

Mummaloo Project: Subterranean Fauna

Final Report

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Top Iron Pty Ltd
by Bennelongia Pty Ltd

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Mummaloo Project: Subterranean Fauna

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EXECUTIVE SUMMARY

Top Iron Pty Ltd has a mineral exploration tenement (E59/1694) 61 km north-east of Wubin in the Shire of Yalgoo – the tenement is currently being converted to a mining tenement. The tenement is 5.5 by 1.6 km (895 ha) and contains iron ore deposits that are being considered for mining as the Mummaloo Project. Geologically the Mummaloo tenement is situated in the Murchison Province of the Yilgarn.

Threat to subterranean fauna was evaluated by a combination of desktop assessment and pilot scale field survey. Searches were made of Western Australian Museum records of stygofauna and troglofauna and results of subterranean surveys elsewhere in the Yilgarn were reviewed during the desktop survey. Twenty troglofauna samples collected during the field assessment yielded a single troglofaunal animal. It belonged to a subfamily of the silverfish group. Troglofaunal members of this group are usually relatively widespread.

The combination of desktop survey and pilot scale field survey lead to the following conclusions:

- 1) There is unlikely to be any conservation threat to stygofauna at Mummaloo. It is unlikely that a significant stygofauna community occurs in the iron ore deposits. Furthermore, the mining depth is only 6 m, whereas the groundwater table is at approximately 35 m and no dewatering is proposed during mining, so that any species present will experience minimal disturbance.

It is unknown whether stygofauna occur in valley creeks outside of the Mummaloo development envelope but no abstraction of water from such areas is planned. Therefore, no stygofauna in calcrete communities will be affected by mining.

- 2) Mummaloo supports a depauperate troglofauna community, with a single species collected. The community does not have significant conservation values. There is unlikely to be any conservation threat to troglofauna at Mummaloo.

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1. INTRODUCTION

Top Iron is planning the development of iron ore deposits at their exploration tenement E59/1694 known as the Mummaloo Project. The tenement, referred to here as Mummaloo, is situated 61 km north-east of Wubin in the Shire of Yalgoo in the Murchison Province of the Yilgarn Craton (Figure 1). The typical components and activities associated with the Mummaloo project are likely to include:

- Shallow open cut mining pits – nominally 6 m deep;
- Stockpiles and waste storage areas;
- Construction of administration offices, accommodation and access roads;
- Development of a dry processing plant and power station; and
- Laydown and fuel storage areas.

Mining activities may potentially threaten subterranean fauna, especially any species restricted to areas being excavated for mine pits or dewatered to enable mining of ore below watertable or to provide processing water. Therefore, the likely impacts of mining on subterranean fauna at Mummaloo have been evaluated in this report.

There are two kinds of subterranean fauna: troglofauna and stygofauna. Troglofauna are air-breathing and live in the air spaces in small fissures and cavities of the underground matrix, whereas stygofauna are aquatic and live in the same kinds of spaces within groundwater aquifers. As a consequence of living underground, subterranean species usually have limited capacity to disperse and, therefore, often have highly localised distributions (Gibert and Deharveng 2002; Harvey 2002). Species with restricted ranges are particularly vulnerable to extinction following habitat destruction or environmental changes (Ponder and Colgan 2002; Fontaine *et al.* 2007). The vulnerability of many subterranean fauna species was recognised by the Environmental Protection Authority (EPA), which provided two Guidance Statements related to subterranean fauna: one outlining policies for their protection during development (EPA 2003) and the other describing the requirements for survey during environmental assessment (EPA 2007).

Information on subterranean fauna at Mummaloo was compiled in two stages: first, a desktop review and, secondly, a pilot-scale troglofauna field survey. In the case of stygofauna, a desktop assessment alone was deemed appropriate because it is anticipated that, iron ore will be mined only above the water table. Owing to the lack of available information about the occurrence of troglofauna and their habitat preferences in the Murchison and Midwest regions, a troglofauna pilot survey was considered necessary to confirm the literature-based conclusions of a desktop review.

The objectives of the desktop review were:

- 1) To determine the extent of subterranean fauna communities occurring, or likely to occur, at Mummaloo;
- 2) To identify likely threats to subterranean fauna from mining at Mummaloo; and
- 3) To evaluate the likelihood of mining threatening subterranean fauna species at Mummaloo.

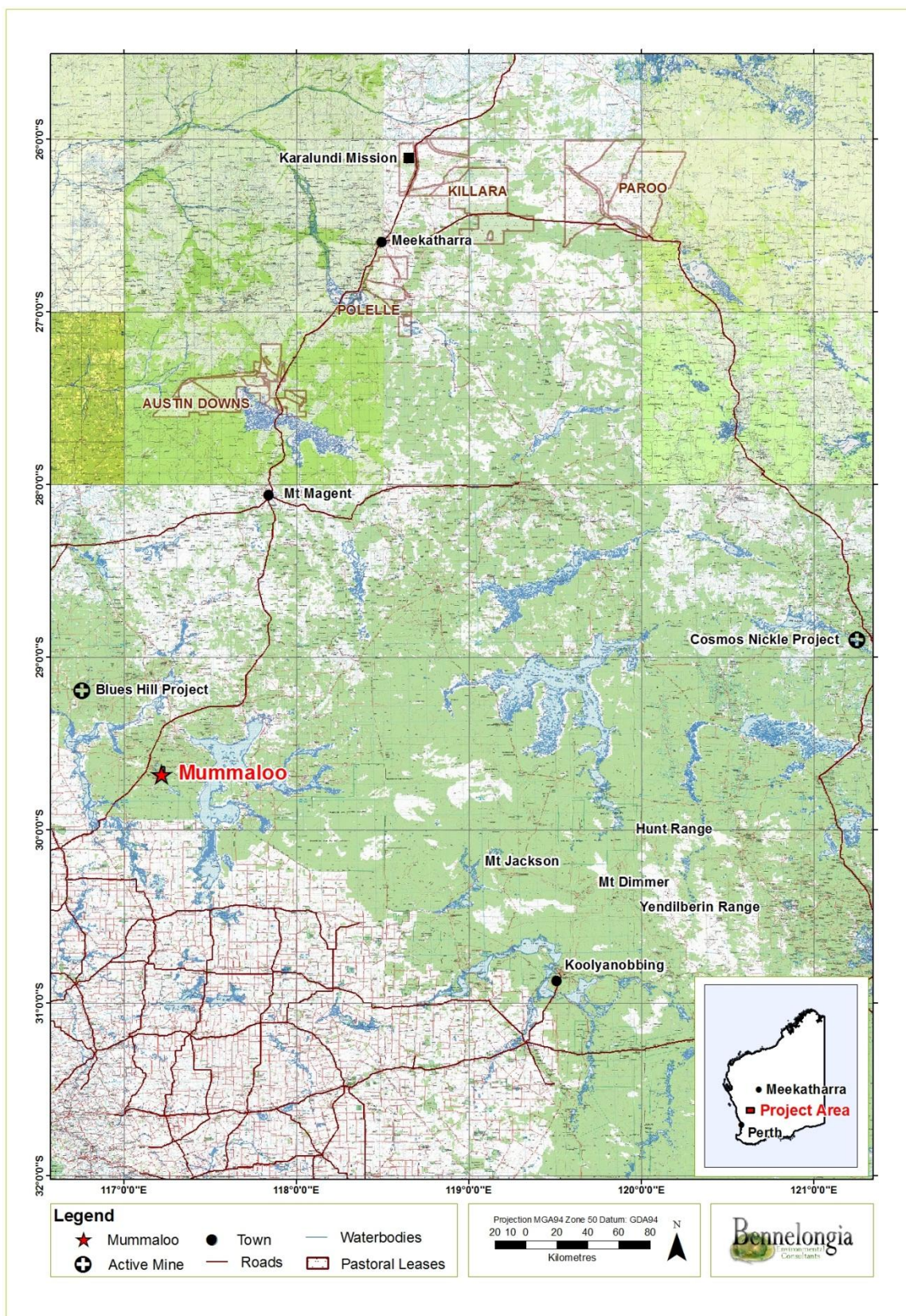


Figure 1. Location of the Mummaloo Hill Project.

2. SUBTERRANEAN FAUNA OVERVIEW

Nearly all subterranean animals are invertebrates, however both stygofaunal fish and troglofaunal reptiles occur in Western Australia (i.e. Whitely 1945, Aplin 1998). As a result of spending all, or most, of their lifecycle underground, subterranean species have acquired various adaptations, including pallid colouration, reduction or loss of eyes, elongate body, long slender appendages and well-developed sensory setae.

Troglofauna usually have more restricted distributions than stygofauna (see Lamoreux 2004) and nearly all troglofauna species would be classified as short range endemics *sensu* Harvey (2002). Whether troglofauna occur in an area is dependent on the availability of habitat, which can be assessed with reasonable accuracy from the geology of the area. Troglofauna habitat extends from the lower layers of loose soil and sand (usually 3-4 m below the ground surface) to the interface with groundwater (see Juberthie *et al.* 1981). The suitability of this habitat for troglofauna is dependent on the pattern of interstitial spaces, fissures and voids. It is important that the subterranean spaces are connected to the ground surface to supply energy and nutrients to the troglofauna community (plant roots are an important surface connection), while lateral connectivity of spaces is crucial to underground dispersal (Juberthie *et al.* 1981). Geological features such as major faults, dykes and rock formations with no voids may block continuity of habitat and act as barriers to dispersal, leading to troglofauna species having highly restricted ranges.

While the diversity and abundance of troglofauna appear to be greater in the Pilbara and, to a lesser extent the Yilgarn, than other areas of Western Australia (Guzik *et al.* 2011), they are known in most regions of Western Australia. There are records from the Kimberley (e.g. Harvey 2001), Cape Range (Harvey *et al.* 1993), Barrow Island (Biota 2005a), Midwest (e.g. Ecologia 2008a), South-west (e.g. Biota 2005b) and Nullarbor (e.g. Moore 1995). Knowledge of the occurrence of troglofauna outside mineralized habitats is not yet well developed because mine development has been the primary motive for most surveys.

Stygofauna occur in an array of different groundwater habitats including porous, karstic and fractured-rock aquifers, springs and the hyporheos of streams (Eberhard *et al.* 2005). Calcrete and alluvium are considered to be productive habitats for stygofauna. Like troglofauna, stygofauna require interstitial spaces, fissures and voids and consequently there is usually a correlation between transmissivity and the suitability of an aquifer for stygofauna.

Stygofauna have mostly been recorded from fresh or hypersaline groundwater but they may occur in salinities up to 60,000 mg/L TDS (Watts and Humphreys 2006; Reeves *et al.*, 2007; Ecologia 2009).

2.1. Troglofauna in the Region

There are relatively few records of troglofauna in the Murchison and Midwest regions. This probably reflects that few environmental assessments have been undertaken. The majority of documented troglofauna records have been collected from the broader Yilgarn.

In comparison to the Pilbara, the Yilgarn has been poorly sampled for troglofauna; however, diversity is expected to be high especially in karstic calcretes (Guzik *et al.* 2011). To date, surveys in the public domain show that modest troglofauna communities have been collected above the watertable in calcretes of the Yilgarn, with groups including palpigrads (Barranco and Harvey 2008),

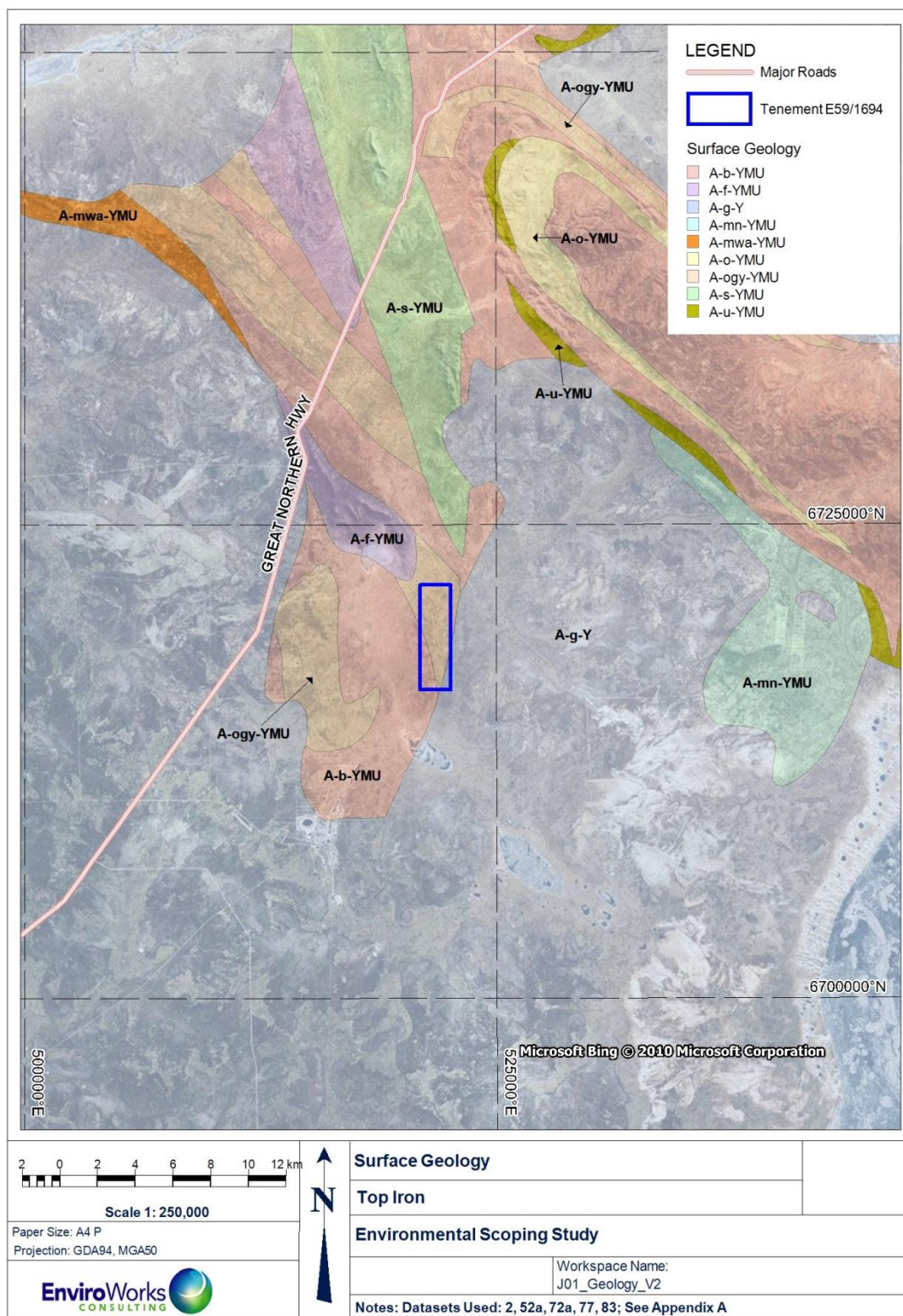


Figure 2. Geology of the Mummaloo Hills Project and Surrounds (supplied by Top Iron/EnviroWorks).

pseudoscorpions (Edward and Harvey 2008), spiders (Platnick 2008) and isopods (S. Tatei 2011 in litt.). Troglifaunal pseudoscorpions and a range of other taxa, including isopods, millipedes, centipedes, spiders, silverfish, beetles, symphylans, cockroaches, pauropods, bristletails and bugs have been collected from Yilgarn banded ironstone formation (BIF; Biota 2007; Bennelongia 2008b,c). Surveys in BIF at Koolyanobbing, Mount Jackson, Hunt Range, Mt Dimmer and Yendilberin Hills to the east of Mummaloo (see Figure 1) have documented either depauperate or moderately developed troglifauna communities, depending on site.

The survey work listed above was undertaken 150 km or more from Mummaloo. A troglifauna survey at the Blue Hills Project, 68 km north-west of Mummaloo, collected one specimen of a new species of troglobitic pseudoscorpion, three potentially troglobitic isopod specimens and a troglobitic spider specimen belonging to the family Gnaphosidae family (Biota 2007; Ecologia 2008a). Such records probably reflect the presence of a moderately developed troglifauna community with the constituent species occurring at a very low abundance.

2.2. Museum Database Search for Troglifauna

A search of the Western Australian Museum database revealed no records of troglifauna within a Search area defined by 29.15-30.15°S, 116.65-117.75°E extending approximately 100 km around Mummaloo (Figure 3).

2.3. Stygofauna in the Region

Surveys over the past decade, principally by the Western Australian Museum (WAM), have shown that the Yilgarn contains very significant stygal communities centred on calcretes in palaeovalleys (Cooper *et al.* 2002, 2007, 2008; Humphreys 2008; Guzik *et al.* 2008). This includes the calcretes in the vicinity of the Austin Downs, Karalundi Mission and Killara Homestead (see Figure 1) (references in Humphreys 2008). Surveys by WAM have shown individual calcrete aquifers frequently contain species of beetle, amphipod, copepod, isopod and bathynellid that are endemic to that aquifer (Humphreys 2001; Cooper *et al.* 2002, 2007, 2008; Guzik *et al.* 2008, 2010; Watts and Humphreys 2006; De Laurentiis *et al.* 2001).

As a result of the sampling by WAM, a large number of Priority Ecological Communities (PECs), based on stygofauna communities of calcretes, have been nominated in the Yilgarn. The listing of PECs is an informal process undertaken by DEC to increase conservation focus on poorly documented communities that are potentially threatened, usually because of their small area of occurrence, by anthropogenic factors (<http://www.dec.wa.gov.au/content/view/849/2017/>). In many cases, there has been little documentation of the composition of the Yilgarn stygofauna PECs. The buffer to the Ninghan Calcrete PEC, which is stygofauna community, extends into parts of Mummaloo (Figure 3).

The small amount of stygofauna sampling in the Yilgarn appears to have produced few species (e.g. Ecologia 2008; Bennelongia 2009a). Surveys in the Jack Hills Range and nearby Blue Hills Project (see Figure 1) recorded a single species of chiltonid amphipod (GHD 2009) and one species of *Microcyclops* copepod, probably the cosmopolitan *Microcyclops varicans* (Ecologia 2008).

2.4. Museum Database Search for Stygofauna

A search of the Western Australian Museum database revealed no records of stygofauna within a search area defined by 29.15-30.15°S, 116.65-117.75°E extending approximately 100 km around Mummaloo (Figure 3).

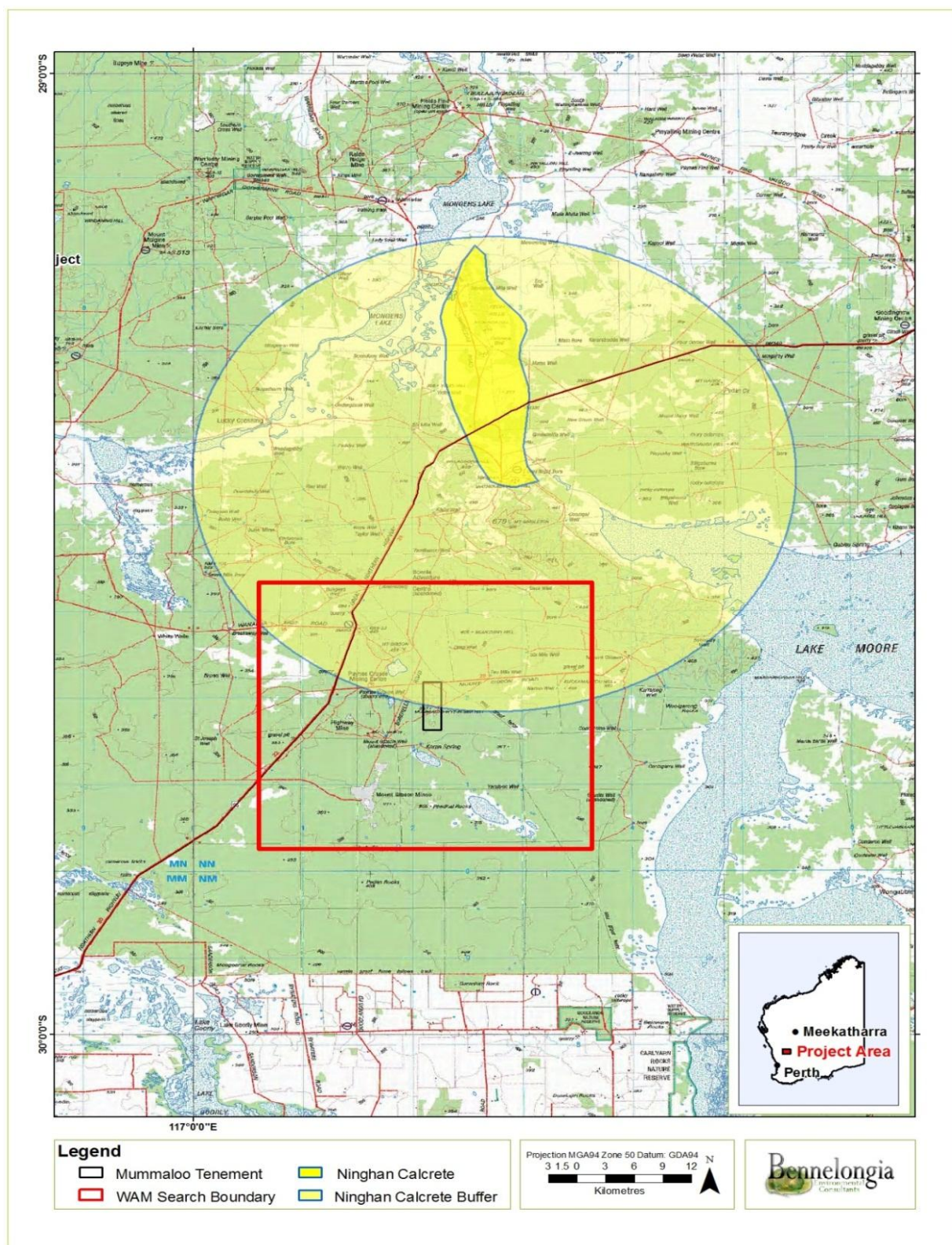


Figure 3. Location of the WAM Search Area (defined by 29.15-30.15°S, 116.65-117.75°E) and PECs.

3. HABITAT ASSESSMENT

3.1. Geology and Hydrogeology of Mummaloo

Mummaloo is situated at the southern tip of the Retaliaion Belt in the south-west portion of the Yalgoo-Singleton Greenstone Belt in the Murchison Province of the Yilgarn Craton (Anand and Smith 2005). The Yilgarn Craton is composed of Archaean rocks, predominantly granitoids, which are crossed by north-northwest trending belts of greenstones. Archaean and the overlaying Proterozoic strata of the Yilgarn were extensively oxidised to depths up to 120 m during formation of the Western Australian Plateau (Morgan 1972). The area has been subjected to a wide range of climates during its history and the regolith has formed a complexly layered structure as a result of leaching of mineral components during wet cycles and precipitation of mineral matter to form ferricrete, silcrete and calcrete during dryer cycles (Morgan 1993). The calcretes often occupy several metres above and below current watertables in deposits extending several to tens of kilometres in ancient drainage lines (Jacobson *et al.* 1988).

The Archaean basement is dominantly volcanic and intrusive mafic and felsic rocks and their sheared equivalents, which have been metamorphosed to the mid-amphibolite facies. The regolith of the Mount Gibson area is dominated by differential erosion of deep lateritic weathering profiles. Detritus from the weathered mantle in local uplands has buried the weathered profile beneath colluvium-alluvium on adjacent foot-slopes and lowlands, producing local erosional-depositional couples. Some of these sediments show inversion of the sequence of the dismantled weathered profile; gravelly detritus at the base of colluvium consists of ferruginous nodules and pisoliths (Figure 2; Anand and Smith 2005).

As shown in Figure 2, the Mummaloo tenement occurs within three surficial geology units:

Table 1: Surficial Geological Units within Tenement E59/1694.

Geological Code	Unit Name	Description
A-b-YMU	Unnamed	Mafic volcanic rocks with minor mafic and ultramafic intrusive rocks; minor felsic rocks
A-ogy-YMU	Unnamed	Gabbro, anorthositic gabbro, anorthosite; may include vanadiferous magnetite
A-g-Y	Yilgarn Granites	Granitic rocks, undivided; metamorphosed

An un-named palaeovalley at Mount Gibson is the only regional site where palaeovalley infill sediments have been investigated in detail (Magee 2009; Rockwater 2005). The aquifer investigated was mapped as consisting of alluvium within a former broad channel cut into Archaean bedrock of granite, mafics and metasediments. Aquifer material comprises sand (mostly fine and silty but locally gravelly), calcrete, and silcrete. Weathered bedrock may also be permeable in places but its connection with the alluvial aquifer material is likely to be uneven because it is commonly overlain by clay. The paleochannel sands are a major confined sedimentary aquifer with large supplies of saline to hypersaline groundwater. The calcrete deposits are major near-surface aquifers with large supplies of fresh to saline groundwater.

The Mummaloo deposit is interpreted to be a channel iron deposit formed in a palaeodrainage channel, which contains colluvial clays, silt and iron mineralisation. The majority of the iron occurs as the maghemite, titanomagnetite, hematite and goethite mineralisation located above bedrock in the colluvium. The geometallurgical work established four zones were present beneath the top soil (Figure 4):

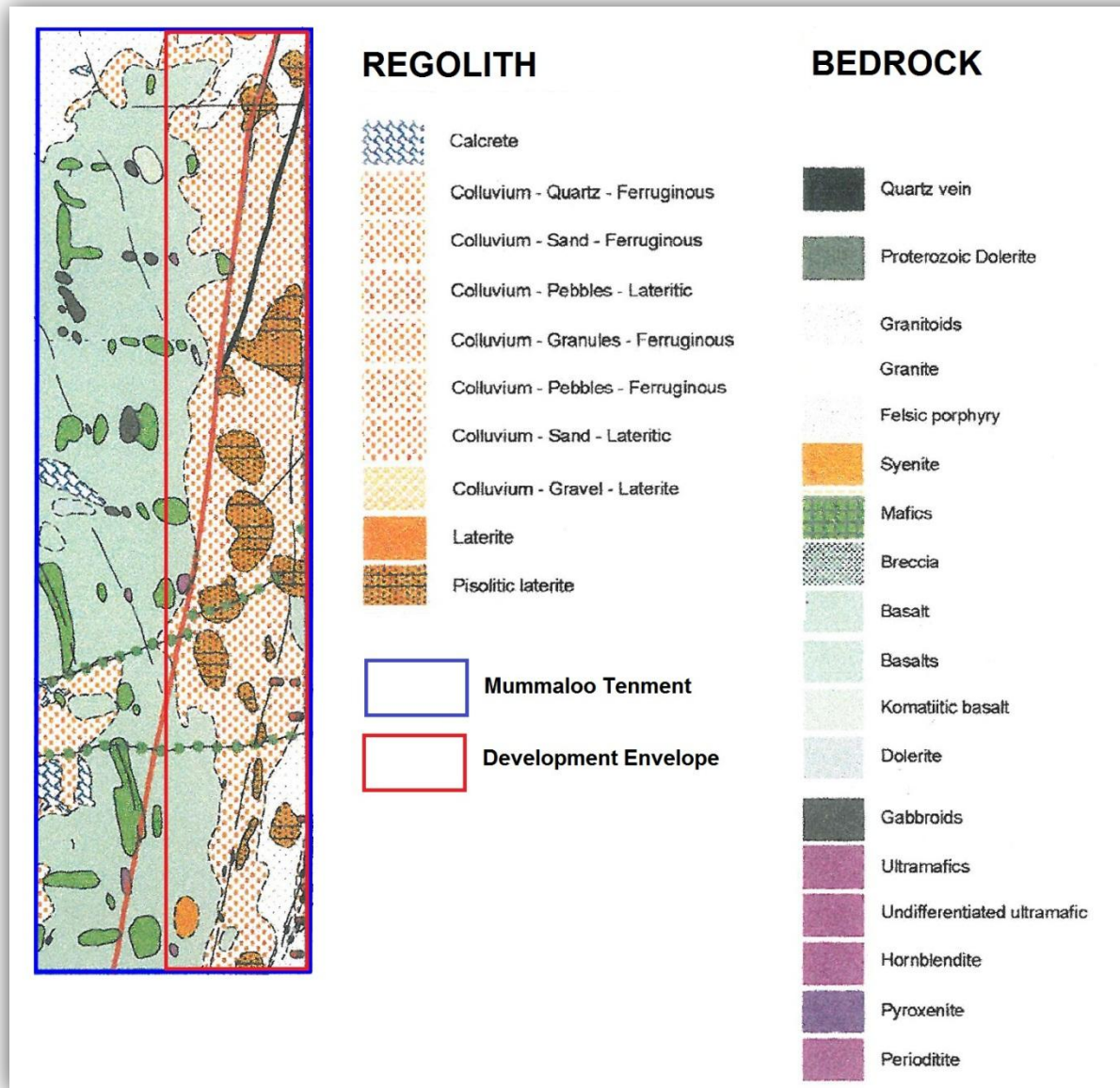


Figure 4. Mummalo Tenement Geology (Provided by Top Iron Pty Ltd).

- Zone 1 comprising 1-5 mm diameter rounded maghemite pisoliths in a white to red clay matrix;
- Zone 2 comprising 1-5 mm diameter maghemite pisoliths and clasts cemented by a hard goethite matrix;
- a basal Zone 3 comprising a red hematitic conglomerate containing 1-40 mm angular to rounded clasts in a soft white to yellow clay matrix; and
- Zone 4 a barren weathered clay-rich basement.

The groundwater table has been identified at approximately 35 m below the surface at Mummalo, whilst mining will only extend to 6 m below the surface (pers. comm. Nick Revell Exploration Manager Top Iron, 2012).

3.1.1. Mummaloo as Stygofauna Habitat

The alluvial material within the deposit is cemented in a clay and goethite matrix which is therefore unlikely to host a surficial aquifer. The groundwater table at Mummaloo has been identified via geological drilling to occur at approximately 35 m below surface (pers. comm. Nick Revell Exploration Manager Top Iron, 2012). Based on the geological profile of Mummaloo and given the groundwater table is well below the proposed depth of mining, it is considered very unlikely that stygofauna would exist within the Mummaloo deposit itself (which only extends 6 m below the surface).

Prospective stygofauna habitat may be found at Mummaloo within the deeper groundwater table, although given that only single species were collected from each of the two closest surveyed areas (Bennelongia unpublished data), it is unlikely that a rich or significant community will be found. Furthermore, the depth of mining is well above the water table, and no borefield will be developed, reducing the risk of impact to any stygofauna that may exist.

3.1.2. Mummaloo as Troglafauna Habitat

Areas of pisolite at Mummaloo are likely to represent the most prospective habitats for the geologies for troglafauna, as well as any calcretes in nearby valleys. Pisolith is widespread at Mummaloo however; it is cemented within a hard goethite matrix in Zone 2 whilst Zones 1, 3 and 4 consist of a clay matrix. Porosity within these zones is low and whilst some pore spaces may exist and be suitable habitat for troglafauna, these zones would not be considered to be highly prospective for a large or diverse range of troglafauna.

4. MINING IMPACTS

Two scales of impact may be recognized as a result of mining and associated activities. Primary impacts are those with the potential to threaten the persistence of subterranean fauna through direct removal of habitat. Secondary impacts are those that may reduce the quality of subterranean fauna habitat and reduce population densities rather than threatening species persistence (Scarsbrook and Fenwick 2003; Masciopinto *et al.* 2006).

On the basis that mining will not extend below the watertable, no dewatering is required and there will be not be a borefield to provide processing or dust suppression water, it is unlikely there will be significant associated groundwater drawdown impacts. It is understood potable and dust suppression water will be sourced off site from an existing water supply, which is already approved.

Pit excavation is the only potential primary impact at Mummaloo. Given the pits are very shallow (6m deep), the orebody is of low porosity and well above the groundwater table, direct impacts to stygofauna and troglafauna are unlikely to be significant. Potential secondary impacts include reduced infiltration of carbon, nutrients or water, because of the construction of overburden stockpiles and waste dumps; and contamination of groundwater by hydrocarbons. Additional background on these factors is given in Appendix 1.

4.1. Stygofauna

Based on current information regarding mining impacts (see above), the persistence of stygofauna communities at Mummaloo is unlikely to be threatened by mining activities.

4.2. Troglofauna

The geology of the local area does not exhibit any landscape features, such as valleys, mesa formations, dykes and major faulting, that would reduce habitat connectivity and restrict troglofauna movement and very few troglofauna records are known from the surrounding area. It is almost certain any troglofauna community present will occur in very low abundance but it is unclear whether the number of species in the community will be low or moderate.

Given the uncertainty about the potential richness of the troglofauna community, a pilot survey for troglofauna was considered necessary to determine the likely richness of the community.

5. METHODS

5.1. Troglofauna Sampling Effort

Twenty samples were collected from 20 exploration drill holes at Mummaloo. All drill holes were within, or in close proximity to, mineral deposits (Figure 5; Appendix 2).

5.2. Sampling methods

In nearly all cases, each troglofauna sample was collected using two separate techniques that provided separate subsamples. The two techniques were trapping and scraping.

- 1) Trapping. Custom made cylindrical PVC traps (270 x 70 mm, entrance holes side and top) were used for trapping. Traps were baited with moist leaf litter (sterilised by microwaving) and to within a few metres of the watertable or end of the drill hole. In every fourth bore, a second trap was set mid-way down the hole. Holes were sealed while traps were set to minimise the ingress of surface invertebrates. Traps were retrieved eight weeks later and their contents (bait and captured fauna) were emptied into a zip-lock bag and road freighted to the laboratory in Perth.
- 2) Scraping. Prior to setting traps, bores were scraped. This was done by lowering a troglofauna net (weighted net, 150 µm mesh with variable aperture according to bore diameter) to the bottom of the bore, or to the watertable, and scraping back to the surface along the bore walls. Each scrape comprised four drop and retrieve sequences with the aim of scraping any troglofauna on the walls into the net. After each scrape, the contents of the net were transferred to a 125 ml vial and preserved in 100% ethanol.

Scrapes were collected and traps were set on 30 April 2012 and 1 May 2012. Traps were retrieved on 30 June 2012.

5.3. Sample Sorting and Species Identification

In the laboratory, samples were elutriated to separate out heavy sediment particles and sieved into size fractions using 250, 90 and 53 µm screens. All samples were sorted under a dissecting microscope. Sorted animals were identified to species or morphospecies using available keys and species descriptions. When necessary, animals were dissected and examined under a compound microscope. Morphospecies determinations were based on characters used in species keys.

5.4. Personnel

Scientists Michael Curran, Grant Pearson and Sean Bennett undertook fieldwork. Samples were sorted by Michael Scanlon and Jeremy Quartermaine and identifications were made by Dean Main.

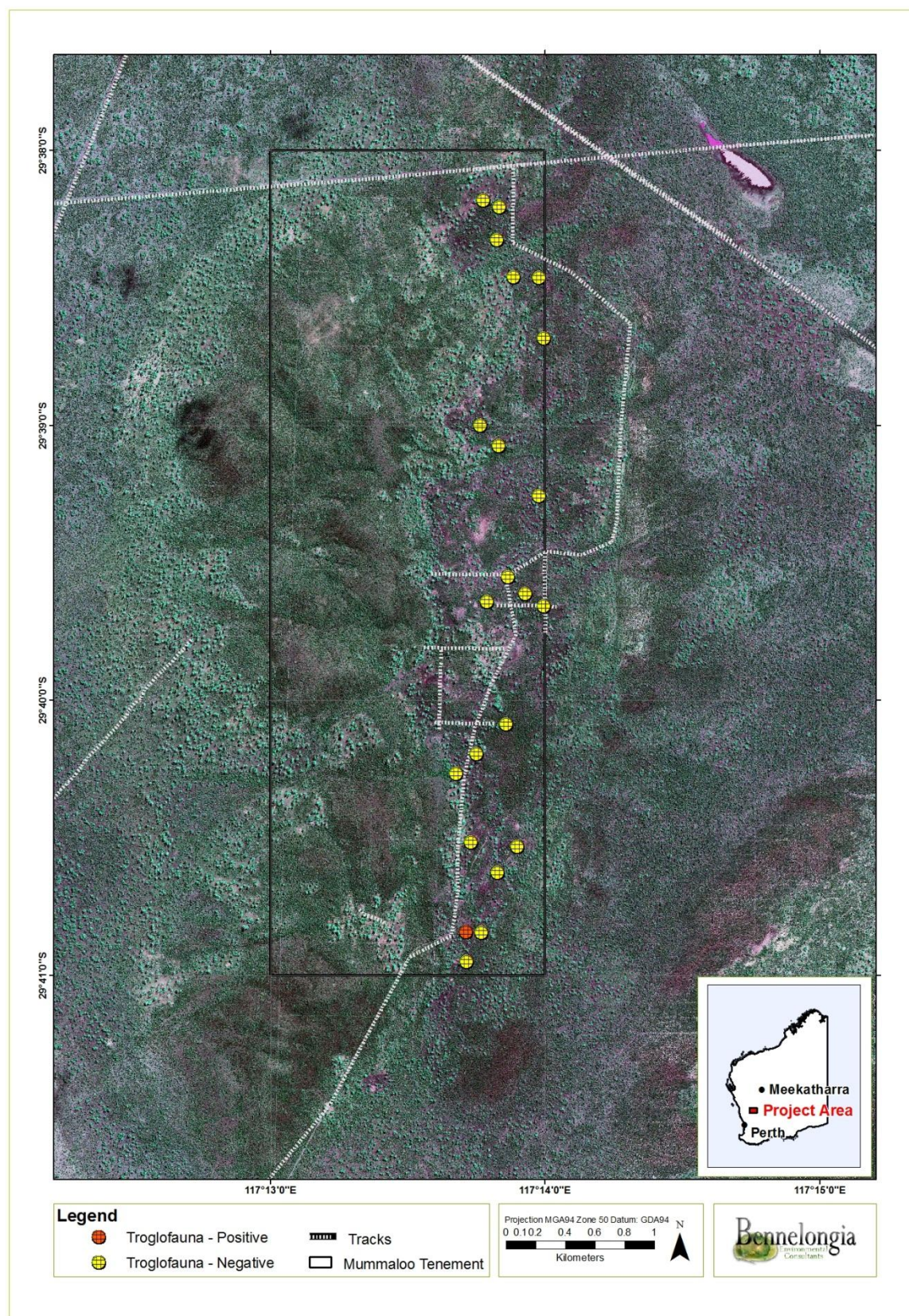


Figure 5. Location of Bores Sampled during Troglifauna Pilot Survey.

6. RESULTS AND DISCUSSION

The 20 troglofauna samples yielded only one troglofauna specimen, a silverfish belonging to the subfamily Atelurinae, which was collected by trapping and could not be identified further due to the specimen's poor condition. No troglofauna species were collected by scraping.

Troglofauna species belonging to the subfamily Atelurinae occur commonly in Yilgarn and Pilbara, where they appear to have relatively large ranges (2009b,c).

With the collection of only one troglofaunal animal in 20 samples and with that animal belonging to a troglofaunal group (silverfish) that is present in almost all subterranean communities in Western Australia, it appears highly unlikely that a significant troglofauna community occurs at Mummaloo.

Therefore, the combination of desktop survey and pilot scale field survey lead to the following conclusions:

- 1) There is unlikely to be any conservation threat to stygofauna at Mummaloo. It is unlikely that a significant stygofauna community occurs in Mummaloo iron ore deposit given it occurs well above the water table. Furthermore, no dewatering is proposed by mining, so that any species present will experience minimal disturbance.

On the basis that mining will not extend below the watertable, no dewatering is required and there will be not be a borefield to provide processing or dust suppression water, it is unlikely there will be significant associated groundwater drawdown impacts. It is understood potable and dust suppression water will be sourced off site from an existing water supply, which is already approved.

It is unknown whether stygofauna occur in valley creeks outside of the Mummaloo development envelope but no abstraction of water from such areas is planned. Therefore, no stygofauna in calcrete communities will be affected by mining.

- 2) Mummaloo supports a depauperate troglofauna community, with a single species collected. The community does not have significant conservation values. There is unlikely to be any conservation threat to troglofauna at Mummaloo.

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8. APPENDICES

Appendix 1. Secondary Impacts of Mining on Subterranean Fauna

Overburden Stockpiles and Waste Dumps

These artificial landforms may cause localised reduction in rainfall recharge and associated entry of dissolved organic matter and nutrients because water runs off stockpiles rather than infiltrating through them and into the underlying ground. The effects of reduced carbon and nutrient input are likely to be expressed over many years and are likely to be greater for troglafauna than stygofauna (because lateral movement of groundwater should bring in carbon and nutrients). The extent of impacts on troglafauna will largely depend on the importance of chemoautotrophy in driving the subterranean system compared with infiltration-transported surface energy and nutrients. Stockpiles are unlikely to cause species extinctions, although population densities of species may decrease.

Aquifer Recharge with Poor Quality Water

Quality of recharge water declines during, and after, mining operations as a result of rock break up and soil disturbance (i.e. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised through management of surface water and installing drainage channels, sumps and pump in pits to prevent of recharge through the pit floor.

Contamination of Groundwater by Hydrocarbons

Any contamination is likely to be localised and may be minimised by engineering and management practices to ensure containment.

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Appendix 2. List of Bores sampled at Mummaloo

Bore Code	Site Type	Latitude	Longitude	Visit Date
MUMUNK01	Impact	-29.6825	117.2286	30-Apr-12
MUMUNK02	Impact	-29.6807	117.2285	30-Apr-12
MUM096	Impact	-29.6807	117.2295	30-Apr-12
MUM102	Impact	-29.6771	117.2304	30-Apr-12
MUM104	Impact	-29.6755	117.2316	30-Apr-12
MUM015	Impact	-29.6753	117.2288	30-Apr-12
MUM115	Impact	-29.6699	117.2291	01-May-12
MUM120	Impact	-29.6681	117.231	01-May-12
MUM085	Impact	-29.6368	117.2305	01-May-12
MUM083	Impact	-29.6364	117.2296	01-May-12
MUM174	Impact	-29.6388	117.2304	01-May-12
MUM171	Impact	-29.6411	117.2329	01-May-12
MUM169	Impact	-29.641	117.2314	01-May-12
MUM164	Impact	-29.6447	117.2333	01-May-12
MUM162	Impact	-29.6513	117.2305	01-May-12
MUM145	Impact	-29.6543	117.2329	01-May-12
MUM093	Impact	-29.6602	117.2321	01-May-12
MUM135	Impact	-29.6609	117.2332	01-May-12
MUM137	Impact	-29.6607	117.2298	01-May-12
MUM155	Impact	-29.65	117.2294	01-May-12

Appendix 3. Number of Higher Order Groups Collected during Troglotauna Sampling at Mummaloo.

The thysanuran (silverfish) was the only troglotaunal animal collected, all other animals were surface species.

Higher Order	Number of Specimens
Arachnida	2
Acariformes	4
Araneae	1
Scutigeromorpha	1
Collembolla	17
Coleoptera	4
Diptera	4
Hemiptera	1
Hymenoptera	1
Isoptera	2
Orthoptera	1
Psocoptera	1
Thysanura	1
Isopoda	6
Nematoda	1
Oligochaeta	1
Total	48