



Jervois Base Metal Project

Stygofauna Pilot Study

Prepared for:

Nitro Solutions on behalf of KGL Resources

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Summary

frc environmental was commissioned by Nitro Solutions on behalf of KGL Resources to assess the potential impacts to stygofauna within the study area of the proposed Jervois Base Metal Project (the Project), to support the approvals processes for the Project.

The Project is located north-east of Alice Springs in the Northern Territory. Currently, the Northern Territory has no guideline for the assessment of stygofauna. However, the 'Scientific Inquiry into Hydraulic Fracturing in the Northern Territory' (Northern Territory Government 2018) states that the Queensland, Western Australia and NSW stygofauna assessment guidelines would each be applicable as the assessment framework for stygofauna assessment in the Northern Territory. Thus, the Queensland guideline was applied to assess stygofauna for the Project.

The Queensland guideline, the 'Environmental Assessment of Subterranean Aquatic Fauna' (the Guideline) firstly requires a 'pilot study' followed by a 'comprehensive survey' if the pilot study detects the presence of significant stygofauna. Therefore, the assessment comprised a stygofauna pilot study in accordance with the Queensland Guideline.

The scope of this study was to assess stygofauna in the Water Supply Investigation area (the borefield area) for the Project, adjacent to Lucy Creek to the north of the proposed mine site, including:

- describe the environmental values of the borefield area relating to stygofauna, including the likely presence and significance of stygofauna likely to be affected by the Project, as required by the Terms of Reference (ToR) for the Project
- assess the potential adverse impacts of the Project on the environmental values of stygofauna, including residual and cumulative impacts, as required by the ToR, and
- present mitigations for avoiding or reducing impacts to environmental values of stygofauna.

Overall, the stygofauna community of the borefield area was assessed as having *low* environmental value based on:

- the limited occurrence of a single *stygoxene* taxon, and
- water quality of groundwater being only *potentially suitable* for stygofauna on the basis of total dissolved solids..

The borefield area is the Water Supply Investigation area for the Project, with water table drawdown the predominant source of impact to stygofauna, with minimal ancillary sources of impact from vegetation clearing and access road construction.

However, a risk-based assessment determined that the mitigated risk of impact was *low* for each of these potential sources of impact.

1 Introduction

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The scope of this study was to assess stygofauna in the Water Supply Investigation area (the borefield area) for the Project, adjacent to Lucy Creek to the north of the proposed mine site (see Appendix A), including:

- describe the environmental values of the borefield area relating to stygofauna, including the likely presence and significance of stygofauna likely to be affected by the Project, as required by the Terms of Reference (ToR) for the Project
- assess the potential adverse impacts of the Project on the environmental values of stygofauna, including residual and cumulative impacts, as required by the ToR, and
- present mitigations for avoiding or reducing impacts to environmental values of stygofauna.

This report presents:

- an overview of stygofauna
- the survey methods and results of the pilot study
- an assessment of the environmental values of stygofauna of the borefield area, and
- an assessment of the significance of potential impacts of the borefield on the environmental values of stygofauna, noting mitigating measures for avoiding or reducing impacts.

2 Project Description

KGL Resources are in the planning and approval stage of developing the Jervois Base Metal Project, located approximately 270 km north-east of Alice Springs within the Georgina River Catchment (Lake Eyre Basin) (Figure 2.1.). The Project involves mining copper and other base metals from a series of discrete ore deposits located on the Jervois tenements.

Ore would be processed onsite using a crushing, grinding and flotation plant, producing copper and lead/zinc concentrate. The process requires approximately 1,200 ML per year of water, to be supplied from an existing fresh water catchment dam and a planned bore field to be established adjacent to Lucy Creek (tributary of Arthur Creek). Waste material would be stored in a tailings dam with two cells and a capacity of 17.37 million tonnes (Mt), and waste rock dumps.

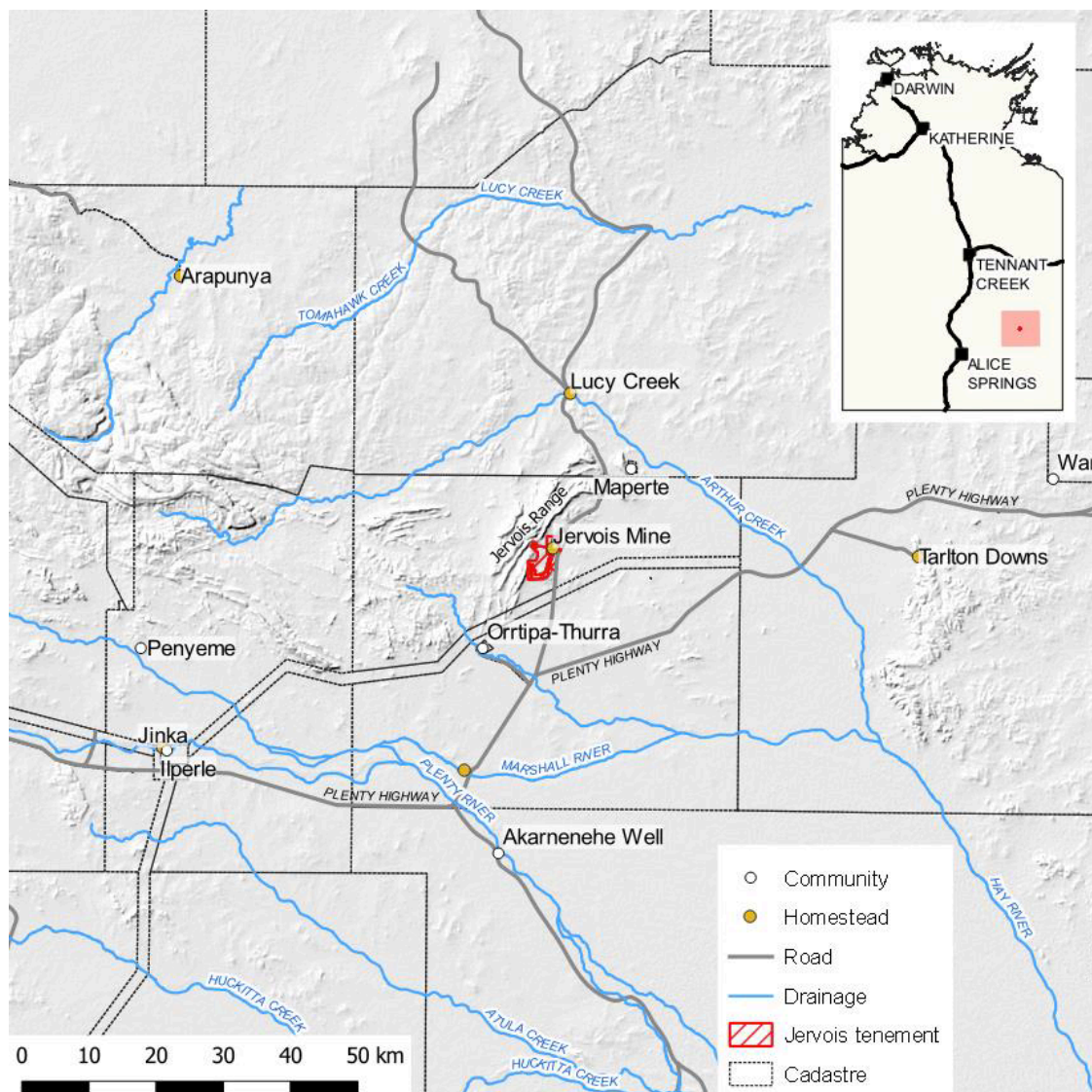


Figure 2.1 Proposed Project Location.

3 Overview of Stygofauna

3.1 Description

Stygofauna are subterranean aquatic animals that live in the pores, voids and cavities of aquifers and other groundwater ecosystems. Many species of stygofauna have specialised adaptations to underground life, including:

- small body size (e.g. many species have a total body length <1 mm)
- lack of pigmentation
- absence of eyes, and
- elongated appendages (for tactile sensing of the surrounding environment).

Crustaceans, including copepods, amphipods, isopods and syncarids, typically dominate the composition of stygofaunal communities, although oligochaetes, molluscs, mites, insects and rotifers are also common. Blind fish and eels are also known from some cave systems, such as those in Western Australia.

Stygofauna taxa are grouped into one of several classes based on the degree of their requirement for subterranean life (Tomlinson & Boulton 2008). For the purpose of this assessment, two classes of stygofauna are considered:

- stygobites: obligate groundwater aquatic fauna that have specialised adaptations to underground life and that live within groundwater systems for their entire life, and
- stygoxenes: aquatic fauna that facultatively use groundwater ecosystems, but are not dependent on groundwater to complete their life cycle.

3.2 Status under Commonwealth and State Legislation

Stygofauna have no conservation listing at the Queensland level. At the Commonwealth level, the following are listed:

- the Cape Range Remiped (*Kumonga exleyi*) in Western Australia, which is listed as Vulnerable under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and
- stygofauna communities associated with Great Artesian Springs (i.e. the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin), which is listed as Endangered under the EPBC Act.

The borefield area is not within the Great Artesian Basin, and is outside the known range of the Cape Range Remiped, therefore listed species of stygofauna do not occur in or surrounding the borefield Area.

As stygofauna diversity and distribution is poorly understood compared to surface water fauna, the National Water Quality Management Strategy recommends the appropriate management of groundwater ecosystems to ensure the ongoing protection of stygofaunal communities (ANZECC & ARMCANZ 2000).

3.3 Distribution

Stygofauna communities are widely distributed across Australia, and have been found in temperate, sub-tropical, tropical, semi-arid and arid regions of Australia (Hancock & Boulton 2008; Tomlinson & Boulton 2008). At the family level stygofauna are widespread and many families that include stygofaunal species also include surface water and marine species (e.g. copepods, rotifers and mites).

However, at the species level many taxa have a narrow distributional range (i.e. stygofauna communities contain species that occur exclusively within a small area), and thus stygofauna communities are generally thought to have high endemism (Boulton et al. 2010; Harvey et al. 2011). For example, about one quarter (i.e. 23%) of the stygofauna species that were sampled on two or more occasions in a long-term study of stygofauna in the Pilbara region were sampled from within the same sub-region, and the median area of distribution of these stygofaunal species was 683 km² (Halse et al. 2014), with almost all stygofaunal species having distributions of less than 1 000 km² (Eberhard et al. 2009). A species of Parabathynellidae was recorded from 3 bores in the Burdekin River Alluvial Aquifer in Queensland, with two of these bores located approximately 20 km apart (Cook et al. 2012), suggesting a potential distribution of approximately 400 km². Additionally, studies in both Western Australia and Queensland have found evidence that sub-catchment boundaries can demarcate locations of turn-over of stygofaunal species (Finston et al. 2007; Little et al. 2016). Therefore, areas of approximately 400 – 600 km² within a single sub-catchment may represent reasonable estimates of distribution of most stygofaunal species, acknowledging that site-specific factors (e.g. highly confined aquifers) may impose further restrictions on distribution in some cases, or create strong population subdivision within species on smaller spatial scales (Cook et al. 2012; Little et al. 2016).

3.4 Ecology and Habitat

Stygofauna are thought to provide important ecosystem services relating to the maintenance of hydrological connectivity and groundwater quality by consuming the microbial communities that form biofilms on the substrate matrix of the aquifer (Boulton et

al. 2008; Hancock & Boulton 2008). Therefore, despite the short length of food webs in groundwater ecosystems (i.e. biofilm $\Rightarrow$ stygofauna), stygofauna occupy a critical trophic position in these food webs that likely sustains the health of groundwater ecosystems.

The suitability of a groundwater ecosystem to provide habitat for stygofauna is dependent on several environmental factors including:

- geology
- groundwater hydrology, and
- groundwater quality.

For example, stygofauna are generally thought to prefer shallow water aquifers with high secondary porosity in groundwater recharge areas, with groundwater of high quality (i.e. neutral pH and low electrical conductivity) intersecting the root zone of terrestrial vegetation (Eamus et al. 2006; Tomlinson & Boulton 2008; Schulz et al. 2013). While there are clear associations between stygofauna diversity and these generalised assumptions of stygofauna habitat suitability, there are also notable exceptions that demonstrate that almost any groundwater ecosystem has the potential to provide habitat for stygofauna (see Glanville et al. 2016). For example, in Queensland stygofauna have been found in areas of natural vegetation, intensively cultivated vegetation (i.e. sugar cane) and in heavily cleared (i.e. very sparsely vegetated) areas (Hancock & Boulton 2008; Cook et al. 2012; GHD 2013); indicating that water tables that intersect the root zone of terrestrial vegetation is not an essential habitat characteristic of aquifers containing stygofauna.

Further discussion of the geological, hydrological and water quality characteristics of groundwater ecosystems that generally provide suitable habitat for stygofauna is presented below.

Geology

Stygofauna have the potential to occur in aquifers composed of any geological unit with sufficient pore space to complete their life cycle (Tomlinson & Boulton 2008). Consequently, stygofauna are less likely in geological units with relatively small pore spaces, such as those dominated by mudstone, siltstone and clays. Preliminary discovery rates of stygofauna in Queensland indicate that (Glanville et al. 2016):

- no stygofauna have been recorded in mudstone and siltstone to date
- stygofauna are less common in clay, coal and basalt dominated geologies
- stygofauna are most common in alluvium, granite, gravel, sand, sandstone, silt, and volcanic geological units.

The diversity of stygofauna in Queensland is highest in alluvium, with 14 described families in alluvial geological units; 5 in both basalt and coal; 4 in both gravel and sand; 2 in sandstone; and one in silt (Glanville et al. 2016). Limestone reportedly has diverse stygofauna communities (Tomlinson & Boulton 2008), with preliminary data indicating the presence of stygofauna in limestone geological units in Queensland (EPA 2006). Available information from stygofauna studies completed in the Northern Territory indicate a similar pattern, with stygofauna reported from alluvial, karst and calcrete geological units, but very limited recorded from fractured rock aquifers within ore-based geologies ERISS 2005; Van Dam 2008; GHD 2011; Chandler et al. 2017).

Groundwater Hydrology

Geological units with large pore spaces also provide for hydrological connectivity through groundwater ecosystems, which influences how quickly organic matter and oxygenated water are replenished, and may also determine the extent to which stygofauna can move through groundwater ecosystems. In alluvial aquifers in eastern Australia the average number of stygofauna taxa was higher within 6 m from the water table height, and where the water table height was less than approximately 15 m below the ground (Hancock & Boulton 2008). Other studies have shown similar results, with a statistically lower diversity of stygofauna in deeper aquifers than shallow aquifers (Halse et al. 2014). However, in Queensland, stygofauna have been recorded from over 60 m below ground (Glanville et al. 2016), indicating that deep groundwater ecosystems can also support stygofaunal communities.

The general trend of higher diversity of stygofauna in shallow aquifers is speculated to be because most shallow groundwater systems have higher concentrations of organic matter and dissolved oxygen than deeper groundwater, as a virtue of proximity to the surface. Proximity to groundwater recharge areas may also represent a favourable habitat characteristic for stygofauna, due to greater organic matter availability and concentration of dissolved oxygen in water. In aquifers with poor to very poor recharge, stygofauna abundance is low, with stygofauna diversity typically higher in aquifers with good to very good recharge (Schulz et al. 2013). Thus, alluvial aquifers close to watercourses that function as groundwater recharge zones often have high abundance and diversity of stygofauna (Hancock & Boulton 2008).

Groundwater Quality

While the mean electrical conductivity of water from which stygofauna have been sampled is less than 4,000 $\mu\text{S}/\text{cm}$, they have been recorded from a broad range of electrical conductivities (i.e. 11.5 – 54,800 $\mu\text{S}/\text{cm}$) (Glanville et al. 2016). Tolerance to high electrical conductivity is likely to vary among taxa, with only crustaceans (i.e. copepods and

syncarids) reported from the upper end of this range (Glanville et al. 2016). Crustaceans found in surface water habitats commonly have a higher salinity tolerance than other taxa (e.g. insects, mites, gastropods) (Dunlop et al. 2008); thus, crustacean taxa may be more likely to occur in groundwater with high electrical conductivity than other stygofaunal taxa.

The minimum concentration of dissolved oxygen needed to support stygofauna communities is unknown. Some taxonomic groups are likely to be more tolerant of very low dissolved oxygen, and others more tolerant of very high dissolved oxygen (Halse et al. 2014). However, bores with the highest diversity of stygofauna had dissolved oxygen levels ranging from approximately 20 to 60% saturation (Halse et al. 2014).

Stygofauna have been recorded from groundwater with pH ranging from 3.5 to 10.3, with diversity highest when pH is between 6.5 and 7.5 (average of 7.0) (Hancock & Boulton 2008). Total dissolved solids (TDS) can strongly influence the diversity of stygofauna, with stygofauna almost always absent where TDS is higher than 15 mg/L (Halse et al. 2014); however, recent survey work found stygofauna where TDS was 1090 mg/L (frc environmental unpublished data). Other water quality parameters, such as ionic composition, may also influence the diversity and taxonomic composition of stygofauna (Halse et al. 2014).

3.5 Threats to Stygofauna

Stygofauna are threatened by activities that impact:

- the quantity of groundwater (i.e. reduced groundwater level and pressure via groundwater extraction or aquifer dewatering). Reduced water levels reduce the amount of habitat available for stygofauna. Reduced groundwater pressure reduces the rate of flow of groundwater, which may in turn reduce the recharge of oxygen-rich water or water with high organic matter concentrations (which supports groundwater food webs).
- the quality of groundwater (e.g. contamination from above ground sources, including nutrients and spills of pesticides and hydrocarbons). Impacts may be lethal or sub-lethal (i.e. reduced rate of reproduction, impacted physiology).
- patterns of recharge and discharge from groundwater ecosystems, such as a reduction in flow in watercourses that provides recharge to underlying aquifers. This may reduce the recharge of oxygen-rich water or water with high organic matter concentrations, and may lower water tables, which reduces habitat availability.
- permeability and void spaces of the aquifer matrix (e.g. compaction of soil by heavy machinery), which reduces habitat quality and habitat availability.
- physical habitat of the aquifer (e.g. excavation of mine pits), which reduces the available habitat for stygofauna.

4 Assessment of Stygofauna Habitat Suitability, Community Composition and Environmental Values

4.1 Assessment Methods

Stygofauna were assessed using a ‘desktop review’ and ‘pilot study’, as described in the *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna* (DoSITIA 2014); see also DES (2018).

Desktop Review

A desktop review was used to determine the suitability of groundwater ecosystems of the borefield area to provide habitat for stygofauna on the basis of geological, hydrological and water quality characteristics of local groundwater ecosystems, and included:

- review of previous studies to determine the recorded presence and distribution of stygofauna in the region
- review of hydrogeological data for the borefield area, and
- review of groundwater pH and electrical conductivity (EC) data within and surrounding the borefield area.

Pilot Study

Ten bores were surveyed for stygofauna between 01 and 02 May 2019 (Table 4.1; Map 3.1). The samples bores were all within the proposed Water Supply Investigation area (borefield area), adjacent to Lucy Creek north of the proposed mine site (Appendix A).

The full water column in each bore was sampled using six hauls of a weighted phreatobiological net (similar to a plankton net). Three of the hauls were with a very fine net (mesh size 50 µm), and three hauls were with a fine net (mesh size 150 µm). Samples were preserved in 100% ethanol and transported to frc environmental’s laboratory where stygofaunal specimens were identified to Order or Family using available taxonomic keys. Each specimen was then identified to morpho-species by trained ecologists as taxonomic keys are not available for species-level identification of stygofauna.

Table 4.1 Bores sampled for stygofauna.

Bore	Easting	Northing	Main Geological Unit Targeted by Bore	Drilled depth (mBLG)
LC4	617949	7511228	calcareous siltstone / dolomite limestone	117
LCP1	621620	7511633	dolomite limestone	60
LC5	621604	7511653	dolomite limestone	101.5
LC6	621914	7513364	dolomite limestone	53.4
LC3	623307	7513283	calcareous siltstone / dolomite limestone	78
LC1	627980	7514060	calcareous siltstone	90
LC9	642219	7510971	dolomite limestone	168
LCP2	638138	7514165	dolomite limestone	69
LC14	638125	7514143	dolomite limestone	150
LC15	637170	7515105	Mudstone with some dolomite limestone	150

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Source: CloudGMS (2018)

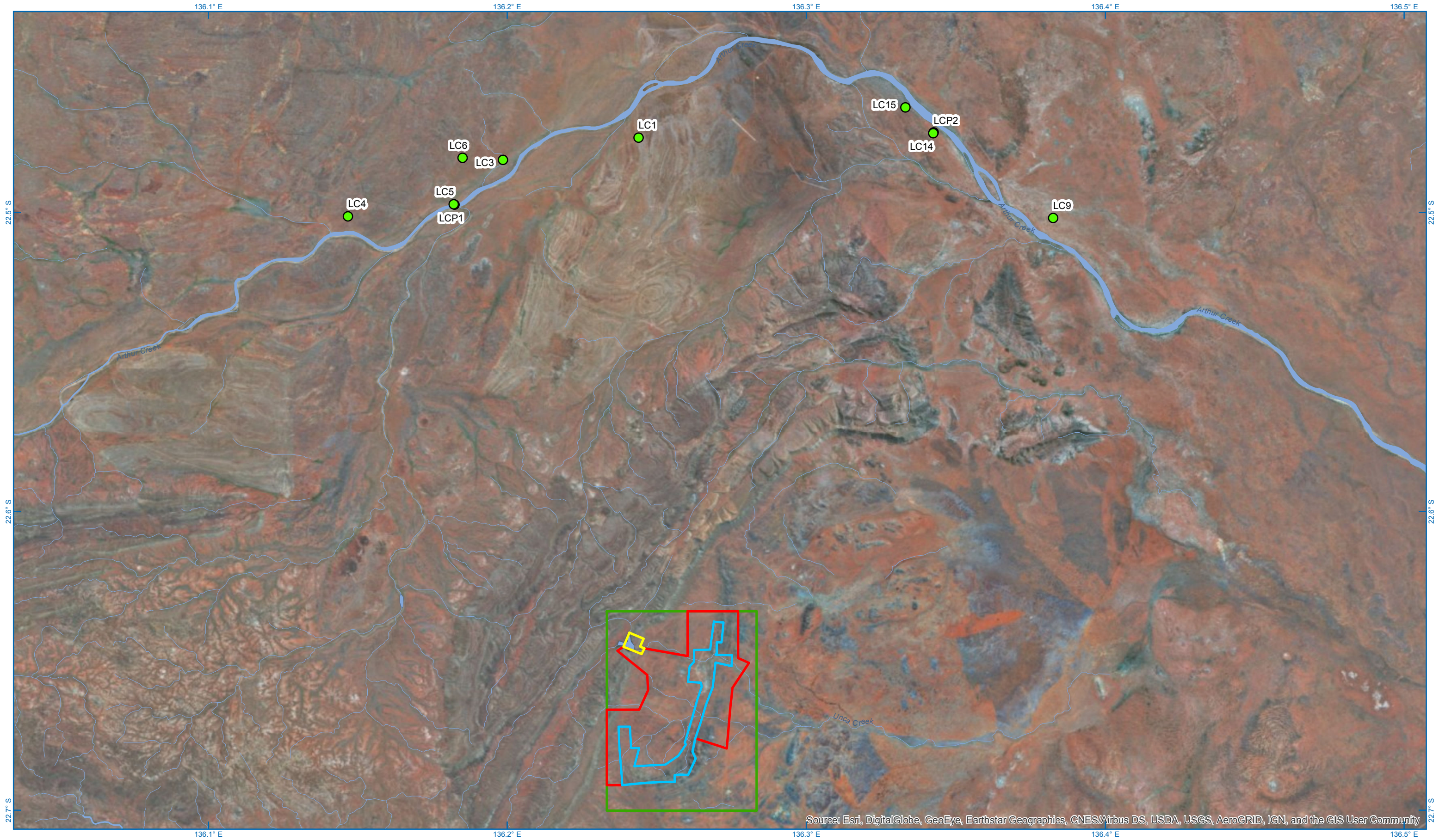
Assessment of Environmental Value

The environmental values of stygofauna of the borefield area were determined using the following criteria:

- high value: threatened species listed under State or National legislation
- moderate value: non-listed stygobites and / or *suitable*¹ habitat for stygofauna present (as defined in Section 3.0), and
- low value: only non-listed stygoxenes and / or *potentially suitable*² habitat for stygofauna present (as defined in Section 3.0).

¹ suitable habitat means geological, hydrological and water quality characteristics of groundwater ecosystems that are generally known to support high diversity of stygofauna, as described in Section 2.4

² potentially suitable habitat means geological, hydrological and / or water quality characteristics of groundwater ecosystems that are outside the general habitat characteristics known to support diverse stygofauna communities, but within the range from which stygofauna have been recorded.



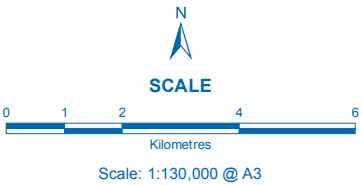
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Jervois Project - Stygofauna Studies

Map 4.1: Surveyed Bores

SOURCES
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- LEGEND**
- Borehole Location
 - EL25429 boundary
 - ML30180 boundary
 - ML30182 boundary
 - ML30829 boundary
 - Major Watercourse
 - Minor Watercourse
 - Lake/Reservoir



PROJECTION
Coordinate System: GCS GDA 1994
Datum: GDA 1994
Units: Degree

DATE
2019-06-06
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4.2 Results of Desktop Assessment

Stygofauna of the Region

In the Northern Territory, stygofauna are known from or likely to occur in Cutta Cutta Caves, calcrete aquifers near Alice Springs, karst aquifers in the Daly River area, and the shallow alluvial aquifer of Magela Creek (ERISS 2005; Van Dam 2008; GHD 2011; Chandler et al. 2017). Stygofauna diversity was high in the saturated sands of Magela Creek (13 taxa) (Chandler et al. 2017), with available data suggesting lower diversity in other geological units.

Stygofauna have been found in shallow aquifers adjacent to watercourses in northern sections of the Lake Eyre Basin (frc environmental, unpublished data).

Geology

The geology of the borefield area is dominated by the:

- Arrinthrunga Formation, composed of dolostone, limestone, minor quartz sandstone, siltstones, shale and marl, and
- Arthur's Creek Formation, composed of dolomite limestone in the upper layers, and carbonaceous black shale and laminated dolostone in the lower layers.

The geology of the borefield area includes units that are likely to provide habitat for stygofauna, as well as some units from which stygofauna have not been reported, e.g. siltstone (Glanville et al. 2016). On the basis of those units that are likely to provide habitat for stygofauna, the geology of the borefield area is considered to be *suitable* for providing habitat for stygofauna.

Hydrology

In eastern Australia the average number of stygofauna taxa was higher when the samples were collected where the water table was less than approximately 15 m below ground (Glanville et al. 2016). The depth to water table is < 15 m below ground at most bores (Table 4.2). Therefore, the shallow groundwater ecosystems of the borefield area have likely *suitable* hydrological characteristics to provide habitat for stygofauna.

Water Quality

The mean electrical conductivity of water from which stygofauna have been sampled, generally, is less than 4,000 $\mu\text{S}/\text{cm}$; however, the range of electrical conductivity concentrations of groundwater that stygofauna have been sampled from is very large (i.e. 11.5 – 54,800 $\mu\text{S}/\text{cm}$) (Glanville et al. 2016). Electrical conductivity recorded from bores in the borefield area ranged from 650 – 3,750 $\mu\text{S}/\text{cm}$ (Table 4.2), and was therefore consistent with the preferred range of electrical conductivity for stygofauna. The electrical conductivity of groundwater of the borefield area is *suitable* for stygofauna.

Stygofauna have been recorded from groundwater with pH ranging from 3.5 to 10.3, but diversity is highest between 6.5 and 7.5 (mean of 7.0) (Hancock & Boulton 2008). The pH of groundwater from the borefield area has been assessed at only two bores, with the recorded values being 6.96 and 7.07, and thus aligned with the range known to support diverse stygofaunal communities (Table 4.2). The pH of groundwater of the borefield area is *suitable* for stygofauna.

In Western Australia, stygofauna were almost always absent where total dissolved solids (TDS) was higher than 15 mg/L (Halse et al. 2014); however, recent survey work found stygofauna where TDS was 1090 mg/L (frc environmental unpublished data). TDS of groundwater from the borefield area has been assessed at only two bores, with the recorded values being 394 mg/L and 1570 mg/L (Table 4.2), and thus at least sometimes outside the range likely to support stygofauna. TDS of the borefield area is *potentially suitable* for stygofauna.

Table 4.2 Environmental characteristics of bores from the borefield area.

Bore	Drilled depth (mBLG)	Depth to water (mBLG)	Geology	Electrical conductivity ($\mu\text{S}/\text{cm}$)	TDS (mg/L)	pH
LC4	117	20.3	calcareous siltstone / dolomite limestone	650	–	–
LCP1	60	14.21	dolomite limestone	680	394	6.96
LC5	101.5	14.46	dolomite limestone	720	–	–
LC6	53.4	21.27	dolomite limestone	1,500	–	–
LC3	78	11.31	calcareous siltstone / dolomite limestone	710	–	–
LC1	90	11.82	calcareous siltstone	3,300	–	–
LC9	168	9.58	dolomite limestone	3,750	–	–
LCP2	69	12.04	dolomite limestone	2,800	1,570	7.07
LC14	150	–	dolomite limestone	2,760	–	–
LC15	150	12.34	mudstone with some dolomite limestone	1,540	–	–

Source of data: CloudGMS (2018)

– no data

TDS total dissolved solids

4.3 Results of the Pilot Study

Of the ten bores surveyed, one bore (LC15) contained stygofauna (Table 4.3): a single copepod. This taxon is a stygoxene (i.e. not obligate inhabitant of groundwater ecosystems).

Table 4.3 Results of the stygofauna pilot study.

Bore ID	Stygofaunal taxon	Common name	Class	Abundance
LC4	–	–	–	–
LCP1	–	–	–	–
LC5	–	–	–	–
LC6	–	–	–	–
LC3	–	–	–	–
LC1	–	–	–	–
LC9	–	–	–	–
LCP2	–	–	–	–
LC14	–	–	–	–
LC15	Cyclopodia 1	copepod	stygoxene	1

– No stygofauna recorded.

4.4 Environmental Values of Stygofauna of the Borefield Area

Overall, the stygofauna community of the borefield area was assessed as having *low* environmental value based on:

- the limited occurrence of a single *stygoxene* taxon, and
- water quality of groundwater being only *potentially suitable* for stygofauna on the basis of total dissolved solids.

5 Impact Assessment and Mitigation

5.1 Potential Sources of Impact to Stygofauna

The borefield area is the Water Supply Investigation area for the Project, with water table drawdown the predominant source of impact to stygofauna, with minimal ancillary sources of impact from vegetation clearing and access road construction.

Physical Disturbance of Groundwater Ecosystems

The following mining activities have the potential to impact stygofaunal communities in the borefield area by directly disturbing groundwater ecosystems:

- drawdown of water tables and reduction of groundwater pressure, notably in the Water Supply Investigation area, which was the target area for this assessment, and
- road transportation for access tracks, which may lead to compaction of soil and aquifers and reduce habitat quality of groundwater ecosystems for stygofauna (i.e. compress voids, pores and cavities within the ground matrix where stygofauna live).

Vegetation Clearing

Terrestrial vegetation overlying shallow groundwater ecosystems, where the water table intersects the root zone of the vegetation, is thought to provide favourable habitat conditions for stygofauna (Eamus et al. 2006; Hancock & Boulton 2008). Clearing of vegetation may therefore reduce the habitat quality of shallow groundwater ecosystems for stygofauna. Potential impacts would be localised to immediate area of clearing.

5.2 Risk-based Impact Assessment

The risk assessment determined the level of risk as an outcome of the consequence and likelihood of the potential impact (Table 5.1 to Table 5.3). The 5 x 3 risk matrix (Table 5.3) gives risk scores ranging between one and 15, with risk being:

- low, when the score is <5
- medium, when the score is >5 but <10, and
- high, when the score is >10.

Table 5.1 Ratings used to assess the likelihood of potential impacts.

Rating	Likelihood of occurrence
Very high (5)	Almost certain to occur frequently
High (4)	Probably would happen sometimes to frequently
Moderate (3)	Could happen sometimes
Low (2)	Remote possibility of occurring or not expected to occur
Very low (1)	Definitely would not happen at all

Table 5.2 Ratings used to assess the consequence of potential impacts.

Rating	Consequence of potential impacts
High	Catastrophic, irreversible or critical long-term environmental harm or loss; significant harm or loss of sensitive components of the environment; significant harm or loss of protected components of the environment, such as protected wetlands or MNES.
Moderate	Significant short-term but reversible harm of the environment; minor environmental harm to sensitive or protected components of the environment, such as protected wetlands or MNES.
Low	Unfavourable impact with no material harm to the environment and no impact on sensitive or protected components of the environment.

Table 5.3 Environmental risk matrix.

		Likelihood				
		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Consequence	Low (1)	1	2	3	4	5
	Moderate (2)	2	4	6	8	10
	High (3)	3	6	9	12	15

Table 5.4 Risk-based Impact Assessment.

Source of Potential Impact	Mitigations	Consequence of Impact	Likelihood of Impact	Mitigated Risk to stygofauna
Physical disturbance of groundwater ecosystems leading to impacts on stygofauna	Implementing water level monitoring across an appropriately designed bore field Develop suitable water level triggers, that if exceeded trigger management response Restricting access tracks to a minimal road network for use by light vehicle only	Low (1) Groundwater systems of the borefield area have low environmental value for stygofauna	Moderate (3) While water level triggers will be developed for the project, it is possible that they could be exceeded sometimes	Low (1 x 3 = 3)
Vegetation clearing leading to impacts on stygofauna	Clearing only the area needed for Project operations	Low (1) Groundwater systems of the borefield area have low environmental value for stygofauna	Low (2) Very limited vegetation clearing is required for the Project around bore sites and access roads	Low (1 x 2 = 2)

6 Conclusions

Overall, the stygofauna community of the borefield area was assessed as having *low* environmental value based on:

- the limited occurrence of a single *stygoxene* taxon, and
- water quality of groundwater being only *potentially suitable* for stygofauna on the basis of total dissolved solids..

The borefield area is the Water Supply Investigation area for the Project, with water table drawdown the predominant source of impact to stygofauna, with minimal ancillary sources of impact from vegetation clearing and access road construction..

However, a risk-based assessment determined that the mitigated risk of impact was *low* for each of these potential sources of impact.

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Appendix A Bore Sampling Plan for Lucy Creek Stygofauna Field Assessment

Jervois Base Metals Project

BORE SAMPLING PLAN FOR LUCY CREEK STYGOFAUNA FIELD ASSESSMENT

ATTENTION	Xuanyu Yang, Nitro Solutions Ben Cook, Principal Ecologist (Freshwater), frc environmental
FROM	Simon Fulton, Hydrogeologist, CloudGMS/Groundwater Enterprises
DATE	5 April, 2019

In preparation for the field stygofauna sampling event to be completed by frc environmental, CloudGMS have nominated a number of target bores for the program. Note that these bores are associated with the water supply investigation and are located on Lucy Creek Station, as opposed to the monitoring bores installed on the Jervois mining lease. This is in line with our understanding that the presence of stygofauna and therefore potential impacts from the mine development is much more likely in the limestone/dolomite aquifer on Lucy Creek rather than the low permeability fractured metasediments on the mining lease.

We have outlined the location and construction details for these bores in Table 1, and have also provided an indicative order for sampling based on location. A map with the bore locations is provided in Figure 2. For further detail on the construction/logs please see the accompanying drilling completion report and drillers logs.

Please note that the monitoring bores are capped with steel flanges (see picture below) and will require a pair of shifters or suitably sized wrenches to gain access.



Figure 1 – Example of flanged monitoring bore completion

Table 1 – Lucy Creek stygofauna sampling target bores and construction details

Bore ID	Site ID	Easting GDA94 Z53	Northing GDA94 Z53	Constructed Depth (mBLG)*	Screen from (mBGL)*	Screen to (mBGL)*	Internal Casing Diameter/material	Indicative recommended sampling order
RN019775	LC4	617949	7511228	117	57^ 105	64 111	100 mm PVC	1
RN019782	LCP1	621620	7511633	58	46	58	200 mm Steel	2
RN019793	LC5	621604	7511653	101.5	47.5^ 89.5	53.5 95.5	100 mm PVC	3
RN019781	LC6	621914	7513364	53.4	41.4	47.4	100 mm PVC	4
RN019776	LC3	623307	7513283	28.5	19.5	25.5	100 mm PVC	5
RN019774	LC1	627980	7514060	90	72	84	100 mm PVC	6
RN019778	LC9	642219	7510971	168	153	165	100 mm PVC	7
RN019794	LCP2	638138	7514165	65	53	65	200 mm Steel	8
RN019779	LC14	638125	7514143	150	132	144	100 mm PVC	9
RN019780	LC15	637170	7515105	148.3	25.3^ 139.3	31.3 145.3	100 mm PVC	10

*mBLG = metres below ground level

^ denotes bore with two screened intervals

