Dual Phase Survey for Short Range Endemic Fauna for the Lake Mackay SOP Project, Western Australia.

Report by Invertebrate Solutions
for Agrimin Ltd

December 2017

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Frontispiece: Sand dunes and claypans near the southern shore of Lake Mackay.

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Executive Summary

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project includes 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA.

Invertebrate Solutions has been requested by Agrimin Ltd (Agrimin) to undertake a desktop assessment and dual field survey for short range endemic (SRE) invertebrates for the Lake MacKay SOP Project.

Invertebrate Solutions completed a SRE survey at the Lake Mackay SOP Project area in May and November 2017. This comprised 15 sites on both the mainland and offshore islands. Sites 1 – 6 and 11 – 14 were surveyed in conjunction with a vertebrate fauna trapping program and used the pitfall traps for collecting potential SRE invertebrates, along with litter sifting and hand searching of appropriate microhabitats. Sites 7 – 10 and 15 consisted of litter sifting and hand searching only for potential SRE invertebrates for 1 human hour per site.

The SRE field survey recorded 22 taxa of invertebrates from three classes, nine orders and 11 families that have the potential to contain SRE taxa. Twelve taxa were identified as Possible SRE species and a single undescribed species of Armadillid isopod is considered a likely SRE species from the Lake Mackay SOP Project area. There were no 'Confirmed' SRE species recorded during the survey. The majority of the species determined to be "Possible" SRE taxa is due to incomplete taxonomy and unknown species distributions. Almost all the possible SRE species were found at multiple locations during the survey indicating that their distributions are wider than the current survey could determine. No species' were recorded solely on the lake islands which indicates that, in general, the offshore islands are simply more depauperate communities of the normal mainland fauna, however, further surveys on the islands in multiple seasons would be required to support this assertion.

The SRE survey at the Lake Mackay SOP Project undertaken in May and November 2017 recorded a diverse range of invertebrate species, many of which are new records for the Lake Mackay region. This is primarily due to the lack of previous collecting in the area, rather than the region containing a unique species assemblage any different from other parts of the central arid region of Australia.

A single species of isopod, Buddelundinae gen nov., sp. nov. that is considered a 'Likely' SRE species was recorded from SRE Site 5 in sand dunes on the southern shore of Lake Mackay. Whilst this habitat does not appear to show microhabitat restrictions no further records of this isopod have been recorded.

The development of the Lake Mackay SOP Project is not anticipated to significantly impact any species recorded in this dual season SRE survey. When the specific Project footprint and location of infrastructure areas is finalised these conclusions should be revisited to ensure they remain valid, however, due to the limited extent of any processing and infrastructure facilities, currently being proposed as part of the SOP Project, this assessment is not expected to alter.

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

- No further surveys for terrestrial SRE invertebrates are required to meet the EPA Technical guidance, sampling of short range endemic invertebrate fauna (EPA 2016), and
- If any proposed development areas are to overlap the known distribution of the isopod Buddelundinae gen nov., sp. nov. then further targeted surveys for this species should be undertaken.

1. Introduction

Agrimin Limited (Agrimin) is developing its Lake Mackay Sulphate of Potash (SOP) Project and requires a number of baseline biological assessments to be carried out. The SOP Project covers 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA.

Invertebrate Solutions has been requested by Agrimin to undertake a desktop assessment and dual season field survey for short range endemic (SRE) invertebrates for the Lake MacKay SOP Project.

1.1 Purpose of this report

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

- Carry out a desktop review to inform the survey planning and report preparation, including identification of all SRE species likely to occur within the Project area;
- Undertake a SRE invertebrate survey to identify significant species and habitat in accordance with EPA Technical Guidance Sampling of short range endemic invertebrate fauna (EPA 2016);
- Undertake the field based survey for SRE invertebrates within the Project area;
- Identify to the lowest practical taxonomic unit all potential SRE specimens recorded during the field survey;
- Provide a comprehensive table of all SRE species likely to occur within the Project area ;
- Provide recommendations and any suggested requirements for further work to comply with relevant legislation;
- Provide recommendations to minimise potential impacts and any suggested requirements for further work to comply with relevant legislation; and
- Provide a written report containing the above items.

1.2 Project area

The Project covers 12 tenements covering the majority of Lake Mackay over a total area of 3,500 square kilometres. Lake Mackay is a seasonally inundated salt lake located on the Western Australia (WA) – Northern Territory (NT) border, with most of the lake located within WA. The Project is situated entirely within WA but is accessed from Alice Springs in the NT, 540 km to the south-east and is shown in Figure 1.

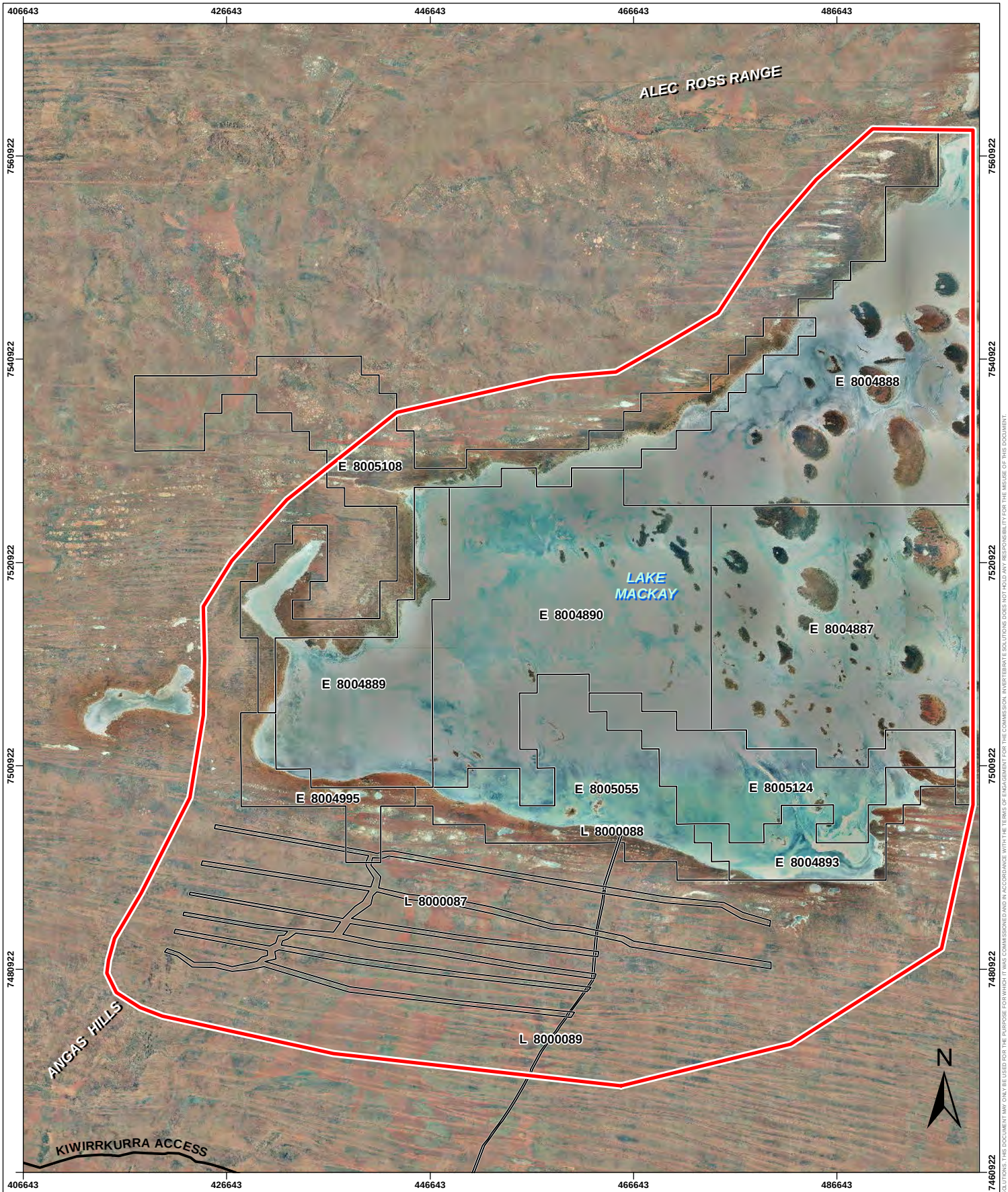
1.3 Survey Effort and Timing

Invertebrate Solutions completed a dual season SRE survey at the Lake Mackay SOP Project area in May and November 2017. This comprised 15 sites on both the mainland and offshore islands. Sites 1 – 6 and 11 – 14 were surveyed in conjunction with a vertebrate fauna trapping program and used the pitfall traps for collecting potential SRE invertebrates, along with litter sifting and hand searching of appropriate microhabitats. Sites 7 – 10 and 15 consisted of litter sifting and hand searching only for potential SRE invertebrates for 1 human hour per site. These active search methods were also used at sites 1 – 6 and 11 – 15.

Table 1 Locations sampled for SRE invertebrates

Sample ID	Easting	Northing	Habitat	Pitfall Trapping Nights	Pitfall Trap Date(s) Sampled	Sieving and Litter Collection
SRE1	481797	7525583	Island	60	10-16 May 2017	13 May 2017
SRE2	484291	7519290	Island	60	10-16 May 2017	13 May 2017
SRE3	464210	7493493	Sand dune	60	10-16 May 2017	14 May 2017
SRE4	477770	7487347	Near freshwater lake	60	11-17 May 2017	15 May 2017
SRE5	464687	7491478	Sand dune	60	11-17 May 2017	15 May 2017
SRE6	442307	7499962	Sand dune	60	12-18 May 2017	14 May 2017
SRE7	451014	7502291	Island	No	-	16 May 2017
SRE8	447315	7501624	Island	No	-	16 May 2017
SRE 9	435754	7499668	Lake shore	No	-	17 May 2017
SRE 10	438621	7497742	Sand dune	No	-	17 May 2017
SRE 11	444853	7499251	Sand dune	60	12-18 Nov 2017	17 Nov 2017
SRE 12	443680	7499479	Sand dune	60	12-18 Nov 2017	17 Nov 2017
SRE 13	431362	7509115	Sand dune	60	13-19 Nov 2017	17 Nov 2017
SRE 14	432047	7510495	Sand Plain	55	14-20 Nov 2017	20 Nov 2017
SRE 15	432360	7510101	Lake shore	No	-	13 Nov 2017

A map showing the locations of the SRE sampling sites is shown in Figure 2.



Legend

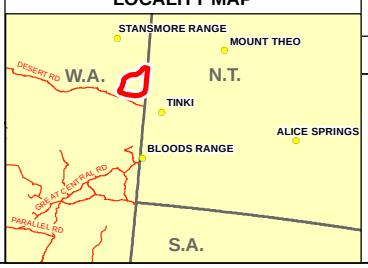
- Project Area
- Mining Tenement

0 3.75 7.5 15
km

Scale: 1:500,000 @ A4

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

LOCALITY MAP



- LOCALITY MAP SOURCED FROM LANDGATE 2006
- MINING TENEMENTS SOURCED LANDGATE 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2017
(© Western Australian Land Information Authority 2017)

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PROJECT ID	DATE
Lake Mackay SOP Project, WA	14/12/2017

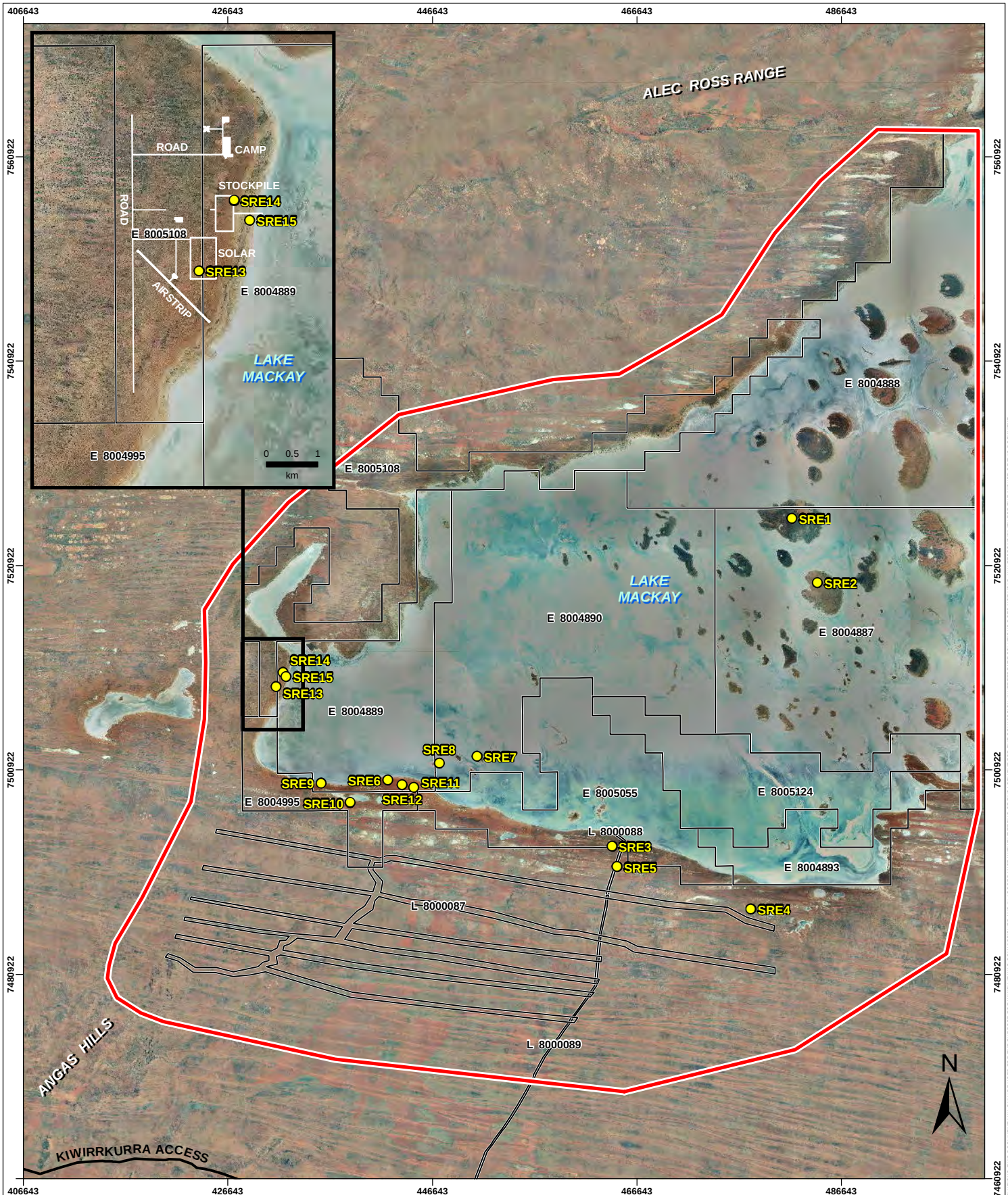
HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
ENVIRONMAPS	TM	TM	0

Dual Phase Survey for Short Range Endemic Fauna for the Lake Mackay SOP Project, Western Australia

Figure 1
Project Area

C:\GIS\Jobs\Invertebrate Solutions\Lake Mackay SOP Project, WA\Figures\LakeMacKay SOP Proj_F01 Project Area_171214.mxd



Legend

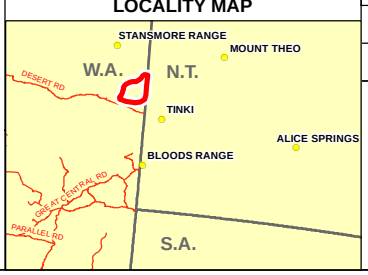
- Project Area
- Mining Tenement
- Short Range Endemic Survey Site

0 3.75 7.5 15
km

Scale: 1:500,000 @ A4

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

LOCALITY MAP



- LOCALITY MAP SOURCED FROM LANDGATE 2006
- MINING TENEMENTS SOURCED LANDGATE 2017
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ENVIRONMAPS	TM	TM	0

Dual Phase Survey for Short Range Endemic Fauna for the Lake Mackay SOP Project, Western Australia

Figure 2
Short Range Endemic Survey Sites

ENVIRONMAPS t: 0406 590 006 Environmental Mapping Solutions www.environmaps.com.au
C:\GIS\Jobs\Invertebrate Solutions\Lake Mackay SOP Project, WA\Figures\LakeMacKay SOP Proj_F02 Short Range Endemic Survey Sites_171214.mxd

1.4 Introduction to SRE fauna

Short range endemic (SRE) invertebrates are species with restricted distributions. The isolation of invertebrates in specific habitats or bioregions leads to endemism at various spatial scales. The vast majority of invertebrates are capable of dispersing substantial distances at some phase of their life cycle. Some groups, however, are susceptible to short-range endemism which describes endemic species with restricted ranges, arbitrarily defined in Western Australia as less than 10,000 km^2 (100 km x 100 km) (Harvey, 2002). Taxa that have been more commonly found to contain SRE representatives include:

- Onychophorans (velvet worms);
- Crustaceans (Isopoda);
- Arachnids (mygalomorph spiders, pseudoscorpions, opiliones, scorpions, schizomids);
- Myriapods (millipedes and centipedes);
- Molluscs (land snails); and
- Insects (hemipterans, grasshoppers, butterflies).

SRE invertebrate fauna taxa are generally found in sheltered, relatively mesic environments such as isolated habitats (e.g. boulder piles, isolated hills, dense patches of vegetation, gullies) and can include microhabitats within these environments such as deep leaf litter accumulation, large logs, under bark, cave areas and springs and permanent water bodies.

Many processes contribute to taxa being susceptible to short range endemism. Generally, these factors are related to the isolation of a species which can include the ability and opportunity to disperse, life history, physiology, habitat requirements, and habitat availability. Taxa that exhibit short range endemism generally exhibit poor dispersal, low growth rates, low fecundity and reliance on habitat types that are discontinuous (Harvey, 2002). Taxa that reside within easily isolated habitats surrounded by physical barriers such as islands, mountains, aquifers, lakes and caves are also more susceptible to becoming SRE species often including additional taxa not otherwise generally forming SREs.

Taxa that exhibit short range endemism are particularly vulnerable to disturbance, either natural or anthropogenic, as they are reliant upon specialised and often restricted habitats (often moist) (Framenau, *et al*., 2008). Short range endemic taxa are unable to disperse to *refugia* when their habitats are threatened or destroyed, thus making them a priority for conservation efforts.

1.5 Conservation Legislation and Guidance Statements

Terrestrial SRE species are protected under state legislation via the Wildlife Conservation (WC) Act (1950), the Environmental Protection Act (1986) and federally under the Environment Protection and Biodiversity Conservation (EPBC) Act (1999). The assessment of SRE fauna for environmental impact assessment (EIA) is undertaken in Western Australia with regard to the Technical Guidance – Sampling of short range endemic invertebrate fauna (EPA2016).

At the state level, the WC Act provides a list of species that have special protection as species listed under the Wildlife Conservation (Specially Protected Fauna) Notice 2015 (DPaW 2015). This notice is updated periodically by the Department of Biodiversity, Conservation and Attractions (DBCA)

(formerly Department of Parks and Wildlife, DPaW) and the current list (December 2016) includes numerous subterranean species, mainly from the Cape Range and Pilbara regions including crustaceans, arachnids and myriapods that are considered to be "rare or likely to become extinct, as critically endangered fauna, or are declared to be fauna that is in need of special protection" (DPaW 2016). In addition to the specially protected fauna, DBCA also maintains a list of Priority fauna that are considered to be of conservation significance but do not meet the criteria for formal listing under the WC Act as Scheduled species. The Priority fauna list is irregularly updated by DBCA and, although it offers no formal legislative protection, these species are generally considered in the EIA process.

There is no current ability for the state government of Western Australia to formally list Threatened or Priority Ecological Communities (TECs/PECs), however, a list of such communities is maintained by DBCA and overseen by the Minister for the Environment. Several subterranean ecological communities are recognised as Threatened including the Bundera Cenote Anchialine community on Cape Range, Cameron's Cave near the townsite of Exmouth on Cape Range, stygal root mat communities in both the Yanchep and Margaret River regions and stygobionts in the Ethel Gorge aquifer in the Pilbara. Communities that are not considered by DBCA to be threatened but may be vulnerable to future impacts are classed as PECs and include numerous calcrete aquifers in the Yilgarn region where each calcrete has been shown to contain an endemic stygal community.

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

The federal EPBC Act protects both species and ecological communities. The most relevant listing for SRE fauna is the mygalomorph spider *Idiosoma nigrum* that occurs in the Wheatbelt region and is listed as Vulnerable.

1.6 Survey Staff Qualifications

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

- Dr Timothy Moulds *BSc (Hons) Geol., PhD. Invert. Ecol.* (Invertebrate Solutions)

Sampling for SRE invertebrates was undertaken by Dr Tim Moulds. Invertebrate extraction, sorting and identification was completed by Dr Timothy Moulds. Survey work was undertaken under the collection licences issued by the Department of Parks and Wildlife:

- 08-001304-1; Licensee Dr Tim Moulds (Invertebrate Solutions); Valid from 09/11/2017.

1.7 Report Limitations and Exclusions

This study was limited to the written scope provided to the client by Invertebrate Solutions (24th October 2017) and in Section 1.1. This study was limited to the extent of information made available to Invertebrate Solutions at the time of undertaking the work. Information not made available to this study, or which subsequently becomes available may alter the conclusions made herein. Assessment of potential impacts to SRE fauna was based on proposed development plans provided by the client.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. Invertebrate

Solutions has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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

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

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

Species were identified to the lowest practical taxonomic level, taking into consideration that the taxonomic framework of many invertebrate groups is incomplete and often in need of substantial revision to enable accurate identification. Short Range Endemic status was assigned using the available information from the WAM database and discussion with appropriate taxonomic authorities for various invertebrate groups. Insufficient information exists for many invertebrate species due to specimens being juvenile, the wrong sex to allow identification, damaged, or inadequate taxonomic frameworks, precluding the assignment of SRE status.

Field surveys for SRE invertebrates require multiple seasonal surveys to fully record all species that may be present in an area, and in varying weather conditions. The current survey was undertaken over two seasons and additional surveys at different times of the year may record additional species.

2. Methods

Invertebrate Solutions undertook the following tasks for the dual season SRE survey of the Lake Mackay SOP Project area:

- SRE desktop assessment based upon Western Australian Museum Records;
- SRE survey of the Project Area (15 sites – 1 hour active searching and litter samples, 10 sites dry pitfall trapping in conjunction with a vertebrate fauna survey).

The survey program was undertaken with regard to the Technical Guidance – Sampling of short range endemic invertebrate fauna (EPA 2016).

2.1 SRE Desktop Methodology

A search of the WAM databases for Arachnids, Crustacea and Molluscs was undertaken for potential SRE taxa occurring in the Lake Mackay region. In addition, other published reports for the area were examined including several reports from the Bushblitz survey undertaken by Western Australian Museum and Queensland Museum staff in 2015. The desktop analysis was used to identify any potential SRE species that may occur in the Lake Mackay region and target those taxa during the subsequent field survey of the Project area.

2.2 SRE Survey Methodology

The SRE pilot survey was undertaken using a combination of sampling techniques and employed both systematic (timed active searching) and opportunistic (litter collection and transect) sampling. Sites were chosen to maximise SRE habitat including south-facing slopes, gullies, rocky outcrops, dense patches of trees and permanent water bodies.

2.2.1 Pitfall traps

At SRE sites 1 – 6 and 11 – 14, dry pitfall trapping for SRE invertebrates was undertaken in conjunction with the vertebrate fauna survey. This involved the use of 10 x 20L plastic buckets buried in two lines of five at each site with a drift fence of flywire placed along the centre line to direct invertebrates (and vertebrate fauna) into the pitfall traps. The pitfall traps were open for approximately seven nights at each site. These traps were checked once a day for invertebrates and more often for vertebrate fauna. Potential SRE invertebrates were collected using forceps, placing specimens into 70% ethanol.

2.2.2 Active searching

Active searching was undertaken at all 15 sites within and adjacent to the proposed disturbance areas, focusing on areas more likely to contain SRE fauna. Active searching consisted of sifting of soil and/or leaf litter from suitable habitat areas within each site (millipedes and land snails); the raking of leaf litter (millipedes, land snails, centipedes, mygalomorph burrows); examination of vegetative material below logs and bark (pseudoscorpions, centipedes, millipedes), and an examination of (if present) areas of rock outcrops and associated rock piles.

A minimum of one person hour active searching per site was undertaken.

2.2.3 Litter collection

Leaf litter was collected from each site surveyed and processed in Tullgren funnels for potential SRE fauna. Approximately 3L of leaf litter was collected from each site and stored in sealed plastic garbage bags.

2.2.4 Opportunistic collection

Various areas that may provide habitat for SRE invertebrates were also opportunistically sampled whilst undertaking other surveys in the survey area. This included searching for burrows of mygalomorph spiders and searching under tree bark and logs for potential SRE species.

2.3 Sorting and curation

Sorting for all SRE samples occurred in the Invertebrate Solutions laboratory using an Amscope 45x dissecting microscope and was undertaken by Dr Timothy Moulds. In the laboratory, fauna was extracted from SRE leaf litter samples using Tullgren funnels and preserved in 70% ethanol. Each taxon was identified to the lowest practical taxonomic rank using published keys and descriptions, and the numbers of each taxon recorded. Each identified taxon was kept in a separate labelled vial and assigned a specimen tracking code. Specimen and site collection data were recorded in an Excel spreadsheet. At the conclusion of the study, all specimens will be lodged at the Western Australian Museum.

2.4 Taxonomy and Nomenclature

Identification of collected invertebrate material was undertaken by Dr Timothy Moulds. Invertebrate groups collected that have no SRE representatives such as ants and flying insects were not identified or reported. The presence of winged adults in most insect groups suggests that they are more capable dispersers and, therefore, less likely to have a restricted range.

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

2.5 Short Range Endemic Status

Taxonomic groups known to contain SRE representatives were examined in more detail to determine if the specimens collected in this study are potentially restricted forms. SRE status will be assigned after comparison with the morphology of other close relatives in the group and current knowledge on their distribution and ecology, where known. Identifications will be confirmed by specialist taxonomists, as necessary.

The allocation of short range endemism status can be difficult due to the often incomplete taxonomic framework of many invertebrate groups and the often frequent need for substantial revision to enable accurate identification. Short Range Endemic status is assigned using the

categories described in Table 2, based upon the available information from the WAM database and discussion with appropriate taxonomic authorities for various invertebrate groups. Insufficient information exists for many invertebrate species due to specimens being juvenile, the wrong sex to allow identification, damaged, or inadequate taxonomic frameworks, precluding the assignment of SRE status.

Table 2 Short Range Endemic Status of Species

SRE Status	Definition
Confirmed	A confirmed SRE species. A known distribution of < 10,000 km^2 (after Harvey 2002). Taxonomy of the group is well known. The group is well represented in collections, or via comprehensive sampling.
Likely	Likely to be a SRE species based upon knowledge of the family/genus, where other closely related species show evidence of short range endemism. Where habitats containing the specimens show discontinuity within the landscape.
Possible	Based upon existing knowledge of the genus / family there is a possibility that the species may have a restricted range. Where habitats containing the specimens may show discontinuity within the landscape. Potential SRE species may be assigned one of the sub categories below: A. Data deficient i.e. new species, lack of distribution, taxonomic or collecting knowledge, juvenile specimens, wrong sex for identification B. Habitat indicators C. Morphology indicators D. Molecular evidence E. Research and expertise of WAM staff/taxonomic specialists
Widespread	Not a SRE, a wide ranging distribution of > 10,000 km^2

3. Results

3.1 Desktop SRE Assessment

A search of the WAM databases for potential SRE taxa occurring in the Lake Mackay region was undertaken (WAM 2017a, b, c). Very little data exists for this region and, prior to a Bushblitz survey in 2015 (Whisson and Kirkendale 2015, Baehr 2015), very few records for any invertebrates existed. No crustacean records are present in the WAM crustacean database although it should be noted that many specimens remain to be databased.

The Bushblitz survey (Whisson and Kirkendale 2015) recorded only five species of mollusc (Table 3). This low diversity was not unexpected due to the time of the year (dry season) and the fact that land snails tend to be most common in areas with rock piles, good amounts of shade and associated vegetation and seasonal wet spots (Solem 1993, Whisson and Kirkendale 2015).

Table 3 Desktop records from WAM of potential SRE Invertebrates in the Kiwirrkurra/Lake Mackay area

Higher Order	Genus and species	Location	SRE Status
Gastropoda: Pupillidae	*Pupoides adelaidae*	Jupiter Well area; N side of Balgo Road	Widespread in arid zone
	Pupoides beltianus	40km NE of Kiwirrkurra; E of Mt Webb	Widespread in central arid zone
	Pupoides eremicolus	Approx 120km E of Kiwirrkurra	Widespread in central arid zone
	Gastrocopta mussoni	100km E of Kiwirrkurra	Widespread across northern and arid Australia
Gastropoda: Planorbidae	*Leichhardtia* sp.	Mumu (NE of Kiwirrkurra); wetland area; SW edge of lake; Roberts Lake; NW of Lake Mackay	Possible (A, E)
Arachnida: Mygalomorphae Barychelidae	Barychelidae sp.	Morgan Range	Possible (A)
Arachnida: Mygalomorphae Nemesiidae	*Aname* sp.	Lake Mackay, WAM site 1; WAM Site 5	Possible (A)
Arachnida: Pseudoscorpiones: Garypidae	*Synsphyronus* 'Kiwirrkurra 1'	120 km E. of Kiwirrkurra; 12 km SSW. of Kiwirrkurra Community	Widespread
	Synsphyronus 'Kiwirrkurra 2'	100 km E. of Kiwirrkurra; 3 km E. of Mt Webb	Widespread
Chilopoda: Scutigeridae	*Pilbarascutigera incola*?	Lake Mackay, WAM site 6	Widespread

Several arachnid records were retrieved from the WAM arachnid database (WAM 2017a), with those likely to be potential SRE taxa recorded in Table 3. The two mygalomorph spiders were not identified beyond family level making a determination of SRE status difficult. The remainder of the pseudoscorpion and centipede records appear to be widespread species, although the taxonomy of these groups is incomplete.

3.2 SRE Field Survey

The SRE field survey recorded 22 taxa of invertebrates from three classes, nine orders and 11 families that have the potential to contain SRE taxa (Table 4). Twelve taxa were identified as Possible SRE species (refer Table 2) primarily due to the groups being considered data deficient, and the absence of other collections in the region making the assignation of SRE status difficult using the data from a single field survey. A single undescribed species of Armadillid isopod is considered a likely SRE species. The potential and likely SRE taxa identified in Table 4 are discussed further in Section 4.1. The majority of species recorded are widespread in the arid and semiarid regions of Australia, although many do represent new records for Lake Mackay primarily due to the lack of previous collecting in the area.

Table 4 Invertebrates recorded and examined for SRE status

Higher Order	Genus and species	Site	Abundance	SRE Status
Crustacea: Isopoda: Armadillidae	*Buddelundia* sp IS01	SRE 1, SRE 2, SRE 6, SRE 10, SRE11, SRE12, SRE13, SRE14	2, 1, 1, 2, 9, 4, 11, 13	Possible (A)
Crustacea: Isopoda: Armadillidae Buddelundiinae	*Buddelundiinae gen. nov. sp 'mackay'*	SRE 5	1	Likely
Arachnida: Aranaeomorpha: Lycosidae	*Lycosidae sp. WAM 27?*	SRE 15	3	Possible (A)
Arachnida: Pseudoscorpiones: Olpiidae	*Indolpium* sp. IS01	SRE 9	1	Possible (A)
	Indolpium sp. IS02	SRE 7	5	Possible (A)
	Indolpium sp. IS03	SRE 14	1	Possible (A)
Arachnida: Scorpiones: Buthidae	*Lychas cf. marmoreus*	SRE 1, SRE 4, SRE 13	1, 1, 3	Possible (A)
	Lychas sp. IS01	SRE 3, SRE 6, SRE 11, SRE 12, SRE 13, SRE 14	5, 4, 8, 15, 2, 1	Possible (A)
Arachnida: Scorpiones: Urodacidae	*Urodacus yaschenkoi*	SRE 3, SRE 5, SRE 6	57, 42, 8	Widespread
	Urodacus sp. 'mottled'	SRE 5, SRE 6	1, 1	Possible (A)
	Urodacus? sp.	SRE 15	1	Unknown (damaged dead specimen)

Higher Order	Genus and species	Site	Abundance	SRE Status
Diplopoda: Polyxenida: Lophoproctidae	*Lophoturus?* sp. nov.	SRE 11	4	Possible (A)
Diplopoda: Polyxenida: Polyxenidae	*Unixenus attemsi*	SRE 9	1	Widespread
Chilopoda: Scolopendromorpha: Scolopendridae	*Arthrorhabdus paucispinus*	SRE 1, SRE 2, SRE 6, SRE 11	1, 1, 1, 1	Widespread
	Arthrorhabdus mjobergi	SRE 4, SRE 6, SRE 11, SRE 12, SRE 13, SRE 14	1, 1, 1, 5, 3, 1	Widespread
	Arthrorhabdus cf. mjobergi	SRE 11, SRE 13	2, 3	Possible (A)
	Scolopendra mositans	SRE 2, SRE 11, SRE 12, SRE 13	1, 1, 1, 2	Widespread
	Scolopendra 'mackay'	SRE 12	1	Possible (A)
Chilopoda: Scutigeridomorpha: Scutigeridae	*Pilbarascutigera incola*?	SRE 12, SRE 14	1, 1	Widespread
Insecta: Blattodea: Blattidae	*Megazosteria purpurascens*?	SRE 7, opportunistic	2	Widespread
Insecta: Coleoptera: Carabidae: Cicindelinae	*Cicindela* sp. *cf. mastersi*	Lake Mackay surface	3	Possible (A)
	Cicindela sp.	SRE4, SRE 15	1, 3	Widespread

Several species were found to be widespread in the arid zone including the highly abundant scorpion species *Urodacus yaschenkoi* from sand dune areas in the Project area. Likewise, the majority of centipedes recorded were widespread species including those taxa recorded from the two islands in Lake Mackay. The Polyxenid millipede *Unixenus attemsi* is a widespread species of the pin cushion millipedes, known to occur throughout Bassian Australia.

Plate 1 The widespread arid zone scorpion *Urodacus yaschenkoi* from a sand dune at SRE Site 3 to the south of Lake Mackay

4. Discussion

4.1 SRE Invertebrate Assessment

The SRE survey recorded 13 potential SRE invertebrate species from the Lake Mackay SOP Project area. There were no 'Confirmed' SRE species recorded during the survey (refer Table 2). The majority of the species determined to be "Possible" SRE taxa is due to incomplete taxonomy and unknown species distributions. Almost all the possible SRE species were found at multiple locations during the survey indicating that their distributions are wider than the current survey could determine.

Table 5 Potential SRE invertebrates recorded in the Project area

Higher Order	Genus and species	Site	Abundance	SRE Status
Crustacea: Isopoda: Armadillidae	*Buddelundia* sp IS01	SRE 1, SRE 2, SRE 6, SRE 10, SRE11, SRE12, SRE13, SRE14	2, 1, 1, 2, 9, 4, 11, 13	Possible (A)
Crustacea: Isopoda: Armadillidae Buddelundiinae	*Buddelundiinae gen. nov. sp 'mackay'*	SRE 5	1	Likely
Arachnida: Aranaeomorpha: Lycosidae	*Lycosidae sp. WAM 27?*	SRE 15	3	Possible (A)
Arachnida: Pseudoscorpiones: Olpiidae	*Indolpium* sp. IS01	SRE 9	1	Possible (A)
	Indolpium sp. IS02	SRE 7	5	Possible (A)
	Indolpium sp. IS03	SRE 14	1	Possible (A)
Arachnida: Scorpiones: Buthidae	*Lychas cf. marmoreus*	SRE 1, SRE 4, SRE 13	1, 1, 3	Possible (A)
	Lychas sp. IS01	SRE 3, SRE 6, SRE 11, SRE 12, SRE 13, SRE 14	5, 4, 8, 15, 2, 1	Possible (A)
Arachnida: Scorpiones: Urodacidae	*Urodacus sp. IS01* 'mottled'	SRE 5, SRE 6	1, 1	Possible (A)
Diplopoda: Polyxenida: Lophoproctidae	*Lophoturus?* sp. nov.	SRE 11	4	Possible (A)
Chilopoda: Scolopendromorpha: Scolopendridae	*Arthrorhabdus cf. mjobergi*	SRE 11, SRE 13	2, 3	Possible (A)
	Scolopendra 'mackay'	SRE 12	1	Possible (A)
Insecta: Coleoptera: Carabidae: Cicindelinae	*Cicindela* sp. *cf. mastersi*	Lake Mackay surface	3	Possible (A)

No species were recorded solely from the islands on the lake itself which currently indicates that, in general, the offshore islands are simply more depauperate communities of the normal mainland fauna, however, further surveys in multiple seasons would be required to support this assertion. The taxonomy of the Olpiidae pseudoscorpions, the *Lychas* scorpions and the Scolopendrid centipedes is generally poor and so specimens have been placed into the closest species/genus possible and it is unlikely than any of these represent true SRE taxa.

4.1.1 Crustacea

Isopoda: Armadillidae: *Buddelundia* sp IS01

The taxonomic framework of slaters in Australia is extremely poorly making assessment of SRE status for this fauna difficult. The armadillid isopods from the Australian genus *Buddelundia* are extremely diverse in arid Australia with over 150 putative species identified in collections, primarily from Western Australia, but requires taxonomic revision at a family level making the proper identification of species difficult (Dalens 1992; Judd and Perina 2013).

A single species of *Buddelundia* (sp. IS01) was identified during the current dual phase survey. The species shows a wide distribution including both the islands within Lake Mackay and the southern shoreline, extending inland. The current level of survey does not allow any definitive assignation of SRE status for the species and it is considered to be data deficient and more regional surveys would be required to confidently refer to *Buddelundia* IS01 as an SRE. The species is considered a Possible (data deficient) SRE species

Isopoda: Armadillidae: Buddelundiinae gen. nov. sp. nov.

A single undescribed specimen of a genus close to *Buddelundia* (subfamily Buddelundiinae) was recorded from SRE Site 5 during the Phase 1 survey. The specimen represents both a gen genus and species (Judd 2017). This undescribed genus is a more primitive form of Armadillidae than *Buddelundia* and contains numerous species, probably all likely SRE species (Judd 2017). This is a significant record for the genus as it has not been recorded this far east before (Judd 2017). This species is considered to be a likely SRE species.

4.1.2 Arachnida

Aranaeomorphae: Lycosidae sp. WAM 27?

Several specimens of Lycosidae sp. WAM27? were collected from the edge of the salt lake at SRE Site 15. They were hand excavated from burrows within the salt pan where they are likely to hide from hot day time temperatures, venturing out at night when temperatures are cooler to hunt. The specimens collected all appear similar to Lycosidae sp. WAM27 (Baehr 2015), however, due to an absence of male specimens from Lake Mackay a comprehensive identification is not possible. This species is likely to be widespread in similar habitats around Lake Mackay but is considered to be a Possible (data deficient) SRE species.

Pseudoscorpionida: Olpiidae: *Indolpium* sp. IS01, IS02 and IS03

The taxonomy of the Olpiidae is poorly known and, until further taxonomic resolution has been obtained, all species are considered to be Possible SRE species in Western Australia due to a deficiency in data. Molecular sequencing of Pilbara and other Western Australian specimens is currently being undertaken by the Western Australian Museum and these data will be used in the future to determine if species are widespread or restricted in distribution. It must be stated, however, there is considerable difference between molecular and morphological data, with generic and species boundaries highly uncertain making meaningful results unlikely, except in the medium to long term.

The Bushblitz arachnid survey (Baehr 2015) recorded two additional unnamed species of Olpiidae, from the genera *Austrohorus* and *Indolpium*, although neither of these species were recorded during the current survey.

Scorpiones: Buthidae: *Lychas* sp. *cf. marmoreus*

The scorpion genus *Lychas* is a diverse genus in Australia, with multiple undescribed species. The taxonomy of the group, however, remains largely unresolved, making identification and assignation of SRE status difficult. The species *Lychas cf. marmoreus* was recorded at three separate sites, mostly sand dune habitats including an island on Lake Mackay, indicating that the species is likely to be widespread. Sandy habitats in the area are continuous and widespread thus indicating that the species is unlikely to be restricted to any of the proposed Project impact areas. The full distribution of *Lychas cf. marmoreus* is unknown and so the species has been classified as a Possible SRE species (data deficient).

Scorpiones: Buthidae: *Lychas* sp. IS01

The species *Lychas* sp IS01 appears to be an undescribed species and was recorded at six separate sites along sandy habitats on the southern and western side of Lake Mackay, indicating that the species is likely to be widespread. Sandy habitats in the area are continuous and widespread thus indicating that the species is unlikely to be restricted to any of the proposed Project impact areas. The full distribution of *Lychas* sp IS01 is unknown and so the species has been classified as a Possible (data deficient) SRE species.

Scorpiones: Urodacidae:Urodacus sp. IS01 'mottled'

The species *Urodacus* sp IS01 *'mottled'* appears to be an undescribed species and was recorded at two separate sites on the southern and western side of Lake Mackay, indicating that the species is likely to be widespread. Sandy habitats in the area are continuous and widespread thus indicating that the species is unlikely to be restricted to any of the proposed Project impact areas. The full distribution of *Urodacus* sp IS01 *'mottled'* is unknown and so the species has been classified as a Possible (data deficient) SRE species.

4.1.3 Diplopoda

Polyxenida: Lophoproctidae: *Lophoturus?* sp. nov.

Four specimens of a potential undescribed species of pin cushion millipede were recorded from a single location (SRE Site 11) by leaf litter sieving. The taxonomy of much of the Polyxenid millipedes remains unresolved with numerous undescribed species present in Australia. The polyxenid millipedes appear to exhibit less endemism than the highly speciose and endemic Paradoxosmatid millipedes such as *Boreohesperus* (Car and Harvey 2013) and *Antichiropis* (Moir et al. 2009). The species is unlikely to be restricted, however, due to an absence of distributional information it is currently classified as a Possible SRE (data deficient) species.

4.1.4 Chilopoda:

Scolopendromorpha: Scolopendridae: *Arthrorhabdus cf. mjobergi*

Five specimens of this centipede were recorded during the Phase 2 survey at both the southern and western edges of Lake Mackay. The specimens appear superficially similar to *Arthrorhabdus mjobergi*, however, they differ in the spination on the ventral surface of the terminal legs. Sandy habitats in the area are continuous and widespread thus indicating that the species is unlikely to be restricted to any of the proposed Project impact areas. The full distribution of *Arthrorhabdus cf. mjobergi* is unknown and so the species has been classified as a Possible SRE species (data deficient).

Scolopendromorpha: Scolopendridae: *Scolopendra* 'mackay'

A single specimen of this scolopendrid centipede was recorded from SRE Site 12 during the Phase 2 sampling. The specimen shows distinct differences in its elongate terminal legs and supination of the anal coxopleuron compared with the described species of *Scolopendra*. Whilst a new genus of Scolopendridae centipede was recently described from Central Australia, *Kanparka leki* (Walkdock and Edgecombe 2012) the specimen recorded from Lake Mackay is different. The specimen at SRE Site 12 is low sand dunes and this habitat is continuous in the region, thus indicating that the species is unlikely to be restricted to any of the proposed Project impact areas. The full distribution of *Scolopendra* 'mackay' is unknown and so the species has been classified as a Possible SRE species (data deficient).

4.1.5 Insecta:

Carabidae: Cicindelinae: *Cicindela sp. cf. mastersi*

This species was collected at two localities during the day from the bed of Lake Mackay during a walking transect between several of the islands. Cicindelid beetles, commonly known as Tiger beetles, are an extremely diverse subfamily of fast moving predaceous ground beetles that often hunt at night (Lawrence and Britton 1991). The species is considered a Possible SRE species as it may be restricted to the bed of Lake Mackay based upon some other Cicindelid beetle distributions and behaviour, however, *Cicindela sp. cf. mastersi* is not anticipated to be significantly impacted due to the size of Lake Mackay compared to the proposed footprint of the Project.

5. Conclusions and Recommendations

The SRE survey at the Lake Mackay SOP Project undertaken in May and November 2017 recorded a diverse range of invertebrate species, many of which are new records for the Lake Mackay region. This is primarily due to the lack of previous collecting in the area, rather than the region containing a unique species assemblage any different from other parts of the central arid region of Australia.

The SRE survey recorded 13 potential SRE invertebrate species from the Lake Mackay SOP Project area. There were no 'Confirmed' SRE species recorded during the survey. The majority of the species determined to be "Possible" SRE taxa is due to incomplete taxonomy and unknown species distributions. Almost all the possible SRE species were found at multiple locations during the survey indicating that their distributions are wider than the current dual season survey could determine. No species were recorded solely from the islands on the lake itself which currently indicates that, in general, the offshore islands are simply more depauperate communities of the normal mainland fauna, however, further surveys in multiple seasons would be required to support this assertion.

A single species of isopod, Buddelundinae gen nov., sp. nov. that is considered a 'Likely' SRE species was recorded from SRE Site 5 in sand dunes on the southern shore of Lake Mackay. Whilst this habitat does not appear to show microhabitat restrictions no further records of this isopod have been recorded.

The development of the Lake Mackay SOP Project is not anticipated to significantly impact any species recorded in this dual season SRE survey. When the specific Project footprint and location of infrastructure areas is finalised these conclusions should be revisited to ensure they remain valid, however, due to the limited extent of any processing and infrastructure facilities, currently being proposed as part of the SOP Project, this assessment is not expected to alter.

5.1 Recommendations

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

- No further surveys for terrestrial SRE invertebrates are required to meet the EPA Technical guidance, sampling of short range endemic invertebrate fauna (EPA 2016).
- If any proposed development areas are to overlap the known distribution of the isopod Buddelundinae gen nov., sp. nov. then further targeted surveys for this species should be undertaken.

6. References

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Appendix 1

Department of Parks and Wildlife Conservation Codes (November 2015)

Department of Parks and Wildlife

CONSERVATION CODES

For Western Australian Flora and Fauna

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

Categories of specially protected fauna and flora are:

T **Threatened species**

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

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

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

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

CR **Critically endangered species**

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

EN **Endangered species**

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

VU **Vulnerable species**

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

EX **Presumed extinct species**

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

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

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

CD Conservation dependent fauna

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

OS Other specially protected fauna

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

P Priority species

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

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

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

1 Priority 1: Poorly-known species

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

2 Priority 2: Poorly-known species

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

3 Priority 3: Poorly-known species

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

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

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

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

Appendix 2

SRE Site locations and habitats

SRE Site 1 481797E 7525583N Island in Lake Mackay	
SRE Site 2 484291E 7519290N Island in Lake Mackay	

SRE Site 3 464210E 7493493N Sand ridge near claypan on south side of Lake Mackay	
SRE Site 4 477770E 7487347N Freshwater claypan on south side of Lake Mackay	

SRE Site 5 464687E 7491478N Sand dune and swale on south side of Lake Mackay	
SRE Site 6 442307E 7499962N Sand dune and swale on south side of Lake Mackay	

SRE Site 7 451014E 7502291N Island in Lake Mackay	
SRE Site 8 447315E 7501624N Sandy Island in Lake Mackay	

SRE Site 9 435754E 7499668N Southern lake shore of Lake Mackay	
SRE Site 10 438621E 7497742N Low sand dune on southern side of lake Mackay	

SRE Site 11 444853E 7499251N Low sand dune on southern side of lake Mackay	
SRE Site 12 443680E 7499479N Low sand dune on southern side of lake Mackay	

SRE Site 13 431362E 7509115N Low sand dune on western side of lake Mackay	
SRE Site 14 432047E 7510495N Sand plain on western side of lake Mackay	

SRE Site 15 432360E 7510101N Salt lake and salt marsh on western side of lake Mackay