



Mega Lake Maitland Pty Ltd

Lake Maitland Uranium Project

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Stygofauna Assessment

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Lake Maitland Uranium Project Stygofauna Assessment

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Executive Summary

Mega Lake Maitland Pty Ltd. (Mega) commissioned Outback Ecology to undertake a Level 2 (baseline) stygofauna assessment of the proposed Lake Maitland Uranium Project (LMUP). The LMUP is located in the eastern Goldfields region of Western Australia, approximately 95 kilometres (km) north east of Leinster, nearly 700 km north east of Perth. The LMUP comprises a shallow open cut uranium mine that will produce uranium peroxide concentrate ($UO_4\, 2\, H_2O$). The current projected life of mine for uranium mining-production is 12 years.

The objective of this assessment reported herein was to investigate the stygofauna values of the LMUP area and to assess if the removal or modification of potential habitat and groundwater drawdown will pose a conservation risk to any species of the Barwidgee calcrete stygofauna assemblage Priority Ecological Community (PEC) that occur within the Carey palaeodrainage on Barwidgee Station. The scope of this assessment encompassed a literature review, database searches and a baseline stygofauna survey of the LMUP.

Survey effort

The stygofauna survey effort (ES Table 1), involved:

- 165 net haul samples from 87 holes were collected over ten rounds of sampling in January 2007, May 2007, December 2008, March 2010, August 2010, February 2011, March 2011, July 2011, September 2011, and November 2011.

ES Table 1: Stygofauna survey effort

Survey period	Non-impact	Impact			Total
		Mining operations area		Borefield drawdown (>0.5m)	
		Drawdown (>0.5m)	Resource		
No. Samples	54	36	54	21	165
No. Holes	23	20	35	9	87

Results

The LMUP stygofauna assessment found the diversity of the Barwidgee calcrete stygofauna PEC to be comparable to the Lake Way associated calcrete PEC's, Lake Violet, Hinkler Well and Uramurdah. The findings are summarised as follows:

- Twenty eight species of stygofauna were recorded. Twenty seven species were collected from 83 of the 165 samples from 28 of the 87 bores sampled. One species, *Limbodessus usitatus,* was not collected but is known from published records to occur in the Barwidgee calcrete outside the LMUP impact zones;
- Twenty three species were recorded from the Barwidgee calcrete and northern Lake Maitland playa system;

- six species were recorded from the upper tributary catchment area to the north of Lake Maitland associated with the proposed borefield;
- three of the 28 stygofauna species recorded were of conservation concern because their distributions were not demonstrated to occur outside of the Mining operations impact areas. These were:
  - o Chiltoniidae sp. SAM4 and *Schizopera* sp. TK1 — not recorded outside the mining operations resource area; and
  - o *Haloniscus* sp. OES1 — not recorded outside the mining operations modelled 0.5 m groundwater drawdown (without mitigation) contour.

Assessment

The proposed mining of the resource area is not considered likely to pose a long term conservation risk to Chiltoniidae sp. SAM4 or *Schizopera* sp. TK1 when taking into consideration the:

- limited area of calcrete habitat removal associated with mining excavation, relative to the much greater expanse of adjacent calcrete habitat remaining;
- broader distribution patterns and habitat preferences of other chiltoniid and *Schizopera* species;
- broader distributions and habitat preferences of other members of the stygofauna assemblage that were collected sympatrically; and
- expected operational life of the LMUP (12 years).

The modelled groundwater drawdowns associated with the proposed mining of the resource area is not considered likely to pose a long term conservation risk to the stygal isopod, *Haloniscus* sp. OES1, when taking into consideration the:

- the depth of the modeled groundwater drawdowns within the 0.5 to 1 m contours are not considered to be of a large enough magnitude to lower the SWL to such an extent to render the inhabited subterranean environments present uninhabitable;
- large lateral and vertical extent of adjacent calcrete habitat remaining outside of the Mining operations impact areas;
- broader distributions and habitat preferences of other sympatric members of the stygofauna assemblage; and
- expected operational life of the LMUP (12 years).

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1. INTRODUCTION

1.1. Project Background

Mega Lake Maitland Pty Ltd. (Mega) proposes to develop the Lake Maitland Uranium Project (LMUP) in the eastern Goldfields region of Western Australia, approximately 95 kilometres (km) north-east of Leinster and 105 km south-east of Wiluna **(Figure 1).** The LMUP will produce uranium peroxide concentrate (UO_4 2 H_2O), which will be transported to a designated uranium export facility in either South Australia or the Northern Territory. The current projected life of mine for uranium mining-production is 12 years, with the potential to extend operations dependent on resource availability and future approvals with the relevant statutory authorities.

At a state level, the Environmental Protection Authority (EPA) set the level of assessment for the LMUP as an Environmental Review and Management Programme (ERMP). Federally, The Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) determined that the proposal is a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This means it will be assessed under the bilateral agreement between the Commonwealth and the Western Australia State Government.

The proposed LMUP consists of a:

- Mining Operations Area;
- shallow open cut uranium mine;
- waste management facilities;
- borefield and associated pipeline;
- mineral processing facility;
- accommodation village;
- external and internal roads; and
- diesel powered electricity generation plant **(Figure 2).**

As part of the requirements for environmental approval of the proposal, Mega commissioned Outback Ecology to undertake a suite of baseline studies to investigate the ecology and potential risk posed by the LMUP. This report is one component of those studies, examining the diversity and distribution of the stygofauna assemblage within the LMUP that are listed as the Barwidgee calcrete stygofauna assemblage Priority Ecological Community (PEC) (Department of Environment and Conservation 2011) (**Figure 2**).

1.2. Scope And Objectives

The overarching objective of this assessment was to document the diversity and abundance of the Barwidgee stygofauna assemblage PEC within the LMUP and to investigate if the removal of potential habitat through excavation and groundwater drawdown will place any stygofauna within the LMUP at risk. Specific objectives of the assessment were to:

- evaluate the habitats within the proposed mining areas that support stygofauna;
- identify any potential risks to obligate stygofauna from the proposed mining activities; and
- consider the conservation significance of any stygofauna species occurring within the LMUP.

The scope of this assessment encompassed a literature review, database searches and a Level 2 stygofauna survey of the LMUP. This report provides the results of the stygofauna survey and presents an Environmental Impact Assessment of the LMUP.

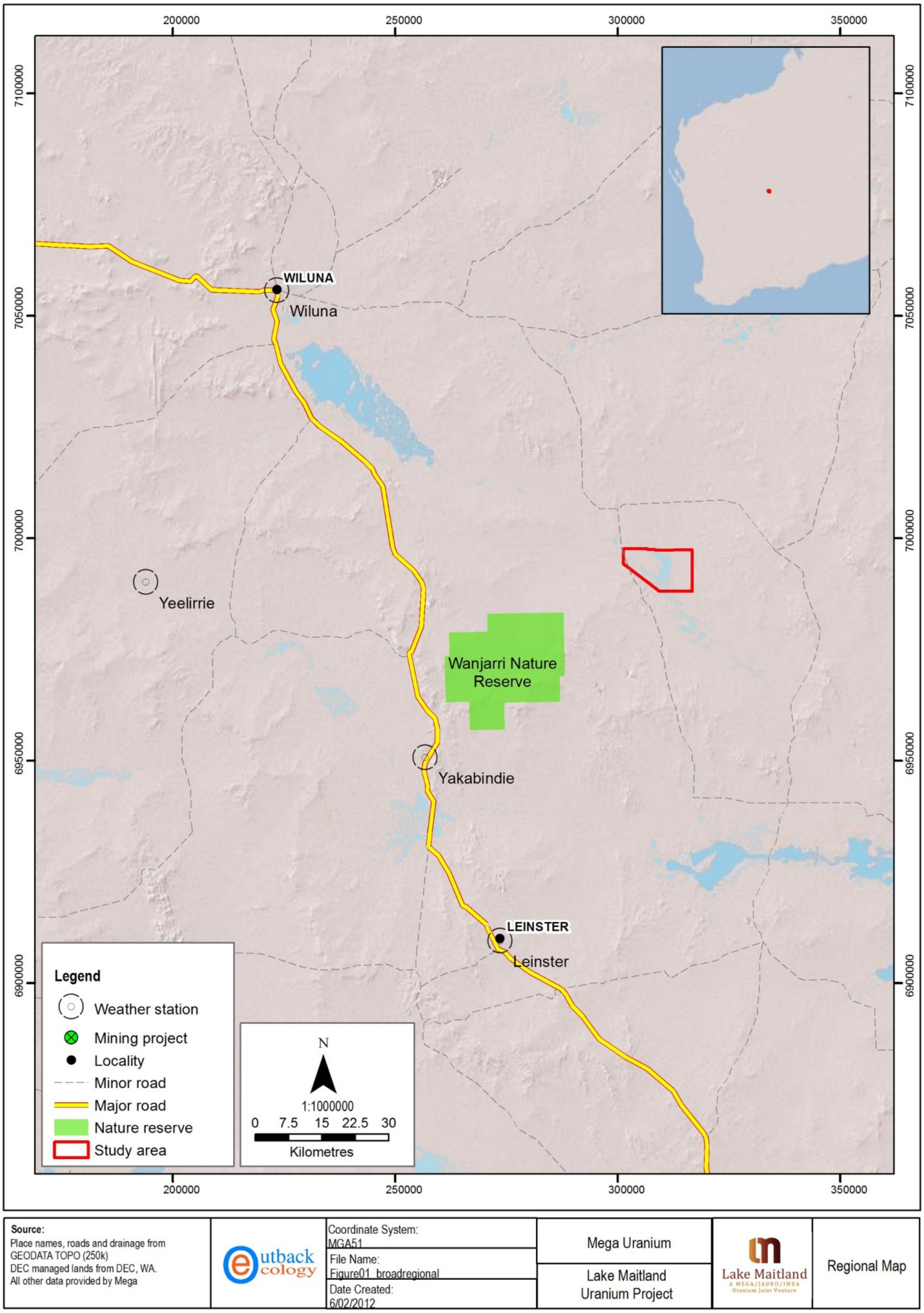

Figure 1: Regional location of the LMUP in the eastern Goldfields region

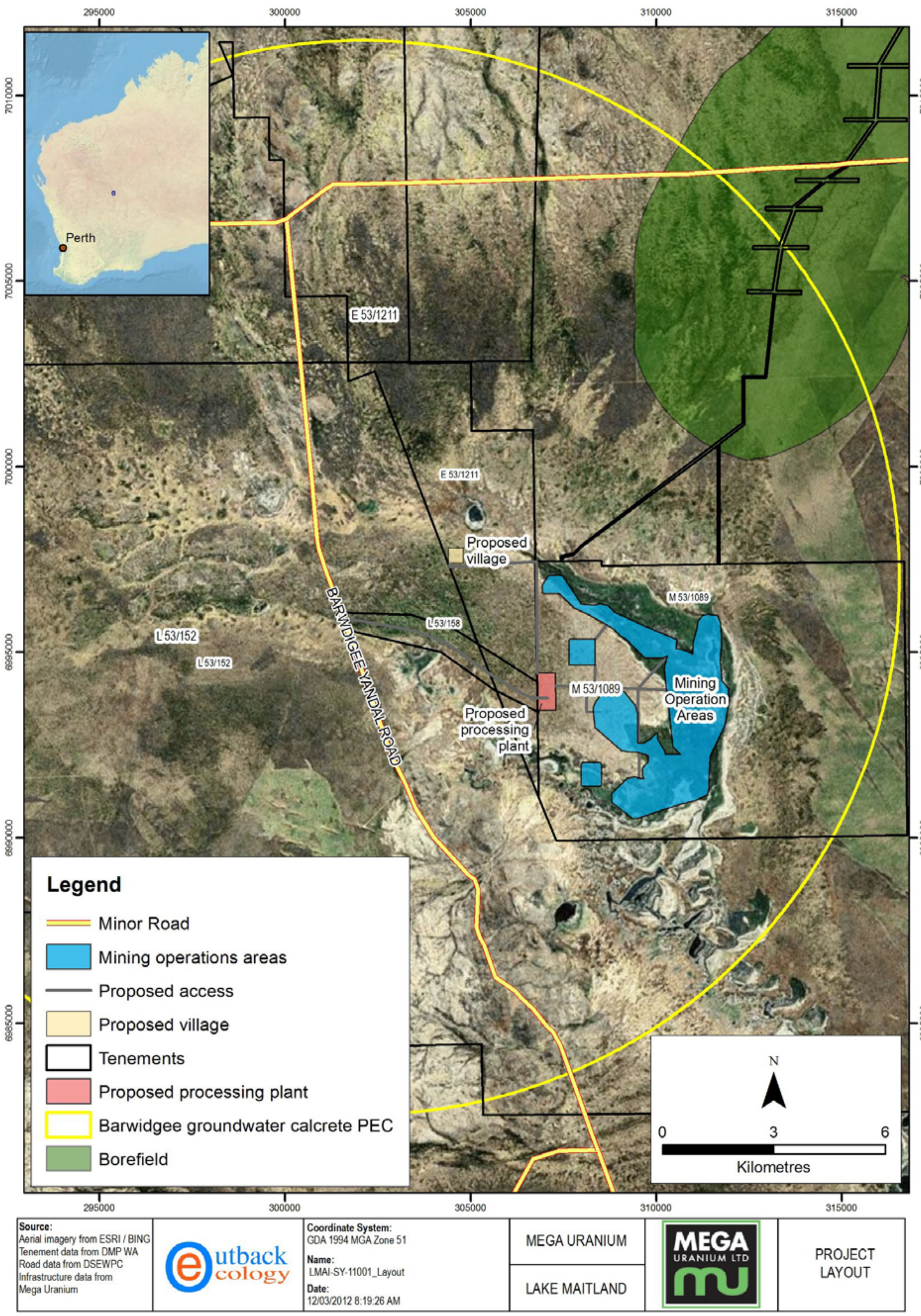

Figure 2: Proposed LMUP borefield, village, processing plant, and mining operations areas.

1.3. Biogeographic Region

The Interim Biogeographic Regionalisation for Australia (IBRA) is a bioregional framework that divides Australia into 85 bioregions and 403 subregions on the basis of climate, geology, landforms, vegetation and fauna. It was developed through collaboration between state and territory conservation agencies with coordination by DSEWPC (2010).

The LMUP is located within the Eastern Murchison (MUR1) subregion of the Murchison Bioregion, which covers an area of 7,847,996 ha **(Figure 3).** This subregion consists of extensive areas of elevated red/red-brown desert sandplains with minimal dune development, breakaway complexes and internal drainage and salt lake systems associated with the occluded Palaeodrainage system. Mulga woodlands dominate the subregion, as well as hummock grasslands, saltbush and samphire shrublands (Cowan 2001). Halophytic shrublands (mainly comprising *Tecticornia*) occur adjacent to salt lake systems (Pringle *et al.* 1994). Land use within the Eastern Murchison subregion comprises of grazing, mining, customary indigenous purposes, unallocated crown land (UCL), crown and conservation reserves. Grazing of stock on pastoral leases is the dominant land use in the subregion, with the area also having an extensive history of mining activity and associated disturbance (Cowan 2001, NLWRA 2002).

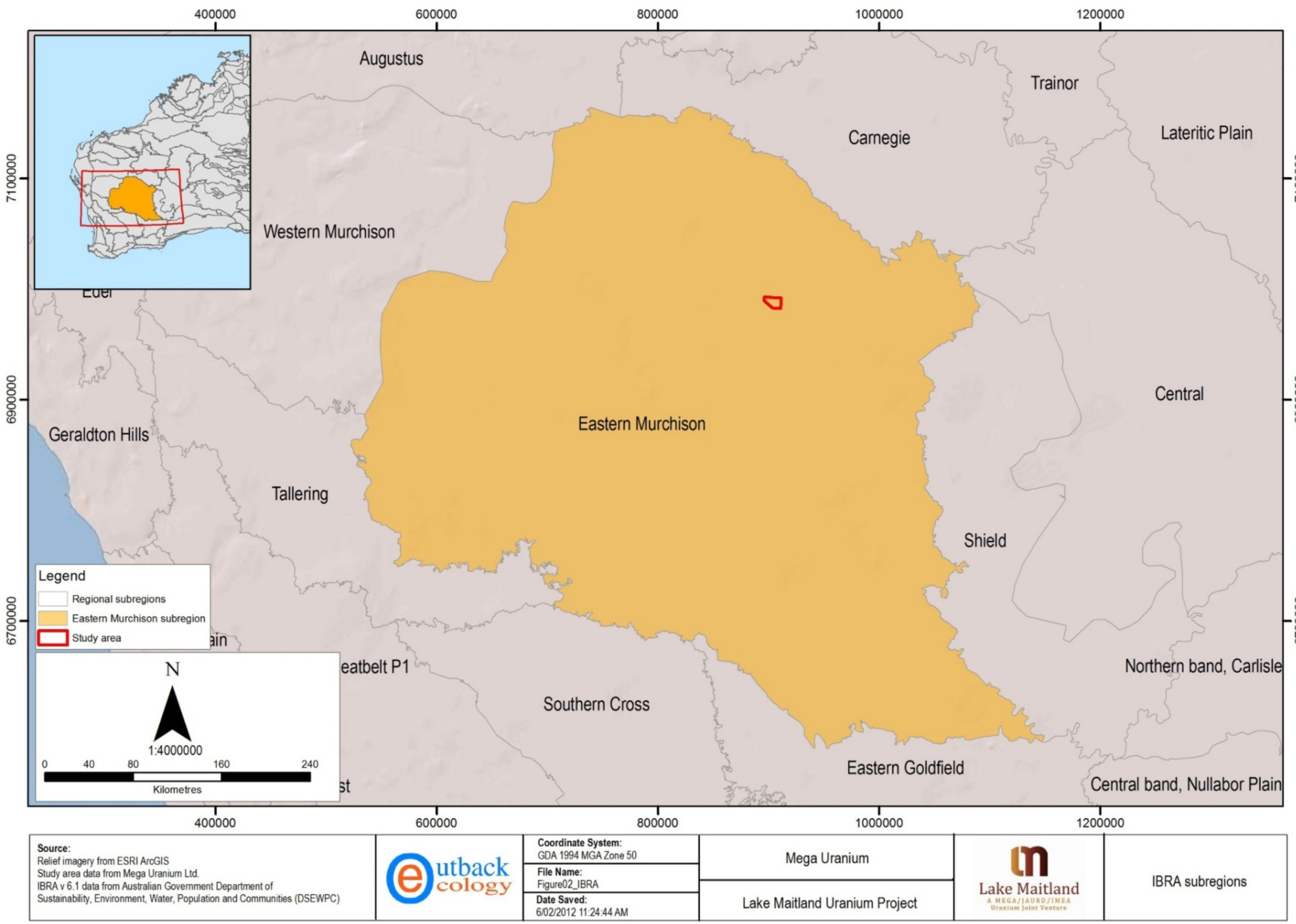

Figure 3: Location of the LMUP within the Eastern Murchison (MUR1) subregion

1.4. Climate

The Murchison Bioregion is characterised as having an arid climate, with hot summers and cool winters. Summer weather is influenced by anti-cyclonic systems to the south-east, creating a pattern of clear skies and easterly winds. The region borders the southern end of the Intertropic Convergence Zone and, as a result, thunderstorm activity and summer rainfall is generated. The anti-cyclonic system also directly influences winter weather patterns, generating westerly winds and rain-bearing frontal systems (Gilligan 1994).

The average annual rainfall from the Wonganoo Weather Station (located approximately 25 km to the east of the LMUP) is 225 mm. The majority of rainfall occurs between January and June **(Figure 4)** resulting from summer cyclonic rains and isolated thunderstorms. Maximum temperatures in summer often exceed 40 °C, in comparison to winter, where temperatures average 20 °C. Evaporation rates are high, exceeding 3,000 mm per annum (BOM 2011).

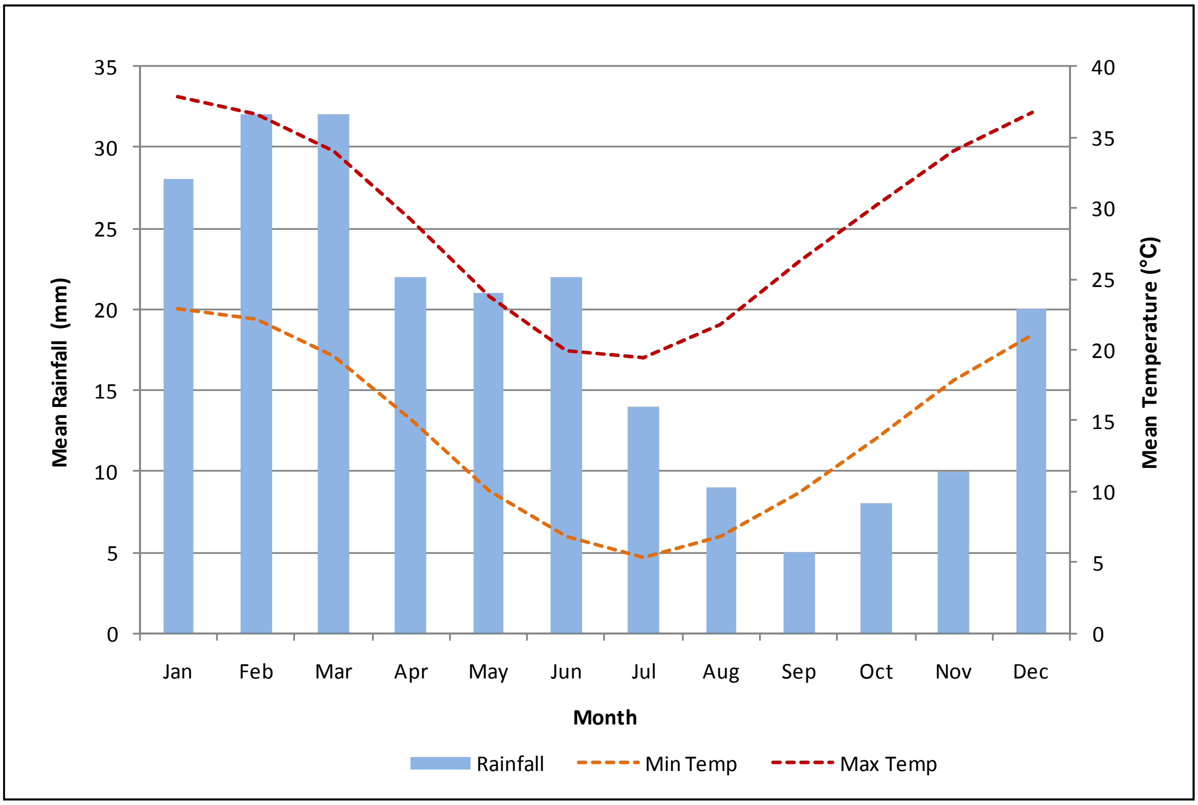

Figure 4: Long-term average monthly rainfall for Wonganoo Weather Station, compared to the minimum and maximum temperatures recorded for the Wiluna Weather Station (Bureau of Meteorology 2011).

1.5. Topography and Surface Hydrology

Lake Maitland is a modern saline remnant of a previously freshwater system that has become saline in response to the long term (over millions of years) drying of the Australian climate (the onset of aridity). The LMUP will be developed within the existing playa of Lake Maitland, which exhibits extremely low topographical relief. The catchment watershed upstream of the LMUP has an overall area of approximately 15,000 km^2 and extends 115 km north-west of Wiluna. Lake Maitland is part of the Carey Palaeodrainage, which is poorly defined and dominated by several large, saline playa systems including Lake Way and Lake Carey.

Drainage is internal and existing streams flow only intermittently following intense rainfall. Flow channels vary in alignment over time, as a result of the low surface gradients and limited vegetative cover. Lake Maitland contains a number of depressions that can hold water for extended periods after heavy rainfall. However, filling events are rare and anecdotal evidence suggests the last substantial inundation event occurred following Cyclone Bobby in March 1995 (Golder Associates 2011).

Claypans are common throughout the region and along the periphery of Lake Maitland. Some may host surface water for several months of the year. These semi-permanent water bodies provide important habitat for biota (including migratory birds), and are culturally significant (Golder Associates 2011).

1.6. Geology and Mineralisation

The LMUP is located within the northern part of the Archaean Yilgarn Craton of Western Australia. The basement rocks in the local area are part of the Yandal greenstone belt, and mostly consist of mafic igneous rocks, granites and quartzofeldspathic gneiss. Felsic volcanic and volcaniclastic rocks and sedimentary rocks are located to the north and south of the LMUP (Golder Associates 2011).

Uranium mineralisation at Lake Maitland occurs predominantly as carnotite, primarily hosted within nodular carbonates, lacustrine clays and fluvial sands in low-lying areas. These sediments are of early Tertiary (basal units) to Quaternary (surfical units) age. The carnotite is generally disseminated within the lacustrine clays and sands and occurs within voids and fractures in the carbonates. Mineralisation arose after the erosion and precipitation of Archaean granitic and greenstone rocks in the catchment, as transporting fluids became concentrated through evaporation (Golder Associates 2011).

1.7. Groundwater Hydrogeology

Groundwater at Lake Maitland typically occurs within 1 m of the surface and the uranium deposit is shallow (5 to 6 m deep). The deposit is located within the main palaeodrainage running from north-west to south-east. The underlying palaeochannel is approximately 60 m below the surface. The deposit and the palaeochannel sands are separated by a thick, semi-confining layer of clay, with low hydraulic gradients and conductivities (Golder Associates 2011).

Calcrete deposits occur at various locations in the palaeodrainage system and flank the playa, having formed in past freshwater systems on the periphery of the lake. They have been subject to weathering and in places are karstic, hosting voids. The surficial calcrete deposits and the deeper palaeochannel sands form long and continuous aquifers. While most of the intervening fine-grained sedimentary sequence is regarded as an aquitard (impermeable), there may be local zones of higher permeability within it (Golder Associates 2011).

Groundwater comprises of dense brines in low-lying areas with salinities in the main trunk of the palaeochannel ranging from 100 ppt to 250 ppt. Discharge mainly occurs by evaporation, with only a very small portion of the groundwater flowing out of the area through the palaeochannel aquifer. Salinity in the calcrete aquifers varies depending on proximity to the playa, ranging from <5 ppt to over 100 ppt (Golder Associates 2011).

2. STYGOFAUNA

2.1. Background

Stygofauna (groundwater fauna) are predominantly comprised of invertebrates, particularly crustaceans. Other invertebrate stygofauna groups can include gastropods, insects, water mites and worms. Stygofauna can be further classified according to their level of dependency on the subterranean environment:

- *stygoxenes* are animals that enter groundwaters passively or accidentally;
- *stygophiles* inhabit groundwaters on a permanent or temporary basis; and
- *stygobites* are obligate groundwater dwellers.

Stygobites are restricted to their subterranean environment and as such can have restricted distributions. Short range endemic species are defined as species that have geographically restricted ranges of less than 10,000 km^2 and are considered more vulnerable to extinction because of their limited distribution range (Harvey *et al.* 2011, Harvey 2002). Stygobites may often be distinguished from surface water dwelling animals by morphological characteristics typical of a subterranean existence, such as a reduction or absence of pigmentation, absence or reduction of eyes, and the presence of extended locomotory and sensory appendages (Humphreys 2008). They can also be defined by ecological parameters such as longer life history stages, lower metabolisms and fecundity rates (Cooper *et al.* 2002, Danielopol and Pospisil 2000).

Stygofauna occur in various types of aquifers that exhibit voids of a suitable size for biological requirements (Humphreys 2008). In Australia, research efforts and improved sampling techniques have revealed a rich stygal community. Although previously thought to be restricted to karst landscapes, stygofauna have now been found in alluvial sediments, fractured rock aquifers, pisolites and thin regoliths (Guzik *et al.* 2011, Humphreys 2006, Humphreys 2008, Subterranean Ecology 2008). In Western Australia, studies have shown that the calcrete and alluvial aquifers associated with palaeodrainage channels of the arid and semi-arid zones contain rich stygofauna communities. The Pilbara and, to a lesser extent, the Yilgarn are considered as global hotspots for stygofauna diversity (Environmental Protection Authority 2007).

2.2. Risks And Relevant Legislation

Subterranean fauna are protected under State and Federal legislation, governed by three acts:

- *Western Australian Wildlife Conservation Act 1950 (WC Act);*
- *Environmental Protection Act 1986 (WA)(EP Act);* and
- *The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).*

The DEC is responsible for administering the *Wildlife Conservation Act 1950*, and maintains a list of rare or threatened species of subterranean fauna, or those with high conservation value. The DEC also recognizes four categories of Threatened Ecological Communities (TEC's), as well as PEC's that are possibly threatened and/or have not yet been adequately defined (Department of Environment and Conservation 2007).

Threatened species and ecological communities that occur in Western Australia may also be listed as nationally threatened under the federal *EPBC Act* (Department of Sustainability Environment Water Population and Communities 2010). These state and federal lists are maintained by the DEC and the DSEWPC and provide important information on significant stygofauna and troglofauna communities that may be at risk from proposed mining activities.

With this legislation in mind, the EPA has developed two key documents to guide the assessment process for activities that could potentially impact on subterranean fauna or habitat:

- *Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves During Environmental Impact Assessment in Western Australia (2003); and*
- *Guidance Statement No. 54a Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (Technical Appendix to Guidance Statement 54) (2007).*

These documents provide advice to proponents and the public on the EPA's minimum requirements for environmental impact assessment (EIA) and management of subterranean fauna. Proposed developments will be subject to formal EIA under the Western Australian *EP Act* if they could have a significant impact on stygofauna or troglofauna habitat by:

- lowering the water table sufficiently to dry out the zone in which some species live, or otherwise artificially changing water tables; or
- changing water quality (e.g. increasing salinity levels or altering haloclines, increasing nutrient levels or the availability of organic matter, or introducing other pollutants); or
- destroying or damaging caves, including changing their temperature and humidity (Environmental Protection Authority 2003).

In accordance with these Guidance Statements, there are components of the Project that require a subterranean fauna assessment:

- *Mining Resource Area.* Mining will involve the physical removal of waste and ore material and the lowering of groundwater levels through mine pit dewatering; and
- *Borefield*. Water abstraction to supply mining activity demands will involve the lowering of groundwater levels.

These mining activities represent potential threats to the Barwidgee calcrete stygofauna assemblage Priority Ecological Community (PEC) within the Carey palaeodrainage on Barwidgee Station. This priority area is recognised due to unique assemblages of stygofauna invertebrates recorded from the groundwater within the calcrete system. The area is classified as a priority 1, under the *Western Australian Wildlife Conservation Act (1950)*, due to the '*poorly known ecological communities'* that are '*known from very few occurrences with a very restricted distribution*' (Department of Environment and Conservation 2011). Therefore, a Level 2 (baseline) stygofauna survey is required to better document the species diversity and distribution of the Barwidgee calcrete stygofauna PEC to assess the potential impacts to species that occur in the area.

Other indirect impacts on the stygofauna assemblage from proposed mining activity include a potential increase in run-off sediment load which:

- could reduce available habitat by infilling of interstitial spaces; and
- lessen input of resources from surface to subsurface during flow periods (Marmonier 1991).

Mining proposals that will potentially impact on subterranean habitats that support stygofauna require a risk assessment to ensure mining operations do not threaten the viability of significant taxa. Proponents must demonstrate that any threatened species within the potential impact zone also occur outside this area. For taxa restricted to the impact zone, a suitable management plan must be developed, which includes ongoing monitoring of troglofauna, ensuring the persistence of species (Environmental Protection Authority 2003).

3. METHODS

3.1. Literature Review

A literature review was conducted to gather relevant publically available information on stygofauna from the vicinity of the LMUP area in similar habitats. The review included technical reports, scientific journal articles and government publications. The most relevant report available was the subterranean fauna assessment of the Lake Way associated calcrete systems (Outback Ecology 2011b).

3.2. Database Search

Both federal and state database searches were undertaken as part of the desktop review to develop a list of taxa which could potentially occur in the LMUP area or surrounds, and to identify any priority or threatened ecological communities in the vicinity. Database searches in specified areas were made using the following database and internet tools:

- Western Australian Museum's (WAM) collection database was searched for subterranean crustaceans using a rectangular search area to retrieve records in the region of the LMUP Area (NW 26°12'29.19"S 119°28'28.44"E, SE: 27°34'20.58"S 121°28'29.31"E);
- DEC's Naturemap database was searched for species records within a 40 km radius of a central co-ordinate 27° 8'6.99"S 121° 5'56.09"E ; and
- DEC Threatened Ecological Communities database was searched for TEC's and PEC's occurring within a 100 km radius of the central co-ordinate 27° 8'6.99"S 121° 5'56.09"E to obtain TEC and PEC buffer zones.

3.3. Groundwater Quality

Basic physicochemical data was collected during the stygofauna surveys (Environmental Protection Authority 2003). The approximate standing water level (SWL) (mbgl) was measured using a Solinst 101 water level meter. A calibrated TPS 90 FLMV multi-parameter field instrument was used to measure pH, water temperature, dissolved oxygen (DO), electrical conductivity (EC), salinity and reduction-oxidation potential (Redox) of the groundwater. The end of hole (EoH) was estimated using the number of rotations of the stygofauna sampling winch reel required to retrieve stygofauna nets.

3.4. Sample Methods

Stygofauna were sampled using haul nets, which have been found to be the most efficient retrieval method (Allford *et al.* 2008). Sampling was consistent with the procedures outlined in the EPA Draft Guidance Statement No. 54a (2007). The sampling method was as follows:

- Samples were collected using two weighted haul nets with mesh sizes of 150 µm and 50 µm. Each net was fitted with a collection vial with a base mesh of 50 µm;
- The 150 µm net was lowered first, near to the bottom of the hole;
- Once at the bottom, the net was gently raised up and down to agitate the sediments;

- The net was then raised slowly to minimise the ‘bow wave’ effect that may result in the loss of specimens, filtering the stygofauna from the water column on retrieval;
- Once retrieved, the collection vial was removed, the contents emptied into a 250 ml polycarbonate vial, and preserved with 100 % undenatured ethanol;
- This process was repeated three times and then carried out using the 50 µm net;
- To prevent cross-contamination, all sampling equipment was washed thoroughly with Decon 90 (2 to 5% concentration) and rinsed with potable water after each site;
- In the field, samples were placed into eskies with ice bricks prior to being transferred into a refrigerated environment on-site at the end of each survey day; and
- Samples were couriered back to the Outback Ecology laboratory in Perth, where they were stored in 100% ethanol and refrigerated at approximately minus 20°C.

3.5. Survey Design and Effort

The stygofauna survey was designed to provide a relatively broad geographical spread of samples from within representative geologies of the proposed impact areas as well as from within representative areas outside of the potential LMUP impacts. Bores sampled for stygofauna were situated within a range of surface geologies throughout the LMUP, ranging from clayey colluvial sands around the shoreline of the lake playa through to calcrete geologies associated with the Barwidgee calcrete.

The survey involved two main impact areas (**Figure 5**):

- The mining operations area included the:
    - o resource area, targeting the northern playa system of Lake Maitland where shallow mining operations are proposed; and
    - o groundwater drawdown (without mitigation, year 12) area within the 0.5 m drawdown contour associated with mine dewatering and which encompasses the Barwidgee calcrete delta area east of the Barwidgee-Yandal Road.
- The proposed borefield development occurring within the 0.5 m groundwater drawdown zone to the north of the proposed mining operations area.

A total of 165 net haul samples from 87 holes were collected over ten rounds of sampling in January 2007, May 2007, December 2008, March 2010, August 2010, February 2011, March 2011, July 2011, September 2011, and November 2011 **(Table 1; Appendix A; Figure 5** and **Figure 6)**. Representative images of bores sampled from LMUP areas surveyed are shown in **Appendix B**. One hundred and eleven samples were from the impact areas, and 54 from non-impact areas. Within the impact zones:

- 54 samples were from the mining operations resource area;
- 36 from within the associated modelled 0.5 m groundwater drawdown contour; and
- 21 from within the modelled 0.5 m drawdown contour in the proposed borefield.

Table 1: Stygofauna sampling effort from net hauls in relation to non-impact and impact areas of the LMUP.

Survey period	Non-impact	Impact			Total
		Mining operations area		Borefield drawdown (>0.5m)	
		Drawdown (>0.5m)	Resource		
January 2007	6		1	2	9
May 2007	4	2	17		23
December 2008	6	5	17	3	31
March 2010	2	1	17		20
August 2010	2	12		2	16
February 2011	9	1		7	17
March 2011	1	12	2		15
July 2011	18	3		7	28
September 2011	3				3
November 2011	3				3
No. Samples	54	36	54	21	165
No. Holes	23	20	35	9	87

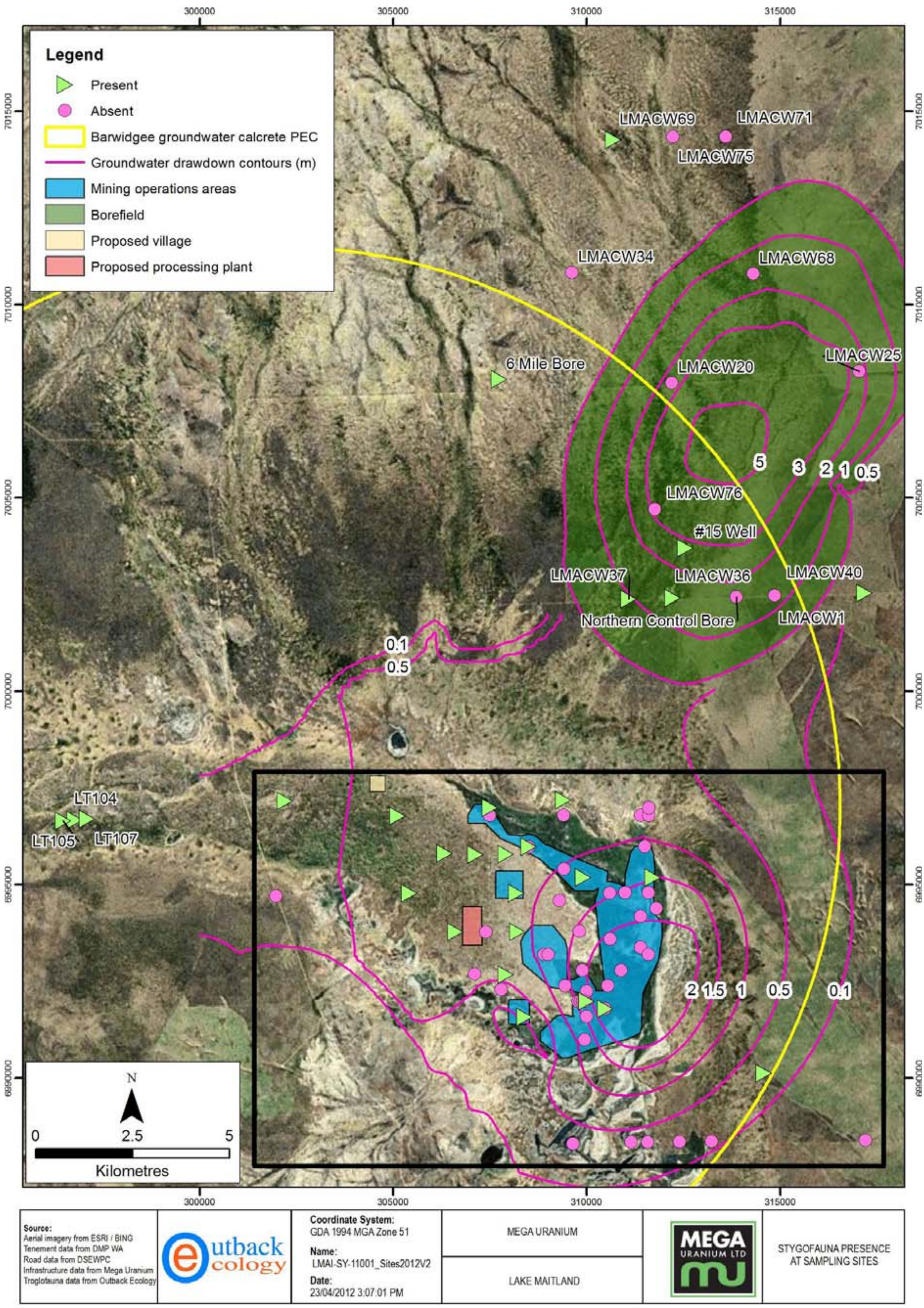

Figure 5: Stygofauna survey bore locations in relation to proposed LMUP footprint and Barwidgee calcrete PEC. Black rectangle indicates area depicted in greater detail in Figure 6.

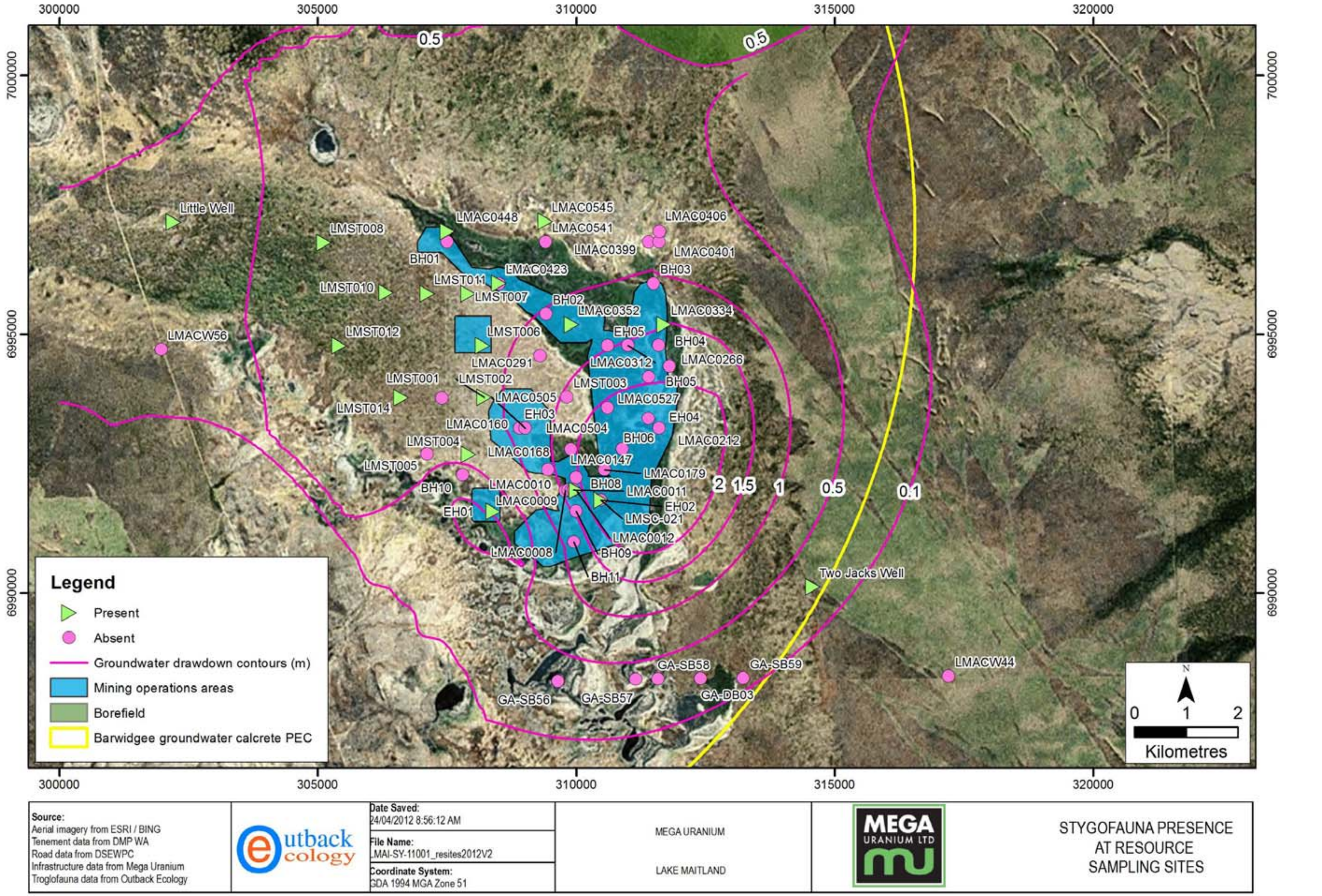

Figure 6: Stygofauna survey bore locations about LMUP mining operations area (area in black rectangle shown in Figure 5).

3.6. Field Personnel and Licences

The field methods and survey efforts employed during the Lake Maitland Uranium Project followed EPA *Guidance Statements 54* and *54a* (Environmental Protection Authority 2003, 2007). Licences to take fauna for scientific purposes (*Wildlife Conservation Act 1950*, Regulation 17) were obtained from the DEC prior to the LMUP stygofauna surveys (Licence Numbers SF005819, SF006730, SF007342, SF007530 and SF007820). Personnel involved in the field sampling included Michael Scanlon, Andre Schmidt, Dr Erin Thomas, Bronwyn Gordon, Dr Fiona Taukulis, Dr Veronica Campagna, Richard de Lange and Nicholas Stevens from Outback Ecology as well as assistance from Mega Lake Maitland representatives Melissa Bolton, Michael Stranger and Thomas Reese.

3.7. Sorting and Identification of Specimens

Preserved samples were sorted manually under Leica MZ6, MZ7.5 and M80 stereomicroscopes. Sorting was conducted by Michael Scanlon, Dr Erin Thomas, Dr Nihara Gunawardene, Richard de Lange, Kimberley Moiler, Syngeon Rodman, Chris Hofmeester and Dr Peter Langlands of Outback Ecology. Once sorted in the laboratory, specimens were preserved in 100 % ethanol and kept at approximately 18 to 20°C to ensure viability for DNA analysis.

Identification was carried out to species or morphospecies level for the majority of taxa, using both published literature and unpublished keys and taxon descriptions. Identifications were undertaken by Michael Scanlon, Dr Erin Thomas, Dr Nihara Gunawardene and Nicholas Stevens of Outback Ecology. Specialist taxonomists were employed to obtain higher taxonomic resolution and provide peer review, where necessary. The specialists and their area of expertise are provided in **Table 2**. Undescribed taxa were assigned morphospecies names based on morphological features. Outback Ecology morphospecies names have also been assigned retrospectively to undescribed taxa that were provisionally named or numbered following DNA analyses or by specialist taxonomists. This was undertaken to adhere to scientific protocol and limit the use of unpublished names, as well as aiding in the differentiation of morphospecies.. A list of these names is presented in **Appendix M**.

An Export Licence (*Wildlife Conservation Act 1950*, Regulation 18) was obtained for the transport of specimens to taxonomists interstate (Licence Number ES002062). Material which required specialist identification outside of Australia was lodged with the Western Australian Museum (WAM) and forwarded to the relevant institutions.

Table 2: Taxonomists involved in the identification of stygal groups from the LMUP area.

Stygal Group	Taxonomist	Affiliated Institution or Company
Amphipoda	Jane McRae (JMM)	Bennelongia Pty Ltd, Perth, Western Australia
Copepoda	Dr Tomislav Karanovic (TK)	Department of Life Sciences, Hanyang University, Korea
Isopoda	Dr Rachael King (RK)	South Australian Museum, Adelaide, South Australia
	Jane McRae (JMM)	Bennelongia Pty Ltd, Perth, Western Australia
Ostracoda	Dr Ivana Karanovic (IK)	Hamburg Zoologisches Museum, Hamburg, Germany
Oligochaeta	Michael Scanlon (MDS)	Bennelongia Pty Ltd, Perth, Western Australia

3.8. Genetic Analysis

Representative specimens of Amphipoda, Bathynellacea, Coleoptera, Copepoda, and Isopoda from the LMUP were sent to Dr Leijs (South Australian Museum) and Oligochaeta sent to Dr Murphy (La Trobe University) for genetic analysis. The aims of the analysis were:

- to test the robustness of identifications based on morphological characters (including juvenile specimens);
- align morphospecies with described and/or previously sequenced taxa from the Carey Palaeodrainage system; and,
- investigate phylogeographic patterns of selected taxa to assess the degree of genetic divergence among populations/species across the LMUP and neighbouring areas.

3.9. Statistical Analysis

The EstimateS software package (Colwell 2009) was used to plot species accumulation curves and to estimate the total species richness that might exist based on survey results. The EstimateS results provide a statistical evaluation of the proportion of the faunal assemblage detected and give an indication of the adequacy of the sampling effort conducted. The species included in this statistical evaluation are listed in **Table 3**.

Table 3: Stygofauna species included in the EstimateS statistical evaluation.

Chiltoniidae sp. OES1	*Mesocyclops brooksi*	*Schizopera* sp. TK6
Chiltoniidae sp. SAM4	*Microcyclops varicans*	*Schizopera* sp. TK8
Atopobathynella sp. OES6	*Ameiropsyllus* sp. TK1	*Haloniscus* sp. OES1
Bathynellidae sp. OES1	*Nitokra lacustris pacifica*	Enchytraeidae sp. OES1
Limbodessus barwidgeensis	*Nitokra* sp. TK3	Enchytraeidae sp. OES2
Halicyclops eberhadi	*Australocamptus similis*	Naididae sp. OES1
Halicyclops sp. TK1	*Kinnecaris* sp. TK3	Naididae sp. OES2
Halicyclops sp. TK2	*Schizopera* sp. TK1	*Candonopsis dani*
Halicyclops sp. TK3	*Schizopera* sp. TK5	*Candonopsis* sp. IK2

3.10. Limitations of the assessment

All specimens were identified to the lowest taxonomic level where possible. However, specimens could not always be identified to the level of species or morphospecies due to:

- loss or damage of important taxonomic features during collection and/or sorting of specimens;
- lack of adult specimens; or
- limitation in taxonomy, in that the current state of taxonomy for a particular group is insufficiently advanced meaning relevant taxonomic keys and descriptions are lacking.

While every effort has been made to assess the taxonomy, distribution and conservation significance of the subterranean fauna collected using in-house data collections, publications, publicly available reports, and information provided by specialist taxonomists, some accounts may be limited if specialist information was unavailable.

4. RESULTS AND DISCUSSION

4.1. Literature Review And Database Searches

4.1.1. Stygofauna Habitat in LMUP Area

4.1.1.1. Geology

Lake Maitland is situated near the northern end of the Carey Palaeodrainage, in the Eastern Goldfields Province of the Yilgarn Craton (Johnson et al. 1999). The region is characterised by four main geological units of relevance to stygofauna habitat:

1. *Archaean Greenstone and Granitoid basement rocks*. Greenstone belts primarily comprise mafic and ultramafic rocks overlain by felsic volcanics and volcaniclastics (in the lower portion), and metamorphosed clastic sedimentary rocks such as chert, quartzite and banded ironstone (in the upper fraction) (Johnson 2004, Johnson *et al.* 1999) (**Figure 7**). Granitoid intrusions into the older Greenstone occur as plutons, and form linear belts of granitic gneiss (Johnson et al. 1999). Proterozoic dykes also intrude the granite-greenstone terrain (Johnson 2004).

2. *Tertiary Palaeochannel sediments*. During the Tertiary period, the Carey Palaeodrainage was incised into the Archaean bedrock to a depth of around 80 m (Golder Associates 2011), and subsequently in-filled with eroded bedrock sediments (Johnson et al. 1999). The basal palaeochannel sediments are granitic sands, and are overlain by dense, plastic clays of weathered mafic origin. The sedimentary sequence varies in different parts of the Carey Palaeodrainage, with alternating sand and clay layers near Lake Maitland (**Figure 7**).

3. *Alluvium and Colluvium*. The Tertiary Palaeochannel sedimentary layers are overlain by more recent alluvial and colluvial deposits, typically silty sands and minor gravels (Johnson 2004, Johnson *et al.* 1999) (**Figure 8**).

4. *Calcrete*. The co-alluvial materials are locally displaced or replaced by calcrete (Johnson et al. 1999), formed by the precipitation of calcium and magnesium carbonates from the groundwater (Mann and Horwitz 1979). Calcrete formation is generally associated with low-lying areas, where the water table is shallow (~5 m below ground level) (Johnson 2004).

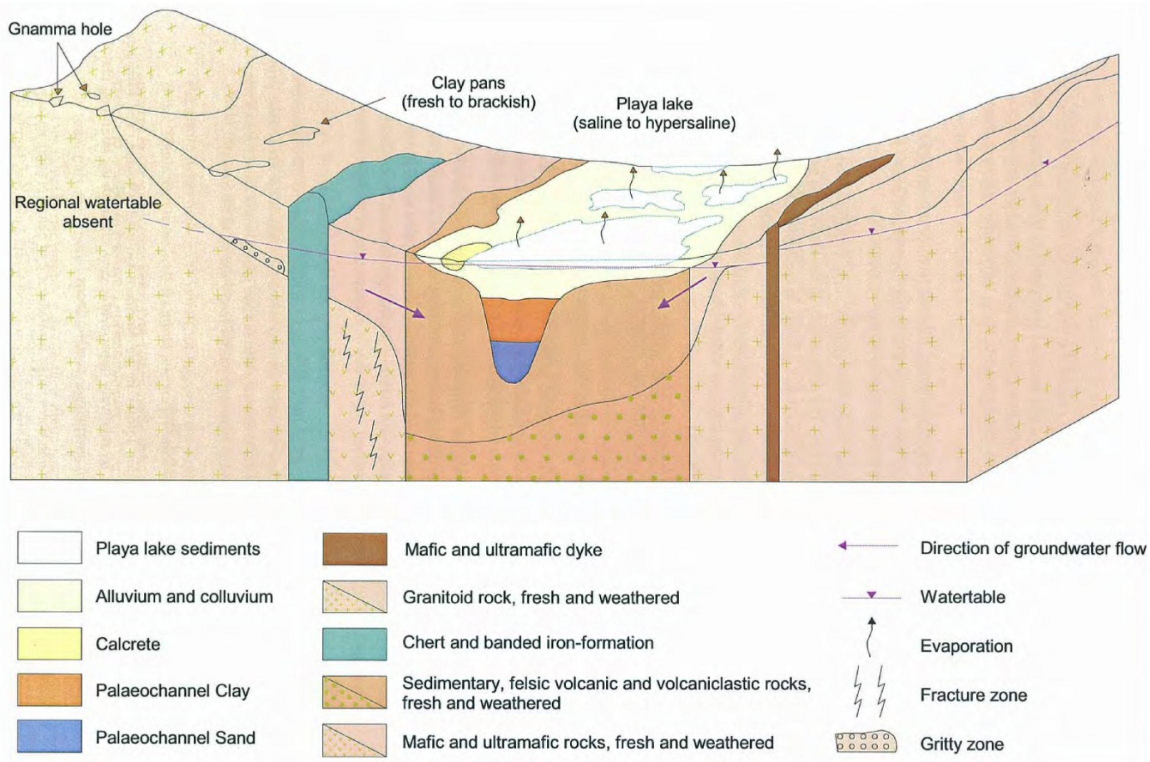

Figure 7: Diagrammatic representation of major geological units in Carey Palaeodrainage. Over time, palaeochannel gradually filled in by eroded sediments from Greenstone and Granitoid bedrock, with surficial layer of more recent, co-alluvial material. In various parts of palaeodrainage channel, calcrete has formed within the surficial layer. Source: Johnson *et al.* (1999).

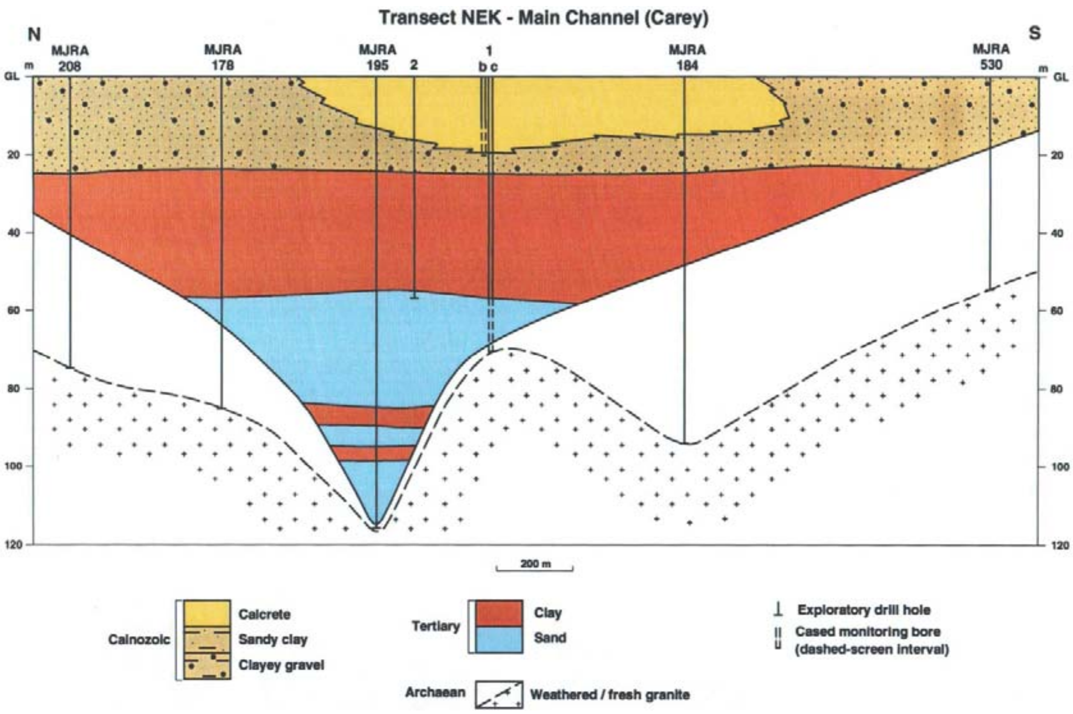

Figure 8: Cross-channel transect depicting the local geology to the immediate west of Lake Maitland (Transect NEK) (Source: Johnson *et al.* (1998) cited in RPS Aquaterra (2011).

4.1.1.2. Hydrogeology

There are distinct aquifer types associated with these four main geological units (**Figure 9**). The Archaean bedrock is characterised by secondary permeability from the chemical weathering of fractures (Johnson 2004), supporting fractured rock aquifers that extend to several hundred metres below ground level (Golder Associates 2011). The permeable palaeochannel sand deposits support substantial aquifers, although they have relatively limited storage capacity (Johnson 2004). The surficial alluvial deposits are of generally lower permeability due to their high silt and clay content, supporting an unconfined aquifer close to the surface of playa lakes (Johnson 2004).

Within the surficial zone, calcrete bodies constitute important local aquifer storages due to their high secondary permeability from chemical dissolution (Johnson 2004, Johnson *et al.* 1999). Calcrete aquifers are also well recognised as providing suitable stygofauna habitat in the Australian arid zone, with important stygofauna associations in the nearby Lake Way and Barwidgee calcretes (Humphreys 2001, Humphreys *et al.* 2009, Outback Ecology 2011b). Within the mining operations area, the calcrete formation is generally between 7 and 10 m thick (Golder Associates 2011), and extends westwards along the palaeochannel towards Lake Way. Lesser calcrete formations also occur along the eastern margin of Lake Maitland. To the north of Lake Maitland the calcrete formations are typically only 2 to 3 m deep, although deeper formations were recorded at LMACW42 (17 m), LMACW48 (14 m) and LMACW52 (5 m) (RPS Aquaterra 2011).

The intrusive dykes and fine, plastic clays are thought to generally serve as aquitards, although there appears to be some degree of hydraulic connectivity among the alluvial, palaeochannel sand and fractured rock aquifer bodies (Golder Associates 2011, Johnson 2004, Johnson *et al.* 1999). There may also be indirect connectivity among the calcrete, the fractured rock and the palaeochannel sand aquifers, where weathered rock material provides an intermediate connection (Golder Associates 2011). However there is likely to be less connectivity where the calcrete body overlies fine, plastic clays (such as the ‘calcrete tongue’) (Golder Associates 2011). In the northern catchment area, the alluvial aquifer is thought to be hydraulically connected to the adjacent clayey sands and calcrete areas of Lake Maitland (RPS Aquaterra 2011).

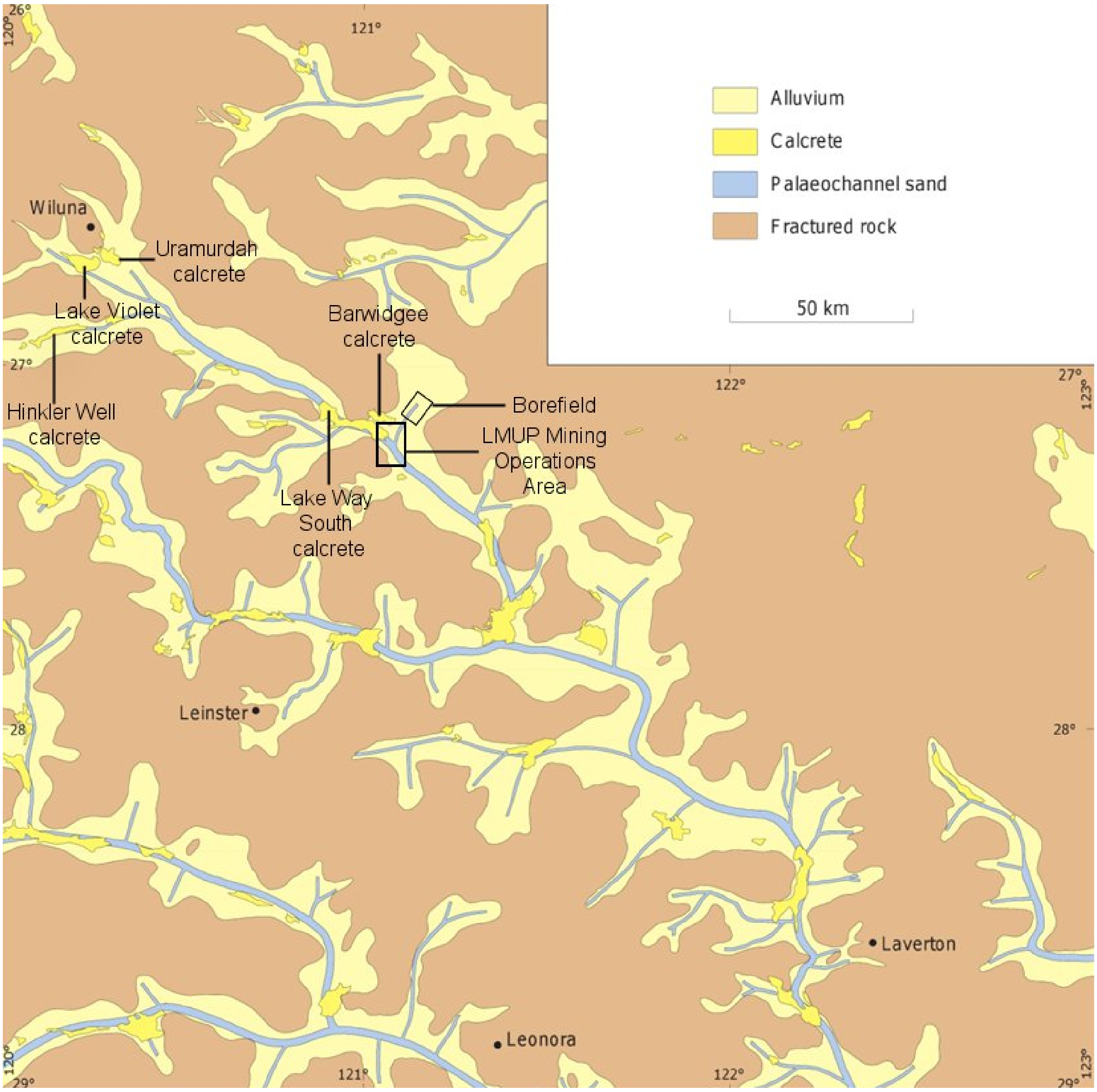

Figure 9: Regional occurrence of the four main aquifer types. Source: Johnson *et al*. 1999.

4.1.1.3. Groundwater Quality

In general, groundwater salinities are fresher near drainage divides and in the minor tributaries, and higher in the main trunk channels of the palaeodrainage (Johnson et al. 1999). For example, in 'Transect NEK', which crosses the palaeochannel approximately 8 km to the west of the Project area (RPS Aquaterra 2011), salinity was much lower in the calcrete aquifer (5.7 ppt TDS) than in palaeochannel sand aquifer (86.5 ppt) (Johnson 2004). Within the mining operations area, salinities are generally higher in the alluvial aquifer (>50 ppt) than in the calcrete (<50 ppt, with a decreasing trend to the west) (Golder Associates 2011). In the northern borefield area, salinities range from fresh in the upper catchment (<2 ppt) to hypersaline in the calcrete and main trunk channel (up to 210 ppt) (RPS Aquaterra 2011).

Dissolved Oxygen (D.O.) concentrations were also recorded in the mining operations area, and ranged from 0.12 to 7.18 ppm (Golder Associates 2011). Calcrete areas were characterised by relatively high D.O. concentrations (>2 ppm), particularly near the eastern end of the calcrete body (>5 ppm) (Golder Associates 2011). The pH concentrations were typically circum-neutral to alkaline, ranging from 6.65 to 8.09 in the mining operations area and 6.6 to 8.2 in the northern borefield area.

4.1.1.4. Groundwater Drawdown on Potential Stygofauna Habitat

The uranium deposit is located approximately 2 to 5 m below the lake surface, and has an average thickness of 1.7 m (range 0.02 to 3.8 m) (Golder Associates 2011). Groundwater drawdown associated with the mining operations dewatering is predicted to range from less than 3 m to 1.0 m in the resource area, with the maximum extent of the 0.5 m drawdown contour extending approximately 5.0 kilometres to the north west from the resource area (**Figure 5**). This drawdown will only impact on surficial aquifers, representing approximately 25% of the saturated depth and approximately 30% of the areal extent of the calcrete aquifer (and much less for the deeper alluvial aquifer).

Groundwater drawdown associated with water extraction in the proposed borefield area is predicted to extend to depths of approximately 6.0 m, with a 0.5 m drawdown contour extending 7.5 km to the north and 4.0 km to the east and west of the borefield (**Figure 5**). This represents approximately 25% of the saturated thickness of the alluvial aquifer. Cumulative drawdown impacts between the mining operations and borefield are not expected to be significant (RPS Aquaterra 2011). It is expected that drawdown impacts will be confined to the local catchment, with 75 % recovery of the surficial aquifers within approximately 30 years.

4.1.2. Stygofauna records in LMUP area

Calcrete associated groundwaters are recognized as providing optimal habitat for stygofauna in the Pilbara and Yilgarn and, as such, generally host more diverse and abundant assemblages than regolith or fractured rock associated aquifers (Allford *et al.* 2008, Cooper *et al.* 2008, Environmental Protection Authority 2007, Humphreys 2008, Outback Ecology 2011a). The only published records of stygofauna species from the Barwidgee calcrete area are two diving beetle species *Limbodessus barwidgeensis* and *Limbodessus usitatus* (Watts and Humphreys 2006). Yilgarn stygal dytiscid species are short range endemics that have been found to be restricted to a particular calcrete only (Watts and Humphreys 2006). However, DNA analysis confirmed the distribution of *Limbodessus wilunaensis* to range from Millbillillie Bubble Well calcrete to the neighbouring Lake Violet calcrete, situated within the same palaeochannel, the Carey, approximately 27 km to the south east.

To date, the most comprehensive subterranean fauna study carried out within salt lake associated calcretes of the Yilgarn, is the study of the Lake Way calcrete systems within the upper northern Carey Palaeochannel, as part of the Toro Wiluna Uranium Project (80 to 110 km NW of the LMUP)(Outback Ecology 2011b). This study occurred within three Lake Way associated calcretes, Hinkler Well, Lake Violet and Uramurdah, which occur within the same palaeochannel drainage system, as the Barwidgee calcrete (**Figure 9**). The study recorded more than 50 stygofauna species and provided insights into the diversity, abundance and distribution patterns for numerous stygofauna groups.

Published molecular and morphological studies have indicated that a calcrete system can act largely as a subterranean island hosting many endemic stygofauna species. In contrast to these published findings, around 60% of species found in each of the three Lake Way calcretes were also recorded from at least one other neighbouring calcrete system, including the Millbillillie Bubble Well calcrete. The results indicated that although many species of a stygofauna assemblage can be confined to a single ‘calcrete island’, numerous other species within the assemblage can be more widespread and occur in close neighbouring calcretes within associated drainage systems (Outback Ecology 2011b).

4.1.3. Western Australian (WAM) Crustacea Database Search

A search of the WAM Crustacea database for the region surrounding the LMUP area, listed many stygobitic Bathynellacea, Copepoda (Cyclopoida and Harpacticoida), Isopoda and Ostracoda taxa (Western Australian Museum 2011) (**Appendix C**). No Amphipoda taxa were present in the database search. This is not because amphipods are not known from the region, rather the current records have not been entered into the database (S. Osbourne, WAM pers. comm. October 2011). Most of the stygofauna representatives in the database search were collected from within calcrete associated aquifers of the Yilgarn region where the majority of sampling has occurred. The closest stygofauna collected to the LMUP within the database search were from the Uramurdah Lake Calcrete (80 km north-west of the project) which included copepod, isopod, parabathynellid, and ostracod species.

4.1.4. Department Of Environment And Conservation (DEC) Naturemap Database Search

A search of the DEC’s NatureMap database for the LMUP area did return any listings of stygofauna or troglofauna species.

4.1.5. DEC Threatened And Priority Ecological Communities Database Search

The DEC Threatened Ecological Communities (TEC’s) and Priority Ecological Communities (PEC’s) database search did identify the ‘Barwidgee calcrete groundwater assemblage type on Carey palaeodrainage on Barwidgee Station’ within the LMUP area (**Figure 2**). This priority area is recognised due to unique assemblages of stygofauna invertebrates recorded from the groundwater within the calcrete system. The area is classified as a priority 1, under the *Western Australian Wildlife Conservation Act (1950)*, due to the ‘poorly known ecological communities’ that are ‘known from very few occurrences with a very *restricted distribution*’ (Department of Environment and Conservation 2011). The designated buffer zone for the Barwidgee calcrete stygofauna PEC does encompass the LMUP mining operations area and southern portion of the proposed borefield area. The results presented herein will represent the first published comprehensive list of the stygofauna species that form part of the Barwidgee calcrete stygofauna PEC.

4.2. Groundwater Quality

Groundwater characteristics varied throughout the LMUP, attributable to factors including the hydrogeology of the area and the seasonal sampling regime (**Table 4; Appendices D-G)**. The standing water level was influenced by topography, the water table being closest to the surface in the resource area, associated with the northern playa of Lake Maitland (typically less than 2 m bgl). Depth to groundwater was greatest within the non-impact area (mean of 5.65 m bgl), particularly at those sites in the tributary palaeochannel catchment to the north of the playa. Consistent with this, the standing water levels at the borefield sites, also located within the northern catchment area, averaged greater than 4 m bgl. These values reflected the increased ground surface elevation away from the playa, following other areas of the Eastern Goldfields (Johnson 2004). The groundwater drawdown area, predominantly associated with the Barwidgee calcrete west of Lake Maitland, tended to have intermediate standing water levels (mean of 3.58 m bgl), corresponding with previous modelling of this area (Golder Associates 2011).

Groundwater salinity ranged from freshwater (<3 ppt)) to hypersaline (>50 ppt) *sensu* (Hammer 1986) with values between 0.04 ppt and 146.60 ppt, a pattern followed by the related variable of electrical conductivity (0.08 mS/cm to 176.40 mS/cm). The highest salinities were recorded from bores within the resource area (mean of 72.41 ppt) linked to the dense brine groundwaters of Lake Maitland and elevated salinities in the main trunk of the palaeochannel. The origin of salts is attributed to evapoconcentration on the surface of the playa. Subsequent sinking and mixing with the underlying groundwater forms a dense brine, with salts accumulating over long time scales in arid climate conditions (Golder Associates 2011).

Salinities tended to decrease with distance from the playa, the lowest values generally recorded from the borefield (mean of 1.24 ppt). The comparatively low salinities reflect the location of the borefield within the elevated northern tributary catchment, the associated aquifer types (alluvial sequences, basal palaeochannel sand and weathered and fractured basement) (RPS Aquaterra 2011) typically displaying low salinities in the upper parts of palaeodrainages (Johnson 2004). Groundwater salinities within the Barwidgee calcrete also supported the trend, with higher values commonly recorded near the resource area of the playa and hyposaline conditions to the west towards the non-impact area (3 ppt to 20 ppt) *sensu* (Hammer 1986),.

Available literature on the salinity tolerance of stygofauna indicates that groundwater salinities greater than 60 ppt are unlikely to support rich stygofauna communities (Environmental Protection Authority 2007). Recent work by Outback Ecology in the northern section of the Carey palaeodrainage system (Outback Ecology 2011b), found that some taxa are capable of surviving in salinities exceeding that level.

Groundwater pH across the LMUP ranged from 6.10 to 8.91, classified as acidic (<6.5) to alkaline (>7.5) *sensu* (Foged 1978). The majority of bores had similar pH values, generally between pH 7 to pH 8. Along with a small number of sites in the resource area, pastoral wells associated with the non-impact area were the primary exceptions, tending to be slightly more alkaline. Calcareous groundwaters between pH 7.2 and pH 8.2 have been shown to support the most diverse stygofauna communities (Humphreys 2008), and while acidic waters may restrict distribution, some ostracods have been documented from waters as low as pH 4.4 (Reeves *et al.* 2007).

Groundwater temperature was variable (16.50 °C to 32.40 °C) in response to factors such as seasonal variation. Dissolved oxygen concentration also varied, ranging from anoxic to highly oxygenated (0.01 ppm to 20.00 ppm), with mean values of 4.48 ppm within the area of groundwater drawdown (primarily calcrete) through to 8.08 ppm in the resource area of the playa. Groundwater taxa have been recorded over a wide range of dissolved oxygen concentrations (Malard and Hervant 1999), commonly occurring in waters with dissolved oxygen values of less than 1 ppm (Humphreys 2008).

Table 4: Summary of groundwater physiochemical parameters of the LMUP area.

Parameters		Impact																			Non-impact									
		Mining operations area													Borefield															
		Groundwater drawdown (0.5m)								Resource																				
		May-07	Dec-08	Mar-10	Aug-10	Feb-11	Mar-11	Jul-11	Overall	May-07	Dec-08	Mar-10	Mar-11	Overall	Jan-07	Dec-08	Aug-10	Feb-11	Jul-11	Overall	May-07	Dec-08	Mar-10	Aug-10	Feb-11	Mar-11	Jul-11	Sep-11	Nov-11	Overall
pH	Min	7.28	7.69	7.62	7.15	7.41	6.67	7.31	6.67	6.96	7.02	6.93	6.98	6.93	7.90	7.73	7.92	7.04	7.04	7.04	7.54	7.45	-	7.41	6.10	7.43	6.58	7.09	6.76	6.10
	Max	7.28	8.12	7.62	7.59	7.41	7.67	7.47	8.12	7.73	8.91	7.95	7.63	8.91	7.90	8.23	8.38	7.53	8.00	8.38	8.27	8.74	-	8.53	7.59	7.43	8.16	7.42	7.07	8.74
	Mean	7.28	7.96	7.62	7.38	7.41	7.26	7.39	7.43	7.38	7.73	7.43	7.31	7.52	7.90	7.98	8.15	7.35	7.70	7.69	7.98	8.12	-	7.97	7.07	7.43	7.39	7.23	6.95	7.46
	SD	-	0.20	-	0.15	-	0.28	0.08	0.30	0.24	55.37	0.29	0.46	0.40	0.00	0.35	0.33	0.22	0.31	0.37	0.33	0.49	-	0.79	0.43	-	0.40	0.17	0.16	0.54
	No.	1	5	1	12	1	12	3	35	14	17	16	2	49	2	2	2	6	7	19	4	6	0	2	9	1	18	3	3	46
EC (mS/cm)	Min	105.20	46.30	74.80	20.09	6.30	20.17	6.82	6.30	45.30	43.50	58.90	123.20	43.50	1.30	3.70	3.76	0.45	0.36	0.36	3.17	2.10	13.13	1.85	0.11	11.89	0.08	9.02	10.00	0.08
	Max	105.20	75.50	74.80	53.20	6.30	68.10	23.80	105.20	176.40	169.00	172.30	130.90	176.40	7.20	3.70	3.96	1.08	3.73	7.20	12.69	12.42	13.13	12.37	26.00	11.89	155.50	10.24	11.65	155.50
	Mean	105.20	62.92	74.80	36.12	6.30	37.50	17.26	41.03	107.92	104.18	115.85	127.05	109.92	4.25	3.70	3.86	0.83	2.14	2.32	7.86	6.80	13.13	7.11	4.27	11.89	47.93	9.75	10.98	21.76
	SD	-	10.67	-	9.54	-	11.71	9.14	20.38	43.80	37.09	30.54	5.44	36.20	4.17	0.00	0.14	0.25	1.78	1.94	3.90	4.02	-	7.44	8.20	-	62.91	0.64	0.87	41.92
	No.	1	5	1	12	1	12	3	35	14	17	17	2	50	2	2	2	6	4	16	4	6	1	2	9	1	16	3	3	45
Salinity (ppt)	Min	70.00	32.40	-	13.23	3.02	9.62	4.26	3.02	29.50	30.20	-	67.40	29.50	-	2.25	2.27	0.19	0.21	0.19	2.10	1.25	-	1.14	0.04	5.31	0.04	5.43	5.58	0.04
	Max	70.00	54.80	-	37.50	3.02	33.90	15.50	70.00	70.00	146.60	-	77.50	146.60	-	2.26	2.44	0.44	2.26	2.44	7.30	8.00	-	7.84	13.00	5.31	129.80	5.78	6.54	129.80
	Mean	70.00	45.18	-	24.69	3.02	17.78	11.35	24.78	57.38	82.71	-	72.45	72.41	-	2.26	2.36	0.33	1.30	1.24	4.50	3.86	-	4.49	2.30	5.31	40.66	5.64	6.15	17.82
	SD	-	8.20	-	7.01	-	6.01	6.17	14.58	15.29	37.77	-	7.14	28.63	-	0.01	0.12	0.10	1.10	1.01	2.15	2.66	-	4.74	4.73	-	52.94	0.19	0.50	36.51
	No.	1	5	0	12	1	12	3	34	14	17	0	2	33	0	2	2	5	4	13	4	5	0	2	7	1	15	3	3	40
Temp (°C)	Min	25.50	25.10	28.50	20.80	25.80	24.90	23.70	20.80	22.80	22.20	24.40	25.90	22.20	-	26.70	18.90	24.90	23.90	18.90	21.70	20.80	24.40	16.50	23.10	27.90	21.10	23.70	25.30	16.50
	Max	25.50	27.30	28.50	23.80	25.80	28.90	26.60	28.90	26.50	26.30	32.40	27.20	32.40	-	26.90	20.50	28.90	26.00	28.90	24.70	27.30	24.40	21.90	27.90	27.90	26.80	25.80	25.70	27.90
	Mean	25.50	26.06	28.50	22.59	25.80	26.18	24.87	24.85	25.03	24.44	27.86	26.55	25.91	-	26.80	19.70	26.43	24.95	25.08	23.33	24.30	24.40	19.20	25.38	27.90	24.24	24.97	25.53	24.38
	SD		0.95	-	0.85	-	1.14	1.53	1.99	0.99	10.95	2.00	0.92	2.09	-	0.14	1.13	1.34	0.85	2.43	1.50	2.64	-	3.82	1.60	-	1.92	1.12	0.21	2.23
	No.	1	5	1	12	1	12	3	35	14	17	17	2	50	0	2	2	6	6	16	4	6	1	2	9	1	17	3	3	46
DO (ppm)	Min	15.88	2.45	-	2.43	4.81	2.58	6.07	2.43	15.10	1.02	0.01	1.91	0.01	-	0.19	2.94	2.33	0.96	0.19	10.68	0.86	0.01	5.04	1.93	4.84	1.83	4.19	-	0.01
	Max	15.88	4.98	-	5.02	4.81	4.44	7.79	15.88	20.00	4.84	7.55	1.93	20.00	-	4.02	6.54	5.36	10.01	10.01	19.52	4.27	0.01	6.35	5.31	4.84	8.92	5.53	-	19.52
	Mean	15.88	3.62	-	4.17	4.81	3.61	6.71	4.48	17.21	3.02	2.17	1.92	8.08	-	2.11	4.74	4.57	5.93	4.86	16.00	1.93	0.01	5.70	3.50	4.84	5.23	4.65	-	5.26
	SD		0.96	-	0.80	-	0.68	0.94	2.31	1.74	1.11	3.37	0.01	7.32	-	2.71	2.55	1.13	3.66	2.79	3.76	1.20	-	0.93	1.31	-	2.48	0.76	-	4.19
	No.	1	5	0	12	1	12	3	34	14	17	5	2	38	0	2	2	6	7	17	4	6	1	2	9	1	18	3	0	44
SWL (m bgl)	Min	1.57	1.50	3.70	2.85	4.01	2.63	3.75	1.50	0.80	1.00	0.95	1.07	0.80	3.80	4.82	4.13	3.60	3.42	3.42	2.72	2.50	4.67	4.26	3.30	4.02	0.81	4.00	3.97	0.81
	Max	1.57	3.50	3.70	4.34	4.01	4.25	4.79	4.79	3.55	4.50	5.30	1.51	5.30	4.60	5.10	4.81	6.21	6.18	6.21	7.60	14.00	4.67	5.20	11.35	4.02	11.35	4.58	4.55	14.00
	Mean	1.57	2.30	3.70	3.88	4.01	3.75	4.27	3.58	1.64	2.01	2.29	1.29	1.93	4.20	4.96	4.47	4.66	4.81	4.68	4.51	5.85	4.67	4.73	7.77	4.02	5.45	4.35	4.34	5.65
	SD		0.84	-	0.42	-	0.48	0.52	0.82	0.69	4.57	0.90	0.31	0.86	0.57	0.20	0.48	1.00	0.99	0.83	2.13	4.12	-	0.66	2.81	-	3.16	0.31	0.32	2.93
	No.	1	5	1	12	1	12	3	35	14	17	17	2	50	2	2	2	6	7	19	4	6	1	2	9	1	18	3	3	47

4.3. Stygofauna assessment

4.3.1. Overview

In total, 830 stygal specimens, representing 27 species from seven higher level taxonomic groups were collected (**Figure 10**, **Table 5**, **Appendix H**). The taxa identified to species or morphospecies were:

- Amphipoda: Chiltoniidae sp. OES1; and
  Chiltoniidae sp. SAM4;
- Bathynellacea: *Atopobathynella* sp. OES6; and
  Bathynellidae sp. OES1
- Coleoptera: *Limbodessus barwidgeensis*;
- Copepoda: *Halicyclops eberhardi*;
  Halicyclops sp. TK1;
  Halicyclops sp. TK2;
  Halicyclops sp. TK3;
  Mesocyclops brooksi;
  Microcyclops varicans;
  Ameiropsyllus sp. TK1;
  Nitokra lacustris pacifica;
  Nitokra sp. TK3;
  Australocamptus similis;
  Kinnecaris sp. TK3;
  Schizopera sp. TK1;
  Schizopera sp. TK5;
  Schizopera sp. TK6; and
  Schizopera sp. TK8;
- Isopoda: *Haloniscus* sp. OES1;
- Oligochaeta: Enchytraeidae sp. OES1;
  Enchytraeidae sp. OES2;
  Naididae sp. OES1; and
  Naididae sp. OES2;
- Ostracoda: *Candonopsis dani*;
  Candonopsis sp. IK2

An additional species, *Limbodessus usitatus* (Coleoptera: Dytiscidae), that was not collected in this study has been recorded from the Barwidgee calcrete previously from outside the LMUP impact zones (Watts and Humphreys 2006) bringing the total number of species recorded to 28. Stygofauna species were recorded in 83 of the 165 samples, from 28 of the 87 bores sampled (**Appendix H**, **Appendix I**). Important findings were:

- stygofauna diversity and abundance was greatest from within the calcrete habitats of the Carey palaeovalley associated with the Barwidgee calcrete system and northern Lake Maitland playa with all seven higher level taxonomic groups present, represented by 23 species (**Figure 11, Table 7**).

- stygofauna diversity and abundance was much lower in the upper tributary catchment area to the north of Lake Maitland associated with the proposed borefield, which is characterised by weathered basement geologies of the Yandal greenstone belt (Golder Associates 2011) (**Figure 9**). Only two higher level groups, Copepoda and Oligochaeta were present, represented by six species.

The pattern of higher stygofauna species diversity and abundance from palaeochannel calcrete associated geologies is consistent with other published findings in the Yilgarn region (Humphreys *et al.* 2009, Outback Ecology 2011b, Watts and Humphreys 2006). The diversity of the Barwidgee calcrete stygofauna PEC recorded was comparable to the Lake Way associated calcrete PEC's , Lake Violet, Hinkler Well and Uramurdah, that have at least 36, 29, and 23 species recorded to date, respectively (Humphreys *et al.* 2009, Outback Ecology 2011b).

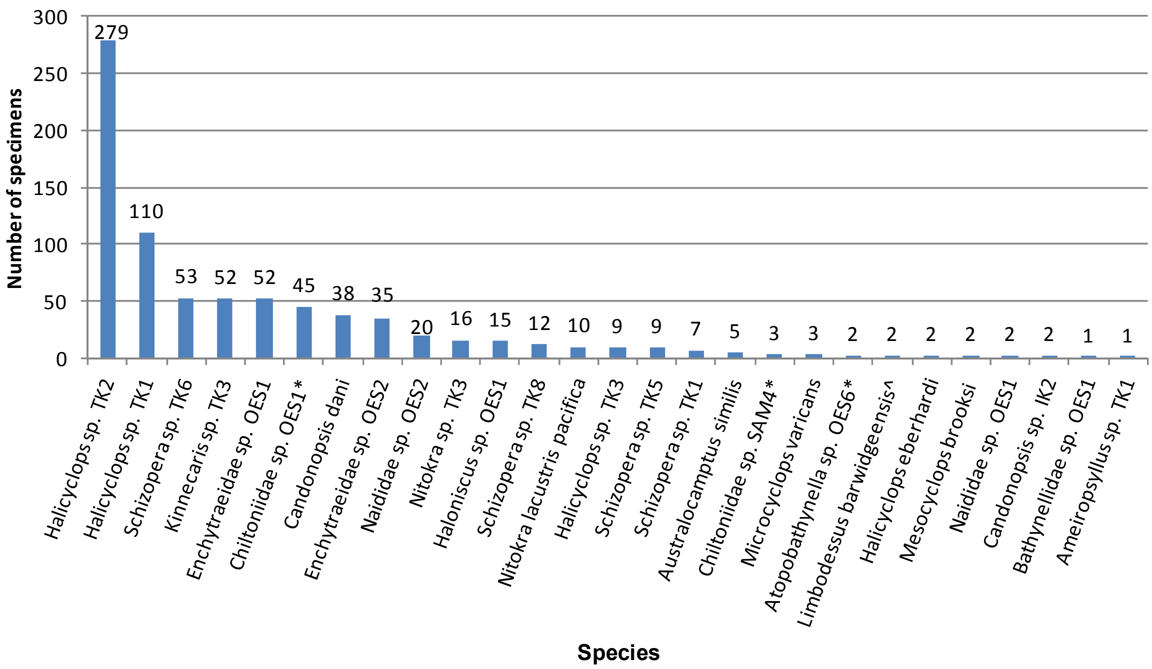

Figure 10: Abundance of stygofauna species collected.

Table 5: Stygofauna species diversity, abundance and distribution. Identified species and morphospecies: shaded in orange found to date in resource area only; shaded in yellow found within groundwater drawdown > 0.5 m. H= Hinkler Well calcrete; LV = Lake Violet calcrete; Ur = Uramurdah calcrete; WS = widespread in region.

Taxa	Abundance	Regional Distribution	LMUP Non-impact	LMUP Impact		
				Mining operations area		Borefield
				> 0.5 m Drawdown	Resource	> 0.5 m Drawdown
Amphipoda: Chiltoniidae						
Chiltoniidae^	44		√	√		
Chiltoniidae sp. OES1*	45		√	√		
Chiltoniidae sp. SAM4*	3				√	
Bathynellacea: Parabathynellidae						
Atopobathynella	1				√	
Atopobathynella sp. OES6*	2		√			
Bathynellidae						
Bathynellidae^	2		√			
Bathynellidae sp. OES1	1		√			
Coleoptera: Dytiscidae						
Limbodessus barwidgeensis^	2		√			
Limbodessus usitatus #			√			
Copepoda: Cyclopoida: Cyclopidae						
Halicyclops eberhardi	2	H, LV, Ur,			√	
Halicyclops sp. TK1	110		√	√	√	
Halicyclops sp. TK2	279		√	√	√	
Halicyclops sp. TK3	9		√			
Mesocyclops brooksi	2	WS	√			
Microcyclops varicans	3	WS	√			
Harpacticoida: Ameiridae						
Ameiropsyllus sp. TK1	1	H			√	
Nitokra lacustris pacifica	10	WS	√		√	
Nitokra sp. TK3	16		√		√	
Canthocamptidae						
Australocamptus similis	5	H, LV				√
Parastenocarididae						
Kinnecaris sp. TK3	52		√			
Miraciidae						
Schizopera sp. TK1	7				√	
Schizopera sp. TK5	9		√	√		
Schizopera sp. TK6	53		√	√		
Schizopera sp. TK8	12		√	√		
Isopoda: Scyphacidae						
Haloniscus sp. OES1	15			√	√	
Oligochaeta: Enchytraeidae						
Enchytraeidae sp. OES1	52		√			√
Enchytraeidae sp. OES2	35		√			√
Naididae						
Naididae sp. OES1	2		√			
Naididae sp. OES2	20		√		√	
Ostracoda: Podocopida: Candonidae						
Candonopsis dani	38	LV	√	√		
Candonopsis sp. IK2	2		√			

* Included in DNA analysis (Appendix I); ^ DNA analysis results pending; # Not collected in this study

4.3.2. Species distributions

The number of stygofauna species that were recorded from each of the LMUP areas and the number of those species that are either shared with, or are unique to, a particular area are indicated in **Table 6**. It is important to note that the total number of species presented for an area in the table will not necessarily be the same as the sum of the individual cells, because widespread species that occur in more than one area will be accounted for multiple times. For example, the total number of species recorded for the Mining operations drawdown (> 5 m) impact area is eight, yet the sum of the number of species in the cells within the row and column for this designated area is 10 because some species that occurred in multiple designated areas are accounted for more than once.

4.3.2.1. Mining Operations Area

Of the ten species recorded from the Mining operations resource impact area:

- four species, representing 14.8 % of the total number of species recorded (28), were unique to the designated area. However, stygophiles *Halicyclops eberhardi* and *Ameiropsyllus* sp. TK1 have been found to occur in other studies from outside the LMUP area (**Table 5**, **Table 7**). Therefore, only two species, Chiltoniidae sp. SAM4 (**Figure 12**), and *Schizopera* sp. TK1 (**Figure 13**, **Figure 15**) have not been found to occur outside the Mining operations resource area;

- three species (10.7 %), *Halicyclops* sp. TK1 (**Figure 14**), *Halicyclops* sp. TK2 (**Figure 14**), and *Haloniscus* sp. OES1 (**Figure** 18) (**Plate 1**), were shared with the Mining operations modelled groundwater drawdown (> 0.5 m) impact area;

- five species (17.9 %), *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, *Nitokra lacustris pacifica* (**Figure 16**), *Nitokra* sp. TK3 (**Figure 16**), and Naididae sp. OES2 (**Figure 17**), were also shared with the non-impact area outside of the Mining operations modelled 0.5 m drawdown contour; and

- no species were shared with the Borefield groundwater drawdown (> 0.5 m) impact area or the non-impact area in the northern catchment outside of the modelled borefield drawdown contour of 0.5 m.

Of the eight species recorded from the Mining operations modelled groundwater drawdown (> 0.5 m) impact area:

- no species were found to be unique to the designated area;

- three species, *Halicyclops* sp. TK1, *Halicyclops* sp. TK2 and *Haloniscus* sp. OES1, referred to above, were shared with the Mining operations resource area. Of these, *Haloniscus* sp. OES1, has not been found to occur outside the Mining operations drawdown contour of 0.5 m;

- seven species (25.9 %), Chiltoniidae sp. OES1 (**Figure 12**) **(Plate 1**), *Halicyclops* sp. TK1, *Halicyclops* sp. TK2 (**Figure 14**), *Schizopera* sp. TK5 (**Figure 15**), *Schizopera* sp. TK6 (**Figure 15**), *Schizopera* sp. TK8 (**Figure 15**), and *Candonopsis dani* (**Figure 18**), were shared with the non-impact area outside of the Mining operations drawdown contour of 0.5 m; and

- no species were shared with the Borefield groundwater drawdown (> 0.5 m) impact area or the non-impact area in the northern catchment outside of the borefield groundwater drawdown contour of 0.5 m.

Of the 19 species known to occur from the non-impact area outside of the Mining operations area modelled drawdown contour of 0.5 m:

- seven species (25.9 %), *Atopobathynella* sp. OES6 (**Figure 17**), Bathynellidae sp. OES1 (**Figure 17**), *Limbodessus barwidgeensis* (**Figure 17**), *Limbodessus usitatus* (**Figure 17**), *Halicyclops* sp. TK3 (**Figure 14**), , *Kinnecaris* sp. TK3 (**Figure 16**), and *Candonopsis* sp. IK2 (**Figure 18**), were unique to the designated area;

- five species (17.9 %), *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, *Nitokra lacustris pacifica*, *Nitokra* sp. TK3, and Naididae sp. OES2, referred to above, were shared with the Mining operations resource area;

- seven species (25.9 %), Chiltoniidae sp. OES1, *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, *Schizopera* sp. TK5, *Schizopera* sp. TK6, *Schizopera* sp. TK8, and *Candonopsis dani*, referred to above, were shared with the Mining operations groundwater drawdown (> 0.5 m) impact area; and

- two species, Enchytraeidae sp. OES1 (**Figure 17**) and Enchytraeidae sp. OES2 (**Figure 17**) were shared with the Borefield groundwater drawdown (> 0.5 m) impact area;

- one species, Enchytraeidae sp. OES1, was shared with the non-impact area outside of the borefield drawdown contour of 0.5 m;

4.3.2.2. Borefield Area

Of the three species recorded in this study from the Borefield groundwater drawdown (> 0.5 m) impact area:

- one species, *Australocamptus similis* (**Figure 16**), was unique to the area. However, *Australocamptus similis* has been found to occur in other studies from outside the LMUP area (**Table 5**, **Table 7**). Therefore, no species have been found to be confined to the Borefield's modelled 0.5 m drawdown contour;

- two species, Enchytraeidae sp. OES1 and Enchytraeidae sp. OES2, referred to above, were shared with the non-impact area outside of the Mining operations area modelled drawdown contour of 0.5 m
- one species, Enchytraeidae sp. OES1, was shared with the non-impact area outside of the borefield drawdown contour of 0.5 m.
- no species were shared with the Mining operations resource or drawdown (> 0.5 m) impact areas.

Of the four species recorded in this study from the non-impact area in the northern catchment outside of the borefield groundwater drawdown contour of 0.5 m:

- three species, *Mesocyclops brooksi* (**Figure 16**), *Microcyclops varicans* (**Figure 16**), and Naididae sp. OES1 (**Figure 17**), were unique to the area. However, both *Mesocyclops brooksi* and *Microcyclops varicans* have been found to occur in other studies from outside the LMUP area (**Table 5**, **Table 7**);
- one species, Enchytraeidae sp. OES1, referred to above, was in common with both the Borefield impact area as well as the non-impact area outside of the Mining operations area; and
- no species were shared with both the Mining operations impact areas.

Table 6: Number of stygofauna species recorded from each LMUP area with number of species shared amongst or unique to each area indicated. Percentage values are of total number of species recorded in LMUP.

<table>
<tr><th colspan="3" rowspan="4">LMUP areas</th><th rowspan="4">No. taxa recorded and as percentage of total taxa found (28)</th><th colspan="5">No. taxa shared amongst and unique to LMUP areas</th></tr>
<tr><th colspan="3">Impact</th><th colspan="2">Non-Impact</th></tr>
<tr><th colspan="2">Mining operations area</th><th>Borefield</th><th colspan="2">Drawdown (<0.5m)</th></tr>
<tr><th>Drawdown (>0.5m)</th><th>Resource</th><th>Drawdown (>0.5m)</th><th>Outside mining area</th><th>Outside borefield</th></tr>
<tr><td rowspan="3">Impact</td><td rowspan="2">Mining operations area</td><td>Drawdown (>0.5m)</td><td>8 (28.6%)</td><td>0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Resource</td><td>10 (35.7%)</td><td>3 (10.7%)</td><td>4 (14.3%)</td><td></td><td></td><td></td></tr>
<tr><td>Borefield</td><td>Drawdown (>0.5m)</td><td>3 (10.7%)</td><td>0</td><td>0</td><td>1 (3.6%)</td><td></td><td></td></tr>
<tr><td rowspan="2">Non-Impact</td><td rowspan="2">Drawdown (<0.5m)</td><td>Outside mining area</td><td>19 (67.9%)</td><td>7 (25.9%)</td><td>5 (17.9%)</td><td>2 (7.2%)</td><td>7 (25.9%)</td><td></td></tr>
<tr><td>Outside borefield</td><td>4 (14.3%)</td><td>0</td><td>0</td><td>1 (3.6%)</td><td>1 (3.6%)</td><td>3 (10.7%)</td></tr>
</table>

Note: Total number of species presented for an area in table will not necessarily be the same as sum of individual cells, because widespread species that occur in multiple areas will be accounted for multiple times.

Table 7: Comments regarding stygofauna species recorded from Barwidgee calcrete – Lake Maitland area. Species shaded in orange found to date in resource area only; Species shaded in yellow found within groundwater drawdown > 0.5 m. Record of modified morphospecies names used by genetic and taxonomic specialists provided in Appendix N.

Taxa	Comments
Amphipoda: Chiltoniidae	
Chiltoniidae^	Likely to belong to Chiltoniidae sp. OES1. DNA identification pending for more recently collected material. LMST002 indet. material in too poor a condition for identification as Chiltoniidae sp. OES1 to be confirmed.
Chiltoniidae sp. OES1*	Undescribed species identified via morphological characteristics and DNA analyses. Has also been collected from other bores west of Little Well during sampling by Western Australian Museum (listed as Chiltoniidae sp. 3) [a].
Chiltoniidae sp. SAM4*	Undescribed species identified via DNA analyses [a].
Bathynellacea: Parabathynellidae	
Atopobathynella	Potentially belongs to *Atopobathynella* sp. OES6 but could not be identified further because immature and damaged.
Atopobathynella sp. OES6*	Undescribed species. Genus is widely distributed in Western Australia, with species recorded from calcrete aquifers of the Yilgarn region and coastal plain aquifers of the Gascoyne and Pilbara regions [b].
Bathynellidae	
Bathynellidae^	Likely to belong to Bathynellidae sp. OES1. DNA identification pending for more recently collected material. Two Jacks Well indet. material immature and could not be identified further.
Bathynellidae sp. OES1	An undescribed taxon. Family has been documented from groundwaters in the Pilbara [c], Yilgarn [d], south-west [e] and south coast of Western Australia [f].
Coleoptera: Dytiscidae	
Limbodessus barwidgeensis^	Only two *Limbodessus* species described from Barwidgee calcrete [2a]. Yilgarn stygal dytiscid species often found restricted to one calcrete only [2a]. However, DNA analysis confirmed *Limbodessus wilunaensis* to occur in both Millbillillie Bubble Well and neighbouring Lake Violet calcretes, with material collected from bores approximately 27 km apart [q]. The closest calcrete system to Barwidgee is Lake Way South calcrete, approximately 30 km to north west. Not known if both Barwidgee *Limbodessus* species also occur in Lake Way South calcrete which has no dytiscid species recorded to date.
Limbodessus usitatus [#]	
Copepoda: Cyclopoida: Cyclopidae	
Halicyclops eberhardi	A widely distributed species in groundwaters of the Yilgarn region [g,h]. DNA analysis of material from a Yilgarn calcrete system indicated presence of one, possibly two cryptic species. Therefore, species likely to be contain various species complexes that require further research to propoerly document [i, j].
Halicyclops sp. TK1	Morphologically identical to *Halicyclops eberhardi* except much in larger size. Stygobitic. Provisionally named Halicyclops 'macroeberhardi' by T. Karanovic (TK). Considered sister species to *Halicyclops* sp. TK2 [i, j].
Halicyclops sp. TK2	Morphologically identical to *Halicyclops eberhardi* except much smaller in size. Stygobitic. Provisionally named *Halicyclops 'microeberhardi'* by TK. Considered sister species to *Halicyclops* sp. TK1 [i, j, k].
Halicyclops sp. TK3	Appears very similar to *Halicyclops eberhardi* and may well be the same species but further research needed to confirm [l].
Mesocyclops brooksi	*Mesocyclops brooksi* is a widely distributed Western Australian copepod species, recorded all over the Yilgarn region and in part of the Pilbara region [m, n], as well as in parts of the WA Weatbelt region (mostly unpublished records). It is probably a stygophile rather than a stygobiont [h, l].
Microcyclops varicans	Widespread in surface waters but also inhabits groundwater and is considered stygophilic [m, n, j].

Table 7 (cont.): Comments regarding stygofauna species recorded from Barwidgee calcrete – Lake Maitland area.

Taxa	Comments
Copepoda (cont.): Harpacticoida: Ameiridae	
Ameiropsyllus sp. TK1	First record of *Ameiropsyllus* in Australia and third species for this genus [g]. Also first non-marine representative. Additional material (at least one female) is needed to verify species generic status. This species also known from groundwaters near Lake Way [o].
Nitokra lacustris pacifica	Very widespread stygophilic species first described from pacific islands and which occasionally occurs in Yilgarn groundwaters [m].
Nitokra sp. TK3	Morphologically similar to species collected near Lake Way [i]. Stygobitic. DNA analyses unsuccessful [a].
Canthocamptidae	
Australocamptus similis	Also recorded from Wiluna area of Yilgarn [h]. Potentially stygophilic [i, m].
Parastenocarididae	
Kinnecaris sp. TK3	Provisionally named *Kinnecaris 'maitlandi'* by TK. Species belongs to *solitaria* species complex that display short range endemism in Yilgarn [p]. Differences amongst species in complex are minute, and Kinnecaris sp. TK3 mostly resembles *Kinnecaris solitaria* and *Kinnecaris lakewayi* [l].
Miraciidae	
Schizopera sp. TK1	Stygobitic species similar to *Schizopera* sp. TK4 from Hinkler Well calcrete associated with Lake Way [g, i, q]. Also appears closely related to *Schizopera* sp. TK5 but not closely related to *Schizopera* sp. TK6 [f, i].
Schizopera sp. TK5*	Stygobitic taxa also similar to to *Schizopera* sp. TK4 from Hinkler Well calcrete associated with Lake Way [i, q]. DNA analyses was unsuccessful [a].
Schizopera sp. TK6*	Initially identified as *Schizopera weelumurra* but following further examination of additional material was provisionally identified as *Schizopera 'dimorpha'* [g,h,i,k,l]. Morphologically similar to *Schizopera* sp. TK7 from Hinkler Well calcrete but further study required to determine if they are same species [i, k, q]. Comparative DNA analysis was unsuccessful [a].
Schizopera sp. TK8	Smallest of *Schizopera* species present [j, k]. Appears closely related to *Schizopera* sp. TK5 and *Schizopera* sp. TK7 with examination of additional material suggesting that morphological variation observed is interspecific [k].
Isopoda: Scyphacidae	
Haloniscus sp. OES1*	Identified by morphological characteristics and DNA [a]. Assigned to *Haloniscus*, however, Yilgarn isopod relationships require further investigation [a]. *Haloniscus* contains both aquatic and terrestrial representatives, with *Haloniscus* sp. OES1 considered likely to be stygofauna rather than troglofauna based on morphology and because only collected in net haul samples.
Oligochaeta: Enchytraeidae	
Enchytraeidae sp. OES1^	Morpho-types based on gross morphological characteristics; DNA analysis results pending. Australian enchytraeid fauna poorly studied, but known to inhabit marine, freshwater and terrestrial soil environments. There are currently no described stygal species [r]. Family known to occur in Pilbara and Yilgarn [q,s,t]. Distribution ranges of enchytraeid species in Yilgarn not well documented. However, distribution patterns for Pilbara enchytreaids and other better known oligochaete groups, such as phreodrilids, show widespread distributions for many species that can occur across major river catchments, with only a few species known from limited ranges s,t,u.
Enchytraeidae sp. OES2^	
Naididae	
Naididae sp. OES1^	Morpho-types based on gross morphological characteristics; DNA analysis results pending. Members of this family has been documented from groundwaters in the Pilbara and Yilgarn regions [c,v].
Naididae sp. OES2^	

Table 7 (cont.): Comments regarding stygofauna species recorded from Barwidgee calcrete – Lake Maitland area.

Taxa	Comments
Ostracoda: Podocopida: Candonidae	
Candonopsis dani	Initially considered conspecific with *Candonopsis dani* originally described from Lake Violet calcrete [w]. Then after examination of additional material, morphological variation was considered to be interspecific [x, y]. However, with further examination of more recent material, variation considered to be intraspecific [l].
Candonopsis sp. IK2	Provisionally named *Candonopsis 'maitlandi'* by Ivana Karanovic (IK) [z].

* Included in DNA analysis (Appendix I); ^ DNA analysis results pending; # Not collected in this study; [a] Leijs (2011) (Appendix J); [b] Cho (2006); [c] Eberhard (2004); [d] De Laurentiis (2001); [e] Bennelongia (2008); [f] Rockwater (2006); [g] Karanovic (2007) (Appendix K); [h] Karanovic (2009b) (Appendix K); [i] Karanovic (2010b) (Appendix K); [j] Karanovic (2011b) (Appendix K); [k] Karanovic (2011c) (Appendix K); [l] Karanovic and Karanovic (2011) (Appendix K); [m] Karanovic (2004); [n] Karanovic (2006); [o] Karanovic (2010c); [p] Karanovic and Cooper (2011); [q] Outback Ecology (2011b); [r] Pinder (2009); [s] Biota (2010); [t] Pinder *et al.*(2010); [u] Pinder (2008); [v] Pinder *et al.* (2006); [w] Karanovic (2009a) (Appendix L); [x] Karanovic (2010a) (Appendix L); [y] Karanovic (2011a) (Appendix L); [z] Karanovic (2011a) (Appendix L); [2a] Watts and Humphreys (2006).

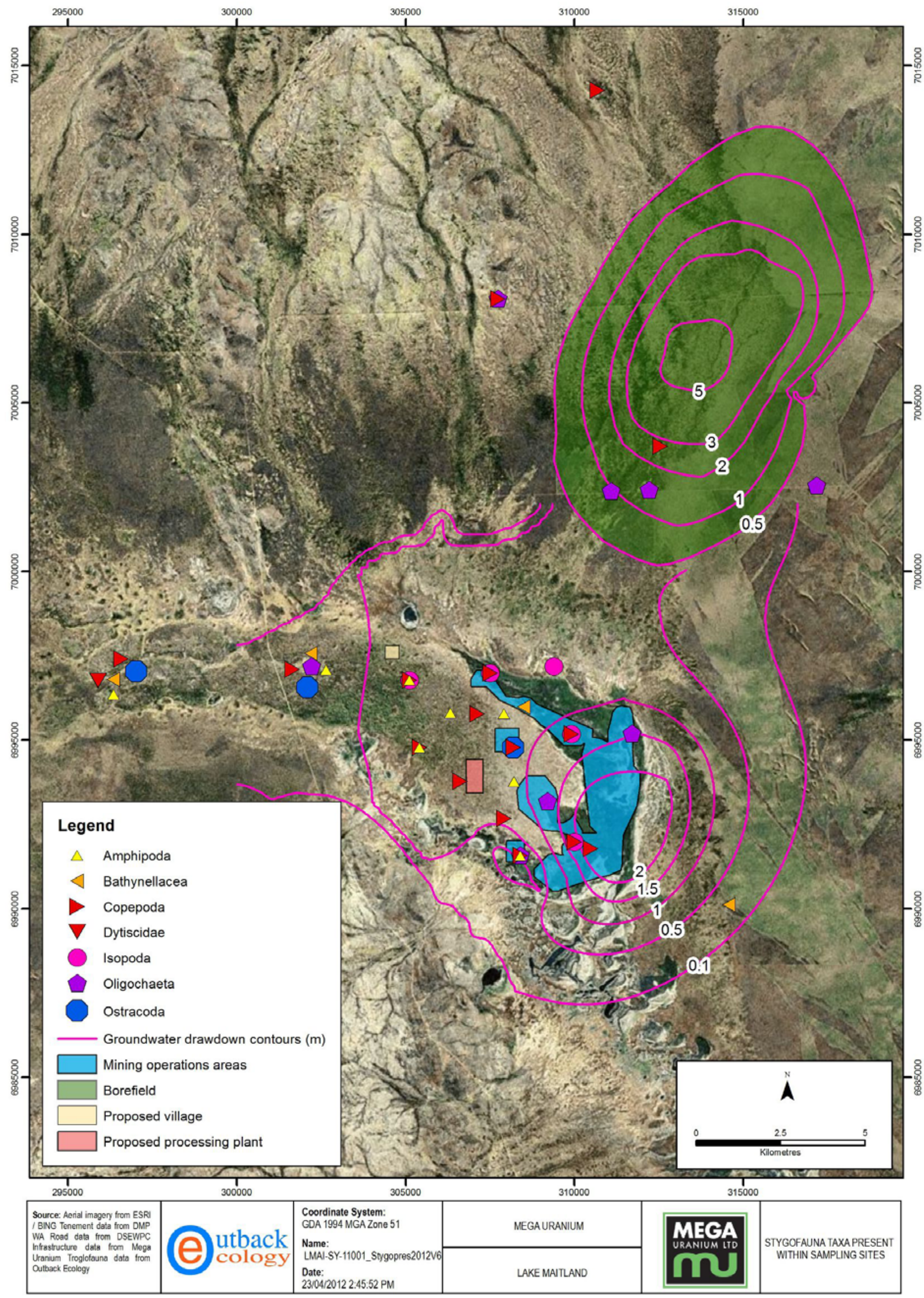

Figure 11: Distribution of stygofauna higher level taxonomic groups.

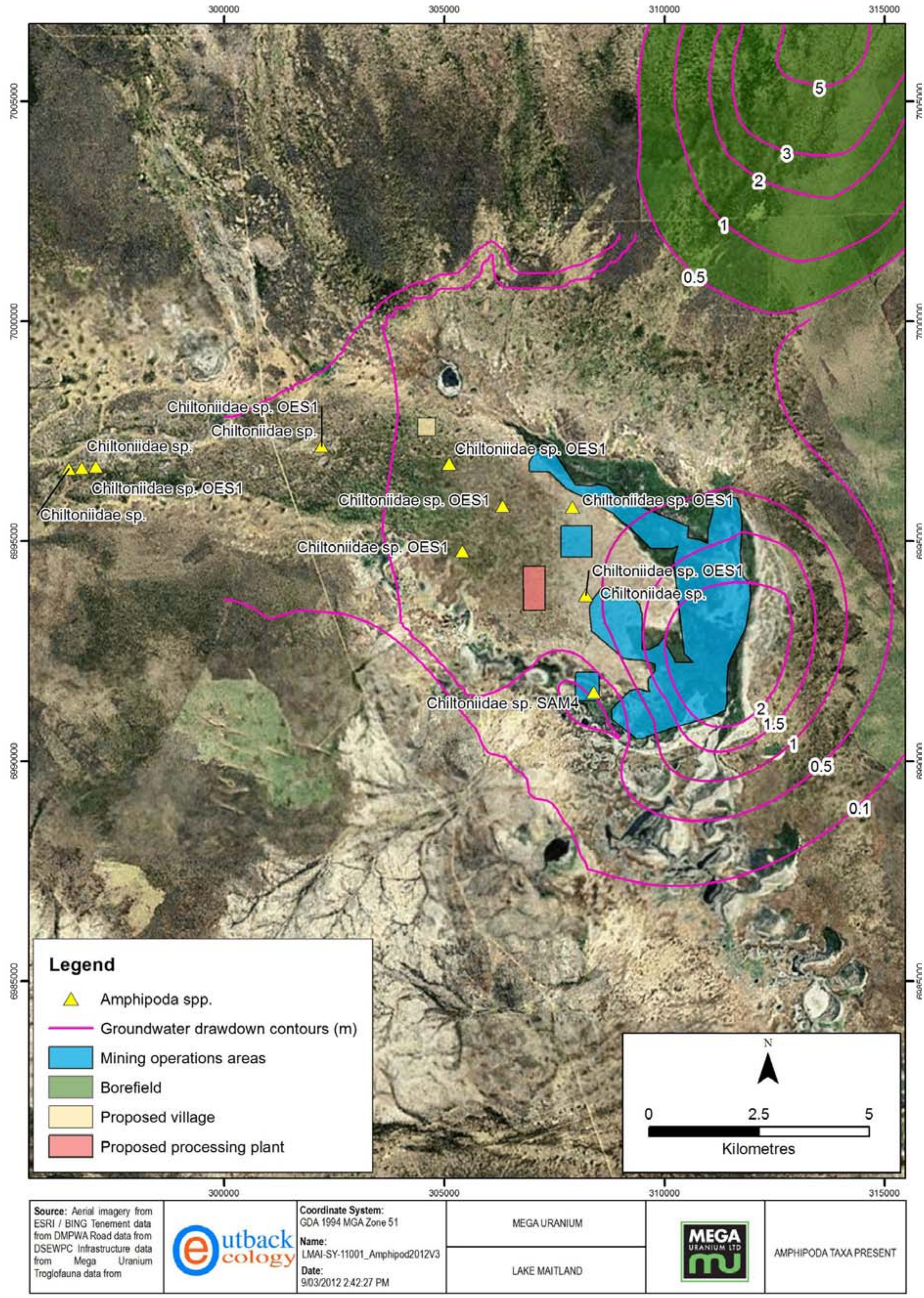

Figure 12: Amphipoda species distributions.

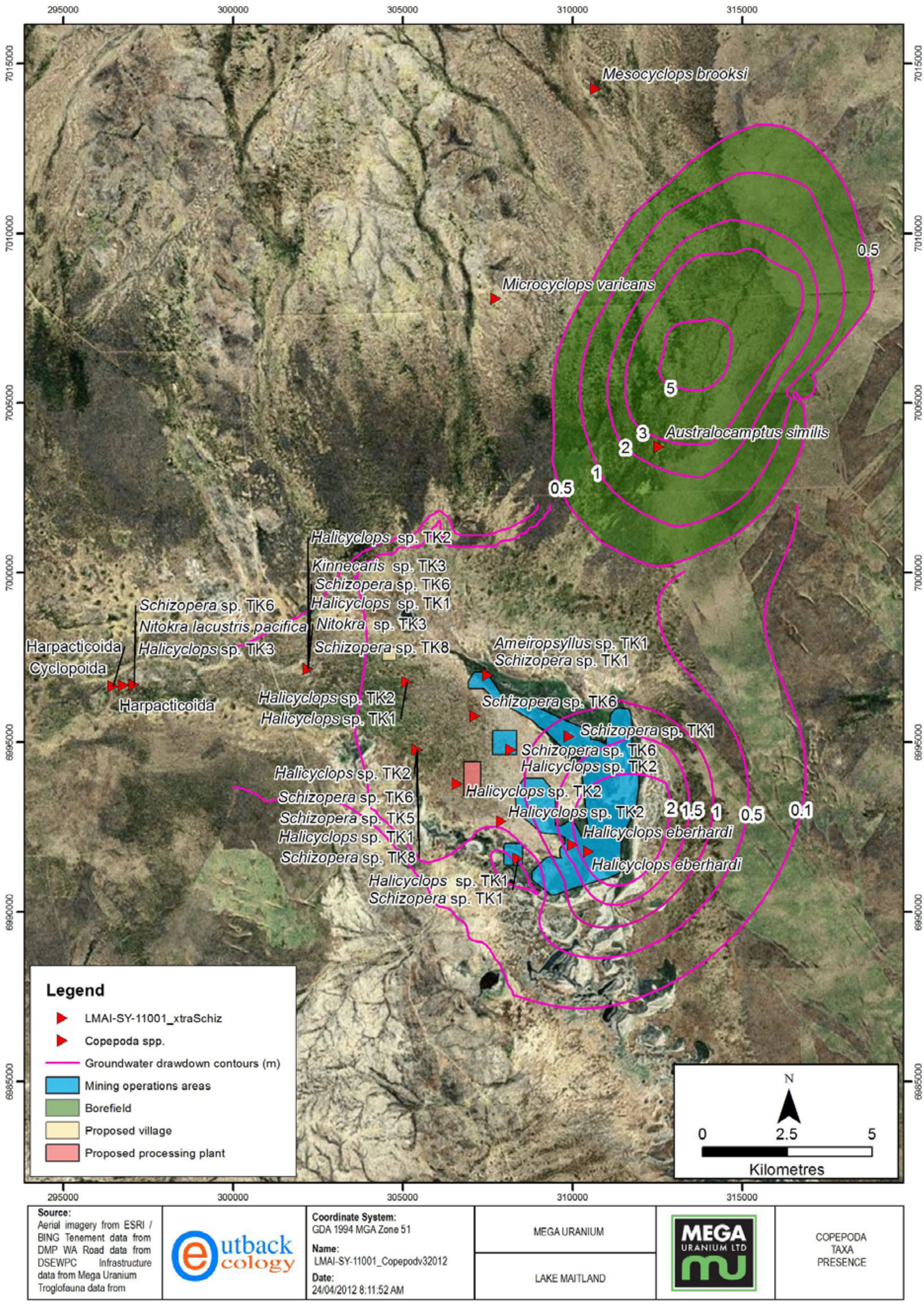

Figure 13: Overview of Copepoda species distributions

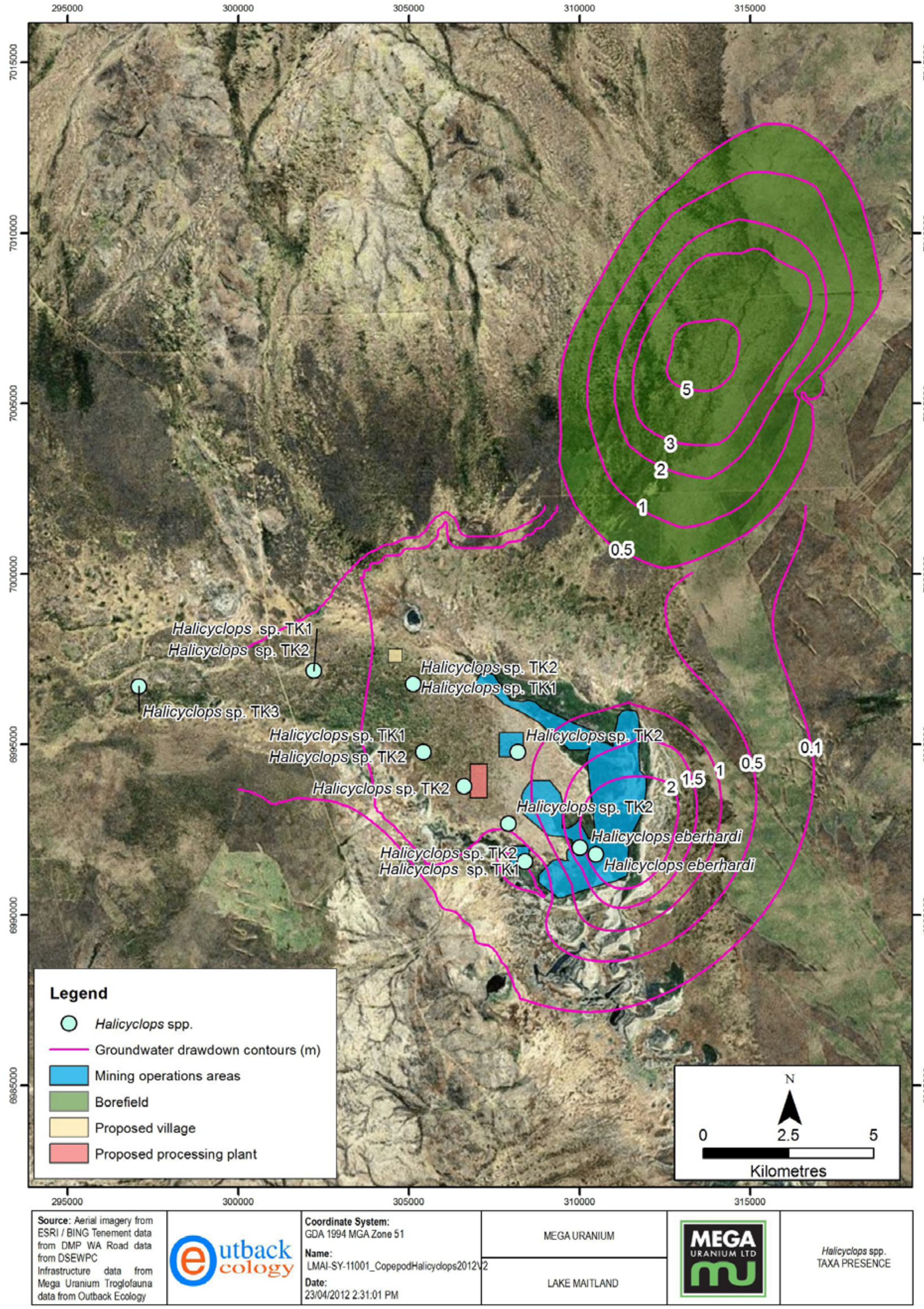

Figure 14: *Halicyclops* (Copepoda) species distributions.

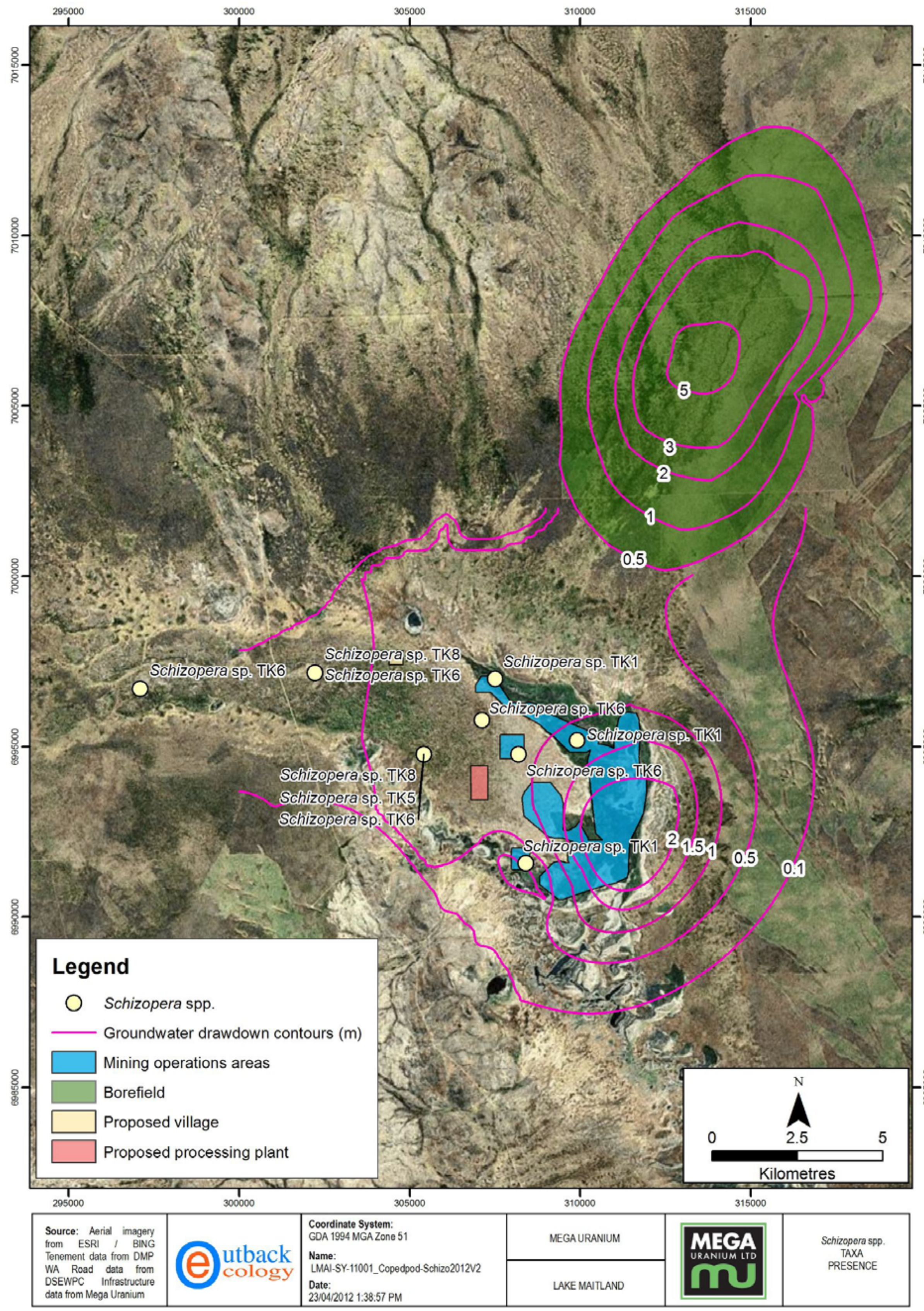

Figure 15: *Schizopera* (Copepoda) species distributions.

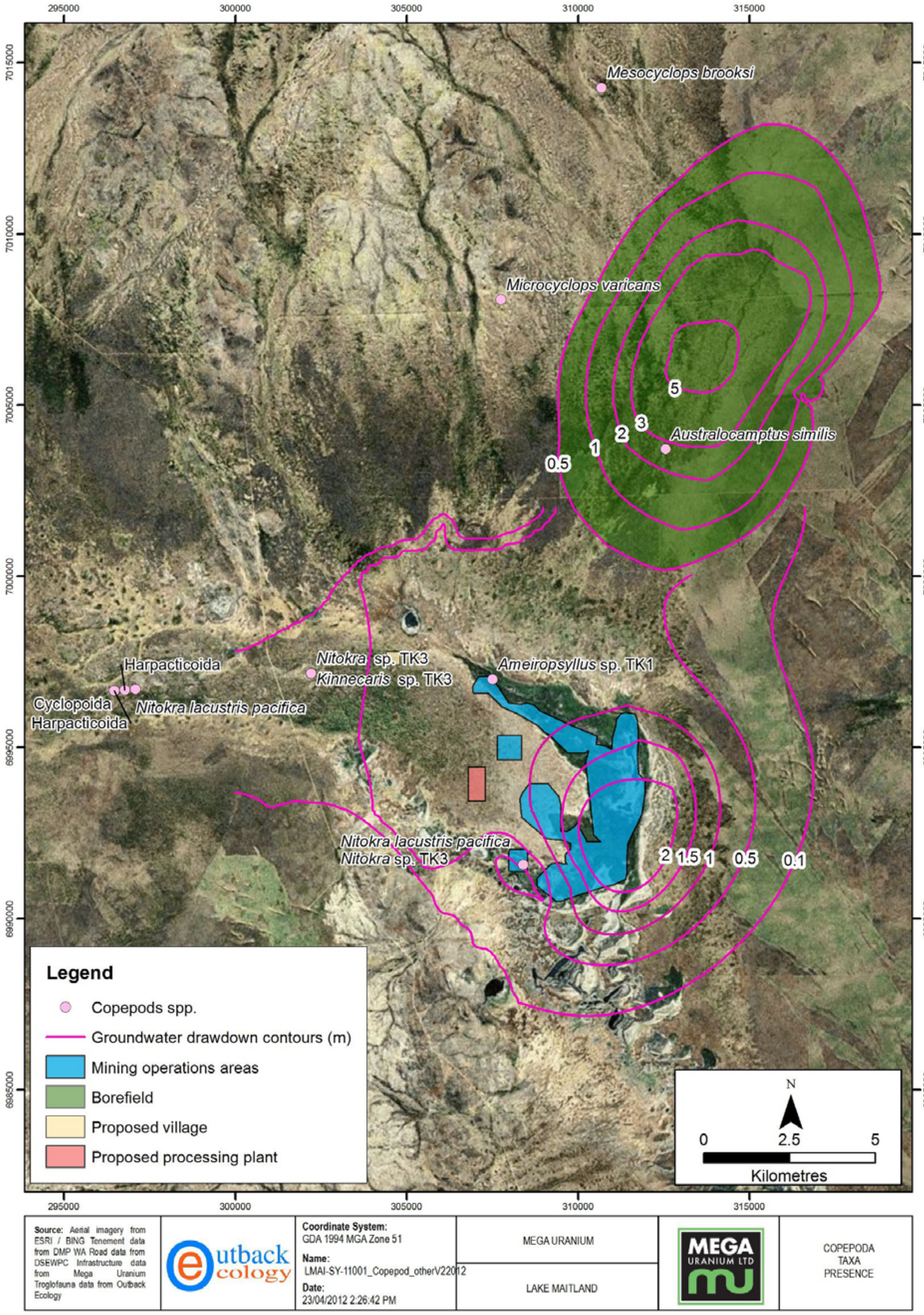

Figure 16: *Ameiropsyllus*, *Australocamptus*, *Kinnecaris*, *Microcyclops*, *Nitokra* (Copepoda) species distributions as well as not yet determined Cyclopoida and Harpacticoida specimens.

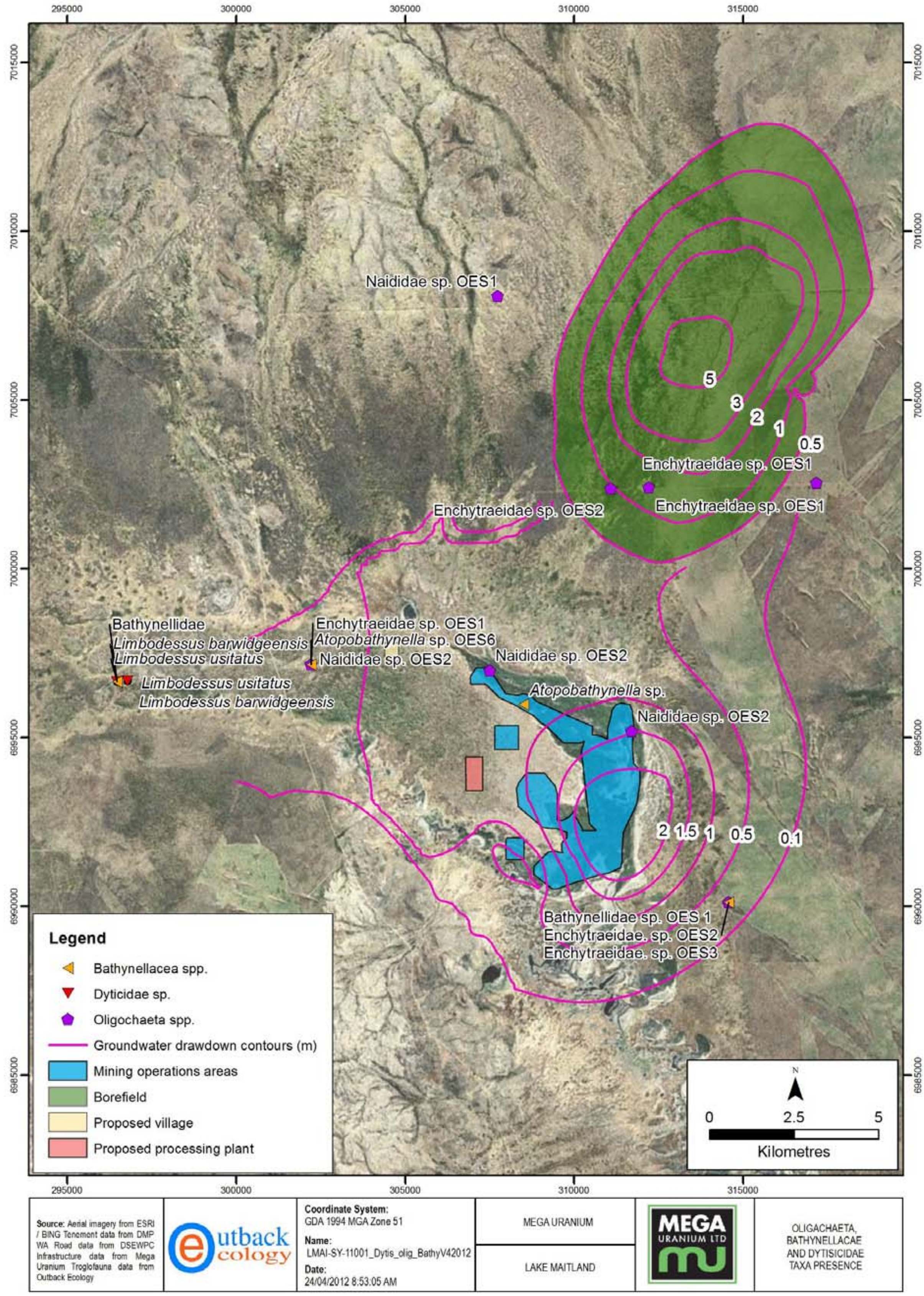

Figure 17: Bathynellacea, Dytiscidae and Oligochaeta species distributions.

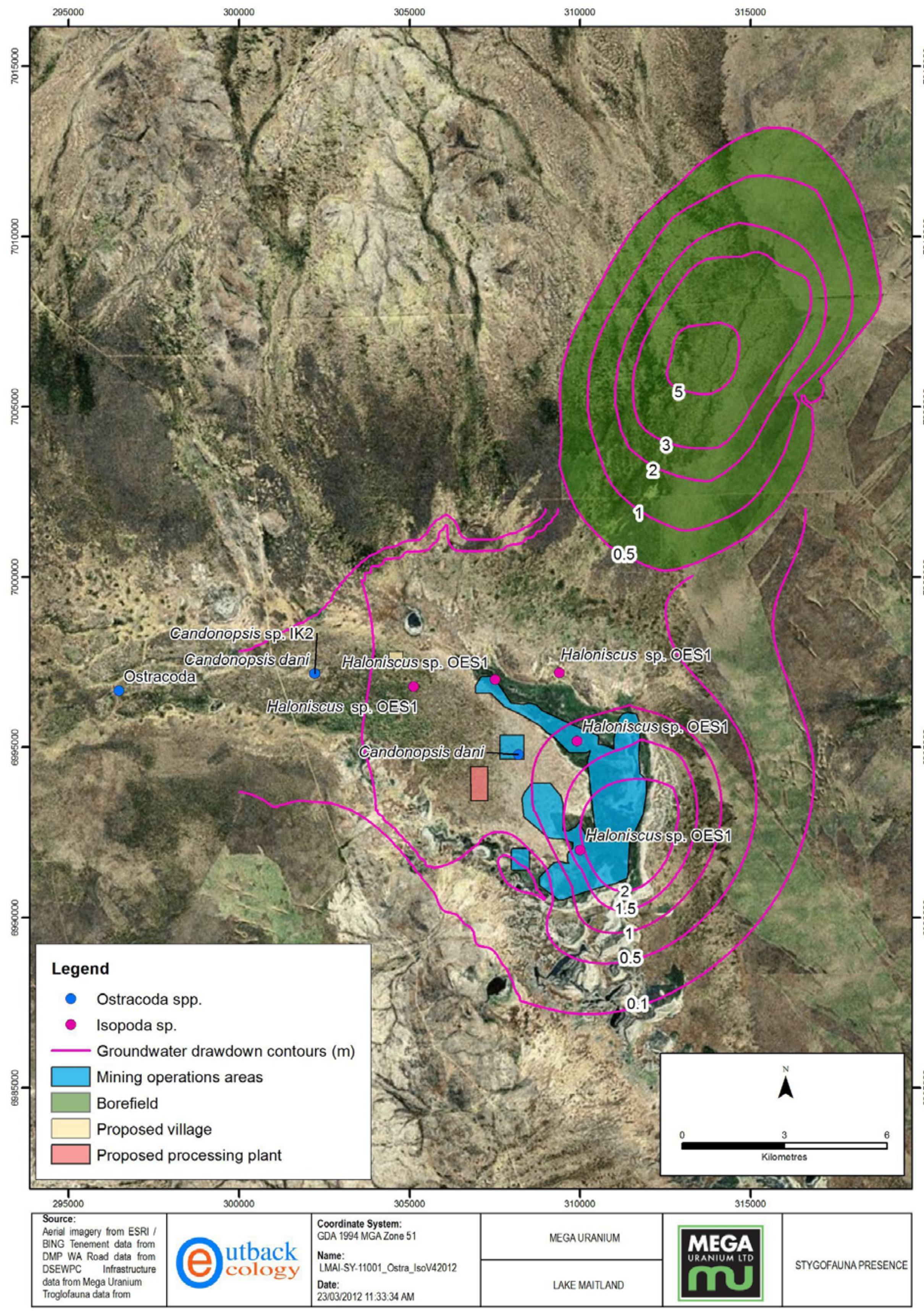

Figure 18: Isopoda and Ostracoda species distributions.

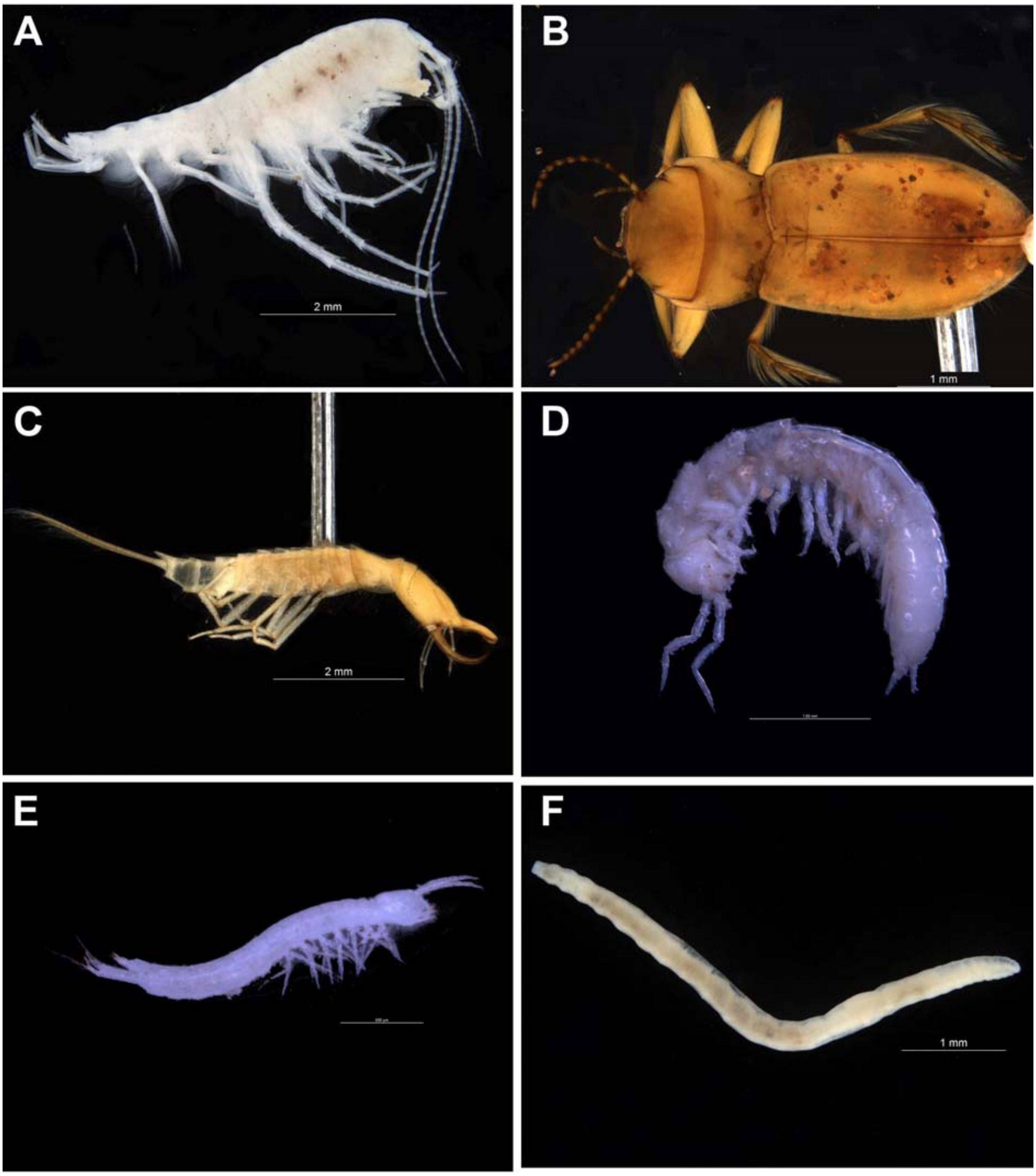

Plate 1: A) Amphipoda Chiltoniidae sp. OES1; B) Dytiscidae adult *Limbodessus barwidgeensis*; C) Dytiscidae larva *Limbodessus barwidgeensis*; D) Isopoda *Haloniscus* sp. OES1; E) Parabathynellidae *Atopobathynella* sp. OES6; F) Oligochaeta – Enchytraeidae sp. OES1.

4.4. Species Diversity Estimates

The species accumulation curve for Lake Maitland shows a relatively constant rate of decline in the rate of new species found which has not reached a plateau by the end of the sample effort conducted (**Figure 19**). An extrapolation of the curve suggests that a further sample round (20 to 30 samples) might yield an additional one, possibly two, stygofauna species.

The various species diversity estimators (e.g., ACE, Bootstrap, Chao, ICE, and Jacknife), excluding MMruns, in EstimateS (Colwell 2009) estimated the total richness of the stygofauna assemblage to range from 28 to 44 species (**Figure 20, Table 8**). The 27 taxa collected in the study (not including species from published records) represent an estimated 97 % to 67 % of the total species predicted to occur in the survey area. MMruns reacted erratically to the data uploaded leading to an unreliable prediction of 98 species occurring (**Figure 20, Table 8**).

The species accumulation curve and various species diversity estimators indicate that further sampling is likely to record new stygofauna species. However, the sample effort required to attempt to collect all stygofauna species that might be present is estimated to need to be at least two to three times more intensive. These results are consistent with species accumulation curves for other subterranean fauna surveys in Australia (e.g. Eberhard *et al.* (2009)) and overseas, many of which do not plateau, even after many years of intensive survey effort (Pipan and Culver 2007). The 111 net haul samples collected from 64 bores in areas which are likely to be impacted by the LMUP exceeds the 40 samples recommended by EPA Guidance Statement 54a (2007). The survey effort undertaken is considered to be more than adequate in providing a reliable characterisation of the stygofauna assemblage present in the LMUP area.

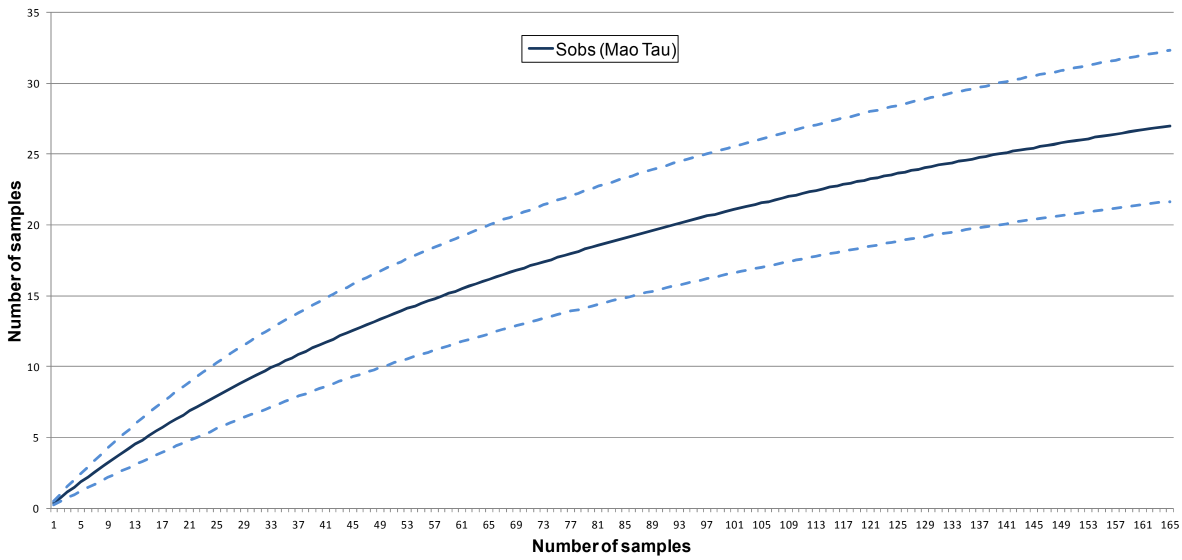

Figure 19: Stygofauna species accumulation curve (Sobs Mao Tau: EstimateS (Colwell 2009)) for Lake Maitland survey area. Dashed lines represent Sobs 95% CI upper and lower confidence intervals.

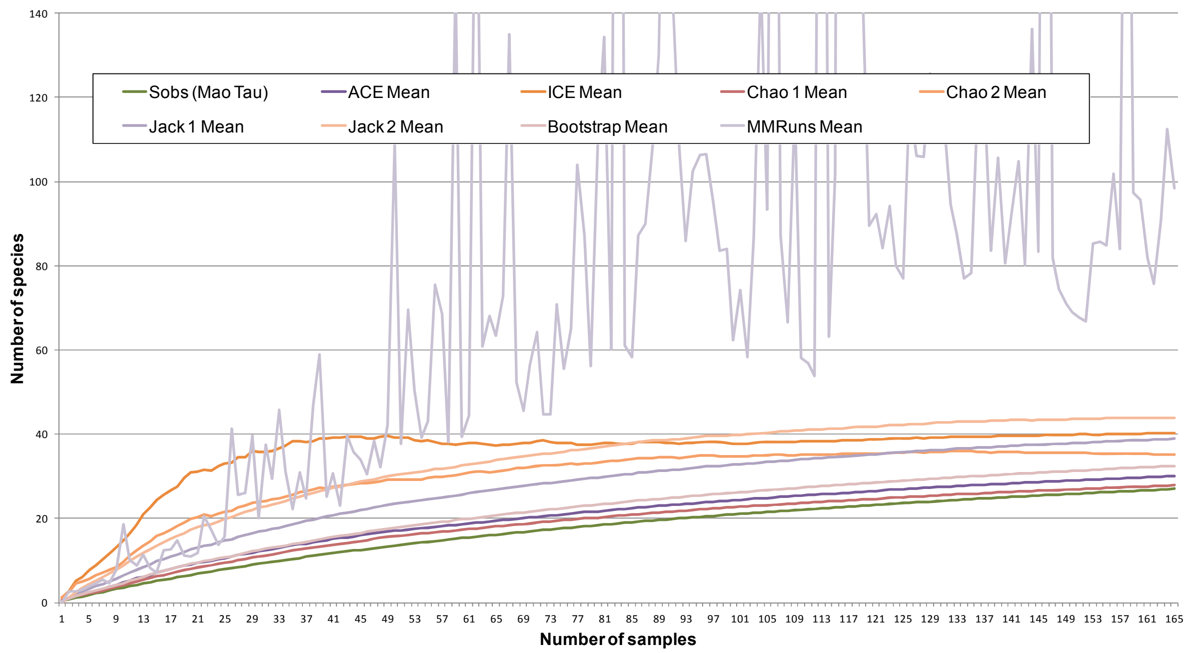

Figure 20: Stygofauna species accumulation curves for various diversity estimators and Sobs Mao Tau EstimateS (Colwell 2009) for Lake Maitland survey area. Y axis truncated as maximum MME value was 580.

Table 8: Observed stygofauna species diversity from Lake Maitland compared to estimated diversity using EstimateS (Colwell 2009) diversity estimators.

Observed v. Diversity Estimators		Obs. & Pred. spp richness	% Predicted collected
Obs.	Sobs (Mao Tau)	27	
Diversity estimators	Chao 1 Mean	27.86	96.91
	ACE Mean	30.04	89.88
	Bootstrap Mean	32.51	83.05
	Chao 2 Mean	35.20	76.70
	Jack 1 Mean	38.93	69.36
	Jack 2 Mean	43.91	61.49
	ICE Mean	40.29	67.01
	MMRuns Mean	98.41	27.44
Range		**27.86 - 98.41**	**27.44 - 96.91**

5. RISK ASSESSMENT

The risk assessment outlined below focuses on the mining operations area only as no species of stygofauna were found to be at risk by the proposed borefield.

5.1. Taxa Of Conservation Concern

The two direct potential impacts of the proposed development of the Mining operations area on stygofauna are the removal of habitat through mining excavation in the resource area and the lowering of the groundwater table through mine pit dewatering. Both impacts pose varying degrees of risk to the conservation of 3 of the 28 stygofauna species recorded that were restricted in distribution to within the mining area or modelled groundwater drawdown contours that exceeded 0.5 m. The removal of habitat through mining excavation poses the higher level of risk to the conservation of stygofauna species relative to the lowering of the groundwater table only.

5.1.1. Mining Excavation

The removal of habitat through mining excavation poses a risk to two of the three species that are of conservation concern. These are Chiltoniidae sp. SAM4 and *Schizopera* sp. TK1.

5.1.1.1. Chiltoniidae sp. SAM4

Chiltoniidae sp. SAM4 is known from three specimens collected in March, 2010 from bore EH01 (**Appendix H**), the only time the bore was sampled (**Appendix A**). Bore EH01 is located south of the surface expression of the Barwidgee calcrete within the lower lying areas fringing the lake playa where groundwater salinity levels present in the upper stratum of the water column of the bore were hypersaline (105.9 mS/cm) (**Figure 6**, **Appendix E**). The low lying environment fringing the lake playa is relatively extensive and consists at the surface of clays/silts with a salt crust (**Appendix B, Plate 2: Figure C**).

The bore lithology for EH01 is not known. Known lithologies of bores BH06 and BH09 to the east of EH01 recorded substantial calcrete strata at depths greater than 10 m bgl (RPS Aquaterra 2010). While to the west of EH01, calcrete was expressed at the surface at bore BH10 (RPS Aquaterra 2010). The surface calcrete layer extended to 4 m bgl with the standing water level occurring at 2.84 m bgl resulting in 1.16 m of saturated calcrete (RPS Aquaterra 2010). At EH01, a thin persistent layer, less than 1 m in thickness, of brown gypcrete/brecciated calcrete that is fractured and sometimes vuggy, was observed to be present approximately 2 m bgl with an underlying layer of low permeable clay (RPS Aquaterra 2010). This thin band of brown gypcrete/brecciated calcrete was observed to be present in at least seven of the ten hydrogeological testing locations conducted at and near to bores BH06, BH08, BH11, EH05, LMAC0147 and LMAC0168 that are located across the southern half of the northern lake playa system (**Figure 6**) (RPS Aquaterra 2010). How extensive this thin band of gypcrete/brecciated calcrete is outside of the resource area has not been investigated. However, the low lying environment fringing the lake playa, beneath which the thin persistent layer of gypcrete/brecciated calcrete is known to occur, does extend beyond the resource area to the west of EH01 and to the south within the southern lake playa system.

The distribution ranges and habitat preferences of stygofauna species that are known from only a few records are difficult to reliably assess. The seemingly restricted distribution of a species to only one or two bores is likely to be an artefact of that species occurring at low population densities and/or possessing an irregular distribution in response to varying habitat factors, biological interactions and availability of energy resources (Boulton 2000, Boulton *et al.* 1998, Humphreys 2009), rather than the actual distribution being confined to such a limited area that perchance was intercepted by a single bore. Reviewing records of closely related species, or species collected sympatrically, can provide further insight into the potential distribution patterns and habitat preferences of species that are known from a few records only.

Genetic data was successfully sequenced from Chiltoniidae sp. SAM4 specimens collected to confirm morphological determination and to investigate evolutionary relatedness with other Chiltoniidae species from the Carey palaeodrainage system. The phylogenetic analysis of the CO1 gene fragment sequenced showed the intraspecific genetic divergence was 2.4 % for the two Chiltoniidae sp. SAM4 specimens that were collected in the same sample (Leijs 2011). This undescribed species is morphologically and genetically distinct from the more abundant and widely distributed Chiltoniidae sp. OES1 that was also collected in this study (**Appendix J**)(Leijs 2011). DNA sequence data showed Chiltoniidae sp. SAM4 was more closely related to Chiltoniidae sp. OES1, with a genetic divergence of 13.8 to 14.9 %, compared to other Chiltoniid species sequenced from Lake Way associated calcretes that showed a genetic divergence of 15.6 to 17.1 % (**Table 3** in Leijs (2011)).

In this study Chiltoniidae sp. OES1 has been shown to occur throughout the Barwidgee calcrete, ranging from near the resource area to more than 10 km westward, and to exist in groundwater environments that range in salinities from hyposaline to mesosaline. In the Lake Way associated calcretes, two chiltoniid species have been confirmed by molecular analysis to be relatively widespread and to also exist within a broad range of groundwater salinity levels (Outback Ecology 2011b). Chiltoniidae sp. SAM3 from the Hinkler Well calcrete was demonstrated to have a distribution that ranged from along the margin of the Lake Way playa, in hypersaline groundwater environments that exceeded 108 mS/cm, to more than 16 km westward up the Hinkler Well calcrete, in fresh groundwater with salinity levels as low as 2.6 mS/cm (Outback Ecology 2011b). More commonly, the salinity levels that Chiltoniidae sp. SAM3 specimens were collected from were in the hyposaline (5–30 mS/cm) to mesosaline (30–70 mS/cm) range. The distribution range of Chiltoniidae sp. SAM1 was found to extend for more than 30 km from Millbillillie Bubble Well calcrete, approximately 18 km north west of Wiluna, to Uramurdah calcrete, approximately 14 km south east of Wiluna (Outback Ecology 2011b). The salinity levels that Chiltoniidae sp. SAM1 specimens were recorded from also ranged from hyposaline to mesosaline groundwater environments (Outback Ecology 2011b). The predominant geological habitat present at the location that each of the chiltoniid species discussed above were collected from contained calcrete. The possible exception to this may be for the bores located near to the Lake Way playa in which Chiltoniidae sp. SAM3 was recorded where the amount of calcrete that may have been present was not known. The data collated indicate that, although chiltoniid species can tolerate hypersaline environments near to salt lake playas where the extent of calcrete may be limited, the preferred environments where species were more commonly collected are less saline conditions within calcrete geologies.

Four other species of stygofauna collected sympatrically with Chiltoniidae sp. SAM4 from Bore EH01, *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, *Nitokra lacustris pacifica*, and *Nitokra* sp. TK3 (**Appendix I**), were also recorded from bores outside of the Mining operations impact areas. Each of these species was found to be able to exist within a broad range of groundwater salinity levels ranging from the hypersaline environment near to the lake playa to hyposaline conditions further westward up the Barwidgee calcrete system at and beyond Little Well (**Appendix G**). The broader distributions and habitat preferences of these four species indicate that contiguous habitable saturated geologies do extend beyond the Mining operations impact areas from along the margins of the northern lake playa system.

A wider distribution range beyond the Mining operations resource area was not demonstrated by this study, or from other accessible records for the area, for Chiltoniidae sp. SAM4. However, when considering the wider expanse of potential habitat outside of the resource area, the wider distribution patterns and habitat preferences of other chiltoniid species, as well as other sympatric stygofauna, it is likely that the distribution range of Chiltoniidae sp. SAM4 is of wider extent within the Barwidgee calcrete ─ Lake Maitland playa system and not confined to the immediate vicinity of the bore from which it was collected.

The proposed mining of the resource area is not considered likely to pose a long term conservation risk to Chiltoniidae sp. SAM4 when taking into consideration the:

- limited area of calcrete habitat removal associated with mining excavation, relative to the much greater expanse of adjacent calcrete habitat remaining;
- broader distribution patterns and habitat preferences of other chiltoniid species;
- broader distributions habitat preferences of other sympatric members of the stygofauna assemblage; and
- expected operational life of the LMUP (12 years).

5.1.1.2. Schizopera sp. TK1

The distribution of *Schizopera* sp. TK1 is known to extend for over 10 km from the northern resource area down to the southern resource area. Six specimens of *Schizopera* sp. TK1 were collected in May, 2007 from bores LMAC0352 and LMAC0448, and in March, 2010 from bore EH01 (**Appendix H**). Only bore LMAC0352 was sampled on one further occasion in 2008, but no additional specimens were collected. All three bores occur within the lower lying areas fringing the lake playa where groundwater salinity levels present in the upper stratum of the water column of the each bore was hypersaline with values ranging from 105.9 to 132.3mS/cm (**Appendix E**). The range in salinity levels other more widely distributed *Schizopera* species have been recorded from in this study as well as from Lake Way (Outback Ecology 2011b) range from hyposaline to hypersaline conditions.

The bore lithology for EH01, as discussed above, is not known. However, lithologies for bores LMAC0352 and LMAC0448 indicate that *Schizopera* sp. TK1 is not confined to calcrete habitat only. For LMAC0352, no calcrete was present with saturated strata present consisting of clay and ferricrete (**Appendix M**). For LMAC0448, over 1.4 m of saturated calcrete habitat was recorded.

Schizopera sp. TK1 has been collected sympatrically with seven species, *Ameiropsyllus* sp. TK1, *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, *Haloniscus* sp. OES1, Naididae sp. OES2, *Nitokra lacustris pacifica*, and *Nitokra* sp. TK3 (**Appendix I**). The distributions of these seven species extended beyond the Mining operations resource area further to the west up the Barwidgee calcrete body and all are known to occur in less saline groundwater and within more substantial calcrete habitats. The broader distributions and habitat preferences of these sympatric species indicate that contiguous habitable saturated geologies do extend beyond the Mining operations resource area from along the margins of the northern lake playa system from where *Schizopera* sp. TK1 was recorded.

A wider distribution range beyond the Mining operations resource area was not demonstrated by this study, or from other accessible records for the area, for *Schizopera* sp. TK1. However, when considering the wider expanse of potential habitat outside of the resource area, the wider distribution patterns and habitat preferences of other *Schizopera* species, as well as other sympatric stygofauna, it is likely that the distribution range of *Schizopera* sp. TK1 is of wider extent within the Barwidgee calcrete ─ Lake Maitland playa system and not confined to the mining operations resource area.

The proposed mining of the resource area is not considered likely to pose a long term conservation risk to *Schizopera* sp. TK1 when taking into consideration the:

- limited area of calcrete habitat removal associated with mining excavation, relative to the much greater expanse of adjacent calcrete habitat remaining;
- broader habitat preferences of other *Schizopera* species;
- broader distribution patterns and habitat preferences of other members of the stygofauna assemblage that were collected sympatrically;
- broader distributions habitat preferences of other sympatric members of the stygofauna assemblage;
- expected operational life of the LMUP (12 years).

5.1.2. Groundwater Drawdown

The removal of habitat through the lowering of the groundwater table through mine pit dewatering poses a risk to *Haloniscus* sp. OES1, one of the three species that are of conservation concern. Groundwater drawdowns of less than 0.5 m fall within the natural variation in standing water levels recorded from the mining operations area, with fluctuations commonly ranging from ± 0.1 to 0.3 m, with less common variations occurring in the range of ± 0.6 to 1.26 m (**Appendix A**). Groundwater drawdowns that exceed the natural variation as a result of human activities are considered to directly impact on stygofauna because can reduce the vertical extent of habitat available (EPA 2007).

5.1.2.1. Haloniscus sp. OES1

The stygal isopod species *Haloniscus* sp. OES1 has a distribution that extends outside of the resource area but has not been collected from outside the mining operations modelled 0.5 m drawdown contour (**Figure 18**). This species is known from 15 specimens collected in total over the May, 2007, December, 2008, March and August, 2010, and March 2011 surveys (**Appendix H**). Eight specimens were collected from within the resource area from bores LMAC0012, LMAC0352, and LMAC0448. The remaining seven specimens were from within the 0.5 m drawdown contour from bores LMAC0545 and LMST008.

Haloniscus sp. OES1 specimens have been recorded from hyposaline and hypersaline environments. The salinity levels recorded in the resource area were hypersaline and ranged from 80 mS/cm at bore LMAC0012 to as high as 132.3 mS/cm at bore LMAC0448. Outside of the resource area within the modelled 0.5 m drawdown, conditions further west up the main Barwidgee calcrete body were hyposaline (20.09 mS/cm) at bore LMST008, but to the north were hypersaline (75.5 mS/cm).

Bore lithologies for LMAC0012, LMAC0352, LMAC0448 and LMAC545 indicate that *Haloniscus* sp. OES1 can occur in non-calcrete sediments. For LMAC0352, no calcrete was present with saturated strata present consisting of clay and ferricrete (**Appendix M**). For LMAC0012, near the eastern margin of the surface expression of the main Barwidgee calcrete body, calcrete began at 1.5 m bgl and was approximately 5 m thick and was mostly saturated with SWL's ranging from 1.5 to 1.8 m bgl (**Appendix M**). For LMAC0448 and LMAC545, the vertical extent of calcrete was less with only 1.43 m and 0.5 m saturated calcrete habitat present, respectively.

The bore lithology for LMST008 is not known but the bore is situated on the main Barwidgee calcrete body, which is expressed near to the surface, in similar surface habitat to what exists at bores Little Well, LT104, LT105 and LT107 that occur westward beyond the 0.5 m drawdown contour (**Figure 5, Figure 6**). Although the vertical extent of saturated calcrete present at LMST008 is unknown, the Barwidgee calcrete formation has been characterised as been generally between 7 and 10 m thick (Golder Associates 2011). Standing water levels recorded at LMST008 ranged from 4.25 to 4.34 m bgl (**Appendix A**). Therefore, it is plausible that approximately 3 to 6 m of saturated could be present in the vicinity of LMST008. As this area would be subjected to a modelled drawdown of between 0.5 to 1 m, approximately 2 to 5 m of saturated calcrete would still remain after proposed 12 years of abstraction without mitigation.

It is likely that the distribution range of *Haloniscus* sp. OES1 does occur outside the Mining operations modelled 0.5 m drawdown contour. The surface expression of the Barwidgee calcrete body extends for a least 10 km westward of the 0.5 m drawdown contour along the palaeochannel towards Lake Way (Figure 5, Figure 9). In addition, *Haloniscus* sp. OES1 has been collected sympatrically with six other stygofauna species, Chiltoniidae sp. OES1, *Ameiropsyllus* sp. TK1, *Halicyclops* eberhardi, *Halicyclops* sp. TK1, *Halicyclops* sp. TK2, and Naididae sp. OES2, (**Appendix I**) whose distributions extend beyond the Mining operations impact areas further to the west up the Barwidgee calcrete body. The broader distributions of these sympatric species and the extent of the habitat indicated by the surface expression of the Barwidgee calcrete reveal that contiguous habitable saturated geologies do extend beyond the Mining operations impact areas from where *Haloniscus* sp. OES1 was recorded.

The modelled groundwater drawdowns associated with the proposed mining of the resource area is not considered likely to pose a long term conservation risk to the stygal isopod, *Haloniscus* sp. OES1, when taking into consideration the:

- the depth of the modeled groundwater drawdowns within the 0.5 to 1 m drawdown contours are not considered to be of a large enough magnitude to lower the SWL to such an extent to render the inhabited subterranean environments present uninhabitable;
- large lateral and vertical extent of adjacent calcrete habitat remaining outside of the Mining operations impact areas;
- broader distribution patterns of other members of the stygofauna assemblage that were collected sympatrically;
- broader distributions habitat preferences of other sympatric members of the stygofauna assemblage; and
- expected operational life of the LMUP (12 years).

6. SUMMARY AND RECOMMENDATIONS

6.1. Stygofauna Assessment

The LMUP stygofauna assessment found the diversity of the Barwidgee calcrete stygofauna PEC to be comparable to the Lake Way associated calcrete PEC's, Lake Violet, Hinkler Well and Uramurdah, that also occur in the Carey Palaeochannel, 110 km to the north west of the LMUP. The findings are summarised as follows:

- Twenty eight species of stygofauna were recorded. Twenty seven species were collected from 83 of the 165 samples from 28 of the 87 bores sampled. One species, *Limbodessus usitatus,* was not collected but is known from published records to occur in the Barwidgee calcrete outside the LMUP impact zones;
- Twenty three species were recorded from the Barwidgee calcrete system and northern Lake Maitland playa system;
    - o 10 species were recorded from inside the mining operations resource area;
    - o eight species were recorded from inside the mining operations modelled 0.5 m groundwater drawdown (without mitigation) contour; and
    - o 19 species were recorded outside the mining operations modelled 0.5 m groundwater drawdown contour;
- six species were recorded from the upper tributary catchment area to the north of Lake Maitland associated with the proposed borefield;
    - o three species were recorded from inside the proposed Borefield groundwater 0.5 m modelled groundwater drawdown contour; and
    - o four species were recorded from outside the proposed Borefield groundwater 0.5 m drawdown contour;
- three of the 28 stygofauna species recorded were of conservation concern because their distributions were not demonstrated to occur outside of the Mining operations impact areas. These were:
    - o Chiltoniidae sp. SAM4 and *Schizopera* sp. TK1 — not recorded outside the mining operations resource area;
    - o *Haloniscus* sp. OES1 — not recorded outside the mining operations modelled 0.5 m groundwater drawdown contour:

The proposed mining of the resource area is not considered likely to pose a long term conservation risk to Chiltoniidae sp. SAM4 or *Schizopera* sp. TK1 when taking into consideration the:

- limited area of calcrete habitat removal associated with mining excavation, relative to the much greater expanse of adjacent calcrete habitat remaining;
- broader distribution patterns and habitat preferences of other Chiltoniid and *Schizopera* species;
- broader distributions habitat preferences of other members of the stygofauna assemblage that were collected sympatrically; and
- expected operational life of the LMUP (12 years).

The modelled groundwater drawdowns associated with the proposed mining of the resource area is not considered likely to pose a long term conservation risk to the stygal isopod, *Haloniscus* sp. OES1, when taking into consideration the:

- the depth of the modeled groundwater drawdowns within the 0.5 to 1 m drawdown contours are not considered to be of a large enough magnitude to lower the SWL to such an extent to render the inhabited subterranean environments present uninhabitable;
- large lateral and vertical extent of adjacent calcrete habitat remaining outside of the Mining operations impact areas;
- broader distribution patterns of other members of the stygofauna assemblage that were collected sympatrically;
- broader distributions habitat preferences of other sympatric members of the stygofauna assemblage; and
- expected operational life of the LMUP (12 years).

6.2. Recommendations

Important recommendations to be considered in the development of an appropriate environmental management plan would be:

- establish a series of monitoring bores around the resource area and running longitudinally westwards along the Barwidgee calcrete; and
- develop an ongoing stygofauna monitoring program to include measuring groundwater parameters such as salinity, as well as stygofauna sampling using net hauling.

It is important that monitoring bores be suitably located and constructed to enable ongoing sampling for stygofauna as well as measuring groundwater parameters. The establishment of monitoring bores and a monitoring program will be important in assisting to determine what variations in the assemblage and/or groundwater parameters are attributed to natural regional scale environmental changes and what may be attributed to proposed mining activities associated with the LMUP.

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8. GLOSSARY

alluvium – sediment deposited by a stream or river

aquatic – relating to water

aquifer – a body of permeable rock or sediment capable of storing groundwater

arid – a region characterised by a severe lack of available water, to the extent that the growth and development of biota is hindered or prevented

bedrock – consolidated rock attached to the earth's crust

biodiversity – the diversity of biota in a particular environment or region

calcrete – carbonate deposits that form in arid environments, as a result of groundwater evaporation

cave – a subsurface cavity of sufficient size that a human could enter

dissolved oxygen – a measure of the amount of gaseous oxygen dissolved in a solution

distribution range – the overall geographic area that a species is known to occur in

divergence – degree of separation from a common ancestor

diversity – species richness

drawdown – the lowering of the adjacent water table or piezometric surface as a result of groundwater extraction

ecotone – zone of transition among different ecosystems

electrical conductivity – an estimate of the total dissolved salts in a solution, or salinity

endemic – having a distribution restricted to a particular geographic region

epigean – pertaining to the surface zone

fractured rock – a rock formation characterized by separation or discontinuity, usually as a result of geological stress (e.g. faulting)

freshwater – salinity less than 5 mS/cm (3 ppt)

geological ages (e.g. Cainozoic) – distinct time periods within the geological history of the earth

groundwater – water occurring below the ground surface

habitat – an ecological or environmental area that is inhabited by a particular animal or plant species

hypersaline – salinity equal to or greater than 70 mS/cm (50 ppt)

hypogean – pertaining to the subterranean zone

hyposaline – salinity ranging from 5–30 mS/cm (3–20 ppt)

hyporheic zone – spatially fluctuating ecotone within the bed of a river or stream between surface and groundwater. Considered important component of groundwater ecosystems and involved in the 'interstitial highway', forming hyporheic corridor linking associated aquifers.

invertebrates – animals lacking vertebrae

karst – a region of limestone or other soluble rock, characterized by distinctive features such as caves, caverns, sinkholes, underground streams and springs

lineage – a group of organisms related by descent from a common ancestor

mesosaline – salinity ranging from 30─70 mS/cm (20─50 ppt)

molecular – pertaining to the genetic characteristics of an organism or group

morphology – the specific form and structure of an organism or taxon

morphospecies – a general grouping of organisms that share similar morphological traits, but is not necessarily defined by a formal taxonomic rank

palaeoriver, palaeochannel, palaeodrainage – a remnant of a stream or river channel cut in older rock and filled by the sediments of younger overlying rock

pH – a measure of the hydrogen ion concentration of a soil or solution (values below pH of 6.5 are 'acidic', and those above pH 7.5 are 'alkaline')

relictual – having survived as a remnant

salinity – the concentration of all dissolved salts in a solution

semi-arid – a climatic region that receives low annual rainfall (250 – 500 mm)

species – a formal taxonomic unit defining a group or population of organisms that share distinctive characters or traits, are reproductively viable and/or are otherwise identifiable as a related group

species diversity – the number of species present in a particular habitat, ecosystem or region

species accumulation curve – a model used to estimate species diversity or richness

standing water level – the depth to groundwater from a particular reference point (e.g. in a monitoring bore)

stygal, stygo – pertaining to groundwater habitat or biota

stygobite – an obligate aquatic species of groundwater habitats

stygobiont – another term used to describe obligate inhabitants of groundwater systems

stygofauna – a general term for aquatic groundwater fauna

stygophile – an aquatic species that temporarily or permanently inhabits groundwater habitats

stygoxene – an aquatic species that has no fixed affinity with groundwater habitats, but may nonetheless occur in groundwater habitats

taxon – an identifiable group of organisms, usually based on a known or inferred relationship or a shared set of distinctive characteristics

void – a pore space in the rock or stratum

Yilgarn – pertaining to the Yilgarn Craton, a 65,000 km^2 body of the earth's crust in south-western Australia that dates back to the Archaean period, 2.6 to 3.7 million years ago

Appendix A

Stygofauna survey effort

Stygofauna survey effort

Bore code	WGS 84 Eastings	WGS 84 Northings	Survey date	Surface Geology	No. of stygofauna	No. of individuals	Non-impact	Impact: Mining operations area – Groundwater drawdown (0.5m)	Impact: Mining operations area – Resource	Impact: Borefield	SWL (m bgl)	EoH (m)	Bore Casing
#15 Well	312544	7003705	23/01/2007	Fine sand and calcrete	1	5				●	3.80	-	
6 Mile Bore	307741	7008070	11/12/2008	Red sand clay and calcrete	0	0	●				5.57	8.00	Wooden logs
6 Mile Bore	307740	7008070	8/03/2010	Red sand clay and calcrete	0	0	●				5.91	13.50	
6 Mile Bore	307740	7008070	18/08/2010	Red sand clay and calcrete	2	5	●				5.20	9.00	Wooden logs
6 Mile Bore	307741	7008070	17/07/2011	Red sand clay and calcrete	0	0	●				6.91	15.00	None
BH01	307495	6996779	9/03/2010	Playa lake sediments - Clay	0	0			●		2.24	12.78	PVC
BH02	309414	6995393	9/03/2010	Playa lake sediments - Clay	0	0			●		2.16	14.09	PVC
BH03	311495	6995979	10/03/2010	Playa lake sediments - Clay	0	0			●		2.21	13.20	PVC
BH04	311594	6994783	10/03/2010	Playa lake sediments - Clay	0	0			●		1.62	14.60	PVC
BH05	311397	6994172	9/03/2010	Playa lake sediments - Clay	0	0			●		1.81	12.45	PVC
BH06	310886	6992779	9/03/2010	Carbonaceous mudstone	0	0			●		1.84	14.53	PVC
BH08	309993	6992230	10/03/2010	Playa lake sediments - Clay	0	0			●		2.36	12.92	PVC
BH09	309994	6991580	8/03/2010	Playa lake sediments - Clay	0	0			●		2.18	-	PVC
BH10	307797	6992281	9/03/2010	Calcrete	0	0		●			3.70	10.45	PVC
BH11	309948	6990980	9/03/2010	Playa lake sediments - Clay	0	0			●		2.34	-	PVC
BJP5	308581	6981024	11/12/2008	Clay and calcrete	0	0	●				14.00	30.00	Steel
Eclipse Well	316616	6975320	25/05/2007	Alluvium and colluvium	0	0	●				2.72	4.00	
Eclipse Well	316616	6975320	11/12/2008	Alluvium and colluvium	0	0	●				2.50	4.00	Wooden logs
EH01	308397	6991573	8/03/2010	Calcrete	2	18			●		2.30	23.00	PVC
EH02	310475	6991789	9/03/2010	Playa lake sediments - Clay	0	0			●		2.12	18.99	PVC
EH03	309004	6993186	9/03/2010	Calcrete	0	0			●		5.30	21.40	PVC
EH04	311393	6993367	9/03/2010	Playa lake sediments - Clay	0	0			●		0.95	16.84	PVC
EH05	310600	6994777	9/03/2010	Calcrete	0	0			●		1.42	22.02	PVC
EH06	308500	6995972	9/03/2010	Calcrete	0	0			●		2.52	23.00	PVC
GA-DB03	312401	6988343	24/01/2007	Alluvium and colluvium	0	0	●				1.85	17.10	PVC
GA-DB03	312401	6988343	19/07/2011	Alluvium and colluvium	0	0	●				1.85	19.00	PVC
GA-SB56	309642	6988293	24/01/2007	Playa lake sediments - Clay	0	0	●				0.81	8.10	PVC
GA-SB56	309642	6988293	19/07/2011	Playa lake sediments - Clay	0	0	●				0.81	9.00	PVC
GA-SB57	311146	6988329	24/01/2007	Playa lake sediments - Clay	0	0	●				4.23	9.00	PVC
GA-SB57	311146	6988329	19/07/2011	Playa lake sediments - Clay	0	0	●				4.23	10.00	PVC
GA-SB58	311580	6988335	24/01/2007	Playa lake sediments - Clay	0	0	●				1.57	9.00	PVC
GA-SB58	311580	6988335	19/07/2011	Playa lake sediments - Clay	0	0	●				1.57	10.00	PVC
GA-SB59	313230	6988353	24/01/2007	Alluvium and colluvium	0	0	●				3.50	10.80	PVC
GA-SB59	313230	6988353	19/07/2011	Alluvium and colluvium	0	0	●				3.50	12.00	PVC

Stygofauna survey effort (cont.)

Bore code	WGS 84 Eastings	WGS 84 Northings	Survey date	Surface Geology	No. of stygofauna	No. of individuals	Non-impact	Impact: Mining operations area: Groundwater drawdown (0.5m)	Impact: Mining operations area: Resource	Impact: Borefield	SWL (m bgl)	EoH (m)	Bore Casing
Little Well	302211	6997164	24/01/2007	Calcrete	1	1	•				-	-	PVC
Little Well	302211	6997164	22/05/2007	Calcrete	1	1	•				3.87	10.00	PVC
Little Well	302211	6997164	11/12/2008	Calcrete	1	1	•				4.51	8.00	PVC
Little Well	302211	6997164	9/03/2010	Calcrete	5	125	•				4.67	-	PVC
Little Well	302210	6997164	18/08/2010	Calcrete	6	103	•				4.26	9.90	PVC
Little Well	302211	6997164	14/03/2011	Calcrete	5	100	•				4.02	10.50	PVC
Little Well	302211	6997164	18/07/2011	Calcrete	6	123	•				3.95	11.00	PVC
LMAC0008*	309784	6991975	23/05/2007	Sandy clay	0	0			•		1.80	8.43	
LMAC0009*	309844	6991983	23/05/2007	Sandy clay	0	0			•		1.80	8.67	
LMAC0009*	309844	6991983	9/12/2008	Sandy clay	1	1			•		2.03	8.00	PVC
LMAC0010*	309897	6991980	23/05/2007	Sandy clay	0	0			•		1.50	8.46	
LMAC0011*	309945	6991984	23/05/2007	Sandy clay	0	0			•		2.18	8.80	
LMAC0011*	309945	6991984	10/12/2008	Sandy clay	1	1			•		1.90	9.00	PVC
LMAC0012*	309998	6991982	22/01/2007	Sandy clay	1	1			•		-	-	
LMAC0012*	309998	6991982	23/05/2007	Sandy clay	1	1			•		1.58	8.13	
LMAC0012*	309998	6991982	10/12/2008	Sandy clay	1	2			•		1.80	9.00	PVC
LMAC0012*	309998	6991982	15/03/2011	Sandy clay	1	1			•		1.51	7.95	PVC
LMAC0147*	309894	6992778	24/05/2007	Sandy clay	0	0			•		2.00	8.00	PVC
LMAC0147*	309894	6992778	10/12/2008	Sandy clay	0	0			•		2.00	8.00	PVC
LMAC0160*	308902	6993181	22/05/2007	Sandy clay and calcrete	0	0			•		3.55	8.75	
LMAC0160*	308902	6993181	9/12/2008	Sandy clay and calcrete	0	0			•		3.50	10.00	PVC
LMAC0168*	309445	6992382	24/05/2007	Calcrete	0	0			•		2.50	9.00	PVC
LMAC0168*	309445	6992382	10/12/2008	Calcrete	0	0			•		2.50	9.00	PVC
LMAC0179*	310547	6992379	23/05/2007	Sandy clay	0	0			•		1.18	8.05	
LMAC0179*	310547	6992379	9/12/2008	Sandy clay	0	0			•		1.45	7.00	PVC
LMAC0212*	311601	6993184	24/05/2007	Sandy clay	1	1			•		0.95	7.70	
LMAC0212*	311601	6993184	10/12/2008	Sandy clay	0	0			•		1.05	9.00	PVC
LMAC0266*	311798	6994380	24/05/2007	Sandy clay	1	1			•		0.80	5.80	
LMAC0266*	311798	6994380	10/12/2008	Sandy clay	0	0			•		1.00	5.00	PVC
LMAC0291*	309298	6994580	24/05/2007	Calcrete	0	0		•			3.50	8.00	PVC
LMAC0291*	309298	6994580	10/12/2008	Calcrete	0	0		•			3.50	8.00	PVC
LMAC0312*	310999	6994782	24/05/2007	Sandy clay	0	0			•		1.36	6.40	
LMAC0312*	310999	6994782	10/12/2008	Sandy clay	0	0			•		2.62	8.00	PVC
LMAC0334*	311703	6995182	24/05/2007	Sandy clay	0	0			•		1.00	6.20	

Stygofauna survey effort (cont.)

Bore code	WGS 84 Eastings	WGS 84 Northings	Survey date	Surface Geology	No. of stygofauna	No. of individuals	Non-impact	Impact			SWL (m bgl)	EoH (m)	Bore Casing
								Mining operations area		Borefield			
								Groundwater drawdown (0.5m)	Resource				
LMAC0334*	311703	6995182	10/12/2008	Sandy clay	1	18			●		1.05	7.00	PVC
LMAC0352*	309905	6995181	24/05/2007	Sandy clay	2	7			●		1.16	6.07	
LMAC0352*	309905	6995181	10/12/2008	Sandy clay	0	0			●		1.38	8.00	PVC
LMAC0399*	311396	6996779	10/12/2008	Sandy clay and calcrete	0	0		●			2.50	8.00	PVC
LMAC0401*	311602	6996780	10/12/2008	Sandy clay and calcrete	0	0		●			1.50	6.00	PVC
LMAC0406*	311603	6996980	10/12/2008	Calcrete	0	0		●			2.50	8.00	PVC
LMAC0423*	308501	6995978	10/12/2008	Sandy clay	1	1			●		1.50	8.00	PVC
LMAC0423*	308501	6995978	9/03/2010	Sandy clay	0	0			●		2.32	7.40	
LMAC0448*	307503	6996986	22/05/2007	Sandy clay	1	1			●		1.30	7.60	
LMAC0448*	307503	6996986	10/12/2008	Sandy clay	1	1			●		1.50	8.00	PVC
LMAC0448*	307503	6996986	9/03/2010	Sandy clay	1	2			●		1.61	7.75	
LMAC0448*	307503	6996986	15/03/2011	Sandy clay	0	0			●		1.07	7.56	PVC
LMAC0505*	309008	6993184	22/05/2007	Sandy clay and calcrete	0	0			●		4.50	6.00	PVC
LMAC0505*	309008	6993184	10/12/2008	Sandy clay and calcrete	0	0			●		4.50	6.00	PVC
LMAC0527*	310603	6993579	22/05/2007	Calcrete	0	0			●		1.70	8.58	
LMAC0541*	309402	6996780	23/05/2007	Sandy clay and calcrete	0	0		●			1.57	8.10	
LMAC0545*	309396	6997182	10/12/2008	Sandy clay and calcrete	1	6		●			1.50	8.00	PVC
LMACW1	314858	7002470	23/01/2007	Sandy clay	0	0				●	4.60	-	PVC
LMACW1	314858	7002470	11/12/2008	Sandy clay	0	0				●	4.82	91.00	PVC
LMACW1	314858	7002470	18/08/2010	Sandy clay	0	0				●	4.81	91.00	PVC
LMACW1	314858	7002470	12/02/2011	Sandy clay	0	0				●	4.60	-	PVC
LMACW1	314858	7002470	17/07/2011	Sandy clay	0	0				●	4.75	99.00	PVC
LMACW20	312195	7007974	12/02/2011	Clay	0	0				●	6.21	39.25	PVC
LMACW20	312195	7007974	17/07/2011	Clay	0	0				●	6.18	42.00	PVC
LMACW25	317044	7008275	12/02/2011	Fine grained topsoil	0	0				●	5.04	57.60	PVC
LMACW25	317044	7008275	16/07/2011	Fine grained topsoil	1	15				●	5.91	63.00	
LMACW30	311820	7019855	13/02/2011	Ferricrete	0	0	●				3.30	36.17	PVC
LMACW30	311820	7019855	16/07/2011	Ferricrete	0	0	●				3.44	-	PVC
LMACW34	309619	7010825	13/02/2011	Calcrete	0	0	●				6.99	45.66	PVC
LMACW34	309619	7010825	16/07/2011	Calcrete	0	0	●				7.00	51.00	PVC
LMACW36	312214	7002409	12/02/2011	Fine sand	1	3				●	3.60	34.73	PVC
LMACW37	310850	7002374	12/02/2011	Fine sand	1	1				●	3.64	31.20	PVC
LMACW37	310850	7002374	17/07/2011	Fine sand	0	0				●	3.42	61.00	PVC
LMACW40	317178	7002538	12/02/2011	Fine to coarse grained topsoil	1	37	●				9.25	27.48	PVC

Stygofauna survey effort (cont.)

Bore code	WGS 84 Eastings	WGS 84 Northings	Survey date	Surface Geology	No. of stygofauna	No. of individuals	Non-impact	Impact			SWL (m bgl)	EoH (m)	Bore Casing
								Mining operations area		Borefield			
								Groundwater drawdown (0.5m)	Resource				
LMACW40	317178	7002538	17/07/2011	Fine to coarse grained topsoil	1	7	●				9.21	13.50	PVC
LMACW41	318338	7002409	12/02/2011	Fine grained topsoil	0	0	●				11.35	29.60	PVC
LMACW41	318338	7002409	17/07/2011	Fine grained topsoil	0	0	●				11.35	29.60	PVC
LMACW44	317200	6988385	13/02/2011	Fine to coarse sand	0	0	●				7.72	37.70	PVC
LMACW52	292281	6997010	13/02/2011	Calcrete	0	0		●			4.01	21.54	PVC
LMACW52	292281	6997010	18/07/2011	Calcrete	0	0		●			4.79	23.00	PVC
LMACW56	301969	6994700	13/02/2011	Sand	0	0	●				3.32	31.29	None
LMACW56	301969	6994700	18/07/2011	Sand	0	0	●				3.23	39.00	None
LMACW68	314300	7010790	13/02/2011	Sand and calcrete/ferricete	0	0				●	5.13	29.28	PVC
LMACW68	314300	7010790	16/07/2011	Sand and calcrete/ferricete	1	10				●	5.08	29.00	PVC
LMACW69	310680	7014260	12/02/2011	Sand and calcrete/ferricete	0	0	●				9.47	45.02	PVC
LMACW69	310680	7014260	16/07/2011	Sand and calcrete/ferricete	2	4	●				9.48	50.00	PVC
LMACW71	313600	7014330	12/02/2011	Fine-medium sand and ferricete	0	0	●				8.98	65.47	PVC
LMACW71	313600	7014330	16/07/2011	Fine-medium sand and ferricete	0	0	●				9.00	74.00	PVC
LMACW75	312230	7014335	12/02/2011	Fine sand and calcrete	0	0	●				9.59	23.64	PVC
LMACW75	312230	7014335	16/07/2011	Fine sand and calcrete	0	0	●				9.63	-	PVC
LMACW76	311765	7004700	10/12/2008	Fine sand and calcrete	0	0				●	4.15	30.60	PVC
LMACW76	311765	7004700	12/02/2011	Fine sand and calcrete	0	0				●	4.34	31.40	PVC
LMACW76	311765	7004700	17/07/2011	Fine sand and calcrete	1	33				●	4.15	30.60	PVC
LMSC-021*	310480	6991784	10/12/2008	Playa lake sediments - Clay	0	0			●		1.64	8.00	PVC
LMSC-030	310480	6991784	10/12/2008	Sandy clay	0	0			●		1.34	24.00	PVC
LMST001	307400	6993767	17/08/2010	Calcrete	0	0		●			4.08	8.10	PVC
LMST001	307400	6993767	15/03/2011	Calcrete	0	0		●			4.10	7.58	PVC
LMST002	308213	6993778	17/08/2010	Calcrete	2	8		●			3.78	8.10	PVC
LMST002	308213	6993778	15/03/2011	Calcrete	0	0		●			3.68	7.12	PVC
LMST003	309812	6993785	17/08/2010	Calcrete	0	0		●			2.85	8.10	PVC
LMST003	309812	6993785	15/03/2011	Calcrete	0	0		●			2.63	6.94	PVC
LMST004	307911	6992673	17/08/2010	Calcrete	0	0		●			4.30	8.10	PVC
LMST004	307911	6992673	15/03/2011	Calcrete	1	4		●			4.12	6.58	PVC
LMST005	307109	6992680	17/08/2010	Calcrete	0	0		●			3.47	8.10	PVC
LMST005	307109	6992680	15/03/2011	Calcrete	0	0		●			3.28	6.00	PVC
LMST006	308186	6994776	17/08/2010	Calcrete	3	46		●			3.87	8.10	PVC
LMST006	308186	6994776	15/03/2011	Calcrete	0	0		●			3.60	7.09	PVC
LMST007	307909	6995780	18/08/2010	Calcrete	0	0		●			3.74	8.10	PVC

Stygofauna survey effort (cont.)

Bore code	WGS 84 Eastings	WGS 84 Northings	Survey date	Surface Geology	No. of stygofauna	No. of individuals	Non-impact	Impact			SWL (m bgl)	EoH (m)	Bore Casing
								Mining operations area		Borefield			
								Groundwater drawdown (0.5m)	Resource				
LMST007	307909	6995780	15/03/2011	Calcrete	1	2		•			3.57	6.98	PVC
LMST008	305115	6996771	17/08/2010	Calcrete	3	5		•			4.34	9.00	PVC
LMST008	305115	6996771	14/03/2011	Calcrete	2	4		•			4.25	8.91	PVC
LMST008	305115	6996771	18/07/2011	Calcrete	2	5		•			4.27	8.00	PVC
LMST010	306324	6995800	17/08/2010	Calcrete	1	1		•			3.73	9.00	PVC
LMST010	306324	6995800	14/03/2011	Calcrete	0	0		•			3.48	766.00	PVC
LMST011	307122	6995775	18/08/2010	Calcrete	1	1		•			4.13	8.10	PVC
LMST011	307122	6995775	14/03/2011	Calcrete	0	0		•			4.21	8.04	PVC
LMST012	305413	6994778	17/08/2010	Calcrete	1	1		•			4.01	8.10	PVC
LMST012	305413	6994778	15/03/2011	Calcrete	3	13		•			3.86	7.15	PVC
LMST012	305413	6994778	18/07/2011	Calcrete	6	71		•			3.75	7.00	PVC
LMST014	306610	6993773	17/08/2010	Calcrete	1	7		•			4.30	8.10	PVC
LMST014	306610	6993773	15/03/2011	Calcrete	1	1		•			4.19	7.18	PVC
LT104	296772	6996671	18/07/2011	Calcrete	0	0	•				4.51	28.00	PVC
LT104	296772	6996671	21/09/2011	Calcrete	0	0	•				4.58	27.00	PVC
LT104	296772	6996671	18/11/2011	Calcrete	0	0	•				4.55	30.00	PVC
LT105	296469	6996651	18/07/2011	Calcrete	1	1	•				4.00	13.00	PVC
LT105	296469	6996651	21/09/2011	Calcrete	0	0	•				4.00	18.00	PVC
LT105	296469	6996651	18/11/2011	Calcrete	0	0	•				3.97	13.00	PVC
LT107	297090	6996697	18/07/2011	Calcrete	5	23	•				4.49	10.00	PVC
LT107	297090	6996697	21/09/2011	Calcrete	0	0	•				4.46	9.00	PVC
LT107	297090	6996697	18/11/2011	Calcrete	0	0	•				4.49	11.00	PVC
Northern Control Bore	313864	7002434	11/12/2008	Sandy clay	0	0				•	5.10	53.00	PVC
Northern Control Bore	313865	7002434	18/08/2010	Sandy clay	0	0				•	4.13	49.50	PVC
Northern Control Bore	313865	7002434	17/07/2011	Sandy clay	0	0				•	4.19	52.00	PVC
Salt Well	307413	6984800	25/05/2007	Mafic rocks	0	0	•				7.60	9.45	
Salt Well	307413	6984800	11/12/2008	Mafic rocks	0	0	•				4.50	6.00	Wooden logs
Two Jacks Well	314571	6990115	21/05/2007	Alluvium and colluvium	0	0	•				3.85	4.50	
Two Jacks Well	314571	6990115	10/12/2008	Alluvium and colluvium	1	1	•				4.00	5.00	Steel

*Bore lithology data available

Appendix B

Representative Survey Bore Photos

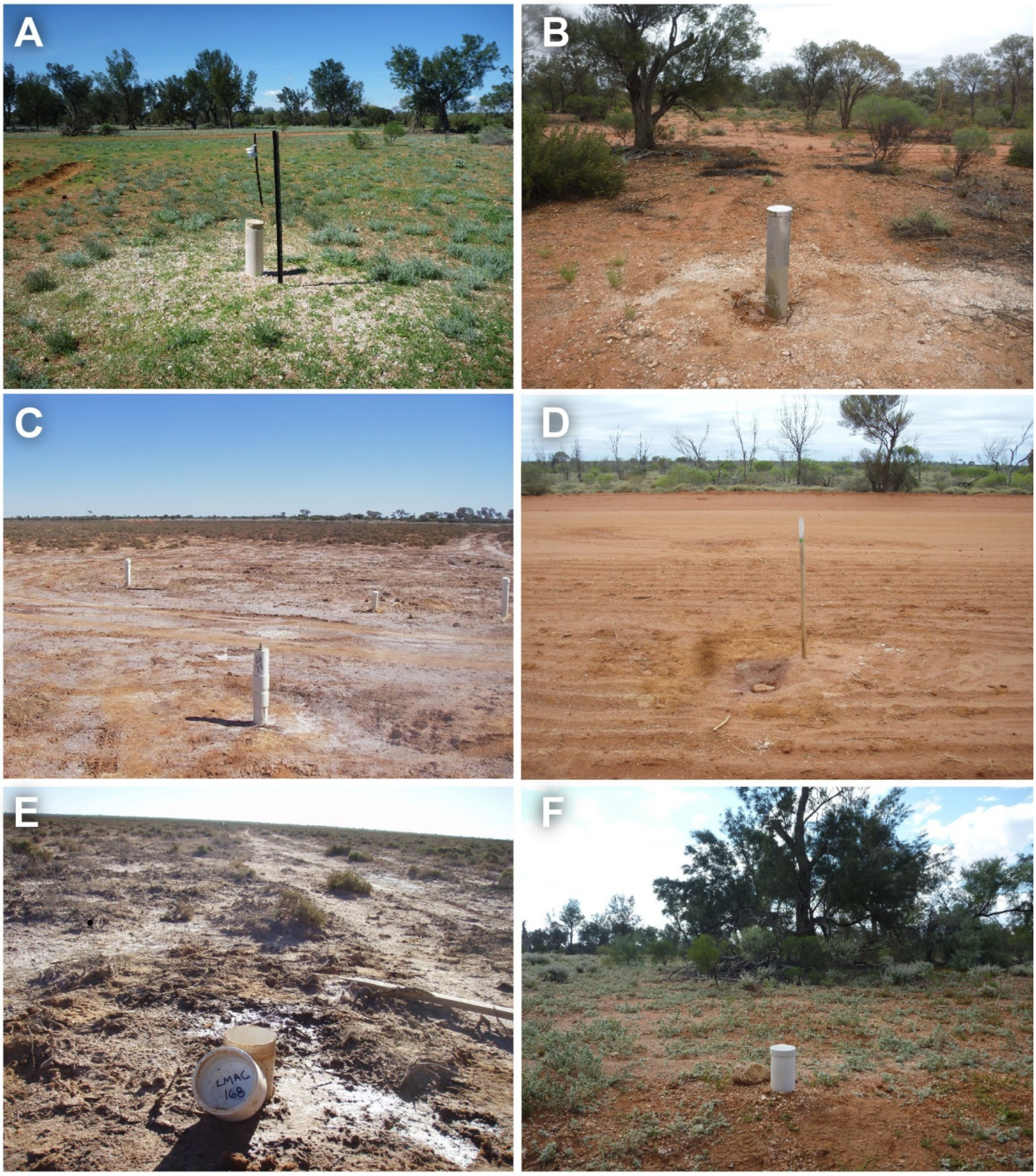

Plate 2: A) Little Well – mining operations non-impact area; B) LMST012 – mining operations groundwater drawdown area; C) EH01/LMSC025 – mining operations resource area; D) LMACW56 – mining operations non-impact area; E) LMAC168 – mining operations resource area; F) LT105 (WAM3) – mining operations non-impact area.

Plate 3: A) #15 well – Borefield groundwater drawdown area; B) LMACW20 – Borefield groundwater drawdown area; C) GA-DB03 – mining operations non-impact area; D) GA-SB59 – mining operations non-impact area; E) LMAC0179 – mining operations resource area; F) LMAC0448 – mining operations resource area.

Appendix C

Lake Maitland WAM Crustacean database search data

Lake Maitland WAM Crustacean database search data

ORDER	FAMILY	GENUS	SPECIES	SITE	LATITUDE	LONGITUDE
Bathynellacea	Parabathynellidae	*Atopobathynella*	*hinzeae*		27°55`48”S	120°03`31”E
				Depot Springs Station, Bore 03	27°58`01”S	120°00`04”E
			wattsi	Millbillillie Station, Main Roads bore north	26°41`04”S	120°12`54”E
				Paroo Station, GSWA 15 south	26°24`01”S	119°45`47”E
				Millbillillie Station, Main Roads bore north	26°41`04”S	120°12`54”E
		Brevisomabathynella	*jundeeensis*	Gascoyne, Jundee Station, JSP 10, South Hill Well BF, Jundee Mine	26°21`22”S	120°38`56”E
Cyclopoida	Cyclopidae	*Metacyclops*	*cf. monacanthus*	Wiluna, Bore Gswa 6c, Paroo Station, Wa	26°26.02`S	119°46.38`E
				Wiluna, Bore Gswa,6a, Paroo Station, Wa	26°26.02`S	119°46.38`E
				Wiluna, Bore Gswa 15c, Paroo Station, Wa	26°24.02`S	119°45.47`E
				Wiluna, Bore Gswa,16, Paroo Station, Wa	26°25.31`S	119°43.43`E
				Wiluna, Bore Gswa,15a, Paroo Station, Wa	26°24.02`S	119°45.47`E
				Wiluna, Bore Gswa,16, Paroo Station, Wa	26°25.31`S	119°43.43`E
				Wiluna, Bore Gswa 6c, Paroo Station, Wa	26°26.02`S	119°46.38`E
				Wiluna, Bore Gswa 5b, Paroo Station, Wa	26°26.25`S	119°46.19`E
			varicans	Wiluna, Comic Court Well, Paroo Station, Wa	26°20.53`S	119°39.17`E
				Wiluna, Bore Gswa,15a, Paroo Station, Wa	26°24.02`S	119°45.47`E
		Fierscyclops	*fiersi*	Murchison Region, Hinkler Well Calcrete, Sample 1, Water Supply Bore	26°41`06"S	120°12`54"E
				Murchison Region, Depot Springs, Friday Well	28°03`36"S	120°04`00"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Next To Pump 1	26°40`30"S	120°13`54"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Next To Pump 5	26°41`06"S	120°13`06"E
				Murchison Region, Wiluna Gold Lake Violet, Small Diameter Bore Wxp5	26°41`08"S	120°13`05"E
		Goniocyclops	*uniartculatus*	Murchison Region, Millbillillie Station, Bore Next Site Of Bubble Well	26°33`36"S	120°02`30"E
				Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
				Murchison Region, Depot Springs Station, Etp13 Groundwater Monitoring Bore	27°55`48"S	120°03`30"E
				Murchison Region, Millbillillie Station, Bore Next Site Of Bubble Well	26°33`36"S	120°02`30"E
				Murchison Region, Depot Springs, Groundwater Monitoring Bore, Site 425	28°03`00"S	120°02`24"E
		Halicyclops	*ambiguus*	Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
				Murchison Region, Friday Well, Depot Springs	28°03`36"S	120°04`00"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°51`16"S	120°20`18"E
				Murchison Region, Depot Springs, Groundwater Monitoring Bore	28°03`00"S	120°02`24"E
			eberhardi	Wiluna, Bore Gswa 15a, Paroo Station	26°24`02"S	119°45`47"E
				Murchison Region, Lake Mason Station, Salt Well	27°32`24"S	119°37`30"E
				Murchison Region, Melrose Station (Lake Darlot), Halfpenny Well	27°42`00"S	121°21`48"E
				Murchison Region, Melrose Station (Lake Darlot), Mineral Exploration Bore Near Halfpenny Well	27°41`48"S	121°20`24"E
				Wiluna, Bore Gswa 15a, Paroo Station	26°24`02"S	119°45`47"E
				Murchison Region, Banjiwarn Station, Croft Well	27°39`00"S	121°21`42"E
				Wiluna, Bore Gswa 6b, Paroo Station	26°24`02"S	119°46`38"E
				Murchison Region, Lake Mason Station, Salt Well	27°32`24"S	119°37`30"E
				Wiluna, Bore Gswa 15a, Paroo Station	26°24`02"S	119°45`47"E
				Murchison Region, Depot Springs, Groundwater Monitoring Bore	28°03`00"S	120°02`24"E
			kieferi	Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°21`12"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp4 Groundwater Monitoring Bore	26°40`54"S	120°13`12"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°20`18"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°21`12"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°51`16"S	120°20`18"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°19`42"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°17`54"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°39`36"S	120°19`18"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`12"S	120°21`12"E
				Murchison Region, Paroo Station, Gswa#15 South Big Groundwater Monitoring Bore	26°26`00"S	119°46`36"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°21`12"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°39`36"S	120°19`18"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`12"S	120°18`12"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°19`36"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°17`54"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°19`42"E
				Murchison Region, Uramurdah Lake Calcrete, Mineral Exploration Bore	26°41`18"S	120°21`12"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore	26°40`30"S	120°13`54"E
				Murchison Region, Uramurdah Lake Calcrete, Saline Bore	26°41`12"S	120°18`12"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Near Pump 1	26°40`30"S	120°13`54"E
		Mesocyclops	*brooksi*	Murchison Region, Site 419, "The Other Home Well", Yeeleerie Station	27°16`54"S	120°05`36"E
				Murchison Region, Townsend Well, Yakabindie Station	27°39`18"S	120°41`12"E
			laurentiisae	Murchison Region, Hinkler Well Calcrete, Main Raods Bore North	26°41`06"S	120°12`54"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp1 Old Bore	26°40`30"S	120°13`54"E
				Murchison Region, Gswa 15 Western Groundwater Monitoring Bore, Paroo Station	26°24`00"S	119°45`48"E
				Murchison Region, Depot Springs Station, Groundwater Monitoring Bore, Location 414	27°58`00"S	120°03`30"E
				Murchison Region, Depot Springs Station, Gums Well	27°55`54"S	120°05`00"E
				Murchison Region, Hinkler Well Calcrete, Dawsons Well	26°51`12"S	120°09`42"E
				Murchison Region, Gswa #6 Small Groundwater Monitoring Bore, Paroo Station	26°26`00"S	119°46`36"E
				Murchison Region, Hinkler Well Calcrete, Abercrombie Well	26°50`54"S	120°18`42"E
				Murchison Region, Hinkler Well Calcrete, Main Raods Bore North	26°41`06"S	120°12`54"E
				Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
				Murchison Region, Paroo Station, Gswa #6 Large Groundwater Monitoring Bore	26°26`00"S	119°46`36"E
				Murchison Region, Paroo Station, Gswa 15 Southern Groundwater Monitoring Bore, Second Sample	26°24`00"S	119°45`48"E
				Murchison Region, Gswa 5 Groundwater Monitoring Bore, Paroo Station	26°25`24"S	119°43`42"E
				Murchison Region, Paroo Station, Gswa 16 Groundwater Monitoring Bore	26°25`30"S	119°43`42"E
				Murchison Region, Paroo Station, Gswa #5 Groundwater Monitoring Bore	26°26`24"S	119°46`18"E
				Murchison Region, Tpb 25/4 Groundwter Monitoring Bore	26°52`48"S	120°09`42"E
				Murchison Region, Depot Springs, Friday Well	28°03`36"S	120°04`00"E
				Murchison Region, Yandil Station, Andy Well	26°28`30"S	119°49`48"E
				Murchison Region, Gswa 15 Southern Groundwater Monitoring Bore, Paroo Station	26°24`00"S	119°45`48"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp1 Old Pump Bore	26°40`30"S	120°13`54"E
			monacanthus cf.	Wiluna, Bore Gswa 5b, Paroo Station	26°26`25"S	119°46`19"E
				Wiluna, Bore Gswa 6a, Paroo Station	26°26`02"S	119°46`38"E
				Wiluna, Bore Gswa 15c, Paroo Station	26°24`02"S	119°45`47"E
				Wiluna, Bore Gswa 6c, Paroo Station	26°26`02"S	119°46`38"E
				Wiluna, Bore Gswa 16, Paroo Station	26°25`31"S	119°43`43"E
				Wiluna, Bore Gswa 15a, Paroo Station	26°24`02"S	119°45`47"E
				Wiluna, Bore Gswa 6b, Paroo Station	26°26`02"S	119°46`38"E
			pilanus	Murchison Region, Depot Springs Station, Gums Well	27°55`54"S	120°05`00"E
			varicans	Wiluna, Comic Court Well, Paroo Station	26°20`53"S	119°39`17"E

Lake Maitland WAM Crustacean database search data (cont.)

ORDER	FAMILY	GENUS	SPECIES	SITE	LATITUDE	LONGITUDE
Harpacticoida	Ameiridae	*Haifameira*	*pori*	Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Next To Pump 1	26°40`30"S	120°13`54"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Near Pump 3	26°40`48"S	120°13`30"E
				Murchison Region, Hinkler Well Calcrete, Sample 1,Site 236, Water Supply Bore	26°41`06"S	120°12`54"E
				Murchison Region, Millbillillie Station, Mineral Exploration Bore Near Site Of Bubble Well	26°33`36"S	120°02`30"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Next To Pump 5	26°41`06"S	120°13`06"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Groundwater Monitoring Bore Next To Pump 4	26°41`00"S	120°13`12"E
				Murchison Region, Millbillillie Station, Bore Next Site Of Bubble Well	26°33`36"S	120°02`30"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp5 Groundwater Monitoring Bore	26°41`08"S	120°13`05"E
				Murchison Region, Groundwater Monitoring Bore Next To Wiluna-Kalgoorlie Road	26°41`06"S	120°12`54"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp3 Groundwater Monitoring Bore	26°42`00"S	120°12`00"E
				Murchison Region, Wiluna Gold Lake Violet Borefield, Xp4 Groundwater Monitoring Bore	26°40`54"S	120°13`12"E
				Murchison Region, Wiluna Gold Lake Violet, Small Diameter Bore W Xp5	26°41`08"S	120°13`05"E
		Haifameira		Murchison Region, Wiluna Gold Lake Violet Borefield, Xp1 Old Bore	26°40`30"S	120°13`54"E
		Nitocrella	*trajani*	Murchison Region, Uramurdah Lake Clacrete, Sample 5b, Site 264, Mineral Exploration Bore	26°41`12"S	120°18`12"E
		Nitokra	*lacustris*	Murchison Region, Melrose Station (Lake Darlot), Mineral Exploration Bore Near Halfpenny Well	27°41`48"S	121°20`24"E
		Parapseudoleptomesochra	*karamani*	Murchison Region, Uramurdah Lake Clacrete, Sample 3, Site 262, Mineral Exploration Bore	26°41`12"S	120°21`12"E
				Murchison Region, Uramurdah Lake Clacrete, Sample 3, Site 285, Mineral Exploration Bore	26°41`18"S	120°20`18"E
				Murchison Region, Hinkler Well Calcrete, Sample 1, Site 236, Water Supply Bore	26°41`06"S	120°12`54"E
				Murchison Region, Uramurdah Lake Clacrete, Sample 3, Site 262, Mineral Exploration Bore	26°41`12"S	120°21`12"E
				Murchison Region, Uramurdah Lake Clacrete, Sample 2, Site 284, Mineral Exploration Bore	26°41`18"S	120°21`12"E
			rouchi	Murchison Region, Uramurdah Lake Clacrete, Site 167, Mineral Exploration Bore	26°41`18"S	120°19`36"E
	Canthocamptidae	*Australocamptus*	*diversus*	Murchison Region, Paroo Station, Gswa#6 Large Groundwater Monitoring Bore	26°26`00"S	119°46`36"E
			hamondi	Murchison Region, Depot Springs Station, Etp13 Groundwater Monitoring Bore	27°55`48"S	120°03`30"E
				Murchison Region, Depot Springs, Friday Well	28°04`00"S	120°04`00"E
				Murchison Region, Depot Springs Station, Etp13 Groundwater Monitoring Bore	27°55`48"S	120°03`30"E
			similis	Murchison Region, Wiluna Borefield East, Groundwater Monitoring Bore W13	26°36`30"S	120°20`36"E
	Diosaccidae	*Schizopera*	*austindownsi*	Murchison Region, Wiluna Gold Lake Violet Borefield, Xp1 Old Pump Bore	26°40`30"S	120°13`54"E
			depotspringsi	Murchison Region, Depot Springs, Groundwater Monitoring Bore, Site 425	28°03`00"S	120°02`24"E
				Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
				Murchison Region, Depot Springs, Groundwater Monitoring Bore, Site 425	28°03`00"S	120°02`24"E
				Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
			jundeei	Murchison Region, Jundee Station, "Sacred" Well Jundee Soak	26°21`24"S	120°38`54"E
			uramurdahi	Murchison Region, Uramurdah Lake Clacrete, No 7, Site 285, Mineral Exploration Bore	26°51`16"S	120°20`18"E
				Murchison Region, Uramurdah Lake Clacrete, Site 167, Mineral Exploration Bore	26°41`18"S	120°19`36"E
	Parastenocaridida e	*Parastenocaris*	*solitaria*	Murchison Region, Depot Springs Station, Bore At Shearing Quarters	27°55`48"S	120°04`48"E
				Murchison Region, Depot Springs, Groundwater Monitoring Bore, Site 425	28°03`00"S	120°02`24"E
Isopoda	Armadillidae	*Troglarmadillo*		Yeelirrie	27°11`23"S	119°51`12"E
	Philosciidae	*Andriphiloscia*	*pedisetosa*	Lake Way, Murchison Region, Wa	26°41.26`S	120°17.87`E
	Scyphacidae	*Haloniscus*	*longiantennatus*	Lake Way, Murchison Region, Wa	26°41.26`S	120°21.16`E
				Lake Way, Murchison Region, Wa	26°41.24`S	120°18.16`E
			stilifer	Lake Way, Murchison Region, Wa	26°41.24`S	120°18.16`E
Ostracoda	Candonidae	*Candonopsis*	*dani*	Xp1 Gwmb Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°40`S	120°14`E
				Mineral Exploration Field Near Bubble Well, Millibillillie Station, Wiluna, Murchison Region	26°34`S	120°02`E
				Gwm Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°40`S	120°14`E
				Mineral Exploration Bore Near Bubble Well, Millbillillie Station, Wiluna, Murchison Region	26°34`S	120°02`E
				Xp4 Gwmb, Lake Violet Borefield, Wiluna, Murchison Region	26°41`S	120°13`E
				Gwm Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°40`S	120°14`E
				Xp5 Gwmb Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°41`08"S	120°13`05"E
				Gwm Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°40`S	120°14`E
				Xp5 Gwmb Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison Region	26°41`08"S	120°13`05"E
			westraliensis	Bore At Shearing Quarters, Depot Springs Station, Murchison Region	27°56`S	120°05`E
				Friday Well, Depot Springs Station, Murchison Region	28°03`36"S	120°04`03"E
				Friday Well, Depot Springs Station, Murchison Region	28°03`36"S	120°04`03"E
			williami	Gswa 6, Paroo Station, Wiluna, Murchison Region	26°20`S	119°47`E
				Gswa 5, Paroo Station, Wiluna, Murchison Region	26°25`S	119°44`E
				Gswa 15(A), Paroo Station, Wiluna, Murchison Region	26°20`02"S	119°45`47"E
				Gswa 15, Paroo Station, Wiluna, Murchison Region	26°20`S	119°47`E
				Gswa 6(C), Paroo Station, Wiluna, Murchison Region	26°24`02"S	119°45`47"E
				Gswa 15, Paroo Station, Wiluna, Murchison Region	26°24`S	119°46`E
				Gswa 16, Paroo Station, Wiluna, Murchison Region	26°25`31"S	119°43`43"E
	Cyprididae	*Riocypris*	*hinzeae*	Friday Well, Depot Springs, Murchison Region	28°04`S	120°04`E
				Puncture Well, Depot Springs, Murchison Region	28°07`S	120°05`E
				Friday Well, Depot Springs, Murchison Region	28°03`S	120°04`E
	Limnocytheridae	*Gomphodella*	*glomerosa*	Site 261, Murchison	26°39`S	120°19`E
				Observation Next To Pump 1, Lake Violet Borefield, Wiluna, Murchison	26°40`S	120°14`E
				Observation Next To Pump 4, Lake Violet Borefield, Wiluna, Murchison	26°41`S	120°13`E
				Mineral Exploration Bore, Lake Way, Uranum Exploration Area, Murchison	26°41`S	120°20`E

Appendix D

Mining Operations groundwater drawdown (> 0.5m) area water quality results

Mining Operations groundwater drawdown (> 0.5m) area water quality results

Bore code	Date	pH	EC (mS/cm)	Salinity (ppt)	Temp (°C)	DO (ppm)	Redox (mv)	SWL (m bgl)	EoH(m)
BH10	9/03/2010	7.62	74.80	-	28.50	NA	-	3.70	10.45
LMAC0291	10/12/2008	8.12	66.60	48.10	26.00	3.56	-	3.50	8.00
LMAC0399	10/12/2008	8.10	61.20	43.80	26.70	3.09	113.00	2.50	8.00
LMAC0401	10/12/2008	7.79	65.00	46.80	25.20	2.45	144.00	1.50	6.00
LMAC0406	10/12/2008	8.08	46.30	32.40	27.30	4.02	195.00	2.50	8.00
LMAC0541	23/05/2007	7.28	105.20	70.00	25.50	15.88	-	1.57	8.10
LMAC0545	10/12/2008	7.69	75.50	54.80	25.10	4.98	-	1.50	8.00
LMACW52	13/02/2011	7.41	6.30	3.02	25.80	4.81	120.00	4.01	21.54
LMACW52	18/07/2011	7.47	6.82	4.26	26.60	6.26	99.00	4.79	23.00
LMST001	17/08/2010	7.27	49.20	34.30	23.60	2.43	184.00	4.08	8.10
LMST001	15/03/2011	7.46	36.20	17.00	26.00	4.40	133.00	4.10	7.58
LMST002	17/08/2010	7.59	35.30	23.70	22.20	4.04	166.00	3.78	8.10
LMST002	15/03/2011	7.47	36.90	17.10	25.40	4.29	170.00	3.68	7.12
LMST003	17/08/2010	7.41	53.20	37.50	22.10	3.83	170.00	2.85	8.10
LMST003	15/03/2011	7.30	68.10	33.90	25.80	2.83	111.00	2.63	6.94
LMST004	17/08/2010	7.49	39.10	26.90	22.10	4.98	150.00	4.30	8.10
LMST004	15/03/2011	7.34	41.80	19.90	25.40	2.58	58.00	4.12	6.58
LMST005	17/08/2010	7.33	44.40	30.70	22.50	3.40	171.00	3.47	8.10
LMST005	15/03/2011	6.67	44.80	21.40	24.90	3.50	81.00	3.28	6.00
LMST006	17/08/2010	7.59	35.40	24.00	22.20	5.02	129.00	3.87	8.10
LMST006	15/03/2011	7.59	37.80	17.80	25.20	4.44	122.00	3.60	7.09
LMST007	18/08/2010	7.58	37.70	26.00	20.80	4.71	150.00	3.74	8.10
LMST007	15/03/2011	7.67	38.40	18.20	25.50	3.27	123.00	3.57	6.98
LMST008	17/08/2010	7.26	20.09	13.23	23.80	4.85	148.00	4.34	9.00
LMST008	14/03/2011	7.23	20.17	9.62	28.90	4.32	106.00	4.25	8.91
LMST008	18/07/2011	7.39	21.15	14.30	23.70	7.79	55.00	4.27	8.00
LMST010	17/08/2010	7.15	29.30	19.60	23.00	4.15	4.15	3.73	9.00
LMST010	14/03/2011	7.21	31.30	14.50	27.20	3.64	187.00	3.48	7.66
LMST011	18/08/2010	7.30	33.40	22.50	22.70	3.34	157.00	4.13	8.10
LMST011	14/03/2011	7.17	35.40	16.60	27.30	2.70	174.00	4.21	8.04
LMST012	17/08/2010	7.30	24.90	16.60	22.40	4.52	198.00	4.01	8.10
LMST012	15/03/2011	7.15	25.80	11.90	26.00	3.47	82.00	3.86	7.15
LMST012	18/07/2011	7.31	23.80	15.50	24.30	6.07	53.00	3.75	7.00
LMST014	17/08/2010	7.30	31.50	21.20	23.70	4.82	189.00	4.30	8.10
LMST014	15/03/2011	6.89	33.30	15.40	26.50	3.92	124.00	4.19	7.18

Appendix E

Mining operations resource area water quality results

Mining operations resource area water quality results

Bore code	Date	pH	EC (mS/cm)	Salinity (ppt)	Temp (°C)	DO (ppm)	Redox (mv)	SWL (m bgl)	EoH(m)
BH01	9/03/2010	7.35	137.8	-	28.4	NA	-	2.24	12.78
BH02	9/03/2010	7.7	114.6	-	28.5	NA	-	2.16	14.09
BH03	10/03/2010	7.1	138.5	-	27	NA	-	2.21	13.2
BH04	10/03/2010	7.08	172.3	-	28.2	NA	-	1.62	14.6
BH05	9/03/2010	7.61	138	-	29.7	NA	-	1.81	12.45
BH06	9/03/2010	7.55	114.6	-	29.6	NA	-	1.84	14.53
BH08	10/03/2010	7.51	116.3	-	25.6	NA	-	2.36	12.92
BH09	8/03/2010	7.33	101	-	28.3	0.05	-	2.18	-
BH11	9/03/2010	7.32	105.7	-	27.4	0.01	-	2.34	-
EH01	8/03/2010	6.93	105.9	-	25.8	7.55	-	2.3	23
EH02	9/03/2010	7.9	114	-	29	NA	-	2.12	18.99
EH03	9/03/2010	-	58.9	-	27.9	NA	-	5.3	21.4
EH04	9/03/2010	7.95	112.3	-	32.4	NA	-	0.95	16.84
EH05	10/12/2008	7.18	146.40	122.10	25.40	2.42	-	1.34	24
EH05	9/03/2010	7.21	157.9	-	29.2	NA	-	1.42	22.02
EH06	9/03/2010	7.51	68.5	-	26.1	0.01	-	2.52	23
LMAC0009	23/05/2007	7.52	66.50	45.2	25.3	17.25	-	1.80	8.67
LMAC0009	9/12/2008	7.80	79.60	58.70	25.40	4.84	164	2.03	8
LMAC0010	23/05/2007	7.55	76.40	53.2	25.9	15.85	-	1.50	8.46
LMAC0011	23/05/2007	7.59	60.60	40.8	25.7	16.87	-	2.18	8.8
LMAC0011	10/12/2008	8.19	77.00	56.60	22.20	4.73	-	1.90	9
LMAC0012	23/05/2007	7.53	80.00	56.1	25.6	15.41	-	1.58	8.13
LMAC0012	10/12/2008	7.88	94.50	72.50	22.70	2.57	146	1.80	9
LMAC0012	15/03/2011	7.63	123.2	67.4	27.2	1.91	143	1.51	7.95
LMAC008	23/05/2007	7.73	51.20	33.70	23.90	19.85	-	1.80	8.43
LMAC0147	10/12/2008	7.79	104.40	80.30	22.40	4.24	144	2.00	8
LMAC0160	22/05/2007	7.60	45.30	29.5	25.6	15.49	-	3.55	8.75
LMAC0160	9/12/2008	8.91	54.60	38.60	26.30	3.88	84	3.50	10
LMAC0168	10/12/2008	8.12	60.30	43.20	22.80	3.55	-	2.50	9
LMAC0179	23/05/2007	7.63	103.60	70	22.8	20.00	-	1.18	8.05
LMAC0179	9/12/2008	7.89	106.20	81.80	25.20	4.02	164	1.45	7
LMAC0212	24/05/2007	6.96	176.40	70	26.5	17.90	-	0.95	7.7
LMAC0212	10/12/2008	7.13	169.00	146.60	25.80	3.61	-	1.05	9
LMAC0266	24/05/2007	7.11	157.20	70	24.9	18.43	-	0.80	5.8
LMAC0266	10/12/2008	7.02	143.00	118.10	25.20	2.37	-	1.00	5
LMAC0312	24/05/2007	7.11	150.20	70	25.1	15.82	-	1.36	6.4
LMAC0312	10/12/2008	7.17	141.90	117.60	26.20	1.92	221	2.62	8
LMAC0334	24/05/2007	7.13	150.00	70	24.7	19.76	-	1.00	6.2
LMAC0334	10/12/2008	7.10	139.40	113.00	25.50	1.97	-	1.05	7
LMAC0352	24/05/2007	7.31	129.60	70	25.4	16.54	-	1.16	6.07
LMAC0352	10/12/2008	7.48	128.10	102.60	25.30	2.86	-	1.38	8
LMAC0423	10/12/2008	8.26	61.90	44.00	23.30	3.28	-	1.50	8
LMAC0423	9/03/2010	7.63	72.2	-	25.1	NA	-	2.32	7.4
LMAC0448	22/05/2007	7.30	132.30	70	23.8	16.04	-	1.30	7.6
LMAC0448	10/12/2008	7.39	122.50	97.00	24.30	2.56	178	1.50	8
LMAC0448	9/03/2010	7.23	141.4	-	24.4	0.01	-	1.61	7.75
LMAC0448	15/03/2011	6.98	130.9	77.5	25.9	1.93	113	1.07	7.56
LMAC0505	10/12/2008	8.17	43.50	30.20	24.40	1.64	123	4.50	6
LMAC0527	22/05/2007	7.39	125.70	70	25.9	15.10	-	1.70	8.58
LMSC-021	10/12/2008	7.45	94.60	71.80	23.50	1.02	136	1.64	8

Appendix F

Borefield groundwater drawdown (> 0.5m) area water quality results

Borefield groundwater drawdown (> 0.5m) area water quality results

Bore code	Date	pH	EC (mS/cm)	Salinity (ppt)	Temp (°C)	DO (ppm)	Redox (mv)	SWL (m bgl)	EoH(m)
#15 Well	23/01/2007	7.90	1.30	-	-	-	-	3.80	-
LMACW1	24/01/2007	7.90	7.20	-	-	-	-	4.60	-
LMACW1	11/12/2008	7.73	3.70	2.26	26.90	0.19	307	4.82	91
LMACW1	18/08/2010	7.92	3.76	2.27	20.5	2.94	-298	4.81	91
LMACW1	17/07/2011	7.8	3.73	2.26	26	1.52	-	4.75	99
LMACW20	12/02/2011	7.45	0.904	0.39	25.9	5.36	128	6.21	39.25
LMACW20	17/07/2011	7.81	-	-	24.7	10.01	-	6.18	42
LMACW25	12/02/2011	7.51	1.014	0.44	26	4.7	136	5.04	57.6
LMACW25	16/07/2011	7.64	-	-	-	6.87	-	5.91	63
LMACW36	12/02/2011	7.04	0.612	0.26	26.5	2.33	102	3.6	34.73
LMACW37	12/02/2011	7.48	1.081	-	24.9	5.15	150	3.64	31.2
LMACW37	17/07/2011	7.72	-	-	24.1	7.43	-	3.42	61
LMACW68	13/02/2011	7.09	0.448	0.19	28.9	4.66	150	5.13	29.28
LMACW68	16/07/2011	7.04	0.364	0.21	25.4	4.9	-	5.08	29
LMACW76	12/02/2011	7.53	0.906	0.39	26.4	5.2	115	4.34	31.4
LMACW76	17/07/2011	7.87	0.85	0.49	23.9	9.84	-	4.15	30.6
Northern Control Bore	11/12/2008	8.23	3.70	2.25	26.70	4.02	10	5.10	53
Northern Control Bore	18/08/2010	8.38	3.96	2.44	18.9	6.54	51	4.13	49.5
Northern Control Bore	17/07/2011	8	3.61	2.22	25.6	0.96	-	4.19	52

Appendix G

Non-impact areas water quality results

Non-impact areas water quality results

Bore	Area	Date	pH	EC (mS/cm)	Salinity (ppt)	Temp (°C)	DO (ppm)	Redox (mv)	SWL (m)	EoH(m)
6 Mile Bore	Outside borefield drawdown	11/12/2008	8.17	2.10	1.25	24.50	1.83	35	5.57	8
6 Mile Bore	Outside borefield drawdown	17/7/2011	8.16	2.2	1.32	21.1	5.25		6.91	15
6 Mile Bore	Outside borefield drawdown	18/8/2010	8.53	1.854	1.136	16.5	6.35	146	5.2	9
BJP5	Outside borefield drawdown	11/12/2008	8.74	4.09	2.51	26.00	0.86		14.00	30
Eclipse Well	Outside borefield drawdown	25/5/2007	8.18	3.17	2.1	21.7	16.75		2.72	4
Eclipse Well	Outside borefield drawdown	11/12/2008	8.38	4.18	2.66	20.80	1.51	86	2.50	4
GA-DB03	Outside mining operations drawdown	19/7/2011	7.72	125.7	99.9	21.3	4.2	24	1.85	19
GA-SB56	Outside mining operations drawdown	19/7/2011	7.44	155.5	129.8	22.2	6.76	101	0.81	9
GA-SB57	Outside mining operations drawdown	19/7/2011	6.85	132.7	106.6	23.4	2.2	31	4.23	10
GA-SB58	Outside mining operations drawdown	19/7/2011	6.77	151.6	127.8	21.3	6.77	495	1.57	10
GA-SB59	Outside mining operations drawdown	19/7/2011	7.58	119.4	94.6	22.3	7.88	273	3.5	12
Little Well	Outside mining operations drawdown	22/5/2007	7.54	12.69	7.3	24.5	19.52		3.87	10
Little Well	Outside mining operations drawdown	11/12/2008	7.45	12.42	8.00	25.80	4.27	140	4.51	8
Little Well	Outside mining operations drawdown	9/3/2010	NA	13.13		24.4	0.01		4.67	
Little Well	Outside mining operations drawdown	18/8/2010	7.41	12.37	7.84	21.9	5.04	127	4.26	9.9
Little Well	Outside mining operations drawdown	14/3/2011	7.43	11.89	5.31	27.9	4.84	113	4.02	10.5
Little Well	Outside mining operations drawdown	18/7/2011	7.5	12.45	8.05	25.1	6.65	65	3.95	11
LMACW30	Outside borefield drawdown	13/2/2011	7.59	1.2	0.55	27.9	3.27	149	3.3	36.17
LMACW30	Outside borefield drawdown	16/7/2011	7.91			24.8	1.96		3.44	
LMACW34	Outside borefield drawdown	13/2/2011	7.5	0.821	0.35	26.9	5.31	146	6.99	45.66
LMACW34	Outside borefield drawdown	16/7/2011	7.56			25.2	8.61		7	51
LMACW40	Outside borefield drawdown	12/2/2011	6.1	2.7		23.4	1.97	121	9.25	27.48
LMACW40	Outside borefield drawdown	17/7/2011	7.23	2.36	1.4	25.6	3.05		9.21	13.5
LMACW41	Outside borefield drawdown	12/2/2011	7.01	2.71		24.1	4.73	124	11.35	29.6
LMACW41	Outside borefield drawdown	17/7/2011	7.01	2.71		24.1	4.73	124	11.35	29.6
LMACW44	Outside mining operations drawdown	13/2/2011	6.93	2.68	1.20	23.1	1.93	136	7.72	37.7
LMACW56	Outside mining operations drawdown	13/2/2011	7.06	26	13.00	26	3.19	96	3.32	31.29
LMACW56	Outside mining operations drawdown	18/7/2011	7.19	27.8	18.6	25.2	2.1	23	3.23	39
LMACW69	Outside borefield drawdown	12/2/2011	7.05	0.107	0.42	25.5	2.12	199	9.47	45.02
LMACW69	Outside borefield drawdown	16/7/2011	7.75	0.586	0.32	26.8	2.25		9.48	50
LMACW71	Outside borefield drawdown	12/2/2011	7.27	1.1	0.48	25.3	4.66	152	8.98	65.47
LMACW71	Outside borefield drawdown	16/7/2011	6.58	0.082	0.43		1.83		9	74
LMACW75	Outside borefield drawdown	12/2/2011	7.16	1.068	0.46	26.2	4.34	139	9.59	23.64
LMACW75	Outside borefield drawdown	16/7/2011	7.27	1.18	0.68	25.4	8.92		9.63	
LT104	Outside mining operations drawdown	18/7/2011	7.49	10.73	6.84	26.2	7.08	56	4.51	28
LT104	Outside mining operations drawdown	21/9/2011	7.09	10.24	5.72	25.4	4.19	166.8	4.58	27
LT104	Outside mining operations drawdown	18/11/2011	7.01	11.65	6.54	25.7		244.6	4.55	30
LT105	Outside mining operations drawdown	18/7/2011	7.51	11.42	7.27	26.4	6.82	54	4	13
LT105	Outside mining operations drawdown	21/9/2011	7.19	9.02	5.43	25.8	4.24	163.3	4	18
LT105	Outside mining operations drawdown	18/11/2011	7.07	10	5.58	25.3		256.5	3.97	13
LT107	Outside mining operations drawdown	18/7/2011	7.55	10.52	6.69	25.6	7.12	78	4.49	10
LT107	Outside mining operations drawdown	21/9/2011	7.42	9.99	5.78	23.7	5.53	164.3	4.46	9
LT107	Outside mining operations drawdown	18/11/2011	6.76	11.28	6.33	25.6		183.7	4.49	11
Salt Well	Outside borefield drawdown	25/5/2007	8.27	8.20	4.6	22.4	17.05		7.60	9.45
Salt Well	Outside borefield drawdown	11/12/2008	8.36	10.26		21.40	1.82	107	4.50	6
Two Jacks Well	Outside mining operations drawdown	21/5/2007	7.93	7.39	3.99	24.7	10.68		3.85	4.5
Two Jacks Well	Outside mining operations drawdown	11/12/2008	7.62	7.73	4.87	27.30	1.30		4.00	5

Appendix H

Stygofauna survey results arranged by taxon

Stygofauna survey results arranged by taxon

Higher level	Family	Taxon ID	No. of individuals	Bore code	Survey date
Amphipoda	Chiltoniidae	Chiltoniidae	29	Little Well	9/03/2010
Amphipoda	Chiltoniidae	Chiltoniidae	10	Little Well	18/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae	5	LMST002	17/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1	Little Well	24/01/2007
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1	Little Well	9/03/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	7	Little Well	18/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	5	Little Well	14/03/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3	LMST002	17/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	9	LMST002	15/03/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	2	LMST007	15/03/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1	LMST008	17/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3	LMST008	14/03/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3	LMST008	18/07/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1	LMST010	17/08/2010
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	5	LMST012	15/03/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3	LMST012	18/07/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1	LT107	18/07/2011
Amphipoda	Chiltoniidae	Chiltoniidae sp. SAM4	3	EH01	8/03/2010
Bathynellacea	Bathynellidae	Bathynellidae	1	LT105	18/07/2011
Bathynellacea	Bathynellidae	Bathynellidae sp. OES1	1	Two Jacks Well	10/12/2008
Bathynellacea	Parabathynellidae	*Atopobathynella* sp.	1	LMAC0423	10/12/2008
Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES6	2	Little Well	18/08/2010
Coleoptera	Dytiscidae	*Limbodessus barwidgeensis*	1	LT104	18/11/2011
Coleoptera	Dytiscidae	*Limbodessus barwidgeensis*	1	LT105	18/11/2011
Cyclopoida	Cyclopidae	*Halicyclops eberhardi*	1	LMAC0012	23/05/2007
Cyclopoida	Cyclopidae	*Halicyclops eberhardi*	1	LMSC-021	10/12/2008
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	12	EH01	8/03/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	50	Little Well	18/07/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	2	LMST008	18/07/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	43	LMST012	18/07/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	6	EH01	8/03/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	62	Little Well	9/03/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	72	Little Well	18/08/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	78	Little Well	14/03/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	4	LMST004	17/08/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	39	LMST006	17/08/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	3	LMST008	17/08/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	1	LMST008	14/03/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	2	LMST012	15/03/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	4	LMST012	18/07/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	7	LMST014	17/08/2010
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	1	LMST014	15/03/2011
Cyclopoida	Cyclopidae	*Halicyclops* sp. TK3	9	LT107	18/07/2011
Cyclopoida	Cyclopidae	*Mesocyclops brooksi*	2	LMACW69	16/07/2011
Cyclopoida	Cyclopidae	*Microcyclops varicans*	3	6 Mile Bore	18/08/2010

Stygofauna survey results arranged by taxon (cont.)

Higher level	Family	Taxon ID	No. of individuals	Bore code	Survey date
Harpacticoida	Ameiridae	*Ameiropsyllus* sp. TK1	1	LMAC0448	22/05/2007
Harpacticoida	Ameiridae	*Nitokra lacustris pacifica*	3	EH01	8/03/2010
Harpacticoida	Ameiridae	*Nitokra lacustris pacifica*	7	LT107	18/07/2011
Harpacticoida	Ameiridae	*Nitokra* sp. TK3	15	EH01	8/03/2010
Harpacticoida	Ameiridae	*Nitokra* sp. TK3	1	Little Well	18/07/2011
Harpacticoida	Canthocamptidae	*Australocamptus similis*	5	#15 Well	23/01/2007
Harpacticoida	Miraciidae	*Schizopera* sp. TK1	2	EH01	8/03/2010
Harpacticoida	Miraciidae	*Schizopera* sp. TK1	4	LMAC0352	24/05/2007
Harpacticoida	Miraciidae	*Schizopera* sp. TK1	1	LMAC0448	22/05/2007
Harpacticoida	Miraciidae	*Schizopera* sp. TK5	3	Little Well	9/03/2010
Harpacticoida	Miraciidae	*Schizopera* sp. TK5	6	LMST012	15/03/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	13	Little Well	14/03/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	14	Little Well	18/07/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	5	LMST006	17/08/2010
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	1	LMST011	18/08/2010
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	16	LMST012	18/07/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK6	4	LT107	18/07/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK8	2	Little Well	14/03/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK8	5	Little Well	18/07/2011
Harpacticoida	Miraciidae	*Schizopera* sp. TK8	1	LMST012	17/08/2010
Harpacticoida	Miraciidae	*Schizopera* sp. TK8	4	LMST012	18/07/2011
Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	1	Little Well	18/08/2010
Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	1	Little Well	18/07/2011
Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	50	Little Well	18/07/2011
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	2	LMAC0012	10/12/2008
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	1	LMAC0012	15/03/2011
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	3	LMAC0352	24/05/2007
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	2	LMAC0448	9/03/2010
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	6	LMAC0545	10/12/2008
Isopoda	Scyphacidae	*Haloniscus* sp. OES1	1	LMST008	17/08/2010
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	12	Little Well	9/03/2010
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	3	LMACW36	12/02/2011
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	37	LMACW40	12/02/2011
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	1	LMACW37	12/02/2011
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	2	Two Jacks Well	21/05/2007
Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	32	Two Jacks Well	10/12/2008
Oligochaeta	Naididae	Naididae sp. OES1	2	6 Mile Bore	18/08/2010
Oligochaeta	Naididae	Naididae sp. OES2	1	Little Well	11/12/2008
Oligochaeta	Naididae	Naididae sp. OES2	18	LMAC0334	10/12/2008
Oligochaeta	Naididae	Naididae sp. OES2	1	LMAC0448	10/12/2008
Podocopida	Candonidae	*Candonopsis dani*	1	Little Well	22/05/2007
Podocopida	Candonidae	*Candonopsis dani*	1	Little Well	11/12/2008
Podocopida	Candonidae	*Candonopsis dani*	21	Little Well	9/03/2010
Podocopida	Candonidae	*Candonopsis dani*	11	Little Well	18/08/2010
Podocopida	Candonidae	*Candonopsis dani*	2	Little Well	18/07/2011
Podocopida	Candonidae	*Candonopsis dani*	2	LMST006	17/08/2010
Podocopida	Candonidae	*Candonopsis* sp. IK2	2	Little Well	14/03/2011

Appendix I

Stygofauna survey results arranged by bore code

Stygofauna survey results arranged by bore code

Bore code	Survey date	Higher level	Family	Taxon ID	No. of individuals
#15 Well	23/01/2007	Harpacticoida	Canthocamptidae	*Australocamptus similis*	5
6 Mile Bore	18/08/2010	Cyclopoida	Cyclopidae	*Microcyclops varicans*	3
6 Mile Bore	18/08/2010	Oligochaeta	Naididae	Naididae sp. OES1	2
EH01	8/03/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. SAM4	3
EH01	8/03/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	12
EH01	8/03/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	6
EH01	8/03/2010	Harpacticoida	Ameiridae	*Nitokra lacustris pacifica*	3
EH01	8/03/2010	Harpacticoida	Ameiridae	*Nitokra* sp. TK3	15
EH01	8/03/2010	Harpacticoida	Miraciidae	*Schizopera* sp. TK1	2
Little Well	24/01/2007	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1
Little Well	22/05/2007	Podocopida	Candonidae	*Candonopsis dani*	1
Little Well	11/12/2008	Oligochaeta	Naididae	Naididae sp. OES2	1
Little Well	11/12/2008	Podocopida	Candonidae	*Candonopsis dani*	1
Little Well	9/03/2010	Amphipoda	Chiltoniidae	Chiltoniidae	29
Little Well	9/03/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1
Little Well	9/03/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	62
Little Well	9/03/2010	Harpacticoida	Miraciidae	*Schizopera* sp. TK5	3
Little Well	9/03/2010	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	12
Little Well	9/03/2010	Podocopida	Candonidae	*Candonopsis dani*	21
Little Well	18/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae	10
Little Well	18/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	7
Little Well	18/08/2010	Bathynellacea	Parabathynellidae	*Atopobathynella* sp. OES6	2
Little Well	18/08/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	72
Little Well	18/08/2010	Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	1
Little Well	18/08/2010	Podocopida	Candonidae	*Candonopsis dani*	11
Little Well	14/03/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	5
Little Well	14/03/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	78
Little Well	14/03/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	13
Little Well	14/03/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK8	2
Little Well	14/03/2011	Podocopida	Candonidae	*Candonopsis* sp. IK2	2
Little Well	18/07/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	50
Little Well	18/07/2011	Harpacticoida	Ameiridae	*Nitokra* sp. TK3	1
Little Well	18/07/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	14
Little Well	18/07/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK8	5
Little Well	18/07/2011	Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	1
Little Well	18/07/2011	Harpacticoida	Parastenocarididae	*Kinnecaris* sp. TK3	50
Little Well	18/07/2011	Podocopida	Candonidae	*Candonopsis dani*	2
LMAC0012	23/05/2007	Cyclopoida	Cyclopidae	*Halicyclops eberhardi*	1
LMAC0012	10/12/2008	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	2
LMAC0012	15/03/2011	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	1
LMAC0334	10/12/2008	Oligochaeta	Naididae	Naididae sp. OES2	18
LMAC0352	24/05/2007	Harpacticoida	Miraciidae	*Schizopera* sp. TK1	4
LMAC0352	24/05/2007	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	3
LMAC0423	10/12/2008	Bathynellacea	Parabathynellidae	*Atopobathynella* sp.	1

Stygofauna survey results arranged by bore code (cont.).

Bore code	Survey date	Higher level	Family	Taxon ID	No. of individuals
LMAC0448	22/05/2007	Harpacticoida	Ameiridae	*Ameiropsyllus* sp. TK1	1
LMAC0448	10/12/2008	Oligochaeta	Naididae	Naididae sp. OES2	1
LMAC0448	22/05/2007	Harpacticoida	Miraciidae	*Schizopera* sp. TK1	1
LMAC0448	9/03/2010	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	2
LMAC0545	10/12/2008	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	6
LMACW36	12/02/2011	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	3
LMACW37	12/02/2011	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	1
LMACW40	12/02/2011	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES1	37
LMACW69	16/07/2011	Cyclopoida	Cyclopidae	*Mesocyclops brooksi*	2
LMSC-021	10/12/2008	Cyclopoida	Cyclopidae	*Halicyclops eberhardi*	1
LMST002	17/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae	5
LMST002	17/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3
LMST002	15/03/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	9
LMST004	17/08/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	4
LMST006	17/08/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	39
LMST006	17/08/2010	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	5
LMST006	17/08/2010	Podocopida	Candonidae	*Candonopsis dani*	2
LMST007	15/03/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	2
LMST008	17/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1
LMST008	17/08/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	3
LMST008	17/08/2010	Isopoda	Scyphacidae	*Haloniscus* sp. OES1	1
LMST008	14/03/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3
LMST008	14/03/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	1
LMST008	18/07/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3
LMST008	18/07/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	2
LMST010	17/08/2010	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1
LMST011	18/08/2010	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	1
LMST012	17/08/2010	Harpacticoida	Miraciidae	*Schizopera* sp. TK8	1
LMST012	15/03/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	5
LMST012	15/03/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	2
LMST012	15/03/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK5	6
LMST012	18/07/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	3
LMST012	18/07/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK1	43
LMST012	18/07/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	4
LMST012	18/07/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	16
LMST012	18/07/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK8	4
LMST014	17/08/2010	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	7
LMST014	15/03/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK2	1
LT104	18/11/2011	Coleoptera	Dytiscidae	*Limbodessus barwidgeensis*	1
LT105	18/07/2011	Bathynellacea	Bathynellidae	Bathynellidae	1
LT105	18/11/2011	Coleoptera	Dytiscidae	*Limbodessus barwidgeensis*	1
LT107	18/07/2011	Amphipoda	Chiltoniidae	Chiltoniidae sp. OES1	1
LT107	18/07/2011	Cyclopoida	Cyclopidae	*Halicyclops* sp. TK3	9
LT107	18/07/2011	Harpacticoida	Ameiridae	*Nitokra lacustris pacifica*	7
LT107	18/07/2011	Harpacticoida	Miraciidae	*Schizopera* sp. TK6	4
Two Jacks Well	21/05/2007	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	2
Two Jacks Well	10/12/2008	Oligochaeta	Enchytraeidae	Enchytraeidae sp. OES2	32
Two Jacks Well	10/12/2008	Bathynellacea	Bathynellidae	Bathynellidae sp. OES1	1

Appendix J

Molecular biodiversity assessment

For Outback Ecology

Molecular biodiversity assessment of the stygofauna from the Lake Maitland and the Wiluna area

Summary

- Two new species of chiltoniid amphipods, one new species of *Atopobathynella* and one new species of an aquatic *Haloniscus* like isopod were recorded from Lake Maitland.

Methods

Biodiversity assessment of a selection of the collected fauna (Table 1) was performed by PCR amplification and sequencing of a 677 bp fragment of CO1, commonly used for DNA barcoding (Hebert et al. 2003). To increase sequencing success rate, PCR's for all specimens were set up with two different sets of primers. For the Copepoda a nested PCR procedure was used. The sequences were added to large datasets that consists of related taxa from the region (Amphipoda: Cooper et al. 2007; Bathynellidae: Guzik et al. 2008; Isopoda; Cooper et al. 2008) complemented with unpublished sequence data at the SA-Museum and data from Genbank.

Table 1. Overview of the analysed specimens. The first column gives the DNA extraction number, the before last column indicates whether the DNA sequencing was successful.

extraction	sample no.	identification Outback Ecology		SAM ident.	bore	Coll.Date	locality	DNA	remarks
ST1341	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1342	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1343	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1344	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1345	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1346	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	no PCR	
ST1347	LN1519	*Nitokra* sp. TK3	*N.* cf. *'megaregis'*		EH01	8/03/2010	Lake Ma	contam.	
ST1348	LN1805	Nitokra sp. TK1	*N. 'megaregis'*		LakeOES42	20/03/2010	Lake Wa	contam.	
ST1349	LN1805	Nitokra sp. TK1	*N. 'megaregis'*		LakeOES42	20/03/2010	Lake Wa	no PCR	
ST1350	LN1805	Nitokra sp. TK1	*N. 'megaregis'*		LakeOES42	20/03/2010	Lake Wa	no PCR	
ST1351	LN0825	*Schizopera* sp. TK6	*S. 'dimorpha'*		Little Well	9/03/2010	Lake Ma	contam.	
ST1352	LN0825	*Schizopera* sp. TK6	*S. 'dimorpha'*		Little Well	9/03/2010	Lake Ma	no PCR	
ST1353	LN0825	*Schizopera* sp. TK6	*S. 'dimorpha'*		Little Well	9/03/2010	Lake Ma	contam.	
ST1354	LN0825	*Schizopera* sp. TK6	*S. 'dimorpha'*		Little Well	9/03/2010	Lake Ma	no PCR	
ST1355	LN0825	*Schizopera* sp. TK6	*S. 'dimorpha'*		Little Well	9/03/2010	Lake Ma	no PCR	
ST1356	LN0522	*Schizopera* sp. TK7	*S. cf 'dimorpha'*		OBS6	18/11/2009	Centipec	contam.	
ST1357	LN0522	*Schizopera* sp. TK7	*S. cf 'dimorpha'*		OBS6	18/11/2009	Centipec	contam.	
ST1358	LN0522	*Schizopera* sp. TK7	*S. cf 'dimorpha'*		OBS6	18/11/2009	Centipec	contam.	
ST1359	LN0522	*Schizopera* sp. TK7	*S. cf 'dimorpha'*		OBS6	18/11/2009	Centipec	no PCR	
ST1360		*Schizopera* sp. TK5	*S.* cf. sp. 2 n. sp		Little Well	9/03/2010	Lake Ma	contam.	
ST1361	LN1518	*Haloniscus* sp. OES11		*'Haloniscus'* sp. nov. 3	LMAC0448	9/03/2010	Lake Ma	seq	voucher kept
ST1362	LN0738	Haloniscus sp. OES2		*'Haloniscus'* sp. nov. 3	LMST008	17/08/2010	Lake Ma	seq	
ST1363	LN1207	*Haloniscus* sp. OES1			LMAC0545	10/12/2008	Lake Ma	no PCR	
ST1364	LN1207	*Haloniscus* sp. OES1			LMAC0545	10/12/2008	Lake Ma	no PCR	
ST1365	LN1214	*Haloniscus* sp. OES1		*'Haloniscus'* sp. nov. 3	LMAC0012	15/03/2011	Lake Ma	seq	
ST1366	LN0783	*Atopobathynella* sp.(juv)	NA	sp. 1	Little Well	18/08/2010	Lake Ma	seq	
ST1367	LN1194	Chiltoniidae sp. OES1	NA	sp. 3	Little Well	18/08/2010	Lake Ma	seq	voucher kept
ST1368	LN1194	Chiltoniidae sp. OES1	NA	sp. 3	Little Well	18/08/2010	Lake Ma	seq	voucher kept
ST1369	LN1208	Chiltoniidae	NA	sp. 4	EH01	8/03/2010	Lake Ma	seq	
ST1370	LN1208	Chiltoniidae	NA	sp. 4	EH01	8/03/2010	Lake Ma	seq	
ST1371	LN0742	Chiltoniidae sp. OES1	NA	sp. 3	LMST002	17/08/2010	Lake Ma	seq	
ST1372	LN0742	Chiltoniidae sp. OES1	NA	sp. 3	LMST002	17/08/2010	Lake Ma	seq	

Phylogenetic analyses using neighbour joining of uncorrected sequence distances in PAUP* (Swofford 1998) were used to estimate the number of species among the received specimens from each of the areas, as well as for checking whether these species were found at other localities in the region. Results of phylogenetic analyses are presented as partial phylogenetic trees showing the target species with some closest related species as well as a matrix of uncorrected ("p") pairwise distances between target species and relevant taxa in the phylogenetic trees. The target species are yellow highlighted in the phylogenetic trees.

Copepoda

Unfortunately none of the Copepods resulted in reliable sequences. DNA extraction was performed on 20 specimens from four different localities. PCRs were set up with different primer combinations, and diluted PCR products were re-amplified using primers specifically developed for Copepoda. This nested PCR approach has increased the success rate of Copepod sequencing at the SA-Museum. Some of the specimens resulted in PCR products, but after sequencing these all appeared to be sequences of contaminant DNA. The reasons for the low success rate in this batch of specimens are unclear, and could be a combination of factors, including: non-optimal primer specificity; non optimal preservation of specimens; and the very small size of these taxa.

Bathynellidae

A single bathynellid specimen was available for molecular analysis. This specimen produced a high quality sequence. Neighbour joining analysis places this specimen within a clade containing species in the genus *Atopobathynella* as recognized in Guzik et al. 2008 (Figure 1). The pairwise sequence divergences of 10.1-15.6% (Table 2) indicate that the specimen from Lake Maitland is a new species.

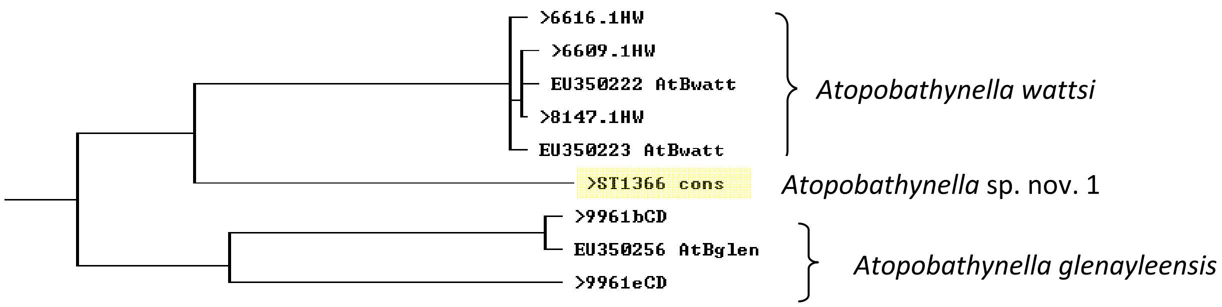

Figure 1.

Uncorrected ("p") distance matrix

	23	24	174	207	208	220
23 >9961bCD	-					
24 >9961eCD	0.09576	-				
174 EU350256 AtBglen	0.00000	0.09559	-			
207 EU350223 AtBwatt	0.12357	0.12605	0.12184	-		
208 EU350222 AtBwatt	0.12517	0.12771	0.12342	0.00158	-	
220 >ST1366 cons	0.14908	0.15658	0.14634	0.10143	0.10147	-

Table 2.

Amphipoda – Chiltoniidae

A large unpublished sequence dataset of chiltoniid amphipods including data from 29 different Yilgarn calcretes exist at the SA-Museum. This dataset was used to compare the chiltoniid amphipods of this project. None of the Yilgarn chiltoniid amphipods are presently described. All six chiltoniid amphipod specimens produced successful PCRs that resulted in clear sequences. Phylogenetic analysis shows that four specimens (ST1367-68, ST1371-72) are conspecific (Figure 2), with pairwise distances less than 1.52% (Table 3). These specimens are conspecific with specimens collected earlier by Humphreys and colleagues from Barwidgee Station, and represent an undescribed species (sp. nov. 3). Figure 2 shows the relationship of sp. nov. 3 with chiltoniid amphipods from Lake Way and West Creek. The *inter*specific pairwise sequence divergence of these species is 14.2-15.5% which indicates distant related species that may belong to the same genus. The remaining two specimens (ST1369-70) are conspecific (pairwise sequence divergence 2.4%, Table 3) and belong to a clade that is not closely related to any of the other Australian chiltoniid amphipods clades in our data set (not shown). The specimens should be considered as a new species (sp. nov. 4). Co-occurring species of chiltoniid amphipods from very distantly related clades are known from a number of other calcrete aquifers in the Yilgarn (SA-Museum unpublished data).

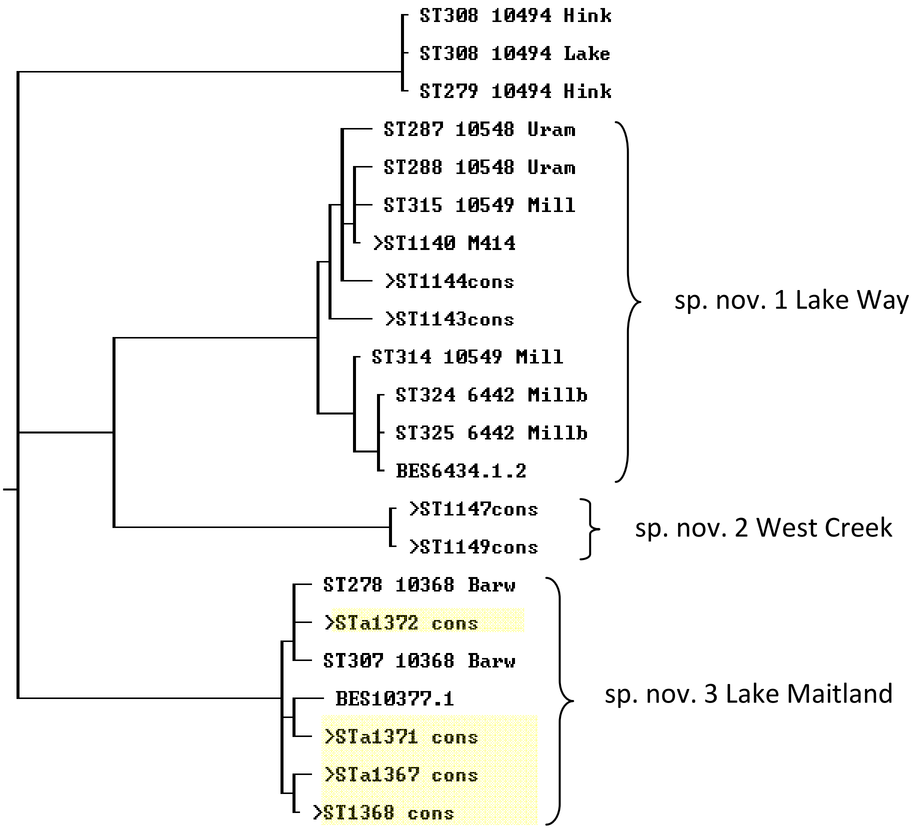

Figure 2.

Uncorrected ("p") distance matrix

	152	180	228	356	357	359	360	361	362	363
152 ST278 10368 Barw	–									
180 ST307 10368 Barw	0.00539	–								
228 BES10377.1	0.01554	0.01235	–							
356 >ST1144cons	0.15244	0.15240	0.15519	–						
357 >ST1147cons	0.15197	0.15191	0.14782	0.12596	–					
359 >STa1367 cons	0.01054	0.01365	0.01389	0.15023	0.14199	–				
360 >ST1368 cons	0.01223	0.01221	0.00926	0.14630	0.14135	0.00603	–			
361 >STa1371 cons	0.01514	0.01202	0.00619	0.15078	0.14284	0.01506	0.00898	–		
362 >STa1372 cons	0.00452	0.00447	0.01382	0.15230	0.14885	0.01354	0.01048	0.01347	–	
363 >ST1369 cons	0.14398	0.14388	0.14463	0.15590	0.16804	0.14283	0.13760	0.14362	0.14212	–
364 >ST1370 cons	0.14559	0.14241	0.14613	0.15753	0.17115	0.14893	0.14372	0.14520	0.14523	0.02368

Table 3.

Isopoda

Initially, only one (ST1365) out five extracted specimens produced a good sequence. The low PCR success rate was probably due to the bad preservation state of the specimens. Additional PCR's using primers that amplify shorter fragments however, produced good sequences for two extra specimens (ST1361-62). The three specimens are conspecific (Figure 3), *intra*specific sequence divergences less than 3.63% (Table 4), and in the neighbour joining analysis are grouping with two specimens also collected from the Lake Maitland area. The pairwise sequence divergences of 11.6-12.9% indicate that these belong to a different species, which may belong to the same genus. The neighbour joining analysis shows that the clade that contain these two species groups with species from the Lake Way area (see report on the Wiluna area fauna Dec 2010). Although some work has been done on isopods of the Yilgarn calcretes (Taiti & Humphreys 2001, Cooper et al. 2008) there is still a lack of understanding of the family relationships of the species that are found in the region (Taiti personal communication). It is therefore unclear of all the stygobitic isopods in the Yilgarn area should be classified as Haloniscus.

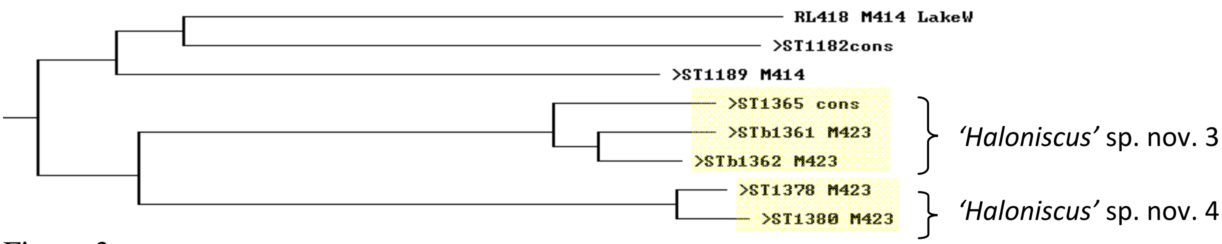

Figure 3.

Uncorrected ("p") distance matrix

		82	90	94	100	102	103	104
82	RL418 M414 LakeW	–						
90	>ST1182cons	0.12599	–					
94	>ST1189 M414	0.12207	0.13301	–				
100	>ST1378 M423	0.13763	0.15612	0.13617	–			
102	>ST1380 M423	0.14557	0.15755	0.13944	0.01108	–		
103	>ST1365 cons	0.14807	0.15387	0.14584	0.12465	0.12975	–	
104	>STb1361 M423	0.13512	0.17754	0.14170	0.12219	0.12211	0.03083	–
105	>STb1362 M423	0.12935	0.16896	0.14156	0.11596	0.12108	0.03626	0.02247

Table 4.

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South Australian Museum, Remko Leijs, 26 April 2011.

Appendix K

Copepoda morphological assessment reports

Prepared by Dr Tom Karanovic

Copepods from the Lake Maitland area (Murchison region), received from Outback Ecology in August 2007 (Job Number: RLM-SY-0107)

Prepared by
Dr. T. Karanovic
August 2007

RESULTS

1. Little Well, 22/05/07, Cyclopoida

a) *Halicyclops (H.) eberhardi* De Laurentiis *et al.*., 2001 – 4 males + 7 females + 2 copepodids (1 male and 1 female dissected on 1 slide each; others in alcohol)

2. Bore LMA C0012, 23/05/07, Cyclopoida

a) *Halicyclops (H.) eberhardi* De Laurentiis *et al.*., 2001 – 1 female in alcohol

3. Bore LMA C448, 22/05/07, Harpacticoida

a) *Schizopera sp. 1,* n. sp. – 1 male dissected on 1 slide

b) *Ameiropsyllus sp. 1,* n. sp. – 1 male dissected on 1 slide

4. Little Well, 22/05/07, Harpacticoida

a) *Schizopera weelumurra* Karanovic, 2006 – 2 copepodids in alcohol

5. Bore LMA C0352, 24/05/07, Harpacticoida

a) *Schizopera sp. 1,* n. sp. – 3 males + 1 female in alcohol

SYSTEMATIC LIST

Order Cyclopoida Rafinesque, 1815

Family Cyclopidae Rafinesque, 1815

Subfamily Halicyclopinae Kiefer, 1927

Genus *Halicyclops* Norman, 1903

Subgenus *Halicyclops* Norman, 1903

1. *Halicyclops (H.) eberhardi* De Laurentiis, Pesce & Humphreys, 2001

Order Harpacticoida G.O. Sars, 1903

Family Diosaccidae G.O. Sars, 1906

Genus *Schizopera* G.O. Sars, 1905

2. *Schizopera weelumurra* Karanovic, 2006
3. *Schizopera sp. 1,* n. sp.

Family Ameiridae Monard, 1927

Genus *Ameiropsyllus* Bodin, 1979

4. *Ameiropsyllus sp. 1,* n. sp.

NOTES

This is the first record of the genus *Ameiropsyllus* in Australia and third species ever from this genus. It is also the first non-marine representative. I would need additional material (at least one female) of this species, both to verify its generic status and to be able to properly describe it. Some additional material of *Schizopera weelumurra* would be also quite welcome, as I didn't have any females from Lake Maitland and they are much more important than males (and the species was described after females only; so they are essential for the confirmation of its specific status). Unlike *S. weelumurra*, *Schizopera sp. 1* n. sp. looks like a real subterranean representative and I have enough material of this species to be able to describe it.

COPEPODA, WA, Eastern Goldfields, Lake Maitland (2nd lot)

Outback Ecology, Job No. RLM-SY-1008, Invoice No. OES 0315

(received and IDed in February 2009)

Prepared by
Dr. T. Karanovic
February 2009

RESULTS

1, Vial Code: RLM004, Bore Code: 6 Mile Bore, GPS Coordinates: 51 J 307740 7008070, 11 December 2008, Cyclopoida, 7, KM

Goniocyclops uniarticulatus Karanovic, 2004 – 1 male + 1 female in alcohol

Mesocyclops brooksi Pesce *et al.*., 1996 – 2 males + 2 females + 1 copepodid in alcohol

2, Vial Code: RLM005, Bore Code: Little Well, GPS Coordinates: 51 J 302210 6997164, 11 December 2008, Harpacticoida, 16, RD

Nitokra lacustris pacifica Yeatman, 1983 – 2 females in alcohol

Schizopera dimorpha n. sp. – 4 males + 5 females + 2 copepodids (1 male & a female dissected together on 1 slide; others in alcohol) [NOTE: this species was present by only two juvenile specimens in your previous lot, and I provisionally identified it as *S. weelumura*]

3, Vial Code: RLM006, Bore Code: LMAC0545, GPS Coordinates: 51 J 309396 6997182, 10 December 2008, Harpacticoida, 1, RD

Nitokra lacustris pacifica Yeatman, 1983 – 1 female in alcohol

4, Vial Code: RLM007, Bore Code: LMAC423, GPS Coordinates: 51 J 308501 6995978, 10 December 2008, Harpacticoida, 1, RD

Nitokra lacustris pacifica Yeatman, 1983 – 1 damaged female in alcohol

5, Vial Code: RLM008, Bore Code: Little Well, GPS Coordinates: 51 J 302210 6997164, 11 December 2008, Cyclopoida, 72, RD

Halicyclops eberhardi De Laurentiis *et al.*. – 6 males + 55 females + 12 copepodids in alcohol

6, Vial Code: RLM009, Bore Code: LMAC423, GPS Coordinates: 51 J 308501 6995978, 10 December 2008, Cyclopoida, 1, RD

Halicyclops eberhardi De Laurentiis *et al.*. – 1 damaged female in alcohol (soft tissue completely decomposed = collected dead)

7, Vial Code: RLM010, Bore Code: LMSC-021, GPS Coordinates: 51 J 310480 6991784, 10 December 2008, Cyclopoida, 1, RD

Halicyclops eberhardi De Laurentiis *et al.*. – 1 copepodid in alcohol

SYSTEMATIC LIST

Order Cyclopoida Rafinesque, 1815

Family Cyclopidae Rafinesque, 1815

Subfamily Halicyclopinae Kiefer, 1927

Genus *Halicyclops* Norman, 1903

Subgenus *Halicyclops* Norman, 1903

1. *Halicyclops eberhardi* De Laurentiis, Pesce & Humphreys, 2001

Subfamily Cyclopinae Rafinesque, 1834

Genus *Mesocyclops* Sars, 1914

2. *Mesocyclops brooksi* Pesce, De Laurentiis & Humphreys, 1996

Genus *Goniocyclops*Kiefer, 1955

3. *Goniocyclops uniarticulatus* Karanovic, 2004

Order Harpacticoida Sars, 1903

FamilyDiosaccidae Sars, 1906

Genus *Schizopera* Sars, 1905

4. *Schizopera dimorpha* n. sp.

Family Ameiridae Monard, 1927

Genus *Nitokra* Boeck, 1865

5. *Nitokra lacustris pacifica* Yeatman, 1983

COMMENTS

Halicyclops eberhardi De Laurentiis, Pesce & Humphreys, 2001

This species was present and very frequent in many materials collected by Outback Ecology and it was also present in your previous lot from Lake Maitland (Job no RLM-SY-0107). It is widely distributed in arid Western Australia (except Pilbara) and probably a stygophile element. I have found this species as far east as SW Northern Territory and there is also a possibility that it is present in arid NSW (near Tamworth), although I only had some juvenile specimens from there.

Mesocyclops brooksi Pesce, De Laurentiis & Humphreys, 1996

This stygophile species has also a very wide distribution in arid Western Australia and it is one of the few endemic Australian elements that can be found both in the Pilbara and Murchison regions. Not present in your previous lot of samples from Lake Maitland.

Goniocyclops uniarticulatus Karanovic, 2004

Not present in your previous lot from Lake Maitland. It is a relatively rear and very small cyclopoid, found in several different localities in the Murchison region. I guess this is partly because of the sampling “error”, as this small species will be more likely to find its niche in small voids rather than in a “large” open water column that bores and wells represent.

Schizopera dimorpha n.sp. [= *S. weelumura* from previous report]

There were only two juvenile specimens of this interesting species in your previous lot of samples, which showed many similarities with a species described from the Pilbara region, *S. weelumura* Karanovic, 2006. Both juveniles had very short caudal rami, which is a characteristic of this species, so I identified them preliminary like this. However, after examining males and females in this lot, it become obvious that this is not at all *S. weelumra* , but a different new species. Its males indeed have very short caudal rami (which are different in females – thus the specific name *dimorpha*), but is more closely related to *S. austindownsi* Karanovic, 2004 than to *S. weelumura* Karanovic, 2006. Other new species, present in your first lot of samples and absent in this (*Schizopera sp. 1* n. sp.), is very different and not closely related. It has huge in inflated caudal rami, among other important characters. It is interesting that two different species of *Schizopera* live in this small area, which was not recorded previously.

Nitokra lacustris pacifica Yeatman, 1983

First described from several South Pacific islands (Tonga, Fiji and Western Samoa) by Yeatman (1983), this interesting subspecies of a cosmopolitan marine/brackish *N. lacustris* was later on redescribed from Papua New Guinea by Fiers (1986). I found and redescribed several specimans in the Murchison region (Karanovic, 2004), which was the first record for Australia. Since then I had this surface water species (stygoxene) several times in samples from subterranean waters, but always in low numbers and always just females. I suspect that the inland populations may be partly or fully parthenogenetic, which is additionally supported by a large variability range (very common for parthenogenetic populations because of lack of the sexual selection).

Best wishes,

Tom Karanovic

Lake Maitland Copepoda Morphological Assessment

Prepared by
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12th August 2010

RE:
Job Number: **RLM-SY-1109**
Taxa: Copepods and ostracods
Region: Lake Maitland
Outback Ecology Purchase Order Number for WAM: OES1381
Outback Ecology Purchase Order Number for Karanovic: **OES1379**
Total Number of Samples: 6 vials

I. RESULTS FOR COPEPODS:

45399, Vial Code LN1430, Little Well, 09/03/2010, Cyclopoida
Halicyclops microeberhardi n. sp. – 11 males + 28 females (8 ovigerous) + 20 copepodids [4 males + 6 females taken for DNA analysis]

45400, Vial Code LN1086, Little Well, 09/03/2010, Harpacticoida
Schizopera dimorpha n. sp. – 5 males + 6 females + 7 copepodids [3 males +3 females for DNA]
Schizopera cf. sp. 2 n. sp. – 2 males + 1 female [for DNA]
Nitokra lacustris pacifica Yeatman, 1983 – 1 male + 2 females (1 ovigerous)

45401, Vial Code LN0766, Bore Code EH01, 08/03/2010, Cyclopoida
Halicyclops macroeberhardi n. sp. – 4 males + 5 females + 3 copepodids [2 males + 3 females for DNA]
Halicyclops microeberhardi n. sp. – 1 male + 5 females [1 male + 3 females for DNA]

45402, Vial Code LN0770, Bore Code EH01, 08/03/2010, Harpacticoida
*Schizopera sp. 1*n. sp. – 1 male + 1 female [for DNA]
Nitokra cf. megaregis n. sp. – 3 males + 4 females + 8 copepodids [1 female for DNA]
Nitokra lacustris pacifica Yeatman, 1983 – 3 females [2 for DNA]

45403, Vial Code LN1371, #15 Well, 23/01/2007, Harpacticoida
Australocamptus similis Karanovic, 2004 – 4 males + 1 female [2 males + 1 female for DNA]

II. SYSTEMATIC LIST:

Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Halicyclopinae Kiefer, 1927
Genus *Halicyclops* Norman, 1903
1. *Halicyclops macroeberhardi* n. sp.
2. *Halicyclops microeberhardi* n. sp.

Order Harpacticoida Sars, 1903

Family Miraciidae Dana, 1846
Genus *Schizopera* Sars, 1905

3. *Schizopera dimorpha* n. sp.
4. *Schizopera sp. 1* n. sp.
5. *Schizopera cf. sp. 2* n. sp.

Family Ameiridae Monard, 1927
Genus *Nitokra* Boeck, 1865

6. *Nitokra cf. megaregis* n. sp.
7. *Nitokra lacustris pacifica* Yeatman, 1983

Family Canthocamptidae Sars, 1906
Genus *Australocamptus* Karanovic, 2004

8. *Australocamptus similis* Karanovic, 2004

III. COMMENTS:

Halicyclops macroeberhardi n. sp.

This is a very large species, which is in every other respect morphologically identical to *H. eberhardi* De Laurentiis *et al.*, 2001. However, in bore EH01 (vial no. LN0766) this species was found together with a much smaller sister species, which is also morphologically identical to *E. eberhardi*. *Halicyclops eberhardi* was in the past considered a widely distributed species in subterranean waters of the Yilgarn region, with some records even outside of WA. Unfortunately, current molecular work on a large population of this morpho-species from one of the calcretes close to Lake Maitland (Karanovic & Cooper, in preparation), revealed a presence of at least one other cryptic species (and maybe even two). Thus, we have to accept a possibility that future molecular work will reveal that this morpho-species consists of a number of isolated cryptic species, with no gene-flow between different and isolated calcretes. To properly solve this complex would require a very wide sampling effort in the Yilgarn, and combining morphological and molecular methods. However, in Lake Maitland we are lucky to have a clear size differentiation between two sister species. One would be able to recognize that *H. macroeberhardi* n. sp. and *H. microeberhardi* n. sp. are two different species even under a dissecting microscope, before knowing which genus they belong to. Size differentiation is a common phenomenon when two closely related, but reproductively isolated, species come into secondary contact after a range expansion, and it has been well documented in the Yilgarn especially for diving beetles (Leys & Watts, 2008). However, it is also very common among copepods, and some examples include *Diacyclops* species from the Pilbara region (Karanovic, 2006), *Schizopera* species from the Yilgarn (Karanovic & Cooper, in preparation), but examples have been found also in the genus *Nitokra* from Lake Way (Karanovic, unpublished report for Outback Ecology). Stygobiont.

Halicyclops microeberhardi n. sp.

Very small species, with very slender males. Otherwise similar to *Halicyclops eberhardi*. Stygobiont.

Schizopera dimorpha n. sp.

This species was present in the previous lot of samples from Lake Maitland, identified in February 2009. Very short caudal rami, but slightly less than in the population from Lake Way that I called *S. cf. dimorpha* (Karanovic, unpublished report for Outback Ecology). Stygobiont.

Schizopera sp. 1 n. sp.

This species was present in the first lot of samples from Lake Maitland, which I identified in 2007, but absent from the second lot from 2009. It has inflated caudal rami in females (not so much in males) and longer than anal somite, body very slender and almost no spinules (except on anal somite posteriorly). The species is apparently closely related to *Schizopera sp. 2* from Lake Way, and *Schizopera cf. sp. 2* from these samples (see below), but none of these two possess such inflated caudal rami. Additionally *S. sp. 1* differs from *S. sp. 2* and *S. cf. sp. 2* in the position of the caudal seta on the caudal rami, which is inserted at 2/3 in the first species (i.e. at the same level as proximal lateral seta), while it is inserted at middle in the last two species (i.e. well anterior of the proximal lateral seta). Stygobiont.

***Schizopera cf. sp. 2* n. sp.**

This species is recorded for the first time in this lot of samples. It is morphologically very similar to a new species from Lake Way (*S. sp. 2* n. sp.), which is reflected in the choice of its provisional name, but some small differences exist. It is very hard to say whether the two populations are conspecific or not, and I would recommend a molecular analysis. Dr Steve Cooper (South Australian Museum) already has a lot of experience in sequencing species from this genus, and a large database of CO1 sequences from some calcretes close to Lake Maitland and Lake Way (Karanovic & Cooper, in preparation). It would be best to do the samples from both localities at the same time. Stygobiont.

***Nitokra cf. megaregis* n. sp.**

This species is also recorded for the first time in this lot of samples. Morphologically very similar to the new species from Lake Way, with the provisional name: *S. megaregis* n. sp. Closely related and belongs to the *Nitokra lacustris pacifica* group of species, of which I already have three others awaiting description. As in Lake Way, and as its name suggests, this is the larger of the two species. Yet another case of size differentiation. Stygobiont.

***Nitokra lacustris pacifica* Yeatman, 1983**

Smaller of the two *Nitokra* species in this lot. It was present in you previous lots from Lake Maitland. First described from several South Pacific islands (Tonga, Fiji and Western Samoa) by Yeatman (1983), this interesting subspecies of a cosmopolitan marine/brackish *N. lacustris* was later redescribed from Papua New Guinea by Fiers (1986). I found and redescribed several specimens in the Murchison region (Karanovic, 2004), which was the first record for Australia. Since then I had this surface water species several times in samples from subterranean waters, but always in low numbers and almost always just females. I suspect that some inland populations in Yilgarn may have given rise to new species, after being isolated from others for some time. It is quite clear that *N. megaregis* n. sp. and *N. microregis* n. sp. from Lake Way, as well as *N. cf. megaregis* from Lake Maitland (see above), are all closely related to each other and to *N. lacutris pacifica*. They all also show stronger stygomorphies than the latter species, which is a consequence of the evolution in a subterranean environment. As for *N. lacustris pacifica*, this is clearly a stygophile.

***Australocamptus similis* Karanovic, 2004**

Species not present in your previous samples from this area. Currently it is unclear whether the species is valid or not. Namely, recent examination of a large number of specimens of a closely related *A. hamondi* Karanovic, 2004 have shown that some of the key morphological characters of *A. similis* occur as variability among some specimens of the former species (Karanovic, unpublished). This would clearly need further examination, which would include material from a number of localities in Yilgarn, and is beyond the scope of this preliminary identification job. For now it is best if we maintain the Lake Maitland population under this name, just as those from Lake Way, to avoid any possible confusion. Possible stygophile.

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Very best wishes,

Tom Karanovic

Seoul, 12 August 2010

Lake Way Copepoda Morphological Assessment

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Seoul 133-791 Korea
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12th August 2010

RE:
Taxa: Copepods and ostracods
Job Number: **TWI-SY-0909_1**
Region: Lake Way
Outback Ecology Purchase Order Number for WAM: OES1381
Outback Ecology Purchase Order Number for Karanovic: **OES1380**
Total Number of Samples: 71 vials

I. RESULTS FOR COPEPODS:

45328, Vial Code LN0350, Bore Code Lake OES 41, 20-Mar-10, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 2 females (1 ovigerous) + 8 copepodids

45329, Vial Code LN0332, Bore Code Lake OES 41, 20-Mar-10, Harpacticoida, T. Karanovic
Schizopera austindownsi Karanovic, 2004 – 1 female
Schizopera uramurdahi Karanovic, 2004 – 1 male + 1 female

45330, Vial Code LN0331, Bore Code Lake OES 42, 20-Mar-10, Harpacticoida, T. Karanovic
Nitokra megaregis n. sp. – 4 females (2 voigerous)
Nitokra microregis n. sp. – 1 male + 1 female [female taken for DNA]

45331, Vial Code LN1698, Bore Code LW11, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 16 males + 24 females (1 ovigerous) + 2 copepodids

45332, Vial Code LN0050, Bore Code LW12, 19-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 1 female

45333, Vial Code LN1694, Bore Code LW3, 19-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 2 males + 4 females
Halicyclops eberhardi De Laurentiis *et al.*., 2001 – 1 ovigerous female + 1 copepodid

45334, Vial Code LN0369, Bore Code LW4, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 1 male + 2 females + 1 coepodid [1 female dissected on 1 slide together with *H. eberhardi*]
Halicyclops eberhardi De Laurentiis *et al.*., 2001 – 2 males + 12 females (2 ovigerous) + 17 copepodids [1 female dissected on 1 slide together with *H. kieferi*]

45335, Vial Code LN0697, Bore Code LW5, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 8 males + 13 females + 14 copepodids

45336, Vial Code LN0379, Bore Code LW7, 17-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 5 males + 11 females + 3 copepodids

45337, Vial Code LN0042, Bore Code XP4A, 19-Nov-09, Cyclopoida, T. Karanovic

Fierscyclops fiersi (De Laurentiis *et al.*., 2001) – 1 copepodids

45338, Vial Code LN0053, Bore Code XP5, 19-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 3 males + 8 females + 5 copepodids

45339, Vial Code LN1706, Bore Code LW11, 18-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 2 females + 1 copepodid
Nitokra microregis n. sp. – 1 ovigerous female
Parapseudoleptomesochra sp. 1 n. sp. – 2 males + 3 females

45340, Vial Code LN1702, Bore Code LW3, 19-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 1 female
Parapseudoleptomesochra sp. 1 n. sp. – 1 male
Haifameira pori Karanovic, 2004 – 1 juvenile

45341, Vial Code LN1047, Bore Code LW4, 18-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 7 males + 15 females + 11 copepodids
Nitokra microregis n. sp. – 4 males + 1 female + 1 copepodid
Parapseudoleptomesochra sp. 1 n. sp. – 4 male + 1 female + 2 copepodids

45342, Vial Code LN1378, Bore Code LW5, 18-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 2 males + 6 females (1 ovigerous) + 1 copepodid
Nitokra microregis n. sp. – 2 males

45343, Vial Code LN1704, Bore Code LW7, 17-Nov-09, Harpacticoida, T. Karanovic
Schizopera austindownsi Karanovic, 2004 – 3 males
Parapseudoleptomesochra sp. 1 n. sp. – 3 males + 2 females + 1 copepodid

45344, Vial Code LN1375, Bore Code XP4A, 19-Nov-09, Harpacticoida, T. Karanovic
Schizopera austindownsi Karanovic, 2004 – 1 male
Nitokra microregis n. sp. – 1 male
Haifameira pori Karanovic, 2004 – 1 copepodid (very young)

45345, Vial Code LN1043, Bore Code XP5, 19-Nov-09, Harpacticoida, T. Karanovic
Schizopera austindownsi Karanovic, 2004 – 2 males + 1 female
Parapseudoleptomesochra sp. 1 n. sp. – 4 males + 5 females [2 males + 2 females for DNA]

45346, Vial Code LN0383, Abercromby Well, 19-Jul-07, Cyclopoida, T. Karanovic
Metacyclops laurentiisae Karanovic, 2004 – 13 males + 24 females (3 ovigerous) + 23 juveniles

45347, Vial Code LN1030, Bore Code NLW22, 17-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001 – 1 female

45348, Vial Code LN0376, Bore Code NVCP2, 17-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 2 males + 1 copepodid

45349, Vial Code LN0388, Bore Code NVCP5, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 2 males + 4 females + 2 copepodids

45350, Vial Code LN0700, Bore Code NVCT0123A, 17-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 3 females

45351, Vial Code LN0036, Bore Code NVCT0174A, 17-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 2 males

45352, Vial Code LN1684, Bore Code NVCT0473, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 2 copepodids

45353, Vial Code LN0698, Bore Code OBS1, 18-Nov-09, Cyclopoida, T. Karanovic

Halicyclops eberhardi De Laurentiis *et al.*., 2001– 1 female

45354, Vial Code LN0039, Bore Code OBS6, 18-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 1 male + 3 females

45355, Vial Code LN0058, Bore Code SB26-1, 20-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 1 female decomposed
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 copepodid (damaged, prosome only)

45356, Vial Code LN1026, Bore Code SB32-1, 21-Nov-09, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 2 males + 7 females
Dussartcyclops uniarticulatus (Karanovic, 2004) –1 females

45357, Vial Code LN0385, Bore Code TPB-18, 20-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 1 copepodid (+ 2 Colembola)

45358, Vial Code LN0373, Bore Code NLW23, 17-Nov-09, Calanoida, T. Karanovic
Acartiella sp. – 1 copepodid (very young and damaged – surface water species)

45359, Vial Code LN0043, Bore Code NVCP2, 17-Nov-09, Harpacticoida, T. Karanovic
Nitokra megaregis n. sp. – 1 female
Nitokra microregis n. sp. – 2 males + 5 females (2 ovigerous)

45360, Vial Code LN1042, Bore Code NVCP4, 18-Nov-09, Harpacticoida, T. Karanovic
Nitokra microregis n. sp. – 1 copepodid

45361, Vial Code LN1040, Bore Code NVCP5, 18-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 1 male + 1 female
Schizopera cf. dimorpha n. sp. – 3 males + 3 females (1 ovigerous) [+ 1 Colembola]
Nitokra megaregis n. sp. – 1 ovigerous female [taken for DNA]
Nitokra microregis n. sp. – 1 male + 1 ovigerous female [taken for DNA]

45362, Vial Code LN1707, Bore Code NVCP6, 18-Nov-09, Harpacticoida, T. Karanovic
Acartiella sp. – 1 copepodid (abdomen missing)

45363, Vial Code LN1373, Bore Code NVCT0123A, 17-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 1 male
Nitokra microregis n. sp. – 1 female

45364, Vial Code LN1357, Bore Code NVCT0174A, 17-Nov-09, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 1 male + 1 copepodid
Nitokra megaregis n. sp. – 1 male + 1 female (both damaged)

45365, Vial Code LN0038, Bore Code NVCT0473, 18-Nov-09, Harpacticoida, T. Karanovic
Nitokra megaregis n. sp. – 1 female (damaged)

45366, Vial Code LN0035, Bore Code OBS1, 18-Nov-09, Harpacticoida, T. Karanovic
Schizopera cf. dimorpha n. sp. – 1 male + 1 female + 1 copepodid

45367, Vial Code LN1703, Bore Code OBS6, 18-Nov-09, Harpacticoida, T. Karanovic
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 male
Schizopera uramurdahi Karanovic, 2004 – 1 male
Schizopera cf. dimorpha n. sp. – 7 males + 3 females [2 males + 2 females for DNA]

45368, Vial Code LN0367, Bore Code SB26-1, 20-Nov-09, Harpacticoida, T. Karanovic
Kinnecaris lakewayensis n.sp. – 1 male + 1 copepodid

45369, Vial Code LN0366, Bore Code SB32-1, 21-Nov-09, Harpacticoida, T. Karanovic
Kinnecaris lakewayensis n.sp. – 3 males + 8 females + 2 copepodids [2 males + 3 females for DNA]

45370, Vial Code LN0044, Bore Code NLW23, 17-Nov-10, Harpacticoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– ½ female (only P4 & Urosome)

45371, Vial Code LN1695, Bores Windmill, 19-Nov-09, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 1 male
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 4 females (1 ovigerous)
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 female

45372, Vial Code LN0051, Bore Code P22, 19-Nov-09, Cyclopoida, T. Karanovic
Dussartcyclops uniarticulatus (Karanovic, 2004) – 13 male + 14 females + 17 copepodids [3 males + 3 females for DNA]

45373, Vial Code LN0374, Well 1 Bore C, 19-Nov-09, Cyclopoida, T. Karanovic
Acartiella sp. – 1 copepodid

45374, Vial Code LN1372, Bores Windmill, 19-Nov-09, Harpacticoida, T. Karanovic
Haifameira pori Karanovic, 2004 – 16 males + 6 females + 22 copepodids [4 males + 2 females for DNA]

45375, Vial Code LN1708, Bore Code P18, 18-Nov-09, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 2 n. sp. – 1 female

45376, Vial Code LN0048, Bore Code P22, 19-Nov-09, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 2 n. sp. – 7 males + 15 females + 18 copepodids [3 males + 3 females for DNA]

45377, Vial Code LN1025, Bore Code Lake OES 41, 27-May-10, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 5 males + 5 females (1 voigerous) + 8 copepodids [1 male for DNA]
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 1 male [for DNA]

45378, Vial Code LN1685, Bore Code Lake OES 41, 27-May-10, Harpacticoida, T. Karanovic
Schizopera austindownsi Karanovic, 2004 – 1 male [for DNA]
Schizopera uramurdahi Karanovic, 2004 – 1 male + 4 females [for DNA]
Nitokra megaregis n. sp. – 1 female

45379, Vial Code LN1038, Bore Code AC09LW0012, 27-May-10, Harpacticoida, T. Karanovic
Schizopera sp. 2 n. sp. – 1 male [for DNA]

45380, Vial Code LN1037, Bore Code AC09LW0046, 27-May-10, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 1 n. sp. – 1 male

45381, Vial Code LN1362, Bore Code LW5, 27-May-10, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 5 male + 3 females (1 ovigerous) + 2 copepodids

45382, Vial Code LN1361, Bore Code LW5, 27-May-10, Harpacticoida, T. Karanovic
Nitokra megaregis n. sp. – 1 male + 2 females (1 decomposed)

45383, Vial Code LN1031, Bore Code LW7, 27-May-10, Harpacticoida, T. Karanovic
Schizopera uramurdahi Karanovic, 2004 – 1 female [for DNA]
Nitokra microregis n. sp. – 1 male + 1 female
Parapseudoleptomesochra sp. 1 n. sp. – 1 female

45384, Vial Code LN1032, Bore Code LW7, 27-May-10, Cyclopoida, T. Karanovic
Halicyclops sp. – 1 copepodid

45385, Vial Code LN1690, Bore Code LW11, 27-May-10, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 1 n. sp. – 2 males + 2 females (1 damaged)

45386, Vial Code LN1689, Bore Code LW11, 27-May-10, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 2 males + 10 females (1 ovigerous)

45387, Vial Code LN1365, Bore Code LW3, 27-May-10, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 1 n. sp. – 1 female (damaged)

45388, Vial Code LN1368, Bore Code LW3, 27-May-10, Cyclopoida, T. Karanovic
Halicyclops kieferi Karanovic, 2004 – 2 females + 1 copepodid
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 female

45389, Vial Code LN1035, Bores Windmill, 28-May-10, Harpacticoida, T. Karanovic
Haifameira pori Karanovic, 2004 – 6 males + 11 females + 12 copepodids

45390, Vial Code LN1367, Bores Windmill, 28-May-10, Cyclopoida, T. Karanovic
Halicyclops eberhardi De Laurentiis *et al.*., 2001– 4 females (2 ovigerous) + 1 copepodid
Dussartcyclops uniarticulatus (Karanovic, 2004) – 2 females + 1 copepodid

45391, Vial Code LN0707, Bore Code P18, 28-May-10, Cyclopoida, T. Karanovic
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 male + 1 female

45392, Vial Code LN0037, Bore Code P22, 28-May-10, Harpacticoida, T. Karanovic
Parapseudoleptomesochra sp. 2 n. sp. – 1 male + 5 females

45393, Vial Code LN1027, Bore Code P22, 28-May-10, Cyclopoida, T. Karanovic
Dussartcyclops uniarticulatus (Karanovic, 2004) – 1 female

45394, Vial Code LN0365, Bore Code Explor5, 28-May-10, Cyclopoida, T. Karanovic,
Halicyclops kieferi Karanovic, 2004 (?) – 1 male

II. SYSTEMATIC LIST:

Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Halicyclopinae Kiefer, 1927
Genus *Halicyclops* Norman, 1903

1. *Halicyclops kieferi* Karanovic, 2004
2. *Halicyclops eberhardi* De Laurentiis, Pesce & Humphreys, 2001

Subfamily Cyclopinae Rafinesque, 1815
Genus *Metacyclops* Kiefer, 1927

3. *Metacyclops laurentiisae* Karanovic, 2004

Genus *Fierscyclops* Karanovic, 2004

4. *Fierscyclops fiersi* (De Laurentiis, Pesce & Humphreys, 2001)

Genus *Dussartcyclops* Karanovic *et al.*., in press [syn. *Goniocyclops* Kiefer partim.]

5. *Dussartcyclops uniarticulatus* (Karanovic, 2004)

Order Harpacticoida Sars, 1903
Family Miraciidae Dana, 1846
Genus *Schizopera* Sars, 1905

6. *Schizopera austindownsi* Karanovic, 2004
7. *Schizopera uramurdahi* Karanovic, 2004
8. *Schizopera cf. dimorpha* n. sp.
9. *Schizopera sp. 2 n. sp.*

Family Ameiridae Monard, 1927
Genus *Nitokra* Boeck, 1865

10. *Nitokra megaregis* n. sp.
11. *Nitokra microregis* n. sp.

Genus *Parapseudoleptomesochra* Lang, 1965

12. *Parapseudoleptomesochra sp. 1* n. sp.

13. *Parapseudoleptomesochra sp. 2* n. sp.

Genus *Haifameira* Por, 1964

14. *Haifameira pori* Karanovic, 2004

Family Parastenocarididae Chappuis, 1940

Genus *Kinnecaris* Jakobi, 1972 [syn. *Parastenocaris* Kessler partim.]

15. *Kinnecaris lakewayensis* n.sp.

Order Calanoida Sars, 1903

Family Acartiidae Sars, 1903

Genus *Acartiella* Sewell, 1914

16. *Acartiella sp.*

III. COMMENTS:

Halicyclops kieferi Karanovic, 2004

Largest of the *Halicyclops* species in the Yilgarn (see Karanovic, 2004), this species was always significantly larger than *H. eberhardi* in your samples. Size differentiation is a common phenomenon when two closely related, but reproductively isolated, species come into secondary contact after a range expansion, and it has been well documented in the Yilgarn, especially for diving beetles (Leys & Watts, 2008). However, it is also very common among copepods, and some examples include *Diacyclops* species from the Pilbara region (Karanovic, 2006), and *Schizopera* species from the Yilgarn (Karanovic & Cooper, in preparation). *Halicyclops kieferi* can be distinguished from *H. eberhardi,* in addition to its size, also by much longer caudal rami, and a more robust habitus. However, the whole genus is morphologically very conservative, with only a few exceptions. Stygobiont.

Halicyclops eberhardi De Laurentiis, Pesce & Humphreys, 2001

Once considered a widely distributed species in subterranean waters of the Yilgarn region, with some records even outside of WA. Unfortunately, current molecular work on a large population of this morpho-species from one of the calcretes close to Lake Way (Karanovic & Cooper, in preparation), revealed a presence of at least one other cryptic species (and maybe even two). Thus, we have to accept a possibility that future molecular work will reveal that this morpho-species consists of a number of isolated cryptic species, with no gene-flow between different and isolated calcretes. For now we have to accept that *H. eberhardi* is a species-complex. I was not able to find any morphological differences between this population in Lake Way and specimens I described in Karanovic (2004). To properly solve this complex, it would require a very wide sampling effort in the Yilgarn, and combining morphological and molecular methods. I speculate that this species is a stygophile, rather than a stygobiont, as its wide distribution is very unlikely to be only active, through the subterranean realm in different peleaeochannels. Even if it proves that this is a species complex, one still has to consider the distribution of the ancestor, which gave rise to all the different cryptic species. This is supported by the fact that the closely related *H. ambiguus* Kiefer, 1967 was originally described from a salt lake in Victoria and later on fund in subterranean waters in the Yilgarn. Also, recently Karanovic & Tang (2009) described another cyclopoid from WA, with surface water populations in the south and subterranean ones in the north, as an example of the role of aridity in habitat shift and colonization of subterranean waters in WA. Possible stygophile.

Metacyclops laurentiisae Karanovic, 2004

This species was described as new in Karanovic (2004) from 45 different localities in the Yilgarn, but was first reported from WA by De Laurentiis *et al.*. (2001), as the New Zealand *M. monacanthus* (Kiefer, 1928). Since then, I have found it quite regularly in the Yilgarn. Stygobiont.

Fierscyclops fiersi (De Laurentiis, Pesce & Humphreys, 2001)

Another relatively common and widely distributed element in the Yilgarn. Reported from 24 different localities in Karanovic (2004), and since then I had it a couple of times from additional areas, in other consulting jobs. Stygobiont.

Dussartcyclops uniarticulatus (Karanovic, 2004)

This species has recently been transferred into a newly erected endemic WA genus *Dussartcyclops* Karanovic, Eberhard & Murdoch (in press). I have other three new species currently from this genus that await description, and they mostly differ in the armature of the swimming legs and proportions of the caudal rami. The population from Lake Way has a characteristic one-segmented endopod of the fourth swimming leg, just like the type specimen from Depot Springs Station. Stygobiont.

Schizopera austindownsi Karanovic, 2004

Significantly smaller of the two species, when it occurs together with *S. uramurdahi* (for example LN0332). Originally found in a Austin Downs Borefield and Wiluna Gold Lake Violet Borefiled, it seems that this species is restricted to a wider area around Wiluna. The genus *Schizopera* is a very successful invader of the WA freshwaters with increased salinity, because a majority of its species worldwide live in the marine littoral and interstitial. Recent morphological and molecular studies in a large calcrete, relatively close to Lake Way (Karanovic & Cooper, in preparation), revealed that detailed sampling shows an explosive radiation of this genus in larger calcretes, with up to 8-10 species. Some of those, however, are quite independent colonisations, and more closely related to species from the Pilbara region than to their sympatric congeners. Although Lake Way calcrete doesn't seem to be so rich, a similar pattern is emerging here as well. I would strongly suggest sequencing the four discovered morpho-species from Lake Way with Dr Steve Cooper (SA Museum), to discover their affinities and precise species boundaries. This is especially because some of them also appear in you samples from Lake Maitland (see below), and others in your Wiluna samples. Possible stygophile.

Schizopera uramurdahi Karanovic, 2004

This species was originally described from the Uramurdah Lake calcrete (Karanovic, 2004), not far away from Lake Way. It is interesting that this species is also present in Lake Way, as it is its sympatric occurrence with *S. austindownsi* (see above), and *S. cf. dimorpha* n. sp. (see below). *Schizopera uramurdahi* is a large harpacticoid, and when it occurs sympatricly with other congeners, it is always the larger of the two. Easily recognizable by its long and elegant caudal rami. Stygobiont.

Schizopera cf. dimorpha n. sp.

This morpho-species is morphologically very similar to the new species from Lake Maitland, I identified for you in 2008 and provisionally called *Schizopera dimorpha* n. sp. Some of the key characters include: very short and somewhat conical caudal rami, body short and stout, well ornamented but not hairy. To determine whether this population is indeed conspecific with that from Lake Maitland, a proper taxonomic study is necessary, which would involve dissection and examination of microcharaters of a larger number of specimens from both locations, and possible from some localities in between (if any), scanning electron micrography, and molecular analysis of the CO1 gene (barcoding). Stygobiont.

Schizopera sp. 2 n. sp.

Only one male of this interesting new species was discovered in the bore AC09LW0012 (LN1038). It looks unlike any other member of the genus, with its extremely smooth (no spinules whatsoever) and slender body (habitus almost like in *Stygonitocrella*). Caudal rami are somewhat longer than anal segment and conical. Endopod of the first swimming leg 3-segmented (normal). I would recommend resampling this bore again on a number of occasions, to search for more specimens and any females, because females are traditionally used in species descriptions in this genus. In the previously mentioned detailed study of a calcrete not far away from Lake Way (Karanovic & Cooper, in preparation), we had one species that was collected only from one bore ever, but on 3 separate occasions. This would be short range endemism in its extreme. Stygobiont.

Nitokra megaregis n. sp.

This and the next new species were also present in your lot of samples from Lake Way I identified in 2007. They are closely related to each other, and belong to the *Nitokra lacustris pacifica* group of species, of which I already have three others awaiting description. As its name suggests, this is the larger of the two species. Yet another case of size differentiation in a completely different family. Stygobiont.

Nitokra microregis n. sp.

Smaller of the two species, and it was also present in your samples from 2007. Stygobiont.

Parapseudoleptomesochra sp. 1 n. sp.

This new species was also present in your samples from Lake Way from 2007. Closely related to *Parapseudoleptomesochra rouchi* Karanovic, 2004, which was originally described from a single male from the neighbouring Uramurdah Lake calcrete. Both species have two rows of large spinules on anal operculum, which is an unusual feature in this family. It is a synapomorphy that suggests both species originated from the same ancestor. Differences are mostly in the ornamentation of the urosome, armature of the swimming legs (small), and proportions of the caudal rami. Stygobiont.

Parapseudoleptomesochra sp. 2 n. sp.

This new species was not present in your samples from 2007. It is very different from the previous one, with integument not well chitinized and very soft. Baseoendopod of the fifth leg without any armature, and anal operculum with only a posterior row of tiny spinules. Stygobiont.

Haifameira pori Karanovic, 2004

This interesting species, with characteristic enormous caudal rami, was not present in your 2007 samples from this area. However, it was described originally from a number of bores from Wiluna Gold Lake Violet (Karanovic, 2004), so it is not surpising to find it in your samples as well. It was also present in your recent lot of samples from Wiluna (Job Number: IMG-SY-0310). Stygobiont.

Kinnecaris lakewayensis n.sp.

Newly discovered new species, relatively closely related to *Kinnecaris solitaria* (Karanovic, 2004). The latter was originally described in the genus *Parastenocaris*, but is transferred by Schminke (2008) into a newly reinstated genus *Kinnecaris* Jakobi, 1972. Recent morpho-molecular analysis of a large number of samples from a calcrete not that far away from Lake Way and further upstream (Karanovic & Cooper, in preparation), revealed a number of closely related but allopatric species from this complex (in addition to one new genus, which lives sympatricly with them). *Kinnecaris lakewayensis* n. sp. differs from all of them by following morphological characters: Fu short (shorter than anal somite), tapering in lateral view after dorsal seta, which inserted at 3/5; outer apical seta on caudal rami inserted much more anteriorly than principal apical seta; spike on P5 sharp, but relatively short; outer subapical spine on male P3 twice as long as apophysis. Cuticular windows, and other morpho characters same as in *P. solitaria*. Stygobiont.

Acartiella sp.

This is a surface water copepod, like the great majority of calanoids. Only juvenile specimens, and mostly also damaged, were present in your samples, so identification to the species level was impossible. My experience from other areas suggests that *Acartia minor* Sewell, 1919 (now: *Acartiella minor* (Sewell, 1919)) can be found sometimes in subterranean waters, but mostly as juveniles or damaged (dead) adult specimens. The species is a trogloxene.

IV. SPECIES NOT PRESENT IN THIS LOT (but recorded previously from Lake Way):

Genus *Ameiropsyllus* Bodin, 1979

17. *Ameiropsyllus sp. 1* n. sp.

Family Canthocamptidae Sars, 1906

Genus *Australocamptus* Karanovic, 2004

18. *Australocamptus similis* Karanovic, 2004

Ameiropsyllus sp. 1 n. sp.

This is the same species I identified from your Lake Maitland material in 2007. There I had only one male and in Lake Way I had both males and females. Interestingly, the species is absent from this lot of samples. It may prove, after further analysis, that this species justifies erection of a new genus, but this was beyond the scope of my preliminary identification job. As I mentioned before, this is the first record of this genus (if it stays in this genus!) from inland waters and also the first record for Australia.

Australocamptus similis Karanovic, 2004

Species was present in your samples from 2007 from this area, but currently it is unclear whether it is valid or not. Namely, recent examination of a large number of specimens of a closely related *A.*

hamondi Karanovic, 2004 have shown that some of the key morphological characters of *A. similis* occur as variability among some specimens of the former species (Karanovic, unpublished). This would clearly need further examination, which would include material from a number of localities in Yilgarn, and is beyond the scope of this preliminary identification job. For now it is best if we maintain the Lake Way population under this name, to avoid any possible confusion. Possible stygophile.

V. REFERENCES

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Karanovic T. (2004): Subterranean Copepoda from arid Western Australia. *Crustaceana Monographs*, 3: 366pp.

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Karanovic T., Cooper S. (in preparation): Explosive radiation of the harpacticoid genus *Schizopera* (Crustacea: Copepoda) in a small subterranean island in Western Australia; unraveling the cases of cryptic speciation, size differentiation, and multiple invasions.

Leys R., Watts C.H. (2008): Systematics and evolution of the Australian subterranean hydroporine diving beetles (Dytiscidae), with notes on *Carabhydrus*. In: Austin AD, Cooper SJB, Humphreys WF, eds. *Subterranean Connections: Biology and evolution in troglobiont and groundwater ecosystems*. Invertebrate Systematics 22: 217–225.

Schminke H.K. (2008): First report of groundwater fauna from Papua New Guinea: *Kinnecaris* Jakobi, 1972 redefined (Parastenocaridae, Harpacticoida) and description of a new species. *Crustaceana* 81: 1241-1253.

Very best wishes,

Tom Karanovic

Seoul, 12 August 2010

Lake Maitland Copepoda Morphological Assessment

Prepared by
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29th January 2011

RE:
Job Number: **RLM-SY-1109**
Taxa: Copepods and ostracods
Region: Lake Maitland
Outback Ecology Purchase Order Number for WAM: OES1582
Outback Ecology Purchase Order Number for Karanovic: **OES1606**
Total Number of Samples: 9 vials

V. RESULTS FOR COPEPODS:

1, WAM C45517, LN0739, LMST004, 307911, 6992673, 27°10'31"S 121°03'40"E, 8/17/2010, Cyclopoida, 4, PRC
Halicyclops microeberhardi n. sp. – 1 female + 3 copepodids

2, WAM C45518, LN0087, LMST006, 308186, 6994776, 27°09'23"S 121°03'51"E, 8/17/2010, Cyclopoida, 39, PRC
Halicyclops microeberhardi n. sp. – 4 males + 13 females + 22 copepodids

3, WAM C45519, LN1075, LMST006, 308186, 6994776, 27°09'23"S 121°03'51"E, 8/17/2010, Harpacticoida, 5, PRC
Schizopera dimorpha n. sp. – 2 males + 3 females

4, WAM C45520, LN1407, LMST008, 305115, 6996771, 27°08'16"S 121°02'01"E, 8/17/2010, Cyclopoida, 3, PRC
Halicyclops microeberhardi n. sp. –3 females

5, WAM C45521, LN1060, LMST011, 307122, 6995775, 27°08'50"S 121°03'13"E, 8/18/2010, Harpacticoida, 1, SR
Schizopera dimorpha n. sp. –1 female

6, WAM C45522, LN0122, LMST012, 305413, 6994778, 27°09'21"S 121°02'10"E, 8/17/2010, Harpacticoida, 1, SR
Schizopera sp. 3 n. sp. – 1 female

7, WAM C45523, LN0743, LMST014, 306610, 6993773, 27°09'54"S 121°02'53"E, 8/17/2010, Cyclopoida, 7, PRC
Halicyclops microeberhardi n. sp. – 2 males + 1 female + 4 copepodids

8, WAM C45524, LN1389, 6 Mile Bore, 307740, 7008070, 27°02'10"S 121°03'42"E , 8/18/2010, Cyclopoida, 3, SR
Microcyclops varicans (Sars, 1863) – 3 females (1 ovigerous)

9, WAM C45525, LN1405, Little Well, 302211, 6997164, 27°08'02"S 121°00'16"E, 8/18/2010, Cyclopoida, 72, PRC

Halicyclops microeberhardi n. sp. – 24 males + 31 females + 19 copepodids

10, WAM C45526, LN0741, Little Well, 302211, 6997164, 27°08'02"S 121°00'16"E, 8/18/2010, Harpacticoida, 14, PRC

THIS VIAL NOT RECEIVED

VI. SYSTEMATIC LIST:

Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Halicyclopinae Kiefer, 1927
Genus *Halicyclops* Norman, 1903

9. *Halicyclops microeberhardi* n. sp.

Subfamily Cyclopinae Rafinesque, 1815
Genus *Microcyclops* Claus, 1893

10. *Microcyclops varicans* (Sars, 1863)

Order Harpacticoida Sars, 1903
Family Miraciidae Dana, 1846
Genus *Schizopera* Sars, 1905

11. *Schizopera dimorpha* n. sp.
12. *Schizopera sp. 3* n. sp.

VII. COMMENTS:

Halicyclops microeberhardi n. sp.

This is a relatively small species, which is in every other respect morphologically identical to *H. eberhardi* De Laurentiis *et al.*, 2001. However, in bore EH01 (vial no. LN0766), in your previous lot of samples, this species was found together with a much larger sister species, which is also morphologically identical to *H. eberhardi*. *Halicyclops eberhardi* was in the past considered a widely distributed species in subterranean waters of the Yilgarn region, with some records even outside of WA (Karanovic, 2004). Unfortunately, current molecular work on a large population of this morpho-species from one of the calcretes close to Lake Maitlan (Karanovic & Cooper, in preparation), revealed a presence of at least one other cryptic species (and maybe even two). Thus, we have to accept a possibility that future molecular work will reveal that this morpho-species consists of a number of isolated cryptic species, with no gene-flow between different and isolated calcretes. To properly solve this complex would require a very wide sampling effort in the Yilgarn, and combining morphological and molecular methods. However, in Lake Maitland we are lucky to have a clear size differentiation between two sister species. One would be able to recognize that *H. macroeberhardi* n. sp. and *H. microeberhardi* n. sp. are two different species even under a dissecting microscope, before knowing which genus they belong to. Size differentiation is a common phenomenon when two closely related, but reproductively isolated, species come into secondary contact after a range expansion, and it has been well documented in the Yilgarn especially for diving beetles (Leys & Watts, 2008). However, it is also very common among copepods, and some examples include *Diacyclops* species from the Pilbara region (Karanovic, 2006), *Schizopera* species from the Yilgarn (Karanovic & Cooper, in preparation), but examples have been found also in the genus *Nitokra* from Lake Way (Karanovic, unpublished report for Outback Ecology). *H. microeberhardi* is a stygobiont and was present in your previous samples from Lake Maitland.

***Microcyclops varicans* (Sars, 1863)**

This is a cosmopolitan and surface water species, recorded many time previously in Australia (Karanovic, 2004, 2006). It explores subterranean waters with good connection to surface habitats, such as pastoral wells, open bores, caves with large entrances, etc. It is a stygophile. This species was not recorded previously in your material from Lake Maitland.

***Schizopera dimorpha* n. sp.**

This species was present in previous two lots of samples from Lake Maitland, identified in February 2009 and in August 2010. Very short caudal rami, but slightly less than in the population from Lake Way that I called *S. cf. dimorpha* (Karanovic, unpublished report for Outback Ecology). Stygobiont.

***Schizopera sp. 3* n. sp.**

Only one female of this interesting new species was collected and examined, although not dissected. It is very hard to establish a new species on a single specimen in this large genus, especially because one cannot be sure if the observed morphological differences are a result of intraspecific variability or are indeed reliable specific characters. Previous knowledge of this group in the Yilgarn region (Karanovic & Cooper, submitted) would suggest the latter hypothesis. Some of the most important characters: Caudal rami about as long as anal somite, and slender, proximal lateral and dorsal setae inserted at about ¾ of ramus length.

VIII. SPECIES REGISTERED BEFORE, BUT ABSENT FROM THIS LOT:

***Halicyclops macroeberhardi* n. sp.**
***Schizopera sp. 1* n. sp.**
***Schizopera cf. sp. 2* n. sp.**
***Nitokra cf. megaregis* n. sp.**
***Nitokra lacustris pacifica* Yeatman, 1983**
***Australocamptus similis* Karanovic, 2004**

IX. REFERENCES

Karanovic T. (2004): Subterranean Copepoda from arid Western Australia. *Crustaceana Monographs*, 3: 366pp.

Karanovic T. (2006): Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

Karanovic T., Cooper S. (submitted): Explosive radiation of the harpacticoid genus *Schizopera* (Crustacea: Copepoda) in a small subterranean island in Western Australia; unraveling the cases of cryptic speciation, size differentiation, and multiple invasions. *Organisms Diversity & Evolution.*

Leys R., Watts C.H. (2008): Systematics and evolution of the Australian subterranean hydroporine diving beetles (Dytiscidae), with notes on *Carabhydrus*. In: Austin AD, Cooper SJB, Humphreys WF, eds. *Subterranean Connections: Biology and evolution in troglobiont and groundwater ecosystems*. Invertebrate Systematics 22: 217–225.

Very best wishes,

Tom Karanovic

Seoul, 29 January 2011

Lake Maitland Copepoda Morphological Assessment

Prepared by
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11th May 2011

RE:
Job Number: **RLM-SY-0311**
Taxa: Copepods and ostracods
Region: **Lake Maitland**
Outback Ecology Purchase Order Number for WAM: OES1923
Outback Ecology Purchase Order Number for Karanovic: **OES1921**
Total Number of Samples: 7 vials

X. RESULTS FOR COPEPODS:

1, WAM C 47392, LN0520, LMST008, 305115, 6996771, 27°08'16"S, 121°02'01"E, 3/14/2011, Cyclopoida, 1
Halicyclops microeberhardi n. sp. – 1 copepodid

2, WAM C 47393, LN0560, Little Well, 302210, 6997164, 27°08'02"S, 121°00'16"E, 3/14/2011, Cyclopoida, 84
Halicyclops microeberhardi n. sp. – 14 males + 56 females + 8 copepodids
Schizopera dimorpha n. sp. – 2 males + 1 female

3, WAM C 47394, LN0559, Little Well, 302210, 6997164, 27°08'02"S, 121°00'16"E, 3/14/2011, Harpacticoida , 18
Schizopera dimorpha n. sp. – 6 males + 4 females
Schizopera sp. 3 n. sp. – 2 females

4, WAM C 47395, LN0561, Little Well, 302210, 6997164, 27°08'02"S, 121°00'16"E, 3/14/2011, Ostracoda, 10
To be sent separately next week!

5, WAM C 47396, LN0847, LMST012, 305413, 6994778, 27°09'21"S, 121°02'10"E, 3/15/2011, Cyclopoida, 6
Halicyclops microeberhardi n. sp. – 1 male + 1 female
Collembola – 1 specimen

6, WAM C 47397, LN0524, LMST012, 305413, 6994778, 27°09'21"S, 121°02'10"E, 3/15/2011, Harpacticoida , 6
Schizopera dimorpha n. sp. – 2 males + 1 female
Schizopera sp. 3 n. sp. – 1 female
Schizopera cf. sp. 2 n. sp. – 1 male + 1 female

7, WAM C 47398, LN0492, LMST014, 306610, 6993773, 27°09'54"S, 121°02'53"E, 3/15/2011, Copepoda, 1
Halicyclops microeberhardi n. sp. – 1 female

XI. SYSTEMATIC LIST:

Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Halicyclopinae Kiefer, 1927
Genus *Halicyclops* Norman, 1903

13. *Halicyclops microeberhardi* n. sp.

Order Harpacticoida Sars, 1903
Family Miraciidae Dana, 1846
Genus *Schizopera* Sars, 1905

14. *Schizopera dimorpha* n. sp.
15. *Schizopera sp. 3* n. sp.
16. *Schizopera cf. sp. 2* n. sp.

XII. COMMENTS:

Halicyclops microeberhardi n. sp.

This is a relatively small species, which is in every other respect morphologically identical to *H. eberhardi* De Laurentiis *et al.*, 2001. However, in bore EH01 (vial no. LN0766), in one of your previous lot of samples, this species was found together with a much larger sister species, which is also morphologically identical to *H. eberhardi*. *Halicyclops eberhardi* was in the past considered a widely distributed species in subterranean waters of the Yilgarn region, with some records even outside of WA (Karanovic, 2004). Unfortunately, current molecular work on a large population of this morpho-species from one of the calcretes close to Lake Maitland (Karanovic & Cooper, in preparation), revealed a presence of at least one other cryptic species (and maybe even two). Thus, we have to accept a possibility that future molecular work will reveal that this morpho-species consists of a number of isolated cryptic species, with no gene-flow between different and isolated calcretes. In Lake Maitland we are lucky to have a clear size differentiation between two sister species. One would be able to recognize that *H. macroeberhardi* n. sp. and *H. microeberhardi* n. sp. are two different species even under a dissecting microscope, before knowing which genus they belong to. Size differentiation is a common phenomenon when two closely related, but reproductively isolated, species come into secondary contact after a range expansion, and it has been well documented in the Yilgarn especially for diving beetles (Leys & Watts, 2008). However, it is also very common among copepods, and some examples include *Diacyclops* species from the Pilbara region (Karanovic, 2006), *Schizopera* species from the Yilgarn (Karanovic & Cooper, in preparation), but examples have been found also in the genus *Nitokra* from Lake Way (Karanovic, unpublished report for Outback Ecology). *H. microeberhardi* is a stygobiont and was present in your previous samples from Lake Maitland.

Schizopera dimorpha n. sp.

This species seems to be quite common in the area and was present in previous three lots of samples from Lake Maitland, identified in February 2009, August 2010, and January 2011. Very short caudal rami, but slightly less than in the population from Lake Way that I called *S. cf. dimorpha* (Karanovic, unpublished report for Outback Ecology). Stygobiont.

Schizopera sp. 3 n. sp.

Only one female of this interesting new species was collected and examined in your previous lot of samples (January 2011). I commented that it is very hard to establish a new species on a single specimen in this large genus, especially because one cannot be sure if the observed morphological differences are a result of intraspecific variability or are indeed reliable specific characters. Previous knowledge of this group in the Yilgarn region (Karanovic & Cooper, submitted) would suggest the latter hypothesis. In this lot of samples there were three females from two different locations, which are certainly conspecific and different species from *S. dimorpha* n.sp. and *S. cf. sp. 2* n.sp.Some of the most important characters of *S. sp. 3* n. sp.: caudal rami about as long as anal somite, and slender, proximal lateral and dorsal setae inserted at about ¾ of ramus length. The three species also differ significantly in size, with *S. sp. 3* being the smallest and *S. cf. sp. 2* the largest.

Schizopera cf. sp. 2 n. sp.

One male and one female of this species were found in the sample LN0524, together with two other congeners (*S. dimorpha* and *S. sp. 3*). The female, however, had its caudal rami overgrown with ciliates and bacteria, so they were not observed adequately. All my attempts to clean them failed. Males differ much less morphologically between species in this genus, so indentification of these two specimens as *S. cf. sp. 2* has to be considered as provisional. A possibility that we are dealing here with yet another new species, cannot be completely discarded.

XIII. SPECIES REGISTERED BEFORE, BUT ABSENT FROM THIS LOT:

Halicyclops macroeberhardi **n. sp.**
Microcyclops varicans **(Sars, 1863)**
Schizopera sp. 1 **n. sp.**
Nitokra cf. megaregis **n. sp.**
Nitokra lacustris pacifica **Yeatman, 1983**
Australocamptus similis **Karanovic, 2004**

XIV. REFERENCES

Karanovic T. (2004): Subterranean Copepoda from arid Western Australia. *Crustaceana Monographs*, 3: 366pp.

Karanovic T. (2006): Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

Karanovic T., Cooper S. (submitted): Explosive radiation of the harpacticoid genus *Schizopera* (Crustacea: Copepoda) in a small subterranean island in Western Australia; unraveling the cases of cryptic speciation, size differentiation, and multiple invasions. *Organisms Diversity & Evolution.*

Leys R., Watts C.H. (2008): Systematics and evolution of the Australian subterranean hydroporine diving beetles (Dytiscidae), with notes on *Carabhydrus*. In: Austin AD, Cooper SJB, Humphreys WF, eds. *Subterranean Connections: Biology and evolution in troglobiont and groundwater ecosystems*. Invertebrate Systematics 22: 217–225.

Very best wishes,

Tom Karanovic

Seoul, 11 May 2011

Lake Maitland Copepoda Morphological Assessment

Prepared by
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7th November, 2011

RE:
Job Number: **LMAI-SY-10001**
Taxa: Copepods and ostracods
Region: **Lake Maitland**
Outback Ecology Purchase Order Number for WAM: OES2544
Outback Ecology Purchase Order Number for Karanovic: **OES2545**
Total Number of Samples: 9 vials

XV. RESULTS FOR COPEPODS AND OSTRACODS:

1, WAM C49014, Lake Maitland, bore LMST012, Easting 305413, Northing 6994778, 18/07/2011, Net Hauling, Cyclopoida, 43, LN3727
Halicyclops microeberhardi n. sp. – 8 males + 7 females + 24 copepodids
Halicyclops microeberhardi n. sp. – 1 male + 3 copepodids

2, WAM C49015, Lake Maitland, bore WAM1-LT107, Easting 297228, Northing 6996855, 18/07/2011, Net Hauling, Cyclopoida, 9, LN4310
Halicyclops cf. eberhardi Laurentiis, Pesce & Humphreys, 2001 – 1 male + 3 females + 5 copepodids

3, WAM C49016, Lake Maitland, bore Little Well, Easting 302210, Northing 6997164, 18/07/2011, Net Hauling, Cyclopoida, 50, LN3731
Halicyclops macroeberhardi n. sp. – 11 males + 16 females + 21 copepodids
Kinnecaris maitlandi n. sp. – 1 female

4, WAM C49017, Lake Maitland, bore LMACW69, Easting 310680, Northing 7014260, 18/07/2011, Net Hauling, Cyclopoida, 2, LN3732
Mesocyclops brooksi Pesce, Laurentiis & Humphreys, 1996 – 2 females

5, WAM C49018, Lake Maitland, bore LMST008, Easting 305115, Northing 6996771, 18/07/2011, Net Hauling, Harpacticoida, 2, LN3121
Halicyclops macroeberhardi n. sp. – 1 male + 1 female

6, WAM C49019, Lake Maitland, bore LMST012, Easting 305413, Northing 6994778, 18/07/2011, Net Hauling, Harpacticoida, 16, LN5358
Schizopera dimorpha n. sp. – 6 males + 1 female + 3 copepodids
Schizopera sp. 3 n. sp. – 1 male + 3 females

7, WAM C49020, Lake Maitland, bore WAM1-LT107, Easting 297228, Northing 6996855, 18/07/2011, Net Hauling, Harpacticoida, 7, LN4307
Schizopera dimorpha n. sp. – 4 males
Nitokra lacustris pacifica Yeatman, 1983 – 1 male + 1 female
Nitokra cf. macroregis n. sp. – 1 female

8, WAM C49021, Lake Maitland, bore Little Well, Easting 302210, Northing 6997164, 18/07/2011, Net Hauling, Harpacticoida, 50, LN3718

Kinnecaris maitlandi n. sp. – 9 males + 13 females + 9 copepodids
Schizopera dimorpha n. sp. – 7 males + 2 females + 5 copepodids
Schizopera sp. 3 n. sp. – 2 males + 3 females

9, WAM C49022, Lake Maitland, bore Little Well, Easting 302210, Northing 6997164, 18/07/2011, Net Hauling, Ostracoda, 2, LN3741

Candonopsis dani Karanovic & Marmonier, 2002 – 2 females

XVI. SYSTEMATIC LIST:

Sybphylum Crustacea Brünich, 1772
Class Maxillopoda Dahl, 1956
Suclass Copepoda H. Milne Edwards, 1840
Order Cyclopoida Rafinesque, 1815
Family Cyclopidae Rafinesque, 1815
Subfamily Halicyclopinae Kiefer, 1927
Genus *Halicyclops* Norman, 1903

17. *Halicyclops macroeberhardi* n. sp.
18. *Halicyclops microeberhardi* n. sp.
19. *Halicyclops cf. eberhardi* Laurentiis, Pesce & Humphreys, 2001

Sunfamily Cyclopidae Rafinesque, 1815
Genus *Mesocyclops* Kiefer, 1927

20. *Mesocyclops brooksi* Pesce, Laurentiis & Humphreys, 1996

Order Harpacticoida Sars, 1903
Family Miraciidae Dana, 1846
Genus *Schizopera* Sars, 1905

21. *Schizopera dimorpha* n. sp.
22. *Schizopera sp. 3* n. sp.

Family Parastenocarididae Chappuis, 1940
Genus *Kinnecaris* Jakobi, 1972 sensu Schminke (2008)

23. *Kinnecaris maitlandi* n. sp.

Family Ameiridae Monard, 1927
Subfamily Ameirinae Monard, 1927
Genus *Nitokra* Boeck, 1865

24. *Nitokra lacustris pacifica* Yeatman, 1983
25. *Nitokra cf. macroregis* n. sp.

Class Ostracoda Latreille, 1806
Subcalss Podocopa Sars, 1866
Order Podocopodida Sars, 1866
Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
Subfamily Candoninae Kafmann, 1900
Tribe Candonopsini Karanovic, 2004
Genus *Candonopsis* Vávra, 1891

26. *Candonopsis dani* Karanovic & Marmonier, 2002

XVII. COMMENTS:

Mesocyclops brooksi and *Kinnecaris maitlandi* are new discoveries for Lake Maitland, while all other species have been recorded here previously a number of times. *Mesocyclops brooksi* is a widely distributed Western Australian copepod species, recorded all over the Yilgarn region and in part of the Pilbara region (Karanovic 2004, 2006), as well as in parts of the WA Weatbelt region (mostly unpublished records). It is probably a stygophile rather than a stygobiont. *Kinnecaris maitlandi* belongs to the *solitaria*-complex of species, which shows a remarkable short range endemism in the Yilgarn (Karanovic & Cooper 2011). Differences between species in this complex are minute, and the new species mostly resembles *Kinnecaris solitaria* (Karanovic, 2004) and *Kinnecaris lakewayi* Karanovic & Cooper, 2011. However, this is just an indication, and more thorough examination of these specimens is needed to make a more informed conclusion. At least detailed drawings under light microscope would be necessary, but SEM photographs and DNA work would be recommended, all of which were outside the scope of this preliminary identification.

Similarly, more work would be required if one is to positively solve intricate differences between *Halicyclops microeberhardi, H. macroeberhardi,* and *H. eberhardi* in every locality. As mentioned in my previous reports, adults of the first two species are easy to distinguish when they are sympatric, but the same cannot be said when only one form is present, or when juveniles are concerned. Futher difficulties would present themselves to distinguish other new species in this complex. For example, specimens in sample no. 2 (bore WAM1-LT107) look very much like those of the typical *H. eberhardi,* but this identification is only provisional. Some recent unpublished molecular work on a large population of this morpho-species from one of the calcretes close to Lake Maitland (Karanovic & Cooper, in preparation), revealed a presence of at least one other cryptic species (and maybe even two). Size differentiation is a common phenomenon when two closely related, but reproductively isolated, species come into secondary contact after a range expansion, and it has been well documented in the Yilgarn especially for diving beetles (Leys & Watts, 2008). However, it is also very common among copepods, and some examples include *Diacyclops* species from the Pilbara region (Karanovic, 2006), *Schizopera* species from the Yilgarn (Karanovic & Cooper, in press), but examples have been found also in the genus *Nitokra* from Lake Way (Karanovic, unpublished report for Outback Ecology).

XVIII. SPECIES REGISTERED BEFORE, BUT ABSENT FROM THIS LOT:

***Microcyclops varicans* (Sars, 1863)**
***Schizopera sp. 1* n. sp.**
***Schizopera cf. sp. 2* n. sp.**
***Australocamptus similis* Karanovic, 2004**

XIX. REFERENCES

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Karanovic T. (2006) Subterranean copepods (Crustacea, Copepoda) from the Pilbara region in Western Australia. *Records of the Western Australian Museum, Supplement* 70: 239pp.

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Leys R. & Watts C.H. (2008): Systematics and evolution of the Australian subterranean hydroporine diving beetles (Dytiscidae), with notes on *Carabhydrus*. In: Austin AD, Cooper SJB, Humphreys WF, eds. *Subterranean Connections: Biology and evolution in troglobiont and groundwater ecosystems*. Invertebrate Systematics 22: 217–225.

Very best wishes,

Tom & Ivana Karanovic Seoul, 07 November 2011

Appendix L

Ostracoda morphological assessment reports

Prepared by Dr Ivana Karanovic

Ostracoda from the Lake Maitland area (Murchison region), received from Outback Ecology in May 2007 (Job Number: RLM-SY-0107)

Prepared by

Dr. I. Karanovic

3. Little Well, 22/05/07

- *Candonopsis tenuis* (Brady, 1886): 1 female dissected on one slide.

7. LMAC0011, 23/05/07

- One valve of a juvenile Candoninae, probably of some *Candonopsis sp.*

Systematics

Family: Candonidae Kaufmann, 1900

Subfamily Candoninae Kaufmann, 1900

Genus: *Candonopsis* Vavra, 1891

Candonopsis tenuis (Brady, 1886)

Remarks

This species is widely distributed in Australia. It is often associated with the subterranean habitats, but it could be found in springs and streams as well. I have often found it in wells in the Murchison and Pilbara regions.

If you have any more questions, or if you need my paper where this species was redescribed, please do not hesitate to contact me.

Best wishes and kind regards.

Ivana Karanovic

1. Lake Maitland Ostracoda Morphological Assessment

Prepared by
Dr. I. Karanovic
February 2009

Outback Ecology. Job No. RLM-SY-1008. Eastern Goldfields.

Results for Ostracoda.

2. RLM001, 6 Mile Bore, 11/12/08
   - *Sarscypridopsis ochracea*: 3 empty shells and 2 juveniles (in alcohol)
3. RLM002, Eclipse Well, 11/12/08
   - *Sarscypridopsis ochracea*: 1♀, 1 juv. (in alc.)
4. RLM003, Little Well, 11/12/08
   - *Candonopsis dani*: 1♂ (on slide), 2 valves (in alcohol).

Systematic Account

Family Candonidae Kaufmann, 1900
Subfamily Candoninae Kaufmann, 1900
Tribe Candonopsini Karanovic, 2004
Genus *Candonopsis* Vávra, 1891

1. *Candonopsis dani* Karanovic & Marmonier, 2002

Family Cyprididae Baird, 1845
Subfamily Cypridopsinae Kaufmann, 1900
Genus *Sarscypridopsis* McKenzie, 1977

2. *Sarscypridopsis ochracea* (Sars, 1924)

Remarks

Candonopsis dani was described from the Lake Violet Borefield (Wiluna) and it is found in many bores in and around Wiluna. It is characterized by a smooth carapace, and the posterior claw on the caudal ramus considerably shorter than anterior one. In the original description both claws on caudal ramus have small (but prominent) thorns. The specimen I have examined from your sample lacks this feature, but is otherwise same as *C. dani*. The presence/absence of such thorns is quite variable in the species of this genus. This species (together with *C. murchisoni* Karanovic & Marmonier, 2002) belongs to a group very similar to *Candonopsis tenuis* (Brady, 1886) and they are very difficult to separate without male. I have noticed that previously I have identified one *Candonopsis* species from Small Well as *C. tenuis*. It was a female specimen, so this should rather be considered as *C. dani* instead.

Candonopsis dani is a subterranean species.

Kind regards,

Ivana

Lake Maitland Ostracoda Morphological Assessment

Prepared by
Dr. I. Karanovic
Biodiversity Laboratory,
Department of Life Sciences
Hanyang University
Seoul 133-791 Korea

18th August, 2010
Identification of Ostracoda for the Outback Ecology
Job Number: RLM-SY-1109
Purchase order number: OES1379

Region: Lake Maitland

1. RESULTS

45404, LN1431, Little Well, 09.03.2010:
Candonopsis cf. dani Karanovic & Marmonier, 2002.: 12 juveniles, 7 females in a vial, 1 male on a slide

2. SYSTEMATIC ACCOUNT

Family: Candonidae Kaufmann, 1900
Subfamily: Candoninae Kaufmann, 1900
Tribe: Candonopsini Karanovic, 2004

Genus: *Candonopsis* Vávra, 1891.

Candonosis (C.) cf. dani Karanovic & Marmoneir, 2002

3. COMMENTS

Candonopsis dani was described from the Lake Violet Borefield (Wiluna) and it is found in many bores in and around Wiluna. It is characterized by a smooth carapace, and the posterior claw on the caudal ramus considerably shorter than anterior one. In the original description both claws on caudal ramus have small (but prominent) thorns. I had samples from the Little Well another two times until now. The first species was identified like *C. tenuis* (Brady, 1886), and the second time as *C. dani*. The species in this last lot was identified as *C. cf. dani* because it somehow differs from the original description in a more rounded dorsal margin on the LV, valves not being so asymmetrical and also by having a different appearance of the caudal ramus. Difference in the morphology of the caudal ramus between the original description and the samples from the Little Well, was also noticed when the species was identified as *C. dani*. Having all these results now, I may reconsider the entire complex and revise the species *C. dani.* This would be a good case for DNA sequencing, and worth considering in your next sampling in this area. *Candonopsis dani* is a subterranean species.

1. Lake Maitland Ostracoda Morphological Assessment

Prepared by
Dr. I. Karanovic
Biodiversity Laboratory,
Department of Life Sciences
Hanyang University
Seoul 133-791 Korea

18th February, 2011

Job number: RLM-SY-1109 for Outback Ecology

Western Australia, Lake Maitland

Results:

LN1736, LMST006, 17/08/2010, WAM C45527: *Candonopsis cf. dani*: 1 disintegrated ♀ dissected on a slide, 1 juv., 1 valve

LN0744, Little Well, 18/08/2010, WAM C45528: *Candonopsis cf. dani*: 11 juveniles, 3 empty shells

Systematic account:

Family: Candonidae Kaufmann, 1900

Subfamily: Candoninae Kaufmann, 1900

Tribe: Candonopsini Karanovic, 2004

Genus: *Candonopsis* Vávra, 1891.

2. *C. (C.) cf. dani* Karanovic & Marmonier, 2002.

Remarks:

As in the previous samples from the Lake Maitland area (LN1431, Little Well, 09.03.2010) this form differs from the original description of the species by a more rounded dorsal margin on the LV, valves not being so asymmetrical and also by having a different appearance of the caudal ramus.

Please note that November 2011 Ostracoda assessment provided as inclusion in Copepoda November 2011 assessment in **Appendix J**.

Appendix M

Bore lithologies, Standing Water Levels, Salinity, Dissolved Oxygen and Stygofauna recorded

Bore lithologies, Standing Water Levels, Salinity, Dissolved Oxygen and Stygofauna recorded.

Stygofauna taxa collected	Bore Code	Depth (m bgl)		Saturated habitat present	SWL	Depth saturated calcrete present	Salinity		DO
		From	To		(m bgl)	(m)	ppt	mS/cm	(ppm)
Ameiropsyllus sp. TK1	**LMAC0448**	1	2	Calcrete	1.07 - 1.61	1.43	70 - 97	122.5 - 141.4	0.01 - 16.04
		2	2.5	Calcrete+Clay					
		2.5	9	Clay+Grit					
Atopobathynella sp.	**LMAC0423**	1	3.5	Calcrete+Clay	1.5 - 2.32	2.5	44	61.9 - 72.2	23.3
		3.5	4	Clay+Calcrete					
		4	7	Clay+Grit					
Halicyclops eberhardi	**LMAC0012**	1.5	4.5	Calcrete	1.51 - 1.8	4.99	56.1 - 72.5	80 - 123.2	2.57 - 15.41
		4.5	6.5	Clay+Calcrete					
		6.5	9	Clay					
	LMSC-021	1.5	2	Calcareous Clay	1.64	0	71.8	94.6	1.02
		2	3	Clay					
		3	4	Sandy Clay					
		9.5	12	Clayey Sand					
Haloniscus sp. OES1	**LMAC0012**	1.5	4.5	Calcrete	1.51 - 1.8	4.99	56.1 - 72.5	80 - 123.2	2.57 - 15.41
		4.5	6.5	Clay+Calcrete					
		6.5	9	Clay					
	LMAC0352	1	1.5	Clay+Ferricete	1.16 - 1.38	0	70 - 102.6	128.1 - 129.6	2.86 - 16.54
		1.5	7	Clay					
	LMAC0448	1	2	Calcrete	1.07 - 1.61	1.43	70 - 97	122.5 - 141.4	0.01 - 16.04
		2	2.5	Calcrete+Clay					
		2.5	9	Clay+Grit					
	LMAC0545	1.5	2	Grit	1.5	1	54.8	75.5	4.98
		2	2.5	Calcrete+Grit					
		3	3.5	Grit+Clay					
Naididae sp. OES2	**LMAC0334**	1	7	Clay	1 - 1.05	0	70 - 113	139.4 - 150	1.97 - 19.76
	LMAC0448	1	2	Calcrete	1.07 - 1.61	1.43	70 - 97	122.5 - 141.4	0.01 - 16.04
		2	2.5	Calcrete+Clay					
		2.5	9	Clay+Grit					
Schizopera sp. TK1	**LMAC0352**	1	1.5	Clay+Ferricete	1.16 - 1.38	0	70 - 102.6	128.1 - 129.6	2.86 - 16.54
		1.5	7	Clay					
	LMAC0448	1	2	Calcrete	1.07 - 1.61	1.43	70 - 97	122.5 - 141.4	0.01 - 16.04
		2	2.5	Calcrete+Clay					
		2.5	9	Clay+Grit					

Bore lithologies, Standing Water Levels, Salinity, Dissolved Oxygen and Stygofauna recorded (cont.)

Stygofauna taxa collected	Bore Code	Depth (m bgl)		Saturated habitat present	SWL	Depth saturated calcrete present	Salinity		DO
		From	To		(m bgl)	(m)	ppt	mS/cm	(ppm)
No stygofauna recorded	**LMAC0008**	1.5	4	Calcrete	1.8	4.2	33.7	51.2	19.85
		4	5	Calcrete+Clay					
		5	6	Clay+Calcrete					
		6	9	Clay					
	LMAC0009	1.5	2	Calcrete+Clay	1.8 - 2.03	4.7	45.2 - 58.7	66.5 - 79.6	4.84 - 17.25
		2	3.5	Calcrete					
		3.5	6.5	Clay+Calcrete					
		6.5	9	Clay					
	LMAC0010	1.5	2	Clay+Calcrete	1.5	5.5	53.2	76.4	15.85
		2	4	Calcrete					
		4	7	Clay+Calcrete					
		7	9	Clay					
	LMAC0011	1.5	3.5	Calcrete	1.9 - 2.18	4.6	40.8 - 56.6	60.6 - 77	4.73 - 16.87
		3.5	4	Calcrete+Clay					
		4	6.5	Clay+Calcrete					
		6.5	9	Clay					
	LMAC0147	2	2.5	Clay	2	0	80.3	104.4	4.24
		2.5	3	Clay+Ferricrete					
		3	9	Clay					
	LMAC0160	3.5	4	Calcrete+Ferricrete	3.5 -3.55	1.5	29.5 - 38.6	45.3 - 54.6	3.88 - 15.49
		4	4.5	Calcrete					
		4.5	5	Clay+Calcrete					
		5	9	Clay					
	LMAC0168	2.5	3	Calcrete	2.5	1	43.2	60.3	3.55
		3	3.5	Calcrete+Clay					
		3.5	9	Clay					
	LMAC0179	1	1.5	Clay	1.18 - 1.45	3.32	70 - 81.8	103.6 - 106.2	4.02 - 20
		1.5	2	Ferricrete+Clay					
		2	2.5	Ferricrete					
		2.5	3	Ferricrete+Calcrete					
		3	3.5	Calcrete+Ferricrete					
		3.5	4	Calcrete					
		4	4.5	Clay+Calcrete					
		4.5	9	Clay					
	LMAC0212	0.5	9	Clay	0.95 - 1.05	0	70 - 146.6	169 - 176.4	3.61 - 17.9
	LMAC0266	0.5	7	Clay	08-.8 - 1	0	70 - 118.1	143 - 157.2	2.37 - 18.43

Bore lithologies, Standing Water Levels, Salinity, Dissolved Oxygen and Stygofauna recorded (cont.)

Stygofauna taxa collected	Bore Code	Depth (m bgl)		Saturated habitat present	SWL (m bgl)	Depth saturated calcrete present (m)	Salinity		DO DO (ppm) (ppm)
		From	To				ppt	mS/cm	
No stygofauna recorded	LMAC0291	3.5	4	Clay+Calcrete	3.5	2.5	48.1	66.6	3.56
		4	4.5	Calcrete+Clay					
		4.5	6	Calcrete					
		6	7	Clay					
	LMAC0312	1	7	Clay	1.36 - 2.62	0	70 - 117.6	141.9 - 150.2	1.62 - 15.82
	LMAC0399	2.5	4	Calcrete	2.5	2.5	43.8	61.2	3.09
		4	4.5	Calcrete+Clay					
		4.5	5	Calcrete					
		5	7	Grit					
	LMAC0401	1.5	3.5	Calcrete	1.5	2	46.8	65	2.45
		3.5	7	Grit+Clay					
	LMAC0406	2.5	5.5	Calcrete	2.5	3	32.4	46.3	4.02
		5.5	7	Grit					
	LMAC0505	4.5	5.5	Calcrete	4.5	5.5	30.2	43.5	1.64
		5.5	8	Clay+Calcrete					
		8	9	Clay					
	LMAC0527	1.5	4	Calcrete	1.7	3.7	70	125.7	15.1
		4	9	Clay+Grit					
	LMAC0541	1.5	3.5	Calcrete	1.57	2.43	70	105.2	15.88
		3.5	4	Clay+Calcrete					
		4	9	Grit					

Appendix N

Record of modified morphospecies names used

Record of morphospecies names assigned by Outback Ecology for previous morphospecies or provisional names assigned by taxonomist or DNA specialist.

Higher classification	Previous morphospecies or provisional name assigned by taxonomist or DNA specialist	Outback Ecology morphospecies name
Amphipoda	Ceinidae/Chiltoniidae sp. 1 (OES), Chiltoniidae sp. 3	Chiltoniidae sp. OES1
	Chiltoniidae sp. 4	Chiltoniidae sp. SAM4
Bathynellacea	*Atopobathynella* sp. 1	Atopobathynella sp. OES6
Copepoda	*Ameiropsyllus* sp. 1	*Ameiropsyllus* sp. TK1
	Halicyclops 'macroeberhardi'	*Halicyclops* sp. TK1
	Halicyclops 'microeberhardi'	*Halicyclops* sp. TK2
	Halicyclops cf eberhardi	*Halicyclops* sp. TK3
	Kinnecaris 'maitlandi'	*Kinnecaris* sp. TK3
	Nitokra cf. 'megaregis'	*Nitokra* sp. TK3
	Schizopera sp. 1	*Schizopera* sp. TK1
	Schizopera sp. 2	*Schizopera* sp. TK2
	Schizopera cf. sp. 2	*Schizopera* sp. TK5
	Schizopera 'dimorpha'	*Schizopera* sp. TK6
	Schizopera sp. 3	*Schizopera* sp. TK8
Isopoda	*Haloniscus* sp. 1 OES, *Haloniscus* sp. nov. 3	*Haloniscus* sp. OES1
Ostracoda	*Candonopsis 'maitlandi'*	*Candonopsis* sp. IK2

APPENDIX O

Natural variations in Standing Water Levels (SWL) from January 2007 to November 2011

Natural variations in Standing Water Levels (SWL) from January 2007 to November 2011.

Area	Bore code	Survey period									
		Jan-07	May-07	Dec-08	Mar-10	Aug-10	Feb-11	Mar-11	Jul-11	Sep-11	Nov-11
Northern Borefield	**6 Mile Bore**			5.57		-0.37			+1.34		
	Eclipse Well		2.72	-0.22							
	LMACW1	4.60		+0.22		+0.21			+0.15		
	LMACW20						6.21		-0.03		
	LMACW25						5.04		+0.87		
	LMACW30						3.30		+0.14		
	LMACW34						6.99		+0.01		
	LMACW37						3.64		-0.22		
	LMACW40						9.25		-0.04		
	LMACW68						5.13		-0.05		
	LMACW69						9.47		+0.01		
	LMACW71						8.98		+0.02		
	LMACW75						9.59		+0.04		
	LMACW76						9.59		-0.19		
	Northern Control Bore			5.10		-0.97			-0.91		
Mining operations area - Resource	**EH05**			1.34	+0.08						
	LMAC0009		1.80	+0.23							
	LMAC0011		2.18	-0.28							
	LMAC0012		1.58	+0.22				-0.07			
	LMAC0160		3.55	-0.05							
	LMAC0179		1.18	+0.27							
	LMAC0212		0.95	+0.10							
	LMAC0266		0.80	+0.20							
	LMAC0312		1.36	+1.26							
	LMAC0334		1.00	+0.05							
	LMAC0352		1.16	+0.22							
	LMAC0423			1.50	+0.82						
	LMAC0448		1.30	+0.20	+0.31			-0.23			
Mining operations area - Drawdown	**Little Well**		3.87	+0.64	+0.80	+0.39		+0.15	+0.08		
	LMACW52						4.01		+0.78		
	LMACW56						3.32		-0.09		
	LMST001					4.08		+0.02			
	LMST002					3.78		-0.10			
	LMST003					2.85		-0.22			
	LMST004					4.30		-0.18			
	LMST005					3.47		-0.19			
	LMST006					3.60		-0.27			
	LMST007					3.74		-0.17			
	LMST008					4.34		-0.09	-0.07		
	LMST010					3.73		-0.25			
	LMST011					4.13		+0.08			
	LMST012					4.01		-0.15	-0.26		
	LMST014					4.19		-0.11			
	Two Jacks Well		3.85	+0.15							
Non-impact	**LT104**								4.51	+0.07	+0.04
	LT105								4.00	0	-0.03
	LT107								4.49	-0.03	0
	Salt Well		7.60	-3.1							