Bennelongia Environmental Consultants

Iron Ore Holdings Ltd

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

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EXECUTIVE SUMMARY

Iron Ore Holdings Ltd (IOH) is planning to mine iron ore at the Iron Valley Project within IOH's Central Pilbara tenements. The Iron Valley Project is 86 km north-northwest of Newman in the Pilbara region of Western Australia (WA). 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 results of troglofauna and stygofauna surveys conducted in 2009 and provides an assessment of the likely impacts of mining on subterranean fauna at the Iron Valley Project. The sampling effort completed meets the requirements laid out in Environmental Protection Authority (EPA) Guidance Statement No. 54a, with a total of 98 troglofauna and 84 stygofauna samples being collected from bores inside the impact zone of the proposed mine.

The troglofauna sampling yielded 106 specimens, representing 11 Orders and 15 species. Two arachnid Orders were recorded: Pseudoscorpionida (one species) and Schizomida (one species). The only crustacean Order collected was Isopoda (two species). Chilopoda were represented by one species of an unknown Order. Diplopoda were represented by one Order containing one species. There were five Orders of hexapods (Entognatha/Insecta): Diplura (two species), Blattodea (two species), Hemiptera (two species), Coleoptera (one species) and Diptera (one species).

Eleven of the 15 troglofauna species recorded at the Iron Valley Project were recorded within the proposed mine pits. Of these 11 species, seven species are known to occur in reference areas outside the mine pits or elsewhere in the Pilbara, while four species are known only from impact bores (the pseudoscorpion *Lagynochthonius* sp. B6, isopods *Troglarmadillo* sp. and Armadillidae sp. B4, centipede Chilopoda sp.). It appears unlikely that the troglofauna species known only from the impact bores are restricted to the proposed mine pit because the habitat within the Iron Valley Project pits does not appear to be isolated from the surrounding geology.

The conservation status of the four troglofauna species known only from within the proposed mine pits at the Iron Valley Project is uncertain. With four species known only from the proposed mine pits, more than 25% of the species in the recorded from the pits may be threatened by Project development, which represents a relatively high level of impact compared with the majority of proposals that have been approved for mining. Additional scrape sampling outside the mine pits is recommended to show wider occurrence of the species that currently appear to be restricted to the mine pits. The rock strata to the north-west of the Project area considered to be prime habitat to target for further sampling.

The stygofauna sampling yielded 2,102 specimens of at least 19 species of six higher level groups (mostly Order), including oligochaetes, mites, ostracods, copepods, amphipods and isopods. Mites and isopods were each represented by one species. Oligochaetes, syncarids and ostracods were each represented by three species. The most diverse groups were the copepods and amphipods, each with four species.

Given that the extent of groundwater drawdown is yet to be defined, a conservative approach was adopted for assessment and it was assumed that drawdown would occur across all of the Iron Valley Project area. Consequently, four species known only from the Iron Valley Project area may be under

threat from mining. These are the ostracod *Meridiescandona* sp. BOS 171 and the syncarids, *Chilibathynella* sp. B4, *Bathynella* sp., and *Atopobathynella* sp.

Additional sampling to the east of the Iron Valley Project along Weeli Wolli Creek is recommended to show wider occurrence of the four species that currently appear to be restricted to the area of groundwater drawdown.

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1. INTRODUCTION

Iron Ore Holdings Ltd (IOH) is planning to mine iron ore at the Iron Valley Project within IOH's Central Pilbara tenements. The Iron Valley Project is 86 km north-northwest of Newman in the Pilbara region of Western Australia (WA) (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 240 million tonnes. The Iron Valley Project encompasses the following tenements: Exploration Licence E 47/1385, M47/1439, M47/1361 and M47/1362. IOH are currently considering a number of options for haulage 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 to access an expected resource of 240 million tonnes over a 15 year mine life. 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 4:1).
- 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 total approximately 326 ha with an approximate depth of 200 m. The watertable lies at approximately 15-40 m below ground surface. Although the area of impact is small relative to the ranges of most restricted species, the pit excavation and dewatering planned (but not defined) for the Iron Valley Project may potentially threaten highly restricted species of subterranean fauna, if they occur within the vicinity of the Project.

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

The specific aims of the troglofauna 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.

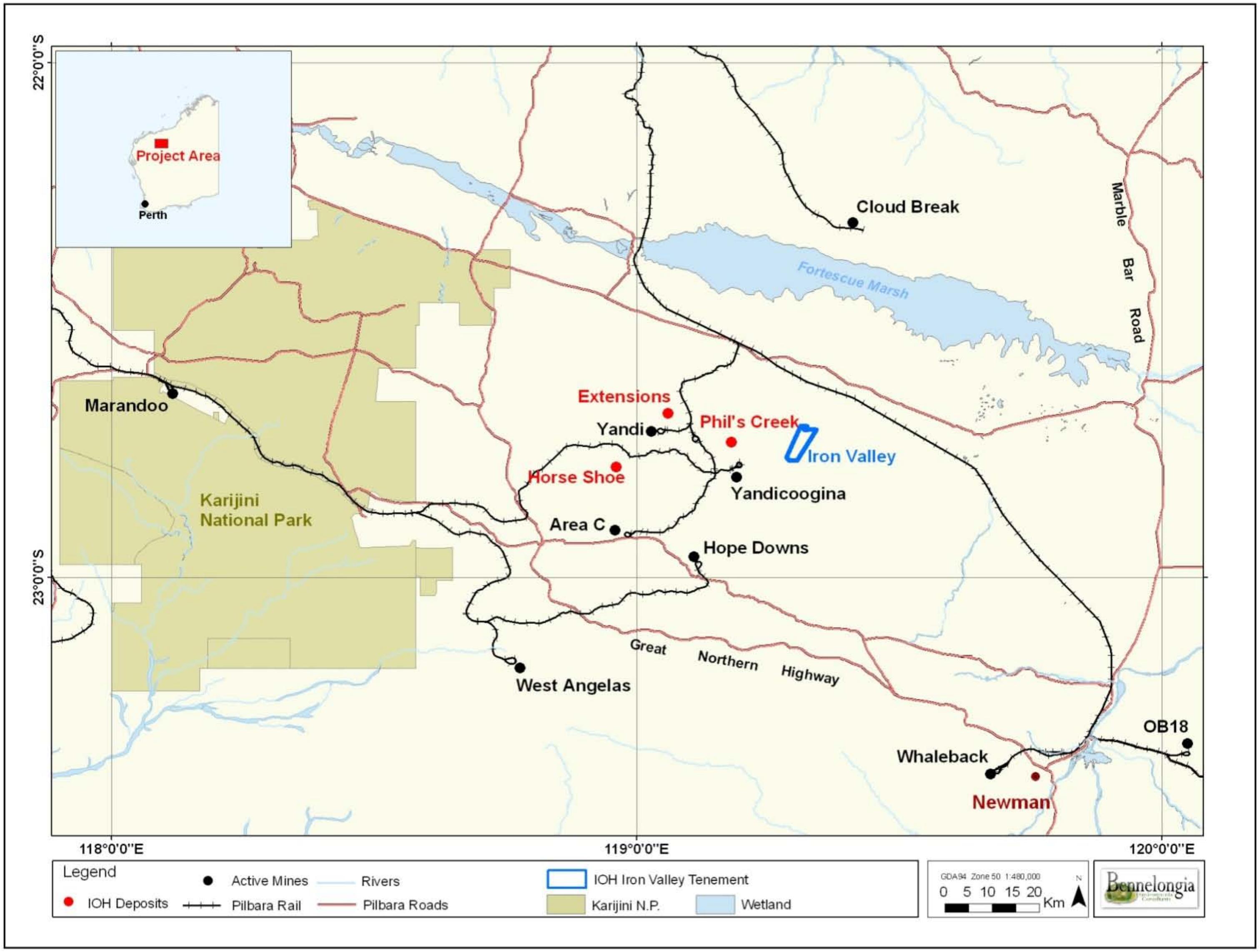


Figure 1.1. Location of the Iron Valley Project.

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 suggests 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. However, the Iron Valley deposit is bisected by a dolerite dyke, which runs east/west. 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. 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 downstream on the northern side (Appendix 3). Around the dyke, gradients are affected by local topography and creek lines. Thus, it is likely that the southern satellite pit, and much of the Iron Valley deposit, is separated from the regional aquifer. In contrast, the northern satellite pit and northern section of the deposit are probably linked to 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) and emerging evidence suggests the same is true for troglofauna (see Biota 2005a, 2006; Subterranean Ecology 2007; Bennelongia 2008a,b,c, 2009a,b).

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 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 pisolite and banded iron ore. 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 (see Section 2.0). 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), Yilgarn (Barranco and Harvey 2008; Platnick 2008; Bennelongia 2009c) and elsewhere (Biota 2005a,b).

3.2. Stygofauna

Survey of stygofauna in the Pilbara began in the 1990s (Humphreys 1999), with a rapid increase in knowledge over the last decade as a result of the systematic stygofauna sampling during the Pilbara Biological Survey (see Eberhard et al. 2005, 2009). 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). 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. in preparation).

4. PROJECT IMPACTS

Activities that cause direct *habitat loss* are considered to be the primary impacts likely to lead to extinction of subterranean species. At the Iron Valley Project these primary impacts are:

1. *Pit excavation*. Removal of troglofauna habitat is likely to lead to significant risk to restricted troglofauna species.
2. *De-watering.* Drawdown of aquifers to prevent flooding of mine pits is likely to lead to significant risk to restricted stygofauna species due to loss of 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 more 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 be minimal impact on the humidity in the unsaturated zone. In addition, troglofauna may be able to avoid undesirable effects of a habitat drying out by moving deeper into the substrate if suitable habitat exists at depth. Overall, de-watering outside the proposed mine pits is not considered to be a significant risk to troglofauna.
2. *Percussion from blasting*. Impacts on both stygofauna and troglofauna may occur through the physical effect of explosions. Blasting may also have indirect detrimental effects through altering underground structure (usually rock fragmentation and collapse of voids) and transient increases in groundwater turbidity. The effects of blasting are often referred to in grey literature but are poorly quantified and have not been related to ecological impacts. Any effects of blasting are likely to dissipate rapidly with distance from the pit and are not considered to be a significant risk to either stygofauna or troglofauna outside the proposed mine pits.

[1] The zone between the surface and groundwater

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 the pit 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 the containment of hydrocarbon products.

5. METHODS

5.1. Survey Rationale

The subterranean fauna survey at Iron Valley was conducted in accordance with the principles laid out in EPA Guidance Statements Nos 54 and 54a (EPA 2003, 2007).

The impact area for troglofauna, as a result of proposed mining at the Iron Valley Project, was defined as the area to be excavated for the mine pits (Figure 5.1). Reference bores, 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 IOH 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 (Figure 1.1).

The impact area for stygofauna, as a result of proposed mining at the Iron Valley Project, should be defined as the area to be dewatered to allow mining within the pits. While the extent of drawdown is yet to be modelled, it is likely that drawdown will extend beyond the tenement boundaries. Conservation of stygofauna will rely on species having wider occurrence than the tenement.

5.2. Troglofauna

5.2.1. Sampling Effort

A total of 98 impact and 37 reference samples were collected during two sampling rounds from 81 bores within the Iron Valley Project (Table 5.1, Figure 5.1). 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 between 11 and 13 January 2010 (retrieving traps). A complete list of bores sampled is provided in Appendix 4.

[2] Microbial oxidation of inorganic compounds as an energy source

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

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

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. S Trap = single trap, D Trap = double trap

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 bore. In every fourth bore, a second trap was set mid-way down the bore. Bores 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, bores were scraped. This was done by lowering a troglofauna net (weighted net, 150 µm mesh with variable aperture according to bore diameter) to the bottom of the bore, or to the watertable, and scraping back to the surface along the bore walls. 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.

5.2.3. 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). 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.

Preserved 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. Troglofauna were identified to species or morphospecies level, unless damaged, juvenile or the wrong sex for identification (EPA 2007). 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.

Representative animals will be lodged with the WA Museum after the assessment process has been completed.

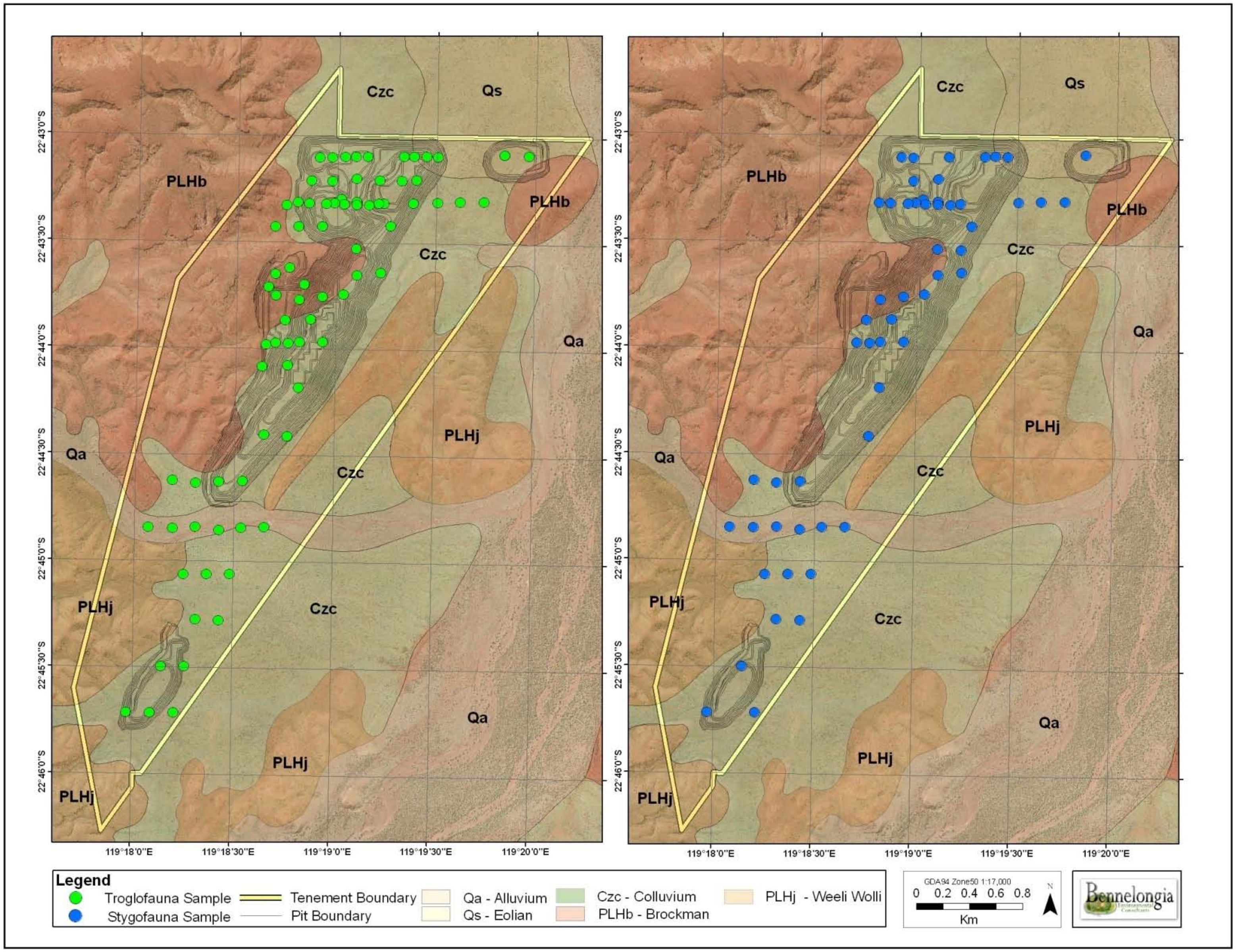


Figure 5.1. Locations of bores sampled for troglofauna and stygofauna at the Iron Valley Project.

5.3. Stygofauna

5.3.1. Sampling Effort

A total of 84 impact samples were collected from within the Iron Valley Project (Table 5.2, Figure 5.1). Round 1 sampling was conducted from 13 to 15 May 2009 and Round 2 sampling was conducted between 3 and 6 November 2009. A complete list of bores sampled is given in Appendix 5.

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

Site Type	Round 1	Round 2
Impact	41	43

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 bore using a Yeo-Cal water quality analyser.

5.3.3. Species Sorting and Identification

In the laboratory, samples were elutriated to separate out heavy sediment particles and sieved into size fractions using 250, 90 and 53 µm screens. All samples were sorted under a dissecting microscope. Sorted animals were identified to species or morphospecies using available keys and species descriptions. When necessary, animals were dissected and examined under a compound microscope. Morphospecies determinations were based on characters used in species keys.

5.4. Compiling Species Lists

Identifications of animals that could not be identified to species/morphospecies 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* sp. B4 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* sp. B4. The purpose of this criterion was to prevent higher level identifications falsely inflating species richness.

5.5. Personnel

Fieldwork was undertaken by Jim Cocking, Mike Scanlon, Dean Main and Andrew Trotter. Sample sorting was done by Jane McRae, Mike Scanlon, Jim Cocking, Heather McLetchie, Grant Pearson, Dean Main and Andrew Trotter. Identifications were made by Jane McRae, Mike Scanlon and Stuart Halse.

6. RESULTS

6.1. Troglofauna

6.1.1. Troglofauna at the Iron Valley Project

Sampling at Iron Valley yielded 106 troglofaunal animals, representing 11 Orders and 15 species. Two arachnid Orders were recorded: Pseudoscorpionida (one species) and Schizomida (one species). The only crustacean Order collected was Isopoda (two species). Chilopoda were represented by one species of an unknown Order. Diplopoda were represented by Polyxenida (one species). There were five Orders of hexapods (Entognatha/Insecta): Diplura (two species), Blattodea (two species), Hemiptera (two species), Coleoptera (one species) and Diptera (one species) (Table 6.1, Figure 6.1).

Four animals that could not be identified to species level because they were damaged, juvenile or the wrong sex for species determination were recorded (Table 6.2). All are likely to belong to species in Table 6.1.

Staphyliinidae sp. B1 and Sciaridae sp. B1 were the numerically dominant species within the Iron Valley Project (Table 6.1, Figure 6.2). All other species were collected in low abundance (≤5 specimens) and seven species were recorded as singletons, i.e. only one animal of that species was collected during the study (Table 6.1, Figure 6.2). Three of these singleton species (Japygidae sp. B4, *Symphyella* sp. B5 and Hemiptera sp. B1) have been previously recorded elsewhere in the central Pilbara (Table 6.1, Bennelongia 2009a,b, unpublished data).

Yields of both specimens and species per samples were higher from reference bores than impact bores (Table 6.3). However, the number of species collected within the mine pit (11) was higher than in the reference area (7), probably largely as a consequence of sampling effort being more than twice as high in impact bores (Table 6.3).

6.1.2. Troglofauna Species of the Proposed Mine Pits

Eleven of the 15 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, seven species are known to occur in reference areas outside the mine pits or at deposits elsewhere in the Pilbara.

The four species known only from impact bores at the Iron Valley Project are (Figure 6.3):

1. *Lagynochthonius* sp. B6 was recorded as a singleton.
2. *Troglarmadillo* sp. was recorded from two bores, with all five specimens juvenile.
3. Armadillidae sp. B4 was recorded as a singleton.
4. Chilopoda sp. was recorded as a singleton (damaged).

6.1.3. Troglofauna Distributions

Almost half of the species collected are known from outside the Project area. Five species (Polyxenida sp. B1, Japygidae sp. B4, *Nocticola* sp. B1, Hemiptera sp. B1 and Sciaridae sp. B1) are very widespread and known from many locations in the Pilbara (Table 6.1, Bennelongia 2009a,b). A sixth species, Meenoplidae sp. (represented by five nymphs from a reference bore), probably belongs to one of two very widespread species (Table 6.1, Bennelongia 2009a). A seventh species, *Symphyella* sp. B5, is known from Phil's Creek approximately 12 km from the Iron Valley Project (Table 6.1).

Table 6.1. Troglofauna species recorded at the Iron Valley Project with known distribution indicated.

Higher Groups		Species	Number of individuals		Known from outside impact area
			Impact	Reference	
Arachnida					
	Pseudoscorpionida				
		Lagynochthonius sp. B6	1		No
	Schizomida				
		Draculoides sp. B4	2	1	Yes
Crustacea					
	Isopoda				
		Armadillidae sp. B4	1		No
		Troglarmadillo sp.	5		No
Chilopoda					
		Chilopoda sp.	1		No
Diplopoda					
	Polyxenida				
		Polyxenida sp. B1	3		Yes - very widespread species [1]
Symphyla					
	Cephalostigmata				
		Symphyella sp. B5		1	Yes, from reference bore and from Phil's Creek[2]
Entognatha					
	Diplura				
		Projapygidae sp. B2		1	Yes, from reference bore only
		Japygidae sp. B4	1		Yes - very widespread species [1]
Insecta					
	Blattodea				
		Nocticola sp. B1	3		Yes - very widespread species [1]
		Nocticola sp. B9	2	1	Yes
	Hemiptera				
		Meenoplidae sp.		5	Probably - one of two widespread species[3]
		Hemiptera sp. B1	1		Yes - very widespread species [1]
	Coleoptera				
		Staphyliinidae sp. B1		43	Yes, from reference bores only
	Diptera				
		Sciaridae sp. B1	8	22	Yes - very widespread species [1]

[1]Bennelongia 2009a,b; [2]Bennelongia unpublished data; [3]Bennelongia 2009a.

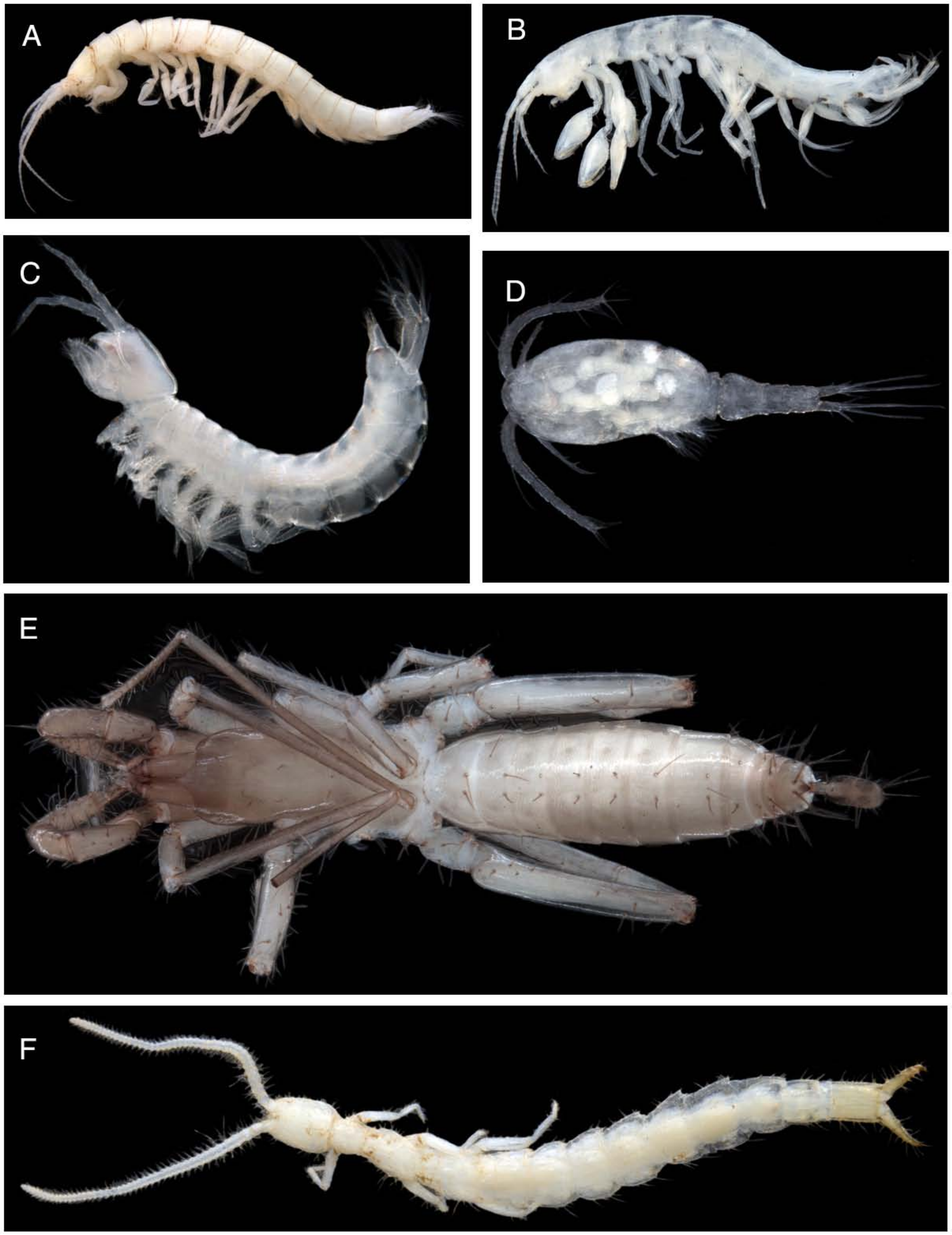


Figure 6.1. Stygofauna (A-D) and troglofauna photographs (E-F).
(A) *Pygolabis* sp. B1 (nr. *humphreysi*) (B) '*Maarrka wolli*' (C) *Chilibathynella* sp. B4 (D) *Thermocyclops aberrans* (E) *Draculoides* sp. B4 (F) Japygidae sp. B4.

Table 6.2. Higher level identifications (immature or incomplete specimens).

Higher Groups	Taxa	Number of individuals		Probable species
		Impact	Reference	
Arachnida				
Schizomida				
	Draculoides sp.		1	*Draculoides* sp. B4
Entognatha				
Diplura				
	Diplura sp.	1		Projapygidae sp. B2 or Japygidae sp. B4
Insecta				
Blattodea				
	Nocticola sp.	2		*Nocticola* sp. B1 or *Nocticola* sp. B9

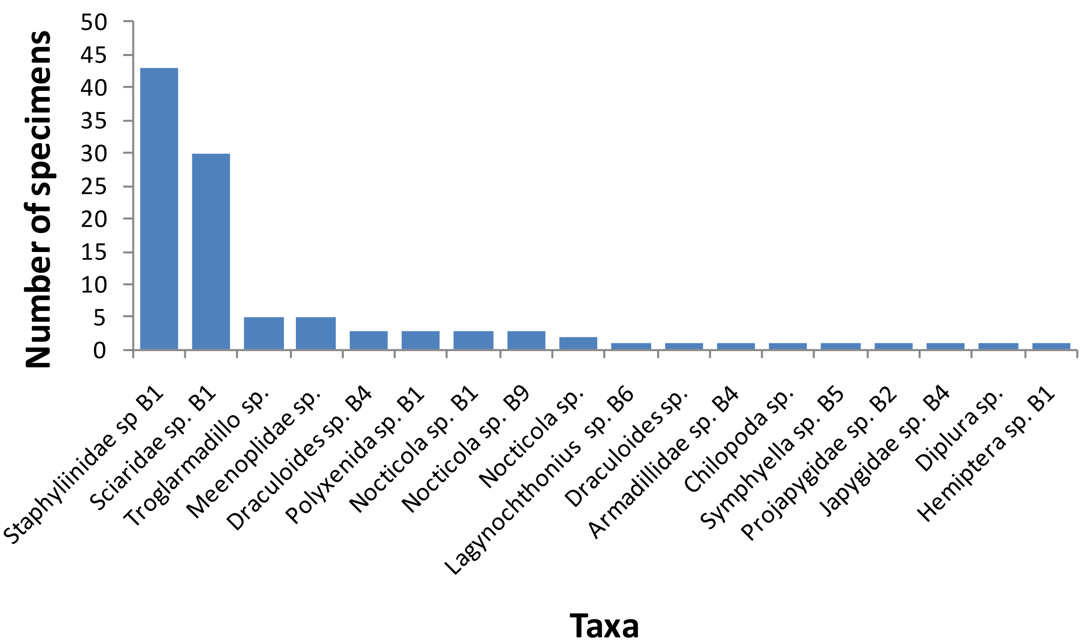


Figure 6.2. Capture abundance of each troglofauna species at the Iron Valley Project.

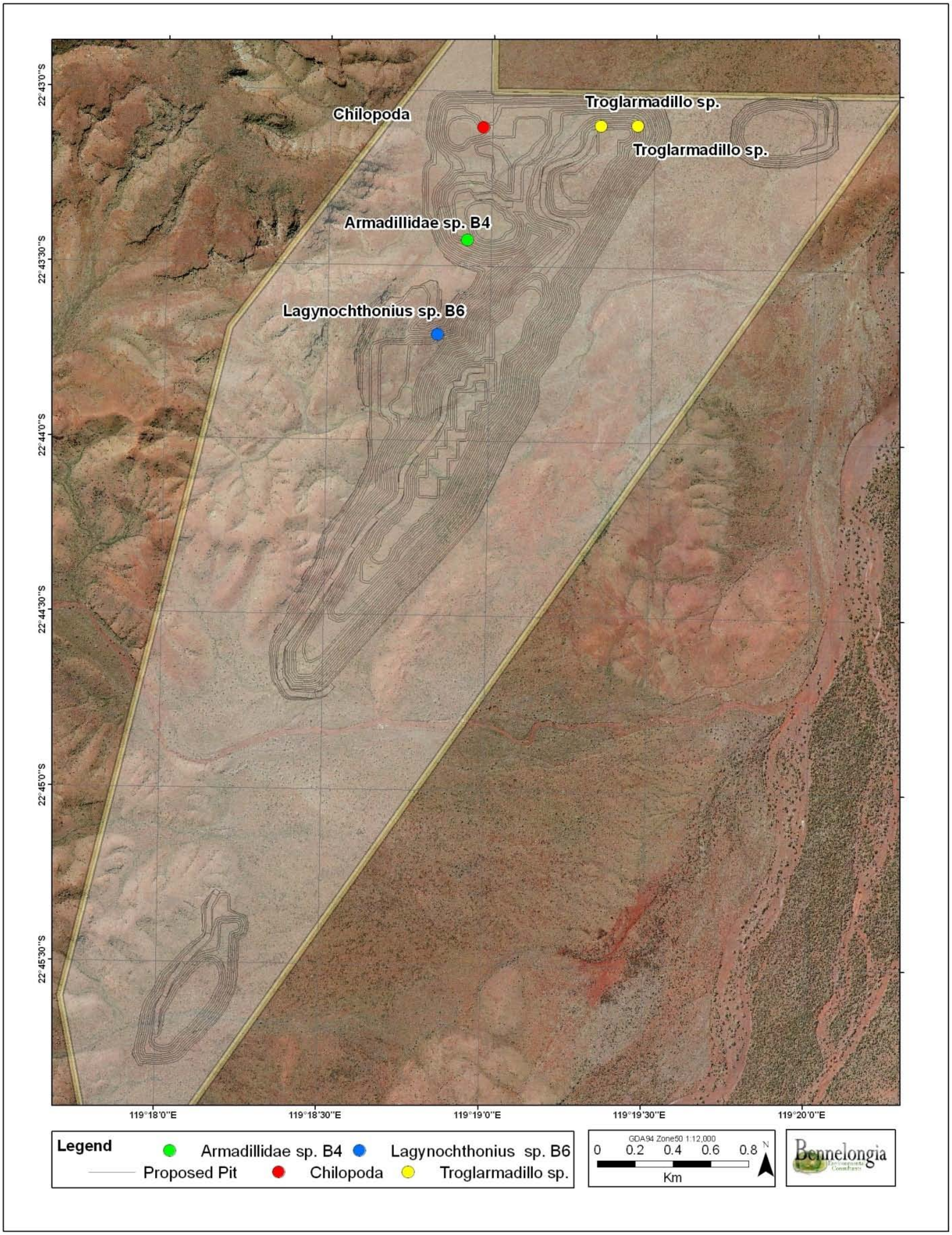


Figure 6.3. Locations of specimens of troglofauna species collected only from impact bores.

Table 6.3. Summary statistics of 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[1]	31	0.32	11	0.18
Reference	37	75	2.03	7	0.27

[1] Note that two samples consisted of single trap or scrape subsamples

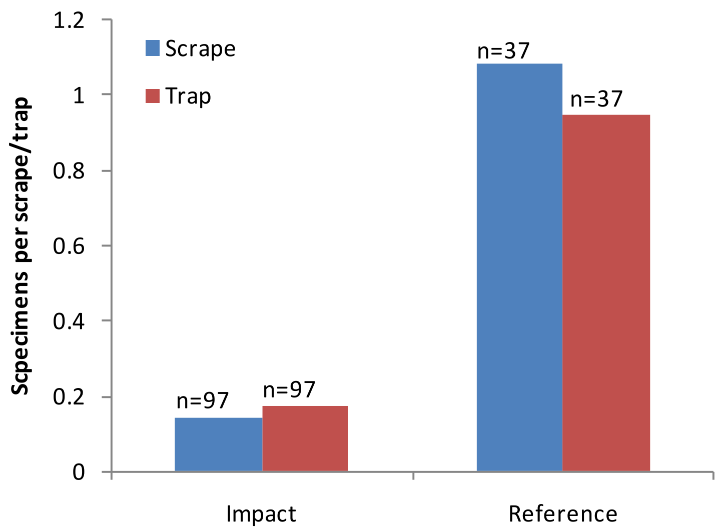


Figure 6.4. Comparison of capture rates between scraping and trapping**.** Sample effort (number of traps or scrapes) is given above each data point.

Of the six species represented by multiple animals in impact bores, three species were recorded from reference area bores and two of the other species are known from outside the Project area. Thus, it is likely additional sampling will show that the species currently known only as singletons within the proposed mine pit have wider ranges.

6.1.4. Sampling Efficiency

Documenting troglofauna communities is difficult because a high proportion of taxa occur in low abundance. This pattern of occurrence was evident at the Project site, where the most abundant third of species accounted for 81% of all troglofaunal animals found and the least abundant third only 5% (Figure 6.2). The average number of troglofaunal animals caught at the Iron Valley Project was 0.79 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 (2.03 specimens per sample versus 0.32, in Table 6.3). Scraping and trapping gave similar yields but reference bores yielded better than impact bores (Figure 6.4).

6.2. Stygofauna

6.2.1. Stygofauna Occurrence and Abundance

Stygofauna sampling yielded 2,102 specimens consisting of at least 19 species of six Classes/Orders, including Oligochaeta (three species), Hydracarina (one species), Ostracoda (three species), Copepoda (four species), Amphipoda (four species) and Isopoda (one species) (Table 6.4, Figure 6.1).

Copepods were the numerically dominant group at the Iron Valley Project, with specimens of oligochaetes, amphipods and syncarids also relatively abundant (Table 6.4). *Diacyclops humphreysi humphreysi* and *Chilibathynella* sp. B4 were the most numerous species (Table 6.4). The majority of taxa were collected at low abundance with the most abundant third of the taxa accounting for 90% of all the animals collected and the least abundant third only 1% (Figure 6.5).

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.

Table 6.4 contains three species identified at genus level: *Bathynella* sp., *Atopobathynella* sp. and *Chydaekata* sp. The taxonomy of both *Bathynella* is poorly resolved and Iron Valley specimens cannot be compared reliably with specimens from elsewhere in the Pilbara although it is considered that a single species occurs at Iron Valley.

Atopobathynella sp. is represented by one immature specimen and represents one species.

The taxonomy of *Chydaekata* sp. has been the subject of considerable genetic research and it is believed a single species of *Chydaekata* in 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 (Appendix 7).

6.2.3. Stygofauna Distributions

Fifteen of the 19 species collected within the Iron Valley Project are known from elsewhere in the Pilbara (Table 6.4). Five of these species are very widespread, either known from throughout the Pilbara or beyond. Seven species are known to have relatively extensive ranges in the central Pilbara/Fortescue catchment. Three species are known from the vicinity of Iron Valley (Table 6.4).

Two species of stygofauna are regarded as being known only from the Iron Valley Project. These are the ostracod *Meridiescandona* sp. BOS 171 and the syncarid *Chilibathynella* sp. B4. Both are known to occur only in the area that will be de-watered (Figure 6.6).

The distributions of two species of syncarid identified only to genus (*Bathynella* sp. and *Atopobathynella* sp.) are uncertain. However, specimens of the same genus have been previously collected about 7 km south-west of the Iron Valley Project and may represent the same species recorded at Iron Valley (Figure 6.7). If *Bathynella* sp. and *Atopobathynella* sp. represent new species, they too are known only from the area that will be de-watered.

Table 6.4. Stygofauna species recorded from the Iron Valley Project.
All specimens collected from impact area. Number of animals and whether species are known from outside impact area are shown.

Higher Groups		Species	Specimens	Known from outside of impact
Oligochaeta	Tubificida			
		Phreodrilid with dissimilar ventral chaetae	53	Yes, Pilbara-wide[1]
		Phreodrilid with similar ventral chaetae	54	Yes, Pilbara-wide[1]
		Enchytraeus Pilbara sp. 1	185	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	36	Yes, Fortescue catchment[1]
		Meridiescandona sp. BOS 171	47	No
	Copepoda			
		Calamoecia n. sp. B1	1	Yes, Fortescue catchment[2]
		Microcyclops varicans	155	Yes, Pilbara-wide and beyond[3]
		Diacyclops humphreysi humphreysi	744	Yes, Pilbara-wide and beyond[4]
		Thermocyclops aberrans	222	Yes, central Pilbara[5]
	Syncarida			
		Bathynella sp.	3	Uncertain
		Chilibathynella sp. B4	297	No
		Atopobathynella sp.	1	Uncertain
	Amphipoda			
		'*Maarrka wolli*' (ms, Finston et al submitted)	1	Yes, local area[6] (also see Appendix 7)
		Chydaekata sp.	9	Yes, Weeli Wollli/Marillana catchment
		Paramelitidae sp. 2	104	Yes, Fortescue catchment[1]
		Paramelitidae cf. sp. 2	30	Yes, Fortescue catchment[1]
	Isopoda			
		Pygolabis sp. B1 (nr. *humphreysi*)	11	Yes, local area[7] (also see Appendix 7)

[1]Halse et al. unpublished data; [2]Bennelongia unpublished data; [3]Sars (1863); [4]Pesce and De Laurentiis (1996); [5]Lindberg (1953); [6]Finston et al. (submitted); [7]Finston et al. (2009).

Table 6.5. Higher level stygofauna identifications (immature or incomplete specimens). Number of animals collected and probable species is shown.

Higher Groups	Taxa	Specimens	Probable species
Oligochaeta			
Tubificida			
	Enchytraeidae sp.	66	Unknown
Crustacea			
Ostracoda	Ostracoda sp.	2	Unknown
Copepoda			
	Diacyclops sp.	2	*Diacyclops humphreysi humphreysi*
	Thermocyclops sp.	2	*Thermocyclops aberrans*
Amphipoda			
	Amphipoda sp.	3	Unknown
	Paramelitidae sp.	69	Unknown
Isopoda			
	Pygolabis sp.	1	*Pygolabis* sp. B1 (nr. *humphreysi*)

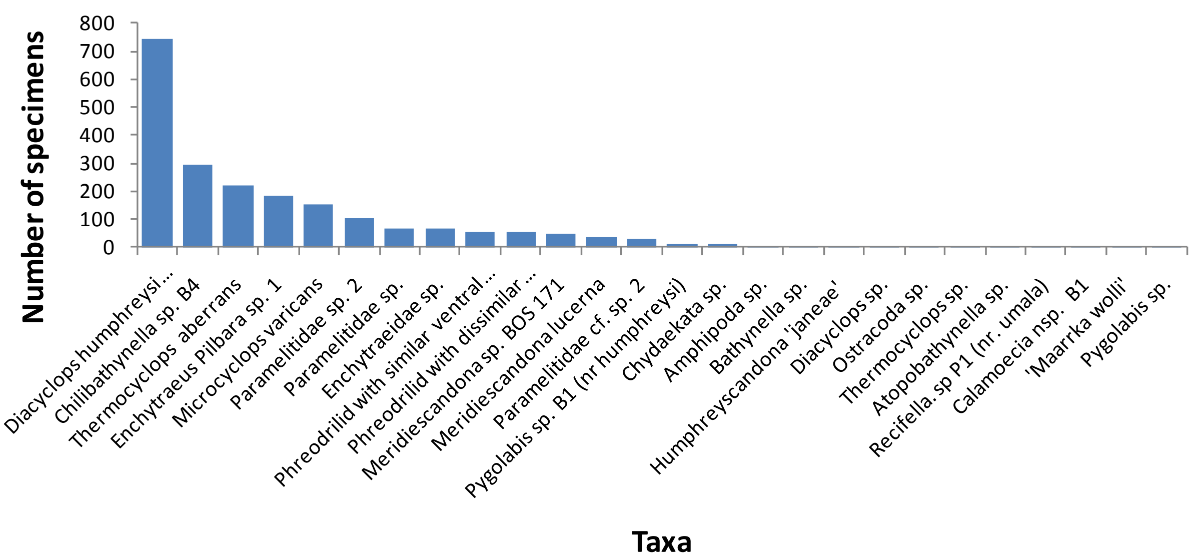


Figure 6.5. Capture abundance of each stygofauna species at the Iron Valley Project.

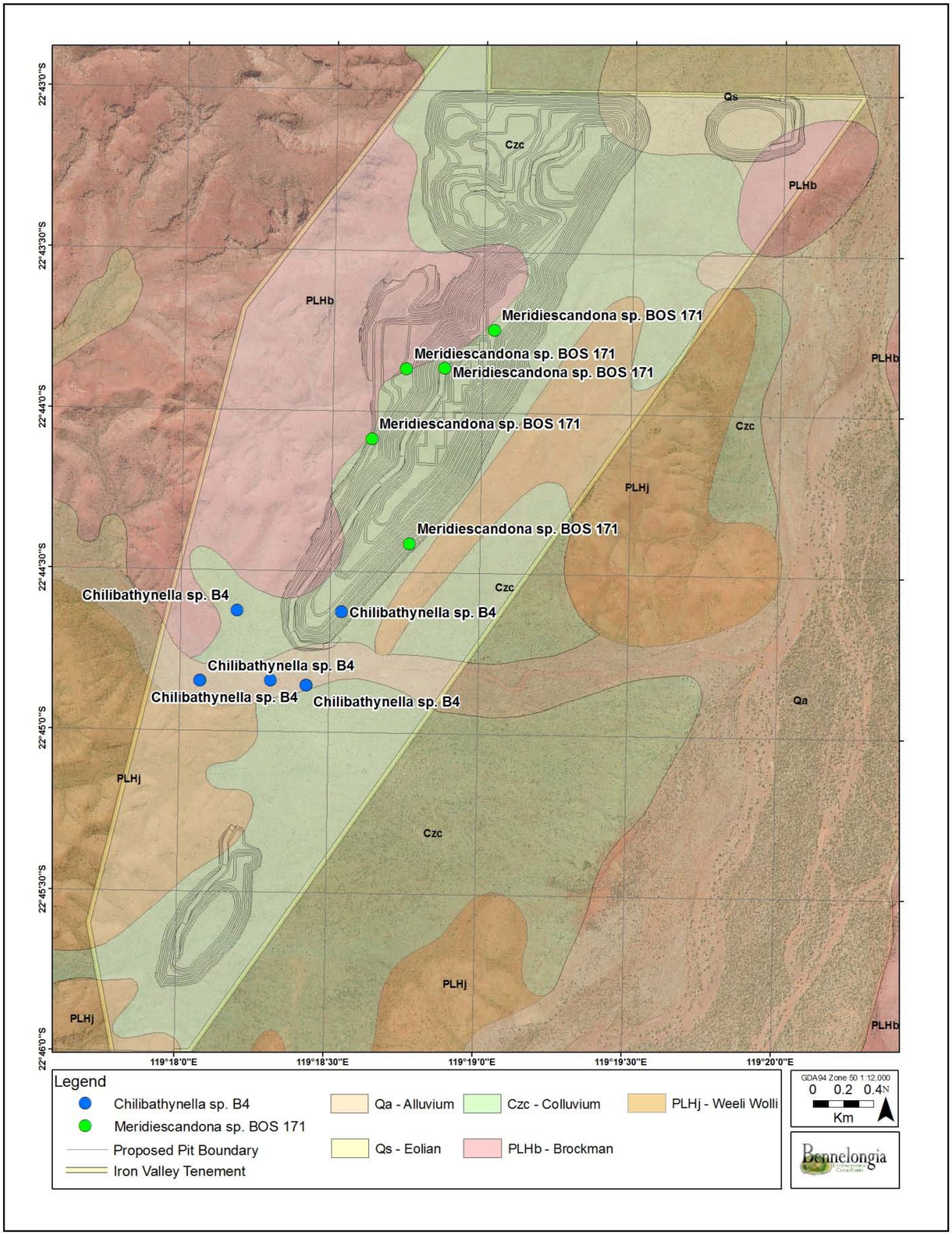


Figure 6.6. Locations of two stygofauna species collected only from bores at the Iron Valley Project. Drawdown cones are expected to extend beyond all of the bores indicated.

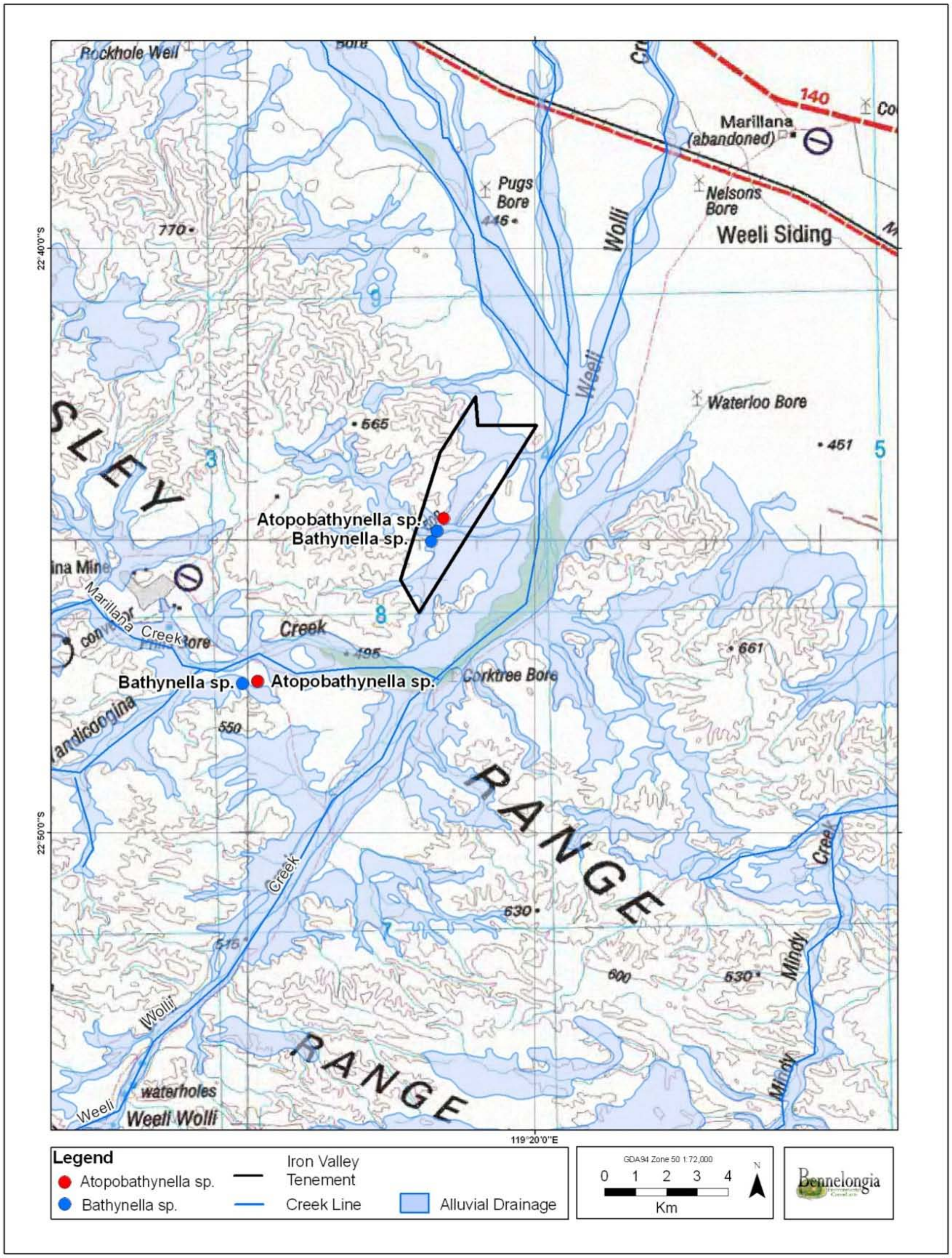


Figure 6.7. Locations of the syncarids identified only to genus.
Specimens from outside the Iron Valley Project were collected during the Pilbara Stygofauna Survey (Halse et. al. unpublished data). Species level relationships are uncertain.

7. DISCUSSION

7.1. Troglofauna

7.1.1. Troglofauna Distributions and Conservation Risks for Species

The range characteristics of different troglofaunal groups in WA are not yet fully described. Troglofauna survey and research has typically focussed on taxonomy and, for the purpose of conservation, the presence or absence of species at particular localities. Little focus has been placed on documenting distributions and the most comprehensive studies to date have been on schizomids, where quite variable (although mostly small) ranges have been identified). Harvey et al. (2008) reported that six species of schizomid in the Robe Valley were each tightly restricted to single mesas (the largest only 989 ha), whereas one species (*Draculoides vinei*) in the Cape Range had a linear range of about 50 km.

Manyof the troglofauna collected at Iron Valley are known more widely in the Pilbara (Table 6.1). Extensive distributions suggest that species have moderately high dispersal ability, either through possessing a surface dispersal phase in their life cycles or because they inhabit well connected subterranean habitats. Whether very widely dispersed species are in fact obligate troglofauna is questionable (they probably have a surface dispersal phase), but there seems little doubt that arachnid species such as *Draculoides* sp. B4 and *Lagynochthonius* sp. B6 are obligate troglofauna. *Draculoides* sp. B4 was found in both impact and reference bores, suggesting that subterranean habitats within the impact and reference areas are connected. Furthermore, the true range of *Draculoides* sp. B4 may be considerably greater than demonstrated, owing to the confined distribution of the sampling at the Iron Valley Project (see Figure 5.1), and subterranean habitat connections may extend well outside the Iron Valley Project area (see Section 7.1.3).

Four species of troglofauna are currently known only from within the proposed mine pits at the Iron Valley Project and the Project poses conservation risks for these species:

1. *Lagynochthonius* sp. B6,
2. Armadillidae sp. B4,
3. *Troglarmadillo* sp., and
4. Chilopoda sp.

Existing information about the likely ranges and the conservation significance of these four species is presented below:

1. *Lagynochthonius* sp. B6 is known from a singleton record. Little can be said about the conservation status of this species, which is morphologically distinct and known to date from a single animal. Many subterranean species of this family are known from the Pilbara, with some species relatively widespread and others tightly restricted (Biota 2006, Bennelongia 2009a,b). At least 14 species singleton records of pseudoscorpions species have been recorded during previous troglofauna environmental impact assessments in the Pilbara (Biota 2006, Bennelongia 2008b, 2009a,b, Biota in Ecologia 2008) and it is a group for which it is often difficult to be determine species ranges. Perhaps ranges are most accurately determined by inference from ranges of other troglobitic arachnids that are more numerous, such as schizomids.

2. *Troglarmadillo* sp. was recorded from two bores approximately 200 m apart near a proposed pit boundary. A number of species of the genus *Troglarmadillo* have been collected in the Pilbara; Bennelongia has records of eight morphospecies. Distributions of these species tend to be relatively small; with linear ranges of 0.7 to 19 km (Bennelongia unpublished data). Given that the five specimens collected were juvenile, the relationship of the Iron Valley animals to other *Troglarmadillo* cannot be made morphologically.
3. Armadillidae sp. B4 is known from a singleton record. Armadillidae sp. B4 is somewhat unusual in that it does not belong to the genus *Troglarmadillo*; troglofaunal isopods collected in the Pilbara are almost exclusively *Troglarmadillo*. It is likely that Armadillidae sp. B4 will have a relatively small range.
4. Chilopoda sp. was recorded as a singleton. The conservation status of this species is very difficult to quantify because the specimen is listed at low taxonomic resolution, Chilopoda are collected relatively rarely and troglobitic assignment is uncertain.
    a. All species of Chilopoda collected by Bennelongia in the Pilbara have been collected at very low abundance (41 specimens from over 4000 troglofauna samples), which makes determination of range very difficult.
    b. In the rare cases where multiple records for a Chilopoda species exist, they have indicated the species have relatively wide ranges for troglofauna. *Cryptops* sp. B7 and *Cryptops* sp. B10 have been shown to have linear ranges of at least 27 and 90 km, respectively (Bennelongia unpublished data).

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 1The dolerite dyke that transects the Project trending in an east/west direction does not appear to represent a barrier to troglofauna because four species recorded at the Project site are known from both sides of the dyke (Appendix 8). Two of these species are very widespread (Polyxenida sp. B1 and Sciaridae sp. B1) and may not be obligate troglofauna, but *Nocticola* sp. B9 and *Draculoides* sp. B4 are troglobites.

7.1.3. Iron Valley Troglofauna Community

The 15 species collected from 135 troglofauna samples show 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 (0.79 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).

Both abundance and richness were considerably greater in reference than impact bores within the Iron Valley Project (Table 6.3). This appears to suggest that surrounding habitat at the Iron Valley Project is more favourable for troglofauna than the commercial grade ore of the pit areas, but reference bore abundance was boosted by high capture of two species (Staphyliinidae sp. B and Sciaridae sp. B1).

7.2. Stygofauna

7.2.1. Stygofauna Distributions and Conservation Risk for Species

Most of the stygofauna species collected are known to, or probably, occur beyond the Iron Valley Project. On the basis of existing data, two species appear to be at risk from Project development (the ostracod *Meridiescandona* sp. BOS 171 and the syncarid *Chilibathynella* sp. B4), while the status of two syncarids identified only to genus is unclear (*Bathynella* sp., and *Atopobathynella* sp.). Existing information about the likely ranges and conservation significance of the four 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 *Meridiescandona* has radiated (see Karanovic 2007; Reeves et al. 2007). *Meridiescandona* sp. BOS 171 was collected from five bores within the Iron Valley Project. The presence of large stygofauna such as '*Maarrka wolli*' ms and *Pygolabis* sp. B1 (nr. *humphreysi*) (the largest Pilbara stygofauna species), both in the Project impact area and more widely in Weeli Wolli/Marillana Creek, suggests that considerable habitat continuity exists in the alluvial drainage channels around the Project (see Appendix 6). It is likely that the much smaller *Meridiescandona* sp. BOS 171 makes use of such habitat connectivity and is not restricted to the Project area, although it is yet to be collected outside the Project area.
2. The syncarid *Chilibathynella* sp. B4 is only known from the Iron Valley Project (Figure 6.6). This species appeared to be associated with the alluvial drainage channel that transects the Project to the south of the main pit. It is expected that this species occurs in the same habitat that is present to the east in the main drainage channel of the Weeli Wolli Creek and, thus, would not be at risk from Project development. However, the wider distribution of the species has not been demonstrated.
3. Two syncarids were identified only to genus level (*Bathynella* sp., and *Atopobathynella* sp.). Both species may have been collected nearby in previous surveys (Figure 6.7) and, therefore, would not at risk from Project development. However, additional collecting and genetic investigation is required to demonstrate this.

Syncarids are a poorly studied group in Australia and are generally regarded as likely to be highly restricted. Globally, two-thirds of known species have linear ranges of <10 km (Camacho and Valdecasas 2008). However, the larger stygofauna species at Iron Valley such as '*Maarrka wolli*' ms and *Pygolabis* sp. B1 (nr. *humphreysi*) are known more widely in the Marillana/Weeli Wolli Creek catchment (see Appendix 6) and it seems unlikely likely that smaller species such syncarids would be restricted in such habitat.

7.2.2. Habitat Characterisation

The dolerite dyke that transects the Project trending in a east/ west direction would appear to be a potential barrier to stygofauna movements because of the hydraulic discontinuity it represents (groundwater level is about 40 m lower on the northern side of the dyke). However, the distribution of stygofauna species suggests the dyke is not a barrier with two amphipods, a copepod and an ostraco found on both sides of the dyke (Paramelitidae cf. sp. 2, Paramelitidae sp. 2, *Diacyclops humphreysi humphreysi* and *Meridiescandona lucerna* (Appendix 7).

7.2.3. Iron Valley Stygofauna Community

The number of stygofauna species collected from the Iron Valley Project (19 species from 84 samples) is relatively modest by Pilbara standards. For example, 34 species from 17 samples were recorded in the upper Fortescue area near Newman (Ethel Gorge community, Halse et al. unpublished data) and the wider Fortescue marsh area yielded 55 species in an extensive sampling program (Bennelongia 2007).

8. CONCLUSION

8.1. Troglofauna

The 135 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 15 species. Two arachnid Orders were recorded: Pseudoscorpionida (one species) and Schizomida (one species). The only crustacean Order collected was Isopoda (two species). Chilopoda were represented by one species of an unknown Order. Diplopoda were represented by Polyxenida (one species). There were five Orders of hexapods (Entognatha/Insecta): Diplura (two species), Blattodea (two species), Hemiptera (two species), Coleoptera (one species) and Diptera (one species).
- Eleven of the 15 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, seven species are known to occur in reference areas outside the mine pit or at deposits elsewhere in the Pilbara.
- Four species recorded at the Iron Valley Project, are known only from impact bores (*Lagynochthonius* sp. B6, *Troglarmadillo* sp., Armadillidae sp. B4 and Chilopoda sp.). Three species were recorded as singletons and the other was represented by two animals. All species are likely to have restricted ranges and, on the basis of existing information, appear to be threatened by Project development.

8.2. Stygofauna

The 84 samples on which this report was based meet the EPA requirement for stygofauna assessment. The following conclusions are drawn from the survey:

- The stygofauna community at the Iron Valley Project is modest for the Pilbara region. At least 19 species of six Classes/Orders were collected, including Oligochaeta (three species), Hydracarina (one species), Ostracoda (three species), Copepoda (four species), Amphipoda (four species) and Isopoda (one species).
- Many species of stygofauna collected in the Iron Valley Project area [including the largest species - sp. B1 (nr. *humphreysi*)] are known to occur in surrounding areas of the Weeli Wolli/Marillana Creek drainage channel and, therefore, it is inferred that habitat connections exist between Iron Valley and these areas.

- Existing data suggest that the ostracod *Meridiescandona* sp. BOS 171, the syncarid *Chilibathynella* sp. B4 and, possibly, the syncarids *Bathynella* sp., and *Atopobathynella* sp. are restricted to the Iron Valley Project area.
- Current information suggests all the Iron Valley Project area will be affect by mine de-watering. Cosequently, the ostracod *Meridiescandona* sp. BOS 171 and, to lesser extents, the syncarids *Chilibathynella* sp. B4, *Bathynella* sp. and *Atopobathynella* sp. appear to be risk from Project development.

9. RECOMMENDATIONS

The four troglofauna species that are only known from the proposed mine pits of the Iron Valley Project (*Lagynochthonius* sp. B6, Armadillidae sp. B4, *Troglarmadillo* sp., and Chilopoda sp.) present considerable uncertainty for conservation assessment. They represent more than 25% of troglofauna species occurring in the Project impact and appear to possibly be threatened by Project development. This level of risk is high compared with the majority of proposals that have been approved for mining. Additional sampling (scraping alone) is recommended to reduce the number of restricted species, with the strata to the north-west of the project area considered to be apprpriate habitat for further sampling.

The level of risk for stygofauna is similar to troglofauna and is relatively high compatred with approved projects. Demonstrating that *Meridiescandona* sp. BOS 171, *Chilibathynella* sp. B4, *Bathynella* sp. and *Atopobathynella* sp. occur more widely in the Weeli Wolli/Marillana Creek catchment would eliminate the uncertainty surrounding the conservation status of these species and the risk to them. This would be best achieved by extra sampling to the east of the Iron Valley Project in the Weeli Wolli Creek drainage channel. *Meridiescandona* sp. BOS 171 and *Chilibathynella* sp. B4 should be considered the primary targets of further sampling.

10. REFERENCES

Aplin, K.P. (1998) Three new blindsnakes (Squamata, Typhlopidae) from north western Australia. *Records of the Western Museum,* **19,**

Barranco, P. and Harvey, M.S. (2008) The first indigenous palpigrade from Australia: a new species of *Eukoenenia* (Palpigradi:Eukoeneniidae). *Invertebrate Systematics* **22,** 227-233.

Bennelongia (2007) Assessment of stygofauna values at the Cloud Break Project, 2007. Report 2007/16. Bennelongia Pty Ltd, Jolimont, 25 pp.

Bennelongia (2008a) Troglofauna survey of the Orebody 18 Mine Modification. Report 2008/27. Bennelongia Pty Ltd, Jolimont, 21 pp.

Bennelongia (2008b) Orebody 24/25 Upgrade Project: troglofauna assessment. Report 2008/40. Bennelongia Pty Ltd, Jolimont, 25 pp.

Bennelongia (2008c) Subterranean Fauna Assessment, BC Iron Nullagine Project. Report 2008/55. Bennelongia Pty Ltd, Jolimont, 27 pp.

Bennelongia (2008d) Appendix D. Subterranean fauna sampling at Balmoral South Iron Ore Project and adjacent areas. *In* Balmoral South Public Environmental Review. GHD and Australasian Resources, Perth.

Bennelongia (2008e) Risk Assessment for Bathynellidae at the Central West Coal Project. Report 2008/54. Bennelongia Pty Ltd, Jolimont, 8 pp.

Bennelongia (2009a) Area C Mining Operation Environmental Management Plan (Revision 4) A, D, P1 and P3 Deposits: Troglofauna Assessment. Report 2008/48. Bennelongia Pty Ltd, Jolimont, 65 pp.

Bennelongia (2009b) Jimblebar Iron Ore Project: Troglofauna Assessment. Report 2009/61. Bennelongia Pty Ltd, Jolimont, 55 pp.

Bennelongia (2009c) Yilgarn Iron Ore Project: Carina Deposit, Subterranean Fauna Assessment. Report 2009/69. Bennelongia Pty Ltd, Jolimont, 24 pp.

Bennelongia (2009d) Phil's Creek Project: Troglofauna Assessment. Report 2009/70. Bennelongia Pty Ltd, Jolimont, 30 pp.

Biota (2005a) Ludlow Mineral Sands Project. Biota Environmental Sciences, Leederville, pp. 14.

Biota (2005b) Barrow Island Gorgon gas development. Biota Environmental Sciences, North Perth, pp. 34 +.

Biota (2006) Mesa A and Robe Valley mesas troglobitic fauna survey. Project No. 291. Biota Environmental Sciences, Leederville, pp. 74++.

Camacho, A.I. and Valdecasas, A.G. (2008) Global diversity of syncarids (Syncarida; Crustacea) in freshwater. *Hydrobiologia,* **595,** 257-266.

Eberhard, S.M., Halse, S.A. and Humphreys, W.F. (2005) Stygofauna in the Pilbara region, north-west Western Australia: a review. *Journal of the Royal Society of Western Australia*, **88**, 167-176.

Eberhard, S.M., Halse, S.A., Williams, M.R., Scanlon, M.D., Cocking, J.S. and Barron, H.J. (2009) Exploring the relationship between sampling efficiency and short range endemism for groundwater fauna in the Pilbara region, Western Australia. *Freshwater Biology* **54**, 885–901.

Ecologia (2008) Koolanooka – Blue Hills Direct Shipping Ore (DSO) Mining Project, Troglofauna Biological Assessment. Ecologia Environment, West Perth, 22 pp.

Edward, K.L. and Harvey, M.S. (2008) Short-range endemism in hypogean environments: the pseudoscorpion genera *Tyrannochthonius* and *Lagynochthonius* (Pseudoscorpiones: Chthoniidae) in the semiarid zone of Western Australia. *Invertebrate Systematics* **22,** 259–293.

EPA (2003) Guidance for the assessment of environmental factors: consideration of subterranean fauna in groundwater and caves during environmental impact assessment in Western Australia. Guidance Statement 54. Environmental Protection Authority, Perth, pp. 12.

EPA (2007) Sampling methods and survey considerations for subterranean fauna in Western Australia (Technical Appendix to Guidance Statement No. 54). Guidance Statement 54A. Environmental Protection Authority, Perth, pp. 32.

Finston, T.L., Francis, C.J. and Johnson, M.S. (2009) Biogeography of the stygobitic isopod Pygolabis (Malacostraca: Tainisopidae) in the Pilbara, Western Australia: Evidence for multiple colonisations of the groundwater. *Molecular Phylogenetics and Evolution* **52**, 448–460.

Finston, T.L., and Johnson, M.S. (2004) Geographic patterns of genetic diversity in subterranean amphipods of the Pilbara, Western Australia. *Marine and Freshwater Research* **55**, 619-628.

Finston, T., Johnson, M.S., Eberhard, S.M, Cocking, J.S., McRae, J.M., Halse, S.A and Knott, B. (submitted). New genus and species of groundwater paramelitid amphipods from the Pilbara, Western Australia: a combined molecular and morphological approach. *Records of the Western Australian Museum*.

Finston, T.L., Johnson, M.S., Humphreys, W.F., Eberhard, S.M., and Halse, S.A. (2007) Cryptic speciation in two widespread subterranean amphipod genera reflects historical drainage patterns in an ancient landscape. *Molecular Ecology* **16**, 355-365.

Halse, S.A., Scanlon, M.D., Cocking, J.S., Barron H.J. and Eberhard, S.M. (in preparation) Pilbara stygofauna: deep groundwater of an ancient landscape contains globally significant radiation of biodiversity.

Harvey, M.S., Gray, M.R., Hunt, G.S. and Lee, D.C. (1993) The cavernicolous Arachnida and Myriopoda of Cape Range, Western Australia. *Records of the Western Australian Museum Supplement* **45,** 129-144.

Harvey, M.S. (2001) New cave-dwelling schizomids (Schizomida: Hubbardiidae) from Australia. *Records of the Western Australia Museum Supplement* **64,** 171-185.

Harvey, M. (2002) Short-range endemism among the Australian fauna: some examples from non-marine environments. *Invertebrate Systematics* **16,** 555-570.

Harvey, M.S, Berry O. Edward K.L. and Humphreys G. (2008) Molecular and morphological systematics of hypogean schizomids (Schizomida : Hubbardiidae) in semiarid Australia. *Invertebrate Systematics* **22**, 167–194.

Humphreys, W .F (1999) Relict stygofaunas living in sea salt, karst and calcrete habitats in arid northwestern Australia contain many ancient lineages. In: The other 99%. The conservation and biodiversity of invertebrates (eds W Ponder and D Lunney). Surrey Beatty, Sydney, pp. 219.227.

Karanovic, I. (2007) Candoninae (Ostracoda) from the Pilbara region in Western Australia. *Crustaceana Monographs*, **7**, 1-432

Lamoreux, J. (2004) Stygobites are more wide-ranging than troglobites. *Journal of Cave and Karst Studies* **66**, 18-19.

Lindberg, K. (1952). Cyclopoides (Crustacés Copépodes) du Royaume du Cambodge. *Bulletin de Institut royal des Sciences naturelles de Belgique* **28**:1-16.

Masciopinto, C., Semeraro, F., La Mantia, R., Inguscio, S., and Rossi, E. (2006) Stygofauna Abundance and Distribution in the Fissures and Caves of the Nardò (Southern Italy) Fractured Aquifer Subject to Reclaimed Water Injections *Geomicrobiology Journal* **23**, 267-278.

Pesce, G. L. and De Laurentiis, P. (1996) Copepods from ground waters of Western Australia, III. *Diacyclops humphreysi* n.sp. and comments on the *Diacyclops crassicaudis* complex (Copepoda, Cyclopoidae). *Crustaceana* **69**: 524-531

Platnick, N.I. (2008) A new subterranean ground spider genus from Western Australia (Araneae:Trochanteriidae). *Invertebrate Systematics* **22,** 295–299.

Reeves J., De Deckker P. and Halse S.A. (2007) Groundwater ostracods from the arid Pilbara region of northwestern Australia: distribution and water chemistry. *Hydrobiologia*, 585, 99–118.

Rio Tinto (2008) Public environmental review, Marandoo mine phase 2. Rio Tinto, Perth, 235 pp. (http://www.riotintoironore.com/documents/Marandoo_Mine_Phase_2_PER.pdf).

Sars, G.O. (1863). Oversigt af de indenlandske Ferskvandscopepoder. *Forhandlinger I Videnskabs-Selskabet I Christiana* **Aar 1862**: 212-262

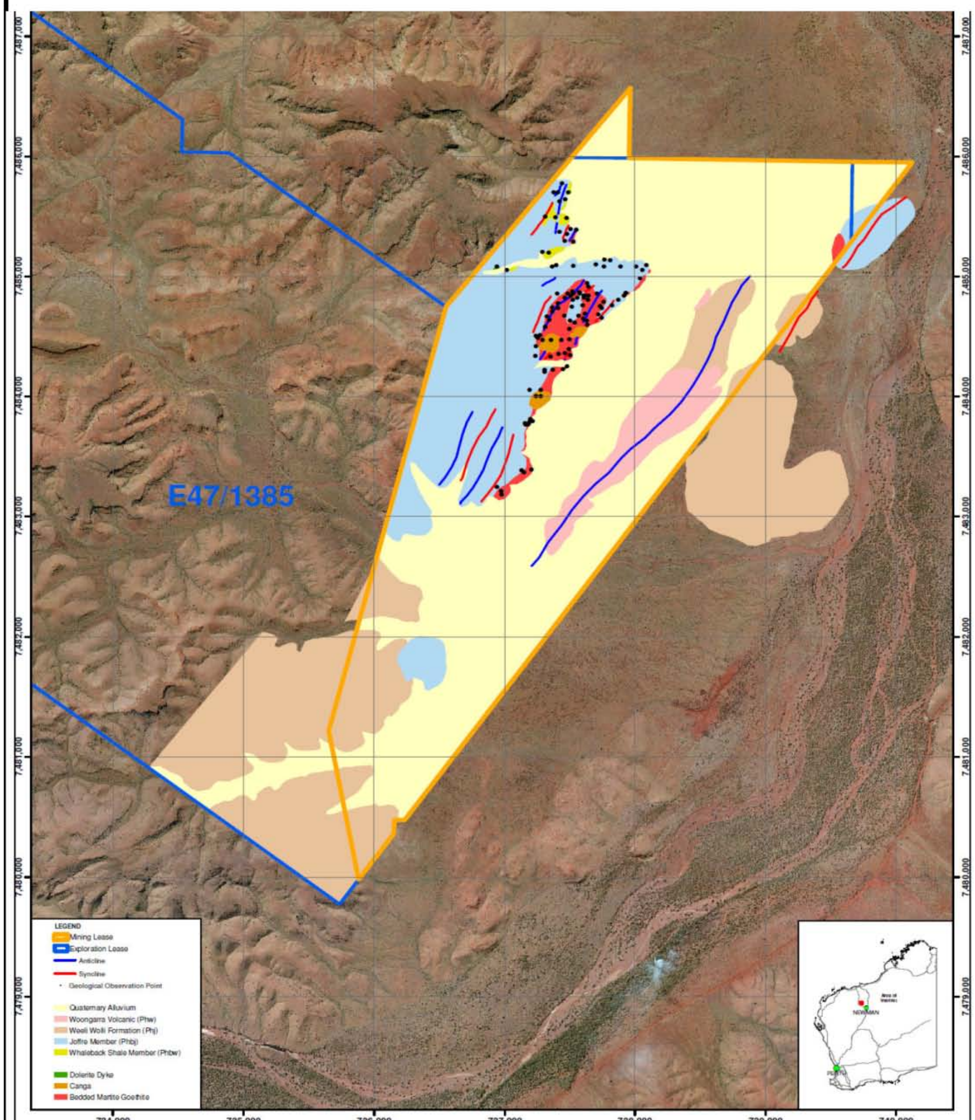
Scarsbrook, M.R., and Fenwick, G.D. (2003) Preliminary assessment of crustacean distribution patterns in New Zealand groundwater aquifers. *New Zealand Journal of Marine and Freshwater Research* **37**, 405-413.

Subterranean Ecology (2007) Pardoo DSO Project. Troglofauna survey. Phase 2 and 3 results. Subterranean Ecology, Greenwood, pp. 91.

Whitely, P.G. (1945) New sharks and fishes from Western Australia. Part 2. *Australian Zoologist,* **11,** 1-45.

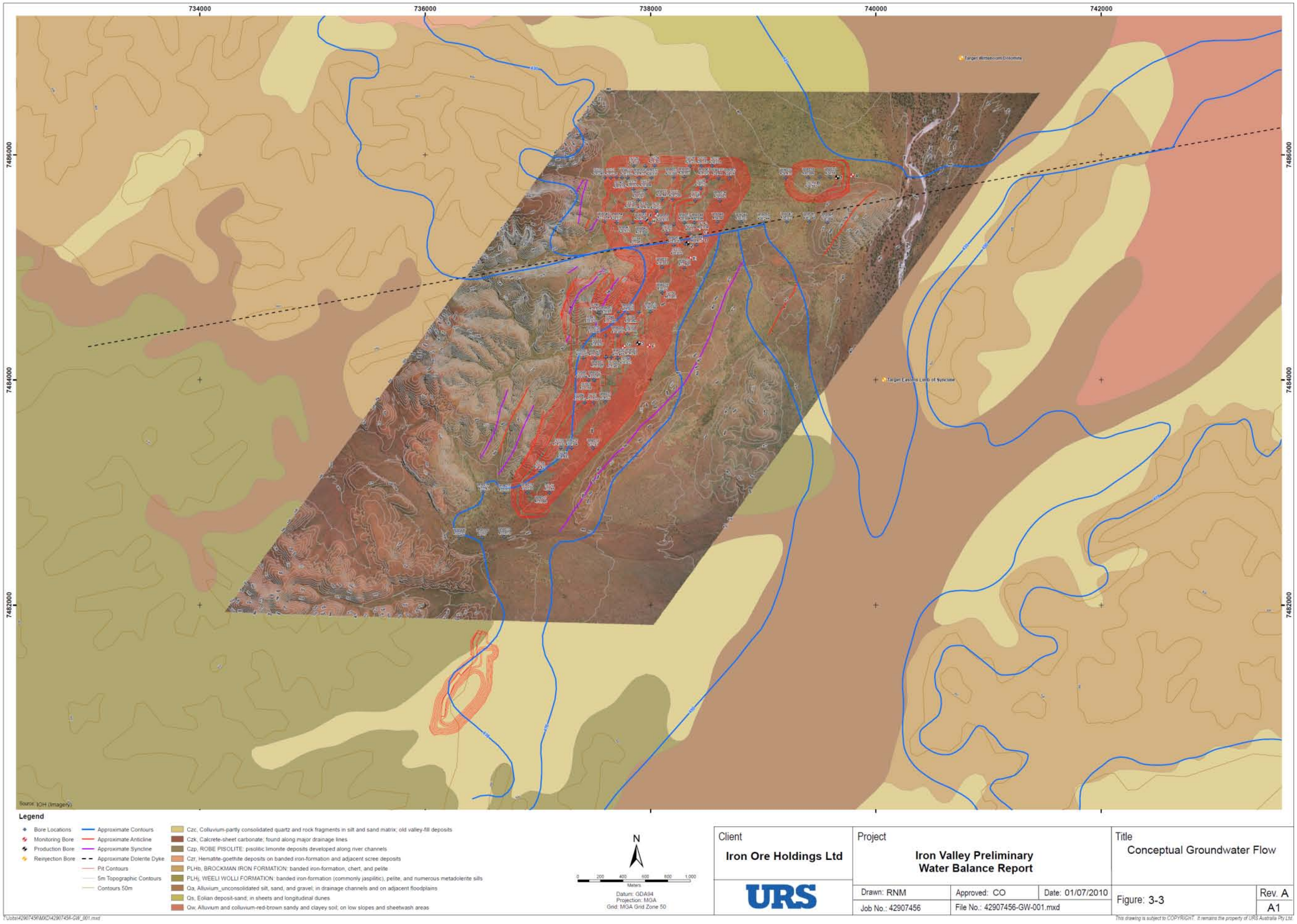
11. APPENDICES

Appendix 1. Geology of the Iron Valley Project

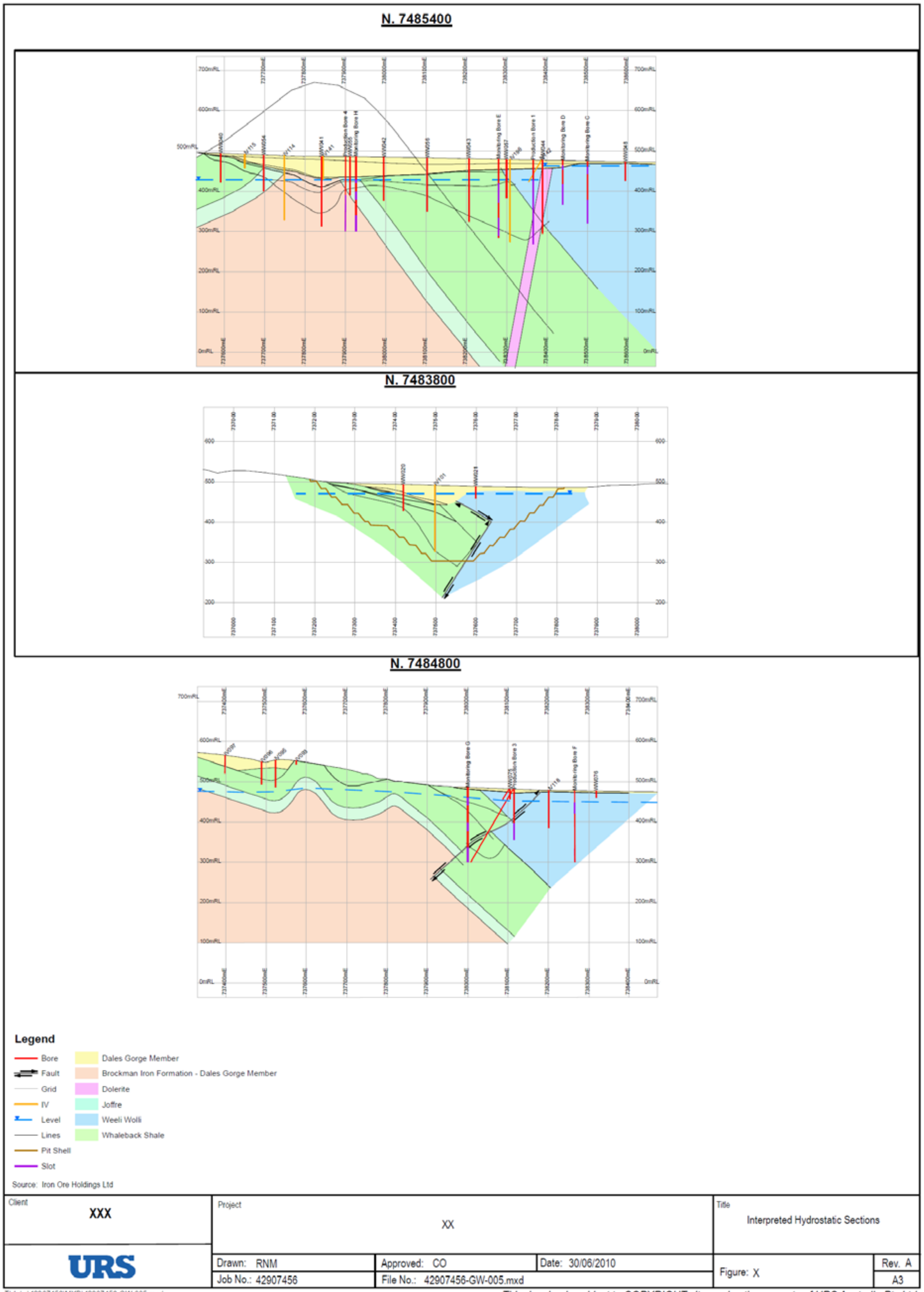


Iron Ore Holdings	Iron Valley Hydrogeological Assessment				Iron Valley Site Geology and Structures (IOH, 2010)	
URS	Job No.	42907456	Chk'd By	IGB	Figure 3-2	Rev. A
	Prep. By	CO 25 Feb '10	Revision No.	0		A4

Appendix 2. Conceptual Groundwater Flow



Appendix 3. Interpreted Hydrostatic Sections.



Appendix 4: Co-ordinates of Bores 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

Bore Code	Site type	Latitude	Longitude
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
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

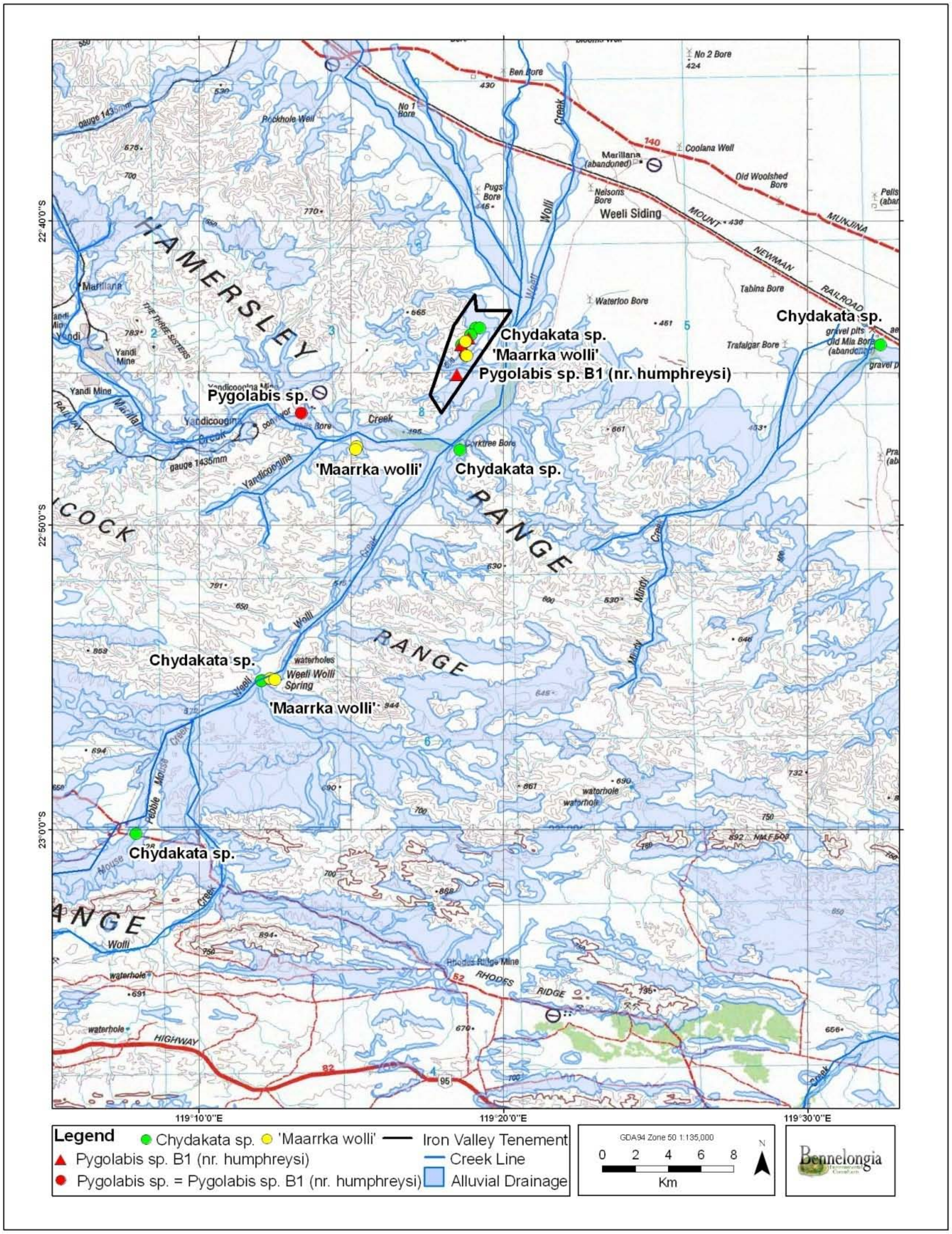
Appendix 5: Co-ordinates of Bores Sampled for Stygofauna at the Iron Valley Project

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

Bore code	Site type	Latitude	Longitude
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
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 Isopods and Amphipods.

Pygolabis spp., *Chydakata* sp. and '*Marrka wolli*' ms specimens collected at the Iron Valley Project (outlined in black) and nearby. Source of data outside the Project: *Pygolabis* sp. = *Pygolabis* sp. B2 (Finston et al. 2009); '*Marrka wolli*' (Halse et. al. unpublished data); *Chydaekata* (Halse et. al. unpublished data, Bennelongia unpublished data).



Appendix 7. Locations of Troglofauna (A) and Stygofauna (B) Species in Relation the Dolerite Dyke that Transects the Iron Valley Project