Baseline Stygofauna Survey at the Image Resources Atlas Project Borefield

Prepared for:

Image Resources

July 2022

Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Baseline Stygofauna Survey at the Image Resources Atlas Project Borefield

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Final	Melanie Fulcher		email	14/07/2022

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EXECUTIVE SUMMARY

Image Resources NL plans to develop the Atlas deposit, a mineral sands project, located on the northern Swan Coastal Plain. The proposed main pit at Atlas covers an area of approximately 190 ha that will be excavated to an average depth of approximately 15 m. Image Resources NL are investigating options (located within a separate external infrastructure development envelope) for the Atlas Project water supply. Investigations into three options have commenced, however, at least one of these locations is planned to provide water supply to the Project via an approximately 300 m deep production bore, likely to the south of the project area. As a result, Bennelongia Environmental Consultants was commissioned to conduct a baseline survey to investigate the occurrence of any stygofauna communities in the borefield area/s to be developed.

The term subterranean fauna includes two groups of underground animals: aquatic stygofauna and air-breathing troglofauna. Subterranean fauna species characteristically have reduced or absent eyes and are poorly pigmented due to lack of light. Many subterranean fauna species are obligate inhabitants of subterranean habitats (stygobites and troglobites), but some also have a life-stage in surface and soil habitats (stygophiles and troglophiles).

Geology influences the presence, richness and distribution of subterranean fauna by providing different types of habitat. Geologies with an extensive network of internal spaces support larger assemblages of subterranean fauna, both in terms of abundance and diversity, than consolidated geologies. The surface geology at Atlas consists of two major types: alluvium deposited by water flow (sand, silt and clay) and non-calcareous sand reworked by eolian processes consisting predominately of Bassendean sands and the Guildford formation (silty and sandy clay). Aquifers within these geologies have been found to be transmissive and therefore may hold appropriate spaces for subterranean fauna.

A database and literature search found 34 subterranean fauna specimens from within the search area including nine stygofauna specimens and 25 troglofauna specimens. The troglofauna specimens were associated with the Nambung karst cave system, approximately 7 km from the Project, while the limited stygofauna records are from the Bennelongia database and Western Australian Museum (WAM). The small number of records of stygofauna within the Atlas desktop search area is likely to in some part, to reflect the shortage or lack of targeted sampling and as a result, analogous geologies in the surrounding landscape were explored to determine the possible subterranean fauna communities that may be present.

A baseline sampling programme was conducted to identify whether stygofauna species are present in and around the Atlas Project Borefield. A troglofauna survey was not required due to the results of the desktop review, which indicated troglofauna is extremely unlikely to occur at the Project. Twelve bores sampled for stygofauna collected nematodes and a single Tubificid. The sampling at the Atlas Project Borefield supports the conclusion of the desktop assessment that the Project is unlikely to host rich stygofauna communities.

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1. INTRODUCTION

Image Resources NL (Image) plans to develop a number of mineral sands deposits located on the northern Swan Coastal Plain. One of these deposits, the Atlas deposit (Atlas) is the focus of this report. Atlas is situated approximately 160 km north of Perth with the nearest major towns being Jurien Bay, 35 km to the north-west and Cervantes, approximately 18 km to the west (Figure 1). Also in the region is the Nambung National Park, which runs along the coast to the west of Atlas. The proposed main pit at Atlas covers an area of approximately 190 ha that will be excavated to a depth of approximately 15 m. Mining will occur below the current water table (within the superficial aquifer), and therefore has the potential to impact on any subterranean fauna species and communities that may be present in the vicinity of the Atlas area. Image Resources NL are investigating options (within a separate external infrastructure development envelope) for the Atlas Project water supply. Early investigations into three options have commenced, however, at least one of these locations is planned to provide water supply to the Project via an approximately 300 m deep production bore. Of these options Image Resources NL hope to use a bore south of the project area. Bennelongia has been requested to conduct a baseline stygofauna survey to assess subterranean fauna values at the Atlas borefield with a view to determining the significance of any species and communities present and to determine whether a more detailed field survey is warranted.

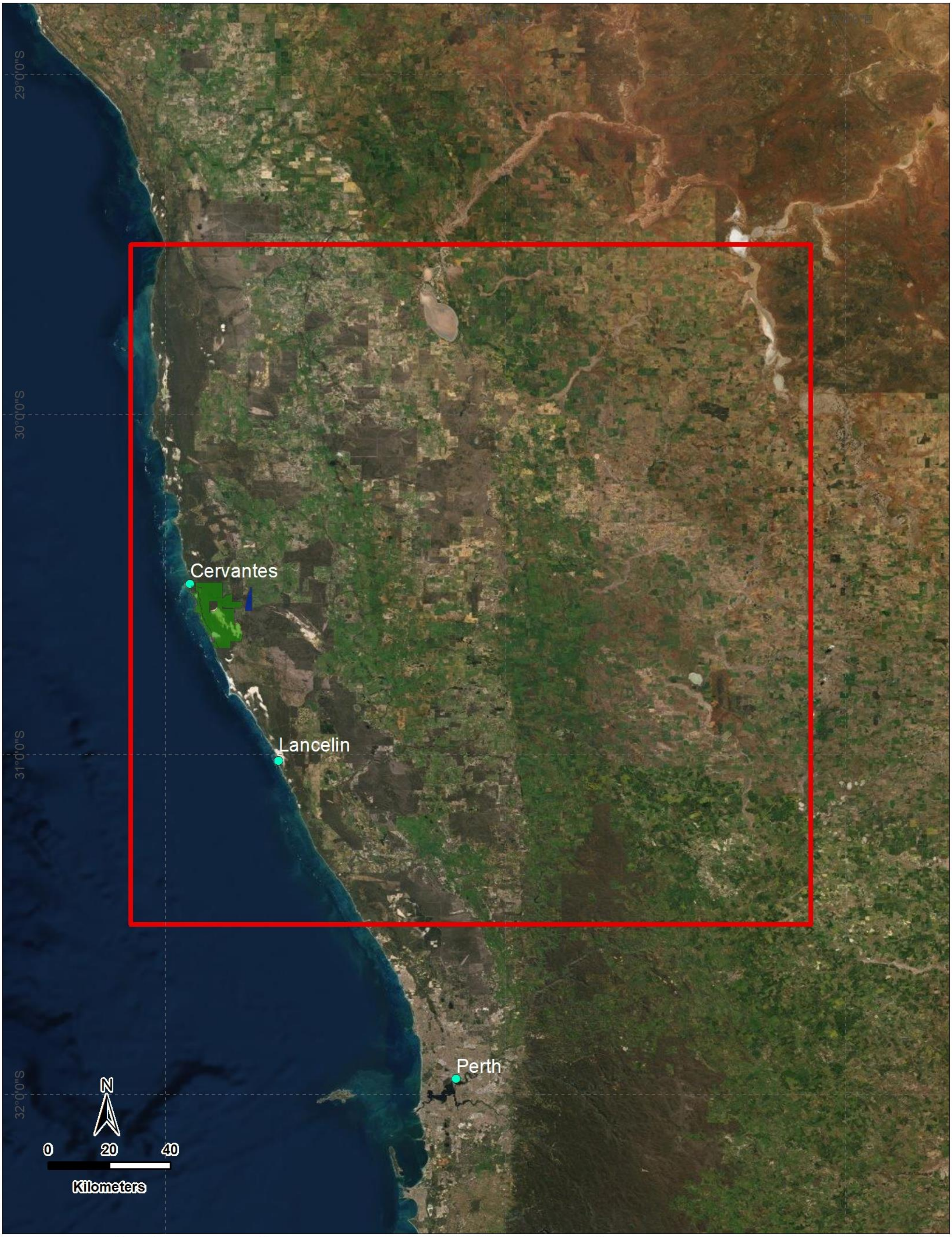
2. SUBTERRANEAN FAUNA AND FRAMEWORK

The term subterranean fauna includes two groups of underground animals: aquatic stygofauna and air-breathing troglofauna. Subterranean species characteristically have reduced or absent eyes and are poorly pigmented due to lack of light. They have often developed vermiform bodies and elongate sensory structures, as well as physiological adaptations such as the loss or reduction of wings, increased lifespan, a shift towards K-selection breeding strategy and lower metabolic rate (Gibert and Deharveng 2002). Except for a few species of fish and snakes, all subterranean fauna species in Western Australia are invertebrates.

Although inconspicuous, subterranean fauna contributes markedly to the overall biodiversity of Australia. The Pilbara, Yilgarn and neighbouring regions of Western Australia are globally important for subterranean fauna, with an estimated 4,500 or more subterranean species likely to occur (Guzik *et al.* 2010; Halse 2018b), the majority of which remain undescribed. Most subterranean species satisfy Harvey's (2002) criteria for short-range endemism (SRE), having total range size of less than 10,000 km^2 and occupying discontinuous or fragmented habitats.

Many subterranean fauna species are obligate inhabitants of subterranean habitats (stygobites and troglobites), but some have a life-stage in surface and soil habitats (stygophiles and troglophiles). Stygophiles and troglophiles are usually considered to have larger distributions than obligate subterranean species as a result of greater dispersal opportunities. Stygoxenes and trogloxenes are species that use subterranean habitats opportunistically and are usually relatively widespread.

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 many subterranean species are highly susceptible to anthropogenic threats. In Western Australia the Environmental Protection Authority (EPA) requires consideration of subterranean fauna as part of environmental impact assessments (EPA 2016a, b, c). Some of the justification for assessing environmental impacts on subterranean fauna in Western Australia is based on the Pilbara and Yilgarn regions of the State being internationally recognised as areas of globally important subterranean fauna radiations. The very limited work to date in near coastal areas of south-western Australia has revealed nowhere near the same species richness and the conservation significance of the fauna is yet to be understood. In line with this, there is currently little information on which to base assessment of the likely richness of the subterranean fauna communities (stygofauna and troglofauna) within the Atlas area.



GCS GDA 1994
Author: mfulcher
Date: 14/07/2022

Legend

- Desktop Search Area
- Project Area
- Nambung National Park
- Towns

Figure 1: Location of the Image Resources Atlas Tenement

2.1. Subterranean Fauna Habitat Requirements

Geology influences the presence, richness and distribution of subterranean fauna by providing different types of habitat (Hose *et al.* 2015). Geologies with an extensive network of internal spaces support larger assemblages of subterranean fauna, both in terms of abundance and diversity, than consolidated geologies.

Early records of subterranean fauna were centred around cave environments (Culver *et al.* 2006; Holthuis 1960; Schneider and Culver 2004; Skubała *et al.* 2013; Whitley 1945), however more recently, it has become clear that subterranean species inhabit voids in geologies throughout the landscape matrix beyond the boundaries of cave systems (Eberhard *et al.* 2005a; Guzik *et al.* 2010)

Stygofauna communities tend to be richest in calcrete and alluvial aquifers (Humphreys 2001), while less transmissive geologies such as banded iron formations (BIF), saprolite, mafic and ultramafic usually contain depauperate communities (ecologia 2009; GHD 2009). It is unusual for silt and clay to support stygofauna because of the lack of interstitial spaces and the associated absence of an aquifer (Korbel and Hose 2011). Geological features such as palaeovalleys are known to be prospective habitat for stygofauna (Humphreys 2001), as well as interstitial spaces in alluvium associated with watercourses, creeks and rivers (Bagas *et al.* 2004; Bennelongia 2012; Eberhard *et al.* 2005b). Clastic alluvial media may host subterranean fauna in the interstitial spaces between constituent sand and gravel. Korbel and Hose (2015) found that coarser sediments tend to host the greatest numbers of stygofauna, with relatively few animals in silty or clay-rich substrates.

Troglofauna have been found to occur widely in mineralised iron formations, calcretes and alluvial-detrital deposits in the Pilbara (Halse 2018a). Troglofauna surveys in Western Australia outside the Pilbara have been limited but surveys in ironstone ranges in the Yilgarn at Koolyanobbing, Mt Jackson and Mt Dimmer have yielded depauperate to moderately rich troglofauna communities (Bennelongia 2008b, c), while significant communities have been recorded in calcretes of the Yilgarn. Records of the occurrence of troglofauna in more coastal areas of south-western Australia are few and mostly from caves (English *et al.* 2003; Knott *et al.* 2007; Knott *et al.* 2008; Knott *et al.* 2009; Moulds 2007b; Tang and Knott 2009).

2.2. Threats to Subterranean Species and Communities

Two broad categories of mine-associated impact on subterranean fauna are recognised in this report:

1. *Primary Impacts* have the potential to threaten the persistence of subterranean species through direct removal of habitat; and
2. *Secondary Impacts* may adversely affect subterranean fauna through reducing population densities but do not threaten species persistence.

This report has focussed on primary impacts in the potential subterranean fauna impact area when considering the possible effects of sand mining on subterranean fauna. More information on factors causing secondary impact is given in Appendix 1.

The most common primary impacts on stygofauna are dewatering to prevent flooding of open pit mines and groundwater abstraction to supply water for ore processing. They have the potential to threaten persistence of any stygofauna species with ranges restricted to the area of groundwater drawdown. In addition, the excavation of a mine pit itself is likely to threaten the persistence of any stygofauna species restricted to the pit, although this impact can be assessed when considering dewatering drawdown because the mine pits are contained within the area of drawdown.

Excavation of mine pits is the most significant (and usually only) primary impact affecting troglofauna. Other mine-related works, such as the groundwater drawdown associated with dewatering, reduced infiltration associated with waste rock dumps and leakage associated with tailings dams, have minimal impact compared with pit excavation and are considered secondary impacts. Excavation may threaten the persistence of any troglofauna species known only from within the proposed pits.

Reinjection of extracted groundwater comprises a second possible primary impact (at mines where it is undertaken) because raising the water table can flood (and reduce the volume of) troglofauna habitat.

3. DESKTOP SEARCH RESULTS

Previous records of subterranean fauna species in the vicinity of the Atlas deposit were collated and evaluated to clarify the likelihood of subterranean fauna species occurring in and around the deposit and tenement. Records were obtained from the Western Australian Museum (WAM) and Bennelongia databases, within a search area of approximately 100 km x 100 km (-29.5, 114.9 and -31.5, 116.9), centred on the tenement. However, the extent of subterranean fauna occurrence on the northern Swan Coastal Plain and Mid-West coast is still being evaluated, with limited survey effort conducted in the area. As a result, areas that are geologically and hydrologically analogous to the Atlas area were assessed as a means of establishing the level of subterranean communities that could feasibly be expected around the search area.

Caves on the coastal plain in southwestern Australia are known to support some stygofauna species (e.g. Karanovic 2003; Karanovic 2005; Knott *et al.* 2007; Knott *et al.* 2008; Knott *et al.* 2009). Other surveys that have recorded stygofauna in coastal plain aquifers in southwestern Australia include surveys of aquifers in the Gnangara Mound (Tang and Knott 2009), Bassendean Sand at Kensington in Perth (Bennelongia 2015) and in limestone sands at Pt Grey beside the Harvey Estuary near Mandurah (Bennelongia 2009a).

In closer proximity to Atlas, karst areas of the Eneabba and Jurien and southern Hill River (Nambung) regions have been explored for subterranean fauna (Moulds 2007a) as have mineral sands deposits at Cooljarloo (Bennelongia 2013a, b).

3.1. Previous Records Within Search Area

The desktop search revealed a total of 34 subterranean fauna specimens from within the search area (Table 1). This included nine stygofauna specimens and 25 troglofauna specimens. All of the troglofauna specimens were collected in the Nambung cave system and classified as either trogloxene (an organism that regularly uses the cave environment for part of its lifecycle), troglophile (an organism that can complete its entire lifecycle within a cave but possess no specific adaptations to the cave environment) or troglobite (obligate cavernicolous organisms – Moulds 2007). Groups of animals collected included spiders (9 specimens from at least 8 species), beetles (three species), isopods (two species), cockroaches (two species), crickets (two species), pseudoscorpions (one species), centipedes (one species), millipedes (one species), diplurans (one species), flies (one species), moths (one species), and bugs (one species). The majority of these species were classified by Moulds (2007) as troglophiles with only two, the cockroach *Neotomnopteryx douglasi* and the true bug Meenopliidae sp1 being classified as troglobites.

The stygofauna search revealed a limited number of species but included ostracods (three undefined specimens), copepods (one species), oligochaete worms (one species), syncarids (one species) and nematode worms (two specimens of notionally one species – not assessed under the Environmental Impact Assessment process). Syncarids are one of the most common groups found in moderately rich to depauperate stygofauna communities in coastal areas of Australia (Camacho and Hancock 2012; Little *et al.* 2016). The ranges of species in the family Bathynellidae are typically small, with many species endemic to single aquifers or sections of regional aquifers. Bennelongia reported however that the linear range of the search area species is close to 50 km (Bennelongia 2008a).

Table 1: Subterranean fauna records from within the desktop search area

Species Lowest Identification	Group	Location	Subterranean Affinity
Baiami sp.	Spider	Nambung Karst	Troglophile
Achaearanea? sp.	Spider	Nambung Karst	Troglophile
Araneae sp1	Spider	Nambung Karst	Troglophile
Araneae sp2	Spider	Nambung Karst	Troglophile
Araneae sp3	Spider	Nambung Karst	Troglophile
Araneae sp4	Spider	Nambung Karst	Troglophile
Araneae sp5	Spider	Nambung Karst	Troglophile
Araneae sp6	Spider	Nambung Karst	Troglophile
Araneae sp.	Spider	Nambung Karst	Troglophile
Protochelifer cavernarum	Psuedoscorpion	Nambung Karst	Troglophile
Laevophiloscia sp1	Isopod	Nambung Karst	Troglophile
Armadillidae sp.	Isopod	Nambung Karst	Troglophile
Allothereura lesueurii	Centipede	Nambung Karst	Troglophile
Polydesmidae sp.	Millipede	Nambung Karst	Troglophile
Japygidae sp.	Dipluran	Nambung Karst	Troglophile
Neotemnopteryx douglasi	Cockroach	Nambung Karst	Troglobite
Ptinus exulans	Beetle	Nambung Karst	Troglophile
Lecanomerus ? sp.	Beetle	Nambung Karst	Troglophile
Carabidae sp.	Beetle	Nambung Karst	Troglophile
Sciaridae? sp.	Fly	Nambung Karst	Troglophile
Monopis crocicapitella?	Moth	Nambung Karst	Troglophile
Gryllidae sp.	Cricket	Nambung Karst	Troglophile
Gryllidae sp.	Cricket	Nambung Karst	Troglophile
Neotemnopteryx cf. *douglasi*	Cockroach	Nambung Karst	Troglobite
Meenopliidae sp1	Bug	Nambung Karst	Troglobite
Leptocaris nr *brevicornis*	Copepod	Jurien	Stygobite/phile
Ostracoda sp. unident.	Ostracod	Cooljarloo West	Stygobite/phile
Ostracoda sp. unident.	Ostracod	Cooljarloo West	Stygobite/phile
Ostracoda sp. unident.	Ostracod	Cooljarloo West	Stygobite/phile
Nematoda spp.	Worm	Cooljarloo West	Stygophile
Nematoda spp.	Worm	Kadathinni	Stygophile
Antarctodrilus sp. WA3	Worm	Kadathinni	Stygobite/phile
Bathynella sp. (Eneabba WA EFB2)	Syncarid	Eneabba Sand Plain	Stygobite
Bathynella sp. (Eneabba WA EFB2)	Syncarid	Eneabba Sand Plain	Stygobite

The lack of records of stygofauna within the Atlas desktop search area is likely to, in some part, to reflect the shortage of sampling. In areas that have not been extensively sampled, it is often the case that when one or two troglofaunal or stygofaunal species are collected, further survey reveals numerous additional species. Extending the search to incorporate regions with analogous geologies revealed a number of records that are representative of the types of stygofauna species that have been documented in the Swan Coastal Plain (SCP).

For a complete list of species and their origins, please refer to Appendix 2.

3.2. Stygofauna From Analogous Geologies

Numerous surveys have been conducted throughout the SCP for stygofauna. These include specific surveys for mining proponents and environmental monitoring at ecologically significant sites and groundwater dependant ecosystems (GDEs). The numbers reported below include possible stygofauna species and taxonomic groups, such as nematodes and rotifers, that are not normally included in environmental impact assessments due to poorly understood ecology and taxonomy.

The Department of Water and Environmental Regulation has conducted environmental monitoring at the Yanchep caves over a number of years that included sampling for subterranean fauna (English *et al.* 2003; Knott *et al.* 2007; Knott *et al.* 2008; Knott *et al.* 2009). Exploration of 11 caves and 2 springs has yielded 68 species of potential stygofauna. Groups collected include copepods (23 species), oligochaete worms (17 species), ostracods (nine species), polychaete worms (five species), amphipods (five species), flatworms (one species) isopods (one species), mites (one species), snails (one species), rotifera (one species), and nematode worms (rotifera and nematode worms not included in EIA assessments). This is a significant stygofauna community located approximately 121 km south of the Atlas area and marginally outside the initial desktop search area.

In close proximity to the Yanchep Caves, and also marginally outside the desktop search area, a study of the aquatic root mat communities at Gnangara Mound was conducted between 2003 and 2008 and yielded 14 species of stygofaunal copepods from 11 caves, five springs and three bores (Tang and Knott 2009). Interestingly, the three bores in this study yielded stygofauna species demonstrating their ability to infiltrate the surrounding landscape matrix beyond the boundaries of cave systems.

A survey conducted at Point Grey, south of Mandurah, by Bennelongia (2009a) sampled 19 bores for stygofauna (and 20 bores for troglofauna). A total of 18 species of stygofauna were collected, including an unidentified species of mite, two species of oligochaete, two species of ostracod (including one marine species), six species of copepod, two species of syncarid and a species of amphipod, as well as nematodes and rotifers.

Sampling of 18 bores in Bassendean Sand at Kensington by Bennelongia (2015), just south of the Perth city centre, yielded 21 species of potential stygofauna, 13 of which were considered to be clearly stygobites. These included six species of copepod, three species of syncarid, three species of oligochaete and one species of aphanoneuran. Of the studies covered by the desktop review, the results at Kensington, are considered the most indicative of potential communities within the Atlas area due to the geological similarity (Bassendean sand dunes).

3.3. Troglofauna From Analogous Geologies

The Nambung Cave collections mentioned in Section 3.1 were a part of a larger search for troglofauna within karst caves throughout the Northern SCP region. The Eneabba and Jurien Caves were also searched resulting in a total of 25 species demonstrating cave adaptations being found in six caves in the Eneabba cave system, while searches of four caves in the Jurien karst area resulted in the collection of 15 troglomorphic species.

The 20 bores sampled for troglofauna at Point Grey by Bennelongia (2009a) yielded a single troglofaunal species, the dipluran Parajapygidae sp. B7. The specimen was recorded in a stygofauna net sample in a bore with a depth to water of just 3 m. Overall, results of this sampling program indicated a very depauperate troglofauna community.

4. POTENTIAL HABITAT

4.1. Geology

The project lies within the northern extent of the Swan Coastal Plain (SCP), which runs from approximately Geraldton in the north to Dunsborough in the south (Bolland 1998; Davidson 1995; Seddon 1972). The SCP is geologically young, being formed within the last 30 million years (Bolland 1998; Davidson 1995; Seddon 1972).

The broader geological units throughout the Atlas area are the deeper Yarragadee formation and overlying Cadda formation and Cattamarra coal measures. The Yarragadee formation underlies the majority of the Atlas area in the south and consists of interbedded sandstones, siltstones, and shales to a depth of 2500 meters. The Cadda formation intersects the northern part of the project and consists predominantly of shale and siltstone. The Cattamarra coal measures lie to the east and consists of siltstone and fine to coarse sandstone.

The surface geology at Atlas consists of alluvium (sand, silt and clay) or non-calcareous sand reworked by eolian processes (Figure 2). The latter consists of pale, deep Bassendean sands with minor components of yellow deep sand, sandy duplexes and wet soils (URS 2013 and references within). The Bassendean sands form dunes, with intervening swampy depressions that contain grey siliceous sands and sometimes an organic or calcareous layer within 2 m of the surface (URS 2013). The dominant succession in the northern area of Atlas is the Guildford formation. This is characterised by Bassendean sands and sandy clay including alluvium.

4.2. Hydrogeology

Beneath the Atlas deposits there is an unconfined superficial aquifer system typically extending from 0 to 17 metres below ground level (m bgl). This superficial aquifer is hosted by Bassendean sands and Guildford clay and is connected hydraulically to the Yarragadee formation, which extends from 17 to 1500 m bgl (URS 2013 and references within). Upward flow from the Yarragadee formation to the superficial aquifer occurs on the eastern side of the project area (Kern 1997).

Depths to the water table in the Atlas area are shallow, varying from as little as 1 m bgl but in general being from 5 to 10 m bgl. The Yarragadee aquifer is only about 20 m bgl. Water quality readings from July and November in 2012 show that the superficial aquifer is fresh to brackish at 760 to 3380 mg/l TDS, with pH ranging from 6.59 to 6.85 (MWES 2012). These water chemistries are considered suitable for stygofauna.

Bassendean sands within the Guildford formation and Yarragadee formations are considered to be relatively transmissive (URS 2013) which suggests that the sands making up these formations is porous (Gibert and Deharveng 2002).

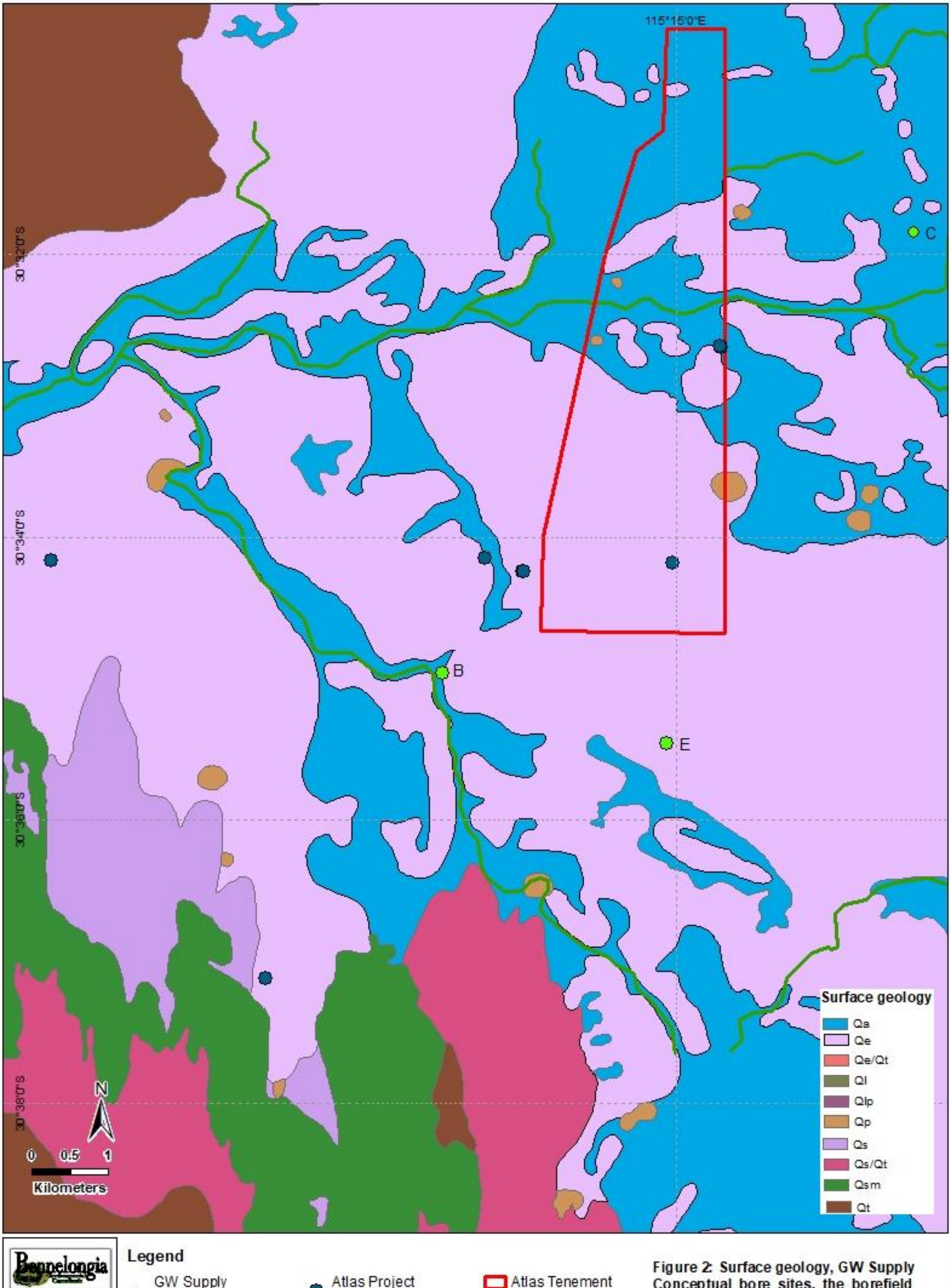


Figure 2: Surface geology, GW Supply Conceptual bore sites, the borefield and water courses at the Image Resources Atlas Tenement

4.3. Assessment of Habitat Prospectivity

Many of the features hosting subterranean fauna in the search area and surrounding sub-region do not occur within the Atlas area. This includes caves (English *et al.* 2003; Knott *et al.* 2007; Knott *et al.* 2008; Knott *et al.* 2009), karst (Moulds 2007) and groundwater environments containing root matt from Tuart trees (Tang and Knott 2009). At the same time, the geology of the Atlas area is similar to areas yielding subterranean fauna elsewhere on the SCP, especially stygofauna, such as Kensington with Bassendean sand (Bennelongia 2015) and Pt Grey with sand over Tamala Limestone (Bennelongia 2009a).

Water quality parameters at Atlas are well within the tolerances of stygofauna and will not be a limiting factor on their occurrence. The groundwater is sufficiently shallow to harbour many stygofauna. The Guildford formations present throughout the Atlas area contain relatively transmissive aquifers (URS 2013) and while the factors influencing transmissivity of a geology or aquifer are complicated, this could be an indication of a porous geology (Gibert and Deharveng 2002) providing spaces such as interstices within the sand that could be utilised by stygofauna. Water courses and drainage lines flow through Atlas (URS 2013) and this potentially provides habitat for animals as has been demonstrated at other locations (Bagas *et al.* 2004; Bennelongia 2012; Eberhard *et al.* 2005b).

Troglofauna in Western Australia are most commonly collected from weathered or mineralised iron formations, calcrete and karst, none of which are present with the Atlas area. They have also been found in alluvium in the Yilgarn, however (Barranco and Harvey 2008; Bennelongia 2008b, c, 2009b; Platnick 2008), and in sand habitats on the SCP (Biota 2003, 2005). Troglofauna habitat is usually considered to extend from the lower layers of loose soil and sand (starting 3-4 m below the ground surface) to the interface with groundwater (see Juberthie 1983). Given the small depth to water and the propensity that the Atlas area has to waterlogging during the winter months (URS 2013), it is considered unlikely that the area supports a significant troglofauna community.

5. POTENTIAL IMPACTS ON SUBTERRANEAN FAUNA

5.1. Stygofauna

Mining at Atlas is planned to occur below the water table and dewatering will be required prior to extraction of sand (URS 2013). As a result, the spatial extent of primary impacts associated with mining at Atlas will be defined by the drawdown footprint. Initial modelling has indicated that the area of drawdown over the life of mine (3-4 years) will be 44 km^2 to a maximum depth of 5 m (after 2 years and returning to 2 m subsequently - URS 2013). In addition, there is expected to be cumulative drawdown impacts associated with the water supply abstraction from the Yarragadee Formation (URS 2013).

Most of the 44 km^2 will experience relatively little drawdown (URS 2013).

5.2. Troglofauna

The primary impact on troglofauna at the Atlas site would be limited to drilling of bores/piezometers and the construction of pipeline corridors. In addition to this, given the relatively small scale of the Atlas pit (190 ha) and the shallow depth to water (URS 2013), limiting available space for troglofaunal habitat, it is not expected that troglofauna will be negatively impacted by the planned developments at Atlas.

5.3. Stygofauna baseline survey

The desktop assessment largely concluded that the borefield area contained moderate amounts of prospective stygofauna habitat, although few species would be likely to occupy ranges this small. Only a few stygofauna species were collected from the search area. However, due to habitat appearing to be prospective for stygofauna, it was recommended that a baseline survey be undertaken to confirm the stygofauna values of the Atlas borefield. Consequently, Image commissioned Bennelongia to undertake this stygofauna survey at the borefield in September 2021.

5.4. Methods

Sampling was conducted according to the general principles laid out in the EPA technical guidance statements (EPA 2016b, c) and EPA environmental factor guideline (EPA 2016a).

5.4.1. Stygofauna Sampling

Stygofauna were sampled at each bore using weighted plankton nets. Six hauls were taken at each site; three using a 50 µm mesh net and three with a 150 µm mesh net. The net was lowered to the bottom of the hole and jerked up and down briefly to agitate benthos (increasing the likelihood of collecting benthic species) and then slowly retrieved. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul, flushed with bore water to reduce fine sediment content, preserved in 100% ethanol, and refrigerated at a constant 4 °C. Nets were washed between holes to minimise site-to-site contamination.

In situ water quality parameters – temperature, electrical conductivity (EC) and pH – were measured at each site, where possible, using a WP 81 field meter. Depth to the water table and total depth of hole were also measured using a Solinst water level meter.

5.4.2. Sample Effort

Twelve bores were identified as prospective stygofauna habitat in the Atlas Project Borefield; ATLUNK01, ATOB01, ATOB03, ATPB03, C29D, C29S, CS34D, C34S, CS35D, CS35S, ML8A, and ML8B. These bores were sampled for stygofauna, and water quality measures were taken where possible (Figure 3; Table 2; Appendix 2). Water quality was not measured at seven bores (C29S, C29D, ML8B, CS35S, CS35D, CS34S, and CS34D) as they were too narrow to sample.

5.4.3. Laboratory Processing

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 and specimens identified to species level where possible using available keys and species descriptions. When necessary for identification, animals were dissected and examined under a compound microscope. If specimens did not represent a described species, they were identified to species/morphospecies where possible using characters from species keys.

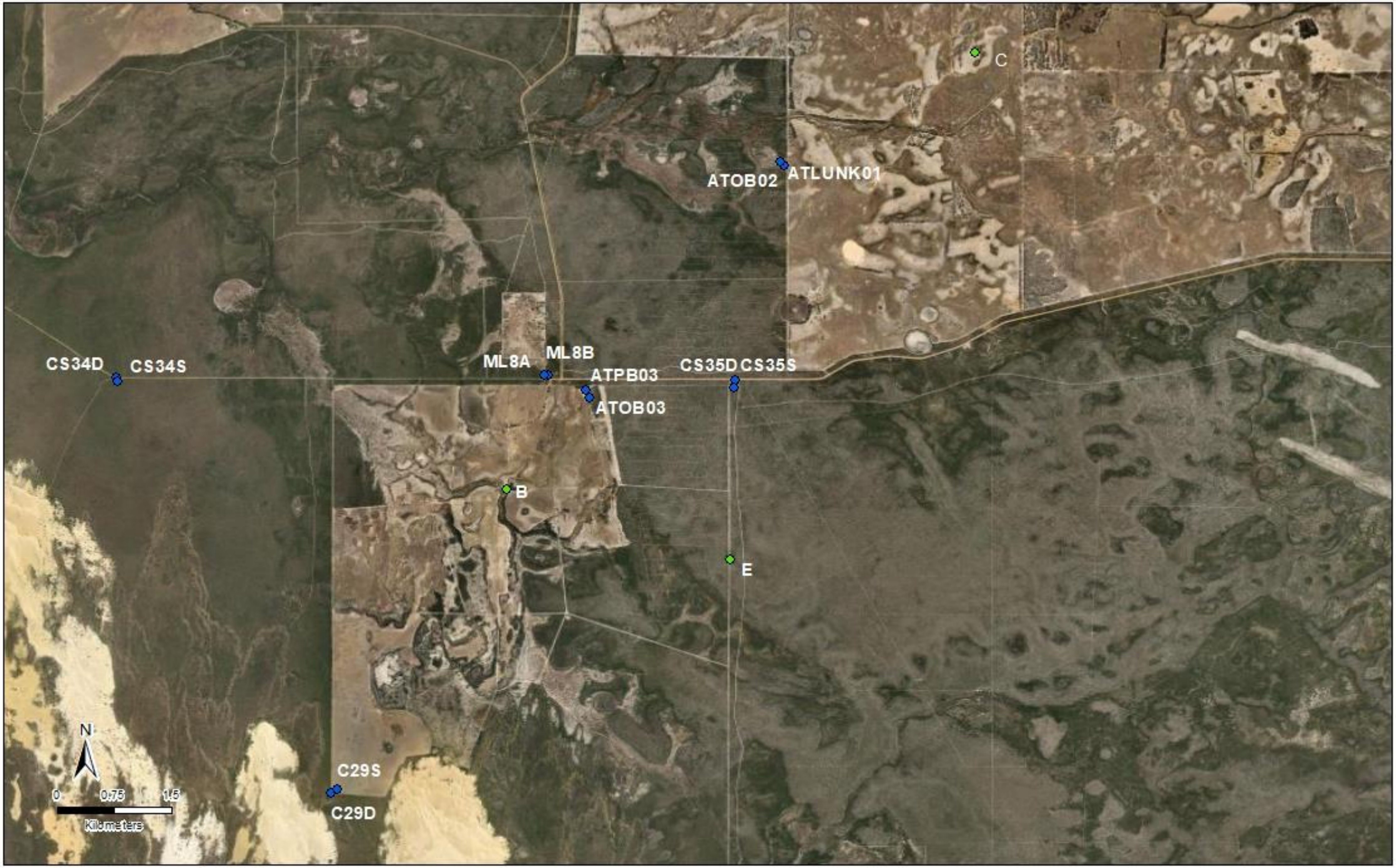
5.5. Results

5.5.1. Water Quality

Water quality parameters showed the aquifer to be moderately fresh and slightly acidic. Salinity (measured as conductivity) of monitoring bores was variable but within the tolerances of stygofauna (Table 2). Water chemistry could not be measured at C29S, C29D, ML8B, CS35S, CS35D, CS34S, and CS34D as the bores were too narrow.

Bore	Temperature	EC	pH
ATLUNK01	21.3	22100	6.46
ATOB02	21.8	19200	6.49
ATOB03	21.4	1510	5.89
ATPB03	20.6	1301	6.32
ML8A	21.6	3070	6.12

Table 2: Summary of bores sampled in the Atlas Project Borefield for water quality measures.



Bonnelongia

GCS GDA 1994
Author: mfulcher
Date: 9/11/2021

Legend

- Bore locations
- GW Supply Conceptual Bore Sites

Figure 3. Atlas Project bore locations and conceptual supply sites

5.5.2. Stygofauna

The only stygofauna collected were 13 nematode specimens from C29S and C29D and one tubificid from bore C29D. Nematodes and tubificids are not assessed in the environmental impact assessment process due to a lack of ecological knowledge and unresolved taxonomy.

6. CONCLUSIONS

The desktop search of 100 km x 100 km around the Atlas area revealed 34 subterranean fauna specimens had previously been collected, including nine stygofauna specimens and 25 troglofauna specimens. All troglofauna specimens were collected in the Nambung cave system, approximately 7 km from the Project, and were not representative of species likely to occur at Atlas. The stygofauna surveys in the area yielded very little despite the geology of the area being considered prospective for stygofauna.

The stygofauna results of surrounding areas were also reflected by results of sampling at Atlas. A pilot survey of the project area and a baseline survey of the borefield for stygofauna only collected nematodes and a tubificid. Despite habitat appearing to be suitable for stygofauna, survey at Atlas showed that at most a depauperate stygofauna community is present.

Habitat at Atlas is unlikely to be prospective for troglofauna because of a shallow water table.

With both stygofauna and troglofauna depauperate, and the relatively little drawdown of groundwater at the Project, it is unlikely that mining in the Atlas tenements will impact significantly on subterranean fauna conservation values.

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APPENDICES

Appendix 1 – Secondary Impacts of Mining on Subterranean Fauna

Mining activities that may result in secondary impacts to subterranean fauna include:

1. *De-watering below troglofauna habitat*. The impact of a lowered watertable on subterranean humidity and, therefore, the quality of troglofauna habitat is poorly studied but it may represent risk to troglofauna species in some cases. The extent to which humidity of the vadose zone is affected by depth to the watertable is unclear. Given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, de-watering may have minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna.

2. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered to be a significant risk to either stygofauna or troglofauna outside the proposed mine pits.

3. *Overburden stockpiles and waste dumps*. These artificial landforms may cause localised reduction in rainfall recharge and associated inflow 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 troglofauna than stygofauna (because lateral movement of groundwater should bring in carbon and nutrients). The extent of impacts on troglofauna 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 under them.

4. *Aquifer recharge with poor quality water*. It has been observed that the 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 the pit to prevent recharge though the pit floor.

5. *Contamination of groundwater by hydrocarbons*. Any contamination is likely to be localised and may be minimised by engineering and management practices to ensure the containment of hydrocarbon products.

Appendix 2 – Atlas Project Bore Information

Bore Code	Latitude	Longitude
ATLUNK01	-30.5443	115.2554
ATOB02	-30.5443	115.2552
ATOB03	-30.5708	115.232
ATPB03	-30.5708	115.2321
C29D	-30.6187	115.2017
C29S	-30.6187	115.2017
CS34D	-30.5694	115.1764
CS34S	-30.5694	115.1764
CS35D	-30.5697	115.2497
CS35S	-30.5696	115.2497
ML8A	-30.5691	115.2276
ML8B	-30.5691	115.2276