Pilot Survey for Subterranean Fauna for the Lake Mackay SOP Project, Western Australia.

Report by Invertebrate Solutions for Agrimin Ltd on behalf of 360 Environmental Pty Ltd

October 2017

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Invertebrate Solutions. (2017). Pilot Survey for Subterranean Fauna for the Lake Mackay SOP Project, Western Australia, October 2017.

Report Number 2017ISJ03_F03_20171031

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Frontispiece: A stygobiontic dytiscid diving beetle, *Paroster* sp. 'mackay' from a calcrete aquifer south of Lake Mackay.

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Executive Summary

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project covers nine tenements covering the majority of Lake Mackay over a total area of 2,560 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA. The Project is situated entirely within WA but is accessed from Alice Springs in the NT, 540 km to the south-east.

Invertebrate Solutions was requested by 360 Environmental Pty Ltd (360 Environmental) on behalf of Agrimin to undertake a desktop assessment for subterranean fauna and a field pilot survey for stygofauna and troglofauna in the proposed borefield area for the Lake MacKay SOP Project.

The pilot survey for subterranean fauna at the Lake Mackay SOP Project was undertaken in May 2017. Although initially planned for May 2017, no troglofauna pilot survey was possible as all available boreholes were cased with PVC to the local watertable thus precluding the sampling of troglofauna from these bores. Five stygofauna samples were obtained from the surficial calcrete aquifer to the south of Lake Mackay. Stygofauna was identified in two of the five samples (Camp Bore and Nr LP008) with at least 10 species present.

The stygofauna collected has been identified to the lowest practical taxonomic level, with eight new species, and two new genera recorded. These results are not entirely unexpected due to the location of the sampling being many hundreds of kilometres from any other subterranean fauna sampling locations. The stygofauna recorded in the calcrete to the south of Lake Mackay is significant in that it contains a new species of dytiscid diving beetle (*Paroster* sp. '*mackay'),* a new species of parabathynellid (*Atopobathynella* sp. '*mackay'*), and multiple new species of Copepoda, some of which show extremely primitive morphological characters (*Mackaycyclops mouldsi* n. g. & sp. and *Schizopera mackay* n. sp.) and may be important in the evolutionary history of Australian stygofauna. Currently, most of these new species are known from single bores, although this is invariably due to the lack of suitable sampling locations within the extensive calcrete located to the south of Lake Mackay. The following recommendations are made with regard to the potential development of the Lake Mackay SOP Project:

- Due to the presence of a stygofaunal community within the proposed borefield area, a Level 2 survey for stygofauna should be undertaken with regard to EPA Technical Guidance – subterranean fauna survey (EPA2016a) and EPA Technical Guidance – sampling methods for subterranean fauna (EPA2016b);
- The Level 2 survey for stygofauna will require, at a minimum, 40 samples from each aquifer within the proposed impact area (EPA2016b);
- A troglofauna pilot survey should be undertaken in the proposed borefield area once suitable bores are available for sampling. In order to meet EPA Guidance (2016a), a minimum of 10 – 15 bores will need to be sampled;
- A stygofauna pilot survey should be undertaken in any available holes augered on the islands within Lake Mackay; and
- Newly constructed bores should be suitable for stygofauna and/or troglofauna sampling.

1. Introduction

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project spans nine tenements covering the majority of Lake Mackay over a total area of 2,560 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA.

Invertebrate Solutions was requested by 360 Environmental Pty Ltd (360 Environmental) on behalf of Agrimin to undertake a desktop assessment for subterranean fauna and a field pilot survey for stygofauna and troglofauna in the proposed borefield area for the Lake MacKay SOP Project.

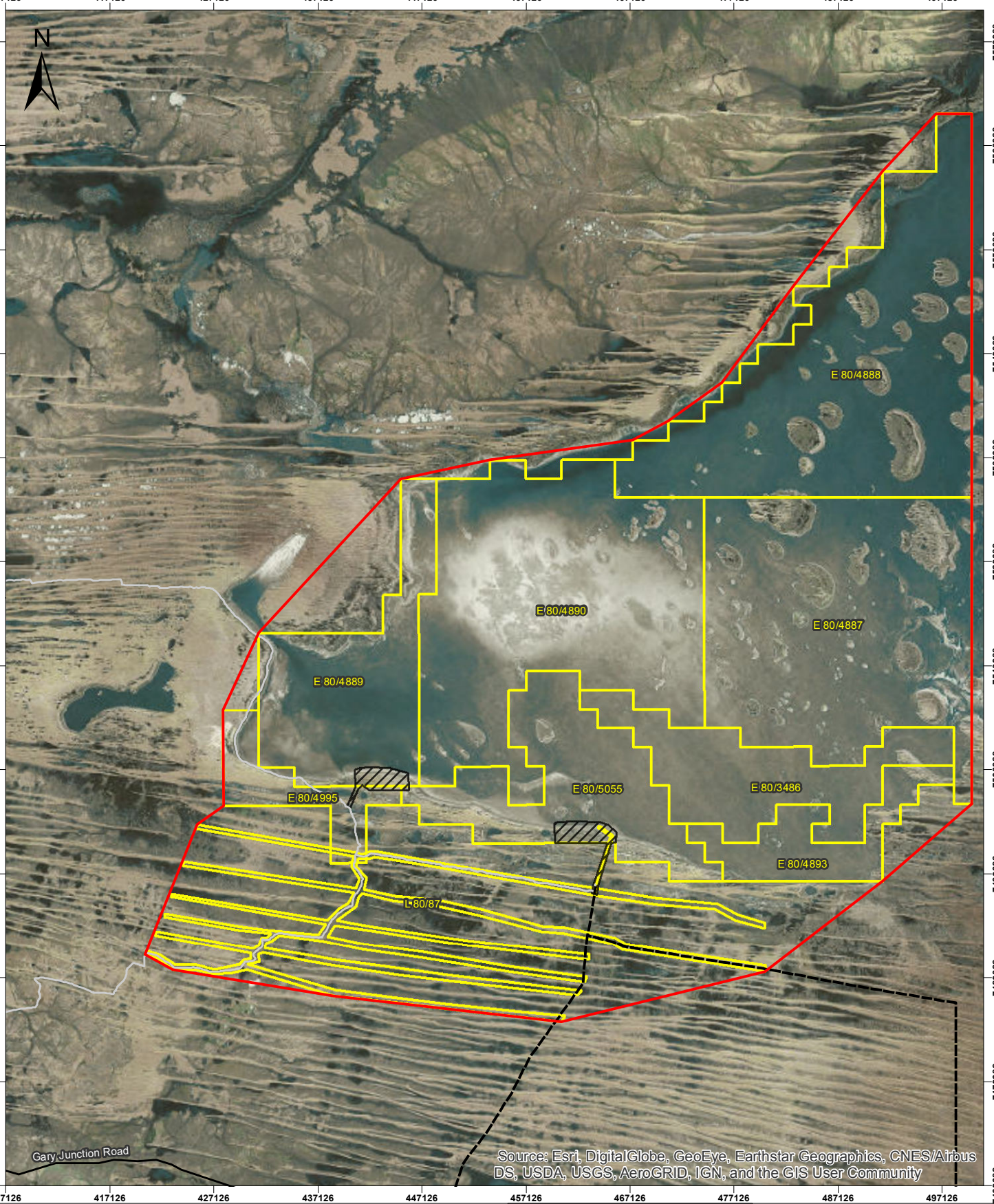
1.1 Purpose of this Report

360 Environmental has requested Invertebrate Solutions to undertake the following scope of works for the Lake Mackay SOP Project area, Western Australia:

- Undertake a desktop assessment for stygofauna and troglofauna in the Project area;
- Undertake a pilot survey for stygofauna and troglofauna in the proposed borefield area;
- 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.

1.2 Project Area

The Project includes nine tenements covering the majority of Lake Mackay over a total area of 2,560 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA. The Project is situated entirely within WA but is accessed from Alice Springs in the NT, 540 km to the south-east and is shown in Figure 1.



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7570388 7560388 7550388 7540388 7530388 7520388 7510388 7500388 7490388 7480388 7470388 7460388

Legend

- Study Area
- Tenements
- Proposed Infrastructure Boundaries
- Existing Road
- Existing Track
- Proposed Track

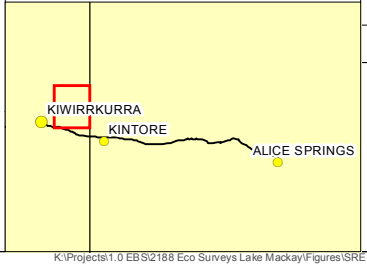
0 2,500 5,000 10,000 15,000 20,000

Meters

1:500,000 @ A4

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

LOCALITY MAP



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- LOCALITY MAP SOURCED FROM LANDGATE 2006
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2017
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PROJECT ID	DATE
2188	30/08/2017

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 52

CREATED	CHECKED	APPROVED	REVISION
EW	SS	SS	0

Pilot survey for subterranean fauna for the Lake Mackay SOP Project, Western Australia

Figure 1
Survey Area

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1.3 Survey Effort and Timing

Invertebrate Solutions completed a pilot survey for stygofauna in the borefield areas in May 2017. A total of five samples were collected from bores within the borefield area (Table 1). The sample obtained from the handpump does not meet the required sampling requirements for a pump sample and is for reference only (refer Section 2.2).

Table 1 Bores sampled for Stygofauna in the Borefield

Bore ID	Easting	Northing	Date Sampled
Camp Bore	463762	7489435	12/05/2017
LD02	463802	7488674	18/05/2017
LD03	449111	7491138	18/05/2017
Nr LP008	448025	7491415	18/05/2017
Handpump	429786	7480760	18/05/2017

A map showing the locations of the bores sampled for troglofauna and stygofauna are shown in Figure 2.

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;

Legend

- Study Area
- Proposed Infrastructure Boundaries
- Existing Road
- Existing Track
- Proposed Track
- Stygofauna Sampling Locations

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Meters

1:500,000 @ A4

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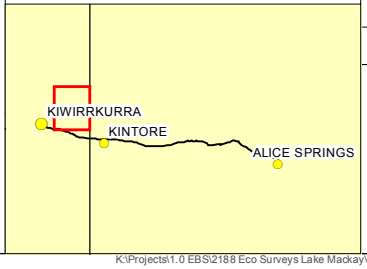
LOCALITY MAP



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Pilot survey for subterranean fauna for the Lake Mackay SOP Project, Western Australia

Figure 2
Stygofauna Sampling Locations

K:\Projects\1.0 EBS\2188 Eco Surveys Lake Mackay\Figures\SRE and Aquatic Macroinverts\2188 SRE Figure 2 Stygofauna.mxd

- 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 Wildlife Conservation (WC) Act (1950), the Environmental Protection Act (1986) and federally under the 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 WC Act provides a list of species that have special protection as species listed under the Wildlife Conservation (Specially Protected Fauna) Notice 2015 (DPaW 2015). 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 2015) 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 WC Act as Scheduled species. 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.

There is no current ability for the state government of Western Australia to formally list Threatened or Priority Ecological Communities (TECs/PECs), however, a list of such communities is maintained by DBCA and overseen by the Minister for the Environment. 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. Communities that are not considered by DBCA to be threatened but may be vulnerable to future impacts are classed as PECs and include numerous calcrete aquifers in the Yilgarn region where each calcrete has been shown to contain an endemic stygal community.

The WC Act is expected to be imminently replaced by the new Biodiversity Conservation Act that has yet to be enacted into law. This new act has been passed by the lower house of the State parliament and will be capable of protecting both species and ecological communities under legislation.

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.*
- Gerry Bradley *BSc (Hons) Zool.* (Agrimin Sustainability Manager).

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:

- 08-000591-1; Licensee Dr Ron Firth (360 Environmental); Valid from 8-22/05/2017.

The pilot survey sampling for stygofauna was undertaken between 12th – 18th May 2017.

1.7 Report Limitations and Exclusions

This study was limited to the written scope provided to the client by Invertebrate Solutions (8th August 2016) 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 Agrimin 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 360 Environmental for Agrimin 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 stygofauna require multiple seasonal surveys to fully record all species that may be present in an area. The current survey was undertaken during a single season and additional surveys at different times of the year may record additional species.

2. Methods

Invertebrate Solutions undertook the following tasks for the pilot survey of the Lake Mackay Project area:

- Desktop subterranean fauna assessment; and
- Stygofauna pilot survey of the proposed borefield.

The pilot 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 'Low', 'Moderate', 'High', or 'Definite'.

2.2 Stygofauna Sampling Methodology

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.

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.

Sampling of the handpump site was undertaken by pumping water through a 50 µm mesh net into bucket of known volume. Approximately 165 L of water was pumped from the bore through the stygofauna net prior to the well going temporarily dry. This volume is well below the recommended

volume of 300 L or three times the bore volume (EPA 2016b) and so this sample should not be regarded as an indication that stygofauna is absent from this bore.

2.3 Water Quality

Water samples were collected in conjunction with stygofauna sampling and analysed *in situ* using a Hanna HI 9811-5 water quality meter. Water samples were collected from the upper 1 - 2 m of the water column prior to stygofauna sampling using a bailer. Four parameters (Temperature, Total Dissolved Solids, Electrical conductivity and pH) were recorded from each bore where a stygofauna sample was collected.

2.3.1 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.

2.3.2 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).

2.3.3 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).

2.3.4 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 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.

2.5 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. Identification of bathynellid specimens was undertaken by Dr Kym Abrams.

3. Desktop Assessment

3.1 Subterranean Fauna in Central Australia

There has been limited sampling for subterranean fauna in central Australia with stygofauna recorded from calcretes in the Ngalia basin north of the MacDonnell Ranges near Alice Springs in the Northern Territory (Balke *et al*. 2004; Taiti and Humphreys 2001; Watts and Humphreys 2006, Leys and Watts 2008, Humphreys 2008). The stygofauna recorded has included multiple species of Dytiscid diving beetles, similar to the fauna recorded in the Yilgarn calcretes, along with a diverse assemblage of stygobiont oniscoid isopods from the genus *Haloniscus,* and Bathynellids from the genus *Atopobathynella* (Cho *et al*. 2006). There has been some sampling of calcretes beyond the Ngalia basin near Nolans Bore approximately 135 km to the north of Alice Springs associated with a rare earth element project (GHD 2010), however, no stygofauna were recorded from this area. Calcrete aquifers have been shown throughout arid and semi-arid Australia to be highly likely to contain stygofauna, hence, if this habitat is likely to be impacted upon during Project development activities (i.e. dewatering or borefield operation) there is a high risk of significant impacts being caused to local stygofauna communities.

There are no records of any subterranean fauna studies being previously undertaken in the vicinity of Lake Mackay and no subterranean specimens are held in the records of the Western Australian Museum (WAM 2017a, 2017b).

3.2 Troglofauna Desktop Assessment

No previous records of troglofauna are present in the databases of the Western Australian Museum (WAM 2017a, 2017b). Suitable habitat for troglofauna is highly likely to occur in the calcrete areas (Figure 3) to the south of Lake Mackay (Bureau of Mineral Resources 1976). The upper unsaturated portions of the calcrete provide suitable conditions for troglofauna in the extensive interconnected void networks found in calcrete outcrops (Plate 1).

3.3 Stygofauna Desktop Assessment

No previous records of stygofaunaare present in the databases of the Western Australian Museum (WAM 2017a, 2017b).

Stygofauna are known from the Ngalia basin to the south east of Lake Mackay with significant diversity present including bathynellids, isopods, copepods, ostracods and subterranean dytiscid diving beetles. The calcrete outcrops identified in the Webb 1:250,000 geological map (Bureau of Mineral Resources 1976) provide suitable habitat for stygofauna. The islands on Lake Mackay may also have some calcrete deposits or horizons within halite and gypsum units (Figure 3, Plate 2). The extent of these calcrete horizons is unknown although, if of a suitable size, they may provide habitat for stygofauna if saturated, however, the salinity of any such groundwater would be anticipated to be very high and thus may reduce the likelihood of any stygofauna being present. It should be noted that high salinity does not necessarily preclude the presence of stygofauna (Leijs 2009).

Plate 1 Exposure of calcrete within a quarry on the southern side of Lake Mackay showing micro and meso caverns that provide suitable habitat for stygofauna (when saturated) and troglofauna.

Plate 2 Exposure of calcrete on an island of Lake Mackay that may provide suitable habitat for stygofauna (when saturated) and troglofauna.

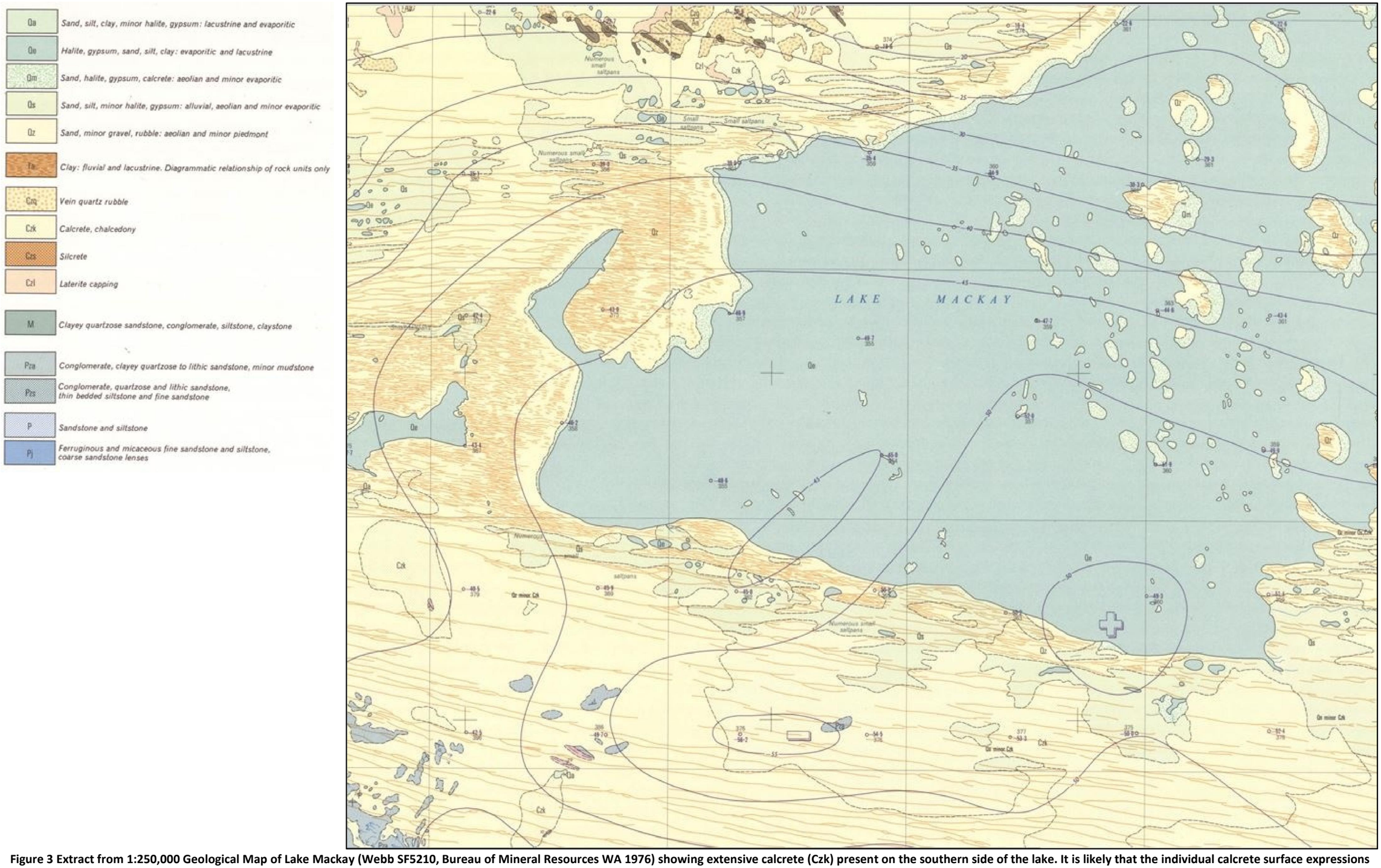

Figure 3 Extract from 1:250,000 Geological Map of Lake Mackay (Webb SF5210, Bureau of Mineral Resources WA 1976) showing extensive calcrete (Czk) present on the southern side of the lake. It is likely that the individual calcrete surface expressions on the southern side of the lake form a continuous outcrop with intermittent surface cover by sand dunes.

4. Stygofauna Pilot Survey Results

The stygofauna pilot survey recorded 10 species and 121 individuals of stygofauna from two of the five bores sampled within the proposed borefield area. The samples included three classes, six orders, seven families and nine genera. The greatest diversity was among the copepods with two orders, three families, five genera and six species recorded, including two new genera and five new species (Karanovic and Karanovic 2017).

Table 2 Stygofauna recorded from the Lake Mackay SOP Proposed Borefield area

Higher Order	Genus and species	Site	Abundance	Notes
Annelida: Oligochaeta	*Phreodrilidae?* sp.	Nr LP008	1	Damaged specimen
Crustacea: Bathynellacea: Parabathynellidae	*Atopobathynella* sp. *'mackay'* n. sp.	Nr LP008	30	New species, likely endemic
Crustacea: Ostracoda: Podocopida: Candonidae	*Abcandonopsis mackay* n. sp.	Nr LP008	1 male	New species, likely endemic
Crustacea: Copepoda: Harpacticoida: Ameiridae	*Mackaynitocrella mouldsi* n. gen., n. sp.	Camp bore	3 females	New genus and species, likely endemic
	Parapsuedoleptomesochra mackay n. sp.	Camp bore	1 male, 2 females	New species, likely endemic
Crustacea: Copepoda: Harpacticoida: Miraciidae	*Schizopera mackay* n. sp.	Nr LP008	9 females, 1 juv.	New species, likely endemic
Crustacea: Copepoda: Cyclopoida: Cyclopidae	*Halicyclops cf. kieferi*	Camp bore	3 males, 8 females	Widespread in the Yilgarn but likely cryptic species complex
	Halicyclops mackay n. sp.	Camp bore	3 males, 3 females, 1 juv.	New species, likely endemic
	Mackaycyclops mouldsi n. gen., n. sp.	Nr LP008, Camp bore	44 male, 9 female, 9 Juv; 2 females	New genus and species, likely endemic
Insecta: Coleoptera: Dytiscidae	*Paroster* sp. *'mackay'* n. sp.	Nr LP008	1	New species, likely endemic

4.1 Water Quality

Water quality parameters were collected from each bore sampled for stygofauna using a Hanna HI 9811-5 water quality meter. Samples were analysed in the field to provide a measure of temperature, total dissolved solids (TDS), electrical conductivity (EC) and pH. Results are shown in Table 3.

Water quality was found to be near fresh to brackish in most areas, with stygofauna recorded from a range of different water quality.

Table 3 Water quality in Borefield bores sampled for stygofauna in May 2017

Bore ID	Temperature ˚C	pH	TDS mg/L	EC µS/cm	Depth to Water (m)	Water Depth (m)	Total Depth (m)
Camp Bore	29.3	6.7	320	660	5	33	38
LD02	27.7	8.2	>1310	>2500	9	32	41
LD03	29.5	8.7	>1310	>2500	7	30	37
Nr LP008	29.5	8.6	3710	7460	2	20	22
Handpump	28.8	8.1	100	210	-	-	-

5. Discussion

The results of the pilot survey have revealed a diverse stygofauna community within the calcrete aquifer to the south of Lake Mackay.

It is currently unknown if other deeper aquifers are present within the immediate area south of Lake Mackay, although airborne magnetic and electromagnetic surveying undertaken by Toro Energy potentially identified a palaeochannel in the area (Hydrominex Geoscience 2016).

The islands within Lake Mackay may also host minor calcrete aquifers, although the extent and depth of calcrete that was observed outcropping is unknown. These units may provide habitat for stygofauna if they are saturated and of a reasonable size.

5.1 Stygofauna Assessment

A pilot survey for stygofauna within the proposed Project borefield recorded 10 species of stygofauna. At least eight of these species are new to science and likely endemic to the individual calcrete situated to the south of Lake Mackay (Figure 3). The majority of species recorded are new to science and likely endemic to the calcrete due to the repeated pattern of endemism found in the Yilgarn and Ngalia basin calcretes (Leys *et al*. 2003, Watts and Humphreys 2006, 2009, Watts and Leys 2005).

The presence of stygofauna within the calcrete to the south of Lake Mackay from the sampling of 5 bores would indicate that a stygofaunal community is present, although its complete diversity and distribution is currently unknown beyond the two bores where stygofauna was identified (Camp Bore and Nr LP008, refer Figure 2). A discussion of the individual species recorded is below.

5.1.1. Annelida: Oligochaeta: Pheodrilidae? sp.

A single specimen of Pheodrilid oligochaete was recorded from bore Nr LP008. The specimen was damaged and so unable to be identified further than family level. Additional collecting from this bore in the future may enable further identification.

5.1.2. Crustacea: Bathynellacea: Parabathynellidae:

Atopobathynella? sp. *'mackay'* n. sp.

Bathynellids are small, groundwater crustaceans that have a worldwide distribution in freshwater environments. There are over 35 genera and 120 species of parabathynellids described worldwide (Cho 2005). The genus *Atopobathynella* was first erected in 1973 and is now one of 10 genera of Parabathynellids in Australia. The genus contains nine described specimens, three from surface waters in Victoria and Tasmania, with the remainder being stygobitic from subterranean waters in Western Australia (Cho, Humphreys and Lee 2006). The specimen recorded from bore Nr LP008 shows morphological differences in the structures of the uropod and pleotelson to other described species of *Atopobathynella*, and so is regarded as a new species (Plate 3).

Plate 3 Lateral view of Parabathynellidae: *Atopobathynella* sp. '*mackay*' from bore Nr LP008. Scale approximately 1mm.

5.1.3. Crustacea: Ostracoda: Podocopida: Candonidae

Abcandonopsis mackay n. sp.

Ostracods are aquatic micro-crustaceans distributed worldwide in virtually every imaginable aquatic habitat, both fresh and saline. This trapezoid species is similar to some congeners from the Murchison region (Karanovic I. 2004) and exhibits a smooth shell surface, pronounced asymmetry in valve shape and size. Details of soft part morphology were not checked, as only one specimen was available, but it is clearly distinct from other congeners in shell shape and ornamentation (Karanovic and Karanovic 2017).

5.1.4. Crustacea: Copepoda: Cyclopoida:

Halicyclops cf. kieferi Karanovic, 2004

This species is large (refer Plate 4) and is clearly distinct from its small-sized congener. It was first described by Karanovic T. (2004) from several bores in the Murchison region, and has been commonly recorded in multiple locations since, often with another smaller congener in the same bore. There are parallels in niche partitioning by size class, similar to that of diving beetles in the Yilgarn region (Watts and Humphreys 2006). To be sure that these specimens from Lake Mackay are indeed *H. kieferi* comparative morphology and possible DNA would have to be studied in detail. Other molecular work on this genus (from other regions of WA) suggest that in most cases we are dealing with cryptic species in separate large calcretes (Karanovic and Karanovic 2017).

Halicyclops mackay n. sp.

This species is small (refer Plate 4) and very similar to *H. eberhardi* De Laurentiis, Pesce & Humphreys, 2001, which was also redescribed from several bores in the Murchison region by Karanovic T. (2004). This new species differs mostly by longer (more slender) caudal rami and larger lateral wings on the genital double somite (Karanovic and Karanovic 2017).

Plate 4 Dorsal view of two adult females of *Halicyclops mackay* n. sp. on the left and two adult females of *Halicyclops cf. kieferi* Karanovic, 2004 on the right. Note the pronounced size differentiation. Image by T. Karanovic. Scale bar approximately 350 µm.

Mackaycyclops mouldsi n. g. & sp.

This cyclopoid is extremely primitive and unlike modern species. It has a unique segmentation of the swimming legs (2/2, 2/2, 3/2, 3/3) and completely reduced outer principal seta on the caudal rami. Other characters include: antennule 11-segmented; antenna without exopod; fifth leg 2-segmented, inner apical element in between genera *Diacyclops* and *Thermocyclops* in size, but a seta is present instead of a spine; genital somite with pronounced lateral corners (as in *Acanthocyclops vernalis*). This species represents an important discovery for Australian copepoda (Karanovic and Karanovic 2017).

5.1.5. Crustacea: Copepoda: Harpacticoida:

Mackaynitocrella mouldsi n. g. & sp.

This new genus of ameirid harpacticoid is somewhat similar to the genus *Nitocrella* (which has several unusual representatives in Australia), but with important differences in the armature of the swimming legs (Exp3P1 and Exp3P2 with 3 outer elements). The most important morphological characters are the P1-P4 armature formula (exp/enp) 0.1.023/1.0.3, 0.1.123/1.2, 0.1.122/1.3, 0.1.222/1.3; Enp1P1 reaching midlength of Exp3P1; ExpA2 with 3 setae; Fu short; female fifth leg similar to *Nitocrella trajani* but with longer setae; no additional rows of spinules on anal somite; male fifth leg with 4 setae on exopod and only 1 on endopodal lobe.

Parapsuedoleptomesochra mackay n. sp.

Several species of this genus have already been described from the Murchison region (Karanovic T. 2004) and several more have been discovered but remain unpublished. This one differs from them all in a unique armature formula of EnpP2-P4. It is relatively similar to *P. rouchi*, but, in addition to different armature formula, it has only one row of spinules on the anal somite (Karanovic and Karanovic 2017).

Schizopera mackay n. sp.

This harpacticoid is another extremely primitive species from the Lake Mackay area. The genus is very common in arid Western Australia, with most diversity in the Murchison region (Karanovic T. 2004; Karanovic and Cooper 2012) but a few species also in the Pilbara (Karanovic 2006; Karanovic & McRae 2013). This new species differs from them all in having extremely long caudal rami (maybe twice as long as in *S. jundeei*) and the outer principal seta are reduced to a minute hair (smaller than inner principal seta). It is unusual to find a character reduced in the same way in two completely unrelated copepods in the same habitat (refer to *Mackaycyclops mouldsi*), and this could plausibly be some kind of convergent adaptation for this specific habitat (Karanovic and Karanovic 2017), although it is very unusual morphologically.

5.1.6. Insecta: Coleoptera

Dytiscidae: *Paroster* sp. 'mackay'

The diving beetle genus *Paroster* currently contains 43 species known to occur in Australia, with the majority being stygobiont species from calcrete aquifers in Western Australia (Leys *et al*. 2003, Watts and Humphreys 2006, 2009, Watts and Leys 2005). Every stygobiont species of *Paroster* known are endemic to individual calcrete aquifers in the Ngalia Basin and Yilgarn Craton (Watts and Humphreys 2006, 2009, Humphreys 2008). This species is currently only known from a single bore (Nr LP008) and is considered an endemic species (Plate 5).

Plate 5 Dorsal view of Dytiscidae: *Paroster* sp. '*mackay*' from bore Nr LP008. Scale approximately 1mm.

5.2 Troglofauna Assessment

No troglofauna sampling was able to be undertaken due to a lack of suitable (uncased) bores, however, the desktop assessment has identified suitable habitat in the form of unsaturated calcrete. This habitat should be sampled for troglofauna as part of a Level 1 pilot survey when suitable bores are located or drilled. Troglofauna may be impacted by borefield development through drawdown reducing available habitat with a saturated humidity upon which troglofauna rely.

5.3 Potential Impacts to Subterranean Fauna

The potential impacts of the resource development, installation of borefields 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 excavation voids such as for trenching and adjacent terrain, including associated aquifer dewatering. 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 trenches 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);
- Dewatering that removes support and leads to physical damage to karstic geology types from the slumping of strata in calcrete aquifers (Humphreys 1999).
- 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.
- Risk of species extinction from reduction and/or fragmentation in habitat.

6. Conclusions and Recommendations

The desktop assessment for subterranean fauna identified suitable habitat in the form of a large continuous calcrete unit on the southern side of Lake Mackay. There is also the potential for subterranean fauna to occur in the smaller calcrete outcrops located on the islands within Lake Mackay, however, the extent of this habitat is unknown without additional subsurface information (such as from drilling, augering or test pits).

The pilot survey for subterranean fauna at the Lake Mackay SOP Project was undertaken in May 2017. No troglofauna sampling was able to be undertaken due to a lack of suitable (uncased) bores, however, the desktop assessment has identified suitable habitat in the form of unsaturated calcrete. Five stygofauna samples were obtained from the surficial calcrete aquifer to the south of Lake Mackay. Stygofauna was identified in two of the five samples (Camp Bore and Nr LP008) with 10 species present.

The stygofauna collected has been identified to the lowest practical taxonomic level, with eight new species, and two new genera recorded. These results are not entirely unexpected due to the location of the sampling being many hundreds of kilometres from any other subterranean fauna sampling locations. The stygofauna recorded in the calcrete to the south of Lake Mackay is significant in that it contains a new species of dytiscid diving beetle (*Paroster* sp. '*mackay'),* a new species of parabathynellid (*Atopobathynella* sp. '*mackay'*), and multiple new species of Copepoda, some of which show extremely primitive morphological characters (*Mackaycyclops mouldsi* n. g. & sp. and *Schizopera mackay* n. sp.) and may be important in the evolutionary history of Australian stygofauna. Currently most of these new species are known from single bores, although this is invariably due to the lack of suitable sampling locations within the extensive calcrete located to the south of Lake Mackay.

6.1 Recommendations

The following recommendations are made with regard to the development of the Lake Mackay SOP Project:

- Due to the presence of a stygofaunal community within the proposed borefield area, a Level 2 survey for stygofauna should be undertaken with regard to EPA Technical Guidance – Subterranean Fauna Survey (EPA2016a) and EPA Technical Guidance – Sampling Methods for Subterranean Fauna (EPA2016b);
- The Level 2 survey for stygofauna will require, at a minimum, 40 samples from each aquifer within the proposed impact area (EPA2016b);
- A troglofauna pilot survey should be undertaken in the proposed borefield area once suitable bores are available for sampling. In order to meet EPA Guidance (2016a), a minimum of 10 – 15 bores will need to be sampled;
- A stygofauna pilot survey should be undertaken in any available holes augered on the islands within Lake Mackay; and
- Newly constructed bores should be suitable for stygofauna and/or troglofauna sampling.

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Appendix 1

Department of Parks and Wildlife Conservation Codes (November 2015)

Department of Parks and Wildlife

CONSERVATION CODES

For Western Australian Flora and Fauna

Specially protected fauna or flora are species* which have been adequately searched for and are deemed to be, in the wild, either rare, at risk of extinction, or otherwise in need of special protection, and have been gazetted as such.

Categories of specially protected fauna and flora are:

T **Threatened species**

Published as Specially Protected under the *Wildlife Conservation Act 1950,* and listed under Schedules 1 to 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).

Threatened fauna is that subset of 'Specially Protected Fauna' declared to be 'likely to become extinct' pursuant to section 14(4) of the Wildlife Conservation Act.

Threatened flora is flora that has been declared to be 'likely to become extinct or is rare, or otherwise in need of special protection', pursuant to section 23F(2) of the Wildlife Conservation Act.

The assessment of the conservation status of these species is based on their national extent and ranked according to their level of threat using IUCN Red List categories and criteria as detailed below.

CR **Critically endangered species**

Threatened species considered to be facing an extremely high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

EN **Endangered species**

Threatened species considered to be facing a very high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

VU **Vulnerable species**

Threatened species considered to be facing a high risk of extinction in the wild. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna and Wildlife Conservation (Rare Flora) Notice for Threatened Flora.

EX **Presumed extinct species**

Species which have been adequately searched for and there is no reasonable doubt that the last individual has died. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora.

IA **Migratory birds protected under an international agreement**

Birds that are subject to an agreement between the government of Australia and the governments of Japan (JAMBA), China (CAMBA) and The Republic of Korea (ROKAMBA), and the Bonn Convention, relating to the protection of migratory birds. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 5 of the Wildlife Conservation (Specially Protected Fauna) Notice.

CD Conservation dependent fauna

Fauna of special conservation need being species dependent on ongoing conservation intervention to prevent it becoming eligible for listing as threatened. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 6 of the Wildlife Conservation (Specially Protected Fauna) Notice.

OS Other specially protected fauna

Fauna otherwise in need of special protection to ensure their conservation. Published as Specially Protected under the *Wildlife Conservation Act 1950,* in Schedule 7 of the Wildlife Conservation (Specially Protected Fauna) Notice.

P Priority species

Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna.

Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations.

1 Priority 1: Poorly-known species

Species that are known from one or a few locations (generally five or less) which are potentially at risk. All occurrences are either: very small; or on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, road and rail reserves, gravel reserves and active mineral leases; or otherwise under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes. Such species are in urgent need of further survey.

2 Priority 2: Poorly-known species

Species that are known from one or a few locations (generally five or less), some of which are on lands managed primarily for nature conservation, e.g. national parks, conservation parks, nature reserves and other lands with secure tenure being managed for conservation. Species may be included if they are comparatively well known from one or more locations but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes. Such species are in urgent need of further survey.

3 Priority 3: Poorly-known species

Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread locations with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several locations but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further survey.

4 Priority 4: Rare, Near Threatened and other species in need of monitoring

(a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.
(b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for Vulnerable, but are not listed as Conservation Dependent.
(c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

*Species includes all taxa (plural of taxon - a classificatory group of any taxonomic rank, e.g. a family, genus, species or any infraspecific category i.e. subspecies or variety, or a distinct population).