Fortescue Metals Group

Solomon Desktop Troglofauna Assessment

Final Report
Prepared Fortescue Metals Group Ltd
by Bennelongia Pty Ltd
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**Cover photo:** Japygidae `DPL010` (previously known as sp. B13)

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**Client – Fortescue Metals Group Ltd**

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EXECUTIVE SUMMARY

Fortescue Metals Group (Fortescue) operates the Solomon iron ore mine, which is located 60 km north of Tom Price in the Pilbara region of Western Australia. The Solomon mine consists of two mining areas, Kings and Firetail, and a rail spur that joins with Fortescue’s Cloudbreak-Port Hedland Railway. Kings comprises three Channel Iron Deposits (CID) called Valley of the Queens, Valley of the Kings (previously known as Valley of the Kings and Trinity) and Zion. Firetail comprises two areas of Bedded and Detrital Iron Deposit (BID and DID) that are known as Firetail North and Firetail South.

In 2011, following a Public Environmental Review (PER), the Minister for the Environment issued conditional approval for Solomon under Ministerial Statement 862 (MS862). Condition 13 of MS862 included the requirement for a troglofauna survey to be undertaken biannually at Solomon to validate predictions of habitat connectivity for troglofauna and to improve knowledge of troglofauna populations. After a series of troglofauna surveys were completed, Condition 13 was formally signed off by the EPA in 2013.

Fortescue is now investigating options to expand its operations at Solomon, including an increase in size of the mine footprint and the development of new borefields. The increased size of the mine footprint reflects a re-evaluation of the extent of the ore resource since the PER was submitted. Fortescue now proposes an overall increase in area of mine pits within Solomon from the approved 3680 ha to 4493 ha. To meet a net water deficit expected for the bulk of the project life, two new borefields are proposed: one approximately 12 km to the north-east of Firetail and one approximately 12 km to the south-east of Kings, known as the Northern Borefield and Southern Borefield, respectively.

The specific aims of this troglofauna assessment were to:
1. Summarise all previous troglofauna studies and assessment undertaken at Solomon; and
2. Assess the conservation implications of the proposed expansion of operations at Solomon for troglofauna species.

Borefield Development

Drawdown of the watertable associated with the proposed Northern and Southern Borefields is unlikely to threaten troglofauna species. The most likely mechanism for groundwater drawdown to reduce troglofauna habitat is through decreases in humidity of troglofauna habitat as the watertable is lowered. However, because small pools of water remain perched in voids as the watertable is lowered, in most situations lowering the watertable probably has little effect on humidity of troglofauna habitat. In fact, lowering of the watertable may often increase the amount of troglofauna habitat available. Therefore, in most situations dewatering is likely to be, at most, a secondary impact on troglofauna.

Pit Expansions

The proposed increase in area of mine pits at Solomon is 863 ha. This increase was divided into four components for assessment: 1) expansion of the potential Kings pits assessed in the PER; 2) additional southern pits at Kings; 3) expansion of the potential pits at Zion assessed in the PER and Condition 13 surveys; and 4) expansion of the potential Firetail pits assessed in the PER. The following conclusions are drawn:

Kings

Based on a large survey effort at Kings and the subsequent understanding of distributions of troglofauna species present in the area, it may be assumed that a modest increase of 7% in pit size at Kings would do little to alter the position of low risk to troglofauna established by the surveys undertaken to fulfil
Condition 13 of MS862. These surveys demonstrated that there is a connection for troglofauna species between habitat within the potential mine pits at Kings and habitat outside the pits. It seems likely that most, if not all, species occurring in the valleys at Kings also occur on the flanks of surrounding ranges and in those ranges.

**Kings (new southern pits)**
The geology of the potential mine pits south of Kings is similar to that at Kings. The alluvial and colluvial sediments of the valleys extend well beyond the areas to be mined, so that there is likely to be habitat connectivity along the valleys for any troglofauna in the sediments. Similarly, there is also likely to be good connectivity from the alluvial deposits and DID on valley flanks into the BIF and hardcap of surrounding ranges. Although no troglofauna survey has been conducted in the potential southern pits, by analogy with the troglofauna community at Kings, it is considered that the threat to the troglofauna species occurring in these areas is likely to be low.

**Zion**
It was concluded in the PER that there was little threat to troglofauna at Zion because 36% of outcropping CID would remain unmined. It is now proposed to increase the area to be mined at Zion by up to 68% (from 258 to 434 ha), which will remove the majority of unmined CID within Zion. However, re-evaluation of the resource has identified additional CID around the proposed mine pits. It is estimated that about 60% of the CID at Zion and its immediate surroundings will be outside the proposed pits. Three species are known only from within the proposed Zion mine pits (the schizomid *Draculoides* 'SCH033', beetle Zuphiini sp. SOLOMON and centipede *Cryptops* sp. SOLOMON 2). While all three species were represented by single animals and there is some uncertainty about their distributions, it is considered probable that they also occur in the CID outside the pits. Consequently, it is considered there will be little threat to troglofauna at Zion as a result of the additional mining proposed.

**Firetail**
The proposed expansion of mine pits at Firetail is very small (8% increase in area) and it has already been demonstrated that there is habitat connectivity for troglofauna between the pits and surrounding areas. Given that the proposed area of mining is smaller than approved under MS682 and occurs almost within the original footprint, it is concluded that mining of the proposed pits is unlikely to threaten troglofauna.
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1. INTRODUCTION
The Environmental Protection Authority (EPA) usually requires that the risks to subterranean fauna are considered when assessing proposed mine developments because subterranean fauna have very limited ranges. Their small ranges make subterranean species particularly vulnerable, as a group, to extinction as a result of anthropogenic activities (EPA 2013a). About 70% of stygofauna in the Pilbara meet the criterion for being short-range endemic (SRE) species (Eberhard et al. 2009) and the proportion of troglofauna that are SREs is likely to be even higher (Lamoreux 2004; Halse and Pearson 2014).

Troglofauna were first recognised as occurring in significant numbers in the Pilbara when Biota (2006) collected them from pisolitic mesas of the Robe River Valley. Although there has not been a single regional-scale survey for troglofauna, such as the Pilbara Biodiversity Survey (McKenzie et al. 2009), there have now been many troglofauna surveys in the Pilbara for environmental impact assessments. From just some of these surveys 570 troglofauna species, nearly all undescribed, have been collected and the region is clearly rich in troglofauna at a global scale (Halse and Pearson 2014). Pilbara troglofauna belong to a wide variety of invertebrate groups, including palpigrads, spiders, schizomids, pseudoscorpions, harvestmen, isopods, millipedes, centipedes, pauropods, symphylans, bristletails, silverfish, cockroaches, bugs, beetles and fungus-gnats.

Fortescue Metals Group (Fortescue) operates the Solomon iron ore mine, which is located 60 km north of Tom Price in the Pilbara region of Western Australia (Figure 1.1). The Solomon mine consists of two mining areas, Kings and Firetail, and a rail spur that joins with Fortescue’s Cloudbreak-Port Hedland Railway. Kings comprises three Channel Iron Deposits (CID) called Valley of the Queens, Valley of the Kings (previously known as Valley of the Kings and Trinity, Subterranean Ecology [2010]) and Zion. Firetail comprises two areas of Bedded and Detrital Iron Deposit (BID and DID) that are referred to as Firetail North and Firetail South.

Following a Public Environmental Review (PER) (FMG 2010), the Minister for the Environment issued conditional approval for mining at Solomon under Ministerial Statement 862 (MS862) on 20 April 2011 (OAC 2011). The conditions included requirement for a troglofauna survey to be undertaken biannually at Solomon to validate predictions of habitat connectivity for troglofauna and to improve knowledge of troglofauna populations (Condition 13). Condition 13 of MS862 was addressed through troglofauna surveys conducted by Bennelongia (2013a, b) and was formally signed off by the EPA in 2013.

Fortescue is now investigating options to expand its operations at Solomon, including an increase in size of the mine footprint and the development of new borefields. The increased size of the mine footprint reflects a re-evaluation the extent of the ore resource since the PER was submitted. Fortescue now proposes to increase the area of the mine pits from the approved 3680 ha to 4493 ha (Figure 1.2). To meet a net water deficit expected during project life, two new borefields are proposed: one approximately 12 km to the north-east of Firetail and one approximately 12 km to the south-east of Kings, known as the Northern Borefield and Southern Borefield, respectively (Figure 1.2).

The specific aims of this troglofauna assessment were to:
1. Summarise all previous troglofauna studies and assessment undertaken at Solomon; and
2. Assess the conservation implications of the proposed expansion of operations at Solomon for troglofauna species.
Figure 1.1. Location of Solomon in the Pilbara.
Figure 1.2. Proposed mine pits and proposed borefields within the footprint of the Solomon Project.
2. TROGLOFAUNA REVIEW
Most troglofauna surveys have focussed on areas of mining development, particularly mineralised iron formations where troglofauna have been widely recorded (e.g. Biota 2006; Bennelongia 2008a, b, c; 2009a, b). There is limited information regarding the occurrence of troglofauna in other geologies, although they have been recorded in calcrete and alluvial detrital deposits in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008) and they occur widely in calcrete in the Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009b). In the Pilbara, troglofauna appear to be collected more frequently high in the landscape where mineralised iron and hardcap occur, and to be less common in the lower palaeovalley sediments, although this preliminary view may mostly reflect sampling effort. The communities higher and lower in the landscape may also have distinct taxonomic compositions.

Troglofauna habitat is usually considered to occur from the lower layers of soil at the ground surface down to the interface with groundwater (Halse and Pearson 2014). Troglofauna occupy interstices, vugs, cavities and fissures within this realm where conditions of stable temperature and high humidity prevail (Culver 1982; Howarth 1983). If no fissures or voids are present, troglofauna will not occur. When subterranean spaces are present, their pattern of occurrence will largely determine the pattern of distribution and abundance of troglofauna. Vertical connectivity of voids 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 is crucial to underground dispersal (Culver 1982; Howarth 1983). Geological features may limit habitat continuity, leading to species having highly restricted ranges (Harvey et al. 2008).

3. GEOLOGY
Solomon lies in the main Hamersley Range and contains a significant section of the Lower Proterozoic Hamersley Group sedimentary sequence. The landscape within the Solomon tenements is typically rugged, with prominent strike ridges and hills of outcropping Brockman Iron Formation that separate palaeochannels incised into relatively flat lying basement rocks, in which thick sequences of iron-rich infill have been locally deposited (MWH 2010).

Solomon deposits typically contain the following palaeochannel units (MWH 2010; Figure 3.1):
1. **Alluvial/Colluvial and Detrital Deposits**: valley in-fill sequence consisting clay, silt and gravel, including 10-60 m thickness of DID derived from BID.
2. **Oakover Formation**: calcrete and silcrete horizons typically overlying CID and varying in thickness from barely present to several metres.
3. **Upper CID**: hard, goethite dominated CID which has been overprinted in places by a hardcap zone of hydrated goethite up to 15 m thick.
4. **Lower CID**: vuggy, clay rich ochreous goethite dominated CID.
5. **Basal Conglomerate**: basal conglomerate and clay unit present at the base of the CID, typically within the deepest parts of the palaeochannel system.
6. **Brockman Iron Formation**: relatively flat lying, predominately unmineralised BIF (Dales Gorge and Joffre Members divided by Mt Whaleback Shale) with zones of mineralised BIF and DID occurring in the adjacent valley walls and margins of the palaeochannels.
Figure 3.1. Schematic diagram of the geology within Solomon.
Adapted and modified from MWH (2010), not drawn to scale and intended to be a general diagrammatic representation of troglofauna habitat in the Solomon area.
All of the CID at Solomon is part of the same geology sequence and is referred to here as CID although it has sometimes been described as Robe Pisolite. Except at Zion, the vast majority of the CID lies below the watertable and does not represent troglofauna habitat (Figure 3.1). At Zion, the outcropping CID sits entirely above the watertable (as a plateau) with little or no overlying alluvium (Figure 3.1). Brockman Iron Formation (BIF) and the underlying Mount McRae Shale form the northern and southern valley walls, hills and ridgelines, as well as the palaeochannel valley floor.

3.1.1. Solomon as Troglofauna Habitat

All of the mineralised lithologies found at Solomon (BID/CID/DID) are known to have vugs or spaces and are recognised as troglofauna habitat in many other parts of the Pilbara (Biota 2006, Bennelongia 2009a, c, 2010, 2011, 2012). The basement lithologies that occur throughout the tenement are predominantly basal conglomerate, banded iron formation (BIF) and shales and are not recognised as prospective for troglofauna, particularly at the depths at which they occur at Solomon. On the other hand, weathered surface BIF occurring on ridgelines and hills (commonly known as the hardcap zone) is considered to be troglofauna habitat because of its almost karstic nature.

The colluvial and alluvial sediments that overlay the CID and flanking DID in the valleys are considered to be less prospective troglofauna habitat, although troglofauna have been found in alluvium (often where calcrite is present) in the Pilbara and elsewhere in Western Australia (Edward and Harvey 2008; Barranco and Harvey 2008; Platnick 2008; Bennelongia unpublished data). Alluvium and colluvium provide essentially the only troglofauna habitat, albeit poorer quality, in the valley floors at Solomon except at Zion where the CID is outcropping. The outcropping CID above the watertable at Zion represents classic troglofauna habitat (Biota 2006). The flanking valley walls and hills at Zion comprise non-commercial grade BID (Dales Gorge and Joffre Member) and hardcap. This hardcap zone is the most prospective troglofauna habitat at Zion outside the potential mine pits.

Metadolerite sills and dolerite dykes are known to cut into the BID within the regional area around Solomon (MWH 2010).

3.2. Habitat Continuity at Solomon

Quantifying habitat connectivity for troglofauna is inherently difficult and in most cases connectivity of habitat between two areas is inferred for particular species because the species occurs in both areas. Connectivity can also be inferred if no obvious barriers to troglofauna movement exist between the two areas that are connected by apparently suitable habitat but small ranges are a characteristic of most troglofauna species and species may not extend widely in an area despite lack of barriers and the occurrence of suitable habitat. Landscape features that are considered to be potential barriers for troglofauna include deep valleys, dolerite dykes and significant faulting. Such features have the potential to block the continuity of the small humid voids and spaces that are required for the presence of troglofauna. In contrast, a transition between lithology/strata (especially from commercial to non-commercial grade mineralisation) rarely indicates a barrier to troglofauna distribution (Bennelongia 2009a, c, 2011, 2012).

The patterns of species distributions recorded in troglofauna surveys have indicated there is considerable habitat connectivity between the various lithologies at Kings, Firetail and Zion (Bennelongia 2010, 2013a, 2013b). For example, more than half of the troglobitic species recorded in CID have been shown to have a whole of Solomon-scale distribution (Bennelongia 2013a). At the same time, troglofauna species do tend to have restricted distributions and sampling to date has suggested there is
some consistent turnover in species composition between areas, which means that the assemblages in each area show differences despite evidence of habitat connectivity (Bennelongia 2010, 2013a, 2013b).

3.3. Previous Troglofauna Surveys and Assessment at Solomon

3.3.1. Survey for the PER
Sampling within the Study Area was undertaken according to the general principles laid out in EPA Environmental Assessment Guideline No. 12, although the sampling preceded release of the guideline, and Guidance Statement No. 54A (EPA 2007, 2013a).

Troglofauna assessment supporting the original 2010 Solomon Iron Project PER was based on 377 samples (Figure 3.2). The 165 samples collected from Kings and Zion by Subterranean Ecology (2010) yielded 28 species, the 263 samples collected from Firetail by Bennelongia (2010) yielded 45 species, and the 49 samples collected around Kings and farther west and north-west of Solomon by Subterranean Ecology (2011) yielded 14 species. At the time Subterranean Ecology (2010) reported, 17 troglofauna species were recorded only from within potential mine pits at Kings, with 10 of these species occurring in the proposed Valley of the Kings or Valley of the Queens mine pits (some also occurred at Zion).

Conditional approval for Solomon was given in April 2011 under MS862, which incorporated the EPA’s (2011) conclusions and recommendations summarised below:

1) It was concluded that the impact to subterranean fauna from the railway spur and mining at Firetail were unlikely to be significant and, thus stated, assessment would focus on the Kings mine;

2) In relation to stygofauna at Kings, the report noted some stygofauna species had been recorded only at Kings but the EPA agreed with the proponent’s hypothesis that the stygofauna community extended beyond the impacted CID aquifer and concluded that the observed distributions were an artefact of sampling; and

3) In relation to troglofauna at Kings, the report noted the higher proportion of troglofauna species restricted to Kings Mine, agreed with the proponent’s hypothesis that further survey would demonstrate that troglofauna communities extended outside the impact, and recommended such survey to validate habitat connectivity beyond the impact area.

The above findings led to development of Condition 13 of MS862 (provided in full in Appendix 1).

3.3.2. Surveys for Compliance with Condition 13

3.3.2.1. Kings
Condition 13-1 required that Fortescue survey troglofauna biannually to validate predictions of habitat connectivity and improve knowledge of troglofauna populations. Accordingly, Bennelongia conducted further surveys at Kings (Figure 3.2) in spring 2011, autumn 2012, spring 2012 and autumn 2013. These surveys and all previous work at Kings were reported in Bennelongia (2013b). Key findings of this report are summarised below.
Figure 3.2. Historical sampling at Solomon, being the original 2010 Solomon Iron Project PER and surveys for compliance with Condition 13 of MS862.
Currently 68 species of troglofauna are known at Kings. Both capture rates and the occurrence of species demonstrated that habitat connectivity exists between the potential mine pits and areas outside them. Furthermore, it appears that better troglofauna habitat occurs outside the potential mine pits than within them.

- At both Valley of the Kings and Valley of the Queens, more than twice as many species are known from outside compared with inside the mine pits (12 inside and 29 outside at Valley of the Kings; 15 and 41 at Valley of the Queens);

- Capture rate in the surrounding area was more than twice that in the potential mine pit at Valley of the Kings (1.91 specimens per sample versus 0.95). Capture rate in the area around Valley of the Queens was also higher than in the mine pit (1.26 specimens per sample versus 0.94).

- All Orders of troglofauna and almost all species collected within the mine pits at the Valley of the Kings and Valley of the Queens have been collected in the surrounding undisturbed areas. Most of the specimens collected outside of the mine pits have been collected on the flanks of the valleys and foothills leading into the surrounding ranges.

- This pattern of troglofauna distribution has been observed at other areas where CID is to be mined from valleys. The geologies at Blacksmith tenement, 24 km west of the Kings mining area, are the same as at the Valley of the Kings and Valley of the Queens. Survey at Blacksmith suggested that hardcap, DID and BID on valley flanks are likely to be better troglofauna habitat than the valley-infill (CID, alluvium and colluvium) that is the target of mining (Bennelongia 2012).

The existence of habitat connectivity between mine pits and surrounding areas was acknowledged by the EPA with formal sign off of Condition 13-1 and 13-3 (EPA 2013c).

3.3.2.2. Zion Deposit
Also among the conditions attached to MS862 was a requirement for survey before development of the approved Zion deposit at Kings (Condition 13-4). Bennelongia conducted surveys in 2011 and 2012 to meet the requirements of Condition 13-4 (Figure 3.2). These surveys and all previous work at Zion were reported in Bennelongia (2013a).

At present, 27 troglofauna species belonging to 14 Orders have been recorded at Zion. Seventeen of the 27 species were recorded in potential mine pits. The patterns of troglofauna species distribution observed at Zion were similar to those at Valley of the Kings and Valley of the Queens. All but three of the 17 species recorded from the potential mine pits have also been recorded in surrounding undisturbed areas, other deposits at Solomon or in the wider Pilbara and almost half of the troglobitic species found at Zion had Solomon-scale distributions. This indicated that there is considerable habitat connectivity for troglofauna in the strata surrounding the potential mine pits at Zion.

This habitat connectivity was acknowledged by the EPA with formal sign off of Condition 13-4 (EPA 2013b).
3.3.3. Species Previously Identified as Known Only from Potential Mine Pits at Solomon

In total, 81 troglobfauna species have been recorded at the Kings mining area, including Zion deposit. Eleven (13%) of them are known only from the potential mine pits (Table 3.1), which is typical of the ratio of ‘restricted’ troglofauna species at approved mine pits (Bennelongia 2008a, c, 2009a, d, e). The proportion of ‘restricted’ species is slightly lower at Firetail, with three of 45 (7%) species known only from the potential mine pits (Table 3.1).

Table 3.1. Troglofauna known only from potential mine pits at Solomon Hub.

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<td>Valley of the Queens</td>
<td>Bennelongia 2013b</td>
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<td>Cryptops sp. SOLOMON 2</td>
<td>Zion</td>
<td>Bennelongia 2013a</td>
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<td>Tetramerocerata</td>
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Species may be recorded only in proposed mine pits because the species does, in fact, have a very small range that lies within the area of the pit. More commonly, however, the species appears to be restricted because it was collected in only one or two samples, which happened to collected within the proposed pit. Reasons for this include sampling methods being ineffective for that species or the species occurring at very low abundance (Magurran and Henderson 2003; Guisan et al. 2006). Thus, the ‘restricted’ ranges of species are usually artefacts of the biology of the species and sampling inefficiency. Caution should be exercised when deciding species have small ranges unless they have been collected in many samples or a high proportion of the species collected from the mine pit are known only from that pit.

Another factor that contributes to a misleading assumption that troglofauna are restricted to potential mine pits is that often a very high proportion of the drill holes available for sampling are within the proposed mine pit. This creates bias in sampling design that makes any species collected in few samples likely to be recorded only from the mine pit.
4. ASSESSMENT

4.1. Impacts on Troglofauna

4.1.1. Borefield Development
Drawdown of the watertable associated with the proposed Northern and Southern Borefields is unlikely to threaten troglofauna species. While groundwater drawdown is a primary impact for stygofauna via loss of habitat, it is typically not considered to be a threat to troglofauna. The most likely mechanism for groundwater drawdown to reduce troglofauna habitat is through decreases in humidity of troglofauna habitat as the watertable is lowered. However, because small pools of water remain perched in voids as the watertable is lowered, in most situations lowering the watertable probably has little effect on humidity of troglofauna habitat. In fact, lowering of the watertable may often increase the amount of troglofauna habitat available. Therefore, in most situations dewatering is likely to be, at most, a secondary impact on troglofauna. Groundwater drawdown at the proposed borefields is not considered further in this report.

4.1.2. Mine Pit Expansion
Direct habitat loss is considered to be the main mining-related threat to troglofauna. In the case of proposed expansion to mining operations at Solomon, pit excavation is the only proposed impact resulting in significant loss of troglofauna habitat. The pit expansion areas are an extension of the CID mineralisation and it is proposed to increase the pit area by about 24%. This is considered a primary impact, and hence this is evaluated in terms of the threat posed to troglofauna species.

4.2. Threat to Troglofauna

4.2.1. Background and Rationale
Under MS862, areas of 2750 ha and 880 ha, respectively, were approved for excavation of potential mine pits at Kings and Firetail (see Appendix 2 for details). This was subsequently amended under Attachment 2 of MS862 to a combined 3630 ha of pit disturbance within the Project Development Area 1. While it was indicated approximately where the mine pits might be located, the precise location of the approved area to be excavation was to be determined later by mine planning (Figure 1.2).

In this report, the proposed increase in area of mine pit excavation is separated into four components so that uneven level of information about different areas can be accommodated more easily and results of previous survey work can be applied more effectively to areas for which extensive information is available. The four components comprise (Figure 4.1):

- Expansion of the potential Kings mine pits assessed in the PER, including deposits formally reported as Valley of the Kings, Valley of the Queens and Trinity in Subterranean Ecology (2010) and Bennelongia (2013c).
- Additional potential mine pits south of Kings.
- Expansion of the potential pits at Zion that were assessed in the PER and Condition 13 surveys (Subterranean Ecology 2010; Bennelongia (2013a,b)).
- Expansion of the potential Firetail pits assessed in the PER (Bennelongia 2010).

Assessments of the expansions at Kings, Zion and Firetail are based on field survey data, while assessment of the new pits south of Kings, is based on habitat characterisation and inferences about the likely troglofauna community of the area based on surveys of other areas of Solomon.
Figure 4.1. Solomon footprint.
4.2.2. Kings

There has been very significant troglofauna survey effort at Kings. A total of 105 samples were collected for the original Solomon Iron Ore Project (Subterranean Ecology 2010) and 448 samples were collected to meet Condition 13 of MS862 (Bennelongia 2013b). Data from these surveys provides a good understanding of the troglofauna community present at Kings.

The most recent study assessing the impact of mine pit excavation at Valley of the Kings and Valley of the Queens was the 30-month report prepared under with Condition 13-1 and 13-3 of MS682 (Bennelongia 2013b). In this study ‘potential’ mine pits with an area totalling 2822 ha were used to demonstrate troglofauna communities extended outside the likely area impact at Kings. The validity of this assessment was acknowledged by the EPA with formal sign off of Condition 13-1 and 13-3 (EPA 2013c).

Fortescue now proposes a 7% increase in the area of mine pits (from 2822 to 3026 ha) at Kings compared with the area assessed by Bennelongia (2013b). This is shown in Figure 4.2 as the difference between the designed and potential mine pits, with the main variation from the Bennelongia’s (2013b) boundaries being a projected increase in the area of CID to be mined along the edge of the valleys, although along some valley edges there is a decrease in area. The changes reflect ongoing re-evaluation of the extent of the commercial grade ore resource and are indicative of the area that may be mined.

Most drill-holes previously used as reference sites (on the valley flanks) are now within the potential mine pits and formal re-analysis of species distributions would result in more species now being known only from the potential mine pits than were identified as restricted by Bennelongia (2013b). In reality, this is an artefact of the ratio of impact to reference holes being very strongly skewed to impact holes. It is likely that all species known only from the potential mine pits occur more widely because there is good connectivity with surrounding areas and evidence that these areas are actually better troglofauna habitat than the mine pit areas (Bennelongia 2013b). In the current situation it is relevant to recognise that lack of reference drill holes constrained Subterranean Ecology’s (2010) assessment of troglofauna at Kings, with the result that there appeared to be a high proportion of apparently restricted species. This led to Conditions 13-1 and 13-3 being imposed in MS682 but subsequent sampling by Bennelongia (2013b) showed all species were likely to be more widely distributed.

The work done under Condition 13-1 of MS682 showed wider habitat connectivity exists beyond the potential mine pits for most troglofauna species and that it is likely that most, if not all, species occurring in valleys also occur on the flanks and ridges of surrounding ranges. Consequently, it can be inferred that there is minimal threat to troglofauna from the proposed expansion at Kings.

4.2.3. Kings (New Southern Pits)

There has been no troglofauna survey in any of the new potential pit areas to the south of Kings and currently the likely pit configuration and area is only estimated (Figure 4.1).

The geology of the areas for which the southern pits are proposed is similar to that found at Kings. The potential troglofauna habitat in valleys is alluvial and colluvial sediments, with CID likely to lie below the watertable (Figure 3.1). Alluvial and colluvial sediments are less prospective troglofauna habitat than geologies such as enriched BID and hardcap on the surrounding valley flanks and ridges (Sections 2 and 3.1.1). Furthermore, the alluvial and colluvial sediments of the valleys extend well beyond the areas to be mined and there is likely to be habitat connectivity along the valleys for any troglofauna in the
Figure 4.2. Changes in pit configuration at Kings between Bennelongia (2013b) and the proposed mine pits.
sediments. Consequently, although some troglofauna species may occur in the sediments, the threat to these species from mining is likely to be low. By analogy with the well-studied Kings to the north, it is also likely there is good connectivity from the alluvial deposits into the surrounding ranges, so that the threat to species occurring in the valley flanks is also likely to be low. Accordingly, the overall impact on troglofauna of excavating new pit areas south of Kings is considered likely to be low.

4.2.4. Zion
There has been considerable troglofauna survey at Zion, with 77 samples collected for the PER and to meet Condition 13 (Subterranean Ecology 2010; Bennelongia 2013a). Data from these surveys provides a sound understanding of the troglofauna present at Zion. Furthermore, the likely impact of pit excavation at Zion was assessed by Bennelongia (2013a) for a potential mine pit area of 258 ha. It was concluded that the Zion troglofauna community extended outside the likely area of pit excavation although *Draculoides* `SCH033`, *Cryptops* sp. SOLOMON 2 and Zuphiini sp. SOLOMON may possibly be restricted to the area of outcropping CID at Zion. This was acknowledged by the EPA by formal sign off of Condition 13-4 (EPA 2013b).

After re-evaluating the resource at Zion, Fortescue proposes to increase the area of potential mine pits from 258 to approximately 434 ha (68% increase, location of potential pits in Figure 4.3 is approximate). The conclusion in Bennelongia (2013a) that there is little threat to troglofauna at Zion continues to apply, despite the majority of outcropping CID within Zion now being mined, because it has been shown that additional CID that extends beyond the proposed mine pits (Figure 4.3). It is estimated that about 60% of CID at Zion will be outside of the pits. *Draculoides* `SCH033`, *Cryptops* sp. SOLOMON 2 and Zuphiini sp. SOLOMON probably occur in this area of additional CID, although to date the three species have been found only in the potential mine pits, because all three species are known from single specimens and will have wider ranges than currently documented (Figure 4.3).

Therefore, there is a degree of uncertainty about whether the three aforementioned troglofauna species will persist as a result of the additional mining at proposed at Zion, although the species are probably widely enough distributed to make the level of threat low.

4.2.5. Firetail
There has been considerable troglofauna survey completed at Firetail, with 263 samples collected by Bennelongia (2010). Data from this survey provide a sound understanding of the troglofauna present at Firetail.

The potential mine pits on which the assessment of threat to troglofauna was based at Firetail in the PER had area of 741 ha. The assessment showed that troglofauna communities at Firetail extended outside this 741 ha (Bennelongia 2010). MS682 approved mining in an area of 880 ha, a slightly larger area than assessed. Following re-evaluation of the resource, the proposed mine pit now covers 797 ha (Figure 4.4), which is a smaller area than the 880 ha approved for mining under the MS862.

The proposed increase in size of mine pits at Firetail is very small and will occur in area already demonstrated to have habitat connectivity for troglofauna with surrounding areas. Given that the proposed area of mining is smaller than approved under MS682 and occurs almost entirely within the original footprint, it is concluded that mining of the proposed pits is unlikely to threaten troglofauna.
Figure 4.3. Differences in configuration of the proposed mine pit at Zion from that shown in Bennelongia (2013a) and singleton species at Zion with unknown distributions.
Figure 4.4. Changes in pit configuration at Firetail between Bennelongia (2010) and the proposed mine pits.
5. CONCLUSION

5.1. Borefield Development
Drawdown of the watertable associated with the proposed Northern and Southern Borefields is most unlikely to threaten troglofauna species. The most likely mechanism for groundwater drawdown to reduce troglofauna habitat is through decreases in humidity of troglofauna habitat as the watertable is lowered. However, because small pools of water remain perched in voids as the watertable is lowered, in most situations lowering the watertable probably has little effect on humidity of troglofauna habitat. In fact, lowering of the watertable may often increase the amount of troglofauna habitat available. Therefore, in most situations dewatering is likely to be, at most, a secondary impact on troglofauna.

5.2. Pit Expansions
The proposed increase in area of mine pits at Solomon is 863 ha. This increase was divided into four components for assessment: 1) expansion of the potential Kings pits assessed in the PER; 2) additional southern pits at Kings; 3) expansion of the potential pits at Zion assessed in the PER and Condition 13 surveys; and 4) expansion of the potential Firetail pits assessed in the PER. The following conclusions are drawn:

**Kings**
Based on a large survey effort at Kings and the subsequent understanding of distributions of troglofauna species present in the area, it may be assumed that a small increase of 7% in pit size at Kings would do little to alter the position of low risk to troglofauna established by the surveys undertaken to fulfil Condition 13 of MS862. These surveys demonstrated that there is a connection for troglofauna species between habitat within the potential mine pits at Kings and habitat outside the pits. It seems likely that most, if not all, species occurring in the valleys at Kings also occur on the flanks of surrounding ranges and in those ranges.

**Kings (new southern pits)**
The geology of the potential mine pits south of Kings is similar to that at Kings. The alluvial and colluvial sediments of the valleys extend well beyond the areas to be mined, so that there is likely to be habitat connectivity along the valleys for any troglofauna in the sediments. Similarly, there is also likely to be good connectivity from the alluvial deposits and DID on valley flanks into the BIF and hardcap of surrounding ranges. Although no troglofauna survey has been conducted in the potential southern pits, by analogy with the troglofauna community at Kings, it is considered that the threat to the troglofauna species occurring in these areas is likely to be low.

**Zion**
It was concluded in the PER that there was little threat to troglofauna at Zion because 36% of outcropping CID would remain unmined. It is now proposed to increase the area to be mined at Zion by up to 68% (from 258 to 434 ha), which will remove the majority of unmined CID within Zion. However, re-evaluation of the resource has identified additional CID around the proposed mine pits. It is estimated that about 60% of the CID at Zion and its immediate surroundings will be outside the proposed pits. Three species are known only from within the proposed Zion mine pits (the schizomid *Draculoides* `SCH033`, centipede *Cryptops* sp. SOLOMON 2 and beetle Zuphiini sp. SOLOMON). While all three species were represented by single animals and there is some uncertainty about their distributions, it is considered probable that they also occur in the CID outside the pits. Consequently, it
is considered there will be little threat to troglofauna at Zion as a result of the additional mining proposed.

*Firetail*

The proposed expansion of mine pits at Firetail is very small (8%) and it has already been demonstrated that there is habitat connectivity for troglofauna between the pits and surrounding areas. Given that the proposed area of mining is smaller than approved under MS682 and occurs almost within the original footprint, it is concluded that mining of the proposed pits is unlikely to threaten troglofauna.
6. REFERENCES


Helix (2010) Molecular systematics of Polyxenida. The University of Western Australia, Crawley, pp. 3.


7. APPENDICES

Appendix 1: Condition 13, Ministerial Statement 862

13-1 The proponent shall undertake troglofauna surveys biannually at a minimum in geological formations similar to the project area to validate predictions of habitat connectivity and improve knowledge of troglofauna populations in the region to inform future management of mining and associated operations, until such time as the Chief Executive Officer of the Office of the Environmental Protection Authority determines that sufficient knowledge of troglofauna populations has been acquired.

13-2 The troglofauna surveys shall be undertaken in accordance with the draft Environmental Protection Authority Guidance Statement 54a – Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia (August 2007) or its revisions and to the satisfaction of the Chief Executive Officer of the Office of the Environmental Protection Authority.

13-3 Within 30 months of ground disturbing activities the proponent shall prepare and submit a technical report based on the results of the surveys required by condition 13-1 to the requirements of the Chief Executive Officer of the Office of the Environmental Protection Authority on advice from the Department of Environment and Conservation.

13-4 Three months prior to commencement of ground disturbing activities associated with the Zion deposit, the proponent shall demonstrate that similar and connected troglofauna habitat exits outside of areas that have been or are likely to be impacted by mining to the satisfaction of the Chief Executive Officer of the Office of the Environmental Protection Authority on advice from the Department of Environment and Conservation.

13-5 The proponent shall prepare and submit annually further technical reports based on the results of the surveys required by condition 13-1 to the requirements of the Chief Executive Officer of the Office of the Environmental Protection Authority on advice from the Department of Environment and Conservation.

13-6 The proponent shall make the reports required by conditions 13-3, 13-4 and 13-5 publicly available in a manner approved by the Chief Executive Officer of the Office of the Environmental Protection Authority.
Appendix 2. Estimated Pit Configuration at the Time of the PER

A) Kings mining area showing approximately 2500 ha (Section 4: FMG 2010) of mine pits. Figure from Subterranean Ecology (2010). Note that an additional 10% disturbance area was authorised by MS682.

Figure 1.2 Map of Solomon Project, Kings Area, indicating resource and tenement areas.
B) Firetail mining area showing approximately 800 ha (Section 4: FMG 2010) of mine pits. Figure adapted from Bennelongia (2010). Note that an additional 10% disturbance area was authorised by the MS682.