Bennelongia Environmental Consultants

North Star Subterranean Fauna Desktop and Survey Report

Prepared for:

Fortescue Metals Group

August 2023

Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

North Star Subterranean Fauna Desktop and Survey Report

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EXECUTIVE SUMMARY

Fortescue Metals Group Ltd was granted approval for mining the North Star magnetite project in 2013. North Star is located approximately 110 km south east of Port Hedland in the Pilbara region of WA. As a part of the original investigations for the project, a subterranean fauna survey and impact assessment was conducted that resulted in the collection of a number of subterranean fauna species. Fortescue is now proposing an expanded Stage 2 of the North Star magnetite project to include the southern extent of the magnetite resource at Glacier Valley. As such, Bennelongia was engaged to further examine the subterranean fauna community and assess the likely impacts associated with the proposed expansion of the Project.

Subterranean fauna includes two distinct animal communities: aquatic stygofauna and air-breathing troglofauna. Due to their evolutionary history in underground habitats, subterranean species typically exhibit many convergent morphological and physiological characteristics; for example, reduced or absent eyes, deficient pigmentation, vermiform bodies, elongate sensory structures, loss of wings, increased lifespan, a shift towards K-selection breeding strategy and decreased metabolism

It is well established that the diversity of subterranean fauna is closely linked to geology, because these animals are restricted to colonising areas with appropriate spaces to provide habitat. Geologies supporting rich troglofauna communities include mineralised or weathered iron formations, calcrete, alluvium, and, sometimes, mafic volcanic rocks. Stygofauna communities are usually richest in alluvial and calcrete aquifers, especially within palaeochannels, although they may also be found in iron formations, especially detrital and channel iron. There are five major geological units at the project including the Pincunah Banded-Iron Member, Cradinal Formation, Kangaroo Caves Formation, Corboy Formation and Ferriginous duricrust regolith, some of which are known to harbour spaces suitable for subterranean fauna.

Habitat information is reflected in the desktop search, which identified a rich subterranean fauna community in the broader landscape including subterranean fauna species from a survey conducted on site in 2011. As such, a field survey was conducted during 2020-21 to determine if there may be any impacts to subterranean fauna through the proposed expansion.

The 2020-21 field survey collected a total of 332 stygofauna specimens from at least 11 species, including copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms (not assessed as a part of the EIA process). Three stygofauna species are currently only known from areas of significant (≥2 m) groundwater drawdown at the Project. These are the worm Tubificidae `BOL066` and the syncarids *Atopobathynella* `BSY214` and Parabathynellidae sp. (however both syncarids were collected in an area previously approved for dewatering). None of these are expected to be impacted by the proposed expansion.

A total of 102 troglofauna specimens from at least 16 species were collected during the survey including beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Seven species of troglofauna are currently known only from impact areas associated with pit voids at the Project. These include the spider *Prethopalpus* `BAR135`, the palpigrade *Eukoenenia* `BPAL048`, the pseudoscorpion *Tyrannochthonius* `BPS439`, the isopods Armadillidae `BIS416` and Armadillidae `BIS438`, Japygidae `BDP187` and the silverfish Atelurinae sp.

Habitat modelling was conducted to demonstrate habitat connectivity extending beyond the proposed impact areas of the mine and the stygofauna model demonstrated that stygofauna is unlikely to be found in the area of significant groundwater drawdown due to the water table being deep and the

limited presence of porous geology that could harbour stygofauna. Therefore, it is believed that the proposal will have a minimal impact on stygofauna.

Troglofauna habitat was demonstrated to extend over much of the modelled area and well beyond the boundaries of the proposed pits. The model suggests that troglofauna habitat extends into the lower lying areas both to the east and west of the Project and is extensive over the strike of the orebody. While there will be habitat loss due to the removal of the pit void, there appears to be sufficient suitable habitat extending beyond the pit boundaries to support the troglofauna community identified at the Project.

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1. INTRODUCTION

Fortescue Metals Group (FMG) Ltd was granted approval for the North Star magnetite project in 2013 under Ministerial Statement 933. The project is located approximately 110 km south east of Port Hedland in the Pilbara region of WA (Figure 1). The project consists of a mining area, slurry pipeline, infrastructure corridor, Canning Basin borefield and water supply pipeline. Construction of the mining area has commenced, and the mine access road and mine accommodation village are operational.

Fortescue is now seeking to expand the North Star mine approval in the Stage 2 North Star magnetite project that will include the southern extent of the magnetite resource at Glacier Valley. Additional development will involve more mine pits, waste rock dumps and supporting infrastructure. As a part of the original investigations for the Project, a subterranean fauna survey and impact assessment was conducted (Subterranean Ecology 2012). This identified a significant troglofauna community at the project.

Bennelongia has been engaged to further examine the subterranean fauna community and assess the likely impacts associated with the planned expansion of the Project.

1.1. Subterranean Fauna

Subterranean fauna includes two distinct animal communities: aquatic stygofauna and air-breathing troglofauna. Due to their evolutionary history in underground habitats, subterranean species typically exhibit many convergent morphological and physiological characteristics; for example, reduced or absent eyes, deficient pigmentation, vermiform bodies, elongate sensory structures, loss of wings, increased lifespan, a shift towards K-selection breeding strategy and decreased metabolism (Gibert and Deharveng 2002). The overwhelming majority of subterranean species in Western Australia are invertebrates, apart from a few species of fish and snakes. Troglofauna includes a wide variety of invertebrate groups such as isopods, palpigrades, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, bristletails, silverfish, cockroaches, true bugs, beetles and fungus-gnats. On the other hand, stygofauna comprises mostly crustaceans, and some species of earthworms, beetles, snails and some other groups that have poorly defined taxonomy, such as nematodes and rotifers (Halse 2018b).

Although inconspicuous, subterranean fauna contributes markedly to the overall biodiversity of Australia. Most subterranean species satisfy Harvey (2002) criterion for short-range endemism (SRE), having total geographic ranges of less than 10,000 km^2 and occupying patchy or discontinuous habitats within those ranges. Given that species with small ranges are more vulnerable to extinction following habitat degradation than wider ranging species (Ponder and Colgan 2002), it follows that subterranean taxa are highly susceptible to anthropogenic threats, particularly large-scale excavation and groundwater abstraction.

Categorisations of subterranean species according to their dependence of subterranean habitats are based on cave habitats (Howarth and Modovan 2018) and their translation to species in the wider subterranean landscape is only approximate. The species dependent on subterranean habitats for their persistence are referred to as troglobites / stygobites if their entire life cycles is completed below ground and as troglophiles / stygophiles if they move to the surface during a life stage (or, in the case of some cyclopoid copepods, have surface populations). Troglophiles and stygophiles usually have larger distributions than troglobites and stygobites, given that there are greater dispersal opportunities at the surface. Species that use subterranean spaces only opportunistically are referred to as trogloxenes and stygoxenes, and are generally much more widespread than the obligate subterranean species.

Understanding of the subterranean fauna in the Pilbara has progressed immensely since the late 1990s (Humphreys 1999; Eberhard *et al.* 2005), in large part due to extensive sampling for the assessments of potential mining impacts on these communities. The diversity of the region is now recognised as globally

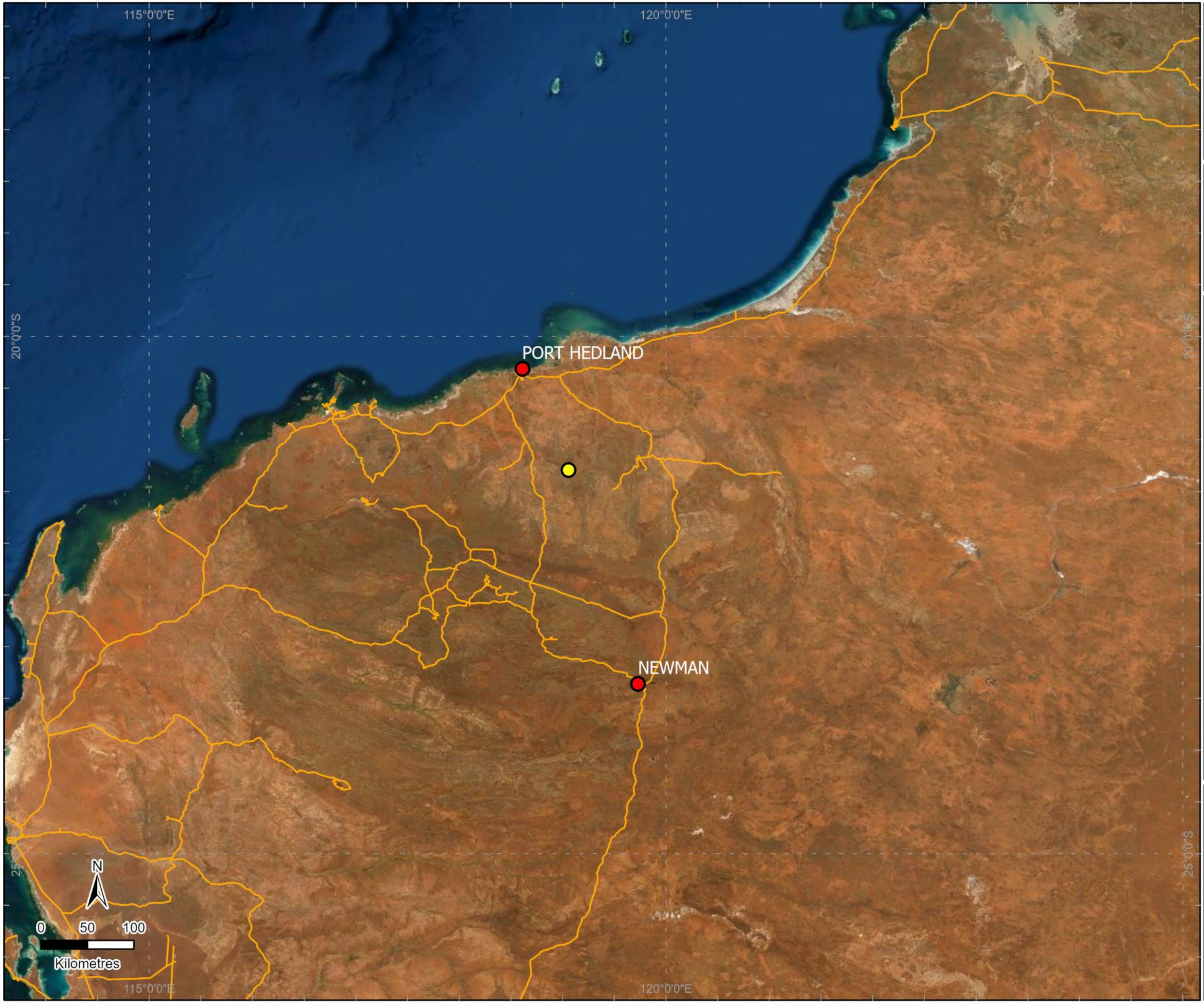

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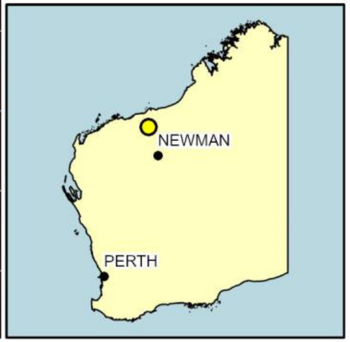
Figure 1. Location of the Project in relation to Port Hedland and Newman

Legend

- The Project
- roads
- towns



significant, with at least 1,500 species of troglofauna and around 1,300 species of stygofauna occurring (Halse 2018a, Halse 2018b), although reliable estimates are hindered by a developing and sometimes non-existent taxonomic framework for some of the animal groups. It is, however, well established that the diversity of subterranean fauna is closely linked to geology because these animals can only colonise areas with appropriate spaces to provide habitat. Geologies supporting rich troglofauna communities include mineralised or weathered iron formations, calcrete, alluvium, and, sometimes, mafic volcanic rocks. Stygofauna communities are usually richest in alluvial and calcrete aquifers, especially within palaeochannels, although they may also be found in iron formations, especially detrital and channel iron (Halse 2018a). As a result of their dependence on the distribution of underground spaces, the composition and richness of both stygofauna and troglofauna communities often varies significantly over short distances. Therefore, knowledge of local geology and cannot provide information about the composition of the subterranean fauna of an area and provides only unreliable estimates of likely species richness. Biological surveys are needed to provide reliable information..

1.2. Framework

Native flora and fauna in Western Australia are protected at both State and Commonwealth levels. At the national level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legal framework to protect and manage nationally and internationally important flora, fauna and ecological communities. However, the threatened fauna lists of the EPBC Act currently place little emphasis on subterranean fauna. The legal framework for protection of flora and fauna at the state level in Western Australia is the *Biodiversity Conservation Act 2016* (BC Act). Most protection is provided for species listed under the BC Act as 'threatened' and this list includes some subterranean species. In addition to the list of threatened species under the BC Act, the Department of Biodiversity, Conservation and Attractions (DBCA) maintains a list of priority species that are of conservation importance but, for various reasons, do not meet the criteria for listing as threatened.

Both the EPBC and BC Acts provide frameworks for the protection of threatened ecological communities (TECs). Within Western Australia, DBCA also informally recognises communities of potential conservation concern, but for which there is not enough information to support listing, as priority ecological communities (PECs). The list of TECs and PECs recognised under the BC Act and by DBCA is larger than the EPBC Act TEC list and has much greater focus on subterranean communities.

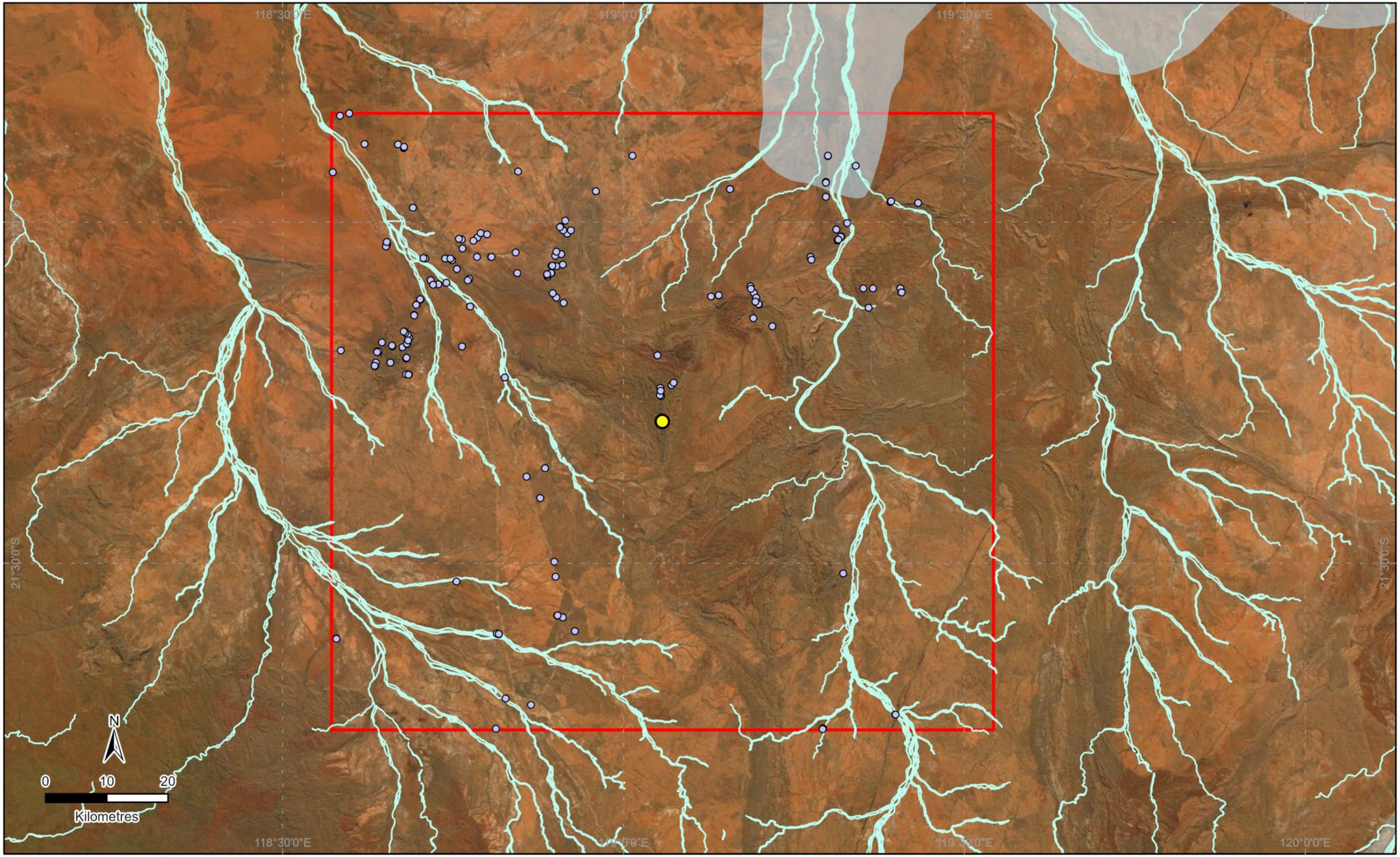
2. DESKTOP

2.1. Methods

A comprehensive review of previous subterranean fauna records was conducted for an area approximately 100 x 100 km around the Study Area (Figure 2 and Figure 3; final decimal degrees search area, top left: -20.8405°S:118.5717°E, bottom right -21.744°S:119.5425°E). This area serves to provide a list of the stygofauna and troglofauna that could possibly occur in the Study Area. The desktop review included a search of the Western Australian Museum (WAM) database, Bennelongia's own database, and previous surveys within the search area including that conducted by Subterranean Ecology (2012). Additionally, lists of conservation-significant communities and species (BC Act and EPBC Act) and records in the Atlas of Living Australia were consulted for the desktop assessment.

2.2. Geology and Hydrogeology

There are five major geological units at the project including the Pincunah Banded-Iron Member, Cradinal Formation, Kangaroo Caves Formation, Corboy Formation and Ferriginous duricrust regolith (Figure 4 and Table 1). Of particular interest are the Pincunah Banded-Iron Member and the Cardinal Formation as both of these consist of weathered geologies that provide the voids and spaces required as habitat by subterranean fauna. Both of these geological units extend in a north/south direction through the Project Area (Figure 4).



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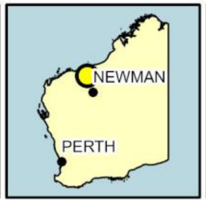

Legend

- The Project
- Desktop Search Area
- Stygofauna specimens
- Palaeovalleys
- Major Rivers

Figure 2. Stygofauna Records in the Desktop Search Area

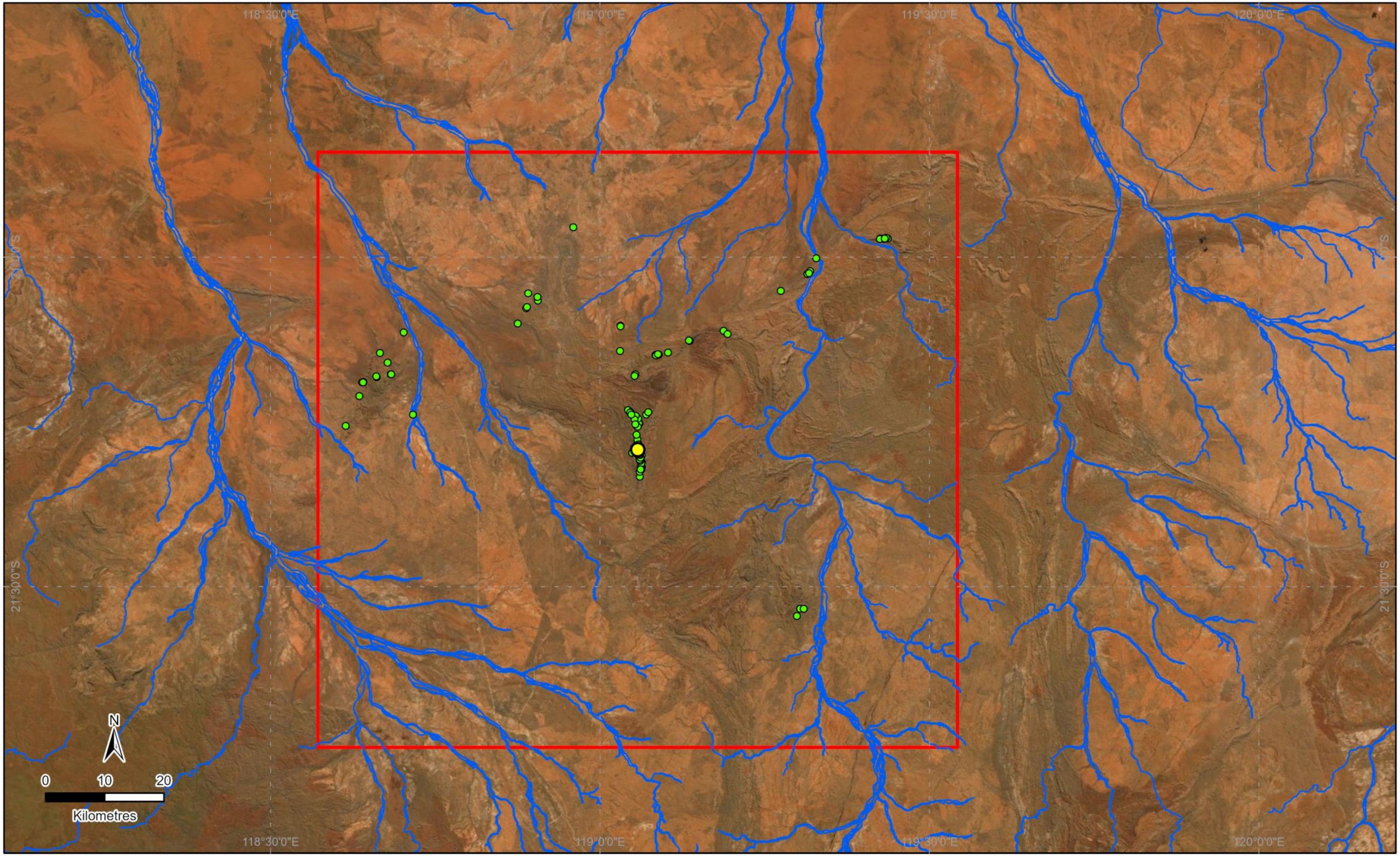

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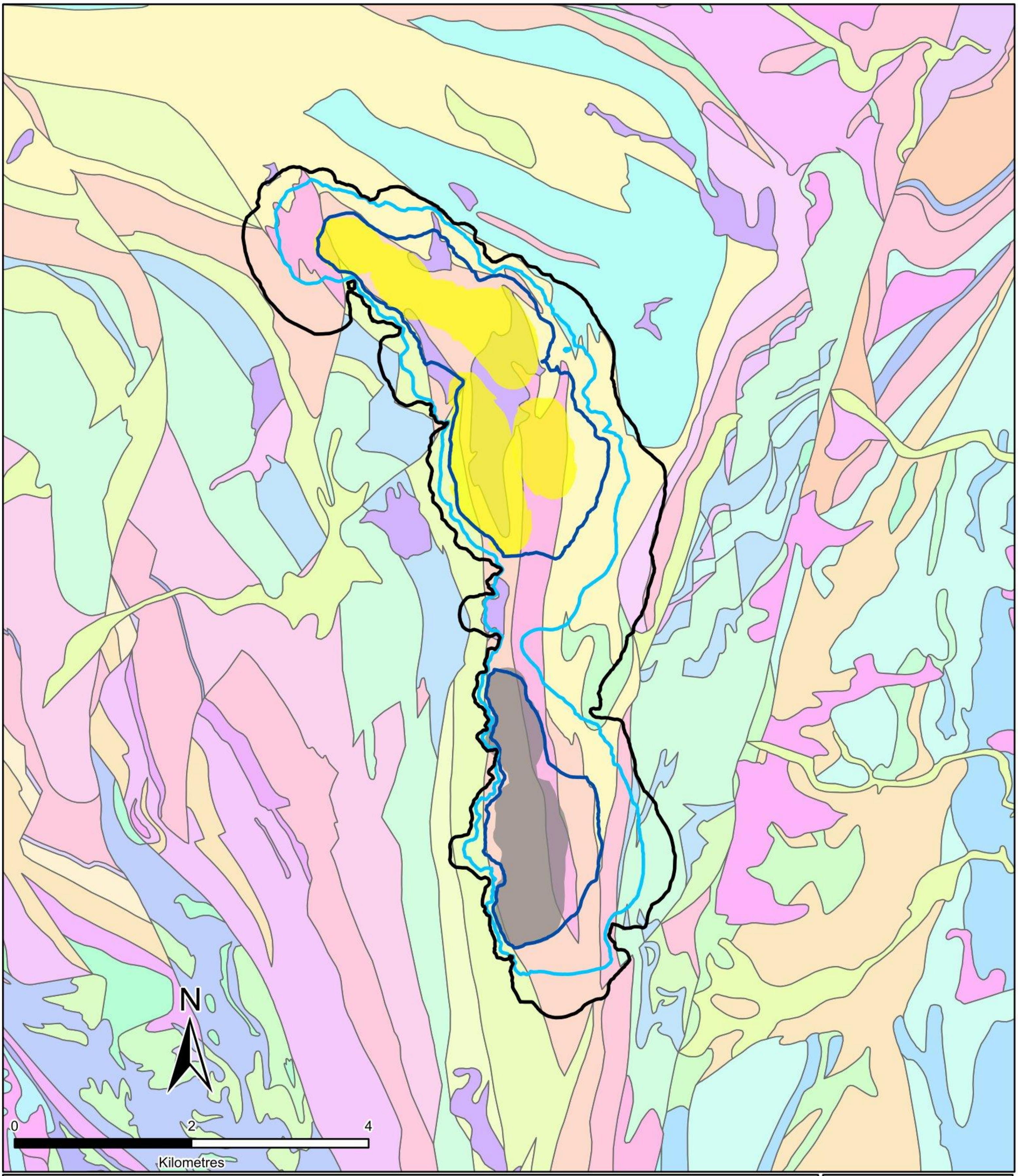
Figure 3. Troglofauna Records in the Desktop Search Area



Legend

Pit Extension	A-CEst-gi	A-KEe-bk	A-SOh-bb	A-SSk-bk	A-SSl-mfq
Approved Pit	A-CEst-gmhb	A-SOa-sh	A-SOp-mi	A-SSk-ccb	A-SSl-sw
Drawdown Contour	A-CEst-od	A-SOa-shz	A-SSc-ccb	A-SSk-ccf	A-musk-P
	A-DA-ad	A-SOc-ml	A-SSc-fa	A-SSk-fd	_A1c
-1	A-DA-ap	A-SOc-mtqm	A-SSc-fat	A-SSk-mbk	_A1f
-5	A-DA-ax	A-SOc-sg	A-SSc-fr	A-SSk-xb-mbs	_C1
-25	A-DA-mapt	A-SOc-sp	A-SSc-sh	A-SSk-xuk-bk	_C2
Geology	A-DA-mats	A-SOc-stq	A-SScp-ci	A-SSl-cc	_R3-f
A-CEka-mggb	A-DA-ocl	A-SOc-sw	A-SSk-bb	A-SSl-fd	_W1-g-pg

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Figure 4. Geology at the Project

Table 1. Geological codes to go with Figure 4

CODE	BRIEF DESCRIPTION
A-CEka-mggb	Meta biotite granodiorite and minor pegmatitic granite; fine to medium grained; foliated
A-CEst-gi	Microdiorite and diorite; metamorphosed
A-CEst-gmhb	Equigranular hornblende--biotite monzogranite; outer phase; rapakivi textures; metamorphosed
A-CEst-od	Dolerite and gabbro; metamorphosed
A-DA-ad	Dunite; partly serpentinized; metamorphosed
A-DA-ap	Peridotite; partly serpentinized; metamorphosed
A-DA-ax	Pyroxenite; includes olivine pyroxenite and orthopyroxenite; metamorphosed
A-DA-mapt	Metaperidotite and serpentine--chlorite schist
A-DA-mats	Serpentinite, schistose
A-DA-ocl	Pyroxene leucogabbro; metamorphosed
A-KEe-bk	Komatiitic basalt; massive and pillowed lavas and subvolcanic intrusions; local pyroxene spinifex texture; metamorphosed
A-SOa-shz	Silicified shale; variegated, layered secondary chert; metamorphosed
A-SOa-sh	Red-weathered, ferruginized black shale, with minor siltstone; local banded iron-formation, chert, sandstone, and conglomerate; metamorphosed
A-SOc-ml	Pelite; metamorphosed siltstone, mudstone, and shale
A-SOc-mtqm	Muscovite-bearing quartzite; minor pelite
A-SOc-sg	Pebble and cobble conglomerate and minor coarse-grained arkosic sandstone; metamorphosed
A-SOc-sp	Sandstone and minor interbedded conglomerate; local siltstone and shale; metamorphosed
A-SOc-stq	Quartz sandstone and quartzite; locally fuchsitic; minor conglomerate and chert; metamorphosed
A-SOc-sw	Wacke and lithic arenite; local sandstone, conglomerate, and shale; metamorphosed
A-SOh-bb	Basalt; metamorphosed
A-SOp-mi	Meta-iron formation
A-SSc-ccb	White, grey, and black layered chert; includes felsic volcaniclastic sandstone and shale; metamorphosed
A-SSc-fa	Andesite and minor basalt; pillowed or massive; local dolerite sills; locally overlain by tuffaceous dacitic to rhyolitic volcaniclastic rocks; metamorphosed
A-SSc-fat	Andesitic volcanic sandstone; tuffaceous; local shale, and chert; metamorphosed
A-SSc-fr	Rhyolite lava and pumice breccia; metamorphosed
A-SSc-sh	Shale; metamorphosed
A-SScp-ci	Banded iron-formation; jaspilitic; minor layered chert and shale; metamorphosed
A-SSk-bb	Basalt; metamorphosed
A-SSk-bk	Komatiitic basalt; massive and pillowed flows; metamorphosed
A-SSk-ccb	White-, blueish black-, and grey-layered chert; metamorphosed
A-SSk-ccf	Bright green, fuchsitic chert; includes local silicified komatiitic basalt flow tops; metamorphosed
A-SSk-fd	Dacite
A-SSk-mbk	Carbonate-altered metamafic volcanic rocks; locally includes chlorite--sericite rock and mafic schist
A-SSk-xb-mbs	Interlayered mafic volcanic rock and mafic schist

CODE	BRIEF DESCRIPTION
A-SSk-xuk-bk	Komatiite and basaltic komatiite; local pyroxene spinifex texture; locally pillowed; metamorphosed
A-SSl-cc	Chert
A-SSl-fd	Dacite; includes local minor felsic schist; metamorphosed
A-SSl-mfq	Silicified fine-grained felsic volcaniclastic rocks; layered grey, white, and cream chert
A-SSl-sw	Wacke; local volcaniclastic sandstone, shale, and quartzite; metamorphosed
A-musk-P	Talc--carbonate and talc--carbonate--chlorite(--magnetite) schist
_A1c	Sand, silt, and gravel in active drainage channels; includes clay, silt, and sand in poorly defined drainage courses on floodplains; unconsolidated
_A1f	Floodplain deposits; sand, silt, clay, and gravel adjacent to main drainage channels; unconsolidated
_C1	Colluvial sand, silt, and gravel in outwash fans; scree and talus; proximal mass-wasting deposits; unconsolidated
_C2	Partly consolidated colluvial sand, silt, and gravel in proximal outwash fans; scree and talus; dissected by present-day drainage
_R3-f	Ferruginous duricrust and ferruginous colluvium; locally includes ferruginous alluvium; consolidated to partly consolidated; related to Hamersley Surface; dissected by present-day drainage
_W1-g-pg	Quartzofeldspathic sand and quartz pebbles in sheetwash fans; derived from mass-wasting of granitic rocks; unconsolidated

There are no paleovalleys in the vicinity of the project with the closest being the De Grey Palaeovalley approximately 40 km north-east of the project (Figure 2). Palaeovalleys are synonymous with the collection of stygofauna as they often harbour transmissive geologies containing appropriate habitat. The project lies on a ridgeline almost exactly halfway between two major rivers, the Turner and the Shaw Rivers. There are many tributaries to these rivers throughout the landscape that may act as pathways and or habitat for stygofauna. However, depth to groundwater at the project can be as deep as 80 m, which is too deep to be prospective for major stygofauna communities (Halse *et al*. 2014).

2.3. Listed species and TECs and PECs

The desktop assessment did not identify any listed or threatened species as occurring in the search area. There are also no TECs or PECs that are likely to be impacted by the proposed development.

2.4. Results

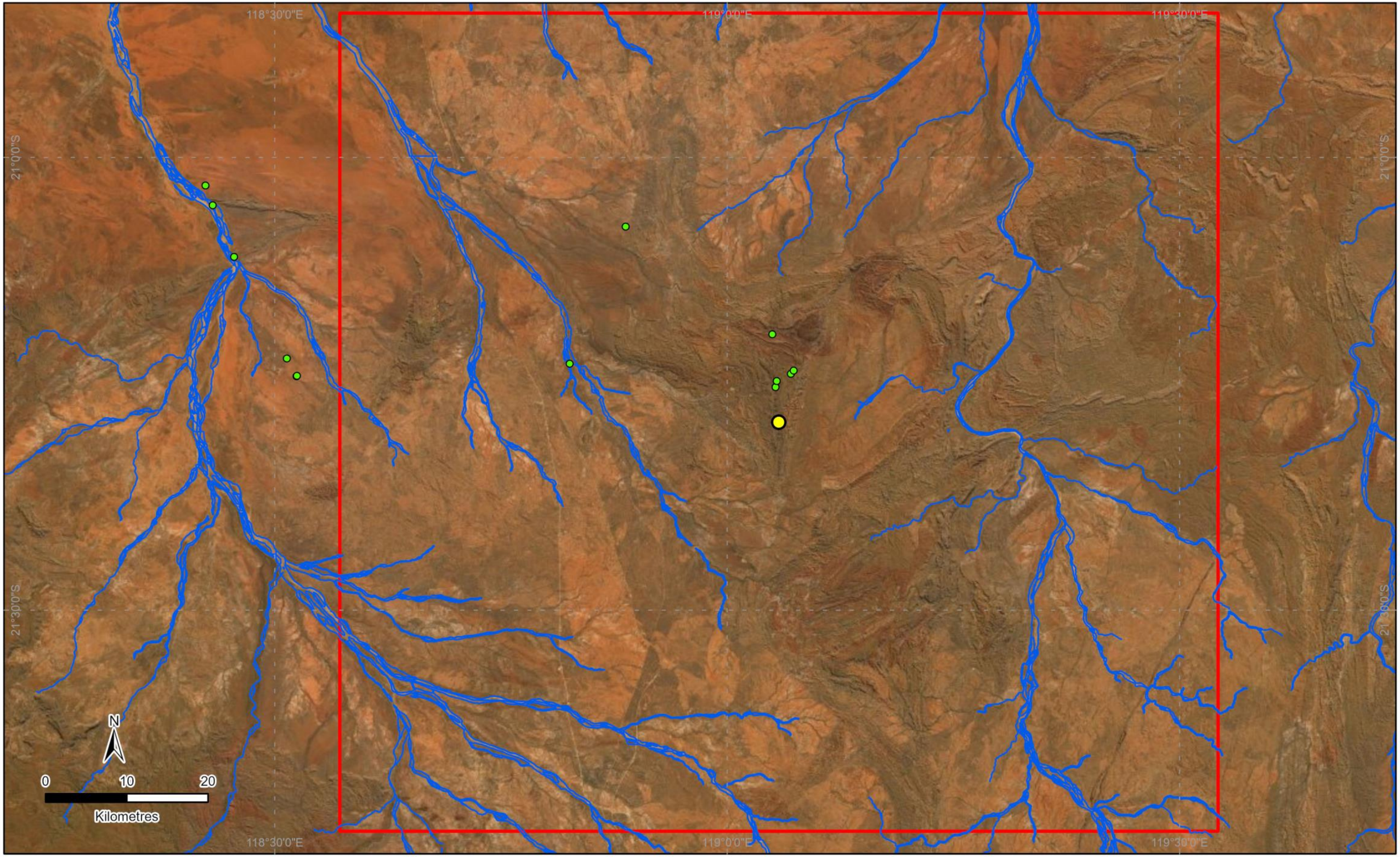
The desktop review identified a total of 157 species of stygofauna previously collected from within the desktop search area. Groups represented are the annelid worms, mites, amphipods, isopods, syncarids, copepods, ostracods, beetles, nematodes, flatworms, and rotifers. This is a significant stygofauna community indicating that stygofauna are consistently found in the vicinity of the project. For a full list of species, please refer to Appendix 1. The vast majority of the stygofauna previously collected appears to be in the north of the search area and closely associated with the Turner and Shaw Rivers (and tributaries). There are a few records to the south-west; these appear to be more associated with the headwaters of the Yule River (Figure 2).

A total of 50 troglofauna species have been previously collected from within the desktop search area. Groups represented include, spiders, pseudoscorpions, schizomids, isopods, diplurans, cockroaches, beetles, flies, bugs, silverfish, millipedes, pauropods, and symphylans. This is a significant troglofauna community and indicates that there is a high chance of encountering troglofauna at the project. For a full list of species, please refer to Appendix 2. The historically collected troglofauna are scattered through the north of the desktop search area, however the highest concentration of animals is from the survey conducted by Subterranean Ecology in 2011 (Figure 3).

2.5. Previous Surveys at the Project

Subterranean Ecology (2012) surveyed the project area and surrounds in 2011 for initial environmental approval. This survey resulted in the collection of at least 17 species of stygofauna. Samples were collected outside of the proposed pits, where the water table is shallower and even as far east as the Yule River where a large proportion of these species were collected (Figure 5). Groups collected included amphipods, syncarids, copepods and oligochaete worms. At the time, no great drawdown was anticipated and, as a result, it was deemed that the potential impacts were minimal with Paramelitidae sp. NS and Melitidae sp. NS1 the only two species mentioned as having minor conservation risk. These have not been considered as restricted species in this survey as records occur up to 68km from the predicted impact area.

A total of 70 troglofauna specimens from at least 11 species were collected during the survey (Subterranean Ecology 2012). This included pseudoscorpions, symphylids, diplurans, cockroaches, beetles, planthoppers and isopods. Troglofauna species were primarily collected in the ridge associated with mining; however a couple of specimens were collected up to 14 km to the north (Figure 6). Subterranean Ecology (2012) concluded that only one of these species, Curculionidae sp. NS, was at risk from mining activities.



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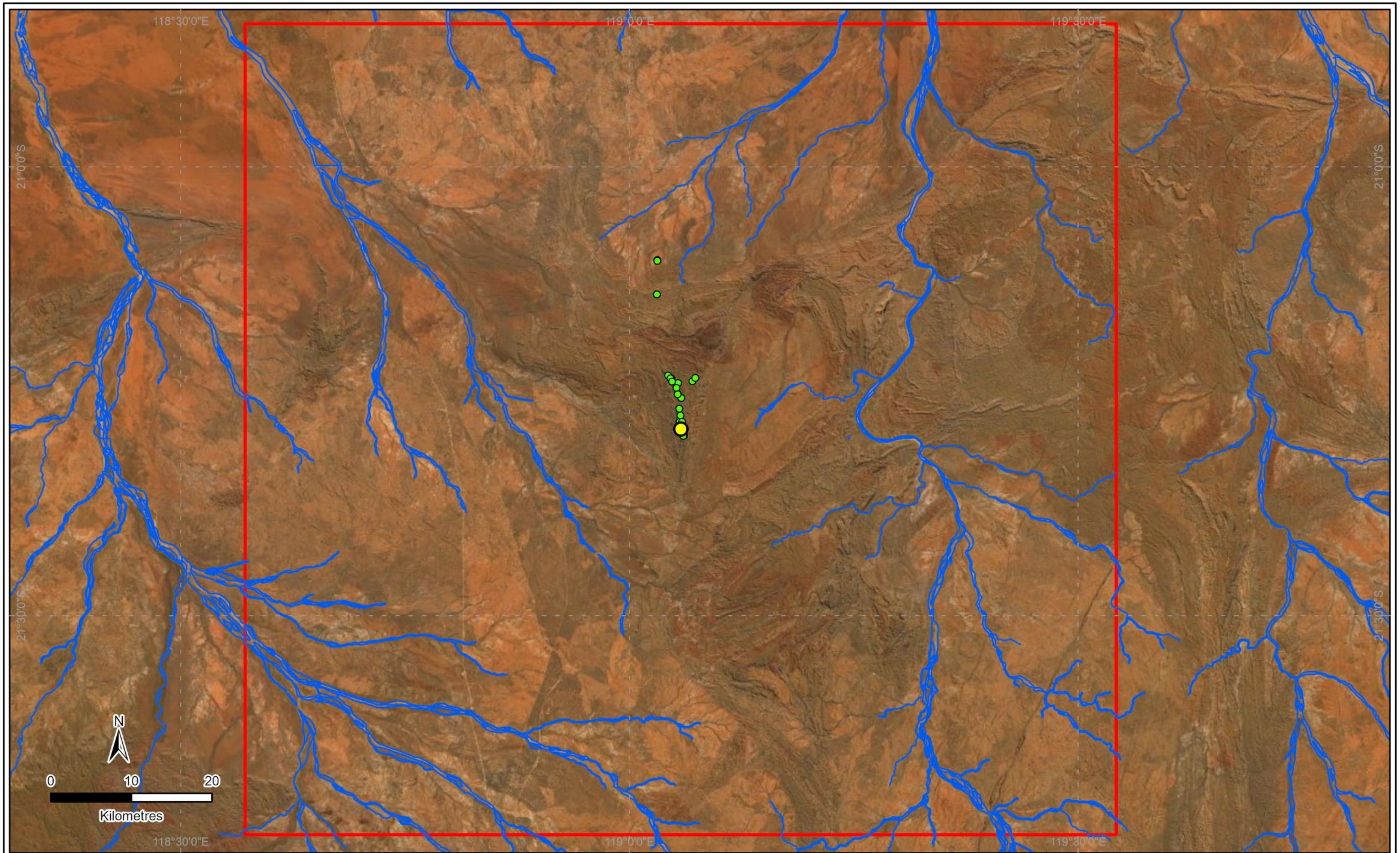
Legend

- The Project
- Desktop Search Area
- Stygofauna specimens
- Major Rivers

Figure 5. Stygofauna specimens collected by Subterranean Ecology (2012)



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Legend

The Project

Desktop Search Area

Troglofauna Specimens

Major Rivers

Figure 6. Troglofauna specimens collected by Subterranean Ecology (2012)

3. FIELD SURVEY

3.1. Methods

The subterranean fauna surveys reported here were conducted according to the general principles laid out for subterranean fauna sampling by the Environmental Protection Authority (EPA) at the time of sampling. The principles are described in *Technical Guidance – subterranean fauna survey* (EPA 2016c), *Technical Guidance – sampling methods for subterranean fauna* (EPA 2016b), and the *Environmental Factor Guideline – subterranean fauna* (EPA 2016a). The surveys conform with the recommendations in *Technical Guidance - subterranean fauna surveys for environmental impact assessment* (EPA 2021) if the sampling effort by Subterranean Ecology (2012) is taken into account.

3.1.1. Stygofauna

Stygofauna was collected by an active sampling technique. At each hole, a small weighted plankton net was lowered to the bottom of the hole and then agitated vigorously to stir benthic and epibenthic fauna into the water column, where animals were then captured as the net was slowly retrieved. Six separate net hauls were made (three with 50 µm mesh net and three with 150 µm mesh net). The contents of the net were transferred to 100% ethanol for preservation after each haul (EPA 2016b). Contamination between sites was avoided by washing the nets between the sampling of different drill holes.

3.1.2. Troglofauna

As far as possible, each troglofauna sample represented the combined results of two different, complementary sampling techniques: scraping and trapping.

Scraping is an active sampling technique that is used prior to setting traps. In each scraping event, a troglofauna net is prepared with a weighted ring net of 150 µm mesh, and a diameter closely matched to 60% of the bore diameter. This net is lowered to the bottom of a bore or to the water table, and subsequently scraped back to the surface at least four times. In each of these *scrapes* a different section of the wall of the hole is targeted (e.g., north, south) to maximize the organisms retrieved. The contents of each scrape are immediately transferred to 100% ethanol for preservation of the sample and its DNA.

Trapping is a passive sampling technique used after the drill hole is scraped. Traps of cylindrical PVC (270 x 70 mm) with holes drilled on the side and top to function as entrances were baited with microwaved leaf litter. Traps were lowered on nylon cord to the end of the bore, or to a few metres above the water table. An additional second trap was set (at half the depth of the first trap) in approximately every fourth hole (where possible), according to Halse *et al*. (2018). Traps were then left inside bores for nine weeks. During that period, the bores were sealed to minimise movement of surface animals into the troglofauna traps. When traps were retrieved, their contents were transferred to a zip-lock bag and transported alive to the laboratory in Perth.

3.1.3. Survey Effort

While calculating sample effort for stygofauna is relatively straightforward, sample effort for troglofauna is slightly more complicated. Sampling effort for troglofauna was calculated on the basis that standard sampling comprised both scraping and trapping. Thus, the combined results scraping and setting one or two traps in a bore on the same date were treated as one sample. If only one trap or a single scrape was collected from the hole the sampling effort was deemed to be 0.5 of a sample.

Two rounds of sampling were conducted in 2020 and 2021. The first round was conducted from 27-31 July 2020 (scrapes and net samples taken, traps set) with trap retrieval occurring on 22-23 July. The second round was undertaken from 10– 12 May (scrapes and net samples taken, traps set) and traps were retrieved on 8-9 July. Totals of 19 stygofauna samples and 80 troglofauna samples were collected across the two rounds (Table 2, Figure 7 and Figure 8). For a complete list of sampled holes, please refer to Appendix 3.

Table 2. Subterranean fauna survey effort conducted throughout 2020 and 2021.

Sampling Round	Stygo Net Haul	Trog Scrape	Trog Trap 1	Trog Trap 2
2020	**17**	**40**	**40**	**11**
2021	**2**	**40**	**40**	**11**
Total	**19**	**80**		

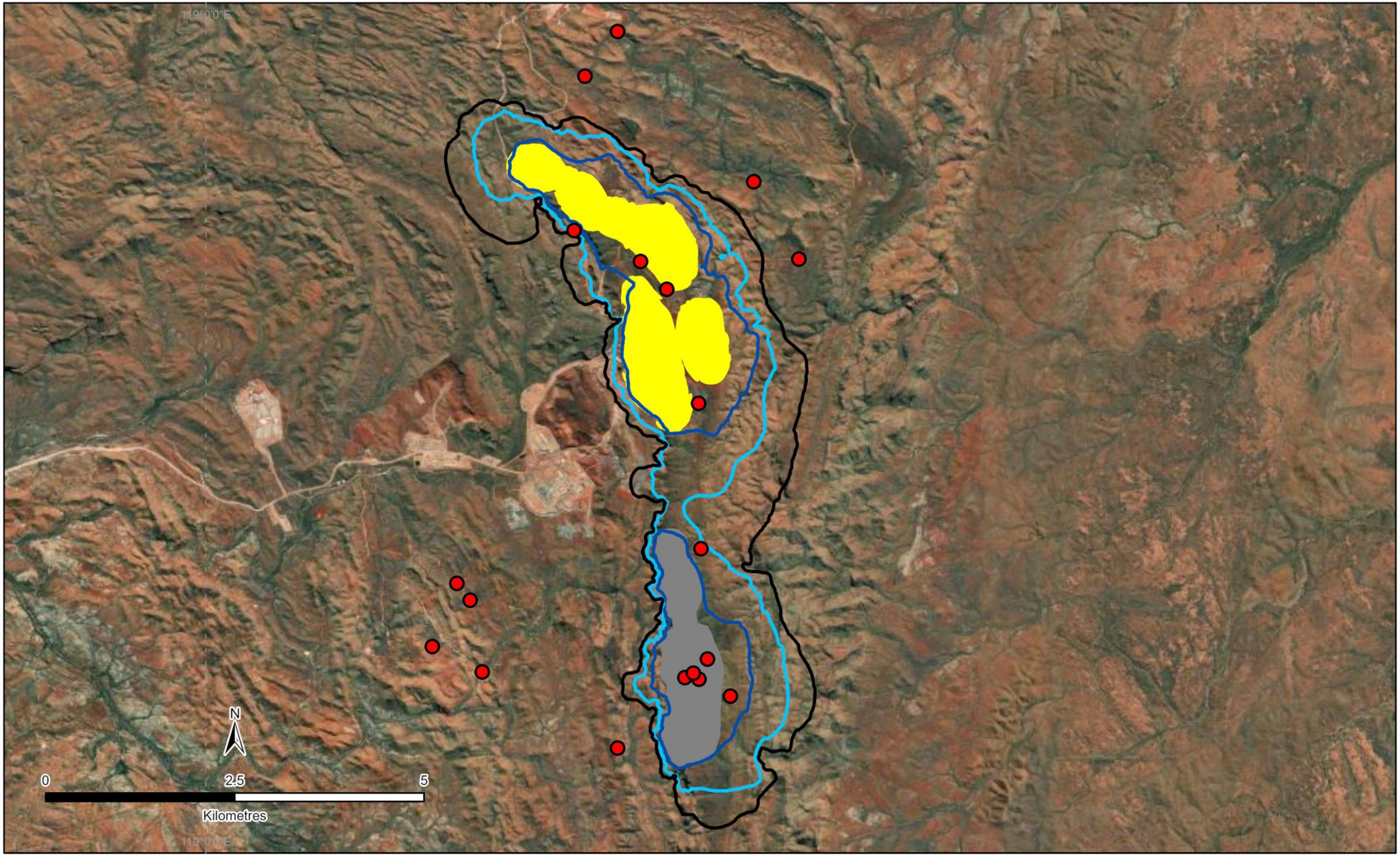
3.1.4. Laboratory Methods

All samples were sorted in the laboratory. Leaf litter retrieved from traps was processed in Tullgren funnels under halogen lamps for 72 hours, during which time the light and heat drives animals downwards and towards a vial containing 100% ethanol as a preservative. Litter was checked after removal from the funnels to ensure no invertebrates remained.

Samples in ethanol from the Tullgren funnels were carefully screened under a dissecting microscope. Troglofauna scape samples and stygofauna net samples were elutriated to separate animals from sediment and put through sieves to fractionate the contents according to size (53, 90 and 250 µm) to improve searching efficiency before screening under a dissection microscope. All potential subterranean animals were removed from these samples for species or morpho-species level identification.

Troglofauna and stygofauna identifications were made using published, unpublished and informal taxonomic keys, as well as species descriptions in the scientific literature. Morphospecies identifications based on the characters of existing species keys were used for undescribed species, and the lowest level of identification possible was reached given the constraints of sex, maturity of the specimens (juveniles and females are often impossible to identity to species level) and possible damage to body parts. During the final phase of identification, dissecting and compound microscopes were used, with the process often requiring dissection of specimens. After the taxonomic assessment was completed, representative animals were lodged with the WAM.

DNA sequencing of 19 animals from the Study Area (along with four reference animals from the surrounding area) were used to confirm morphological identifications or provide names for juvenile or damaged animals. Depending on the size of the specimens, legs or whole animals were used for DNA extractions using a Qiagen DNeasy Blood & Tissue kit (Qiagen 2006). Elute volumes varied from 30 µL to 80 µL depending on age, condition and quantity of material. Primers combinations used for PCR amplifications were: LCO1490:HCO2198, C1J1718:HCO2198, and LCO1490:HCOoutout for the MT-CO1 gene (Folmer *et al.* 1994; Schwendinger and Giribet 2005); and SRJ14197:SRN1474S for the 12S gene (Kambhampati and Smith 1995; Simon *et al.* 1994). Next, dual-direction sanger sequencing was undertaken for PCR products by the Australian Genome Research Facility (AGRF). The sequences returned were edited and aligned in Geneious (Kearse *et al.* 2012), where neighbour-joining phylogenetic trees were then calculated using 1000 bootstraps. Genetic distances (using the Tamura-Nei method) between unique sequences were measured as uncorrected p-distances (total percentage of nucleotide differences between sequences). Sequences on GenBank and in grey literature were included in phylogenetic analysis to provide a framework for assessing intra and interspecific variation, as well as to examine levels of differentiation among individuals within described species across their geographic ranges.

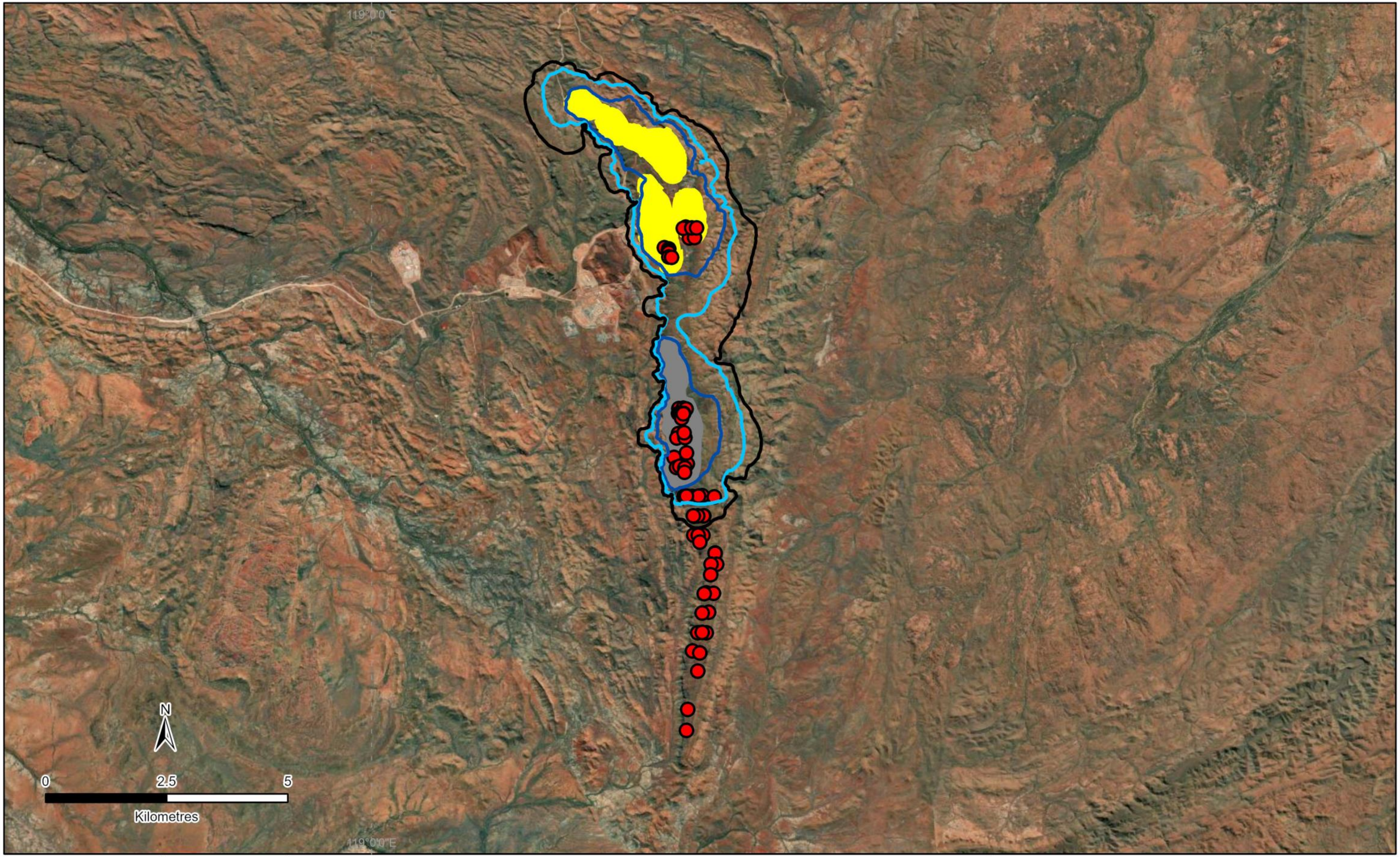


GCS GDA 1994
Author: Rhare
Date: 12/05/2023

Legend

- Stygofauna Sample
- Drawdown Contour
  - -25
  - -5
  - -1
- Extension footprint
- Approved pit voids

Figure 7. Stygofauna samples taken during 2020-2021



GCS GDA 1994
Author: rhare
Date: 9/05/2023

Legend

Extension footprint
Approved footprint
Troglofauna Sample
Drawdown Contour
-1
-5
-25

Figure 8. Troglofauna samples taken during 2020-2021

3.2. Results

3.2.1. Genetic Analysis Results

Stygofauna

Four stygofauna specimens were sequenced for genetic analysis. These included three syncarid specimens (two *Atopobathynella* `BSY214` and Parabathynellidae sp.) and the oligochaete Tubificidae `BOL066`. Unfortunately, sequencing for all three syncarid specimens failed and as a result, no comparisons to sequences held at Bennelongia or in the public domain could be made. The identification of these animals remains the morphological identification made by the taxonomists.

Tubificidae `BOL066` returned a successful sequence and as such could be compared to other known sequences. No match could be found, however, with the nearest species being 15.9% divergent in the Mt-COI gene. As a result, the Tubificidae `BOL006` remains a singleton currently only known from within the drawdown impact area.

Troglofauna

Sixteen specimens of troglofauna collected at the Project were sequenced. Results are outlined in Table 3. Sequencing for five animals failed to return adequate data for comparison and only morphological identifications are available. Seven individuals did not match any available sequences while two matched sequences either from the Bennelongia database or from the public domain (Table 3). All results obtained from genetic analysis are incorporated in the species lists in Table 4 and Table 5. Further discussion of results for individual groups is provided below.

Table 3. Genetic sequencing undertaking and results for troglofauna at the Project.

Identification	Sequence result	Match found
Armadillidae gen. indet.`BIS438`	Failed	NA
Atelurinae sp.	Failed	NA
Atopobathynella `BSY214`	Failed	NA
Carabidae sp.	Failed	NA
Gracilanillus `BCO217`	Successful	No match
Curculionidae Genus 1 `BCO218`	Successful	Match
Cryptops sp. B06	Successful	Match
Cryptops `BSCOL076`	Successful	No match
Dalodesmidae `BDI073`	Successful	No match
Eukoenenia `BPAL048`	Failed	NA
Japygidae `BDP187`	Successful	No match
Nocticola `BLA006`	Successful	No match
Blattidae sp. B06	Successful	Match
Oonopidae `BAR134`	Successful	No match
Prethopalpus `BAR135`	Successful	No Match
Tyrannochthonius `BPS439`	Successful	No Match

Isopods

Unfortunately, the Armidillidae gen. indet. `BIS438` failed to return a successful sequence. As a result, the morphological identification stands. While the genus of this individual could not be determined, it is very close to *Troglarmadillo*. As a result, we can confidently say this is not the species collected by Subterranean Ecology (2012) and listed in their report as *Troglarmadillo* sp. NS. Distinctive anatomical features separate the two Armidillidae species (`BIS438` and `BIS416`) collected during the current survey. For example, Armidillidae gen. indet. `BIS438` has a very distinctive head and telson shape while Armidillidae gen. indet. `BIS416` has very wide schisma, a feature allowing isopods to roll into a ball.

Silverfish

A single damaged specimen of silverfish (Atelurinae sp.) was collected. Only the head and thorax were present resulting in the morphological identification only reaching subfamily level. Unfortunately, genetic sequencing was unsuccessful, so no further information could be derived from this individual. The desktop search identified a single other Atelurinae specimen (genus *Dodecastyla*) from 52 km to the northeast of the project. Unfortunately, there is no way to ascertain if these individuals are conspecific or not.

Beetles

A total of 16 carabid beetles were collected during the 2020-21 survey. Seven adults were identified morphologically as *Gracilanillus* `BCO217`. DNA analysis was conducted on one specimen in an attempt to align it with other species in the area. This individual was sequenced for the Mt-COI gene and was found to be 12.8% divergent from the nearest match, *Gracilanillus* sp. B04 (Figure 9). This level of divergence in Mt-COI is more consistent with interspecific, rather than intraspecific, divergence (Guzik *et al.* 2009) and as such maintains its status as a new species.

The remaining nine specimens collected during the current survey were larvae and most likely are members of the aforementioned morpho-species. Unfortunately, genetic sequencing was unsuccessful on the larvae and as a result no further information could be provided on these specimens. Subterranean Ecology (2012) collected three individuals identified at subtribe level as Anillini sp. NS. It is possible these are *Gracilanillus* `BCO217`.

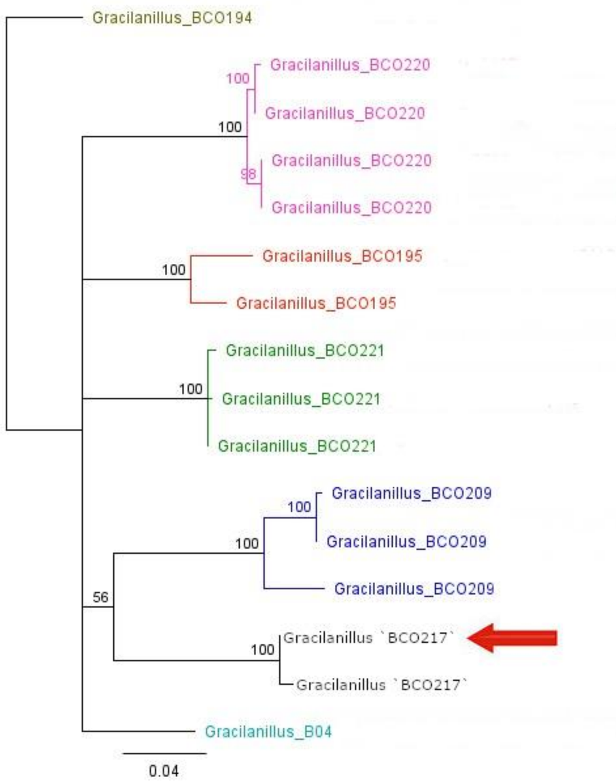


Figure 9. Maximum likelihood tree from the genus *Gracilanillus*.
The species from the current survey is highlighted with a red arrow.

Eleven specimens of Curculionidae Genus 1 `BCO218` were collected during the survey and are currently only known from the Project Area. Genetic sequencing was conducted to ascertain if conspecifics had been collected previously. A successful sequence for the Mt-COI gene was returned and resulted in a blast match with an individual, Curculionidae sp. 5 JAH-2016 (accession code KU519731) from outside the Project (Figure 10). We have retained the assigned morpho-species code here but acknowledge the match with a previously identified conspecific individual from outside the project.

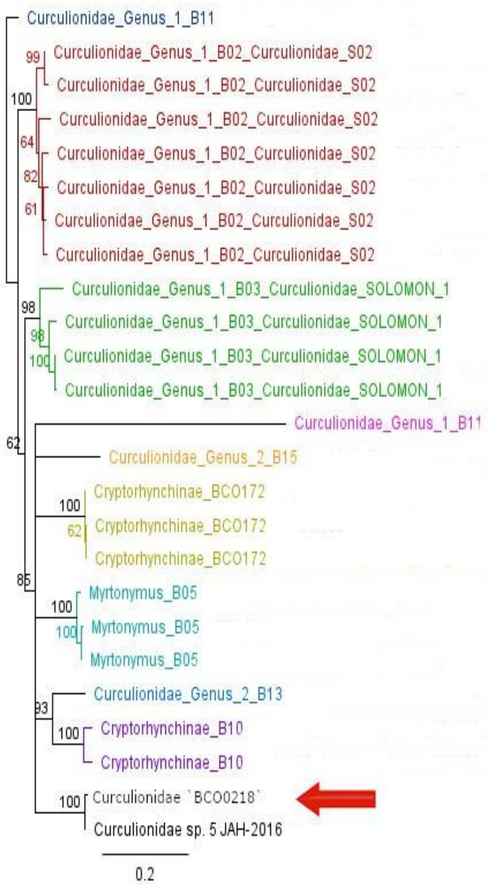


Figure 10. Maximum likelihood tree from the family Curculionidae.
The species from the current survey is highlighted with a red arrow.

Centipedes

Two centipede specimens assigned to two morphospecies were collected during the survey. These individuals were sequenced for the Mt-COI gene to confirm the morphological separation of these morpho-species and to identify any conspecific individuals from the Bennelongia database or the public domain.

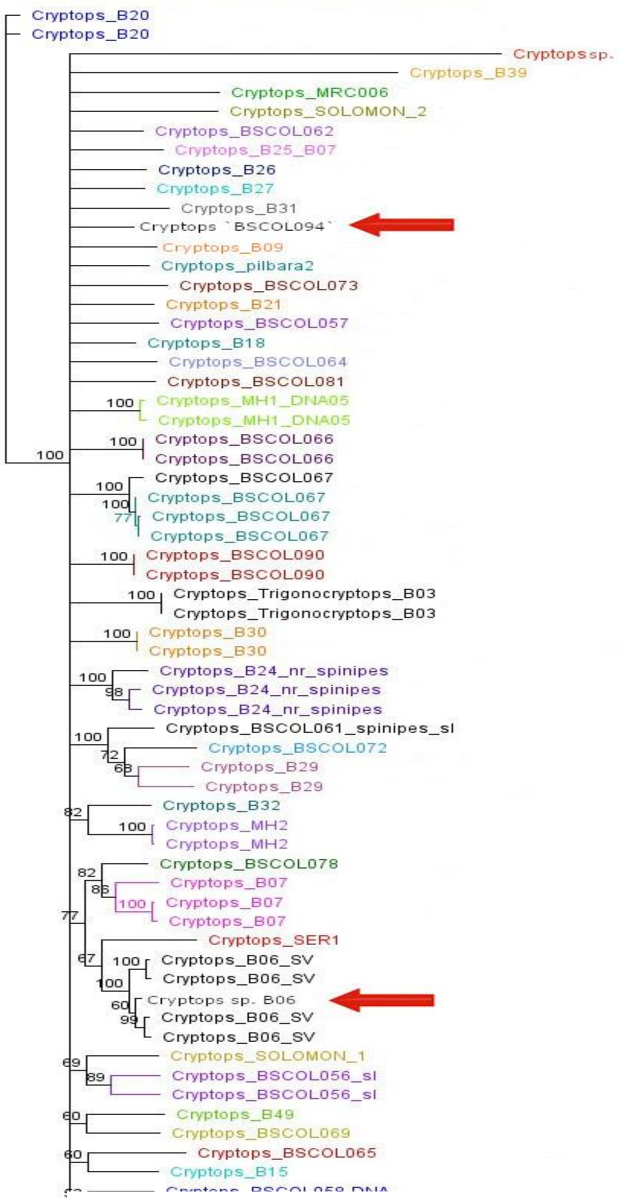


Figure 11. Maximum likelihood tree from the genus *Cryptops*.
The species from the current survey is highlighted with a red arrow.

One individual was found to match *Cryptops* sp. B06 with an interspecific divergence between 4.3 and 7.2% (Figure 11). As a result, these species have been synonymised and attributed to *Cryptops* sp. B06 in Table 5. This species has a distribution throughout the Hamersley ranges.

The closest match to *Cryptops* `BSCOL076` is *Cryptops* sp. B09 which was 22.3% divergent for the 12S gene. As a result, Cryptops `BSCOL076` is considered a new species that has not been previously collected and is known only from reference sites at the Project area.

Millipedes

A single specimen of dalodesmid millipede was collected during the 2020-21 survey. Morphologically, this species did not match any known specimen and was therefore identified as Dalodesmidae `BDI073`. Sequencing for the Mt-COI gene was conducted on this specimen in an attempt to find a conspecific in the surrounding region, however no match was found. The closest match was an individual from the Hamersley Ranges which was 17.5% divergent (Figure 12). These two specimens are considered to be two different species.

The desktop did not identify any other specimens from the Dalodesmidae family in the search area. The specimen collected at the Project retains the name Dalodesmidae `BDI073` and is considered a new species known only from reference sites at the Project.

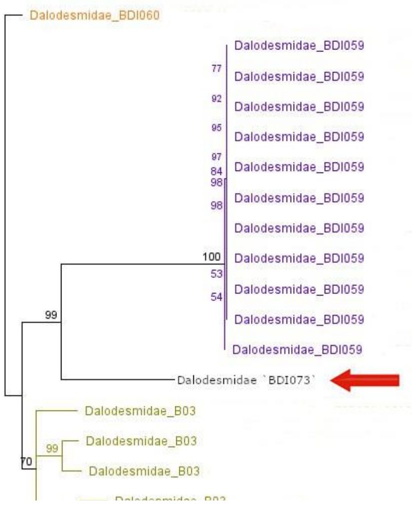


Figure 12. Maximum likelihood tree from the family Dalodesmidae.
The species from the current survey is highlighted with a red arrow.

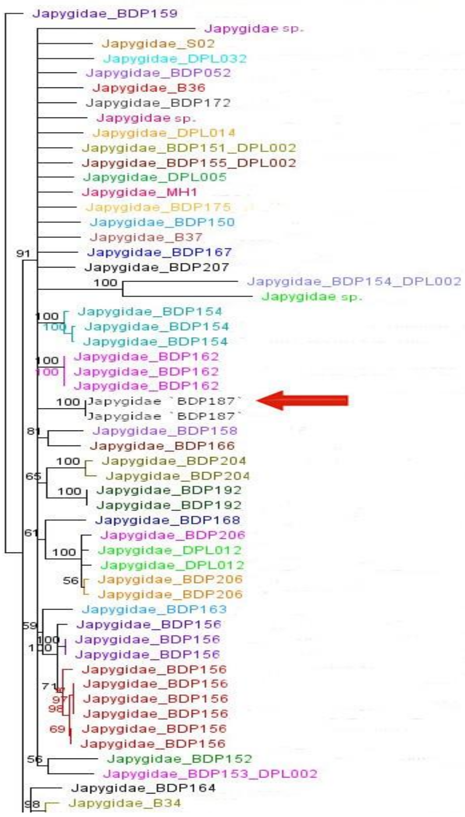


Figure 13. Maximum likelihood tree from the family Japigidae.
The species from the current survey is highlighted with a red arrow.

Palpigrads

A single palpigrad specimen was collected within impact areas at the project. It was placed in the genus *Eukoenenia*. This specimen did not match any known species, and the desktop search failed to identify any other palpigrad specimens from within the search area. Genetic analysis was undertaken to locate a conspecific individual outside of impact. Unfortunately, sequencing failed and due to the lack of other palpigrads in the desktop search area, this species is considered new and has been assigned the name *Eukoenenia* `BPAL048`. It is currently only known from within impact areas at the Project.

Diplurans

Two dipluran specimens were collected, both within impact areas at the Project. They were an adult and nymph. The adult was identified as Japygidae `BDP187` and it is likely that the juvenile will belong to the same species. The Mt-COI gene was sequenced to identify any conspecifics outside of the Project area. The closest match was Japygidae `BDP172` from the western end of the Hamersley Range. These individuals were 13.7% divergent and are therefore considered to be separate species (Figure 13).

Cockroaches

The cockroaches were represented by 47 individuals from two families. The 42 Nocticolidae included 12 adults which aligned morphologically closest to *Nocticola currani*. Genetic analysis of the Mt-COI gene was conducted to compare the specimens from the Project with *N. currani* and other *Nocticola* species. The individuals at the project did not match any other known species and were 17.5% divergent from *Nocticola* sp. B33, which was the closest match (Figure 14). As a result, the animals collected at the project are considered to be a new species and have been assigned to the morpho-species *Nocticola* \`BLA006\`. These animals were collected in both impact and reference sites.

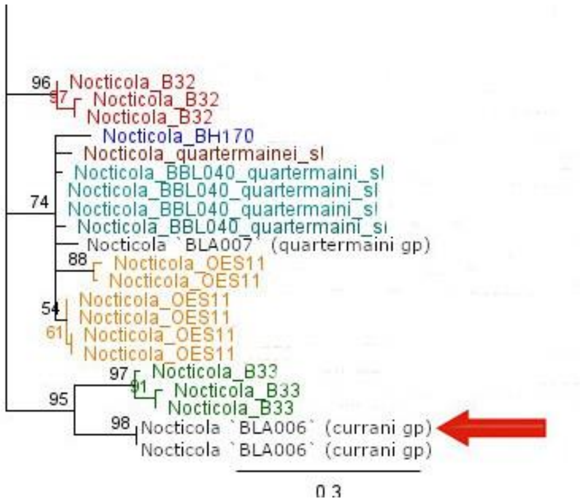


Figure 14. Maximum likelihood tree from the genus *Nocticola*.
The species from the current survey is highlighted with a red arrow.

The desktop search identified both *Nocticola currani* and *Nocticola quartermainei* as having been collected in the area before and it is likely that at least some of these *N. currani* individuals are representatives of *Nocticola* \`BLA006\`. In addition, Subterranean Ecology (2012) collected 53 specimens of *Nocticola* representing two morpho-species, *Nocticola* sp. NS1 and *N*. Sp. NS2. It is likely one of these morphospecies are members of the *Nocticola* \`BLA006\` species.

Five specimens from the Blattidae family were collected, one adult and four juveniles. Morphologically, the adult matched Blattidae sp. B06 and as such has been assigned to this morpho-species. Genetic analysis was conducted to confirm this morphological ID as this would be a range extension for this species. The induvial from the Project matched Blattidae sp. B06 for the Mt-COI gene with an intraspecific divergence of between 4.2 and 5% (Figure 15).

Figure 15. Maximum likelihood tree from the family Blattidae
The species from the current survey is highlighted with a red arrow.

Spiders

Two troglofaunal spiders were collected during the survey. Both of these species are members of the family Oonopidae. No members of this family were identified during the desktop search. Oonopidae \`BAR134\` was represented by a single specimen from a reference site. This species did not match any other animals based on morphology and as such, genetic analysis for the Mt-COI gene was conducted. The closest match was *Prethopalpus* sp. B29 with a divergence of 21.5% and as a result, Oonopidae \`BAR134\` remains a singleton known from a reference site.

One Juvenile from the genus *Prethopalpus* was collected from within project impact. No similar individuals have been noted from within the desktop search area and this genus is known to have restricted distributions. Genetic sequencing was undertaken to identify any conspecifics, however no genetic match was found. *Prethopalpus* `BAR117 was 14.3% divergent from the animal collected at the project, which is consistent with interspecific divergence. As a result it is currently considered to be a new species *Prethopalpus* `BAR135`.

Pseudoscorpions

A single specimen of *Tyrannochthonius* `BPS439` was collected from within impact at the project. Seven other *Tyrannochthonius* species were identified during the desktop assessment and an eighth species, Chthoniidae sp. NS has been collected at the project by Subterranean Ecology (2012). *Tyrannochthonius* `BPS439` was sequenced for Mt-COI but no match was detected. The nearest match was from a BLAST and was 15.3% divergent (Figure 16). However, only one of the species reported in the desktop had sequences available for comparisons, and *Tyrannochthonius* `BPS439` is possibly one of these species.

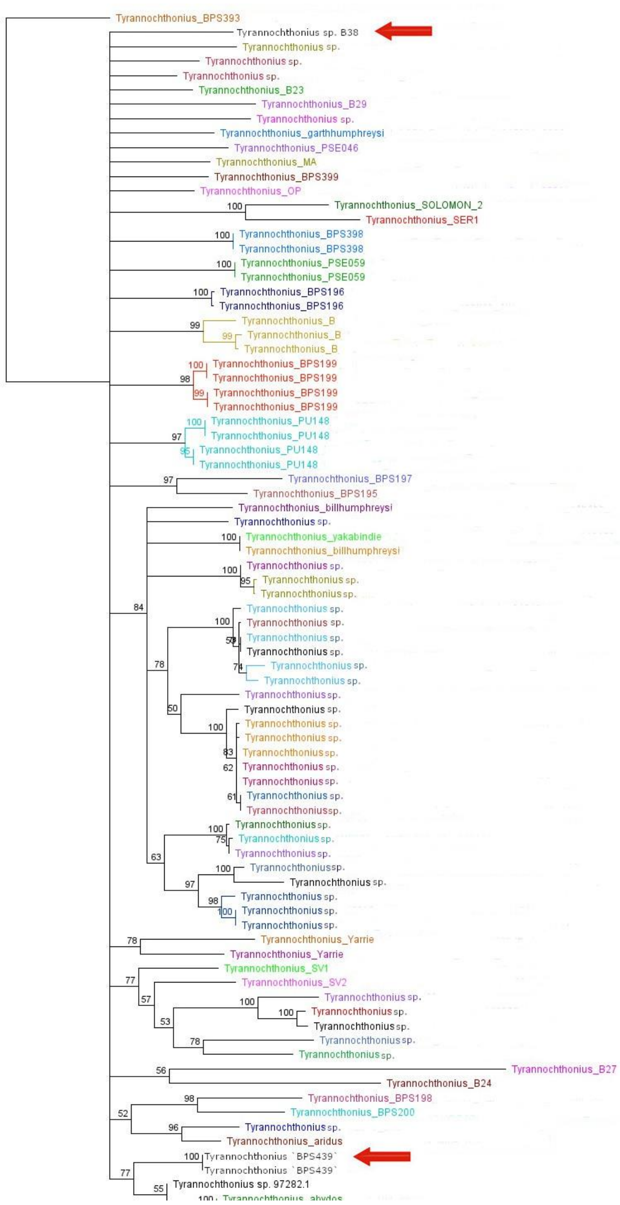


Figure 16. Maximum likelihood tree from the genus *Tyrannochthonius*.
The species from the current survey is highlighted with a red arrow.

3.2.2. Stygofauna Survey Results

The 2020-21 field survey collected 332 stygofauna specimens of at least 11 species (Table 4) including copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms (not assessed as a part of the EIA process). Seven of these species have been collected outside of the project area. Three species are currently only known from a single bore and are therefore referred to as singletons. One of these species, *Parastenocaris* `BHA298`, was collected in a reference site and therefore will not be impacted by planned activities. The worm Tubificidae `BOL066 and two syncarid species (*Atopobathynella* `BSY214` and Parabathynellidae sp.), have currently only been collected from within impact areas (defined as ≥2m of drawdown – Figure 17) and are therefore considered to be at higher risk of impacts associated with mining related drawdown. Parabathynellidae sp., is listed in Table 4 as a higher order identification because of damage but it was clear from morphology that it does not belong to the other syncarid species collected in the current survey. Both syncarids were collected marginally inside the impact area in a location previously approved for dewatering and thus are not considered in the context of the current expansion. The stygofauna community is considered to be low to moderately diverse with only three low-abundance species considered to be at risk from development.

3.2.3. Troglofauna Survey Results

The 2020-21 survey collected 102 troglofauna specimens from at least 16 species (Table 5), including members of the beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Four of these animals have been collected outside of the Project area and are not considered to be at risk by the development. Five species, currently only known from the project were collected in reference areas and as a result will not be impacted by mining activities. Seven species, including the higher order identification, Atelurinae sp., are discussed in more detail as they are considered to be singletons that are at a greater risk of impacts associated with mining activities as they have all currently only known from within impact areas (Figure 18).

The troglofauna community collected during the survey is considered to be moderately rich with seven species known only from proposed impact areas.

Table 4. Stygofauna specimens and species collected during the 2020-21 subterranean fauna survey.

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Annelida						
Oligochaeta						
Enchytraeidae	Enchytraeidae `3 bundle` s.l. (short sclero)	33	Widespread	GV0207 GVD0009 SS0063 NS0305 1B-NST-M01 SS0036A	Both	Species complex known throughout Western Australia. Probably contains many undescribed species Could be Enchytraeidae sp. indet from 2011 survey
Phreodrilidae	Phreodrilidae sp. AP DVC s.l.	1	Widespread	NSEXS35	Reference	Species complex known throughout Western Australia. Probably contains many undescribed species Could be Phreodrillidae sp. indet from 2011 survey
Tubificidae	Tubificidae `BOL066`	8	Singleton	SS0003	Impact	Currently only known from a single location at the Project
Arthropoda						
Crustacea						
Syncarida						

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Atopobathynella	Atopobathynella \`BSY214\`	57	Singleton	NS-Obs14	Impact	Currently only known from a single location at the Project Could be Parabathynellidae sp. NS from 2011 survey
	Parabathynellidae sp.	1	Higher order	NS-Obs14	Impact	Not the same as Atopobathynella \`BSY214\` as it is either a Brevisomabathynella or Billibathynella Could be Parabathynellidae sp. NS from 2011 survey
Copepoda						
Cyclopoida						
Diacyclops	Diacyclops humphreysi s.l.	18	Widespread	GV0224 NS-Obs14	Both	Species complex known throughout Western Australia. Probably contains many undescribed species Also collected in 2011
Pescecyclops	Pescecyclops pilbaricus	9	Widespread	SS0034A	Reference	Known from throughout the Pilbara

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
Harpacticoida						
Elaphoidella	Elaphoidella humphreysi	3	Widespread	GV0224	Reference	Known from throughout the Pilbara Also collected in 2011
Parastenocarididae						
Parastenocaris	Parastenocaris `BHA298`	3	Singleton	SS0034A	Reference	Currently only known from a single location at the Project
Ostracoda						
Areacandona	Areacandona yuleae	2	120 km	NSEXS35	Reference	also known from a location approx. 50 km south west of Port Hedland
Nematoda	Nematoda spp.	197	Widespread	GV0206 GV0208 GVD0009 NS0789 NS0794 SS0002 SS0002A SS0005 SS0016 SS0018 SS0026 SS0032 SS0034A	Both	Higher order identification. Nematodes not assessed through the EIA process

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection locations	Impact or Reference	Notes on taxonomy
				SS0036 SS0036A SS0040 SS0042 SS0047 SS0048		

Table 5. Troglofauna specimens and species collected during the 2020-21 subterranean fauna survey.

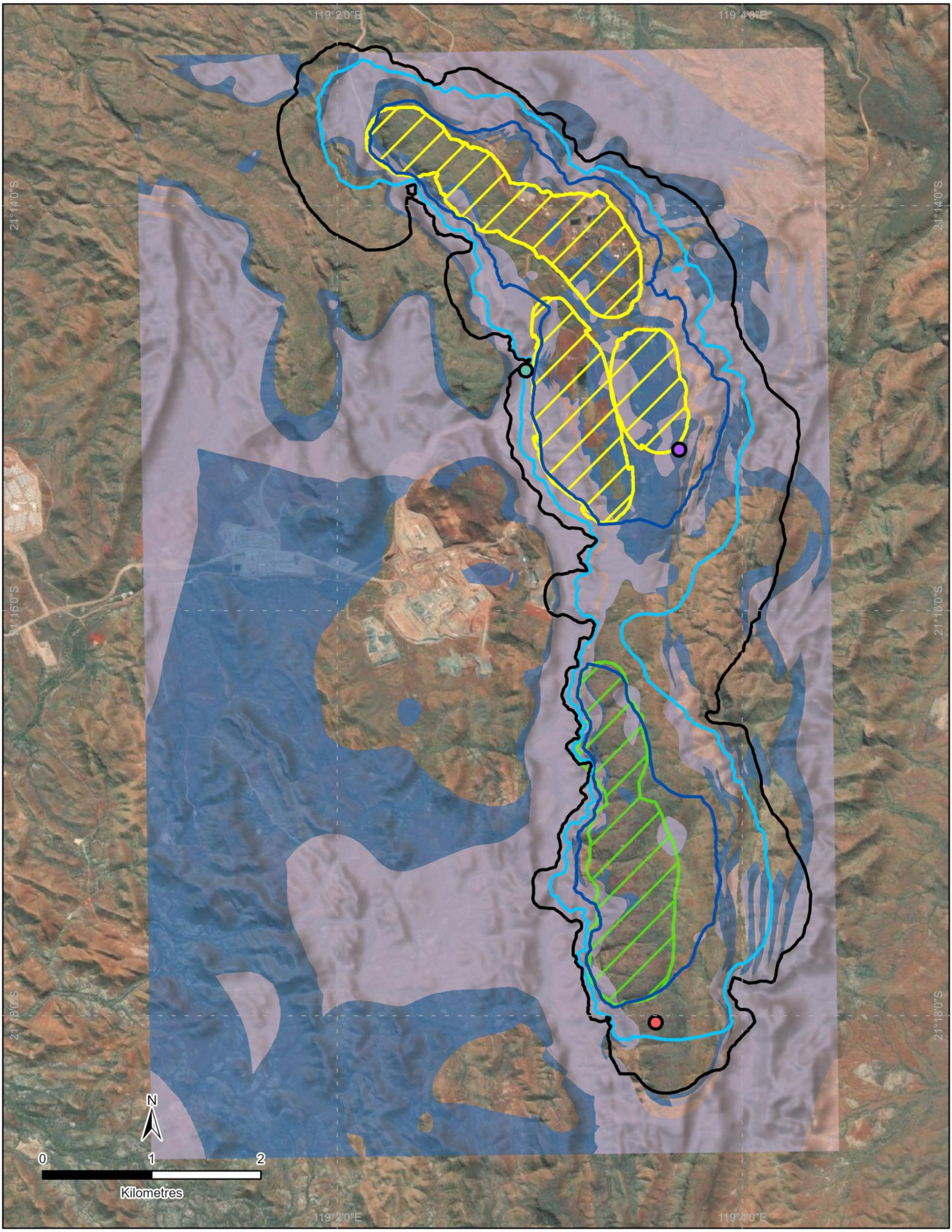
Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Arthropoda						
Araneae						
Oonopidae						
Oonopidae Genus 2	Oonopidae \`BAR134\`	1	Singleton	SS0028	Reference	Currently only known from a single location at the Project
Prethopalpus	Prethopalpus \`BAR135\`	1	Singleton	NS0306	Impact	Currently only known from a single location at the Project
Palpigradi						
Eukoenenia	Eukoenenia \`BPAL048\`	1	Singleton	NS0752	Impact	Currently only known from a single location at the Project
Pseudoscorpiones						
Chthoniidae						
Tyrannochthonius	Tyrannochthonius \`BPS439\`	1	Singleton	NS0795	Impact	Currently only known from a single location at the Project Could be Chthoniidae sp. NS from 2011.
Crustacea						
Isopoda						
Armadillidae	Armadillidae \`BIS416\`	1	Singleton	GV0207	Impact	Currently only known from a single location at the Project

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
	Armadillidae `BIS438`	1	Singleton	NS0788	Impact	Currently only known from a single location at the Project
Hexapoda						
Diplura						
Japygidae	Japygidae `BDP187`	1	Singleton	GV0213	Impact	Currently only known from a single location at the Project
	Japygidae sp.	1		GV0207	Impact	Higher order, maybe another member of Japygidae `BDP187`
Insecta						
Blattidae	Blattidae sp. B06	1	Widespread	GV0208	Impact	Also known from throughout the Hamersley Ranges Could be the same as Blattidae sp. indet from 2011
	Blattidae sp.	4		SS0007 SS0005	Reference	Higher order, maybe another member of Blattidae sp. B06
Nocticolidae						
Nocticola	Nocticola `BLA006`	12	54 km	GV0208 NS0305 NS0794 NS0790 NS0755 SS0042	Both	Also known 54 km north east of the Project Could be Nocticola sp. NS1 or NS2 from 2011 survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
				SS0016A SS0032A		
	Nocticola sp.	25		GV0208 GV0229 GV0254 NS0755 NS0759 NS0795 SS0005 SS0017 SS0028 SS0042	Both	Higher order, maybe another member of listed Nocticolid species above
	Nocticolidae sp.	5		GV0211	Impact	Higher order, maybe another member of listed Nocticolid species above
Coleoptera						
Carabidae						
Gracilanillus	Gracilanillus `BCO217`	7	10.5km	GVW06 SS0071 NS0752 SS0042	Both	Only known from the Project maybe other members of Anillini sp. NS from 2011 survey
	Carabidae sp.	9		GV0207 SS0048 SS0002 SS0040B	Both	Higher order maybe other members of Gracilanillus `BCO217` above or Anillini sp. NS from 2011 survey

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Curculionidae						
Curculionidae Genus 1	Curculionidae Genus 1 `BCO218`	11	8.4 km	GV0207 NS0788 NS0790 SS0054 SS0003 SS0028 SS0034A	Both	Only known from the Project Could be Curculionidae sp. NS from 2011 survey
Coleoptera gen 1	Coleoptera gen 1 sp. B08	16	32 km	SS0007 NS0794 NS0759 SS0004A SS0026	Both	Also known from 32 km northwest of the Project
Zygentoma						
Nicoletiidae	Atelurinae sp.	1		GV0207	Impact	Higher Order Identification however no known members of this genus from nearby projects
Myriapoda						
Chilopoda						
Cryptopidae						
Cryptops	Cryptops `BSCOL076`	1	Singleton	SS0005	Reference	Currently only known from a single location at the Project
	Cryptops sp. B06 (=SV, B14)	1	240 km	SS0018	Reference	Also known throughout the Hamersley Ranges
Diplopoda						

Higher Order Identification	Lowest Identification	Number of specimens	Linear Distribution	Collection Location	Impact or Reference	Notes on taxonomy
Dalodesmidae	Dalodesmidae `BDI073`	1	Singleton	SS0005	Reference	Currently only known from a single location at the Project



Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 31/07/2023

Legend

- Approved Pits
- Pit Extension

Stygofauna

- Atopobathynella `BSY214`
- Naididae sp. NS
- Tubificidae `BOL066`

Stygofauna Habitat

- Completely Weathered
- Transition Zone

Drawdown Contour

- -1
- -5
- -25

Figure 17. Stygofauna currently known only form impact areas, with associated modelled stygofauna habitat.

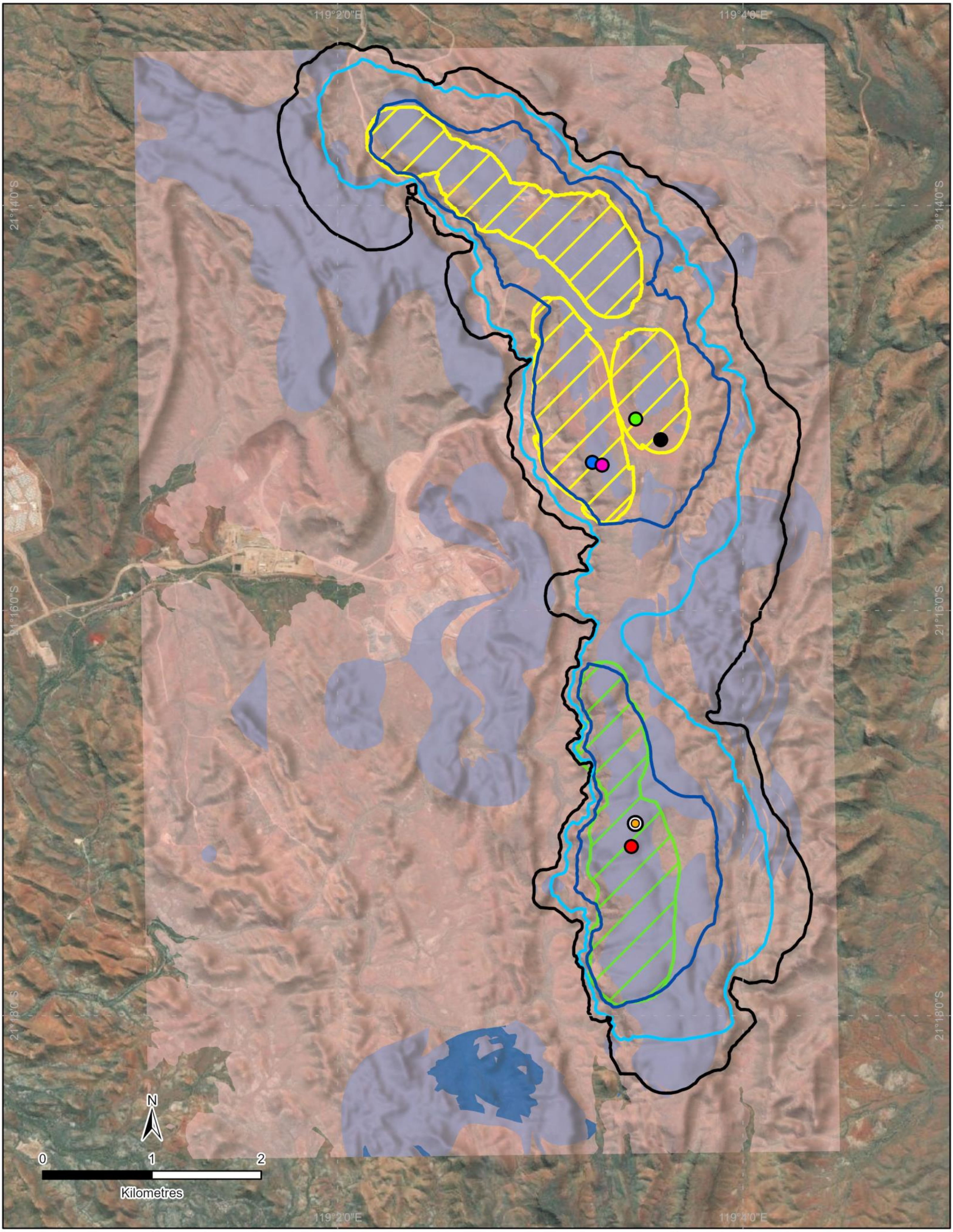


Figure 18. Troglofauna currently known only from impact areas, with associated troglofauna habitat model. All samples collected in 2020-21.

4. GEOLOGICAL MODELLING

Habitat modelling was conducted by AQ2 to infer the presence of habitat extending outside of the proposed pits. The AQ2 full report can be found in Appendix 5 but the results are summarised below.

AQ2 identified that the most likely location for subterranean fauna is within the oxidised zone at depths of between 60 and 70 mbgl. Oxidation zones are defined as weathered and transition zones and fractured bedrock. The models for both stygofauna and troglofauna demonstrated that available habitat extends well beyond the boundaries of the pits and into the surrounding floodplain.

5. DISCUSSION

This Discussion section considers results from both the 2011 survey (Subterranean Ecology 2012) and the 2020-21 survey (this report) as a single dataset. Combined sampling data are presented in Figures 21 and 22 in Appendix 4.

5.1. Habitat Modelling

The stygofauna model demonstrated that stygofauna are unlikely to be found in the pit area due to deep water table and relatively little porous below water-table geology that could harbour stygofauna. Areas where stygofauna were found during the 2020-21 survey often coincided with drainage lines where groundwater was shallower and also a higher incidence of saturated weathered material (Figure 17). In lower lying areas, weathered bedrock more commonly intersects groundwater, providing more appropriate habitat for stygofauna.

Troglofauna habitat was demonstrated to extend over much of the modelled area and well beyond the boundaries of the proposed pits (Figure 18). This is supported by the assessment that all drill holes intersect possible troglofauna habitat. The model suggests that troglofauna habitat extends into the low lying areas both to the east and west of the Project and is considered extensive over the strike of the orebody.

5.2. Stygofauna

Four stygofauna species are currently only known from within proposed impact (2 m drawdown) at the Project, but none of these are expected to be affected by Project activities: these are the worms Tubificidae `BOL066' and Naididae sp. NS and the syncarids *Atopobathynella* `BSY214` and Parabathynellidae sp. (Figure 17). Naididae sp. NS was collected during the 2011/2012 sampling round by Subterranean Ecology (2012) and was located only within the area approved for impact. However, this species was not listed as having conservation concern.

Tubificid Worms

Information is largely lacking on subterranean Tubificidae outside of a handful of descriptions from the various parts of Australia (Pinder and Brinkhurst 2000; Pinder *et al.* 2006). Despite this, it is not uncommon to collect Tubificidae worms in subterranean fauna surveys.

Eight specimens of Tubificidae `BOL066` were collected from a single bore south of the southern extension, situated at the top of the ridge (Figure 17). Depth to water at this location was 35 m and the species will not experience much more than 5 m of drawdown. It occurs in a fractured BIF aquifer. The species is expected to persist in situ.

Other subterranean worms in the area have been collected either from only one hole or as species with wider distributions, such as Enchytraeidae `3 bundle` s.l. (short sclero) collected during the current survey across the length of the strike (Figure 19) and Enchytraeidae sp. indet. which was collected in 2011 (they could be the same species).

Syncarids

Syncarids are small crustaceans that are almost exclusively groundwater inhabitants. The Western Australian syncarid fauna is significantly diverse (Guzik *et al.* 2008; Perina *et al.* 2018). The ranges of many syncarid species (such as Bathynellidae and Parabathynellidae) are typically small with many species endemic to single aquifers or sections of regional aquifers (Guzik *et al.* 2008).

Syncarids are heavily reliant on geological features such as palaeovalleys and calcretes, as they hold water, providing suitable habitat (Guzik *et al.* 2008). While many syncarid species are restricted to specific calcrete aquifers or palaeodrainages, these species are well adapted to life in interstitial spaces through both morphological adaptation (elongate body and reduced appendages) and life history traits such as multiple larval stages (Cho *et al.* 2006).

Atopobathynella `BSY214` and Parabathynellidae sp. were collected from a production bore (NS-Obs14) within a small drainage line only 40 m from the edge of the impact area. This bore is located within a previously approved drawdown so will not be impacted by the current expansion. It is also likely that these species were collected from interstitial spaces associated with the drainage line and therefore have distributions that extend beyond the defined impact area as the drainage line itself extends beyond the impact area.

Widespread species

Enchytraeidae `3 bundle` s.l. (short sclero) is the only species recorded in the impact area that is known to have more widespread occurrence (Figure 19). It was collected from fractured BIF aquifers in both the impact area and outside it. The species occurs across most of Western Australia in a variety of geologies.

5.3. Troglofauna

Seven species of troglofauna are currently only known from impact areas associated with pit voids at the Project (Figure 18). Of these, four are restricted to the approved pit voids: the isopod Armadillidae `BIS438`; the palpigrade *Eukoenenia* `BPAL048`; the spider *Prethopalpus* `BAR135`; and the pseudoscorpion *Tyrannochthonius* `BPS439`. The remainder are restricted to the proposed pit void: the dipluran Japygidae `BDP187`; the isopod Armadillidae `BIS416`; and the silverfish Atelurinae sp. All seven of these species were collected by Bennelongia in the 2020-21 survey; no troglofauna species from the 2011 survey are known to be restricted to impact areas.

Prethopalpus

Prethopalpus sp. was collected from a trap within the approved pit boundary. The standing water level was 55 mbgl and the trap depth was 10 mbgl. This individual is located 200 m from the closest pit wall (Figure 18). The median range for spiders in the Pilbara is 3.7 km (Halse and Pearson 2014). This juvenile individual could not be classified to species; however, given that no other *Prethopalpus* specimens have been recorded from within the desktop search area, it is likely that this will represent a new species.

Palpigrads

The palpigrade *Eukoenenia* `BPAL048` was collected only 89 m from the spider mentioned above, within the approved pit boundary. This individual was collected from a bore that had a standing water level of 90 mbgl from a trap set 20 mbgl. Approximately 300 m from the edge of the pit at its closest point and no other palpigrads were identified in the desktop search area. However, subterranean palpigrads have a median range of 345 km (Halse and Pearson 2014) making it less likely this species will be restricted to the project area.

Pseudoscorpions

Collected at the southern end of the northern deposits, within the approved pit boundary, *Tyrannochthonius* `BPS439` was collected from a bore that had no water and was only 22 m deep. This individual was collected in a trap which was set 20 mbgl. Subterranean pseudoscorpions have a median range of 22 km (Halse and Pearson 2014) and this individual was collected 120 m from the edge of the pit. While this species was not matched through genetics, six of the eight species identified as potential conspecifics in the desktop assessment did not have sequences available for comparison.

Isopods

Two isopod specimens representing two species were collected during the 2020-21 survey. Armadillidae `BIS438` was collected at the southern end of the north star deposits, within the approved pit boundary. Approximately 125 m from the nearest edge of the pit this species was collected from a bore with a standing water depth of 49 m. Unfortunately, the sequence of this failed and has a result could not be compared genetically with other specimens from the region.

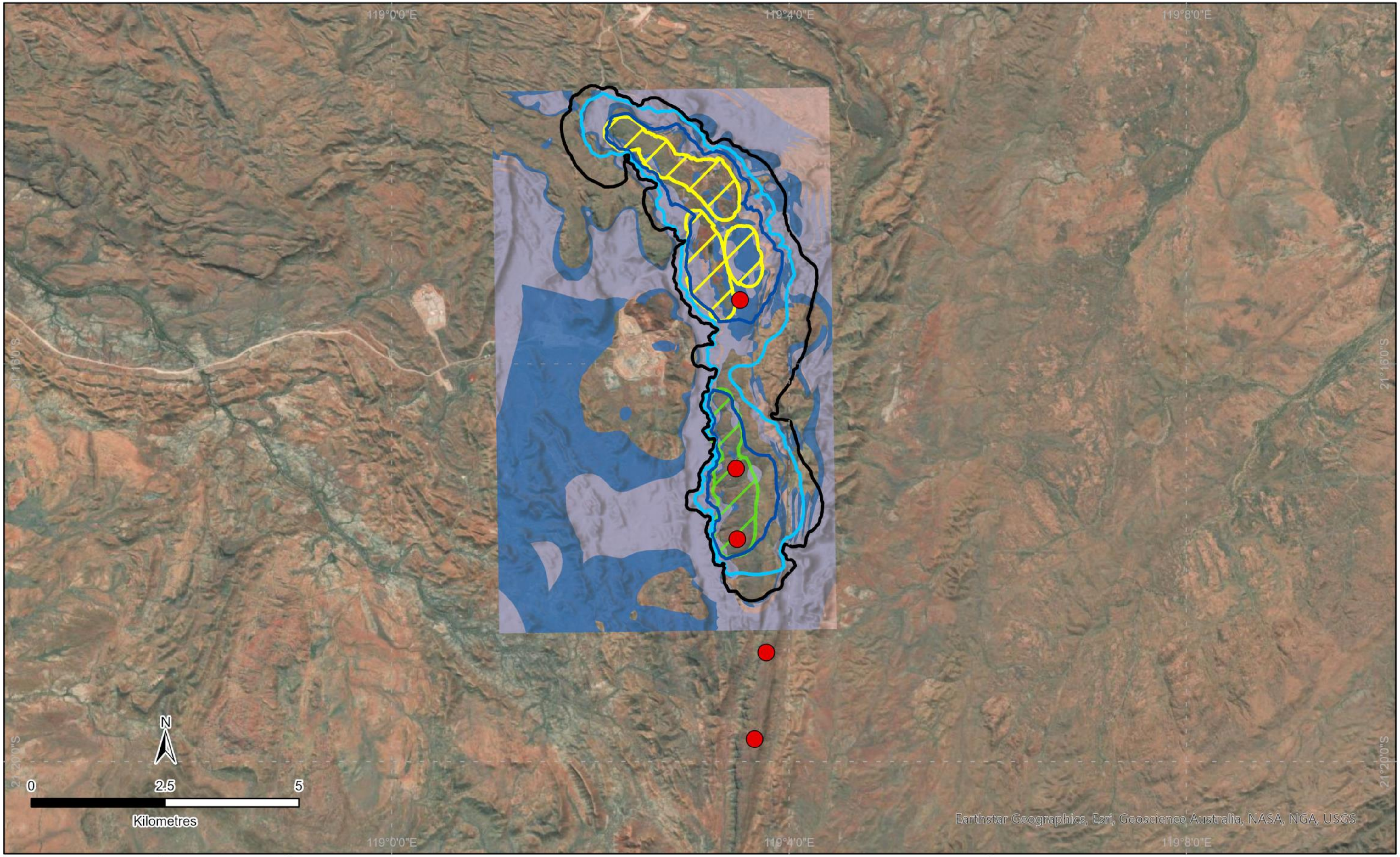


Figure 19. Widespread stygofauna and habitat inside and outside of disturbance areas.

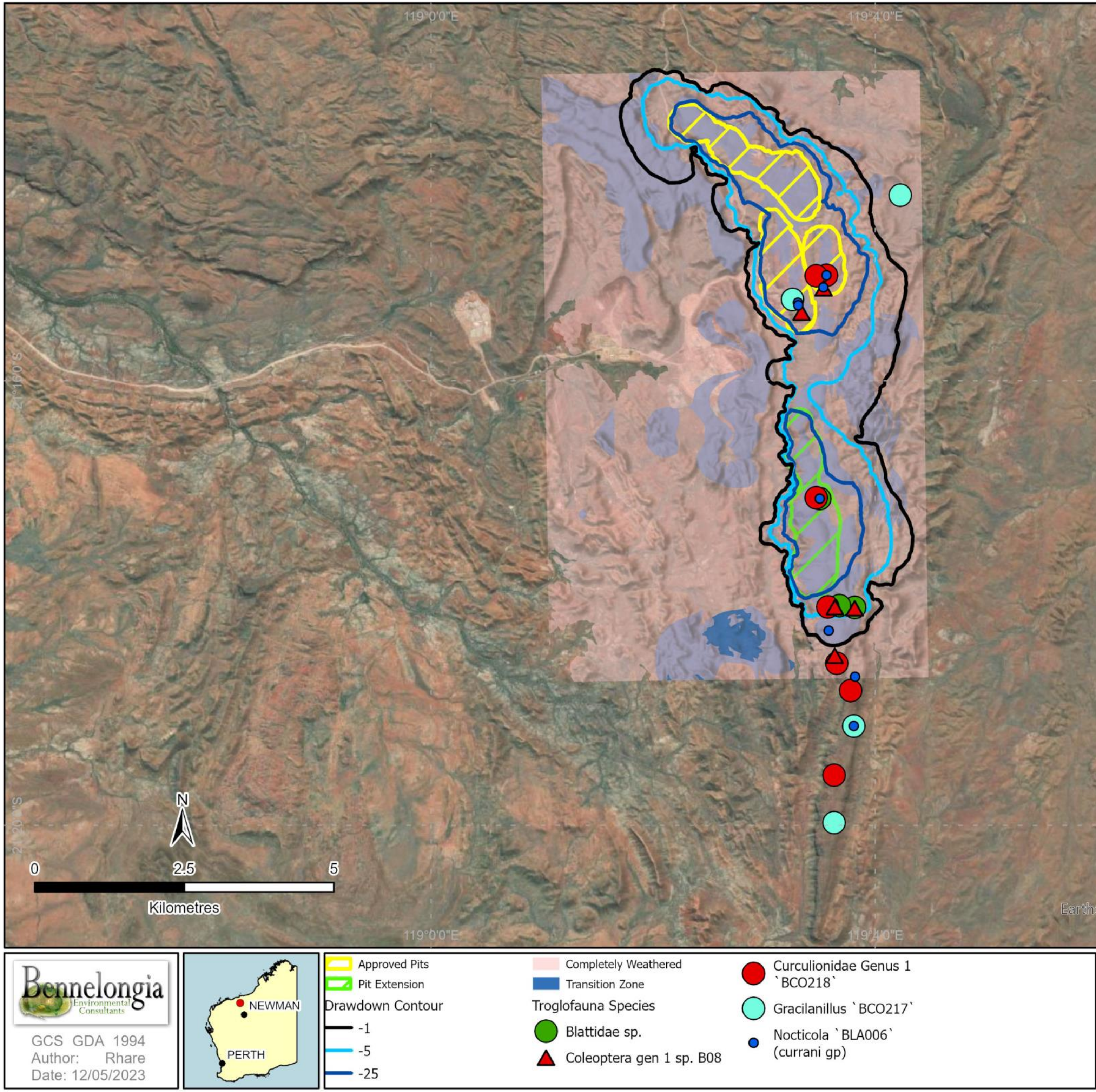


Figure 20. Widespread troglofauna and habitat inside and outside of disturbance areas.

Armadillidae `BIS416` was collected from the centre of the proposed expansion boundary, approximately 240 m from the edge of the pit. The specimen was dead when collected and as a result was not suitable for sequencing. Armadillidae `BIS416` was collected from a scrape in a bore that had a standing water level of 52 m and contained a lot of root material, which provides habitat and energy for subterranean animals.

Isopods have a median distribution of 2.5 km making them one of the more restricted of the troglofauna groups (Halse and Pearson 2014).

Japygids

The taxonomic framework for subterranean diplurans in Australia is underdeveloped at this stage and there is little basis for assessing species ranges besides local collection and habitat data. Having said that, Halse and Pearson (2014) predicted a median range of 16 km for diplurans based on assessing 15 known species. Two individuals of the family Japygidae were collected during the current survey, and adult and a juvenile. Both of these individuals were collected in impact. The adult was assigned the morpho-species Japygidae `BDP187` based on there being no morphological or genetic match.

Japygidae `BDP187` was collected from a bore in the middle of the southern extension (Figure 18). This bore had a standing water depth of 68 mbgl and Japygidae `BDP187` was collected in a trap at a depth of 40 mbgl. This individual was collected approximately 345 m from the edge of the planned pit.

Silverfish

The silverfish Atelurinae sp. was collected from the same bore as Armadillidae `BIS416`, in the proposed expansion, which contained root material and had a standing water depth of 52 m. Approximately 240 m from the edge of the pit, Halse and Pearson (2014) determined that silverfish have a median range of 11 km.

Widespread species.

The four or five species in the impact area with wider local distributions (depending on whether Blattidae sp. is Blattidae sp. B06) all appear to occur moderately widely along strike in BIF (Figure 20), with linear ranges larger than the pits. If this pattern of occurrence occurs is common, the species known only from pits are likely to occur outside as well. Although habitat modelling suggested weathering was limited outside the proposed pits, species occurrence suggests weathering is sufficiently developed along strike to provide habitat for all species known from the proposed pits.

6. CONCLUSION

Historical work conducted at the Project indicated that subterranean fauna exists within the weathered geologies at the Project. The desktop assessment revealed a significant subterranean fauna community throughout the surrounding landscape, with 157 species of stygofauna and 50 species of troglofauna having been previously collected in a 100 X 100 km square surrounding the project. A survey conducted in 2011 collected 17 stygofauna species and 11 troglofauna species (Subterranean Ecology 2012). This survey concluded that there would be very little impact to stygofauna and only one restricted troglofauna species, Curculionidae sp. NS, was at risk from the planned project.

Fortescue is exploring the option of extending the project to the south and as a result, another subterranean survey was required. Bennelongia conducted a two season survey across 2020-21, which resulted in collection of 332 stygofauna specimens from at least 11 species and 102 troglofauna specimens from at least 16 species.

Stygofauna groups represented include the copepods (four species), oligochaete worms (three species), syncarids (two species), ostracods (one species) and nematode worms. Three of these species are currently only known from within predicted drawdown areas at the project, and as such, are at risk due to mining processes. These species are the worm Tubificidae `BOL066` and the syncarids *Atopobathynella* `BSY214` and Parabathynellidae sp.

Eight specimens of Tubificidae `BOL066` were collected from a single bore south of the southern extension (Figure 17). The bore from which this species was collected contained 235 m of water column, providing ample habitat below the anticipated drawdown at this location. AQ2 (Appendix 4), through geological modelling, anticipated that the majority of subterranean fauna would be collected between 60 and 70 mbgl. Additionally, similar species such as Enchytraeidae `3 bundle` s.l. (short sclero) and as Enchytraeidae sp. indet, which could in fact be conspecifics have ranges extending well beyond the planned impact associated with drawdown. As such, it is likely that Tubificidae `BOL066` also has a range extending beyond planned impact.

A total of 57 specimens of *Atopobathynella* `BSY214` and a single higher order syncarid (Parabathynellidae sp.) were collected from a bore (NS-Obs14) from within an area previously approved for dewatering and under 40 m from the edge of the defined impact area. The depth to water at this site was 3.18 m bgl and was located with a drainage line. Knowing that syncarids are well adapted to life in interstitial spaces (Cho *et al.* 2006), it is likely that these species inhabit such spaces associated with the drainage line and therefore have distributions that extend outside of any impact area.

Troglofauna groups collected include beetles (three species), spiders (two species), isopods (two species), cockroaches (two species), centipedes (two species), palpigrads (one species), pseudoscorpions (one species), diplurans (one species), silverfish (one species) and millipedes (one species). Seven of the species have known distributions restricted to impact areas. These are the spider *Prethopalpus* `BAR135`, the palpigrade *Eukoenenia* `BPAL048`, the pseudoscorpion *Tyrannochthonius* `BPS439`, the isopods Armadillidae `BIS416` and Armadillidae `BIS438`, Japygidae `BDP187` and the silverfish Atelurinae sp. All of these individuals were collected at the top of the ridge where modelling by AQ2 has indicated that troglofauna habitat extends extensively along strike and broadly throughout the landscape through low lying areas to the east and west (Appendix 4).

Each of these species were collected withing 400 m of the edge of impact which is smaller than the median ranges for all groups outlined by Halse and Pearson (2014). While impacts on troglofauna will be experienced, the relative amount of habitat removed compared to that modelled throughout the landscape indicates that troglofauna species will have ranges extending beyond the edges of the pit boundaries.

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Appendix 1 – Stygofauna Species Identified During the Desktop Search and Surveys

Impact of current project refers to whether the taxon is known from the impact area (2 m drawdown) of the current project. 0 indicates the taxon is not present in the impact area; 1 indicates the taxon is present in the impact area. Higher order classifications cannot be assigned presence or absence in the impact area because the specimens may belong to one of several species, some of which may be present in the impact area and others of which may not. Distribution categories have been assigned based on sampling and biological information available (VW: very widespread, RW: regionally widespread, LW: locally widespread, LR: locally restricted).

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
Annelida			
Aeolosomatidae			
Aeolosoma	Aeolosoma sp. 1 (PSS)	0	VW
Clitellata	Oligochaeta sp.		Higher order identification
	Oligochaeta sp. S01	0	LW
Enchytraeida			
Enchytraeidae	Enchytraeidae `3 bundle` s.l. (short sclero)		Higher order identification
	Enchytraeidae sp.		Higher order identification
	Enchytraeidae sp. B23	0	LR
	Enchytraeidae sp. B24	0	LR
Enchytraeus	Enchytraeus sp. AP PSS1 s.l.	0	VW
Haplotaxida			
Naididae	Naididae sp. indet		Higher order identification
	Naididae sp. NS	0	LR
Dero	Dero furcata	0	VW
Pristina	Pristina longiseta	0	VW
Phreodrilidae	Phreodrilidae sp. AP DVC B14	0	LR
	Phreodrilidae sp. AP DVC B15	0	LR
	Phreodrilidae sp. AP DVC s.l.		Higher order identification
	Phreodrilidae sp. AP SVC s.l.		Higher order identification
	Phreodrilidae sp. indet		
Tubificidae	Tubificidae `BOL049`	0	LR
	Tubificidae `BOL050`	0	LR
	Tubificidae `BOL066`	1	LR
	Tubificidae `BOL075`	0	LR
	Tubificidae `stygo type 1` (imm Ainudrilus ?WA25/26) (PSS)	0	RW
	Tubificidae `stygo type 4`	0	RW
Monopylephorus	Monopylephorus sp. nov. WA29 (ex Pristina WA3) (PSS)	0	RW
Arthropoda			
Arachnida			
Trombidiformes			

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
Halacaridae	Halacaridae sp.		Higher order identification
`Genus indet.`	Halicaridae `Genus indet.` `sp. 1`		LR
Hydryphantidae			
Wandesia	Wandesia sp.		Higher order identification
Mideopsidae			
Tillia	Tillia `sp.`		Higher order identification
Crustacea			
Malacostraca			
Amphipoda	Amphipoda sp.		Higher order identification
Bogidiellidae	Bogidiellidae sp.		Higher order identification
	Bogidiellidae sp. NS	0	LR
Eriopisidae			
Nedsia	Nedsia `hurlberti group` sp. 1 spine		Higher order identification
	Nedsia hurlberti s.l.		Higher order identification
	Nedsia sp.		Higher order identification
Melitidae	Melitidae `BAM147` (sp. 1 group)	0	LR
	Melitidae `BAM149` (sp. 1 group)	0	LW
	Melitidae `BAM160` (sp. 1 group)	0	LR
	Melitidae sp. 1 group (PSS) s.l.		Higher order identification
	Melitidae sp. B08 (sp. 1 group)	0	LW
	Melitidae sp. NS		
Paramelitidae	Paramelitidae `BAM144`	0	LR
	Paramelitidae `BAM161`	0	LW
	Paramelitidae sp.		Higher order identification
	Paramelitidae sp. 2 s.l. (PSS)		Higher order identification
	Paramelitidae sp. 6 s.l. (PSS)		Higher order identification
	Paramelitidae sp. 7 s.l. (PSS)		Higher order identification
	Paramelitidae sp. NS	1	LR
Molina	Molina sp.		Higher order identification
Paramelitidae Genus 2	Paramelitidae Genus 2 `BAM148`	0	LR
	Paramelitidae Genus 2 `BAM163`	0	LR
	Paramelitidae Genus 2 `BAM164`	0	LR
	Paramelitidae Genus 2 sp.		Higher order identification
	Paramelitidae Genus 2 sp. B15	0	LR
Pilbarus	Pilbarus `BAM145`	0	LR
	Pilbarus sp. S02 (PSS)	0	LW
Isopoda			
Microcerberidae	Microcerberidae `BIS346-DNA`	0	LR
	Microcerberidae `BIS356` (B01 gp)	0	LR

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
	Microcerberidae `BIS357`	0	LR
	Microcerberidae sp.		Higher order identification
	Microcerberidae sp. B11	0	LR
	Microcerberidae sp. B12	0	LR
	Microcerberidae sp. B18	0	LR
Syncarida	Syncarida sp.		Higher order identification
Bathynellidae	Bathynellidae `BSY200`	0	LR
	Bathynellidae sp.		Higher order identification
	Bathynellidae sp. NS	0	LR
Bathynella	Bathynella sp. B25	0	LR
Parabathynellidae	Parabathynellidae sp. NS	0	LR
	Parabathynellidae sp.	1	Higher order identification
Atopobathynella	Atopobathynella `A`	0	LR
	Atopobathynella `BSY201`	0	LR
	Atopobathynella `BSY214`	1	LR
	Atopobathynella sp. B36	0	LR
	Atopobathynella sp. B37	0	LR
Billibathynella	Billibathynella `BSY199`	0	LR
	Billibathynella `sp. MW`	0	LR
	Billibathynella sp. B17	0	LR
Brevisomabathynella	Brevisomabathynella sp. B11	0	LR
Chilibathynella	Chilibathynella sp.		Higher order identification
Hexabathynella	Hexabathynella sp.		Higher order identification
	Hexabathynella sp. B10	0	LR
	Hexabathynella sp. B13	0	LR
Notobathynella	Notobathynella sp.		Higher order identification
nr Brevisomabathynella	nr Brevisomabathynella sp. B12	0	LR
Parabathynellidae gen. nov. 1	Parabathynellidae gen. nov. 1 sp. B10	0	LR
	Parabathynellidae gen. nov. 1 sp. B12	0	LR
Maxillopoda	Copepoda sp.		Higher order identification
Cyclopoida	Cyclopoida sp.		Higher order identification
Cyclopidae			
Diacyclops	Diacyclops `BCY062` (humphreysi s.l.)	0	LW
	Diacyclops `BCY087`	0	LW
	Diacyclops cockingi	0	RW
	Diacyclops einslei	0	RW
	Diacyclops humphreysi s.l.	0	Higher order identification
	Diacyclops humphreysi unispinosus	0	RW

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
	Diacyclops scanloni	0	RW
	Diacyclops sobeprolatus	0	RW
	Diacyclops sp.	0	Higher order identification
	Diacyclops sp. B01 = Diacyclops sp. 4 (PSS)	0	LW
Dussartcyclops	Dussartcyclops (Dussartcyclops) mortoni	0	RW
Meridiecyclops	Meridiecyclops baylyi	0	VW
Mesocyclops	Mesocyclops brooksi	0	VW
	Mesocyclops notius	0	VW
	Mesocyclops sp.		Higher order identification
Metacyclops	Metacyclops sp.		Higher order identification
Microcyclops	Microcyclops varicans	0	VW
nr Goniocyclops (1222)	nr Goniocyclops (1222) `BCY061`	0	LR
Orbuscyclops	Orbuscyclops westaustraliensis	0	RW
Pescecyclops	Pescecyclops `BCY065`	0	LR
	Pescecyclops `BCY066`	0	LR
	Pescecyclops pilbaricus	0	VW
Harpacticoida	Harpacticoida sp.		Higher order identification
Ameiridae			
Gordanitocrella	Gordanitocrella trajani	0	LR
Megastygonitocrella	Megastygonitocrella bispinosa	0	RW
	Megastygonitocrella dec	0	LR
	Megastygonitocrella sp. B05	0	LW
	Megastygonitocrella trispinosa	0	RW
	Megastygonitocrella unispinosa s.l.		Higher order identification
Megastygonitocrella			
Stygonitocrella	Stygonitocrella sp.		Higher order identification
Canthocamptidae	Canthocamptidae `BHA267`	0	LR
	Canthocamptidae sp.		Higher order identification
Australocamptus	Australocamptus `BHA258`	0	LR
Elaphoidella	Elaphoidella humphreysi s.l.		Higher order identification
	Elaphoidella sp.		Higher order identification
	Elaphoidella sp. B09	0	LR
Ectinosomatidae			
Pseudectinosoma	Pseudectinosoma galassiae	0	RW
Parastenocarididae	Parastenocarididae sp.		Higher order identification
Parastenocarididae n. gen.	Parastenocarididae n. gen. `BHA259`	0	LR
	Parastenocarididae n. gen. `BHA265`	0	LW
	Parastenocarididae n. gen. sp. B01	0	LR

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
Parastenocaris	Parastenocaris `BHA268`	0	LR
	Parastenocaris `BHA298`	0	LR
	Parastenocaris jane	0	VW
	Parastenocaris sp.		Higher order identification
	Parastenocaris sp. nov. B03 (PIL)		LR
Ostracoda	Ostracoda `BOS1293`	0	LR
	Ostracoda `BOS645`	0	LR
	Ostracoda sp. NS1	0	LR
	Ostracoda sp. NS2	0	LR
	Ostracoda sp. NS3	0	LR
	Ostracoda sp. unident.		Higher order identification
Podocopida			
Candonidae	Candonidae `BOS1292`	0	LR
	Candonidae `BOS1332`	0	LR
	Candonidae `BOS1333`	0	LR
	Candoninae sp.		Higher order identification
?Candoninae	?Candoninae sp.		Higher order identification
Areacandona	Areacandona ?incogitata	0	LR
	Areacandona `BOS579`	0	LR
	Areacandona `calmi` (PSS)	0	RW
	Areacandona akatallele	0	LW
	Areacandona dec	0	LW
	Areacandona jessicae	0	LW
	Areacandona yuleae	0	RW
	Areacandona nr korallion	0	LW
Candonopsis	Candonopsis `1` (PSS)	0	LW
	Candonopsis nr tenuis	0	LW
	Candonopsis pilbarae	0	RW
	Candonopsis tenuis	0	VW
Leicacandona	Leicacandona `BOS1343`	0	LR
	Leicacandona `BOS1354`	0	LR
	Leicacandona `BOS1356`	0	LR
	Leicacandona `BOS1357`	0	LR
	Leicacandona lite	0	LR
Meridiescandona	Meridiescandona lucerna	0	LW
Cypridiae	Cypridiae sp. indet		Higher order identification
Cyprididae	Cyprididae sp.		Higher order identification
?Ampullacypris	?Ampullacypris `BOS1341`	0	VW
?Cypretta	?Cypretta sp.		Higher order identification
Cypretta	Cypretta `BOS1353`	0	LR
	Cypretta seurati	0	RW

Higher Order Identifications	Lowest Identification	Impact of current project	Distribution categories
	Cypretta sp.		Higher order identification
Cypridopsis	Cypridopsis `BOS1337`	0	LR
	Cypridopsis sp.		Higher order identification
Cyprinotus	Cyprinotus kimberleyensis s.l.		
Heterocypris	Heterocypris sp.		Higher order identification
Ilyodromus	Ilyodromus sp.		Higher order identification
Riocypris	Riocypris fitzroyi	0	RW
Stenocypris	Stenocypris major	0	RW
Strandesia	Strandesia sp.		Higher order identification
Darwinulidae	Darwinulidae sp.		Higher order identification
Penthesilenula	Penthesilenula brasiliensis	0	RW
Vestalenula	Vestalenula matildae	0	RW
Ilyocyprididae			
Ilyocypris	Ilyocypris sp.		Higher order identification
Limnocytheridae			
Gomphodella	Gomphodella `6` (PSS)	0	LW
	Gomphodella aura	0	LR
	Gomphodella pilbarensis	0	LR
	Gomphodella sp.		Higher order identification
Limnocythere	Limnocythere dorsosicula	0	VW
Hexapoda			
Insecta			
Coleoptera	Coleoptera `sp.`		Higher order identification
Nematoda	Nematoda sp. 17 (PSS)	0	LR
	Nematoda sp. 20 (PSS)		
	Nematoda spp.		Higher order identification
Platyhelminthes			
Turbellaria	Turbellaria sp.		Higher order identification
Rotifera			
Eurotatoria			
Bdelloidea	Bdelloidea sp. 2:2	0	VW

Appendix 2 – Troglofauna Species Identified During the Desktop Search and Surveys

Impact of current project refers to whether the taxon is known from within the pit boundaries of the current project. 0 indicates the taxon is not present in the impact area; 1 indicates the taxon is present in the impact area. Higher order classifications cannot be assigned presence or absence in the impact area because the specimens may belong to one of several species, some of which may be present in the impact area and others of which may not. Distribution categories have been assigned based on sampling and biological information available (VW: very widespread, RW: regionally widespread, LW: locally widespread, LR: locally restricted).

Higher Order Identification	Lowest Identification	Impact of current Project	Distribution categories
Arthropoda			
Arachnida			
Oonopidae	Oonopidae 'BAR134'	0	LR
	Prethopalpus 'BAR135'	1 (approved pit)	LR
Anapistula	Anapistula `sp. MW`	0	LR
	Anapistula sp.		Higher order identification
Pseudoscorpiones			
Chthoniidae	Chthoniidae sp. NS	0	LR
Tyrannochthonius	Tyrannochthonius `abydos`	0	LR
	Tyrannochthonius `BPS228`	0	LR
	Tyrannochthonius 'BPS439'	1 (approved pit)	LR
	Tyrannochthonius `sp. AB A`	0	LR
	Tyrannochthonius `sp. AB B`	0	LR
	Tyrannochthonius `sp. AB`	0	LR
	Tyrannochthonius aridus	0	RW
	Tyrannochthonius sp. B38	0	LR
Hyidae			
Indohya	Indohya `BPS201`	0	LR
	Indohya `BPS202`	0	LR
	Indohya `sp. MW`	0	LR
Schizomida			
Draculoides	Draculoides `sp. MW`	0	LR
Palpigradi			
Euloenenia	Eukoenenia 'BPAL48'	1 (approved pit)	LR
Crustacea			
Isopoda			
Armadillidae	Armadillidae "BIS416'	1 (expansion pit)	LR

	Armadillidae "BIS438'	1 (approved pit)	LR
	Armadillidae sp. B13	0	LR
?Troglarmadillo	?Troglarmadillo `sp.`		Higher order identification
Troglarmadillo	Troglarmadillo sp.		Higher order identification
	Troglarmadillo sp. NS	0	LR
Hexapoda			
Diplura			
Anajapygidae	Anajapygidae sp. NS	0	LR
Japygidae	Japygidae 'BDP187'	1 (expansion pit)	LR
Parajapygidae	Parajapygidae `BDP181`	0	LR
	Parajapygidae sp. B40	0	LR
Insecta			
Blattodea	Blattodea `sp. AB_NS`	0	RW
Blattidae	Blattidae sp. B06	0	RW
Nocticolidae			
Nocticola	Nocticola currani	0	LW
	Nocticola quartermainei	0	RW
	Nocticola 'BLA006'	0	RW
	Nocticola sp. S5_NS1	0	LR
	Nocticola sp. NS2	0	LR
Coleoptera			
Carabidae	Anillini `sp.`		Higher order identification
	Anillini sp. NS	0	LR
Gracilanillus	Gracilanillus 'BCO217'	0	LR
Curculionidae	Curculionidae `sp.`		Higher order identification
	Curculionidae Genus 1 'BCO218'	0	LR
	Cryptorhynchinae `BCO192`	0	LR
	Curculionidae sp. NS	1	LR
Ptiliidae			
Ptinella	Ptinella sp.		Higher order identification
Coleoptera gen 1	Coleoptera gen 1 sp. B08	0	LW
Diptera			
Allopnyxia	Allopnyxia sp. B01	0	VW
Hemiptera			

Meenoplidae	Meenoplidae `sp.`		Higher order identification
	Meenoplidae sp. NS	0	LR
Phaconeura	Phaconeura sp.		Higher order identification
Zygentoma			
Nicoletiidae			
Dodecastyla	Dodecastyla sp.		Higher order identification
Hemitrinemura	Hemitrinemura sp.		Higher order identification
Subtrinemura	Subtrinemura sp.		Higher order identification
	Subtrinemura sp. B03	0	LR
Trinemura	Trinemura `BZY088`	0	LR
	Trinemura sp.		Higher order identification
Trinemurodes	Trinemurodes sp.		Higher order identification
Myriapoda			
Chilopoda			
Cryptopidae			
Cryptops	Cryptops 'BSCOL076'	0	RW
	Cryptops sp. Bo6	0	RW
Dalodesmidae	Dalodesmidae 'BDI073'	0	RW
Diplopoda			
Prosopodesmus	Prosopodesmus nr `OES8`	0	LR
Polyxenida	Polyxenida sp. indet		Higher order identification
Spirobolida			
Trigoniulidae	Trigoniulidae sp.		Higher order identification
Pauropoda			
Tetramerocerata			
Pauropodidae	Pauropodidae `BPU083`	0	LR
	Pauropodidae `BPU084`	0	LR
	Pauropodidae `BPU085`	0	LR
	Pauropodidae `BPU086`	0	LR
	Pauropodidae sp. B01 s.l.	0	VW
	Pauropodidae sp. B38 (B04 group)	0	LR
Symphyla			
Symphylella	Symphylella sp.		Higher order identification
	Symphylella sp. B22	0	LR

Scutigerellidae			
Scutigerella	Scutigerella sp.		Higher order identification
	Symphyla sp.		Higher order identification

Appendix 3 – Sampled holes for 2020-2021 subterranean fauna survey

Field code	Latitude	Longitude	Sample Type
1B-NST-M01	-21.256	119.0585	Stygofauna
GV0206	-21.2842	119.057	Troglofauna
GV0207	-21.2842	119.0578	Troglofauna
GV0208	-21.2844	119.0583	Troglofauna
GV0209	-21.2852	119.0569	Troglofauna
GV0210	-21.2851	119.0574	Troglofauna
GV0211	-21.2852	119.0579	Troglofauna
GV0213	-21.2861	119.0575	Troglofauna
GV0224	-21.2879	119.0328	Stygofauna
GV0226	-21.2889	119.0569	Troglofauna
GV0227	-21.2863	119.0595	Stygofauna
GV0228	-21.2887	119.0585	Stygofauna
GV0229	-21.2897	119.0566	Troglofauna
GV0232	-21.2908	119.0623	Stygofauna
GV0232	-21.2896	119.0581	Troglofauna
GV0241	-21.2946	119.0577	Troglofauna
GV0243	-21.2945	119.0585	Troglofauna
GV0250	-21.2925	119.0584	Troglofauna
GV0254	-21.2933	119.0561	Troglofauna
GV0263	-21.2952	119.0565	Troglofauna
GV0264	-21.295	119.0572	Troglofauna
GV0266	-21.2952	119.0581	Troglofauna
GVD0009	-21.2961	119.058	Troglofauna
GVD0011	-21.2886	119.0569	Stygofauna
GVD0012	-21.288	119.0578	Stygofauna
GVRD0289	-21.2888	119.058	Troglofauna
GVW06	-21.2389	119.0704	Stygofauna
IBM01	-21.2732	119.0588	Stygofauna
NS0079	-21.2392	119.0516	Stygofauna
NS0305	-21.2549	119.0551	Troglofauna
NS0306	-21.2547	119.0551	Troglofauna
NS0624	-21.2297	119.065	Stygofauna
NS0663	-21.2119	119.0489	Stygofauna
NS-Obs14	-21.2469	119.0489	Stygofauna
NS0752	-21.2545	119.0543	Troglofauna
NS0755	-21.2554	119.0551	Troglofauna
NS0759	-21.2563	119.0556	Troglofauna
NS0760	-21.2562	119.0551	Troglofauna
NS0788	-21.2509	119.0578	Troglofauna
NS0789	-21.2507	119.0583	Troglofauna
NS0790	-21.2508	119.0593	Troglofauna
NS0791	-21.2508	119.0603	Troglofauna

Field code	Latitude	Longitude	Sample Type
NS0794	-21.2527	119.0589	Troglofauna
NS0795	-21.2526	119.0599	Troglofauna
NSEXS35	-21.2774	119.0298	Stygofauna
NSEXS36	-21.2794	119.0314	Stygofauna
NSOBS024	-21.2172	119.045	Stygofauna
NSOBS029	-21.2355	119.0437	Stygofauna
NSOBSS19	-21.2849	119.0269	Stygofauna
NSPB01	-21.2425	119.0547	Stygofauna
SS0001	-21.3005	119.058	Troglofauna
SS0002	-21.3006	119.0596	Troglofauna
SS0002A	-21.3005	119.0584	Troglofauna
SS0003	-21.3006	119.0595	Troglofauna
SS0004	-21.3005	119.0607	Troglofauna
SS0004A	-21.3005	119.0606	Troglofauna
SS0005	-21.3004	119.0613	Troglofauna
SS0006	-21.3005	119.0585	Troglofauna
SS0007	-21.3006	119.0636	Troglofauna
SS0016	-21.3042	119.0598	Troglofauna
SS0016A	-21.3042	119.0597	Troglofauna
SS0017	-21.3041	119.0605	Troglofauna
SS0018	-21.3041	119.0617	Troglofauna
SS0018A	-21.3041	119.0616	Troglofauna
SS0025B	-21.3078	119.0597	Troglofauna
SS0026	-21.3077	119.0606	Troglofauna
SS0027	-21.3077	119.0615	Troglofauna
SS0028	-21.309	119.0609	Troglofauna
SS0032	-21.311	119.0637	Troglofauna
SS0032A	-21.3111	119.0637	Troglofauna
SS0034A	-21.3131	119.063	Troglofauna
SS0035	-21.3131	119.064	Troglofauna
SS0036	-21.315	119.0629	Troglofauna
SS0036A	-21.3151	119.0629	Troglofauna
SS0040	-21.3184	119.0621	Troglofauna
SS0040B	-21.3185	119.0617	Troglofauna
SS0042	-21.3185	119.0634	Troglofauna
SS0047	-21.3222	119.0613	Troglofauna
SS0048	-21.322	119.0625	Troglofauna
SS0054	-21.3258	119.0605	Troglofauna
SS0055	-21.3257	119.0613	Troglofauna
SS0056	-21.3258	119.0621	Troglofauna
SS0061	-21.3292	119.0595	Troglofauna
SS0063	-21.3296	119.0609	Troglofauna
SS0071	-21.3329	119.0605	Troglofauna
SS0082	-21.34	119.0587	Troglofauna

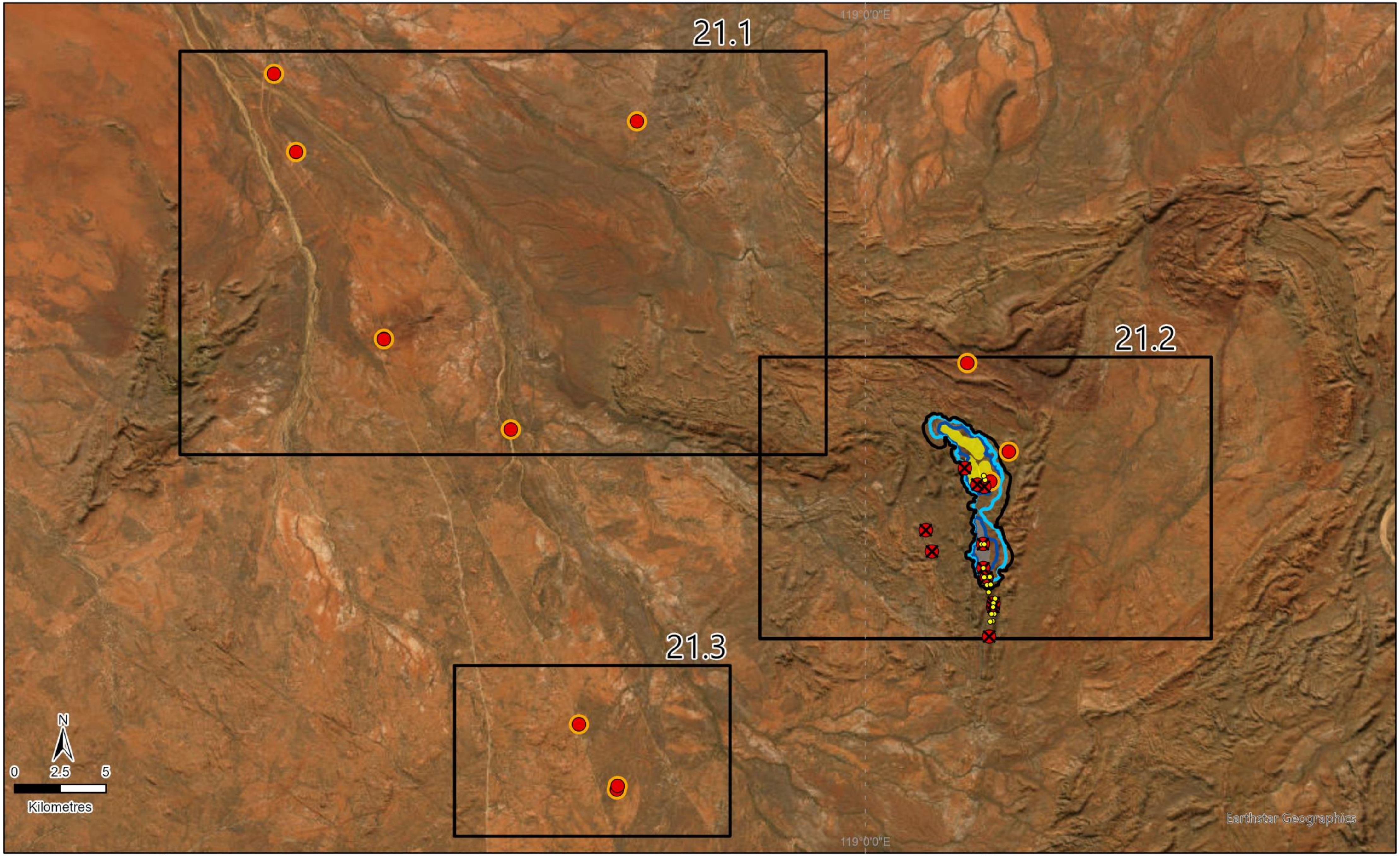
Field code	Latitude	Longitude	Sample Type
SS0083	-21.2852	119.0578	Troglofauna
SS0086	-21.3439	119.0584	Troglofauna

Appendix 4 – Additional maps

The maps on the following pages display all the records collected across both surveys (2011, conducted by Subterranean Ecology; and 2020-2021, conducted by Bennelongia) for stygofauna and troglofauna.

For stygofauna, one overview map is presented, followed by three maps providing detail of the main map.

For troglofauna, there is one overview map and four detailed sub-maps.



Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 31/07/2023

Legend

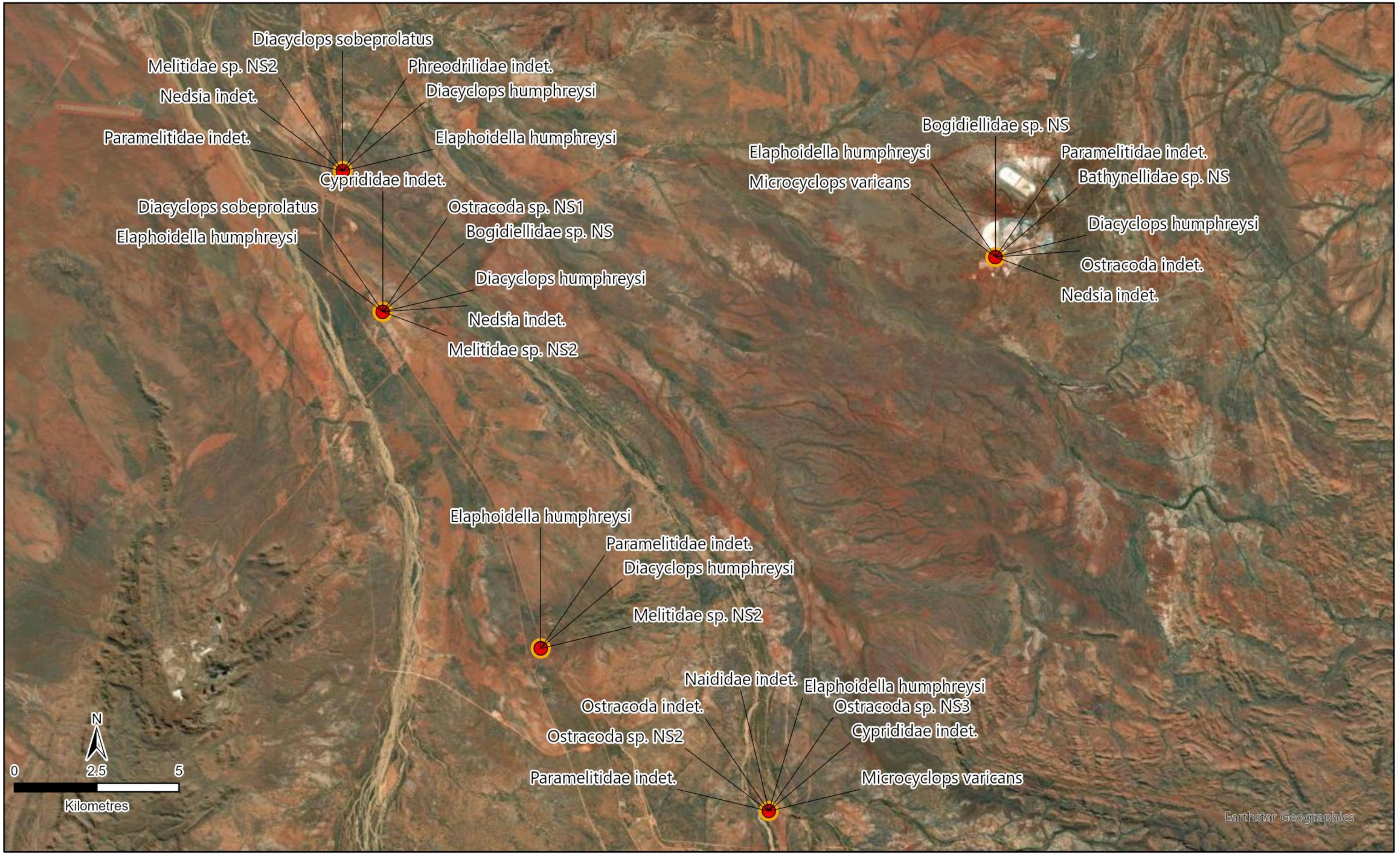
- Stygofauna
- Subterranean Ecology samples
- Bennelongia samples
- Nematoda spp. (not assessed)

Drawdown Contour

- -1
- -5
- -25

- Approved Pit
- Pit Extension

Figure 21. Combined stygofauna data from 2011 (Subterranean Ecology) and 2020-2021 (Bennelongia) surveys. Labelled insets are expanded in subsequent maps.

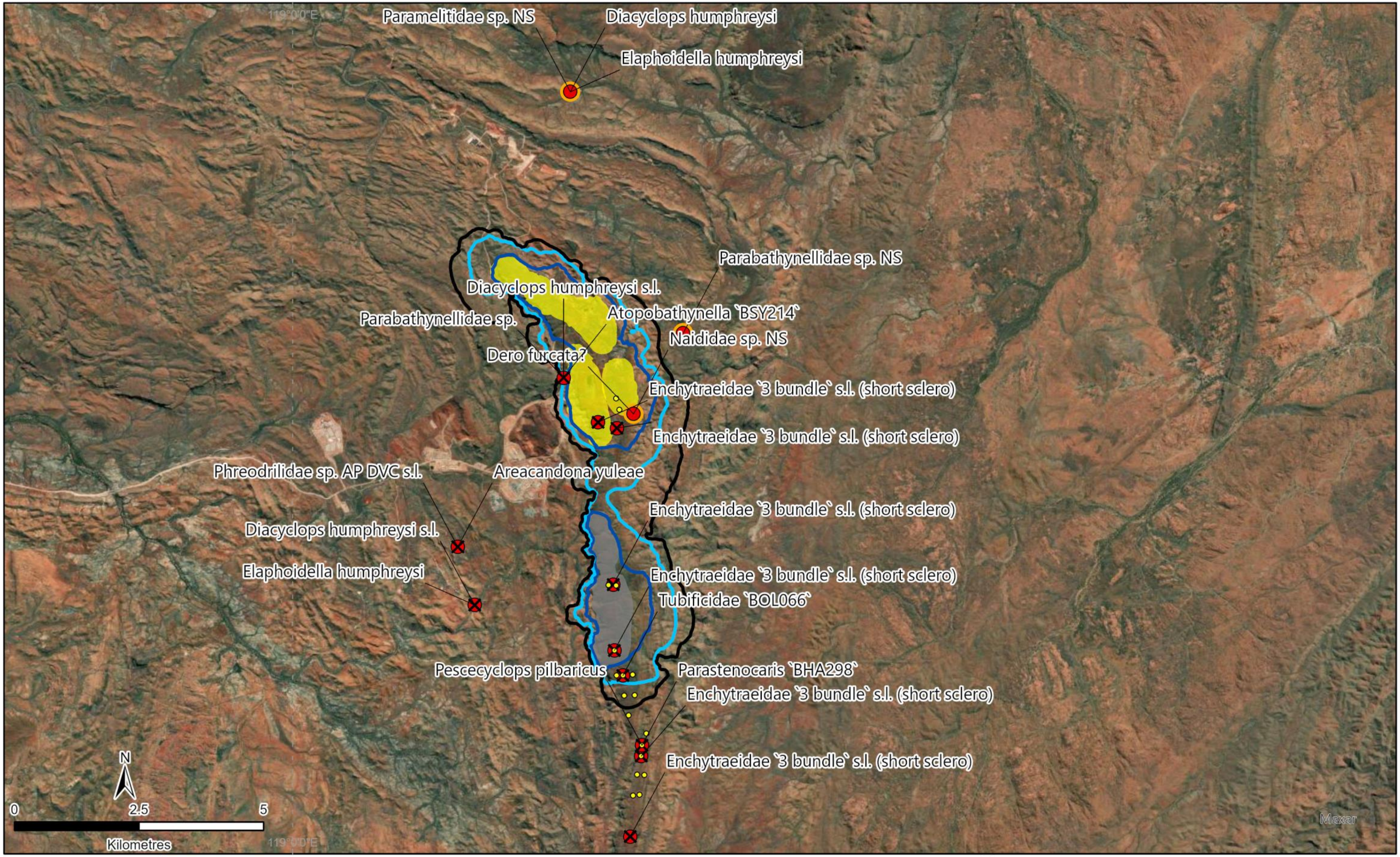


Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 14/07/2023

Legend
- Stygofauna
- Subterranean Ecology samples

Figure 21.1. Detail of stygofauna collected across both surveys (2011 and 2020-2021), 1 of 3.



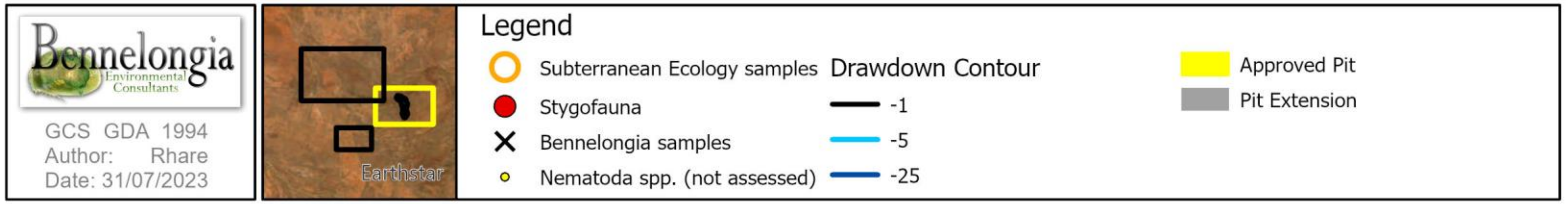
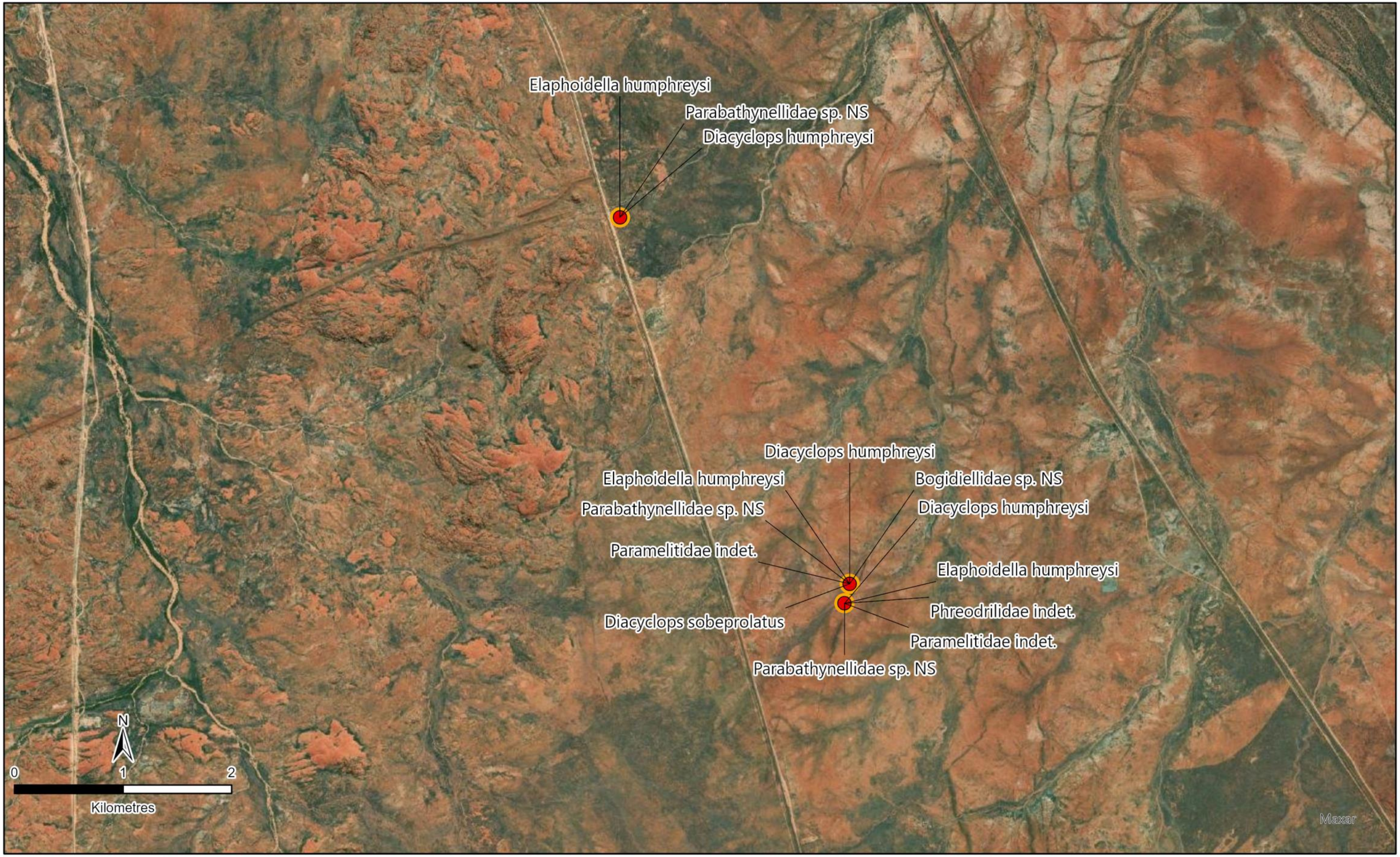
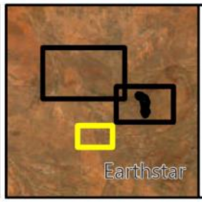


Figure 21.2. Detail of stygofauna collected across both surveys (2011 and 2020-2021), 2 of 3.



Bennelonga Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 14/07/2023



Legend

- Stygofauna
- Subterranean Ecology samples

Figure 21.3. Detail of stygofauna collected across both surveys (2011 and 2020-2021), 3 of 3.

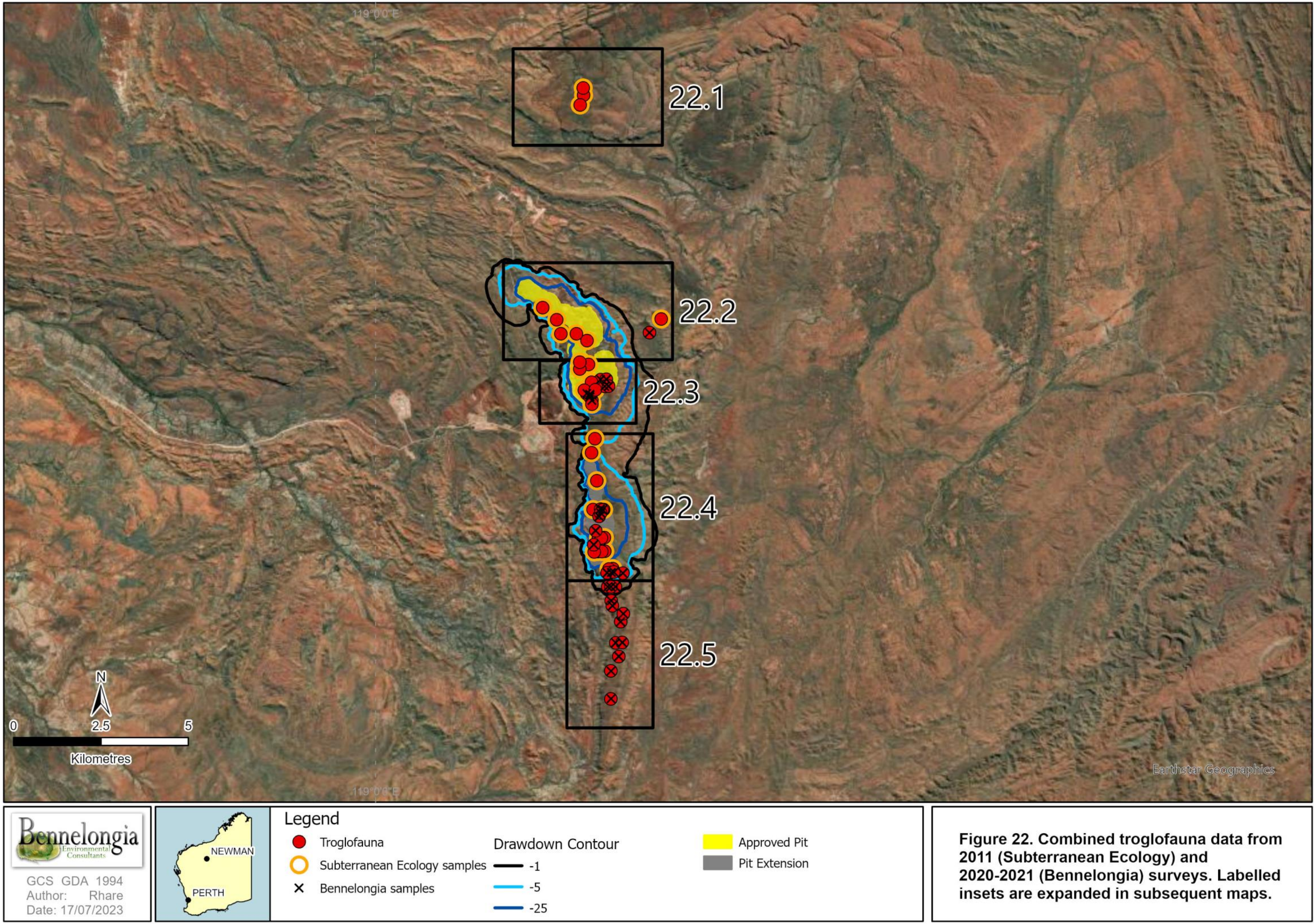
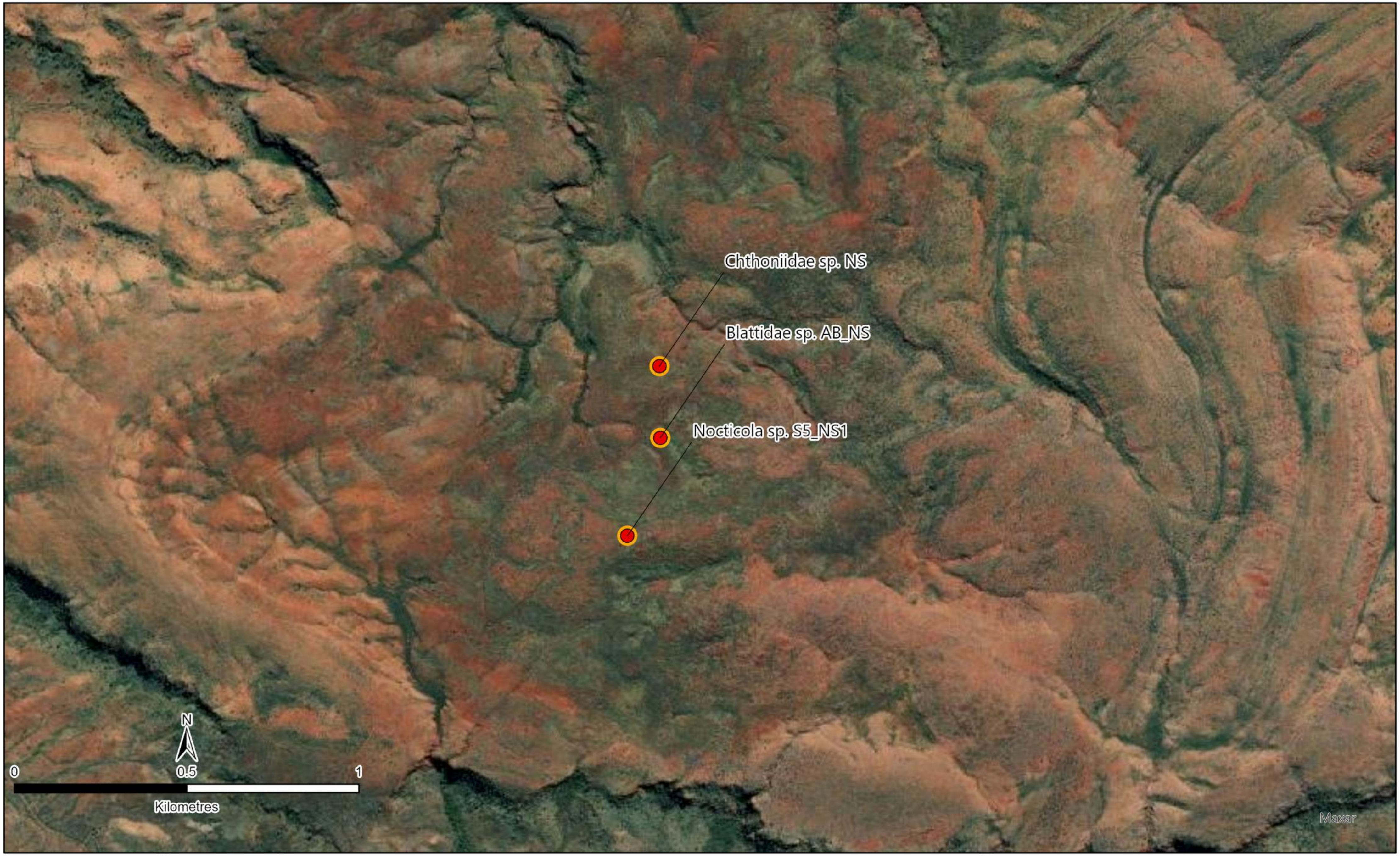


Figure 22. Combined troglofauna data from 2011 (Subterranean Ecology) and 2020-2021 (Bennelongia) surveys. Labelled insets are expanded in subsequent maps.



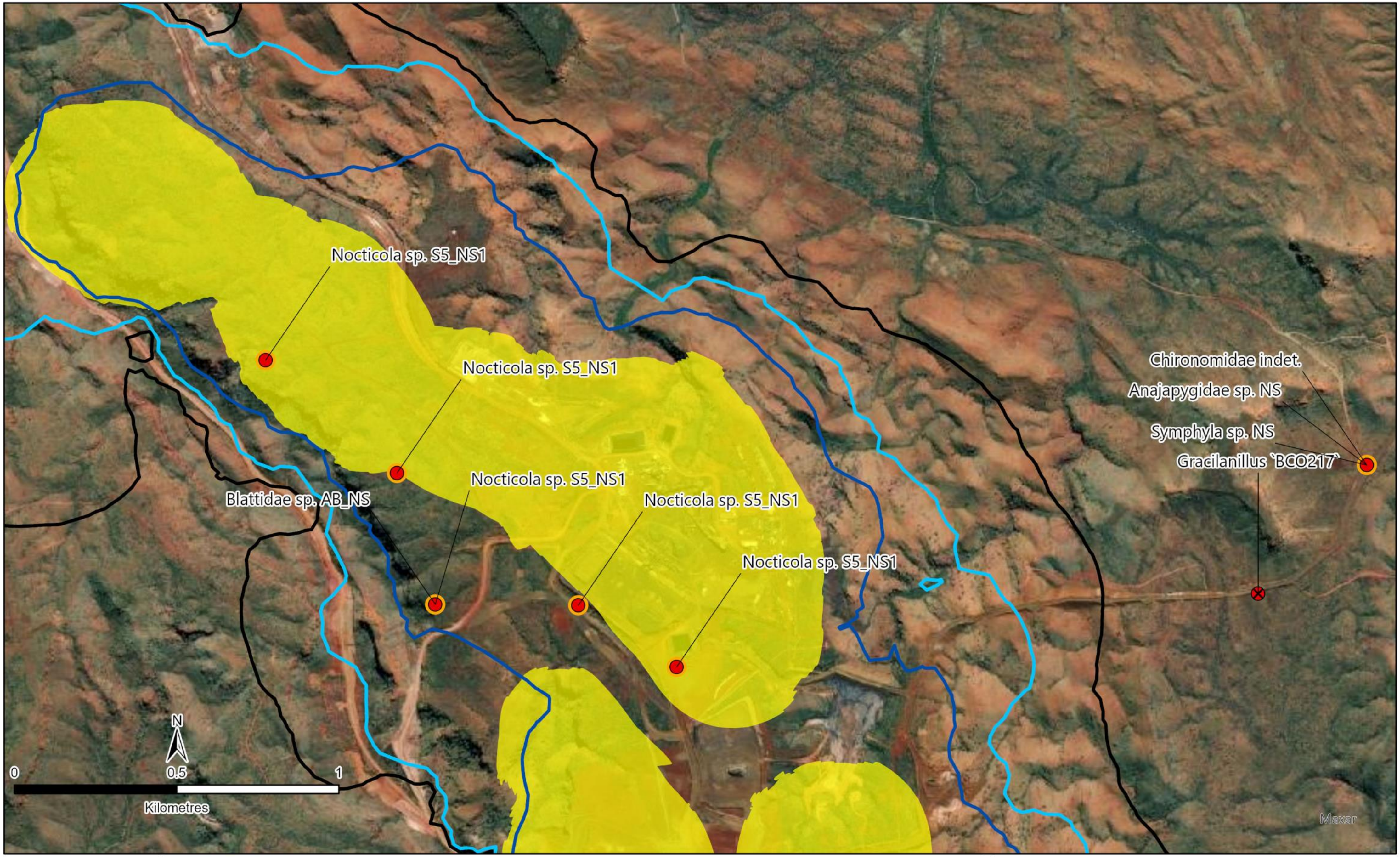
Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 17/07/2023

Legend

- Troglofauna
- Subterranean Ecology samples
- × Bennelongia samples

Figure 22.1. Detail of troglofauna collected across both surveys (2011 and 2020-2021), 1 of 5.



Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 17/07/2023

Legend

- Troglofauna
- Subterranean Ecology samples
- × Bennelongia samples

Drawdown Contour

- -1
- -5
- -25

- Approved Pit
- Pit Extension

Figure 22.2. Detail of troglofauna collected across both surveys (2011 and 2020-2021), 2 of 5.

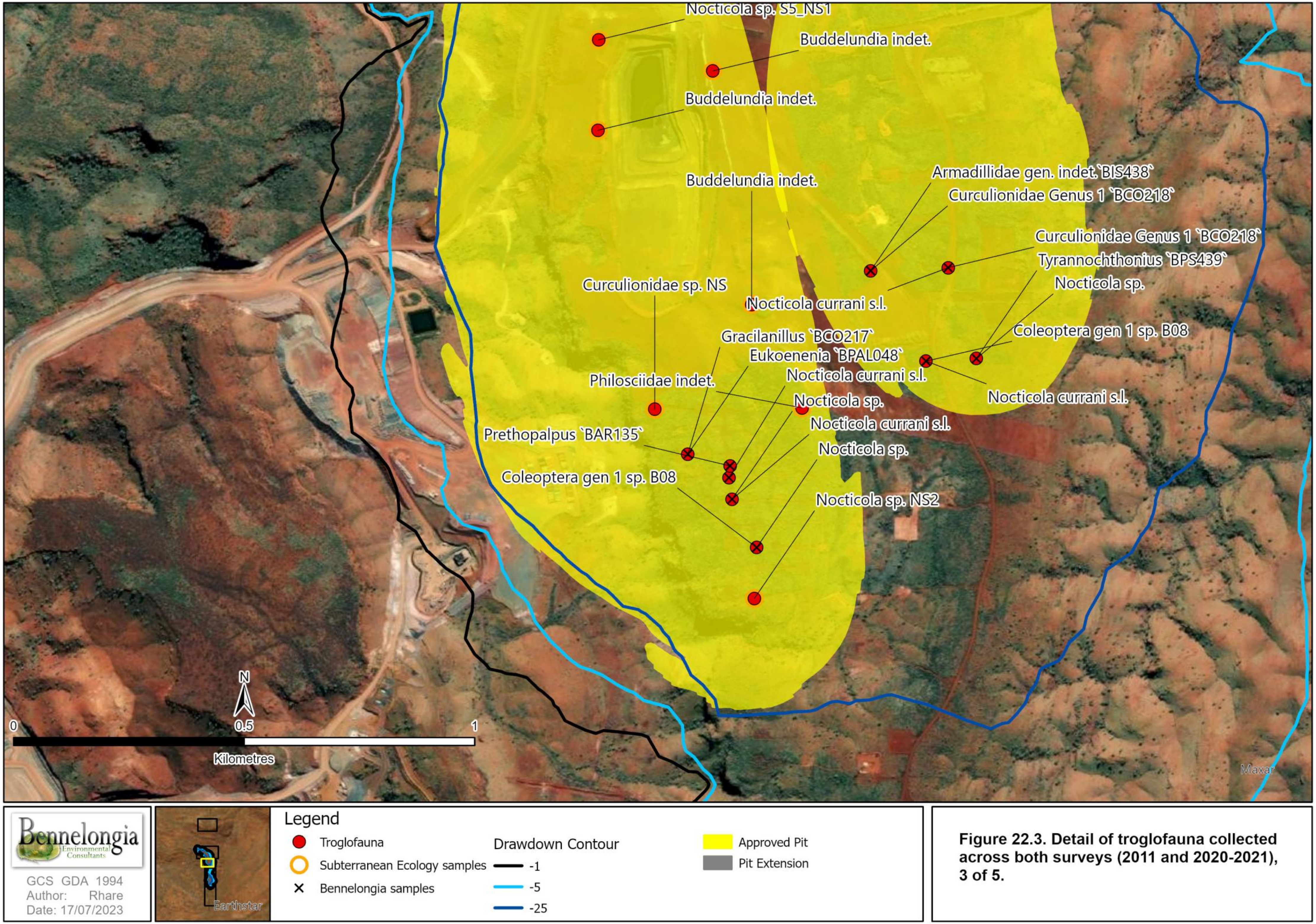


Figure 22.3. Detail of troglofauna collected across both surveys (2011 and 2020-2021), 3 of 5.

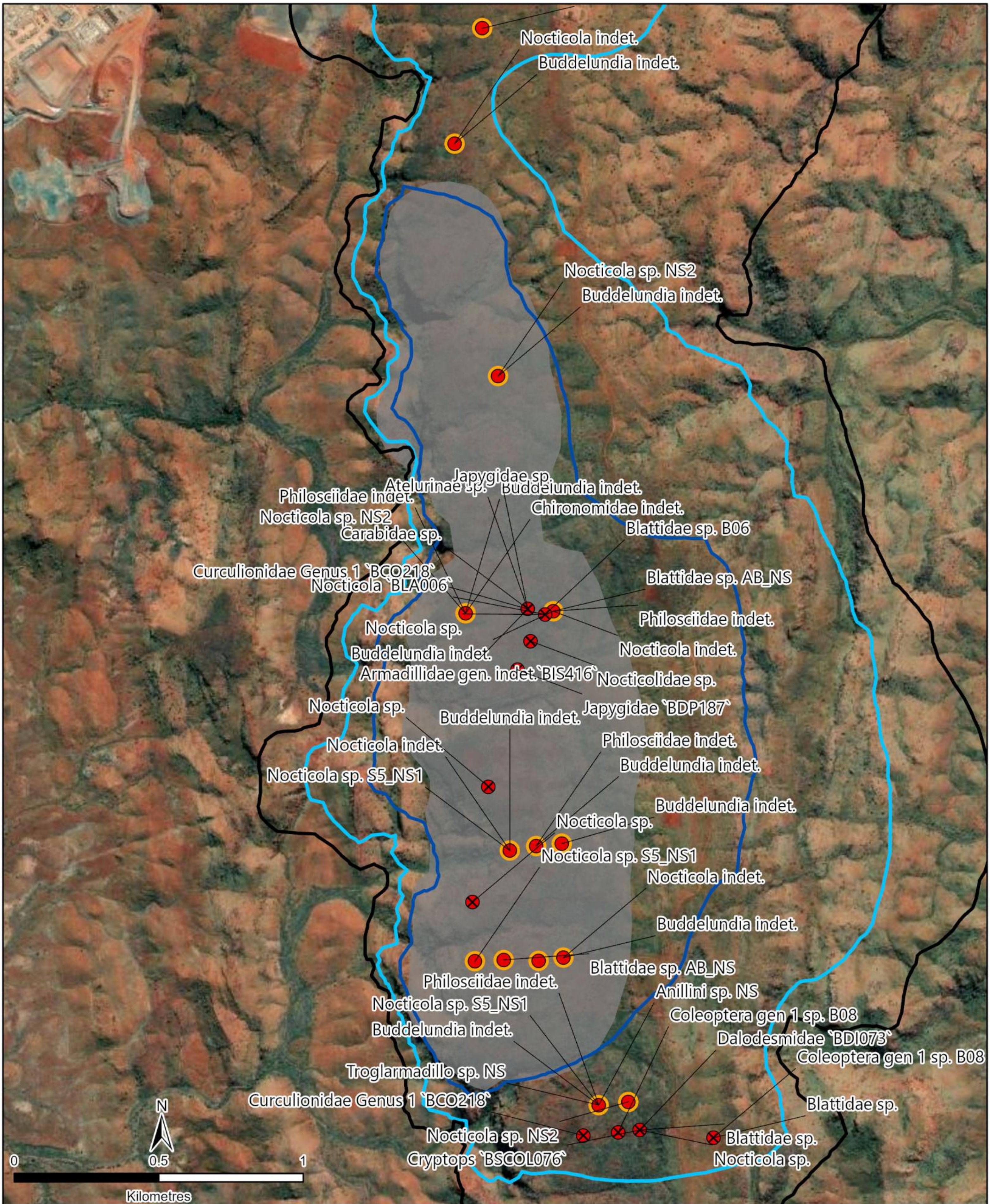


Figure 22.4. Detail of troglofauna collected across both surveys (2011 and 2020-2021), 4 of 5.

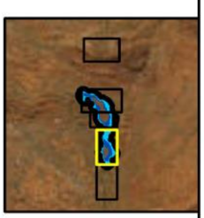
Legend

- Troglofauna
- Subterranean Ecology samples
- × Bennelongia samples

Drawdown Contour

- -1
- -5
- -25

Pit Extension



Bennelongia Environmental Consultants

GCS GDA 1994
Author: Rhare
Date: 17/07/2023

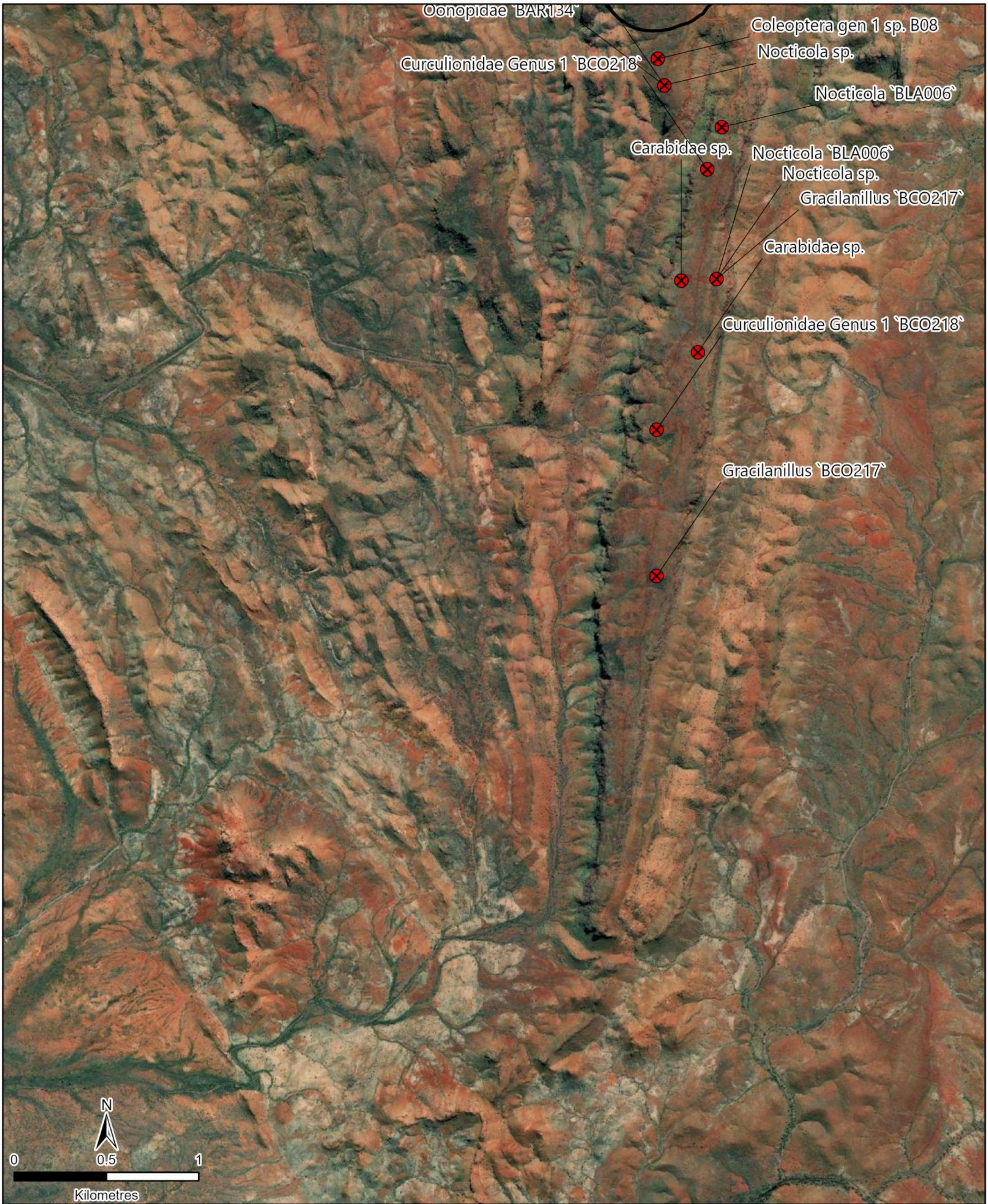


Figure 22.5. Detail of troglofauna collected across both surveys (2011 and 2020-2021), 5 of 5.

Legend

Troglofauna

Subterranean Ecology samples

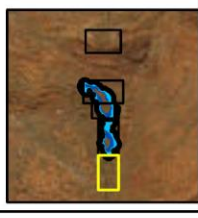
× Bennelongia samples

Drawdown Contour

-1

-5

-25



Bennelongia Environmental Consultants

GCS GDA 1994

Author: Rhare

Date: 17/07/2023

Appendix 5 – AQ2 habitat modelling report

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Memo

To	Huon Clark / Stuart Halse	Company	Bennelongia Environmental Consultants
From	Alex Storey / Duncan Storey	Job No.	432
Date	09/06/2022	Doc No.	003b
Subject	Iron Bridge Sub-terranean Fauna Habitat Modelling		

We are pleased to present our assessment of possible sub-terranean (troglofauna and stygofauna) habitat around FMGL's Iron Bridge Magnetite Project area.

1. INTRODUCTION

Bennelongia are undertaking a habitat assessment for sub-terranean species for FMGL's Iron Bridge Magnetite Project in the Pilbara region of Western Australia. The study is located ~1200 km north-northeast of Perth and ~110 km southeast of Port Hedland. This study aims to assess the extent and continuity of specific geological environments that are habitable for troglofauna and stygofauna. Bennelongia have undertaken sub-terranean fauna sampling on existing FMG mineral exploration holes, and the data has been used to assess the distribution of troglofauna and stygofauna. Bennelongia engaged AQ2 to assist with habitat assessment and our results are detailed below.

2. HABITAT CRITERIA

The sub-terranean fauna habitat assessment modelling has been developed based on the following criteria:

- Troglofauna inhabit air filled voids and/or vugs within the vadose zone (above water table) of a geological environment.
- Stygofauna inhabit permeable/porous material within the phreatic zone (below water table) of a geologic environment.
- The water table represents the lower limits of possible troglofauna habitat and upper limits of possible stygofauna habitat.
- The areal and vertical extent of vuggy rock (above the water table) and permeable/porous material (below water table) represent further limits on possible troglofauna and stygofauna habitats, respectively.
- A maximum depth to water of 40 mbgl has been adopted as an additional limit of potential stygofauna habitat.

3. GEOLOGY

The area comprises a north-south orientated ridge aligned along the local geological strike which is host to the orebody. To the west, the orebody features a steeply dipping scarp leading into an area of low topographic relief. Surface water runoff to the West is directed to the Turner River, located 8 km from the project area, through minor ephemeral creeks. The east of the orebody slopes more gradually into numerous ephemeral creeks that feed the Shaw River, located 20 km from the project area. Groundwater levels in the area range between ~80 mbgl (elevated areas) and ~5 mbgl (low lying plains).

The orebody is located on the western limb of the Pilgangoora Syncline. The geology within the project area is steeply dipping and made up of the Sulphur Springs Group, comprising Kangaroo Caves Formation to the West, Pincunah Member as the orebody host and Corboy Formation to the east. No significant Tertiary Detritals exist within the study area.

The dominant geological units found within the study area are as followed:

- Bedrock Units:
  - Kangaroo Caves Formation- BIF bands interbedded with Chert and Shale.
  - Pincunah Member, consisting of 3 main units:
    - Western shale sequence.
    - Western BIF (main orebody), grading into siltstone/sandstone.
    - Upper BIF, occurring outside of resource.
  - Eastern Shale Sequence/Corboy Formation- Shale dominated, grading into sandstones and conglomerates.

From review of core photographs and existing groundwater reports, all fresh bedrock units are massive with limited vuggy/porous horizons. As such, it is understood that any sub-terranean fauna samples/intersections are likely to have come from the oxidised zone. Oxidations zones have been defined by:

- Weathered/Transition Zone, occurring at depths up to 60-70 mbgl.
- Fractured bedrock.

4. MODEL DEVELOPMENT

The habitat assessment model was developed using Leapfrog Geo 3D modelling software (Seequent).

4.1 Data Used

A range of data sets were supplied by FMG, and subsequently used for the development of the habitat model. These data included:

- Topographic surface – used to define the topographic setting and upper boundary to the model.
- Water table surface – used to define the base of potential troglofauna habitat (i.e. troglofauna do not occur in saturated conditions) and top of potential stygofauna habitat.
- Weathering surfaces (including Base of Complete Oxidation (BOCO) and Top of Fresh Rock (TOFR)) – used to define zones where vuggy potential habitat may have developed through weathering and oxidation processes. Extents of the received surfaces were limited to the orebody area and were extrapolated to cover the model domain.
- Final pit shells- used to define zone of disturbance from mining.

4.2 Model Boundaries

The extents of the geological model were identified using the following:

- Laterally, the model domain was defined by the extents of vuggy material and/or the extents of the received data from the client (i.e. topographic surface).
- A topographic surface was used to define the top of the model.
- A combination of water table and top of fresh rock surfaces (which ever was highest) was used to define the base of potential troglofauna habitat, while top of fresh rock below the water table was used to define the base of stygofauna habitat.

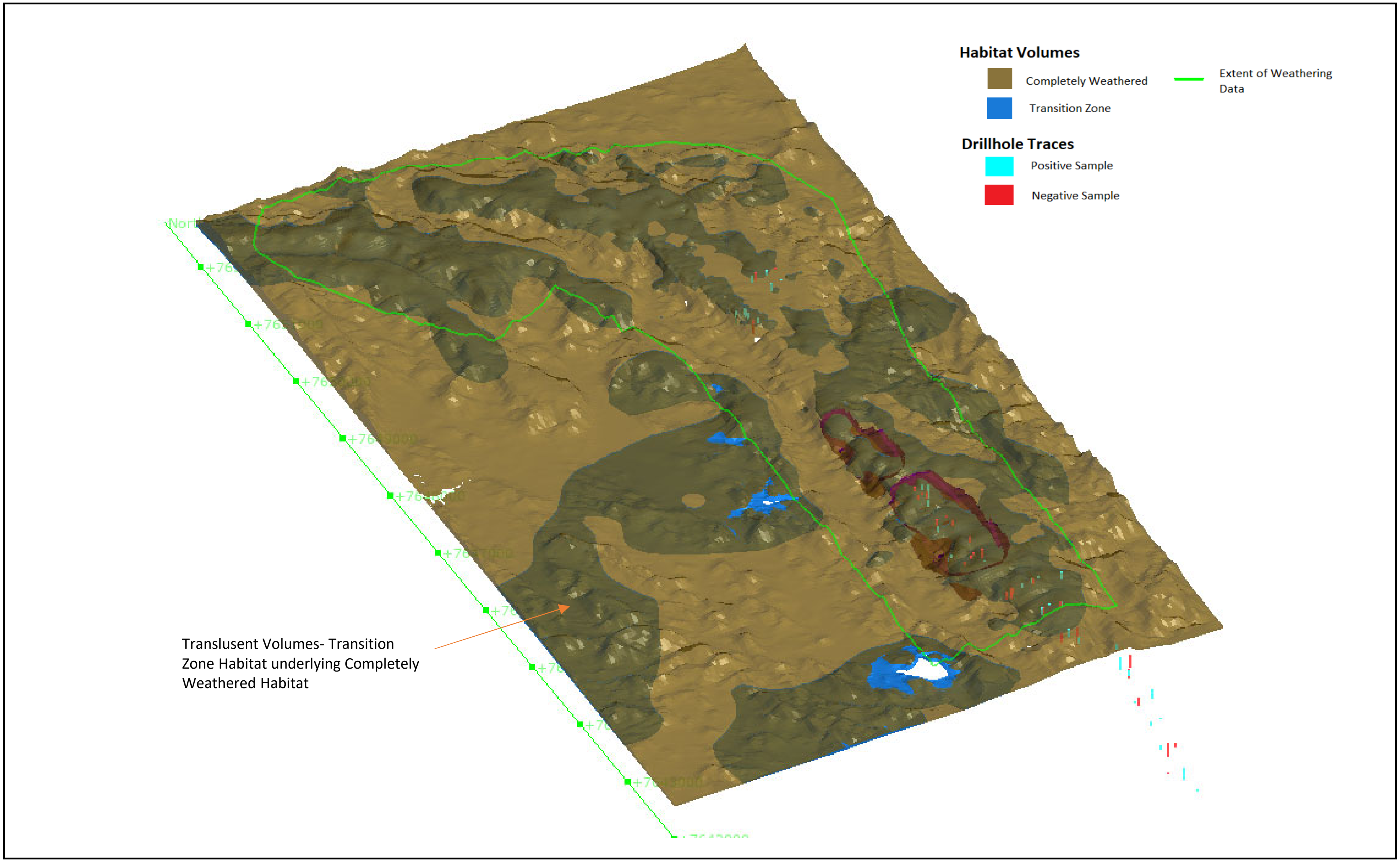
5. MODELLING RESULTS

5.1 Troglofauna

Figures 1 and 2 show the modelled distribution of potential troglofauna habitat with traces of drillholes used for sampling.

Troglofauna sampling completed by Bennelongia was focused on the elevated ridge that hosts the orebody. Troglofauna sampling was completed using scrapes (near surface) and traps set at different depths within selected drill holes. It is understood that troglofauna tend to migrate within the open borehole, meaning trap depths are not necessarily representative of the habitat location of the sampled troglofauna. Significant troglofauna species have been identified in mineral holes along strike of the orebody.

- The model indicates that potential troglofauna habitat (unsaturated weathered bedrock) extents over much of the project area.
- The model suggests that the distribution of troglofauna intersections from Bennelongia sampling are arbitrary in nature. Referring to Figure 1, all sampled drill holes intersect possible troglofauna habitat, but only select holes yielded troglofauna. There may be additional factors controlling troglofauna habitat that cannot be determined from the available data.
- Although no troglofauna sampling was conducted away from the elevated ridge hosting the orebody, modelling suggests potential habitat extends to the east and west into the low-lying areas. Troglofauna maybe fewer in number in the low-lying areas due to the shallower depth to water and subsequent reduction in thickness of habitable areas.



Potential Troglofauna Habitat- All Habitats

FIGURE 1

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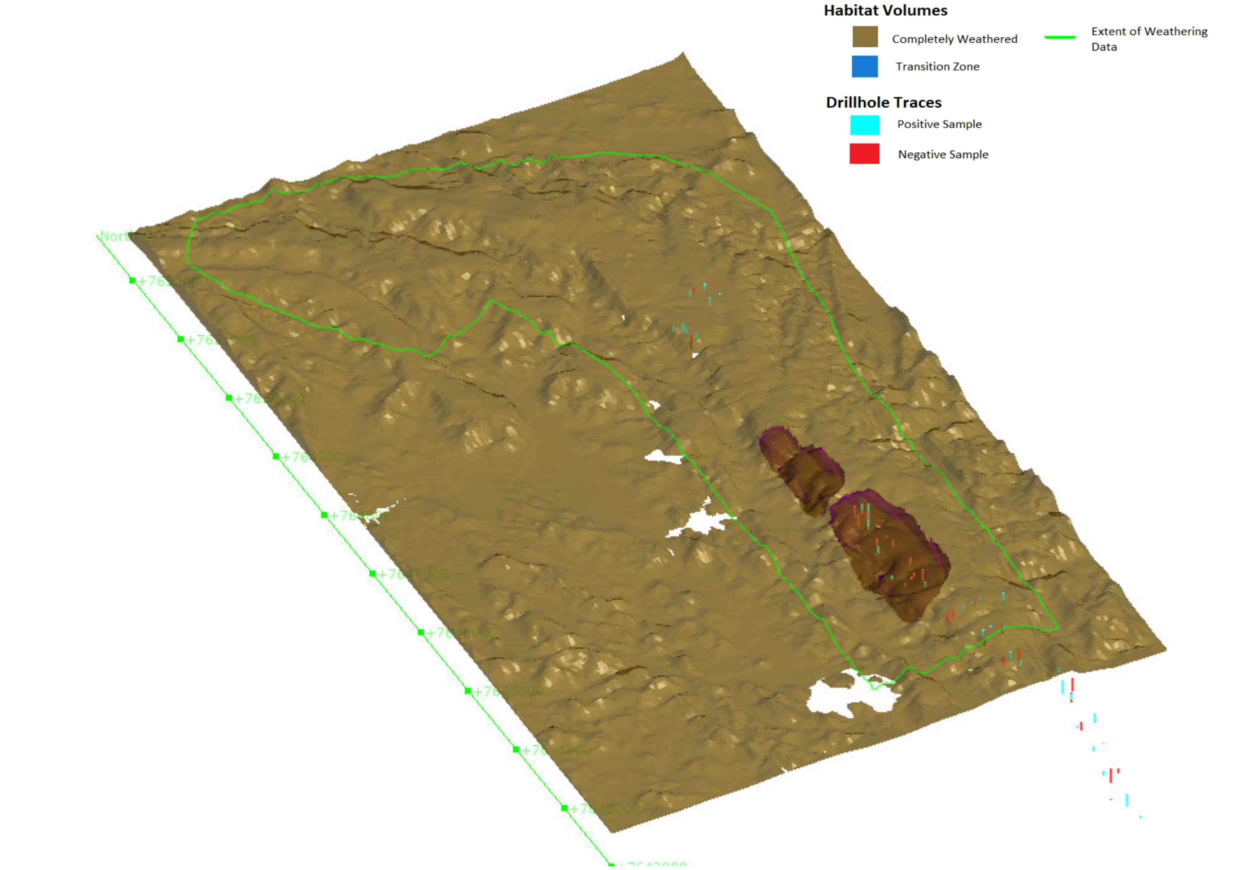
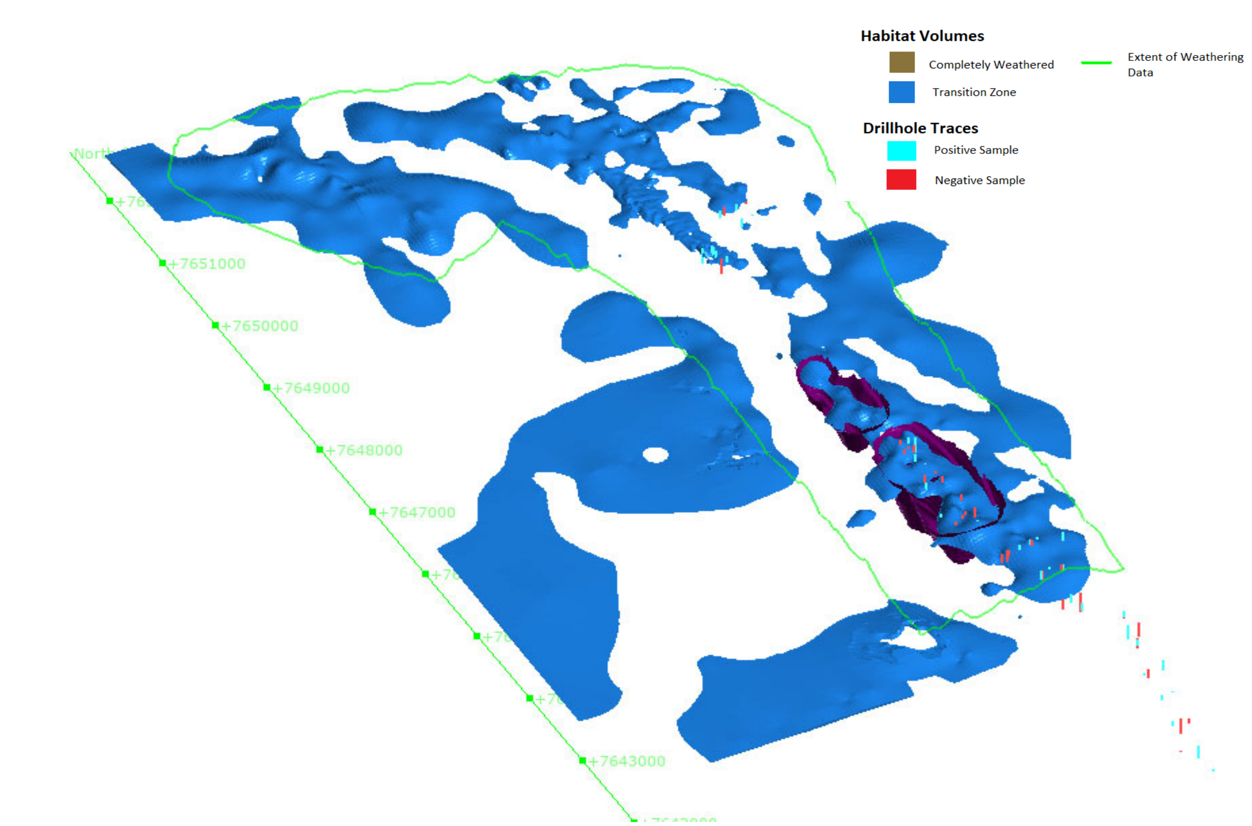
Completely Weathered Troglofauna Habitat



Transition Zone Troglofauna Habitat



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Potential Troglofauna Habitat- Individual Habitats

FIGURE 2

5.2 Stygofauna

Figures 3 and 4 show the modelled distribution of potential stygofauna habitat with traces of drillholes used for sampling.

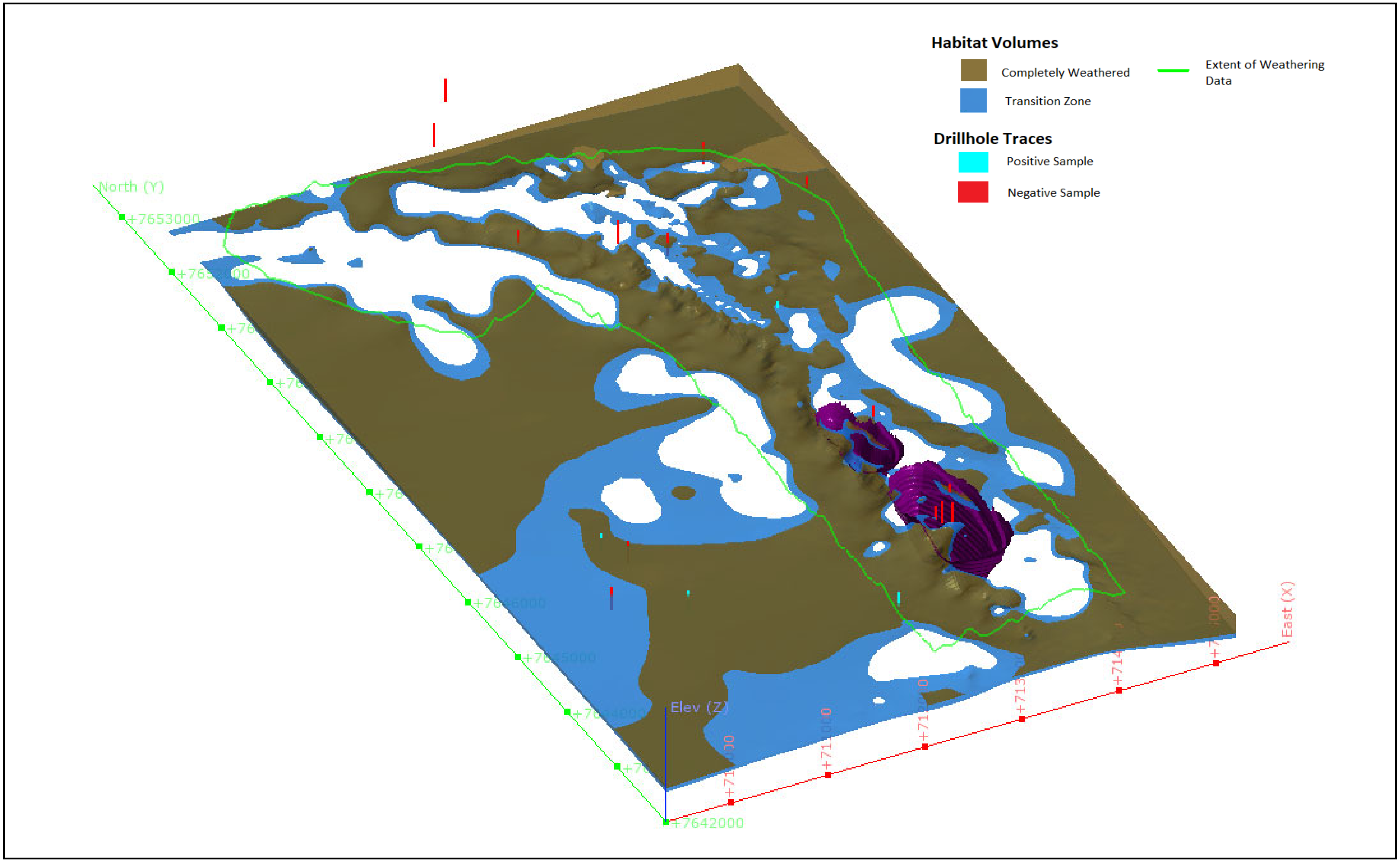
Stygofauna sampling was conducted on drill holes located on the elevated ridge and in lower-lying areas to the west and east. Stygofauna sampling was completed using a net to sample specific intervals of drill holes. It is understood that stygofauna also migrate within an open drillhole, and net depths are not representative of the location of the potential stygofauna habitat. Salient points from the stygofauna model are outlined below:

- Elevated fresh rock interface over the orebody area and subsequent reduction in thickness of permeable/porous material, combined with deep water levels (>40 mbgl) means the presence of stygofauna within the pit areas is unlikely. An outlier was observed in drillhole 1B-NST-M01, located within the elevated ore body area, which returned positive stygofauna results. The drillhole collar is situated in a minor drainage line which possibly has a lower depth to water (due to lower ground elevation and/or higher groundwater level because of enhanced groundwater recharge), increasing the likelihood of stygofauna in the weathered material. Additionally, infiltration from creek flow may increase nutrient availability locally in this area.
- Drill holes NS0664, GV0224 and NSEXS35, located on the western low-lying areas, yielded positive stygofauna samples. Potential habitat formed in the weathered bedrock was intersected by drill all holes and this, combined with shallow groundwater levels (<40mbgl) extends both north and south adjacent to the ridge. It is noted that stygofauna sampling nets in holes NSOBSS19 and NSEXS36, located proximal to NSEXS35 and GV0224, yielded no stygofauna. This implies there maybe additional factors controlling the distribution of stygofauna that cannot be determined from the available data.

Results from the stygofauna sampling are summarised in Table 1.

Table 1 Stygofauna Sampling

Hole ID	Easting	Northing	SWL (mbgl)	Stygofauna Identified?	Geological Formation	Area	Habitat Comments
GVW06	714864.7	7650010.0	15.32	NO	Corboy	North East	No identified stygofauna species, although potential habitat extends to this area. Weathered zone of Corboy Formation possibly less habitable for stygofauna.
NS0663	712667.4	7653028.8	3.07	NO	Corboy	North East	
NS0624	714317.4	7651030.5	5.45	NO	Corboy	North East	
NSOBS024	712257.9	7652444.9	7.28	NO	Corboy	North East	
NSOBS029	712099.9	7650422.5	13.45	NO	Kangaroo Caves	North West	
GVD0011	713388.5	7644526.2	45.02	NO	Pincunah	Orebody	Potential habitat extends along strike of orebody, but depth to water is typically too great for stygofauna to inhabit. Outlier 1B-NST-M01 is noted as being located on topographic low on the ridge.
GVD0012	713488.9	7644582.4	43.87	NO	Pincunah	Orebody	
GV0227	713666.7	7644769.5	35.34	NO	Pincunah	Orebody	
GV0228	713560.5	7644506.2	41	NO	Pincunah	Orebody	
NS0079	712913.7	7650003.3	37.74	NO	Pincunah	Orebody	
NSPB01	713231.8	7649633.7	36.05	NO	Pincunah	Orebody	
IBM01	713608.8	7646218.8	74	NO	Pincunah	Orebody	
1B-NST-M01	713600.5	7648129.4	36.74	YES	Pincunah	Orebody	
NSEXS36	710754.3	7645578.1	8.37	NO	Kangaroo Caves	South West	Highest potential of hosting stygofauna with porous/permeable material and shallow depth to water.
NSOBSS19	710279.4	7644972.8	25.23	NO	Kangaroo Caves	South West	
GV0224	710892.6	7644634.9	11.86	YES	Kangaroo Caves	South West	
NS0664	712544.2	7643613.5	3.18	YES	Kangaroo Caves	South West	
NSEXS35	710592.1	7645800.5	10.95	YES	Kangaroo Caves	South West	

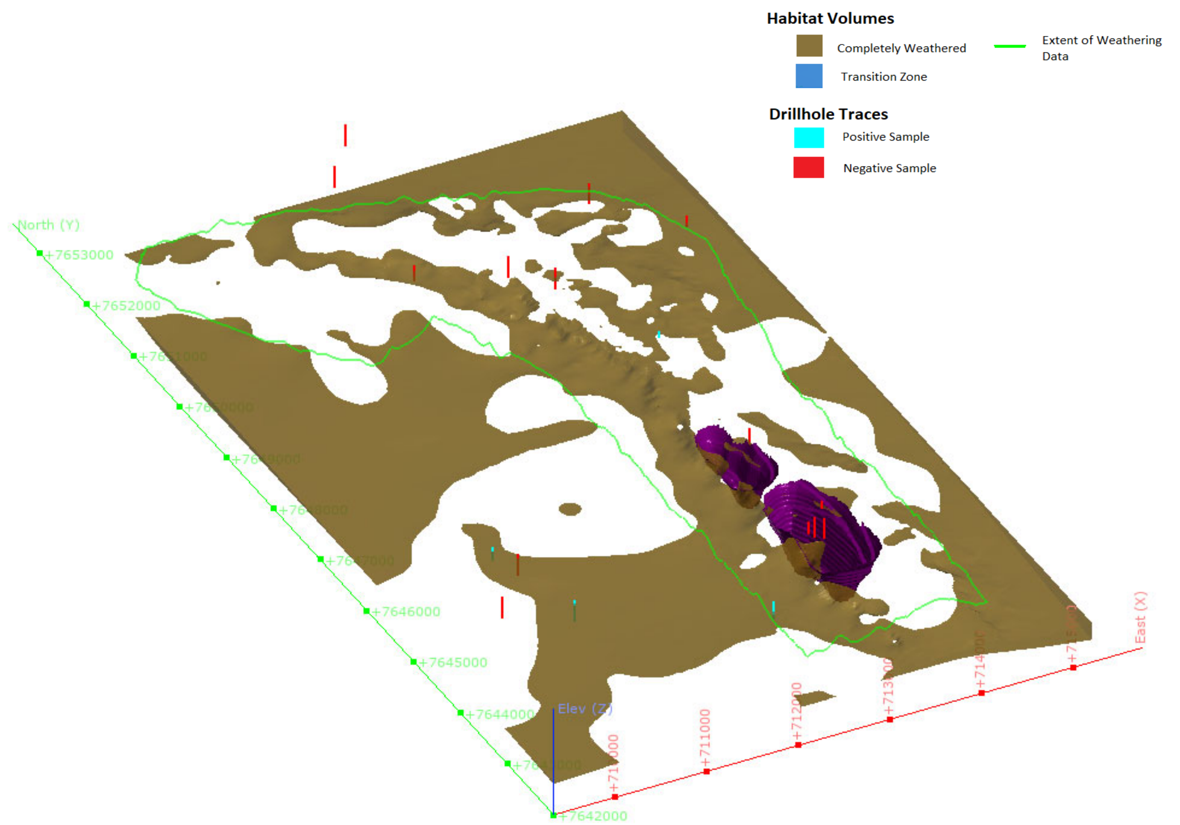


F:\432\3_C&R\Reports\Figures\[Figs.xlsx]Figure 3

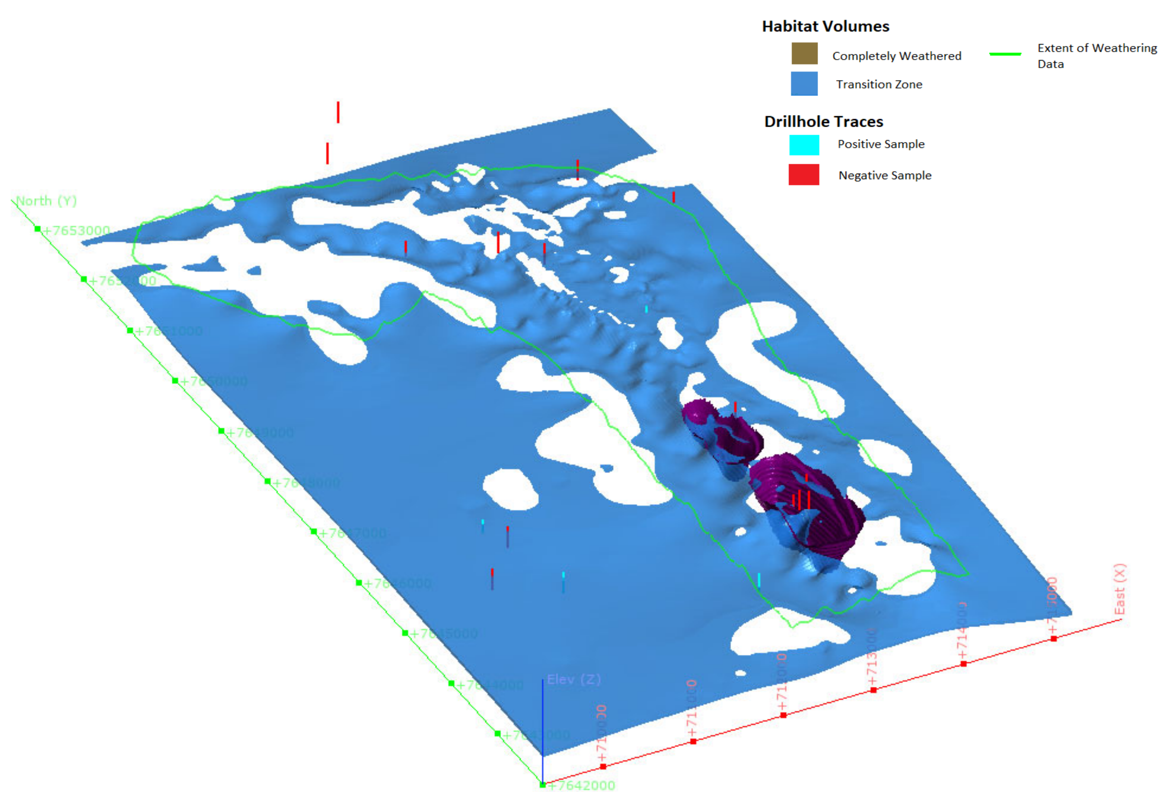
Potential Stygofauna Habitat- All Habitats

FIGURE 3

Completely Weathered Stygofauna Habitat



Transition Zone Stygofauna Habitat



Potential Stygofauna Habitat- Individual Habitats
FIGURE 4

5.3 Habitat Loss

The analysis of troglofauna habitat loss was restricted to the Glacier Valley deposit (GV North and GV South) due to limitations in received data (no pit shells for Northstar deposit). Loss of potential sub-terranean habitat is shown in Figure 5, Table 2 and summarised below:

- Due to the orebody being located on the ridge, where the potential habitat is thickest, mining activities will have the greatest impact on troglofauna, with respect to habitat loss.
- Stygofauna habitat will be the least impacted due to the immediate orebody area typically having a deeper water table (>40m) and low permeable nature of the surrounding rocks meaning a relatively small drawdown extent (high potential stygofauna habitat in the west will not be impacted).

Table 2 Potential Sub-terranean Habitat Loss

Species	Habitat Loss	
	Surface Area (ha)	Volume (m^3)
Troglofauna*	149	5.58 x 107
Stygofauna	120	1.59 x 107

*Potential habitat loss analysis completed on Glacier Valley only

6. SUMMARY

Sub-terranean fauna sampling has yielded both troglofauna and stygofauna within the Iron Bridge project area. Troglofauna sampling was focused on the orebody area, and species have been identified in and around proposed pits. Modelling suggests that although positive troglofauna samples were inconsistent over the orebody area, the potential habitat is likely extensive over the strike of the orebody. Mining will have a significant impact on this through the physical removal of habitat.

Stygofauna species are less likely to be encountered over the orebody area due to deep water levels and elevated fresh rock interface, and more likely to inhabit the vuggy material in the low-lying areas. The generally low permeability nature of the ground limits the propagation of water level drawdown and a relatively small area of stygofauna habitat will be impacted.

Regards,

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Author: ATS (09/06/22)
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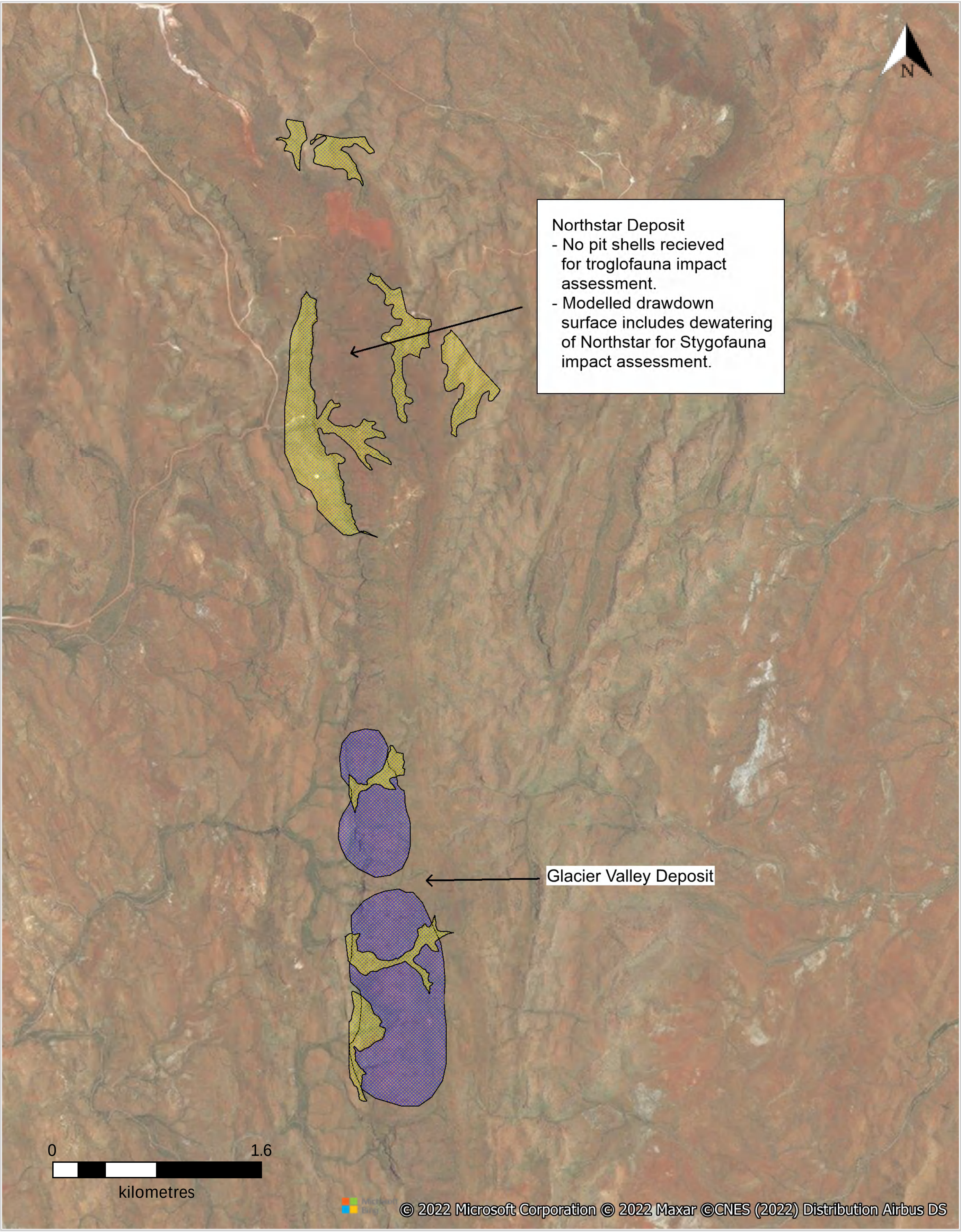
Reviewed: DGS (09/06/22)



LEGEND

Potential Stygofauna Habitat Impact Area

Potential Troglofauna Habitat Impact Area

AUTHOR: ATS
DRAWN: ATS
DATE:

REPORT NO: 003a
REVISION: A
JOB NO: 432

NOTES & DATA SOURCES:

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FIGURE 5

POTENTIAL IMPACTS FROM MINING ON SUBTERRANEAN HABITATS

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