HASTINGS
Technology Metals Limited

APPENDIX 3-1

Subterranean Fauna Assessment

Yangibana Project Biological Assessment: Subterranean Fauna

Hastings Technology Metals Limited

ecoscape

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF MAPS

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ACRONYMS AND ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS	
BAM Act 2007	Western Australian *Biosecurity and Agriculture Management Act 2007*
BoM	Bureau of Meteorology
C1, C2, C3	Declared Pest categories under the *BAM Act 2007*
CALM	Department of Conservation and Land Management (prior to becoming DEC)
DEC	Department of Environment and Conservation (now, in part, DPaW)
DPaW	Western Australian Department of Parks and Wildlife
DEE	Commonwealth Department of the Environment and Energy
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (now DEE)
Ecoscape	Ecoscape (Australia) Pty Ltd
EP Act 1986	Western Australian *Environmental Protection Act 1986*
EPA	Western Australian Environmental Protection Authority
EPBC Act 1999	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GDA 94	Geographic Datum of Australia 1994
GDE	Groundwater Dependent Ecosystem
GWA	Government of Western Australia
IBRA	Interim Biogeographic Regionalisation for Australia
OEPA	Office of the Environmental Protection Authority
PEC	Priority Ecological Community
PF	Priority-listed Flora, Priority Flora
P1, P2, P3, P4, P5	Priority Flora species rankings
SoW	Scope of Works
sp.	Species (generally referring to an unidentified taxon or when a phrase name has been applied)
TEC	Threatened Ecological Community
TF	Threatened Flora (formerly termed Declared Rare Flora, DRF, in Western Australia)
WAOL	Western Australian Organism List
WC Act 1950	Western Australian *Wildlife Conservation Act 1950*

EXECUTIVE SUMMARY

Hastings Technology Metals Limited (Hastings) is currently progressing its Yangibana Rare Earths Project (the Project) located in the Upper Gascoyne Region of Western Australia.

Ecoscape was commissioned by Hastings to conduct the biological assessments for the Project. This report details the results of the subterranean fauna (stygofauna and troglofauna) assessment. Very little subterranean fauna assessment and survey has previously been undertaken in the Project area and surrounding region (areas within 150 km with comparable habitats). Database searches were compiled and include five species of subterranean fauna of conservation concern from the Pilbara region (three records) and the Gascoyne region (two records), and found that the Project area intersected with a portion of the northern section of the Priority 1 Gifford Creek Calcrete Priority Ecological Community.

Two phases of stygofauna sampling were completed, post wet season (May 2015) and during the dry season (September 2015). Troglofauna sampling was undertaken over two phases, with the first phase completed four weeks after the wet season (between 16 May and 15 July 2015). The second phase was undertaken in spring between 26 September and 25 November 2015.

Thirteen drill holes were sampled for stygofauna during phase 1 and a total of 18 drill holes during phase 2. Of these, eight drill holes were sampled during both phases. Water chemistry measurements were taken from all sampled drill holes.

A total of 34 drill holes were sampled for troglofauna, of which 11 were sampled during both phases of surveying. This resulted in 43 traps being installed. Of this, 18 traps were set-up during the wet season survey (phase 1) and an additional 25 traps were installed during the dry season (phase 2). In addition to trapping, troglofauna scraping was undertaken at 32 drill holes.

In this survey, stygofauna were collected from four locations in the mineral exploration area (Lions' Ear, Yangibana North, Hook, and Kane's Gossan) and one location outside the potential impact area (Andy's Bore). In total, 236 stygofauna specimens from four families representing ten species were recorded from eight drill holes in the Project area. Of these, three taxa are likely to be of conservation concern. This is primarily based on the species represented not being previously recorded, or from the genus being known to include species with a limited distribution.

In addition, 11 troglofauna specimens from five orders representing at least five separate species were recorded from six drill holes (Fraser's, Kane's Gossan and Bald Hill deposit) in the Yangibana study area. At least five of these species are of conservation concern with the sixth species consisting of a specimen in very poor condition. For this reason, the identity, characteristic features and conservation status species cannot be determined.

Suitable conditions for the subterranean fauna were recorded from a number of areas. The project lies within the boundaries of the northern portion of the Gifford Creek Calcrete Priority Ecological Community (PEC). However, the proposed deposits cover a total of 101.52 hectares (Ha) of the mapped PEC, which equates to only 0.034% of the total PEC area. It is proposed to mine only four of the deposits sampled (Yangibana North, Yangibana West, Fraser's and Bald Hill).

Habitat analysis indicated that there is no obvious link between the calcrete habitats of the PEC and the occurrence of subterranean fauna in the Project area. The drill logs from mineral exploration activities and geological datasets have shown that calcrete is not present within the mineral exploration areas of the Project, indicating that subterranean fauna habitat is not typical of that recorded from PEC calcrete areas, although it may overlap and be representative of that on the fringes of the Gifford Creek PEC.

The geological unit of economic interest to Hastings comprises a series of ferro-carbonatite, phoscorite, magnetite and quartz veins that have intruded the heavily structured granite, gabbro and meta-sedimentary

host sequences. Rare earths mineralisation is predominantly hosted by the mineral monazite that occurs within the ferro-carbonatite and phoscorite veins.

The structures that host the mineralised veins are associated with the west-northwest trending Lyons River Fault and the parallel Bald Hill Lineament. Veins of varying width occur both sub-parallel and perpendicular to these structures. Mineralisation quantity and grade does not appear to relate to the host lithology, being structurally controlled.

Exploration drill holes to test the mineralisation are collared in the hangingwall to the mineralisation, whether granite (between Yangibana West and Kane's Gossan), gabbro (Bald Hill South) or meta-sediments (Fraser's), then pass through the mineralisation into footwall units, again whether granite, gabbro or metasediments.

Stygofauna were found in drill holes at Yangibana North, Lion's Ear, Hook and Kane's Gossan. Each of these prospects is hosted by granite and the stygofauna occur in both the hangingwall and footwall granites. Troglofauna have been found at Bald Hill and Fraser's deposits that are hosted by gabbro and meta-sediments respectively. The troglofauna species found did not show a preference to a specific geological unit.

Sampling from a water bore (Andy's Bore), away from the area of interest, tested calcrete near Fraser's Creek and returned a range of stygofauna species.

The effect of mining activities on stygofauna is expected to occur through pit dewatering. Abstracting groundwater will directly impact stygofauna, in particular through temporary habitat loss. However, the overall diversity of stygofauna within the broader PEC is unlikely to be impacted due to the limited extent of the open pits and associated drawdowns. The area of direct and indirect impact is expected to be smaller than the typical range of stygofauna species of conservation concern (<1,000,000 Ha) because the species recorded from the study area are likely to extend well beyond the impact area of the Project.

The impacts of the development on troglofauna are mostly direct as troglofauna and associated habitat is proposed to be removed through mine pit excavation. While new species were discovered within the mineral exploration areas, the habitat was not confined to one geological unit. Therefore, it is likely that they occur over a much broader area. Little information is available on indirect impacts on troglofauna habitats.

1.0 INTRODUCTION

1.1 PROJECT OVERVIEW

Hastings Technology Metals Limited (Hastings) is proposing to develop the Yangibana Rare Earths Project (Yangibana project) in the Upper Gascoyne Region of Western Australia. The rare earths deposits in the Yangibana project area contain a predominance of Neodymium, Praseodymium, Dysprosium and Europium, which are used in many advancing technologies such as electric vehicles, wind turbines, robotics and digital devices.

Ecoscape was commissioned by Hastings to conduct the biological assessments of the Yangibana project. This report details the results of the subterranean fauna (i.e. stygofauna and troglofauna) assessment.

1.1.1 STUDY AREA LOCATION

The Project area **(Figure 1)** is located within the Wanna Station pastoral lease in the Upper Gascoyne Region; approximately 270 km north east of Carnarvon and 170 km south west of Paraburdoo. Hastings has established a significant tenement package covering approximately 650 km^2. The Yangibana project consists of four major deposits, namely Yangibana West, Yangibana North, Bald Hill and Fraser's although sampling was undertaken across all locations of the mineral exploration areas, which included additional deposits.

1.2 SURVEY OBJECTIVES

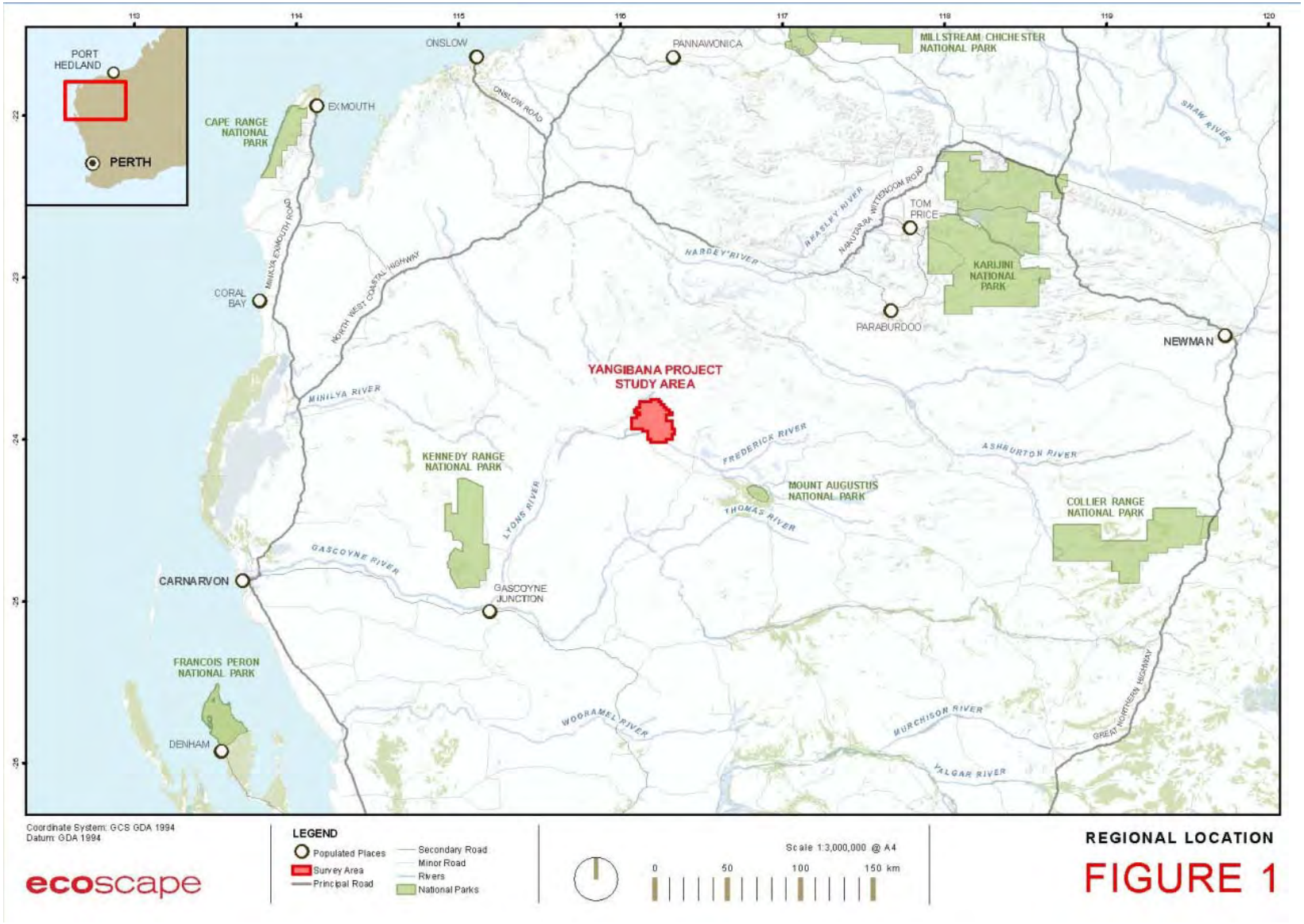
The subterranean fauna assessment was conducted to:

- Meet requirements of the Environmental Protection Authority (EPA) L1 low intensity sampling and a subsequent L2 high intensity sampling;
- Provide sufficient information to allow for an assessment of potential impacts;
- Follow *Technical Appendix to Guidance Statement No. 54a – Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (EPA 2007);
- Follow *Environmental Assessment Guideline for Consideration of subterranean fauna in environmental impact assessment in Western Australia* (EPA 2013); and
- Follow *Position Statement No.* 3 – *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002).

The assessment consisted of:

- Desktop assessment identifying the physical and biological attributes of the study area;
- Level 1 low intensity sampling, resulting in an understanding of the presence or absence of subterranean fauna, and their representation over a broader area; and
- Report including figures and maps showing the hydrogeology, land systems, sample locations, and findings and outcomes from the assessment.

Figure 1: Yangibana Project Study Area



1.3 LEGISLATION AND POLICIES

This assessment was conducted in accordance with the following Commonwealth and State legislation and guidelines:

- Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (1999);
- Western Australian *Environmental Protection (EP) Act 1986* (1986);
- Western Australian *Wildlife Conservation (WC) Act 1950* (1950); and
- Department of Environment Water Heritage and the Arts (2009) *Matters of National Environmental Significance. Significant impact guidelines 1.1 - Environment Protection and Biodiversity Conservation Act 1999*.

In addition to those listed above, the assessment complied with the Office of the Environmental Protection Authority (OEPA) requirements for environmental survey and reporting in Western Australia, as outlined in:

- EPA (2013) *Environmental Assessment Guideline (EAG 12) for Consideration of subterranean fauna in environmental impact assessment in Western Australia*;
- EPA (2002) *Terrestrial Biological Surveys as an Element of Biodiversity Protection Position Statement No.* 3;
- EPA (2008) *Guidance Statement No. 33: Environmental Guidance for Planning and Development*; and
- EPA (2003) *Guidance Statement No. 55: Implementing Best Practice in Proposals Submitted to the Environmental Impact Assessment Process.*

1.4 PREVIOUS SURVEYS

The study area was subject to a reconnaissance survey in November 2014 by *ecologia* Environment (Ecologia 2014). During this reconnaissance survey, terrestrial habitats and potentially suitable subterranean fauna habitat were recorded.

Subterranean fauna surveys and assessments for the Yangibana project area are limited, (within an acceptable distance i.e. approximately 150 km). A literature survey on stygofauna across Western Australia was undertaken to gather background information on impacts relating to the study area:

- Guzik *et* al. (2010): Is the Australian subterranean fauna uniquely diverse?
- Humphrey (2001): Groundwater calcrete aquifers in the Australian arid zone: the context to an unfolding plethora of stygal biodiversity.
- Ecologia (2014): Terrestrial and Subterranean Desktop Fauna assessment of the Millipede Tenements.

In addition to previous surveys, database searches were undertaken to determine the fauna species that could potentially occur within the study area, with particular emphasis on subterranean fauna of conservation concern. Database results for subterranean fauna consisted of five taxa of conservation concern recorded from the Pilbara (three records) and the Gascoyne region (two records). These findings will be taken into consideration when assessing the conservation status of the recorded species from site.

Table 1: Western Australian Museum Database Search Results

Higher taxa	Species	Location
Copepoda		
Cyclopoidae	*Diacyclops humphreysi*	Ratty Springs Bore (Pilbara)
Diplostraca		
Limnadiidae	*Limnadopsis pilbarensis*	Pirraburda Creek (near Paraburdoo)
Isopoda		
Tainisopidae	*Pygolabis gascoyne*	Stonetank Well Bore, Wanna Station
Podocopida		
Candonidae	*Deminutiocandona aporia*	Turee Creek Bore Field
	Bennelongia bidgelangensis	Bidgelang Pool, Callytharra Springs Station

1.5 CALCRETE AQUIFERS AND STYGOFAUNA

In 2001, Humphreys (2001) published a paper describing a hypothesis on the development of groundwater calcrete aquifers in the Australian arid zone and how this could lead to the isolation of stygofauna communities and the subsequent speciation across these communities thus resulting in high levels of biodiversity. The hypothesis is based on the idea that as salinity moves upstream along palaeodrainage systems, stygofauna become isolated in the upper tributaries (Humphreys 2001). This hypothesis also includes the addition of repeated hydro-chemical cycles along each palaeochannel, which result in several hypersaline groundwater/calcrete discontinuities, which in turn act as barriers to dispersal for stygofauna.

Humphreys (2001) identified hundreds of calcrete aquifers across the arid zone of Western Australia that potentially contain unique stygofauna communities. Sampling of 12 sites on the Western Shield confirmed that unique stygofauna communities are linked with these aquifers.

The Department of Parks and Wildlife (DPaW) have allocated 78 calcrete groundwater assemblages Priority Ecological Community (PEC) status. These are listed in **Table 14** in **Appendix Two** and shown in **Map 1**.

1.6 GEOLOGY AND TROGLOFAUNA

The geology within the Yangibana project is relatively simple, being dominated by a series of granitic intrusives into older gabbro and meta-sedimentary units. These basement rocks have been heavily structured with the major, regional, west-northwest trending Lyons River Fault defining its southern edge. The parallel Bald Hill Lineament appears to be a splay from the Lyons River Fault and the heavily fractured units have been the focus for later rare earths-bearing intrusives comprising ferro-carbonatites, phoscorites, magnetite and quartz.

The ferro-carbonatites, known informally as ironstones, and phoscorite are the host of the target mineralisation and these occur throughout the Project area. The ironstone is generally porous and permeable with numerous voids therefore providing suitable conditions for troglofauna. The ironstone is constrained by granite which is less porous but heavily faulted and fractured. For this reason, the water table is strongly constrained to the ironstone by the less permeable granite country rock.

Troglofauna are generally found in geological layers that provide air-filled pockets and cavities that provide dark and humid conditions (Subterranean Ecology 2010). Cavities are also required to be connected with other air-filled pockets, building a network of cells, to fulfil the criteria for suitable troglofauna habitats. The presence of permanent groundwater ensures that humidity levels are high enough for the requirements of troglofauna survival. Soil-filled cavities or isolated cavities are not considered suitable. Porous geological layers which enhance the circulation of water, air and nutrients allow troglofauna movement.

2 EXISTING ENVIRONMENT

The following sections outline the results of the desktop assessment.

2.1 PHYSICAL ENVIRONMENT

2.1.1 CLIMATE

According to the Köppen-Geiger climate classification, the study area is located in the BWh climate zone (Peel *et al*. 2007), considered to be dry (arid and semiarid) climates, desert with an average annual temperature above 18°C.

The study area is within an area impacted by a number of different climate influences including the west coast trough, northwest cloudbanks, tropical cyclones, frontal systems and subtropical ridge (Bureau of Meteorology [BoM] 2010).

The west coast trough is a semi-permanent feature that is the dominant influence on weather conditions during the warmer months in the southwest of Western Australia. It is a zone of low pressure that develops at the boundary between the warm continental easterly winds driven by the sub-tropical ridge to the south and cooler maritime air from the Indian Ocean. The development of the trough depends on the prevailing conditions. In general, areas to the east of the trough experience hot days in excess of 40°C, with occasional thunderstorms accompanied by periodic heavy rainfall. Areas to the west of the trough experience milder conditions (*ibid*.).

The northwest cloudbanks are also active during the warmer months and are formed when warm, moist tropical air originating over the Indian Ocean moves south-eastward, and is forced to rise over the colder mid-latitude air. Widespread heavy rain is sometimes associated with the northwest cloudbanks (*ibid*.).

The study area is located in an area that may also be affected by tropical cyclones. The cyclone season is officially from November to April although there tends to be fewer cyclones early in the season. Destructive winds and high rainfall can be associated with tropical cyclones (*ibid*.).

Frontal systems can also impact on the study area. Cold fronts, most frequently in winter, can also bring rainfall, at times for extended periods of up to a week. The subtropical ridge suppresses frontal activity during the warmer months when it is located to the south of the continent; in the winter the ridge moves over central Australia, permitting cold fronts to extend further northwards (*ibid*.).

Given the number of climate influences that may be active and affecting the study area, it is unsurprising that the rainfall is erratic and bimodal (i.e. occurring in both winter and summer) (Desmond *et al*. 2001; Kendrick 2002).

BoM rainfall zone mapping places the study area in the Arid low rainfall (less than 350 mm) zone and Warm humid summer climate zone based on temperature and humidity (BoM 2012).

Rainfall and temperature data for the nearest BoM station with long-term rainfall data (Mt Phillip, active from 1902 (BoM 2015), approximately 70 km south of the study area; data accessed on 4 March 2015) is shown in **Figure 2**. **Figure 2** shows the bimodal nature of the rainfall, with two periods of higher rainfall; January to March and May-July, the latter corresponding with the southern (frontal) influences.

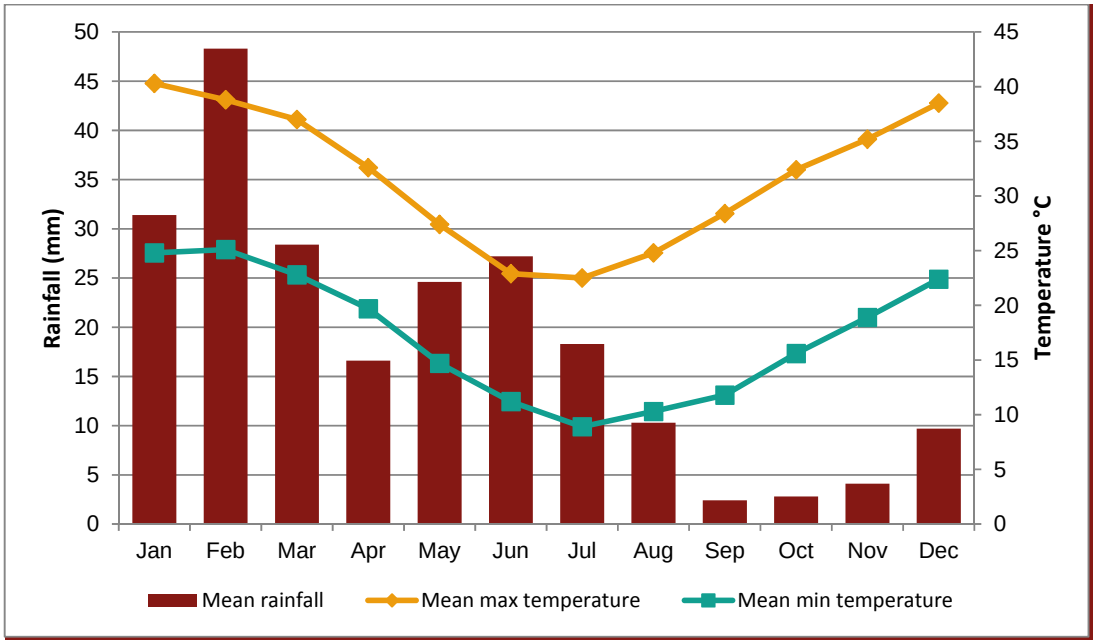


Figure 2: Monthly Rainfall, Daily Maxima and Minima for Mt Phillip (BoM 2015)

2.1.2 LAND SYSTEMS

The Pastoral Board of Western Australia commissioned the first joint Department of Land Administration-Agriculture Western Australia rangeland survey of the Gascoyne River catchment in 1969. The rangeland resource surveys, comprehensively described and mapped the biophysical resources of the Gascoyne River catchment, together with an evaluation of the condition of the soils and vegetation (from an agricultural perspective) (Wilcox & McKinnon 1972).

As part of this process an inventory of land systems and land units with particular use capabilities were established to assist in land use planning. According to this mapping, 10 land systems (grouped according to land type on the basis of a combination of landform, soil, vegetation, and drainage characteristics) intersect with the study area (Wilcox & McKinnon 1972).

The land systems are described in **Table 2** and their extents within the study area and Gascoyne bioregion is shown in **Table 3** and on **Map 2**.

Table 2: Land system descriptions (Wilcox & McKinnon 1972)

Land system	Description
Agamemnon System	Rocky hills, with peaks and ridges above extensive stony slopes, supporting scattered tall shrublands of mulga and other acacias
Augustus System	Rugged ranges, hills, ridges and plateaux with skeletal soils supporting mulga and other acacia shrublands in southern parts or hard spinifex grasslands in northern parts
Collier System	Undulating stony uplands, low hills, ridges, stony plains and drainage floors supporting mulga shrublands and some spinifex
Gascoyne System	River channels and associated narrow alluvial plains and inclusions, supporting river redgum fringing woodlands, also mulga and other acacias, *Senna* spp. And buffel grass
Glenburgh System	Rugged granite hills, stony uplands and lower plains supporting scattered tall shrublands of mulga and other acacias
James System	Low hills, ridges and tors of granite and quartz, with stony lower plains, rises and drainage floors, supporting scattered tall shrublands of mulga and other acacias

Land system	Description
Jamindie System	Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey
Nadarra System	Plains and calcrete rises with chenopod shrublands and hard spinifex grasslands
Phillips System	Low hills and undulating uplands on gneiss and quartz supporting mulga and other acacia tall shrublands
Yinnietharra System	Scattered granite tors and domes above stony slopes, broad sandy plains with groved vegetation and wide drainage tracts; supporting tall shrublands of mulga and other acacias

Table 3: Extent of land systems within the study area and region (Wilcox & McKinnon 1972)

Land system	Extent within study area (km^2)	Proportion of study area (%)	Gascoyne extent (km^2)	Representation within the study area (%)
Agamemnon System	31.23	5.8	4304.58	0.73
Augustus System	6.77	1.3	19190.25	0.04
Collier System	0.39	0.1	4822.86	0.01
Gascoyne System	17.84	3.3	2152.81	0.83
Glenburgh System	50.93	9.5	702.05	7.25
James System	167.32	31.2	2029.33	8.24
Jamindie System	33.88	6.3	9952.62	0.34
Nadarra System	95.04	17.7	1156.70	8.22
Phillips System	115.92	21.7	8082.93	1.43
Yinnietharra System	16.12	3.0	1413.37	1.14
TOTAL	**535.43**	**100.0**	**53807.50**	

1.1.1 GEOLOGY

Table 15 in **Appendix Three** lists the 56 geological units mapped within the study area with their extent inside the study area and within the region (Department of Mines and Petroleum 2002; 2007). The regional extent is based on mapsheets (1:100,000) Edmund (sheet 2150) and Mt Phillips (sheet 2149). **Map 3** shows the distribution of these geological units across the study area. The most common geological units, those with greater than 10% coverage of the study area, are:

- Pimbyana Granite (Plgpi) covering 12,037 Ha of the study area (22.5%);
- Sand and gravel with ferruginous cement (A3ti), deeply dissected by present-day drainage (14.9%); and
- Calcrete (Rk), developed in and adjacent to alluvial channels (11.6%).

2.1.3 DRAINAGE

The study area is located within the Gascoyne River catchment. A tributary of the Gascoyne River, the Lyons River is associated with the southern portion of the study area, and flows in a general north-western direction. The Edmund River, considered to represent a tributary of the Lyons River, is associated with the western edge of the study area and flows in a general southern direction. Both rivers are considered as ephemeral, and only flow after rainfall although permanent or semi-permanent waterholes are likely to occur along their length and along tributaries.

Several tributaries of these rivers traverse the study area; Yangibana and Fraser's Creeks are tributaries of the Lyons River, occupy the southern portion of the study area and flow in a generally southern direction, whilst Rock Hole and Dingo Creeks are tributaries of the Edmund River, flow in a general western direction and occur in the northern portion of the study area. There are also several unnamed tributaries within the study area.

Rivers and creeks of the study area are shown in **Map 1**.

2.2 BIOLOGICAL ENVIRONMENT

2.2.1 BIOGEOGRAPHICAL REGION

Biogeographic regions are delineated on the basis of similar climate, geology, landforms, vegetation and fauna and are defined in the Interim Biogeographical Regionalisation for Australia (IBRA) (Department of the Environment [DoE] 2014).

The study area is located within the Gascoyne IBRA region that consists of three major subregions; Ashburton, Augustus and Carnegie (Thackway & Cresswell 1995). The majority of the study area is included in the Augustus (GAS3) subregion, described in the 2002 Biodiversity Audit of Western Australia's 53 Biogeographical Subregions (Desmond *et al*. 2001) as:

> *Rugged low Proterozoic sedimentary and granite ranges divided by broad flat valleys. Also includes the Narryera Complex and Bryah Basin of the Proterozoic Capricorn Orogen (on northern margin of the Yilgarn Craton), as well as the Archaean Marymia and Sylvania Inliers. Although the Gascoyne River System provides the main drainage of this subregion, it is also the headwaters of the Ashburton and Fortescue Rivers. There are extensive areas of alluvial valley-fill deposits. Mulga woodland with* Triodia *occur on shallow stony loams on rises, while the shallow earthy loams over hardpan on the plains are covered by Mulga parkland. A desert climate with bimodal rainfall. The subregional area for GAS3 is 10,687,739 ha.*

There is a small section near the northern edge of the study area located within the Ashburton (GAS1) subregion, described by Kendrick (2002) as:

> *Mountainous range country divided by broad flat valleys, associated with Ashburton River Catchment of the Ashburton Basin (shales, sandstones and conglomerates), and the north-western part of Bangemall Basin (sandstone, shale, carbonates). Mulga/snakewood low woodlands occur on shallow earthy loams over hardpan on the plains, with mulga scrub and Eremophila shrublands on the shallow stony loams of the ranges. Low mixed shrublands on hills with other areas supporting large areas of* Triodia. *Arid (desert) climate with bimodal (winter and summer) rainfall, with tropical monsoon influences. The subregional area of GAS1 is 4,039, 387 ha.*

2.2.2 SUBTERRANEAN FAUNA

2.2.2.1 Previous Surveys

Aside from a terrestrial reconnaissance survey conducted in 2014 and the current terrestrial fauna Level 2 survey, there are no known subterranean fauna surveys conducted in the vicinity of the study area. Regional

information and assessment undertaken on subterranean fauna in the wider Yilgarn region and partially Pilbara region have been reviewed and are listed in **Section 1.4**.

2.2.3 VEGETATION

2.2.3.1 Vegetation Association Mapping

During the 1970s, John Beard and Associates conducted a systematic survey of native vegetation, describing the vegetation systems in Western Australia at a scale of 1:250 000 in the south-west and at a scale of 1:1 000 000 in less developed areas. The vegetation survey of Western Australia maps and explanatory memoirs (1974-1981) are credited to J.S. Beard (or Beard with various co-authors).

Beard's vegetation maps attempted to depict the native vegetation as it was presumed to be at the time of settlement, and is known as the pre-European vegetation type and extent and has since been developed in digital form by Shepherd *et al.* (2002), updated by DAFWA (2012).

The pre-European vegetation associations identified from the study area (DAFWA 2012) and their pre-European and current extents within the Gascoyne bioregion is shown in Table 4 (Government of Western Australia 2013). The pre-European vegetation is shown on Map 4.

Table 4: Vegetation Associations within the Gascoyne Bioregion (Gov. WA 2013)

Vegetation Association	Gascoyne Bioregion			Extent within Study Area	
	Pre-European Extent (Ha)	Current Extent (Ha)	% Remaining	Extent (Ha)	Proportion (%)
18 Low woodland; mulga (*Acacia aneura*)	3273579.71	3271339.12	99.93	21555.74	0.66%
165 Low woodland; mulga and snakewood (*Acacia eremaea*)	697447.83	697445.48	100.00	30841.06	4.42%
166 Low woodland; mulga & *Acacia victoriae*	309650.29	309645.58	100.00	286.69	0.09%
181 Shrublands; mulga & snakewood scrub	1632078.44	1631913.77	99.99	860.02	0.05%

2.2.3.2 Threatened and Priority Ecological Communities

TECs are categorised at both Commonwealth (Commonwealth of Australia 1999) and State (DEC 2010) level, whilst PECs are categorised at State level (DEC 2010). The definitions of Commonwealth and State categories are summarised in **Table 12** and **Table 13** respectively in **Appendix One**.

Review of DPaW TEC list (DPaW Species & Communities Branch 2014a) indicates that there are no TECs listed for the Gascoyne bioregion, nor are there any Commonwealth-listed TECs (DoE & Australian Government 2015).

There are 84 PECs known from the Midwest DPaW region (DPaW Species & Communities Branch 2014b).

2.2.3.3 DPaW Ecological Communities Database Search

A DPaW Ecological Communities database search (search reference 29-01114Ec) was conducted for the study area and a 50 km buffer in November 2014. This search identified the P1 'Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations' PEC partly intersects the Yangibana Project area. This PEC comprises potentially unique assemblages of invertebrates that have been identified in the groundwater calcretes (DPaW Species & Communities Branch 2014b). The PEC location is shown in **Map 10**.

2.2.3.4 Groundwater Dependent Ecosystems

Groundwater Definition

Groundwater is water that is found in the saturated zone of the soil, where all soil pores are filled with water. It occurs below the water table in an unconfined aquifer or may be held under pressure in a confined aquifer. Groundwater may also occur as a perched aquifer where it is located above unsaturated rock formations.

Kendrick (2002) states "There are no known centres of endemism with GAS1, however there is a strong possibility of troglofauna in calcrete deposits associated with the Lyons River."

3 METHODS

3.1 SAMPLING METHODS

3.1.1 STYGOFAUNA

Stygofauna sampling within the study area followed the recommendations of the EPA Environmental Assessment Guideline (EAG) 12 (EPA 2013). Each drill hole was sampled using a modified plankton net of appropriate diameter (50 – 100 mm) which was slowly lowered to the bottom of the drill hole. The net was then gently raised and lowered, in order to stir up the sediments. After this process, the net was left on the bottom for approximately two minutes to allow the sediment to settle. For the actual sampling process, the net was then hauled up through the water column at a rate of approximately 1 meter per second. All contents of the net were immediately emptied into a 50 µm Endicott sieve which then was washed into a vial using absolute ethanol in order to preserve DNA of any potential specimens. Each vial was labelled with the drill hole location and name, the date and the names of the collectors. The sampling was undertaken with two different sizes of mesh (150 µm and 50 µm) and each net was hauled three times per bore hole.

All stygofauna samples were taken back to Perth and then sorted and processed in collaboration with Bennelongia Environmental Consultants (Bennelongia).

3.1.2 WATER CHEMISTRY

In addition to sampling, a number of water quality measurements were collected using a Cyberscan PC300 and Oxygen Meter (Insite IG, Model 3100) during Phase 1 and a YSI ProPlus Multi-parameter Meter was used during Phase 2 of surveying. The following parameters were measured for each bore hole that was sampled:

- Depth of bore (m)
- Depth to ground water
- Temperature
- pH
- Conductivity (ms/cm)
- Total Dissolved Salts (TDS/ppK)
- Oxygen Reduction Potential (ORP/mV)
- Dissolved Oxygen (DO/ppM)
- Salinity (ppt).

3.1.3 TROGLOFAUNA

The results of the desktop survey and the reconnaissance survey indicate that habitat for troglofauna is likely to be present within the study area. A Level 2 comprehensive survey was therefore conducted to provide information about the occurrence of troglofauna present within the study area. Two phases of troglofauna sampling were undertaken of which the first phase took place four weeks after the wet season (between 16 May and 15 July 2015). The second phase was undertaken in spring from 26 September to 25 November 2015.

The sampling consisted of a trap deployment stage, an eight to nine-week colonisation period and finally a trap collection stage. Each troglofauna trap (**Figure 3**) was filled with damp sterilised leaf litter, which was previously soaked in water for seven days prior to trap installation. Anecdotal experience suggests that troglofauna can be encouraged to colonise the leaf litter within each trap with the addition of banana as bait (1 cm^3 each), which was utilised during the current survey. To sample a range of microhabitats, each drill hole contained one troglofauna trap, which was installed at varying depths of 10-25 m below the surface (above the water table).

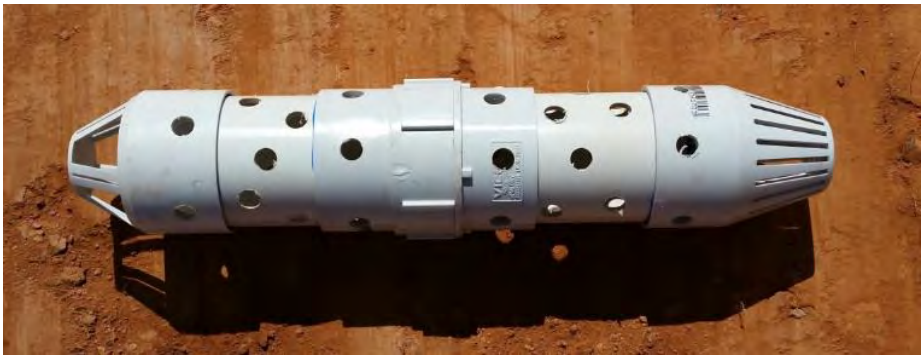


Figure 3: Troglofauna trap used during current assessment

In addition to trapping, troglofauna scraping was undertaken after trap retrieval. Troglofauna scraping is known to be highly successful in recording troglofauna species (Halse & Pearson 2014). This technique involves the use of a modified tube with netting. The scraping tube was lowered into the drill holes and slowly hauled back up to sample the outside of the drill hole. This was repeated three times and the content was then emptied into a vial. Each vial was then filled with 100% Ethanol for preservation.

3.2 SITE SELECTION

The results from the desktop and reconnaissance survey have shown that subterranean fauna has a potential to occur within the study area. Available information on geology and hydrology is inconclusive and the proposed impact area is partly unknown. Information about 161 boreholes was available and supplied to Ecoscape prior to surveying. Of these, a number of boreholes were part of the drilling program undertaken during the time of the survey so that sampling at those locations was not completed to avoid any impacts in the form of destruction of traps and high levels of vibrations.

During the first phase of surveying (wet season), stygofauna was sampled as part of a Level 1 subterranean survey as defined in the EPA Environmental Assessment Guideline (EAG) 12 (EPA 2013). This sampling involved a moderate number of samples, 13 drill holes, from across the proposed deposits to provide an overview of the presence of stygofauna at the Yangibana project (**Table 16**). More sampling was undertaken in the dry season during the second phase of surveying, taking samples from another 18 drill holes. Of these, eight drill holes were sampled during both phases. The stygofauna samples were spread across four geological units (Rk, C1f, Plgpi and Plgpix) of which the majority of samples were taken from boreholes within the geological unit PlgPi. Details and locations of all drill holes are listed in **Table 16** in **Appendix Four** and displayed in **Map 5**.

Water chemistry measurements were taken from all drill holes during phase 1 and from 18 of the drill holes sampled in phase 2 of surveying (**Table 17** in **Appendix Five**).

Troglofauna sampling was undertaken at a total of 34 drill holes, of which 11 were sampled during both phases of surveying. This resulted in 43 traps being installed at the Yangibana project. Of this, 18 traps were set-up during the wet season survey (phase 1) and an additional 25 traps were installed during the dry season (phase 2). In addition to trapping, troglofauna scraping was undertaken at 32 drill holes. Details and locations of all sampled drill holes are listed in **Table 18** in **Appendix Six** and shown in **Map 6.**

3.3 SURVEY TIMING

As subterranean environments are typically stable throughout the year, the temperature and humidity are also regulated by the depth of rocks and soils. Sampling is therefore possible throughout the majority of the year and spreading sampling across two seasons may be appropriate. A preferred season has not been identified in the Environmental Assessment Guidelines No. 12 (EPA 2013). Stygofauna sampling was undertaken post wet season (16-18 May 2015) and during dry season (25-30 September 2015). Troglofauna trapping was conducted between 16 May 2015 and 15 July 2015, which represents the beginning of the dry season, following the wet season and also during the dry season (prior to wet season) between 26

September and 24 November 2015. In addition to trapping, troglofauna scraping was conducted during each trapping program. Dates of each sampling method are listed in **Table 5.**

Table 5: Sampling dates for each method

Sampling type	Season	Dates
Stygofauna sampling	Wet season	23-26 May 2015
	Dry season	25-30 Sep2015
Troglofauna trapping	Wet season	16 May–15 Jul 2015
	Dry season	26 Sep-24 Nov 2015
Troglofauna scraping	Wet season	16-18 May 2015
	Dry season	25-30 Sep 2015

3.4 TAXONOMIC IDENTIFICATION

All stygofauna and troglofauna samples were sorted in Bennelongia' laboratory in Perth and separated into taxonomic groups. These were submitted to Bennelongia Environmental Consultants and identified by subterranean taxonomist Jane McRae.

3.5 SURVEY TEAM

The Ecoscape team members involved in the subterranean fauna assessment of the study area are listed in **Table 6.**

Table 6: Ecoscape staff utilised for this assessment

Name	Qualification	Expertise
Damien Cancilla	BSc. (Zool. Hons.)	Zoologist
Jared Nelson	BSc. (Agric., Hons.)	Ecologist
Astrid Heidrich	MSc. (Biol.)	Zoologist
Chris Parker	B.Aq.Sc, BSc	Ecologist
Jesse Forbes-Harper	BSc. (Zool. Hons.)	Zoologist

4 RESULTS

4.1 STYGOFAUNA

During the current survey, 236 stygofauna specimens from four families representing 10 species were recorded from eight drill holes in the Project area. Stygofauna were collected from four mineral exploration areas (Lions' Ear, Yangibana North, Hook, Kane's Gossan) each testing granitic terrain and one location outside the impact area (Andy's Bore) that tested calcrete. Details of all stygofauna records are listed in **Table 7** and their location shown in **Map 7**. The identification summaries below are taken from the identification report completed by Bennelongia (2016b), which is also presented in **Appendix Four**.

4.1.1 COPEPODA

Four species of Copepoda were collected in the current survey belonging to two families, *Cyclopidae* and *Ameiridae*.

Ameiridae gen. nov. sp. B04

Four specimens were collected from calcrete at Andy's Bore that represent a new genus based on taxonomic characteristics (**Figure 4**). It may be most closely related to *Archinitocrella* and *Nitocrellopsis*, in having a unique arrangement of the setae on exopodal segments P2-P4 (setation pattern 3/2/2 in the new genus; 2/2/2 in *Archinitocrella* and *Nitocrellopsis*).

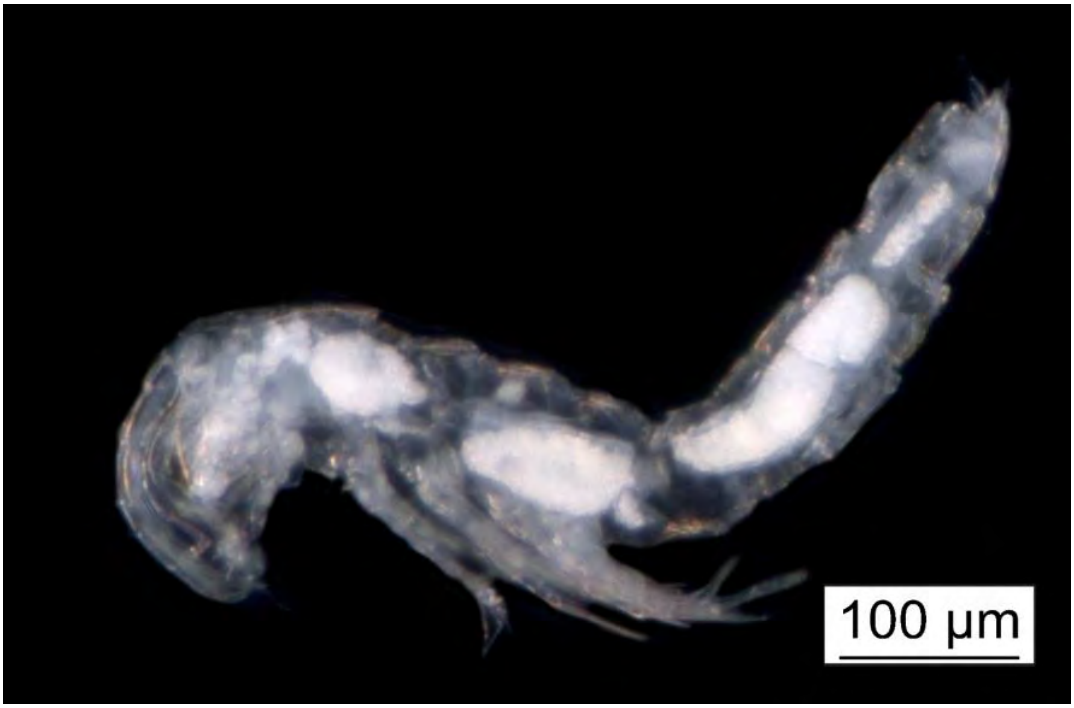


Figure 4: *Ameiridae* gen. nov. sp. B04

Taxonomic resolution in the Australian *Ameiridae* fauna is poor and species identification difficult. However, most species in this group from subterranean habitats have short ranges. *Ameiridae* gen. nov. sp. B04 is currently known only from Andy's Bore and a potential SRE with deficient data. It is of potential conservation concern.

Diacyclops cockingi

This species is wide ranging throughout the Pilbara and is not of conservation concern (**Figure 5**).

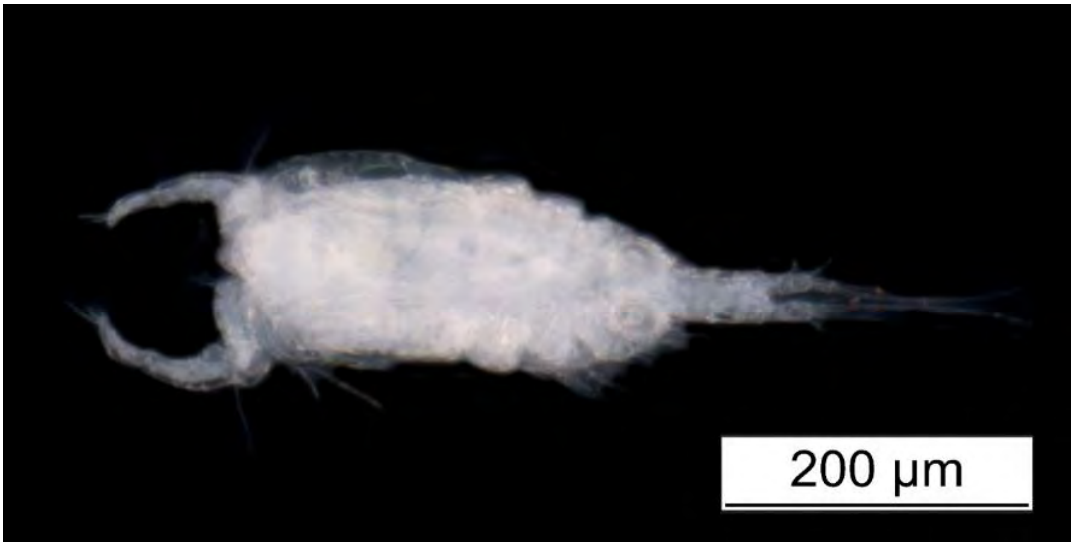


Figure 5: ***Diacyclops cockingi***

Diacyclops humphreysi humphreysi

This species is wide ranging throughout the Pilbara and is not of conservation concern.

Orbuscyclops westraliensis

This species is wide ranging throughout the Pilbara and is not of conservation concern.

4.1.2 OSTRACODA

A single species of Ostracoda was recorded in the survey belonging to the genera *Areacandona*.

Areacandona sp. BOS550

Ten specimens of this new species were collected from calcrete at Andy's Bore (**Figure 6**). This species is close to Are*acandona triangulorum* which has a small complex hemipenis with three distal lobes, but differs in that the furca has a much reduced posterior claw and setae. *Areacandona* species in the Pilbara can have very short ranges (Karanovic 2007) and *Areacandona* sp. BOS550 is a potential SRE based on previous research. It is presently known only from this record and likely to be of potential conservation concern.

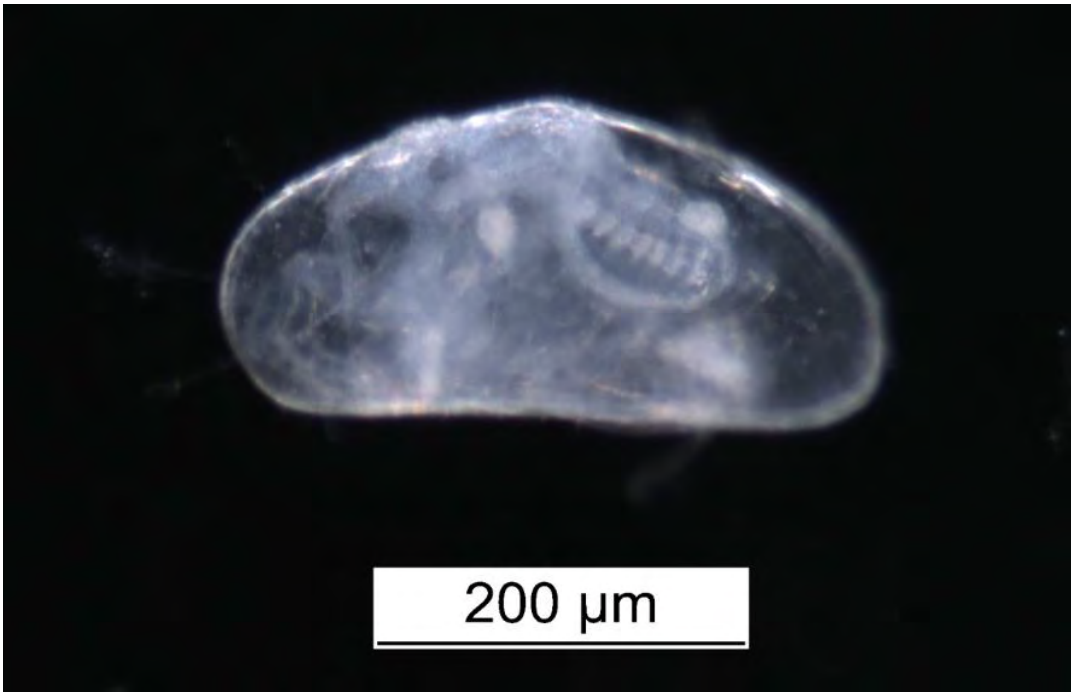


Figure 6: *Areacandona* sp. BOS550

4.1.3 AMPHIPODA

Amphipods are common in subterranean surveys of the Pilbara and Yilgarn regions of Western Australia, however taxonomic resolution is very poor and it is likely that there are many undescribed genera and many species will have restricted ranges. Only one taxa was recorded during the current survey with two unidentifiable juveniles linked to adult specimens recorded in close proximity.

Paramelitidae sp. B49

Nine adult specimens in the family *Paramelitidae* were collected from one drill hole (LERC010) at the Lion's Ear deposit (**Figure 7**). There is no taxonomic framework for *Paramelitidae* in Western Australia and species identification is difficult. However, many subterranean *Paramelitidae* in Australia have short ranges. Endemism in this fauna is pronounced and species are typically confined to single karst systems or calcretes (Eberhard *et al.* 2005). *Paramelitidae* sp. B49 is a potential SRE with deficient data and likely to be of potential conservation concern.

Figure 7: *Paramelitidae* sp. B49

Two juvenile *Paramelitidae* species were recorded from bore HKRC002 and could not be identified to species level. These animals are likely to be *Paramelitidae* sp. B49 as bore HKRC002 is in close proximity to bore LERC010 (**Map 7**).

4.1.4 OLIGOCHAETA

Oligochaetes are very common in environmental surveys in arid Australia. Taxonomic resolution is often poor in this fauna. At least three species of Oligochaeta were collected in this survey from two families, *Phreodrilidae* and *Enchytraeidae.*

Phreodrilus peniculus

Seven specimens were collected from two bores in this survey, four from HKRC002 and three from LERC010. This species is wide ranging throughout the Pilbara and is not of conservation concern.

Phreodrilidae with dissimilar ventral chaetae

Three specimens were collected from two bores in this survey, two from calcrete at Andy's Bore and one from LERC008. This is a grouping of several species of juvenile phreodrilids. It is conventionally treated, however, as a wide ranging species in the Pilbara and not of conservation concern.

Enchytraeus sp. 1 (PSS) Pilbara

Nineteen specimens were collected from two bores YGRC057 and HKRC002. This species is wide ranging throughout the Pilbara and is not of conservation concern.

4.1.5 NEMATODA

Nematodes are widespread and very common in environmental surveys in Australia. Almost nothing is known about free-living nematodes in WA outside agricultural situations. For this reasons, the status of nematodes is not assessed in environmental assessments.

Table 7: Stygofauna Recorded from the Project Area

Higher order (family)	Species id	Total No.	Deposit	Hole id	Coordinates		Depth sampled	Geological unit	Comments
					Eastings	Northings			
Copepoda									
Ameiridae	Ameiridae gen. nov. sp. B04	4	-	Andy's Bore	425888	7358719	10	Calcrete	Represents a new genus that has not been recorded elsewhere at this time
Cyclopidae	*Diacyclops cockingi*	20	-	Andy's Bore	425888	7358719	10	Calcrete	All three species have been recorded across the Pilbara and are not of conservation concern
		41	Lion's Ear	LERC008	419943	7360619	60	Pimbyana Granite	
		22	Lion's Ear	LERC010	419836	7360689	60	Pimbyana Granite	
		31	Yangibana North	YGRC063	417130	7362484	28	Pimbyana Granite	
		42	Hook	HKRC002	421721	7360502	50	Pimbyana Granite	
	Diacyclops sp. (partial *D. cocking*)	1	Hook	HKRC002	421721	7360502	50	Pimbyana Granite	
	Diacyclops humphreysi humphreysi	10	Kane's Gossan	KGRC017	425000	7358976	30	Pimbyana Granite	
	Orbuscyclops westaustraliensis	2	-	Andy's Bore	425888	7358719	10	Calcrete	
Ostracoda									
Candonidae	*Areacandona* sp. BOS550	10	-	Andy's Bore	425888	7358719	10	Pimbyana Granite	Similar morphology to *Areacandona triangulorum*. Presently only known from this record
Amphipoda									
Paramelitidae	Paramelitidae sp. B49	9	Lion's Ear	LERC010	419836	7360689	35	Pimbyana Granite	No taxonomic framework however many subterranean Paramelitidae spp. In Australia have short ranges and show high endemism
	Paramelitidae sp.	2	Hook	HKRC002	421721	7360502	50	Pimbyana Granite	Juvenile specimens that are likely to be Parameltidae sp. B49
Oligochaeta									
Enchytraeidae	*Enchytraeus* sp. 1 (PSS) Pilbara	4	Hook	HKRC002	421721	7360502	50	Pimbyana Granite	All species wide ranging and not of conservation concern
		15	Yangibana North	YGRC057	417189	7362389	22	Pimbyana Granite	
Phreodrilidae	Phreodrilidae with dissimilar ventral chaetae	2	-	Andy's Bore	425888	7358719	10	Calcrete	
		1	Lion's Ear	LERC008	419943	7360619	60	Pimbyana Granite	
	Phreodrilus peniculus	4	Hook	HKRC002	421721	7360502	50	Pimbyana Granite	

Higher order (family)	Species id	Total No.	Deposit	Hole id	Coordinates		Depth sampled	Geological unit	Comments
					Eastings	Northings			
		3	Lion's Ear	LERC010	419836	7360689	35	Pimbyana Granite	
Nematoda									
	Nematoda sp.	5	Gossan	GSRC009	418412	7361003	80	Pimbyana Granite	This taxa is not assessed in EIA
		6	Lion's Ear	LERC010	419836	7360689	35	Pimbyana Granite	
		2	Yangibana North	YGRC063	417130	7362484	28	Pimbyana Granite	

4.1.6 WATER CHEMISTRY

Water chemistry was measured at a total of 31 drill holes (13 holes during wet season and 18 holes during dry season) (**Table 17**). Water levels varied between 14 m and 34.8 m in the wet season (first phase) and 6.3 m and 32.7 m during the dry season (second phase), which shows no great variance between the seasons. The pH samples all resulted in values between 6.87 and 7.55, dominated by higher values (above 7.06) in the dry season. Conductivity varied a little more widely, in particular between the two seasons. Values of 3.2-5.94 ms/cm were recorded during the wet season whereas lower values of 0.72-2.84 ms/cm were measured in the dry season (**Table 17**). Temperatures were relatively consistent between the two seasons with 28.9°C to 32.1°C. The salinity was relatively stable with values between 0.7 and 2.95 ppt (parts per thousand). Values for the Total Dissolved Solids (TDS) and the Oxidation-Reduced Potential (ORP) were recorded from phase 2 only due to the different model of water quality meter used during phase 1 of the survey.

The water chemistry values for each drill hole are listed in **Table 17** in **Appendix Five**.

4.2 TROGLOFAUNA

4.2.1 SAMPLING

During the current survey, 11 troglofauna specimens from five orders representing at least five separate species were recorded from five drill holes in the Yangibana study area. The details of each record are summarised in **Table 8**, mapped and described in more detail in the below sections. The identification summaries below are taken from the identification report completed by Bennelongia (2016b) which is also presented in **Appendix Seven**.

4.2.2 ISOPODA

A single species of troglobitic isopod was recorded from the study area, which has been identified as *Troglarmadillo* sp. B60.

4.2.2.1 Armadillidae

***Troglarmadillo* sp. B60**

Three specimens of this species were recorded from one drill hole at Fraser's deposit (FFRC010) (**Figure 8**). There are no other known records of this genus from the vicinity of the study area and *Troglarmadillo* sp. B60 is most likely a new species. Troglobitis isopods in Western Australia are almost always restricted in range and local endemism in this group is very high. There is no taxonomic framework for *Troglarmadillo* and the three specimens were only recorded from one drill hole within the Yangibana project. The species is considered a potential SRE due to the deficiency of data, making it to be of potential conservation concern.

Figure 8: ***Troglarmadillo*** **sp. B60**

4.2.3 DIPLURA

4.2.3.1 Projapygidae

Projapygidae **sp. B19**

One specimen was collected from a drill hole at the Kane's Gossan deposit (KGRC007) (**Figure 9**). There are no other records of projapygids in the vicinity of the project and this is almost certainly a new species. Local endemism in the projapygid fauna is very high and almost all species have very short ranges in subterranean habitats. *Projapygidae* sp. B19 is classified as a potential SRE with deficient data according to the SRE framework of the Western Australian Museum. The species is likely to be of conservation concern.

Figure 9: ***Projapygidae*** **sp. B19**

4.2.4 INSECTA

4.2.4.1 Nicoletiidae

Trinemura sp. B29

Five specimens were collected from three locations at Bald Hill, Fraser's and Kane's Gossan prospects (FFRC010, KGRC007 and BHRC002), which are located within 10 km from each other (**Figure 10**). These specimens belong to an undescribed species and do not key out to any known species (Smith 1988). The genus *Trinemura* can be moderately widespread in subterranean habitats although ranges are almost always smaller than the threshold of SREs (10,000 km^2). *Trinemura* sp. B29 is a potential SRE with deficient data and of potential conservation concern.

Figure 10: *Trinemura* sp. B29

4.2.5 CHILOPODA

4.2.5.1 Geophilidae

Geophilida centipedes are thought to have comparatively restricted ranges, although in reality so little is known about the ranges of troglofaunal centipedes that this is an unreliable generalisation.

***Geophilidae* sp.**

One specimen was collected from a drill hole at the Kane's Gossan deposit (KGRC011) but was in such poor condition when preserved that identification beyond order was not possible. It is not possible to assess this specimen or its conservation status further.

4.2.6 MYRIAPODA

4.2.6.1 Scutigerellidae

***Scutigerella* sp. B09**

One specimen was collected from the Bald Hill deposit (drill hole BHRC006) and almost certainly represents a new species (**Figure 11**). There are no additional records of this group from near the vicinity of the Yangibana project. Most symphylans in subterranean habitats have very small ranges that are far smaller than the current SRE threshold of 10,000 km2 (Harvey 2002). There is no taxonomic framework for symphylans in Australia and the identification of species is difficult. Consequently, *Scutigerella* sp. B09 is classified here as a potential SRE with deficient data. This is a singleton species, presently known only from this project, and likely to be of conservation concern.

Figure 11: *Scutigerella* sp. B09

Table 8: Troglofauna Recorded from the Project Area

Higher order (family)	Species	Total no.	Deposit	Hole id	Coordinates		Depth sampled	Geological Unit	Comments
					Eastings	Northings			
Isopoda									
Armadillidae	*Troglarmadillo* sp. B60	3	Frasers	FFRC010	429713	7350794	25	Unconsolidated ferruginous rubble	Only record of the genus in the vicinity, species is therefore of conservation concern
Diplura									
Projapygidae	Projapygidae sp. B19	1	Kane's Gossan	KGRC007	424783	7359167	15	Pimbyana Granite	New species and no other records known. Of conservation concern
Insecta									
Nicoletiidae	*Trinemura* sp. B29	1	Bald Hill	BHRC002	428330	7355776	20	Pimbyana Granite	Deficient data, species is of conservation concern
Nicoletiidae	*Trinemura* sp. B29	2	Fraser's	FFRC010	429713	7350794	14	Unconsolidated ferruginous rubble	
Nicoletiidae	*Trinemura* sp. B29	2	Kane's Gossan	KGRC007	424783	7359167	15	Pimbyana Granite	
Chilopoda									
Geophilidae	Geophilidae sp.	1	Kane's Gossan	KGRC011	424845	7359037	14	Pimbyana Granite	Specimen in very poor condition, unknown conservation concern
Myriapoda									
Scutigerellidae	*Scutigerella* sp. B09	1	Bald Hill	BHRC006	428247	7355876	15	Unconsolidated ferruginous rubble	Singleton species, only known from Yangibana project. Of conservation concern

5 DISCUSSION

5.1 STYGOFAUNA

Literature and database searches resulted in very limited data available from the region and no other assessment on stygofauna has been completed within a reasonable distance (approximately 150 km) within the northern Yilgarn region where habitats and geology are similar to that found within the study area. The number of bores available for sampling was deemed adequate with bores sampled at each deposit (**Table 16, Map 5**). All drill holes were deemed suitable for stygofauna sampling with appropriate age classes of more than six months. However, the sampled bores were drilled between August and September 2014, eliminating sampling at bores that are older than 12 months by the second phase of surveying. This is not thought to be a limiting factor but may slightly decrease the overall number of recorded stygofauna. The water quality readings sampled from the bores at the Yangibana study area were suitable for stygofauna across all deposits and are unlikely to be a limiting factor.

The results from the stygofauna sampling indicate that a stygofauna community occurs within the Yangibana Project area. Sampling resulted in stygofauna being recorded from four areas (Lions' Ear, Yangibana North, Hook, Kane's Gossan) each of which are hosted by granite and one location outside the impact area (Andy's Bore) hosted by calcrete. No stygofauna were collected from the three remaining areas despite a number of samples at each location over two phases of surveying: Bald Hill (seven samples), Gossan (two samples) and Fraser's (four samples).

Of the stygofauna recorded during the survey, at least three taxa are likely to be of conservation concern. The records were made from three locations: Lion's Ear and Hook and outside the mineral exploration area at Andy's Bore. These locations are within the Pimbyana granite and calcrete.

In total, six geological units are present within the proposed mining pits. Based on stygofauna records, the most significant unit is the Pimbyana granite from which 10 of the 12 stygofauna taxa were recorded during this survey. The remaining two species were recorded from outside the proposed pit extent, in the calcrete. The Pimbyana granite is a widespread unit both locally and regionally, with 15,796 Ha within the mapsheets and 12,037 Ha within the study area. This represents 76.2% of the regional extent. A total of 88.91 ha of this geological unit is located within the proposed deposits, representing 0.17% of its regional extent. Any direct impacts resulting from development of the deposits will be on a negligible with a very low percentage of the geological units' extent being impacted. All remaining geological units occurring within the proposed deposits are also present outside the impact areas.

As a result of extensive sampling undertaken by the Western Australian Museum (WAM), several PEC calcrete aquifers have been identified and mapped within the Yilgarn region. In most cases, the knowledge of the composition and diversity of stygofauna within these PECs is often unknown, which makes it difficult to manage these areas sustainably (Humphreys 2001). The Project area intersects the northern portion of the Gifford Creek PEC, which covers a total of 296,142 Ha. However, the proposed deposits cover a total of 101.52 Ha inside the PEC (**Map 10**). Until groundwater studies and modelling has been completed, the proposed area of direct impact to the Gifford Creek PEC, through drawdown and mining activities, cannot be determined. Hook and Lion's Ear (not planned to be mined), from which two of the four stygofauna of conservation concern were recorded are located across the border (Lion's Ear) and outside the PEC (Hook), although they may still be a component of the PEC (**Map 10**). The remaining two stygofauna records that may be of conservation concern were recorded from outside the deposits at Andy's Bore, screening the calcrete unit, and are not expected to be directly impacted by the development of the Project.

The remaining sampled drill holes are located within the Gifford Creek PEC. When comparing the samples and records from inside and outside the PEC area, it shows that the number of specimen recorded inside the PEC is higher than the number of stygofauna specimens recorded from outside the PEC, which is proportional to the number of samples (27 samples inside, five samples outside; **Figure 12**). The number of

species recorded from only inside the PEC was with seven species higher than those recorded from boreholes located outside the PEC (two species); however, an additional three species were recorded from boreholes inside and outside the PEC calcrete (**Figure 12**). This result may indicate that the significance of the PEC on a local level may be lower than currently anticipated and suitable conditions for stygofauna are also present outside the mapped PEC area.

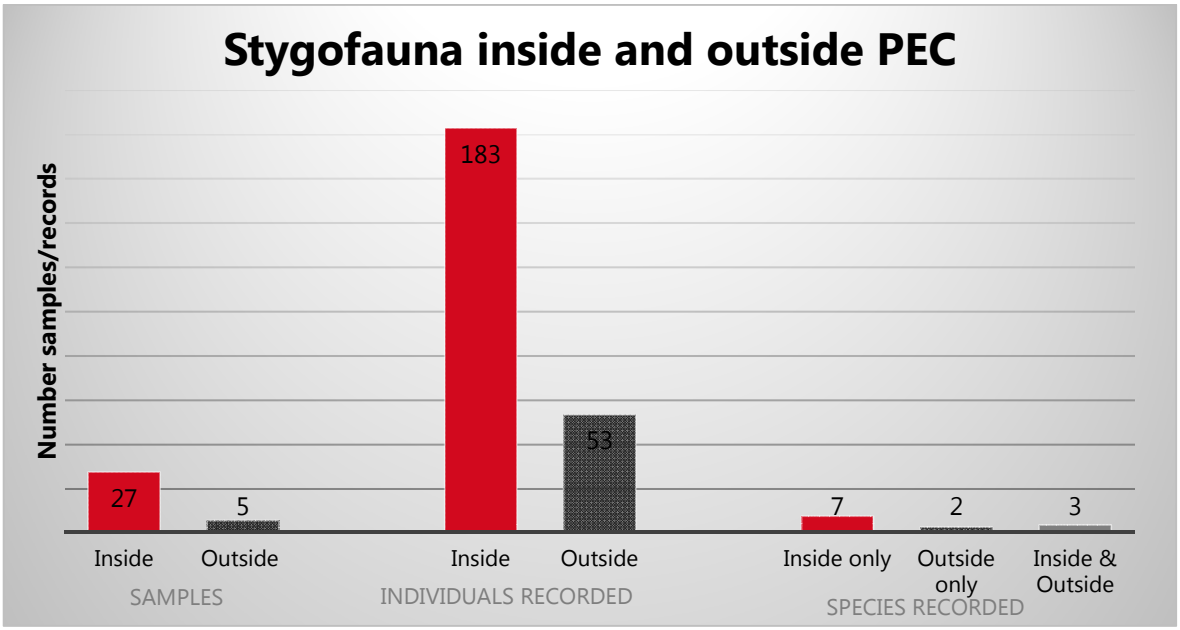


Figure 12: Stygofauna in relation to Gifford Creek PEC

In regards to stygofauna, Guzik *et* al. (2010) describes that between 11.5% and 41.1% of the total of stygofauna present in Australia are known and described. The estimated number of species per stygofauna group exceeds the currently known species, which contributes to species being classified as conservation concern. However, this percentage of short ranged species is relatively low with only four species out of 12 species recorded in total (**Table 7**).

Mining activities have the potential to impact stygofauna through the dewatering process. Abstracting groundwater has the potential to directly impact stygofauna, in particular through direct habitat loss. However, the diversity of stygofauna is unlikely to be impacted due to the extent of the mining pits and associated drawdowns. This area of direct and indirect impact is expected to be smaller than the typical range of stygofauna species of conservation concern (<1,000,000 Ha) (Harvey 2002) and the species recorded from the Project area are likely to extend well beyond the impact area of the Yangibana project.

5.2 TROGLOFAUNA

Troglofauna were recorded from three of the eight sampled mineral exploration areas: Fraser's, Kane's Gossan and Bald Hill. All of the troglofauna recorded are likely to be of conservation concern with one species (*Geophilidae* sp.) being of unknown status due to the poor condition of the specimen. This resulted in limited information about morphological features, and the taxa of the specimen could not be identified adequately to determine the conservation status. The troglofauna were recorded from drill hole FFRC010 which is located in Fraser's, from site KGRC007 and KGRC011 at Kane's Gossan, and from BHRC002 and BHRC006 at Bald Hill.

No troglofauna were recorded from Gossan (three samples), Hook (seven samples), Lion's Ear (six samples) and Yangibana North (seven samples). The sampling intensity was deemed adequate given that the remaining three exploration areas were sampled using nine traps and seven scrapes at Fraser's, four traps and two scrapes at Kane's Gossan, and 10 traps plus nine scraping samples at Bald Hill. This resulted in 11 specimens, representing at least five separate species of troglofauna recorded. Sampling effort is considered adequate across all prospective mineral exploration areas within the Project.

Troglofauna that may be of conservation concern were recorded from Bald Hill, hosted by gabbro; from Fraser's hosted by metasediments; and from Kane's Gossan hosted by granite. Each of these units occurs extensively throughout the Project area, well away from the proposed mining areas. Troglofauna have been identified in samples collected in both the hangingwall and the footwall to the mineralised zone.

All three deposits are located in the eastern section of the Project, and within the northern edge of the Gifford Creek PEC. The greater sampling effort within the PEC (66 samples) compared to outside the PEC (nine samples) skews the results presented in **Figure 13**. No clear correlation can be determined from the outcomes of this survey, or associated habitat analysis.

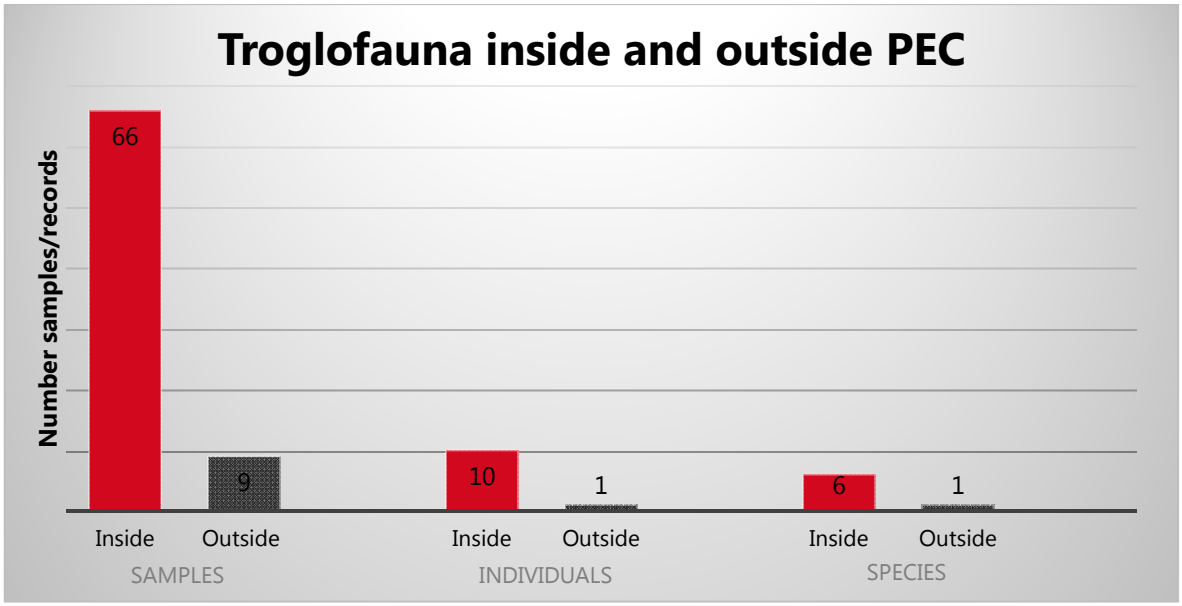


Figure 13: Troglofauna in relation to Gifford Creek PEC

Descriptions of the geological environments in which the troglofauna were sampled are provided below and shown in associated cross-sections.

Fraser's deposit is hosted by metasediments near the contact with later granite. Locally, pegmatites cut both units. The ironstone crops out strongly at Fraser's and in this area the mineralised zone dips at around 70o to the northwest. Proceeding to the northeast the mineralisation flattens out such that it dips at around 30^{o} towards its north-eastern limit at which point it appears to be terminated by a west-northwest trending fault

structure. Sampling of FFRC010 resulted in troglofauna being recorded from samples taken above (10m) and below (25m) the mineralised zone.

Kane's Gossan deposit is based on outcropping ironstone intruded into granite. The mineralisation dips quite consistently at 50^{o} to the southwest. Troglofauna were recorded from three drill holes at Kane's Gossan (KGRC007, KGRC010 and KGRC011). In each case the sample hosting the fauna was derived from fresh granite.

The third deposit from which troglofauna was recorded, was Bald Hill. The mineralised zone at Bald Hill is relatively shallow-dipping, ranging from 30^{o} to sub-horizontal. An extensive zone of saprolite occurs in the southern and central portions of the deposit. Troglofauna were recorded at Bald Hill from two drill holes (BHRC002 and BHRC006) in the eastern and central section of the deposit (**Map 8**). These locations correlate closest with the drill holes consisting of saprock and clay.

The results summarised above show that troglofauna was recorded from several units with no obvious association with the mineralisation. There is no immediate correlation between the troglofauna occurrence and the type of rocks the subterranean fauna was recorded from.

There was no calcrete layer recorded from any of the deposits (**Figure 14** - **Figure 20**).

The impacts of the development of the project are mostly direct as troglofauna habitat is typically only removed through mine pit excavation (Bennelongia 2016a).

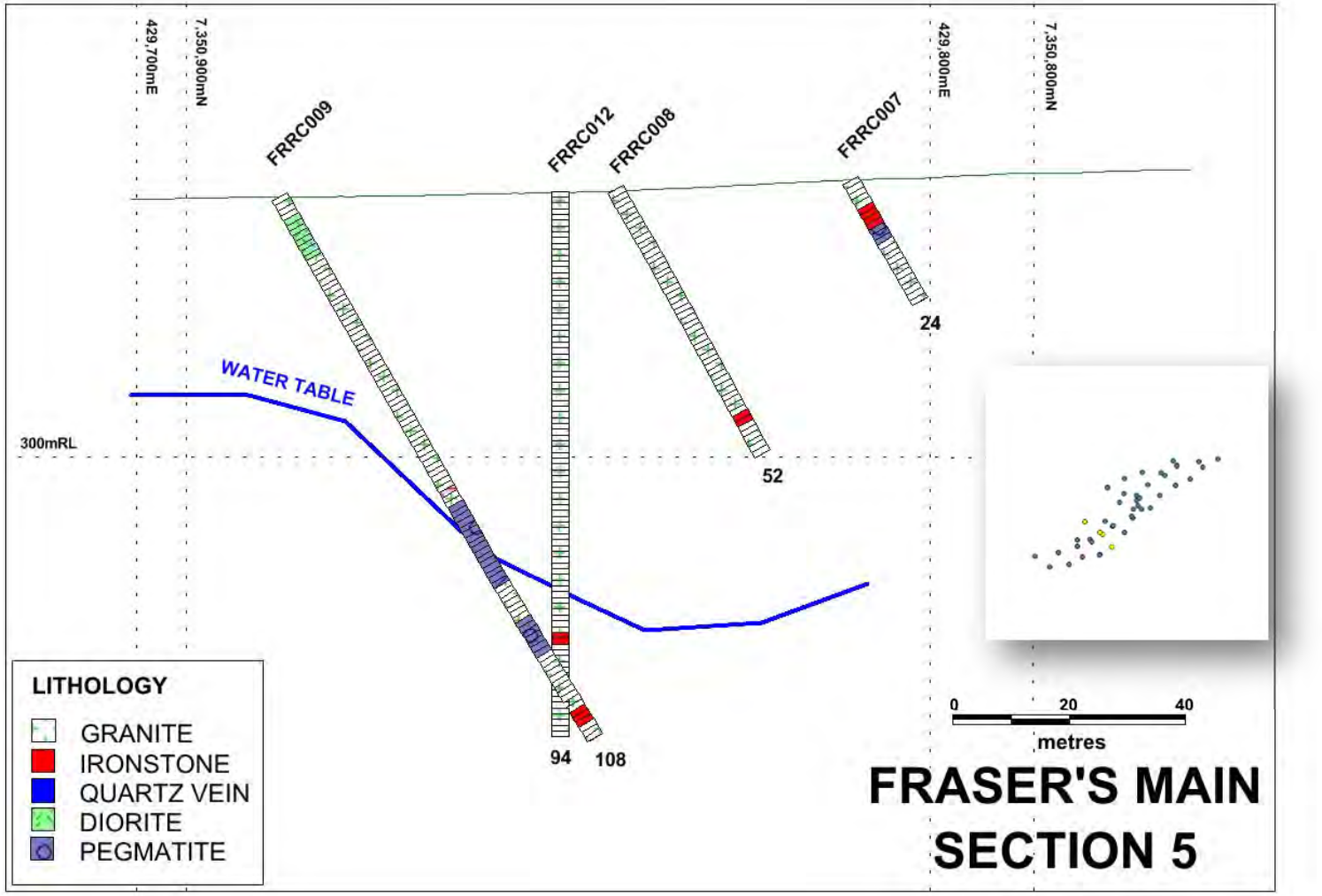


Figure 14: Geological unit diagram Fraser's Main deposit

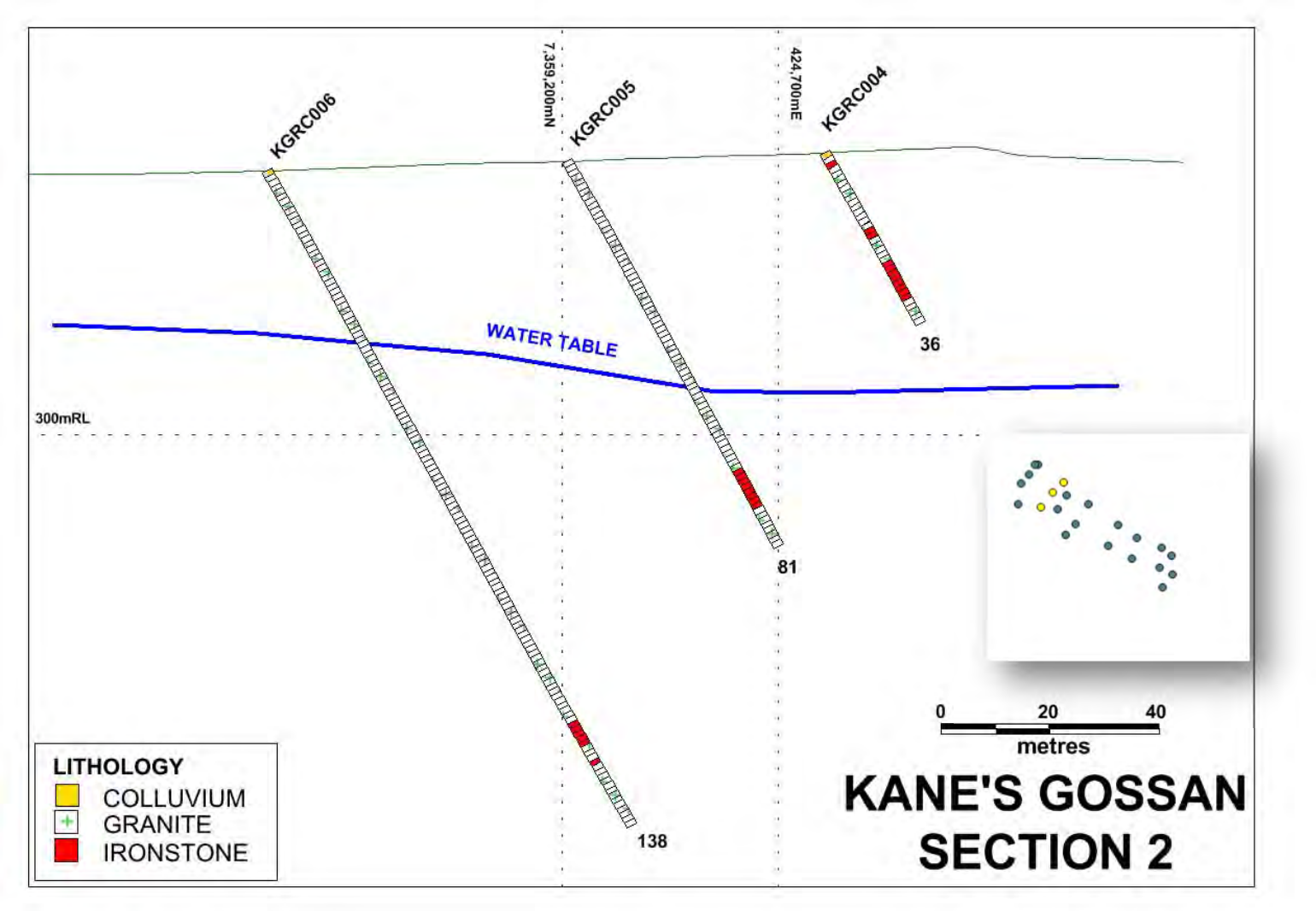


Figure 15: Geological unit diagram Kane's Gossan deposit

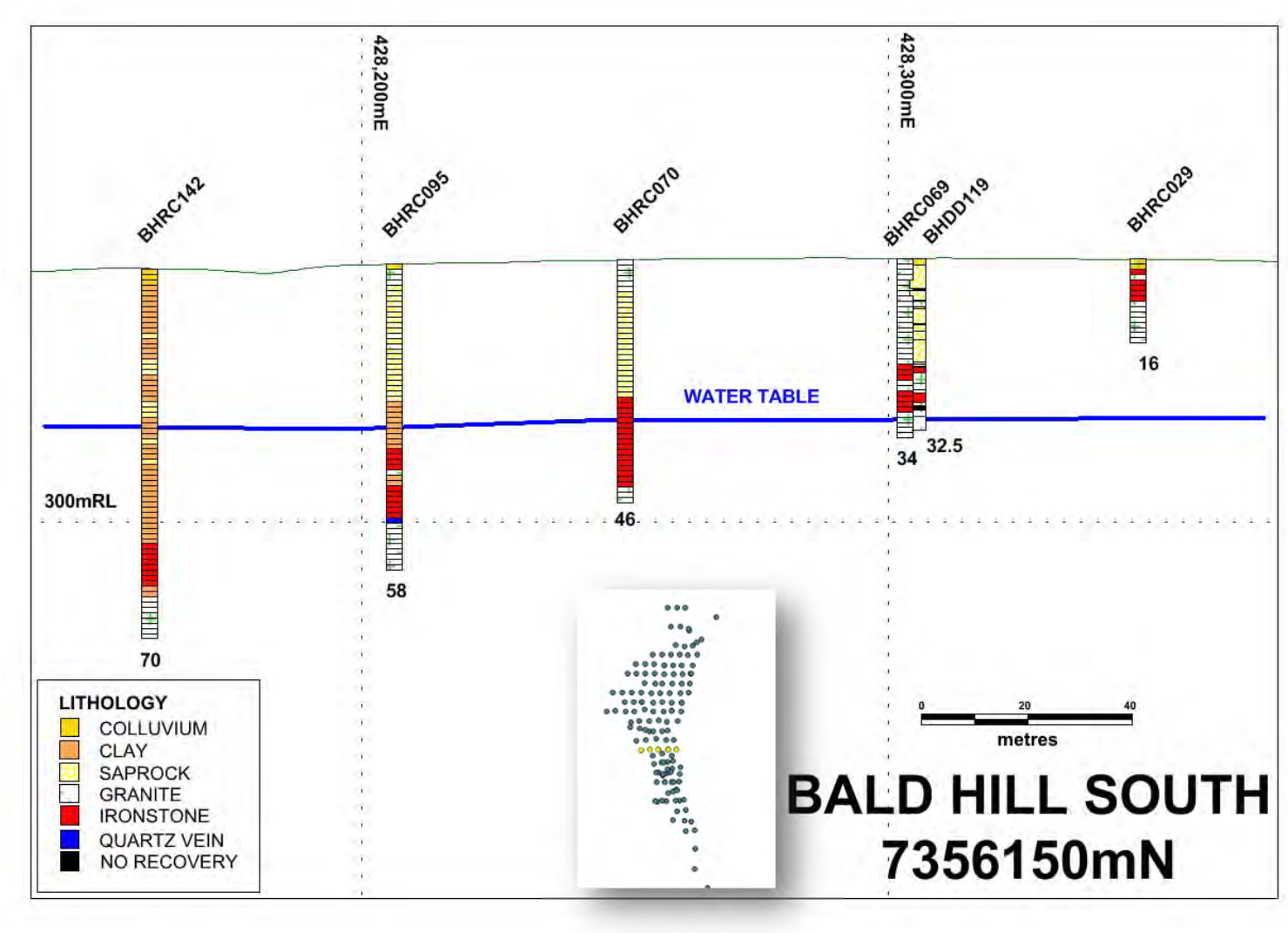


Figure 16: Geological unit diagram Bald Hill South deposit

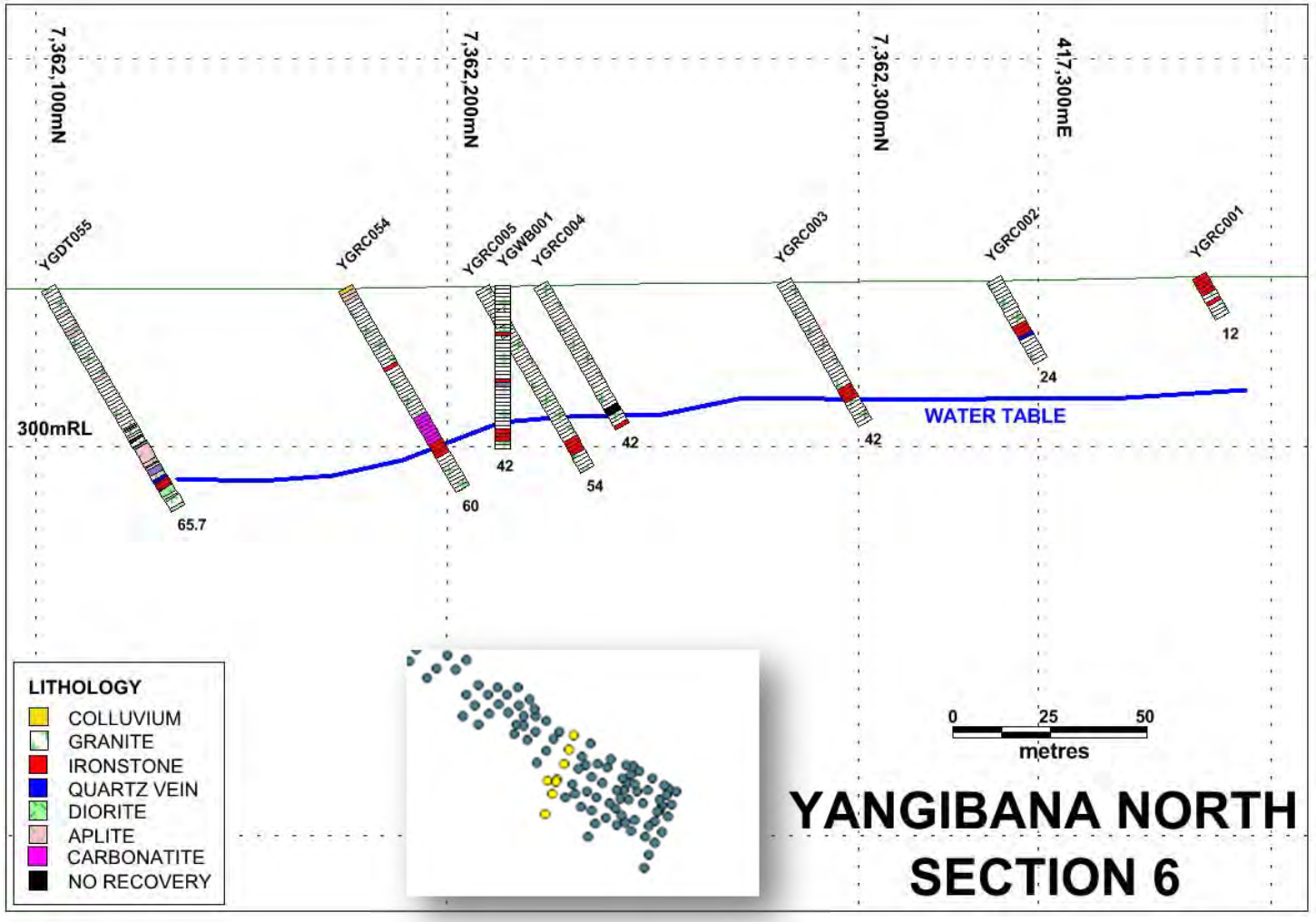


Figure 17: Geological unit diagram Yangibana North deposit

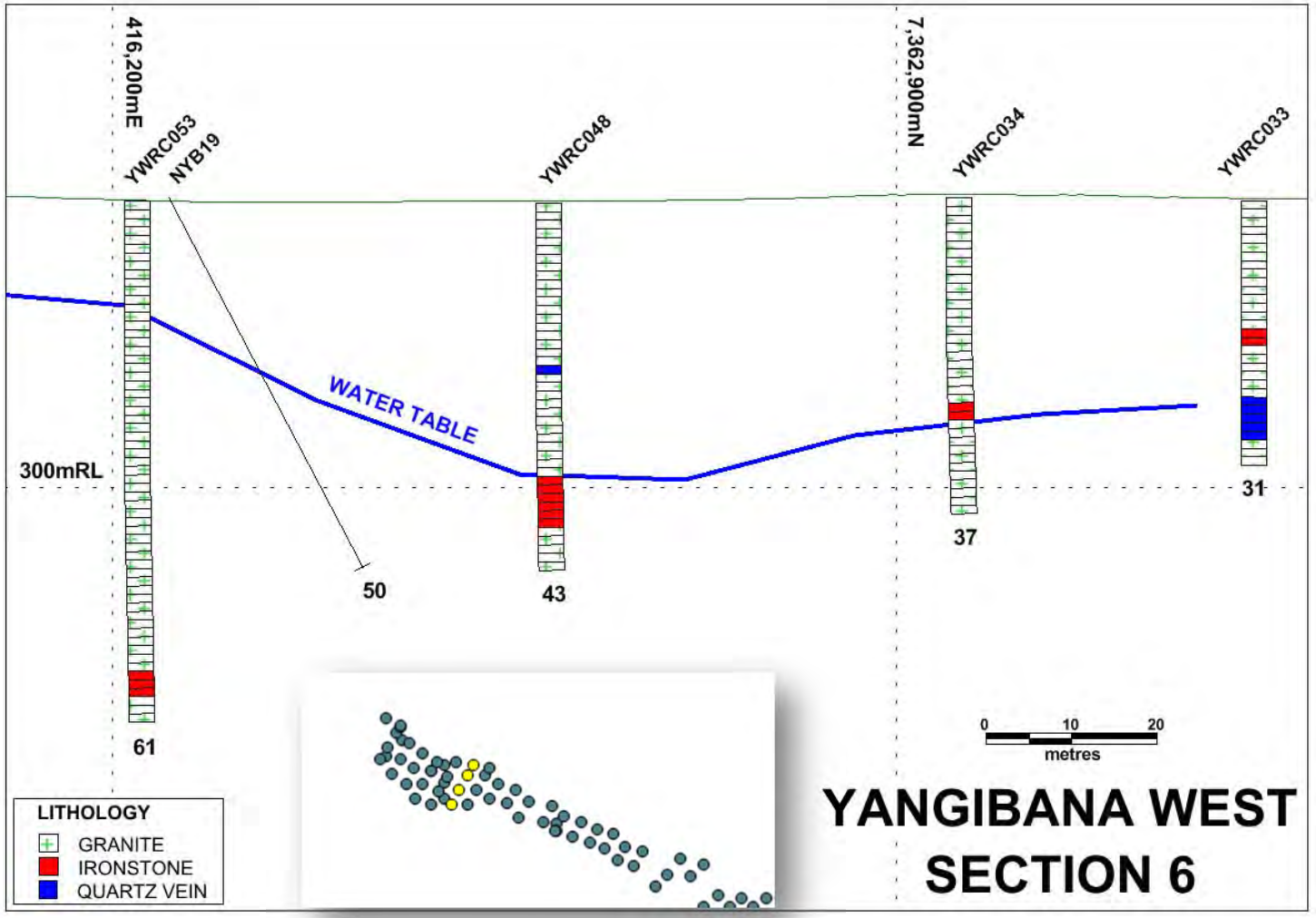


Figure 18: Geological unit diagram Yangibana West deposit

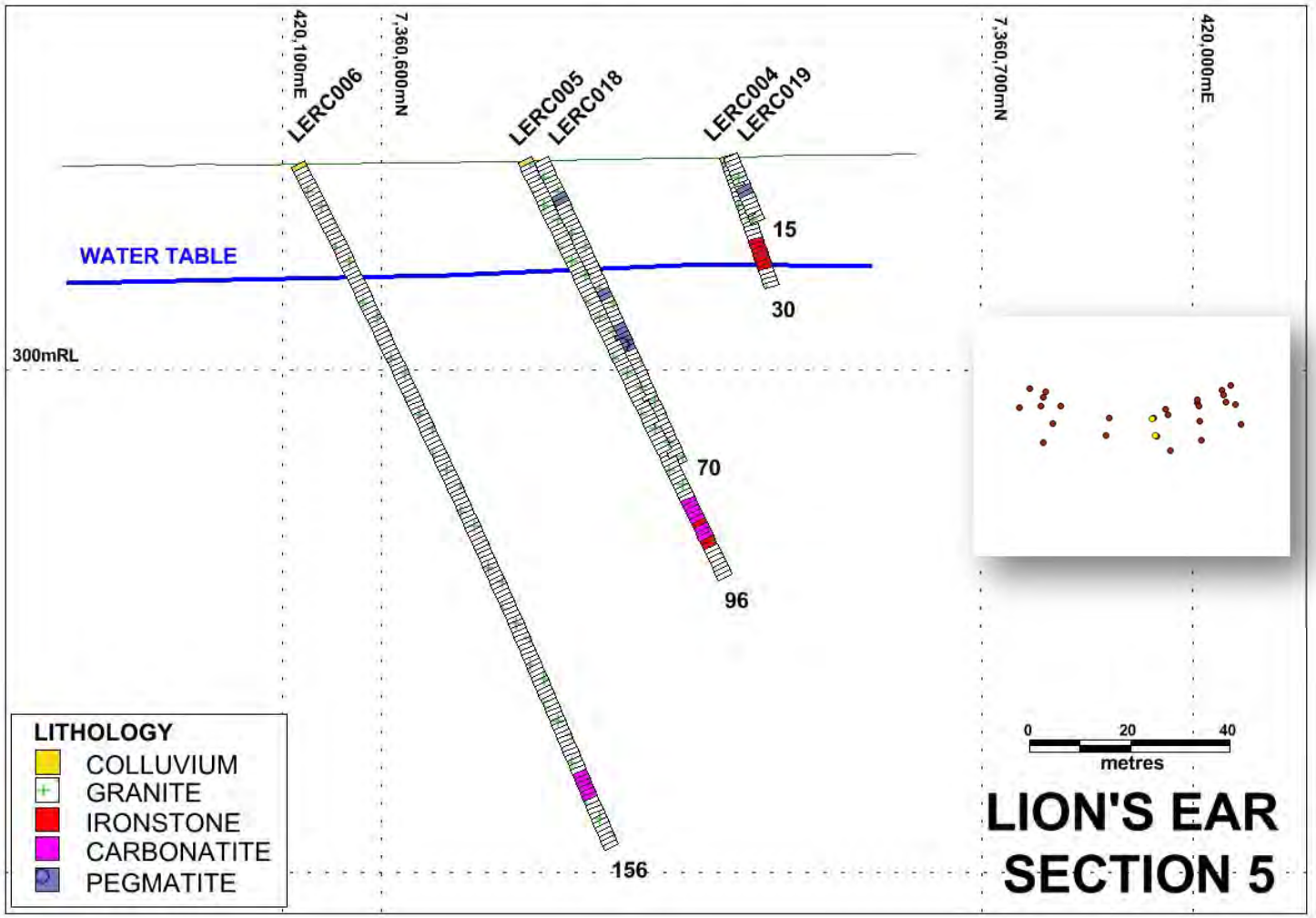


Figure 19: Geological unit diagram Lion's Ear deposit

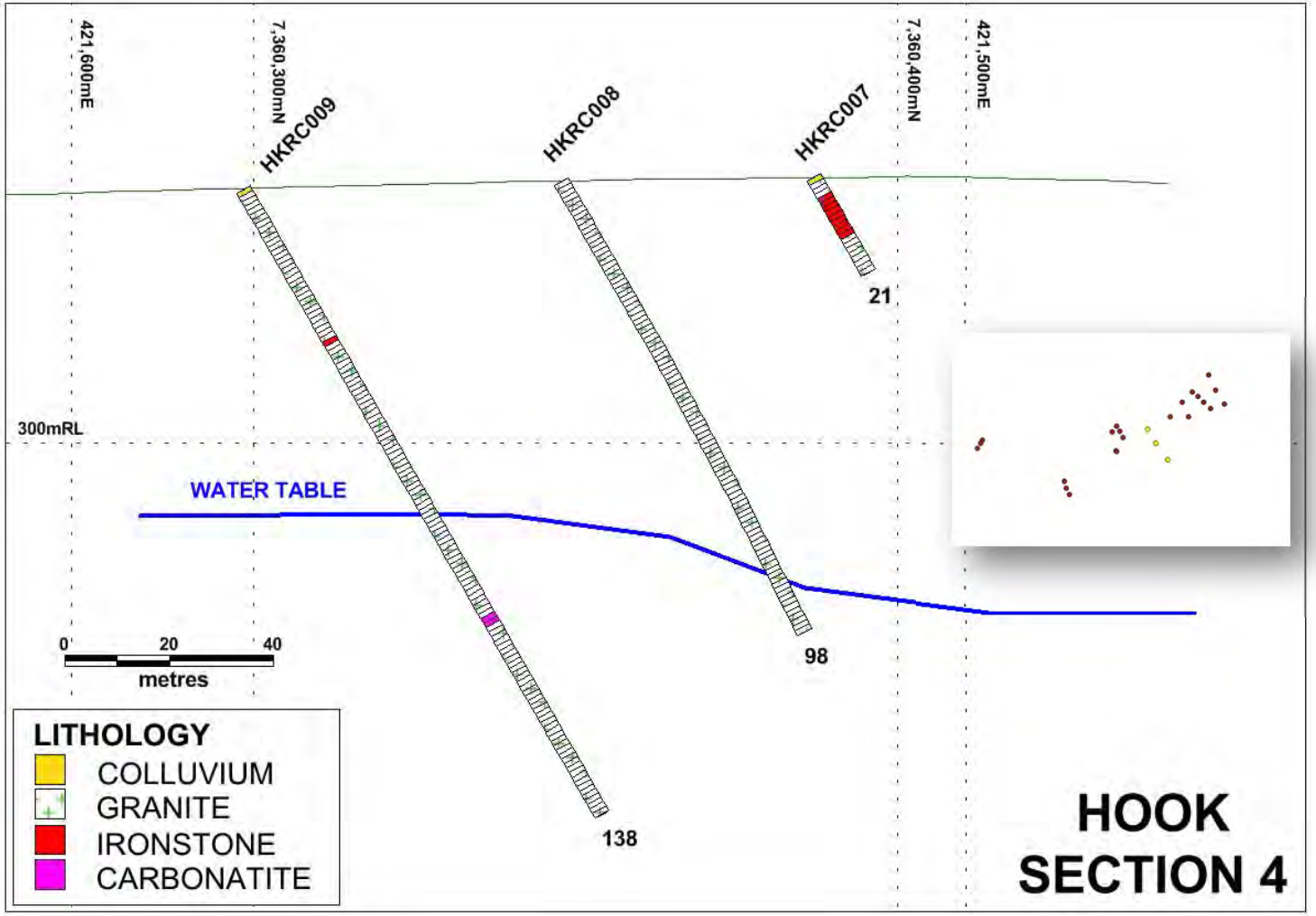


Figure 20: Geological unit diagram Hook deposit

SUMMARY AND CONCLUSIONS

The key results and conclusions of the two-phase subterranean fauna assessment of the Yangibana study area are:

- The study area occurs on the northern fringes of the Gifford Creek Priority Ecological Community (PEC), which consists of a network of shallow calcrete aquifers covering an area of 296,142 ha.
- The proposed deposits cover 101.52 ha within the PEC area, which equates to approximately 0.034% of the total PEC in area.
- Only fauna identified in Andy's Bore have a direct association with calcrete.
- No publically available surveys have been conducted within a reasonable distance (150 km) of the study area.
- Database searches identified five species of subterranean fauna of conservation concern, which were recorded from the Pilbara region (three records) and the Gascoyne region (two records).
- Thirteen drill holes were sampled for stygofauna during phase 1 of surveying and a total of 18 drill holes during phase 2. Of these, eight drill holes were sampled during both phases.
- Troglofauna sampling was undertaken using 43 traps at the Yangibana project. Of this, 18 traps were set-up during the wet season survey (phase 1) and an additional 25 traps were installed during the dry season (phase 2). In addition to trapping, troglofauna scraping was undertaken at 32 drill holes.
- Stygofauna were collected from four mineral exploration areas (Lions' Ear, Yangibana North, Hook, Kane's Gossan) and one location beyond the mineral exploration areas (Andy's Bore).
- Eleven troglofauna specimens from five orders representing at least five separate species were recorded from six drill holes (at Fraser's, Kane's Gossan and Bald Hill deposit).
- The drill logs from mineral exploration activities and geological datasets have shown that calcrete is not present within the mineral exploration areas of the Yangibana project, indicating that subterranean fauna habitat is not typical of that recorded from PEC calcrete areas, although it may overlap and be representative of that on the fringes of the Gifford Creek PEC.
- The calcrete (geological unit Rk) was sampled at one location outside the proposed development, which resulted in five stygobitic species (two of which are of conservation concern); however this calcrete unit lies outside of the current proposed impact area.
- The effect of mining activities on the stygofauna is expected to occur through pit dewatering. Abstracting groundwater will directly impact stygofauna, in particular through temporary habitat loss. However, the overall diversity of stygofauna within the broader PEC is unlikely to be impacted due to the extent of the open pits and associated drawdowns. The area of direct and indirect impact is expected to be smaller than the typical range of stygofauna species of conservation concern (<1,000,000 ha) because the species recorded from the study area are likely to extend well beyond the Project impact area.
- The impacts of the development on troglofauna are mostly direct as troglofauna habitat is typically only removed through mine pit excavation. While new species were discovered within the mineral exploration areas, the habitat was not confined to one geological unit. Therefore, it is likely that they occur over a much broader area. Not much information is available on indirect impacts on troglofauna habitats.

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MAPS

Map 1: PEC Groundwater Calcrete Assemblages (also see Table 14: Appendix 2)

350000
400000
450000
7400000
7350000
7300000

MAROONAH ROAD
HENRY RIVER
GUM CREEK
ASHBURTON RIVER
IRREGULLY CREEK
MAROONAH
WILE-COOEBING
ULLAWARRA
MOKKOBOGGANOONA
MINTHANNA
MUNTHARRA TABLETOP
MINNIERRA RANGE
WHITE CLIFFS
YANNARIE RIVER
MAROONAH SOUTH ROAD
HIGH RANGE
BARLEE RANGE
EDMUND
EDMUND RIVER
COOLINGBAH OUTCAMP
ALMA OUTCAMP
LYNDON MINNIE CREEK ROAD
BLACK RANGE
MANGAROON
ALMA RIVER
OAKEY ROCK
LYONS RIVER
WANNA
MINNIE CREEK
MINNIE CREEK
BIG MINNIE CREEK
SEVENTEEN MILE OUTCAMP
GIFFORD CREEK
WANNA ROAD
KOORABOOKA CREEK
COBRA GIFFORD CREEK ROAD
PILBARA
FREDERICK RIVER
PEEDAWARRA FLAT
COBRA
BANGEMALL
COBRA MOUNT AUGUSTUS ROAD
MOUNT AUGUSTUS
MOUNT AUGUSTUS NATIONAL PARK
ULLAWARRA ROAD
CALBRAJACKA CREEK
EUDAMULLAH ROAD
MOUNT SANDIMAN
EUDAMULLAH
ONSLOW CREEK
THIRTY ONE RIVER
MORRISSEY CREEK
HOUSE CREEK
MOUNT PHILLIPS
THOMAS RIVER
MOUNT AUGUSTUS ROAD
LAWNOR
LOCKIER RANGE
CAIRN MINING CENTRE
MORRISSEY HILL MINING CENTRE
THIRTY THREE RIVER

SERVICE LAYER CREDITS: SOURCES: ESRI, USGS, NOAA

GDA 1994 MGA Zone 50

LEGEND

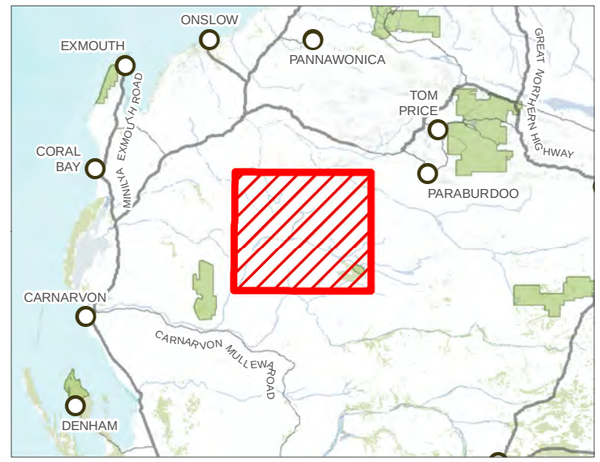
- Place Names
- Homesteads
- Minor Road
- Track
- Rivers
- Flats/Indundation areas
- National Parks
- Survey Area
- DPaW databases search area

DPaW Communities Database

Priority 1 Ecological Community

- Gifford Creek/Mangaroon/Wanna Calcrete: Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations

OVERVIEW



ecoscape

AUTHOR: CP/JN
DATE: MAR-15
REVIEWED: SB
PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

DATABASE SEARCH RESULTS

MAP 2

SCALE 1:550,000 @ A3

0 10 20 30 km

Map 2: Land Systems

405000 410000 415000 420000 425000 430000 435000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND

EDMUND RIVER

ULLAWARRA ROAD

COBRA GIFFORD CREEK ROAD

LYONS RIVER

Ph Na Du Na Ja Yi Jm Jm Na Ja Au Na Co Au Ph Jm Ag Ag Gb Ph Gb Na Au Na Au Na Au Na Ga Ph Ph Na Na Du Ph Na Au

LEGEND

- Homesteads
- Roads
- Rivers
- Creeks
- Survey Area

Project Tenements

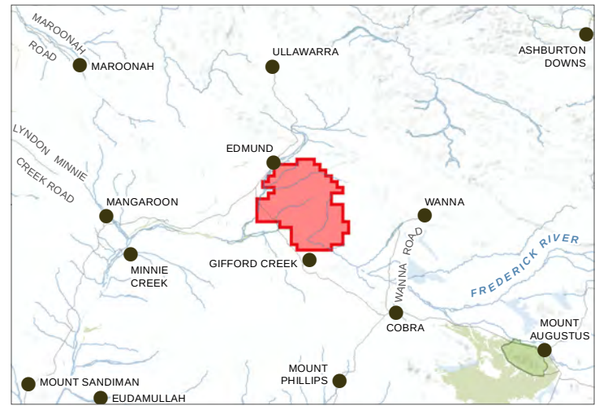
Type

- General Purpose Lease
- Mining Lease
- Miscellaneous Lease
- Proposed Infrastructure

Land Systems (DAFWA, 2012)

- Agamemnon System (Ag): Rocky hills, with peaks and ridges above extensive stony slopes, supporting scattered tall shrublands of mulga and other acacias.
- Augustus System (Au): Rugged ranges, hills, ridges and plateaux with skeletal soils supporting mulga and other acacia shrublands in southern parts or hard spinifex grasslands in northern parts.
- Collier System (Co): Undulating stony uplands, low hills, ridges, stony plains and drainage floors supporting mulga shrublands and some spinifex.
- Durlacher System (Du): Stony plains, lower tributary drainage plains and low stony rises, supporting scattered tall shrublands of mulga, other acacias and chenopod low shrubs.
- Gascoyne System (Ga): River channels and associated narrow alluvial plains and inclusions, supporting river redgum fringing woodlands, also mulga and other acacias, Senna spp. and buffel grass.
- Glenburgh System (Gb): Rugged granite hills, stony uplands and lower plains supporting scattered tall shrublands of mulga and other acacias.
- James System (Jm): Low hills, ridges and tors of granite and quartz, with stony lower plains, rises and drainage floors, supporting scattered tall shrublands of mulga and other acacias.
- Jamindie System (Ja): Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey.
- Nadarra System (Na): Plains and calcrete rises with chenopod shrublands and hard spinifex grasslands.
- Phillips System (Ph): Low hills and undulating uplands on gneiss and quartz supporting mulga and other acacia tall shrublands.
- Yinnietharra System (Yi): Scattered granite tors and domes above stony slopes, broad sandy plains with groved vegetation and wide drainage tracts; supporting tall shrublands of mulga and other acacias.

OVERVIEW



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AUTHOR: CP/JN REVIEWED: SB
DATE: NOV-16 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

LAND SYSTEMS

MAP 2

SCALE 1:110,000 @ A3

0 1 2 3 4 5 km

GDA 1994 MGA Zone 50

Map 3: Geological Units

405000 410000 415000 420000 425000 430000 435000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND

EDMUND RIVER

ULLAWARRA ROAD

LYONS RIVER

COBRA GIFFORD CREEK ROAD

Edmund

Mount Phillips

A1 A3ti W/A3 C1/PLgpi PLgpi Rk A W PLgdi Rg A3ti A3/PLgpi Rg/PLgpi PLgpi PLgynx PLgpix PLls PLgyn PLgpix PLgpi A1/Rk A3ti/Rk W/Rk W/A3ti A2 A3 Rg PLgynx PLgpi C1tss _R-k _C1-t-ss _A1

SERVICE LAYER CREDITS: SOURCES: ESRI, USGS, NOAA; SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

GDA 1994 MGA Zone 50

LEGEND

- Homesteads
- Roads
- Rivers
- Geological Survey of WA (GSWA) 1:100,000 Geological Map Sheet Boundaries
- Survey Area

GSWA 1:100,000 Geological Map*

Edmund Sheet

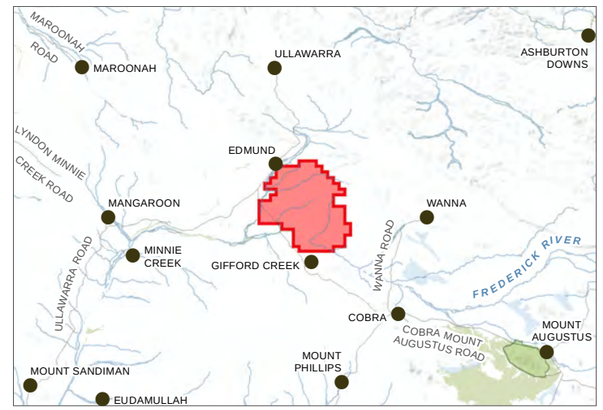
C, C1, A1f, PLgpit, C1tss, PLMEi, PLgpi, W/A3, A, Rk/PLgpi, PLMEy, A1c, W/PLgpi, C1q, Rg/PLgpi, PLge, PLgyn, A3ti/PLgpi, PLMEd, PLgdi, A3ti, A3ti/Rk, L, A3/PLgpi, Rk, PLgynx, A3ti/PLgyn, C1/Rk, A3ti/Rg, Rg, W/A3ti, A1/Rk, A3, Rf, PLd12, PLgpix, PLls, PLngo, W, W/Rk, A2, A2/Rk, PLu, C1/PLgpi, C1f, A1, A3/Rk, PLMEk, PLgto

Mount Phillips Sheet

P_-DUyn-gmi, P_-MEk-sf, P_-MOgo-mgn, P_-PO-mtsf, _A1, _A1-cb, _A1c, _A2, _Ad, _C1-t-ss, _R-k, _W

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



ecoscape

AUTHOR: CP/JN REVIEWED: SB
DATE: MAR-15 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

GEOLOGY

MAP 1

SCALE 1:115,000 @ A3

0 1 2 3 4 5 km

Map 4: Pre-European Vegetation

405000 410000 415000 420000 425000 430000 435000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND

EDMUND RIVER

ULLAWARRA ROAD

COBRA GIFFORD CREEK ROAD

LYONS RIVER

Ashburton

Augustus

18 181 165 166 29

SERVICE LAYER CREDITS: SOURCES: ESRI, USGS, NOAA; SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

GDA 1994 MGA Zone 50

LEGEND

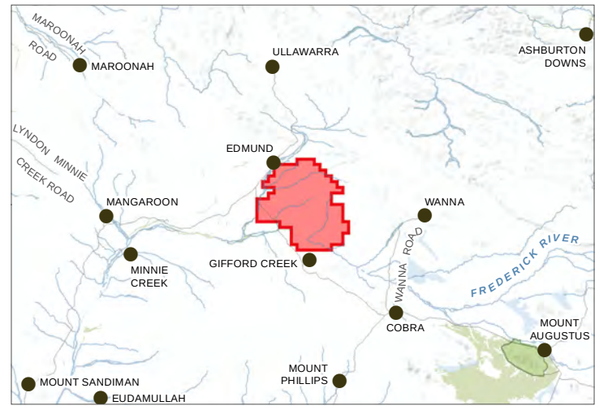
- Homesteads
- Roads
- Rivers
- Creeks
- Survey Area
- IBRA 7 Subregions

Beard Pre-European Vegetation (DAFWA 2012)

Vegetation Association

- 18: Low woodland; mulga (*Acacia aneura*)
- 29: Sparse low woodland; mulga, discontinuous in scattered groups
- 165: Low woodland; mulga and snakewood (*Acacia eremaea*)
- 166: Low woodland; mulga and *Acacia victoriae*
- 181: Shrublands; mulga and snakewood scrub

OVERVIEW



ecoscape

AUTHOR: CP/JN REVIEWED: SB
DATE: MAR-15 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

PRE EUROPEAN VEGETATION

MAP 3

SCALE 1:110,000 @ A3

0 1 2 3 4 5 km

Map 5: Location of Stygofauna Samples

410000 415000 420000 425000 430000

7365000

7360000

7355000

7350000

Yangibana North

Yangibana South

Gossan

Lions Ear

Hook

Kanes

Bald Hill

Fraser's

COBRA GIFFORD CREEK ROAD

SERVICE LAYER CREDITS:

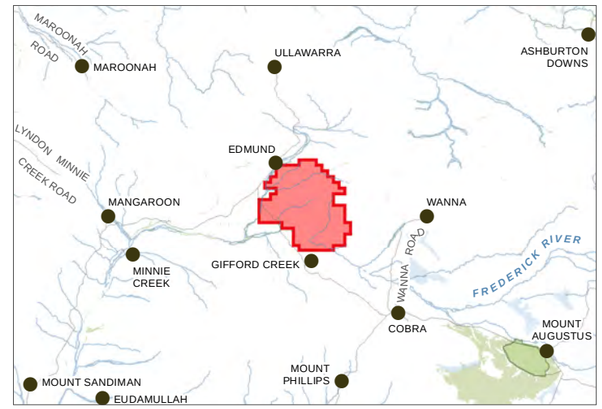
GDA 1994 MGA Zone 50

LEGEND

- Stygofauna samples
- Roads
- Rivers
- Survey Area
- Proposed Pits
- Other Infrastructure

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



ecoscape

AUTHOR: CP/JN/AH REVIEWED: SB
DATE: NOV-16 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

STYGOFAUNA SAMPLE LOCATIONS

MAP 5

SCALE 1:80,000 @ A3

0 0.7 1.4 2.1 2.8 3.5 km

Map 6: Location of Troglofauna Samples

415000 420000 425000 430000

7365000 7360000 7355000 7350000

Yangibana North
Yangibana South
Gossan
Lions Ear
Hook
Kanes
Bald Hill
Fraser's

SERVICE LAYER CREDITS:

GDA 1994 MGA Zone 50

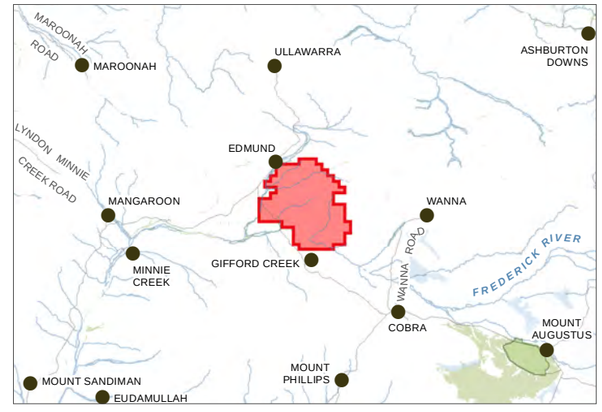
LEGEND

Troglofauna Samples

- Scraping only
- Trapping & scraping
- Roads
- Rivers
- Survey Area
- Proposed Pits
- Other Infrastructure

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



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AUTHOR: CP/JN/AH REVIEWED: SB
DATE: MAR-23 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

TROGLOFAUNA SAMPLE LOCATIONS

MAP 6

SCALE 1:70,000 @ A3

0 0.65 1.3 1.95 2.6 3.25 km

Map 7: Location of Recorded Stygofauna

405000 410000 415000 420000 425000 430000 435000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND

EDMUND RIVER

ULLAWARRA ROAD

COBRA - GIFFORD CREEK ROAD

LYONS RIVER

Yangibana North

Yangibana South

Gossan

Lions Ear

Hook

Kanes

Andy's bore

Bald Hill

Fraser's

Edmund

Mount Phillips

SERVICE LAYER CREDITS:

GDA 1994 MGA Zone 50

LEGEND

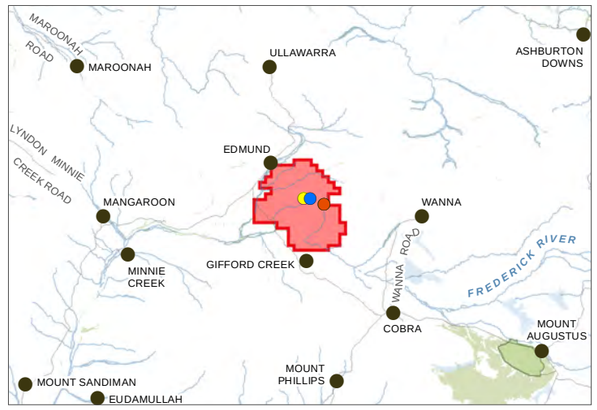
- Homesteads

Stygofauna records of conservation concern

- Paramelitidae sp.
- Paramelitidae sp. B49
- Roads
- Rivers
- Geological Survey of WA (GSWA) 1:100,000 Geological Map Sheet Boundaries
- Survey Area
- Proposed Pits
- Other Infrastructure

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



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AUTHOR: CP/JN/AH REVIEWED: SB
DATE: NOV-16 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

STYGOFAUNA RECORDS

MAP 7

SCALE 1:115,000 @ A3

0 1 2 3 4 5 km

Map 8: Location of Recorded Troglofauna

405000 410000 415000 420000 425000 430000 435000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND RIVER

ULLAWARRA ROAD

COBRA - GIFFORD CREEK ROAD

Yangibana North

Yangibana South

Gossan

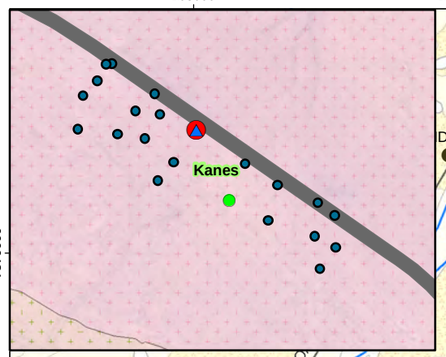
Lions Ear

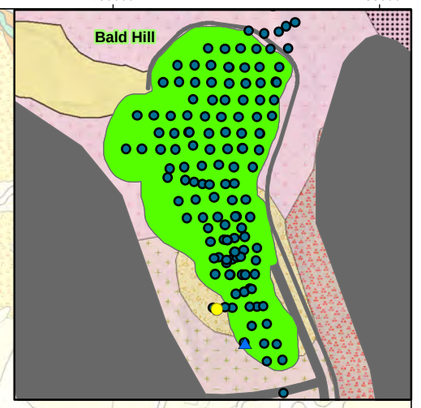
Hook

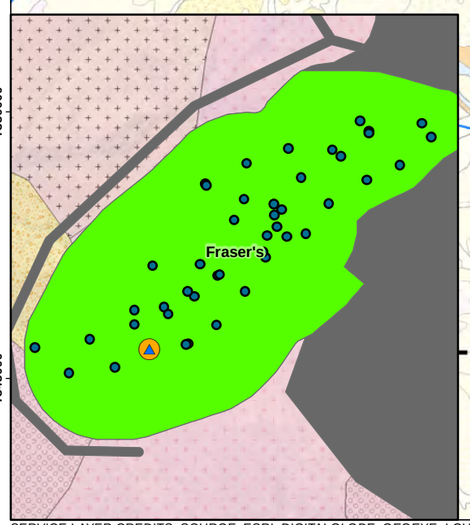
Kanes

Bald Hill

Fraser's







SERVICE LAYER CREDITS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY

GDA 1994 MGA Zone 50

LEGEND

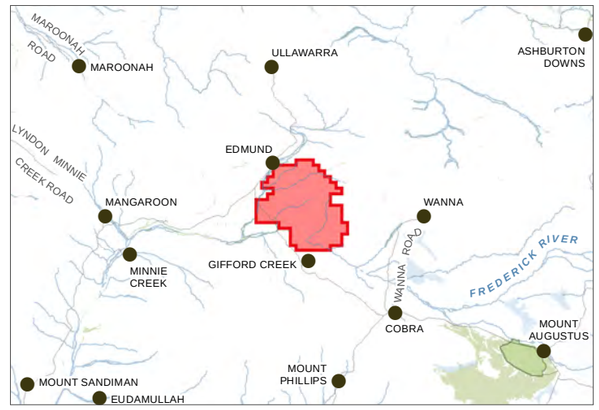
- Homesteads
- Existing drillholes

Troglofauna of conservation concern

- Geophilidae sp.
- Projapygidae sp. B19
- Scutigerella sp. B09
- Trinemura sp. B29
- Troglarmadillo sp. B60
- Roads
- Rivers
- Geological Survey of WA (GSWA) 1:100,000 Geological Map Sheet Boundaries
- Survey Area
- Proposed Pits
- Other Infrastructure

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



ecoscape

AUTHOR: CP/JN/AH REVIEWED: SB
DATE: NOV-16 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

TROGLOFAUNA RECORDS

MAP 8

SCALE 1:115,000 @ A3

0 1 2 3 4 5 km

Map 9: Proposed Deposits within Calcrete Unit

405000 410000 415000 420000 425000 430000

7370000 7365000 7360000 7355000 7350000 7345000

EDMUND

EDMUND RIVER

ULLAWARRA ROAD

COBRA GIFFORD CREEK ROAD

LYONS RIVER

Yangibana North

Yangibana South

Gossan

Lions Ear

Hook

Kanes

Bald Hill

Fraser's

Edmund

Mount Phillips

SERVICE LAYER CREDITS:

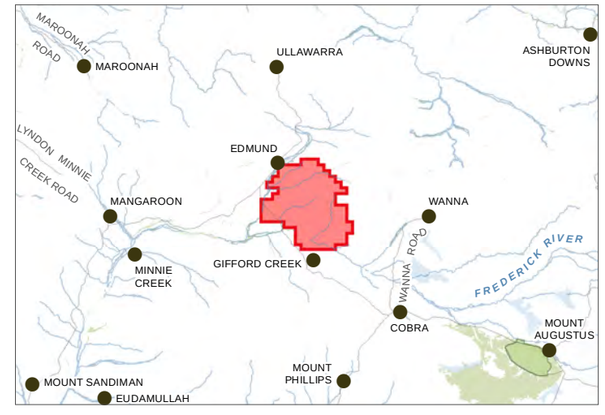
GDA 1994 MGA Zone 50

LEGEND

- Homesteads
- Roads
- Rivers
- Geological Survey of WA (GSWA) 1:100,000 Geological Map Sheet Boundaries
- Survey Area
- Geological unit Rk
- Proposed Pits
- Other Infrastructure

* Data and symbology downloaded from Department of Mines and Petroleum http://geodownloads.dmp.wa.gov.au/datacentre/datacentreDb.asp

OVERVIEW



ecoscape

AUTHOR: CP/JN/AH REVIEWED: SB
DATE: NOV-16 PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

PROPOSED DEPOSITS WITHIN CALCRETE UNIT Rk

MAP 9

SCALE 1:115,000 @ A3

0 1 2 3 4 5 km

Map 10: Deposits within Gifford Creek PEC

350000
400000
450000
7400000
7350000
7300000

Yangibana North
Yangibana South
Gossan
Lions Ear
Hook
Kanes
Bald Hill
Fraser's

MAROONAH ROAD
MAROONAH
HENRY RIVER
GUM CREEK
WILE-COOEBING
ULLAWARRA
MOKKOBOGGANOONA
MINTHANNA
YANIYARIE RIVER
HIGH RANGE
COOLINGBAH OUTCAMP
ALMA OUTCAMP
BARLEE RANGE
EDMUND
EDMUND RIVER
See Enlargement
LYNDON MINNIE CREEK ROAD
BLACK RANGE
MANGAROON
ALMA RIVER
OAKEY ROCK
LYONS RIVER
WANNA
MINNIE CREEK
MINNIE CREEK BIG MINNIE CREEK
SEVENTEEN MILE OUTCAMP
GIFFORD CREEK
KOORABOOKA CREEK
COBRA GIFFORD CREEK ROAD
WANNA ROAD
PILBARA
FREDERICK RIVER
PEEDAWARRA FLAT
COBRA
COBRA MOUNT AUGUSTUS ROAD
BANGEMALL
MOUNT AUGUSTUS
MOUNT AUGUSTUS NATIONAL PARK
ULLAWARRA ROAD
CALBRAJACKA CREEK
EUDAMULLAH ROAD
MOUNT SANDIMAN
EUDAMULLAH
ONSLOW CREEK
THIRTY ONE RIVER
MORRISSEY CREEK
HOUSE CREEK
MOUNT PHILLIPS
THOMAS RIVER
MOUNT AUGUSTUS ROAD
LANDOR ROAD
LOCKIER RANGE
CAIRN MINING CENTRE
MORRISSEY HILL MINING CENTRE
THIRTY THREE RIVER

SERVICE LAYER CREDITS: SOURCES: ESRI, USGS, NOAA

GDA 1994 MGA Zone 50

LEGEND

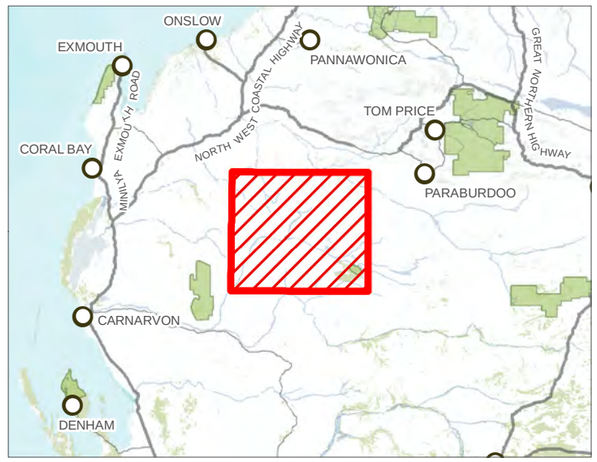
- Homesteads
- Place Names
- Minor Road
- Track
- Rivers
- Survey
- Flats/Indundation areas
- National Parks

DPaW Communities Database

Priority 1 Ecological Community

- Gifford Creek calcrete groundwater assemblage type on Lyons palaeodrainage
- Proposed Pits
- Other Infrastructure

OVERVIEW



ecoscape

AUTHOR: CP
DATE: NOV-16
REVIEWED: SB
PROJECT NO: 3397-15

YANGIBANA BIOLOGICAL ASSESSMENT

CLIENT: HASTINGS

DEPOSITS WITHIN THE GIFFORD CREEK PEC

MAP 09

SCALE 1:550,000 @ A3

0 10 20 30 km

APPENDIX ONE: DEFINITIONS AND CRITERIA

Table 9: *EPBC Act 1999* categories for flora and fauna (Commonwealth of Australia 1999)

EPBC ACT 1999 category	Definition
Extinct	A native species is eligible to be included in the extinct category at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
Extinct in the wild	A native species is eligible to be included in the extinct in the wild category at a particular time if, at that time: (a) it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically Endangered (CE)	A native species is eligible to be included in the critically endangered category at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered (EN)	A native species is eligible to be included in the endangered category at a particular time if, at that time: (a) it is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable (VU)	A native species is eligible to be included in the vulnerable category at a particular time if, at that time: (a) it is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation Dependent	A native species is eligible to be included in the conservation dependent category at a particular time if, at that time: (a) the species is the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) the species is a species of fish; (ii) the species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised; (iii) the plan of management is in force under a law of the Commonwealth or of a State or Territory; (iv) cessation of the plan of management would adversely affect the conservation status of the species.

Table 10: Conservation codes for Western Australian flora and fauna (DPaW 2014)

Conservation Codes for Western Australian Flora and Fauna	
T	**Threatened species** – Listed as Specially Protected under the *Wildlife Conservation Act 1950*, published under Schedules 1-3 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). • Fauna that is rare or likely to become extinct are declared to be fauna that is need of special protection • Flora that are extant and considered likely to become extinct, or rare and therefore in need of special protection, are declared to be rare flora: species* which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such. Threatened Fauna and Flora are ranked according to their level of threat using IUCN Red List categories and criteria. The number of Schedules published under the Wildlife Conservation Act has recently changed, with older Schedule 1 (all Threatened categories) replaced by Schedules 1-3. A list of the current rankings can be downloaded from the Parks and Wildlife Threatened Species and Communities webpage at http://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities
CR	**Critically Endangered** (Schedule 1) • Threatened fauna 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 as 'Fauna that is rare or is likely to become extinct as critically endangered fauna'. • Threatened flora taxa that are extant and considered likely to become extinct or rare, as critically endangered flora, and therefore in need of special protection
EN	**Endangered** (Schedule 2) – • Threatened fauna 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 as 'Fauna that is rare or is likely to become extinct as endangered fauna' • Threatened flora taxa that are extant and considered likely to become extinct or rare, as endangered flora, and therefore in need of special protection
VU	**Vulnerable** (Schedule 3) – • Threatened fauna 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 as 'Fauna that is rare or is likely to become extinct as vulnerable fauna' • Threatened flora taxa that are extant and considered likely to become extinct or rare, as vulnerable flora, and therefore in need of special protection
EX	**Presumed extinct** (Schedule 4) – • Fauna 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 as 'Fauna presumed to be extinct' • Flora species which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such. Listed as Specially Protected under the Wildlife Conservation Act 1950, published under Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora (which may also be referred to as Declared Rare Flora).
IA	**Migratory birds protected under an international agreement** – (Schedule 5) 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** – (Schedule 6) 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** – (Schedule 7) 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 Species that may be threatened or near threatened but are data deficient, have not yet been adequately surveyed to be listed under the Schedules of the Wildlife Conservation (Specially Protected Fauna) Notice or the Wildlife Conservation (Rare Flora) Notice 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 list 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.	

Conservation Codes for Western Australian Flora and Fauna	
P1	**Priority One: Poorly-known species (on threatened lands)** 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 or 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 localities 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 study.
P2	**Priority Two: Poorly-known species (some on conservation lands)** 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 localities 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 study.
P3	**Priority Three: Poorly-known species (some on conservation lands)** Species that are known from several locations, and the species does not appear to be under imminent threat, or from few but widespread localities 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 localities but do not meet adequacy of survey requirements and known threatening processes exist that could affect them. Such species are in need of further study.
P4	**Priority Four: 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 do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. (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, variety or forma).	

Table 11: IUCN Red List Categories and Criteria (IUCN 2012)

Additional detail is available in the quoted reference.

IUCN Category	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form
Extinct in the Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see below), and it is therefore considered to be facing an extremely high risk of extinction in the wild. If, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future.
	A: Reduction in population size based on a defined criteria (including a reduction of ≥90% or ≥80% over the last 10 years, depending on other defined factors) B: Geographic range in the form of either B1 (extent of occurrence <100 km^2 and fragmented, continuing to decline or fluctuating) or B2 (area of occupancy <10 km^2 and fragmented, continuing to decline or fluctuating) or both C: Population size estimated to number fewer than 250 mature individuals and shows continuing decline or extreme fluctuations D: Population size estimated to number fewer than 50 mature individuals E: Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years)
Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see below), and it is therefore considered to be facing a very high risk of extinction in the wild.
	A: Reduction in population size based on a defined criteria (including a reduction of ≥70% or ≥50% over the last 10 years, depending on other defined factors) B: Geographic range in the form of either B1 (extent of occurrence <5,000 km^2 and fragmented, continuing to decline or fluctuating) or B2 (area of occupancy <500 km^2 and fragmented, continuing to decline or fluctuating) or both C: Population size estimated to number fewer than 2,500 mature individuals and shows continuing decline or extreme fluctuations D: Population size estimated to number fewer than 250 mature individuals E: Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years)
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see below), and it is therefore considered to be facing a high risk of extinction in the wild.
	A: Reduction in population size based on a defined criteria (including a reduction of ≥50% or ≥30% over the last 10 years, depending on other defined factors) B: Geographic range in the form of either B1 (extent of occurrence <20,000 km^2 and fragmented, continuing to decline or fluctuating) or B2 (area of occupancy <2,000 km^2 and fragmented, continuing to decline or fluctuating) or both C: Population size estimated to number fewer than 10,000 mature individuals and shows continuing decline or extreme fluctuations D: Population size very small or restricted and estimated to number fewer than 1,000 mature individuals or occupy typically < 20 km2 or five or less locations E: Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future
Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Table 12: *EPBC Act* categories for TECs (Commonwealth of Australia 1999)

***EPBC* act category**	**Definition**
Critically Endangered (CR)	If, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	If, at that time, it is not critically endangered, and is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	If, at that time, it is not critically endangered or endangered, and is facing a high risk of extinction in the medium-term future.

Table 13: DPaW definitions and criteria for TECs and PECs (DEC 2010)

Criteria	**Definition**
Threatened Ecological Communities	
Presumed Totally Destroyed (PD)	An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be totally destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future. An ecological community will be listed as presumed totally destroyed if there are no recent records of the community being extant and either of the following applies (A or B): A. Records within the last 50 years have not been confirmed despite thorough searches of known or likely habitats or B. All occurrences recorded within the last 50 years have since been destroyed
Critically Endangered (CR)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated. An ecological community will be listed as Critically Endangered when it has been adequately surveyed and is found to be facing an extremely high risk of total destruction in the immediate future. This will be determined on the basis of the best available information, by it meeting any one or more of the following criteria (A, B or C): A. The estimated geographic range, and/or total area occupied, and/or number of discrete occurrences since European settlement have been reduced by at least 90% and either or both of the following apply (i or ii): i. geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is imminent (within approximately 10 years); ii. modification throughout its range is continuing such that in the immediate future (within approximately 10 years) the community is unlikely to be capable of being substantially rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): i. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the immediate future (within approximately 10 years); ii. there are very few occurrences, each of which is small and/or isolated and extremely vulnerable to known threatening processes; iii. there may be many occurrences but total area is very small and each occurrence is small and/or isolated and extremely vulnerable to known threatening processes. C. The ecological community exists only as highly modified occurrences that may be capable of being rehabilitated if such work begins in the immediate future (within approximately 10 years).

Criteria	Definition
Endangered (EN)	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the near future. An ecological community will be listed as Endangered when it has been adequately surveyed and is not Critically Endangered but is facing a very high risk of total destruction in the near future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B, or C): A. The geographic range, and/or total area occupied, and/or number of discrete occurrences have been reduced by at least 70% since European settlement and either or both of the following apply (i or ii): i. the estimated geographic range, and/or total area occupied and/or number of discrete occurrences are continuing to decline such that total destruction of the community is likely in the short term future (within approximately 20 years); ii. modification throughout its range is continuing such that in the short term future (within approximately 20 years) the community is unlikely to be capable of being substantially restored or rehabilitated. B. Current distribution is limited, and one or more of the following apply (i, ii or iii): iii. geographic range and/or number of discrete occurrences, and/or area occupied is highly restricted and the community is currently subject to known threatening processes which are likely to result in total destruction throughout its range in the short term future (within approximately 20 years); iv. there are few occurrences, each of which is small and/or isolated and all or most occurrences are very vulnerable to known threatening processes; v. there may be many occurrences but total area is small and all or most occurrences are small and/or isolated and very vulnerable to known threatening processes. C. The ecological community exists only as very modified occurrences that may be capable of being substantially restored or rehabilitated if such work begins in the short-term future (within approximately 20 years).
Vulnerable (VU)	An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continue or begin operating throughout its range. An ecological community will be listed as Vulnerable when it has been adequately surveyed and is not Critically Endangered or Endangered but is facing a high risk of total destruction or significant modification in the medium to long-term future. This will be determined on the basis of the best available information by it meeting any one or more of the following criteria (A, B or C): A. The ecological community exists largely as modified occurrences that are likely to be capable of being substantially restored or rehabilitated. B. The ecological community may already be modified and would be vulnerable to threatening processes, is restricted in area and/or range and/or is only found at a few locations. C. The ecological community may be still widespread but is believed likely to move into a category of higher threat in the medium to long term future because of existing or impending threatening processes.

APPENDIX TWO: PEC CALCRETE GROUNDWATER ASSEMBLAGES

Table 14: Calcrete groundwater assemblages with PEC status

Geological units with PEC status
Badja calcrete groundwater assemblage type on Moore palaeodrainage on Badja Station
Belele calcrete groundwater assemblage type on Murchison palaeodrainage on Belele Station
Beringarra calcrete groundwater assemblage type on Murchison palaeodrainage on Beringarra Station
Black Range South and Windsor groundwater calcrete assemblage type on Raeside and Murchison palaeodrainage on Lake Mason and Windsor Stations
Bunnawarra calcrete groundwater assemblage type on Moore palaeodrainage on Bunnawarra Station
Byro Central and Byro HS calcrete groundwater assemblage types on Murchison palaeodrainage on Byro Station
Challa, Challa North and Wondinong calcrete groundwater assemblage type on Murchison palaeodrainage on Challa and Wondinong Stations
Cogla Downs calcrete groundwater assemblage type on Murchison palaeodrainage on Yarrabubba Station
Curbur calcrete groundwater assemblage type on Gascoyne palaeodrainage on Curbur Station
Dalgety and Landor calcrete groundwater assemblage type on Gascoyne palaeodrainage on Dalgety Downs and Landor Stations
Doolgunna calcrete groundwater assemblage type on Gascoyne palaeodrainage on Doolgunna Station
Gabyon calcrete groundwater assemblage type on Moore palaeodrainage on Gabyon Station
Gifford Creek, Mangaroon, Wanna calcrete groundwater assemblage type on Lyons palaeodrainage on Gifford Creek, Lyons and Wanna Stations
Hillview calcrete groundwater assemblage type on Murchison palaeodrainage on Hillview Station
Innouendy calcrete groundwater assemblage type on Murchison palaeodrainage on Innouendy Station
Karalundi calcrete groundwater assemblage type on Murchison palaeodrainage on Karalundi Station
Killara calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station
Killara North calcrete groundwater assemblage types on Murchison palaeodrainage on Killara Station
Lake Austin calcrete groundwater assemblage type on Murchison palaeodrainage on Austin Downs Station
Maranalgo west calcrete assemblage type on Moore palaeodrainage on Maranalgo Station
Meeberrie calcrete groundwater assemblage type on Murchison palaeodrainage on Meeberrie Station
Meka calcrete groundwater assemblage type on Murchison palaeodrainage on Meka Station
Milgun central calcrete groundwater assemblage types on Gascoyne palaeodrainage on Milgun Station
Milgun south calcrete groundwater assemblage types on Gascoyne palaeodrainage on Milgun Station
Milly Milly calcrete groundwater assemblage type on Murchison palaeodrainage on Milly Milly Station
Mount Augustus calcrete groundwater assemblage type on Lyons palaeodrainage on Mount Augustus Station
Mt Clere calcrete groundwater assemblage type on Gascoyne palaeodrainage on Mt Clere Station
Mount Narryer calcrete groundwater assemblage type on Murchison palaeodrainage on Mount Narryer Station
Mount Padbury calcrete groundwater assemblage type on Murchison palaeodrainage on Mount Padbury Station
Muralgarra calcrete groundwater assemblage type on Murchison palaeodrainage on Muralgarra Station
Murchison Downs calcrete groundwater assemblage type on Murchison palaeodrainage on Murchison Downs Station
Ninghan calcrete groundwater assemblage type on Moore palaeodrainage on Ninghan Station
Nowthanna Hill calcrete groundwater assemblage type on Murchison palaeodrainage on Yarrabubba Station
Paroo calcrete groundwater assemblage type on Carey palaeodrainage on Paroo Station
Polelle calcrete groundwater assemblage type on Murchison palaeodrainage on Polelle Station
Taincrow calcrete groundwater assemblage type on Murchison palaeodrainage on Taincrow Station
Three Rivers calcrete groundwater assemblage types on Gascoyne palaeodrainage on Three Rivers Station
Three Rivers Plutonic calcrete groundwater assemblage types on Gascoyne palaeodrainage on Three Rivers Station

Geological units with PEC status
Wagga Wagga and Yalgoo calcrete groundwater assemblage type on Yalgoo and Moore palaeodrainage on Wagga Wagga and Bunnawarra Stations
Windimurra calcrete groundwater assemblage type on Murchison palaeodrainage on Windimurra Station
Wooramel calcrete groundwater assemblage type on Wooramel palaeodrainage on Innouendy Station
Yarrabubba east calcrete groundwater assemblage types on Murchison palaeodrainage on Yarrabubba Station
Yarrabubba west calcrete groundwater assemblage types on Murchison palaeodrainage on Yarrabubba Station
Yoweragabbie calcrete groundwater assemblage type on Moore palaeodrainage on Yoweragabbie Station
Albion Downs calcrete groundwater assemblage type on Carey palaeodrainage on Albion Downs Station
Banjawarn and Melrose (Lake Darlot) calcrete groundwater assemblage type on Carey palaeodrainage on Banjawarn and Melrose Stations
Barwidgee calcrete groundwater assemblage type on Carey palaeodrainage on Barwidgee Station
Black Range North calcrete groundwater assemblage type on Raeside palaeodrainage on Lake Mason Station
Cunyu SBF and Cunyu Sweetwater calcrete groundwater assemblage types on Nabberu palaeodrainage on Cunyu Station
Dandaraga calcrete groundwater assemblage type on Raeside palaeodrainage on Dandaraga Station
Glenayle and Carnegie Downs calcrete groundwater assemblage type on Burnside palaeodrainage on Glenayle Station
Hinkler Well calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station
Lake Way South calcrete groundwater assemblage type on Carey palaeodrainage on Lake Way Station
Jundee Homestead calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station
Jundee South Hill calcrete groundwater assemblage type on Carnegie palaeodrainage on Jundee Station
Kaluwiri calcrete groundwater assemblage type on Raeside palaeodrainage on Kaluwiri Station
Lake Mason calcrete groundwater assemblage type on Raeside palaeodrainage on Lake Mason Station
Lake Miranda east calcrete groundwater assemblage types on Carey palaeodrainage on Yakabindie Station
Lake Miranda west calcrete groundwater assemblage types on Carey palaeodrainage on Yakabindie Station
Lake Violet south and Lake Violet calcrete groundwater assemblage types on Carey palaeodrainage on Millbillillie Station
Laverton Downs calcrete groundwater assemblage type on Carey palaeodrainage on Laverton Downs Station
Lorna Glen calcrete groundwater assemblage type on Carnegie palaeodrainage on Lorna Glen Station
Melita calcrete groundwater assemblage type on Raeside palaeodrainage on Melita Station (Sons of Gwalia)
Millbillillie: Bubble calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station
Mount Morgan calcrete groundwater assemblage type on Carey palaeodrainage on Mount Weld Station
Nambi calcrete groundwater assemblage type on Carey palaeodrainage on Nambi Station
Old Cunya calcrete groundwater assemblage type on Nabberu palaeodrainage on Cunyu Station
Perrinvale (Pine Well) calcrete groundwater assemblage type on Raeside palaeodrainage on Perrinvale Station
Pinnacles calcrete groundwater assemblage type on Raeside palaeodrainage on Pinnacles Station
Sturt Meadows calcrete groundwater assemblage type on Raeside palaeodrainage on Sturt Meadows Station
Uramurdah Lake calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station
Wiluna BF calcrete groundwater assemblage type on Carey palaeodrainage on Millbillillie Station
Windidda calcrete groundwater assemblage type on Carnegie palaeodrainage on Windidda Station
Yakabindie calcrete groundwater assemblage type on Carey palaeodrainage on Yakabindie Station
Yandal calcrete groundwater assemblage type on Carey palaeodrainage on Yandal Station
Yeelirrie calcrete groundwater assemblage type on Carey palaeodrainage on Yeelirrie Station
Yuinmery calcrete groundwater assemblage types on Raeside palaeodrainage on Yuinmery Station
Mingah Springs calcrete groundwater assemblage type on Gascoyne palaeodrainage on Mingah Spring Station

APPENDIX THREE: GEOLOGICAL UNITS

Table 15: Geological units present within study area (DMP 2002; 2007)

Unit	Description	Area in study area (ha)	Percentage of study area (%)	Area in Mapsheets* (ha)	Percentage of Mapsheets* extent (%)
A1	Unconsolidated silt, sand, and gravel in active drainage channels and floodplains; includes ferruginous deposits	3,980	7.4	46,880	8.49
A1-cb	Swelling clay (gilgal) developed on alluvial flats	44	0.1	531	8.29
A1c	Clayey alluvium developed on alluvial flats	63	0.1	5,250	1.20
A2	Partly consolidated silt, sand, and gravel; partly dissected by present-day drainage	875	1.6	22,051	3.97
Ad	Unconsolidated, fine-grained deposits in alluvial drainage depressions, claypans, perennial lakes, and swamps; low-lying areas with internal drainage; typically thickly vegetated	69	0.1	1,109	6.22
C1-t-ss	Sandstone fragments in a silt and sand matrix; derived from sandstone	213	0.4	1,295	16.45
W	Sandy and clayey distal sheetwash and slope deposits, no clearly defined drainage	599	1.1	29,171	2.05
A	Silt, sand, and gravel in drainage channels and adjacent to floodplains; includes ferruginous deposits	236	0.4	8,903	2.65
A1/Rk	Unconsolidated silt, sand, and gravel in active drainage channels; includes ferruginous deposits	350	0.7	676	51.78
A1f	Unconsolidated ferruginous silt, sand, and gravel	33	0.1	809	4.08
A2/Rk	Partly consolidated silt, sand, and gravel; partly dissected by present-day drainage	156	0.3	1,059	14.73
A3	Weakly cemented and compacted silt, sand, and gravel; deeply dissected by present-day drainage	152	0.3	6,263	2.43
A3/PLgpi	Weakly cemented and compacted silt, sand, and gravel; deeply dissected by present-day drainage	157	0.3	157	100.00
A3/Rk	Weakly cemented and compacted silt, sand, and gravel; deeply dissected by present-day drainage	27	0.1	347	7.78
A3ti	Sand and gravel with ferruginous cement; deeply dissected by present-day drainage	7,986	14.9	26,564	30.06
A3ti/PLgpi	Sand and gravel with ferruginous cement; deeply dissected by present-day drainage	44	0.1	44	100.00
A3ti/PLgyn	Sand and gravel with ferruginous cement; deeply dissected by present-day drainage	49	0.1	49	100.00
A3ti/Rg	Sand and gravel with ferruginous cement; deeply dissected by present-day drainage	249	0.5	331	75.23
A3ti/Rk	Sand and gravel with ferruginous cement; deeply dissected by present-day drainage	179	0.3	362	49.45
C	Quartz and rock fragments in a silt and sand matrix; includes ferruginous deposits	305	0.6	4,185	7.29

Unit	Description	Area in study area (ha)	Percentage of study area (%)	Area in Mapsheets* (ha)	Percentage of Mapsheets* extent (%)
C1	Quartz and rock fragments in an unconsolidated silt and sand matrix; includes ferruginous deposits	67	0.1	20,505	0.33
C1/PLgpi	Quartz and rock fragments in an unconsolidated silt and sand matrix; includes ferruginous deposits	786	1.5	826	95.16
C1/Rk	Quartz and rock fragments in an unconsolidated silt and sand matrix; includes ferruginous deposits	3	<0.1	11	27.27
C1f	Unconsolidated ferruginous rubble and scree	23	<0.1	23	100.00
C1q	Quartz fragments in an unconsolidated silt and sand matrix, derived from quartz veins and quartzose rocks	21	<0.1	595	3.53
C1tss	Sandstone fragments in an unconsolidated silt and sand matrix, derived from sandstone	217	0.4	701	30.96
L	Unconsolidated, fine-grained deposits in claypans, perennial lakes, and swamps; low-lying areas with internal drainage; typically thickly vegetated	30	0.1	699	4.29
P_-DUyn-gmi	Equigranular to locally weakly porphyritic, medium-grained biotite--muscovite monzogranite with abundant inclusions of metasedimentary rock or porphyritic granodiorite	44	0.1	720	6.11
P_-MEk-sf	Siltstone, mudstone, and thin- to very thick-bedded quartz sandstone; minor dolostone and conglomerate	54	0.1	2,614	2.07
P_-MOgo-mgn	Strongly foliated, porphyritic metagranodiorite and metamonzogranite, and augen gneiss	<0.01	<0.01	33	0.03
P_-PO-mtsf	Psammitic schist and gneiss, and feldspathic metasandstone; includes interbedded pelite, quartzite, and granule metaconglomerate	97	0.2	1,255	7.73
PLd12	Dolerite and gabbro sills intruded into Edmund Group; oldest suite (PLd2) dated at c.1465 Ma 2 3 and youngest suite (PLd2) dated at c.1070 Ma 2 3	7	<0.1	28,862	0.02
PLgdi	DINGO CREEK GRANITE: porphyritic biotite-muscovite granite; fine to medium grained with tabular feldspar phenocrysts; locally contains abundant broken phenocrysts of feldspar	1,255	2.3	1,633	76.85
PLge	Even-textured, medium-grained biotite monzogranite	11	<0.1	15	73.33
PLgpi	PIMBYANA GRANITE: porphyritic, medium- to coarse-grained biotite-muscovite granodiorite to syenogranite, with abundant large tabular phenocrysts of K-feldspar; even-textured to porphyritic, fine- to	12,037	22.5	15,796	76.20
PLgpit	Even-textured, fine- to medium-grained biotite tonalite to quartz diorite	65	0.1	65	100.00

Unit	Description	Area in study area (ha)	Percentage of study area (%)	Area in Mapsheets* (ha)	Percentage of Mapsheets* extent (%)
PLgpix	Porphyritic, medium- to coarse-grained biotite-muscovite granodiorite to syenogranite, with abundant xenoliths of metasedimentary and metamafic rocks; abundant large tabular phenocrysts of K-feldspar;	3,270	6.1	3,376	96.86
PLgto	Biotite-muscovite-cordierite tonalite with abundant inclusions of pelitic schist, biotite schist, and calc-silicate gneiss	28	0.1	28	100.00
PLgyn	YANGIBANA GRANITE: even-textured to locally weakly porphyritic, medium-grained biotite-muscovite monzogranite; locally contains tourmaline; may contain xenoliths of metasedimentary rock or porphyritic	1,988	3.7	2,151	92.42
PLgynx	Even-textured to weakly porphyritic, medium-grained biotite-muscovite(-tourmaline) monzogranite with abundant xenoliths of metasedimentary rock or porphyritic granodiorite	3,778	7.1	5,358	70.51
PLls	Metasedimentary schist and gneiss, including psammite, calc-silicate rock, and quartzite; typically metamorphosed at medium grade	1,871	3.5	2,880	64.97
PLMEd	DISCOVERY FORMATION: massive or laminated chert, and carbonaceous mudstone and siltstone; locally sulfidic	9	0.0	5,628	0.16
PLMEi	IRREGULLY FORMATION: stromatolitic and non-stromatolitic dolostone, dolomitic siltstone, quartz sandstone, and conglomerate	98	0.2	366	26.78
PLMEk	KIANGI CREEK FORMATION: thin to very thick bedded quartz sandstone, and siltstone and mudstone; minor dolostone and conglomerate	92	0.2	9,507	0.97
PLMEy	YILGATHERRA FORMATION: sandstone, siltstone, and conglomerate	134	0.3	652	20.55
PLngo	GOOCHE GNEISS: strongly foliated, porphyritic granodiorite to augen gneiss	154	0.3	205	75.12
PLu	Ultramafic sills and dykes	59	0.1	59	100.00
Rf	Ferruginous deposits, including lateritic, ferruginous, and manganiferous duricrust	3	0.0	765	0.39
Rg	Weathered quartzofeldspathic rock with locally derived sand and sandy clays	1,750	3.3	1,901	92.06
Rg/PLgpi	Weathered quartzofeldspathic rock with locally derived sand and sandy clays	882	1.6	891	98.99
Rk	Calcrete, developed in and adjacent to alluvial channels; carbonate and vuggy opaline silica; dissected by major present-day drainage	6,247	11.6	16,008	39.02
Rk/PLgpi	Calcrete, developed in and adjacent to alluvial channels; carbonate and vuggy opaline silica; dissected by major present-day drainage	243	0.5	307	79.15

Unit	Description	Area in study area (ha)	Percentage of study area (%)	Area in Mapsheets* (ha)	Percentage of Mapsheets* extent (%)
W/A3	Sandy and clayey distal sheetwash and slope deposits; no clearly defined drainage	490	0.9	1,142	42.91
W/A3ti	Sandy and clayey distal sheetwash and slope deposits; no clearly defined drainage	439	0.8	8,892	4.94
W/PLgpi	Sandy and clayey distal sheetwash and slope deposits; no clearly defined drainage	45	0.1	431	10.44
W/Rk	Sandy and clayey distal sheetwash and slope deposits; no clearly defined drainage	1,480	2.8	3,140	47.13

Mapsheets= refers to 1:100,000 mapsheets Edmund (sheet 2150) and Mt Phillips (sheet 2149)

APPENDIX FOUR: STYGOFAUNA SAMPLE LOCATIONS

Table 16: Boreholes Sampled for Stygofauna

Sample	Deposit	Hole ID	Coordinates		Date	Total depth (m)	Depth to water (m)	Depth sampled (m)	Geology
			Easting	Northing					
Phase 1									
YS S001	Bald Hill	BHRC009	428273	7356014	16/05/15	72	32	34	C1f
YS S002	Bald Hill	BHRC006	428247	7355876	16/05/15	90	26	28	C1f
YS S003	Bald Hill	BHRC002	428330	7355776	16/05/15	84	24	50	PLgpix
YS S004	Gossan	GSRC002	418284	7361169	17/05/15	50	32	50	PLgpi
YS S005	Hook	HKRC002	421721	7360502	17/05/15	90	14	40	PLgpi
YS S006	Hook	HKRC009	421578	7360296	17/05/15	138	18	100	PLgpi
YS S007	Hook	HKRC011A	421436	7360316	17/05/15	72	18	70	PLgpi
YS S008	Kane's Gossan	KGRC017	425000	7358976	16/05/15	54	22	30	PLgpi
YS S009	Kane's Gossan	KGRC007	424783	7359167	16/05/15	36	22	30	PLgpi
YS S010	Lion's Ear	LERC011	419820	7360645	17/05/15	84	16	92	PLgpi
YS S011	Yangibana North	YGRC057	417194	7362389	18/05/15	24	18	24	PLgpi
YS S012	Yangibana North	YGRC063	417129	7362480	18/05/15	30	15	30	PLgpi
YS S013	Fraser's	FRRC011	429696	7350820	18/05/15	70	34.8	60	C1f
Phase 2									
YS S014	-	Andy's Bore	425888	7358719	25/09/15	-	6.3	10	Rk
YS S015	Bald Hill	BHRC151	427978	7356353	25/09/15	78	33.5	40	PLgpi
YS S016	Bald Hill	BHRC002	428330	7355776	26/09/15	84	28	40	PLgpix
YS S017	Bald Hill	BHRC009	428278	7356015	26/09/15	72	32.5	60	C1f
YS S018	Bald Hill	BHRC067	428239	7356209	26/09/15	46	28.8	35	PLgpi
YS S019	Yangibana N	YGRC063	417130	7362484	27/09/15	30.5	15.8	28	PLgpi
YS S020	Yangibana N	YGRC057	417189	7362389	27/09/15	24	16.5	22	PLgpi
YS S021	Gossan	GSRC009	418412	7361003	28/09/15	96	28	80	PLgpi
YS S022	Lion's Ear	LERC010	419836	7360689	28/09/15	36	17	35	PLgpi
YS S023	Lion's Ear	LERC011	419818	7360647	28/09/15	84	16.5	76	PLgpi
YS S024	Lion's Ear	LERC007	419950	7360660	28/09/15	24	19.5	22	PLgpi
YS S025	Lion's Ear	LERC008	419943	7360619	28/09/15	90	14	60	PLgpi
YS S026	Hook	HKRC011A	421424	7360320	29/09/15	72	19	70	PLgpi
YS S027	Hook	HKRC002	421721	7360502	29/09/15	90	14.5	50	PLgpi
YS S028	Kane's Gossan	KGRC011	424845	7359037	29/09/15	78	19.5	70	PLgpi
YS S029	Kane's Gossan	KGRC018	425016	7358903	29/09/15	108	19	900	PLgpi
YS S030	Frasers	FRRC011	429697	7350822	30/09/15	72	34	70	C1f
YS S031	Frasers	FRRC020	429930	7351012	30/09/15	58	54	57	PLgpi
YS S032	Frasers	FRRC022	429961	7351040	30/09/15	52	32.7	50	PLgpi

Zone: 50K, Datum: GDA 94

APPENDIX FIVE: WATER CHEMISTRY

Table 17: Water chemistry data collected from stygofauna boreholes

Bore Hole ID	Total Depth	DTW (M)	PH	DO (PPM)	Conductivity (MS/CM)	ORP (MV)	TDS (G/L)	Salinity (PPT)	Temp (°C)
Phase 1									
BHRC009	72	32	7.07	3.11	3.2	Δ	Δ	2.9	28.9
BHRC006	90	26	6.87	2.99	5.23	Δ	Δ	2.58	29.8
BHRC002	84	24	6.9	2.01	5.64	Δ	Δ	2.84	30.5
GSRC002	50	32.2	7.32	1.96	5.7	Δ	Δ	2.84	30.1
HKRC002	90	14	7.33	2.62	4.94	Δ	Δ	2.31	30.5
HKRC009	100	18.2	7.31	-*	4.73	Δ	Δ	2.35	31.4
HKRC011A	72	18	7.09	1.18	4.89	Δ	Δ	2.45	30.8
KGRC017	54	22	6.92	-*	5.53	Δ	Δ	2.60	30.8
KGRC007	36	22	7.46	-*	4.20	Δ	Δ	2.11	30.8
LERC011	84	16	7.47	1.93	4.65	Δ	Δ	2.32	30.2
YGRC057	24	18	7.32	2.29	3.62	Δ	Δ	1.8	29.8
YGRC063	30	15	7.27	2.59	3.76	Δ	Δ	1.87	30.4
FRRC011	70	34.8	7.48	-*	5.94	Δ	Δ	2.95	30.3
Phase 2									
Andy's Bore	24	6.3	7.27	1.78	2.17	-6.2	1.3	1.98	29.2
BHRC151	78	33.5	7.08	1.89	2.11	27.1	1.20	1.85	31.9
BHRC002	84	28	7.19	2.50	2.42	32.1	1.4	2.15	32.1
BHRC009	72	32.5	7.18	1.79	2.55	39.7	1.5	2.25	31.9
BHRC067	30.5	28.8	7.28	1.75	2.41	31.5	1.4	2.14	31.3
YGRC063	30	15.8	7.36	1.65	1.53	52.6	0.9	0.70	31.1
YGRC057	24	24	7.39	1.3	1.64	61.9	0.9	0.72	32
GSRC009	96	27.55	7.14	2.01	2.27	37.6	1.3	1.02	31.1
LERC010	36	28	7.53	1.61	0.72	32.0	0.4	0.30	31.8
LERC011	84	17	7.4	1.77	2.3	49.5	1.3	10.3	31.5
LERC007	24	16.5	7.36	1.85	2.73	68.0	1.5	1.23	31.4
LERC008	90	19.5	7.25	3.44	2.20	66.8	1.3	0.99	31.9
HKRC011A	72	14	7.06	1.53	2.19	56.1	1.3	0.99	31.1
HKRC002	90	19	7.38	2.26	2.24	60.3	1.3	1.01	31.4
KGRC011	78	14.5	7.25	1.69	2.39	87.8	1.4	1.07	31.9
KGRC018	108	19.5	7.55	2.99	2.05	88.4	1.2	0.92	31.5
FRRC011	72	34	7.29	2.62	2.63	93.2	1.5	1.18	31.7
FRRC022	52	32.7	7.51	0.88	2.84	89.8	1.6	1.29	31.5

*Oxygen meter malfunction, no data available for this sample location

Δ Water chemistry meter used during this survey did not record this value (ORP and TDS)

DO=Dissolved Oxygen, TDS=Total Dissolved Solids

APPENDIX SIX: TROGLOFAUNA SAMPLE LOCATIONS

Table 18: Troglofauna sample locations during current survey

Sample	Deposit	Hole id	Coordinates		Date	Total depth (m)	Depth to water (m)	Depth sampled (m)	Geology
			Easting	Northing					
Phase 1 Trapping									
YS TT001	Bald Hill	BHRC012	428318	7356032	16/05/15–16/07/15	70	24	20	C1f
YS TT002	Bald Hill	BHRC006	428247	7355876	16/05/15–16/07/15	90	26	15	C1f
YS TT003	Bald Hill	BHRC002	428330	7355776	16/05/15–16/07/15	84	24	15	PLgpix
YS TT004	Gossan	GSRC001	418312	7361205	17/05/15–16/07/15	50	32.9	20	PLgpi
YS TT005	Gossan	GSRC002	418284	7361169	17/05/15–14/07/15	50	32	25	PLgpi
YS TT006	Hook	HKRC001	421699	7360547	17/05/15–14/07/15	18	17	10	PLgpi
YS TT007	Hook	HKRC002	421721	7360502	17/05/15–15/07/15	90	14	10	PLgpi
YS TT008	Hook	HKRC011A	421436	7360316	17/05/15–15/07/15	72	18	15	PLgpi
YS TT009	Kane's Gossan	KGRC017	425000	7358976	16/05/15–15/07/15	54	22	10	PLgpi
YS TT010	Kane's Gossan	KGRC007	424783	7359167	16/05/15–15/07/15	36	22	15	PLgpi
YS TT011	Lion's Ear	LERC010	419837	7360679	18/05/15–15/07/15	36	-	10	PLgpi
YS TT012	Lion's Ear	LERC011	419820	7360645	18/05/15–15/07/15	84	16	10	PLgpi
YS TT013	Yangibana North	YGRC057	417194	7362389	18/05/15–15/07/15	24	18	10	PLgpi
YS TT014	Yangibana North	YGRC059	417186	7362472	18/05/15–15/07/15	18	-	10	PLgpi
YS TT015	Yangibana North	YGRC063	417129	7362480	18/05/15–15/07/15	30	15	10	PLgpi
YS TT016	Fraser's	FFRC007	429788	7350819	18/05/15–16/07/15	24	-	20	C1f
YS TT017	Fraser's	FFRC010	429713	7350794	18/05/15–16/07/15	26.5	-	25	C1f
YS TT018	Fraser's	FRRC011	429696	7350820	18/05/15–16/07/15	70	34.8	25	C1f
Phase 2 Trapping									
YS TT019	Bald Hill	BHRC151	427978	7356353	25/09/15-24/11/15	78	6.3	5	PLgpi
YS TT020	Bald Hill	BHRC061	428299	7356299	26/09/15-24/11/15	84	33.5	20	PLgpi
YS TT021	Bald Hill	BHRC133	428319	7356653	26/09/15-24/11/15	46		15	PLgpi
YS TT022	Bald Hill	BHRC047	428272	7356499	26/09/15-24/11/15	40		20	PLgpi
YS TT023	Bald Hill	BHRC002	428330	7355776	26/09/15-24/11/15	84	28	20	PLgpix
YS TT024	Bald Hill	BHRC009	428278	7356015	26/09/15-24/11/15	72	32.5	10	C1f
YS TT025	Bald Hill	BHRC067	428239	7356209	26/09/15-24/11/15	46	28.8	15	PLgpi
YS TT026	Yangibana N	YGRC063	417130	7362484	27/09/15-24/11/15	30.5	15.8	8	PLgpi

Sample	Deposit	Hole id	Coordinates		Date	Total depth (m)	Depth to water (m)	Depth sampled (m)	Geology
			Easting	Northing					
YS TT027	Yangibana N	YGRC057	417189	7362389	27/09/15-24/11/15	24	17.1	8	PLgpi
YS TT028	Yangibana N	YGRC059	417186	7362472	27/09/15-24/11/15	19	-	9	PLgpi
YS TT029	Yangibana Proposed Camp	YGWB002	413164	7361422	27/09/15-24/11/15	31	-	8	A3ti
YS TT030	Gossan	GSRC009	418412	7361003	28/09/15-24/11/15	96	28	10	PLgpi
YS TT031	Lion's Ear	LERC010	419836	7360689	28/09/15-24/11/15	36	17	13	PLgpi
YS TT032	Lion's Ear	LERC011	419818	7360647	28/09/15-24/11/15	84	16.5	18	PLgpi
YS TT033	Lion's Ear	LERC007	419950	7360660	28/09/15-25/11/15	24	19.5	14	PLgpi
YS TT034	Lion's Ear	LERC008	419943	7360619	28/09/15-25/11/15	90	14	12	PLgpi
YS TT035	Hook	HKRC011A	421424	7360320	29/09/15-25/11/15	72	19	16	PLgpi
YS TT036	Hook	HKRC002	421721	7360502	29/09/15-25/11/15	90	14.5	10	PLgpi
YS TT037	Kane's Gossan	KGRC011	424845	7359037	29/09/15-25/11/15	78	19.5	14	PLgpi
YS TT038	Kane's Gossan	KGRC018	425016	7358903	29/09/15-25/11/15	108	19	14	PLgpi
YS TT039	Frasers	FRRC007	429790	7350821	30/09/15-25/11/15	25	-	14	C1f
YS TT040	Frasers	FRRC010	429711	7350794	30/09/15-24/11/15	26	-	14	C1f
YS TT041	Frasers	FRRC011	429697	7350822	30/09/15-25/11/15	72	34	25	C1f
YS TT042	Frasers	FRRC020	429930	7351012	30/09/15-25/11/15	58	54	30	PLgpi
YS TT043	Frasers	FRRC022	429961	7351040	30/09/15-25/11/15	52	32.7	20	PLgpi
YS TT044	Frasers	FRRC023	430031	7351034	30/09/15-25/11/15	28	-	23	PLgpi
Phase 1 - scraping									
YS TS001	Bald Hill	BHRC012	428318	7356032	16/05/15	70	24	entire dry column	C1f
YS TS002	Hook	HKRC001	421699	7360547	17/05/15	18	17	entire dry column	PLgpi
YS TS003	Hook	HKRC007	421521	7360393	19/05/15	21	-	entire dry column	PLgpi
YS TS004	Lion's Ear	LERC010	419837	7360679	17/05/15	36	-	entire dry column	PLgpi
YS TS005	Yangibana North	YGRC059	417186	7362472	18/05/15	18	-	entire dry column	PLgpi
YS TS006	Fraser's	FFRC010	429713	7350794	18/05/15	26.5	-	entire dry column	C1f
Phase 2 - scraping									
YS TS007	Bald Hill	BHRC151	427978	7356353	25/09/15	78	6.3	entire dry column	PLgpi
YS TS008	Bald Hill	BHRC061	428299	7356299	26/09/15	84	33.5	entire dry column	PLgpi
YS TS009	Bald Hill	BHRC133	428319	7356653	26/09/15	46	-	entire dry column	PLgpi

Sample	Deposit	Hole id	Coordinates		Date	Total depth (m)	Depth to water (m)	Depth sampled (m)	Geology
			Easting	Northing					
YS TS010	Bald Hill	BHRC047	428272	7356499	26/09/15	40	-	entire dry column	PLgpi
YS TS011	Bald Hill	BHRC002	428330	7355776	26/09/15	84	28	entire dry column	PLgpix
YS TS012	Bald Hill	BHRC009	428278	7356015	26/09/15	72	32.5	entire dry column	C1f
YS TS013	Bald Hill	BHRC067	428239	7356209	26/09/15	46	28.8	entire dry column	PLgpi
YS TS014	Yangibana N	YGRC063	417130	7362484	27/09/15	30.5	15.8	entire dry column	PLgpi
YS TS015	Yangibana N	YGRC057	417189	7362389	27/09/15	24	17.1	entire dry column	PLgpi
YS TS016	Yangibana N	YGRC059	417186	7362472	27/09/15	19	-	entire dry column	PLgpi
YS TS017	Yangibana Proposed Camp	YGWB002	413164	7361422	27/09/15	31	-	entire dry column	A3ti
YS TS018	Gossan	GSRC009	418412	7361003	28/09/15	96	28	entire dry column	PLgpi
YS TS019	Lion's Ear	LERC010	419836	7360689	28/09/15	36	17	entire dry column	PLgpi
YS TS020	Lion's Ear	LERC011	419818	7360647	28/09/15	84	16.5	entire dry column	PLgpi
YS TS021	Lion's Ear	LERC007	419950	7360660	28/09/15	24	19.5	entire dry column	PLgpi
YS TS022	Lion's Ear	LERC008	419943	7360619	28/09/15	90	14	entire dry column	PLgpi
YS TS023	Hook	HKRC011A	421424	7360320	29/09/15	72	19	entire dry column	PLgpi
YS TS024	Hook	HKRC002	421721	7360502	29/09/15	90	14.5	entire dry column	PLgpi
YS TS025	Kane's Gossan	KGRC011	424845	7359037	29/09/15	78	19.5	entire dry column	PLgpi
YS TS026	Kane's Gossan	KGRC018	425016	7358903	29/09/15	108	19	entire dry column	PLgpi
YS TS027	Frasers	FRRC007	429790	7350821	30/09/15	25	-	entire dry column	C1f
YS TS028	Frasers	FRRC010	429711	7350794	30/09/15	26	-	entire dry column	C1f
YS TS029	Frasers	FRRC011	429697	7350822	30/09/15	72	34	entire dry column	C1f
YS TS030	Frasers	FRRC020	429930	7351012	30/09/15	58	54	entire dry column	PLgpi
YS TS031	Frasers	FRRC022	429961	7351040	30/09/15	52	32.7	entire dry column	PLgpi
YS TS032	Frasers	FRRC023	430031	7351034	30/09/15	28	-	entire dry column	PLgpi

Zone: 50K, Datum: GDA 94

APPENDIX SEVEN: TAXONOMIC REPORTS

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Damien Cancilla
Group Leader Environment
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Dear Damien

Re: Subterranean Fauna Identifications for Hastings Rare Metals

1 Background

As requested, this short report provides our identifications for invertebrate species in the subterranean target groups and provides additional information on their status according to the framework of the Western Australian Museum. It also includes the collecting localities for each species and some general information on the groups present at the Project. The SRE status of all species is assessed according to the current framework of the Western Australian Museum.

2 Methods

Animals were identified morphologically using dissecting and compound microscopes, as necessary, and the available taxonomic literature, unpublished keys and reference collections. All animals were identified by Jane McRae.

3 Stygofauna

Overall, 236 stygofauna specimens from four families were collected from eight bores and represent at least ten species.

3.1 Copepoda

Four species of Copepoda were collected in the current survey belonging to two families, Cyclopidae and Ameiridae. A fragment from a single *Diacyclops* specimen was collected from HKRC002 and identification beyond genus was not possible due to a lack of key taxonomic characters.

Diacyclops cockingi
This species is wide ranging throughout the Pilbara and is not of conservation concern.

Diacyclops humphreysi humphreysi
This species is wide ranging throughout the Pilbara and is not of conservation concern.

Orbuscyclops westraliensis
This species is wide ranging throughout the Pilbara and is not of conservation concern.

Ameiridae gen. nov. sp. B04
Four specimens were collected from Andy's Bore. The taxonomic characters did not key to any known genus and the species was treated as belonging to a new genus. It differs from *Archinitocrella* and *Nitocrellopsis*, the genera it may be most closely related to, in having a unique arrangement of the setae on exopodal segments P2-P4 (setation pattern 3/2/2 in the new genus; 2/2/2 in *Archinitocrella* and *Nitocrellopsis*). Taxonomic resolution in the Australian Ameiridae fauna is poor and species identification difficult. However, most species in this group from subterranean habitats have short ranges. *Ameiridae* gen. nov. sp. B04 is currently known only from Andy's Bore and a potential SRE with deficient data. It is of potential conservation concern.

3.2 Ostracoda

A single species of Ostracoda was recorded in the survey belonging to the genera *Areacandona*.

Areacandona sp. BOS550
Ten specimens of this new species were collected from Andy's Bore. This species is close to *Areacandona triangulorum* which has a small complex hemipenis with three distal lobes, but differs in that the furca has a much reduced posterior claw and setae. *Areacandona* species in the Pilbara can have very short ranges (Karanovic 2007) and *Areacandona* sp. BOS550 is a potential SRE based on previous research. It is presently known only from this record and likely to be of potential conservation concern.

3.3 Amphipoda

Amphipods are common in subterranean surveys of the Pilbara and Yilgarn regions of Western Australia, however taxonomic resolution is very poor and it is likely that there are many undescribed genera and many species will have restricted ranges.

Paramelitidae sp. B49
Nine adult specimens in the family Paramelitidae were collected from LERC010. There is no taxonomic framework for Paramelitidae in Western Australia and species identification is difficult. However, many subterranean Paramelitidae in Australia have short ranges. Endemism in this fauna is pronounced and species are typically confined to single karst systems or calcretes (Eberhard *et al.* 2005). Paramelitidae sp. B49 is a potential SRE with deficient data and likely to be of potential conservation concern.

Paramelitidae sp.
Two juvenile Paramelitidae species were recorded from bore HKRC002 and could not be identified to species level. These animals are likely to be Paramelitidae sp. B49 as bore HKRC002 is in close proximity to bore LERC010.

3.4 Oligochaeta

Oligochaetes are very common in environmental surveys in arid Australia. Taxonomic resolution is often poor in this fauna. At least three species of Oligochaeta were collected in this survey from two families, Phreodrilidae and Enchytraeidae.

Phreodrilus peniculus
Seven specimens were collected from two bores in this survey, four from HKRC002 and three from LERC010. This species is wide ranging throughout the Pilbara and is not of conservation concern.

Phreodrilidae with dissimilar ventral chaetae
Three specimens were collected from two bores in this survey, two from Andy's Bore and one from LERC008. This is a grouping of several species of juvenile phreodrilids. It is conventionally treated, however, as a wide ranging species in the Pilbara and not of conservation concern.

Enchytraeus sp. 1 (PSS) Pilbara
Nineteen specimens were collected from two bores YGRC057 and HKRC002. This species is wide ranging throughout the Pilbara and is not of conservation concern.

3.5 Nematoda
Nematodes are widespread and very common in environmental surveys in Australia. Almost nothing is known about free-living nematodes in WA outside agricultural situations. For this reasons, the status of nematodes is not assessed in environmental assessments.

Thirteen specimens were collected in the current survey.

4 Troglofauna
Eleven troglofauna specimens from five orders were collected from five bores and represent at least five species.

4.1 Isopoda
Three specimens were collected from FFRC010. There are no other records of this genus from the vicinity of the Project and *Trogloarmadillo* sp. B60 is almost certainly a new species. Subterranean slaters in Western Australia almost always have short ranges and local endemism in this fauna is very high. There is no taxonomic framework for *Trogloarmadillo* but the species collected in this survey is known only from a single bore and classified here as a potential SRE with deficient data. It is likely to be of potential conservation concern.

4.2 Thysanura
Trinemura sp. B29
Five specimens were collected from three locations (FFRC010, KGRC007 and BHRC002), all within 10 km from each other. These specimens belong to an undescribed species and do not key out to any known species (Smith 1988). *Trinemura* can be moderately widespread in subterranean habitats although ranges are almost always smaller than 10,000 km^2. *Trinemura* sp., B29 is a potential SRE with deficient data and of potential conservation concern.

4.3 Geophilida
Geophilida centipedes are thought to have comparatively restricted ranges, although in reality so little is known about the ranges of troglofaunal centipedes that this is an unreliable generalisation.

One specimen was collected from KGRC011 but was in such poor condition when preserved that identification beyond order was not possible. It is not possible to assess this specimen further.

4.4 Diplura
Projapygidae sp. B19
One specimen was collected from KGRC007. There are no other records of projapygids in the Project vicinity and this is almost certainly a new species. Local endemism in the projapygid fauna is very high and almost all species have very short rangers, often just a few km^2 in subterranean habitats. Projapygidae sp. B19 is classified here as a potential SRE with deficient data according to the SRE framework of the Western Australian Museum. The species is likely to be of conservation concern.

4.5 Symphyla

Scutigerella sp. B09

One specimen was collected from BHRC006 and almost certainly represents a new species because there are no additional records of this group from near the Project vicinity. Most symphylans in subterranean habitats have very small ranges that are far smaller than the current SRE threshold of 10,000 km^2 (Harvey 2002). There is no taxonomic framework for symphylans in Australia and the identification of species is difficult. Consequently, *Scutigerella* sp. B09 is classified here as a potential SRE with deficient data. This is a singleton species, presently known only from the impact area, and likely to be of conservation concern.

For a discussion of species ranges within different orders, look at Halse et al. (2014).

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