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RE: Ravensthorpe Gold Project, Subterranean Fauna

Dear Mitch,

The purpose of this memo is to review the previous desktop assessment of subterranean fauna at the Ravensthorpe Gold Project (RGP) (Outback Ecology 2010) and provide an updated conclusion taking into account results of recent stygofauna survey in the vicinity.

Background

The RGP is situated approximately 20 km south of Ravensthorpe in southwestern Australia. Relevant tenements cover more than 140 km^2 and encompass two resource deposits; Kundip (gold and copper) and Trilogy (polymetallic) (Figure 1). Mining at Kundip started in the early 1900s while Trilogy, which occurs to the south on cleared farmland, remains undeveloped in terms of resource extraction.

Besides processing and support infrastructure (processing plant, tailings storage facility, waste rock landforms), proposed developments include:

- Trilogy: a mine pit at to a depth of 160–240 m
- Kundip: nine open pits (a number of which will extend below the water table) and three underground mines that will be accessed via the bases of open pits.

Subterranean Fauna

Subterranean fauna comprise two groups of animals: stygofauna, which are aquatic and inhabit groundwater aquifers; and troglofauna, which breath air and inhabit spaces above the watertable. Both groups typically lack eyes and exhibit other physical, physiological and behavioural adaptations to underground habitats.

Geology influences the presence, richness and distribution of subterranean fauna by providing different types of habitat. Abundance and diversity of subterranean communities tend to increase with the occurrence and size of underground spaces such as vuggs, fissures and karsts. The abundance and richness of subterranean fauna communities are also influenced by depth below the ground because energy inputs from the surface attenuate with depth.

While rich assemblages of stygofauna and troglofauna are known to occur throughout the Yilgarn and Pilbara, the southwestern parts of the state appear to host less-abundant and less-speciose communities, although the region is comparatively understudied. The RGP has the potential to impact subterranean fauna by excavating and dewatering potential habitat.

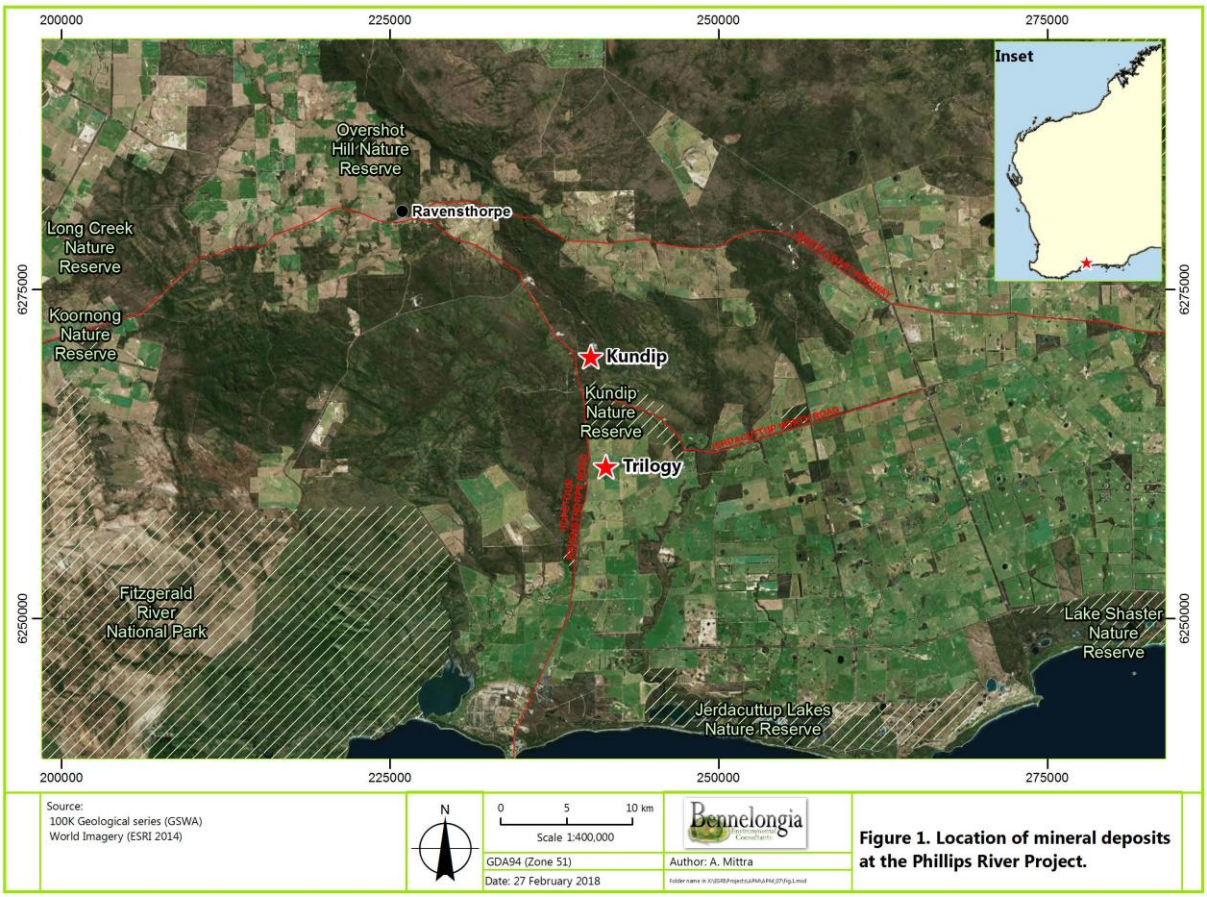

Figure 1. Location of the Ravensthorpe Gold Project

Previous Records

A search of Western Australian Museum (WAM) databases in 2018 for an area of 100 km x 100 km surrounding the RGP confirms that targeted sampling effort for subterranean fauna in the vicinity remains very low. This has resulted in limited understanding of subterranean fauna in the area.

A previous literature review by Outback Ecology (2010) identified five sources of information or records for stygofauna in southwestern Australia. The closest of these to the RGP was at the Ravensthorpe Nickel Project (approximately 30 km east), where stygofauna were not detected, although details regarding sampling effort for that study are unavailable.

Rockwater (2006) recorded candonid ostracods and three species of syncarids at the Southdown Magnetite Project, 170 km southwest of Ravensthorpe. These animals were recorded in the Pallinup Siltstone aquifer, which does not extend into the RGP, but is known to occur approximately 7 km from Trilogy. Additional stygofauna species were collected from fractured bedrock but are not obligate groundwater inhabitants (Outback Ecology 2010). Remaining records identified by Outback Ecology (2010) were from 400–600 km away and are not considered here to be analogous to the RGP.

Other sampling programs in the southwest have mostly been on the west coast and include the work of Tang and Knott (2009). They recorded 14 species of copepod in the Gnangara Mound on the Swan Coastal Plain but many of these species occurred in surface springs or pools within caves, rather than occurring in deeper regional aquifers.

Repeated sampling of a regional aquifer in Bassendean Sand, also on the Swan Coastal Plain, collected 21 species of stygofauna, although this included six rotifer species, a nematode and a turbellarian. (Bennelongia 2015). Again, due to geological differences and geographic separation, these studies are not considered analogous to the RGP.

Most recently, Bennelongia 2018 surveyed 17 bores at the nearby Mt Cattlin Project, 20 km northwest of Kundip, and recorded at least six stygofauna species. When combined with the results of previous sampling by Outback Ecology (2010) it is possible that 10 stygofauna species have been collected from 29 samples at Mt Cattlin (nematode, oligochaetes, copepods, syncarid); however, it is more likely that only eight species have been collected, with identification issues probably accounting for the additional two species. Two of the recorded copepod species are widespread stygophiles that are known from surface water populations.

Stygofauna at Mt Cattlin were collected across at salinities of 4,120–52,400 µS cm^{-1} (approx. 2,640–33,500 mg/L) and across a pH range of 6.3–7.6. (A nematode and a stygophilic copepod, known to occur in surface water, were recorded at a pH or 4.95.) Considering geological strata and static water levels, it is inferred that stygofauna were collected from fractured basalt. It is likely that bore construction limited sampling efficiency due to inadequate slotting in some bores and survey probably failed to capture the complete suite of present species. Overall, the stygofauna community at Mt Cattlin appears to have low-to-moderate richness.

In addition to stygofauna, two species of troglofauna species (a centipede and a dipluran) were collected by Outback Ecology (2010) at Mt Cattlin. It is considered probable that the species were collected from fractured basalt above the water table (although it is also possible that they inhabited overlying alluvium).

Habitat

The prospectivity of habitat for both stygofauna and troglofauna at the RGP will depend on the occurrence of sufficiently fractured, weathered and vuggy zones within the geology, as well as sufficient permeability to allow energy inflow. For stygofauna, there will be the additional requirement for suitable groundwater levels and chemistry. A summary of environmental conditions at Mt Cattlin, where stygofauna and troglofauna have been recorded, and at the RGP is provided in Table 1. Groundwater salinities at both Trilogy and Kundip are unlikely to preclude stygofauna.

The lead-zinc mineralised core of the Trilogy deposit contains vuggs, however the surrounding graphitic siltstone is stated to "characteristically show little vugg development" (Outback Ecology 2010), suggesting reduced external connectivity and low prospectivity for subterranean fauna (both troglofauna and stygofauna depending on the water table). However, it is reiterated that despite low predicted prospectivity due to a lack of connectivity, subterranean fauna were recorded at Mt Cattlin in fractured rock.

Table 1. Overview of subterranean environments at the RGP and Mt Cattlin.

	Trilogy	Kundip	Mt Cattlin
Geology	Schist, shale (vuggy) and minor sandstone surrounded by graphitic siltstone	Mafic, ultramafic and BIF; alluvium	Fractured basalt; alluvium
Depth to groundwater (m)	27–40	4-58	1-24
Salinity (mg/L)	15,200–25,400	22,000-38,000	2,640–33,500
pH	3.3-3.8 (>90 mbgl); circumneutral outside mineralised zone	circumneutral	4.2-7.6

Groundwater levels at Trilogy were 27–40 m in January 2004 (Rockwater 2009). It is considered that this depth to groundwater, coupled with low transmissivity in overlying strata and low levels of recharge (Outback Ecology 2010), will result in low energy inputs into the subterranean environment and therefore low prospectivity. For instance, Halse *et al.* 2014 found that yields of stygofauna were low where the depth to groundwater was >30 m, although it is noted that stygofauna were collected in bores with static water levels up to 24 mbgl at Mt Cattlin (Bennelongia 2018).

Low pH values (3.3–3.8) have been recorded at depths of >90 m within the Trilogy mineralised zone, although pH higher up in the mineralised zone is reportedly 5.6 (Outback Ecology 2010). Therefore, it is uncertain whether or not pH would preclude stygofauna throughout the Trilogy deposit. Although pH is reported to be circumneutral to basic outside the mineralised zone, low airlift yields suggest low water volumes and low permeability (Outback Ecology 2010).

Potential habitat for troglofauna in the form of vuggs in weathered schist (7–11 mbgl) was identified to the north of the proposed Trilogy pit but will not be impacted by excavations (Outback Ecology 2010).

Groundwater in the Kundip mining area is predominantly associated with joints and fractures in the mineralised zone. While groundwater chemistry in the area (Table 1) will not preclude stygofauna, air lift tests demonstrated low permeability and, by implication, poor-quality habitat for stygofauna (Outback Ecology 2010). Bore (KBM6) yielded substantial volumes of water, however, the largely consolidated mafic geology below the water table at this site is unlikely to be prospective for stygofauna.

The water table along the Steere River drainage line is approximately 4 mbgl (bore KBM5) and it is possible that stygofauna habitat exists here in alluvium, although as with other drainage lines in the vicinity prospectivity will depend on the ratio of clay to coarse alluvial sands and gravels, which would determine the size of interstices. Alluvial habitats in drainage lines at Mt Cattlin yielded stygofauna (Bennelongia 2018). Results of airlift testing at KBM5 (Rockwater 2011) suggest low connectivity between alluvium and underlying fractured rock, which may serve to reduce dewatering drawdown.

Consistent with Outback Ecology (2010), it is considered that the most prospective potential troglofauna habitat in the Kundip area is around KBM1 where there is some fractured basalt overlying slightly vuggy BIF/quartz above the water table. This geology may be similar to the fractured basalt geology at Mt Cattlin from which two troglofauna species were probably collected. Some highly weathered geologies elsewhere at Kundip, including BIF and chert, may provide some potential troglofauna habitat but do not appear to have significant voids or vuggs (Outback Ecology 2010).

Conclusions

Overall, both the Trilogy and Kundip areas are considered to have limited prospectivity for stygofauna due to limited underground spaces; low connectivity, permeability and recharge; and, potentially, water chemistry (Trilogy). Potential habitat for troglofauna is also limited, with only small areas of fractured or vuggy rock identified in bore logs. These geologies occur primarily outside proposed pits. Assemblages of subterranean fauna at the RGP, if present, are certainly likely to be low in terms of both abundance and species.

Despite this, it reiterated that geology at Mt Cattlin was similarly assumed to have low prospectivity and to some extent reflects the environment at both Trilogy and Kundip, with primary potential habitats confined to fractured rock within mineralised deposits, as well as some alluvium associated with drainage lines. The collection of both stygofauna and troglofauna at Mt Cattlin, 20 km northwest of the RGP, supports the notion that a low-diversity subterranean fauna community may occur at the RGP. A low-intensity pilot study sampling existing bores across both Trilogy and Kundip could be used to determine subterranean fauna values of the RGP.

Yours sincerely,

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Bennelongia Environmental Consultants Pty Ltd

References

Bennelongia (2015) CSIRO Geothermal Project - Stygofauna Survey. Unpublished memorandum to CSIRO., Bennelongia, Jolimont, 7 pp.

Bennelongia (2018) Mt Cattlin Project. Level 1 Survey for Stygofauna. Unpublished Report to Galaxy Resources Ltd., Bennelongia, Jolimont, 17 pp.

Halse, S.A., Scanlon, M.D., Cocking, J.S., Barron, H.J., Richardson, J.B., and Eberhard, S.M. (2014) Pilbara stygofauna: deep groundwater of an arid landscape contains globally significant radiation of biodiversity. *Records of the Western Australian Museum* **Supplement 78**, 443-483.

Outback Ecology (2010) Tectonic Resources NL Phillips River Project Subterranean fauna desktop risk assessment. Outback Ecology Services, Jolimont, WA, 42 pp.

Rockwater (2006) Southdown Magnetite Project. Regional Stygofauna Sampling Programme. Redmond - King River Area and Proposed Southdown Mine (Phase Three Results and Final Report). Rockwater Pty Ltd, Jolimont, 23 pp.

Rockwater (2009) Phillips River Project Results of Hydrogeological Investigations, Trilogy Polymetallic Deposit December 2009 Report for Tectonic Resources NL. Report 253.1/09/01, Rockwater Pty Ltd, **Jolimont, WA**, 56 pp.

Rockwater (2011) Kundip Copper & Gold Project Impact of Final Mine Voids on Groundwater Flow System February 2011 Report From Tectonic Resources NL. Report No. 253.1/11/0, Rockwater Pty Ltd, Jolimont, WA, 13 pp.

Tang, D., and Knott, B. (2009) Freshwater cyclopoids and harpacticoids (Crustacea: Copepoda) from the Gnangara Mound region of Western Australia. *Zootaxa* **2029**, 1-70.