Fortescue Metals Group

Christmas Creek Project Water Management Scheme: Troglofauna Assessment

Final Report

Prepared for
Fortescue Metals Group Ltd
by Bennelongia Pty Ltd

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Christmas Creek Project Water Management Scheme: Troglofauna Assessment

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Cover photo: Chichester Range

Client – Fortescue Metals Group Ltd

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EXECUTIVE SUMMARY

Fortescue Metals Group Ltd is developing the Pilbara Iron Ore and Infrastructure Project, which includes a series of iron ore mines in the Pilbara region of Western Australia and rail and port infrastructure for export of iron ore via Port Hedland. One of the mines within the Pilbara Iron Ore and Infrastructure Project is the Christmas Creek Mine, on the footslopes of the Chichester Range in the central Pilbara region of Western Australia. Fortescue is currently increasing mining to 45 million tonnes of iron ore annually at the Christmas Creek mine and is planning to increase dewatering to 50 gigalitres per annum and begin injection of unused water below ground. This development is known as the '*Christmas Creek Project Water Management Scheme'*.

The Christmas Creek mine was approved under Ministerial Statement 707 (Pilbara Iron Ore and Infrastructure Project: East-West Railway and Mine Sites, Stage B), which required Fortescue to carry out surveys for subterranean fauna at the project in accordance with an approved sampling plan (Condition 10.1). This '*Stygofauna Survey Plan'*, which was approved by the Department of Environment and Conservation, identified stygofauna as the subterranean group likely to be at risk from mining activities at the Christmas Creek mine.

Recently, an improved understanding of groundwater characteristics and changes to pit configuration at Christmas Creek have resulted in required water production from the borefield being increased from 11.4 GL/a to a maximum of 50 GL/a to dewater and improve access to ore below the watertable. The proposed dewatering will be achieved using the established borefield, with all abstracted water that is not used in processing or other activities being injected back below the watertable at sites away from the mine pits. The injection of unused water will result in mounding of the watertable, with a maximum rise of 2 m east and west of the borefield and 1 m south of the borefield, at the edge of Fortescue Marsh, where the hypersaline water will be hypersaline. The total area impacted by groundwater mounding will be approximately 12,044 ha and the total area impacted by dewatering will be 13,291 ha.

This report considers likely impacts of dewatering and groundwater injection on troglofauna in the Christmas Creek Project water management area. At the time environmental approval was originally obtained for the Christmas Creek mine, troglofauna were relatively unknown outside of karstic habitats in Western Australia and their occurrence in the Fortescue Valley was not expected. Therefore, troglofauna were not included in the framework for environmental assessment. However, it is likely troglofauna occur within the Project area. Species belonging to 15 broad groups of troglofauna have been collected in nearby parts of the Chichester Range, including pseudoscorpions, schizomids, palpigrads, spiders, isopods, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus gnats. The troglofauna community is likely to be richer on the footslopes of the Chichester Range than close to the Fortescue Marsh, where depth to the watertable is less.

The primary risk to troglofauna from the Christmas Creek Project Water Management Scheme is that groundwater injection will cause loss of up to 19% of troglofauna habitat within the injection areas, via groundwater mounding (flooding). Close to Fortescue Marsh where hypersaline water will be injected into the Oakover Formation, the loss of habitat will be much greater but it is considered unlikely that any species will be restricted to this area of hypersaline groundwater injection. In the footslopes of the Chichester Range, where the troglofauna community is likely to be richer, no more than 10% of troglofauna habitat within the area of injection will be lost. The extensive geological continuity along the Fortescue valley and footslopes of the Chichester Range make it unlikely that any species will be restricted to the area of groundwater injection.

Groundwater abstraction will lower the watertable by up to 40 m around the mine pits. It is difficult to predict the effect of this dewatering on soil humidity within potential troglofauna habitat, although they may be minimal in the habitats actually occupied by troglofauna. Furthermore, the extensive geological continuity along the Fortescue valley and footslopes of the Chichester Range make it unlikely that persistence of any species will be threatened by changes to humidity in the area of groundwater abstraction.

Within the significant constraints associated with a desktop study, the risks to troglofauna species persistence posed by the groundwater abstraction and injection as a result of the Christmas Creek Project Water Management Scheme are considered to be acceptably low.

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1. INTRODUCTION

Fortescue Metals Group Ltd (Fortescue) is developing the Pilbara Iron Ore and Infrastructure Project, which includes a series of iron ore mines in the Pilbara region of Western Australia and rail and port infrastructure for export of iron ore via Port Hedland. One of the mines within the Pilbara Iron Ore and Infrastructure Project is the Christmas Creek Mine, on the footslopes of the Chichester Range in the central Pilbara region of Western Australia (Figure 1). Fortescue is currently increasing mining to 45 million tonnes of iron ore annually at the Christmas Creek mine and is planning to increase dewatering to 50 gigalitres per annum and begin injection of unused water below ground. This development is known as the '*Christmas Creek Project Water Management Scheme'*.

The Christmas Creek mine was approved under Ministerial Statement 707 (Pilbara Iron Ore and Infrastructure Project: East-West Railway and Mine Sites, Stage B), which required Fortescue to carry out surveys for subterranean fauna at the project in accordance with an approved sampling plan (Condition 10.1). This '*Stygofauna Survey Plan'* (Ecologia 2006), which was approved by the Department of Environment and Conservation, identified stygofauna as the subterranean group likely to be at risk from mining activities at the Christmas Creek mine. At that time, troglofauna were relatively unknown outside of karstic habitats in Western Australia and their occurrence in the Fortescue Valley was not expected. Therefore, troglofauna were not included in the framework for environmental assessment of the Christmas Creek mine.

Troglofauna have since been found to have widespread occurrence in vuggy and fractured rock habitats, especially pisolite and banded iron (Bennelongia 2008a,c 2009a,b; Biota 2006) as well as in calcrete and alluvium (Edward and Harvey 2008; Rio Tinto 2008; Barranco and Harvey 2008; Platnick 2008). This advance in knowledge has led to more emphasis on troglofauna during environmental impact assessments in the Pilbara. Accordingly, this desktop assessment considers the possible impacts of the Christmas Creek Water Management Scheme on troglofauna. The specific aims of this assessment are:

1. Document the troglofauna communities occurring, or are likely to occur, within the Christmas Creek mining area;
2. Identify the potential threats to troglofauna species arising from the Christmas Creek Project Expansion; and to
3. Assess the risk to troglofauna species from the Christmas Creek Project Expansion.

2. HABITAT AND GEOLOGY

Troglofauna presence is dependent on geology and, if no fissures or voids are present in the strata, no troglofauna will occur. If subterranean spaces are present, the pattern of their occurrence will largely determine the density and distribution of troglofauna. Vertical connectivity with the surface is important for supplying carbon and nutrients to maintain populations of different species (plant roots are an important surface connection), while lateral connectivity of voids is crucial to underground dispersal. Geological features such as major faults and dykes may block off the continuity of habitat and act as barriers to dispersal leading to species having highly restricted ranges.

The Christmas Creek Project is located on the southern footslopes of the Chichester Range, which lies within the Hamersley Basin, where granitoid rocks of the Pilbara Craton are 2800 - 3500 million years old. Bedrock iron ore mineralization in the Hamersley Province is hosted by the Brockman and Marra Mamba Iron Formations of the Hamersley Group, which are overlain throughout most of the Project

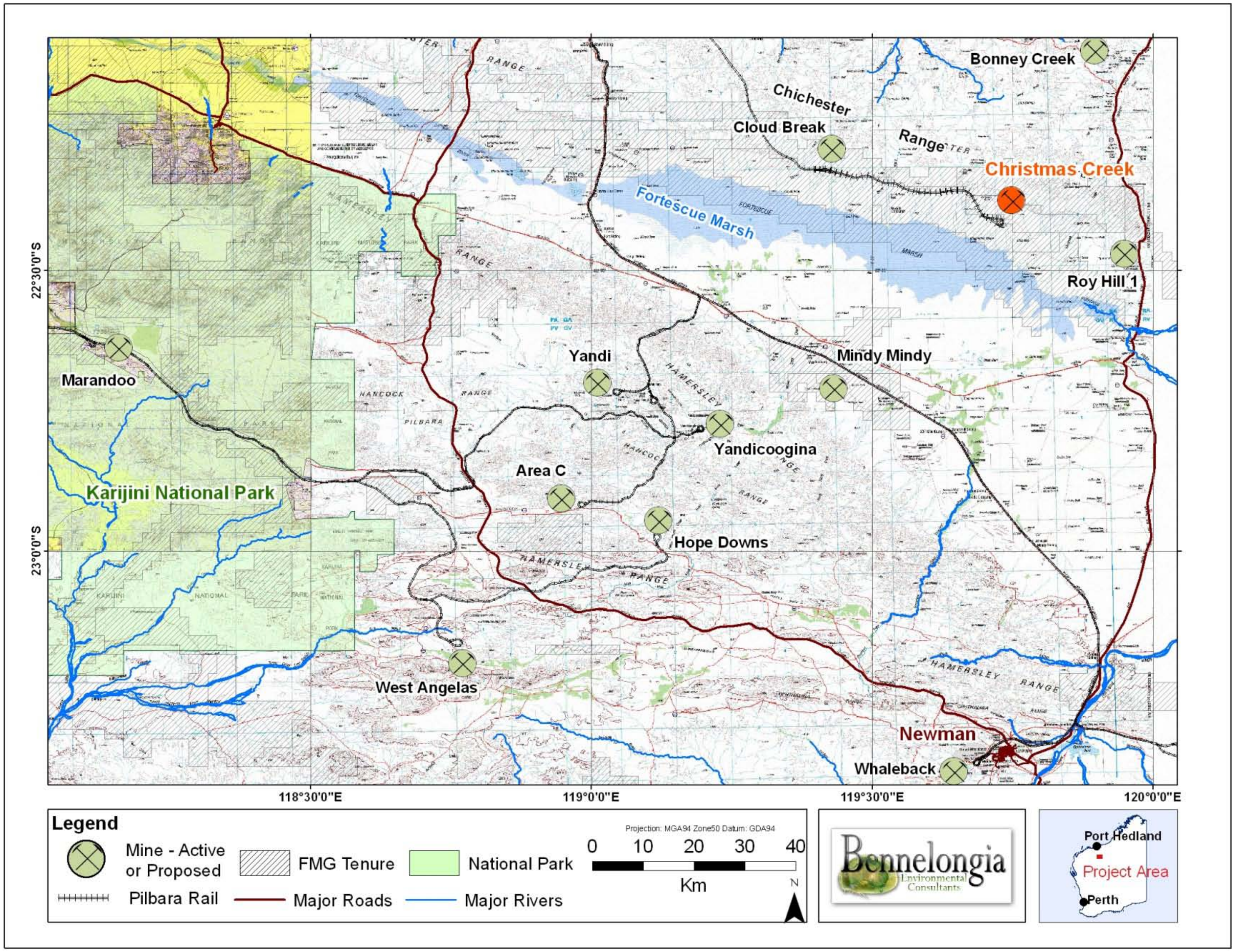

Figure 1. Location of the Christmas Creek Project in relation to other existing or proposed mine sites.

area by sedimentary rocks (Figure 2). The basal Nammuldi Member of the Marra Mamba Iron Formation outcrops along the Chichester Range and hosts the mineralization. Un-mineralized Nammuldi Member comprises interbedded yellow Banded Iron Formation (BIF) and chert with thin shale interbeds and is approximately 60 - 80 m thick. Underlying the Nammuldi Member is the Roy Hill Shale Member of the Jeerinah Formation. To the south of the Chichester Range the Nammuldi Member is concealed beneath Oakover Formation (calcrete and silcrete) sands, clays and gravels of Tertiary age (see Trendall 1990). Cavities and vuggy pores occur widely in the rock strata of the Project area, which have little or no Tertiary overlay.

Natural groundwater depths in the Christmas Creek Project Water Management area lie between 6 and 30 m below the surface, depending on distance from the Marsh, local topography and season Bennelongia 2008b). The strata above the water table comprise the Marra Mamba Formation and Tertiary sediments (Oakover Formation, alluvium, and colluvium comprised of sands, clays and gravels).

Troglofauna habitat is usually considered to occur from the lower layers of loose soil and sand at the surface to the interface with the groundwater (see Juberthie et al. 1981). The animals occupy interstices, vugs, cavities and fissures in this subterranean space. Troglofauna occur widely in the mineralized iron formations of the Pilbara (Bennelongia 2008a,c, 2009a,b; Biota 2006). Sampling outside mineralised areas has shown that troglofauna also occur in Pilbara calcrete and alluvium (Edward and Harvey 2008; Rio Tinto 2008). Similar patterns have been observed in the Yilgarn (e.g. Barranco and Harvey 2008; Platnick 2008) and elsewhere (Biota 2005a,b).

3. PROJECT DESCRIPTION

The Christmas Creek Project mines iron ore by surface scraping. Ore is transported by rail to Port Hedland for shipping.

The estimated resource at Christmas Creek is 1000 million tonne of Marra Mamba iron ore. The currently approved production rate is 45 Mta (Ministerial Statement 707). All mine infrastructure is to be contained within the currently approved 10,135.5 ha area of disturbance with an average pit depth of 60 m. Ore will be beneficiated at the Christmas Creek mine.

Water requirements approved under Ministerial Statement 707 are limited to 11.4 GL per annum. An improved understanding of groundwater characteristics, and changes to pit configuration, have shown that up to 50 GL per annum of dewatering will be required to improve access to ore below the watertable. Proposed changes in pit configuration are minor and are contained within the approved 10,135.5 ha disturbance area.

The proposed increase in dewatering around the mine pits will be achieved using bores within the established borefield (Figure 3). Abstracted groundwater that cannot be used for ore processing will be injected locally into the underlying aquifers. Brackish water will be injected east and west of the borefield, while hypersaline water will be injected south of the borefield. Injection will result in mounding of groundwater to a maximum of 2 m east and west of the borefield and 1 m south of the borefield on the fringe of Fortescue Marsh. The total area impacted by groundwater mounding is estimated to be 12,044 ha and the total area impacted by dewatering is estimated to be 13,291 ha. The estimated total area of changed watertables is 250% larger than the currently approved area of disturbance (Figure 3).

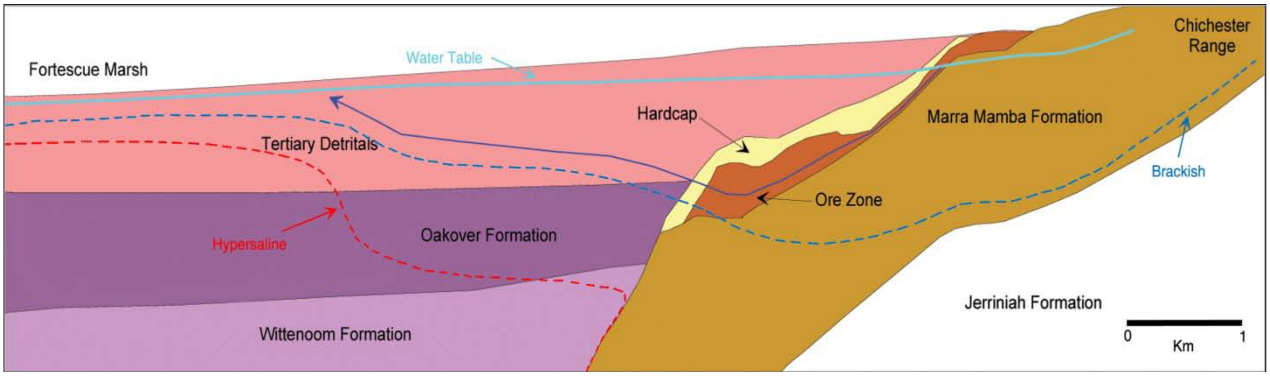

Figure 2. Schematic diagram of the geology of the Christmas Creek Project Water Management Scheme area and its aquifers.

4. SUBTERRANEAN FAUNA IN THE REGION

Subterranean fauna spend all, or most, of their lifecycle underground and are typically highly adapted to a subterranean lifecycle. Commonly these adaptations include pallid colouration, reduction or loss of eyes, elongate body, long slender appendages and well developed sensory setae. Subterranean fauna are represented by terrestrial (troglofauna) and aquatic (stygofauna) species. Troglofauna occur in subterranean cavities above the watertable, whilst stygofauna occur in groundwater. Nearly all subterranean animals are invertebrates; however both stygofaunal fish and troglofaunal reptiles occur in Western Australia (Whitely 1945, Aplin 1998).

Subterranean fauna have significant scientific value and a high proportion of subterranean species are short-range endemics (SREs), which are defined by Harvey (2002) as species with ranges of <10,000 km^2. The very limited ranges of SRE species means they are particularly vulnerable to extinction as a result of anthropogenic activities and, therefore, they are a focus for conservation. About 70% of stygofauna in the Pilbara are SREs (Eberhard et al. 2009) and the proportion of troglofauna that are SREs is likely to be even higher (see Lamoreux 2004). Consequently, the Environmental Protection Authority (EPA) usually requires that the risks to subterranean fauna are considered when assessing proposed mine developments (EPA 2003).

4.1. Troglofauna

Troglofauna studies have historically focussed on caves; however, surveys during the past five years have shown that troglofauna are widespread in Pilbara landforms and are represented by numerous invertebrate groups, including pseudoscorpions, schizomids, palpigrads, spiders, harvestmen, isopods, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus gnats. Although troglofauna abundance and diversity appear to be greatest in the Pilbara, at a regional scale troglofauna are ubiquitous in WA and have been recorded from the Kimberley (Harvey 2001), Cape Range (Harvey et al. 1993), Barrow Island (Biota 2005b), Mid-West (Ecologia 2008), Yilgarn (Bennelongia 2009c, and South-West (Biota 2005a).

Most troglofauna surveys for environmental assessment have been undertaken in areas of pisolite or banded iron formation. The micro-habitats that troglofauna occupy within these lithologies are still being defined but it is inferred that they utilise the fissures and voids associated with weathering, enrichment and faulting. Information about the occurrence of troglofauna outside mineralized habitats

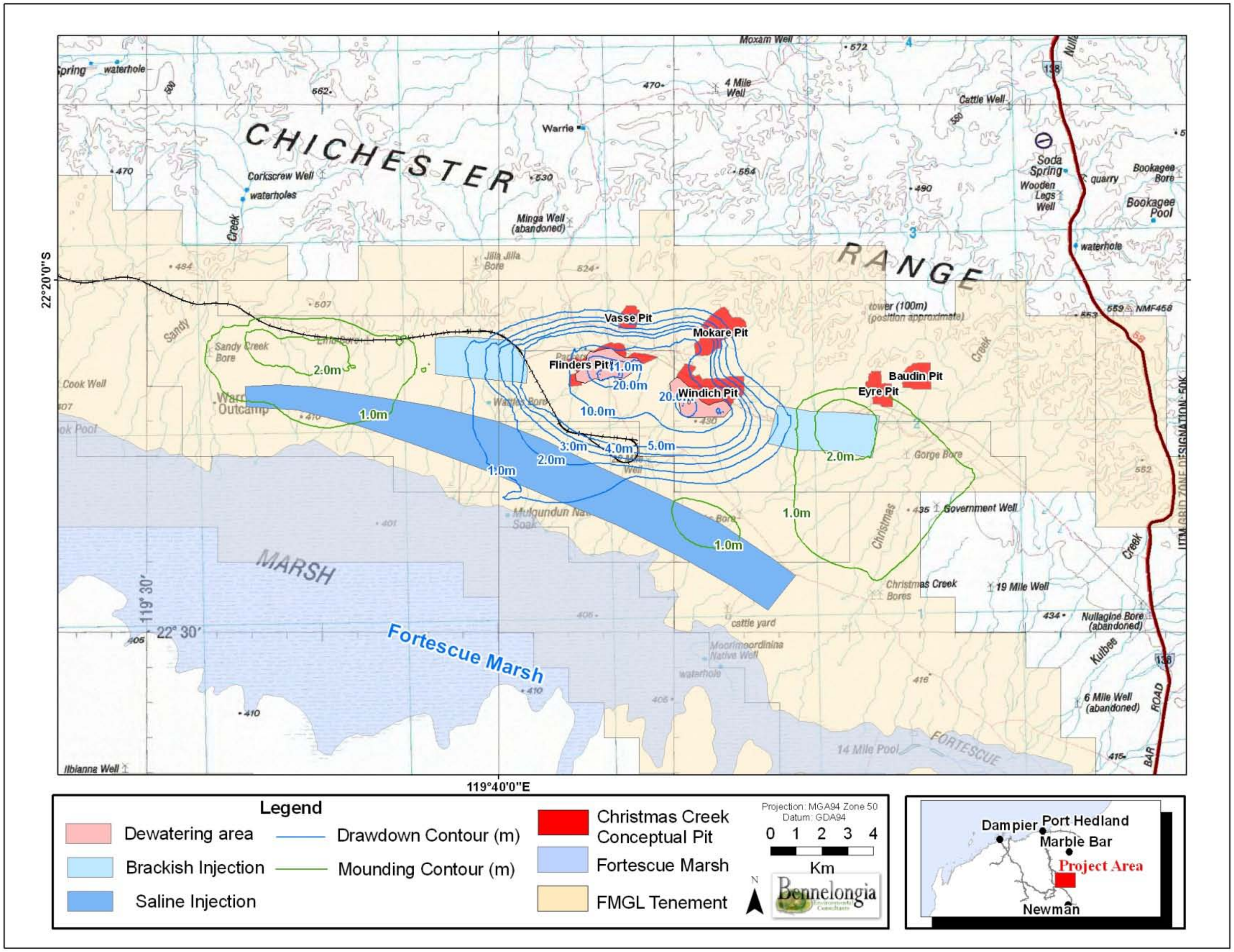

Figure 3. Key aspects of the Christmas Creek mine: 1) conceptual pits, 2) abstraction borefield, and 3) proposed drawdown (negative) and injection mounding (positive) contours.

is limited because mine development has been the primary reason for most of the surveys. However, it has been demonstrated that troglofauna occur in calcrete and alluvium in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009c) and elsewhere (Biota 2005a,b).

5. POTENTIAL THREATS TO TROGLOFAUNA FROM THE PROPOSAL

Direct loss of habitat is typically considered the most significant threat to troglofauna. In the case of mining operations, pit excavation typically represents the most significant loss of troglofauna habitat. The Christmas Creek Project Water Management Scheme does not propose any expansion of pits beyond the area currently approved for mining. The only unapproved activity associated with the Christmas Creek Project Water Management Scheme that may result in direct loss of troglofauna habitat is groundwater injection. Habitat loss will be caused by flooding as groundwater rises as a result of mounding (Figure 2). A similar phenomenon already occurs more-or-less annually as monsoonal rainfall recharges the aquifer, with a consequent rise in the watertable of 2-3 m (Johnson and Wright 2001).

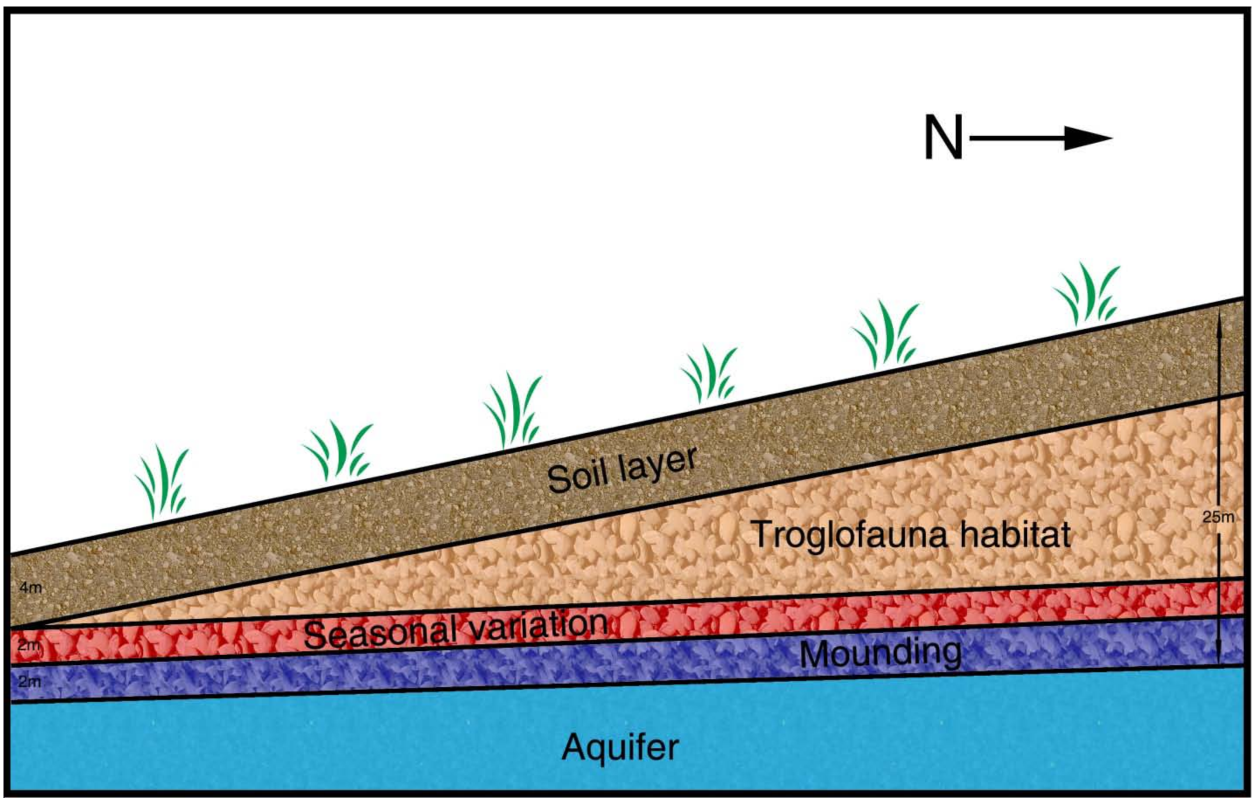

Figure 4. Schematic diagram of potential troglofauna habitat loss at the Christmas Creek mine as a result of groundwater mounding.

Quantitatively, the volume of habitat lost because of groundwater mounding will be less than 19%. This figure assumes a rise in watertable of 2 m across the entire 12,044 ha of predicted mounding and, therefore, overestimates the habitat loss (Figure 4). Some additional habitat degradation may occur in the southern part of the Water Management area (see Figure 3) as a result of the injected water being hypersaline. Although this water will be injected into the Oakover Formation (see Figure 3), it is possible that higher salinity levels will occur in the vicinity of the hypersaline injection bores.

There has been little study of how mining activities, other than those causing habitat losses, affect troglofauna. However, troglofauna are known to require humidity greater than about 80% (Humphreys 1990, Hadley et al. 1991) and groundwater abstraction (or dewatering) is probably that most likely activity, after direct loss of habitat, to have detrimental effects on troglofauna. Lowering the watertable has the potential to reduce humidity in the strata above the natural watertable, although perhaps most dewatering operations have little effect (see Bennelongia 2008d). Drying of habitat adjacent to mine pits, through the pit walls, may be more common.

Altogether, 13,291 ha will be dewatered. However, less than half the area will experience more than 5 m drawdown. A drawdown of 5 m is of similar magnitude to the changes in water level that occur naturally over decadal cycles (annual fluctuations are 2-3 m, Johnson and Wright 2001).

6. TROGLOFAUNA AT THE CHRISTMAS CREEK MINE

There has been no dedicated sampling of troglofauna at the Christmas Creek mine. Hence, to assess the likelihood of troglofauna occurring in the Christmas Creek Water Management area, records of troglofauna were compiled within a search area surrounding the mine (defined by 21.97-22.76°S, 119.3-120.23°E; see Figure 5). Records were assembled from the arachnid and myriapod databases of the Western Australian Museum and from previous troglofauna surveys conducted in the search area (Bennelongia 2008c; SMEC 2009).

The Museum databases contained no records of troglofauna within the search area. However, surveys in surrounding parts of the Chichester Range have shown that significant troglofauna communities do occur and the Museum results appeared to reflect local lack of surveys and lodged specimens. The surrounding surveys collected species belonging to 15 broad groups of troglofauna, including pseudoscorpions, schizomids, palpigrads, spiders, isopods, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus gnats (Table 1).

The troglofauna community at Bonney Creek, 35 km north-west of Christmas Creek, contained 18 species in pisolitic iron deposits (Table 1, Figure 5; Bennelongia 2008c). Troglofauna surveys undertaken at Roy Hill (Marra Mamba iron deposits), 15 km to the south-east of Christmas Creek, documented nine species that are likely to be troglofauna (SMEC 2009). A further two species of troglofauna were collected at Fortescue's Cloudbreak mine 25 km west of the Christmas Creek mine as by-catch during stygofauna sampling (Bennelongia 2008b).

Given that troglofauna are rarely collected during sampling of cased boreholes, it is likely that a richer troglofauna community occurs in the Cloudbreak area than the above two records suggest (Bennelongia 2010b). The Cloudbreak and Christmas Creek mines are both located on a 90 km strike length of the Chichester Range with similar geological stratigraphy and would be expected to support troglofauna communities of similar richness.

Geology suggests that, within the Christmas Creek Water Management area, the troglofauna community is likely to be richer in the north, closer to the footslopes of the Chichester Range where the depth to watertable is about 20 m and the volume of potential habitat is greater. This area encompasses the Vasse, Mokare, Eyre and Baudin pits (Figure 3). Conversely, the troglofauna community is likely to be more modest in areas closer to Fortescue Marsh that are covered by Tertiary Detritals because the depth to watertable is less than 10 m and the potential habitat layer is thin. However, recent sampling

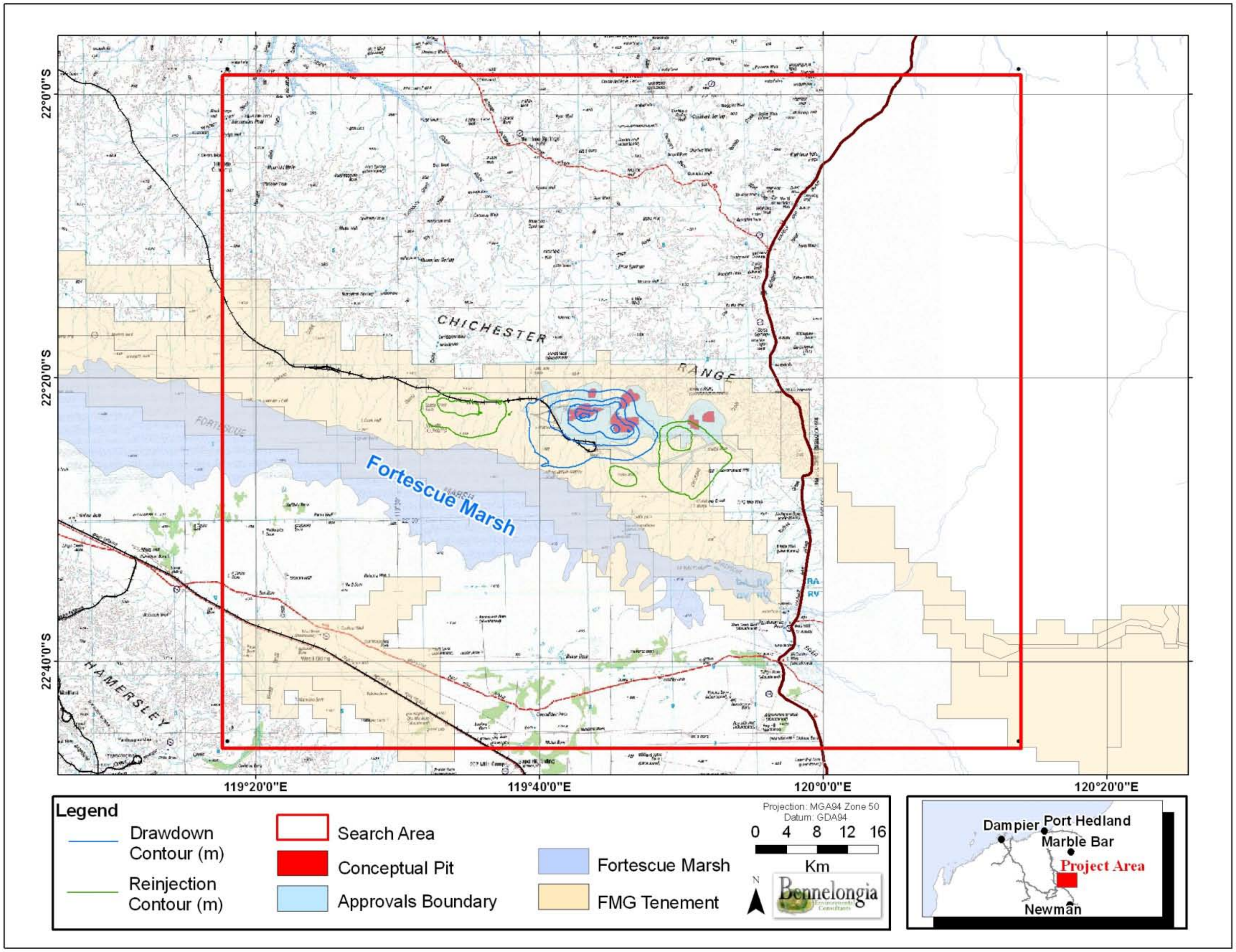

Figure 5. The Christmas Creek search area (21.97-22.76°S, 119.3-120.23°E), with key aspects of the mine and Water Management Scheme indicated.

Table 1. Records of troglofauna collected at Bonney Creek, Cloudbreak (stygofauna sampling by-catch) and Roy Hill.

Higher Rank	Bonney Creek[1]	Cloudbreak[3]	Roy Hill[2]
Pseudoscorpion			
	Tyrannochthonius sp. B3 (nr *basme*)		
Palpigradi			
	Palpigradida sp.		Palpigradi
Schizomida			
	Draculoides sp. B3		
Spider			
	Araneomorphae sp. B3		Araneae (3 species)
Isopoda			
		Philosciidae sp. B5	
		Troglarmadillo sp. B15[4]	
Millipede			
	Polyxenida sp.		
Centipede			
	Cryptops sp. B4 (nr *megalophora*)		
Pauropoda			
			Pauropoda
Symphyla			
			Symphyla
Diplura			
	Japygidae sp.		
Silverfish			
	Trinemura sp.		Diplura
Cockroach			
	Blattidae sp. B2		Blattodea (2 species)
	Nocticola sp. B4		
	Nocticola sp. B5		
	Nocticola sp. B6		
Bug			
	Ploiaria sp. B1		
	Hemiptera sp. B2		
	Meenoplidae sp. B3		
	Meenoplidae sp B1		
Beetle			
	Coleoptera sp. B2		
Fungus-gnat			
	Sciaridae sp. B1		

1. Bennelongia 2008c
2. SMEC 2009
3. Bennelongia 2007
4. Previously known as Oniscidae sp. B3 (Bennelongia 2007).

has shown that some troglofauna do occur in such habitats (see Edward and Harvey 2008; Rio Tinto 2008; Barranco and Harvey 2008; Platnick 2008).

6.1. Risks from the Christmas Creek Project Expansion

The primary risk to troglofauna from the Christmas Creek Project Water Management Scheme is that groundwater injection will cause habitat loss via groundwater mounding (flooding). This injection will cause a maximum of 2 m of mounding above the natural watertable over an estimated area of 12,044 ha (Figure 2). However, this loss of habitat is considered unlikely to threaten troglofauna species.

The total volume of habitat lost to flooding will be less than 19% of the habitat in the mounded area. In the northern part of the Project area, at the footslopes of the Chichester Range, where the troglofauna community is expected to be richer, no more than 10% of habitat will be lost. A much larger proportion of the habitat will be lost in small areas of injection close to the Marsh, where troglofauna habitat is naturally only a few metres thick. However, loss of this habitat is considered unlikely to threaten the persistence of troglofauna species because geological and troglofauna habitats along the Fortescue valley are very unlikely to be restricted and so species ranges are unlikely to be constrained. The area does not contain landforms, such as mesas or major faulting, where troglofauna have been documented with highly restricted ranges (e.g. Biota 2006).

A secondary risk to troglofauna from the Christmas Creek Project Expansion is that groundwater drawdown will result in drying of some subterranean habitat, making it inhospitable to troglofauna (see Biota 2006). The potential impacts of drawdown are difficult to assess at Christmas Creek, where depth to groundwater ranges from 6-30 m and plant roots are likely to penetrate most of the strata above the watertable. Within the root zone, soil humidity is determined mainly by plant water requirements but humidity increases with depth until field capacity (100% humidity) is reached below the root zone (Sands 2001). Three factors will affect whether drawdown has substantial impact on troglofauna at Christmas Creek:

1. De-watering is rarely complete and in most cases pockets of water remain in the dewatered area and maintain a saturated atmosphere. The pockets of water partly represent water trapped in voids and fissures and partly represent lateral recharge of the dewatered area. Up to 50% of the original volume of water may remain in dewatered profiles (Aquaterra 2008).
2. The relatively shallow watertable means that troglofauna are likely to be found in habitats where plant roots are relatively abundant. The humidity regime in these habitat is maintained by the balance between the upwards capillary movement of water from the aquifer and the adhesion of that water to the matrix (which both retard the downwards drainage of water) and evaporation and transpiration processes (which reduce humidity). The extent of changes in humidity as a result of dewatering will vary with the amount of drawdown and are difficult to predict without field measurements.
3. Humidity is one of the parameters troglofauna are likely to use to select the micro-habitats they occupy within the broader subterranean matrix. Provided other habitat requirements are met, troglofauna may move vertically to maintain themselves in appropriate humidity. Thus, even if more superficial habitats dry after dewatering, troglofauna may be able to persist by following the watertable down and remaining in a constant humidity.

There may be additional risk to troglofauna if soil salinities increase around sites of hypersaline injection. Salinity tolerances of troglofauna in the Fortescue are unknown but elevated salinities are likely to increase osmotic stress and exacerbate any effects of reduced humidity.

7. CONCLUSION

Data with which to characterise the troglofauna community at the Christmas Creek Project Water Management Scheme are very limited but sampling at mine sites in the vicinity has collected a variety of troglofauna species, including pseudoscorpions, schizomids, palpigrads, spiders, isopods, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus gnats. Given that these troglofauna are occupying similar geologies to those at Christmas Creek, it is very likely that troglofauna species occur within the Christmas Creek Project Water Management Scheme area.

The primary risk to troglofauna from the Christmas Creek Project Water Management Scheme is that groundwater injection will cause loss of up to 19% of troglofauna habitat within the injection areas, via groundwater mounding (flooding). Close to Fortescue Marsh where hypersaline water will be injected into the Oakover Formation, the loss of habitat will be much greater but it is considered unlikely that any species will be restricted to this area of hypersaline groundwater injection. In the footslopes of the Chichester Range, where the troglofauna community is likely to be richer, no more than 10% of troglofauna habitat within the area of injection will be lost. The extensive geological continuity along the Fortescue valley and footslopes of the Chichester Range make it unlikely that any species will be restricted to the area of groundwater injection.

Groundwater abstraction will lower the watertable by up to 40 m around the mine pits. It is difficult to predict the effect of this dewatering on soil humidity within potential troglofauna habitat, although they may be minimal in the habitats actually occupied by troglofauna. Furthermore, the extensive geological continuity along the Fortescue valley and footslopes of the Chichester Range make it unlikely that persistence of any species will be threatened by changes to humidity in the area of groundwater abstraction.

Within the significant constraints associated with a desktop study, the risks to troglofauna species persistence posed by the groundwater abstraction and re-injection as a result of the Christmas Creek Expansion Project are considered to be acceptably low.

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