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AGRIMIN LIMITED
MACKAY SOP PROJECT
SUBTERRANEAN FAUNA RISK ASSESSMENT

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1 INTRODUCTION AND OBJECTIVES

Agrimin Limited (Agrimin) proposes to develop the Mackay Sulphate of Potash (SOP) Project (the Project), located at Lake Mackay on the Western Australia-Northern Territory Border. The Project currently holds five exploration licenses on the Western Australian side of Lake Mackay and one exploration licence application on the Northern Territory side.

Agrimin requires a suite of ecological studies to support future environmental approvals for the Project. As part of this, Agrimin contracted *ecologia* Environment (*ecologia*) to deliver a Subterranean Fauna Risk Assessment (this Assessment), to identify the likely requirements for subterranean fauna field studies in light of the Project's approvals strategy.

The overarching purpose of this Assessment was to provide a high-level synopsis of the issues that subterranean fauna may pose for the Project. The specific objectives were to:

- determine whether the EPA is likely to identify subterranean fauna as a Key Environmental Factor;
- discuss options for addressing subterranean fauna as a Key Environmental Factor; and
- should further subterranean fauna studies be warranted, provide recommendations as to how these studies should be scoped in order to best support Agrimin's approvals strategy.

1.1 BRIEF BACKGROUND TO SUBTERRANEAN FAUNA

Subterranean fauna are a group of fauna that live their entire lives below the surface of the earth and, accordingly, have adaptations such as reduced pigmentation and poorly-functioning or non-existing eyes. Fauna that use a subterranean environment for only part of the day or season, e.g. birds, bats and/or burrowing species, are not considered subterranean fauna in an impact assessment context.

There are both invertebrate and vertebrate subterranean fauna species, although the vast majority are invertebrates. Subterranean fauna species are divided into two groups:

- stygofauna, which are aquatic and live in groundwater; and
- troglofauna, which are air-breathing and live in caves and voids.

1.2 INFORMATION SOURCES

To obtain expert technical advice on subterranean fauna issues potentially associated with the Project, *ecologia* engaged specialist subterranean fauna consultant Dr Stuart Halse, of Bennelongia Environmental Consultants. The expert advice prepared by Dr Halse, as finalised following *ecologia*'s review and required revisions, is presented in Section 4. *ecologia* subsequently reviewed and interpreted the advice obtained, within the context of the Project and its recommended approvals strategy; the conclusions prepared by Dr Halse, as reviewed and interpreted by *ecologia*, are presented in Section 5.

ecologia obtained and supplied background information to support the provision of the technical advice. The following data package was compiled for Dr Halse:

- a broad geological/hydrogeological report for the Project area (Brooker and Fulton 2016a);
- a detailed hydrological report including water quality data (Brooker and Fulton 2016b);
- borefield tenement location, drill collar locations, water depths;
- maps of the tenements and Project area locations;
- maps of terrestrial Project layout and disturbance; and
- Western Australian Museum invertebrate database search results for the Project Area (Crustacea; database search commissioned by *ecologia* 28 July 2016).

2 TECHNICAL DISCUSSION: PROJECT RISKS TO SUBTERRANEAN FAUNA

Arid areas in the western half of Australia have been shown to be very rich in subterranean fauna (Guzik *et al*. 2010). Generally, aquifers in calcrete and alluvium in these areas are likely to support a rich assemblage of stygofauna species and areas of banded iron formation and calcrete are likely to support troglofauna species. Other geologies may also support subterranean fauna but their prospectively is less well documented.

Lake Mackay is east of the main known habitat areas for subterranean fauna in Western Australia, namely the Pilbara and Yilgarn regions (Halse *et al*. 2014), but stygofauna have been found in the adjacent Ngalia basin in the Northern Territory (e.g. Balke *et al*. 2004). They could, therefore, be expected to occur in calcrete and alluvial aquifers at Lake Mackay, provided salinity is suitable.

Information on the salinity tolerances of stygofauna is sparse. While it is clear that stygofauna may occur in groundwater with seawater salinity levels (35,000 mg/L), there is also some evidence for occurrence in much higher salinities (e.g. Outback Ecology 2012). This is difficult to reconcile with the low levels of energy thought to be available to stygofauna species to sustain intensive osmotic regulation but, when considering the likelihood of stygofauna occurrence in an aquifer, it should be recognized that many arid zone aquifers are stratified, with a thin layer of fresh water on top of a more saline waterbody (Humphreys 2006). Available measurements often reflect the salinity of the deeper aquifer rather than the overlying fresh water.

Lake Mackay lies within the Wilkinkarra palaeovalley, which contains many areas of calcrete (Brooker and Fulton 2016a). The lake morphology reflects that the main source of water to the lake is discharge from a shallow, regional groundwater aquifer. Trenching in the lake shows the depth to groundwater being little more than 1 m in some sections, with groundwater typically having an electrical conductivity of >200 mS. This does not convert easily to a salinity measurement, but indicates that salinity is very high and approximately 200,000 mg/L. Agrimin has drilled on an approximate 5 km by 5km across Lake Mackay and the brine analysis testing has reported an average salinity of >250,000 mg/L. Despite the overall setting at Lake Mackay being a very saline one, there are some small vegetated islands on the lake under which lenses of fresh to brackish water occur. There are also likely to be some freshwater lenses under some of the dunal systems around the perimeter of the lake.

The available literature suggests that no stygofauna and almost no species of invertebrate will persist at salinities around 200,000 mg/L (Pinder *et al*. 2005; Kefford *et al*. 2007). It is possible that some styglophilic species with widespread surface populations, such as the cyclopid copepods *Microcyclops varicans* and *Mesocyclops brooksi*, occur in the fresh to brackish water lenses under the islands but otherwise the fresher systems are considered to be too small (and too ephemeral in a geological sense) to support stygofauna, although it would be useful to have more information about the size and formation of the lenses.

In considering the synthesised information above, the potash extraction activities proposed at Lake Mackay are unlikely to affect local stygofauna conservation values. Any species present in fresh to brackish groundwater are also likely to occur elsewhere, while the regional aquifer underlying the lake is likely to be too saline for stygofauna to persist.

Similarly, troglofauna will not occur in the shallow lacustrine sediments of the lakebed above the watertable. This is because the fine grained sediment is unlikely to provide suitable interstitial spaces for the movement of troglofauna and because the high salinity levels make the habitat osmotically intolerant. Most troglofauna have very limited osmotic regulation capabilities and require a saturated, 'fresh water' atmosphere. Consequently, potash extraction activities at Lake Mackay are unlikely to affect troglofauna conservation values.

The situation regarding a water supply for processing water from the western Wilkinkarra palaeochannel is quite different. Brooker and Fulton (2016b) reported that the project will require "a large volume of process water during a planned operational life in excess of 15 years (preferred 20+)". The latest estimates are for a process water requirement of 2.5 GL per annum for 20 years, totalling 50 GL (pers. comm. T. Lyons to M. Young, Sept. 2016). The area suggested for further investigation to supply this water covers an area 45 m x 30 km south of Lake Mackay (Figure 10, Brooker and Fulton 2016b; Appendix A).

According to Brooker and Fulton (2016b), calcrete occurs in the area to be investigated for water supply. The calcrete mapping shown in Figure 5.10 of Brooker and Fulton (2016a; Appendix A) shows the extent of this calcrete within the northern portion of the proposed water supply investigation area. Data from the area shows high uranium levels, suggesting that the calcrete is likely to host a rich stygofauna community (e.g. Bennelongia 2015). Salinity measurements are not available for this area, but conductivity (= salinity) of the groundwater is thought to be low. The calcrete layer begins between 0 and 10 m below ground and has a thickness of up to 10 m (Brooker and Fulton 2016b).

Measurements of depth to groundwater in the northern part of the groundwater investigation vary from 10-21 m (n = 3), while measurements from extensive drilling at the southern edge of the field show depths of 9 – 54 m. Brooker and Fulton (2016b) conclude the calcrete unit is mostly not saturated but saturation of only a small thickness of calcrete may have important implications for the type of stygofauna community present and it is unclear whether Brooker and Fulton took this into account, rather than more general water yield considerations, when making their comments on the extent of saturation.

The area to be investigated for supply of processing water (or at least part of this area) is potentially prospective for stygofauna for the following reasons:

- water is to be abstracted from a palaeochannel aquifer, which are known for yielding stygofauna;
- extensive areas of calcrete occur:
    - o while the extent of saturation is unclear, it is likely there are at least pockets of saturated calcrete that may be suitable stygofauna habitat;
    - o calcrete in the palaeochannel contains uranium, which is likely to increase the number of species present;
    - o nearby portions of the aquifer in alluvium that have a carbonate signal in their water chemistry are also likely to be prospective for stygofauna; and
- the depth to groundwater across most of the aquifer is relatively shallow (≤20 m), suggesting that connectivity to the surface will be relatively high – this increases prospectivity for stygofauna.

There is currently no information on the predicted extent and depth of drawdown in the processing water borefield, nor is there information about the size of the fresh to brackish water lenses under islands on the lake. While not large, the proposed annual abstraction of 2.5 GL per annum of processing water has the potential to create a significant area of drawdown. The limited depth of saturated calcrete makes it likely that even relatively small drawdowns could de-water the prime stygofauna habitat in the area. This may potentially threaten stygofauna species that are restricted to the area of drawdown. It has been shown repeatedly in research programmes, as well as in impact assessments, that stygofauna species occurring in calcretes mostly have highly restricted distributions (this is often referred to as the calcrete island hypothesis; Cooper *et al*. 2002).

3 CONCLUSIONS AND RECOMMENDATIONS

Following Environmental Assessment Guideline 12 (EAG 12; Table 2, EPA 2013), the specific characteristics of the Project warrant a comprehensive Level 2 stygofauna survey in the proposed borefield, for the following reasons:

- likelihood of occurrence of stygofauna is 'High', because of occurrence of calcrete and alluvial formations in a palaeochannel aquifer (Table 1 of EAG 12);
- although currently undefined, the likely degree of impact is considered 'Moderate' as the indicative volumes to be abstracted are relatively small and the duration of abstraction fairly short (20 years or more).

A comprehensive Level 2 survey requires repeated sampling, usually in the form of two seasons of sampling. Samples should be collected from within the area of proposed drawdown and in hydrogeologically similar areas outside the borefield. It may also be useful to sample the lenses of fresher water under the islands. EAG 12 provides limited guidance about sampling design but states that "survey should be sufficient to ensure that the subterranean fauna is adequately understood in the context of the project footprint and surrounding areas".

While the occurrence of extensive areas of calcrete makes the groundwater investigation area prospective for troglofauna, groundwater abstraction would be expected to have, at worst, only a low level of impact on troglofauna. Accordingly, following Table 2 of EAG 12, it is considered that a Level 1 survey is more appropriate for troglofauna. This could be done entirely as a desktop review or, if uncased drill holes are available, a small reconnaissance survey for troglofauna could be undertaken in conjunction with stygofauna sampling.

In summary, the EPA is likely to identify subterranean fauna as a Key Environmental Factor for environmental impact assessment of the Project. For Agrimin to adequately address this, field surveys for subterranean fauna would be required in the first instance. *ecologia* therefore recommends the following as part of Agrimin's broader environmental approvals strategy:

- no subterranean fauna investigations for mining operations within Lake Mackay itself;
- a Level 2 survey for stygofauna in the groundwater investigation area (proposed borefield), possibly over two seasons (contingent on the first season's outcomes); and
- a Level 1 survey for troglofauna in the groundwater investigation area (proposed borefield), either as a desktop study only or as a desktop study and small reconnaissance survey.

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APPENDIX A SUPPORTING FIGURES

Figure 10 extracted from Brooker, M.R and Fulton, A. (2016) Lake Mackay Process Water Evaluation (Version 2D). Hydrominex Geoscience Consulting, Sydney, 12 pp.

Fig 5.10 extracted from Brooker, M.R and Fulton, A. (2016) Technical report on the Lake Mackay Potash Project, Western Australia. Hydrominex Geoscience Consulting, Sydney, 77 pp.

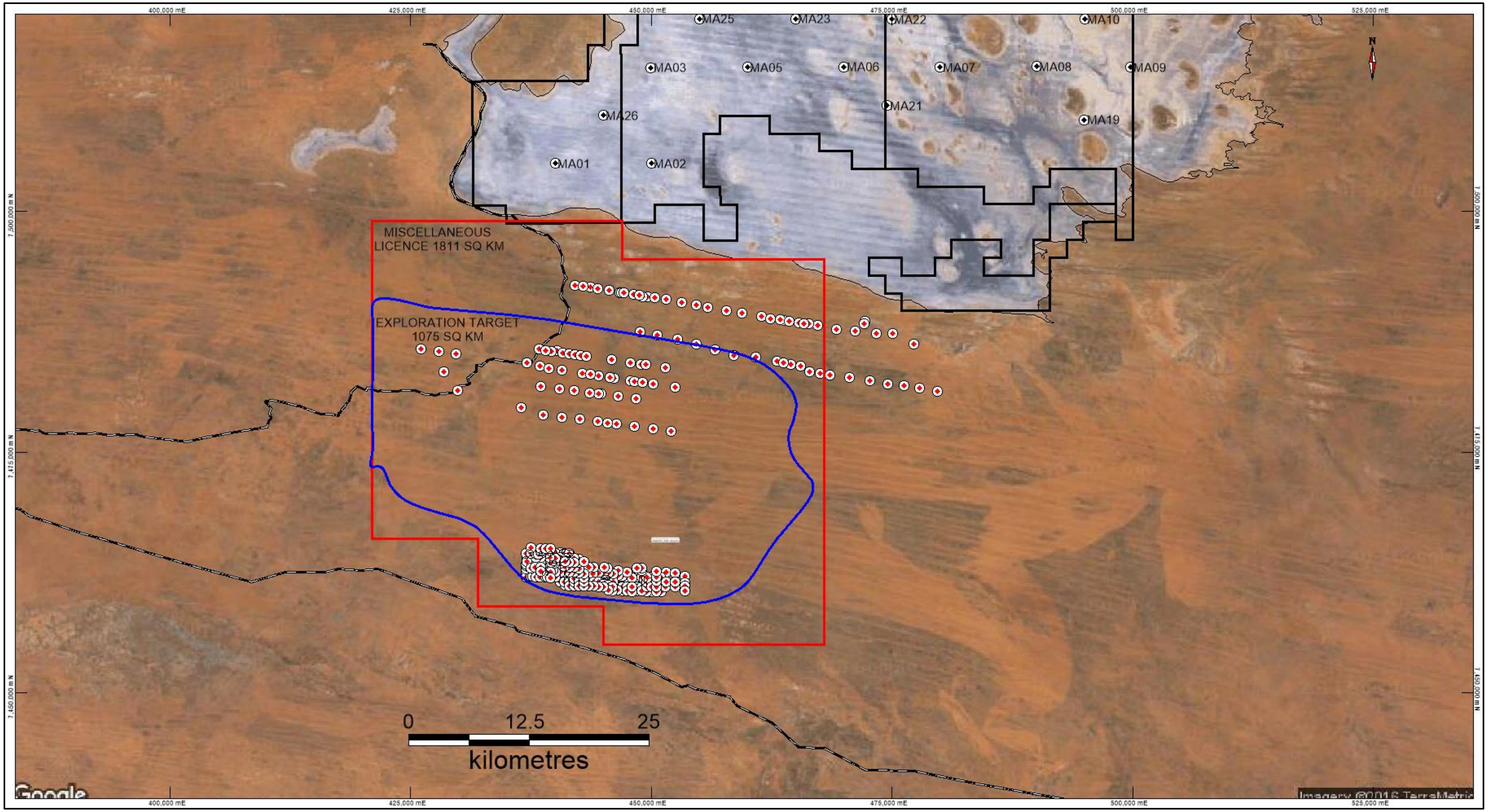

Figure 10: Proposed miscallaneous licence (red outline) and exploration target volume (blue outline) discussed in the preceeding section. Agrimin tenementas as of 2015 are shown as black outlines

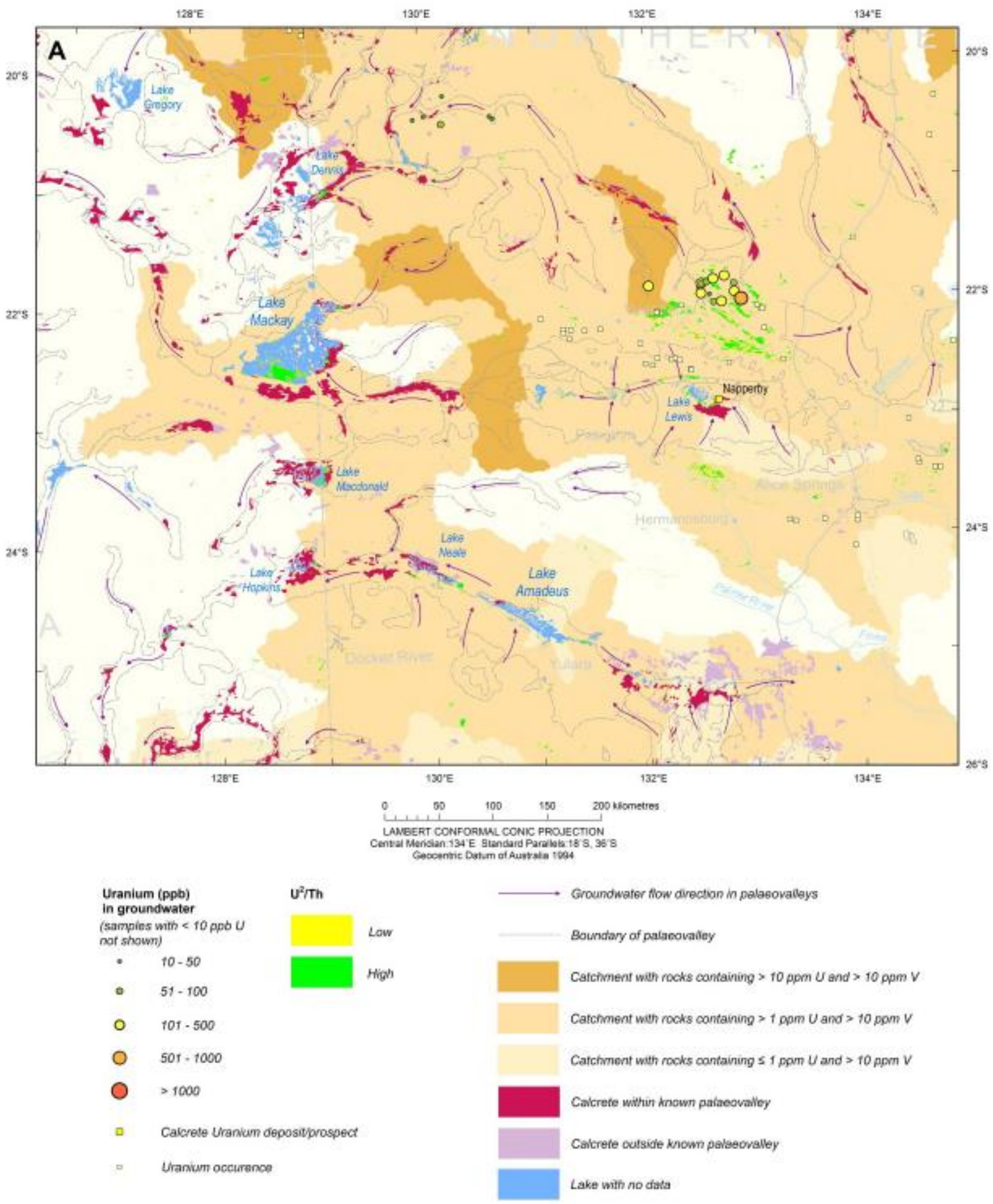

Figure 5.39 (Inset A, Map 4, Appendix B). Map of lake systems in Arunta region. The lake systems host a few valley- and playa-type calcrete-hosted uranium deposits and prospects. Note the spatial correlation between high U^2/Th values and palaeovalleys hosting uranium deposits and prospects.

Figure 5.10: Distribution of calcretes in the vicinity of Lake Mackay