BC Iron Limited

Iron Valley Project: Subterranean Fauna Assessment

Final Report

Prepared for Iron Ore Holdings Ltd
by Bennelongia Pty Ltd

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Iron Valley Project: Subterranean Fauna Assessment

Bennelongia Pty Ltd
5 Bishop Street
Jolimont WA 6014
www.bennelongia.com.au
ACN 124 110 167

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EXECUTIVE SUMMARY

BC Iron is planning to mine iron ore at the Iron Valley Project within its Central Pilbara tenements. The Iron Valley Project is 86 km north-northwest of Newman in the Pilbara region of Western Australia. Production of up to 20 million tonnes per annum is expected, with mine life estimated to be 15 years from ore reserves of 240 million tonnes.

This subterranean fauna report presents the results of Level 2 troglofauna and stygofauna surveys conducted in 2009 and 2011 and subsequent targeted sampling in 2015 for two potentially restricted stygofauna species. The report provides an assessment of the likely impacts of mining on subterranean fauna at the Iron Valley Project. Overall, 98 troglofauna samples were collected from within the proposed mine pits and 70 samples were collected from reference areas. A total of 84 stygofauna samples were collected from within the area of groundwater drawdown associated with mine de-watering and 14 samples were collected from surrounding reference areas.

Troglofauna sampling yielded 112 troglofaunal animals, representing seven Classes, 11 Orders and 16 species. Two arachnid Orders were recorded: Pseudoscorpionida (1 species) and Schizomida (1 species). The only crustacean Order collected was Isopoda (3 species). Chilopoda were represented by one species of an unknown Order (a partial and damaged specimen prevented identification based on morphology). Diplopoda were represented by Polyxenida (1 species) and Symphyla by Cephalostigmata (1 species). There were five Orders of hexapods (Entognatha/Insecta): Diplura (2 species), Blattodea (2 species), Hemiptera (2 species), Coleoptera (1 species) and Diptera (1 species).

Eleven of the 16 species recorded at the Iron Valley Project were recorded within the proposed mine pits (i.e. the impact area). Nine of these 11 species have been recorded outside of the mine pits. Two species (Chilopoda sp. and *Lagynochthonius* 'PSE43') are currently known only from within the proposed mine pits. Both species were recorded as singletons. Their conservation status cannot be directly quantified because only single animals were collected, which provides no information about the spatial extent of their ranges. In addition, the poor level of identification of the Chilopoda specimen limits inferences that can be drawn about the likely range of this species. However, it is considered likely that both species occur outside the proposed mine pits and that the threat to troglofauna conservation values as a result of mining at the Iron Valley Project will be low.

Stygofauna sampling yielded 2,152 specimens consisting of at least 22 species belonging to at least eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (6 species), Isopoda (1 species) and nematodes of unknown order/s.

Many of the stygofauna species collected in the Iron Valley Project area, including the largest stygofauna species known from the Pilbara (*Pygolabis* sp. B01), are known to occur in surrounding parts of the Weeli Wolli/Marillana Creek drainage channel. This suggests there is habitat connectivity between the area of predicted groundwater drawdown at the Project and surrounding parts of the Weeli Wolli/Marillana Creek catchments. This habitat connectivity may be provided direct movement between areas or may reflect another mechanism of connectivity, such as colonisation of both areas from a relatively wide surface range.

Two of the 22 species collected during survey were recorded only within the area of predicted groundwater drawdown. While it is concluded that there is no threat to most of the stygofauna community within the predicted groundwater drawdown area at the Iron Valley Project, there is uncertainty about the conservation status of the syncarid *Bathynella* sp. B24 and ostracod

Meridiescandona sp. BOS171. *Bathynella* sp. B24 is known only from two samples from one drill hole and its currently highly restricted range is likely to be, to least some degree, an artefact of sampling. In addition, *Bathynella* sp. B24 may be the same species as a syncarid specimen previously recorded at Marillana Creek close to the boundary of the groundwater drawdown area.

Meridiescandona sp. BOS171 was collected from five drill holes within the area of predicted groundwater drawdown. The causes of its small known range and the degree of threat to the species are unclear. Sampling results suggest *Meridiescandona* sp. BOS171 is possibly restricted to an area south of an east-west dolerite dyke that results in hydrological discontinuity. However, ranges of some other abundant species at Iron Valley suggest there is habitat connectivity across the dyke, although species occur at lower densities to the north because of a greater depth to groundwater. It appears likely there is periodic habitat connectivity across the dyke as a result of groundwater overtopping the dyke after cyclonic rain events. Thus, *Meridiescandona* sp. BOS171 may have a similar range to other species found both north and south of the dyke. The failure to collect *Meridiescandona* sp. BOS171 immediately north of the dyke may be the result of the large depth to groundwater in this area, which reduces the abundance of *Meridiescandona* sp. BOS171 to the point where collection is unlikely.

In fact, the range of *Meridiescandona* sp. BOS171 may continue farther north to areas where groundwater is shallower, so that a significant proportion of the population would be outside the predicted area of groundwater drawdown. This would mean that *Meridiescandona* sp. BOS171 would have a range of the same order of magnitude as other species of *Meridiescandona* ostracods.
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1. INTRODUCTION

BC Iron is planning to mine iron ore at the Iron Valley Project within BC Pilbara Iron Ore Pty Ltd.'s (BCPIO) Central Pilbara tenements. The Iron Valley Project is 86 km north-northwest of Newman in the Pilbara region of Western Australia (Figure 1-1). Production of up to 20 million tonnes per annum is expected from the Iron Valley Project. The mine life is estimated to be 15 years from ore reserves of approximately 300 million tonnes. The Iron Valley Project encompasses tenement M47/1439. A number of options are currently being considering for haulage of iron ore off-site, including the use of road, rail and/or conveyor.

Key mining components and activities of the proposed Project include:

- Mining of the ore deposit by conventional open pit methods. This will involve drilling and blasting, digging and loading using hydraulic excavators and front-end loaders, and transport by haul trucks.
- De-watering of the ore deposit to access approximately 75 to 80% of the ore that is located below the water table. The de-watering discharge will be used on-site for dust suppression, ore processing and within the mine facilities and accommodation village. Other options are under consideration for the disposal of excess water.
- Processing of ore on-site, with waste dumps located outside of the pit (with a strip ratio of waste to ore of 1:6).
- Supporting infrastructure including an accommodation village, mine site offices and utilities.

The proposed area of mine pits at the Iron Valley Project is expected to be approximately 326 ha with an approximate depth of 200 m. The water table lies approximately 15-40 m below ground surface and groundwater will be abstracted to a depth of 200 m. The proposed area of groundwater drawdown of >2 m is 5681 ha (56.8km^2 or 11 km × 6km).

A high proportion of subterranean species have small ranges. Most are short range endemics according to Harvey's (2002) criterion of the species having a range of <10,000 km^2. Most subterranean fauna species have much smaller ranges (Eberhard *et al*. 2009; Halse and Pearson 2014; Halse *et al*. 2014). The very limited ranges of subterranean fauna species means they are particularly vulnerable to extinction as a result of anthropogenic activities and, therefore, they are a focus of conservation policy. Consequently, the Environmental Protection Authority (EPA) usually requires that the risks to subterranean fauna are considered when assessing proposed mine developments where subterranean fauna are likely to occur (EPA 2013).

The specific aims of the subterranean fauna survey at the Iron Valley Project were to:

1. Document the subterranean fauna communities of the Project area and their constituent species.
2. Determine the likely impact of the Iron Valley Project on the subterranean fauna community.
3. Assess the conservation status of potentially range restricted species through targeted sampling.

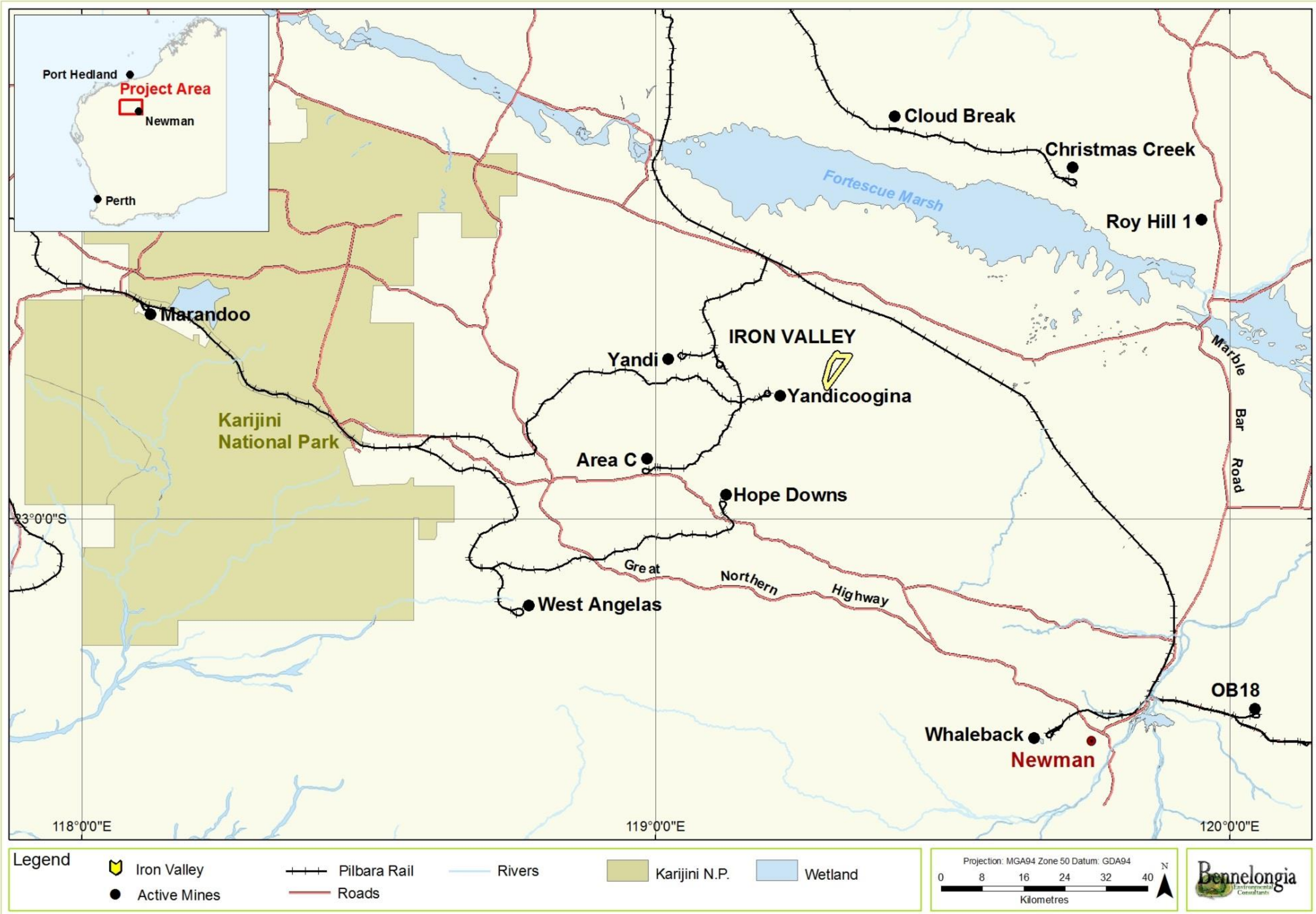

Figure 1-1. Location of the Iron Valley Project.

2. HYDROGEOLOGY

The iron ore deposit proposed to be mined by the Iron Valley Project is located in a southwards-inclined anticline of Brockman Iron Formation in the Hamersley Range (Appendix 1). Most of the mineralisation is on the eastern side of this anticline and is confined to the Upper Joffre Member. However, additional mineralisation occurs within the core of the anticline in the Dales Gorge Member. Much of the mineralisation is overlain with Quaternary Detritals (alluvium and colluvium). Although not fully characterised, existing data suggest in broad terms that geology is similar both inside and outside the proposed mine pits of the Iron Valley Project and the proposed pit boundaries reflect the extent of economic grade ore rather than prospective subterranean fauna habitat.

Hydrology of the Iron Valley Project is complex. The Project lies on the western side of a valley containing Weeli Wolli Creek. Groundwater levels typically reflect surface elevation and so are higher in the scarp to the west than in the valley and creek line. Mineralisation is associated with a north-south running fault and an east-west running dolerite dyke bisects the main mine pit. The dyke is part of a regional feature approximately 150 km in length (Appendix 2) and interrupts the northwards flow of groundwater towards the mouth of Weeli Wolli Creek under normal groundwater conditions. The interruption of flow appears to be a localised feature, with the watertable being approximately 40 m higher to the south of the dyke than immediately downstream on the northern side (Appendix 3).

Around the dyke, watertable gradients are affected by local topography and creek lines and the depth to watertable slowly deceases to the north. Thus, it is likely that south of the dyke both the mine pit and much of the Iron Valley deposit lie within an aquifer that is separated from the regional aquifer under most groundwater conditions. In contrast, the northern section of the deposit and the mine pit lie within the regional aquifer.

While the dyke extends above the mineralisation at the main mine pit, it does not reach the surface and is overlain by about 10 m of alluvium. The watertable at this point is close to the top pf the dyke and, after re-charge associated with cyclonic rain, the aquifer south of the dyke may periodically overtop the dyke and discharge into the regional aquifer.

3. EXISTING INFORMATION ON SUBTERRANEAN FAUNA

There are two kinds of subterranean fauna: stygofauna and troglofauna. Stygofauna are aquatic and occur in groundwater. Troglofauna are air-breathing and occur in underground cavities, fissures and interstitial spaces above the watertable. Nearly all subterranean fauna are invertebrates, although both stygofaunal fish and troglofaunal reptiles have been recorded in WA (Whitely 1945; Aplin 1998).

The Pilbara is recognised as a global hotspot for stygofauna (Eberhard *et al*. 2009; Halse *et al.* 2014) and the same is true for troglofauna (see Halse and Pearson 2014).

3.1. Troglofauna

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

Much of the focus of troglofauna survey for environmental assessment has been in areas of channel iron deposit and banded iron formation. The micro-habitats that troglofauna occupy within these lithologies are still being determined but it is inferred that they utilise the fissures and voids associated with weathering, enrichment and faulting. There is relatively little information about the occurrence of troglofauna outside mineralized habitats because mine development has been the primary reason for most of the sampling programs. However, it has been shown that troglofauna also occur in calcrete and alluvium in the Pilbara (Edward and Harvey 2008; Rio Tinto 2008; Halse *et al.* 2014), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009c) and elsewhere (Biota 2005a,b).

Troglofauna species tend to have smaller ranges than stygofauna (Lamoreux 2004) and many Pilbara troglofauna species with multiple records have known linear ranges as small as 1 km, so that it is likely that actual ranges of <10 km^2 are quite common (see Halse and Pearson 2014).

3.2. Stygofauna

Survey of stygofauna in the Pilbara began in the 1990s (Humphreys 1999), with a rapid increase in knowledge over the last 15 years as a result of the systematic stygofauna sampling during the Pilbara Biological Survey (Halse *et al*. 2014). It has been estimated that the Pilbara has between 500 and 550 stygofauna species, with the density of species being relatively uniform across the region (Eberhard *et al*. 2009). High endemism is a key feature of stygofauna in the Pilbara and it is considered that 98% of stygobites and 83% of the other groundwater species occur only within this region. This makes the Pilbara a globally important region for stygofauna, supporting species densities greater than anywhere other than the Dinaric karst in Europe (Halse *et al.* 2014). Alluvium and calcrete are usually considered to be the most productive habitats for stygofauna, although mafic volcanics may support rich populations and stygofauna occur in moderate abundance in banded iron formations (Halse *et al*. 2014). The most abundant and species-rich groups are ostracods, copepods, amphipods and oligochaete worms (Halse *et al.* 2014).

Stygofauna often have tightly restricted distributions and it has been suggested that more than half of the species will have ranges less than 680 km^2. Consequently, projects involving extensive groundwater drawdown have the potential to affect a large proportion of the population of a restricted species or to threaten the persistence of species with particularly small ranges.

4. PROJECT IMPACTS

Activities that cause direct *habitat loss* are considered to be the primary impacts likely to lead to extinction of subterranean species. The common primary impacts associated with mining are:

1. *Pit excavation*. Removal of troglofauna habitat may threaten the persistence of species restricted to the proposed mine pit.
2. *Groundwater abstraction.* Drawdown of groundwater as a result de-watering to prevent flooding of mine pits or use of groundwater for processing may threaten stygofauna species that have ranges restricted to the area of predicted drawdown.
3. *Groundwater reinjection.* A rise in the watertable as a result of re-injection of surplus groundwater from de-watering may reduce the volume of unsaturated habitat available for troglofauna and may also, depending how re-injection is achieved, reduce the suitability of the remaining habitat.

The ecological impacts of activities that reduce the quality of subterranean fauna habitat have been little studied in Australia (or elsewhere) but it is considered that these impacts are usually likely to reduce population size than cause species extinction (see Scarsbrook and Fenwick 2003; Masciopinto *et al*. 2006). Therefore, these impacts are considered to be of secondary importance.

Mining activities at the Iron Valley Project that may result in secondary impacts to subterranean fauna include:

1. *De-watering below troglofauna habitat*. The impact of a lowered water table on subterranean humidity and, therefore, the quality of troglofauna habitat is poorly studied, but it may represent risk to troglofauna species in some cases. The extent to which humidity of the vadose[1] zone is affected by depth to the watertable is unclear. Given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, de-watering may have minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna.
2. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered to be a significant threat to either stygofauna or troglofauna outside the proposed mine pits.
3. *Overburden stockpiles and waste dumps*. These artificial landforms may cause localised reduction in rainfall recharge and associated entry of dissolved organic matter and nutrients because water runs off stockpiles rather than infiltrating through them and into the underlying ground. The effects of reduced carbon and nutrient input are likely to be expressed over many years and are likely to be greater for troglofauna than stygofauna (because lateral movement of groundwater should bring in carbon and nutrients). The extent of impacts on troglofauna will largely depend on the importance of chemoautotrophy[2] in driving the subterranean system compared with infiltration-transported surface energy and nutrients. Stockpiles are unlikely to cause species extinctions, although population densities of species may decrease.
4. *Aquifer recharge with poor quality water*. Quality of recharge water declines during, and after, mining operations as a result of rock break up and soil disturbance (i.e. Gajowiec 1993; McAuley and Kozar 2006). Impacts can be minimised through management of surface water and installing drainage channels, sumps and pump in pits to prevent of recharge though the pit floor.
5. *Contamination of groundwater by hydrocarbons*. Any contamination is likely to be localised and may be minimised by engineering and management practices to ensure containment.

5. METHODS

5.1. Survey Rationale

[1] The zone between the surface and groundwater
[2] Microbial oxidation of inorganic compounds as an energy source

The subterranean fauna survey at Iron Valley was conducted in accordance with the principles laid out in EPA Guidance Statement 54 and Environmental Assessment Guideline 12 (EPA 2007, 2013).

The impact area for troglofauna was defined as the area to be excavated for the mine pits (Figure 5.1). Reference drill holes, sampled to show the wider distribution of the troglofauna species collected in the mine pits, were located outside the pits but within the Iron Valley Project tenement (Figure 5.1). Troglofauna were also collected from other sampling programs at nearby iron ore deposits, namely the Extension tenement (26 km west-northwest of the Iron Valley Project), Phil's Creek tenement (12 km west) and Horse Shoe tenement (34 km west-southwest) to show wider distribution of species.

The impact area for stygofauna was defined as the area where groundwater drawdown is modelled to be >2 m. This drawdown covers an area of 5681 ha (or approximately 11 km × 6 km) and stretches across multiple tenements (AM 7000270, AM 7000274; E 4701191, E 4701385, 4703254; L 4700254; M 4701439 and M 4701461) with leases held by BHP Billiton Iron, Rio Tinto and Fortescue Metals Group. The anticipated maximum depth of drawdown will be 200 m (the watertable lies approximately 15-40 m below ground surface).

5.2. Troglofauna

5.2.1. Sampling Effort

A total of 98 impact and 70 reference samples were collected during three sampling rounds from 115 drill holes within the Iron Valley Project (Table 5.1, Figure 5.1). Significant groundwater drawdown will occur

Table 5.1. Numbers of troglofauna samples collected from Iron Valley.

Round 1	**Impact**	**Reference**
Scrape	54	20
S Trap	37	15
D Trap	16	5
Samples	*54**	*20*
Round 2		
Scrape	43	17
S Trap	28	14
D Trap	16	3
Samples	*44**	*17*
Round 3		
Scrape		33
S Trap		25
D Trap		8
Samples		*33*
Total Samples	**98**	**70**

Samples consisted of a scrape and trapping event with one or two traps, S trap, one trap; D trap, two traps (shallow and deep).

*In two cases, either a trap or scrap was not collected owing to sampling difficulties.

Calculation of total sampling effort is based on all sampling (i.e. scrape alone or a scrape with trap/s) during a visit to a site being considered as one sample.

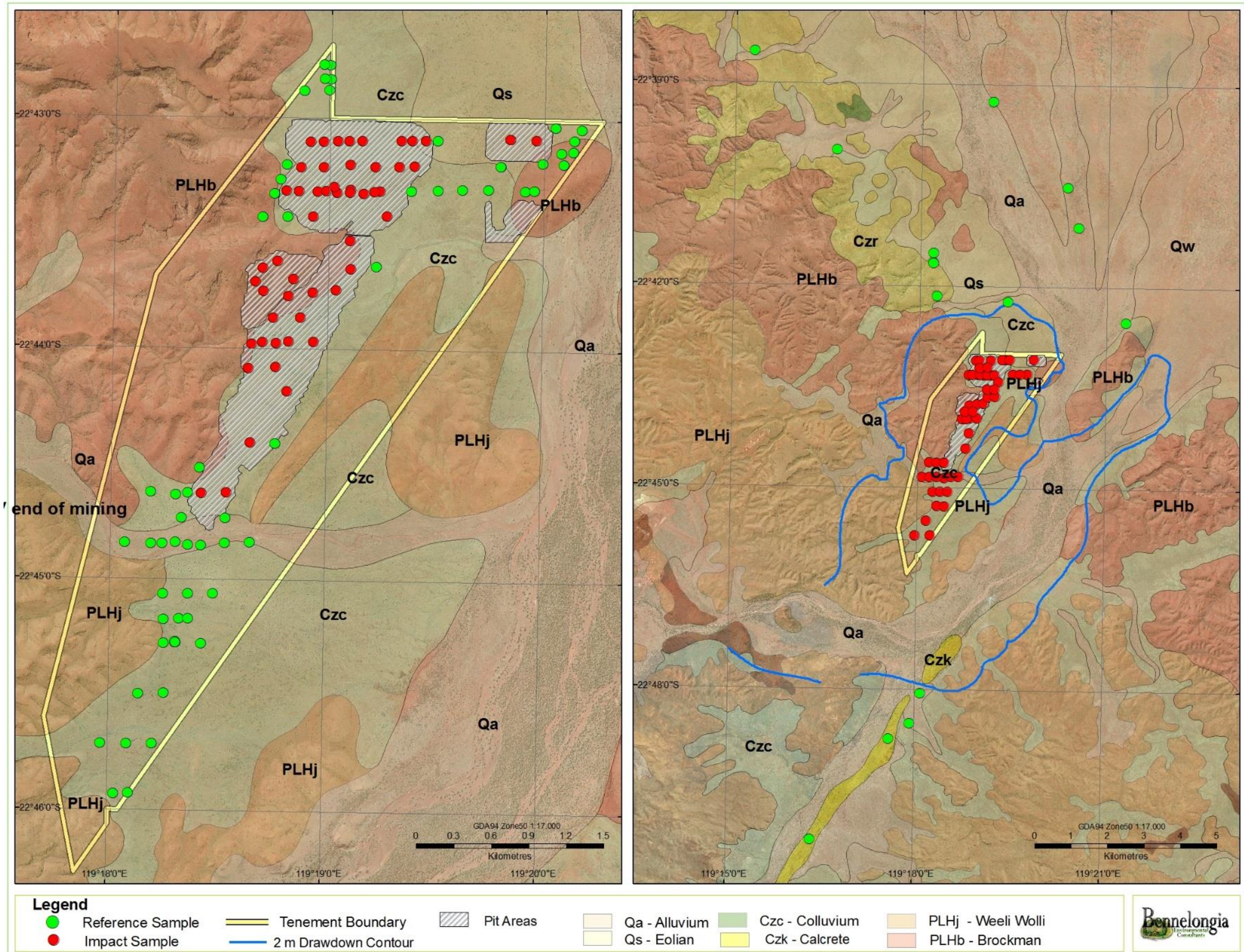

Figure 5-1. Locations of drill holes sampled for troglofauna and stygofauna at the Iron Valley Project.

at all reference sites but this drawdown is not expected to affect relative humidity and, therefore, should not affect the quality of habitat for troglofauna.

Fieldwork for Round 1 sampling was conducted from 13 to 18 May 2009 (scraping and setting traps) and on 8 and 9 July 2009 (retrieving traps). Round 2 sampling was conducted from 3 to 6 November 2009 (scraping and setting traps) and 11 to 13 January 2010 (retrieving traps). Round 3 sampling was conducted at the request of the Department of Parks and Wildlife (DPaW) on the 11 October 2011 (scraping and setting traps). These traps were retrieved on 6 December 2011. The purpose of thesampling was to make further efforts to collect species previously known only from within the proposed mine pit.

A complete list of bores sampled is provided in Appendix 4.

5.2.2. Sampling Methods

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

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

5.3. Stygofauna

5.3.1. Sampling Effort

A total of 84 impact and 14 reference samples were collected from 69 drill holes in the vicinity of Iron Valley between 2009 and 2015 (Table 5.2, Figure 5.1). A further 27 reference samples were collected

Table 5.2. Numbers of stygofauna samples collected from Iron Valley.

Round 1	**Impact**	**Reference**
Net	41	-
Round 2		
Net	43	-
Round 3		
Net		27*
Round 4		
Net	-	14
Total Samples	**84**	**41**

*Collected as reference samples but now in impact area.

from other deposits in the sub-region (see below). A complete list of bores sampled is given in Appendix 5.

Round 1 sampling was conducted from 13 to 15 May 2009 and Round 2 sampling occurred between 3 and 6 November 2009. To comply with a request from DPaW that further reference stygofauna sampling be conducted, 27 bores were sampled in Round 3 at Yandicoogina, Boundary and Phil's Creek deposits between 10 and 13 October 2011. These deposits are in the Weeli Wolli catchment and 15, 44 and 12 km, respectively, from Iron Valley. Round 4 consisted of targeted survey of 14 drill holes between 21 and 22 December 2015 for two potentially restricted stygofauna species, the ostracod *Meridiescandona* sp. BOS171 and syncarid *Bathynella* sp. All holes sampled were close to, but outside, the area of groundwater drawdown at Iron Valley (Figure 5.1).

5.3.2. Sampling Methods

Stygofauna sampling followed the methods outlined in Eberhard *et al*. (2005) and recommended by the EPA (2007). At each bore, six net hauls were collected using a weighted plankton net. After the net was lowered to the bottom of the bore it was jerked up and down briefly to agitate benthic and epibenthic stygofauna into the water column prior to a slow retrieve of the net. Contents of the net were transferred to a 125 ml polycarbonate vial after each haul and the contents were preserved in 100% ethanol. Nets were washed between bores to minimise contamination between sites. Three hauls were taken using a 50 µm mesh net and three with a 150 µm mesh net.

Electrical conductivity (used to infer salinity), pH, and temperature were measured at each drill hole using a Yeo-Cal water quality analyser.

5.4. Sample Sorting and Species Identification

Troglofauna caught in traps were extracted from the leaf litter using Berlese funnels under halogen lamps. Light drives troglofauna and soil invertebrates out of the litter into the base of the funnel containing 100% ethanol (EPA 2007, 2013). After about 72 hours, the ethanol and its contents were removed and sorted under a dissecting microscope. Litter from each funnel was also examined under a microscope for any remaining live or dead animals.

Stygofauna samples and preserved troglofauna scrapes were elutriated to separate animals from heavier sediment and sieved into size fractions (250, 90 and 53 µm) to remove debris and improve searching efficiency. Samples were then sorted under a dissecting microscope.

All fauna picked from samples were examined for troglomorphic characteristics (lack of eyes and pigmentation, well developed sensory organs, elongate appendages, vermiform body shape). Surface and soil-dwelling species were identified only to Order level. Stygofauna and troglofauna were identified to species or morphospecies level, unless damaged, juvenile or the wrong sex for identification (EPA 2007, 2013). Identifications were made under dissecting and/or compound microscope, with specimens being dissected as necessary. Unpublished and informal taxonomic keys were used to assist identification of taxa for which no published keys exist. Specimens were dissected and slide-mounted if necessary to aid the identification process.

Representative animals of all subterranean fauna species will be lodged with the Western Australian Museum.

5.5. Compiling Species Lists

Identifications of animals that could not be identified to species level (i.e. family level identification of a specimen that was immature or damaged) were included in calculations of species richness only if the specimens could not belong to species already recorded. For example, specimens of *Draculoides* sp. and *Draculoides* 'SCH020' were treated as a single species because it was likely that the animals identified to genus *Draculoides* were, in fact, those already recorded as *Draculoides* 'SCH020'**.** The purpose of this criterion was to prevent higher level identifications falsely inflating species richness.

5.6. Personnel

Fieldwork was undertaken by Jim Cocking, Mike Scanlon, Sean Bennett, Dean Main and Andrew Trotter. Sample sorting was done by Jane McRae, Lucy Gibson, Jeremy Quartermaine, Sean Bennett, Mike Scanlon, Jim Cocking, Heather McLetchie, Grant Pearson, Dean Main and Andrew Trotter. Identifications were made by Jane McRae, Mike Scanlon and Stuart Halse. Maps were produced by Mike Scanlon.

5.7. Other Sampling

Both troglofauna captured as by-catch from stygofauna sampling and stygofauna captured as by-catch during troglofauna sampling are included in species lists and interpretations of species distributions.

6. RESULTS

6.1. Troglofauna

6.1.1. Troglofauna at the Iron Valley Project

Sampling at Iron Valley yielded 112 specimens of troglofauna, representing seven Classes, 11 Orders and 16 species. Two arachnid Orders were recorded: Pseudoscorpionida (1 species) and Schizomida (1 species). The only crustacean Order collected was Isopoda (3 species). Chilopoda were represented by one species of an unknown Order (the damaged specimen could not be further identified morphologically). Diplopoda were represented by Polyxenida (1 species) and Symphyla by Cephalostigmata (1 species). There were five Orders of hexapods (Entognatha/Insecta): Diplura (2 species), Blattodea (2 species), Hemiptera (2 species), Coleoptera (1 species) and Diptera (1 species). (Table 6.1, Figure 6-1).

Seven of the specimens collected could not be properly identified to species level because they were damaged, juvenile or the wrong sex (Table 6.2). All are likely to belong to species in Table 6.1.

Staphyliinidae sp. B01 and Sciaridae sp. B01 were the numerically dominant species at the Iron Valley Project (Table 6.1, Figure 6.2). Nearly all other species were collected in low abundance (≤5 specimens) and eight species were recorded as singletons, i.e. only one animal of that species was collected during the study (Table 6.1). Three of these singleton species (Japygidae sp. B04, *Symphyella* sp. B05 and Hemiptera sp. B01) have been previously recorded elsewhere in the central Pilbara (Table 6.1, Bennelongia 2009a,b, unpublished data).

The number of troglofaunal specimens collected per sample was about three times higher from reference drill holes than impact holes. The number of species collected within the mine pit (11) was higher than in the reference area (8), probably largely as a consequence of impact area sampling effort being more than twice as great as reference area sampling (Table 6.3).

Table 6.1. Troglofauna species recorded at the Iron Valley Project with known distribution indicated. Species potentially known only from proposed mine pits are highlighted in grey.

Higher Groups		Species	Number of individuals		Known from outside impact area
			Impact	Reference	
Arachnida					
	Pseudoscorpionida				
		Lagynochthonius 'PSE043'	1		Probably more widespread in the Iron Valley
	Schizomida				
		Draculoides 'SCH020'	2	1	Yes
Crustacea					
	Isopoda				
		Armadillidae sp. B04	1		Yes, known elsewhere in the Hamersley Range[2]
		Troglarmadillo sp. B26	5		Yes, known elsewhere in the Hamersley Range[2]
		nr *Andricophiloscia* sp. B03		1	Yes, from reference bores only
Chilopoda					
		Chilopoda sp.	1		Uncertain
Diplopoda					
	Polyxenida				
		Lophoproctidae sp. B01	3		Yes - very widespread species[1]
Symphyla					
	Cephalostigmata				
		Symphyella sp. B05		1	Yes, from reference bore and from Phil's Creek[2]
Entognatha					
	Diplura				
		Projapygidae sp. B02		1	Yes, from reference bore only
		Japygidae sp. B04	1		Yes - very widespread species[1]
Insecta					
	Blattodea				
		Nocticola sp. B01	3		Yes - very widespread species[1]
		Nocticola sp. B09	2	1	Yes
	Hemiptera				
		Meenoplidae sp.		6	Probably - one of two widespread species[1]
		Hemiptera sp. B01	1		Yes - very widespread species[1]
	Coleoptera				
		Staphyliinidae sp. B01		43	Yes, from reference bores only
	Diptera				
		Sciaridae sp. B01	8	22	Yes - very widespread species[1]

[1]Bennelongia 2009a; [2]Bennelongia unpublished data.

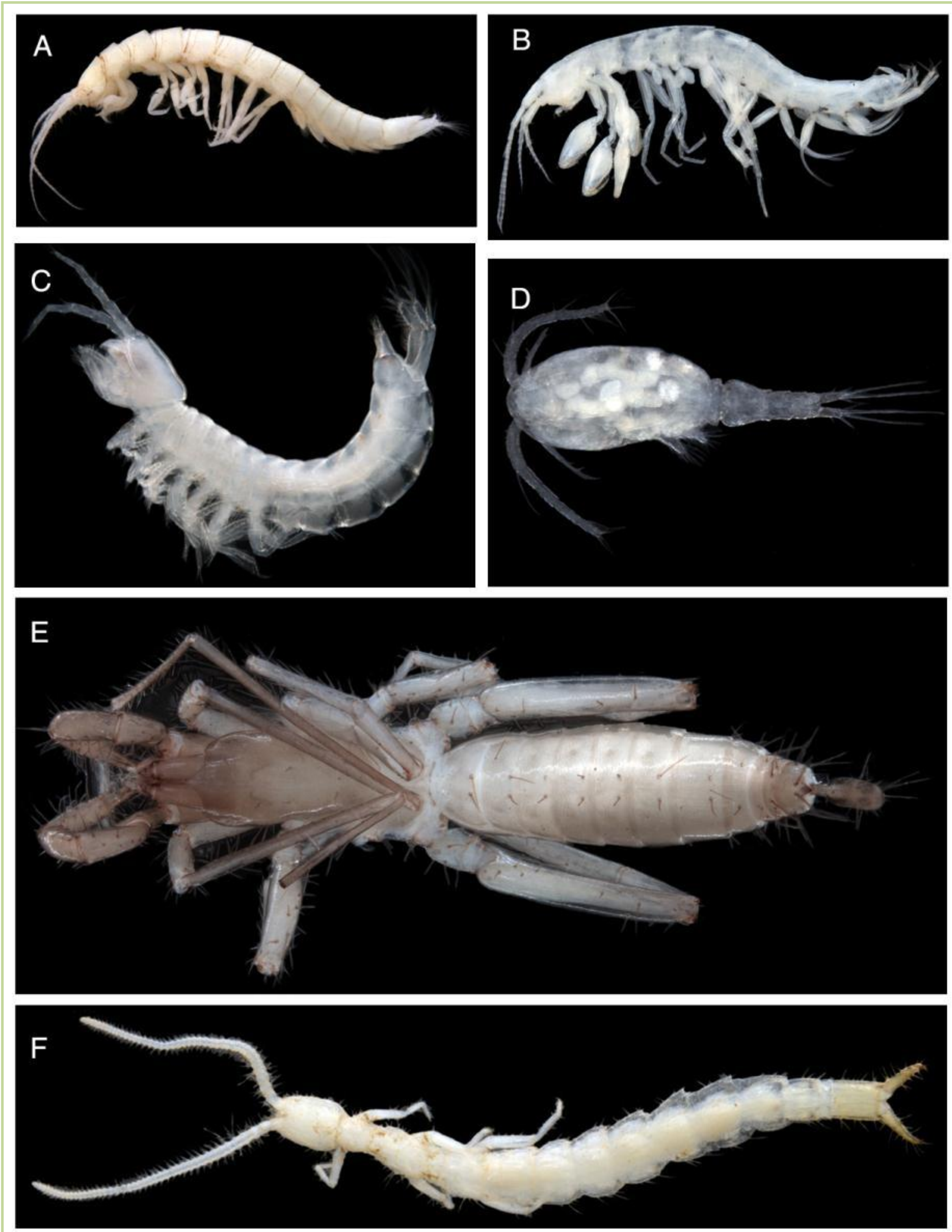

Figure 6-1. Stygofauna (A-D) and troglofauna photographs (E-F).
(A) *Pygolabis* sp. B06 (B) *Maarrka weeliwollii* (C) nr *Billibathynella* sp. B01 (D) *Thermocyclops aberrans* (E) *Draculoides* 'SCH020' (F) Japygidae sp. B04.

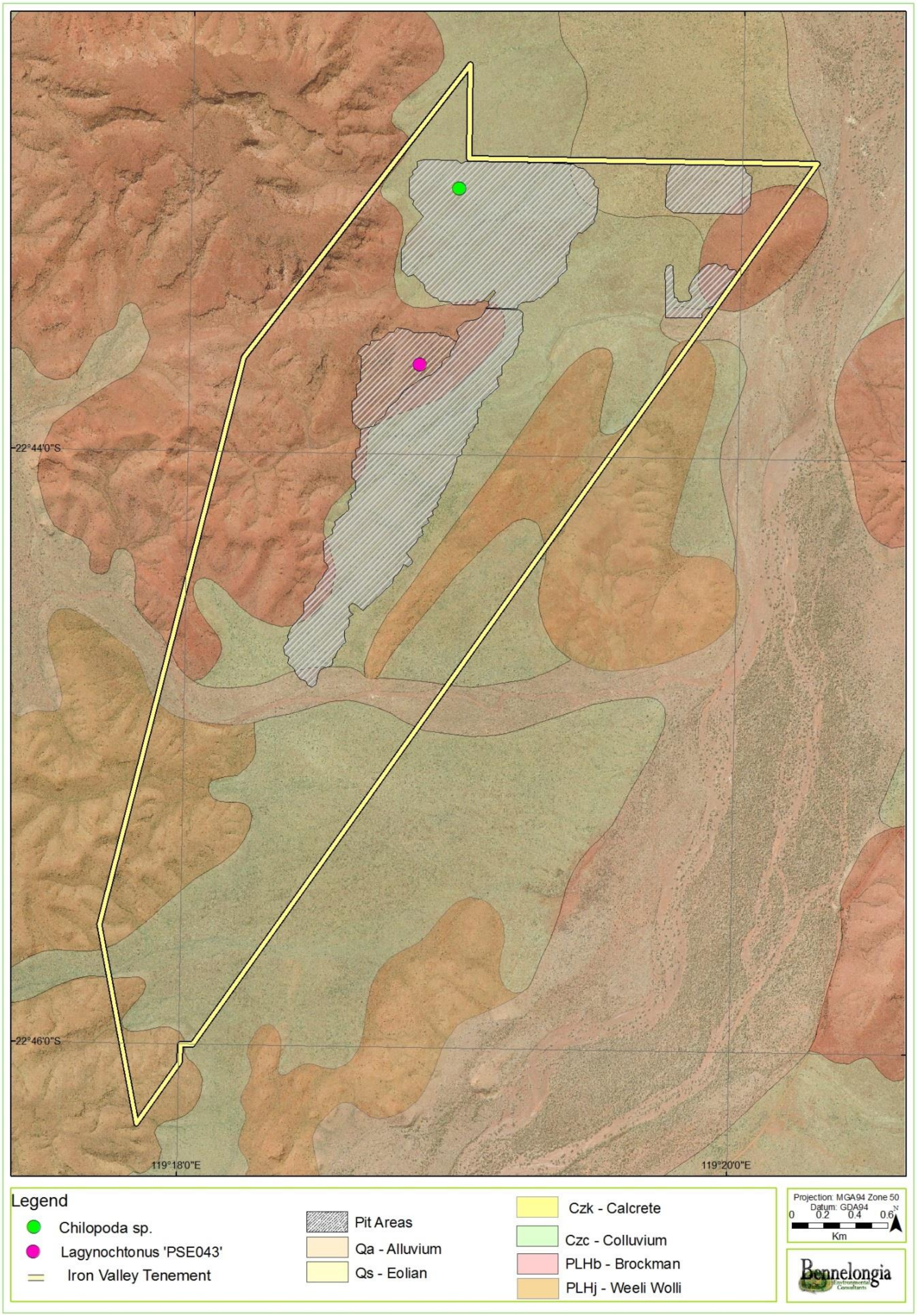

Figure 6-2. Locations of troglofauna species potentially known only from impact areas.

Table 6.2. Troglofauna identified only to higher level (immature or incomplete specimens).

Higher Groups		Taxa	Number of individuals		Probable species
			Impact	Reference	
Arachnida					
	Schizomida				
		Draculoides sp.		2	*Draculoides* 'SCH020'
Entognatha	Diplura				
		Diplura sp.	1		Projapygidae sp. B02 or Japygidae sp. B04
Insecta					
	Blattodea				
		Nocticola sp.	2	3	*Nocticola* sp. B01 or *Nocticola* sp. B09

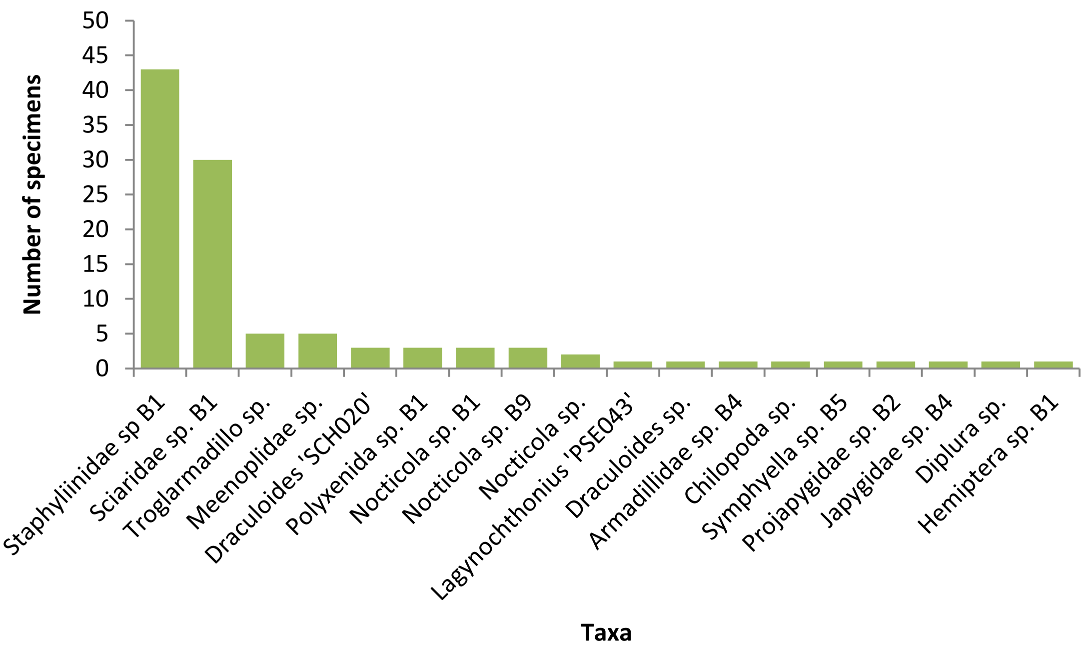

Figure 6-3. Capture abundance of each troglofauna species at the Iron Valley Project.

Table 6.3. Summary statistics for troglofauna sampling at the Iron Valley Project.

Bore type	No. of Samples	Total Specimens	Mean specimens per sample	No. of Species	Mean species per sample
Impact	98	31	0.32	11	0.17 ± 0.04
Reference	70	81	1.16	8	0.17 ± 0.05

6.1.2. Troglofauna Species in the Proposed Mine Pits

Eleven of the 16 species recorded at the Iron Valley Project were recorded within the proposed mine pits (i.e. the impact area) (Table 6.1). Of these 11 species, nine species are known to occur in reference areas outside the mine pits or at deposits elsewhere in the Pilbara. Two species, Chilopoda sp. (recorded as a singleton based on a damaged specimen) and *Lagynochthonius* sp. 'PSE043' (recorded as a singleton based on a juvenile) are only known from the proposed mine pit (Figure 6.2).

6.1.3. Troglofauna Distributions

Nearly 60% of the troglofauna species collected during survey are known from outside the Project area (which is larger than the proposed mine pits, Figure 5.1). Five species are very widespread and known from many locations in the Pilbara (Lophoproctidae sp. B01, Japygidae sp. B04, *Nocticola* sp. B01, Hemiptera sp. B01 and Sciaridae sp. B01) (Table 6.1, Bennelongia 2009a,b). A sixth species, Meenoplidae sp. (represented by five nymphs from a reference hole), probably belongs to one of two species that are very widespread in the Pilbara (Table 6.1, Bennelongia 2009a).

Three species are known from the wider area around Iron Valley. The symphylan *Symphyella* sp. B5 is known from Phil's Creek approximately 12 km from the Iron Valley Project. The slaters Armadillidae sp. B04 and *Troglarmadillo* sp. B26 are known from outside the Project area but more locally from within the Hamersley Range (Table 6.1).

Seven species are known only from the Project area. Two of these species were collected in both the impact and reference areas, two were collected as singletons and one as multiple animals outside the proposed mine pits and two were collected as singletons within the mine pits (the pseudoscorpion *Lagynochthonius* 'PSE043' and Chilopoda sp.). It should also be noted that three of the species known to occur more widely were collected at Iron Valley only within the proposed mine pits as singletons (Armadillidae sp. B04, Japygidae sp. B04 and Hemiptera sp. B01).

6.1.4. Sampling Efficiency

Documenting the composition of troglofauna communities and the distribution of the species within them is difficult because a high proportion of troglofauna species occur in low abundance. In fact, the most abundant third of troglofauna species accounted for 87% of all specimens. Only two species were represented by more than five animals (Figure 6.3).

Despite the low abundance of most individual species, the average number of troglofaunal animals caught at the Iron Valley Project was 0.66 per sample, which is well above the historical capture rate of 0.25 for the Pilbara (Subterranean Ecology 2007). Capture rates were higher in the reference area than impact area (1.16 specimens per sample versus 0.32, in Table 6.3). Scraping and trapping gave similar yields but reference holes yielded better than impact holes.

6.2. Stygofauna

6.2.1. Stygofauna Occurrence and Abundance

Stygofauna sampling in 2009 and 2011 yielded 2,152 specimens consisting of at least 22 species of eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (6 species), Isopoda (1 species) and nematodes of unknown order (Table 6.4, Figure 6-1).

Copepods were the numerically dominant group within the Project area with species of oligochaetes, amphipods and syncarids also relatively abundant (Table 6.4, Figure 6.5). *Diacyclops humphreysi humphreysi*, *Thermocyclops aberra* and nr *Billibathynella* sp. B01 were the most numerous species (Table 6.4, Figure 6.5). The majority of taxa were collected at low abundance with the most abundant third of the species accounting for 91% of all the animals collected and the least abundant third only 1% (Figure 6.5).

Targeted stygofauna sampling in 2015 yielded 283 specimens in eight Orders. Ostracods and oligochaete worms were the most abundant groups with 100 and 30 specimens, respectively, followed by amphipods with 17 specimens. Species level identifications were undertaken only for the ostracods and syncarids and are not presented here, other than for syncarids. Two juvenile specimens of the syncarid *Bathynella* sp. B23 were collected in the reference area but no *Meridiescandona* sp. BOS171 ostracods were found.

6.2.2. Species Identification Issues

Some stygofauna could not be identified to species level (Table 6.5). It is probable that all belong to species in Table 6.4 but in most cases the animals were too juvenile or damaged for identification below family or order level. It is noted in Table 6.5, although not part of Bennelongia's sampling, that results of

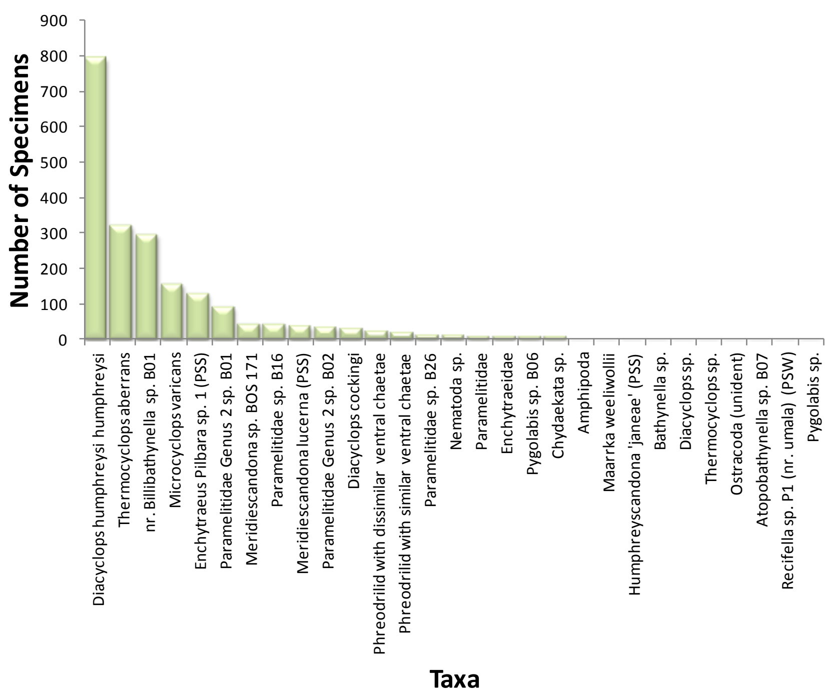

Figure 6-4. Capture abundance of each stygofauna species at the Iron Valley Project.

Table 6.4. Stygofauna species recorded from the Iron Valley Project, with known distributions indicated.
All specimens collected from impact area. Species potentially known only from groundwater drawdown area are highlighted in grey.

Higher Groups		Species	Specimens	Known from outside of impact
Nematoda				
		Nematoda sp.	15	Not assessed in EIAs, widespread in the Pilbara
Oligochaeta	Tubificida			
		Phreodrilid with dissimilar ventral chaetae	27	Yes, Pilbara-wide[1]
		Phreodrilid with similar ventral chaetae	23	Yes, Pilbara-wide[1]
		Enchytraeus Pilbara sp. 1	132	Yes, Pilbara-wide[1]
Acariformes				
	Hydracarina			
		Recifella sp. P1 (nr *umala*)	1	Yes, central Pilbara[1]
Crustacea	Ostracoda			
		Humphreyscandona 'janeae'	3	Yes, Fortescue catchment[1]
		Meridiescandona lucerna	40	Yes, Fortescue catchment[1]
		Meridiescandona sp. BOS171	47	No
	Copepoda			
		Microcyclops varicans	158	Yes, Pilbara-wide and beyond[2]
		Diacyclops cockingi	34	Yes, Pilbara-wide[3]
		Diacyclops humphreysi humphreysi	795	Yes, Pilbara-wide and beyond[4]
		Thermocyclops aberrans	323	Yes, central Pilbara[5]
	Syncarida			
		Bathynella sp. B23	2	Yes, 2015 target survey
		sp. B24	3	Uncertain
		nr *Billibathynella* sp. B01	298	Yes, known from lower Weeli Wolli and Marillana Creeks[6]
		Atopobathynella sp. B07	2	Yes, known from Marillana Creek[6]
	Amphipoda			
		Maarrka weeliwollii	3	Yes, widespread in Weeli Wolli/Marillana catchment[6,7]
		Chydaekata sp.	10	Yes, widespread in Weeli Wolli/Marillana catchment[6,8]
		Paramelitidae Genus 2 sp. B01	93	Yes, lower Weeli Wolli Creek[2]
		Paramelitidae Genus 2 sp. B02	37	Yes, widespread in Weeli Wolli/Marillana catchment[6]
		Paramelitidae sp. B16	45	Yes, known from lower Weeli Wolli and Marillana Creeks[6]
		Paramelitidae sp. B26	16	Yes, known from southern floodplain of the Fortescue Marsh[6]
	Isopoda			
		Pygolabis sp. B06	11	Yes, known from lower Weeli Wolli and Marillana Creeks[6]

[1]Halse *et al*. unpublished data; [2]Sars (1863); [3]Karanovic (2006); [4]Pesce and De Laurentiis (1996); [5]Lindberg (1952); [6]Bennelongia unpublished data; [7]Finston *et al*. (2011); [8]Finston *et al*. (2009).

Table 6.5. Stygofauna identified only to higher level (immature or incomplete specimens; specimens not available for study).

Higher Groups	Taxa	Specimens	Probable species
Oligochaeta			
Tubificida			
	Enchytraeidae sp.	13	*Enchytraeus* Pilbara sp. 1
Crustacea			
Ostracoda	Ostracoda sp.	2	One of the three ostracods in Table 6.4
Copepoda			
	Diacyclops sp.	2	*Diacyclops humphreysi humphreysi* or *Diacyclops cockingi*
	Thermocyclops sp.	2	*Thermocyclops aberrans*
Amphipoda			
	Amphipoda sp.	3	One of the amphipods in Table 6.4
	Paramelitidae sp.	13	One of the paramelitid in Table 6.4
Isopoda			
	Pygolabis sp.	1	*Pygolabis* sp. B06
Syncarida			
	Bathynella sp.	NA	Possibly *Bathynella* sp. 24

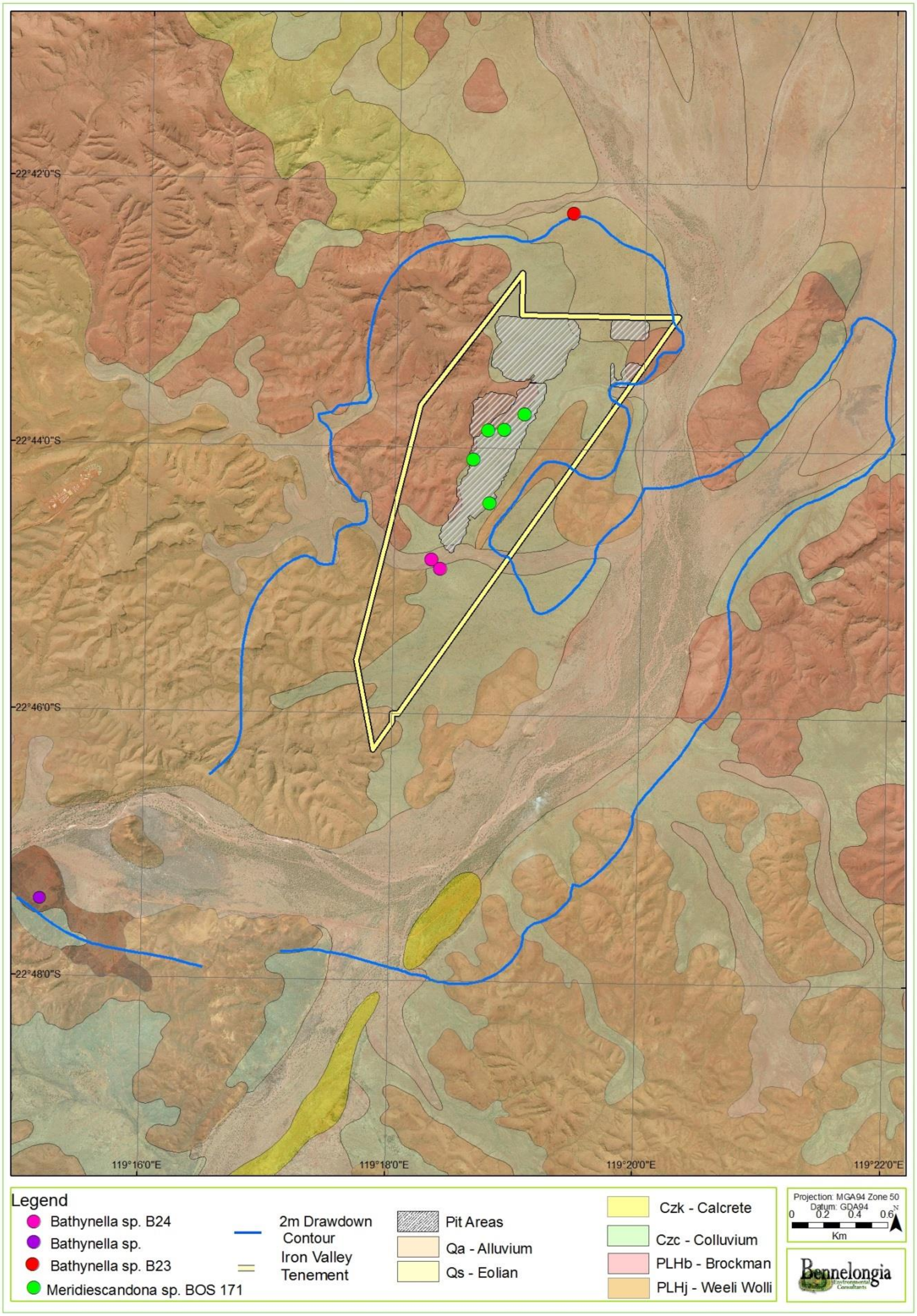

Figure 6-5. Locations of selected stygofauna species in relation to impact area.
Bathynella sp. B24 is represented by two samples from one hole. Drawdown cones are expected to extend beyond all of the bores indicated.

the Pilbara Biodiversity Survey show a species of *Bathynella* collected to the south-west of the Project area but the specimen was not identified to species and is no longer available (see also Figure 6.6).

Only two higher level identifications clearly represented additional species. These were the amphipod *Chydaekata* sp. and the round worm Nematoda sp. The taxonomy of nematodes in Australia is poorly resolved and Iron Valley specimens cannot be compared reliably with specimens from elsewhere in the Pilbara. The taxonomy of *Chydaekata* sp. has been the subject of considerable genetic research and it is believed a single species of *Chydaekata* is present within the Weeli Wolli/Marillana catchment (see Finston and Johnson 2004; Finston *et al*. 2007). This species has been recorded from a number of locations on Weeli Wolli Creek and the Fortescue Marsh, with the closest record to Iron Valley being 6.5 km away.

6.2.3. Stygofauna Distributions

Twenty of the 22 species collected within the Iron Valley Project are known from elsewhere in the Pilbara (Table 6.4). Seven of these species are very widespread, either known from throughout the Pilbara or beyond. Four species are known to have relatively extensive ranges in the central Pilbara/Fortescue catchment. Nine species are known from either the Weeli Wolli/Marillana catchment or the southern floodplain of the Fortescue Marsh (Table 6.4).

Two species potentially have more localised ranges. These are the ostracod *Meridiescandona* sp. BOS171 and the syncarid *Bathynella* sp. B24. *Meridiescandona* sp. BOS171 has to date been collected only from the area of groundwater drawdown, where it has been found in five drill holes (Figure 6.6). Its currently known linear range is 1.3 km. This undescribed species belongs to a genus with three described species that are all known from multiple records from subterranean waters in the central Pilbara (Karanovic 2007). *Meridiescandona facies* has a known linear range of about 110 km, *M. lucerna* has a linear range of 80 km, and *M. marillanae* has a linear range of <20 km except for one outlying record that gives a species range of about 35 km (Karanovic 2007; Bennelongia unpublished). These ranges suggest that *Meridiescandona* sp. BOS171 is likely to have a distribution extending beyond the area of proposed groundwater drawdown.

While a larger range of *Meridiescandona* sp. BOS171 is expected, the species was not collected north of the east-west dyke and it is possible this hydrological barrier constrains the northern extent of the species' range. Alternatively, the failure to collect *Meridiescandona* sp. BOS171 north of the dyke may have been an artefact of the species being at low abundance in this area because of the depth to groundwater being >40 m. Only low numbers of stygofauna are collected when depth to groundwater exceeds 30 m (Halse et al. 2014). It is suggested that *Meridiescandona* sp. BOS171 may extend north of the dyke at low abundance and then become more abundant as depth returns to <20 m closer to Fortescue Valley (Figure 6.7). In this case, *Meridiescandona* sp. BOS171 would be exhibiting a pattern of distribution similar to other stygofauna species that were collected on both sides of the dolerite dyke. These include amphipods, copepods and the related *Meridiescandona lucerna* (Appendix 6).

The syncarid *Bathynella* sp. B24 has also been collected only from the area to be de-watered (at hole WW010 in both May and November 2009). It differs from *Bathynella* sp. B23, a second species that was collected just outside the northern boundary of the Iron Valley Project during the 2015 target survey, because it has much longer furcal and uropodal setae. An additional *Bathynella* specimen was collected by DPaW in 2005 from about 7 km south-west of the Project area at Marillana Creek. This location is just within the groundwater drawdown area. It is possible that the DPaW specimen belongs to *Bathynella* sp. B24 because the specimen were collected only 7 km from the hole yielding *Bathynella* sp. BOS 24 with

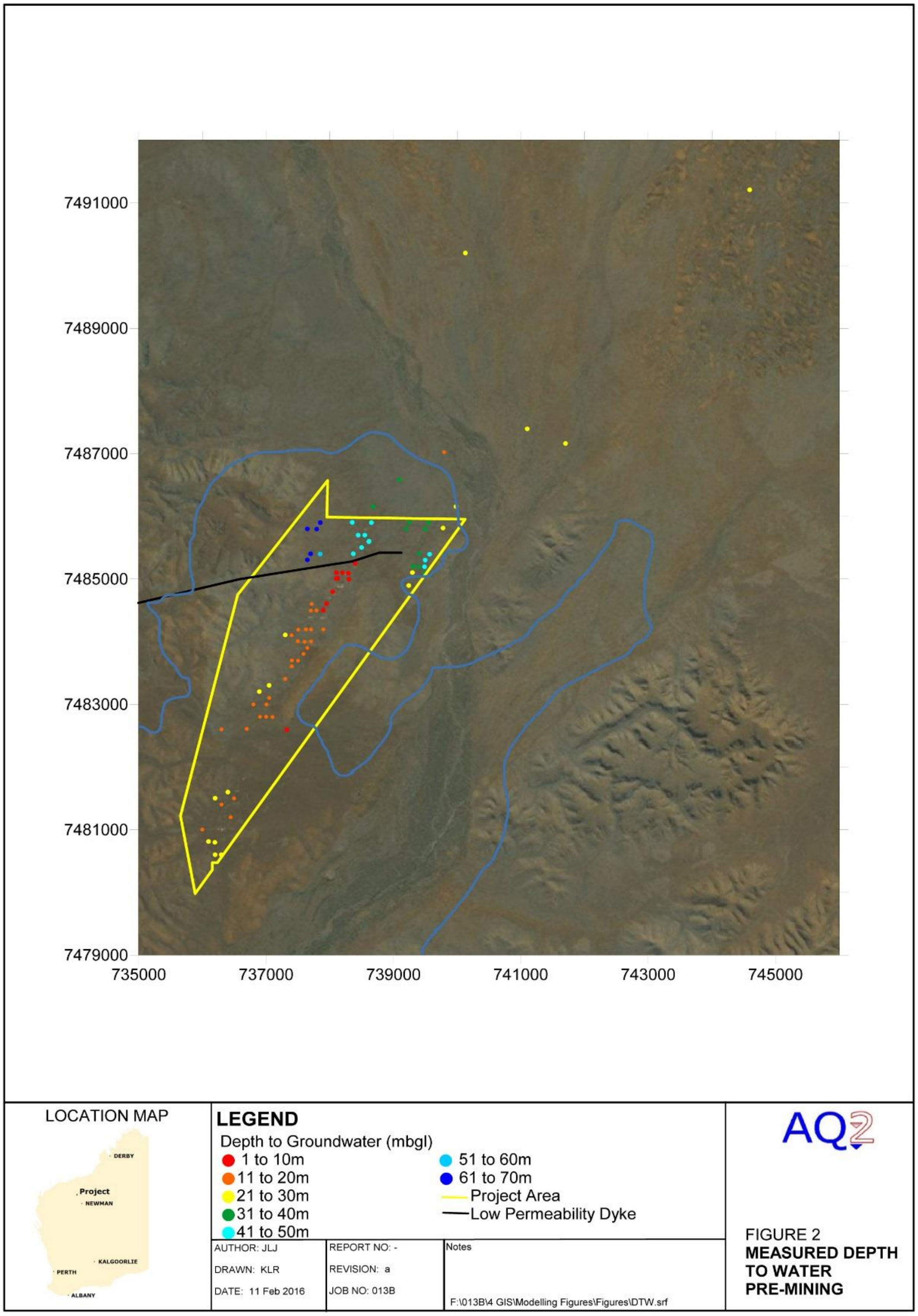

Figure 6-6. Depth to groundwater at Iron Valley.

Depth (m) at measured bores, tenement and predicted area of groundwater drawdown >2 m. Figure supplied by AQ2.

potential habitat connectivity between the two sites. Ranges of this magnitude are quite common among syncarids (Camacho and Valdecasas 2008).

7. DISCUSSION

7.1. Troglofauna

7.1.1. Iron Valley Troglofauna Community

The 16 species collected from 168 troglofauna samples indicate that the Iron Valley troglofauna community is moderately species rich by Pilbara standards. Large areas such as the Jirrpalpur and Packsaddle Ranges are substantially richer, having about 80 species in total; the larger Cape Preston area is also richer with at least 29 species; while the similar sized Bonnie Creek area south of Nullagine has comparable richness (18 species). The Pardoo area (12 species) and a section of the Chichester Ranges (9 species) seem to have fewer species (Subterranean Ecology 2007; Bennelongia 2008d, 2009a,b).

Abundance at the Iron Valley Project (0.66 animals per sample, impact and reference data combined) was similar to that observed for many areas of the Pilbara. Some previous rates of collection are 0.64 specimens per sample at Ore Body 24 in the Opthalmia Range, 0.70 in the Jirrpalpur Range, 0.87 at the Packsaddle Range, 0.95 at Phil's Creek and 1.1 in the Bonnie Creek area south of Nullagine (Bennelongia 2008b,c, 2009a,c).

Abundance was considerably greater in reference than impact holes within the Iron Valley Project (Table 6.3). While this suggests that surrounding habitat at the Iron Valley Project is more favourable for troglofauna than the commercial grade ore of the pit areas, reference hole abundance was boosted by high capture of two species that tend to cluster (Staphyliinidae sp. B01 and Sciaridae sp. B01) and, in reality, the quality of habitat is probably similar in both areas.

7.1.2. Habitat Characterisation

The occurrence of troglofauna 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.

Although not fully characterised, existing data suggest that, in broad terms, geology is similar both inside and outside the proposed mine pits of the Iron Valley Project. The proposed pit boundaries reflect the extent of economic grade ore rather than prospective subterranean fauna habitat (see Section 2, Appendix 1).

7.1.3. Troglofauna Distributions as Indicators of Habitat Connectivity

Many of the troglofauna collected at Iron Valley are known more widely in the Pilbara (Table 6.1). While some of these species may have a surface dispersal phase, the abundant schizomid *Draculoides* 'SCH020' is highly likely to be a troglobiont without any surface dispersal. Therefore, the distribution of this abundant species can be used as an indicator of the degree of habitat connectivity between impact and reference areas at Iron Valley. Given that *Draculoides* 'SCH020' occurs both within and to the south of the impact area, there is evidence of some habitat connectivity between the mine pits and the area to the south of them (Appendix 6). *Nocticola* sp. B09, which is also considered to be a troglobite, has the same pattern of distribution.

Troglofauna distributions suggest that the dolerite dyke that transects the Project trending in an east/west direction is not a barrier to troglofauna. Four species recorded at the Project site are known from both sides of the dyke (Appendix 6). Two of these species are very widespread (Lophoproctidae sp. B01 and Sciaridae sp. B1) and may be troglophiles but *Nocticola* sp. B09 and *Draculoides* 'SCH020' are troglobites.

7.1.4. Conservation Threats to Species

Two species of troglofauna (centipede Chilopoda sp. and pseudoscorpion *Lagynochthonius* 'PSE043') are currently known only from within the proposed mine pits. Both species were recorded as singletons. The conservation status of Chilopoda sp. cannot be quantified because the specimen was too damaged for species identification and represents an order level identification. As such, the identity of the species at Iron Valley is unknown. It may be a quite widespread species or may be restricted. More generally, determining the ranges of troglofaunal centipedes has been difficult because all centipede species collected by Bennelongia in the Pilbara have been found at very low abundance (110 specimens from over 10,000 troglofauna samples). It may be that these large troglofauna species are adept at escaping capture. Low capture rates make it difficult to determine species ranges. Considerable collecting effort would be required to assess the status of Chilopoda sp. further, with the caveat that it is quite likely the effort will not provide additional information about the species' range

The pseudoscorpion *Lagynochthonius* 'PSE043' is known from a single juvenile, which provides no information about the spatial extent of species' range. The ranges of other troglofaunal *Lagynochthonius* species vary, with some species having moderately wide ranges. For example*, Lagynochthonius* 'PSE039' is known from several deposits at Mining Area C, Yandicoogina and at least three orebodies at Jinidi in the Pilbara. Other species have more tightly restricted distributions, such as *Lagynochthonius asema* which is restricted to Mesa A in the Robe Valley (Edward and Harvey 2008). Considering the habitat connectivity demonstrated by the distribution of other troglofauna species in the Iron Valley, and the fact that species of *Lagynochthonius* may be widespread, it is considered likely that the range of *Lagynochthonius* 'PSE043' extends outside the proposed mine pits.

Consequently, it is concluded that the threat to troglofauna conservation values from mining at the Iron Valley Project is low.

7.2. Stygofauna

7.2.1. Iron Valley Stygofauna Community

The number of stygofauna species collected from the Iron Valley Project (22 species from 84 samples) is relatively modest by Pilbara standards. For example, sampling in the wider Fortescue Marsh area yielded 55 species (Bennelongia 2007) and 34 species were recorded in the upper Fortescue area near Newman from only 17 samples (Ethel Gorge community, Halse *et al*. unpublished data). Subsequent sampling near Ethel Gorge has vastly increased the number of species known from the area.

7.2.2. Habitat Characterisation

The dolerite dyke that transects the Project trending in an east/ west direction would appear to be a possible barrier to stygofauna movement because of the hydraulic discontinuity it represents (groundwater level is about 40 m lower on the northern side of the dyke). Species to the north and south of the dyke are probably occupying different aquifers and hence lack habitat connectivity under normal groundwater conditions. Nevertheless, the occurrence of five stygofauna species on both sides of the dyke (Paramelitidae Genus 2 sp. B01, Paramelitidae sp. B16, Paramelitidae sp. B26, *Diacyclops humphreysi humphreysi* and *Meridiescandona lucerna*) (Appendix 6) suggests the dyke is not a range constraint for some species and this may be because groundwater in the south overtops the dyke after cyclonic rain recharge. If this is the case there is a periodic northwards connection between the southern aquifer and the regional aquifer to the north so that all species found south of the dyke have potential habitat connectivity with the regional aquifer.

While it is possible that the dyke provides a range constraint for *Meridiescandona* sp. BOS171, and possibly other species of the southern aquifer, including *Bathynella* sp. B24, hydrogeological evidence suggests this is unlikely to be the case. Thus, while *Bathynella* sp. B23 may replace *Bathynella* sp. B23 north of the dyke because the dyke acts as a barrier to dispersal (Figure 6.6), it is equally likely some other factor is controlling the distribution of these species. Similarly, while the failure to collect *Meridiescandona* sp. BOS171 north of the dyke may reflect the dyke forming a physical barrier, it may also be the result of the dyke increasing depth to groundwater and reducing abundance of *Meridiescandona* sp. BOS 171, or because some other unknown process is affecting sampling yields or resulting in a patchy species distribution.

In this respect it should be noted that four of the five abundant species occurring on both sides of the dyke were found in the same number of, or in more, samples where groundwater is shallow south of the dyke (Paramelitidae Genus 2 sp. B01 8 south, 2 north; Paramelitidae sp. B16 6 south, 1 north; Paramelitidae sp. B26 3 south, 6 north; *Diacyclops humphreysi humphreysi* 14 south, 5 north; and *Meridiescandona lucerna* 2 south, 2 north). The overall number of samples yielding specimens of these species north of the dyke is significantly fewer than expected (Chi square 5.9, 1 df, $P < 0.02$), which fits with the observation by Halse et al. (2014) that large numbers of animals were collected only when the depth to groundwater was <32 m. At greater depths to the watertable species occur in low abundance and the probability of collecting rarer species of the community is low.

7.2.3. Stygofauna Distributions and Conservation Threats to Species

Most of the stygofauna species collected are known to occur beyond the Iron Valley Project. Two species have been collected only within the area of predicted groundwater drawdown (ostracod *Meridiescandona* sp. BOS 171 and syncarid *Bathynella* sp. B24). Existing information about the likely ranges and conservation significance of both species is discussed below:

1. *Meridiescandona* sp. BOS 171 is known only from the Iron Valley Project (Figure 6.6), which lies within the small area where the genus *Meridiescandona* has radiated (see Karanovic 2007; Reeves *et al*. 2007). *Meridiescandona* sp. BOS171 was collected from five bores within the groundwater drawdown area during the 2009 survey in shallow depths to groundwater (5-18 m) but was not re-collected in either the regional survey of 2011 or the targeted survey outside the drawdown area in 2015. The presence of large stygofauna such as *Maarrka weeliwollii* and *Pygolabis* sp. B06 (the largest Pilbara stygofauna species) more widely in Weeli Wolli/Marillana Creek shows that for some species there is habitat connectivity between the Project area and the surrounding area, or at least a mechanism that has created ranges extending into surrounding areas (see Appendix 7). *Meridiescandona* sp. BOS171 may also utilise the habitat connectivity or other connecting mechanism but for various reasons be poorly collected across much of its range, except for the cluster of samples from the Project impact area. For example, *Meridiescandona* sp. BOS171 may extend farther north across the dyke but the depth to groundwater immediately north of the

dyke reduces the abundance of the species to the point where collection is unlikely. Depth to the watertable becomes shallow again (<20 m) north of the groundwater drawdown area, where *Meridiescandona* sp. BOS171 may occur more abundantly. If this scenario is correct, the range of *Meridiescandona* sp. BOS171 would be of similar magnitude to the related *Meridiescandona marillanae* and some other stygofauna species (Appendix 6).

2. *Bathynella* sp. B24 is presently known only from two specimens collected from one drill hole in the area of predicted groundwater drawdown (Figure 6-6). A specimen of *Bathynella* collected in 2005 near Marillana Creek to the south-west may also belong to *Bathynella* sp. B24 but the specimen could not be examined. This specimen was close to the southern boundary of the drawdown area. Given that at least 20 of the 22 stygofauna species collected in the vicinity of the Project area occur outside the area of predicted groundwater drawdown, it is likely that the range of *Bathynella* sp. B24 also extends beyond the drawdown area, despite *Bathynella* species usually having small ranges. However, while the species is known from only one drill hole such conclusions about it likely range are tentative.

Overall, it is concluded that there is no threat to most of the stygofauna community within the predicted groundwater drawdown area at the Iron Valley Project. There is uncertainty about the status of two of the 22 stygofauna species collected. In the case of *Bathynella* sp. B24 the uncertainty is associated with its collection from a single drill hole. The causes of the small known range of *Meridiescandona* sp. BOS171 are less clear because it appears likely there is periodic connectivity between its documented habitat and the regional aquifer to the north..

8. CONCLUSION

8.1. Troglofauna

The 168 samples on which this report was based met EPA guidelines for troglofauna assessment and the following conclusions can be drawn:

- The troglofauna community at the Iron Valley Project consists of 11 Orders and 16 species. Two arachnid Orders were recorded: Pseudoscorpionida (1 species) and Schizomida (1 species). The only crustacean Order collected was Isopoda (3 species). Chilopoda were represented by one species of an unknown Order (a partial and damaged specimen prevented identification based on morphology). Diplopoda were represented by Polyxenida (1 species) and Symphyla by Cephalostigmata (1 species). There were five Orders of hexapods (Entognatha/Insecta): Diplura (2 species), Blattodea (2 species), Hemiptera (2 species), Coleoptera (1 species) and Diptera (1 species).
- Eleven of the 16 species recorded at the Iron Valley Project were recorded within the proposed mine pits (i.e. the impact area) (Table 6.1). Nine of these 11 species have been recorded outside of the mine pits.
- Two species (Chilopoda sp. and *Lagynochthonius* 'PSE43') are currently known only from within the proposed mine pits. Both species were recorded as singletons and their conservation status cannot be quantified because single animals were collected and perhaps, in the case of Chilopoda sp., because of poor level of identification. It is considered likely that both species occur outside the proposed mine pits and that the threat to troglofauna conservation values as a result of mining at the Iron Valley Project will be low.

8.2. Stygofauna

The 125 samples on which this report was based meet the EPA requirement for stygofauna assessment. The following conclusions are drawn from the survey:

- Stygofauna sampling yielded 2,152 specimens consisting of at least 22 species of at least eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (6 species), Isopoda (1 species) and nematodes of unknown order/s.
- Many of the stygofauna species collected in the Iron Valley Project area, including the largest species Pilbara stygofauna species *Pygolabis* sp. B01, are known to occur in surrounding areas of the Weeli Wolli/Marillana Creek drainage channel. This suggests there is habitat connectivity between the area of predicted groundwater drawdown at the Project and surrounding areas.
- Two of the 22 species collected during survey were recorded only within the area of predicted groundwater drawdown. These are the ostracod *Meridiescandona* sp. BOS 171 and syncarid *Bathynella* sp. B24. It is possible that *Bathynella* sp. B24 and a syncarid specimen previously recorded at Marillana Creek close to the boundary of the groundwater drawdown area are the same species.
- It is concluded that there is no threat to most of the stygofauna community within the predicted groundwater drawdown area at the Iron Valley Project. There is, however, uncertainty about the conservation status of *Bathynella* sp. B24 and *Meridiescandona* sp. BOS171. In the case of *Bathynella* sp. B24 the uncertainty is associated with its collection from a single drill hole and its currently highly restricted range is, at least to some degree, a sampling artefact.
- *Meridiescandona* sp. BOS171 was collected from five drill holes within the area of predicted groundwater drawdown. The causes of its small known range and the degree of threat to the species, are unclear. Sampling results suggest *Meridiescandona* sp. BOS171 is possibly restricted to the groundwater drawdown area and the occurrence of the dyke downstream of its known occurrence provides one possible explanation for this limited known range. Another possible explanation is that the species' range extends north across the dyke but the greater depth to groundwater immediately north of the dyke reduces the abundance of the species to the point where collection is unlikely. Given that the ranges of some other species at Iron Valley suggest the area has habitat connectivity at both the local scale and more widely (or at least a mechanism promoting relatively wide species ranges), *Meridiescandona* sp. BOS171 would be expected to have a range extending outside the groundwater drawdown area as does the related *Meridiescandona lucerna*.

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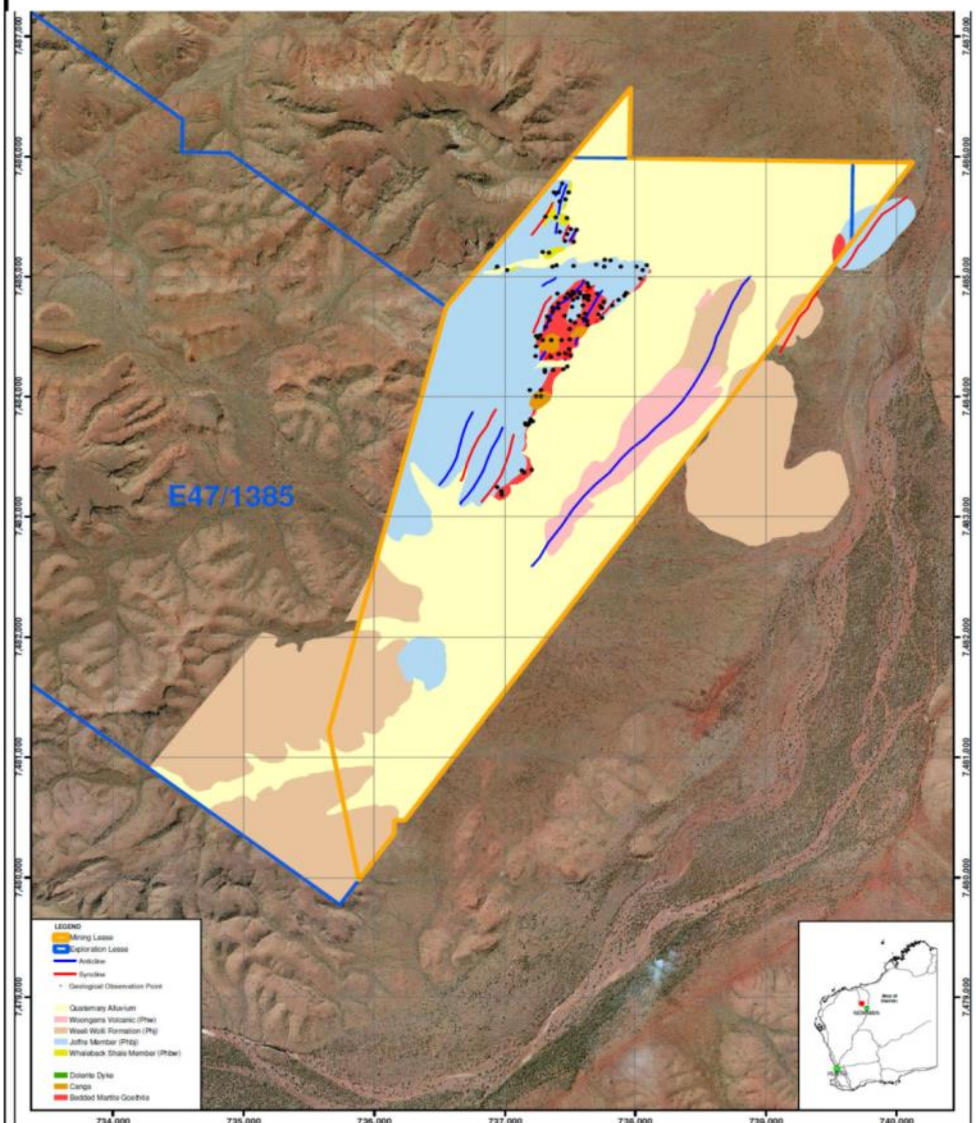
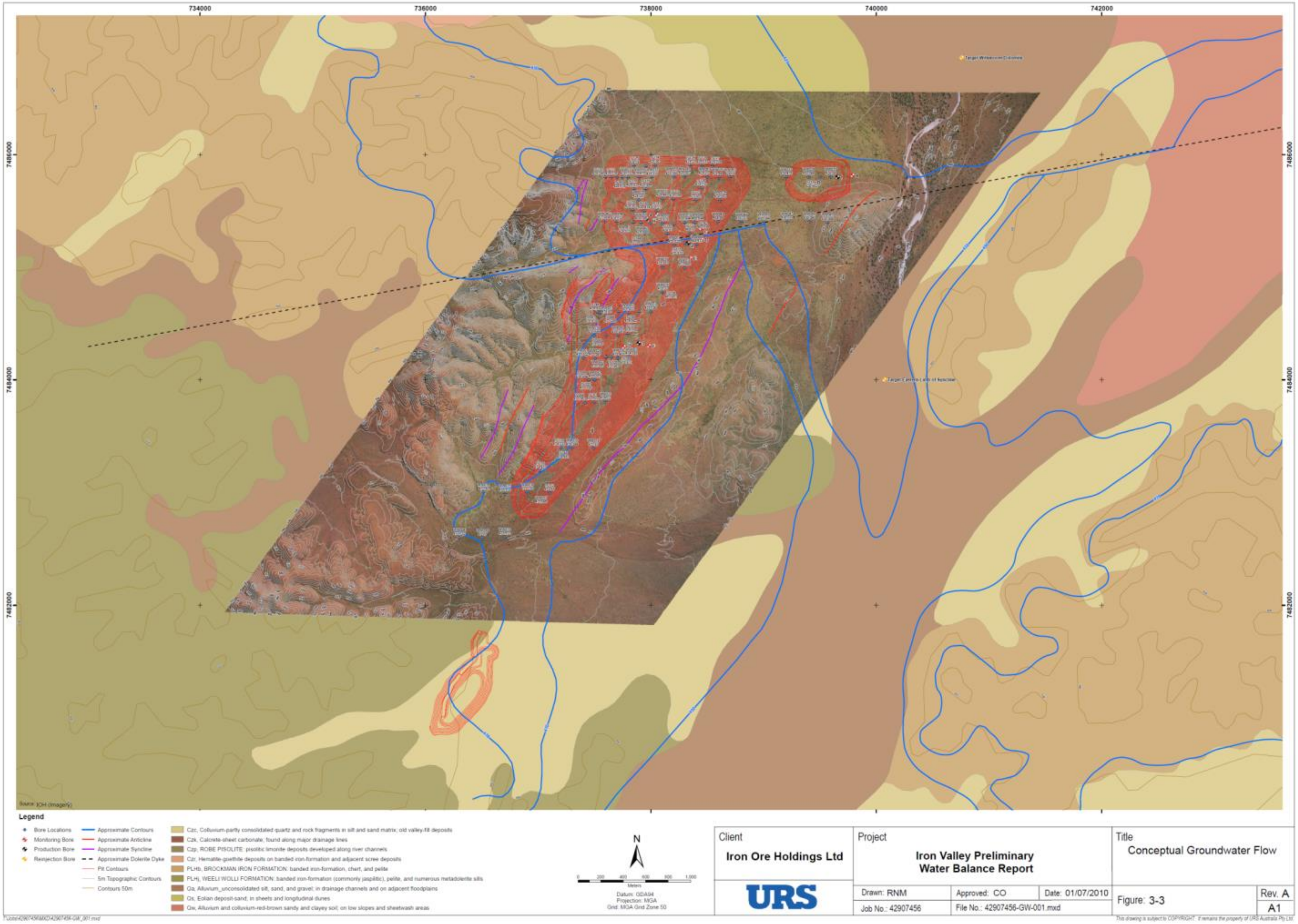
10. APPENDICES

Appendix 1: Geology of the Iron Valley Project

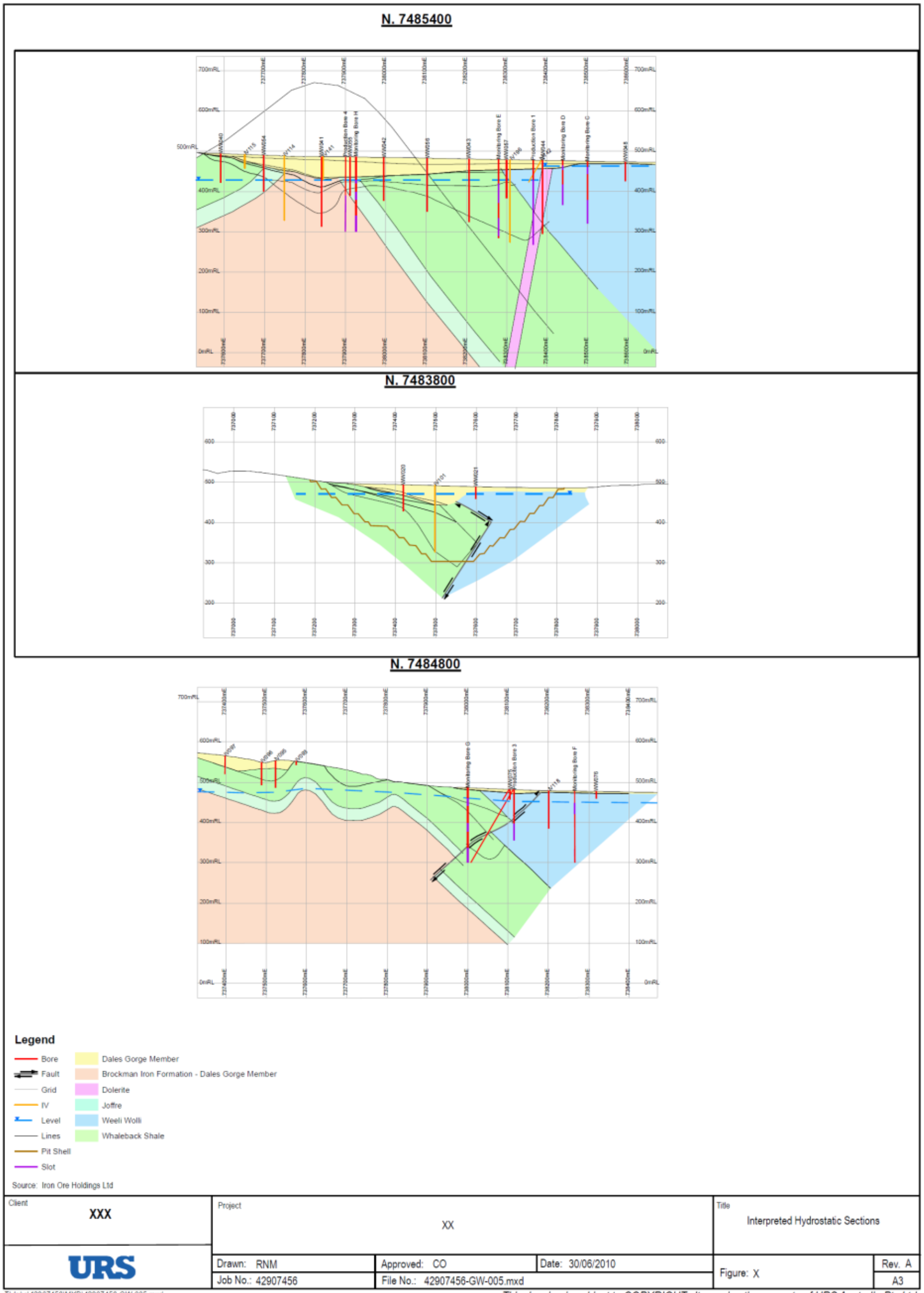


Iron Ore Holdings	Iron Valley Hydrogeological Assessment				Iron Valley Site Geology and Structures (IOH, 2010)	
URS	Job No.	42907456	Chk'd By	IGB	Figure 3-2	Rev. A
	Prep. By	CO 25 Feb '10	Revision No.	0		A4

Appendix 2: Conceptual Groundwater Flow



Appendix 3: Interpreted Hydrostatic Sections



Appendix 4: Co-ordinates of Drill Holes Sampled for Troglofauna at the Iron Valley Project

Bore Code	Site type	Latitude	Longitude
WW022	Impact	-22.76192	119.29939
WW023	Impact	-22.76194	119.30139
WW025	Impact	-22.75831	119.30228
WW016	Impact	-22.74381	119.30694
WW017	Impact	-22.74375	119.30892
WW019	Impact	-22.74019	119.31264
WW018	Impact	-22.74011	119.31069
WW021	Impact	-22.73639	119.3135
WW082	Impact	-22.73467	119.31258
WW081	Impact	-22.73478	119.31044
WW001	Impact	-22.73289	119.31156
WW029	Impact	-22.73294	119.31261
WW002	Impact	-22.73281	119.31356
WW051	Impact	-22.72953	119.3135
WW052	Impact	-22.72928	119.31542
WW080	Impact	-22.73106	119.31447
WW079	Impact	-22.73111	119.31233
WW077	Impact	-22.7255	119.31822
WW003	Impact	-22.73281	119.3155
WW053	Impact	-22.72906	119.31719
WW076	Impact	-22.72736	119.32031
WW075	Impact	-22.72756	119.31831
WW068	Impact	-22.72369	119.32108
WW048	Impact	-22.72189	119.32294
WW044	Impact	-22.72192	119.3205
WW074	Impact	-22.72008	119.32319
WW073	Impact	-22.72014	119.32197
WW036	Impact	-22.71822	119.32497
WW062	Impact	-22.71822	119.32403
WW045	Impact	-22.72181	119.31822
WW046	Impact	-22.72164	119.31694
WW037	Impact	-22.71808	119.33264
WW038	Impact	-22.71803	119.33058
WW039	Impact	-22.71803	119.33058
WW061	Impact	-22.71825	119.32214
WW033	Impact	-22.71831	119.31911
WW059	Impact	-22.71831	119.31808
WW035	Impact	-22.71822	119.32297
WW032	Impact	-22.71833	119.31719
WW058	Impact	-22.71839	119.31611
WW031	Impact	-22.71839	119.31508
WW069	Impact	-22.72022	119.31436
WW070	Impact	-22.72022	119.31614
WW071	Impact	-22.72003	119.31819
WW072	Impact	-22.72014	119.32014
WW057	Impact	-22.72194	119.32008
WW043	Impact	-22.72208	119.31925
WW056	Impact	-22.72203	119.31819
WW042	Impact	-22.72203	119.31717
WW055	Impact	-22.72194	119.31633
WW041	Impact	-22.72197	119.31567

Bore Code	Site type	Latitude	Longitude
WW054	Impact	-22.72197	119.31422
WW040	Impact	-22.72192	119.31325
WW065	Impact	-22.72378	119.31536
IV135	Impact	-22.73303	119.31072
IV095	Impact	-22.72703	119.31264
IV097	Impact	-22.72753	119.31147
IV098	Impact	-22.72831	119.31389
IV100	Impact	-22.72853	119.31092
IV099	Impact	-22.72919	119.31156
WW024	Reference	-22.76192	119.30339
WW026	Reference	-22.75825	119.30425
WW028	Reference	-22.75467	119.30708
WW027	Reference	-22.75461	119.30511
WW013	Reference	-22.75103	119.30797
WW011	Reference	-22.75108	119.30408
WW012	Reference	-22.75106	119.30603
WW007	Reference	-22.74733	119.31078
WW006	Reference	-22.74739	119.30883
WW005	Reference	-22.74758	119.30697
WW010	Reference	-22.74736	119.305
WW009	Reference	-22.74747	119.30308
WW004	Reference	-22.74742	119.30106
WW015	Reference	-22.74392	119.30497
WW014	Reference	-22.74375	119.30306
WW047	Reference	-22.72172	119.32892
WW050	Reference	-22.72175	119.32689
WW049	Reference	-22.72181	119.325
WW063	Reference	-22.72383	119.31142
WW064	Reference	-22.72381	119.31336
IV182	Reference	-22.72214	119.31233
IV109	Control	-22.720056	119.31325
IV204	Control	-22.71975	119.333111
IV207	Control	-22.72	119.329889
IV208	Control	-22.72	119.329889
IV209	Control	-22.721778	119.331778
IV223	Control	-22.754611	119.305083
IV235	Control	-22.745611	119.305444
IV239	Control	-22.7545	119.305083
IV241	Control	-22.745583	119.308861
IV242	Control	-22.764111	119.304
IV244	Control	-22.764194	119.305972
IV247	Control	-22.765556	119.300444
IV248	Control	-22.765472	119.301583
IV273	Control	-22.754667	119.304167
IV274	Control	-22.752917	119.304167
IV275	Control	-22.752861	119.305361
IV276	Control	-22.752861	119.306056
IV338	Control	-22.743806	119.305889
IV344	Control	-22.741972	119.306806
IV367	Control	-22.721111	119.312778
IV444	Control	-22.714639	119.316472
IV445	Control	-22.713861	119.316583
IV446	Control	-22.712861	119.316528
IV448	Control	-22.714722	119.314528
IV449	Control	-22.713833	119.316111

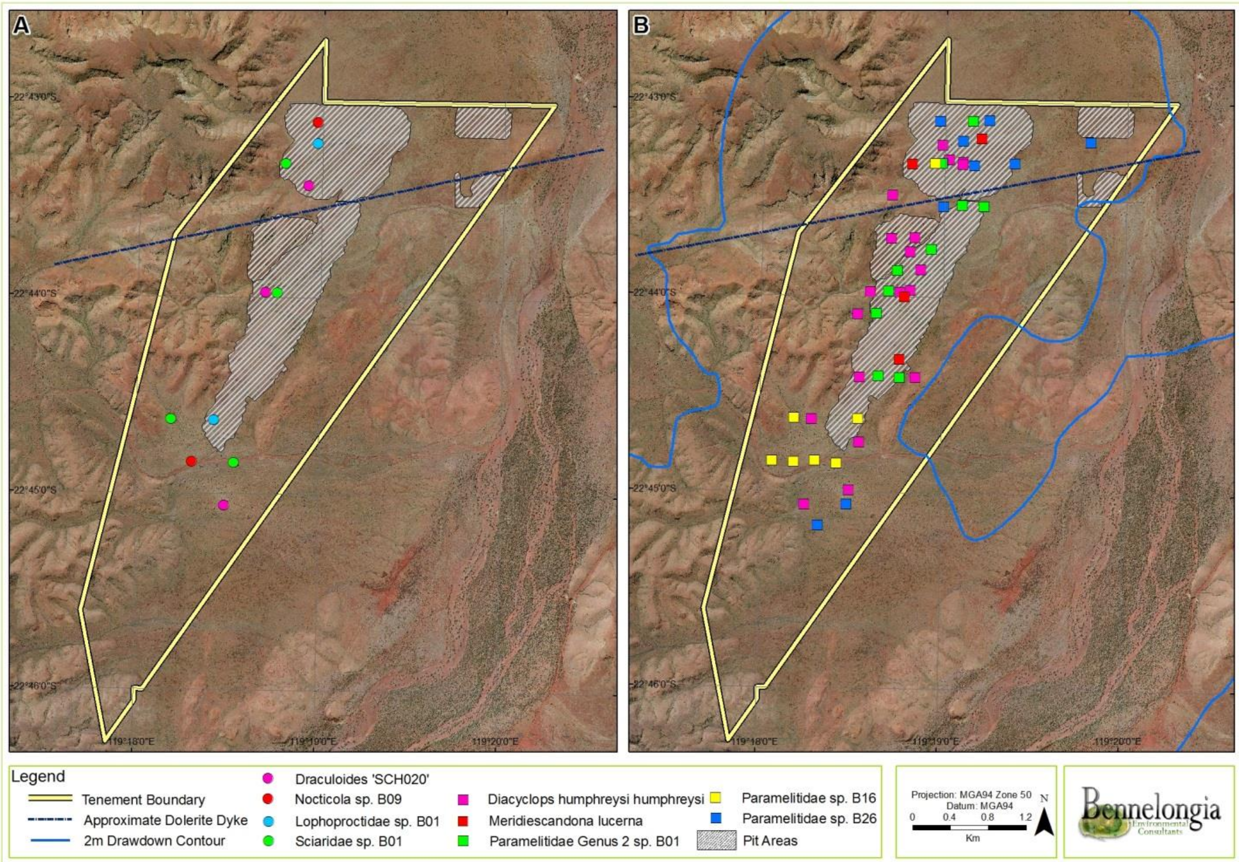
Bore Code	Site type	Latitude	Longitude
IV450	Control	-22.712833	119.316028
IV452	Control	-22.717194	119.334083
IV453	Control	-22.719833	119.33475
IV454	Control	-22.718917	119.3355
IV460	Control	-22.718083	119.335583
IV463	Control	-22.717306	119.336139
IV464	Control	-22.719028	119.334556
IVUNK01	Control	-22.72175	119.3325

Appendix 5: Co-ordinates of Drill Holes Sampled for Stygofauna at the Iron Valley Project

Bore code	Site type	Latitude	Longitude
WW025	Impact	-22.758306	119.302278
WW001	Impact	-22.732889	119.311556
WW029	Impact	-22.732944	119.312611
WW002	Impact	-22.732806	119.313556
WW051	Impact	-22.729528	119.3135
WW052	Impact	-22.729278	119.315417
WW080	Impact	-22.731056	119.314472
WW079	Impact	-22.731111	119.312333
WW077	Impact	-22.7255	119.318222
WW045	Impact	-22.721806	119.318222
WW046	Impact	-22.721639	119.316944
WW038	Impact	-22.718028	119.330583
WW061	Impact	-22.71825	119.322139
WW033	Impact	-22.718306	119.319111
WW035	Impact	-22.718222	119.322972
WW058	Impact	-22.718389	119.316111
WW070	Impact	-22.720222	119.316139
WW057	Impact	-22.721944	119.320083
WW043	Impact	-22.722083	119.31925
WW056	Impact	-22.722028	119.318194
WW042	Impact	-22.722028	119.317167
WW055	Impact	-22.721944	119.316333
WW054	Impact	-22.721972	119.314222
WW040	Impact	-22.721917	119.31325
WW031	Impact	-22.718389	119.315083
WW071	Impact	-22.720028	119.318194
WW022	Impact	-22.761917	119.299389
WW016	Impact	-22.743806	119.306944
WW019	Impact	-22.740194	119.312639
WW021	Impact	-22.736389	119.3135
WW003	Impact	-22.732806	119.3155
WW053	Impact	-22.729056	119.317194
WW076	Impact	-22.727361	119.320306
WW075	Impact	-22.727556	119.318306
WW068	Impact	-22.723694	119.321083
WW041	Impact	-22.721972	119.315667
WW078	Impact	-22.725583	119.320194
WW062	Impact	-22.718222	119.324028
WW024	Reference	-22.761917	119.303389
WW028	Reference	-22.754667	119.307083
WW027	Reference	-22.754611	119.305111
WW013	Reference	-22.751028	119.307972
WW011	Reference	-22.751083	119.304083
WW012	Reference	-22.751056	119.306028
WW007	Reference	-22.747333	119.310778
WW006	Reference	-22.747389	119.308833
WW005	Reference	-22.747583	119.306972
WW010	Reference	-22.747361	119.305
WW009	Reference	-22.747472	119.303083
WW004	Reference	-22.747417	119.301056
WW047	Reference	-22.721722	119.328917

Bore code	Site type	Latitude	Longitude
WW050	Reference	-22.72175	119.326889
WW049	Reference	-22.721806	119.325
WW014	Reference	-22.74375	119.303056
WW015	Reference	-22.743917	119.304972

Appendix 6: Locations of Troglofauna (A) and Stygofauna (B) Species in Relation the Dolerite Dyke that Transects the Iron Valley Project



Appendix 7: Locations of Isopods and Amphipods

Pygolabis spp., *Chydakata* sp. and *Maarrka weeliwollii* specimens collected at the Iron Valley Project (outlined in black) and nearby. Source of data outside the Project: *Pygolabis* sp. = *Pygolabis* sp. B06 (Finston *et al*. 2009); *Maarrka weeliwollii* (Halse *et al*. unpublished data); *Chydaekata* sp. (Halse *et al*. unpublished data, Bennelongia unpublished data).