traps

Troglofauna was sampled using litter traps suspended in drill holes following EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b).

The traps comprise 50 mm diameter PVC pipe cut to a length of 140 mm. Leaf litter comprising mainly of spinifex (*Triodia* sp.) was soaked in water and irradiated for 10 minutes in a microwave set on high power, to kill any terrestrial invertebrates present. The sterilised litter was packed inside the traps with one end of the tube covered with 10 mm mesh. The packed traps were sealed in garbage bags to retain moisture and sterile conditions prior to deployment.

The traps were suspended in the holes using venetian blind cord. Where possible, the traps were aligned at depths corresponding to recorded cavities in drill logs. Traps were left in place for seven months to allow colonisation by subterranean fauna and meet operational constraints. When traps are recovered the condition (moist or dry) of the hole environment and the litter in each trap is recorded. The traps from each drill hole were sealed in zip lock bags for transport to the laboratory.

2.4 Water Quality

Water samples were collected in conjunction with stygofauna sampling and analysed *in situ* using a Hanna HI 9298194 water quality meter (Plate 2, Appendix 5). Water samples were collected from the upper 1 – 2 m of the water column prior to stygofauna sampling using a bailer. Five parameters (Temperature, Total Dissolved Solids, Electrical conductivity, pH and ORP) were recorded from each bore where a stygofauna sample was collected.

2.4.1 Temperature

The temperature of ground water in arid Australia is generally fairly constant throughout the year and reflects the average surface temperature of the area. Ground water temperature was measured in degrees Celsius (°C). Stygofauna have been recorded from a variety of temperatures in the Ngalia Basin, and in the Yilgarn and Pilbara cratons, and currently no direct correlation has been detected between temperature and either presence, diversity or abundance of stygofauna.

2.4.2 Total Dissolved Solids

Total dissolved solids (TDS) was measured in milligrams per litre (mg/L) and provides a measure of all organic and inorganic substances such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates dissolved in groundwater. The measurement provides a general indication of the quality of the water with lower values (less than 500 mg/L) associated with high quality drinking water while seawater is approximately 35,000 mg/L. Stygofauna have been detected in a wide variety of water qualities from completely fresh to groundwater that is equivalent to seawater. Species response to TDS cannot be generalised and will be species specific (Leijs 2009).

2.4.3 Electrical Conductivity

Electrical conductivity was measured in milli Siemens per centimetre (mS/cm) and provides an indication of salinity. Stygofauna have been detected in a wide variety of salinities from completely fresh to groundwater that is equivalent to seawater. Species response to salinity cannot be generalised and will be species specific (Leijs 2009).

Plate 1 Stygofauna haul nets used for sampling stygofauna for the Yogi project.

Plate 2 Hanna HI 9298194 water quality meter used for the Yogi project.

2.4.4 pH

The concentration of hydrogen ions (H+) is shown as a logarithmic scale where a low value indicates a high concentration and higher values indicate a more basic solution. The neutral value of 7 is more likely to support stygofauna, however, communities of stygofauna have previously been found to occur in a wide variety of pH values.

2.4.5 Oxidation Reduction Potential (ORP)

The oxidation reduction potential (ORP) or redox potential of groundwater is a measure of a systems capacity to oxidise materials through chemical reactions. During reduction-oxidation reactions, one chemical species loses electrons (is oxidised) while another gains electrons (is reduced). Redox is measured indirectly as the ability of an aquatic system to conduct electricity, in millivolts (mV).

The redox state of aquatic environments, i.e. whether they are in an oxidising or reducing environment, is defined by the oxygen content. Typically, in well-aerated aquatic environments, the water provides an oxidising environment and has a positive, or nearing positive, ORP value. Anoxic (zero oxygen) waters and soils are often the result of high biological (BOD) and/or chemical oxygen demand (COD) and have low redox potential (often measured as negative millivolts, mV). The redox potential of aquatic environments controls the reactivity and solubility of many chemical constituents including metals. For example the redox potential of groundwater has important implications for metal mobility, bio-availability and toxicity. The amount of oxygen does not appear to be a limiting factor to the presence of stygofauna communities, and studies show no regular correlation between species richness and amount of oxygen (Leijs 2009).

2.5 Sorting and Curation

Sorting for all samples occurred in the Invertebrate Solutions laboratory using an Amscope 45x dissecting microscope and was undertaken by Dr Timothy Moulds. Each taxon was identified to the lowest practical taxonomic rank using published keys and descriptions, and the numbers of each taxon recorded. Each identified taxon was kept in a separate labelled vial and assigned a specimen tracking code. Specimen and site collection data were recorded in an Excel spreadsheet. At the conclusion of the study, all specimens will be lodged at the Western Australian Museum.

2.6 Taxonomy and Nomenclature

Identification of collected invertebrate material was undertaken by Dr Timothy Moulds. The level of specimen identification achievable is dependent on the level of taxonomic knowledge and expertise available. The majority of the taxonomic expertise relating to subterranean taxa resides with the staff of the Western Australian Museum, while some groups are also worked on by researchers within other government departments and academic institutions. Taxonomic treatments are available for some invertebrate groups, but not all. The EPA expects that invertebrates collected for identification will be identified to the lowest taxonomic level possible. Ideally, this is to the species level, but there will be limits due to the nature of specimens and the availability of taxonomic keys.

Taxonomic groups known to contain troglobitic or stygobitic representatives were examined in more detail to determine if the specimens collected in this study are subterranean or non-subterranean forms. Obligate subterranean forms were distinguished by the possession of troglomorphic characters such as depigmentation, reduction or loss of eyes, elongation of appendages and sensory structures. Troglobitic/stygobitic status was assigned after comparison with the morphology of other close relatives in the group, and current knowledge on their distribution and ecology where known. Identifications of copepods and ostracods were undertaken by Drs Tomislav Karanovic and Ivana Karanovic, respectively. Isopods were identified by Dr Simon Judd.

3. Desktop Assessment

3.1 Subterranean Fauna in the Mid West

Stygofauna communities in Australia are dominated by crustaceans (amphipods, isopods, copepods, and ostracods). They may contain oligochaetes, insects and other invertebrate groups. Stygofauna are microscopic in size and occur in various limestone, calcrete, fractured rock (including Banded Iron Formation (BIF)) and alluvial aquifers. Many species of stygofauna exhibit extreme short range endemism (Harvey 2002) often restricted to a single aquifer. This makes them highly susceptible to impacts such as dewatering or aquifer destruction. In Western Australia, stygofauna have been documented from most regions and areas including the Kimberley, Pilbara (Pilbara craton and Barrow Island), Carnarvon (Cape Range), Murchison, Goldfields, South West (Perth Basin and Leeuwin Naturaliste Ridge), and South Coast (Albany and Nullarbor Plain).

Stygofauna is widespread and occurs in a range of hydrogeological environments including karstic, fractured rock, vuggy Channel Iron Deposit (CID) and porous aquifers, in addition to springs, parafluvial and hyporheic environments (Eberhard et al. 2005). In the Pilbara region, sampling conducted in the last decade has revealed the Pilbara to be a globally significant hotspot for stygofauna diversity (Humphreys 2000b; Eberhard et al. 2006).

Calcretes in the northern Yilgarn have been sampled extensively for stygofauna, which revealed the diverse dytiscid (diving beetle) fauna consisting of over 100 species (Cooper et al. 2002; Humphreys 2005; Watts and Humphreys 2003; Watts and Humphreys 2004). Balke & Ribera (2004) revised the genera *Boongurrus* Larson, *Limbodessus* Guignot, *Tjirtudessus* and the Australian members of *Liodessus* Guignot and synonymised them all under *Limbodessus* (Watts and Humphrey 2006). Initial sampling within the calcrete aquifers has predominately been undertaken by researchers from the Western Australian Museum (WAM), South Australian Museum (SAM) and the University of Adelaide. Many of these sites have since been resampled and smaller adjacent calcretes have been sampled as part of impact assessment studies for resource development projects by environmental consultancies. Numerous calcrete deposits in the Cue and Mt Magnet have previously been sampled including some to the south and west of Yalgoo. All of these calcrete deposits, which are nested within the alluvium filling palaeochannels, contain significant stygofauna communities. Stygofauna appears to be less common within the surrounding alluvial deposits, although these areas have received more limited sampling.

There are no records of any subterranean fauna studies being previously undertaken within the Yogi Project Area or the immediately surrounding area. The Desktop Study area extending around the Project Area in an approximately 50 km rectangle contains no records of subterranean specimens in the Western Australian Museum databases (WAM 2018a, 2018b).

3.2 Hydrogeological regime

The groundwater aquifers within the Yogi tenement has been investigated by SRK (2017) and by GHD (2019). The detailed investigation by GHD identified five different aquifers in the local area as shown in Table 3 and Plate 3.

Table 3 Geological units within the Yogi Project Area and their suitability for subterranean fauna.

Unit	Description / Remarks	Subterranean Fauna Suitability
Alluvium	Mixed gravel, silt and sand alluvium	Moderate for stygofauna if within the saturated zone. Low for troglofauna.
Calcrete	Badja, Bunnawarra, Gabyon, Muralgarra, Wagga Wagga and Yalgoo Calcretes.	High/Definite for stygofauna High for troglofauna (above watertable)
Palaeochannel	Moore and Murchison palaeodrainage systems	Moderate Stygofauna Nil for troglofauna (below watertable)
BIF	Medium grained dolerite	Low for stygofauna Moderate for troglofauna (above watertable)
Granites	Porphyritic granite to adamellite, overprinting with mafic minerals	Low for stygofauna. Low for troglofauna (above watertable).

The overlying shallow alluvial aquifers form within drainage and palaeodrainage systems and are comprised of sands and gravels often with finer grained silts and clays interbedded that limit groundwater potential (GHD 2019). Many of pastoral wells throughout the Project area are within this aquifer.

Calcrete aquifers are common in the Mid West, often in association with the margins of present day salt lakes or within palaeodrainages, No calcrete aquifers are known to occur within the Yogi Project area, although some are present to the south east of the Project and regionally (Table 4). Calcrete aquifers have high porosity and connectivity due to their karstic nature and provide excellent habitat for stygofauna.

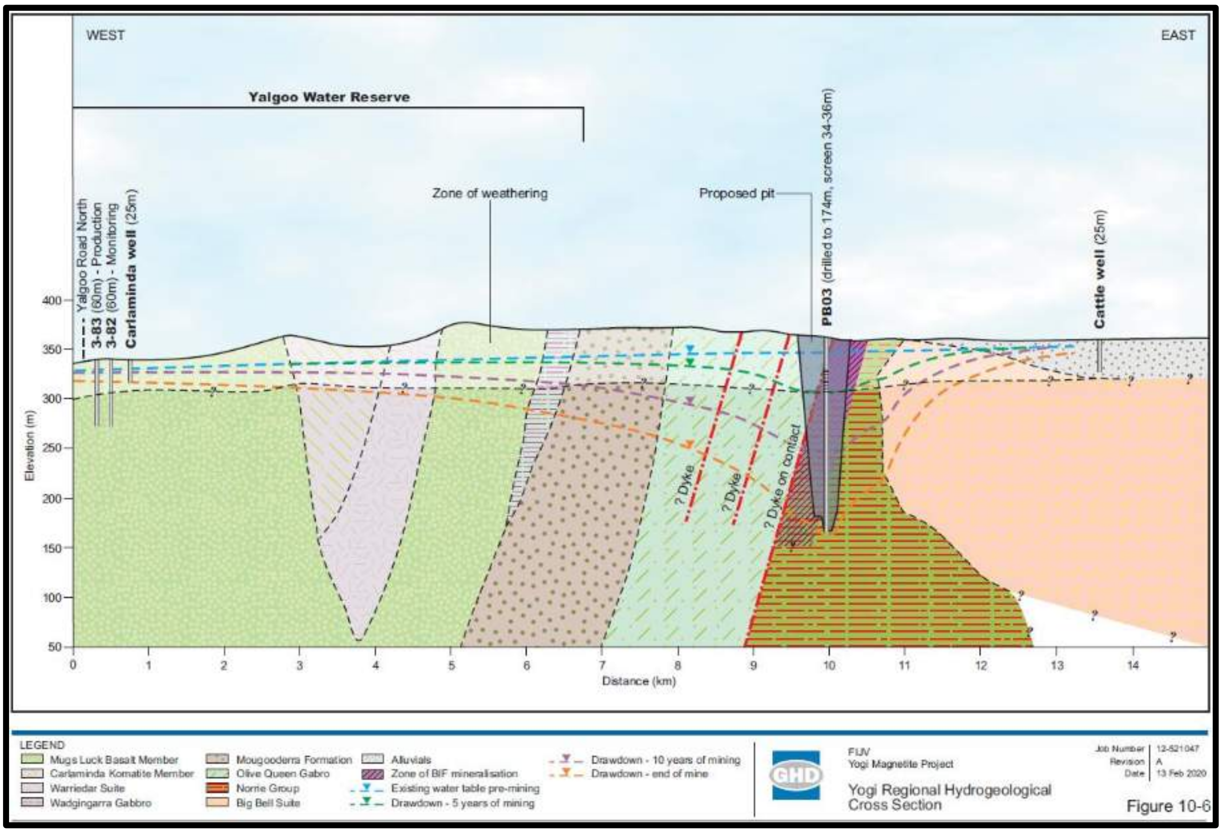

Plate 3 Regional hydrogeological cross section of Yogi Project (After GHD 2019, Figure 10-6).

Palaeodrainage systems occur throughout the Mid West region although the sediments that comprise them vary and they are often poorly known in detail (Johnson, 2006). Palaeovalley aquifers typically contain large volumes of water and show better hydraulic conductivity than adjacent extensively weathered and fractured basement aquifers, and bores can yield relatively significant quantities of water (GHD 2019).

Also within the project area are fractured-rock aquifers that are present within the BIF ridges associated with the mineralised area proposed to be extracted and the underlying granitoids basement (GHD 2019). These fractured rock aquifers are highly variable and although often low yielding, some faulted areas can contain larger amounts of water (GHD 2019).

Plate 4 Example of calcrete in cross section showing the interconnected voids and cavities that provide habitat for subterranean fauna.

3.3 Troglofauna Desktop Assessment

No previous records of troglofauna are present in the databases of the Western Australian Museum (WAM 2018a, 2018b) from within the Desktop Study area. Suitable habitat for troglofauna is highly likely to occur in calcrete areas (Table 3, Plate 5) to the south of the Geraldton Mt Magnet Rd (Bureau of Mineral Resources 1976) where the upper unsaturated portions of the calcrete provide suitable conditions for troglofauna in the extensive interconnected void networks found in calcrete outcrops (e.g. Table 3, Plate 4). The likelihood of troglofauna occurring in various lithologies within the Desktop Study Area are shown in Table 3. The BIF located in the pit void has a moderate likelihood based on other BIF outcrops in the region, however, no photographs of core was available for examination from the Yogi project area to confirm the presence of interconnected cracks of voids.

3.4 Stygofauna Desktop Assessment

No previous records of stygofauna are present in the databases of the Western Australian Museum (WAM 2018a, 2018b) for the Desktop Study Area. Five stygofauna communities, all listed as Priority 1 Ecological Communities (under the BC Act) are known to occur in the calcrete areas (Table 4, Plate 5) in the region (Enviroworks Consulting 2017, after DBCA 2017). All these calcretes were listed due to the presence of stygobiont Dytiscid diving beetles that occur in virtually every calcrete in the Mid West (Cooper et al. 2002; Humphreys 2005; Watts and Humphreys 2003; Watts and Humphreys 2004), and although these species make up only some of the stygobiontic fauna there is often little known of the rest of the community for the majority of sites. The dytiscid diving beetles do not show in the searches of Western Australian Museum databases as the Entomological collection is largely un-databased and not available for searches.

The remainder of the Project area contains various groundwater aquifers, both within the overlaying alluvium and also within the magnetite and potentially within fractures within the granite areas (Table 3). The likelihood of stygofauna occurring in various lithologies within the Desktop Study Area are shown in Table 3 based on currently available information.

Table 4 Stygofauna conservation significant communities (after Enviroworks Consulting 2017, after DBCA 2017)

Calcrete Name	Community Name	Conservation listing	Buffer (m)	Distance from Yogi tenements (km)
Badja	Badja calcrete groundwater assemblage type on Moore palaeodrainage (Badja Station)	Priority 1	2000	38.6
Bunnawarra	Bunnawarra calcrete groundwater assemblage type on Moore palaeodrainage (Bunnawarra Station)	Priority 1	2000	36.0
Gabyon	Gabyon calcrete groundwater assemblage type on Moore palaeodrainage (Gabyon Station)	Priority 1	2000	22.1
Muralgarra	Muralgarra calcrete groundwater assemblage type on Murchison palaeodrainage (Muralgarra Station)	Priority 1	2000	33.3
Wagga Wagga and Yalgoo	Wagga Wagga and Yalgoo calcrete groundwater assemblage type on Yalgoo palaeodrainage (Wagga Wagga Station), and Moore palaeodrainage (Yoweragabbie Station)	Priority 1	2000	4.7

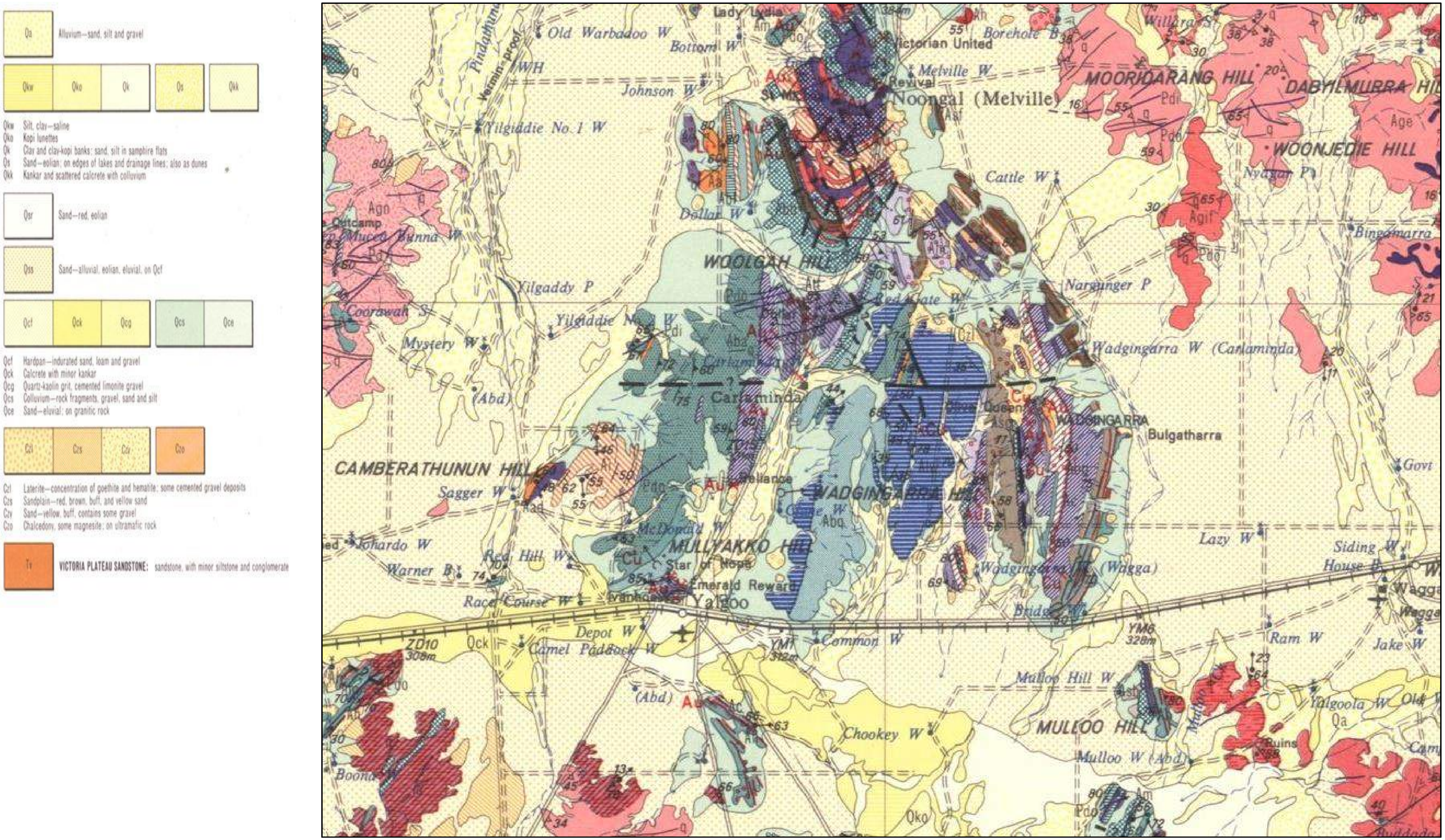

Plate 5 Extract from 1:250,000 Geological Map of Yalgoo (Yalgoo SH5002, Bureau of Mineral Resources WA 1975) showing extensive calcrete (Qck) present on the southern side of the Project Area.

4. Subterranean fauna Survey Results

4.1 Stygofauna Survey

The stygofauna Phase 1 survey was undertaken in August 2018 recorded six species and 155 individuals of stygofauna from six of the 22 bores sampled within the Project Area (Table 5, Appendix 3). The samples included two classes, three orders, three families and six genera. The greatest diversity was among the copepods with two orders, two families, four genera and four species recorded, including one new species (*Schizopera yalgoo* n. sp.) that is likely endemic (Karanovic and Karanovic 2018).

The stygofauna Phase 2 survey was undertaken in November 2019 recorded 17 individuals of one species of ostracod, *Sarscypridopsis ochracea* from two of the 24 bores sampled within the Project Area (Figure 2, Appendix 3). This was the same species previously recorded from Melville Well in Phase 1 that was previously only known from South Africa (Karanovic 2020).

The distribution of stygofauna with potentially restricted distributions is shown in Figure 2. Abundance data for each bore is shown in Appendix 3. Individual species are discussed in Sections 4.1.1 – 4.1.3.

Table 5 Stygofauna recorded from the Yogi Magnetite Project area Phase 1 and 2.

Higher Order	Genus and species	Locality	Timing	Notes
Crustacea: Ostracoda: Podocopida: Cyprididae	*Sarscypridopsis ochracea*	Cattle Well, Melville Well, Wadjingarra Well	Phase 1 and 2	Known from South Africa and WA. First ever male specimens from Australia
	Cyprididae sp.	Bingarmarra Well, Bridge Well, Cattle Well, Wadjingarra Well	Phase 1	Juvenile specimens, identification requires adults (probably *Sarscypridopsis ochracea*)
Crustacea: Copepoda: Cyclopoida: Cyclopidae	*Apocyclops dengizicus*	Lazy Well	Phase 1	Cosmopolitan.
	Mesocyclops brooksi	Bingarmarra Well	Phase 1	Widespread, stygophilic species
	Metacyclops laurentiisae	Melville Well	Phase 1	Found throughout Murchison region of WA, stygophilic species
Crustacea: Copepoda: Harpacticoida: Miraciidae	*Schizopera yalgoo n. sp.*	Lazy Well	Phase 1	New species, likely endemic

4.1.1 Crustacea: Ostracoda: Podocopida: Cyprididae

Sarscypridopsis ochracea (Sars, 1924)

This ostracod species was described from South Africa but it has also been recorded numerous times in wells in WA (unpublished data cited in Karanovic and Karanovic 2018). It is a surface water species, with predominantly female populations. This is the first time males have been found in Australia. It is possible that the South African and WA populations are distinct species, but old and rudimentary drawings of the South African population do not allow for this distinction. It is likely that some of the empty valves found in other wells also belong to this species, but that would be difficult to determine, especially with immature specimens (Karanovic and Karanovic 2018).

4.1.2 Crustacea: Copepoda: Cyclopoida:

Apocyclops dengizicus (Lepeschkin, 1900)

This copepod is almost cosmopolitan in distribution, and is a surface water species. It is commonly found in arid regions and waters of increased salinity. It has been reported throughout WA and from other Australian states (Karanovic 2004).

Mesocyclops brooksi Pesce, De Laurentiis & Humphreys, 1996

This species is widely distributed in WA, and especially common from wells in the Murchison (Yilgarn) region (Karanovic 2004). It is considered a stygophile as it is also found in some surface waters (Karanovic 2004).

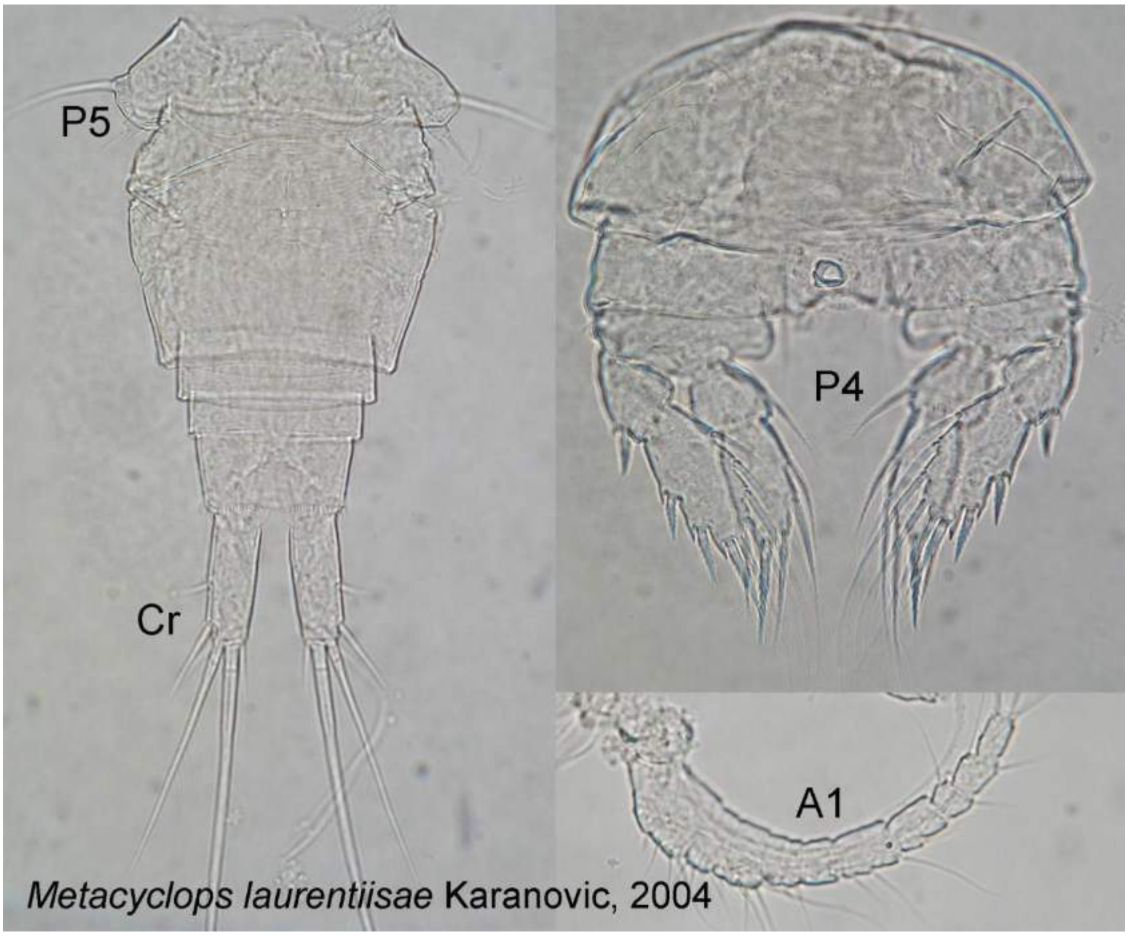

Plate 6 Defining morphological characteristics of the copepod *Metacyclops laurentiisae*.

Metacyclops laurentiisae Karanovic, 2004

This species is also very common in the Murchison region of WA (Karanovic 2004), but is probably better adapted for subterranean life than *Mesocyclops brooksi*, as it was found mostly in bores not in open stock wells. It differs from other similar species in this region by the shape of its caudal rami (Cr) and fifth leg (P5) (refer Plate 6).

4.1.3 Crustacea: Copepoda: Harpacticoida:

Schizopera yalgoo n. sp.

Very short caudal rami (Cr) distinguish this undescribed species from all other described Australian endemics from *Schizopera* (see Plate 7, Karanovic 2004; Karanovic & Cooper 2012; Karanovic & McRae 2103; Karanovic et al. 2016). Every species of *Schizopera* are considered to be short-range endemics. In addition to these species, Halse et al. (2002) reported *S. clandestina* (Klie, 1924) from surface waters of Lake Coyrecup (~25 km east of Katanning), but without any illustrations or comments. However, *S. clandestina* also has caudal rami that are longer than wide (see Lang 1948) and also six setae on the female fifth leg exopod (only five are present in *S. yalgoo*). Additional species of *Schizopera* with short caudal rami, mostly from Lake Way have been recorded (Karanovic 2018 unpublished data), but never as short as *S. yalgoo* n. sp. The species is considered endemic and a stygobiont.

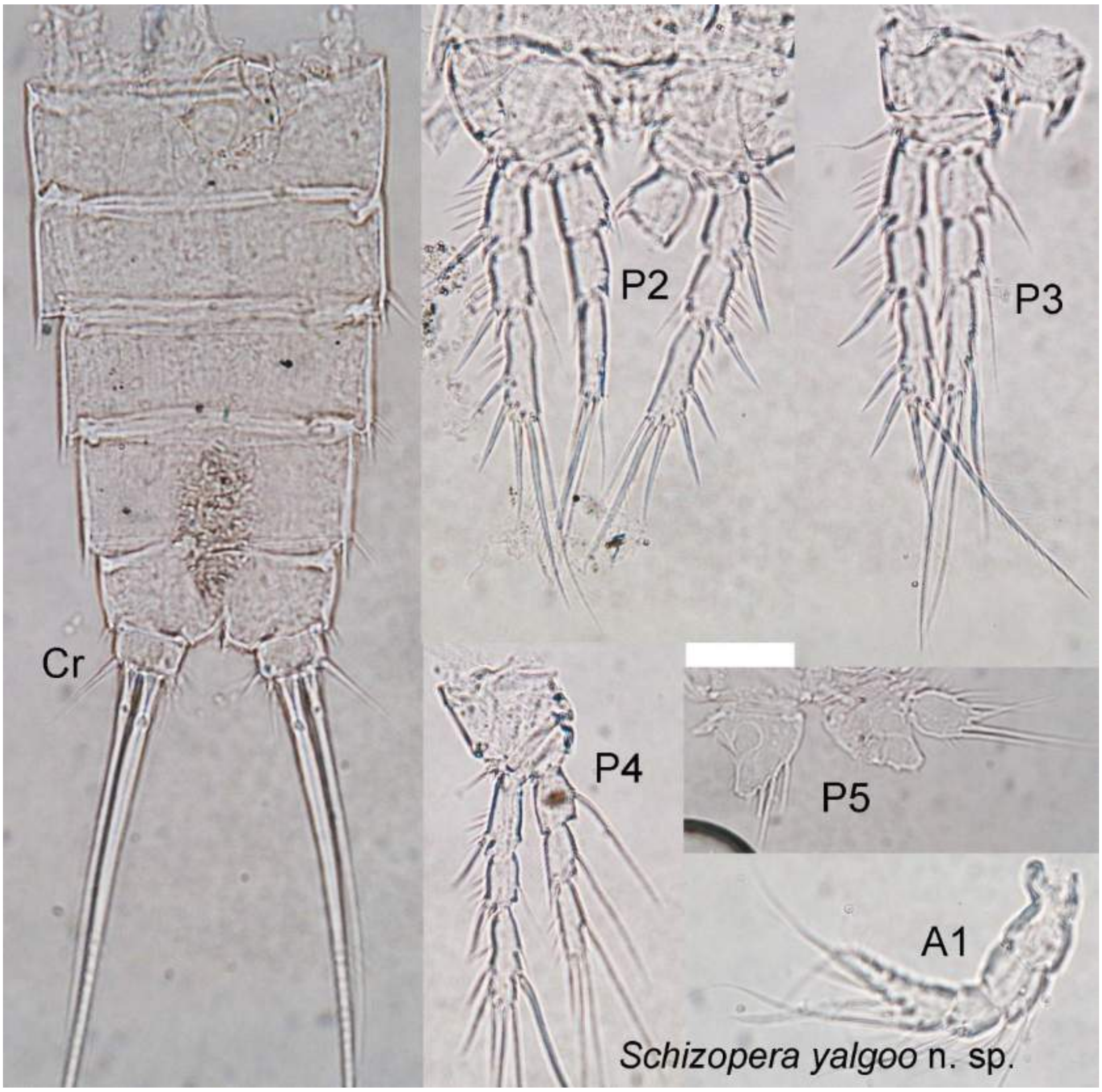

Plate 7 Defining morphological characteristics of the endemic *Schizopera yalgoo* n. sp. from Lazy Well.

4.2 Troglofauna Sampling Results

The phase 1 troglofauna leaf litter traps recorded three individuals from two classes and two families that may represent obligate subterranean forms (Table 6, Appendix 4). Two specimens of an undescribed Philoscid isopod were recorded from YRC2 and YORC128. These specimens were initially considered to be an obligate subterranean species due to specimens exhibiting troglomorphic characters including loss of pigmentation and reduced eyes these specimens, however, they are now considered to be troglophilic after further material was obtained in Phase 2 sampling, but the species is likely to show a restricted distribution (Judd 2019).

The phase 2 troglofauna leaf litter traps recorded 30 individuals from two classes and four families that may represent obligate subterranean forms (Table 6, Appendix 4). The phase 2 survey recorded an obligate troglobiont species of Armadillid isopod from YORC071, a troglomorphic species of Paraplatyarthrid isopod from YRC04 and YORC077 and a juvenile pseudoscorpion from the family Cheliferidae? that are not commonly obligate subterranean species and is considered to be epigean.

The distribution of troglomorphic species is shown in Figure 3.

The abundance and tracking numbers are available in Appendix 4.

Table 6 Troglofauna recorded from the Yogi Magnetite Project area Phase 1 and 2.

Higher Order	Genus and species	Locality	Phase 1 and/or 2	Notes
Crustacea: Isopoda:				
Armadillidae	*Troglarmadillo sp. indet*	**YORC071**	Phase 2	Troglobiont
Paraplatyarthridae	*Paraplatyarthridae sp. indet.*	**YRC04, YORC077**	Phase 2	Troglomorphic
Philosciidae	*Philosciidae sp. 'yalgoo'.*	**YRC02, YORC128, DDINF4**	Phase 1 and 2	Troglomorphic
Arachnida:				
Pseudoscorpionida	Chelifieridae? sp. indet. juvenile	**YRC03**	Phase 2	Epigean
Myriapoda: Diplopoda:				
Polyxenida	*Unixemus* sp.	**YRC12**	Phase 1	Epigean with likely wide distributions

4.2.1 Crustacea: Isopoda:

Armadillidae: *Troglarmadillo* sp. indet.

This genus contains very small, troglobitic Armadillidae. A single male specimen was recorded from bore YORC71 and is a true obligate subterranean species. *Troglarmadillo* are known from various locations in the northern half of Western Australia and all show restricted distributions and this species is also likely to show a restricted distribution (Judd 2020).

Philosciidae: *Unknown genus, sp. indet.*

Most of the specimens collected including those specimens from Phase 1 sampling in 2018 represent this species. The taxonomy of the Philosciidae in WA is largely unknown, but this appears to be a different genus to the Philosciidae normally found in epigean habitats. The species is partially troglomorphic as it has reduced pigmentation but with well-developed eyes. The specimens also exhibit body elongation (Judd 2020). This species has been recorded at three bores over the dual phase survey being recorded at bore YORC128 in 2018 and 2019, at bore YRC02 in 2018 and at bore at DDINF4 in 2019 (Figure 3).

Paraplatyarthridae: *Paraplatyarthrus? sp. indet.*

Two specimens of an undescribed Paraplatyarthridae were collected at bore YORC77 and bore YRC04 (Figure 3). This species has reduced eyes and a lack of pigmentation indicating that it represents a troglomorphic form (Judd 2020). It should be noted, that all Western Australian Paraplatyarthridae are at least partially subterranean (Javidkar et al 2017) and commonly show restricted distributions

Plate 8 Paraplatyarthridae species from near Laverton where the family was first described in 2017 (image after Javidkar 2017) similar to the species recorded within the Yogi Project area.

4.3 Water Quality

Water quality parameters were collected from each bore sampled for stygofauna using a Hanna HI 9298194 water quality meter. Results for the Phase 1 and Phase 2 survey are shown in Appendix 5. Water quality was found to be near fresh to brackish in most shallow bores accessing superficial alluvial aquifers, with stygofauna recorded only from the bores accessing the superficial alluvial aquifers.

5. Discussion

The results of the dual phase survey have revealed the presence of a stygofauna community within the superficial alluvial aquifers within the Project area tenements containing species new to science. No stygofauna was recorded from within the proposed mining pit or from the palaeochannel aquifer to the south east of the Project area. Three troglofauna species have been recorded from within the proposed mining pit

5.1 Stygofauna Assessment

The dual phase stygofauna survey recorded six species of stygofauna from six of the 45 bores sampled within the Project Area. Only a single species is new to science and likely endemic to the region, however the alluvial aquifer where the species was recorded is laterally extensive, and they likely occur far beyond the Project area of any potential water drawdown areas.

Stygofauna have only been recorded within the surficial alluvial aquifer and have not been recorded within the palaeochannel or overlaying fractured rock aquifers in the BIF and surrounding lithologies. The low water yields from the fractured rock aquifer associated with the BIF ridge where the proposed pit is located would indicate that there are few fractures (GHD 2019) and thus limited habitat for stygofauna.

The extensive sampling undertaken in November 2019 within the palaeochannel aquifer recorded no stygofauna or surface water species indicating that stygofauna are not present in this palaeochannel aquifer.

5.2 Troglofauna Assessment

Three species of troglofauna, all terrestrial slaters (isopods) have been recorded from within the proposed mining pit (Figure 3). Whilst these species have only been recorded from within the mining pit the geological units (Olive Queen Gabbro and the Youanmi Terrane greenstones) from which they have been recorded extends far beyond the Project area to the north and south following the strike of the geology (Figure 3). Two of the three troglomorphic isopod species have been recorded at multiple locations indicating that there is connectivity throughout the sampled area for troglofauna, that likely extends well beyond the proposed mining area.

The species' have been described as having a restricted distribution as they have only thus far been recorded from within the proposed mine pit where all sampling has occurred to date. This is not to say that their distributions do not extend more widely, especially in the same geological units that have provided habitat for these species (Figure 3). The potential habitat for these species extends far beyond the proposed mine pit and the entire project area to the north and south of the sampled area and these two species are highly likely to occur throughout these geological units where they have previously been found to occur. In addition due to the relatively shallow depths at which the troglofauna traps have been placed in the Yogi project area (often <10m) due to the water table and blockages or collapses in the holes the species may be utilising the "Mesovoid Shallow Substratum" (MSS – refer to Ortuño 2013), the interconnected network of voids and cavities within the overlaying colluvium and alluvium to increase their potential habitat far beyond the area sampled thus far for troglofauna. It is therefore likely that both these troglobiont isopods (Paraplatyarthridae:

Paraplatyarthrus? sp. indet. and Armadillidae: *Troglarmadillo* sp. indet.) have potential habitat and distributions within the local region far exceeding the currently identified occurrences. The potential troglofauna habitat to be removed by the proposed mine pit is only 3.5% of the total volume of these geological units with 96.5% remaining as troglofauna habitat in the local area (GHD 2019, section 6.13.3). It is for these reasons that is it reasonable to conclude that no significant impacts to either of these species is likely from the development of the project.

5.3 Potential Impacts to Subterranean Fauna

The following discussion of potential impacts is general in nature and based solely upon the mine plan layout provided to Invertebrate Solutions and impacts may alter in nature and severity with changes to the mine plan and additional information regarding pit depth, volume and source of construction and operation water and to what extent dewatering is required for mining activities. The potential impacts of resource development including, the pit void, developing a borefield in the region to the south of the Project Area, and general construction activities on subterranean fauna may be categorised as being either direct or indirect impacts.

Direct impacts are the obvious and unavoidable destruction or degradation of habitat that occurs in excavating voids such as pit voids including associated aquifer dewatering. Current modelling of the mine pit dewatering (GHD 2019) even when using a highly conservative estimate shows only minimal drawdown of between 1 – 2 m at Lazy Well where the copepod *Schizopera yalgoo* n. sp. was recorded. This level of drawdown, even over an extended period is not likely to significantly impact upon the available habitat for this species.

Indirect impacts are generally gradational, and more difficult to predict and manage because they may occur at moderate to large distances from the Project footprint. These impacts may be expressed some time after Project development has begun. Some examples include changes to hydrology, nutrient and microclimate regimes, contamination, reduced habitat area, water quality, and population viability. The zone of influence for indirect impacts may be considerably larger than the immediate area of the pit or disturbance area. Potential indirect impacts of excavation include:

- Alteration of surface hydrology that affects groundwater recharge regimes, sedimentation, and water quality (e.g. under and adjacent to remediation areas, roads and infrastructure);
- Changes to subterranean microclimate in the zone of influence of groundwater abstraction from bores for construction or operational water requirements (causing drying of habitat);
- Surface and groundwater contamination from plant equipment and infrastructure (e.g. chemical pollutants, hydrocarbons or waste water of lower quality);
- Salinisation of groundwater systems caused by changes to surface and subsurface hydrology;
- Reduction in organic inputs beneath areas cleared of vegetation and sealed surfaces;
- Vibration disturbance from construction and operational activities; and
- Risk of species extinction from reduction and/or fragmentation in habitat.

The above impacts are considered to be low in the context of the Yogi Project due to the relatively small size of the development compared with the size of remaining subterranean fauna habitat outside of the Project area.

6. Conclusions and Recommendations

No previous records of stygofauna or troglofauna are present in the databases of the Western Australian Museum from within the Desktop Study area. Suitable habitat for stygofauna and troglofauna is highly likely to occur in calcrete areas to the south of the Geraldton Mt Magnet Rd. Five stygofauna communities, all listed as Priority 1 Ecological Communities are known to occur in the calcrete areas in the region. All these calcretes were listed due to the presence of stygobiont Dytiscid diving beetles that occur in virtually every calcrete in the Mid West.

The dual phase stygofauna survey recorded six species and 172 individuals of stygofauna from six of the 45 bores sampled. Whilst Phase 1 sampling was entirely within the alluvial aquifer, Phase 2 sampling included the fractured rock aquifer within the mining pit and the palaeochannel aquifer to the south east of the Project area, with no stygofauna recorded except from the laterally extensive alluvial aquifer. No significant impacts to stygofauna are anticipated from the mine development as the modelled drawdown is minimal at 1 – 2 m where the copepod *Schizopera yalgoo* n. sp. was recorded. This level of drawdown, even over an extended period is not likely to significantly impact upon the available habitat for this species

The dual phase troglofauna survey within the mine pit recorded three subterranean isopod species from five different bores. Two of the three troglomorphic isopod species have been recorded at multiple locations indicating that there is connectivity throughout the sampled area for troglofauna, that likely extends well beyond the proposed mining area. The species' have been described as having a restricted distribution as they have only thus far been recorded from within the proposed mine pit where all sampling has occurred to date. This is not to say that their distributions do not extend more widely, especially in the same geological units that have provided habitat for these species (Figure 3). The potential habitat for these species extends far beyond the proposed mine pit and the entire project area to the north and south of the sampled area and these two species are highly likely to occur throughout these geological units where they have previously been found to occur.

In addition due to the relatively shallow depths at which the troglofauna traps have been placed in the Yogi project area (often <10m) due to the water table and blockages or collapses in the holes the species may be utilising the "Mesovoid Shallow Substratum" (MSS – refer to Ortuño 2013), the interconnected network of voids and cavities within the overlaying colluvium and alluvium to increase their potential habitat far beyond the area sampled thus far for troglofauna. It is therefore likely that both these troglobiont isopods (Paraplatyarthridae: *Paraplatyarthrus*? sp. indet. and Armadillidae: *Troglarmadillo* sp. indet.) have potential habitat and distributions within the local region far exceeding the currently identified occurrences. The potential troglofauna habitat to be removed by the proposed mine pit is only 3.5% of the total volume of these geological units with 96.5% remaining as troglofauna habitat in the local area (GHD 2019, section 6.13.3). It is for these reasons that is it reasonable to conclude that no significant impacts to either of these species is likely from the development of the project.

Due to the absence of vertical bores within the mining pit void no troglofauna scrape sampling was able to be undertaken.

The impacts to subterranean fauna are considered to be low in the context of the Yogi Project due to the relatively small size of the development compared with the size of remaining subterranean fauna habitat outside of the Project area, with no significant impacts anticipated.

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Appendix 1

Stygofauna sample locations, Phase 1 and 2

Bore ID	Easting	Northing	Phase 1	Phase 2	Date sampled
Bingamarra Well	491957	6878170	+		10/08/2018
Bridge Well	482811	6864302	+		9/08/2018
Carlaminda Well	473018	6872561	+		11/08/2018
Cattle Well	481765	6879540	+	+	9/08/2018 and 21/11/2019
Dolerin Well	479961	6887554	+		11/08/2018
Drillers Bore	476535	6879673	+		8/08/2018
Geology Camp Bore	478318	6879518	+	+	8/08/2018 and 21/11/2019
Government Well	493704	6869233	+		10/08/2018
Lazy Well	489160	6867440	+		10/08/2018
Lazy Well Bore	489160	6867433	+	+	10/08/2018 and 21/11/2019
MVA327	476642	6882851	+		8/08/2018
MVA328	476546	6882848	+		8/08/2018
MVA329	476445	6882849	+		8/08/2018
MVR079	476536	6882953	+		8/08/2018
Ram Well	489166	6863764	+		9/08/2018
Wadjingarra Well	482712	6873496	+	+	9/08/2018 and 21/11/2019
Water Bore 1	483491	6869205	+		9/08/2018
Water Bore 2	483962	6867946	+		9/08/2018
Melville Well	476731	6883201	+		8/08/2018
YORC120	479357	6886441	+		11/08/2018
YORC122	479347	6886443	+		11/08/2018
Bore 1	476725	6883150	+		8/08/2018
AC02	488307	6869973		+	21/11/2019
AC04	486953	6867430		+	20/11/2019
AC05	489148	6865772		+	20/11/2019
AC07	486607	6864804		+	20/11/2019
AC08	487603	6867443		+	21/11/2019
AC09	485598	6864635		+	20/11/2019
AC10	485981	6864732		+	20/11/2019
EH01	480951	6877183		+	19/11/2019
EH02	481037	6877321		+	19/11/2019
EH03	481826	6875419		+	20/11/2019
EH04	482155	6875472		+	20/11/2019
MB01	479555	6878297		+	19/11/2019
MB02	480117	6877732		+	19/11/2019
MB03	480622	6877097		+	19/11/2019
MB04	480976	6876431		+	20/11/2019
PB03	480615	6877088		+	19/11/2019
PB04	481034	6876450		+	20/11/2019
YPB01	485628	6864633		+	20/11/2019
YPB02	486985	6867409		+	20/11/2019

Appendix 2

Troglofauna sample locations, Phase 1 and 2

Phase 1 Troglofauna traps

Bore ID	Easting	Northing	Litter Trap number	Date placed	Date retrieved
DDINF1	480407	6877217	2	6/08/2018	14/10/2018
DDINF1A	480408	6877220	2	6/08/2018	14/10/2018
DDINF2	480191	6877564	2	6/08/2018	13/10/2018
DDINF3	479948	6877859	2	6/08/2018	13/10/2018
DDINF4	479642	6878132	2	6/08/2018	13/10/2018
YORC071	480466	6877023	1	7/08/2018	13/10/2018
YORC077	480054	6877662	2	7/08/2018	13/10/2018
YORC128	480588	6876868	1	7/08/2018	14/10/2018
YORC134	480111	6877718	2	7/08/2018	13/10/2018
YRC1	480152	6877759	2	7/08/2018	13/10/2018
YRC2	480211	6877813	1	7/08/2018	13/10/2018
YRC3	479823	6877997	1	7/08/2018	13/10/2018
YRC4	479773	6877951	1	7/08/2018	13/10/2018
YRC5	479771	6877948	1	7/08/2018	13/10/2018
YRC6	479878	6878049	2	6/08/2018	13/10/2018
YRC7	479571	6878301	1	7/08/2018	14/10/2018
YRC8	479524	6878248	1	7/08/2018	13/10/2018
YRC9	479464	6878183	1	7/08/2018	13/10/2018
YRC10	479622	6878349	1	7/08/2018	13/10/2018
YRC11	479426	6878437	1	7/08/2018	13/10/2018
YRC12	481844	6875087	1	7/08/2018	14/10/2018
Total Phase 1			28		

Phase 2 Troglofauna traps

Bore ID	Easting	Northing	Litter Trap number	Date placed	Date retrieved
DDINF1	480407	6877217	1	14/10/2018	18/11/2019
DDINF1A	480408	6877220	1	14/10/2018	18/11/2019
DDINF2	480191	6877564	2	13/10/2018	18/11/2019
DDINF3	479948	6877859	2	13/10/2018	18/11/2019
DDINF4	479642	6878132	2	13/10/2018	18/11/2019
YORC071	480466	6877023	2	13/10/2018	18/11/2019
YORC077	480054	6877662	2	13/10/2018	18/11/2019
YORC128	480588	6876868	2	14/10/2018	18/11/2019
YRC1	480152	6877759	2	13/10/2018	18/11/2019
YRC2	480211	6877813	1	13/10/2018	18/11/2019
YRC3	479823	6877997	1	13/10/2018	18/11/2019
YRC4	479773	6877951	1	13/10/2018	18/11/2019
YRC5	479771	6877948	1	13/10/2018	18/11/2019
YRC6	479878	6878049	2	13/10/2018	18/11/2019
YRC7	479571	6878301	1	14/10/2018	18/11/2019
YRC8	479524	6878248	1	13/10/2018	18/11/2019
YRC9	479464	6878183	1	13/10/2018	18/11/2019
YRC12	481844	6875087	1	14/10/2018	18/11/2019
Total Phase 2			26		

Appendix 3

Species and abundance data Stygofauna - Phase 1 and 2

Location	Sub Phylum	Class	Order	Family	Genus and sp	Known Distribution	Abundance	Site	Date	Collection Method	Tracking number	Identified by	Residing currently
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	Cyprididae sp.	unknown	1	Bridge Well	9/08/2018	Stygofauna net haul	ISTN262	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	Cyprididae sp.	unknown	1	Wadjingarra Well	9/08/2018	Stygofauna net haul	ISTN259	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	Cyprididae sp.	unknown	1	Cattle Well	9/08/2018	Stygofauna net haul	ISTN258	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	*Sarscypridopsis ochracea*	South Africa, Yalgoo	4	Melville Well	8/08/2018	Stygofauna net haul	ISTN250	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	*Sarscypridopsis ochracea*	South Africa, Yalgoo	16	Wadjingarra Well	21/11/2019	Stygofauna net haul	ISTN1538	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	*Sarscypridopsis ochracea*	South Africa, Yalgoo	1	Cattle Well	21/11/2019	Stygofauna net haul	ISTN1539	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Ostracoda	Podocopida	Cyprididae	Cyprididae sp.	unknown	4	Bingarmarra Well	10/08/2018	Stygofauna net haul	ISTN266	Dr Ivana Karanovic	Hanyang University
Yalgoo	Crustacea:	Copepoda	Cyclopoida	Cyclopidae	*Apocyclops dengizicus*	Widespread	17	Lazy Well	10/08/2018	Stygofauna net haul	ISTN265	Dr Tomislav Karanovic	Hanyang University
Yalgoo	Crustacea:	Copepoda	Cyclopoida	Cyclopidae	*Mesocyclops brooksi*	Widespread	123	Bingarmarra Well	10/08/2018	Stygofauna net haul	ISTN266	Dr Tomislav Karanovic	Hanyang University
Yalgoo	Crustacea:	Copepoda	Cyclopoida	Cyclopidae	*Metacyclops laurentiisae*	Widespread	3	Melville Well	8/08/2018	Stygofauna net haul	ISTN250	Dr Tomislav Karanovic	Hanyang University
Yalgoo	Crustacea:	Copepoda	Harpacticoida	Miraciidae	*Schizopera yalgoo n. sp.*	Project area only	1	Lazy Well	10/08/2018	Stygofauna net haul	ISTN265	Dr Tomislav Karanovic	Hanyang University

Appendix 4

Species and abundance data Troglofauna - Phase 1 and 2

Location	Sub Phylum	Class	Order	Family	Genus and sp	Known Distribution	Abundance	Site	Date	Collection Method	Tracking number	Identified by	Residing currently
Yalgoo	Crustacea:		Isopoda	Armadillidae	Troglarmadillo sp. indet.	unknown	1	YORC071	18/11/2019	Troglofauna leaf litter trap	ISTN1543	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Paraplayarthridae	Paraplayarthridae sp. indet.	unknown	1	YORC077	18/11/2019	Troglofauna leaf litter trap	ISTN1542	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Paraplayarthridae	Paraplayarthridae sp. indet.	unknown	1	YRC04	18/11/2019	Troglofauna leaf litter trap	ISTN1556	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Philosciidae	Philosciidae sp. 'yalgoo'	unknown	1	YRC02	13/10/2018	Troglofauna leaf litter trap	ISTN540	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Philosciidae	Philosciidae sp. 'yalgoo'	unknown	1	YORC128	14/10/2018	Troglofauna leaf litter trap	ISTN537	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Philosciidae	Philosciidae sp. 'yalgoo'	unknown	21	YORC128	18/11/2019	Troglofauna leaf litter trap	ISTN1541	Simon Judd	Simon Judd
Yalgoo	Crustacea:		Isopoda	Philosciidae	Philosciidae sp. 'yalgoo'	unknown	4	DDINF4	18/11/2019	Troglofauna leaf litter trap	ISTN1547	Simon Judd	Simon Judd
Yalgoo	Chelicerata	Arachnida	Pseudoscorpionida	Cheliferidae?	Cheliferidae sp. indet. juvenile	Widespread	1	YRC03	18/11/2019	Troglofauna leaf litter trap	ISTN1554	T Moulds	Invertebrate Solutions
Yalgoo	Myriapoda	Diplopoda	Polyxenida	Polyxenidae	sp.	Widespread	1	YRC12	14/10/2018	Troglofauna leaf litter trap	ISTN534	T Moulds	Invertebrate Solutions

Appendix 5

Water Quality from bores sampled for stygofauna Phases 1 and 2

Water quality in wells and bores sampled for stygofauna in August 2018

Bore ID	Temperature ˚C	EC µS/cm	TDS mg/L (ppm)	ORP (mV)	pH	Depth to Water (m)	Water Depth (m)	Total Depth (m)	Notes
Bingamarra Well	21.01	4597	2281	49.1	8.09	12.8	4.3	17.1	
Bridge Well	22.39	1384	691	42.8	7.53	9.2	3.1	12.2	
Carlaminda Well	24.34	2708	1350	48	7.39	21.4	2.4	23.8	
Cattle Well	21.35	2948	1470	44.2	7.35	17.1	7.9	25.0	
Dolerin Well	23.41	2574	1287	48.3	8.02	18.3	7.9	26.2	
Drillers Bore	26.24	1564	781	42.4	7.05	21.4	43.3	64.7	
Geology Camp Bore	24.91	814	407	39.5	7.27	16.5	53.7	70.2	
Government Well	22.25	5642	2810	50.1	7.54	14.6	6.7	21.4	
Lazy Well	20.01	8905	4451	48.1	8.04	12.8	4.3	17.1	Endemic stygofauna
Lazy Well Bore	23.76	7176	3581	45	7.15	10.4	20.7	31.1	
MVA327	24.72	1764	881	47.5	7.04	16.5	23.8	40.3	
MVA328	25.62	2197	1099	46.8	6.79	15.9	9.8	25.6	
MVA329	25.54	2046	1023	45.1	7.02	17.1	24.4	41.5	
MVR079	25.88	1542	771	45.8	6.98	14.6	25.0	39.7	
Ram Well	21.51	23920	11960	48.3	7.63	6.1	3.1	9.2	
Wadjingarra Well	21.6	3208	1604	42.8	7.42	10.4	2.4	12.8	
Water Bore 1	25.75	1445	722	44	7.02	21.4	37.8	59.2	
Water Bore 2	25.46	1545	773	44.5	7.42	12.2	35.4	47.6	
Melville Well	22.6	1768	895	46.6	7.24	15.9	2.4	18.3	
YORC120	24.24	1745	872	49.5	7.84	30.5	154.3	184.8	
YORC122	23.67	1761	881	49.5	7.79	35.4	150.7	186.1	
Bore 1	24.36	1620	808	43.1	6.87	15.9	39.0	54.9	

Water quality in wells and bores sampled for stygofauna in November 2019

Bore ID	Temperature ˚C	EC µS/cm	TDS mg/L (ppm)	ORP (mV)	pH	Depth to Water (m)	Water Depth (m)	Total Depth (m)	Notes
AC02	25.86	1143	5713	64.2	6.91	14.4	40.8	55.2	
AC04	26.20	12590	6293	77.7	6.91	12	57.6	69.6	
AC05	26.43	20050	10030	-136.3	6.74	10.8	21.6	32.4	
AC07	25.83	4894	2428	58.3	7.0	8.4	24	32.4	
AC08	26.05	3311	1653	-244.5	6.66	12	36.6	48.6	
AC09	26.34	6420	3206	64.9	7.55	8.4	32.4	40.8	
AC10	26.13	3996	1996	59.0	7.09	7.2	27	34.2	
Cattle Well	25.04	2596	1293	53.8	6.80	21	3	24	
EH01	27.33	2043	1021	53.4	6.46	12	9	21	
EH02	26.45	1908	935	-193.6	6.9	12	57	69	
EH03	26.57	1600	799	-175.4	6.97	16.2	23.4	39.6	
EH04	25.58	1896	946	61.3	6.74	12	29.4	41.4	
Geology Camp Bore	27.24	1529	764	42.1	6.96	16.8	55.2	72	
Lazy Well Bore	25.16	7224	3603	65.9	7.06	12.6	21	33.6	
MB01	27.31	1702	852	-276.9	7.46	27	1.8	28.8	Kink in hole restricting access below this point
MB02	27.73	1440	724	-228.9	7.19	27	147	174	
MB03	27.63	1286	643	-175.6	6.86	14.4	55.2	68.4	
MB04	26.15	1954	954	63.8	6.44	11.4	33	44.4	
PB03	27.44	1310	655	44	6.73	14.4	54.6	69	
PB04	25.84	1553	764	62.5	6.59	10.8	36	46.8	
Wadjingarra Well	24.05	2824	1399	48.7	7.23	10.2	1.8	12	
YPB01	26.41	6105	3026	64.1	7.39	8.4	44.4	52.8	
YPB02	26.28	10070	5033	73.7	6.98	10.8	64.8	75.6	

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