

Appendix D

Fauna Studies

Appendix D1 Vertebrate Fauna



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Iron Valley Project (BC Iron)

Implications of a revised impact footprint upon fauna values and adequacy of existing assessments

Introduction

The Iron Valley Project, owned by BC Iron, was approved in 2012 for above water level mining only, but the proposal has subsequently been modified to include below water level mining. This modification involves some changes that could affect the original assessment of impacts upon fauna:

- The area of direct impact is increased by about 314 ha (an increase of 47%).
- Dewatering of the below water level mine will result in drawdown outside the area of direct impact.
- Dewatering of the below water level mine will result in discharge of water into the nearby Weeli Wolli Creek, with the effect of making water flow in the creek permanent rather than seasonal.
- Dewatering for the Iron Valley project will interact with discharges from upstream mining activities.

In addition to these project changes, there have been some changes to the conservation status of species that need to be considered. These are:

Crest-tailed Mulgara *Dasyercus cristicauda*. Listed under state and federal legislation, but all records of Mulgara in the Pilbara are now considered to be Brush-tailed Mulgara *Dasyercus blythi*. This is considered only to be a Priority 4 species in WA, so is of lesser concern. A Mulgara was recorded immediately adjacent to the project area and some of the environment would provide habitat for the species.

Ghost Bat *Macroderma gigas*. Listed as a Priority 4 species previously but now listed under Schedule 3 (Vulnerable) of the WA Wildlife Conservation Act. Not recorded during field investigations and no primary roosting habitat present, but species likely to be a regular foraging visitor.

Grey Falcon *Falco hypoleucos*. Listed as a Priority 4 species previously but now listed under Schedule 3 (Vulnerable) of the WA Wildlife Conservation Act. Not recorded during field investigations but large trees along Weeli Wolli Creek may provide nesting habitat.

Bush Stone-curlew *Burhinus grallarius*. Formerly listed as Priority 4 but has been de-listed.

Australian Bustard *Ardeotis australis*. Formerly listed as Priority 4 but has been de-listed.

The key significant species identified in the original report were those listed under the EPBC Act, considered likely to be present (or confirmed), and for which impacts might be

significant. These were the Pilbara Olive Python, Crest-tailed Mulgara and Northern Quoll. Of these, only the Crest-tailed Mulgara has changed in that it is no longer considered to occur in the Pilbara, with the Mulgara recorded being the Brush-tailed species. Thus, there are only two EPBC species to be discussed with respect to the revised impact footprint and impacts: the Northern Quoll and the Pilbara Olive Python. Note that while the Pilbara Olive Python was reported by station staff and is very likely to be resident in the area, the Northern Quoll was not recorded and in repeated surveys in the general region (as noted in the original fauna report) it has been found only very infrequently.

Altered area of direct impact

The increased area of direct impact is large relative to the scale of the project (a 47% increase in footprint) but small with respect to surrounding landscapes, and does not affect Vegetation and Substrate Associations not within the approved impact area. There is thus no change in the sorts of fauna habitats being directly impacted and no change in the species likely to be impacted.

The original fauna report calculated the proportion of habitat of key significant species that would be directly impacted, based upon land systems and their representation over a region within 15km of the project area, and upon vegetation types mapped within the overall project area (Table 1). Within the project area, both the Northern Quoll and Pilbara Olive Python rely largely upon the Newman Land System. This is very extensive within 15km of the project area (39,882ha), with 277ha (0.7%) within the approved (above water level) clearing footprint. The revised (below water level) clearing footprint affects an additional 218ha, which brings the proportional impact upon the Newman Land System within a 15km radius to 1.2%. In the case of the Pilbara Olive Python, it may also use the River Land System, with 6367ha within 15km, but none within either the above water level or below water level footprint. Therefore, the proportional habitat loss for the Pilbara Olive Python within a 15km radius of the project area is 0.6% and 1.07% under the above water level and below water level clearing scenarios respectively.

Three vegetation types lie within the project area and will be affected by clearing (Table 1). These do not correspond directly with land systems although Rocky hills and crests are a major component of the Newman Land System, while the Plains correspond closely with the Boolgeeda Land System. The Rocky hills and crests provide habitat for the Northern Quoll and Pilbara Olive Python, while the Creeks and drainage lines provide habitat for the Pilbara Olive Python. Using these vegetation types as an indication of areas of habitat within the clearing footprints, and compared with land systems that provide habitat within a radius of 15km, the proportional habitat loss for each species is low under either scenario:

- Northern Quoll: 278ha and 482ha under above water level and below water level scenarios, representing 0.7% and 1.2% of the Newman Land System within 15km.
- Pilbara Olive Python: 278ha and 482ha under above water level and below water level scenarios, representing 0.6% and 1.04% of the combined Newman and River Land Systems within 15km.

While the area of direct impact does not alter greatly, the greater southern extent of the footprint could disturb a minor drainage line that was considered would provide a movement corridor for the Pilbara Olive Python, allowing animals to move between Weeli Wolli Creek and the rocky hills to the west. This drainage line could be important for the dispersal and movement of other fauna as well and will therefore be retained.

Table 1. Vegetation types within the project area and areas within clearing footprints

Vegetation type	Area of clearing approved under the above groundwater scenario	Additional area for clearing under the proposed below groundwater scenario	Total area for clearing
Creeks and drainage lines	60.1	36.8	96.9
Rocky hills and crests	217.9	167.1	385.0
Plains	351.7	129.0	480.7

Dewatering impacts

Dewatering of the mine and associated discharge have the potential to affect Groundwater Dependent Vegetation (GDVs) and thus the fauna that depend upon these ecosystems, including the Pilbara Olive Python. Therefore, a field and desktop review of the dewatering impacts upon GDVs was carried out by Astron (2015). This considered both the dewatering effects from the Iron Valley project (the Base Case scenario) and the Iron Valley dewatering combined with dewatering from a proposed Rio Tinto Yandicoogina mine expansion upstream (the Rio Tinto scenario). Models of groundwater impacts were applied across the landscape over a 10km radius from the centre of the Iron Valley project and this encompassed 2,542ha of GDV (essentially woodlands of *Eucalyptus victrix*, *E. camaldulensis* and *Melaleuca argentea*). The model was applied to the end of mining at Iron Valley in 2025.

Modelling by Astron (2015) included assigning a risk to GDV related to changes in groundwater levels (falls or rises). Changes in groundwater levels under the two scenarios were different, with extensive falls (and some rises) in groundwater levels under the Base Case Scenario, but rises (and some falls) in groundwater levels under the Rio Tinto scenario, but the actual area of GDV expected to be at high risk of decline was similar: 591 and 583ha respectively. This represents about a quarter of the GDV within 10km of the Iron Valley mine. Hydrological change is expected to extend to about 6km downstream of the Iron Valley discharge point (Astron 2016), and therefore impacts upon the Fortescue Marshes are not anticipated. The Astron report concluded that the groundwater levels would reach equilibrium within about 10 years of mine closure, and that while some tree death could be expected during this period, recovery of the ecosystem could be expected, especially if dewatering and discharge were reduced progressively to avoid abrupt changes in groundwater levels.

Astron (2015) does not give a figure for the area of GDV that will be directly impacted through clearing, but it is probably very low. Therefore, the risk of change to about 25% of GDV within 10km of the Iron Valley mine represents a large change from the impacts of the original mining proposal (above water level mining only). The GDV is likely to support Pilbara Olive Pythons and large riverine eucalypts may also provide habitat for Northern Quoll. The GDV is also likely to be generally rich in fauna species but was not included in the original fauna assessment as the GDV lay outside the areas of direct or indirect impact (Everard *et al.* 2012).

The almost 600ha of GDV at high risk of decline will not be cleared but will be modified by vegetation deaths, altered vegetation composition and changes in soil moisture. The GDV

will change again when discharge ceases. Such changes will have both adverse and positive effects on the fauna assemblage. Olive Pythons may be robust in the face of predicted changes, as they can shelter in living or dead trees and feed on a range of animals. There may be a change in the proportional representation of some other species in the assemblage as a result of changes in their local pattern of distribution. Species associated with moist conditions could expand their local distribution at the expense of more arid-adapted species; and *vice versa*.

A concluding remark in the Astron (2015) executive summary is important to consider:

“...it appears possible that current and future disposal of water from Rio Tinto’s mining operations could mitigate any potential negative impacts of drawdown from the Iron Valley Project along the southern (upstream) portion of the Weeli Wolli Creek system. However, discharge from the Iron Valley Project may potentially lead to an additional discharge impact along the mid to northern (downstream) portion of the Creek, which could be either positive in some areas and negative in others depending on species, spatial distribution of vegetation in the creek bed and surrounding areas, and tolerance to inundation and waterlogging.”

This is effectively saying that the greatest changes may be restricted to north (downstream) of the Iron Valley mine and are likely to involve increased groundwater levels and increased surface water. This may adversely impact some species but may benefit others, probably including the Olive Python that is often associated with mesic environments.

References

Astron (2015). Iron Valley Groundwater Dependent Ecosystem Investigation. Unpubl. report prepared for BC Iron.

Everard, C., Bamford, M., Huang, N. and Gamblin, T. (2012). Vertebrate fauna assessment of the Iron Valley Project Area. Unpubl. report to Iron Ore Holdings, prepared by Bamford Consulting Ecologists, Kingsley.

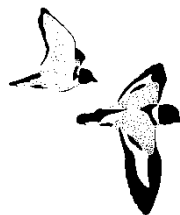
Vertebrate Fauna Assessment of the Iron Valley Project Area



Rocky hills within the Iron Valley Project Area

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13th September 2012

EXECUTIVE SUMMARY

Iron Ore Holdings Ltd (IOH) proposes to develop an iron ore mine within its Iron Valley tenement (the Project Area) located in the Eastern Pilbara Region of Western Australia. As part of the Environmental Impact Assessment (EIA) for the Project, Bamford Consulting Ecologists (BCE) was commissioned to conduct a Fauna Assessment and investigation of the vertebrate fauna within the Project Area. BCE uses an impact assessment process with the following components:

- The identification of fauna values:
 - Assemblage characteristics: uniqueness, completeness and richness;
 - Recognition of ecotypes or vegetation and substrate associations (VSAs) that provide habitat for fauna; particularly those that are rare, unusual and/or support significant fauna;
 - Patterns of biodiversity across the landscape;
 - Species of conservation significance; and
 - Ecological processes upon which the fauna depend.
- The review of impacting ecological processes such as:
 - Habitat loss leading to population decline;
 - Habitat loss leading to population fragmentation;
 - Ongoing mortality from operations;
 - Species interactions including feral and overabundant native species;
 - Hydrological change;
 - Altered fire regimes; and
 - Disturbance (dust, light, noise).
- The recommendation of actions to mitigate impacts.

The Project Area is located within in an extensively-surveyed area with several operating iron ore mines nearby. Based on the available information from previous surveys, a standard Level 2 trapping survey was not required for the Iron Valley Project. Instead, the Office of the Environmental Protection Authority agreed to field investigations to target conservation significant species and identify key fauna environments and ecological processes that maintain the fauna assemblage. Conservation significant species were targeted during field surveys if they were considered likely to occur in the Project Area based on previous records and/or presence of suitable habitat.

Field investigations included walking transects to look for evidence of significant species, Elliott trapping, cave searching, raking, use of motion-sensitive cameras, bat surveys, spotlighting, opportunistic observations and habitat assessment.

The desktop assessment of the Project Area identified 293 species, including: five frog, 105 reptile, 138 bird and 36 native mammal and nine introduced mammal species. A total of 21 conservation significant species is considered likely to occur within the Project Area, including

two reptile, 11 bird and eight mammal species. A total of 97 fauna species was recorded during the field surveys. This comprised one frog, 25 reptile, 58 bird, 11 native mammal and two introduced mammal species.

Five conservation significant fauna species were recorded during the field surveys: the Rainbow Bee-eater (commonwealth-listed); the Mulgara (commonwealth-listed); the Western Pebble-mound Mouse and Australian Bustard (both priority-listed by the WA Department of Environment and Conservation); and the Rufous-crowned Emu-wren (not listed but locally significant). These species could be residents within the Project Area, or move through the Project Area regularly.

Three major VSAs were identified during the field investigations:

1. Drainage Lines – characterised by mixed *Acacia* shrubs, *Triodia* and Buffel grass over clay soils (Boolgeeda land system);
2. Plains – comprising of flat plains of *Triodia* and mixed shrubland (Mulga) over clay loam soils with varying fire ages, with the occasional low stony rise in the landscape (Boolgeeda land system); and
3. Rocky Hills – Stony rocky hills dominated by *Triodia* on gravelly soils and rock outcrops. Lower slopes with scattered smooth barked eucalypts, shrubs and *Triodia* over pebbles and stones (Newman land system).

The Drainage Lines VSA may be most impacted by the Project as it is restricted in the region and likely to support conservation significant fauna. Any changes to hydrology have the potential to impact significantly upon this VSA and local fauna populations. The Plains VSA is likely to experience a moderate impact by the project due to its widespread distribution in the region and potential to support conservation significant fauna. The Rocky Hills VSA is well-represented outside the Project Area, although may still be sensitive to landscape-scale impacts such as hydrological change and altered fire regimes.

Among the fauna species of conservation significance that may occur in the area, impacts on most species are expected to be negligible or minor. Species where impacts may be of concern are:

- Pilbara Olive Python – species at low population density, restricted in habitat selection such as drainage lines and sensitive to roadkill;
- Night Parrot – species very poorly known so impact hard to predict; species is highly significant, although unlikely in the Project Area;
- Mulgara – species present at a location adjacent to the Project Area; the only recent record from the south side of the Fortescue Marshes. There is limited suitable habitat within the Project Area but extensive habitat to the north and north-west. The species may be sensitive to cumulative habitat loss from multiple development projects in the

region, and to landscape scale processes such as fire regimes, livestock grazing and feral predators.

- Bush Stone-curlew – species at low population density and sensitive to roadkill and feral predators;
- Lakeland Downs Mouse – species not recorded, however highly variable and may be present; and
- Pebble-mound Mouse – species present in Project Area and sensitive to habitat loss.

Of the impacting ecological processes, concerns can be summarised as follows:

- Loss of habitat leading to population decline – possibly some concern in the Boolgeeda land system within the Project Area. Cumulative impacts with other mining in the region need to be considered;
- Loss of habitat leading to population fragmentation – may be a concern along the Boolgeeda land system as the project may lead to fragmentation and disrupt fauna movement;
- Increased mortality – of concern for some fauna species, especially Pilbara Olive Python, Australian Bustard and Bush Stone-curlew;
- Hydrological changes – downstream effects along the River land system of Weeli Wolli Creek, potential impacts to local fauna populations if hydrological changes not avoided;
- Species interactions – such interactions are already occurring. There is potential for both negative and positive impacts from the proposed project upon feral species;
- Dust, noise, light and disturbance – impacts uncertain but some precautions are advised; and
- Changes in fire regime – a major ecological factor in the region's fauna with potential for both negative and positive impacts from the proposed project.

Impacts were generally considered to be minor because most of the VSAs and fauna habitats are contiguous and well-represented outside the Project Area. However, the fauna are likely to rely on the hydrological situation remaining intact and changes to this process (and the VSA Drainage Lines) may result in potentially significant changes to local fauna populations. Management recommendations are made concerning minimising habitat loss and mortality, protecting landscape permeability, hydrological management, fire management and control of feral species.

CONTENTS

EXECUTIVE SUMMARY	i
CONTENTS.....	iv
LIST OF TABLES	vi
LIST OF FIGURES	vi
1 Introduction	1
1.1 Background.....	1
1.2 General Approach to Fauna Assessment	1
1.3 Location and Project Description.....	2
1.4 Regional Description	4
1.5 Land Types and Land Systems	6
1.6 Previous Fauna Surveys	8
2 Methods	9
2.1 Desktop Assessment	9
2.1.1 Sources of Information.....	9
2.1.2 Nomenclature and Taxonomy	10
2.1.3 Interpretation of Species Lists.....	10
2.2 Field Surveys	11
2.2.1 Overview	11
2.2.2 Survey Timing and Weather Conditions.....	12
2.2.3 Personnel and Licences.....	13
2.2.4 Conservation Significant Species Targeted	13
2.2.5 Western Pebble-mound Mouse and Mulgara Transects.....	14
2.2.6 Elliott Traps and Cave Searches	16
2.2.7 Motion-sensitive Cameras.....	16
2.2.8 Bat Surveys	18
2.2.9 Spotlighting.....	18
2.2.10 Opportunistic Observations and Searching.....	18
2.2.11 Habitat Assessment.....	18
2.2.12 Summary of Field Effort.....	19
2.3 Impact Assessment.....	20
2.3.1 Fauna values and ecological processes	20
2.3.2 Criteria for impact assessment	20
2.4 Limitations of Investigations	21
3 Results	23
3.1 Threatened Ecological Communities	23
3.2 Vegetation and Substrate Associations	23
3.3 Vertebrate Fauna	25
3.3.1 Overview and Characteristics of Fauna Assemblage.....	25
3.3.2 Western Pebble-mound Mouse and Mulgara Transects.....	29

Iron Valley Project Area - Fauna Assessment

3.3.3	Elliott Traps and Cave Searches	29
3.3.4	Motion-sensitive Cameras.....	31
3.3.5	Bat Surveys	31
3.3.6	Spotlighting.....	31
3.3.7	Opportunistic Observations.....	31
3.4	Patterns of Distribution and Abundance	32
3.5	Conservation Significant Species.....	33
3.5.1	Overview	33
3.5.2	Reptiles	37
3.5.3	Birds.....	38
3.5.4	Mammals.....	41
3.6	Ecological Processes upon which Fauna depend.....	44
4	Impact Assessment	45
4.1	Vegetation and Substrate Associations	45
4.2	Conservation Significant Species.....	48
4.3	Ecological Processes	53
4.3.1	Loss of Habitat Leading to Population Decline	53
4.3.2	Loss of Habitat Leading to Population Fragmentation	53
4.3.3	Increased Mortality	53
4.3.4	Hydrological changes.....	53
4.3.5	Species Interactions, including Predation and Competition.....	54
4.3.6	Dust, Noise, Light and Disturbance	54
4.3.7	Changes in Fire Regime	54
4.3.8	Summary of Impacts to Ecological Processes	55
4.4	Summary by EPA Guidance	56
5	Management Recommendations.....	57
5.1	Loss of Habitat.....	57
5.2	Fragmentation of Habitat	57
5.3	Increased Mortality during Operations	57
5.4	Hydrological Changes.....	57
5.5	Species Interactions	58
5.6	Dust, Noise, Light and Disturbance.....	58
5.7	Changes in Fire Regime	58
6	References	59
7	Appendices	64

LIST OF TABLES

Table 1. Land Types and Systems represented within the region (from van Vreeswyk <i>et al.</i> 2004).	6
Table 2. Previous fauna surveys within the vicinity of the Iron Valley Project Area.	8
Table 3. Details of literature and database search.....	10
Table 4. Details of survey techniques used in May and September surveys	12
Table 5. Details of motion-sensitive camera surveys	16
Table 6. Criteria for impact assessment.....	20
Table 7. Survey limitations as outlined by EPA (2004).	21
Table 8. Composition of vertebrate fauna expected to occur and recorded within the Project Area	26
Table 9. Conservation significant fauna species expected to occur in the Project Area (conservation categories as defined in Appendix 3).	27
Table 10. Details of Western Pebble-mound Mouse mounds recorded.....	29
Table 11. Status of conservation significant species likely to occur in the Project Area.	34
Table 12. Potential impacts and significance of VSAs within Project Area	46
Table 13. Area of local (15km radius) land systems and land systems found within Project Area	47
Table 14. Potential impacts on conservation significant species expected to occur in the Project Area.....	50
Table 15. Summary of potential impacts of the Project on fauna as assessed following the guidance of the EPA's Guidance Statement No. 56.	56

LIST OF FIGURES

Figure 1. Location of the Iron Valley Project Area	3
Figure 2. IBRA Subregions in Western Australia. Note the Project Area lies in PIL3: Hamersley subregion.....	5
Figure 3. Land Systems within the Project Area (see map or Table 1 for Land System codes). ...	7

Iron Valley Project Area - Fauna Assessment

Figure 4. Locations of Western Pebble-mound Mouse and Mulgara transects and burrows. Tenement M 47/1439 indicates boundary of Project Area.	15
Figure 5. Location of Elliott traps, motion-sensitive cameras and AnaBat surveys. Tenement M 47/1439 indicates boundary of Project Area.....	17
Figure 6. The Iron Valley Project Area, showing the extent of the Boolgeeda Land System (habitat for the Mulgara) and the location of Mulgara records near the Project Area.....	30

1 Introduction

1.1 Background

Iron Ore Holdings Ltd (IOH) proposes to develop an iron ore mine within its Iron Valley tenement (the Project Area) located in the Eastern Pilbara Region of Western Australia. As part of the Environmental Impact Assessment (EIA) for the Project, Bamford Consulting Ecologists (BCE) was engaged to conduct a Fauna Assessment of the vertebrate fauna within the Project Area. Based on the available information from previous surveys in the vicinity of the Project Area (see Section 1.6), a standard Level 2 trapping survey was not required for the Iron Valley Project, as agreed to in consultation with the Office of the Environmental Protection Authority (OEPA). Instead, the OEPA agreed to field investigations to target conservation significant species and identify key fauna environments and ecological processes that maintain the fauna assemblage.

1.2 General Approach to Fauna Assessment

The purpose of impact assessment is to provide government agencies with the information they need to decide upon the significance of impacts of a proposed development. BCE uses an impact assessment process with the following components:

- The identification of fauna values:
 - Assemblage characteristics: uniqueness, completeness and richness;
 - Recognition of ecotypes or vegetation and substrate associations (VSAs) that provide habitat for fauna; particularly those that are rare, unusual and/or support significant fauna;
 - Patterns of biodiversity across the landscape;
 - Species of conservation significance; and
 - Ecological processes upon which the fauna depend.
- The review of impacting ecological processes such as:
 - Habitat loss leading to population decline;
 - Habitat loss leading to population fragmentation;
 - Ongoing mortality from operations;
 - Species interactions including feral and overabundant native species;
 - Hydrological change;
 - Altered fire regimes; and
 - Disturbance (dust, light, noise).
- The recommendation of actions to mitigate impacts.

In the present report, the identification of fauna values includes the results of the desktop assessment and baseline surveys conducted in May 2011 (autumn) and September 2011 (spring). The review of impacting ecological processes and recommendations to mitigate impacts are provided in the final sections of the report. Descriptions and background information on the above fauna values, conservation significance levels and ecological processes can be found in Appendices 1 to 4. Based on this impact assessment process, the objectives of the investigations

are therefore to: identify fauna values; review impacting processes with respect to these values and the proposed development; and provide recommendations to mitigate these impacts.

1.3 Location and Project Description

The Project Area is located within the Marillana Pastoral Station in the Hamersley Range of the Eastern Pilbara Region of Western Australia. The Project is located approximately 1100 km north-east of Perth and 90 km north-west of Newman (Figure 1). The Project occurs within Mining Lease M47/1439 in the Shire of East Pilbara. IOH also holds an Exploration tenement (E47/1385) located directly to the west of the Project Area.

The Iron Valley tenement lies on the lower slopes and low hills of a broad valley adjacent to Weeli Wolli Creek. The Project Area is separated from Weeli Wolli Creek by a hilly range, with the creek spreading out across a plain before entering the Fortescue Marsh approximately 20 km north of the Project Area.

IOH proposes to mine iron ore at Iron Valley, ore will be crushed and screened on-site prior to sale, with waste rock being stored on-site, and mining will take place above the water table only..

Iron Valley Project Area - Fauna Assessment

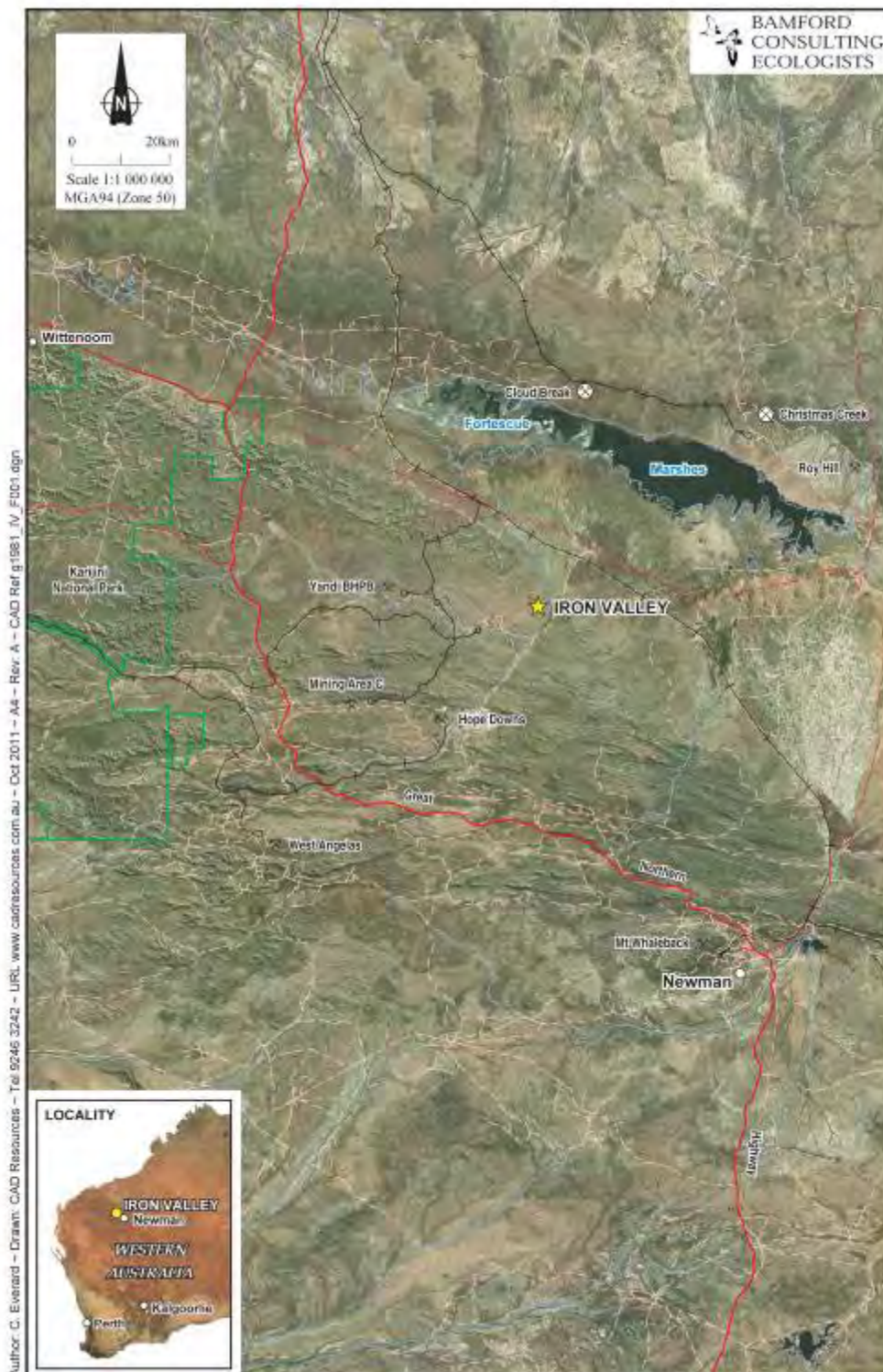


Figure 1. Location of the Iron Valley Project Area

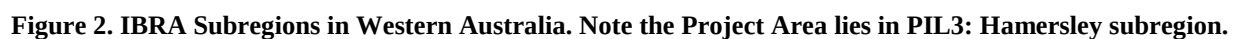
1.4 Regional Description

The Project Area lies within the Hamersley subregion of the Pilbara Bioregion (Figure 2). The regions are described by the Interim Biogeographical Regionalisation for Australia (IBRA) classification system (Environment Australia 2000; McKenzie *et al.* 2003). The Pilbara Bioregion falls within the Bioregion Group 2 classification (EPA 2004). Bioregions within Group 2 have been described as areas of “native vegetation that is largely contiguous but is used for commercial grazing”. The Project is located in the north-eastern corner of the Hamersley subregion, and abuts the Fortescue Plains. This subregion contains the Fortescue Marshes and is considered an important area for faunal biodiversity.

The general features of the Hamersley subregion are summarised by Kendrick 2001. The subregion has an area of approximately 6,215,092 ha, consisting largely of Proterozoic sedimentary ranges and plateaux, dissected by gorges (basalt, shale and dolerite). It is characterised by Mulga low woodland over bunch grasses on fine textured soils in valley floors, and *Eucalyptus leucophloia* over *Triodia brizoides* on skeletal soils of the ranges (Kendrick 2001). The climate of the region is semi desert tropical, with an average rainfall of 300 mm, falling mainly in summer cyclonic events. The dominant land uses in this subregion include grazing, Crown reserves and mining.

Kendrick 2001 notes that 7.75% of the Pilbara IBRA Region is under some form of conservation tenure (reservation class 3). Within the bioregion, PIL3 (Hamersley subregion) has 14.10% of the land area under conservation management, which is the highest in the Pilbara Region, with Kendrick 2001 recommending that a higher priority for reservation is appropriate to include riverine systems and wetlands. This subregion contains most of the Karijini National Park and parts of the Cane River Conservation Park. Note that while the Project Area appears to be adjacent to the PIL2 Fortescue subregion (see Figure 2), it lies within the PIL3 Hamersley subregion and its landscape is strictly that of the Hamersley subregion and not of the Fortescue marshes.

BAMFORD Consulting Ecologists



1.5 Land Types and Land Systems

Land types and systems in the Pilbara have been classified and mapped by van Vreeswyk *et al.* (2004). Land types are classified according to similarities in landform, soil, vegetation, geology and geomorphology. There are three major land types in the vicinity of the Project Area, with two land types occurring within the Project Area (Table 1).

Land types are further divided into land systems based on similarities of vegetation, landform and soil. The land systems in the region provide an indication of the fauna habitats present and are indicated in Table 1. The Project Area occurs within the Newman and Boolgeeda land systems, while the River land system is present in the Weeli Wolli creek area outside of the Project Area to the south and east (Figure 3). The McKay land system lies in close proximity to the Project Area but is not located within the Project Area.

The western section of the Project Area is dominated by the Newman land system, which comprises rugged jaspilite plateaux's with ridges supporting hard spinifex grasslands. The rocky ridges extend west beyond the tenement boundary and form part of the greater Hamersley Range. The eastern part of the Project Area consists of the Boolgeeda land system, including stony lower slopes and plains with spinifex grasslands or mulga shrublands.

The Weeli Wolli Creek flows parallel along the eastern boundary of the Project Area before draining into the Fortescue Marsh and contains the River land system, which is characterised by active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands (van Vreeswyk *et al.* 2004). The Project Area is separated from the Weeli Wolli Creek system by a hilly range.

Table 1. Land Types and Systems represented within the region (from van Vreeswyk *et al.* 2004).

Land Type Code	Land Type Description	Land Systems
1- RGENEW	Hills and ranges with spinifex grasslands (occurs within the Project Area)	Newman
8-RGEBGO	Stony Plains with spinifex grasslands (occurs within the Project Area)	Boolgeeda
17-RGERIV	River plains with grassy woodlands and shrublands, and tussock grasslands (adjacent to the Project Area)	River

Iron Valley Project Area - Fauna Assessment

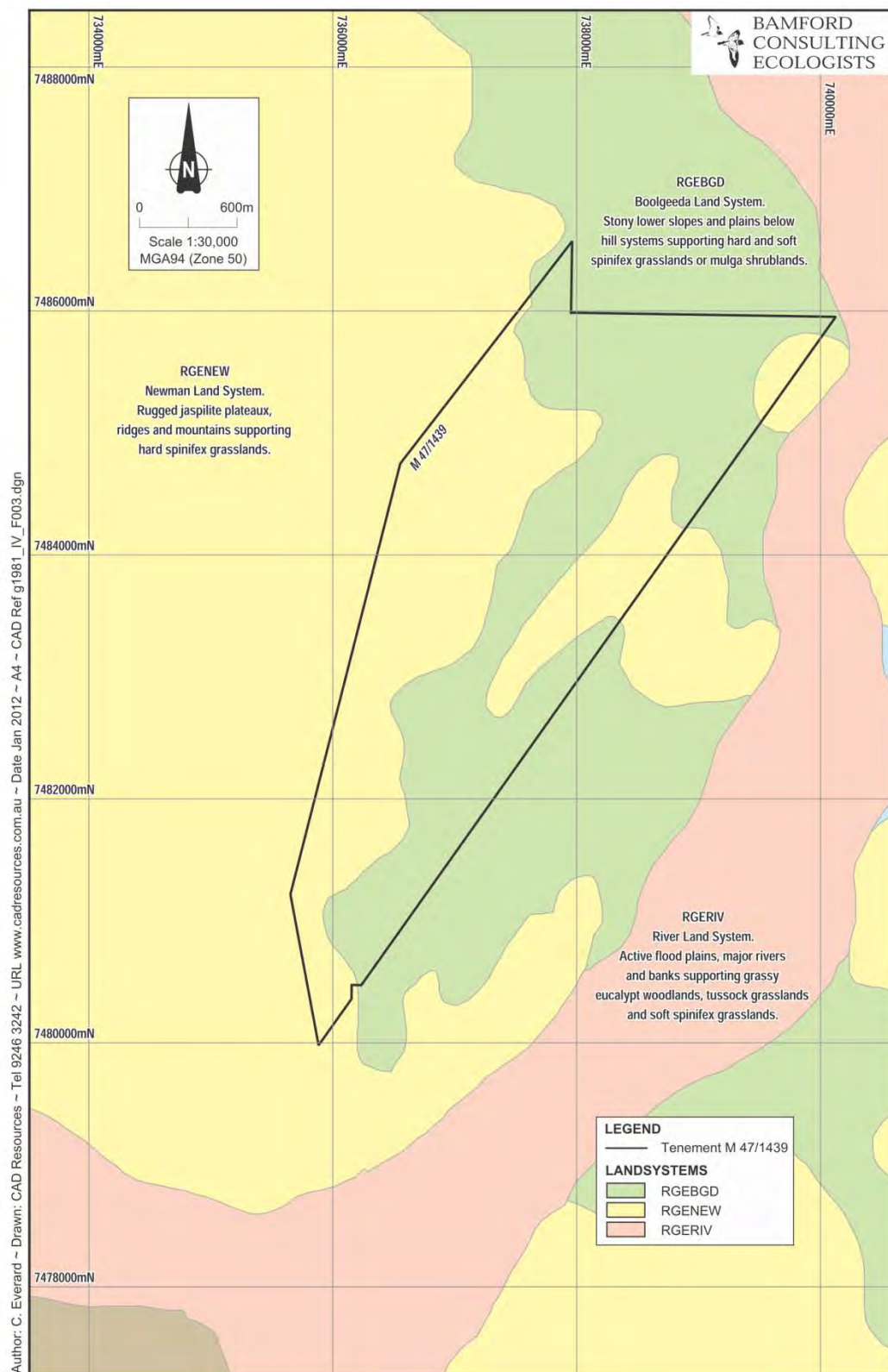


Figure 3. Land Systems within the Project Area (see map or Table 1 for Land System codes).

1.6 Previous Fauna Surveys

The Iron Valley Project Area is located in close proximity to a number of operating iron ore mines, including Fortescue Metals Group's (FMG) Cloudbreak operation, Rio Tinto Iron Ore's Yandicoogina operation and BHP Billiton Iron Ore's Yandi operation. Brockman Resources also has a proposed project located a few km north-west of the Project Area. Recent (2011) fauna surveys involving detailed trapping have previously been undertaken in the tenements for these companies (within approximately 20 km of the Project Area), including another Project for IOH located 20 km to the west (Kurrajura tenement; BCE 2011b) and FMG's Nyidinghu tenement (abuts Iron Valley to the north; BCE 2011a). Older fauna surveys in the area, dating back to the early 2000s, 1990s and even early 1980s, have also been undertaken within the vicinity of the Project Area. Some of these survey sites are located within one km of the Project Area and are located within similar land systems. Details of previous fauna surveys conducted in the area are listed in Table 2.

Table 2. Previous fauna surveys within the vicinity of the Iron Valley Project Area.

Consultant	Date	Report
Bamford Consulting Ecologists	2011	Fauna Assessment FMG Nyidinghu Iron Ore Project
Biota Environmental Sciences	2011	Hope Downs Project Life of Mine Targeted Fauna Survey
Biota Environmental Sciences	2010	Yandicoogina Junction South West and Oxbow Fauna Survey
Ecologia	2010	Christmas Creek Terrestrial Vertebrate Fauna Desktop Assessment
Bamford Consulting Ecologists	2010	Report on December 2009 search for Night Parrot. A Fortescue Metals Group Project
Biota Environmental Sciences	2009	Yandicoogina Targeted Northern Quoll Survey
Ninox Wildlife Consulting	2009	A Vertebrate Fauna Survey of The Proposed Hope Downs 4 Option 6 Infrastructure Corridor
Ecologia	2009	Marillana Iron Ore Project Vertebrate Fauna Assessment
Western Wildlife	2009	Phil's Creek Project Area Fauna Survey
Bamford Consulting Ecologists	2005	Fauna Survey of Proposed Cloudbreak Mine
Biota Environmental Sciences	2005	Fauna Habitats and Fauna Assemblage of the Proposed FMG Stage B Rail Corridor

2 Methods

2.1 Desktop Assessment

2.1.1 Sources of Information

Information on the fauna assemblage of the Project Area was drawn from a wide range of sources. These included State and Commonwealth government databases, BCE's local database and results of other recent baseline vertebrate fauna studies (see Section 1.6).

Furthermore, BCE undertook a desktop assessment and a comprehensive Level 2 trapping program at IOH's nearby Kurrajura tenement (located approximately 20 km north-east of Iron Valley). These surveys were conducted concurrently with the Iron Valley field surveys in May and September 2011 (BCE 2011b). Note that at the time of writing the Kurrajura tenement was no longer held by IOH, but the results of the survey and impact assessment have been used by BCE to support the findings at the Iron Valley Project.

Databases accessed by BCE include the Department of Environment and Conservation's (DEC) Naturemap (incorporating the Western Australian Museum's FaunaBase and the DEC Threatened and Priority Fauna Database), Birds Australia's Atlas Database (BA), Commonwealth EPBC Protected Matters Search Tool, Atlas of Living Australia database and BCE's local database (Table 3).

Information from the above sources was supplemented with species expected in the area based on general patterns of distribution from BCE's experience and broader literature. Sources of information used for these general patterns included:

- Allen *et al.* (2002) - freshwater fish;
- Tyler and Doughty (2009) - frogs;
- Storr *et al.* (1983); Storr *et al.* (1990); Storr *et al.* (1999); Storr *et al.* (2002) and Wilson and Swan (2008) - reptiles;
- Blakers *et al.* (1984); Johnstone and Storr (1998, 2004) and Barrett *et al.* (2003) - birds; and
- Strahan (1995); Menkhorst and Knight (2001); Strahan (2004); Churchill (2008); and Van Dyck and Strahan (2008) - mammals.

Table 3. Details of literature and database search.

Database	Type of records held on database	Area searched
NatureMap (DEC 2011)	Records in the WA Museum and DEC databases. Includes historical data and records on Threatened and Priority species in WA.	Point search from: 22°44' 5'' S, 119°18' 27'' E. Plus 40 km radius.
Birds Australia Atlas Database	Records of bird observations in Australia, 1998-2011.	Species list for the 1 degree grid cell containing: 22°44' 5'' S, 119°18' 27'' E.
EPBC Protected Matters Search Tool	Records on matters protected under the Commonwealth EPBC Act, including threatened species and conservation estate.	Point search from: 22°44' 5'' S, 119°18' 27'' E. Plus 10 km radius.
Atlas of Living Australia Database	Records of species distributions and mapping tools.	General area search: Pilbara Bioregion

2.1.2 Nomenclature and Taxonomy

As per the recommendations of EPA (2004), the nomenclature and taxonomic order presented in this report are based on the Western Australian Museum's *Checklist of the Vertebrates of Western Australia 2010*. The authorities used for each vertebrate group were: amphibians (Doughty and Maryan 2010a), reptiles (Doughty and Maryan 2010b), birds (Christidis and Boles 2008), and mammals (How *et al.* 2009). English names of species, where available, are used throughout the text; Latin species names are presented with corresponding English names in tables in the appendices.

2.1.3 Interpretation of Species Lists

Species lists generated from the review of information sources are generous as they include records drawn from a large region and possibly from environments not represented in the Project Area. Therefore, some species that were returned by one or more of the data searches have been excluded because their ecology, or the habitat types within the Project Area, meant that it was highly unlikely that these species would be present.

In general, however, species returned by the desktop review process are considered to be potentially present in the Project Area whether or not they were recorded during field surveys.

This is because fauna are highly mobile, often seasonal and frequently cryptic. This is particularly important for significant species that are often rare and hard to find during field investigations.

Interpretation of species lists generated through the desktop review included assigning an expected status to species of conservation significance that are likely to be present) within the Project Area. This is particularly important for birds that may naturally be migratory or nomadic, and for some mammals that can also be highly mobile or irruptive (or 'boom and bust' populations). The status categories used within this report are:

- Resident: species with a population permanently present in the Project Area;
- Regular migrant or visitor: species that occurs within the Project Area regularly in at least moderate numbers, such as part of an annual cycle;
- Irregular Visitor: species that occurs within the Project Area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades, but when the species is present, it utilises the Project Area in at least moderate numbers and for some time, such as weeks or months.
- Vagrant: species that occurs within the Project Area on an unpredictable basis, in small numbers and/or for very brief periods. Therefore, the Project Area is unlikely to be an important home range for the species; and
- Locally extinct: species that have not been recently recorded in the local area and for which adequate searches have been undertaken; therefore almost certainly no longer present in the Project Area.

2.2 Field Surveys

2.2.1 Overview

The field survey included several components:

1. targeted searching for conservation significant fauna including Western Pebble-mound Mouse and Mulgara transects, Elliott trapping for Northern Quoll, cave searching for Northern Quoll scats, and raking (raking through piles of loose soil and turning over fallen vegetation principally for reptiles);
2. use of motion-sensitive cameras;
3. bat surveys;
4. spotlighting;
5. opportunistic observations; and
6. habitat assessment.

The sampling methodology outlined in the Commonwealth Guidelines for the Northern Quoll was taken into consideration during the survey (DSEWPac 2011a). A summary of survey techniques used during the May and September field surveys is provided in Table 4.

Table 4. Details of survey techniques used in May and September surveys

Survey Techniques	First Survey Period 9-19 May 2011	Second Survey Period 29-30 September 2011
Targeted Western Pebble-mound Mouse and Mulgara transects	X	X
Elliott trapping (Northern Quoll)	X	
Targeted cave searches	X	X
Motion-sensitive cameras (Northern Quoll)	X	
Motion-sensitive cameras (Mulgara)	X	X
AnaBat surveys	X	X
Spotlighting	X	
Opportunistic observations and searching	X	X

2.2.2 Survey Timing and Weather Conditions

The timing of field surveys was determined by Guidance Statement 56 (EPA 2004), which states: “fauna and faunal assemblage surveys conducted for baseline information should be multiple surveys conducted in each season appropriate to the bioregion and the faunal group. The most important seasonal activity times for many faunal groups is related to rainfall and temperature. Thus, a survey in the season that follows the time of maximum rainfall is generally the most productive and important survey time. In some cases there may also be a need to time surveys according to the seasonal activity patterns of particularly important species (such as Specially Protected Fauna or Priority species) or particular assemblages (e.g. amphibians [and migratory birds])”. The two surveys were undertaken in May 2011, following summer rain, and in September 2011, following winter rain.

The first field survey was conducted between the 9th and 19th May 2011. During this period the weather was generally cool for the region with some light rainfall (approximately 8 mm, recorded at Marillana Meteorological Station during the survey period). The daily maximum temperatures recorded at Newman Meteorological Station during the survey period ranged from 18.8°C to 28.4°C (Bureau of Meteorology 2011).

The second field survey was conducted on the 29th and 30th of September 2011, when conditions were warm to hot. Daily maximum temperatures ranged from 34.2°C to 34.7°C (Bureau of Meteorology 2011). These periods are considered a suitable time for maximising trap captures in the north-west of Western Australia.

2.2.3 *Personnel and Licences*

Field work was conducted by:

- Dr Mike Bamford (B.Sc. Hons. Ph.D.)
- Natalia Huang (B.Sc. Hons.)
- Ian Harris (B.Sc. Hons.)
- Brendan Metcalf (B.Sc. Hons.)
- Robert Browne-Cooper (B.Sc.)
- Peter Smith (Dip. Ag.)
- Sarah Smith (B.Sc.)
- Gillian Basnett (B.Sc. MSc.)
- Dr John Scanlon (B.Sc. Hons. Ph.D. [Ecoscape])
- Claudia McHarrie (B.Sc. Hons. [Ecoscape])
- Cameron Everard (B.Sc.)

This document was prepared by Cameron Everard, Mike Bamford, Natalia Huang and Tim Gamblin (B.Sc.). The field surveys were conducted under DEC Regulation 17 licence number SF007970.

2.2.4 *Conservation Significant Species Targeted*

Significant fauna species identified during the desktop assessment include several species that can be found by targeted searching for evidence of their activities (e.g. scats, tracks, diggings and burrows), and opportunistic observations of these were recorded throughout the surveys. Species were targeted if they were considered likely to occur in the Project Area based on previous records and/or presence of suitable habitat.

The species targeted were:

- Pilbara Olive Python (*Liasis olivaceus barroni*);
- Northern Quoll (*Dasyurus hallucatus*);
- Bilby (*Macrotis lagotis*);
- Western Pebble-mound Mouse (*Pseudomys chapmani*);
- Mulgara (*Dasyercus cristicauda*)*;
- Ghost Bat (*Macroderma gigas*); and
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*).

*Note there was historical taxonomic confusion between the Crest-tailed Mulgara and the similar Brush-tailed Mulgara (*D. blythi*). This means that the distribution of the two Mulgara species is presently unclear, with even the identity of museum specimens being uncertain. The Brush-tailed Mulgara is listed as Priority 4 by the DEC in WA, but is not recognised under EPBC legislation (whereas the Crest-tailed Mulgara is). BCE has taken a precautionary approach in this instance and determined that the species that may occur within the Project Area is the Crest-tailed Mulgara that is listed under the EPBC Act (see Section 3.5.4). In a recent publication (DSEWPac 2011c), it is stated that the Crest-tailed Mulgara does not occur in WA, but as the EPBC Act stands now, DSEWPac would consider any Mulgara to be *D. cristicauda*.

2.2.5 Western Pebble-mound Mouse and Mulgara Transects

Targeted searches were carried out for the Western Pebble-mound Mouse (burrow systems) and Mulgara (burrows, foraging holes, tracks and scats) as there was suitable habitat for both species within and adjacent to the Project Area. Searching was approached systematically by walking with 2-3 personnel in a line, spaced about 20 m apart, so that a transect of a known length and width (and therefore area) was searched. Eight transects were carried out within the Project Area (Figure 5). A total area of 88 ha was surveyed by transects. All personnel involved in searching were familiar with the evidence of each species, or were trained by experienced personnel on site. All observations and locations of fauna were recorded. Transects were carried out throughout the Project Area in various habitat types (Figure 4). In addition, opportunistic observations of the Western Pebble-mound Mouse and Mulgara were recorded throughout the surveys, including in suitable habitat immediately outside the Project Area.

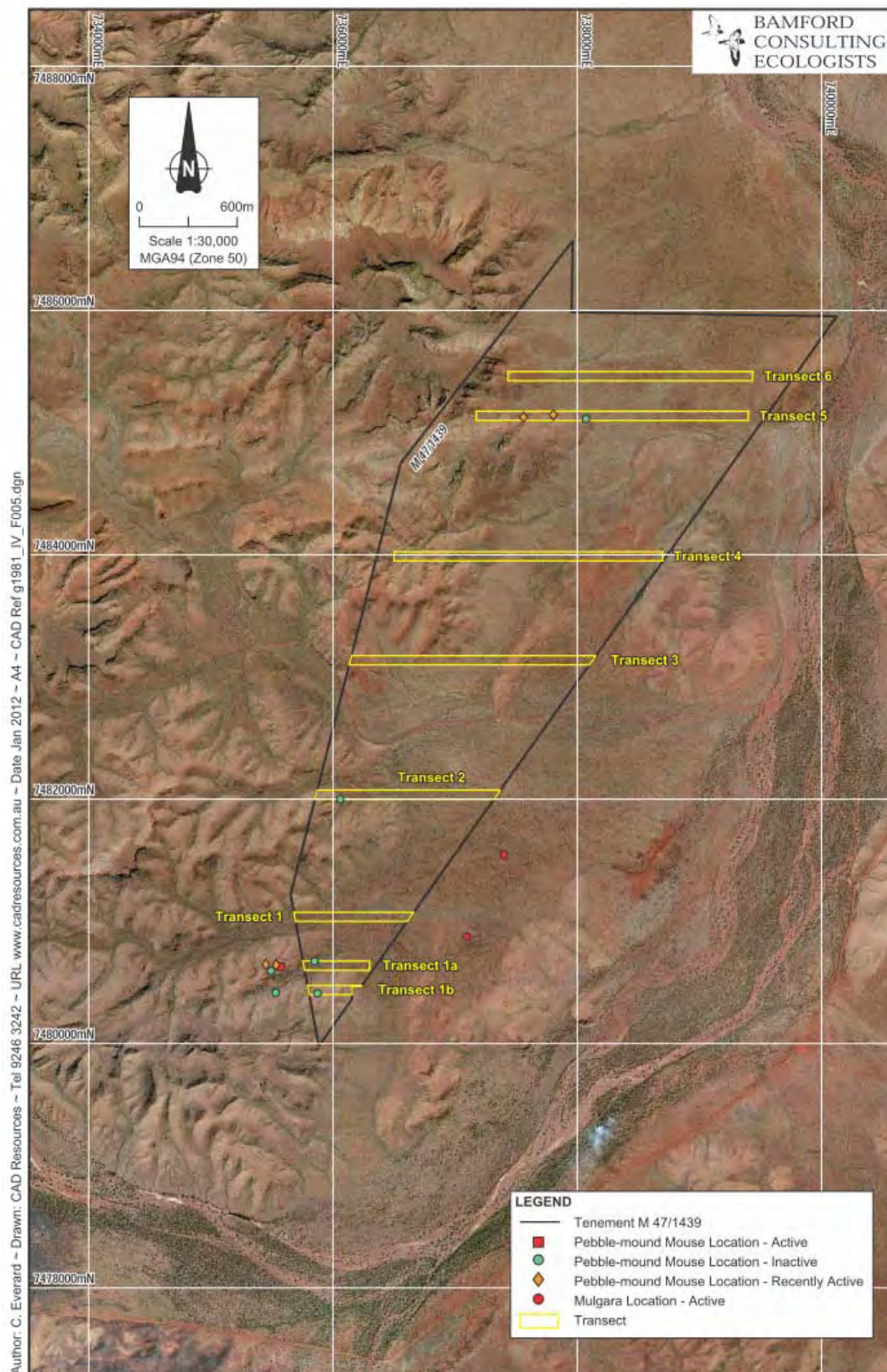


Figure 4. Locations of Western Pebble-mound Mouse and Mulgara transects and burrows. Tenement M 47/1439 indicates boundary of Project Area.

2.2.6 Elliott Traps and Cave Searches

A transect of ten Elliott traps was set in a rocky area where Northern Quoll were considered likely to occur. Elliott traps were spaced approximately 25 m apart and were set for five nights in May and were baited with universal bait (rolled oats, peanut paste and sardines). Locations of each Elliott trap are provided in Appendix 5 and shown in Figure 5. Targeted searches in potential suitable cave habitat were carried out in the Project Area and focused on locating possible roost sites of conservation significant bat species such as the Pilbara Leaf-nosed Bat and Ghost Bat, as well as any evidence of the Northern Quoll (e.g. scats).

2.2.7 Motion-sensitive Cameras

It was considered likely that the Northern Quoll may occur in the rocky environments of the Project Area (located on the western and eastern boundaries of the Project Area). This species can be difficult to detect but can be recorded using motion-sensitive cameras. These operate in daylight or at night, and were set in suitable rocky habitat with universal bait within the camera detection zone. Three cameras were set for four or eight nights in May in rocky areas to target the Northern Quoll (Table 5, Figure 5). Two cameras were also set in habitat considered suitable for Mulgara (low spinifex over sand); one camera was set for two nights in May and one camera was set for one night in September (Table 5, Figure 5). These locations were outside the Project Area (about 300 m east) and were selected on the basis of opportunistic evidence that the Mulgara was present. All species photographed were identified.

Table 5. Details of motion-sensitive camera surveys

Camera No.	Start Date	Finish Date	Survey Nights	Easting	Northing
BC2	14-5-2011	18-5-2011	4 nights	737045	7483998
BC4	14-5-2011	18-5-2011	4 nights	737440	7484672
BC6	10-5-2011	18-5-2011	8 nights	736045	7482976
Aud1	16-5-2011	18-5-2011	2 nights	737094	7480873
Aud5	29-9-2011	30-9-2011	1 night	737397	7481545

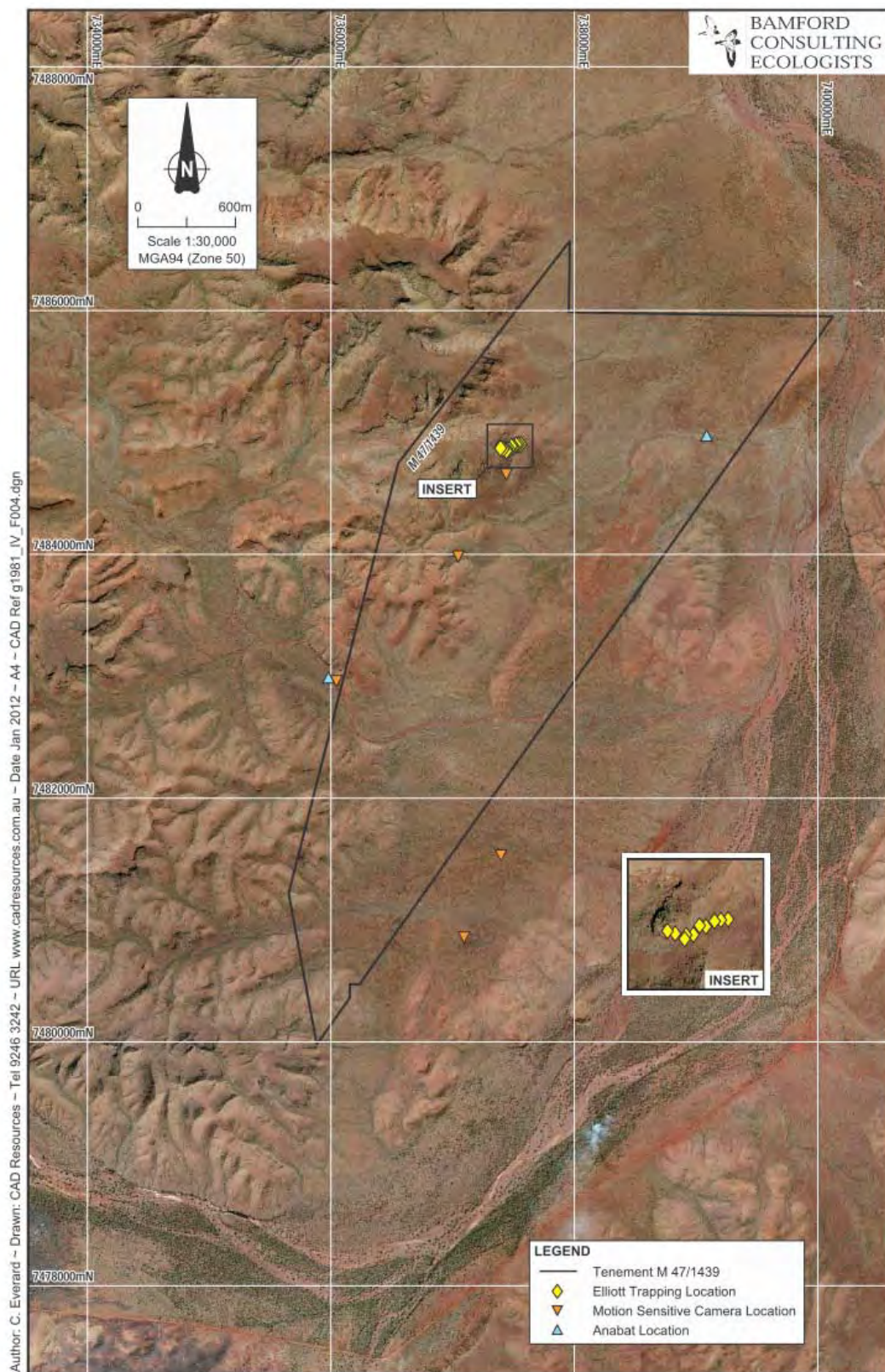


Figure 5. Location of Elliott traps, motion-sensitive cameras and AnaBat surveys. Tenement M 47/1439 indicates boundary of Project Area.

2.2.8 Bat Surveys

Bat echolocation calls were recorded using the AnaBat system (Titley Electronics, Ballina, NSW), where calls were recorded through the AnaBat II Bat Detector onto an audio recorder. At a later stage the recorded calls were assessed using AnaBat software to analyse the call characteristics. AnaBat detectors were set at two locations (14th May 2011: 736045E, 7482976N and 29th September 2011: 739087E, 7484960N; see Figure 4) within the Project Area. AnaBat recordings were analysed by Kyle Armstrong of Specialised Zoological and Brenden Metcalf (BCE). All species recorded were identified.

2.2.9 Spotlighting

Spotlighting was conducted both on foot, using head-torches (referred to as head-torching), and from a vehicle using the vehicle headlights and a hand-held spotlight. Where necessary, animals were captured for identification purposes and then released. Spotlighting was conducted during evenings on the 14th, 15th and 17th of May (three nights) when conditions were considered most suitable (on warm clear evenings).

2.2.10 Opportunistic Observations and Searching

Throughout both survey periods, opportunistic observations of fauna that contributed to the accumulation of information about the fauna of the Project Area were recorded. These included such casual observations as birds or reptiles seen while travelling through the site. Opportunistic searching for fauna, such as raking through leaf-litter and turning over logs, was also carried out throughout the Project Area. Such raking/searching involved about 10 person-hours of effort in the May survey.

2.2.11 Habitat Assessment

Vegetation and substrate associations (VSAs) were assessed during the desktop assessment and as part of the field survey investigations. A VSA combines broad vegetation types, soils or other substrate with which they are associated, and landform (see Appendix 1). This information on VSAs is supplemented in the Pilbara Region by a Land Systems Analysis (van Vreeswyk *et al.* 2004) that provides information on the regional distribution, abundance and management of these VSAs. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. Within the Project Area each major VSA was visited to develop an understanding of major fauna habitat types present and to assess the likelihood of conservation significant species being present in the area.

2.2.12 Summary of Field Effort

Across the May and September field trips, survey effort can be summarised as follows:

Field time: 60 person-days (estimated as some time shared between Iron Valley and Kurrajura).

Elliott traps 50 trapnights

Motion-sensitive cameras 19 camera-nights

Anabat recording 6 unit-nights

Cave searching 5 person-hours

Searching by raking 10 person-hours (May only)

Transect searching for burrows and tracks 20 person hours (estimated)

Spotlighting 3 nights

2.3 Impact Assessment

2.3.1 Fauna values and ecological processes

As outlined in Section 1.2, the impact assessment process involves identifying fauna values and reviewing impacting ecological processes. Fauna values include fauna assemblage and distribution, VSAs, and conservation significant fauna (see Appendix 1). Ecological processes that may impact upon these fauna values are discussed in Appendix 2, with processes specific to this project examined in Section 4.3. While some impacts are unavoidable during a development, of concern are long-term, deleterious impacts upon biodiversity. These are discussed under the following categories:

- VSAs. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna.
- Conservation significant fauna. Impacts may be significant if species of conservation importance are affected.
- Processes. Ecological processes are complex and can include hydrology, fire, predator/prey relationships and spatial distribution of a population (see discussion below). Impacts upon ecological processes may be significant if large numbers of species or large proportions of populations are affected.

2.3.2 Criteria for impact assessment

Impact assessment criteria are based on the severity of impacts on the fauna assemblage and conservation significant fauna, and were quantified on the basis of predicted population change (Table 6). Population change can be the result of direct habitat loss and/or impacts upon ecological processes.

Table 6. Criteria for impact assessment

Impact Category/Significance Level	Observed Impact
Negligible	No population decline
Minor	Short-term population decline (recovery after end of project) within survey area, no change in viability of conservation status of population
Moderate	Permanent population decline, no change in viability of conservation status of population
Major	Permanent population decline resulting in change in viability or conservation status of population
Critical	Taxon extinction

2.4 Limitations of Investigations

The EPA Guidance Statement 56 (EPA 2004) outlines a number of limitations that may arise during surveying of fauna. These survey limitations are discussed in the context of the BCE fauna survey at the Project Area, and detailed in Table 7.

Table 7. Survey limitations as outlined by EPA (2004).

EPA Limitation	BCE Comment
Level of survey.	The targeted survey approach was deemed adequate by the OEPA to identify significant fauna and habitats occurring in the Project Area, when combined with information from similar surveys undertaken in the region.
Competency/experience of the consultant(s) carrying out the survey.	The authors and project personnel have had extensive experience in conducting fauna assessments in the Pilbara Region.
Scope (What faunal groups were sampled and were some sampling methods not able to be employed because of constraints?).	The survey focussed on significant species (reptiles, mammals, bats and birds). A range of survey methods were undertaken.
Proportion of fauna identified, recorded and/or collected.	All vertebrate fauna observed (including from trapping etc) were identified.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	Sources include previous reports on the fauna of the region and databases (BCE, Naturemap, BA, DEC, ALA and EPBC).
The proportion of the task achieved and further work which might be needed.	The targeted survey is complete (two season survey).
Timing/weather/season/cycle.	Seasonal surveys were conducted from the 9 th to 19 th May and 29 th to 30 th September 2011. Conditions were cool during the May survey, which may have affected the presence and/or abundance of some species. Conditions were good (warm to hot) during the September survey.
Disturbances (e.g. fire, flood, accidental human intervention etc.), which affected results of survey.	No disturbances affected the survey. Recent fires may have affected the abundance and distribution of species such as the Mulgara.
Intensity (In retrospect, was the intensity adequate?).	Survey intensity was adequate to record conservation significant fauna and habitats.
Completeness (e.g. was relevant area fully surveyed).	Targeted survey is complete, but as noted above, some species not recorded may be present under different seasonal conditions, but the habitat assessment allows such species to be considered.
Resources (e.g. degree of expertise available in animal identification to taxon level).	All vertebrate species have been identified to species (sometimes sub-species) level. All survey personnel are adequately trained and deemed competent to conduct animal identification to taxon level.

Iron Valley Project Area - Fauna Assessment

EPA Limitation	BCE Comment
Remoteness and/or access problems.	No access problems were experienced.
Availability of contextual (e.g. biogeographic) information on the region.	Extensive regional information was available (including from another IOH survey conducted at the same time) and was consulted during the desktop assessment and results analysis.

3 Results

3.1 Threatened Ecological Communities

No Threatened Ecological Communities (TECs) were identified within the vicinity of the Project Area during the desktop review.

3.2 Vegetation and Substrate Associations

Three major VSAs were identified during the field investigations and are listed below from low to high in the landscape (see Plates 1 and 2).

1. Drainage Lines – characterised by mixed *Acacia* shrubs, *Triodia* and Buffel grass over clay soils (Boolgeeda land system);
2. Plains – comprising of flat plains of *Triodia* and mixed shrubland (Mulga) over clay loam soils with varying fire ages, with the occasional low stony rise in the landscape (Boolgeeda land system); and
3. Rocky Hills – Stony rocky hills dominated by *Triodia* on gravelly soils and rock outcrops. Lower slopes with scattered smooth bark Eucalypts, shrubs and *Triodia* over pebbles and stones (Newman land system).

Within the Project Area, the VSA Drainage Lines is likely to be most significant for fauna as it supports a key ecological process (hydrology) that maintains the fauna assemblage in the Project Area (see Section 3.6). The rocky hills also consisted of several steep cliffs and small caves with occasional Eucalypts over *Triodia*. These specialised habitats are important for significant species (e.g. Northern Quoll) and were the focus of targeted searches, Elliott trapping and motion-sensitive cameras.



Plate 1. Plains of *Triodia* over clay loam soils with rocky hills in the background.



Plate 2. Rocky hills with *Triodia* over rock and gravelly soils.

3.3 Vertebrate Fauna

3.3.1 Overview and Characteristics of Fauna Assemblage

The vertebrate fauna with the potential to occur (including those also recorded) in the Project Area is presented in Appendix 6. These lists are based largely upon known species distributions and available habitats, and exclude species that may have appeared in databases but are obviously likely on the site only as vagrants, such as seabirds, or for which the site has no suitable habitat, such as marine mammals (see Section 2.1.3).

The desktop assessment identified 293 vertebrate species potentially occurring in the Project Area, including: five frog, 105 reptile, 138 bird, 36 native mammal and nine introduced mammal species (Table 8). A total of 21 conservation significant species is considered likely to occur within the Project Area (either as a resident or as a visitor on seasonal basis, see Table 8). This includes two reptile (1 CS1, 1 CS2), 11 bird (5 CS1, 4 CS2, 2 CS3) and eight mammal (4 CS1, 4 CS2) species.

A total of 97 fauna species was recorded during the field survey. This comprised 1 one frog, 25 reptile, 58 bird, 11 native mammal and two introduced mammal species (Table 8 and Appendix 6). Five conservation significant fauna species were recorded during the field surveys (Appendix 6). Details of each conservation significant species expected to occur in the survey area are provided in Table 9, with details of conservation significance categories provided in Appendix 3.

Overall, the assemblage of vertebrate fauna expected to occur within the Project Area reflects the community structure of the Pilbara Region of Western Australia. The fauna assemblage is not considered unique, with the environment widespread in the region, and the assemblage considered typical of the region. In terms of completeness, the overall assemblage is lacking a few of the usual mammals but is otherwise substantially complete. Fauna expected include a number of terrestrial fauna that are unique to the region, such as the Pilbara Leaf-nosed Bat (*Rhinyonycteris aurantius*), the Pilbara Olive Python (*Liasis olivaceus barroni*) and the blind snake *Ramphotyphlops ganei*, and some more diverse representatives of northern and arid Australia. As a result, a diverse fauna assemblage is expected to occur across the Project Area where ranges of species with predominantly Torresian (tropical Australian) and Eyreaen (Inland Australian) distributions overlap.

Table 8. Composition of vertebrate fauna expected to occur and recorded within the Project Area

Taxon	Number of species expected	Number recorded	Significant fauna expected	Significant fauna recorded
Frogs	5	1	-	-
Reptiles	105	25	2	0
Birds	138	58	11	3
Native Mammals	36	11	8	2
Introduced Mammals	9	2	-	-
Total	293	97	21	5

Note: Survey focussed on targeting significant species and habitats compared to a usual Level 2 trapping program.

Iron Valley Project Area - Fauna Assessment

Table 9. Conservation significant fauna species expected to occur in the Project Area (conservation categories as defined in Appendix 3).

Species are considered likely to occur in the Project Area based on database searches, literature and authors' experience.

Species		EPBC Act 1999	WA Wildlife Conservation Act 1950	DEC Priority
Conservation Significance Level 1				
Pilbara Olive Python	<i>Liasis olivaceus barroni</i>	Vulnerable	Schedule 1	
Peregrine Falcon	<i>Falco peregrinus</i>		Schedule 4	
Night Parrot	<i>Pezoporus occidentalis</i>	Endangered	Schedule 1	
Fork-tailed Swift	<i>Apus pacificus</i>	Migratory	Schedule 3	
Rainbow Bee-eater	<i>Merops ornatus</i>	Migratory	Schedule 3	
Fork-tailed Swift	<i>Apus pacificus</i>	Migratory	Schedule 3	
Eastern Great Egret	<i>Ardea modesta</i>	Migratory	Schedule 3	
Northern Quoll	<i>Dasyurus hallucatus</i>	Endangered	Schedule 3	
Crest-tailed Mulgara	<i>Dasyurus cristicauda</i>	Vulnerable	Schedule 1	
Greater Bilby	<i>Macrotis lagotis</i>	Vulnerable	Schedule 1	
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantius</i>	Vulnerable		
Conservation Significance Level 2				
Blind snake	<i>Ramphotyphlops ganei</i>			Priority 1
Australian Bustard	<i>Ardeotis australis</i>			Priority 4
Bush Stone-curlew	<i>Burhinus grallarius</i>			Priority 4
Grey Falcon	<i>Falco hypoleucos</i>			Priority 4
Star Finch	<i>Neochmia ruficauda subclarescens</i>			Priority 4
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>			Priority 4

Iron Valley Project Area - Fauna Assessment

Species		EPBC Act 1999	WA Wildlife Conservation Act 1950	DEC Priority
Lakeland Downs Mouse	<i>Leggadina lakedownensis</i>			Priority 4
Long-tailed Dunnart	<i>Sminthopsis longicaudata</i>			Priority 4
Ghost Bat	<i>Macroderma gigas</i>			Priority 4
Conservation Significance Level 3				
Rufous-crowned Emu-wren	<i>Stipiturus ruficeps</i>			
Striated Grasswren	<i>Amytornis striatus</i>			

3.3.2 Western Pebble-mound Mouse and Mulgara Transects

Western Pebble-mound Mouse

Two recently active and four inactive Western Pebble-mound Mouse burrow systems (mounds) were recorded within the Project Area (Table 10, Figure 4). There were additional mounds observed opportunistically just outside (<500 m) the Project tenement boundary (Figure 4). Western Pebble-mound Mouse mounds were recorded in the northern and southern parts of the Project Area on the gravelly slopes of rocky hills. Most of the Pebble-mound Mouse activity and suitable habitat appeared to be outside the Project Area.

Table 10. Details of Western Pebble-mound Mouse mounds recorded

Western Pebble-mound Mouse mounds	Active mounds	Recently active mounds	Inactive mounds	Total number of mounds
Mounds recorded within the Project Area	0	2	4	6
Mounds recorded adjacent to the Project Area (<500m)	1	2	2	5

Mulgara

A single active Mulgara burrow was recorded just outside the south eastern tenement boundary in May 2011, on the flat *Triodia* plain with clay-loam soil (Zone 50, 737094E, 7480873N) (Figure 4). A motion-sensitive camera located next to this burrow system did not record any Mulgara. Opportunistic searching in the same area conducted in September 2011 identified a second active Mulgara burrow (Zone 50, 737397E, 7481545N). A Mulgara was recorded by a motion-sensitive camera at this burrow (see Section 3.3.4). These two burrows and the confirmed Mulgara were in the flat *Triodia* plains typical of the Boolgeeda land system, and lay about 300m from the boundary of the Project Area. Some of this land system is present in the Project Area, but it is more extensive to the north and north-west (Figure 6).

3.3.3 Elliott Traps and Cave Searches

No Northern Quoll or other mammal species were recorded from the Elliott trapping conducted in the rocky hills of the Project Area. Several cave systems throughout the Project Area were searched for signs of fauna activity, however most were considered too small for bats. Several Common Sheath-tail Bats (*Taphozous georgianus*) were recorded in one cave. No Northern Quoll activity (scats and tracks) were observed during cave searches.

Iron Valley Project Area - Fauna Assessment

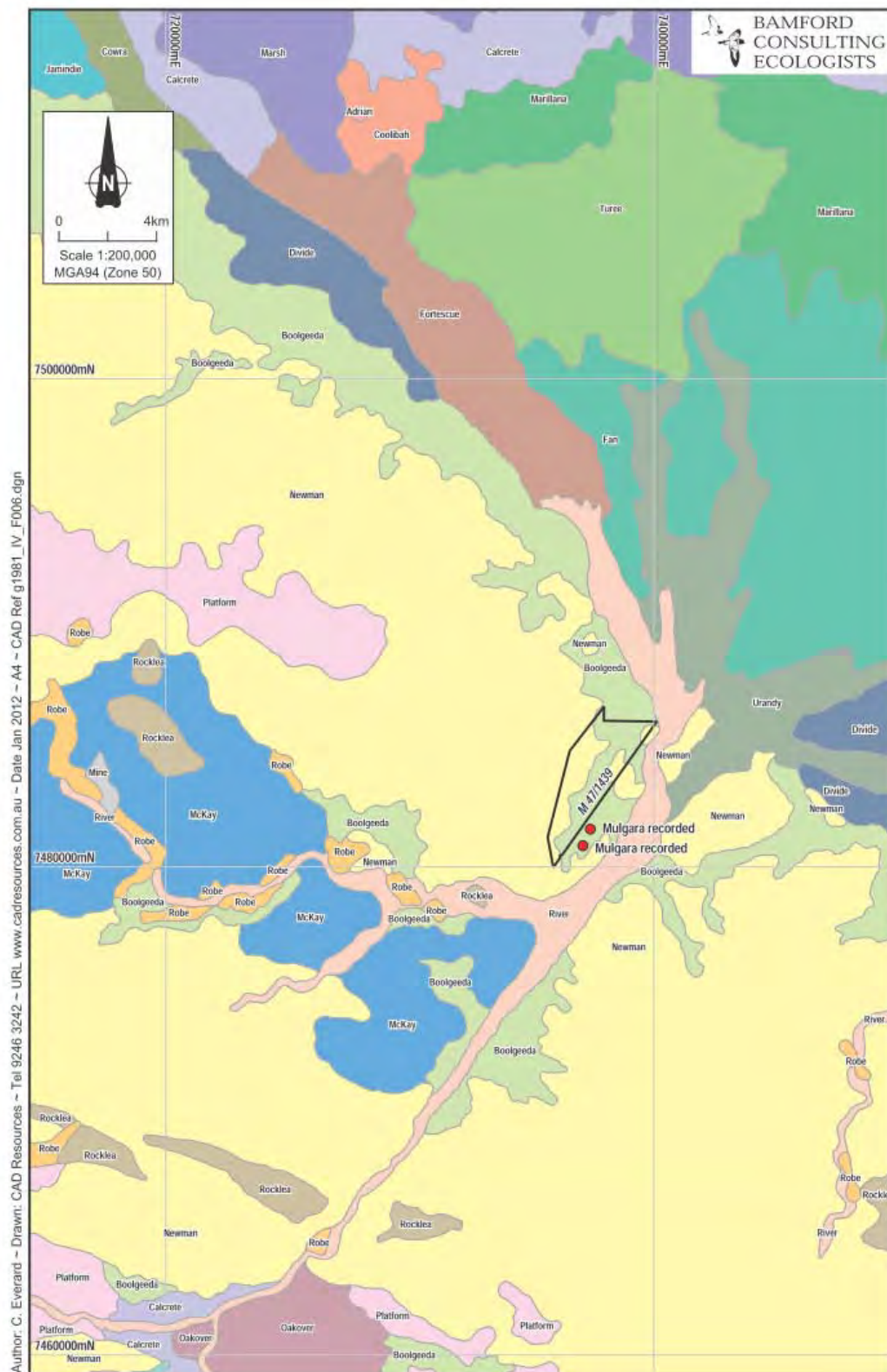


Figure 6. The Iron Valley Project Area, showing the extent of the Boolgeeda Land System (habitat for the Mulgara) and the location of Mulgara records near the Project Area.

3.3.4 Motion-sensitive Cameras

The Mulgara was recorded on a motion-sensitive camera, with no other species recorded (Plates 3 and 4). The individual was recorded at a burrow system found opportunistically (see Section 3.3.2). Although this record is located approximately 300 m outside the Project tenement boundary, it confirms the presence of Mulgara in the local area.



Plates 3 and 4. Mulgara confirmed outside of Project tenement boundary with motion-sensitive camera.

3.3.5 Bat Surveys

Six bat species were recorded through the AnaBat system from the Project Area during the two surveys and included: Yellow-bellied Sheathtail Bat *Saccolaimus flaviventris*, *Chaerephon jobensis*, Common Sheathtail Bat *Taphozous georgianus*, Gould's Wattled Bat *Chalinolobus gouldii*, *Scotorepens greyii* and *Vespadelus finlaysoni*. None of these species is of conservation significance. No calls of either the Ghost Bat or the Pilbara Leaf-nosed Bat were recorded.

3.3.6 Spotlighting

Eleven reptile species and 33 individuals (29 geckoes, one skink, one dragon and two snakes) were recorded while spotlighting (Appendix 6). All species observed are common to the region.

3.3.7 Opportunistic Observations

During the investigation, 96 species were opportunistically recorded including:

- One frog species;
- 25 reptile species;
- 12 mammal species (includes two introduced species); and
- 58 bird species.

Of the 25 reptile species observed, there were two dragons, 11 geckoes, seven skinks, two legless lizards and three snakes identified. All species recorded during the assessment are indicated in Appendix 6.

3.4 Patterns of Distribution and Abundance

Overall, the composition of the vertebrate fauna observed is as expected for the region (see Section 3.3.1). A number of general trends in the distribution and abundance of fauna can be drawn from the data.

As with the reptile assemblage, all of the birds recorded were expected. Many of the expected species not recorded during the survey are associated with environments (such as wetlands, large cave systems and deeply incised gorges), that are not present in the Project Area. In addition, a number of bird species expected but not recorded are likely to be either regular or intermittent visitors to the area.

Almost all the species that were confirmed are widespread, and despite targeted approaches being used to locate conservation significant-listed mammals such as the Bilby, Mulgara, Northern Quoll, Ghost Bat and Pilbara Leaf-nosed Bat, only two significant mammal species (the Mulgara and Western Pebble-mound Mouse) were recorded. This may in part be due to the lack of suitable habitat for some of these species. For example, the Bilby prefers a light sandy substrate and vegetation with different fire ages, while the Ghost Bat and Pilbara Leaf-nosed Bat prefer large, humid cave systems. Both habitat types were limited or absent within the Project Area, thus the two bat species might forage through the area (since they occur regionally) but are highly unlikely to have important roost sites within the Project Area. The rocky habitat appeared suitable for Northern Quoll, but the species was not recorded and the results of other surveys in the region indicate that the species is very scarce in this part of the Hamersley Ranges.

The Western Pebble-mound Mouse was found on the rocky hills and gravelly slopes of the Newman land system which occupies about half the Project Area (Figure 3), although not all the land system may be suitable for the species. Records were confined to the south of the Project Area despite searching more widely across the area.

As discussed, transect searching and motion-sensitive cameras confirmed the presence of Mulgara just outside the eastern part of the tenement within the flat *Triodia* plains of the Boolgeeda land system. This system occurs within the Project Area but is more extensive outside (to the north and west, see Figure 6). Numerous bird species including the Australian Bustard and Rainbow Bee-eater are also likely to forage throughout this area adjacent to the Project Area. Several frog and bird species are likely to use the drainage lines of the Boolgeeda and River and system to the east of the Project Area. The Pilbara Olive Python (if present), may also frequent the drainage lines in times of flooding to move through the Project Area in search of prey.

3.5 Conservation Significant Species

3.5.1 Overview

Of the 21 species of conservation significance expected to occur within the Project Area (Table 9), five species were recorded. These include the:

- Australian Bustard (CS2);
- Rainbow Bee-eater (CS1);
- Rufous-crowned Emu-wren (CS3)
- Mulgara (CS1); and
- Western Pebble-mound Mouse (CS2).

Conservation significant species can be difficult to detect and may not always be present for several reasons. Significant species that were recorded, their habitat and expected status (presence/absence) in the Project Area are presented in Table 11. Significant species are further discussed below under each taxon. Impacts upon significant species and management recommendations are discussed in Section 4. Appendix 7 presents additional information on areas of land systems and vegetation types both within the lease area and within 15km of the lease area. Proportional impacts on vegetation types within the lease area and on land systems within 15km are indicated, and the importance of each vegetation type and land system to each significant species is considered.

Table 11. Status of conservation significant species likely to occur in the Project Area.

Preferred habitat derived from literature (Section 2.1.1).

Species	Recorded in Project Area	Habitat	Expected status in Project Area
Conservation Significance Level 1			
Pilbara Olive Python <i>Liasis olivaceus barroni</i>		Generally associated with riverine woodland areas, gorges and large rock holes and swamps.	Likely resident
Peregrine Falcon <i>Falco peregrinus</i>		Habitat generalist favouring areas with cliffs and abandoned nests in tall, wooded forests.	Likely resident
Night Parrot <i>Pezoporus occidentalis</i>		Mature spinifex grasslands and chenopod Shrublands, particularly where the two are closely juxtaposed. Fortescue Marsh is a current hotspot for the species.	Uncertain; may be cryptic resident or irregular visitor
Fork-tailed Swift <i>Apus pacificus</i>		Nomadic aerial forager following low pressure storm systems, with no reliable reports of them coming to land.	Irregular visitor
Rainbow Bee-eater <i>Merops ornatus</i>	Recorded	Any habitat suitable for hawking for insects. Breeds in a wide variety of sandy habitats.	Regular migrant
Eastern Great Egret <i>Ardea modesta</i>		Extensive wetlands of the Fortescue Marshes, however no wetlands in the Project Area but individuals may visit nearby Weeli Wolli Creek.	Irregular visitor
Northern Quoll <i>Dasyurus hallucatus</i>		Rocky and broken country in open Eucalypt forest.	Irregular visitor
Crest-tailed Mulgara <i>Dasyercus cristicauda</i>	Recorded nearby	Mature Spinifex grasslands on sandy substrates.	Irregular visitor

Iron Valley Project Area - Fauna Assessment

Species	Recorded in Project Area	Habitat	Expected status in Project Area
Bilby <i>Macrotis lagotis</i>		Woodlands and grasslands on sandplains and dunefields, often close to drainage systems.	Probably locally extinct
Pilbara Leaf-nosed Bat <i>Rhinonictes aurantius</i>		Roosts in warm humid caves, likely to forage throughout Project Area	Regular visitor
Conservation Significance Level 2			
Blind snake <i>Ramphotyphlops ganev</i>		Uncertain; may prefer moist gorges and gullies or grasslands, Shrublands and woodlands.	Resident
Australian Bustard <i>Ardeotis australis</i>	Recorded	Open or lightly-wooded grasslands and shrublands.	Resident
Bush Stone-curlew <i>Burhinus grallarius</i>		Grassy woodlands with minimal to no human disturbance.	Resident
Grey Falcon <i>Falco hypoleucos</i>		Habitat generalist including shrubland, grassland and wooded watercourses.	Resident
Star Finch <i>Neochmia ruficauda subclarescens</i>		Grasslands near water.	Regular visitor
Western Pebble-mound Mouse <i>Pseudomys chapmani</i>	Recorded nearby	Hummock grassland on skeletal soils containing an abundance of small pebbles on spurs and the lower slopes of ridges.	Resident
Lakeland Downs Mouse <i>Leggadina lakedownensis</i>		Cracking clays and adjacent habitats in open shrublands and hummock and tussock grasslands.	Uncertain
Long-tailed Dunnart <i>Sminthopsis longicaudata</i>		Scree slopes surrounding rock hills and mesas.	Likely Resident
Ghost Bat <i>Macroderma gigas</i>		Roosts in warm humid caves, likely to forage throughout Project Area	Regular visitor

Iron Valley Project Area - Fauna Assessment

Species	Recorded in Project Area	Habitat	Expected status in Project Area
Conservation Significance Level 3			
Rufous-crowned Emu-wren <i>Stipiturus ruficeps</i>	Recorded	Spinifex, often including at least some long-unburnt	Resident
Striated Grasswren <i>Amytornis striatus</i>		Spinifex, often including at least some long-unburnt	Resident

3.5.2 Reptiles

Two conservation significant reptile species are expected to occur in the Project Area. Neither of these species was recorded during the surveys.

Conservation Significance Level 1 (CS1)

Pilbara Olive Python (*Liasis olivaceus barroni*)

The Pilbara Olive Python is listed as Schedule 1 (Vulnerable) under the WA Wildlife Conservation Act and Vulnerable under the Commonwealth's EPBC Act. This subspecies is restricted to ranges within the Pilbara Region and is often recorded near waterholes (Wilson and Swan 2008). In some locations this species is considered stable and in sizeable numbers (Pearson 2003).

Pilbara Olive Pythons occur in rocky areas such as gorges, caves and rock crevices, and can also burrow beneath rocks or shelter in hollow logs. They are often associated with water and may also search for prey in grassy areas surrounding rocky outcrops (DSEWPac 2011b). The Pilbara Olive Python has been recorded from the Weeli Wolli Creek area (DEC 2011) and may move through the river system through the Project Area. It is therefore likely to be present along major drainage lines in times of flooding and rocky habitats throughout the Project Area.

Conservation Significance Level 2 (CS2)

Ramphotyphlops ganei

The blind snake *Ramphotyphlops ganei* is listed as Priority 1 by DEC. Only described as a new species in 1998 (Aplin 1998), virtually nothing of the ecology or biology of *Ramphotyphlops ganei* is known. Wilson and Swan (2008) suggest that it may be associated with moist gorges and gullies. The species is known only from a small number of voucher specimens collected from the region (DEC 2011). This species has also been recorded from ironstone ridge slopes and crests (BCE database). It is considered likely that the species is present in the Project Area, but is difficult to detect due to its cryptic nature.

3.5.3 Birds

Eleven conservation significant bird species are expected to occur in the Project Area, with three of these recorded during the field surveys.

Conservation Significance Level 1 (CS1)

Rainbow Bee-eater (*Merops ornatus*) - Recorded

The Rainbow Bee-eater is listed as Migratory under the Commonwealth's EPBC Act. It was recorded within the Project Area during the surveys. It is likely to be a breeding visitor (spring to autumn) to the Project Area as suitable breeding habitat exists. It is found in almost any habitat suitable for hawking for insects, but is usually restricted to the better-watered regions (Johnstone and Storr 1998). The Rainbow Bee-eater breeds in a wide variety of sandy habitats across much of the state, in the north Kimberley, on the Swan Coastal Plain and in the south west and east as far as Twilight Cove (Johnstone and Storr 1998). Although the Rainbow Bee-eater is listed under the EPBC Act as Migratory and recognised by the Japan-Australia Migratory Bird Agreement (JAMBA), this is a widespread species that is opportunistic in its use of habitat. The Rainbow Bee-eater was observed within the Boolgeeda land system of the Project Area.

Peregrine Falcon (*Falco peregrinus*)

The Peregrine Falcon is listed as Schedule 4 (Other Specially Protected Fauna) under the WA Wildlife Conservation Act. This species occurs in a variety of habitats, and may breed in the Project Area, possibly utilising tree hollows in ephemeral riverine habitat or cliff ledges along gullies and hills (Johnstone and Storr 1998). This species was recorded during the Kurrajura tenement area survey (located approximately 20 km north-west of Iron Valley), which was undertaken concurrently with the Iron Valley survey, and may be nesting in the area in nearby cliff-faces.

The distribution of the Peregrine Falcon is often tied to the abundance of prey as this species predares heavily on other birds. The Peregrine Falcon lays its eggs in recesses of cliff faces, tree hollows or in large abandoned nests of other birds (Birds Australia 2011). The Peregrine Falcon mates for life with pairs maintaining a home range of about 20-30 km² throughout the year. Blakers *et al.* (1984) consider that Australia is one of the strongholds of the species, since it has declined in many other parts of the world. The Peregrine Falcon has also been recorded in the general vicinity of the Project Area (Birds Australia 2011).

Night Parrot (*Pezoporus occidentalis*)

The Night Parrot is listed as Schedule 1 (critically endangered) under the WA Wildlife Conservation Act, and as endangered under the Commonwealth's EPBC Act. This is a poorly-known species with very few recent records in Australia. The only recent verified record of this species in the Pilbara Region is from the northern side of the Fortescue Marsh on Mulga Downs

Station, some 40km from the Project Area (Davis and Metcalf 2008). Little is known of the species' habitat requirements, however many recent records come from Spinifex grasslands and chenopod shrublands (Birds Australia 2011), although Higgins (1999) lists a wide range of vegetation types utilised by the species. Several surveys by BCE and other consultants to locate this species have been unsuccessful. This species is considered a likely resident or regular nomadic visitor within the Fortescue Marsh, and may be an irregular visitor to the Project Area.

Fork-tailed Swift (*Apus pacificus*)

The Fork-tailed Swift is listed as Migratory under the Commonwealth's EPBC Act. This is a largely aerial species that occurs independent of terrestrial habitat types and is likely to be an irregular visitor to the Project Area.

Eastern Great Egret (*Ardea modesta*)

The Fortescue Marshes situated approximately 30 km north of the Project Area are important for migratory waterbirds, but in general the Project Area does not provide suitable habitat for these species. The Eastern Great Egret is one species that may occasionally forage up minor watercourses and thus could occur in the Project Area, but only as an irregular visitor in small numbers.

Conservation Significance Level 2 (CS2)

Australian Bustard (*Ardeotis australis*) - Recorded

The Australian Bustard is listed as Priority 4 by the DEC and inhabits grasslands. This species was recorded in the Project Area in the flat *Triodia* plains and is likely to vary in abundance seasonally and annually. The Australian Bustard is considered common in the Pilbara, with suitable habitat being widespread. It is likely to be a resident in the Project Area.

Bush Stone-curlew (*Burhinus grallarius*)

This species is listed as Priority 4 by the DEC. In the Pilbara, the Bush Stone-curlew it is often associated with woodlands and shrublands along ephemeral or permanent watercourses (M. Bamford pers. obs.). Although not recorded during the surveys, this species may be present within the Project Area, but is notoriously cryptic when not calling; furthermore, the calling season can be unpredictable. The Bush Stone-curlew has been recorded north of the Project Area (approximately 30 km) in the vicinity of the Fortescue Marsh (DEC 2011, BCE database).

Grey Falcon (*Falco hypoleucos*)

The Grey Falcon is listed as Priority 4 by the DEC. It appears to have a distribution centred around ephemeral or permanent drainage lines and may breed in the Project Area, utilising old nests of other species situated in the tallest trees along drainage systems (Garnett and Crowley 2000). The Grey Falcon has been recorded on the northern side of the Fortescue Marsh (BCE

database), and is very likely to be resident along major river systems (such as Weeli Wolli Creek) in the region.

Star Finch (*Neochmia ruficauda subclarescens*)

This species is listed as Priority 4 by the DEC. The western race of the Star Finch is generally found in and around grassland near water (Slater *et al.* 2003, Simpson and Day 2004, Slater *et al.* 2003). The Star Finch has been recorded approximately ten km south-west of the Iron Valley Project at Rio Tinto's Yandicoogina operations (Biota 2010). Due to a lack of suitable riparian grasslands and rushes in the Project Area, this species is likely to be only an occasional visitor.

Conservation Significance Level 3 (CS3)

Rufous-crowned Emu-wren (*Stipiturus ruficeps*)

Striated Grasswren (*Amytornis striatus*)

The Rufous-crowned Emu-wren and Striated Grasswren have a scattered distribution in the Pilbara and are associated with long-unburnt spinifex. When found they are often only present in low numbers. Their presence in the Project Area would be of conservation interest due to their patchy distribution and reliance on rare habitat.

3.5.4 Mammals

Eight conservation significant mammal species are expected to occur in the Project Area, with two of these recorded during the field surveys.

Conservation Significance Level 1 (CS1)

Northern Quoll (*Dasyurus hallucatus*)

The status of the Northern Quoll has recently been upgraded to Endangered under the Commonwealth's EPBC Act. This change in status is due to the negative impact of the Cane Toad *Bufo marinus* in the north and east of the Northern Quoll's range, and the threat of Cane Toads in the west of its range.

This species inhabits rock crevices, tree hollows and termite mounds. The Northern Quoll is often associated with rocky areas in the Pilbara but also occurs along watercourses. The Northern Quoll formerly occurred across much of northern Australia from the Pilbara to Brisbane, but now occurs in a number of fragmented populations across its former range (DSEWPac 2011b).

Opportunistic searching, Elliott trapping and the use of motion-sensitive cameras for the Northern Quoll did not detect any evidence of the species within the Project Area. There are very few confirmed records of the species in the Hamersley Ranges south of the Fortescue Marshes (DEC 2011), and therefore it is expected only as an occasional visitor in the Project Area even though there is suitable habitat present, with no evidence of resident and substantial populations. The species has been recorded approximately 25 km south of the Project Area near Hope Downs (Biota 2011) with several unconfirmed sightings at Rio Tinto's Yandicoogina operations ten km away (Biota 2010).

Crest-tailed Mulgara (*Dasyercus cristicauda*)

The Crest-tailed Mulgara is listed as Vulnerable under the Commonwealth's EPBC Act. The Crest-tailed Mulgara prefers mature spinifex grasslands on sandy substrates across the arid zone of Western Australia (Woolley 1995). Suitable mulgara habitat is present in the eastern section of the Project Area (lower parts of the landscape) and outside the Project Area/tenement. Although not recorded inside the Project Area, two active Mulgara burrows and a confirmed sighting (by motion-sensitive camera) were recorded outside the south eastern boundary of the

Project Area. There is more extensive habitat (Boolgeeda Land System) to the north and north-west of the Project Area. It is expected that this species persists in low numbers throughout the region. Note that the record from near the Project Area is the only recent confirmation of the species on the south side of the Fortescue Marshes. There are several recent (e.g. 2009) database records from the north side of the Fortescue Marshes.

There may be a certain “boom and bust” nature to the lifestyle of the Mulgara, with populations contracting to core habitat during poor seasons for resources such as low rainfall, and expanding rapidly when the conditions improve (Woolley 1995). Further, Woolley (1995) cites examples of local populations disappearing for several years before being re-invaded and repopulated by Mulgara in subsequent years.

Note that there is uncertainty regarding the distribution of the Crest-tailed Mulgara and the similar Brush-tailed Mulgara (*D. blythi*). For most of the last 30 years only the Crest-tailed Mulgara was recognised. More recently, Woolley (2005, 2006) re-assigned the species to the Brush-tailed Mulgara and Crest-tailed Mulgara. The historical taxonomic confusion means that the distribution of the two Mulgara species is unclear (Woolley 2005, 2008) and even museum specimens need to be reviewed. However, both species have suffered significant population reduction and fragmentation over the past 80 years (Woolley 2008). The Brush-tailed Mulgara is listed as Priority 4 by the DEC in WA, but is not recognised under EPBC legislation (whereas the Crest-tailed Mulgara is). As the specimen was recorded by motion-sensitive camera only, and could not be identified to species level, BCE has taken a precautionary approach, and determined that the species is the Crest-tailed Mulgara that is listed under the EPBC Act. Under the current EPBC list, any Mulgara found in WA is considered to be *D. cristicauda* by DSEWPaC. However, a recent publication by DSEWPaC (2011c) does recognise the revised taxonomy and states that *D. cristicauda* does not occur in WA. This does not alter the EPBC listing but the situation should be discussed with DSEWPaC.

Bilby (*Macrotis lagotis*)

The Bilby is listed as Vulnerable under the Commonwealth’s EPBC Act and Schedule 1 under the WA Wildlife Conservation Act. It is also listed as Vulnerable (VU C2a) by the IUCN Red List. Once very widespread, the Bilby is now confined to northern and mostly inland locations of Australia, particularly sandy deserts where they have an affinity for dunefields (Moseby and O'Donnell 2003) and *Acacia* shrublands associated with paleo-drainage systems (M. Bamford pers. obs.). Johnson (1995) suggests that populations of the species in central Australia are still declining and fragmenting, and Lavery and Kirkpatrick (1997) suggest that very small populations may leave traces that incorrectly suggest much larger numbers and healthier populations exist than is actually the case. There are some historic (early 1980s) records of the Bilby on Marillana Station (N. Dunlop pers. comm.) but the species is probably locally extinct. It is quite an easy species to locate when present because of its distinctive tracks, burrows and foraging holes, however is unlikely to occur in the Project Area on the basis of lack of suitable habitat and confirmed records.

Pilbara Leaf-nosed Bat (*Rhinonicteris aurantius*)

The Pilbara Leaf-nosed Bat is classified as Vulnerable by Duncan *et al.* (1999), the Commonwealth's EPBC Act and the WA Wildlife Conservation Act. The Pilbara Leaf-nosed Bat has very specific requirements for roosting caves, which need to provide a stable, hot (28 – 32 °C) and very humid (96 – 100%) environment. There was no evidence of such caves within the Project Area, but the species is likely to be a foraging visitor and transient animals may even roost overnight in crevices and tree hollows, with such habitats present in rocky areas and along drainage lines in the Project Area.

Lakeland Downs Mouse (*Leggadina lakedownensis*)

This species is listed as Priority 4 by the DEC and listed as Low Risk / Near Threatened (LR/NT) by the IUCN Red List. Covacevich (1995) notes that this species is secretive and apparently rare, yet notes that the only two known voucher collections were made at sites where the mice were common enough to be hand-captured. This suggests that the species persists in a “boom-bust” life cycle. Biota (2005) cite a forthcoming publication that states the number of records of the species has increased, and note most of their captures have been made on cracking clays and adjacent habitats in open shrublands and hummock and tussock grasslands. This species was not recorded during the surveys but may be a resident (but highly variable in abundance) in the area.

Conservation Significance Level 2 (CS2)

Western Pebble-mound Mouse (*Pseudomys chapmani*) - Recorded

The status of the Western Pebble-mound Mouse has recently been downgraded from Schedule 1 under the WA Wildlife Conservation Act to DEC Priority 4. The Western Pebble-mound Mouse inhabits hummock grassland areas of *Triodia*, *Cassia*, *Acacia* and *Ptilotus* on skeletal soils containing an abundance of small pebbles (Start and Kitchener 1995). These conditions are most common on spurs and the lower slopes of ridges within the Project Area. Transect surveys identified two recently active and four inactive Western Pebble-mound Mouse burrow systems within the Project Area, confirming this species as present and resident. A further one active, two recently active and inactive burrow systems were identified outside (<500m) the Project boundary.

Long-tailed Dunnart (*Sminthopsis longicaudata*)

The Long-tailed Dunnart is listed as Priority 4 by the DEC. This species occupies scree slopes surrounding rock hills and mesas, but little is known of their biology (Burbidge *et al.* 1995). Four specimens from the Pilbara, all from areas in the south of the biogeographical region, have been lodged with the Western Australian Museum. The closest specimens were recorded just west of Newman (DEC 2011) and also at Mt Nicholas, east of the Fortescue Marshes (Biota 2010). Current understanding of the breeding biology (Woolley and Valente 1986) suggests that they probably exhibit a “boom-bust” lifestyle. This species may be a resident within the

Boolgeeda land system and may occur throughout the Hamersley Ranges, including within the Project Area.

Ghost Bat (*Macroderma gigas*)

The Ghost Bat is listed as Priority 4 by the DEC, Vulnerable by the IUCN, and Lower Risk (near threatened) by Duncan *et al.* (1999). The Ghost Bat formerly occurred over a wide area of central, northern and southern Australia, however has declined significantly in the southern parts of its range in the last 200 years (DSEWPC 2011b). It now occurs in only a few highly disjunct sites across northern Australia and in Western Australia is now confined to the Kimberley and Pilbara.

The distribution of Ghost Bats is influenced by the availability of suitable caves and mines for roost sites. The preferred roosting habitats of Ghost Bats in the Pilbara are deep, complex caves beneath bluffs of low rounded hills composed of Marra Mamba geology, Brockman Iron Formations, granite rock-piles and abandoned mines (Armstrong and Anstee 2000). Churchill (2008) notes that the Ghost Bat has a preference for caves with warm and humid microclimates (27°C, 80% humidity).

The Ghost Bat is carnivorous, feeding on large insects, spiders, termites and many types of small vertebrates, including birds, reptiles and other bats (Churchill 2008). It forages over an area of approximately 60 ha, within a radius of approximately two km from its roost, with up to 20 bats having overlapping ranges (Armstrong and Anstee 2000). However, BCE (unpubl data) caught a Ghost Bat (mist-net) flying over the samphire of the Fortescue Marshes (probably >5 km from the nearest possible roost). The Ghost Bat is also known from the Hope Downs rail corridor, West Angeles and Weeli Wolli Springs (Biota 2005). There is unlikely to be suitable habitat for the species to roost within the Project Area, but it may be a regular foraging visitor.

3.6 Ecological Processes upon which Fauna depend

There are several ecological processes upon which fauna and ecosystems depend, with certain processes making ecosystems more sensitive to change than others (see Appendix 4). Within the Iron Valley Project Area, the key ecological process of importance to the fauna assemblage is considered to be hydrology. The fauna are likely to rely on the hydrological situation remaining intact and changes to this process (and the VSA Drainage Lines) may result in potentially significant changes to local fauna populations. Potential impacts on ecological processes relevant to the Project are discussed in the following section.

4 Impact Assessment

Potential impacts from the Project upon fauna are assessed in accordance with EPA Guidance Statement No. 56 (EPA 2004) and considered under the categories outlined in Section 2.3.1: impacts to VSAs, conservation significant fauna and ecological processes that may affect the fauna assemblage. These are discussed in the following sections.

4.1 Vegetation and Substrate Associations

The significance of impacts upon VSAs is related to the fauna they support and the degree of impact from the proposed development. The main VSAs in the Project Area are described in Section 3.2 above. Potential impacts and significance of each VSA within the Project Area is discussed in Table 12. Appendix 7 gives details of how the proposed disturbance to VSAs in the project area may affect conservation significant species on a local scale.

Habitats and VSAs of conservation significance tend to be those that are both rare across the landscape and that are important for significant species and/or for biodiversity. In particular, one VSA within the Project Area is regionally restricted, supports high proportions of conservation significant fauna and may be highly susceptible to impacts from the Project. This VSA is:

- Drainage Lines – characterised by mixed *Acacia* shrubs, *Triodia* and Buffel grass over clay soils (Boolgeeda land system).

The Drainage Lines VSA may be particularly sensitive to changes in surface hydrology, with any changes potentially leading to significant impacts to local fauna populations. Impacts to this VSA are considered to be minor to moderate (Table 12). The Plains VSA is expected to experience a minor to moderate impact from the Project due to habitat loss and fragmentation (Table 12). It is widespread in the region but may support conservation significant fauna. Impacts on the Rocky Hills VSA are expected to be minor with little of such habitat present in the impact area (Table 12). Cumulative impacts with other mining projects in the region also need to be considered. Table 13 compares the areas of all local land systems and the land systems found within the project area. In the case of the Boolgeeda land systems, 5.2% of this system present within 15km of the lease area falls within the lease. In comparison, only 1.4% of the only other land system represented in the lease area, Newman, lies within the lease area.

Table 12. Potential impacts and significance of VSAs within Project Area

VSA	Representation	Conservation Significance	Possible Impacts	Significance of Impact
Drainage Lines - characterised by mixed <i>Acacia</i> shrubs, <i>Triodia</i> and buffel grass over clay soils. Boolgeeda land system	Restricted in region. Drainage lines feed into the Weeli Wolli Creek east of the Project Area.	Potentially supports a rich fauna, including significant fauna, and may provide nesting habitat for conservation significant fauna.	Project Area extends across several creeklines and has the potential to cause some hydrological disruptions to surface flow, including loss and fragmentation of important fauna habitat.	Minor to Moderate. Habitat fragmentation and changes to hydrology may impact fauna; also loss of large habitat trees may impact breeding of some species.
Plains – comprising of flat plains of <i>Triodia</i> and mixed shrubland over clay loam soils with varying fire ages, with the occasional low stony rise. Boolgeeda land system	Patchily distributed although widespread regionally, although the majority is in good condition. Covers the northern, central and south-eastern parts of the Project Area.	Has a diverse vertebrate fauna and is likely to provide core habitat to several conservation significant fauna, including Mulgara (confirmed), Lakeland Downs Mouse (unconfirmed) and Australian Bustard (confirmed).	Considerable loss and fragmentation of this VSA.	Moderate to minor. VSA is restricted and patchy outside impact areas, and represents a large component of the proposed development footprint. Habitat fragmentation may impact some conservation significant fauna.
Rocky Hills – Stony rocky hills dominated by <i>Triodia</i> on gravelly soils and rock outcrops. Lower slopes with scattered Eucalypts, shrubs and <i>Triodia</i> over pebbles and stones Newman land system	Widespread in the region and the majority in good condition. Mostly confined to the western and southern parts of the Project Area, and extending into the ridges of the Hamersley Ranges outside the Project Area.	Has the most depauperate fauna association within the Project Area, but with potentially some habitat specialist conservation significant fauna such as the Northern Quoll, Ghost Bat and Pilbara Leaf-nosed Bat.	Some loss of this VSA, however most is outside the impact area.	Minor as little direct impact. VSA is widespread outside Project Area, and only represents a small part of the project footprint.

Table 13. Area of local (15km radius) land systems and land systems found within Project Area

Land System	Area Within 15km Radius of Boundary (ha)	Area Within Lease M47/1439 (ha)
Adrian	31.04	0
Boolgeeda	10473.06	540.41
Calcrete	7805.11	0
Coolibah	1453.90	0
Cowra	234.83	0
Divide	6241.71	0
Fan	19726.86	0
Fortescue	5714.53	0
Marillana	13248.25	0
Marsh	5415.55	0
McKay	8809.62	0
Newman	39881.75	546.38
Oakover	2515.82	0
Pindering	18.68	0
Platform	3738.23	0
River	6366.60	0
Robe	1031.81	0
Rocklea	2130.24	0
Turee	10885.97	0
Urandy	10495.97	0

4.2 Conservation Significant Species

Among the fauna species of conservation significance, impacts on most species are expected to be negligible or minor (Table 14). Potential impacts on conservation significant species expected to occur in the Project Area are discussed in Table 14. Species where impacts may be of concern are:

- Pilbara Olive Python – recorded from Weeli Wolli Creek, species at low population density, restricted in habitat selection such as drainage lines and sensitive to roadkill;
- Night Parrot – species very poorly known so impact hard to predict; species is highly significant, although unlikely in the Project Area;
- Mulgara – species present adjacent to the Project Area with limited suitable habitat within the Project Area. There is probably a low density population throughout suitable habitat (Boolgeeda Land System) in the region, and this may be sensitive to a range of impacting processes such as cumulative habitat loss from multiple development projects in the region, altered fire regimes, livestock grazing and feral predators;
- Bush Stone-curlew – species at low population density and sensitive to roadkill and feral predators;
- Lakeland Downs Mouse – species not recorded, however highly variable and may be present; and
- Pebble-mound Mouse – species present in Project Area and sensitive to habitat loss.

Appendix 7 examines the proportional impact of the proposed development upon habitat of each species of conservation significance. Habitat is not necessarily the same for each species, and was initially defined based upon land systems and vegetation types that corresponded with the known habitat preferences (Appendix 7; Table 1). Vegetation type correlates most closely with preferred habitat, but for proportional impacts (within a 15km radius of the project area), the habitat for each species within the clearing footprint, based on land system or vegetation type, can only be compared with the total area of corresponding land system, since vegetation mapping for the greater area is not available. This correlation is not exact for each species but it does provide a sense of scale of the extent of preferred habitat being cleared within the wider area. The percentage impacts are presented in Appendix 7 and also in Table 14. Whichever approach is taken percentage impacts are low; most below 1% but for a few species reliant upon the Boolgeeda land system as high as 3.82%.

For key species of conservation interest (listed under the EPBC Act: Crest-tailed Mulgara, Northern Quoll and Pilbara Olive Python), habitat was also defined through interpretation of the preferred habitat with respect to land systems and vegetation types. For each of these species,

preferred habitat within and immediately adjacent to the tenement is illustrated in Appendix 7. This approach allows for a different calculation of proportional impact within a 15km radius of the project area.

For each species, area of habitat within disturbance footprint is calculated in three ways: based upon land systems, based upon vegetation type and based upon an interpretation of both vegetation type and land system that reflects the known habitat preference of the species (interpreted habitat). Proportional local impacts within 15km radius (in parenthesis) are based upon land systems as only these are mapped outside the lease area.

These proportional impacts are provided in Table 2 of Appendix 7. Proportional impacts using habitat areas based upon the interpretation of land systems and vegetation types are low. For the three species of greatest conservation interest, percentage impacts are as follows:

Crest-tailed Mulgara – 3.36% (based on vegetation type) to 3.82% (based on land system or interpreted habitat) of habitat within 15km falls within the clearing footprint;

Pilbara Olive Python – 0.13% (based on vegetation type) to 0.6% (based on land system) of habitat within 15km falls within the clearing footprint;

Northern Quoll – 0.17% (based on interpreted habitat) to 0.7% (based on land system) of habitat within 15km falls within the clearing footprint.

Table 14. Potential impacts on conservation significant species expected to occur in the Project Area

Descriptions of each species are given in Section 3.5. Potential impacts include threatening processes as listed in Appendix 2. Impact assessment criteria as defined in Section 2.3.2. Proportional impacts on preferred habitat within 15km of the project area are presented in parentheses, where different methods of interpreting habitat result in different proportional impacts the higher value is used, for all values see Appendix 7.

Species	Potential impacts	Impact Assessment
Conservation Significance Level 1		
Pilbara Olive Python <i>Liasis olivaceus barroni</i>	Some loss and fragmentation of habitat. Potential roadkill. (0.6%)	Minor. Suitable habitat is outside Project Area.
Peregrine Falcon <i>Falco peregrinus</i>	Possibility of loss of a nest site. (0.7%)	Negligible
Night Parrot <i>Pezoporus occidentalis</i>	Possibly some loss of habitat and possibility of increased mortality on roadsides. (~1.35%)	Minor. Status of species in Project Area is not known, however unlikely to be present regularly in the Project Area.
Fork-tailed Swift <i>Apus pacificus</i>	None as mainly aerial species. (1.35%)	Negligible
Rainbow Bee-eater <i>Merops ornatus</i>	Some localised loss of breeding habitat. (2.45%)	Minor. Species very widespread.
Eastern Great Egret <i>Ardea modesta</i>	Impact unlikely due to lack of suitable habitat (wetlands) in the Project Area, although may use drainage lines intermittently. (0.94%)	Negligible
Northern Quoll <i>Dasyurus hallucatus</i>	Low possibility of some loss of habitat. (0.7%)	Minor. Core habitat is outside the Project Area and population in region not confirmed.
Crest-tailed Mulgara <i>Dasymercus cristicauda</i>	The species is sensitive to landscape scale impacts such as fire regimes, livestock grazing and feral species, which are not directly related to the proposal. There may also be cumulative impacts due to habitat loss from multiple resource development projects in the region. (3.82%)	Minor-Moderate. Species may utilise habitats within and outside the Project Area, and is susceptible to several impacts. The individuals located are probably part of a low density population across the Boolgeeda Land System in the region. The impact of the proposed

Iron Valley Project Area - Fauna Assessment

Species	Potential impacts	Impact Assessment
		development is Minor to Moderate because only a small amount of suitable habitat will be directly impacted.
Bilby <i>Macrotis lagotis</i>	Impact unlikely as species probably locally extinct. If present, could lose some habitat and be affected by roadkill, altered fire regimes and changes in abundance of feral species. (3.93%)	Minor. Species probably locally extinct. Fire management and feral control as part of environmental stewardship could benefit species.
Pilbara Leaf-nosed Bat <i>Rhinonictis aurantius</i>	Some loss of foraging habitat. No roosting habitat expected in Project Area. (0.7%)	Minor. Core roosting habitat is outside the Project Area.
Conservation Significance Level 2		
blind snake <i>Ramphotyphlops ganei</i>	Some loss and fragmentation of habitat. (2.45%)	Minor. Status of species is uncertain.
Australian Bustard <i>Ardeotis australis</i>	Some loss of habitat and possibility of increased mortality on roadsides. (3.82%)	Minor. Species is widespread and versatile in natural and altered habitats.
Bush Stone-curlew <i>Burhinus grallarius</i>	Some loss of breeding habitat, feral predation and possibility of increased mortality on roadsides. (2.38%)	Minor. Species is widespread but generally in low numbers.
Grey Falcon <i>Falco hypoleucos</i>	Low possibility of loss of a nest site. (0.94%)	Negligible
Star Finch <i>Neochmia ruficauda subclarescens</i>	Some loss of habitat. (0.94%)	Minor. Species is widespread and suitable habitat in Project Area is limited.
Western Pebble-mound Mouse <i>Pseudomys chapmani</i>	Some loss of habitat. (0.7%)	Moderate. Habitat is also outside the Project Area but project will contribute to cumulative habitat loss for this species.
Lakeland Downs Mouse <i>Leggadina lakedownensis</i>	Habitat loss, fragmentation and feral predation. (2.45%)	Minor. Habitat is also outside the Project Area but project will contribute to cumulative habitat loss for this species.
Long-tailed Dunnart <i>Sminthopsis</i>	Low possibility of some loss of habitat. (0.7%)	Minor. Core habitat is outside the

Iron Valley Project Area - Fauna Assessment

Species	Potential impacts	Impact Assessment
<i>longicaudata</i>		Project Area.
Ghost Bat <i>Macroderma gigas</i>	Some loss of foraging habitat. No roosting habitat expected in Project Area. (0.7%)	Minor. Core habitat is outside the Project Area.
Conservation Significance Level 3		
Rufous-crowned Emu-wren <i>Stipiturus ruficeps</i>	Habitat loss and fragmentation. (3.93%)	Minor. Habitat exists outside of Project Area.
Striated Grasswren <i>Amytornis striatus</i>	Habitat loss and fragmentation. (3.93%)	Minor. Habitat exists outside of Project Area.

4.3 Ecological Processes

4.3.1 Loss of Habitat Leading to Population Decline

The proposed development lies on land that may be broadly categorised as undeveloped, and has previously been used for rangelands pastoralism. These areas constitute native vegetation that will be affected by the proposed development, and the extent to which these areas will be impacted is uncertain. Since the area is surrounded by similar VSAs and land systems that will remain unaffected by this project, the proportional loss of fauna habitats will generally be low. However, cumulative impacts may also need to be considered. Of the VSAs identified, the Boolgeeda land system is extensively targeted for mining and while generally low in biodiversity, is favoured by the Pebble-mound Mouse and Mulgara. Therefore substantial disturbance in the region could result in some population declines.

4.3.2 Loss of Habitat Leading to Population Fragmentation

The Project Area lies on the Newman and Boolgeeda land systems and therefore the extent of fragmentation will depend initially upon the amount of vegetation disturbed and the pattern in which this disturbance is undertaken. If small blocks are excised from the surrounding landscape without disruption, then the impact on fragmentation will be low. If the landscape is disturbed in a mosaic pattern of disturbance then the impact will be higher. The effectiveness of rehabilitation may or may not mitigate these impacts. Mining within the central region of the Project Area may fragment fauna which is restricted to the Boolgeeda land system between the northern and south-eastern parts, although this may not be an issue. It should be noted that numerous other mining projects are proposed for the region from companies such as FMG, BHP Billiton and Rio Tinto, which may lead to further fragmentation of habitat.

4.3.3 Increased Mortality

Mortality of fauna during clearing and other operations is inevitable, but ongoing mortality may be significant for larger species that may have low population sizes. The major source of ongoing mortality is likely to be roadkill affecting mammals such as kangaroos, Bilby (if present), and Mulgara, and larger reptiles such as monitor lizards and snakes (potentially including Pilbara Olive Python). The Australian Bustard and Bush Stone-curlew are also sensitive to roadkill but individuals are highly mobile and therefore localised mortality is unlikely to have a significant impact on their populations.

4.3.4 Hydrological changes

Changes in hydrology within the landscape may result from the Project, particularly where drainage lines are affected, and may lead to significant impacts to the local fauna. The area of greatest concern is the ephemeral creek lines located within the flat spinifex plains of the Boolgeeda land system and the Weeli Wolli Creek (River land system) located to the south and east of the Project Area (Figure 2). Roads,

mining pits, waste dumps and other infrastructure from the project may alter both surface and sub-surface hydrology. Stormwater diversion and drainage from the project may alter the current flow regime, increase infiltration into new areas and decrease waterflow in other areas downstream. Changes to hydrology may impact fauna that use the drainage lines for breeding, such as amphibians and some conservation significant species.

4.3.5 Species Interactions, including Predation and Competition

The fauna assemblage in the Project Area and region includes species sensitive to predation by feral species such as the Fox and Feral Cat. In addition, feral species such as the Rabbit can affect rehabilitation. Vegetation degradation by cattle overgrazing can make fauna more vulnerable to additional impacts, particularly in vegetation along the drainage lines. Feral species often increase in abundance due to disturbance and human activities, but the project also provides opportunities for the control of feral species (see Section 5).

4.3.6 Dust, Noise, Light and Disturbance

Impacts of dust, noise, light and disturbance upon fauna are difficult to predict, but some experience from existing mines in the South-West (Worsley and Alcoa operations), and other operations in the Pilbara (BHP Billiton Nimingarra, Cattle Gorge, Sunrise Hill) suggest that fauna, including fauna of conservation significance, are tolerant of these forms of disturbance. Exceptions include species that have very specific refugial habitat requirements, such as the Pilbara Leaf-nosed Bat and the Ghost Bat, but neither of these species is expected to have major roosts within the Project Area due to a lack of suitable habitat. Generally, impacts of such disturbances are poorly documented, but the introduction of light has the potential to attract fauna to the area and alter species interactions or lead to increased roadkill.

4.3.7 Changes in Fire Regime

The Project is likely to increase the potential for bushfire in the region because of ignition sources from machinery and increased human activity. Van Vreeswyk *et al.* (2004) suggest that the Newman and Boolgeeda land systems are naturally subject to fire, and therefore they may be at high risk of increased fire events and intensity as a result of the development. Changing fire regimes have direct (*i.e.* loss of individuals) and indirect (*i.e.* population depression) effects on the fauna of the Project Area, particularly some conservation significant taxa, and it is important that this risk be recognised and managed. In addition to the impacts of fire, van Vreeswyk *et al.* (2004) note that these land systems are subject to increased erosion if the vegetation is removed (either directly or by fire).

4.3.8 *Summary of Impacts to Ecological Processes*

Of the impacting processes, concerns can be summarised as follows:

- Loss of habitat leading to population decline – possibly some concern in the Boolgeeda land system within the Project Area. Cumulative impacts with other mining in the region need to be considered;
- Loss of habitat leading to population fragmentation – may be a concern along the Boolgeeda land system as the project may lead to fragmentation and disrupt fauna movement;
- Increased mortality – of concern for some fauna species, especially Pilbara Olive Python, Australian Bustard and Bush Stone-curlew;
- Hydrological changes – possible downstream effects along the River land system of Weeli Wolli Creek and potential impacts to local fauna populations, but effects expected to be limited to local changes in surface hydrology.;
- Species interactions – such interactions are already occurring. There is potential for both negative and positive impacts from the proposed project upon feral species;
- Dust, noise, light and disturbance – impacts uncertain but some precautions are advised; and
- Changes in fire regime – a major ecological factor in the region's fauna with potential for both negative and positive impacts from the proposed project.

The Project has the potential to impact most significantly upon the hydrology in the area, with any changes to hydrology considered to have the greatest impact upon local fauna populations.

4.4 Summary by EPA Guidance

According to criteria set out in the EPA Guidance Statement No. 56, the impacts of the project upon fauna in the survey area can be summarised as given in Table 15.

Table 15. Summary of potential impacts of the Project on fauna as assessed following the guidance of the EPA's Guidance Statement No. 56.

Factor	Scale and Nature of Impact (EPA No. 56)	Explanation
Degree of habitat degradation or clearing within the local area or region	Low	Project Area is largely undisturbed, so project will introduce disturbance into the local area where there is little current disturbance. The VSAs proposed for disturbance are not regionally restricted, however they could provide potential core habitat for multiple conservation significant fauna. Fragmentation is unlikely to impart ongoing impacts.
Size/scale of proposal/impact	Low	Project is comparatively small within the region.
Rarity of vegetation and landforms	Low	The project proposes to disturb the Newman and Boolgeeda land systems, which are regionally common.
Refugia	Low	Typical refugial habitat (e.g. cliffs and gorges) are also common outside of the Project Area. Some of the habitats with the Project Area, such as large trees, may provide important habitat for species.
Fauna protected under international agreements or treaties, Specially Protected or Priority Fauna	Moderate	Several species of conservation significance may be impacted; of greatest interest to the project are the Northern Quoll, Mulgara, Pebble-mound Mouse and Pilbara Olive Python.
Size of remnant and condition/intactness of habitat and faunal assemblage	Low	Remnants are mostly large and contiguous within and outside the Project Area. Fragmentation is unlikely to impart ongoing impacts.
Ecological linkage	Low	Many of the conservation significant fauna within the habitats are not particularly susceptible to fragmentation impacts. Fragmentation is unlikely to impart ongoing impacts.
Heterogeneity or complexity of the habitat and faunal assemblage	Moderate	Habitats are complex.

5 Management Recommendations

The impact assessment (Section 4) identified a range of impacts upon fauna that could result from the proposed development. Management strategies are recommended below to reduce these potential impacts on fauna species.

5.1 Loss of Habitat

The loss of habitat from vegetation clearing should be minimised where possible, for example, by avoiding clearing/disturbance of native vegetation where possible, minimising the disturbance footprint, clearly delineating the permitted clearing area and progressively rehabilitating disturbed areas as soon as practical.

5.2 Fragmentation of Habitat

Habitat fragmentation is a concern because while the landscape consists mainly of flat plains and rocky hills, there are some linear environments such as the distribution of the Boolgeeda land system through the centre of the Project Area and the Weeli Wolli Creek system (although located outside the Project Area). The fauna in these linear environments may be particularly sensitive to fragmentation. Areas of particular concern are the northern, central and south-eastern regions of the Project Area as these areas are within the proposed mine pits.

Potential effects of fragmentation can be minimised by limiting footprint size and by planning the disturbance areas in discrete blocks, rather than in a mosaic pattern that results in many small, discontinuous fragments. Furthermore, infrastructure such as roads and even pipelines can affect fauna movements. Placement of such infrastructure should be considered to avoid dividing blocks of contiguous habitat. Roads should be unbunded where possible, since even this may be enough to disrupt the movement of small animals (including conservation significant fauna such as the Mulgara and Lakeland Downs Mouse), while pipelines can be raised or buried to avoid limiting movement of small, terrestrial species. Rehabilitation can be used selectively to facilitate linkage.

5.3 Increased Mortality during Operations

Some mortality is inevitable during operations and sources of ongoing mortality could include collision with vehicles or striking infrastructure. Fauna may be attracted into mine areas in search of food, such as dead insects underneath lights. Mortality from collision with vehicles can be reduced through education of mine personnel (inductions), and implementing minimum speed limits (for example, some mine-sites have speed limits of 60 to 80 km/h during the day, and 50 km/h during the evening and night). In areas of known wildlife activity signs should be placed to alert drivers.

5.4 Hydrological Changes

Hydrological changes have the potential for impacts of minor to moderate significance, with changes potentially leading to impacts upon local fauna populations, including conservation significant species. Efforts should be made to avoid significantly changing the hydrology of the area. Such efforts could include the usage of waste dumps and drainage sumps. It is understood that the project will not

require de-watering. The potential for impacts upon hydrology along drainage lines needs to be investigated, especially surrounding the Weeli Wolli Creek to the south and east of the Project Area.

5.5 Species Interactions

Factors that are likely to attract feral species or lead to increases in local populations of feral species should be minimised, for example, by implementing standard waste management measures for foodstuffs to limit introduced species' access to food resources. The presence of feral species, such as the feral Cat, Fox and Cattle, should be discouraged. It is recommended that a feral fauna control program should be established in consultation with the Western Australian Agriculture Department and the Department of Environment and Conservation (DEC).

5.6 Dust, Noise, Light and Disturbance

Disturbances from these factors are poorly understood, but a precautionary approach is recommended. Management strategies to reduce possible impacts on fauna from disturbances could include directing lighting away from areas of native vegetation, and implementing dust suppression and traffic management strategies.

5.7 Changes in Fire Regime

The Project should not become a source of unplanned fires which will require a system of fire-awareness and management. This should be development in consultation with a fire management specialist. Note there is potential for conservation benefits from a fire management plan that aims to reintroduce something approaching the natural fire regime that probably consisted of frequent but small less-intense fires.

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7 Appendices

Appendix 1. Explanation of fauna values

Fauna values are the features of a site and its fauna that contribute to biodiversity, and it is these values that are potentially at threat from a development proposal. Fauna values can be examined under the five headings outlined below. It must be stressed that these values are interdependent and should not be considered equal, but contribute to an understanding of the biodiversity of a site. Understanding fauna values provides opportunities to predict and therefore mitigate impacts.

Assemblage characteristics

Uniqueness. This refers to the combination of species present at a site. For example, a site may support an unusual assemblage that has elements from adjacent biogeographic zones, it may have species present or absent that might be otherwise expected, or it may have an assemblage that is typical of a very large region. For the purposes of impact assessment, an unusual assemblage has greater value for biodiversity than a typical assemblage.

Completeness. An assemblage may be complete (ie. has all the species that would have been present at the time of European settlement), or it may have lost species due to a variety of factors. Note that a complete assemblage, such as on an island, may have fewer species than an incomplete assemblage (such as in a species-rich but degraded site on the mainland).

Richness. This is a measure of the number of species at a site. At a simple level, a species rich site is more valuable than a species poor site, but value is also determined, for example, by the sorts of species present.

Vegetation and substrate associations (VSAs)

VSAs combine broad vegetation types, the soils or other substrate with which they are associated, and the landform. In the context of fauna assessment, VSAs are the environments that provide habitats for fauna. The term habitat is widely used in this context, but by definition an animal's habitat is the environment that it utilises (Calver *et al.* 2009), not the environment as a whole. Habitat is a function of the animal and its ecology, rather than being a function of the environment. For example, a species may occur in eucalypt canopy or in leaf-litter on sand, and that habitat may be found in only one or in several VSAs. VSAs are not the same as vegetation types since these may not incorporate soil and landform, and recognise floristics to a degree that VSAs do not. Vegetation types may also not recognise minor but often significant (for fauna) structural differences in the environment. VSAs also do not necessarily correspond with soil types, but may reflect some of these elements.

Because VSAs provide the habitat for fauna, they are important in determining assemblage characteristics. For the purposes of impact assessment, VSAs can also provide a surrogate for detailed information on the fauna assemblage. For example, rare, relictual or restricted VSAs should automatically be considered a significant fauna value. Impacts may be significant if the VSA is rare, a large proportion of the VSA is affected and/or the VSA supports significant fauna. The disturbance of even small amounts of habitat in a localised area can have significant impacts to fauna if rare or unusual habitats are disturbed.

Patterns of biodiversity across the landscape

This fauna value relates to how the assemblage is organised across the landscape. Generally, the fauna assemblage is not distributed evenly across the landscape or even within one VSA. There may be zones of high biodiversity such as particular environments or ecotones (transitions between VSAs). There may also be zones of low biodiversity. Impacts may be significant if a wide range of species is affected even if most of those species are not significant *per se*.

Species of conservation significance

Species of conservation significance are of special importance in impact assessment. The conservation status of fauna species in Australia is assessed under Commonwealth and State Acts such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the *Western Australian Wildlife Conservation Act 1950* (Wildlife Conservation Act). In addition, the Western Australian Department of Environment and Conservation (DEC) recognises priority levels, while local populations of some species may be significant even if the species as a whole has no formal recognition. Therefore, three broad levels of conservation significance can be recognised and are used for the purposes of this report and are outlined below. A full description of the conservation significance categories, schedules and priority levels mentioned below is provided in Appendix 3.

Conservation Significance (CS) 1: Species listed under State or Commonwealth Acts.

Species listed under the EPBC Act are assigned to categories recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994), or are listed as migratory. Migratory species are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA), the Republic of South Korea Australia Migratory Bird Agreement (ROKAMBA), and/or the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals). The Wildlife Conservation Act uses a series of Schedules to classify status, but also recognizes the IUCN categories.

Conservation Significance (CS) 2: Species listed as Priority by the DEC but not listed under State or Commonwealth Acts.

In Western Australia, the DEC has produced a supplementary list of Priority Fauna, being species that are not considered threatened under the Wildlife Conservation Act but for which the DEC feels there is cause for concern. Some Priority species are also assigned to the Conservation Dependent category of the IUCN.

Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

This level of significance has no legislative or published recognition and is based on interpretation of distribution information, but is used here as it may have links to preserving biodiversity at the genetic level (EPA 2002). If a population is isolated but a subset of a widespread (common) species, then it may not be recognised as threatened, but may have unique genetic characteristics. Conservation significance is applied to allow for the preservation of genetic richness at a population level, and not just at a species level. Species on the edge of their range, or that are sensitive to impacts such as habitat fragmentation, may also be classed as CS3, as may colonies of waterbirds. The Western Australian Department of Environmental Protection, now DEC (2000), used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of the Perth Bushplan.

Invertebrate species considered to be short range endemics (SREs) also fall within the CS3 category, as they have no legislative or published recognition and their significance is based on interpretation of distribution information. Harvey (2002) notes that the majority of species that have been classified as short-range endemics have common life history characteristics such as poor powers of dispersal or confinement to discontinuous habitats. Several groups, therefore, have particularly high instances of short-range endemic species: Gastropoda (snails and slugs), Oligochaeta (earthworms), Onychophora (velvet worms), Araneae (mygalomorph spiders), Pseudoscorpionida (pseudoscorpions), Schizomida (schizomids), Diplopoda (millipedes), Phreatoicidea (phreatoicidean crustaceans), and Decapoda (freshwater crayfish). The poor understanding of the taxonomy of many of the short-range endemic species hinders their conservation (Harvey 2002).

Introduced species

In addition to these conservation levels, species that have been introduced (INT) are indicated throughout the report. Introduced species may be important to the native fauna assemblage through effects by predation and/or competition.

Ecological processes upon which the fauna depend

These are the processes that affect and maintain fauna populations in an area and as such are very complex; for example, populations are maintained through the dynamic

Iron Valley Project Area - Fauna Assessment

of mortality, survival and recruitment being more or less in balance, and these are affected by a myriad of factors. The dynamics of fauna populations in a project may be affected by processes such as fire regime, landscape patterns (such as fragmentation and/or linkage), the presence of feral species and hydrology. Impacts may be significant if processes are altered such that fauna populations are adversely affected, resulting in declines and even localised loss of species. Threatening processes as outlined below are effectively the ecological processes that can be altered to result in impacts upon fauna.

Appendix 2. Explanation of threatening processes

Potential impacts of proposed developments upon fauna values can be related to threatening processes. This is recognised in the literature and under the EPBC Act, in which threatening processes are listed (see Appendix 4). Processes that may impact fauna values with respect to mining are discussed below. Processes specific to the project are discussed in Section 5. Rather than being independent of one another, processes are complex and often interrelated. They are the mechanisms by which fauna can be affected by development. Impacts may be significant if large numbers of species or large proportions of populations are affected. Impacting processes are outlined below.

Loss of habitat affecting population survival

Clearing for a development can lead to habitat loss for a species with a consequent decline in population size. This may be significant if the smaller population has reduced viability. Conservation significant species or species that already occur at low densities may be particularly sensitive to habitat loss affecting population survival.

Loss of habitat leading to population fragmentation

Loss of habitat can affect population movements by limiting movement of individuals throughout the landscape as a result of fragmentation. Obstructions associated with the development, such as roads, pipes and drainage channels, may also affect movement of small, terrestrial species. Fragmented populations may not be sustainable and may be sensitive to effects such as reduced gene flow.

Increased mortality

Increased mortality can occur during project operations; for example from roadkill, animals striking infrastructure and entrapment in trenches. Roadkill as a cause of population decline has been documented for the Eastern Barred Bandicoot, *Perameles gunni* ((Dufty 1989), Eastern Quoll, *Dasyurus viverrinus* and Tasmanian Devil *Sarcophilus harrisii* ((Jones 2000). Increased mortality due to roadkill is often more prevalent in habitats that have been fragmented ((Scheick and Jones 1999; Clevenger and Waltho 2000; Jackson and Griffin 2000).

Increased mortality of common species during development is unavoidable and may not be significant for a population. However, the cumulative impacts of increased mortality of conservation significant species or species that already occur at low densities may have a significant impact on the population.

Species interactions, including predation and competition

Changes in species interactions often occur with development. Introduced species, including the feral Cat, Fox and Rabbit may have adverse impacts upon native species and development can alter their abundance. In particular, some mammal species are very sensitive to introduced predators and the decline of many mammals in Australia has been linked to predation by the Fox, and to a lesser extent the feral Cat (Burbidge and McKenzie 1989). Introduced grazing species, such as the Rabbit, Goat, Camel and domestic livestock, can also degrade habitats and deplete vegetation that may be a food source for other species.

Changes in the abundance of some native species at the expense of others, due to the provision of fresh watering points, can also be a concern. (Harrington 2002) found the presence of artificial fresh waterpoints in the semi-arid mallee rangelands to influence the abundance and distribution of certain bird species. Common, water-dependent birds were found to out-compete some less common, water-independent species. Over-abundant native herbivores, such as kangaroos, can also adversely affect less abundant native species through competition and displacement.

Hydroecology

Interruptions of hydroecological processes can have major effects because they underpin primary production in ecosystems and there are specific, generally rare habitats that are hydrology-dependent. Fauna may be impacted by potential changes to groundwater level and chemistry and altered flow regime. These changes may alter vegetation across large areas and may lead to habitat degradation or loss. Impacts upon fauna can be widespread and major.

Changes to flow regime across the landscape may alter vegetation and may lead to habitat degradation or loss, affecting fauna. For example, Mulga has a shallow root system and relies on surface sheet flow during flood events. If surface sheet flow is impeded, Mulga can die (Kofoed 1998), which may impact on a range of fauna associated with this vegetation type.

Fire

The role of fire in the Australian environment and its importance to vertebrate fauna has been widely acknowledged (e.g. Letnic *et al.* 2004). Fire is a natural feature of the environment but frequent, extensive fires may adversely impact some fauna, particularly mammals and short-range endemic species. Changes in fire regime, whether to more frequent or less frequent fires, may be significant to some fauna. Impacts of severe fire may be devastating to species already occurring at low densities or to species requiring long unburnt habitats to survive. Fire management may be considered the responsibility of managers of large tracts of land.

Dust, light, noise and vibration

Impacts of dust, light, noise and vibration upon fauna are difficult to predict. Some studies have demonstrated the impact of artificial night lighting on fauna, with

lighting affecting fauna behaviour more than noise (Rich and Longcore 2006). Effects can include impacts on predator-prey interactions, changes to mating and nesting behaviour, and increased competition and predation within and between invertebrates, frogs, birds and mammals.

The death of very large numbers of insects has been observed around some remote mine sites and attracts other fauna, notably native and introduced predators (M.Bamford pers. obs). The abundance of some insects can decline due to mortality around lights, although this has previously been recorded in fragmented landscapes where populations are already under stress (Rich and Longcore 2006). Artificial night lighting may also lead to disorientation of migratory birds. Aquatic habitats and open habitats such as grasslands and dunes may be vulnerable to light spill.

Appendix 3. Categories used in the assessment of conservation status

IUCN categories (based on review by Mace and Stuart 1994) as used for the EPBC Act and the WA Wildlife Conservation Act.

- Extinct.** Taxa not definitely located in the wild during the past 50 years.
- Extinct in the Wild.** Taxa known to survive only in captivity.
- Critically Endangered.** Taxa facing an extremely high risk of extinction in the wild in the immediate future.
- Endangered.** Taxa facing a very high risk of extinction in the wild in the near future.
- Vulnerable.** Taxa facing a high risk of extinction in the wild in the medium-term future.
- Near Threatened.** Taxa that risk becoming Vulnerable in the wild.
- Conservation Dependent.** Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened.
- Data Deficient (Insufficiently Known).** Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.
- Least Concern.** Taxa that are not Threatened.

Schedules used in the WA Wildlife Conservation Act.

- Schedule 1.** Rare and Likely to become Extinct.
- Schedule 2.** Extinct.
- Schedule 3.** Migratory species listed under international treaties.
- Schedule 4.** Other Specially Protected Fauna.

WA Department of Environment and Conservation Priority species (species not listed under the Conservation Act, but for which there is some concern).

- Priority 1.** Taxa with few, poorly known populations on threatened lands.
- Priority 2.** Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
- Priority 3.** Taxa with several, poorly known populations, some on conservation lands.
- Priority 4.** Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are

considered not currently threatened or in need of special protection, but could be if present circumstances change.

Priority 5. Taxa in need of monitoring. Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years (IUCN Conservation Dependent).

Appendix 4. Ecological and threatening processes identified under legislation and in the literature

Ecological processes are processes that maintain ecosystems and biodiversity. They are important for the assessment of impacts of development proposals, because ecological processes make ecosystems sensitive to change. The issue of ecological processes, impacts and conservation of biodiversity has an extensive literature. Following are examples of the sorts of ecological processes that need to be considered.

Ecological processes relevant to the conservation of biodiversity in Australia (Soule *et al.* 2004):

- Critical species interactions (highly interactive species);
- Long distance biological movement;
- Disturbance at local and regional scales;
- Global climate change;
- Hydroecology;
- Coastal zone fluxes;
- Spatially-dependent evolutionary processes (range expansion and gene flow); and
- Geographic and temporal variation of plant productivity across Australia.

(Taken from http://www.wilderness.org.au/articles/wc_science)

Threatening processes (EPBC Act)

Under the EPBC Act, a key threatening process is an ecological interaction that threatens or may threaten the survival, abundance or evolutionary development of a threatened species or ecological community. There are currently 17 key threatening processes listed by the federal Department of Sustainability, Environment, Water, Population and Communities).

- Competition and land degradation by feral/unmanaged Goats (*Capra hircus*);
- Competition and land degradation by feral Rabbits (*Oryctolagus cuniculus*);
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*);
- Incidental catch (bycatch) of Sea Turtles during coastal otter-trawling operations within Australian waters north of 28 degrees South;
- Incidental catch (or bycatch) of seabirds during oceanic longline fishing operations;

- Infection of amphibians with chytrid fungus resulting in chytridiomycosis;
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris;
- Land clearance;
- Loss of biodiversity and ecosystem integrity following invasion by the Yellow Crazy Ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean;
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases;
- Predation by exotic rats on Australian offshore islands of less than 1000 km² (100,000 ha);
- Predation by feral Cats (*Felis catus*);
- Predation by the European Red Fox (*Vulpes vulpes*);
- Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs (*Sus scrofa*);
- Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species;
- The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*);
- The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta*.

(taken from <http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl>)

General processes that threaten biodiversity across Australia (The National Land and Water Resources Audit):

- Vegetation clearing;
- Increasing fragmentation, loss of remnants and lack of recruitment;
- Firewood collection;
- Grazing pressure;
- Feral animals;
- Exotic weeds;
- Changed fire regimes;
- Pathogens;
- Changed hydrology—dryland salinity and salt water intrusion;
- Changed hydrology—other such as altered flow regimes affecting riparian vegetation; and
- Pollution.

(taken from Cork S, Sattler P and Alexandra J (2006), 'Biodiversity' theme commentary prepared for the 2006 Australian State of the Environment Committee, Department of the Environment and Heritage, Canberra, <http://www.deh.gov.au/soe/2006/commentaries/biodiversity/index.html>)

Appendix 5. GPS locations of Elliott traps within rocky areas of Iron Valley

Elliott Trap ID	Easting	Northing
IVE1	737560	7484903
IVE2	737540	7484901
IVE3	737523	7484898
IVE4	737499	7484883
IVE5	737482	7484886
IVE6	737465	7484861
IVE7	737445	7484860
IVE8	737441	7484849
IVE9	737415	7484864
IVE10	737394	7484871

Appendix 6. Species expected to occur (and recorded) within the Iron Valley Project Area

Expected species are based on reviews of the NatureMap (DEC), Birds Australia (BA), the EPBC Protected Matters Search Tool (EP) databases, the Bamford Consulting Ecologists (BCE) database, and of the broader literature (Lit). Species recorded during other surveys in the region (BCE 2011a and 2011b, Biota 2010 and Western Wildlife 2008) are indicated under 'Other'. Species recorded during the present May and September 2011 surveys are indicated under '2011'. Levels of conservation significance are listed under "CS". Significant species that were recorded during BCE surveys are highlighted in green.

FROGS

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
HYLIDAE									
Main's Frog	<i>Cyclorana maini</i>			x		x		x	
Waterholding Frog	<i>Cyclorana platycephala</i>					x	x	x	
Desert Tree Frog	<i>Litoria rubella</i>			x		x		x	x
MYBATRACHIDAE									
Douglas' Toadlet	<i>Pseudophryne douglasi</i>			x				x	
Russell's Toadlet	<i>Uperoleia russelli</i>			x				x	
Total Frog Species: 5									1

REPTILES

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
CHELUIDAE									
Flat-shelled Tortoise	<i>Chelodina steindachneri</i>			x		x		x	
CARPHODACTYLIDAE									
	<i>Nephrurus wheeleri</i>			x		x		x	x
Barking Gecko	<i>Nephrurus milii</i>			x				x	
DIPLODACTYLIDAE									
Clawless Gecko	<i>Crenadactylus ocellatus</i>			x				x	
Fat-tailed Gecko	<i>Diplodactylus conspicillatus</i>			x		x		x	x
	<i>Diplodactylus pulcher</i>			x				x	
	<i>Diplodactylus savagei</i>			x				x	
	<i>Lucasium stenodactylum</i>			x		x		x	x
	<i>Lucasium wombeyi</i>			x				x	x
Marbled Velvet Gecko	<i>Oedura marmorata</i>			x				x	x
Beaked Gecko	<i>Rhynchoedura ornata</i>			x		x		x	x
	<i>Strophurus elderi</i>			x				x	
	<i>Strophurus jeanae</i>			x				x	
	<i>Strophurus wellingtonae</i>			x				x	
GEKKONIDAE									
	<i>Gehyra pilbara</i>			x				x	
	<i>Gehyra punctata</i>			x				x	x
	<i>Gehyra purpurascens</i>			x				x	x
	<i>Gehyra variegata</i>			x		x		x	x
Bynoe's Gecko	<i>Heteronotia binoei</i>			x		x		x	x
Desert Cave Gecko	<i>Heteronotia spelea</i>			x		x		x	x
PYGOPODIDAE									
	<i>Delma butleri</i>			x				x	
	<i>Delma elegans</i>			x				x	
	<i>Delma haroldi</i>			x				x	x
	<i>Delma nasuta</i>			x				x	
	<i>Delma pax</i>			x				x	
	<i>Delma tinctoria</i>			x				x	
	<i>Lialis burtonis</i>			x		x		x	x
	<i>Pygopus nigriceps</i>			x				x	
SCINCIDAE									
	<i>Carlia munda</i>			x		x		x	
	<i>Carlia triacantha</i>			x				x	
	<i>Cryptoblepharus buehneri</i>			x		x		x	
	<i>Cryptoblepharus plagiocephalus</i>			x				x	
	<i>Cryptoblepharus ustulatus</i>			x				x	x
	<i>Ctenotus ariadnae</i>			x				x	

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
	<i>Ctenotus duricola</i>			x				x	
	<i>Ctenotus grandis</i>			x				x	
	<i>Ctenotus hanloni</i>			x				x	
	<i>Ctenotus helenae</i>			x				x	
	<i>Ctenotus leonhardii</i>							x	
Leopard Ctenotus	<i>Ctenotus pantherinus</i>			x		x		x	x
	<i>Ctenotus rubicundus</i>			x		x		x	
	<i>Ctenotus rutilans</i>			x				x	
Rock Ctenotus	<i>Ctenotus saxatilis</i>			x		x		x	x
	<i>Ctenotus schomburgkii</i>			x				x	
	<i>Ctenotus serventyi</i>			x				x	
	<i>Ctenotus uber</i>			x				x	
Slender Blue-tongue	<i>Cyclodomorphus melanops</i>			x		x		x	x
Pygmy Spiny-tailed Skink	<i>Egernia depressa</i>			x				x	
	<i>Egernia formosa</i>			x				x	
Narrow-banded Sand Swimmer	<i>Eremiascincus fasciolatus</i>			x				x	
Broad-banded Sand Swimmer	<i>Eremiascincus richardsonii</i>			x				x	
	<i>Lerista amicornum</i>			x				x	
	<i>Lerista bipes</i>			x				x	
	<i>Lerista labialis</i>			x				x	
	<i>Lerista jacksoni</i>			x				x	
	<i>Lerista muelleri</i>			x				x	
	<i>Lerista neander</i>			x				x	
	<i>Lerista timida</i>						x	x	
	<i>Lerista zietzi</i>			x				x	x
	<i>Menetia greyii</i>			x		x		x	
	<i>Menetia surda</i>			x				x	
	<i>Morethia ruficauda</i>			x		x		x	x
	<i>Notoscincus ornatus</i>			x				x	
	<i>Proablepharus reginae</i>			x				x	
Central Blue-tongue	<i>Tiliqua multifasciata</i>			x		x			x
AGAMIDAE									
	<i>Amphibolurus longirostris</i>			x		x		x	x
	<i>Caimanops amphiboluroides</i>			x				x	
	<i>Ctenophorus caudicinctus</i>			x		x		x	x
	<i>Ctenophorus isolepis</i>			x				x	
	<i>Ctenophorus nuchalis</i>			x		x		x	
	<i>Ctenophorus reticulatus</i>			x		x		x	
	<i>Diporiphora valens</i>			x				x	
	<i>Pogona minor</i>			x		x		x	
	<i>Tympanocryptis</i>			x				x	

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
	<i>cephalus</i>								
VARANIDAE									
Spiny-tailed Monitor	<i>Varanus acanthurus</i>			x		x		x	
Short-tailed Pygmy Monitor	<i>Varanus breviceauda</i>			x		x		x	
Pilbara Mulga Monitor	<i>Varanus bushi</i>			x		x		x	
	<i>Varanus caudolineatus</i>			x				x	
Pygmy Desert Monitor	<i>Varanus eremius</i>			x				x	
Perentie	<i>Varanus giganteus</i>			x				x	
Bungarra or Sand Monitor	<i>Varanus gouldii</i>			x				x	
Yellow-spotted Monitor	<i>Varanus panoptes</i>			x		x		x	
Pilbara Rock Monitor	<i>Varanus pilbarensis</i>			x				x	
Racehorse Monitor	<i>Varanus tristis tristis</i>			x		x		x	
TYPHLOPIDAE									
	<i>Ramphotyphlops ammodytes</i>			x		x		x	
	<i>Ramphotyphlops ganei</i>	CS2		x			x	x	
	<i>Ramphotyphlops grypus</i>			x		x		x	
	<i>Ramphotyphlops hamatus</i>			x				x	
	<i>Ramphotyphlops waitii</i>			x				x	
BOIDAE									
Pygmy Python	<i>Antaresia perthensis</i>			x		x		x	
Stimson's Python	<i>Antaresia stimsoni</i>			x		x		x	
Black-headed Python	<i>Aspidites melanocephalus</i>			x		x		x	x
Pilbara Olive Python	<i>Liasis olivaceus barroni</i>	CS1		x	x		x	x	
ELAPIDAE									
Pilbara Death Adder	<i>Acanthophis wellsi</i>			x		x		x	
NW Shovel-nosed Snake	<i>Brachyuropsis approximans</i>			x				x	
Yellow-faced Whipsnake	<i>Demansia psammophis</i>			x		x		x	
Rufous Whipsnake	<i>Demansia rufescens</i>			x				x	
Moon Snake	<i>Furina ornata</i>			x				x	
Monk Snake	<i>Parasuta monachus</i>			x				x	
Mulga Snake	<i>Pseudechis australis</i>			x		x		x	x
Ringed Brown Snake	<i>Pseudonaja modesta</i>			x				x	
Western Brown Snake	<i>Pseudonaja nuchalis</i>			x				x	
Rosen's Snake	<i>Suta fasciata</i>			x				x	x
Spotted Snake	<i>Suta punctata</i>			x				x	
Pilbara Bandy-bandy	<i>Vermicella snelli</i>			x			x	x	
Total Reptile Species: 105									25

BIRDS

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
CASUARIIDAE									
Emu	<i>Dromaius novaehollandiae</i>		x	x		x		x	x
PHASIANIDAE									
Brown Quail	<i>Coturnix ypsilophora</i>			x		x	x	x	
ANATIDAE									
Plumed Whistling-Duck	<i>Dendrocygna eytoni</i>		x	x		x			
Australian Shelduck	<i>Tadorna tadornoides</i>		x	x				x	
Australian Wood Duck	<i>Chenonetta jubata</i>		x	x				x	
Grey Teal	<i>Anas gracilis</i>		x	x		x		x	
Pacific Black Duck	<i>Anas superciliosa</i>		x	x		x		x	
Hardhead	<i>Aythya australis</i>		x	x					
PODICIPEDIDAE									
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>		x	x			x		
Hoary-headed Grebe	<i>Poliocephalus poliocephalus</i>			x			x		
COLUMBIDAE									
Common Bronzewing	<i>Phaps chalcoptera</i>		x	x		x		x	x
Crested Pigeon	<i>Ocyphaps lophotes</i>		x	x		x		x	x
Spinifex Pigeon	<i>Geophaps plumifera</i>		x	x		x		x	x
Diamond Dove	<i>Geopelia cuneata</i>		x	x		x		x	x
Peaceful Dove	<i>Geopelia striata</i>		x	x		x		x	
PODARGIDAE									
Tawny Frogmouth	<i>Podargus strigoides</i>		x					x	
EUROSTOPODIDAE									
Spotted Nightjar	<i>Eurostopodus argus</i>		x			x		x	x
AEGOTHELIDAE									
Australian Owlet-nightjar	<i>Aegotheles cristatus</i>		x	x				x	x
APODIDAE									
Fork-tailed Swift	<i>Apus pacificus</i>	CS1			x		x	x	
ANHINIGIDAE									
Australasian Darter	<i>Anhinga novaehollandiae</i>		x	x				x	
PHALACROCORCIDAE									
Little Pied Cormorant	<i>Microcarbo melanoleucos</i>		x	x		x		x	
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>		x	x		x		x	
CICONIIDAE									
Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>		x					x	
ARDEIDAE									
White-necked Heron	<i>Ardea pacifica</i>		x	x		x	x	x	x
Eastern Great Egret	<i>Ardea modesta</i>	CS1	x	x		x	x	x	

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
White-faced Heron	<i>Egretta novaehollandiae</i>		x	x		x		x	
Little Egret	<i>Egretta garzetta</i>		x	x				x	
Nankeen Night-Heron	<i>Nycticorax caledonicus</i>					x	x	x	
THRESKIORNITHIDAE									
Straw-necked Ibis	<i>Threskiornis spinicollis</i>		x	x		x		x	
Royal Spoonbill	<i>Platalea regia</i>		x						
Yellow-billed Spoonbill	<i>Platalea flavipes</i>		x	x		x			
ACCIPITRIDAE									
Black-shouldered Kite	<i>Elanus axillaris</i>			x			x	x	
Square-tailed Kite	<i>Lophoictinia isura</i>		x			x			
Black-breasted Buzzard	<i>Hamirostra melanosternon</i>						x	x	x
Whistling Kite	<i>Haliastur sphenurus</i>		x	x		x		x	x
Black Kite	<i>Milvus migrans</i>		x	x				x	
Brown Goshawk	<i>Accipiter fasciatus</i>		x	x		x		x	
Collared Sparrowhawk	<i>Accipiter cirrocephalus</i>		x	x		x	x	x	
Spotted Harrier	<i>Circus assimilis</i>		x	x		x		x	
Swamp Harrier	<i>Circus approximans</i>			x				x	
Wedge-tailed Eagle	<i>Aquila audax</i>		x	x		x		x	x
Little Eagle	<i>Hieraaetus morphnoides</i>		x	x		x		x	x
FALCONIDAE									
Nankeen Kestrel	<i>Falco cenchroides</i>		x	x		x		x	x
Brown Falcon	<i>Falco berigora</i>		x	x		x		x	x
Australian Hobby	<i>Falco longipennis</i>		x	x		x		x	
Grey Falcon	<i>Falco hypoleucos</i>	CS2		x		x	x	x	
Peregrine Falcon	<i>Falco peregrinus</i>	CS1	x	x		x	x	x	
RALLIDAE									
Buff-banded Rail	<i>Gallirallus philippensis</i>		x						
OTIDIDAE									
Australian Bustard	<i>Ardeotis australis</i>	CS2	x	x		x	x	x	x
BURHINIDAE									
Bush Stone-curlew	<i>Burhinus grallarius</i>	CS2				x	x	x	
RECURVIROSTRIDAE									
Black-winged Stilt	<i>Himantopus himantopus</i>			x		x		x	
CHARADRIDAE									
Black-fronted Dotterel	<i>Elseya melanops</i>		x	x		x		x	
Red-kneed Dotterel	<i>Erythronyctes alba</i>			x		x		x	
TURNICIDAE									
Little Button-quail	<i>Turnix velox</i>		x	x		x		x	x
CACTUIDAE									
Galah	<i>Eolophus roseicapillus</i>		x	x		x		x	x
Little Corella	<i>Cacatua sanguinea</i>		x	x		x		x	x
Cockatiel	<i>Nymphicus hollandicus</i>		x	x		x		x	x
PSITTACIDAE									

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
Australian Ringneck	<i>Barnardius zonarius</i>		x	x		x		x	x
Budgerigar	<i>Melopsittacus undulatus</i>		x	x		x		x	x
Bourke's Parrot	<i>Neopsephotus bourkii</i>			x		x	x		
Night Parrot	<i>Pezoporus occidentalis</i>	CS1			x	x	x		
CUCULIDAE									
Horsfield's Bronze-Cuckoo	<i>Chalcites basal</i>		x	x		x		x	x
Black-eared Cuckoo	<i>Chrysococcyx osculans</i>			x		x		x	
Pallid Cuckoo	<i>Cacomantis pallidus</i>		x	x		x		x	x
STRIGIDAE									
Barking Owl	<i>Ninox connivens</i>			x		x	x	x	
Southern Boobook	<i>Ninox novaeseelandiae</i>		x	x		x		x	x
TYTONIDAE									
Barn Owl	<i>Tyto alba</i>			x				x	
HALCYONIDAE									
Blue-winged Kookaburra	<i>Dacelo leachii</i>		x	x		x		x	
Red-backed Kingfisher	<i>Todiramphus pyrrhopygia</i>		x	x		x		x	x
Sacred Kingfisher	<i>Todiramphus sanctus</i>		x	x		x		x	
MEROPIIDAE									
Rainbow Bee-eater	<i>Merops ornatus</i>	CS1	x	x	x	x	x	x	x
PTILONORHYNCHIDAE									
Western Bowerbird	<i>Ptilonorhynchus guttatus</i>		x	x				x	
MALURIDAE									
White-winged Fairy-wren	<i>Malurus leucopterus</i>		x	x		x		x	x
Variegated Fairy-wren	<i>Malurus lamberti</i>		x	x		x		x	x
Rufous-crowned Emu-wren	<i>Stipiturus ruficeps</i>	CS3		x				x	x
Striated Grasswren	<i>Amytornis striatus</i>	CS3	x	x				x	
ACANTHIZIDAE									
Redthroat	<i>Pyrrholaemus brunneus</i>		x	x				x	
Weebill	<i>Smicrornis brevirostris</i>		x	x		x		x	x
Western Gerygone	<i>Gerygone fusca</i>		x	x		x		x	
Slaty-backed Thornbill	<i>Acanthiza robustirostris</i>			x		x	x	x	
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>			x		x	x	x	
Chestnut-rumped Thornbill	<i>Acanthiza uropygialis</i>		x	x		x		x	
Inland Thornbill	<i>Acanthiza apicalis</i>		x	x		x		x	
PARDALOTIDAE									
Red-browed Pardalote	<i>Pardalotus rubricatus</i>		x	x		x		x	x
Striated Pardalote	<i>Pardalotus striatus</i>		x	x		x		x	
MELIPHAGIDAE									
Pied Honeyeater	<i>Certhionyx variegatus</i>			x			x	x	
Singing Honeyeater	<i>Lichenostomus virescens</i>		x	x		x		x	x
Grey-headed Honeyeater	<i>Lichenostomus keartlandi</i>		x	x		x		x	x
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>		x	x		x		x	x

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
White-fronted Honeyeater	<i>Phylidonyris albifrons</i>			x				x	
Yellow-throated Miner	<i>Manorina flavigula</i>		x	x		x		x	x
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>		x	x		x		x	
Grey Honeyeater	<i>Conopophila whitei</i>					x	x	x	
Crimson Chat	<i>Epthianura tricolor</i>		x	x		x		x	x
Orange Chat	<i>Epthianura aurifrons</i>			x		x	x	x	
Black Honeyeater	<i>Sugomel niger</i>			x				x	x
Brown Honeyeater	<i>Lichmera indistincta</i>		x	x		x		x	x
Black-chinned Honeyeater	<i>Melithreptus gularis</i>			x			x	x	
POMATOSTOMIDAE									
Grey-crowned Babbler	<i>Pomatostomus temporalis</i>		x	x		x		x	
White-browed Babbler	<i>Pomatostomus superciliosus</i>		x					x	
PSOPHODIDAE									
Chestnut-breasted Quail-thrush	<i>Cinclosoma castaneothorax</i>			x			x	x	
Chiming Wedgebill	<i>Psophodes occidentalis</i>		x	x					
NEOSITTIDAE									
Varied Sittella	<i>Daphoenositta chrysoptera</i>			x		x	x	x	
CAMPEPHAGIDAE									
Ground Cuckoo-shrike	<i>Coracina maxima</i>			x		x	x	x	
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>		x	x		x		x	x
White-winged Triller	<i>Lalage sueurii</i>		x	x		x		x	x
PACHYCEPHALIDAE									
Rufous Whistler	<i>Pachycephala rufiventris</i>		x	x		x		x	x
Grey Shrike-thrush	<i>Colluricincla harmonica</i>		x	x		x		x	x
Crested Bellbird	<i>Oreoica gutturalis</i>		x	x		x		x	
ARTAMIDAE									
Masked Woodswallow	<i>Artamus personatus</i>		x	x		x		x	x
Black-faced Woodswallow	<i>Artamus cinereus</i>		x	x		x		x	x
Little Woodswallow	<i>Artamus minor</i>		x	x		x		x	x
Grey Butcherbird	<i>Cracticus torquatus</i>		x	x		x		x	
Black-backed Butcherbird	<i>Cracticus mentalis</i>							x	
Pied Butcherbird	<i>Cracticus nigrogularis</i>		x	x		x		x	x
Australian Magpie	<i>Cracticus tibicen</i>		x	x		x		x	x
RHIPIDURIDAE									
Grey Fantail	<i>Rhipidura albiscapa</i>			x		x	x	x	x
Willie Wagtail	<i>Rhipidura leucophrys</i>		x	x		x			x
CORVIDAE									
Little Crow	<i>Corvus bennetti</i>		x	x				x	
Torresian Crow	<i>Corvus orru</i>		x	x		x		x	x
MONARCHIDAE									
Magpie-lark	<i>Grallina cyanoleuca</i>		x	x		x		x	x

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
PETROICIDAE									
Red-capped Robin	<i>Petroica goodenovii</i>		x	x		x		x	
Hooded Robin	<i>Melanodryas cucullata</i>		x	x		x		x	x
ALAUDIDAE									
Horsfield's Bushlark	<i>Mirafrja javanica</i>		x	x		x		x	x
ACROCEPHLIDAE									
Australian Reed-Warbler	<i>Acrocephalus australis</i>		x					x	
MEGALURIDAE									
Rufous Songlark	<i>Cincloramphus mathewsi</i>		x	x		x		x	x
Brown Songlark	<i>Cincloramphus cruralis</i>		x	x		x		x	x
Spinifexbird	<i>Eremiornis carteri</i>			x				x	x
HIRUNDINIDAE									
Welcome Swallow	<i>Hirundo neoxena</i>		x			x			
Fairy Martin	<i>Petrochelidon ariel</i>		x	x				x	
Tree Martin	<i>Petrochelidon nigricans</i>		x	x				x	
NECTARINIIDAE									
Mistletoebird	<i>Dicaeum hirundinaceum</i>		x	x		x		x	
ESTRILDIDAE									
Zebra Finch	<i>Taeniopygia guttata</i>		x	x		x		x	x
Star Finch	<i>Neochmia ruficauda subclaescens</i>	CS2				x	x	x	
Painted Finch	<i>Emblema pictum</i>		x	x		x		x	x
MOTCILLIDAE									
Australasian Pipit	<i>Anthus novaeseelandiae</i>		x	x		x		x	
Total Bird Species: 138									58

Iron Valley Project Area - Fauna Assessment

MAMMALS

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
TACHYGLOSSIDAE									
Echidna	<i>Tachyglossus aculeatus</i>					x	x	x	x
DASUYRIDAE									
Mulgara	<i>Dasycercus cristicauda/ D. blythi</i>	CS1					x		x*
Kaluta	<i>Dasykaluta rosamondae</i>			x		x		x	
Northern Quoll	<i>Dasyurus hallucatus</i>	CS1			x		x	x	
Pilbara Ningau	<i>Ningau timealeyi</i>			x		x		x	
Wongai Ningau	<i>Ningau ridei</i>			x				x	
Undescribed Pilbara planigale	<i>Planigale sp. 1(ingrami)</i>			x		x	x		
Undescribed Pilbara planigale	<i>Planigale sp. 2</i>					x			
Rory's Pseudantechinus	<i>Pseudantechinus roryi</i>						x		
Woolley's Pseudantechinus	<i>Pseudantechinus woolleyae</i>			x			x	x	
Stripe-faced Dunnart	<i>Sminthopsis macroura</i>			x		x	x	x	
Long-tailed Dunnart	<i>Sminthopsis longicaudata</i>	CS2					x	x	
THYLACOMYIDAE									
Greater Bilby	<i>Macrotis lagotis</i>	CS1		x	x		x	x	
MACROPODIDAE									
Euro	<i>Macropus robustus</i>			x		x		x	x
Red Kangaroo	<i>Macropus rufus</i>			x		x		x	x
Rothschild's Rock-Wallaby	<i>Petrogale rothschildi</i>						x	x	
MEGADERMATIDAE									
Ghost Bat	<i>Macroderma gigas</i>	CS2		x		x	x	x	
HIPPOSIDERIDAE									
Pilbara Leaf-nosed Bat	<i>Rhinonictis aurantia</i>	CS1		x	x		x	x	
EMBALLONURIDAE									
	<i>Taphozous georgianus</i>			x		x		x	x
	<i>Taphozous hilli</i>			x			x	x	
Yellow-bellied Sheath-tail Bat	<i>Saccolaimus flaviventris</i>						x	x	x
MOLOSSIDAE									
White-striped Mastiff Bat	<i>Tadarida australis</i>			x		x	x	x	
	<i>Chaerephon jobensis</i>			x		x		x	x
Beccari's Freetail-bat	<i>Mormopterus beccarii</i>			x			x	x	
VESPERTILLIONDAE									
Lesser Long-eared Bat	<i>Nyctophilus geoffroyi</i>			x		x		x	
Northwestern Long-eared Bat	<i>Nyctophilus bifax daedalus</i>			x			x	x	
Gould's Wattled Bat	<i>Chalinolobus gouldii</i>			x		x		x	x
Chocolate Wattled Bat	<i>Chalinolobus morio</i>			x			x	x	

Iron Valley Project Area - Fauna Assessment

Common Name	Species	CS	BA	DEC	EP	BCE	Lit	Other	2011
	<i>Scotorepens greyii</i>			x		x		x	x
	<i>Vespadelus finlaysoni</i>			x		x		x	x
MURIDAE									
Lakeland Downs Mouse	<i>Leggadina lakedownensis</i>	CS2					x	x	
House Mouse	<i>Mus musculus</i>	INT		x		x		x	
Spinifex Hopping Mouse	<i>Notomys alexis</i>			x				x	
Western Pebble-mound Mouse	<i>Pseudomys chapmani</i>	CS2		x		x	x	x	x
Desert Mouse	<i>Pseudomys desertor</i>			x		x	x	x	
Sandy Inland Mouse	<i>Pseudomys hermannsburgensis</i>			x		x		x	
Rock Rat	<i>Zyzomys argurus</i>			x		x		x	
LEPORIDAE									
Rabbit	<i>Oryctolagus cuniculus</i>	INT		x	x	x		x	
CANIDAE									
Dingo	<i>Canis lupus dingo</i>	INT		x		x	x	x	x
Fox	<i>Vulpes vulpes</i>	INT		x	x	x		x	
FELIDAE									
Cat	<i>Felis catus</i>	INT		x	x	x		x	x
EQUIDAE									
Horse	<i>Equus caballus</i>	INT		x		x	x		
Donkey	<i>Equus asinus</i>	INT		x		x		x	
CAMELIDAE									
Dromedary Camel	<i>Camelus dromedarius</i>	INT				x	x		
BOVIDAE									
European Cattle	<i>Bos taurus</i>	INT		x		x	x	x	
Total Mammal Species:45									11 (and 2 Int)

*Note: Mulgara recorded just outside Iron Valley tenement boundary. Depending upon taxonomy recognised, species may be *D. blythi*

Appendix 7.

Table 1. Habitat preference and likely proportion of local disturbance to all conservation significant species expected to occur (and recorded) within the Iron Valley Project Area. Habitat is based upon land systems and is refined within the lease area to vegetation types within these systems. Proportional local impacts (within 15km radius) are based upon land systems as only these are mapped outside the lease area.

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Conservation Significance Level 1							
Pilbara Olive Python <i>Liasis olivaceus barroni</i>	Not recorded	Generally associated with riverine woodland areas, gorges and large rock holes and swamps.	Only Newman within the project area is likely to support resident animals, also uses River. (277.9)	Creek Line/Drainage (60.1)	46,248.35	0.13	0.6
Peregrine Falcon <i>Falco peregrinus</i>	Not recorded	Habitat generalist favouring areas with cliffs and abandoned nests in tall, wooded forests.	Newman but may forage anywhere (277.9)	Rocky Hillslopes/Hill Crests (217.9)	39,881.75	0.55	0.7

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Night Parrot <i>Pezoporus occidentalis</i>	Not recorded	Mature spinifex grasslands and chenopod Shrublands, particularly where the two are closely juxtaposed. There are recent records from the Fortescue Marsh.	Unknown. (677.9; Assuming equally likely to be in any land system)	Unknown (677.9; Assuming equally likely to be in any veg type)	~50,354.81 Assuming equally likely to be in any land system	~1.35	~1.35
Fork-tailed Swift <i>Apus pacificus</i>	Not recorded	Nomadic aerial forager following low pressure storm systems, with no reliable reports of them coming to land.	Any land system (677.9)	Any veg type (677.9)	50,354.81	1.35	1.35
Rainbow Bee-eater <i>Merops ornatus</i>	Recorded, likely throughout area	Any habitat suitable for hawking for insects. Breeds in a wide variety of sandy habitats.	Boolgeeda, River, likely to forage elsewhere (400)	Creek Line/Drainage, Plains 1-4 (411.8)	16,839.66	2.45	2.38

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Eastern Great Egret <i>Ardea modesta</i>	Not recorded	Extensive wetlands of the Fortescue Marshes, however no wetlands in the Project Area but individuals may visit nearby Weeli Wolli Creek.	May visit River. (0)	May visit Creek Line/Drainage (60.1)	6,366.6	0.94	Negligible
Northern Quoll <i>Dasyurus hallucatus</i>	Not recorded	Rocky and broken country in open Eucalypt forest.	Newman (277.9)	Rocky Hillslopes/Hill Crests (217.9)	39,881.75	0.55	0.7
Crest-tailed Mulgara <i>Dasyercus cristicauda</i>	Active Burrow 737094 7480873 Active Burrow + photograph 737397 7481545	Mature Spinifex grasslands on sandy substrates.	Boolgeeda (400)	Plains 1-4. (351.7)	10,473.06	3.36	3.82

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Bilby <i>Macrotis lagotis</i>	Not recorded	Woodlands and grasslands on sandplains and dunefields, often close to drainage systems.	Boolgeeda (400)	Plains 1-4, Creek Line/Drainage. (411.8)	10,473.06	3.93	3.82
Pilbara Leaf-nosed Bat <i>Rhinonicteris aurantius</i>	Not recorded	Roosts in warm humid caves, likely to forage throughout Project Area	Newman (277.9)	Rocky Hillslopes/Hill Crests (217.87)	39,881.75	0.55	0.7
Conservation Significance Level 2							
Blind snake <i>Ramphotyphlops ganei</i>	Not recorded	Uncertain; may prefer gorges and gullies or grasslands, Shrublands and woodlands.	Boolgeeda, River (400)	Plains 1-4, Creek Line/ Drainage (411.76)	16,839.66	2.45	2.38

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Australian Bustard <i>Ardeotis australis</i>	Recorded, likely throughout area	Open or lightly-wooded grasslands and shrublands.	Boolgeeda (400)	Plains 1-4 (351.7)	10,473.06	3.35	3.82
Bush Stone-curlew <i>Burhinus grallarius</i>	Not recorded	Grassy woodlands with minimal to no human disturbance.	Boolgeeda, River (400)	Plains 1-4 (351.7)	16,839.66	2.09	2.38
Grey Falcon <i>Falco hypoleucos</i>	Not recorded	Habitat generalist including shrubland, grassland and wooded watercourses.	River but may forage anywhere (0)	Creekline/Drainage, may forage anywhere. (60.1)	6,366.6	0.94	Negligible
Star Finch <i>Neochmia ruficauda subclarescens</i>	Not recorded	Grasslands near water.	River (0)	Creekline/Drainage (60.1)	6,366.6	0.94	Negligible

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Western Pebble-mound Mouse <i>Pseudomys chapmani</i>	Inactive and very old 735849 7480674 Active 735572 7480629 Recently Active 735534 7480644 Inactive 735493 7480596 Recently Active 735451 7480648	Hummock grassland on skeletal soils containing an abundance of small pebbles on spurs and the lower slopes of ridges.	Newman (277.9)	Rocky Hillslopes/Hill Crests (217.9)	39,881.75	0.55	0.7
Lakeland Downs Mouse <i>Leggadina lakedownensis</i>	Not recorded	Cracking clays and adjacent habitats in open shrublands and hummock and tussock grasslands.	Possibly River and Boolgeeda (400)	Possibly Creekline/Drainage, Plains 1-4 (411.76)	16,839.66	2.45	2.38

Iron Valley Project Area - Fauna Assessment

Species	Coordinates	Habitat	Land Systems that correspond to habitat. Area of land system within clearing footprint in parenthesis	Veg Type within lease that corresponds to habitat. Area of veg type within clearing footprint in parenthesis	Area of land systems within 15km	Percentage of habitat within clearing footprint compared with corresponding land system within 15km	
						Based on veg type in footprint	Based on land system in footprint
Long-tailed Dunnart <i>Sminthopsis longicaudata</i>	Not recorded	Scree slopes surrounding rock hills and mesas.	Newman (277.9)	Rocky Hillslopes/Hill Crests (217.87)	39,881.75	0.55	0.7
Ghost Bat <i>Macroderma gigas</i>	Not recorded	Roosts in warm humid caves, likely to forage throughout Project Area	Newman, may forage anywhere (277.9)	Rocky Hillslopes/Hill Crests (217.87)	39,881.75	0.55	0.7
Conservation Significance Level 3							
Rufous-crowned Emu-wren <i>Stipiturus ruficeps</i>	On track near Mulgara burrows, precise coordinates not known	Spinifex, often including at least some long-unburnt	Boolgeeda (400)	Plains 1-4, Creek Line/Drainage (411.8)	10,473.06	3.93	3.82
Striated Grasswren <i>Amytornis striatus</i>	Not recorded	Spinifex, often including at least some long-unburnt	Boolgeeda (400)	Plains 1-4, Creek Line/Drainage (411.8)	10,473.06	3.93	3.82

Table 2. Habitat preference and likely proportion of local disturbance to key conservation significant species expected to occur (and recorded) within the Iron Valley Project Area. For each species, area of habitat within disturbance footprint is calculated in three ways: based upon land systems, based upon vegetation type and based upon an interpretation of both vegetation type and land system that reflects the known habitat preference of the species (interpreted habitat). Proportional local impacts within 15km radius (in parenthesis) are based upon land systems as only these are mapped outside the lease area.

Species	Habitat	Land system corresponding with habitat	Hectares of land system within 15km	Hectares of land system corresponding with habitat within clearance footprint	Hectares of vegetation corresponding with habitat within clearance footprint	Hectares of interpreted habitat within clearance footprint
Crest-tailed Mulgara <i>Dasyercus cristicauda</i>	Mature Spinifex grasslands on sandy substrates.	Boolgeeda	10473.06	400 (3.82%)	351.7 (3.36%)	400 (3.82%)
Pilbara Olive Python <i>Liasis olivaceus barroni</i>	Generally associated with riverine woodland areas, gorges and large rock holes and swamps	Newman, River	46248.35	277.9 (0.6%)	60.1 (0.13%)	105 (0.23%)
Northern Quoll <i>Dasyurus hallucatus</i>	Rocky and broken country in open Eucalyptus forest.	Newman	39881.75	277.9 (0.7%)	217.9 (0.55%)	68 (0.17%)

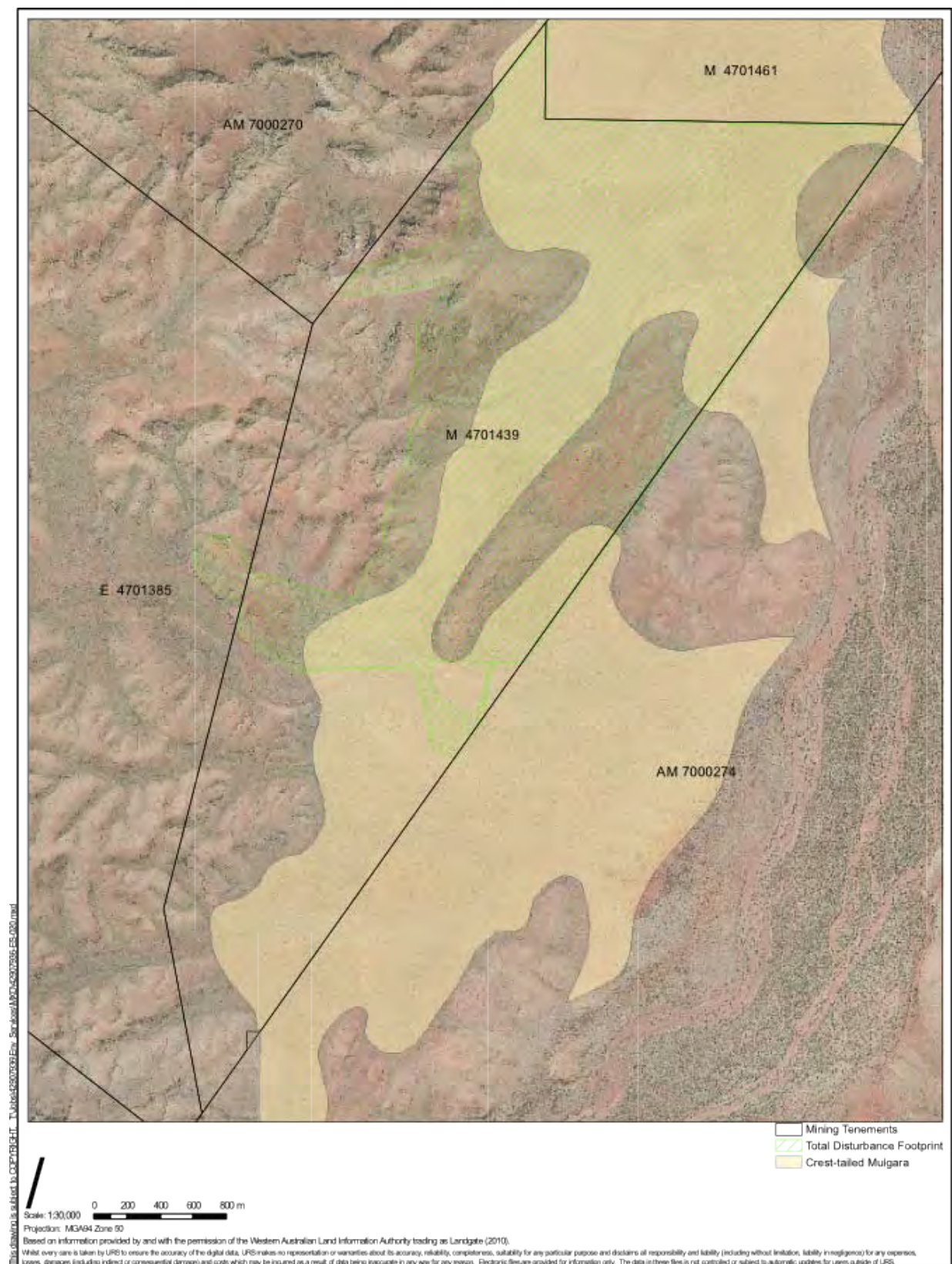


Figure 1. Interpreted habitat of Crest-tailed Mulgara.

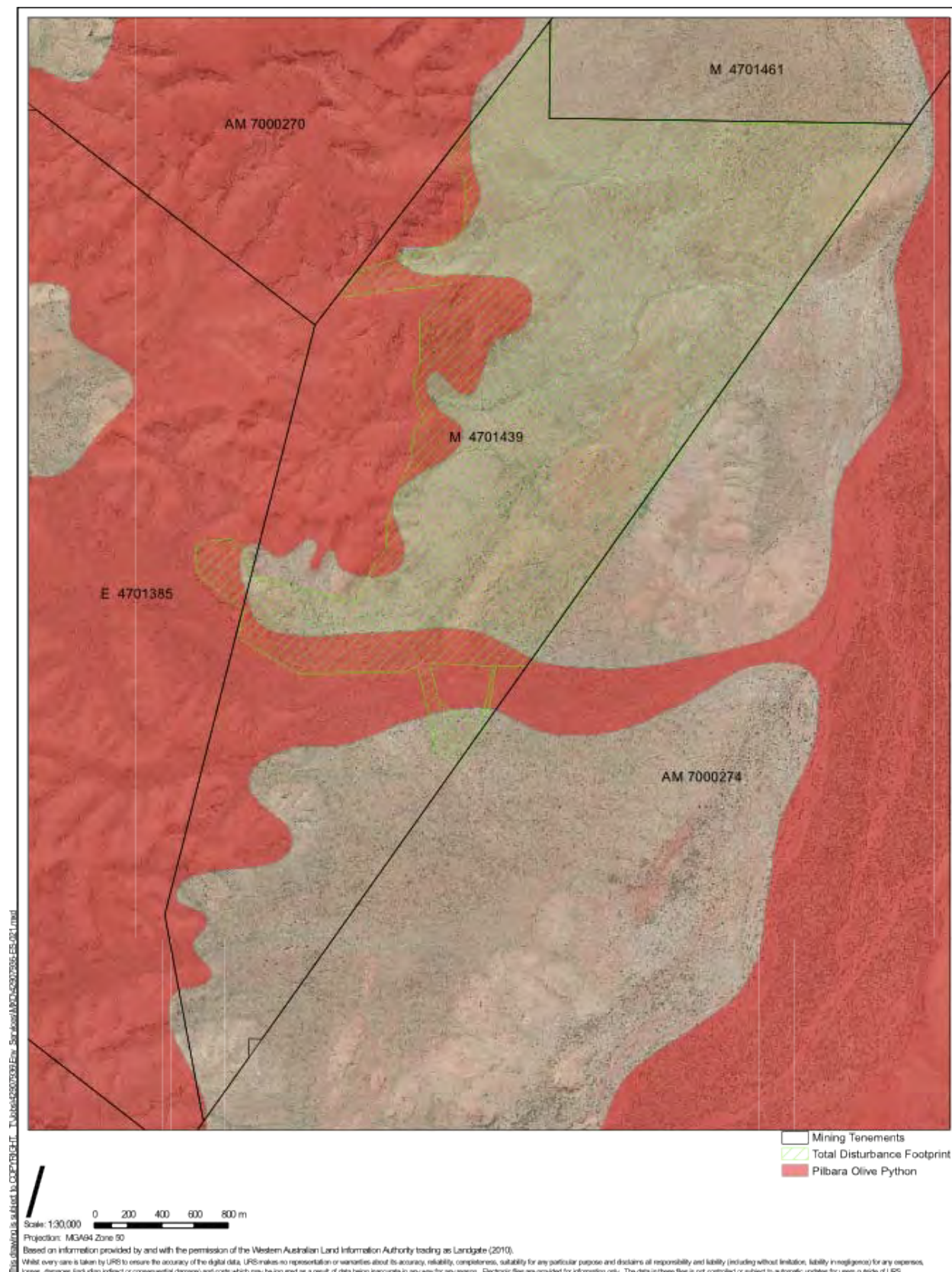


Figure 2. Interpreted habitat of Pilbara Olive Python.

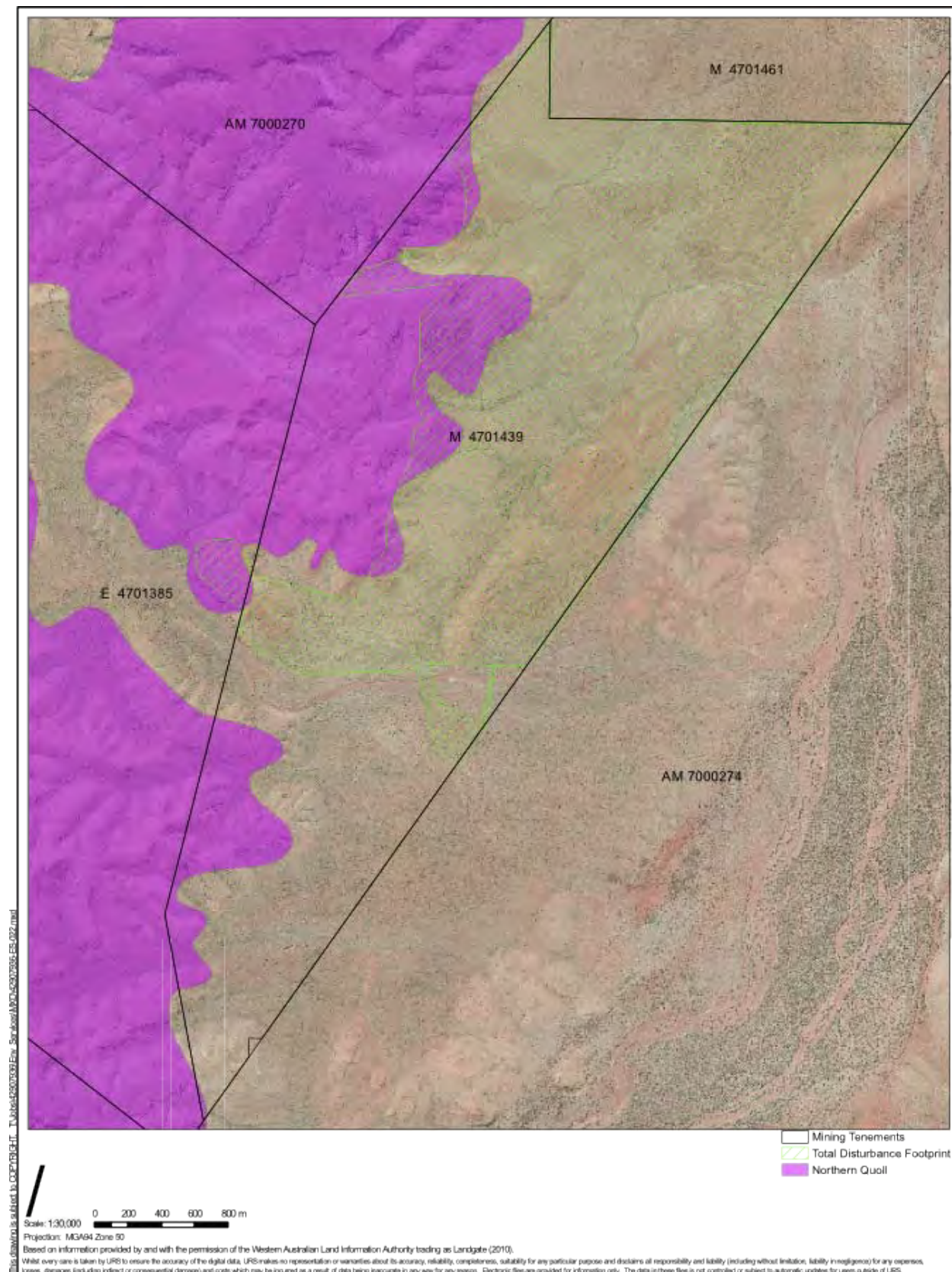


Figure 3. Interpreted habitat of Northern Quoll.

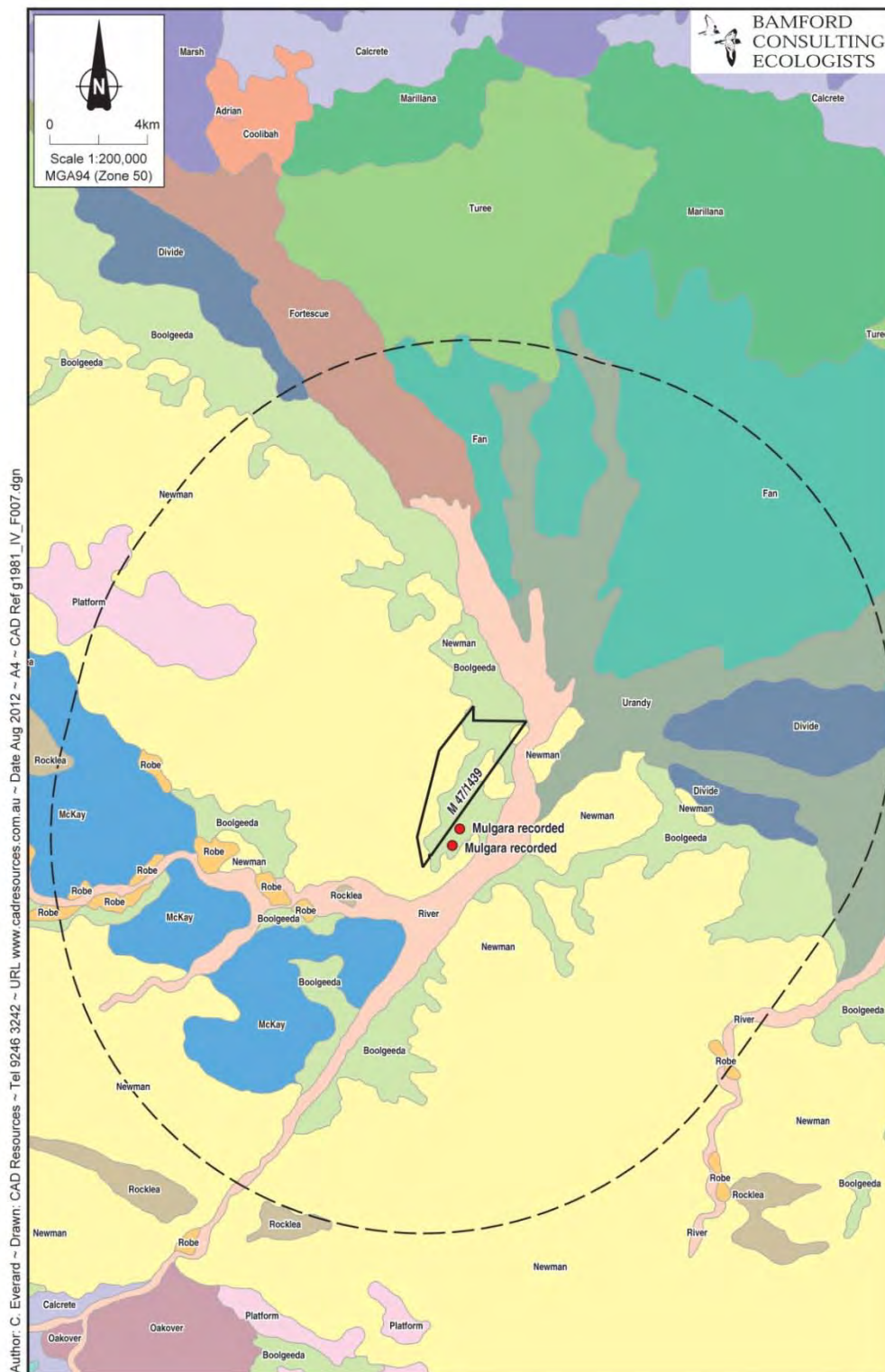


Figure 4. Land systems within 15km of the Iron Valley lease area, upon which local land system areas calculated.



Appendix D2 Aquatic Fauna



Iron Valley Project

Potential Impacts to Aquatic Systems: Literature Review



September 2015

Iron Valley Project

Potential Impacts to Aquatic Systems: Literature Review

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Final Report
September 2015

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Disclaimer

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CONTENTS

EXECUTIVE SUMMARY	VI
1 INTRODUCTION.....	1
1.1 Project background	1
1.1.1 <i>Legislative framework</i>	1
1.2 Study area.....	2
1.3 Climate and hydrology.....	3
2 ECOLOGICAL VALUES OF AQUATIC SYSTEMS IN THE PROJECT AREA	3
2.1 Microinvertebrates.....	4
2.2 Hyporheos	7
2.2.1 <i>General</i>	7
2.2.2 <i>Short-range endemics</i>	8
2.3 Macroinvertebrates.....	9
2.3.1 <i>General</i>	9
2.3.2 <i>Conservation listed taxa</i>	10
2.3.3 <i>Locally (Pilbara) restricted taxa of significance</i>	11
2.3.4 <i>Restricted taxa relatively new to science</i>	11
2.4 Fish.....	12
2.4.1 <i>General</i>	12
2.4.2 <i>Conservation listed taxa - Fortescue grunter</i>	13
3 POTENTIAL IMPACTS TO AQUATIC FAUNA AND DEVELOPMENTAL CONSIDERATIONS	14
3.1 Excessive water abstraction and dewatering drawdown	14
3.1.1 <i>Potential impacts to ecosystems</i>	14
3.1.2 <i>Discussion of impacts in relation to aquatic fauna</i>	14
3.1.3 <i>Developmental/management considerations</i>	15
3.2 Changes to the hydrological regime via groundwater discharge	15
3.2.1 <i>Potential impacts to ecosystems</i>	15
3.2.2 <i>Discussion of impacts in relation to aquatic fauna</i>	15
3.2.3 <i>Developmental/management considerations</i>	16
3.3 Changes to surface water quality via groundwater discharge	17
3.3.1 <i>Potential impacts to ecosystems</i>	17
3.3.2 <i>Developmental/ management considerations</i>	19
3.4 AMD, NMD and stormwater runoff.....	19
3.4.1 <i>Potential impacts to ecosystems</i>	19
3.4.2 <i>Discussion of impacts in relation to aquatic fauna</i>	20
3.4.3 <i>Developmental/management considerations</i>	20
3.5 Creek/channel diversion.....	21
3.5.1 <i>Potential impacts to ecosystems</i>	21
3.5.2 <i>Discussion of impacts in relation to aquatic fauna</i>	21
3.5.3 <i>Developmental/management considerations</i>	21
3.6 Dust and other disturbance	22
3.6.1 <i>Potential impacts to ecosystems</i>	22
3.6.2 <i>Discussion of impacts in relation to aquatic fauna</i>	22
3.6.3 <i>Developmental/management considerations</i>	22
3.7 Cumulative impacts on WWC.....	22
4 PROPOSED BASELINE AQUATIC FAUNA SAMPLING	23
4.1 Compliance	23
4.2 Sites and sampling design.....	23
5 CONCLUSION.....	25
REFERENCES	26
APPENDICES	32

Appendix 1. Locations of IUCN listed aquatic fauna within 50 km of the Project area.....	33
Appendix 2. Locations of stygal short-range endemic amphipod, <i>Chydaekata</i> sp.....	34
Appendix 3. Locations of stygal short-range endemic amphipod, <i>Maarrka weeliwolli</i>	35
Appendix 4. Locations of stygal short-range endemic amphipod, <i>Pygolabis weeliwolli</i>	36
Appendix 5. Locations of stygal short-range endemic amphipod, Paramelitidae sp. B.	37
Appendix 6. Locations of stygal short-range endemic amphipod, Paramelitidae sp. D.	38
Appendix 7. Locations of stygal short-range endemic Syncarida	39

List of Tables and Plates

Table E1. Summary of species of conservation and/or scientific value	vii
Table 1. Summary of published aquatic studies.....	5
Plate 1. Pilbara emerald, <i>Hemicordulia koomina</i> , and Pilbara pin, <i>Eurysticta coolawanyah</i>	11
Plate 2. Western rainbowfish <i>Melanotaenia australis</i> , spangled perch <i>Leiopotherapon unicolor</i> and Hyrtl's tandan <i>Neosilurus hyrtlui</i>	12
Plate 3. Fortescue grunter <i>Leiopotherapon aheneus</i>	13

EXECUTIVE SUMMARY

A desktop review was undertaken to evaluate potential impacts to aquatic ecosystems in the vicinity of the proposed BC Iron Limited (BCI) Iron Valley Project (M47/1439) (the Project), in the East Pilbara. A section of the regionally significant Weeli Wolli Creek (WWC) flows adjacent to the Project, with three ephemeral tributaries of WWC located upstream, to the south-west of the tenement. The Project will require groundwater dewatering and diversion of ephemeral tributaries. The Project is also located downstream of a number of operating below water table (BWT) iron ore mines which currently discharge groundwater from dewatering to WWC.

The current review precedes and informs targeted baseline aquatic fauna sampling planned for the late wet season (March/April) 2015. Sampling will include macroinvertebrates, microinvertebrates (zooplankton), hyporheic invertebrates and fish, at locations both within (exposed sites) and outside (reference sites) the likely zone of influence of operations. Opportunistic sightings of frogs and turtles will also be recorded.

Legislation relevant to this review and to the baseline sampling includes the *Environmental Protection Act 1986* (EP Act), the *Wildlife Conservation Act 1950* (WC Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The review and baseline sampling together constitute a Level 1 survey for environmental impact assessment, as described under Environmental Assessment Guideline (EAG) No. 12 (EPA 2013) and in accordance with EAG No. 8 (EPA 2015) with the focus on hydrological processes and ecosystem maintenance.

Historic records of aquatic fauna in the vicinity of the Project were gathered from published literature and the State Government database NatureMap. Other than groundwater fauna (stygo fauna), aquatic fauna within the Project tenement has not been sampled previously. Creekline surveys have been conducted at nearby locations, including Marillana Creek and WWC to the south and south-west, the Fortescue Marsh, 25-30 km to the north-east, and a number of permanent or semi-permanent waterbodies within a 50 km radius of the Project. More data are known to exist for these and other nearby catchments (Coondiner Creek, Kalgan Creek, Mindy Mindy Creek, Fortescue River) but are not available in the public domain; the majority belonging to private mining companies.

More than 140 microinvertebrate (zooplankton) species, 60 hyporheic invertebrate species (including stygal species), 170 macroinvertebrate species and three fish species have been recorded from creeklines within a 50 km radius of the Project. None are currently listed for conservation significance under State or Federal legislation. Two species, however, are listed on the International Union for Conservation of Nature (IUCN) Red List as 'Near Threatened'; the Pilbara pin damselfly *Eurysticta coolawanyah* and the Pilbara emerald dragonfly *Hemicordulia koomina*. There are also a number of stygal short-range endemics (SREs) and epigeal species of scientific interest, being uncommonly recorded from Australia. Most of these species are highly likely to occur within the Project tenement. Published records of all IUCN listed species, SREs and species of scientific interest occurring within 20 km of the Project area are summarised in Table E1. Maps of known occurrences of IUCN listed species and SREs are provided in the Appendices.

Comprehensive data on the extent of drawdown and volume and quality of groundwater to be discharged are not yet available. A conservative approach was therefore adopted for assessment of potential effects by assuming, i) drawdown would occur across all of the Project area, ii) quality of dewatering discharge would differ from that of surface water in receiving creeklines, and iii) dewatering discharge volumes would alter flow regimes in WWC, taking into consideration cumulative effects of combined discharge from other BWT projects in the area. Other activities that may negatively impact aquatic communities (e.g. acid mine / neutral mine drainage, minor creek re-alignment, dust) were based on the URS (2012) Assessment on Proponent Information (API) prepared for the above water table Iron Valley Project.

The main issue was considered to be cumulative impacts of combined groundwater dewatering discharge to WWC. WWC currently receives dewatering discharge from the Rio Tinto Hope Downs 1 and Yandicoogina operations, and from BHP Billiton Yandi. The surface water footprint from cumulative discharge from these mines currently extends up to 17 km along WWC downstream of the Marillana/WWC confluence. Commencement of discharge in association with Project operations may extend the footprint further towards the Fortescue Marsh. The volume, rather than the quality, of groundwater was considered to pose greatest risk to creekline and Marsh fauna through potential changes to hydrological regime. There is also increased risk of creek bed armouring due to carbonate (calcite and dolomite) precipitation from groundwater discharge. Should extensive armouring occur, flow rate and longitudinal extent of the discharge footprint may also increase. Armouring also reduces habitat heterogeneity, which may result in localised reductions in biodiversity along affected sections of WWC.

Based on the desktop review, there are at least two creekline species known only from the Project tenement that may be threatened by the development. These include stygal syncarid (crustacean) species from the families Bathynellidae and Parabathynellidae, which are known to occur in groundwater bores within the tenement and (likely) hyporheic zones of creeks.

Table E1. Summary of creekline (including hyporheic zone) species of conservation and/or scientific value occurring or likely to occur within the Project area. Records are from published literature and the State government database NatureMap.

Species	Common name	Conservation / Scientific value	Occurrence within 20 km of Project area	Likely occurrence within Project area	Occurrence elsewhere
Microinvertebrates					
<i>Australoeucyclops karaytugi</i>	Copepod (micro-crustacean)	Pilbara endemic	Marillana Ck	High	Ashburton R.(Palm Springs, Glen Herring Pool, Wannagunna Pool, Horrigan's Pool); DeGrey R. (Bamboo Springs, Skull Springs, Coppin Gap, DeGrey); Yule R.(Billan Ballan)
<i>Paracyclops</i> sp. 6	Copepod(micro-crustacean)	Pilbara endemic	Marillana Ck	High	Uncertain
Hyporheos					
<i>Vestenula</i> n. sp.	Ostracod (seed shrimp, micro-crustacean)	Species new to science	Weeli Wolli Spring	High	Deep wells in the Ashburton catchment; likely Pilbara-wide
<i>Chydaekata</i> sp.	Stygol paramelitid amphipod	Stygol SRE	Bores within tenement; Weeli Wolli Ck; Marillana Ck	Does occur	Coondiner Ck; Mindy Mindy Ck; Kalgan Ck
Paramelitidae sp. B and sp. D.	Stygol paramelitid amphipods	Stygol SRE	Bores within tenement; Weeli Wolli Spring, Weeli Wolli Ck; Marillana Ck	Does occur	Fortescue R.; Kalgan Ck;Coondewanna Flats area
<i>Maarrka weeliwolli</i>	Stygol paramelitid amphipods	Stygol SRE	Bores within Project tenement; Weeli Wolli Ck; Marillana Ck	Does occur	Uncertain
<i>Pygolabis weeliwolli</i>	Stygol isopod	Stygol SRE	Weeli Wolli Ck; Marillana Ck	High	Uncertain
<i>Pygolabis</i> sp. (nr. <i>humphreysi</i>)	Stygol isopod	Stygol SRE	Bores within tenement;	Does occur	Uncertain
Bathynellidae species	Stygol syncarid	Stygol SRE	Bores within tenement;	Does occur	Uncertain. Family widespread but species have restricted distributions
Parabathynellidae species	Stygol syncarid	Stygol SRE	Bores within tenement;	Does occur	Uncertain. Family widespread but species have restricted distributions
Macroinvertebrates					
<i>Hemicordulia koomina</i>	Pilbara emerald dragonfly	IUCN, Near Threatened	Weeli Wolli Spring; Weeli Wolli Ck; Marillana Ck	High	Fortescue R., Coondiner Ck; now known to be widespread throughout the Pilbara, though infrequently collected
<i>Eurysticta coolawanyah</i>	Pilbara pin damselfly	IUCN, Near Threatened	Weeli Wolli Spring, Weeli Wolli Ck	High	Ashburton R. (Bobswim Pool); Kalgan Ck; Coondiner Ck; Fortescue R; now known to be widespread throughout the Pilbara, though infrequently collected
<i>Ictinogomphus dobsoni</i>	Pilbara tiger dragonfly	Pilbara endemic; restricted distribution	Weeli Wolli Spring, Marillana Ck	High	Fortescue R.; Robe R.; Ashburton R.; Yule R.; DeGrey R.; Sherlock R.

Species	Common name	Conservation / Scientific value	Occurrence within 20 km of Project area	Likely occurrence within Project area	Occurrence elsewhere
<i>Nannophlebia injibandi</i>	Pilbara archtail dragonfly	Pilbara endemic; restricted distribution	Marillana Ck	High	Fortescue R. catchment, but uncommonly collected
<i>Laccobius billi</i>	Aquatic beetle	Pilbara endemic; restricted distribution	Marillana Ck	High	Yual River (Cangan Pool); rarely encountered
<i>Haliphus fortescueensis</i>	Aquatic beetle	Pilbara endemic relatively new to science	Unknown	Moderate-High	Fortescue Marsh; Fortescue R.; claypan near Port Headland; likely Pilbara-wide but rarely encountered
<i>Haliphus halsei</i>	Aquatic beetle	Pilbara endemic relatively new to science	Unkown	Moderate-High	Fortescue Marsh; Pilbara-wide but rarely encountered
<i>Aspidiobates pilbara</i>	Water mite	Pilbara endemic; restricted distribution	Weeli Wolli Spring	Low-Moderate	Fortescue R. (Millstream, Fortescue Falls); De Grey (Bamboo Spring); Robe R. (Nyeetbury Spring); but uncommonly collected
<i>Wandesia</i> sp.	Water mite	Pilbara endemic; restricted distribution	Weeli Wolli Spring	Low-Moderate	De Grey R. (Minigarra Creek); Yule R. (Cangan Pool)
Fish					
<i>Leiopotherapon aheneus</i>	Fortescue grunter	DPaW P4 (Near Threatened), IUCN (Near Threatened)	Unknown	Low – likely only if upper and lower Fortescue R. connect during flood	Fortescue R (below Fortescue Marsh); Robe R.; Ashburton R.

1 INTRODUCTION

1.1 Project background

BC Iron Limited (BCI) is currently undertaking baseline environmental studies for the proposed below water table (BWT) development of the Iron Valley Project (hereafter referred to as “the Project”) in the East Pilbara region of Western Australia. The Project is located in the Weeli Wolli Creek (WWC) catchment, within the vicinity of a number of existing iron ore mines, including the Fortescue Metals Group (FMG) Nyidinghu operation (15 km to the north), Rio Tinto Iron Ore (RTIO) Yandicoogina (10 km to the west) and Hope Downs 1 operations (30 km to the south west), and the BHP Billiton Iron Ore (BHPBIO) Yandi operation (25 km to the west). Preliminary hydrogeological modelling indicates that groundwater dewatering will be required to mine below the water table, which could potentially require surface water discharge of excess water into WWC. Any substantial discharge will add to the cumulative impacts of combined discharge from the numerous operations upstream on WWC.

Though the quality of groundwater to be discharged into surface water courses is unknown, discharge and disturbance of creeklines poses potential risk to the health of adjacent and downstream aquatic ecosystems which need to be appropriately assessed. To that end, BCI commissioned *Wetland Research and Management* (WRM) to undertake a desktop review of the known ecological values of the creeklines involved, evaluate potential impacts to aquatic ecosystem health and provide recommendations for a baseline sampling program to address any knowledge gaps. Baseline sampling is proposed for the late wet season (late March/early April) 2015.

1.1.1 Legislative framework

At a State level, aquatic fauna are protected under the *Wildlife Conservation Act 1950* (WC Act) and their environment is protected under the *Environmental Protection Act 1986* (EP Act). This includes freshwater turtles, frogs, fish and invertebrates (including hyporheic and stygal invertebrates). Hyporheic invertebrates (collectively referred to as hyporheos) inhabit subsurface interstitial spaces in coarse creek bed sediments. Stygal invertebrates are aquatic, obligate groundwater-dwelling species known to be present in a variety of rock types and are often also present in the hyporheos.

The WC Act provides for species and ecological communities to be specially protected and listed as either ‘threatened’ because they are under identifiable threat of extinction, or ‘priority’ because they are rare, or otherwise in need of special protection. This encompasses species with small distributions (occupying an area of less than 10, 000 km²) defined as short range endemics, or SREs (Harvey 2002, EPA 2009). The majority of stygal invertebrates are also SREs. The Environmental Protection Authority of Western Australia (EPA) expects that environmental impact assessments will consider impacts on conservation of SRE species (EPA 2004).

The Department of Parks and Wildlife (DPaW) uses the International Union for Conservation of Nature (IUCN) Red List criteria for assigning species and communities to threat categories under the WC Act. Not all Western Australian species listed by the IUCN are also listed by DPaW.

At a Federal level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for native fauna and their habitats to be specially protected and listed as nationally or internationally important.

Relatively few aquatic species in Western Australia are listed as threatened or endangered under the WC Act or EPBC Act. Aquatic invertebrates in particular, have historically been under-studied. Lack of knowledge of their distributions often precludes aquatic invertebrates for listing as threatened or

endangered. The EPA has stated that listing under legislation should therefore not be the only conservation consideration in environmental impact assessment (EPA 2004).

The current review and proposed baseline sampling together constitute a Level 1 survey for environmental impact assessment, as described under the State Environmental Protection Authority (EPA) Environmental Assessment Guideline (EAG) No. 12 (EPA 2013), and in accordance with EAG No. 8 (EPA 2015) with the focus on hydrological processes and ecosystem maintenance.

1.2 Study area

The Project tenement is situated in the East Pilbara region of Western Australia, within Mining Lease M47/1439 and a small area of Exploration Licence E47/1385. The co-ordinates of M47/1439 are as follows:

- NW Corner 22° 42' 05"S 119° 19' 02"E
- NE Corner 22° 43' 02"S 119° 20' 30"E
- SE Corner 22° 46' 33"S 119° 17' 56"E
- SW Corner 22° 45' 35"S 119° 16' 28"E

The Project is located within the Marillana (pastoral) Station, with land-use in the area comprising predominately pastoral activities and more recently, mining. The regional topography of the Eastern Pilbara is dominated by the Chichester Ranges in the north and the Hamersley Plateau to the south, with these features being divided by the Fortescue Valley. The main drainage system in the area is the Fortescue River, which flows north and then northwest into the Fortescue Marsh.

A section of the regionally significant WWC flows adjacent to the Project. WWC, approximately 70 km in length and with a catchment area of 4100 km², is fed in its mid-reaches by Weeli Wolli Spring, located approximately 20 km upstream (south) of the Project. Owing to the historical permanency of Weeli Wolli Spring, WWC is of high ecological, cultural and social significance. Prior to dewatering discharge from RTIO's Hope Downs (HD1) mine, the Weeli Wolli Spring provided perennial surface flows of around 2 km along WWC. However, as a result of the current discharge regime, approximately 25 - 30 km of the creek is now influenced by surface flows (A.W. Storey, WRM, pers. obs.).

Marillana Creek, a major tributary of WWC, converges with WWC approximately 4.5 km upstream of the Project. BHPBio Yandi and RTIO Yandicoogina mines are located along Marillana Creek upstream of the confluence, with dewatering discharge likely to result in surface and subsurface flows adjacent to the Project in the near future. The cumulative impacts of mining operations along WWC and Marillana Creek upstream of the current Project are considered as part of this assessment.

Flowing to the north, WWC drains into the Fortescue River via the Fortescue Marsh. However, the two systems are only connected during flooding associated with intense cyclonic events (Kendrick 2001). The Fortescue Marsh, an episodically inundated samphire marsh, approximately 100 km long and 10 km wide (Kendrick 2001, DEC 2009), is located 25 - 30 km downstream, and to the north-east, of the Project. The Marsh is described as an extensive, irregularly inundated inland floodplain system, and is considered to be a highly unique wetland landform in Western Australia (Environment Australia 2001). It is listed on the national Directory of Important Wetlands of Australia (WA066), and is a Priority 1 Priority Ecological Community (PEC) under the Department of Parks and Wildlife (DPaW) list of Priority Ecological Communities (DPaW 2014). Current and potential threats to the Marsh include changes to hydrology, overgrazing by cattle, and pollution of surface inflow water from mine sites (Environment Australia 2001).

1.3 Climate and hydrology

The climate of the Pilbara is semi-arid, with relatively dry winters and hot summers. Most rainfall occurs during the summer months and is predominantly associated with cyclonic events; when flooding frequently occurs along creeks and rivers (BOM 2015). Due to the nature of cyclonic events and thunderstorms, total annual rainfall in the region is highly unpredictable and individual storms can contribute several hundred millimetres of rain at one time. Average annual pan evaporation in the Pilbara is ten times greater than rainfall (BOM 2015). Most rainfall occurs during the summer months, between November and March.

Two Department of Water (DoW) gauging stations are located in the vicinity of the Project, including one on WWC, downstream of the confluence with Marillana Creek (Waterloo Bore GS), and one on Marillana Creek, upstream of all mining operations (Flat Rocks GS) (DoW 2015). The Waterloo Bore GS lies approximately 3.5 km downstream of the current extent of surface flow from cumulative dewatering discharge. Flows at this station, however, will likely become more heavily influenced by discharge operations in the future.

Long-term average rainfall at Flat Rocks and Waterloo Bore was 382.9 mm and 395.7 mm, respectively. Total annual rainfall varies greatly between years. Between 2006 and 2010, rainfall at both gauging stations was regularly below the long-term average. Recently, rainfall has been above the long-term average at Waterloo Bore since 2010. Rainfall at Flat Rocks was above the long-term average in 2012 and 2013. Rainfall during the wet of 2011 was influenced by the La Niña event which contributed to numerous and significant floods throughout northern Australia. In January 2011, Tropical Cyclone Bianca brought heavy rain across the Pilbara (BOM 2015).

Like rainfall, streamflow is also highly seasonal and variable. Flows occur as a direct response to rainfall, with peak flows tending to occur within 24 hours of a major rainfall event and continuing for several days. The Flat Rocks gauging station is located upstream of all mining operations and as such is not influenced by additional inputs from discharge or reductions in flow due to dewatering. The highest flow on record was 144, 472 ML/yr in 1975 when rainfall was 717 mm and well above the long-term average (392.60 mm). At WWC's Waterloo Bore gauging station, seven zero flow years were recorded between 1986 and 2012 (1986, 1989, 1991, 1996, 2005, 2007 & 2010). The greatest flow recorded was 215, 473 ML/yr in 2000. At this time, rainfall was 753.1 mm; almost twice the long-term average. Despite the fact that rainfall in 2012 was lower than that recorded in 2011, streamflow at Waterloo Bore was higher (11, 646 ML/yr in 2011 compared to 35, 357 ML in 2012). This may be related to some influence from mining discharge upstream. In 2012, total annual flow at both stations was equivalent to the long-term average. The long-term average flow at these stations ranged from 10,514.92 ML at Flat Rocks to 33,542.63 ML at Waterloo Bore.

2 ECOLOGICAL VALUES OF AQUATIC SYSTEMS IN THE PROJECT AREA

Many aquatic surveys have been conducted within the broader northwest region of Western Australia, including the Pilbara region (Dames and Moore 1975, Miles and Burbidge 1975, Taylor 1985, Masini and Walker 1989, Kay *et al.* 1999, Smith *et al.* 1999), though knowledge of the aquatic fauna in the immediate vicinity of the Project is limited. Recent studies have included sites along Marillana and WWC to the south and south-west, the Fortescue Marsh to the north-east, and a number of permanent or semi-permanent waterbodies within a 50 km radius of the Project (*i.e.* Halse *et al.* 2001, Halse *et al.* 2002, Pinder *et al.* 2010, WRM 2011) See Table 1 for a summary of previous aquatic fauna studies.

It is likely that more data exist for aquatic systems in the area, but these data are not published, with the majority belonging to private mining companies. For example, the authors have sampled a number

of sites along the Weeli Wolli and Marillana creeks for other mining companies, as well as other nearby creeks such as Mindy Mindy Creek, Coondiner Creek, Kalgan Creek and the Fortescue River. However these data are not publicly available at present. It is possible that more data will become available over time as part of Public Environmental Review documents and continued development of Western Australian State fauna databases.

As part of their licence requirements to collect fauna, DPaW and the Department of Fisheries (DoF) require all environmental consultants and researchers to submit an annual return of their fauna captures. Capture data is uploaded to the DPaW Fauna Survey Database and the DoF Freshwater Fish Distribution database. Once submitted to the relevant government databases, however, these data are not readily accessible by either the licence holder or the general public. Distribution records for species are also held in the online State government database, NatureMap, however records for most aquatic fauna species are not presently available through the NatureMap website. For the current literature survey therefore, direct requests were made to DPaW in order to obtain NatureMap records on distribution of any threatened, priority and vulnerable aquatic fauna. This information is included in the current review.

2.1 Microinvertebrates

Microinvertebrate fauna consists of microscopic fauna including micro-crustacea (ostracods, copepods and cladocera), protists and rotifers. Microinvertebrates are used as bioindicators throughout the world for many reasons. Firstly, the microinvertebrate community holds a strategic position in food webs (Bunn and Boon 1993, Zrum and Hann 1997, Bunn and Davies 1999, Jenkins and Boulton 2003). They regulate the biomass of phytoplankton in the water column and epiphyton on submerged aquatic macrophytes through grazing (Zrum and Hann 1997). They also provide a food source for other organisms, such as macroinvertebrates (Bunn and Boon 1993, Jenkins and Boulton 2003) and waterbirds (Crome 1985). Most fish species also depend on them for their first feed after hatching (Geddes and Puckridge 1989). Therefore, any change in the microinvertebrate community will ultimately result in changes to the entire aquatic ecosystem. Secondly, due to their short life cycle, rapid changes occur in their populations in response to disturbance in the ecosystem (Kaur and Ansal 1996). Lastly, they have intimate contact with the surrounding environment, being planktonic, and continually exposed to the ambient water quality. Hence, they are vulnerable to environmental pollutants and provide a useful biomonitoring tool (Kaur and Ansal 1996). The microinvertebrate community also plays a role in nutrient cycling within wetland systems (Baldwin and Mitchell 2000).

Table 1. Summary of published aquatic studies which have featured creekline sites within 50 km of the Project. Stygofauna fauna assessment for the Project is also listed, together with methodologies (fauna refers to the type of aquatic fauna targeted, *i.e.* Macro = macroinvertebrate; Micro = microinvertebrate; Hypo = hyporheic zone fauna; Stygo = stygofauna; Fish).

Program	Sampled by	Locations sampled	Fauna	Methods used	Taxonomic level of identification	Sampling dates	Reference
First National Assessment of River Health (AusRivAS)	DPaW	Sites along the upper Fortescue River, including: - Weeli Wolli Spring (located 20 km upstream of the Project); - One site on Marillana Creek, located downstream BHBPIO and RTIO Yandi operations, ~ 7.5 km south-west of the Project (Mar-DEC).	Macro	Kick sampling (250 µm mesh net) all habitats.	Family	March-98 & Nov-98.	Halse <i>et al.</i> (2001)
Sampling of the hyporheic zone of Pilbara creeks and springs	Stuart Halse, Mike Scanlon, Jim Cocking	Numerous sites throughout the Pilbara, including Weeli Wolli Spring 20 km upstream of the Project, but none within the current project area.	Hypo	- Stirring up sediments and sweeping with a 250 µm mesh dip net. - Digging up sediments to a depth of 30 cm and collecting fauna caught with 50 µm and 250 µm mesh nets (Karaman-Chappuis method).	Species	Sep-01	Halse <i>et al.</i> (2002)
Pilbara Biological Study (PBS)	DPaW	Numerous sites throughout the Pilbara, but none within the current Project area. Sites sampled include: - Weeli Wolli Spring; - Two sites on either end of Fortescue Marsh: Fortescue Marsh East and Fortescue Marsh West.	Macro Micro	- Macro - Kick sampling (250 µm net) all habitats. - Micro – sweep netting (50 µm mesh).	Species	Sep-03 & May-05	Pinder <i>et al.</i> (2010)
Iron Valley Project Subterranean Fauna Assessment	Bennelongia	84 impact bores within the Project tenement	Stygo	Replicate hauls with weighted plankton nets (50 µm & 150 µm mesh).	Species	May-09 & Nov-09	Bennelongia (2010)
Koodaideri Spring Baseline Surveys	Bennelongia	Koodaideri Spring and 9 locations along Koodaideri Creek	Macro Micro Hypo Fish	- Macro – kick sampling (250 µm net) all habitats. - Micro – sweep netting (53 µm net) water column. - Hypo – Karaman-Chappuis method (53 µm net). - Fish – seine nets, baited traps, hand lines	Species	Oct-10 & Apr-11	Bennelongia (2011)

Program	Sampled by	Locations sampled	Fauna	Methods used	Taxonomic level of identification	Sampling dates	Reference
Rio Tinto Yandi Aquatic Fauna Monitoring	WRM	- Twelve sites on Marillana Creek; 6 immediately downstream of BHPBIO's Yandi, and 6 downstream of Rio Tinto's Yandicoogina; - Flat Rocks (upstream of all mining activity on Marillana Creek, 30 km west of the Project); - Mar-DEC.	Macro Micro Hypo Fish	- Macro – kick sampling (250 µm net) all habitats. - Micro – sweep netting (53 µm net) water column. - Hypo – Karaman-Chappuis method (53 µm net). - Fish – electrofishing, seine nets & gill nets.	Species	Biannually (wet & dry seasons) since 2008; ongoing. Only dry 2008 - wet 2011 data available in public domain.	WRM (2011)

The microinvertebrate fauna of creeklines in the vicinity of the Project is poorly known. There are only three published studies of microinvertebrate fauna from nearby locations and no other currently available data. Published studies include those of Weeli Wolli Springs and the Fortescue Marsh, which were sampled as part of the Pilbara Biological Study (PBS) by the the Department of Environment and Conservation (Pinder *et al.* 2010), Marillana Creek which was sampled by WRM (2011) as part of bi-annual monitoring for Rio Tinto, and Koodaideri Spring, sampled by Bennelongia (2011) for Rio Tinto. In each study, microinvertebrate fauna was generally found to be typical of tropical/sub-tropical systems (*e.g.* Koste and Shiel 1983, Tait *et al.* 1984, Smirnov and De Meester 1996, Segers *et al.* 2004). No species listed for conservation significance were recorded, though two Pilbara endemics were collected along with four species potentially new to science.

The PBS (Pinder *et al.* 2010), recorded a total of 43 taxa of microinvertebrates from Weeli Wolli Springs, approximately 20 km upstream of the Project area. Of interest were the Pilbara endemic cyclopoid copepods *Australoeucyclops karaytugi* and *Paracyclops* sp. 6. *Australoeucyclops karaytugi* is known from a number of other spring and permanent pool systems within the Pilbara, including the Ashburton River catchment (Palm Springs, Glen Herring Pool, Wannagunna Pool, Horrigan's Pool), the DeGrey River catchment (Bamboo Springs, Skull Springs, Coppin Gap, DeGrey), and the Yule River catchment (Billan Ballan).

WRM (2011) also collected *Australoeucyclops karaytugi* from Marillana Creek, just upstream of the confluence with WWC (4.5 km upstream of the Project), but no other taxa of significance. In total, WRM (2011) collected 143 microinvertebrate taxa over six sampling events prior to 2011, comprising mainly of Protista, Rotifera, Ostracoda (seed shrimp) and Copepoda.

Of the above-mentioned species, it is likely that the Pilbara endemic copepods *Australoeucyclops karaytugi* and *Paracyclops* sp. 6 occur in creeks adjacent to the Project, although given the widespread distribution of these species across the Pilbara, associated developments are not likely to adversely effect regional populations of these species. However, microinvertebrates remain an important aspect of the proposed aquatic fauna sampling regime, given the limited knowledge of microinvertebrate taxa in the region, and the ongoing potential for the discovery of new species.

2.2 Hyporheos

2.2.1 General

The hyporheic zone, comprising subsurface interstitial spaces in coarse creek bed sediments, is recognised as a critical component of many streams and rivers (Edwards 1998). The hyporheic zone provides a rearing habitat and important refuge for aquatic invertebrates, and importantly in the context of the Pilbara region, buffering from floods (Palmer *et al.* 1992, Dole-Oliver and Marmonier 1992), disturbance in food supply (Edwards 1998) and drought (Cooling and Boulton 1993, Coe 2001, Hose *et al.* 2005).

There have been no previous surveys of hyporheos within the Project area, though Bennelongia (2010) surveyed stygofauna in groundwater bores, a number of species of which are frequently encountered in hyporheic zones. Surveys of the hyporheos within and adjacent to the Project tenement therefore may reveal the presence of stygal amphipods, isopods, syncarids and other fauna of conservation significance. Typically, hyporheic zone fauna have poor dispersal capabilities, are confined to discontinuous habitats, are highly seasonal (usually more active in the wet season following significant

flows), have low levels of fecundity, and are commonly classified as short range endemics (SRE) as defined by Harvey (2002)¹.

The hyporheos of Weeli Wolli Spring was sampled by Halse *et al.* (2002) during a study of groundwater-dependent springs of the Pilbara. A new species of ostracod (seed shrimp), *Vestenula* n. sp., was discovered. The new species of *Vestenula* is not restricted to the WWC catchment, as Halse *et al.* (2002) also collected specimens from deep wells in the Ashburton catchment. Halse *et al.* (2002) suggested the new species is likely to have a Pilbara-wide distribution, and hence has the potential to be recorded in the Project area, though associated developments are not likely to impact regional populations of this species.

2.2.2 Short-range endemics

A number of stygobitic SREs of high conservation significance have been recorded within 10 km of the Project (WRM 2011). These species are:

- Paramelitidae sp. D (amphipod);
- Paramelitidae sp. B (amphipod);
- *Chydaekata* sp. (amphipod);
- *Maarrka weeliwolli* (amphipod); and
- *Pygolabis weeliwolli* (isopod).

Each of these species is discussed below, and locations of previous recordings in relation to the Project area are provided in Appendices 2 to 7.

Paramelitidae sp. D and Paramelitidae sp. B are both currently undescribed SRE species, which have been recorded in bores and the hyporheic zone along the length of Weeli Wolli and Marillana creeks, upstream and adjacent to the Project (WRM 2011, DPaW 2015). These species are also present in bores within the Project tenement (Bennelongia 2010). Of particular interest is Paramelitidae sp. D, whose WWC and Marillana Creek populations, despite their close geographical proximity, have been found to be genetically different based on over 4 million years of reproductive isolation (WRM 2011).

Chydaekata sp. is also an undescribed SRE species. It is known from bores within the Project tenement (Bennelongia 2010) as well as the hyporheic zone of a small number of nearby creeks; WWC, Marillana Creek, Coondiner Creek and Mindy Mindy Creek (DPaW 2015). *Chydaekata* sp. has previously been recorded in the hyporheic zone along the length of Marillana Creek (WRM 2011), as well as from bores along the Weeli Wolli and Marillana creeks (DPaW 2015) and adjacent to the Project tenement (Bennelongia 2010).

The stygobitic amphipod *Maarrka weeliwolli* has previously been recorded from multiple bores along Weeli Wolli and Marillana creeks, as well as the Project tenement (Bennelongia 2010, DPaW 2015). *M. weeliwolli* has also been recorded from the hyporheic zone of WWC and Marillana Creek downstream of RTIO Yandicoogina operations (Finston *et al.* 2011, WRM 2011).

The stygobitic isopod *Pygolabis weeliwolli* is also known only from Marillana and Weeli Wolli creeks, and is an SRE of high conservation value. *Pygolabis* (family Tainisopidae) is an isopod genus, all species of which appear to be restricted to groundwaters (including hyporheic zones) of one or several creek drainages of the Pilbara region: the Fortescue, Ashburton or Robe River catchments (Keable and Wilson 2003). *P. weeliwolli* has been recorded from bores and the hyporheic zone along WWC (DPaW 2015) and Marillana Creek downstream of RTIO Yandicoogina operations (WRM 2011). Further, Keable and

¹ Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10,000 km².

Wilson (2003) suggest another species, *P. humphresi*, may occur in the WWC catchment, and Bennelongia (2010) recorded a similar species, *Pygolabis* sp. (nr. *humphreysi*) in bores within the Project tenement.

The stygobitic syncarid families Bathynellidae and Parabathynellidae are also considered likely to occur in hyporheic zones within or near the Project, as they are known to frequent the groundwater and hyporheic zone of creeks of the Pilbara (and WWC) region (Serov 2002, DPaW 2015), and have been recorded in recent subterranean surveys of bores within the Project tenement (Bennelongia 2010).

Each of these SREs have the potential to occur in the hyporheic zone of creeks within or adjacent to the Project, particularly during the wet season when greater connectivity between ground and surface waters is established. Increased surface and subsurface flows following the commencement of dewatering discharge associated with Project operations will likely encourage many deep-dwelling stygobitic species of high conservation value to infiltrate the hyporheic zone. As such, careful consideration must be taken to ensure the fauna of the hyporheic zone is adequately monitored and managed appropriately.

2.3 Macroinvertebrates

2.3.1 General

Macroinvertebrates (*i.e.* fauna retained by a 250 µm aperture mesh) typically constitute the largest and most conspicuous component of aquatic invertebrate fauna in both lentic (still) and lotic (flowing) waters. Macroinvertebrates are used as a key indicator group for bioassessment of the health of Australia's streams and rivers under the National River Health Program (Schofield and Davies 1996), and have inherent value for biological monitoring of water quality (ANZECC/ARMCANZ 2000).

The aquatic macroinvertebrate fauna of the Project area has not been sampled previously, however macroinvertebrate surveys have been conducted at numerous nearby locations, including Weeli Wolli Spring (Halse *et al.* 2001, Pinder *et al.* 2010), Marillana Creek (Halse *et al.* 2001, WRM 2011), Koodaideri Spring (Bennelongia 2011) and the Fortescue Marsh (Pinder *et al.* 2010) (refer Table 1).

As part of the AusRivAS study by DPaW, a total of 37 macroinvertebrate families from 10 orders were recorded from Weeli Wolli Spring, and 23 families from nine orders were recorded from Marillana Creek (Halse *et al.* 2001). A number of habitats were sampled, including channel, riffle, macrophytes, and pool rocks. Sampling was conducted during the second phase in an Australia-wide program, known as the Monitoring River Health Initiative (MRHI), to develop a biomonitoring system for assessing river condition based on aquatic macroinvertebrates (Halse *et al.* 2001).

During the Pilbara Biological Study, a total of 149 macroinvertebrate taxa ('species') were recorded from Weeli Wolli Spring, 49 taxa from Fortescue Marsh East and 65 from Fortescue Marsh West (Pinder *et al.* 2010). The taxonomic list comprised freshwater Cnidaria (freshwater hydra), Turbellaria (flat worms), Nematoda (round worms), Gastropoda (freshwater snails), Annelida (segmented worms), Acarina (freshwater mites), Coleoptera (water beetles), Hemiptera (true aquatic bugs), Diptera (true flies), Ephemeroptera (mayflies), Lepidoptera (moth larvae), Odonata (dragonflies and damselflies), and Trichoptera (caddisflies) (Pinder *et al.* 2010).

WRM (2011) recorded a total of 173 taxa of macroinvertebrates from the 14 sites sampled on Marillana Creek between the dry season of 2008 and the wet season of 2011. The macroinvertebrate fauna included freshwater hydra, Gastropoda, Oligochaeta, Amphipoda, Acarina, Ephemeroptera, Odonata, Hemiptera, Coleoptera, Diptera, Trichoptera and Lepidoptera. The majority of macroinvertebrate taxa

were common, ubiquitous species, with distributions extending across Northern Australia, Australasia, and the world (WRM 2011).

Of the macroinvertebrate fauna known from near the Project, including those recorded in species distribution data provided by DPaW (DPaW 2015), two species are listed for conservation significance, five are Pilbara endemics with restricted distributions, and two are Pilbara endemic and relatively new to science (see section 2.3.4). All have been recorded within 50 km of the Project, and as such all have the potential to occur in waterbodies within or near the Project tenement:

IUCN Redlist species (Appendix 1):

- *Hemicordulia koomina* (dragonfly);
- *Eurysticta coolawanyah* (damselfly).

Pilbara endemic taxa with restricted distributions:

- *Ictinogomphus dobsoni* (dragonfly);
- *Nannophlebia injibandi* (dragonfly);
- *Aspidiobates pilbara* (water mite);
- *Wandesia* sp. (water mite);
- *Laccobius billi* (hydrophilid beetle).

Pilbara endemic taxa relatively new to science:

- *Haliphus fortescueensis* (haliplid beetle);
- *Haliphus halsei* (haliplid beetle).

Further description of these species is provided in the sections below.

2.3.2 Conservation listed taxa

The Pilbara Pin damselfly, *Eurysticta coolawanyah* (Plate 1), is restricted to the Pilbara region, where it prefers riverine pools. Near the Project tenement, this species has been recorded from Weeli Wolli Spring, Ben's Oasis (a permanent pool on WWC, 15 km upstream of Weeli Wolli Spring), Flat Rocks (a permanent pool 30 km west of the Project on Marillana Creek), and Koodaideri Spring (30 km to the north-west of the Project) (Pinder *et al.* 2010, DPaW 2015). This species is listed as **Near Threatened** on the IUCN Redlist (IUCN 2014), based on its restricted distribution to an area of less than 500 km², and it being thought to occur at less than five locations (Millstream Station, Nanuturra Pools, Palm Pool and the Millstream area). However, it has since been recorded from over 40 locations throughout the Pilbara (Pinder *et al.* 2010). Hawking (2009a) lists no known threats currently, or in the near future, to this species.

The Pilbara emerald dragonfly *Hemicordulia koomina* (Plate 1) has been recorded at multiple locations within a 50 km radius of the Project, including Eagle Rock Pool (on Coondiner Creek, 45 km to the south-east of the Project), Ben's Oasis, and Koodaideri Spring (DPaW 2015). This species is listed as **Near Threatened** on the IUCN Redlist (IUCN 2014). However, revision of its listing is considered necessary given its more recent collection from a number of localities across a range greater than 500 km², including sites in the Fortescue River system (Hamersley Gorge and Fortescue Falls in Karijini National Park, and Kalgan Pool on Kalgan Creek), Robe River system (Nyeetbury Spring, Red Hill Creek pools and Wackiline Creek Pool), the DeGrey River (Bamboo Springs and Minigarra Creek pools at Woodie Woodie), Ashburton River system (Moreton Pool, Creek Pool near Mt Amy, Henry River pools, and Pool at Gorge Junction), Cane River (House Pool), Sherlock River (Pool Spring), and the Shaw River (Panorama Spring) (Pinder *et al.* 2010). Despite this, it is still considered rare, as it is infrequently collected and rarely recorded. The major threat to this species is considered to be loss of habitat (*i.e.* drying of pools/waterways) through groundwater abstraction (Hawking 2009b).

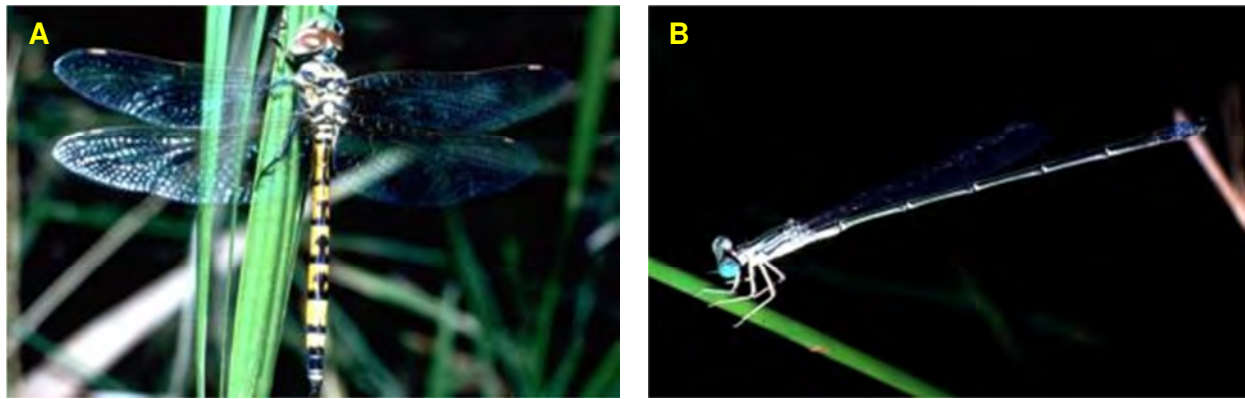


Plate 1. (A) Adult Pilbara emerald dragonfly, *Hemicordulia koomina*, and (B) adult Pilbara pin damselfly, *Eurysticta coolawanyah* (photos taken and provided by Jan Taylor ©). Larval stages of all dragonflies and damselflies are aquatic.

2.3.3 Locally (Pilbara) restricted taxa of significance

The endemic Pilbara tiger dragonfly, *Ictinogomphus dobsoni*, is recorded infrequently and in low abundances from permanent still or sluggish waters of the Pilbara region (Watson 1991). It is known from a number of sites along the Fortescue River, Robe River, Ashburton River, Yule River, DeGrey River, and Sherlock River (DEC 2009, Pinder *et al.* 2010, CSIRO 2015). *I. dobsoni* has been previously recorded at Weeli Wolli Spring (DPaW 2015), as well as multiple locations downstream of BHPBIO operations along Marillana Creek south-west of the Project tenement (WRM 2011).

The dragonfly *Nannophlebia injibandi* is also endemic to the Pilbara. This species was recorded infrequently during the PBS (Millstream Delta and Gregory Gorge in the Fortescue River catchment; Pinder *et al.* 2010). *N. injibandi* is known from Marillana Creek, downstream of BHPBIO and RTIO discharge operations (WRM 2011).

The water mite *Aspidiobates pilbara* was recorded from Weeli Wolli Spring during the PBS (Pinder *et al.* 2010). This species appears to have a limited distribution, and has only been recorded from Weeli Wolli Spring, two locations in Millstream National Park (Harvey 1988, Pinder *et al.* 2010), Bamboo Spring on the DeGrey River (Pinder *et al.* 2010), Fortescue Falls in Karijini National Park (Pinder *et al.* 2010), and Nyeetbury Spring on the Robe River (Halse *et al.* 2002).

The water mite *Wandesia* sp. was also recorded from Weeli Wolli Spring during the PBS (Pinder *et al.* 2010). This species has only two other known occurrences; Minigarra Creek on the DeGrey River and Cangan Pool on the Yule River (Pinder *et al.* 2010).

The hydrophilid beetle *Laccobius billi*, recorded previously from Marillana Creek by WRM (2011), is a Pilbara endemic rarely collected. It was only recorded from one site during the comprehensive PBS; Cangan Pool on the Yule River (Pinder *et al.* 2010), approximately 100 km north-west of the Project tenement.

2.3.4 Restrictd taxa relatively new to science

The haliplid beetle *Haliphus fortescueensis* was first described from a specimen collected from Fortescue Marsh during the PBS (Pinder *et al.* 2010, Watts and McRae 2010). It appears to be mainly restricted to the Fortescue River, and is most abundant in the Fortescue Marsh (Watts and McRae 2010). However, it has also been collected on one occasion from a claypan near Port Headland (Watts and McRae 2010).

Haliphus halsei is endemic to the Pilbara, but appears to occur widely throughout the region (Watts and McRae 2010). *Haliphus halsei* is currently known from the Cane River, Myanore Creek, Glen Ross Creek, Kumina Creek, Coondiner Pool, Fortescue Marsh West, Chalyarn Pool, Moreton Pool, Paradise Pool,

Munreemya Billabong, Wackilina Creek Pool, West Peawah Creek Pool, Harding River Pool, and an unnamed creek in Millstream (Watts and McRae 2010). It was recorded during the PBS from Fortescue Marsh in the wet season of 2006 (Pinder *et al.* 2010).

2.4 Fish

2.4.1 General

There is only one published study documenting the fish fauna in the vicinity of the Project, that of Marillana Creek by WRM (2011). Only three of the 12 freshwater fishes known from the Fortescue River system were recorded during biannual (wet & dry season) sampling between 2008 and 2011; the spangled perch (*Leiopotherapon unicolor*), western rainbowfish (*Melanotaenia australis*) and Hyrtl's tandan (*Neosilurus hyrtlui*) (Plate 2).

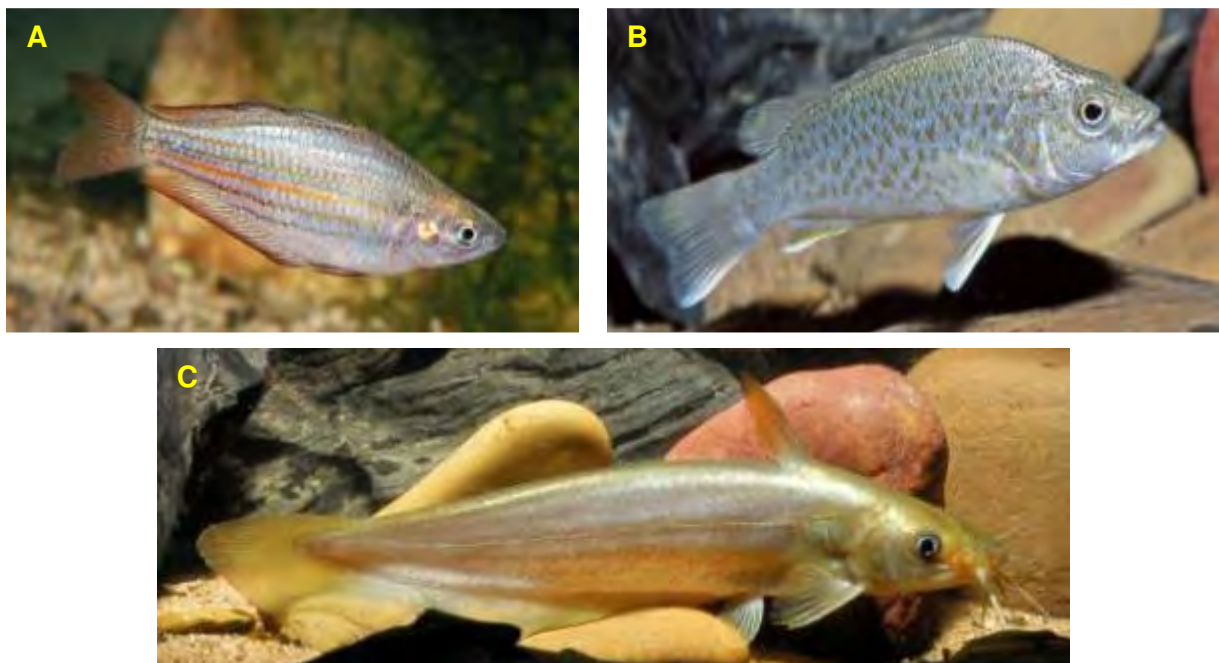


Plate 2. Fish species recorded from Marillana Creek by WRM; (A) western rainbowfish *Melanotaenia australis*, (B) spangled perch *Leiopotherapon unicolor* and (C) Hyrtl's tandan *Neosilurus hyrtlui* (photos taken and provided by Mark Allen ©).

The fish fauna of the Pilbara is characterised by low species diversity and high levels of endemism; over 42% of species recorded are restricted to the region (Unmack 2001, Allen *et al.* 2002). These fish species are adapted to the extreme conditions of the region, and many have strategies for surviving drought (Unmack 2001). For example, Australia's most widespread native fish, the spangled perch, is thought to aestivate in wet mud or under moist leaf litter in ephemeral waterbodies during periods of drought (Allen *et al.* 2002).

The reproductive strategies of fish species in the Pilbara are 'opportunistic' and 'periodic', reflecting the seasonal yet unpredictable nature of rainfall and streamflow in the region (Beesley 2006). Breeding of many species occurs during the wet season and during this time, multiple spawning events are known to occur (Beesley 2006). Therefore, any alterations to streamflow patterns and discharge are likely to impact on life history strategies of local populations.

Morgan *et al.* (2009) found that the diversity of fish species was considerably greater in the lower sections of the Fortescue River, compared to the middle and upper reaches (including the current

Project area). A total of five species were reported from the upper Fortescue River by Morgan *et al.* (2009), including the potentially new catfish *Neosilurus* sp., Hyrtl's tandan, spangled perch, western rainbowfish and the Fortescue grunter (*Leiopotherapon aheneus*).

2.4.2 Conservation listed taxa - Fortescue grunter

The Fortescue grunter (Plate 3) has a restricted distribution within the Pilbara, and is only known from the Fortescue, Robe and Ashburton River systems (Allen *et al.* 2002). It is considered to be reasonably common within this range. The Fortescue grunter is currently listed on the IUCN Red List of Threatened Species as **Lower Risk/ Near Threatened** (IUCN 2014), and as a Priority 4 Species on the Department of Parks and Wildlife Priority Fauna List (DPaW 2014). Priority 4 species are those in need of monitoring (DPaW 2014). In the Fortescue River system, the Fortescue grunter has been recorded as far east as Fortescue Falls (WRM unpub. data) and Fern Pool (Morgan and Gill 2004), although in a desktop review, FMG (2009) suggested that it may occur in the Fortescue Marsh (Appendix 1). The authors consider this likely only if the upper and lower Fortescue River systems are connected by a cyclonic rainfall event.



Plate 3. Fortescue grunter *Leiopotherapon aheneus*. Photo by Chris Hofmeester/WRM ©.

3 POTENTIAL IMPACTS TO AQUATIC FAUNA AND DEVELOPMENTAL CONSIDERATIONS

3.1 Excessive water abstraction and dewatering drawdown

3.1.1 Potential impacts to ecosystems

- Drawdown and permanent drying of ephemeral pools, for example those along tributaries flowing into WWC.
- Drawdown and desiccation of semi-permanent pools west of the main channel of WWC, adjacent to the Project.
- A reduction or cessation of ephemeral surface flows along the main channel of WWC adjacent to the Project.
- A reduction or cessation of subsurface flows through the alluvial (hyporheic) zone of WWC (and surrounding tributaries) within and adjacent to the Project.
- Changes to the water quality of impacted pools, for example evapoconcentration in receding pools leading to increased electrical conductivity (salinity).

3.1.2 Discussion of impacts in relation to aquatic fauna

If excessive dewatering substantially reduces water table levels, permanent drying of non-perched permanent, semi-permanent and ephemeral pools within the immediate vicinity of the Project may result. It is currently unknown whether pools which lie off the main WWC channel are perched or non-perched. In the arid Pilbara region, these pools act as important refuges for aquatic fauna, in particular the fish and aquatic invertebrates which lack strategies to survive drought and desiccation. These pools also support a variety of terrestrial fauna, including waterbirds, reptiles, amphibians and mammals.

Further, the ephemeral WWC and tributaries, with seasonal periods of filling and drying, are likely to harbour many species which reside in the creekbed during drought, and adopt a variety of strategies to avoid desiccation. When water is available (*i.e.* during the wet season), these fauna emerge and rapidly complete their lifecycles before the system dries. Excessive drawdown has the potential to reduce the period of flow for ephemeral creeks in the area, and consequently reduce the time available for these fauna to complete their life cycles, leading to a localised loss in biodiversity.

Hyporheic fauna, many of which are SREs of high conservation significance, may also be impacted by dewatering drawdown. Any reduction in the hyporheic habitat along WWC and its tributaries, or reduction in connectivity between underlying groundwater and the surface, may have detrimental impacts on the abundance and diversity of hyporheic SRE fauna, which are known to be particularly vulnerable to anthropogenic impacts (Bennelongia 2010), and in extreme cases, may cause the extinction of any locally endemic species (Halse *et al.* 2002).

The water quality of groundwater-dependent waterholes within the dewatering drawdown zone which do not completely dry may be affected through evapoconcentration if waters recede substantially more than natural seasonal change. This could lead to localised increases in electrical conductivity outside adaptations of resident aquatic fauna. The impacts of salinity on aquatic fauna are discussed further in section 3.3.

3.1.3 Developmental/management considerations

The water table of the Project area lies approximately 15 - 40 m below the surface, and current modelling suggests dewatering will be required to access 75 - 80% of ore located below the water table (Bennelongia 2010). The area of impact is relatively small when placed in context with other mining operations in the area, however dewatering operations still have the potential to threaten surface and subsurface aquatic fauna in the immediate vicinity.

Dewatering drawdown which extends to the WWC main channel has the potential to reduce flows along the section of WWC adjacent to the Project. Any abstraction is likely to be offset by the significant volume of groundwater discharged into the system by other mining operations further upstream (*i.e.* Rio Tinto HD1 and Yandicoogina, and BHPBIO Yandi). Considerations in relation to local aquatic fauna include:

- Adequate modelling of the drawdown area to ascertain the extent of potential impacts to aquatic habitats in the vicinity of the Project, including WWC and its ephemeral tributaries, semi-permanent pools off the main channel of WWC, permanent groundwater-fed pools, and the sub-surface hyporheic zone.
- Water quality monitoring of any groundwater-dependent habitat within the drawdown zone, to assess any threats to aquatic fauna in relation to changes in physicochemistry.
- Monitoring of hyporheic and subterranean fauna to assess direct impacts of dewatering to the hyporheic and groundwater environments, including loss of habitat for conservation significant SRE fauna and stygofauna.

3.2 Changes to the hydrological regime via groundwater discharge

3.2.1 Potential impacts to ecosystems

- Permanent surface flow replacing ephemeral (seasonal) flows along the receiving creekline (WWC).
- Development of aseasonal flows along WWC, *i.e.* surface flows during the dry season, when the system is normally reduced to a series of receding pools.
- Saturation of the alluvium, allowing the WWC and its tributaries to flow sooner and for longer periods following significant rainfall events.

3.2.2 Discussion of impacts in relation to aquatic fauna

Invertebrate fauna

The development of permanent surface flows due to dewatering discharge would likely cause an increase in habitat heterogeneity and diversity at the receiving section of WWC. Habitat heterogeneity and diversity are known to play a crucial role in the structure and trophic organisation of invertebrate communities (Miserendino 2001). The increasing extent of habitats, such as aquatic macrophytes, complex habitat (snags, logs and roots), riffle zones and overhanging riparian vegetation, will likely result in greater abundance and diversity of macroinvertebrates. Although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along the receiving section of WWC, macroinvertebrate assemblage and community structure will likely shift away from those occurring naturally, and these values will be lost upon cessation of discharge.

Combined dewatering discharge from the Project and upstream Rio Tinto and BHPBIO mines may also cause permanent inundation of WWC downstream of the Project. The switch from an ephemeral to

permanent system has implications for fauna specifically adapted to temporary environments. For example, many invertebrates adopt strategies to avoid desiccation, such as drought-resistant spores, eggs or larval stages, burrowing into moist sediments, or sealing the entrance to protective body parts (e.g. shells in snails and bivalves; Balla 1994). As these species are adapted to the drying and refilling cycles, they will eventually be superseded by opportunistic, fugitive and predatory species if the system becomes permanent. Therefore, variation in hydrology can lead to the loss of fauna which favour ephemerality from the system, and changes to invertebrate community structure and life-history patterns may ensue (Bunn *et al.* 1989).

Fish

Increased flows associated with discharge are also likely to influence fish abundance and community structure in the vicinity of the Project. Permanent inundation of the receiving section of WWC may lead to the creation of pools of greater water depth, which plays an important role in the structure and function of fish assemblages. Generally, greater water depth increases the availability of complex habitat (e.g. woody debris) and vertical space in the water column for mid-water schooling species (e.g. western rainbowfish), provides greater physicochemical stability, and is an important factor in the avoidance of terrestrial predators (Lisle 1987, Capone and Kushlan 1991, Harvey and Stewart 1991).

As with macroinvertebrates, increased abundance and size of fish through provision of increased surface water may be regarded as enhancing ecological values. However, this would cause a shift away from the natural ecology of the system, and these values will likely be lost upon cessation of discharge.

Other fauna

The native flat-shelled turtle, *Chelodina steindachneri*, is known from WWC (WRM 2011). These turtles are adapted to prevent desiccation and survive drought by burrowing into the dried-up river beds (Kuchling 1988). Only one clutch of seven to eight relatively small eggs is laid each year; a pattern that appears to be adapted to a relatively long period of aestivation of up to three years (Kuchling 1988). Aseasonal releases via discharge could adversely affect turtles residing in WWC near the Project, by providing triggers for them to break aestivation at unfavourable times of the year, or not providing sufficient conditions for breeding or laying down energy reserves to survive further aestivation.

Many frog species in the Pilbara also aestivate over dry periods to avoid desiccation, emerging following rains to opportunistically breed and spawn (Tyler and Doughty 2009). Provision of permanent flows along the receiving section of creek may be initially advantageous to some frog species, resulting in increased populations. However as with fish, these populations would collapse upon mine closure/cessation of discharges.

An increase in flows along WWC may also act as an attractant for stock and feral animals, with associated impacts, such as overgrazing, trampling of banks and vegetation, erosion, increased turbidity and elevated nutrient levels.

3.2.3 Developmental/management considerations

Current plans for Project dewatering discharge include on-site use for dust suppression, ore processing, and within mine facilities and accommodation. Other options are under consideration, including the discharge of excess water into the adjacent section of WWC.

If excess water is to be released into WWC, impacts to the receiving section via alterations to the hydrological regime must be considered. As discussed above, the structure and function of a riverine ecosystem and many adaptations of its biota are determined by patterns of temporal variation in river

flows. Therefore, it is suggested that discharge operations mimic, as much as possible, the natural flow regime, taking into consideration the magnitude, frequency and timing of flow events.

Unseasonal availability of surface water would likely affect species adapted to the current flow regime, and it would be expected that intermittently available surface water in the wet season would be more readily adapted to than intermittently available water in the dry season. As such, the main considerations for protecting aquatic fauna and ecological values, where possible, include:

- Intermittent, seasonal discharge to mimic, as much as possible, the natural flow regime.
- Alternate use of discharge points to allow infiltration, and to prevent surface flows developing.
- Reducing scouring of the receiving creekline, by reducing flow velocity where possible.
- Careful consideration of cumulative impacts of Project related discharge and other discharge operations further upstream, including the increased discharge footprint along WWC towards the Fortescue Marsh.

3.3 Changes to surface water quality via groundwater discharge

3.3.1 Potential impacts to ecosystems

- Thermal pollution - increased water temperature to the receiving creekline (WWC).
- Dissolved metals, ions and streambed compaction - increased concentrations of dissolved metals, ions, and the potential for creekbed armouring and compaction due to ion precipitation.
- Eutrophication and algal blooms - the exposure of potentially nutrient enriched groundwater to the receiving creekline, leading to eutrophic conditions and algal blooms.
- Saline intrusion - the exposure of saline groundwater to the receiving creekline.
- Erosion and siltation - the scouring and erosion of the receiving creekline caused by discharge, with increased siltation and turbidity, leading to the smothering of habitats and suffocation of aquatic fauna.

3.3.2 Discussion of impacts in relation to aquatic fauna

Thermal pollution (Increased water temperature)

There is the potential for changes to surface water temperature (thermal pollution), and associated impacts to the receiving section of WWC, due to the discharge of excess dewatered groundwater of different temperature to surface waters. Surface water temperatures tend to reflect ambient air temperature, but are also influenced by water colour, water depth and degree of riparian shading (ANZECC/ARMCANZ 2000). Groundwater tends to be warmer than ambient surface water, especially as depth of abstraction increases. Discharge of excess dewatering water will likely provide warmer water to the creek in the dry season, when ambient temperatures tend to be lower. The change in surface water temperature can impact the ecosystem through decreased oxygen supply (Chang *et al.* 1992, Meyer *et al.* 1999), increased metabolic rate of aquatic fauna (Rouse *et al.* 1997, Gillooly *et al.* 2001), changes to the timing of breeding, spawning and other life-history cycles, increased primary production leading to algal blooms (Robarts and Zohary 1987, Ochumba and Kibaara 1989) and, can ultimately reduce aquatic biodiversity (Parker *et al.* 1973, Ward 1976).

Dissolved metals, ions and streambed compaction

There is also the potential for changes to the water chemistry (increases in dissolved ions or metals), and dissolution of calcrete, in the receiving section of WWC as a result of discharge. When groundwater with high concentrations of calcium and sulphate mix with stream water already nearly saturated with calcite, degassing of carbon dioxide and the common ion effect quickly causes calcite precipitation (Zaihua *et al.* 1995). The precipitation of calcite results in creek bed armouring and ultimately a reduction in habitat for aquatic macroinvertebrates. As mentioned previously, habitat heterogeneity is known to play a crucial role in the structure and trophic organisation of invertebrate communities (Bis *et al.* 2000; Miserendino 2001). Ultimately, a decrease in habitat heterogeneity and diversity would likely lead to a decrease in taxa richness.

Eutrophication and algal blooms

Naturally high levels of nitrate have been reported from arid-zone groundwaters in Australia, and there is evidence to suggest that the groundwater of many aquifers of the Pilbara region is naturally high in nutrients, particularly nitrates (Barnes *et al.* 1992, WRM 2011). The exposure of nutrient-enriched groundwater to the surface may cause eutrophic conditions along the receiving section of WWC. Eutrophication, particularly in the warm and high light conditions of the Pilbara, can lead to the proliferation of benthic algal communities (algal blooms) (Davis and Koop 2006). Aquatic environmental impacts caused by algal blooms include loss of pollution-intolerant invertebrate taxa, smothering of the substrate, degradation of water quality (particularly dissolved oxygen) leading to fish-kills, and aesthetic degradation (Biggs 2000).

Another possible issue associated with eutrophication is the establishment of potentially toxic cyanobacteria communities. Toxic cyanobacteria are known to produce substances toxic to animals and humans. Toxins are often produced during blooms in eutrophic waterbodies, but the trigger for toxin production in cyanobacteria is largely unknown. The level of toxicity is dependent on the species of cyanobacteria and the density/extent of algal blooms. Obvious signs that a bloom is toxic include numbers of dead fish, waterbirds or other animals in or around the water body (Jones *et al.* 2002, NHMRC 2008).

Surface waters in the receiving section of WWC are likely already nutrient-enriched, due to pastoral cattle stocking in the surrounding catchment, and discharge of nitrate-enriched groundwater from upstream mines (WRM 2011).

Saline intrusion

Groundwater monitoring in the vicinity of the Project has indicated that a saline wedge of groundwater may occur to the north of the tenement, associated with the accumulation of salts in the Fortescue Marsh (URS 2012). Excessive dewatering drawdown may cause saline water to move towards the Project area, and discharge of this water may increase salinity at the receiving section of WWC.

Naturally, surface waters in arid/semi-arid zones exhibit more concentrated salinity levels in the dry season, as a consequence of high evaporation levels and low rainfall. Although some dilution occurs following wet season rains, salinity can often remain high due to the variability of flows and flushing of stored salts (Jolly *et al.* 2008).

On a broad scale, plant and animal species richness correlates negatively with increasing salinity (Kay *et al.* 2001), although the implications of salinity shifts for arid-zone stream macroinvertebrates are poorly understood. In the event that saline groundwater from Project operations be discharged into WWC, increases in electrical conductivity outside the natural range of the creek and outside adaptations of resident aquatic fauna could occur. In which case, an initial decline in biodiversity may ensue, with the loss of salinity-sensitive taxa, for example baetid mayflies and trichoptera (caddisflies) from the system

(Kefford *et al.* 2003). The long term impacts of salinity increases on aquatic fauna of the receiving creekline are currently unknown and would require ongoing monitoring.

Erosion and siltation

Poorly designed discharge points, or large volumes of discharge may lead to scouring and erosion, and consequent increases in turbidity and siltation at the receiving section of WWC. Siltation/sedimentation is a major threat to the ecology of rivers in arid and semi-arid areas (*i.e.* Cohen *et al.* 1993, Prosser *et al.* 2001). Increased suspended sediment concentrations from erosion can change the channel and bed morphology (Schumm 1977, Milhous 1998), smother large woody debris and other benthic and hyporheic habitats (Bartley and Rutherford 1999, Rutherford 2000), and coat organic deposits and algae upon which aquatic fauna depend as a food source (Arruda *et al.* 1983, McCabe and O'Brien 1983). Increased sediment loads also increases turbidity which alters the light regime, affecting phytoplankton habitat and reducing the rate of photosynthesis, and consequently primary production is inhibited (Hoyer and Jones 1983, Grobbelaar 1985, Davies-Colley *et al.* 1992). Impacts to macroinvertebrate communities include mortality (Newcombe and MacDonald 1991), and decreased abundance and diversity (Quinn *et al.* 1992, Metzeling *et al.* 1995). Fish may also be affected by increased levels of fine sediment through reduced feeding efficiency (Vinyard and O'Brien 1976, Gardner 1981, Berkman and Rabeni 1987), decreased growth rates (Bianchi 1963, Hausle and Coble 1976) and increased disease (Koehn and O'Connor 1990).

If siltation is severe, pools will become shallower, water temperatures will increase, as will diurnal changes in oxygen levels, making the pools less suitable for fauna. Eventually, the pools may be totally in-filled. Large flood events may subsequently scour sediment from the pools, but usually this is after the ecological values in the pools have been lost. The scoured material will then be transported downstream to progressively affect other pools and their resident fauna. If this process occurs along the receiving length of WWC, losses in biodiversity may eventuate.

3.3.2 Developmental/ management considerations

- Comprehensive baseline and ongoing monitoring of groundwater quality to be discharged into the creekline, including water temperature, ions, salinity and nutrient levels.
- Comprehensive baseline and ongoing monitoring of surface water quality of the receiving creekline, involving the aforementioned physico-chemical parameters, in order to assess and act on any potential threats to aquatic fauna.
- Reducing scouring of the receiving creekline, by reducing flow velocity at the discharge point(s) where possible.
- Consideration into the design of the discharge point(s), in order to reduce the impacts of erosion and scouring on the receiving creekline, and thereby reduce potential impacts on the receiving environment, such as increased turbidity and siltation.

3.4 AMD, NMD and stormwater runoff

3.4.1 Potential impacts to ecosystems

- AMD (Acid Mine Drainage), with runoff causing decreased pH and increased dissolved metal concentrations at WWC and its tributaries.

- NMD (Neutral Mine Drainage), or metalliferous drainage, with the release of heavy metals at near neutral conditions.
- Exposure of creeks and tributaries to hydrocarbons, pollutants and other contaminants via stormwater runoff or accidental spillage.

3.4.2 Discussion of impacts in relation to aquatic fauna

AMD (Acid Mine Drainage) is caused by exposure of acid generating rock-types to air and water through mining/construction operations. AMD runoff into aquatic habitats is known to cause decreased pH and increased dissolved metal concentrations, and vast reductions in the abundance and diversity of aquatic biota (DeNicola and Stapleton 2002). AMD can also cause elevated bioaccumulation of metals in aquatic organisms, with varying degrees of toxicity. The precipitation of metals released through AMD can bury hard substrates and organisms, while also extending the time of recovery in streams following mine closure (DeNicola and Stapleton 2002).

AMD runoff is known to cause significant shifts in macroinvertebrate assemblage structure, where acid/metal tolerant taxa, and taxa which favour extremely stressed areas, such as fugitive, predatory and opportunistic groups tend to increase, and acid/metal sensitive taxa such as Crustacea, molluscs and Ephemeroptera are superseded (Gerhardt *et al.* 2004). The lack of predatory pressure from fish in these environments also allows predatory macroinvertebrates such as Coleoptera and Hemiptera to dominate (Gerhardt *et al.* 2004). Gerhardt *et al.* (2004) reported that even small decreases in pH and elevations in metal concentrations related to AMD runoff can have adverse impacts on the behaviour of fish and macroinvertebrates.

NMD (neutral mine drainage or metalliferous drainage) can occur when iron ores are excavated from below the water table, stockpiled and allowed to oxidise. Selenium has been identified as a constituent of concern for NMD, both in Western Australia (EPA 2012) and overseas (Fitzgerald *et al.* 2008). This is because selenium typically occurs as selenite under reducing conditions below the water table, but when material is removed and stockpiled, selenite can oxidise to selenate; a weakly adsorbing form which is unable to remain attached to mineral surfaces at near neutral pH and can therefore be released into the receiving environment (Lipinski *et al.* 1987, Gruebel *et al.* 1995, Su and Suarez 2000). While selenium is an essential nutrient in aquatic systems, it can be toxic to fish and other aquatic biota at concentrations slightly higher than nutritional requirements (Lemly and Smith 1987, Maier and Knight 1993).

Stormwater runoff, which can introduce a variety of pollutants to aquatic systems, is also known to adversely impact these environments. Impacts include changes to water chemistry and macroinvertebrate assemblage structure (shift to more pollution tolerant taxa), the introduction of pollutants to substrates making them readily available to aquatic organisms, and bioaccumulation of pollutants in some fish and invertebrate species (Masterman and Bannerman 1994).

3.4.3 Developmental/management considerations

Initial analysis indicates that the risk of AMD in the vicinity of the Project is low (URS 2012). However, the risks of AMD, NMD and stormwater runoff still exist and must be managed appropriately through:

- Appropriate encapsulation and management of exposed stockpiled and overburden materials to minimise the risk of AMD/NMD runoff into the surrounding aquatic environment.
- Regular monitoring of pH and dissolved metals in surface waters of WWC and surrounding tributaries to enable detection of any AMD/NMD impacts on stream ecosystem health.
- Appropriate on-site surface water and runoff prevention infrastructure and management.

- Appropriate on-site hydrocarbon and chemical management procedures, to prevent the release of pollutants into the surrounding aquatic habitat.
- Minimisation and management of vegetation clearing and creek crossings, to reduce the impact of runoff and erosion on the aquatic environment.

3.5 Creek/channel diversion

3.5.1 Potential impacts to ecosystems

- Siltation and mobilisation of sediments into WWC by earthworks and erosion from diverted tributaries.
- Cumulative impacts on the hydrology of WWC, whereby the diversion of channels which flow into the creek may exacerbate localised drying caused by water abstraction or other developmental activities.
- Siltation and mobilisation of sediments, and reduced flows adversely impacting on the sub-surface hyporheic habitat of WWC and surrounding tributaries.

3.5.2 Discussion of impacts in relation to aquatic fauna

A major consideration of channel realignment is the ultimate fate of silt and sediment mobilised by earthworks and eroded from the realigned channel. The impact of siltation and sedimentation on aquatic fauna is discussed above in section 3.3.

If groundwater abstraction associated with the Project is found to affect the hydrology of the area, the diversion of minor tributaries may exacerbate localised drying of WWC in the vicinity of the Project. The impact of reduced flows or permanent drying on the aquatic fauna of WWC is discussed above in section 3.1.

3.5.3 Developmental/management considerations

Development of site infrastructure associated with the Project requires the diversion of three ephemeral tributaries of WWC (URS 2012). Along with appropriate runoff management and flood protection infrastructure, any new realigned channel should be designed as an ecologically functioning channel, and not a homogenous, 'trapezoidal' culvert. Design features appropriate to aquatic fauna which need to be considered include:

- Heterogeneity in plan form (meanders as opposed to a straight channel) and longitudinal profile (pools and riffles rather than a single gradient).
- Appropriate bank profiles to avoid a steep, incised channel.
- Construction of benches upon which riparian vegetation can ultimately establish (or be established using propagation and planting).
- Sufficient conveyance capacity to cater for low frequency but high magnitude rainfall/run off events.
- Creation of alluvial bed habitats within the channel to act as dry-season refuges for invertebrate fauna with resistant life stages.
- Areas in the channel where silt/sand can deposit to avoid the diversion having a uniform rock substrate, providing 'habitat' for spores/eggs of invertebrate fauna to reside.

- Stabilisation of banks of constructed channel using natural materials (*i.e.* woody debris, matting, rocks, brushing and revegetation).
- Revegetation to limit erosion and sediment loading and reduce the run-off and excessive deposition of fine silts that may smother benthos and hyporheos.
- Point of re-entry of the realignment into the natural channel that avoids excessive velocities from the diversion into the natural creek and so avoid excessive erosion.

3.6 Dust and other disturbance

3.6.1 Potential impacts to ecosystems

- Dust and disturbance from construction and mining activities leading to the sedimentation and siltation of WWC and associated habitats.

3.6.2 Discussion of impacts in relation to aquatic fauna

The impact of siltation and sedimentation on aquatic fauna is discussed above in section 3.3.

3.6.3 Developmental/management considerations

- Appropriate use of dust suppression during construction and mining activities.
- Baseline and ongoing monitoring of suspended sediment loads in the surface waters of WWC and associated aquatic systems.

3.7 Cumulative impacts on WWC

As mentioned previously, Project operations have the potential to add to the cumulative impacts of mine-related activities on WWC. This may include increased sediment loads, changes to water quality, and further alterations to the hydrological regime.

WWC currently receives discharge from the Rio Tinto HD1 mine, which creates perennial surface-flows extending 25 - 30 km downstream. BHPBIO and RTIO also discharge groundwater into Marillana Creek, which converges with WWC approximately 4.5 km upstream of the Project. Hydrological modelling indicated a further discharge footprint of 17 km along WWC downstream of the Marillana/WWC confluence (EPA 2012). Commencement of discharge in association with Project operations would likely extend the footprint further towards the Fortescue Marsh.

In the context of the aforementioned large-scale mining activities upstream, previous modelling by URS (2012) indicated that Project operations were likely to provide a negligible contribution to cumulative impacts on surface water quantity and quality, particularly if appropriate impact management measures were put into place. Additional modelling is currently in progress as part of BWT approvals to provide insight into potential abstraction volumes, drawdown contours, and dewatering discharge extents along WWC.

4 PROPOSED BASELINE AQUATIC FAUNA SAMPLING

4.1 Compliance

There are no specific guidance statements for undertaking aquatic fauna surveys or monitoring impacts to aquatic ecosystems. However, it is recommended that field surveys employ sampling designs, methods and technical approaches consistent with the following:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000);
- EPA (2013) Environmental Assessment Guideline No. 12, *Consideration of Subterranean Fauna in Environmental Impact Assessment in WA*;
- EPA (2009) Guidance No. 20, *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia*;
- EPA (2003) Guidance No. 55, *Implementing Best Practice in Proposals Submitted to the Environmental Impact Assessment Process*;
- EPA (2002) Position Statement No. 3, *Terrestrial Biological Surveys as an Element of Biodiversity Protection*;
- EPA (2004) Guidance No. 56, *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia*.

4.2 Sites and sampling design

There are a variety of aquatic habitats within the immediate vicinity of the Project which may be affected by Project operations, each likely to harbour different ecological values. These include ephemeral pools along the main channel of WWC adjacent to, and downstream of the Project tenement, the flowing riverine section immediately downstream of the WWC/Marillana Creek confluence, ephemeral pools of tributaries which transverse the Project tenement and flow into WWC, and a number of permanent and semi-permanent pools to the west of WWC.

WRM will undertake baseline aquatic fauna sampling for the Project, consistent with methodology used by government and universities for similar surveys, including the Pilbara Biological Survey (*i.e.* Pinder *et al.* 2010) and National Monitoring River Health Initiative (Department of Environment Sport and Territories *et al.* 1994). The aim of the sampling is to i) assess the existing ecological values of watercourses potentially affected by Project operations, ii) provide a statistically robust baseline against which to compare any future changes, and iii) provide a means of separating effects (if any) of the Project from those of operating mines upstream (*e.g.* Rio Tinto HD1, Yandicoogina and BHPBIO Yandi).

The proposed sampling is based on a statistically robust design and includes 12 sites along ephemeral reaches of WWC: six reference sites upstream of the Project and six potentially exposed sites downstream. Upstream reference sites will provide additional data on the 'natural' variability of the system, allowing any future monitoring to separate mine related effects from non-mine related, such as those due to climate variability. Potentially exposed sites will be located within the zone of influence of Project operations. Baseline sampling is scheduled for the end of the current wet season (March/April 2015).

In addition to the main channel of WWC, WRM recommend assessing the ecological and conservation values of tributaries transversing the Project tenement, and the permanent/long-term pools located west of the main WWC channel. These tributaries and pools likely harbour significantly different aquatic faunal assemblages to those of the main WWC channel, while also supporting terrestrial fauna such as waterbirds, reptiles, amphibians and mammals. These ecosystems may be impacted by dewatering drawdown, and as such, WRM has proposed adding an additional three sites (dependent on availability of surface water) in order to account for the ecological values of, and potential threats to these habitats.

5 CONCLUSION

This desktop review was undertaken to identify the current ecosystem values of aquatic ecosystems in vicinity of the Project, and evaluate potential impacts to these systems from proposed BWT mining and dewatering discharge of excess groundwater into Weeli Wolli Creek. The current review precedes and informs targeted baseline aquatic fauna sampling planned for the late wet season, 2015. The desktop review and baseline sampling together constitute a Level 1 survey for environmental impact assessment, as described under Environmental Assessment Guideline (EAG) No. 12 (EPA 2013) and in accordance with EAG No. 8 (EPA 2015), with the focus on hydrological processes and ecosystem maintenance.

More than 140 microinvertebrate (zooplankton) species, 60 hyporheic invertebrate species (including stygal SRE species), 170 macroinvertebrate species and three fish species have been reported from waterbodies within a 50 km radius of the Project. None are currently listed for conservation significance under State or Federal legislation. Two species, however, are listed on the International Union for Conservation of Nature (IUCN) Red List as 'Near Threatened'; the Pilbara pin damselfly *Eurysticta coolawanyah* and the Pilbara emerald dragonfly *Hemicordulia koomina*. Also reported were a number of stygal SRE and epigeal crustacean species of scientific interest. Most of these species are highly likely to occur within the Project tenement.

In evaluating potential impacts to aquatic ecosystems, the main issue was considered to be cumulative impacts of combined groundwater dewatering discharge to Weeli Wolli Creek (WWC). The surface water footprint from existing discharge operations upstream of the Project (RTIO HD1 & Yandicoogina, BHPBio Yandi) currently extends up to 17 km downstream of the Marillana/WWC confluence. Commencement of discharge in association with Project operations may extend the footprint further towards the Fortescue Marsh. The volume, rather than quality, of groundwater was considered to pose greatest risk to WWC and Fortescue Marsh fauna through potential changes to hydrological regime. There is also increased risk of creek bed armouring due to carbonate (calcite and dolomite) precipitation from groundwater discharge. Should extensive armouring occur, flow rate and longitudinal extent of the discharge footprint may also increase. Armouring also reduces habitat heterogeneity, which may result in localised reductions in biodiversity along affected sections of WWC.

Based on the desktop review, there are at least two creekline species known only from the Project tenement that may be threatened by the development. These include stygal syncarid (crustacean) species from the families Bathynellidae and Parabathynellidae, which are known to occur in groundwater bores within the tenement and (likely) hyporheic zones of creeks.

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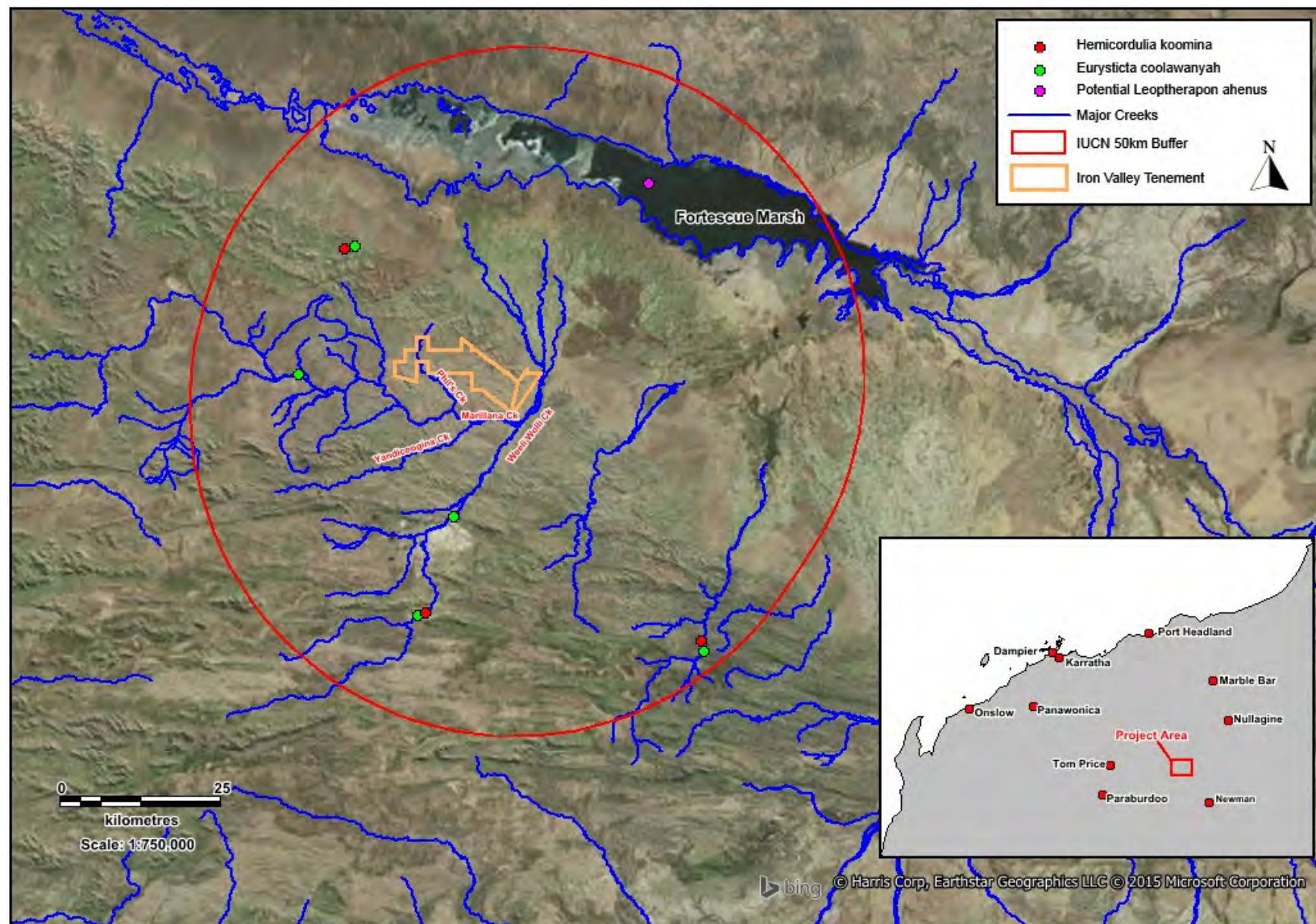
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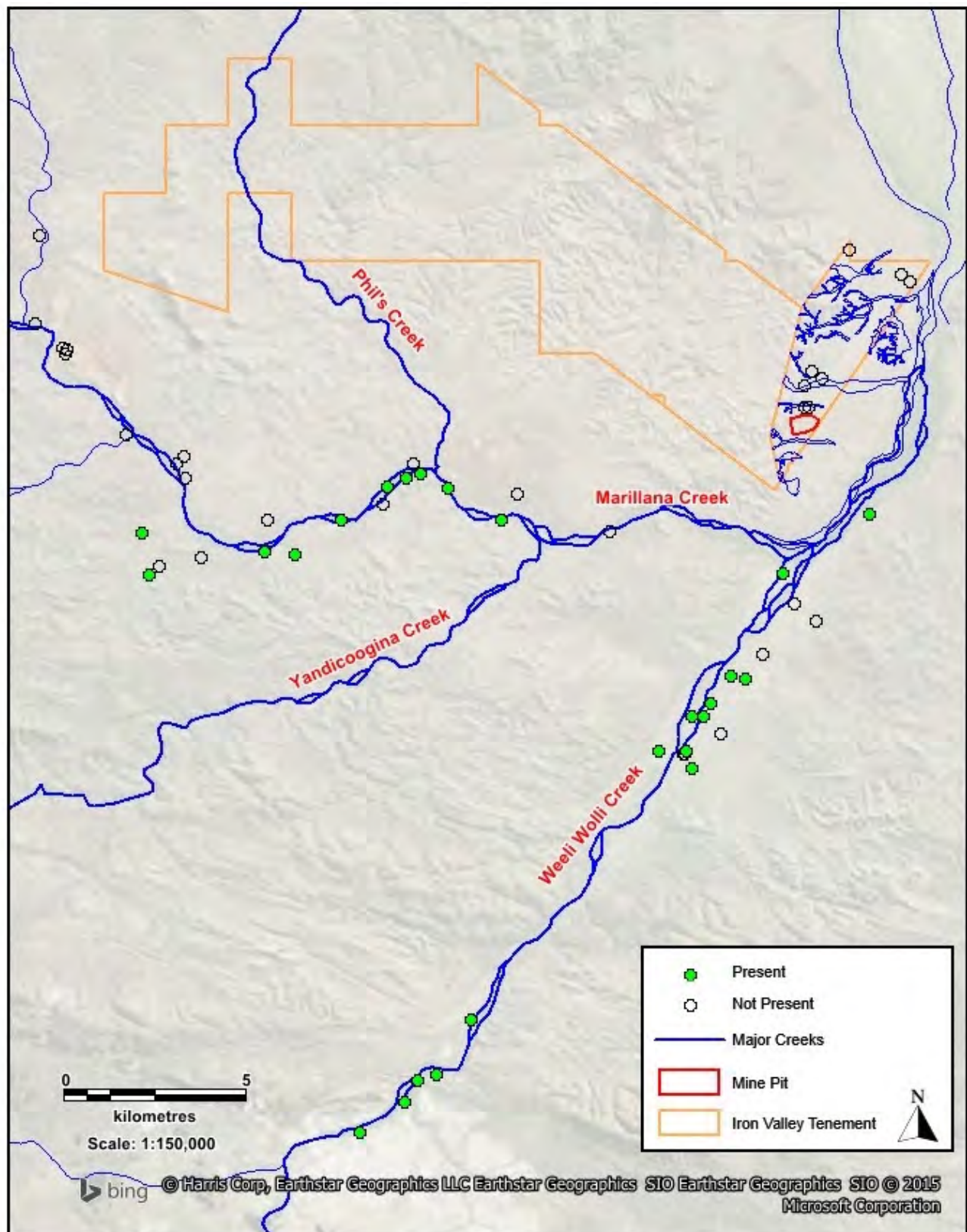
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APPENDICES

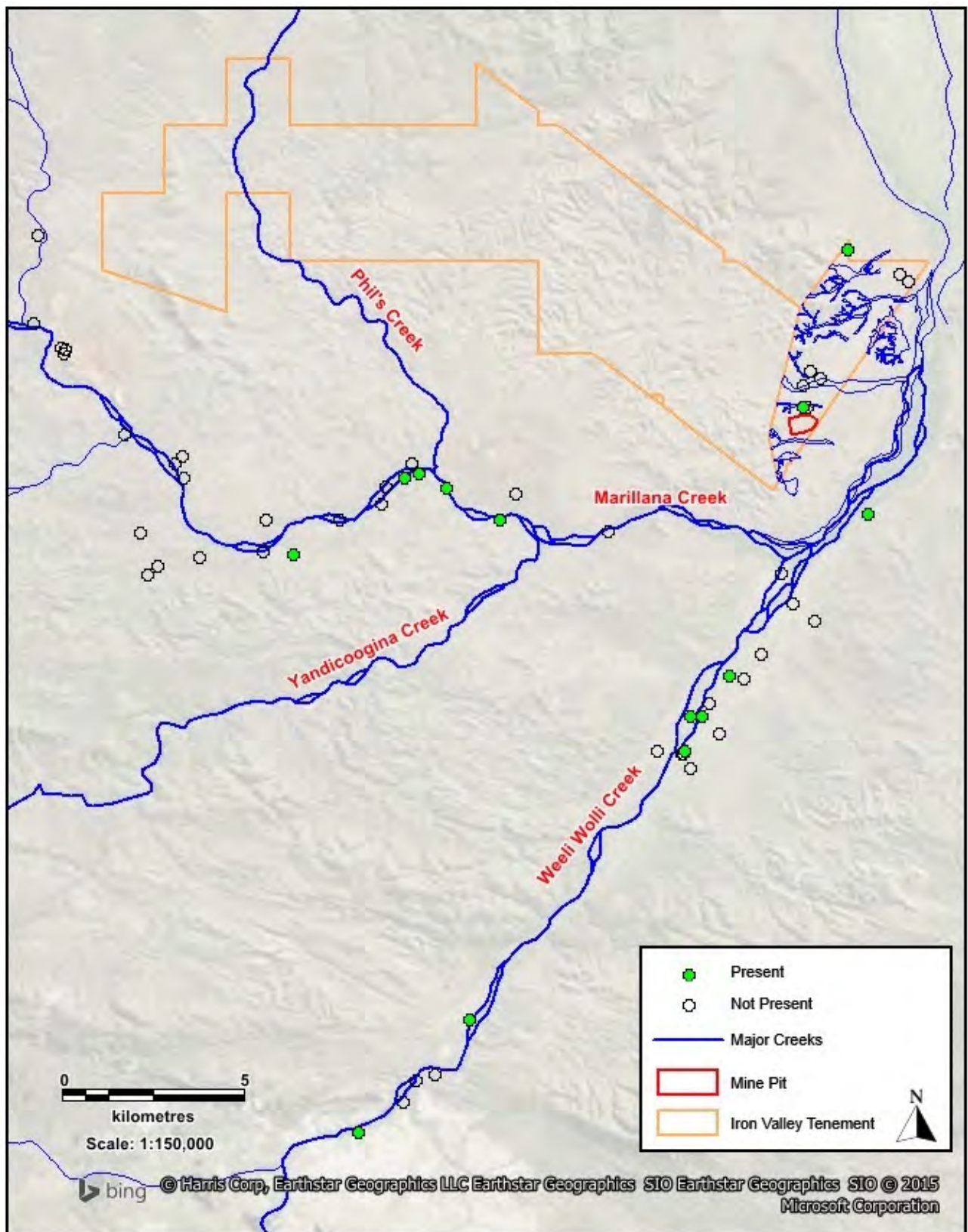
Appendix 1. Locations of IUCN listed aquatic fauna within 50 km of the Project area



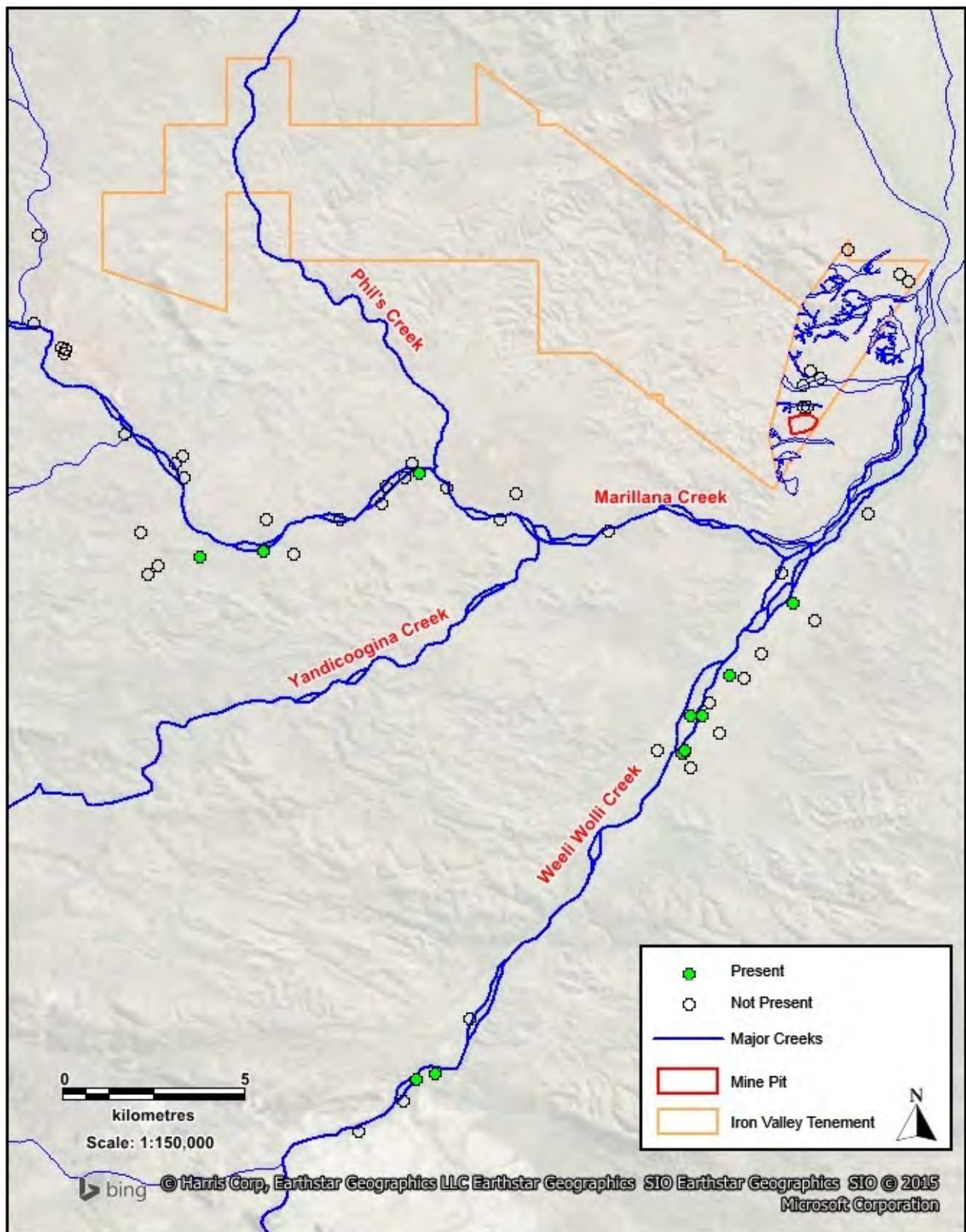
Appendix 2. Locations of stygal short-range endemic amphipod, *Chydaekata* sp.



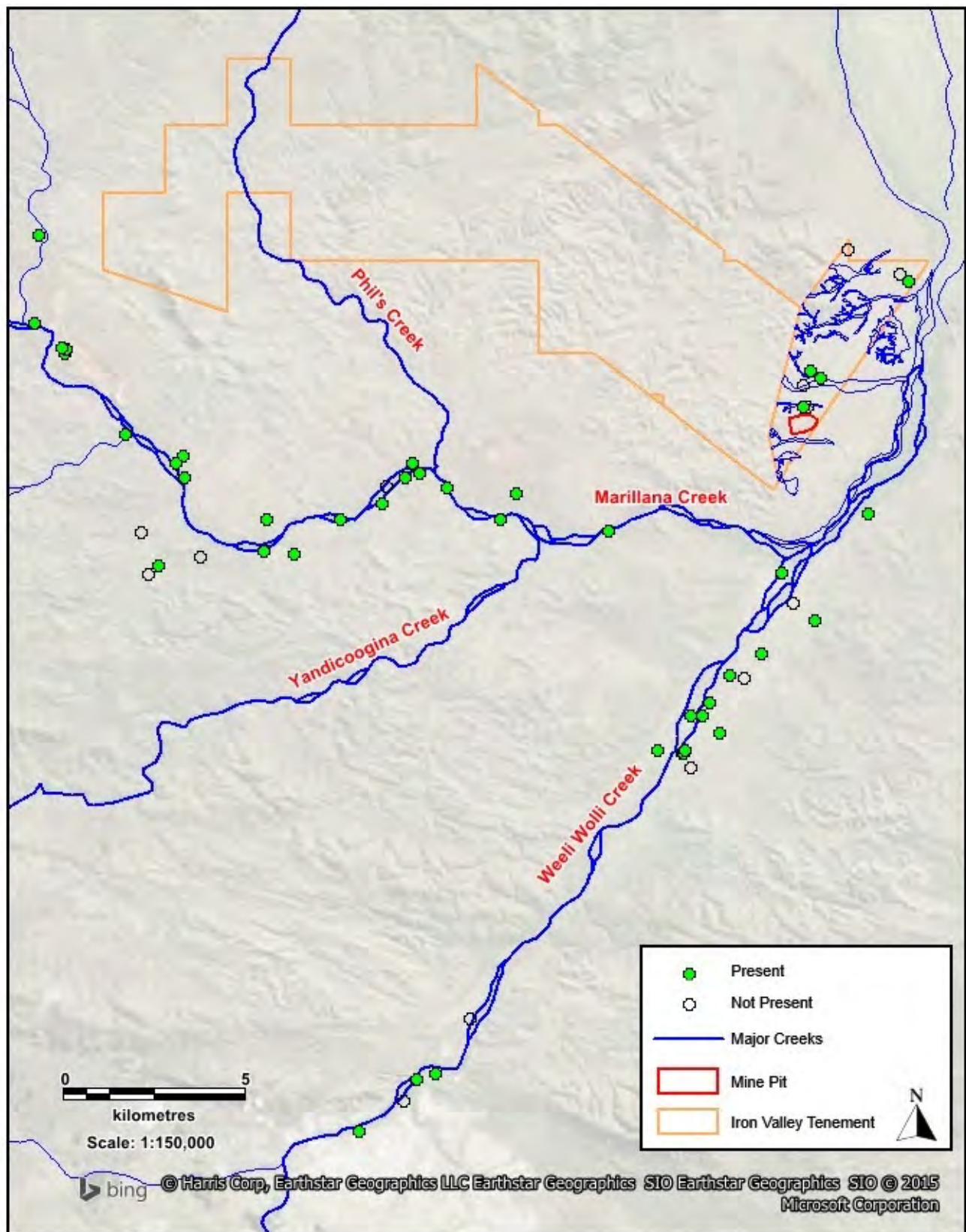
Appendix 3. Locations of stygal short-range endemic amphipod, *Maarrka weeliwolli*.



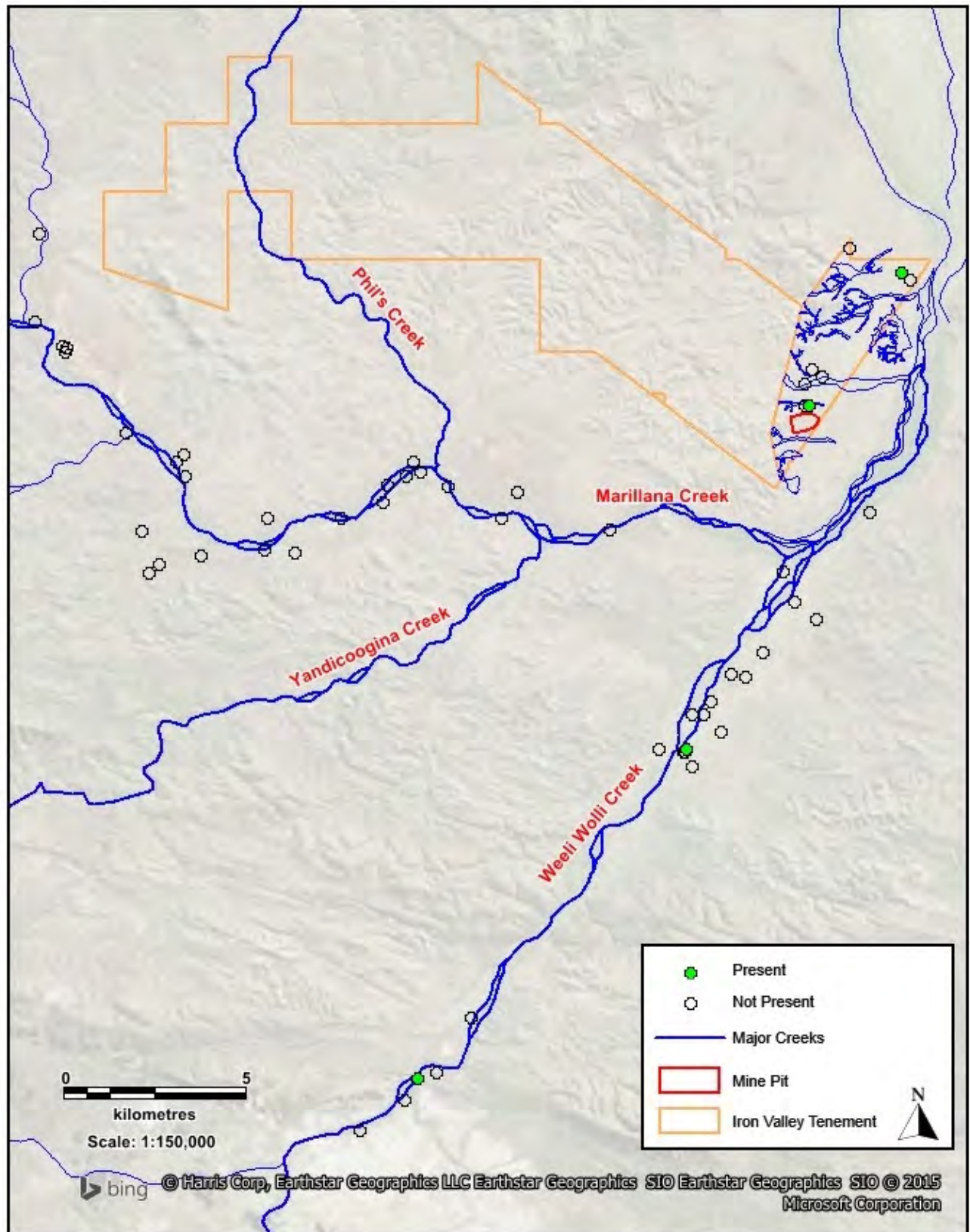
**Appendix 4. Locations of stygal short-range endemic amphipod,
Pygolabis weeliwolli.**

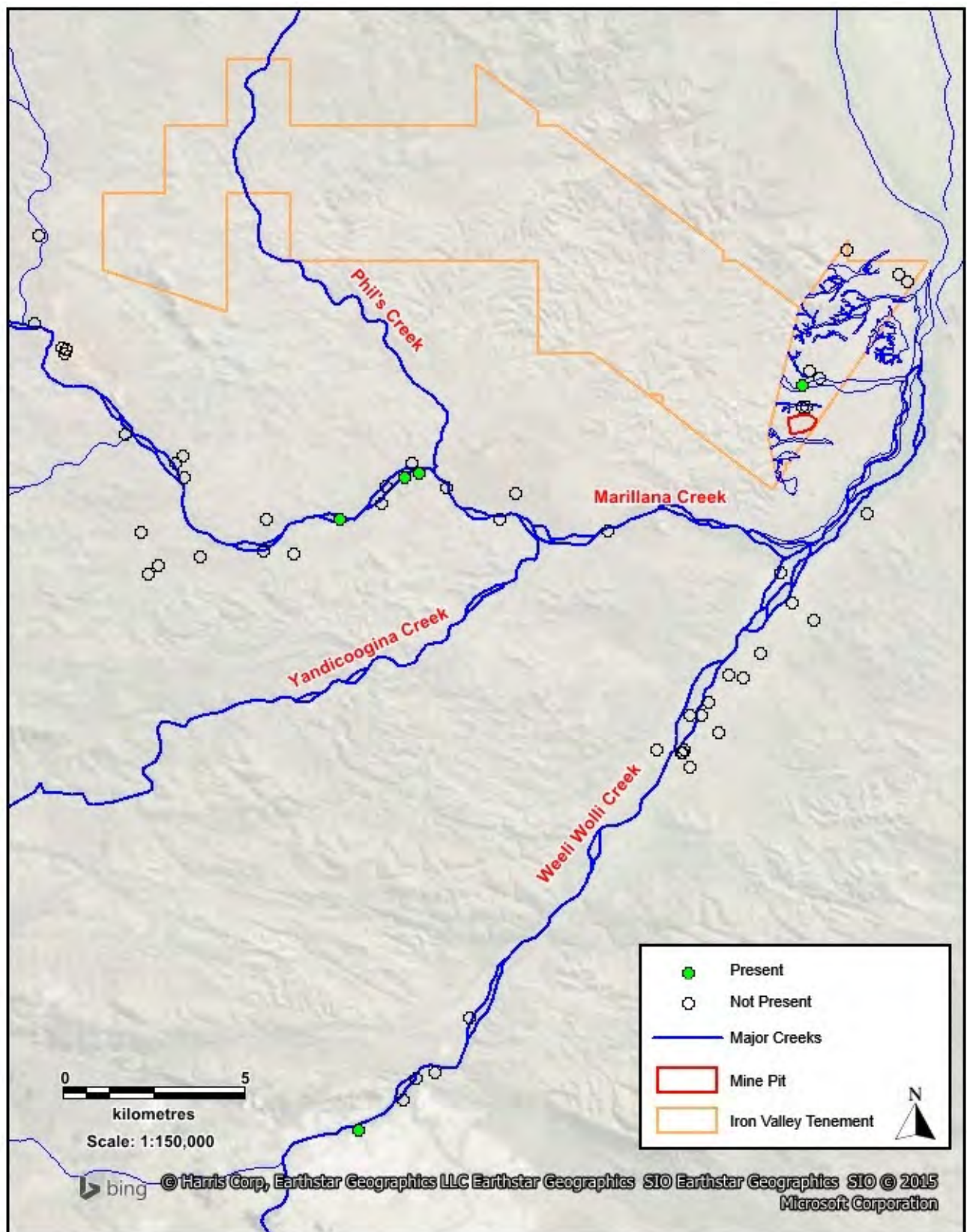


Appendix 5. Locations of stygal short-range endemic amphipod, *Paramelitidae* sp. B.



Appendix 6. Locations of stygal short-range endemic amphipod, *Paramelitidae* sp. D.



Appendix 7. Locations of stygal short-range endemic Syncarida



Iron Valley Project

Baseline Aquatic Fauna Survey:
Weeli Wolli Creek
Wet Season 2015



November 2015



Iron Valley Project
Baseline Aquatic Fauna Survey:
Weeli Wolli Creek
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Final Report
November 2015

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Disclaimer

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CONTENTS

EXECUTIVE SUMMARY.....	VII
1 INTRODUCTION.....	9
1.1 Background.....	9
1.2 Legislative framework	9
1.3 Study objectives	10
2 STUDY AREA.....	11
2.1 Description	11
2.2 Climate and hydrology	12
2.2.1 General.....	12
2.2.2 Rainfall prior to March 2015 sampling	12
3 SURVEY METHODS	13
3.1 Compliance.....	13
3.2 Sites and sampling design	14
3.3 Field sampling.....	16
3.3.1 Water quality.....	16
3.3.2 Habitat characteristics	16
3.3.3 Invertebrate fauna	17
3.3.4 Fish	18
3.4 Data analysis.....	19
3.4.1 General analysis	19
3.4.2 Multivariate analysis.....	19
4 RESULTS AND DISCUSSION	20
4.1 Water quality.....	20
4.1.1 Comparison against default ANZECC/ARMCANZ (2000) trigger values.....	20
4.1.2 Spatial patterns in water quality (multivariate analysis)	24
4.2 Substrate and habitat characteristics.....	25
4.2.1 Substrate characteristics	25
4.2.2 In-stream habitat	26
4.3 Microinvertebrates (zooplankton)	27
4.3.1 Taxonomic composition and species richness	27
4.3.2 Microinvertebrate taxa of regional/scientific importance	28
4.3.3 Spatial patterns in microinvertebrate assemblages (multivariate analysis).....	29
4.4 Hyporheic fauna	30
4.4.1 Taxonomic composition	30
4.4.2 Hyporheic fauna	31
4.4.3 Short range endemics (SREs).....	31
4.5 Macroinvertebrates.....	32
4.5.1 Taxonomic composition and species richness	32
4.5.2 Macroinvertebrate taxa of regional/scientific importance	35
4.5.3 Spatial patterns in macroinvertebrate assemblages (multivariate analysis).....	36
4.6 Fish	37
4.6.1 Species composition	37
4.6.2 Species abundance	37
4.6.3 Age-class structures	39
5 SYNOPSIS AND CONCLUSIONS	42
5.1 General.....	42
5.2 Water quality.....	42

5.3	Microinvertebrates.....	43
5.4	Hyporheic fauna	43
5.5	Macroinvertebrates.....	44
5.6	Fish	44
5.7	Conclusions.....	45
REFERENCES.....		46
APPENDICES.....		51
Appendix 1. Site Photographs.....		52
Appendix 2. ANZECC/ARMCANZ (2000) trigger values for the protection of aquatic systems in northern Australia.....		54
Appendix 3. Water quality parameters and habitat characteristics.....		56
Appendix 4. Microinvertebrate fauna data recorded during March 2015 sampling.....		59
Appendix 5. Hyporheic fauna data recorded during March 2015 sampling.....		63
Appendix 6. Macroinvertebrate fauna data recorded during March 2015 sampling.....		68

List of Tables. Figures and Plates

TABLE 1. AQUATIC FAUNA AND WATER QUALITY SAMPLING SITES AND REACHES, SHOWING DATE SAMPLED IN MARCH 2015, AND GPS COORDINATES FOR EACH SITE.....	16
TABLE 2. SUMMARY OF WATER QUALITY VARIABLES MEASURED EITHER <i>IN SITU</i> OR FROM SAMPLES COLLECTED IN THE FIELD.	17
TABLE 3. SUMMARY OF MICROINVERTEBRATE COMPOSITION AND TAXA RICHNESS.	27
TABLE 4. SRE TAXA RECORDED IN THE HYPORHEIC ZONES OF OFF-CHANNEL AND MAIN CHANNEL SITES, VERSUS SRE TAXA EXPECTED TO OCCUR IN THE STUDY AREA.	32
TABLE 5. SUMMARY OF MACROINVERTEBRATE COMPOSITION AND ABUNDANCE AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	33
TABLE 6. AGE-CLASS CLASSIFICATIONS FOR EACH FISH SPECIES.	39
FIGURE 1. DAILY RAINFALL (MM) RECORDED AT MARILLANA GAUGING STATION DURING MARCH 2015..	13
FIGURE 2. LONG-TERM AVERAGE RAINFALL, AND TOTAL 2015 MONTHLY RAINFALL RECORDED AT MARILLANA GAUGING STATION.	13
FIGURE 3. OVERVIEW OF BASELINE SURVEY SITES ALONG WEELI WOLLI CREEK, SAMPLED IN MARCH 2015.	15
FIGURE 4. IN SITU WATER QUALITY READINGS OF DISSOLVED OXYGEN, pH AND ELECTRICAL CONDUCTIVITY AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH ANZECC/ARMCANZ (2000) TRIGGER VALUES OVERLAIN.	21
FIGURE 5. NUTRIENT LEVELS, INCLUDING NITROGEN OXIDES, TOTAL NITROGEN, AND TOTAL PHOSPHOROUS RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH ANZECC/ARMCANZ (2000) EUTROPHICATION AND TOXICITY TRIGGER VALUES OVERLAIN.	23
FIGURE 6. DISSOLVED BORON AND DISSOLVED ZINC CONCENTRATIONS RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH ANZECC/ARMCANZ (2000) TRIGGER VALUES OVERLAIN.	24
FIGURE 7. UNCONSTRAINED NMDS PLOTS OF WATER QUALITY PARAMETERS AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.....	25
FIGURE 8. SUBSTRATE DIVERSITY RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	25
FIGURE 9. PERCENT COVER OF MINERAL SUBSTRATE, EMERGENT MACROPHYTE, ALGAE AND SUBMERGED MACROPHYTE RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	26
FIGURE 10. HABITAT DIVERSITY RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	27
FIGURE 11. TAXA ('SPECIES') RICHNESS AND TOTAL ABUNDANCE OF MICROINVERTEBRATES RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	28

FIGURE 12. UNCONSTRAINED NMDS PLOT OF MICROINVERTEBRATE SPECIES ASSEMBLAGES AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH SPEARMAN RANK CORRELATIONS OF HABITAT VARIABLES (> 0.5) AS VECTORS OVERLAIN.....	30
FIGURE 13. TAXA ('SPECIES') RICHNESS OF MACROINVERTEBRATES RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	33
FIGURE 14. LINEAR REGRESSION PLOT OF MACROINVERTEBRATE TAXA RICHNESS AGAINST HABITAT DIVERSITY WITHIN THE MAIN CHANNEL OF WEELI WOLLI CREEK.	34
FIGURE 15. SHADE PLOT OF FLOW-ADAPTED (LOTIC) TAXA AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH SHADED BOX SHOWING LOG_{10} ABUNDANCE OF TAXA AT EACH SITE.	35
FIGURE 16. UNCONSTRAINED NMDS PLOT OF MACROINVERTEBRATE SPECIES ASSEMBLAGES AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES, WITH SPEARMAN RANK CORRELATIONS OF HABITAT VARIABLES (> 0.5) AS VECTORS OVERLAIN.....	37
FIGURE 17. TOTAL ABUNDANCE OF WESTERN RAINBOWFISH, SPANGLED PERCH AND HYRTL'S TANDAN RECORDED FROM OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.	39
FIGURE 18. AGE-CLASS POPULATION STRUCTURE OF SPANGLED PERCH AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES.....	40
FIGURE 19. AGE-CLASS POPULATION STRUCTURE OF WESTERN RAINBOWFISH AND HYRTL'S TANDAN AT OFF-CHANNEL AND MAIN CHANNEL WEELI WOLLI CREEK SITES	41
 PLATE 1. HYPORHEIC SAMPLING OF THE WEELI WOLLI CREEK MAIN CHANNEL USING THE KARAMAN-CHAPPIUS METHOD AND SAMPLING FOR MACROINVERTEBRATES USING A 250 MM MESH POND NET.	18

EXECUTIVE SUMMARY

BC Iron Limited (BCI) is currently undertaking baseline environmental studies for the proposed below water table (BWT) development of the Iron Valley Project (“the Project”) in the East Pilbara region of Western Australia. Groundwater dewatering will be required to mine BWT, which could potentially require the discharge of excess water into the regionally significant Weeli Wolli Creek (WWC). This would add to the cumulative impacts of existing dewatering discharge operations on WWC, with several mines (RTIO HD1, RTIO Yandicoogina and BHPBIO Yandi) located upstream. Existing dewatering discharge operations upstream currently provide permanent surface flows extending approximately 25 – 30 km along the main channel of WWC.

Surface water discharge has numerous implications for the ecology of WWC, in terms of changes in extent and duration of surface water flows, creekline hydrology in general, and cumulative impacts to the creekline at a local level. Therefore, BCI commissioned Wetland Research and Management (WRM) to undertake baseline aquatic fauna and water quality sampling of WWC adjacent to the Project, in order to document the ecological condition of the creekline, identify current ecological values (i.e. rare, listed fauna, new species) and develop a baseline dataset to which future monitoring can be compared.

The objectives of the baseline study were to:

- I. Systematically sample aquatic fauna (macroinvertebrates, microinvertebrates, hyporheic fauna, fish & other vertebrate fauna, if present) and water quality (*in-situ*, ions, dissolved metals, nutrients, TSS & turbidity) at sites within and adjacent to WWC during the wet season 2015;
- II. Report water quality data against default ANZECC/ARMCANZ (2000) water quality guidelines for the protection of aquatic ecosystems (95% & 99% species protection), and assess spatial variability in results;
- III. Identify invertebrate specimens to species level, where possible;
- IV. Analyse fauna data to assess spatial variability, with consideration to species occurrence at ‘reference’ (off-channel) and potentially exposed (main channel) sites;
- V. Assess the conservation status of recorded aquatic fauna, with focus on species occurring in potentially exposed sites.

The key findings of the baseline survey were:

- I. Rainfall in the weeks prior to sampling likely resulted in increased surface flows adjacent to, and downstream of the Project, with newly inundated pools observed at the time of sampling (evidenced by a lack of in-stream habitat; A.Harman, pers. comm). Short residence time of surface waters (either flowing or pools) at downstream sites along WWC likely provided insufficient time for a number of aquatic invertebrates to establish populations prior to sampling.
- II. *In situ* spot measurements indicated surface waters were generally circum-neutral to slightly alkaline, relatively fresh (however, one site, WWOCR3, was considered brackish), with dissolved oxygen concentrations ranging from low to supersaturated.
- III. Nitrogen oxides exceeded ANZECC/ARMCANZ (2000) eutrophication trigger values (TVs) at all main channel sites, and toxicity TVs at WWC8. Total nitrogen and total phosphorous also exceeded eutrophication TVs at WWOCR3 and several main channel sites. Elevated nutrients were likely due to a number of factors; unrestricted livestock access to WWC from pastoral stations nearby, first flushing catchment runoff, and unknown water quality entering WWC from dewatering discharge activities upstream.
- IV. Microinvertebrate fauna was diverse and abundant at off-channel pools WWOCR1 and WWOCR2. In comparison, microinvertebrates were depauperate at main channel sites,

particularly those receiving high surface flows. Multivariate analysis indicated that species assemblages were significantly different between off-channel and main channel sites.

- V. Microinvertebrate taxa of scientific value (regionally restricted taxa, uncommon taxa or potential new species) included *Australoeucyclops karaytugi*, *Mesocyclops holynskae*, *Simocephalus* spp., cf. *Anthalona* sp. and *Boeckella fluvialis*.
- VI. Hyporheic sampling revealed the presence of three short range endemic (SRE) amphipod species of conservation significance: Paramelitidae sp. B, Paramelitidae sp. D, and *Chydaekata* sp.
- VII. There was evidence of a longitudinal gradient in macroinvertebrate taxa richness along the main channel of WWC upstream and adjacent to the Project. Taxa richness was greatest upstream at WWC1, declining with increasing distance downstream to WWC6. Regression analysis indicated a significant linear relationship between in-stream habitat diversity and macroinvertebrate richness within the main channel, with richness decreasing with lower habitat diversity.
- VIII. Macroinvertebrate diversity was relatively low at off-channel sites, compared to main channel sites. This was somewhat unexpected, given the documented habitat-species richness patterns observed along the main channel, and considering habitat diversity at off-channel sites was more diverse (macrophytes, algae etc) than main channel sites. Low diversity may in part reflect hydrology and water quality at off-channel sites (i.e. low dissolved oxygen, lack of surface flows, elevated ions & metals, etc.), with flowing water in the main channel providing additional habitats (e.g. riffle zones) for lotic (flow-adapted) species.
- IX. Multivariate analysis indicated macroinvertebrate assemblages at off-channel and main channel sites were significantly different from one another, with a number of flow-adapted taxa (e.g. mayflies and caddisflies) either absent, or recorded in reduced abundance at off-channel sites. This reflected the standing nature of pools, and lack of surface flow at off-channel sites.
- X. No conservation listed (IUCN Red List or DPaW priority) macroinvertebrate species were recorded in the study area. However, one SRE amphipod (Paramelitidae sp. B), and four Pilbara endemic Coleoptera (aquatic beetle) species were recorded, including *Limbodessus occidentalis* and the recently described *Haliplus fortescueensis*.
- XI. Three native fish species were recorded in the study area; the western rainbowfish *Melanotaenia australis*, the spangled perch *Leiopotherapon unicolor*, and the Hyrtl's tandan (eel-tailed catfish) *Neosilurus hyrtlui*. Diversity and abundance of fish species at sites reflected in-stream habitat diversity, permanence of flow, and effects of predation.
- XII. Although a number of stygobitic, SRE hyporheic and Pilbara endemic microinvertebrate and macroinvertebrate taxa were recorded in the current study, the majority of these taxa have known local and/or regional distributions outside the Project area.

1 INTRODUCTION

1.1 Background

BC Iron Limited (BCI) is currently undertaking baseline environmental studies for the proposed below water table (BWT) development of the Iron Valley Project (hereafter referred to as “the Project”) in the East Pilbara region of Western Australia. The Project is located in the Weeli Wolli Creek (WWC) catchment, within the vicinity of a number of existing iron ore mines, including the Fortescue Metals Group (FMG) Nyidinghu operation (15 km to the north), Rio Tinto Iron Ore’s (RTIO) Yandicoogina (10 km to the west) and Hope Downs 1 operations (30 km to the south west), and the BHP Billiton Iron Ore (BHPBIO) Yandi operation (25 km to the west).

Groundwater dewatering will be required to mine BWT, which could potentially require the discharge of excess water into WWC if dewatering volumes are surplus to operational requirements. Further, it is likely the Project will require a provision for emergency discharge into WWC in the event of high rainfall periods. Surface water discharge has numerous implications for the ecology of WWC, in terms of changes in surface water flows, creekline hydrology, and cumulative impacts to the creekline at a local level (WRM 2015).

In March 2015, WRM were commissioned by BCI to undertake baseline aquatic fauna and water quality sampling of WWC adjacent to the Project, in order to document the ecological condition of the creekline, identify current ecological values (i.e. rare, listed fauna, new species), and develop a baseline dataset to which future monitoring can be compared.

This report provides sampling methodology and all aquatic fauna and water quality baseline data from the March 2015 survey.

1.2 Legislative framework

A number of State and Commonwealth acts and policies are relevant to the proposed development in terms of environmental protection and legislation.

At a State level, aquatic fauna are protected under the *Wildlife Conservation Act 1950* (WC Act) and their environment is protected under the *Environmental Protection Act 1986* (EP Act). This includes freshwater turtles, frogs, fish and invertebrates (including hyporheic and stygal invertebrates). Hyporheic invertebrates (collectively referred to as “hyporheos”) inhabit subsurface interstitial spaces in coarse creek bed sediments. Stygal invertebrates are obligate groundwater-dwelling species known to be present in a variety of rock types, and are often also present in the hyporheos.

The WC Act provides for species and ecological communities to be protected and listed as either ‘threatened’, because they are under identifiable threat of extinction, or ‘priority’, because they are rare, or otherwise in need of protection. This encompasses species with small distributions (occupying an area of less than 10,000 km²) defined as short range endemics, or SREs (Harvey 2002, EPA 2009). The majority of stygal invertebrates are also SREs. The Environmental Protection Authority of Western Australia (EPA) expects that environmental impact assessments will consider the conservation of SRE species (EPA 2004).

The Department of Parks and Wildlife (DPaW) uses the *International Union for Conservation of Nature* (IUCN) Red List criteria for assigning species and communities to threat categories under the WC Act. Not all Western Australian species listed by the IUCN are also listed by DPaW.

At a Federal level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for native fauna and their habitats to be specially protected and listed as nationally or internationally important.

Relatively few aquatic species in Western Australia are listed as threatened or endangered under the WC or EPBC acts. Aquatic invertebrates in particular have historically been under-studied. Lack of knowledge of their distributions often precludes aquatic invertebrates for listing as threatened or endangered. The *State Environmental Protection Authority* (EPA) has stated that listing under legislation should therefore not be the only conservation consideration in environmental impact assessment (EPA 2004).

Other relevant state legislation for the protection of water and native fauna species include the *Rights in Water and Irrigation Act 1914* (RIWI Act) and the *Fish Resources Management Act 1994*. The Department of Water (DoW) administers the RIWI Act, which provides for the sustainable use and development of the State's water resources, the protection of natural ecosystems and the control of activities that may be detrimental to ecosystem condition. Part 4 of the RIWI Act 1914 provides:

- (1) *The objects of this Part [Control of Water Resources] are —*
- (a) *to provide for the management of water resources, and in particular —*
 - (i) *for their sustainable use and development to meet the needs of current and future users; and*
 - (ii) *for the protection of their ecosystems and the environment in which water resources are situated.*

Under this Act, licences are required for groundwater abstraction and permits required for any interference with the bed and banks of proclaimed watercourses; all watercourses in the Pilbara are proclaimed under the RIWI Act. All native fish and their habitats are protected under the *Fish Resources Management Act 1994*.

The current baseline dataset, together with the prior desktop assessment (WRM 2015) constitute a Level 1 survey for environmental impact assessment, as described under the EPA Environmental Assessment Guideline (EAG) No. 12 (EPA 2013), and in accordance with EAG No. 8 (EPA 2015) with the focus on hydrological processes and ecosystem maintenance.

1.3 Study objectives

The objectives of the baseline water quality and aquatic fauna study were to:

- I. Systematically sample aquatic fauna (macroinvertebrates, microinvertebrates, hyporheic fauna, fish & other vertebrate fauna, if present) and water quality (*in-situ*, ions, dissolved metals, nutrients, TSS & turbidity) at sites within and adjacent to WWC during the wet season 2015;
- II. Report water quality data against default¹ ANZECC/ARMCANZ (2000) water quality guidelines for the protection of aquatic ecosystems (95% and 99% species protection), and assess spatial variability in results.
- III. Identify invertebrate specimens to species level, where possible;

¹ Default TVs are to be applied to systems for which there are no baseline data or where baseline data are insufficient to adequately describe the natural or existing seasonal or annual fluctuations in water quality. Local conditions are naturally variable between river systems and because of this, ANZECC/ARMCANZ (2000) recommend that TVs should be 'tailored' to local conditions through the development of 'local guideline levels'. It is recommended historic (baseline) data are used to derive local (i.e. site-specific) TVs in accordance with ANZECC/ARMCANZ (2000) protocols.

- IV. Analyse fauna data to assess spatial variability, with consideration to species occurrence at 'reference' (off-channel) and potentially exposed (main channel) sites;
- V. Assess the conservation status of recorded aquatic fauna, with focus on species occurring in potentially exposed sites.

2 STUDY AREA

2.1 Description

The Project is situated in the East Pilbara region of Western Australia, within Mining Lease M47/1439 and a small area of Exploration Licence E47/1385. The co-ordinates of M47/1439 are as follows:

- NW Corner 22° 42' 05"S 119° 19' 02"E
- NE Corner 22° 43' 02"S 119° 20' 30"E
- SE Corner 22° 46' 33"S 119° 17' 56"E
- SW Corner 22° 45' 35"S 119° 16' 28"E

The Project is located within the Marillana (pastoral) Station, with land-use in the area comprising predominately of pastoral activities and more recently, mining. The regional topography of the Eastern Pilbara is dominated by the Chichester Ranges in the north and the Hamersley Plateau to the south, with these features being divided by the Fortescue Valley. The main drainage system in the area is the Fortescue River, which flows north and then northwest into the Fortescue Marsh.

A section of the regionally significant WWC flows adjacent to the Project. Approximately 70 km in length, and with a catchment area of 4100 km², WWC is fed in its mid-reaches by Weeli Wolli Spring, located approximately 20 km upstream (south) of the Project. Owing to the historical permanency of Weeli Wolli Spring, WWC is of high ecological, cultural and social significance. Prior to dewatering discharge from RTIO's Hope Downs 1 (HD1) mine, Weeli Wolli Spring provided perennial surface flows of around 2 km along WWC. However, due to a number of mines (RTIO Hope Downs 1, BHPBIO Yandi, and RTIO Yandicoogina) located on Marillana Station commencing dewatering discharge operations within the last decade, approximately 25 - 30 km of Weeli Wolli Creek is now influenced by surface flows (A.W. Storey, pers. comm.). Cumulative impacts from dewatering discharge on WWC are likely to intensify with time, as construction is currently underway at RTIO's Billiards Project (south of the WWC and Marillana Creek confluence), and planned for mid-2016 is FMG's Nyidinghu Project (directly downstream of the Project tenement). Both projects have substantial ore deposits BWT. BHPBIO also have intentions to develop additional BWT deposits on WWC upstream of RTIO's HD1 mine. Therefore, it is likely that cumulative dewatering discharge will result in permanent/semi-permanent surface and subsurface flows adjacent to the Project in the near future.

Flowing to the north, WWC drains into the Fortescue River via the Fortescue Marsh. The two systems are only connected during flooding associated with intense cyclonic events (Kendrick 2001). The Fortescue Marsh, an episodically inundated samphire marsh, approximately 100 km long and 10 km wide (Kendrick 2001, DEC 2009), is located 25 - 30 km downstream, and to the north-east, of the Project. The Marsh is described as an extensive, irregularly inundated inland floodplain system, and is considered to be a highly unique wetland landform in Western Australia (Environment Australia 2001). It is listed on the national Directory of Important Wetlands of Australia (WA066), and is a Priority 1 Priority Ecological Community (PEC) under the DPaW list of Priority Ecological Communities (DPaW 2014). It is also acknowledged that if nominated, the Marsh meets the criteria for listing as a Wetland of International Importance under the Ramsar Convention (Jaensch & Watkins 1999). The Fortescue Marsh and surrounding pastoral leases are earmarked for reservation by DPaW when leases are up for renewal in 2015 (FMG 2011). Current and potential threats to the Marsh include changes to hydrology,

overgrazing by cattle, and pollution of surface inflow water from mine sites (Environment Australia 2001).

2.2 Climate and hydrology

2.2.1 General

The climate of the Pilbara is semi-arid, with relatively dry winters and hot summers. Most rainfall occurs during the summer months (November to March) and is mainly associated with cyclonic events or thunderstorms, when flooding frequently occurs along creeks and rivers (BOM 2015). Due to the nature of cyclonic events and thunderstorms, total annual rainfall in the region is highly unpredictable and individual storms can contribute several hundred millimetres of rain at one time. However, average annual pan evaporation in the Pilbara is ten times greater than rainfall (BOM 2015).

Two Department of Water (DoW) gauging stations are located in the vicinity of the Project, including one on WWC, downstream of the confluence with Marillana Creek (Waterloo Bore GS), and one on Marillana Creek, upstream of all mining operations (Flat Rocks GS; DoW 2015). The Waterloo Bore GS lies approximately 3.5 km downstream of the current wetting front (extent of surface flow from cumulative dewatering discharge operations located upstream). Flows at this station, however, will likely become more influenced by discharge operations in the future.

Long-term average rainfall at Flat Rocks and Waterloo Bore was 382.9 mm and 395.7 mm, respectively. Total annual rainfall varies greatly between years. Between 2006 and 2010, rainfall at both gauging stations was regularly below the long-term average. Recently (i.e. since 2010), rainfall has been above the long-term average at Waterloo Bore. Rainfall at Flat Rocks was above the long-term average in 2012 and 2013. Rainfall during the wet of 2011 was influenced by the La Niña event, which contributed to numerous and significant floods throughout northern Australia. In January 2011, Tropical Cyclone Bianca brought heavy rain across the Pilbara (BOM 2015).

Like rainfall, streamflow is also highly seasonal and variable. Flows occur as a direct response to rainfall, with peak flows tending to occur within 24 hours of a major rainfall event and continuing for several days. The Flat Rocks gauging station is located upstream of all mining operations and as such is not influenced by additional inputs from discharge or reductions in flow due to dewatering. The highest flow on record was 144,472 ML in 1975, when total annual rainfall was 717 mm, well above the long-term average (392.60 mm). At Waterloo Bore, seven zero-flow years were recorded between 1986 and 2012 (1986, 1989, 1991, 1996, 2005, 2007 & 2010). The greatest flow recorded was 215,473 ML in 2000. At this time, rainfall was 753.1 mm; almost twice the long-term average. The long-term average flow at these stations ranged from 10,514.92 ML at Flat Rocks to 33,542.63 ML at Waterloo Bore.

2.2.2 Rainfall prior to March 2015 sampling

The Project area experienced a major rainfall event just prior to March 2015 sampling by WRM. The Bureau of Meteorology's Marillana Gauging Station, located approximately 14 km north-east of the Project, recorded 51 mm of rainfall in the six days (21st – 26th March 2015) prior to sampling (44 mm of which was recorded between the 24th and 25th of March; Figure 1). Total rainfall recorded in March 2015 (134.7 mm) was also well above the Marillana Gauging Station long-term March average (49.7 mm; Figure 2).

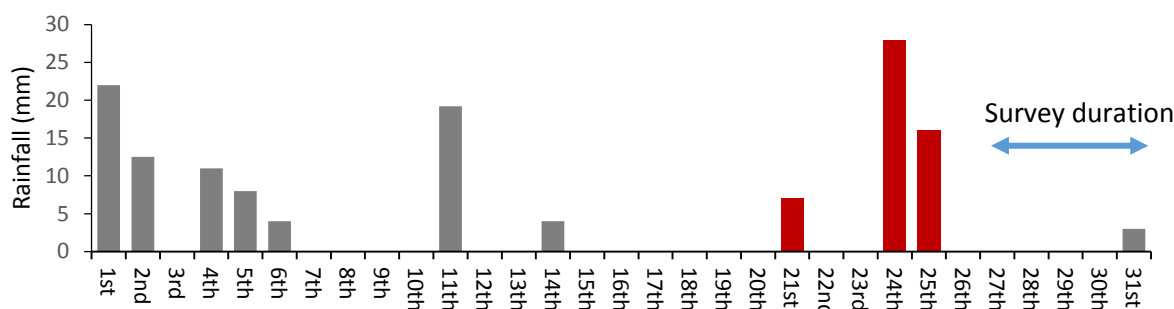


Figure 1. Daily rainfall (mm) recorded at Marillana Gauging Station during March 2015. Columns highlighted in red represent rainfall recorded in the seven days prior to sampling. Survey duration is shown by blue arrow.

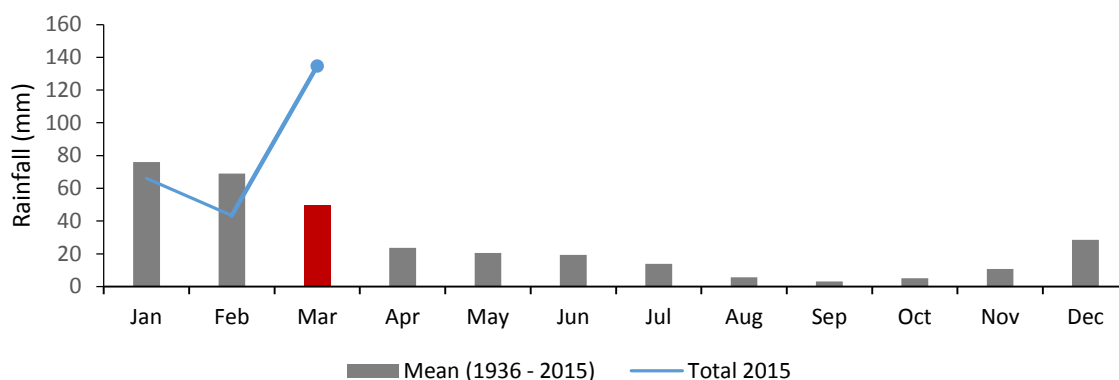


Figure 2. Long-term average rainfall and total 2015 monthly rainfall recorded at Marillana Gauging Station. Column highlighted in red indicates month of sampling.

Therefore, gauging station data indicate rainfall during the weeks leading up to the field trip appears substantially greater than the long term average. Consequently, streamflow at WWC adjacent to the Project was high at the time of sampling, with channel width, depth and flow greater than normally observed at this time of year (A. Harman, pers. comm.). The reach of WWC downstream of the Project is ephemeral in nature, and was likely completely dry prior to the rainfall event, however, the reach held large pools on the first afternoon when visited. Of note was the rate at which surface water (pools and connected flowing reaches) receded over the course of field sampling ($n = 5$ days), predominantly at downstream reaches.

3 SURVEY METHODS

3.1 Compliance

Baseline field surveys employed sampling design, methods and general approaches consistent with the following:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000);
- EPA Guidance No. 20, Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA 2009);
- EPA Position Statement No. 3, Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002);

- EPA Guidance No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2004).

Aquatic fauna sampling by WRM is consistent with methodology used by government and universities for similar surveys, including the Pilbara Biological Survey (Pinder *et al.* 2010).

This study was conducted under Fisheries licence EXEM 2314 (Instruments of Exemption to the Fish Resources Management Act 1994 for Scientific Research Purposes) and DPaW licence SF010240 (Reg. 17; Licence to Take Fauna for Scientific Purposes). As a condition of these licences, taxa lists and reports are required to be submitted to the respective authorities.

3.2 Sites and sampling design

The survey took place during the late-wet season, between 27th and 31st March, 2015. In order to accurately document the water quality and composition and distribution of aquatic fauna of WWC adjacent to the Project, sampling targeted two main ecosystem types: pools/riffle zones within the main channel of WWC, and off-channel pools, which are most likely perched permanent/semi-permanent pools, which are elevated above, and to the west of, the main channel of WWC (and therefore not likely to be influenced by cumulative discharge operations upstream).

Statistical analyses rely on adequate replication to characterise variability within and between groups in a given parameter (e.g. species richness, assemblage composition). Adequate replication provides the necessary statistical power to test for differences between groups (e.g. reference vs. potential impact sites), and thereby detect statistically significant differences should they exist. Therefore, to obtain adequate statistical robustness, nine replicate sites ($n = 9$) were sampled along the main channel of WWC. Additionally, three replicate off-channel 'reference' sites ($n = 3$) were sampled. This design allows spatial comparisons of faunal assemblages between off-channel 'reference' sites (WWOCR1, WWOCR2 & WWOCR3), and potentially impacted main channel WWC sites (WWC1 to WWC9). GPS co-ordinates for sampling locations, and a map of the survey area are provided in Figure 3 and Table 1, respectively. Site photographs are provided in Appendix 1.

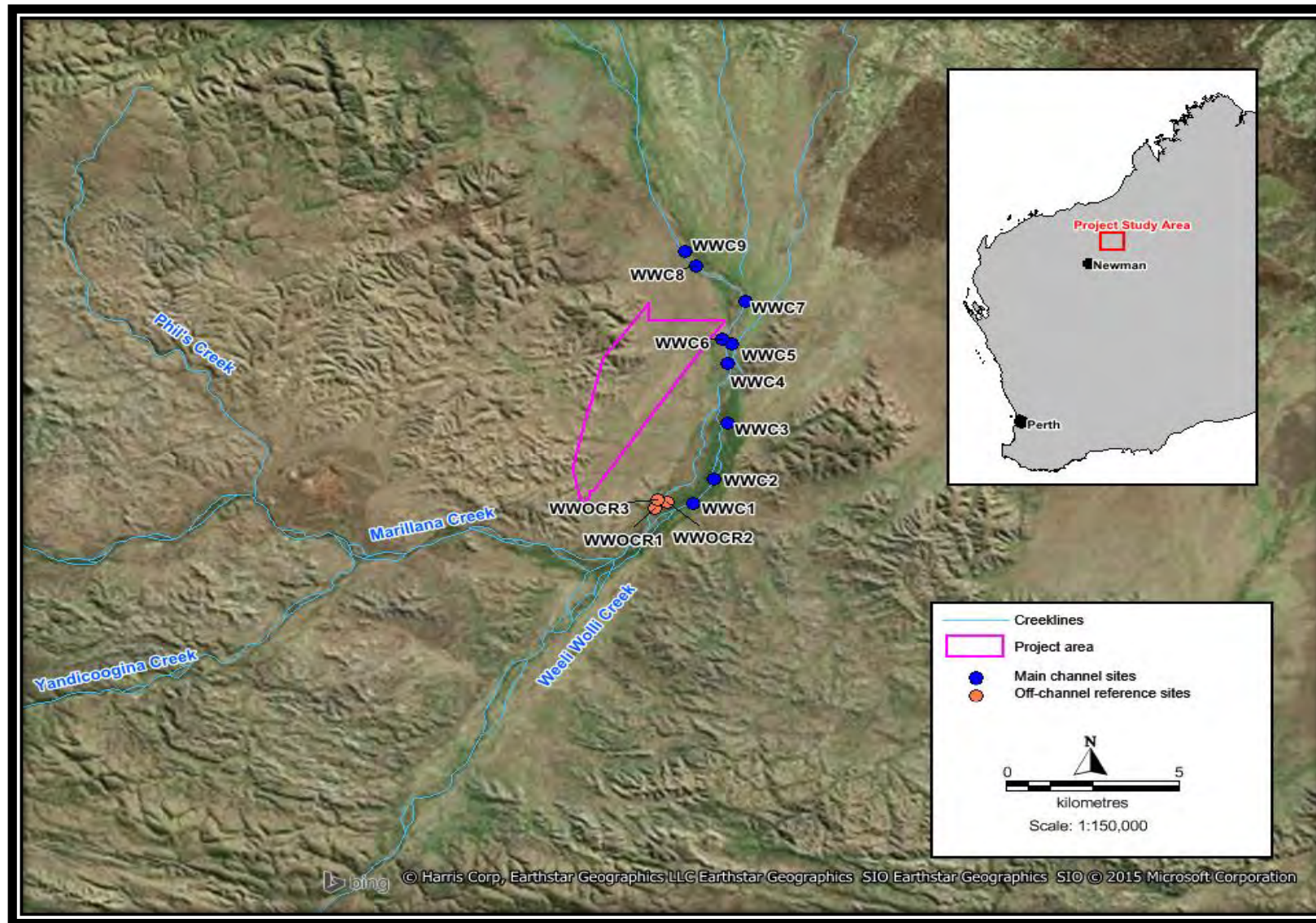


Figure 3. Overview of baseline survey sites along Weeli Wolli Creek, sampled in March 2015. Main channel sites are blue, and off-channel reference sites are orange. The Project tenement is denoted by pink outline.

Table 1. Aquatic fauna and water quality sampling sites and reaches, showing date sampled in March 2015, and GPS coordinates for each site.

Reach	Site	Date	GPS Co-ordinates		
			Zone	Easting	Northing
Main channel	WWC1	29/03/2015	50 K	739105	7480029
	WWC2	29/03/2015	50 K	739726	7480812
	WWC3	29/03/2015	50 K	740156	7482620
	WWC4	30/03/2015	50 K	740199	7484539
	WWC5	29/03/2015	50 K	740309	7485174
	WWC6	30/03/2015	50 K	740032	7485325
	WWC7	31/03/2015	50 K	740719	7486557
	WWC8	27/03/2015	50 K	739338	7487739
	WWC9	30/03/2015	50 K	739011	7488199
Off-channel	WWOCR1	28/08/2015	50 K	738016	7479866
	WWOCR2	28/03/2015	50 K	738352	7480071
	WWOCR3	28/03/2015	50 K	738095	7480149

3.3 Field sampling

3.3.1 Water quality

At each site, *in situ* measurements of dissolved oxygen (DO; % and mg/L), water temperature (°C) and pH were taken using portable hand-held Wissenschaftlich-Technische-Werkstätten (WTW) field meters. Water depth was measured using a graduated pole. In addition, undisturbed water samples were collected for laboratory analyses of major ions, alkalinity, dissolved metals, nutrients, TSS and turbidity. Water samples for nutrients and dissolved metals were filtered in the field through 0.45 µm millipore nitrocellulose filters. To avoid contamination, all sample bottles and filtering equipment were acid-washed (0.1% nitric acid) prior to use. Water samples for dissolved metals were taken using nitrile gloves, with sample bottles wrapped in polyethylene bags after collection. All water samples were kept cool in an esky while in the field, and either refrigerated (ions & metals), or frozen (nutrients) as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by ChemCentre, Bentley, WA (a NATA accredited laboratory). All water quality variables measured are summarised in Table 2.

3.3.2 Habitat characteristics

Qualitative visual observations of habitat characteristics were made at each site, which assist in explaining patterns in faunal assemblages. Habitat assessments were based on the Australian Monitoring River Health AusRivAS protocol, a standardised rapid method for the collection of data on geomorphological, physical and riparian habitat (Parsons *et al.* 2002, Parsons *et al.* 2004). WRM have standard worksheets for this task so that recordings between sites remain as comparable as possible. Recorded habitat characteristics included proportional (%) cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris, detritus, roots and trailing vegetation. Details of substrate composition were also recorded, and included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt and clay.

When undertaking habitat assessments there can be a small degree of variation in scoring habitat cover. AusRivAS acknowledges this, but generally considers that the variation in habitat scoring is smaller than the differences required to fundamentally affect fauna assemblages. WRM attempt to minimise erroneous variation in scoring between sites by the same person assessing habitat at all sites.

Table 2. Summary of water quality variables measured either *In situ* or from samples collected in the field.

Parameter	Units	Parameter	Units
<i>In situ</i>		<i>Dissolved metals</i>	
pH	pH units	Aluminium (Al)	mg/L
Electrical conductivity	µS/cm	Arsenic (As)	mg/L
Redox potential	mV	Boron (B)	mg/L
Dissolved oxygen	% saturation	Barium (Ba)	mg/L
Dissolved oxygen	mg/L	Cadmium (Cd)	mg/L
Water temp	°C	Cobalt (Co)	mg/L
		Chromium (Cr)	mg/L
		Copper (Cu)	mg/L
		Iron (Fe)	mg/L
<i>Ionic composition</i>		Manganese (Mn)	mg/L
Sodium (Na)	mg/L	Mercury (Hg)	mg/L
Potassium (K)	mg/L	Molybdenum (Mo)	mg/L
Calcium (Ca)	mg/L	Nickel (Ni)	mg/L
Magnesium (Mg)	mg/L	Lead (Pb)	mg/L
Chloride (Cl)	mg/L	Sulfur (S)	mg/L
Carbonate (CO ₃)	mg/L	Selenium (Se)	mg/L
Hydrogen carbonate (HCO ₃)	mg/L	Uranium (U)	mg/L
Sulfate (SO ₄)	mg/L	Vanadium (V)	mg/L
Alkalinity	mg/L	Zinc (Zn)	mg/L
Hardness	mg/L		
<i>Nutrients</i>		<i>Other</i>	
Nitrate + nitrite (N _{NO_x})	mg/L	Total suspended solids (TSS)	mg/L
Ammonia (N _{NH₃})	mg/L	Turbidity	NTU
Total Nitrogen (total N)	mg/L		
Total Phosphorus (total P)	mg/L		

3.3.3 Invertebrate fauna

Microinvertebrates (i.e. zooplankton) were collected from the water column using a 53 µm mesh pond net to sweep over a standard 15 m distance at each site. Samples were transferred into 250 ml PET vials, preserved in 70% ethanol, and were sent to Dr. Russ Shiel, Adelaide University, for laboratory enumeration and identification. Samples were processed by identifying the first 200-300 individuals encountered in an agitated sample decanted into a 125 mm² gridded plastic tray, with the tray then scanned for additional missed taxa, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e. species or morphotypes, under a high power compound microscope.

Hyporheic fauna were collected using the Karaman-Chappuis method (Delamare-Deboutteville 1960). This involved digging a 30 cm deep x 40 cm diameter hole in alluvial gravels adjacent to the water's edge (see Plate 1). The hole was allowed to fill with water percolating through the gravel, and then was swept with a small 110 µm mesh hand-net (Plate 1). Each sample was transferred to a 250 ml PET vial and preserved in 70% ethanol for laboratory enumeration and identification. Collected specimens were identified in the WRM laboratory to the lowest possible taxonomic level (typically genus or species), under either low power dissecting microscopes, or high power compound microscopes (amphipods, oligochaetes). Taxa were enumerated to log₁₀ scale abundance (i.e. 1 = 1 individual, 2 = 2 - 10 individuals, 3 = 11 – 100 individuals, 4 = 101-1,000 individuals, etc.).

Benthic macroinvertebrates were collected using a 250 µm mesh pond net (Plate 1). All in-stream habitats, including trailing riparian vegetation, woody debris, open water column and benthic sediments were sampled at each site, to maximise taxa diversity. Each sample was washed through a 250 µm sieve to remove fine sediment, while leaf litter and other debris were carefully washed by hand in the sieve to remove attached macroinvertebrates, and then discarded. Samples were preserved in 70% ethanol for laboratory enumeration and identification. In the WRM laboratory, samples were sifted through a three-tiered sieve system (3.35 mm, 1 mm & 0.25 mm 'fractions'), and specimens were carefully removed from each fraction under low power dissecting microscopes. Collected specimens were then identified to the lowest possible taxonomic level (typically genus or species) using published taxonomic keys, and by reference to WRM's established voucher collection. Taxa were enumerated to log₁₀ scale abundance.



Plate 1. Hyporheic sampling of the Weeli Wolli Creek main channel using the Karaman-Chappuis method (left) and sampling for macroinvertebrates using a 250 µm mesh pond net (right). Photos by WRM ©.

3.3.4 Fish

Fish were sampled using a number of methods, including seine netting, gill nets, dip nets and electrofishing. Electrofishing was conducted with a Smith-Root Model LR24 battery powered backpack electrofisher (see Box 1). Light-weight fine mesh gill nets (10 m net, with a 2 m drop, using 10 mm, 13 mm, 19 mm and 25 mm stretched mesh nets) were used at each site and were set in deeper water for the duration of sampling at that site. Smaller species and juveniles were sampled by beach seine (10 m net, with a 2 m drop and 6 mm mesh) deployed in shallow areas where there was little vegetation or large woody debris. Generally, two hauls of the seine were conducted at each site to maximise the number of individuals caught. Fish were identified in the field, with standard length² (SL) measurements taken, and then released alive.

² Standard length (SL) - measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e. this measurement excludes the length of the caudal fin).

Box 1. Principles of electrofishing.

A DC voltage is passed from a negative electrode (cathode) to a positive electrode (anode) whilst the electrodes are immersed in water. If a fish is caught in the electrical field, a process referred to as 'galvanotaxis' occurs. Galvanotaxis is the involuntary movement of the fish towards the anode, until it reaches an electrical field strong enough to stun ('galvanoarcosis'). Once the current is switched-off, or the fish removed from the electrical field, the fish quickly recovers. The operator of the electrofisher carries the anode (in the form of a modified pond net) whilst trailing the cathode (a stainless steel cable approximately 3.5 m long). The Smith-Root backpack electrofisher has an effective range of approximately 3 m. Galvanotaxis can be used to 'pull' fish out from under debris, logs, boulders and bank undercuts, where conventional netting methods are less effective.

3.4 Data analysis

3.4.1 General analysis

Samples were grouped *a priori* into categories according to ecosystem type (off-channel 'reference' or main channel). Water quality, habitat and species metrics data were plotted to illustrate spatial differences between and within ecosystem types. Where appropriate, water quality parameters were compared against ANZECC/ARMCANZ (2000) trigger values for the protection of 99% and 95% of species in tropical northern Australian waterways (see Appendix 2). Where there appeared to be a linear pattern in macroinvertebrate species metrics, regression analysis was performed using the Data Analysis add-on in Microsoft Excel, in order to determine whether these patterns were significant ($p < 0.05$) and could be explained by variation in habitat variables. Where sufficient numbers of each fish species were collected, length-frequency histograms were plotted.

3.4.2 Multivariate analysis

Spatial variability in water quality parameters, and microinvertebrate and macroinvertebrate species assemblage data was examined using multivariate procedures in the PRIMER v7 software package (Clarke & Gorley 2006). Non-metric Multi-Dimensional Scaling (nMDS) ordination plots (Clarke & Warwick 2001) were constructed to visualise similarity/dissimilarity between and within off-channel and main channel sites. nMDS ordinations were based on Euclidean distance measures for water quality data and Bray-Curtis similarity matrices for species abundance data. Ordinations were depicted as two-dimensional plots.

One-way permutational multivariate analysis of variance (PERMANOVA) was used to test for significant ($p < 0.05$) spatial effects on data (Anderson 2001, McArdle & Anderson 2001, Anderson *et al.* 2008). Where there were significant differences in species assemblages, the similarity percentage analysis (SIMPER) routine within PRIMER was used to determine those species contributing most to the similarity/dissimilarity between groupings.

Relationships between species data and environmental data were assessed using BIOENV in PRIMER to calculate the smallest sub-set of environmental variables (habitat characteristics) that explain the greatest percentage of variation in the species ordination patterns, as measured by Spearman rank correlation (ρ) (Clarke & Warwick 2001). Values for environmental variables were based on Euclidean distances.

Unless indicated otherwise, default values or procedures recommended by Clarke and Gorley (2006) or Anderson *et al.* (2008) were employed for all PRIMER and PERMANOVA routines, respectively.

4 RESULTS AND DISCUSSION

4.1 Water quality

4.1.1 Comparison against default ANZECC/ARMCANZ (2000) trigger values

Dissolved oxygen (DO)

Spot measurements of DO (% saturation) ranged between 27% at WWOCR1 and 147% at WWC8 (Figure 4). DO was below the lower ANZECC/ARMCANZ (2000) TV (80%) at WWOCR1, WWOCR2 and WWOCR3 off-channel, and WWC1, WWC3, WWC6 and WWC8 within the main channel (Figure 4). DO was considered particularly low at each of the off-channel reference sites (Figure 4), which is likely a reflection of the hydrological characteristics of these pools (standing water, with little aeration due to lack of surface flows). Additionally, DO depletion in part is likely due to aerobic heterotrophic bacteria utilising water column dissolved oxygen as they decompose organic matter (dead plant material). Emergent and submergent macrophyte was abundant within each off-channel pool (A. Harman pers. obs.). The actual DO depletion experienced will depend upon the biodegradable organic matter loading, microbial activity and the amount of respiration occurring.

While the oxygen needs of aquatic biota differ between species and life history stages, DO concentrations below 20% are known to be lethal to many freshwater macroinvertebrate taxa, and concentrations between 25 - 35% can severely limit recruitment (Connolly *et al.* 2004). Butler and Burrows (2007) reported acute toxicity in six northern Australian fish species at DO concentrations between 25% and 30% (at 23°C - 33°C), while some studies have reported chronic responses in macroinvertebrates and fish to saturation levels below 50% (Butler *et al.* 1970, Davis 1975, Alabaster & Lloyd 1982). Therefore, it is likely DO saturation levels recorded at WWOCR sites in the current study present ecological conditions of 'stress' to resident aquatic fauna.

Conversely, DO was in exceedance of the upper ANZECC/ARMCANZ (2000) TV (120%) at WWC5 and WWC8 (Figure 4), and therefore these sites were considered "supersaturated". Supersaturation occurs in areas of high turbulence (e.g. riffle zones), or when net photosynthesis exceeds total oxygen consumption, and is common where there is high algal and macrophyte growth (Tadesse *et al.* 2004). Supersaturated waterbodies as a result of excess photosynthesis are likely to experience oxygen stress overnight, when respiration by plants, algae and fauna depletes oxygen levels. Supersaturation is also well known to cause gas bubble disease in fish (Bouck 1980). However, it should be noted that dissolved oxygen generally exhibits a diurnal pattern, reflecting the flux between aquatic respiration and photosynthesis, so spot measurements of DO such as these provide only a snapshot of typical daily conditions, which may vary considerably depending on the time of measurement.

pH

Generally, pH was circum-neutral to slightly basic, and ranged from 7.37 (WWC6) to 8.36 (WWC5; Figure 4). pH was slightly in exceedance of ANZECC/ARMCANZ (2000) TVs (pH 6 - 8) at five main channel sites (WWC2, WWC3, WWC4, WWC5 and WWC8; Figure 4). This was not considered to be of ecological concern, given that slightly basic pH has been widely recorded in surface waters across the East Pilbara (Johnson & Wright 2001, WRM unpub. data).

Electrical conductivity (EC)

EC was in exceedance of ANZECC/ARMCANZ (2000) guidelines at all sites, ranging from 449 $\mu\text{S}/\text{cm}$ (WWC6) to 1930 $\mu\text{S}/\text{cm}$ (WWOCR3; Figure 4). However, most sites were considered “fresh”, as defined by the Department of Environment (2003)³, with the exception of WWOCR3, which was classified as “brackish”. Surface waters in arid/semi-arid zones such as the Pilbara naturally exhibit elevated EC levels, particularly in the dry season, due to high evaporation rates and low rainfall. Although some dilution occurs following wet season rains, EC will often remain high due to the variability of flows and flushing of stored salts (Jolly *et al.* 2008). Relatively high EC at WWOCR3 may reflect some saline groundwater influence at this site, which may also explain the persistence of this pool off the main channel. There is a general acceptance that when conductivity is below 1500 $\mu\text{S}/\text{cm}$, freshwater ecosystems experience little ecological stress (Hart *et al.* 1991, Horrigan *et al.* 2005). However, with EC above 1500 $\mu\text{S}/\text{cm}$ at WWOCR3 despite good rainfall in the days prior to sampling, it is likely that aquatic fauna will experience some ecological stress during the dry season, when evapo-concentration is expected to further elevate EC.

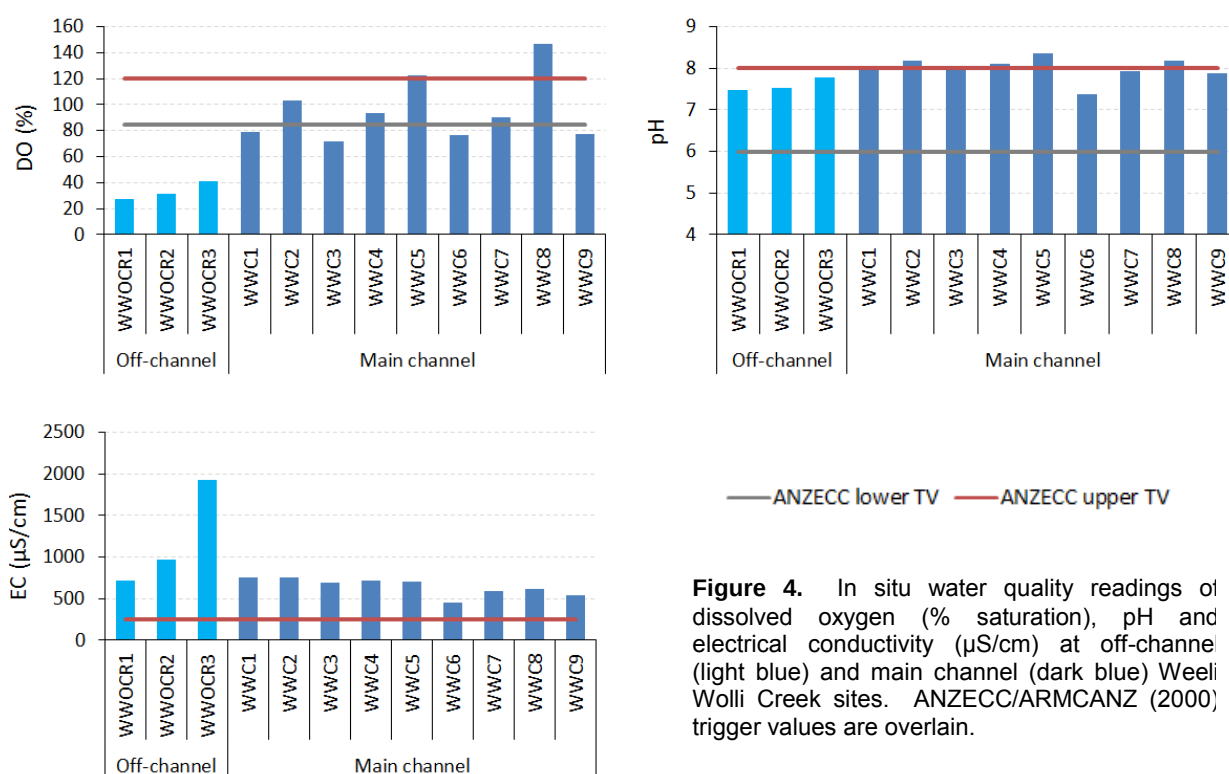


Figure 4. In situ water quality readings of dissolved oxygen (% saturation), pH and electrical conductivity ($\mu\text{S}/\text{cm}$) at off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites. ANZECC/ARMCANZ (2000) trigger values are overlain.

Turbidity and TSS

Turbidity levels were below ANZECC/ARMCANZ (2000) TVs (i.e. > 15 NTU) at all sites. TSS was also relatively low at most sites, though both parameters were slightly elevated at WWOCR3 (Appendix 3). In natural systems, turbidity and TSS can increase during periods of overland flow (runoff), which, coupled with increased streamflow, can cause the erosion of riverbanks and the suspension of finer benthic substrates. However, anthropogenic disturbances, such as livestock activity, can also raise suspended sediment loads *via* physical disturbance of benthic substrates. Slightly raised TSS and turbidity at WWOCR3 likely reflects the disturbance of benthic substrates (predominantly clay and silt; Appendix 3) by heavy livestock activity, causing suspension of fine particulates in the water column.

³ Fresh defined as < 1500 $\mu\text{S}/\text{cm}$, Brackish = 1500 – 4500 $\mu\text{S}/\text{cm}$, Saline = 4500 – 50,000 $\mu\text{S}/\text{cm}$, Hypersaline > 50,000 $\mu\text{S}/\text{cm}$ (DoE 2003). Classifications were presented as TDS (mg/L) in DoE (2003), so a conversion factor of 0.68 was used to convert to conductivity $\mu\text{S}/\text{cm}$, as recommended by ANZECC/ARMCANZ (2000).

Alkalinity

Alkalinity is an expression of the buffering capacity of waterbodies, and helps protect systems against rapid pH swings. Alkalinity of less than 20 mg/L is considered low, and in poorly buffered waters pH can rise rapidly in response to the removal of carbon dioxide during photosynthesis (Sawyer & McCarty 1978, Romaine 1985, Lawson 2002). Well buffered systems also help neutralise ARD/AMD and help reduce toxicity/bioavailability of dissolved metals (ANZECC/ARMCANZ 2000). Alkalinity in the current study ranged between 148 mg/L (WWC6) and 386 mg/L (WWOCR3; Appendix 3), suggesting the buffering capacities of both off-channel and main channel sites are good.

Ions

Concentrations of most dissolved ions were relatively high at WWOCR3, compared to other off-channel and main channel sites, and reflect elevated EC at this site (Appendix 3). Dissolved chloride (dCl) was particularly elevated at WWOCR3 (374 mg/L), which was more than three times greater than the next highest dCl value recorded off-channel (108 mg/L at WWOCR2), and five times greater than the highest dCl value recorded from main channel sites (74 mg/L at WWC1 & WWC2). Similarly, dissolved potassium (dK) and dissolved sodium (dNa) from WWOCR3 was more than three times greater than the highest corresponding values from other off-channel sites, and over four times greater than those recorded from main channel sites. Physical disturbance and suspension of benthic substrates, evapo-concentration, and/or saline groundwater influence are likely contributing factors to elevated dissolved ions at WWOCR3.

Nutrients

Inorganic nitrogen oxides (nitrate + nitrite; N-NO_x) ranged from below the limit of detection (LOD; < 0.01) at WWOCR1 and WWOCR3, to 0.23 mg/L at WWC8 (Figure 5). N-NO_x was in exceedance of the ANZECC/ARMCANZ (2000) eutrophication TV (0.01 mg/L) at all main channel sites. Values also exceeded the ANZECC/ARMCANZ (2000) 95% toxicity TV for nitrate (NO₃; 0.7 mg/L)⁴ at main channel site WWC8 (Figure 5). However, the current ANZECC/ARMCANZ (2000) default 95% TV for nitrate as a toxicant is currently under review, as it is considered too conservative. The new ANZECC/ARMCANZ (2000) 95% TV for NO₃ is likely to be around 11 mg/L (2.5 mg/L N-NO_x), and will incorporate most recent data from acute and chronic toxicity testing in New Zealand (Hickey 2013, R. van Dam, *eriss*, pers. comm.). Recently published guidelines for Canada also recommend a higher NO₃ guideline of 13 mg/L (2.9 mg/L N-NO_x) for protection against toxicity in freshwaters (CCME 2014).

Nitrogen oxides can lower acid-neutralising capacities of waterbodies, impede the growth, survival and reproduction of aquatic fauna, and stimulate eutrophication and algal blooms (Camargo & Alonso 2006). Anthropogenic sources of inorganic nitrogen include agricultural, urban or mine related runoff, livestock waste, deposition of nitrogen-rich atmospheric emissions into surface waters, or the discharge of nitrogen rich groundwaters into receiving surface waters (Camargo & Alonso 2006). The cause of elevated N-NO_x concentrations within WWC main channel is currently unknown, however, may in part reflect rain-induced runoff of nutrient rich waters into WWC reflecting catchment pastoral activity, and/or unrestricted cattle access to WWC.

Total nitrogen concentrations ranged between 0.11 mg/L (WWOCR1 & WWOCR2) and 1.2 mg/L (WWOC3). Total nitrogen exceeded the ANZECC/ARMCANZ (2000) TV (0.3 mg/L) at main channel sites WWC6, WWC8 and WWC9, and was four times greater than the ANZECC/ARMCANZ (2000) TV at off-channel site WWOCR3 (Figure 5). Total phosphorous ranged from below the LOD (WWC1, WWC2, WWC3, WWC4, WWC7 & WWC9), to 0.11 mg/L (WWOCR3; Figure 5). Total phosphorous slightly exceeded the ANZECC/ARMCANZ (2000) TV (0.01 mg/L) at WWOCR1, WWOCR2 and WWC8, and total phosphorous was 11 times greater than the ANZECC/ARMCANZ (2000) TV at WWOCR3 (Figure 5). Nutrient enrichment at WWOCR3 can probably be attributed to recent livestock activity in the area, and

⁴ NO₃ (mg/L) = N-NO_x (mg/L)*4.43.

nutrient concentrations are likely to further increase due to evapo-concentration as the pool recedes in dry season months.

Nutrient enrichment in aquatic systems can lead to eutrophication, and consequent ecological issues such as excessive algal and cyanobacterial growth, particularly towards the end of the dry season as water levels recede and water temperatures increase. Such nuisance blooms can result in adverse impacts to aquatic systems, through toxicity and reduced DO as blooms decay, with consequent losses in biodiversity (ANZECC/ARMCANZ 2000). Highly eutrophic waters tend to support high abundances of pollution-tolerant species, but few rare taxa, and overall, less complexity in community structure (ANZECC/ARMCANZ 2000). Eutrophic waters and consequent reduced dissolved oxygen levels can adversely impact fish, causing loss of equilibrium, increased breathing and heart rate, reduction in hatching success and growth rate, and in extreme cases, death (ANZECC/ARMCANZ 2000). Although nutrient levels often exceeded ANZECC/ARMCANZ (2000) TVs in the current study, these guidelines were developed primarily for water bodies other than those in the arid and semi-arid tropics. The acceptable or 'normal' range of nutrients common to waterbodies of the Pilbara remains poorly understood and consequently, the guidelines should be applied with caution.

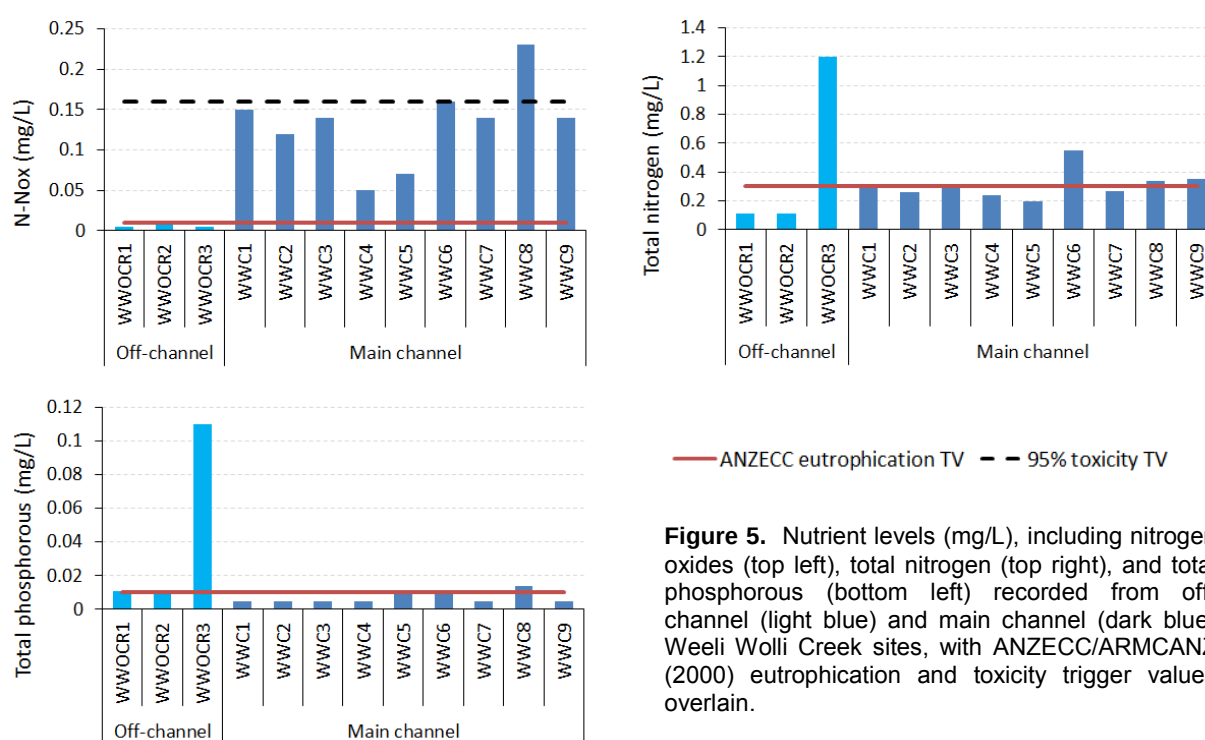


Figure 5. Nutrient levels (mg/L), including nitrogen oxides (top left), total nitrogen (top right), and total phosphorous (bottom left) recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites, with ANZECC/ARMCANZ (2000) eutrophication and toxicity trigger values overlain.

Metals

Dissolved metal concentrations were generally low in the study area, although some metals, e.g. cobalt, iron, manganese, boron and zinc were noticeably elevated at WWOCR3, relative to other off-channel/main channel sites (Appendix 3). Dissolved boron (dB) exceeded the ANZECC/ARMCANZ (2000) TV for the protection of 99% of species at all sites, however, only at WWOCR3 was dB in exceedance of the TV for the protection of 95% of species (Figure 6). This is not likely to be of ecological concern; dB appears to be naturally elevated in Pilbara waterways, and similarly elevated concentrations have been reported previously from other systems (WRM unpub. data). It is likely the aquatic fauna of this region have adapted to high levels of dissolved boron over time. It is important to be aware of naturally elevated potential contaminants prior to operations commencing, so that no blame is attributed to the Project for any perceived impact.

Dissolved zinc (dZn) was above the 99% ANZECC/ARMCANZ (2000) TV at most sites, excluding WWOCR1 and WWC4 (Figure 6). At WWOCR3, dZn also exceeded the 95% ANZECC/ARMCANZ (2000) TV. However, as mentioned previously, water hardness (alkalinity) is known to affect the toxicity of some dissolved metals, including zinc, such that greater hardness may ameliorate toxicity (Markich *et al.* 2001, Charles *et al.* 2002). ANZECC/ARMCANZ (2000) provide algorithms to calculate trigger values for these metals which take hardness into account⁵. Once water hardness was taken into account, dZn concentrations at WWOCR3 did not exceed either 99% or 95% HMTVs.

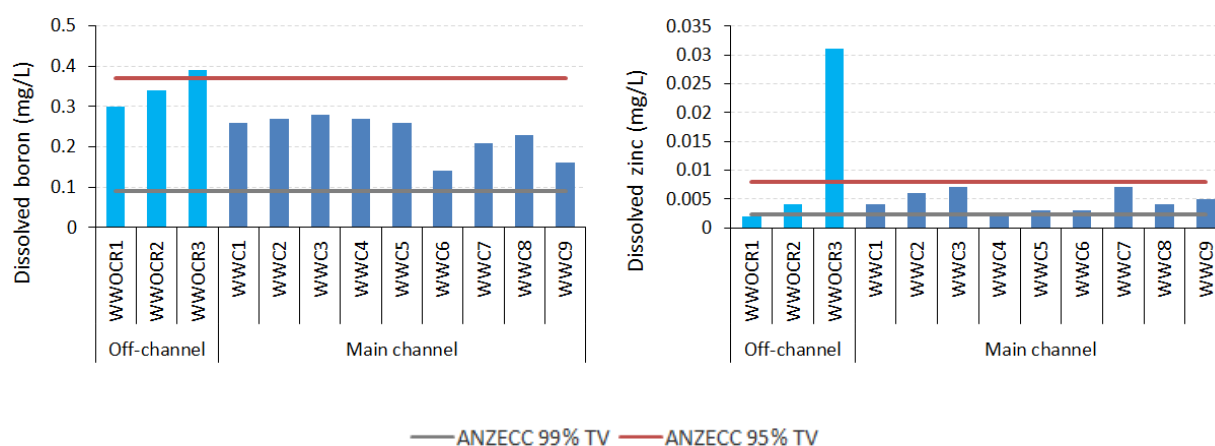


Figure 6. Dissolved boron and dissolved zinc concentrations (mg/L) recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites, with ANZECC/ARMCANZ (2000) trigger values overlain.

4.1.2 Spatial patterns in water quality (multivariate analysis)

PERMANOVA confirmed there was a significant difference in water quality parameters between off-channel 'reference' and main channel sites ($df = 1$, $MS = 41.92$, $Pseudo-F = 4.381$, $p = 0.014$). Cluster analysis and nMDS ordination suggested that WWOCR3 was separate from all other sites (including WWOCR1 & WWOCR2) at a Euclidean distance of 12 (Figure 8A). This reflected between-site comparisons of water quality spot measurements (Section 4.1.1), where numerous analytes (e.g. EC, TSS, dCl, dK, dNa, total N, total P, dZn) were elevated at WWOCR3, in comparison to other off-channel and main channel sites. When considering the nMDS ordination with WWOCR3 removed, off-channel sites WWOCR1 and WWOCR2 were also distinct from all main channel sites (Figure 8B). Separation of WWOCR2 from other sites was influenced by relatively high EC, dCl, dNa, HCO_3 and alkalinity recorded at this site, whereas relatively higher pH and DO were the main causal factors influencing the separation of the majority of main channel sites from off-channel sites (Spearman rank correlations; Figure 8B).

⁵ ANZECC/ARMCANZ HMTV algorithm (zinc) = Default TV*(Hardness/30)^{0.85}

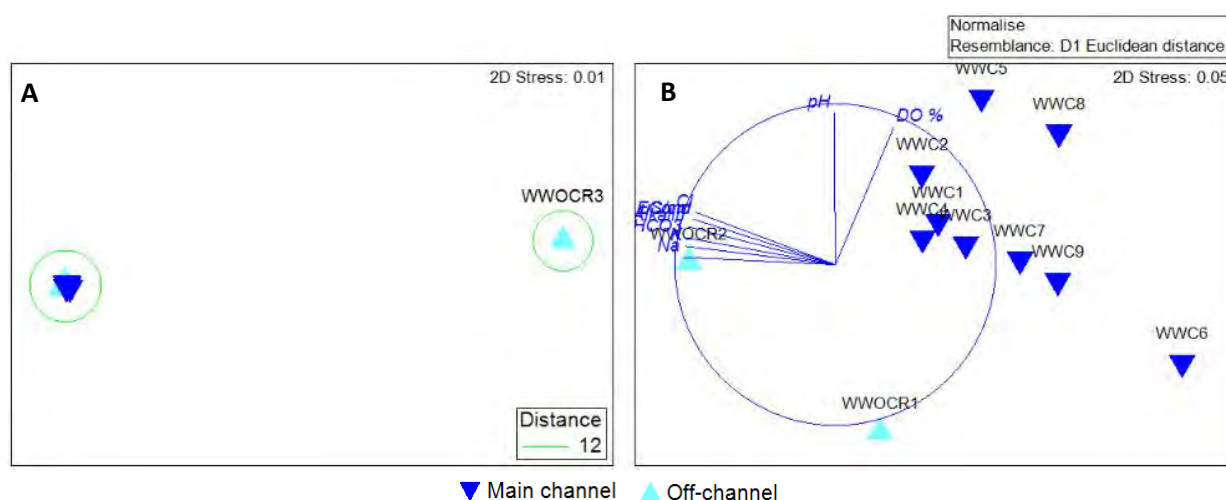


Figure 7. Unconstrained nMDS plots of water quality parameters at off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites. Plot A (left) depicts the ordination with all sites included in the analysis, with samples grouped within green circles at a Euclidean distance of 12. Plot B (right) depicts the ordination with WWOCR1 removed, and with spearman rank correlations (> 0.9) as vectors overlain.

4.2 Substrate and habitat characteristics

Overall, there appeared to be distinct differences in habitat characteristics between off-channel and main channel sites. In particular, off-channel pools were diverse in habitat, with emergent and submerged macrophyte recorded in abundance. Conversely, mineral substrates were dominant within the main channel of WWC, with main channel habitat generally homogeneous between sites.

4.2.1 Substrate characteristics

The inorganic substrate at the majority of sites was dominated by cobbles, pebbles, gravel and sand, with the exception of WWOCR3, where the only two substrate types observed were clay (80%) and silt (20%). Consequently, overall substrate diversity was lower at this site compared to other off-channel and main channel sites (Figure 8). The structure and diversity of substrates are known to influence macroinvertebrate assemblages, with greater substrate complexity generally equating to higher species richness and abundance (Erman & Erman 1984, O'Connor 1991, Jähnig & Lorenz 2008).

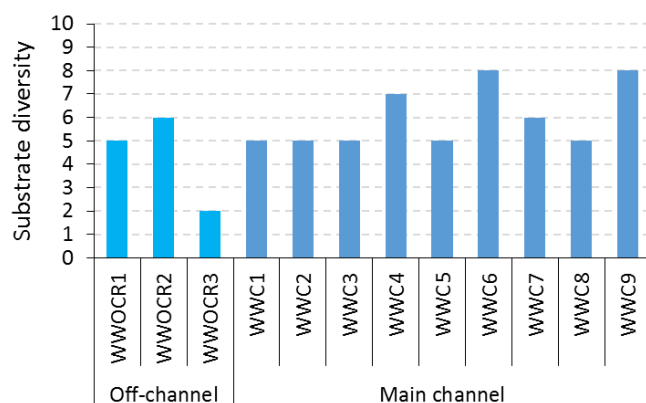


Figure 8. Substrate diversity (no. of substrate types/sizes) recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites.

4.2.2 In-stream habitat

Diversity of in-stream habitat can also play a crucial role in influencing the richness, abundance and assemblage structure of aquatic fauna, with greater habitat complexity (such as aquatic macrophyte, detritus and large woody debris) generally leading to increased species diversity and abundance (Erman & Erman 1984, Heino 2000). Mineral substrate was the dominant habitat type within the main channel of WWC (Figure 9). At off-channel sites, mineral substrates were supplemented by relatively high percentages of emergent macrophyte (e.g. typha and other reeds), submerged macrophyte and algal cover (Figure 9). Overall in-stream habitat diversity was highest at the three off-channel sites, and at main channel site WWC1 (7 habitat types each; Figure 9). Greater habitat diversity at WWO CR sites reflected the greater permanence of water, and reduced flows in comparison to main channel WWC sites, allowing for habitat types such as macrophytes and algae to establish.

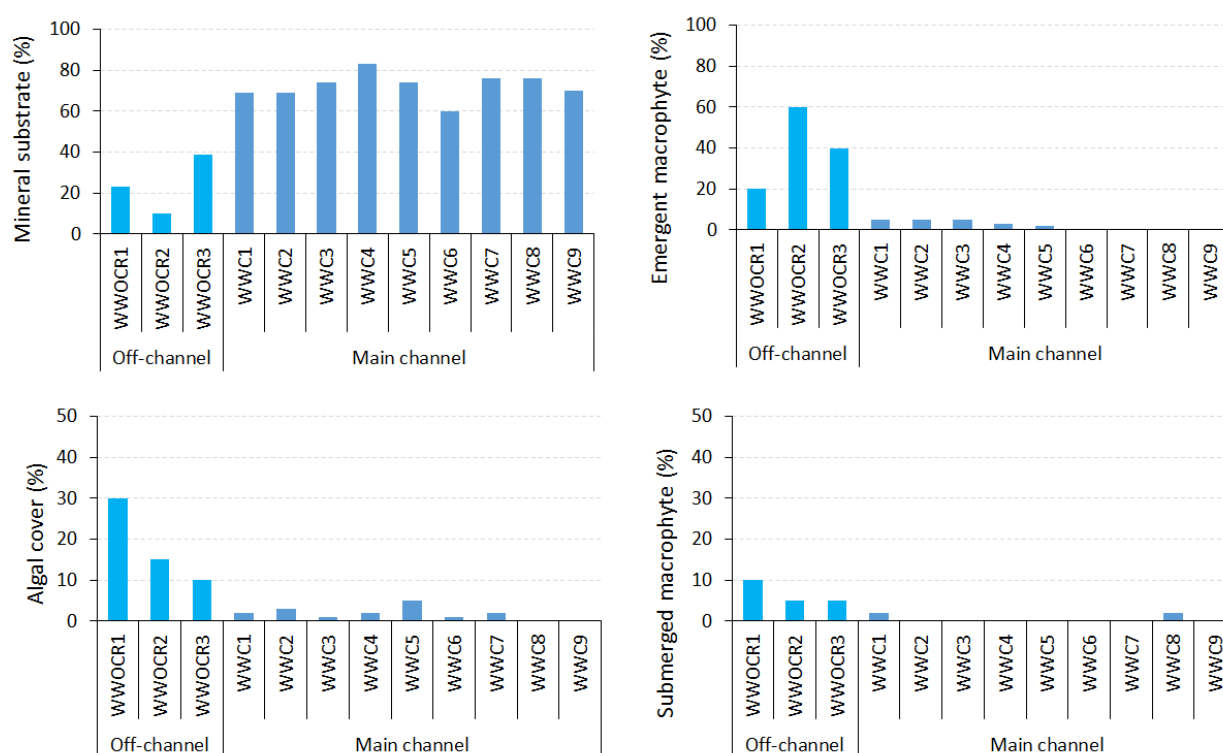


Figure 9. Percent (%) cover of mineral substrate, emergent macrophyte, algae and submerged macrophyte recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites.

There appeared to be a slight negative gradient of habitat diversity within the main channel of WWC, with diversity decreasing with distance downstream of WWC1 (Figure 10). Habitat diversity was lowest at WWC9 (four habitat types), which was a receding remnant pool at the time of sampling. The lack of habitat diversity at main channel sites, particularly downstream of WWC5 (Figure 10), was not unexpected, given that it was likely these sites had only recently flooded following heavy rainfall, and there would not have been enough time for aquatic macrophyte, algae and other vegetation to establish before sampling commenced.

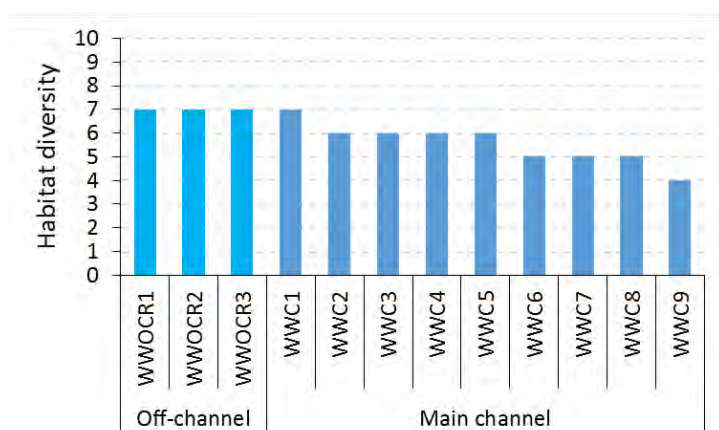


Figure 10. Habitat diversity (no. of habitat types) recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites.

4.3 Microinvertebrates (zooplankton)

4.3.1 Taxonomic composition and species richness

A total of 72 microinvertebrate taxa were recorded during the current study, of which, 46 taxa were recorded from off-channel sites, and 42 taxa were recorded from within the main WWC channel (Table 3). These include groups which could not be identified to species level due to unresolved taxonomy and/or immature specimens. Therefore, the total microinvertebrate species richness is likely greater than that reported here. The microinvertebrate fauna comprised Protista (Ciliophora & Rhizopoda), Rotifera (Bdelloidea & Monogononta), Copepoda (Calanoida & Cyclopoida), Cladocera (water fleas), and Ostracoda (seed shrimp; Table 3). The microinvertebrate fauna was typical of tropical systems across the world, with lecanids dominating the Rotifera, and chydorids prominent within Cladocera (e.g. Koste and Shiel 1983, Tait *et al.* 1984, Smirnov and De Meester 1996, Segers *et al.* 2004).

Table 3. Summary of microinvertebrate composition and taxa richness.

	Off-channel	Main channel	Total no. species
Protista	15	8	18
Rotifera	21	14	27
Cladocera	4	10	13
Copepoda	4	7	9
Ostracoda	2	3	5
Total	46	42	72

WWOCR1 supported the highest microinvertebrate taxa ('species') richness (35 taxa), whilst lowest taxa richness was recorded from WWC4 (two taxa; Figure 11). Microinvertebrates were notably abundant at the three off-channel pools, with 187 individuals (in 29% of settled volume counted) at WWOCR1, 201 individuals (in 6.4% of settled volume counted) at WWOCR2, and 205 individuals (in 0.2% of settled volume counted) at WWOCR3 (Figure 11; Appendix 4). Within the main channel, microinvertebrates were relatively depauperate at sites receiving higher surface flows (i.e. WWC1, WWC2, WWC3 & WWC4), while slightly higher taxa richness and abundances were recorded at more ephemeral sites further downstream (Figure 11; Appendix 4). The majority of zooplankton typically prefer low flow or still water habitats, which would explain the high microinvertebrate abundance recorded at off-channel pools, and in ephemeral sites further downstream within the main channel (upstream main channel sites are affected by dewatering discharge from mines located further upstream). It is likely that zooplankton are adapted to a narrow range of water quality, and imposing altered water quality *via*

dewatering discharge may have reduced the abundance of more susceptible species in Weeli Wolli Creek (R. Shiel, University of Adelaide, pers. com.).

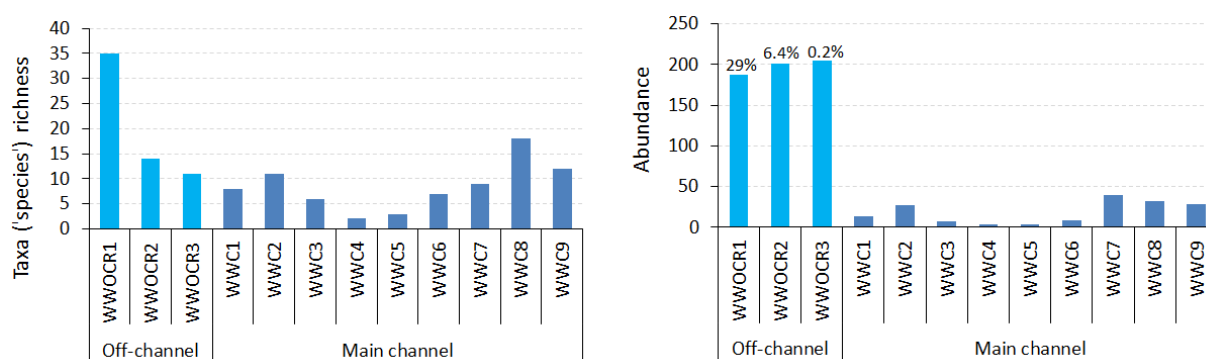


Figure 11. Taxa ('species') richness (left), and total abundance of microinvertebrates (right) recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites. Percentages (%) denote the portion of settled volume counted for abundance values. Where not specified (i.e. at main channel sites), 100% of settled volume was counted.

4.3.2 Microinvertebrate taxa of regional/scientific importance

The majority of microinvertebrate taxa from both off-channel and main channel sites were common, ubiquitous species, usually Australasian or cosmopolitan in distribution. However, a number of regionally significant taxa were recorded, including the Pilbara endemic copepods *Australoeucyclops karaytugi* and *Mesocyclops holynskae*. Two cladocerans of the genus *Simocephalus* were collected, which, although cosmopolitan in distribution, are rarely encountered in the Pilbara. The cladoceran cf. *Anthalona* sp. (family Chydoridae) was of scientific interest, as no species of this recently-erected genus have been described from Australia. Finally, the unexpected collection of the copepod *Boeckella fluvialis*, previously considered restricted to eastern Australia, initiates some interesting discussion. Each of these species are discussed in greater detail below.

The Pilbara endemic copepod *Australoeucyclops karaytugi* was collected from main channel site WWC2. This species is known from a number of other spring and permanent pool systems within the Pilbara, including the Ashburton, DeGrey and Yule River catchments (Pinder *et al.* 2010). WRM (2011) also collected *A. karaytugi* from Marillana Creek, just upstream of the confluence with WWC (4.5 km upstream of the Project). *Mesocyclops holynskae*, also restricted to the Pilbara, was recorded from off-channel pool WWOCR3. Previously, this species has been recorded from surface pools, as well as groundwater environments (bores) across the Pilbara region (Karanovic 2006).

Simocephalus exspinosus and *Simocephalus gibbosus* (Cladocera, family Daphniidae) are very rarely collected from the Pilbara (R. Shiel, University of Adelaide, pers. comm.). During the comprehensive Pilbara Biological Survey (PBS), in which 98 sites across the Pilbara were sampled between 2003 and 2006, *S. exspinosus* was only once collected, from a pool on the Ashburton River (Pinder *et al.* 2010). *S. gibbosus* was not recorded during the PBS (Pinder *et al.* 2010).

Anthalona is a recently described (2011) cladoceran genus, which is restricted to tropical and sub-tropical climates due to its stenothermic preference for warm waters (Van Damme *et al.* 2011). A number of species have been described from Central and South America, the Mediterranean, Africa, the Middle East, southern China and South-East Asia, however several species, which are awaiting taxonomic description, also occur in northern Australia (Van Damme *et al.* 2011). In the current study, *Anthalona* specimens (cf. *Anthalona* sp.) were collected from main channel sites WWC2, WWC6 and WWC7, though it is currently unknown whether these represent a new Australian species, or a range extension for a previously described species (R. Shiel, University of Adelaide, pers. comm.).

The collection of calanoid copepod *Boeckella fluvialis* at WWC9 was unexpected, given that this species is considered restricted to the eastern Australian states of Queensland, New South Wales and Victoria (Bayly 1985). The Western Australian Department of Parks and Wildlife (DPAW) have no record of *B. fluvialis* in Western Australia (A. Pinder, DPAW, pers. comm.), however, Bayly (1985) did record this species in ponds outside the Canning Town Council (City of Canning) buildings in the Perth-Metropolitan area between 1978 and 1985. The Canning Town Council ponds were located on a site previously used as a stone fruit nursery, with potted seedlings imported from Victoria and NSW and planted between 1935 and 1960 (Bayly 1985). Therefore, Bayly (1985) suggested that *B. fluvialis* was most likely introduced to these ponds *via* resting cysts, which were stored in the soil of imported potted seedlings.

It is considered unlikely that the presence of *Boeckella fluvialis* in the WWC9 microinvertebrate sample was caused by contamination, as WRM have not recently processed samples from the Eastern States (and have never recorded this species before), and Dr. Russel Shiel, who is sub-contracted by WRM to identify microinvertebrates, has not observed *B. fluvialis* in samples for over four years (R. Shiel, University of Adelaide, pers. comm.). Therefore, the collection of *B. fluvialis* from WWC9 constitutes either a range extension for this species, or more likely, a synanthropic introduction of this species to the study area, *via* imported soil or some other mode of transport, such as waterbird-mediated passive dispersal (R. Shiel, University of Adelaide, pers. comm.). Although uncommon, the introduction of calanoid copepods to foreign waterbodies has been previously recorded; along with the introduction of *B. fluvialis* to the Perth-Metropolitan area from eastern Australia, at least three other calanoid species have been introduced to New Zealand man-made ponds from Australia (Bayly 1985). Another *Boeckella* species, *B. triarticulata*, has been synanthropically introduced to ponds in Northern Italy, either through the stocking of introduced fish species, or through resting cysts associated imported crop seeds (Ferrari & Rossetti 2006).

Although a number of microinvertebrate taxa of scientific value (Pilbara endemic, rarely collected, potential new species) were recorded from main channel and off-channel sites in the current study, all species have known distributions outside the Project area, with the possible exception of the undescribed cf. *Anthalona* sp.

4.3.3 Spatial patterns in microinvertebrate assemblages (multivariate analysis)

PERMANOVA indicated that there was a significant difference in microinvertebrate species assemblages between off-channel and main channel sites ($df = 1$, $MS = 5243.4$, $Pseudo-F = 1.8316$, $p = 0.039$). SIMPER analysis suggested that there was 83.2% average dissimilarity (Bray-Curtis similarity) between off-channel and main channel sites, with taxa contributing most to these differences including; the cyclopoid copepod *Microcyclops varicans*, the rotifers *Sinantherina procera* and *Tripleuchlanis plicata*, the protists *Arcella discoides* and *Arcella bathystoma*, along with a number of *Diffugia* protists, indeterminate copepods and Bdelloidea rotifers. Each of these taxa was higher in average abundance at off-channel sites.

Non metric multidimensional scaling (nMDS) ordination (Figure 12) displayed clear separation of microinvertebrate assemblages at off-channel sites WWOCR1 and WWOCR2 from all other sites, as identified by PERMANOVA and SIMPER. BIOENV analyses (BEST procedure) suggested that five habitat variables (boulders, submerged macrophyte, algal cover, trailing vegetation & roots) influenced the variation of these assemblages, though the strength of the correlation was moderate ($\rho = 0.629$, $p = 0.05$). Spearman rank correlations (correlation > 0.5) indicated that submerged macrophyte most influenced the separation of WWOCR1 and WWOCR2 from other sites, while high percentages of roots, pebbles and large woody debris appeared to influence the separation of the majority of main channel sites (Figure 12).

As mentioned previously, microinvertebrates are known to prefer natural, sluggish or still waterbodies in preference to areas of high flow and altered hydrological regime. Microinvertebrate assemblage

composition in the study area broadly reflected these preferences, where there was a distinct separation of off-channel sites WWOCR1 and WWOCR2 from main channel assemblages, with higher abundances of numerous taxa recorded at these standing off-channel pools (Figure 12). The separation of microinvertebrate assemblages at WWOCR1 and WWOCR2 from WWOCR3 appeared to be influenced mainly by the presence of submerged macrophytes and other vegetation. Periphytic taxa (i.e. obligate inhabitants of aquatic plant surfaces), such as Lecanid rotifers and testate protists, were notably diverse and abundant at WWOCR1 (and to a lesser extent WWOCR2), in comparison to other off-channel and main channel sites (R. Shiel, University of Adelaide, pers. comm.), highlighting the influence of submerged habitat (particularly aquatic macrophytes) on microinvertebrate assemblage structure in the study area.

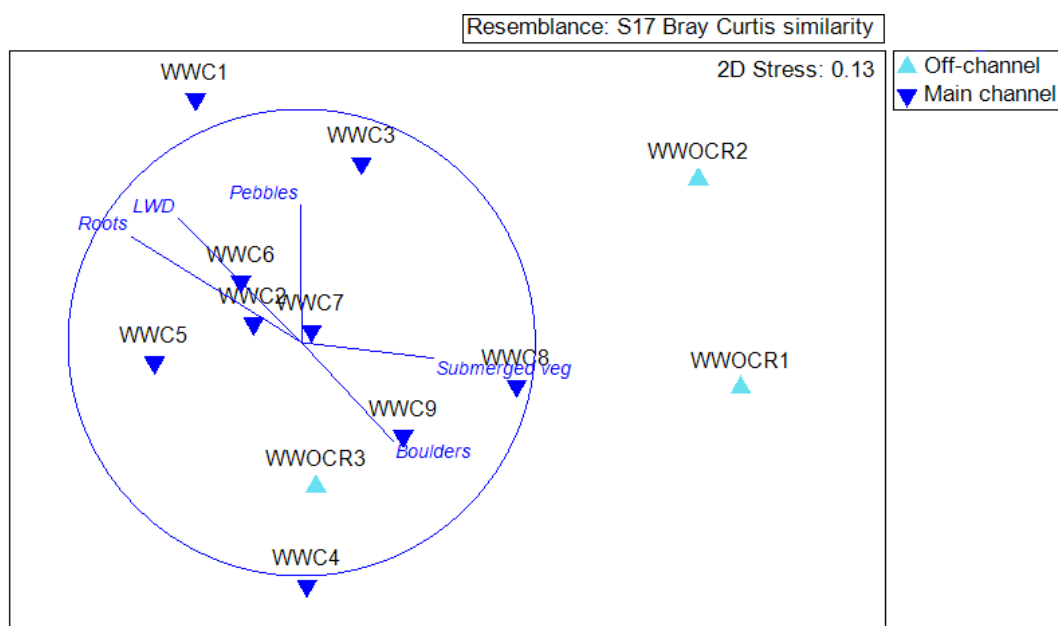


Figure 12. Unconstrained nMDS plot of microinvertebrate species assemblages at off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites, with spearman rank correlations of habitat variables (> 0.5) as vectors overlain.

4.4 Hyporheic fauna

4.4.1 Taxonomic composition

A total of 74 taxa were recorded from hyporheic samples taken in the Project area. A hyporheic sample could not be taken at WWOCR3 due to unsuitable substrate composition, i.e., predominantly clay and silt, with limited interstitial habitat for the movement of hyporheic fauna.

The majority of taxa recorded from both off-channel and main channel sites were considered “stygoxene”, i.e. they do not show specialised adaptations to groundwater or interstitial habitats (Appendix 4). Only four taxa were considered to be restricted to the hyporheic zone (stygoxite⁶). These included the ostracod *Candonopsis tenuis*, and three Paramelitidae amphipod species, which were also considered short range endemics (SREs). Taxa which were not true hyporheic fauna, but do show some morphological adaption to groundwater environments (occasional hyporheos stygophile⁷), included the cyclopoid copepod *Microcyclops varicans*, and a number of aquatic segmented worm (Oligochaeta) and aquatic beetle (Coleoptera) taxa. These classifications followed those by Boulton (2001), however, this

⁶ Taxa that show specialised adaptations to groundwater environments, e.g. lack eyes, pigmentation.

⁷ Species that are occasionally recorded in groundwater/hyporheic zones, and show some morphological adaptation to groundwater environments.

type of analysis must be considered with caution, as results are likely to be affected by availability of information on life-history, taxonomic resolution and interpretation of classification categories.

4.4.2 Hyporheic fauna

The stygobitic ostracod *Candonopsis tenuis* was recorded from main channel site WWC2. *C. tenuis* was originally described from eastern Australia (Brady 1886, Sars 1896) and is commonly recorded from groundwater environments across the Pilbara (Halse *et al.* 2002) and Australia (DeDeckker 1982, Karanovic & Marmonier 2002).

The occasional hyporheos stygophile *Microcyclops varicans* was collected from off-channel site WWOCR1, and from WWC2, WWC4, WW7, WWC8 and WWC9 within the main channel. *M. varicans* occurs widely in Pilbara surface waters and groundwater environments, including deep bores and hyporheic zones (Martens & Rossetti 2002, Pesce *et al.* 1996, Halse *et al.* 2002, DEC 2009).

A number of aquatic oligochaete (segmented worm) taxa were recorded at both off-channel and main channel sites. Although not specifically adapted to subterranean habitats, a majority of freshwater oligochaete groups appear to be morphologically pre-adapted to hyporheic environments, with their small size allowing them to move easily in interstitial spaces (Des Châtelliers *et al.* 2009). Further, oligochaetes of the family Naidinae, including *Pristina* and *Dero* species, are known to be active exchangers between surface and groundwaters (Lafont *et al.* 1992).

The coleopteran families of Hydraenidae and Scirtidae, larvae of which were collected from a number of main channel sites during the current study, have commonly been reported from hyporheic habitats throughout the world (Boulton *et al.* 1997, del Rosario & Resh 2000, Matthaei & Townsend 2000, Olsen & Townsend 2003, Langhans 2006), and therefore, are classified as occasional hyporheos stygophiles. The Dytiscid beetle *Limbodessus occidentalis* is also considered an occasional hyporheos stygophile, as it has been collected in calcrete aquifers, surface waters and hyporheic environments across the Pilbara region (Watts & Humphreys 2004, Pinder *et al.* 2010). Many calcrete aquifers across inland Western Australia have recently been discovered to support unique diving beetle (Dytiscid) assemblages (commonly including *L. occidentalis*), which also frequent surface waters and hyporheic zones connected to aquifers (Leys *et al.* 2003, Watts & Humphreys 2006). In the current study, *L. occidentalis* was recorded from WWOCR1.

4.4.3 Short range endemics (SREs)

Three short range endemic (SRE) species, as defined by Harvey (2002)⁸, were recorded in the study area. These were the stygobitic amphipods Paramelitidae sp. B, Paramelitidae sp. D, and *Chydaekata* sp. These taxa comprised only 50% of SRE species likely to occur in the hyporheic zone of WWC adjacent to the Project, as identified by WRM (2015) (Table 4). However, it should be noted that these results only present a snapshot of hyporheic assemblages present in the study area, and it is likely that other species would be identified if sampling were to be conducted at more sites and at differing times of the year.

Paramelitidae sp. D was recorded in the hyporheic zone of WWC2, and Paramelitidae sp. B was recorded at off-channel sites WWOCR1 and WWOCR2. Both species have been previously collected from the hyporheic zones of WWC and Marillana Creek, upstream of the Project (WRM 2011, DPaW 2015). These species have also been collected in bores within the Project tenement (Bennelongia 2010). Of particular interest is Paramelitidae sp. D, whose WWC and Marillana Creek populations, despite their close geographical proximity, have been found to be genetically distinct, based on over four million years of reproductive isolation (WRM 2011).

⁸ Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10, 000 km².

Table 4. SRE taxa recorded in the hyporheic zones of off-channel and main channel sites, versus SRE taxa expected to occur in the study area as identified by WRM (2015). * indicates species was also collected in surface water (macroinvertebrate) samples.

Taxa		Observed		Likely to occur
		Off-channel	Main channel	
Amphipoda	Paramelitidae sp. B	✓	*	✓
	Paramelitidae sp. D		✓	✓
	<i>Chydaekata</i> sp.	✓		✓
	<i>Maarrka weeliwolli</i>			✓
Isopoda	<i>Pygolabis weeliwolli</i>			✓
Syncarida	Bathynellidae/Parabathynellidae			✓

Chydaekata sp. (family Paramelitidae) is known previously from bores within the Project tenement (Bennelongia 2010), as well as the hyporheic zone of a small number of nearby creeks; WWC, Marillana Creek, Coondiner Creek and Mindy Mindy Creek (DPaW 2015). In the current study, this species was recorded at off-channel site WWOCR1.

Along with Paramelitidae sp. B, Paramelitidae sp. D and *Chydaekata* sp., a number of immature stygal amphipods of the family Paramelitidae were also collected at WWOCR1, WWOCR2 and WWC2. These may have represented any of the aforementioned amphipod species, or possibly *Maarrka weeliwolli*, another stygal Paramelitidae amphipod known from the Project area, which was not recorded in the current study. Because of the immature condition of the specimens, it was not possible to definitively identify them to species level.

Although a number of stygobitic and SRE hyporheic taxa were recorded at WWC main channel and off-channel sites in the current study, all taxa have known local and/or regional distributions outside the Project area.

4.5 Macroinvertebrates

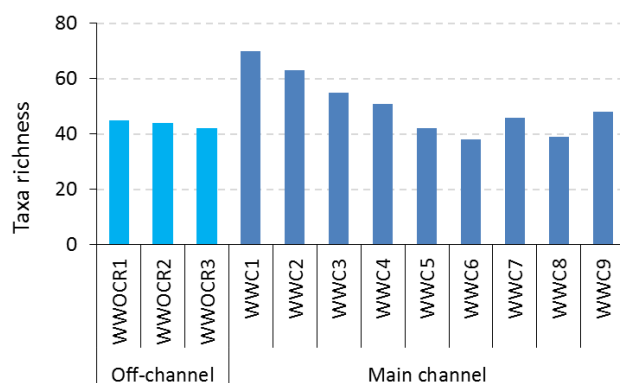
4.5.1 Taxonomic composition and species richness

A total of 172 macroinvertebrate taxa ('species') were recorded from WWC during the current study; 78 were collected from off-channel sites, and 151 were collected from the main channel (Table 5). As for microinvertebrates, these include groups which could not be identified to species level due to unresolved taxonomy and/or immature specimens, and total macroinvertebrate species richness is likely greater than that reported here. Taxa comprised predominately of fugitive, opportunistic and/or predatory groups, i.e. Coleoptera (27%) and Diptera (27%) and Hemiptera (12%). Other taxa included Acarina (aquatic mites), Collembola (spring tails), Gastropoda (aquatic snails), Ephemeroptera (mayflies), Lepidoptera (aquatic caterpillars), Odonata (dragonflies & damselflies), Trichoptera (caddisflies), Amphipods (side swimmers) and Oligochaeta (segmented worms) (Table 5).

Highest macroinvertebrate taxa ('species') richness was recorded from WWC1 (70 taxa), whereas lowest richness was recorded from WWC6 (38 taxa; Figure 13). Within the main channel, there was a general decline in macroinvertebrate taxa richness downstream of WWC1, and particularly between WWC1 and WWC6 (Figure 13). This appeared to follow a similar trend to in-stream habitat diversity within the main channel, which also declined with distance downstream of WWC1 (see Section 4.2.1).

Table 5. Summary of macroinvertebrate composition and abundance at off-channel and main channel Weeli Wolli Creek sites.

Taxa	Off-channel	Main channel	Total no. species
Acarina (aquatic mites)	2	2	3
Collembola (spring tails)	2	2	3
Gastropoda (aquatic snails)	2	2	2
Coleoptera (aquatic beetles)	15	39	46
Diptera (true flies)	22	41	46
Ephemeroptera (mayflies)	6	9	9
Hemiptera (true bugs)	8	19	21
Lepidoptera (aquatic caterpillars)	1	3	4
Odonata (dragonflies & damselflies)	10	14	16
Trichoptera (caddisflies)	4	10	12
Amphipods (side swimmers)	0	1	1
Oligochaeta (segmented worms)	6	9	9
Total	78	151	172

**Figure 13.** Taxa ('species') richness of macroinvertebrates recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites.

Regression analysis indicated there was a significant correlation between habitat diversity and macroinvertebrate taxa richness within the main WWC channel ($R^2 = 0.46$, $F = 5.93$, $p = 0.045$), with taxa richness increasing with greater habitat diversity (Figure 14). This was in accordance with other studies (e.g. Erman & Erman 1984, Heino 2000), which suggest that complexity and heterogeneity of in-stream habitat can play a crucial role in influencing macroinvertebrate richness and abundance.

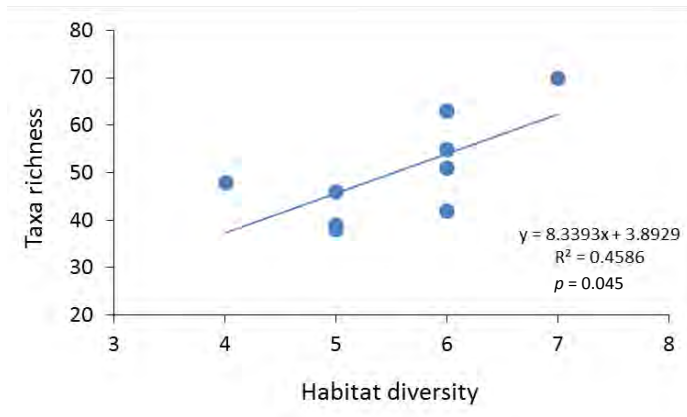


Figure 14. Linear regression plot of macroinvertebrate taxa richness against habitat diversity within the main channel of Weeli Wolli Creek. Regression equation, with R^2 and p value is displayed.

Reduced richness at main channel sites adjacent and downstream of the Project area (WWC5 - WWC9), relative to sites further upstream, likely reflects the ephemeral nature of the downstream reach of WWC. The current wetting front from dewatering discharge operations upstream of the Project likely affects upstream sites (WWC1 – WWC3), providing permanent or semi-permanent flows/inundation, however, sites further downstream still maintain ephemerality. As the survey took place immediately following a high rainfall event (and following above average rainfall for the month), downstream reaches would have recently filled, allowing limited time for macroinvertebrate fauna to colonise these pools prior to the survey commencing. This may in part provide reason for the lower richness observed at these sites, in comparison to upstream sites, which have greater permanency of surface water and connectivity between pools.

Taxa richness was relatively low at the three off-channel sites, with 45, 44 and 42 taxa recorded at WWOCR1, WWOCR2 and WWOCR3, respectively (Figure 13). Richness was lower than expected, given the high diversity of in-stream habitat, particularly aquatic macrophytes, present at these sites. Raw taxa lists indicated a number of species adapted to flowing conditions (lotic species) were either absent or present in reduced abundance at off-channel sites, compared to main channel sites (Figure 15). It is possible that comparatively poor water quality, such as low dissolved oxygen, and elevated EC and nutrients (See section 4.1), may have influenced taxa richness at these sites. However, it is more likely, lack of surface flow / riffles / rapids at off channel sites (isolated pools), provides reason for the observed absence of a number lotic species, compared to main channel sites.

Furthermore, isolated habitats, such as the off-channel pools, tend to support lower macroinvertebrate species richness than stream channels, due to the aerial dispersal patterns of macroinvertebrates (Bogan & Boersma 2012). Winged-adult forms allow many groups (e.g. Odonata, Coleoptera, Hemiptera, Ephemeroptera etc.) to avoid inbreeding and predation in isolated habitats, and migrate from waterbodies when environmental conditions become unfavourable (Palmer et al. 1996, Leibold et al. 2004, Bogan & Boersma 2012). Heavy rainfall also serves as a cue for many aquatic invertebrate taxa to disperse from perennial waterbodies to nearby ephemeral channels, which provide important migratory corridors for macroinvertebrates (Lytle & Poff 2004, Bogan & Boersma 2012). Therefore, differences in hydrology, dispersal patterns and heavy rainfall prior to the survey provide plausible causation for lower diversity recorded at off-channel pools during the current study.

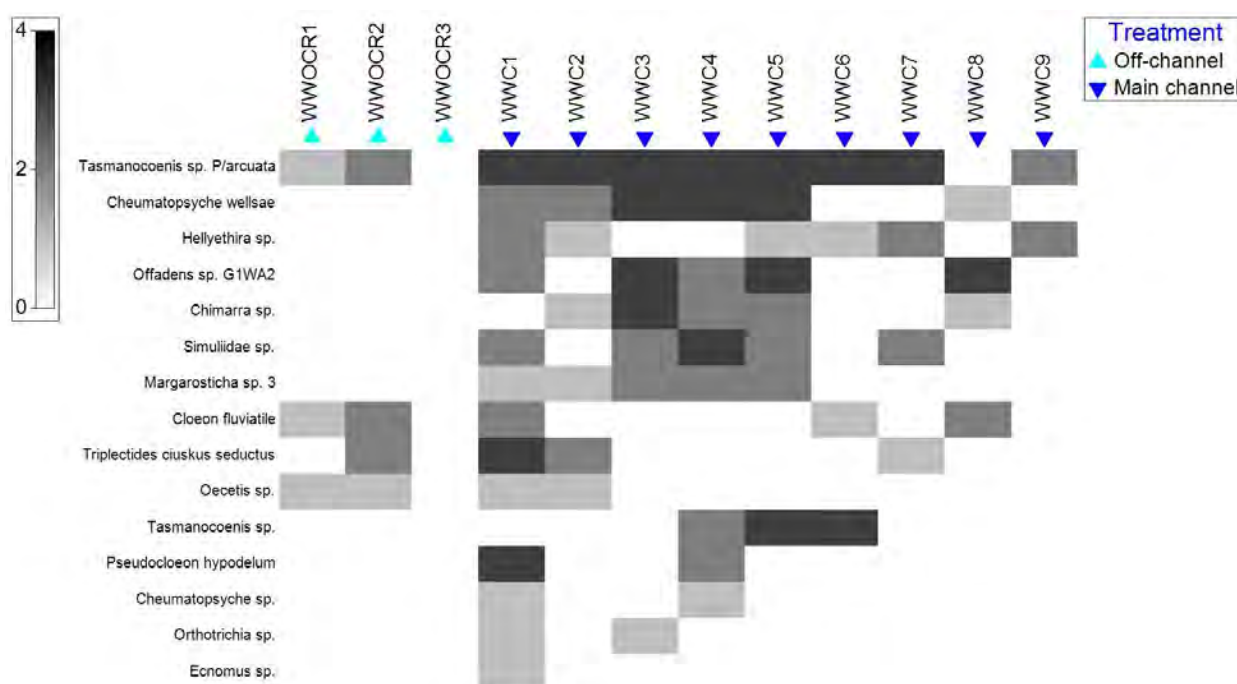


Figure 15. Shade plot of flow-adapted (lotic) taxa at off-channel and main channel Weeli Wolli Creek sites, with shaded box showing log₁₀ abundance of taxa at each site.

4.5.2 Macroinvertebrate taxa of regional/scientific importance

No conservation listed (IUCN Red List or DPaW priority) macroinvertebrate species were recorded in the study area. However, one SRE amphipod (Paramelitidae sp. B), and four Pilbara endemic Coleoptera (aquatic beetle) species were recorded, including *Limbodessus occidentalis* (discussed in Section 4.4.2) and the recently described *Halipus fortescueensis*.

The stygal SRE amphipod Paramelitidae sp. B was collected from the surface waters of WWC2. This species was also collected in the hyporheic zone of off-channel sites WWOCR1 and WWOCR2. The conservation significance of Paramelitidae sp. B is discussed in detail in Section 4.4.2.

The Halipid beetle *Halipus fortescueensis* is a Pilbara endemic relatively new to science. It was first described from a specimen collected from the Fortescue Marsh during the PBS (Pinder *et al.* 2010, Watts & McRae 2010). It appears to be mainly restricted to the Fortescue River, and most abundant in the Fortescue Marsh (Watts & McRae 2010). However, this species has also been collected once from a claypan near Port Hedland (Watts & McRae 2010), and also from a Claypan on Coondiner Creek (DPaW 2015, WRM unpub. data). During the current study, *H. fortescueensis* was recorded from the furthest-downstream (i.e. closest to Fortescue Marsh) main channel site, WWC9. This species appears largely restricted to ephemeral waterbodies.

The Pilbara endemic beetles *Tiporus tambreyi* (Dytiscidae) and *Laccobius billi* (Hydrophilidae) were recorded from a number of main channel sites. *Tiporus tambreyi* appears to be common and ubiquitous across the Pilbara region (Pinder *et al.* 2010, DPaW 2015, WRM unpub. data). However, *Laccobius billi* is a Pilbara endemic rarely collected. It was only recorded once during the PBS, from Cangan Pool on the Yule River, approximately 100 km north-west of the Project (Pinder *et al.* 2010). It has also been recorded previously by the authors from Weeli Wolli Creek, Coondiner Creek and Mindy Mindy Creek (DPaW 2015, WRM unpub. data).

Limbodessus occidentalis, *Tiporus tambreyi*, *Laccobius billi* and Paramelitidae sp. B have known local and/or regional distributions outside the Project area. As such, any potential impact to local populations of these species as a result of dewatering discharge is unlikely to impact their regional populations. However, the collection of *Halipis fortescueensis* from main channel site WWC9 is of some interest. This species appears largely restricted to ephemeral waterbodies. As such, if dewatering discharge creates permanent surface flows along WWC downstream of the Project, it is possible that the local population of *H. fortescueensis* could be adversely affected.

4.5.3 Spatial patterns in macroinvertebrate assemblages (multivariate analysis)

As there appeared to be distinct differences in taxa richness between and within main channel and off-channel pools, multivariate analysis was used to investigate the variation in macroinvertebrate species assemblages within and between these ecosystem types. PERMANOVA indicated there was a significant difference in macroinvertebrate species assemblages between off-channel and main channel sites ($df = 1$, $MS = 4133.7$, Pseudo- $F = 2.95$, $p = 0.005$). SIMPER analysis suggested there was 62.7% average dissimilarity (Bray-Curtis similarity) between off-channel and main channel groups. Taxa contributing mostly to these differences were a large number of chironomid (non-biting midge) species, which were generally higher in average abundance at WWOCR3 compared to other sites. As indicated by shade plotting (Figure 15), taxa which are known to prefer high flows and lotic conditions (e.g. the mayflies *Tasmanocoenis* sp. *P/arcuata*, *Cloeon* sp. Red Stripe & *Offadens* sp. G1WA2, and the caddisfly *Cheumatopsyche wellssae*), were all higher in average abundance at main channel sites, compared to off-channel sites (SIMPER). This was expected, given the presence of flowing riffle habitats within the main channel, which were absent at off-channel sites. However, each of the aforementioned taxa contributed less than 3% to the overall variation between groups.

The nMDS ordination (Figure 16) displayed the differences in macroinvertebrate species assemblages between and within main channel and off-channel sites, where WWOCR3 was distinct from all other sites. This may have reflected a response of macroinvertebrate fauna to relatively poor water quality at this site (i.e. brackish water, low dissolved oxygen, elevated nutrients and/or elevated suspended sediment loads). BIOENV analysis indicated that five water quality variables (boron, iron, magnesium, N-NO_x & turbidity) best influenced the variation in macroinvertebrate species assemblages ($\rho = 0.732$, $p = 0.01$). Spearman rank correlations (correlation > 0.5) showed that emergent vegetation, algae, submerged vegetation and silt influenced the separation of WWOCR1 and WWOCR2 from main channel sites, whereas a variety of substrates (pebbles, sand, clay) and max. depth (m) influenced the separation of main channel sites from off-channel pools (Figure 16).

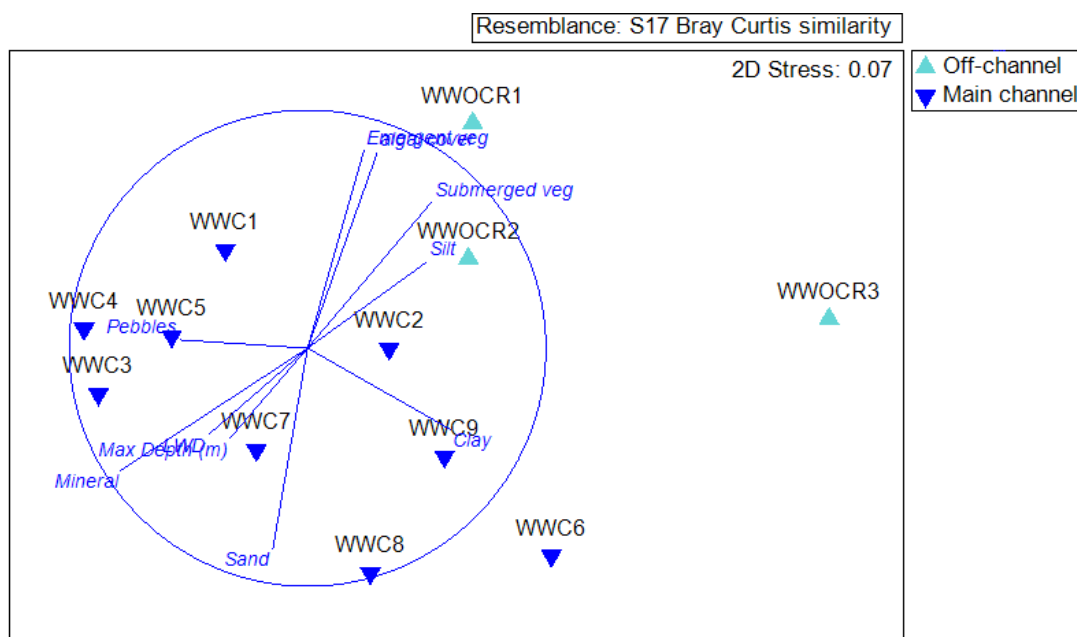


Figure 16. Unconstrained nMDS plot of macroinvertebrate species assemblages at off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites, with spearman rank correlations of habitat variables (> 0.5) as vectors overlain.

4.6 Fish

4.6.1 Species composition

A total of 411 fish were caught, measured and released during the current study, of which 68 individuals were from off-channel sites, and 343 individuals were from main channel sites. Three of the 12 freshwater fish species known from the Pilbara were recorded; the western rainbowfish *Melanotaenia australis*, the spangled perch *Leiopotherapon unicolor*, and the Hyrtl's tandan (eel-tailed catfish) *Neosilurus hyrtl*. Each of these species are common, ubiquitous and widespread across the Pilbara region.

Results reflected those of previous studies of freshwater fish in the vicinity of the Project. For example, WRM (2011), during bi-annual sampling of Marillana Creek between 2008 and 2011, recorded the same three species as recorded in the current study. Low diversity of fish fauna is common in the upper reaches of the Fortescue River and its tributaries (including WWC), in comparison to the lower Fortescue River and other catchments across the Pilbara (Morgan *et al.* 2009).

4.6.2 Species abundance

The western rainbowfish was the most common fish species of the study area, comprising 67% of all fish caught. This was mainly due to the high abundances of rainbowfish recorded at WWC1 and WWC2, where 105 and 85 individuals were caught, respectively (Figure 17). Rainbowfish abundance was relatively low at all other sites (i.e. < 28). No rainbowfish were caught or observed at WWC5 or WWC6 (Figure 17). Rainbowfish of the genus *Melanotaenia* are the most common freshwater fish of tropical Australian waterways (Allen *et al.* 2002). Rainbowfish are generally shoaling, omnivorous species, which utilise the entire water column to forage, and can occupy a range of hydrological habitats, from high velocity streams to stagnant pools (Allen *et al.* 2002, McGuigan *et al.* 2003).

A total of 78 spangled perch were recorded in the current study. The highest abundance of spangled perch was recorded at WWC1 (19 individuals), however, spangled perch were also relatively abundant

at off-channel sites WWOCR1 (12 individuals) and WWOCR2 (15 individuals; Figure 17). Lowest spangled perch abundance was at WWC6 (one individual), and no spangled perch were recorded at either WWOCR3, WWC7 or WWC9 (Figure 17). Spangled perch are widespread throughout Australian inland waters, owing to their tolerance of extremes in water quality (Gehrke & Fielder 1988). For example, they are known to survive in waterbodies with dissolved oxygen concentrations of 1mg/L, temperatures from 5 - 44° Celsius, and salinities over 50,000 $\mu\text{S}/\text{cm}$ (Gehrke & Fielder 1988). Further, this species is thought to aestivate in wet mud or under moist leaf litter in order to avoid desiccation during the dry season, when remnant pools recede or dry out (Allen *et al.* 2002).

Hyrtl's tandan was the least common species recorded in the study, comprising only 14% of fish caught. As with western rainbowfish and spangled perch, highest Hyrtl's tandan abundance was recorded at WWC1 (23 individuals), with the species also relatively abundant at WWC2 (18 individuals; Figure 17). Abundance of Hyrtl's tandan was relatively low (< 8 individuals) at all other sites, with no individuals recorded at WWC6, WWC7 or WWC9 (Figure 17). The Hyrtl's tandan is known to occupy a diverse range of habitats across northern Australia, including still or flowing water of streams, billabongs and pools (Allen *et al.* 2002).

In the current study, the upstream main channel sites WWC1 and WWC2, which experience permanent/semi-permanent flows due to dewatering discharge operations upstream, supported relatively high abundances of each fish species. The hydrological and habitat characteristics of WWC1 and WWC2 were considered favourable for fish populations, i.e., they were wide (20 – 40 m), relatively shallow (~0.8 m) and fast-flowing (~25 litres/sec), with good in-stream habitat complexity. As the downstream reaches are ephemeral and lack surface-water connectivity between pools, these likely support naturally small fish populations. Further, given the survey followed a high rainfall event, it is probable that fish did not have enough time to successfully colonise newly inundated sites prior to sampling, with consequent lack of in-stream habitat and prey animals at these sites (i.e. micro and macroinvertebrates) influencing low fish abundance (Figure 17).

Spangled perch were relatively abundant at WWOCR1 and WWOCR2 (Figure 17). In comparison, western rainbowfish and Hyrtl's tandan numbers were low at off-channel these sites. Predatory pressure from spangled perch, with lack of connectivity between pools preventing recolonisation, were likely the main causal factors influencing low rainbowfish and Hyrtl's tandan abundance at these sites. Further, dense emergent and submerged macrophytes made these sites more difficult to fish, which may have affected catch data (Figure 17). All fish species were low in abundance (or absent in the case of the spangled perch) at WWOCR3 (Figure 17). This was also likely due to the high density of aquatic macrophytes at this site hampering catch rates, rather than the influence of environmental variables or stochastic factors.

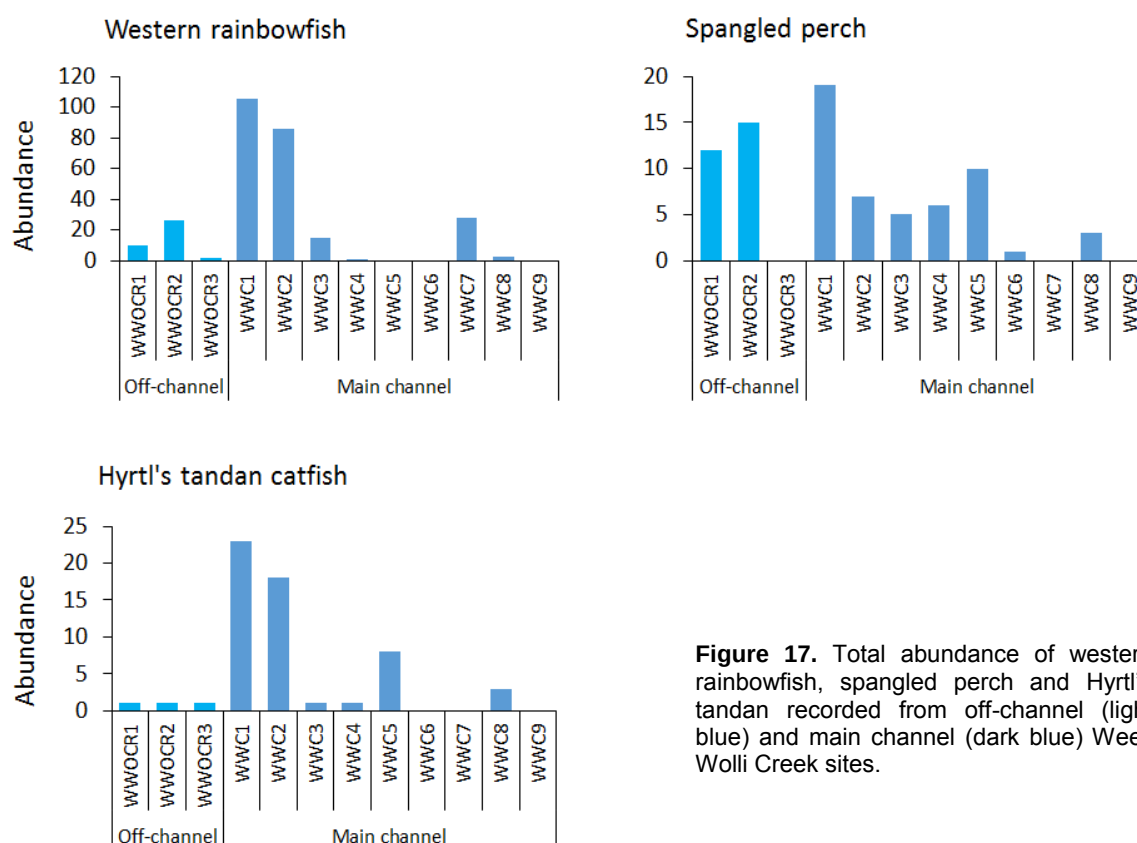


Figure 17. Total abundance of western rainbowfish, spangled perch and Hyrtl's tandan recorded from off-channel (light blue) and main channel (dark blue) Weeli Wolli Creek sites.

4.6.3 Age-class structures

The reproductive strategies of Pilbara fish species are 'opportunistic' and 'periodic', reflecting the seasonal yet unpredictable nature of rainfall and streamflow in the region (Beesley 2006). Breeding of many species occurs during the wet season, when there is increased connectivity between and within systems. During flood events, adults of most species travel upstream, where multiple spawning events are known to occur (Beesley 2006). In order to further examine population structures of fish in the study area, length-frequency data for each species were split into age-classes estimated from published literature (i.e. Lake 1971, Bishop *et al.* 2001, Morgan *et al.* 2002, Beesley 2006; Table 6).

Table 6. Age-class classifications for each fish species.

Species	Age-class	Size mm (SL)
Western rainbowfish	New recruit	< 30
	Juvenile	31-40
	Sub-adult	41-50
	Adult	>51
Spangled perch	New recruit	< 30
	Juvenile	31-50
	Sub-adult	51-70
	Adult	>71
Hyrtl's tandan	New recruit	< 30
	Juvenile	31-70
	Sub-adult	71-90
	Adult	>91

The population structure of western rainbowfish and Hyrtl's tandan at off-channel sites, and sites downstream of WWC2, were difficult to assess due to the low abundance of each species recorded. However, the populations of western rainbowfish at the two most upstream main channel sites (WWC1 & WWC2) appeared to be healthy, with individuals from all age classes represented, including new recruits (Figure 20). This indicates western rainbowfish are breeding in upstream reaches of main channel, where there is favourable streamflow and habitat characteristics for preproduction and predator avoidance.

Comparatively, no Hyrtl's tandan new recruits were recorded in the study area, and only four juvenile Hyrtl's tandan were recorded in total (all at WWC1; Figure 20). However, a variety of other age classes were present, particularly at WWC1 and WWC2 (Figure 20). Similarly, no spangled perch new recruits were recorded, either within the main channel or at off-channel sites (Figure 19). Sites which supported the most spangled perch juveniles were WWOCR1 and WWC1, with sub-adults and adults also represented at these sites (Figure 19). Adult spangled perch were the most common age-class captured across all other sites, although four sub-adults were recorded from off-channel site WWOCR2 (Figure 19).

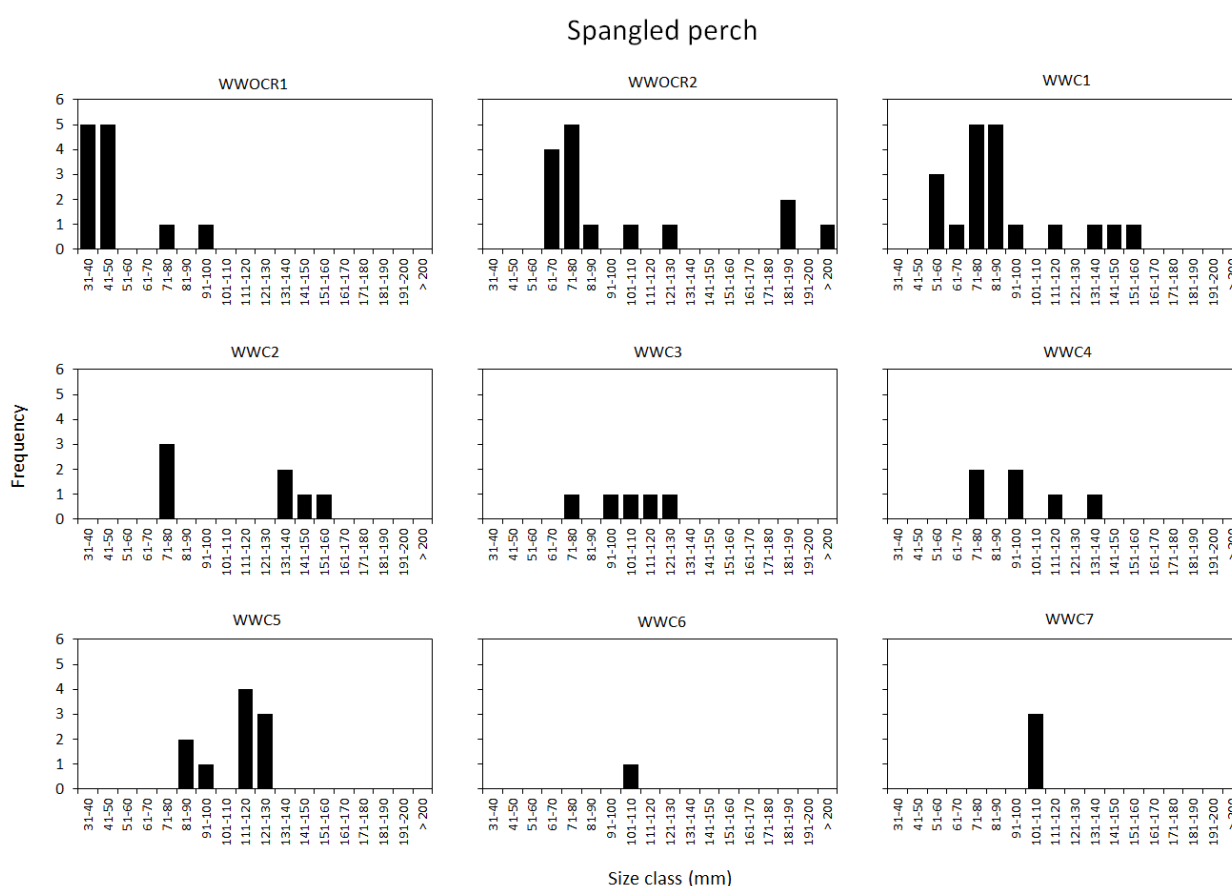


Figure 18. Age-class population structure of spangled perch at off-channel and main channel Weeli Wolli Creek sites.

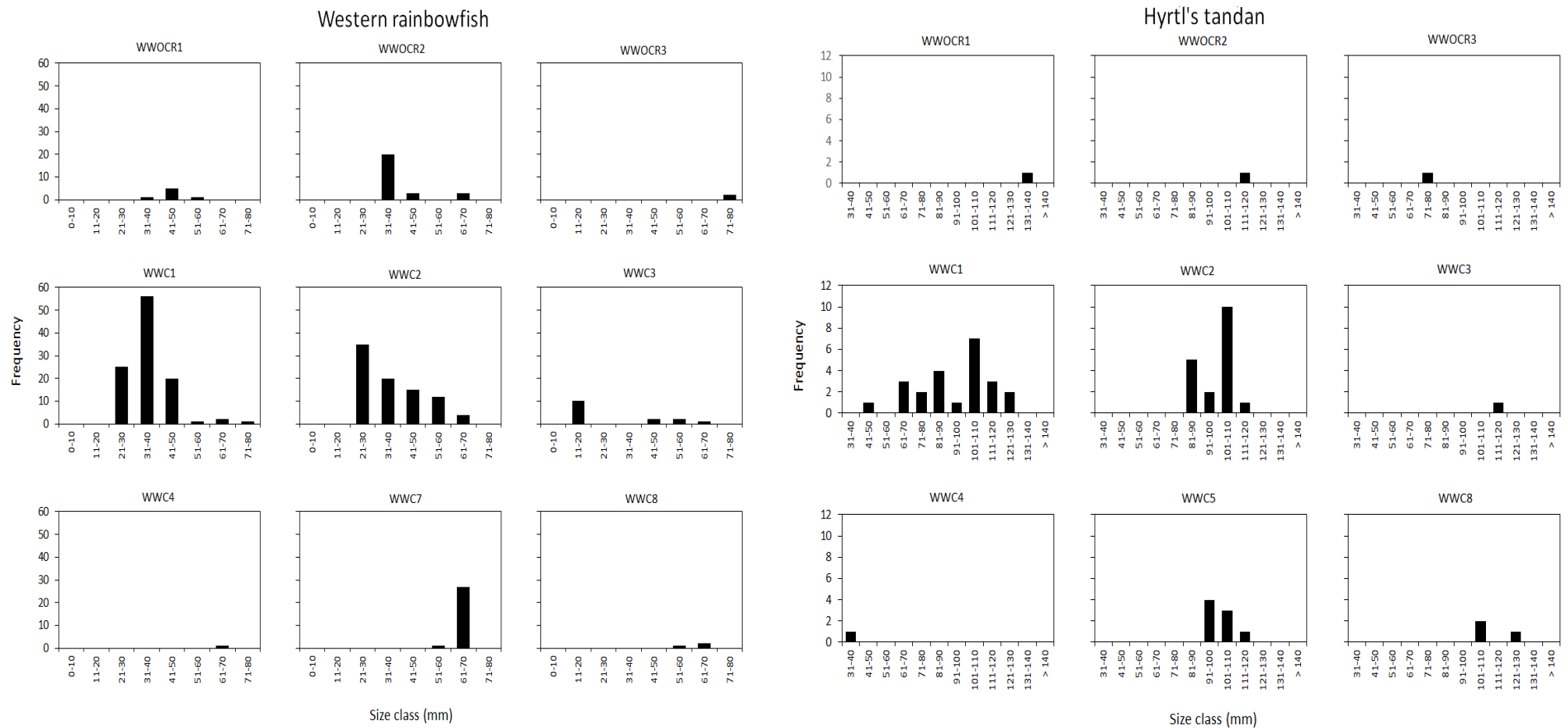


Figure 19. Age-class population structure of western rainbowfish (right) and Hyrtl's tandan (left) at off-channel and main channel Weeli Wolli Creek sites

5 SYNOPSIS AND CONCLUSIONS

5.1 General

- Established dewatering discharge operations upstream of the Project (i.e. RTIO HD1, RTIO Yandicoogina, and BHBPIO Yandi) have resulted in semi-permanent / permanent surface water flows along Weeli Wolli Creek (main channel) immediately upstream, and adjacent to the tenement. Currently, surface flows as a result of dewatering discharge do not extend to sites further downstream along Weeli Wolli Creek (i.e. WWC5 – WWC9). Flows at these downstream sites remains ephemeral in nature, with surface flow currently still rainfall dependent, generally lasting for a period of days to weeks.
- Rainfall in the weeks prior to sampling likely resulted in increased surface flows adjacent to, and downstream of the Project, with newly inundated pools observed at the time of sampling (evidenced by a lack of in-stream habitat, A.Harman pers. comm). Short residence time of surface waters (either flowing or pools) at downstream sites along WWC likely provided insufficient time for a number of aquatic invertebrates and fish to establish populations prior to sampling, resulting in lower taxa richness at these sites in comparison to permanently inundated sites upstream.

5.2 Water quality

- *In situ* spot measurements indicated surface waters were generally circum-neutral to slightly alkaline, relatively fresh (however, WWOCR3 was considered brackish), with dissolved oxygen concentrations ranging from low to supersaturated.
- Low dissolved oxygen concentrations recorded at off-channel 'reference' sites have the potential to adversely affect many aquatic fauna (invertebrates and fish). Low DO reflects the standing nature of these pools, with limited aeration due to lack of surface flows, along with the use of DO by aerobic heterotrophic bacteria oxygen as they decompose the organic matter (dead plant material).
- Nitrogen oxide (N_{NO_x}) concentrations at all main channel WWC sites, and total nitrogen (TN) and total phosphorus (TP) levels at WWOCR3, were in exceedance of respective default ANZECC/ARMCANZ (2000) TV for stressors for slightly disturbed ecosystems (equivalent to 95% protection of species). Additionally, nitrate (NO_3) levels at main channel site WWC8 exceeded the TV for toxicants for 95% protection of species. Elevated nutrient concentrations could reflect inherent natural variation in background levels, however, groundwater in the Pilbara is naturally elevated in nutrients, and levels recorded in the current study might be influenced by dewatering discharge activities upstream, and unrestricted livestock access to the creekline from pastoral stations nearby.
- Dissolved metal concentrations were generally low, however, dissolved boron (dB) and dissolved zinc (dZn) concentrations at a number of sites were above respective ANZECC/ARMCANZ (2000) TVs for toxicants for 95% protection of species. Exceedances were considered to be of little ecological concern, with naturally elevated dB levels widely reported in Pilbara creeklines, and dZn levels were below hardness-modified trigger values (HMTVs) when water hardness was taken into consideration.
- Multivariate analysis indicated overall water quality at off-channel site WWOCR3 was distinct in comparison to other off-channel and all main channel WWC sites. Water quality data indicated dB, dZn, TN, TP and EC concentrations were elevated, and exceeded respective default ANZECC/ARMCANZ (2000) TVs. Additionally, ionic composition, dCo, dFe, dMn, TSS and turbidity were elevated, relative to all other sites sampled.

5.3 Microinvertebrates

- Microinvertebrate fauna was abundant at off-channel sites, and particularly diverse at WWOCR1. In comparison, microinvertebrates were relatively depauperate at main channel WWC sites, particularly upstream sites which receive permanent surface flows from dewatering discharge operations. Multivariate analysis indicated microinvertebrate assemblage composition was significantly different between off-channel and main channel WWC sites, with periphytic taxa in particular dominant at off-channel site WWOCR1. Results broadly reflect the hydrological preferences of microinvertebrates, which generally favour standing or slow-flowing waters (lentic conditions).
- The majority of microinvertebrate taxa recorded at off-channel and main channel WWC sites were common, ubiquitous species, mostly Australasian or cosmopolitan in distribution. However, a number of regionally significant taxa were recorded, including;
 - the Pilbara endemic copepods *Australoeucyclops karaytugi* and *Mesocyclops holynskae*.
 - two cladocerans of the genus *Simocephalus*, which although cosmopolitan in distribution, are rarely collected from the Pilbara.
 - the cladoceran cf. *Anthalona* sp. (family Chydoridae). Specimens could not be identified to species level. It is unknown whether individuals represent a new Australian species, or a range extension for a previously described species (R. Shiel, University of Adelaide, pers. comm.). No species of this recently-erected genus have been described from Australia to date.
 - the copepod *Boeckella fluvialis*. This record was unexpected, as *B. fluvialis* is considered restricted to eastern Australia. Causation could not be determined for presence of this species in the current study.
- Although a number of microinvertebrate taxa of scientific value (Pilbara endemic, rarely collected, potential new species) were recorded in the current study, all species, except the unidentified cladoceran cf. *Anthalona* sp. have known local and/or regional distributions outside the Project area.

5.4 Hyporheic fauna

- The majority of taxa recorded from hyporheic samples were classified as stygoxene, and do not have specialised adaptations to groundwater or interstitial habitats. Only four taxa were considered to be restricted to the hyporheic zone (stygobitic fauna). These included the ostracod *Candonopsis tenuis*, and three amphipod species; *Paramelitidae* sp. B, *Paramelitidae* sp. D, and *Chydaekata* sp., which are considered to be short range endemics (SREs) and therefore of conservation significance. Taxa which were not true hyporheic fauna, but show some morphological adaption to groundwater environments (occasional hyporheos stygophiles), included the cyclopoid copepod *Microcyclops varicans*, and a number of aquatic segmented worms (Oligochaeta) and aquatic beetles (Coleoptera).
- Although a number of stygobitic and SRE hyporheic taxa were recorded in the current study, all taxa have known local and/or regional distributions outside the Project area.

5.5 Macroinvertebrates

- There was evidence of a longitudinal gradient in macroinvertebrate taxa richness along the main channel of WWC upstream of, and adjacent to, the Project. Taxa richness was greatest upstream at WWC1, declining with increasing distance downstream to WWC6. Regression analysis indicated a significant linear relationship between habitat diversity and macroinvertebrate richness within the main channel, with richness decreasing with lower in-stream habitat diversity.
- Macroinvertebrate diversity was relatively low at off-channel sites, compared to main channel sites. This was somewhat unexpected, given the documented habitat-richness patterns along the main channel, particularly considering habitat at off-channel sites was more diverse (macrophytes, algae, etc.) compared to that of main channel sites. Low taxa diversity at off-channel pools likely reflected hydrology and water quality (i.e. low dissolved oxygen, lack of surface flows, elevated ions & metals, etc.), with lack of surface flow in particular depriving flow-adapted taxa (e.g. caddisflies and mayflies) of specific habitat requirements (e.g. riffle zones).
- Multivariate analysis indicated macroinvertebrate assemblage composition was significantly different between off-channel and main channel WWC sites, with a number of flow-adapted taxa (e.g. mayflies and caddisflies) either absent, or recorded in reduced abundance at off-channel sites. This further reflected the influence of the standing nature of these off-channel pools, with lack of specific habitat (e.g. riffle zones) for these flow-adapted taxa.
- No conservation listed (IUCN Red List or DPaW priority) macroinvertebrate species were recorded in the study area. However, one SRE amphipod (Paramelitidae sp. B), and four Pilbara endemic Coleoptera (aquatic beetle) species were recorded, including *Limbodessus occidentalis* and the recently described *Halipus fortescueensis*.
- Although a number of endemic/SRE macroinvertebrate fauna were recorded in the current study, no State, nationally or internationally listed species of conservation significance were recorded. However, *Halipus fortescueensis*, collected at WWC9, appears largely restricted to ephemeral waterbodies within the Pilbara region. Should dewatering discharge result in permanent surface flows along WWC downstream of the Project, it is possible local populations of *H. fortescueensis* will be adversely affected.

5.6 Fish

- Three of the 12 freshwater fish species known from the Pilbara were recorded from the study area. These were the western rainbowfish *Melanotaenia australis*, the spangled perch *Leiopotherapon unicolor*, and the Hyrtl's tandan (eel-tailed catfish) *Neosilurus hyrtlii*. Low diversity of fish fauna is common in the upper reaches of the Fortescue River and its tributaries (including WWC), in comparison to the lower Fortescue River and other catchments across the Pilbara.
- Along the main channel of WWC, fish diversity was highest upstream (WWC1 & WWC2), reflecting the greater permanence of water, and higher diversity of in-stream habitat at this reach. Fish diversity and abundance were lower further downstream (e.g. WWC5 – WWC9), with short residence time of surface water following recent inundation, and consequent lack of in-stream habitat and food source, not allowing for successful fish colonisation prior to sampling.
- Additionally, low diversity and abundance of fish recorded at off-channel sites, compared to main channel sites, may in part reflect challenges whilst sampling due to dense macrophyte growth reducing the efficiency of fishing methods. However, it cannot be discounted that reduced diversity and abundance of fish reflects predation effects by larger spangled perch in the confined off-channel sites, and the lack of connectivity to main channel sites preventing recolonisation of these pools.

5.7 Conclusions

Data reported herein provide insight into water quality and aquatic fauna present at WWC main channel sites and off-channel pools during the late wet season, 2015. It should be noted that the current dataset does not account for any temporal and/or seasonal (wet and dry season) variation in water quality parameters and aquatic faunal assemblages, and hence, provides only a snapshot of ecosystem values at one point in time. Therefore, it is likely ecosystem values, both within the main channel of WWC and at off-channel pools within vicinity of the Project, are greater than reported in the current study.

Baseline water quality data indicated a number of parameters measured at off channel sites (and to a lesser degree main channel sites) were in exceedance of, and in some instances outside (i.e. below recommended range), default ANZECC/ARMCANZ (2000) TVs for toxicants/stressors, including; EC, daytime DO, pH, total N, total P, N-NO_x, dB and dZn. These differences could be related in part to the standing (lentic) nature of isolated off-channel pools, which showed evidence of impacts from unrestricted livestock access. Elevated nutrient and dissolved metal concentrations could reflect inherent natural variation in background levels. However, groundwater in the Pilbara is naturally elevated in nutrients and some dissolved metals (dB), and therefore, levels recorded in the current study might be influenced by unknown dewatering discharge activities upstream.

Aquatic invertebrate data indicated off-channel and main channel WWC sites support different (i.e. distinct) microinvertebrate and macroinvertebrate species assemblages, which likely reflect variation in habitat, water quality and hydrology between these ecosystem types. Although no conservation listed fauna were recorded in the current study, several regionally and/or scientifically important taxa were present, and stygobitic SRE taxa of conservation significance were collected at both off-channel and main channel WWC sites.

Along the main channel of WWC, macroinvertebrates and fish were generally more diverse and abundant at upstream sites, which possessed greater in-stream habitat, and permanence of surface flows due to the influence of dewatering discharge operations upstream. Comparatively, sites further downstream, which are more ephemeral in nature, and therefore only recently inundated prior to sampling, were relatively depauperate in macroinvertebrate and fish fauna.

Generally, microinvertebrate diversity and abundance was higher at off-channel sites, compared to main channel WWC sites, reflecting the preference of these fauna for still (lentic) conditions. Conversely, macroinvertebrate diversity was lower at off-channel pools, compared to main channel sites. These differences were influenced by the reduced abundance and/or absence of a number of fauna at off-channel sites, including mayflies and caddisflies, which are adapted to flowing (lotic) conditions, and which were common in the main channel. Lentic conditions are unsuitable for filter feeding species such as mayflies and caddisflies, with these taxa being replaced by a number of non-biting midge species at off-channel sites, which are adapted to living in benthic sediments and thrive in non-flowing conditions.

Although a number of stygobitic and SRE hyporheic, microinvertebrate, and macroinvertebrate taxa were recorded in the current study, the majority of these taxa have known local and/or regional distributions outside the Project area.

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APPENDICES

Appendix 1. Photographs of WWC sites sampled during March 2015



WWC1



WWC2



WWC3



WWC4



WWC5



WWC6



WWC7



WWC8



WWC9



WWOCR1



WWOCR2



WWOCR3

Appendix 2. ANZECC/ARMCANZ (2000) trigger values for the protection of aquatic systems in northern Australia

Table A2-1. Default trigger values for some physical and chemical stressors for tropical Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH₄⁺ = ammonium). Data derived from trigger values supplied by Australian states and territories, for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east (ANZECC/ARMCANZ 2000).

	TP ($\mu\text{g L}^{-1}$)	FRP ($\mu\text{g L}^{-1}$)	TN ($\mu\text{g L}^{-1}$)	NOx ($\mu\text{g L}^{-1}$)	NH ₄ ⁺ ($\mu\text{g L}^{-1}$)	DO % saturation ^f	pH
Aquatic Ecosystem							
Upland River ^e	10	5	150	30	6	90-120	6.0-7.5
Lowland River ^e	10	4	200-300 ^h	10 ^b	10	85-120	6.0-8.0
Lakes & Reservoirs	10	5	350 ^c	10 ^b	10	90-120	6.0-8.0
Wetlands ³	10-50 ^g	5-25 ^g	350-1200 ^g	10	10	90 ^b -120 ^b	6.0-8.0

b = Northern Territory values are 5 $\mu\text{g L}^{-1}$ for NO_x, and <80 (lower limit) and >110% saturation (upper limit) for DO;

c = this value represents turbid lakes only. Clear lakes have much lower values;

e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;

f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;

g = higher values are indicative of tropical WA river pools;

h = lower values from rivers draining rainforest catchments.

Table A2-2. Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC/ARMCANZ 2000).

Salinity	($\mu\text{S/cm}$)	Comments
Aquatic Ecosystem		
Upland & lowland rivers	20-250	Conductivity in upland streams will vary depending on catchment geology. The first flush may result in temporarily high values
Lakes, reservoirs & wetlands	90-900	Higher conductivities will occur during summer when water levels are reduced due to evaporation

Table A2-3. Trigger values for toxicants at alternative levels of protection. Values are in ug/L.

		<i>Trigger values for freshwater</i>			
		<i>Level of protection (% species)</i>			
<i>Compound</i>		<i>99%</i>	<i>95%</i>	<i>90%</i>	<i>80%</i>
METALS & METALLOIDS					
Aluminium	pH > 6.5	27	55	80	150
Aluminium	pH < 6.5	ID	ID	ID	ID
Arsenic (As III)		1	24	94	360
Arsenic (As IV)		0.9	13	42	140
Boron		90	370	680	1300
Cadmium		0.06	0.2	0.4	0.8
Cobalt		ID	ID	ID	ID
Chromium (Cr III)		ID	ID	ID	ID
Chromium (Cr VI)		0.01	1	6	40
Copper		1	1.4	1.8	2.5
Iron		ID	ID	ID	ID
Manganese		1200	1900	2500	3600
Molybdenum		ID	ID	ID	ID
Nickel		8	11	13	17
Lead		1	3.4	5.6	9.4
Selenium (Se total)		5	11	18	34
Selenium (Se IV)		ID	ID	ID	ID
Uranium		ID	ID	ID	ID
Vanadium		ID	ID	ID	ID
Zinc		2.4	8	15	31
NON-METALLIC INORGANICS					
Ammonia		320	900	1430	2300
Chlorine		0.4	3	6	13
Nitrate		17	700	3400	17000

Appendix 3. Water quality parameters and habitat characteristics

Table A3 - 1. *In situ* water quality parameters recorded during March 2015 sampling. Highlighting indicates values were outside of ANZECC/ARMCANZ (2000) TVs.

	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Temp °C	28.1	28.4	27.4	28.7	31.6	27.6	27.8	30.8	31.3	26.6	29.5	27.5
pH	7.48	7.53	7.79	8.00	8.18	8.04	8.10	8.36	7.37	7.93	8.17	7.88
Redox	-46.1	-49.3	-63.5	-78.9	-88.3	-79.1	-83.2	-98.0	-40.8	-77.1	-87.7	-68.4
DO (%)	27.2	31.2	41.3	79.1	102.8	71.5	93.4	122.8	76.6	89.9	147.1	77.1
DO (mg/L)	2.21	2.31	3.22	6.19	7.58	5.58	7.43	9.17	5.69	7.11	11.20	6.06
EC (µS/cm)	718	967	1930	760	753	691	720	706	449	585	611	546

Table A3 - 2. Dissolved ions, metals and other water quality parameters recorded during March 2015 sampling. Highlighting indicates values were in exceedance of ANZECC/ARMCANZ (2000) TVs.

	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Al	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Alkalinity	243	297	386	254	261	231	238	234	148	189	202	171
As	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	0.3	0.34	0.39	0.26	0.27	0.28	0.27	0.26	0.14	0.21	0.23	0.16
Ba	0.041	0.051	0.098	0.031	0.03	0.03	0.032	0.03	0.031	0.028	0.023	0.031
CO ₃	<1	<1	<1	<1	<1	<1	<1	8	<1	<1	8	<1
Ca	43.4	56.5	72.9	46.4	45.4	42.4	45.9	42	35.1	39.8	39	37.9
Cd	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cl	70	108	374	74	74	65	72	70	41	55	58	55
Co	0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cr	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cu	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fe	0.11	0.036	0.2	0.009	0.01	0.011	0.016	0.008	0.013	<0.005	0.006	0.006
HCO ₃	296	362	470	309	318	282	290	269	180	230	230	208
Hardness	260	340	470	290	280	260	260	250	150	210	220	200

	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
K	7.8	9.3	34.2	7.4	7.4	7.1	7.2	7.2	5.3	6.3	6.5	6
Mg	36.4	47.8	68.8	41.1	40.1	36.6	36.5	34.1	15.4	25.7	30.2	24.7
Mn	0.054	0.023	0.23	0.003	0.002	<0.001	0.005	0.001	0.004	<0.001	<0.001	0.006
Mo	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N_NH3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01
N_NOx	<0.01	0.01	<0.01	0.15	0.12	0.14	0.05	0.07	0.16	0.14	0.23	0.14
Total N	0.11	0.11	1.2	0.29	0.26	0.29	0.24	0.2	0.55	0.27	0.34	0.35
Na	51.2	68	218	50.9	49.3	47.1	48.2	46.1	33.9	40	42.7	36.2
Ni	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
OH	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total P	0.011	0.011	0.11	<0.010	<0.010	<0.010	<0.010	0.01	0.01	<0.010	0.014	<0.010
Pb	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
S	11	19	21	14	14	13	14	13	8.7	11	11	11
SO4_S	33.8	56.3	64.4	43.3	42.3	39.3	41.3	38.3	26.2	32.9	34.4	31.8
Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TSS	2	2	13	<1	2	2	2	<1	2	2	<1	2
Turbidity (NTU)	1.3	0.6	2.6	1.1	1.4	<0.5	<0.5	<0.5	0.6	<0.5	0.5	0.7
U	0.0005	0.0015	0.001	0.0007	0.0007	0.0008	0.001	0.0009	0.0002	0.0007	0.0007	0.0007
V	0.0005	0.0011	0.0014	0.0028	0.0031	0.003	0.0035	0.0038	0.0018	0.0033	0.0041	0.0029
Zn	0.002	0.004	0.031	0.004	0.006	0.007	0.002	0.003	0.003	0.007	0.004	0.005

* all values are in mg/L, unless specified otherwise

Table A3 - 3. Habitat and substrate data recorded *in situ*.

	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Bedrock %	0	0	0	0	0	0	2	0	5	0	0	10
Boulders %	1	2	0	0	0	0	5	0	2	0	2	5
Cobbles %	5	20	0	5	5	23	15	5	11	5	18	5
Pebbles %	25	60	0	50	30	45	35	28	25	63	40	10

	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Gravel %	57	11	0	40	58	20	36	60	20	15	30	15
Sand %	2	5	0	3	5	10	5	5	15	5	10	20
Silt %	10	2	20	2	2	2	2	2	2	2	0	20
Clay %	0	0	80	0	0	0	0	0	20	10	0	15
Mineral %	23	10	39	69	69	74	83	74	60	76	76	70
Emergent veg %	20	60	40	5	5	5	3	2	0	0	0	0
Submerged veg %	10	5	5	2	0	0	0	0	0	0	2	0
Floating Veg %	0	0	0	0	0	0	0	0	0	0	0	0
Algal cover %	30	15	10	2	3	1	2	5	1	2	0	0
Detritus %	10	2	2	3	1	3	5	1	20	5	5	25
Trailing veg %	2	5	2	2	2	2	2	2	2	2	2	2
LWD %	5	3	2	15	20	15	5	15	15	15	15	3
Other (roots) %	0	0	0	2	0	0	0	1	2	0	0	0
Approx. velocity (litres/second)	< 3	No flow	No flow	25	25	25	25	25	No flow	< 3	25*	No flow
Max. Depth	0.5	2	0.7	0.8	0.8	1.2	1.7	1	1	1.6	1.2	1.8
Length (m)	40.00	90.00	40.00	20.00	30.00	100.00	20.00	20.00	70.00	70.00	200.00	200.00
Width (m)	15.00	20.00	15.00	20.00	40.00	20.00	35.00	25.00	10.00	15.00	30.00	7.50
Habitat diversity	7	7	7	7	6	6	6	6	5	5	5	4
Substrate diversity	5	6	2	5	5	5	7	5	8	6	5	8

* Site was sampled on a day following substantial rainfall, and was flowing for less than 24 hrs.

Appendix 4. Microinvertebrate fauna data (total abundance) collected during March 2015 sampling.

Higher taxon	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Protista													
Ciliophora													
	Euplotes sp.		1										
Rhizopoda													
Arcellidae													
	Arcella bathystoma	1	3										
	Arcella discoides	3	5			1	1			1		1	
	Arcella hemisphaerica		4										
	Arcella megastoma	1											
	Arcella sp. a [tiny, blue]											1	
	Arcella sp. b [sm, disc, br.]	1											
	Arcella sp. c [med., domed, br.]	1											
	Centropyxidae												
	Centropyxis aculeata												1
	Centropyxis ecornis	6								1			
	Centropyxis sp. [sm, br]						2				1		
	Diffugiidae												
	Diffugia cf. globulosa	5											
	Diffugia sp. a [sm. spher.]		2								2	1	
	Diffugia sp. b [sm. pyrif.]	16											
	Diffugia sp. c [lg. glob.]	19											
	Diffugia sp. d [med. ov.]	1				1							
Lesquereusiidae													
	Lesquereusia spiralis	21										3	1
	Trigonopyxidae												

Higher taxon	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Rotifera	Cyclopyxis kahlII	2											
Bdelloidea													
	indet. bdell a [sm.]	1											
	indet. bdell b [lg.]	14	8										
Monogononta													
Asplanchnidae													
	Asplanchnopus hyalinus		*										
Brachionidae													
	Platylabus quadricornis												1
Dicranophoridae													
	Dicranophorus epicharis	1											
Euchlanidae													
	Tripleuchlanis plicata	10	2										2
	Euchlanis cf. meneta									2	20		8
Flosculariidae													
	Sinantherina procera	3	171		1								
Lecanidae													
	Lecane aculeata	2										1	
	Lecane cf. braumi											1	
	Lecane bulla	20	*		1							7	
	Lecane curvicornis		3									2	
	Lecane ludwigii	3											
	Lecane luna	1											
	Lecane lunaris	2										2	
	Lecane noobijupi	2											1
	Lecane cf. obtusa	2											
	Lecane papuana	1										1	
	Lecane rhenana	1											
	Lecane rhytida	3											
	Lecane thalera	1											

Higher taxon	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
	Lecane unguitata											2	
	Lecane (M.) a												
	Lecane (M.) b					1							
	Lecane (s. str.)												
Lepadellidae													
	Colurella sp.	1											
	Lepadella sp.										1		
	Testudinellidae												
	Testudinella patina	2											
Cladocera													
Chydoridae													
	Alona sp.						1					1	
	cf. Anthalona sp.					2				1	4		
	Armatalona macrocopa					1							
	Chydorus sp.											1	
	Karualona karua												1
Daphnidae													
	Simocephalus exspinosus				1								
	Simocephalus gibbosus				1								
	Simocephalus sp. [juv]			*									
	Ilyocryptidae												
	Ilyocryptus sp. [juv]				1								
	Macrotrichidae												
	Macrothrix sp. [juv]										1	1	2
Moinidae													
	Moina micrura			*									
Copepoda													
	copepodite	4	2	13	3	7	2		1	2	3	1	3
	nauplii	7		191		5		2	1	1	7	3	6
	indet. adult a [med]												2

Higher taxon	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Calanoida													
	Boeckella fluvialis												1
Cyclopoida													
	Australoeucyclops karaytugi					*							
	Microcyclops varicans	1	*		1		1	2				2	
	Mesocyclops holynskae			*									
Ostracoda													
	indet. juv.				6	8			1	1			
Cyprididae													
	Cypretta sp. [juv.]						1						
	cf. cypridopsid	25											
Darwinulidae													
	Vestalenula sp.	3											
Limnocytheridae													
	Limnocythere sp.					1					1	1	
Richness		35	14	11	8	11	6	2	3	7	9	18	12
Total abundance		187	201	205	14	27	8	4	3	9	40	32	29
Portion sample counted:		29%	6.4%	0.2%	100%	100%	100%	100%	100%	100%	100%	100%	100%

* = in scan of tray after initial count

Appendix 5. Hyporheic fauna data recorded during March 2015 sampling. Values are LOG₁₀ abundance categories, where 1 = 1 individual, 2 = 2-10 individuals, 3 = 11-100, 4 = 101-1000. Hyporheic Classifications: Stygobitic (S), Occasional hyporheous stygophile (O), Possible hyporheic (P), Stygoxene (X), and Unknown (U).

Higher taxon	Lowest taxon ID	Classification	WWOCR1	WWOCR2	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Arachnida													
Astigmata													
	Astigmata sp.	X			1								
Mesostigmata													
	Mesostigmata sp.	X					1	1					
Trombidiformes													
	Hydracarina sp.	P					2	1	1				
	Acarina sp.	X	1	1				1	2			1	
Entognatha													
Entomobryomorpha													
	Entomobryoidea sp.	O							1	2		1	
Poduromorpha													
	Poduroidea sp.	O	2				2	1	3		1		
Symphyleona													
	Symphyleona sp.	O					2	1	3				
Insecta													
Coleoptera													
Dytiscidae													
	Allodessus bistrigatus	X									1		
	Bidessini sp.	X				1							
	Dytiscidae sp. (L)	X						1					
	Hydrovatus sp. (L)	X							1				
	Limbodessus compactus	X									1		
	Limbodessus occidentalis	O	1										

Higher taxon	Lowest taxon ID	Classification	WWOCR1	WWOCR2	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
	Tiporus sp. (L)	X									2		
Hydraenidae													
	Hydraenidae sp.	O						2					
Hydrophilidae													
	Paracymus sp. (L)	X						1					
Scirtidae													
	Scirtidae sp. (L)	O				3							
Staphylinidae													
	Staphylinidae sp.	X					2						
Diptera													
Cecidomyiidae													
	Cecidomyiidae sp.	X					1	1					
Ceratopogonidae													
	Ceratopogonidae sp. (P)	X	1									1	1
	Ceratopogoninae sp.	X	2	2	2	3	2	3	2	2	2		2
	Dasyheleinae sp.	X							2				
Chironomidae													
	Ablabesmyia hilli	X				2					2		
	Chironomidae sp. (P)	X								1			1
	Chironomini sp. (WWC34)	X				1		2					
	Cladopelma curtivalva	X				2			1		1		
	Cladotanytarsus sp. (WWTS4)	X				2			1		2		1
	Cricotopus albitarsis	X									1		1
	Cryptochironomus griseidorsum	X				2			1				
	Dicrotendipes sp. 1	X				2					2	1	1
	Dicrotendipes sp. 2	X				2		2			3	2	3
	Larsia albiceps	X				3					3		2
	Paramerina sp. (WWT1)	X		1		1			2		1		1
	Paramerina sp. 2	X						1	2		3		
	Paratanytarsus sp. (WWTS2)	X											2

Higher taxon	Lowest taxon ID	Classification	WWOCR1	WWOCR2	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
	Polypedilum sp. 1	X										1	
	Polypedilum sp. 2	X				2			1		1		
	Polypedilum watsoni	X											1
	Procladius sp. (WWT5)	X				2							
	Rheotanytarsus sp. 1	X				1							1
	Skusella subvittata	X				2							
	Tanytarsus sp. (WWTS1)	X		2		3		2	2		2	2	2
	Thienemanniella sp. (WWO4)	X									1		
Dolichopodidae													
	Dolichopodidae sp.	X						1					
Tipulidae													
	Tipulidae sp.	X									2		
Ephemeroptera													
Baetidae													
	Baetidae sp.	X							2		3		
	Cloeon sp. Red Stripe	X									2		
Caenidae													
	Caenidae sp.	X							2		3		
	Tasmanocoenis sp. M	X									2		
	Tasmanocoenis sp. P/arcuata	X									3		
Odonata													
Libellulidae													
	Diplacodes haematodes	X									1		
Trichoptera													
Leptoceridae													
	Leptoceridae sp.	X				2							
Malacostraca													
Amphipoda													
Paramelitidae													
	Chydaekata sp.	S		1									

Higher taxon	Lowest taxon ID	Classification	WWOCR1	WWOCR2	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Oligochaeta	Paramelitidae sp.	S	3	3		3							
	Paramelitidae sp. B	S	3	2									
	Paramelitidae sp. D	S				1							
	Oligochaeta sp.	U				1			1				
	Tubificida												
	Naididae												
	Allonais paraguayensis	P				1		1					
	Allonais pectinata	P						2					
	Allonais ranauana	P										1	
	Dero sp.	P									1		
Nematoda	Naididae sp.	P						1			3		
	Naidinae sp.	P					2		2				2
	Pristina leidy	P					1	2	2			2	1
	Pristina sp.	P									2		
	Phreodrilidae												
	Phreodrilidae sp.	P		2									
	Nematoda												
	Nematoda sp.	X	1										
	Cladocera												
	Macrotrichidae												
Copepoda	Macrothrix sp.	X									2	1	
	Cyclopoida												
	Cyclopidae												
	?Diacyclops sp. [3 -seg P1-4]	X		1									
	Metacyclops sp.	X							3			1	
	Microcyclops varicans	O	2			3		3			3	3	3
	immature												
	copepodites/nauplii	U					2			1			

Higher taxon	Lowest taxon ID	Classification	WWOCR1	WWOCR2	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Ostracoda													
Candonidae													
	Candonopsis tenuis	S				2							
Darwinulidae													
	Vestalenula sp.	U					1						
Richness			10	8	2	24	11	20	21	5	28	12	16

Appendix 6. Macroinvertebrate fauna data recorded during March 2015 sampling. Values are LOG₁₀ abundance categories, where 1 = 1 individual, 2 = 2-10 individuals, 3 = 11-100, 4 = 101-1000.

Higher taxon	Family	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Arachnida														
Trombidiformes														
		Hydracarina sp.	3	2		3	1	2	1	2		3		2
		Trombidioidea sp.			1									
		Acarina sp.										1		
Entognatha														
Entomobryomorpha														
		Entomobryoidea sp.		2	2						2			
Poduromorpha														
		Poduroidea sp.		1										
Symphyleona														
		Symphyleona sp.				2				1				
Gastropoda														
Hygrophila														
	Lymnaeidae	Bullastra vinosa		1		2	2		1			1	1	
	Planorbidae	Gyraulus sp.	2	3	1	3	3	2	2	2	1	2		
Insecta														
Coleoptera														
	Curculionidae	Curculionidae sp.							2					
	Dytiscidae	Batrachomatus sp. (L)						1						
		Bidessini sp. (L)	2		1									
		Cybister sp. (L)			2								1	
		Hydroglyphus grammopterus			2			1						
		Hydroglyphus leai	2											
		Hydroglyphus orthogrammus						2				1		1
		Hydrovatus sp. (L)	2		1									
		Hyphydrus lyratus												1
		Hyphydrus sp. (L)			1									
		Laccophilus clarki					1							
		Laccophilus sharpi									1			1
		Laccophilus sp. (L)			3									
		Limbodessus compactus									1			2

Higher taxon	Family	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
		Limbodessus occidentalis	1						1					
		Onychohydus sp. (L)	1			2								
		Platynectes decempunctatus var. decempunctatus						2	2					
		Platynectes sp. (L)				1								
		Tiporus sp. (L)						1		1		2	1	1
	Elmidae	Tiporus tambreyi				1			2			1		
		Austrolimnius sp.						1		1				
		Elmidae sp. (L)					1							
	Gyrinidae	Dineutus australis					1							
		Dineutus australis (L)									2			
		Dineutus sp.												1
		Dineutus sp. (L)						1						
		Macrogyrus paradoxus				2								
	Halipilidae	Halipilus fortescueensis												2
	Hydraenidae	Hydraena sp.				3	2		2					
		Hydraena sp. (L)											1	
		Limnebius sp.							1			1		
	Hydrochidae	Hydrochus sp.				2	2	2		1	1	2		
		Hydrochus sp. (L)						1						
	Hydrophilidae	Berosus dallasae	1					2	1					
		Berosus sp. (L)			1					1		1	2	1
		Enochrus sp. (L)						1	1					
		Helochaes sp.						2				2		
		Helochaes sp. (L)	2	2	1	2			1		1			
		Helochaes tatei												1
		Laccobius billi							1					
		Paracymus sp. (L)					1		2	1				
		Regimbartia attenuata (L)				1								
		Regimbartia sp. (L)			2						1			
	Noteridae	Neohydrocoptus subfasciatus										2		
	Scirtidae	Scirtidae sp. (L)		1	1	2	3	3	2	1				

Higher taxon	Family	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWOC1	WWOC2	WWOC3	WWOC4	WWOC5	WWOC6	WWOC7	WWOC8	WWOC9
Diptera	Spercheidae	Spercheus sp. (L)			2									
	Cecidomyiidae	Cecidomyiidae sp.											1	
	Ceratopogonidae	Ceratopogonidae sp. (P)	2		3						2		1	
		Ceratopogoninae sp.	2	2			2	1	2			2	2	2
		Dasyheleinae sp.	3	2	3	1	1							1
	Chironomidae	Ablabesmyia hilli				2	2			2	3	2	3	2
		Ablabesmyia notabilis									2			
		Chironomidae sp. (P)	2	2	3	2	2	2	2	3	3	3	3	2
		Chironomini sp. (WWC34)					2							
		Chironomus sp. (WWC3)	3	3	4		2				3		3	2
		Cladopelma curivalva	2			2	2	1	2			2		2
		Cladotanytarsus sp. (WWTS4)	3	2		3	3	1	2	2	2	2		
		Coelopymia pruinosa					2							
		Corynoneura sp. (WWO5)				3								
		Cricotopus albitarsis				3		3	3			3	3	
		Cryptochironomus griseidorsum					2		2			3	2	2
		Dicrotendipes sp. 1				3		3	3	2	3	3	2	2
		Dicrotendipes sp. 2				3		2	3	3		3	3	2
		Harnischia sp. (WWC22)					2							2
		Kiefferulus intertinctus			2									
		Larsia albiceps	3	4	2	3	3	3	3	3	3	3	3	3
		Orthoclaadiinae sp. (WWO7)												2
		Parachironomus sp. K2		2										
		Paracladopelma sp. K2						2						
		Paramerina sp. (WWT1)		2		3	2	2	3	3		2	1	2
		Paramerina sp. 2	2	2	3	2	2	1			3	2	1	3
		Paratanytarsus sp. (WWTS2)	3	3	3		2							2
		Paratendipes sp. K1		2										
		Polypedilum sp. 1	2	2	3	2	2			2				2
		Polypedilum sp. 2					2				2			2
		Polypedilum watsoni	2					2						
		Procladius sp. (WWT5)					3				3	2	3	3

Higher taxon	Family	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Ephemeroptera	Culicidae	Rheocricotopus sp. (WWO1)				2		2	3	3				
		Rheotanytarsus sp. 1	2	2		3	2	3	4	3		3	3	2
		Skusella subvittata					3				3		3	2
		Tanytarsus sp. (WWTS1)	4	3	3	3	3	2	3	3	4	3	3	3
		Thienemanniella sp. (WWO4)				4		3	3	3		2		
		Thienemannimyia sp. (WWT2)				2		1						
		Anopheles sp.			2				1		2			
		Culex sp.		3	3									
		Culicidae sp. (P)			3									
	Dolichopodidae	Dolichopodidae sp.						2						
	Simuliidae	Simuliidae sp.				2		2	3	2		2		
		Simuliidae sp. (P)							1					
	Stratiomyidae	Stratiomyidae sp.	2			1								
	Tabanidae	Tabanidae sp.						1						
	Tipulidae	Tipulidae sp.						1						
	Baetidae	Baetidae sp.	2	3	2	3	3	2	3	3	2	2	3	3
		Cloeon fluviatile	1	2		2					1		2	
		Cloeon sp.			2		3				2			
		Cloeon sp. Red Stripe		3	2		2	3	1		3	3	3	3
		Offadens sp. G1WA2				2		3	2	3			3	
		Pseudocloeon hypodelum				3			2					
	Caenidae	Caenidae sp.	2	2		3	3	3		1		3	2	2
		Tasmanocoenis sp.							2	3	3			
		Tasmanocoenis sp. P/arcuata	1	2		3	3	3	3	3	3	3		2
	Belostomatidae	Diplonychus sp.	2	1	3	3	2	2	1	1	2	2	3	1
	Corixidae/Micronectidae	Corixidae/Micronectidae sp.				2			1					1
	Gerridae	Gerridae sp.		2		2			2	1				
	Limnogonidae	Limnogonus fossarum gilguy	2	2		3		2	2	2				1
		Limnogonus sp.	1		2									
		Limnogonus sp.	2											
Hemiptera	Hebridae	Hebridae sp.	2											
		Merragata hackeri	1			2	1					2		
	Mesoveliidae	Mesovelgia hungerfordi				2								

Higher taxon	Family	Lowest taxon ID	WMOCR1	WMOCR2	WMOCR3	WMOC1	WMOC2	WMOC3	WMOC4	WMOC5	WMOC6	WMOC7	WMOC8	WMOC9
Lepidoptera	Micronectidae	Mesovelgia vittigera				2		1					1	
		Micronecta gracilis				1								
		Micronecta paragoga				1								
		Micronecta robusta							2					
		Micronecta sp.	1		2								1	
	Nepidae	Ranatra sp.					1							
	Notonectidae	Anisops hackeri					1							
		Anisops sp.												1
		Notonectidae sp.			2		1						1	
	Pleidae	Paraplea sp.				3					2	2		
		Pleidae sp.											2	
	Veliidae	Microvelia peramoena				1						1		
		Veliidae sp.				1						2		
	Crambidae	Acentropinae sp.				1	1	3					1	
		Margarosticha sp. 3				1	1	2	2	2				
		Margarosticha sp. WRM01							1					
		Parapoynx sp.	1											
Odonata	Zygoptera sp.	Anisoptera sp.	2	2		3	3	2	2	2	3	3	3	3
		Zygoptera sp.		2	2	3	1				2	2		2
		Aeshnidae sp.			2									
	Aeshnidae	Hemianax papuensis			2						1			
		Coenagrionidae												
	Coenagrionidae	Argiocnemis sp.					2							
		Argiocnemis rubescens	2	1		2	2	1		1				
		Ischnura aurora		1	2	2	1					1	1	1
		Pseudagrion aureofrons		1		2								1
	Gomphidae	Pseudagrion microcephalum									1			
		Austrogomphus gordonii										1		
	Libellulidae	Diplacodes bipunctata			2					2				
		Diplacodes haematodes	2	1	1	2	2	1	2	2				1
		Diplacodes sp.									1			
		Orthetrum caledonicum				1	2				2		2	1
		Pantala flavescens										1		

Higher taxon	Family	Lowest taxon ID	WWOCR1	WWOCR2	WWOCR3	WWC1	WWC2	WWC3	WWC4	WWC5	WWC6	WWC7	WWC8	WWC9
Trichoptera	Ecnomidae	Tramea sp.			1									
		Ecnomus sp.				1								
	Hydropsychidae	Cheumatopsyche sp.				1			1					
		Cheumatopsyche wellsae				2	2	3	3	3				1
	Hydroptilidae	Hellyethira sp.				2	1			1	1	2		2
		Orthotrichia sp.				1		1						
	Leptoceridae	Leptoceridae sp.					2							
		Leptocerus sp.					1							
		Oecetis sp.	1	1		1	1							
		Setodes sp.		1										
		Triplectides ciuskus seductus		2		3	2					1		
	Philopotamidae	Chimarra sp.					1	3	2	2				1
	Polycentropodidae	Paranyctiophylax sp. AV5		1										
Malacostraca														
Amphipoda	Paramelitidae	Paramelitidae sp. B					1							
Oligochaeta		Oligochaeta sp.	2	1			2	1	2					
Tubificida	Naididae	Allonais paraguayensis	2											
		Allonais pectinata	3	1	2	2		1		2	2		1	1
		Allonais ranauana					1							
		Naidinae sp.	3	2		2	1			2		1		1
		Nais variabilis	2			1	1			2				
	Pristina leidy	2	1						1					
	Pristina sp.					3								
	Phreodrilidae	Phreodrilidae sp.						2						
Richness			45	44	42	70	63	55	51	42	38	46	39	48

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25 February 2016

**BC Iron Limited - Iron Valley Project
Cumulative Change Assessment
Lower Weeli Wolli Creek Aquatic Ecosystems**

Dear Les,

Current condition of lower Weeli Wolli Creek represents extensive change in surface water regime, surface water quality, and aquatic fauna from baseline condition (pre-mining), which has resulted from various mining developments in the immediate vicinity of the creekline (i.e. operations close enough to cause additive effects on the environment). Following our discussion, please find below a memorandum which outlines, to the best of our knowledge, cumulative change in the aquatic ecosystem along Weeli Wolli Creek downstream of the confluence with Marillana Creek (referred to as lower Weeli Wolli Creek) to date. Additionally, we outline potential changes in surface water regime, water quality and aquatic faunal assemblage structure from preliminary hydrological modelling of dewatering drawdown and surface water disposal of groundwater associated with BC Iron's Iron Valley Project, and Rio Tinto's Pocket and Billiard South Project.

If you have any queries, please don't hesitate to contact me.

Kind Regards,
Adam



Adam Harman | Principal Environmental Consultant

CUMULATIVE CHANGE ASSESSMENT

LOWER WEELI WOLLI CREEK AQUATIC ECOSYSTEMS

Introduction

‘Baseline condition’ in ecological monitoring and impact assessment often infers a pristine or minimally-disturbed state for a system prior to development, against which future change may be assessed. Impacts of a mining project are often assessed in isolation through comparison of the post-closure condition to documented pre-development baseline. However, on a system that has been subjected to multiple developments over time, baseline for future developments may no longer be pristine/minimally-disturbed, but will reflect a modified state. This modified state will still be regarded as ‘baseline’ for a future development, but will reflect the effects of all past/current developments. These combined effects are therefore the cumulative impacts of all development to that point in time. Although the current condition of a system subjected to cumulative impacts is no longer pristine/minimally-disturbed, it is still the baseline against which a future development would assess their impacts. Therefore, the concept of shifting baselines, allows for a significant change in a system from its original ‘pristine’ state.

In the case of Weeli Wolli Creek (WWC), current (2016) condition represents extensive change in surface water regime, surface water quality, and aquatic fauna values from pristine/minimally-disturbed condition. This is the result of various mining developments along the creekline and upstream of the Project (i.e. operations close enough to cause additive effects on the environment). Established dewatering and/or discharge operations upstream of the Project include Rio Tinto’s Hope Downs 1 and BHPBIO Area C mines adjacent WWC and Rio Tinto’s Yandicoogina and BHPBIO Yandi operations on Marillana Creek. These operations have resulted in permanent surface flows from Weeli Wolli Springs to the confluence of WWC with Marillana Creek, and semi-permanent / permanent surface water flows extending approximately 6-7km downstream from the confluence of Marillana Creek and Weeli Wolli Creek (i.e. to sampling site WWC3). This represents a considerable change in water regime from seasonal flows under pre-development baseline condition (pre-2007), to perennial flows under current condition (2016).

Background

BC Iron Limited (BCI) is currently undertaking baseline environmental studies for the proposed below water table (BWT) development of the Iron Valley Project (hereafter referred to as “BCI IV Project”) in the East Pilbara region of Western Australia. Preliminary hydrogeological modelling indicates that groundwater dewatering will be required to mine below the water table, which will require surface water discharge of excess water into WWC. Any substantial discharge will add to the cumulative impacts of combined discharge from the numerous operations upstream on WWC. To that end, BCI commissioned Wetland Research and Management (WRM) to undertake a desktop review of the known ecological values of the creeklines involved, evaluate potential impacts to aquatic ecosystem health, and undertake wet season baseline sampling in 2015 (April) to characterise current water quality and aquatic ecosystem values.

Following completion of the first baseline survey for the Iron Valley Project (WRM, 2015a), BC Iron has commissioned WRM to provide a memorandum which assesses cumulative change in aquatic ecosystem values along lower WWC to date, from 'baseline' or pre-development condition, as well as outlining potential further changes which may occur should the Iron Valley Project, and Rio Tinto's proposed Pocket and Billiard South Project commence dewatering and discharge activities.

Scope of works

The scope of work includes:

- (1) Document baseline or pre-development water regime and aquatic ecosystem values of Weeli Wolli Creek,
- (2) Document current (2016) water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek, providing an assessment of cumulative changes to date,
- (3) Outline potential changes to water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek associated with predicted dewatering drawdown and surface water discharge operations at BC Iron's Iron Valley Project,
- (4) Outline additional potential changes to water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek associated with predicted dewatering drawdown and surface water discharge operations at Rio Tinto's Pocket and Billiard South Project,

Study Area

The Project tenement is situated in the East Pilbara region of Western Australia, within Mining Lease M47/1439 and a small area of Exploration Licence E47/1385. The co-ordinates of M47/1439 are as follows:

- NW Corner 22° 42' 05"S 119° 19' 02"E
- NE Corner 22° 43' 02"S 119° 20' 30"E
- SE Corner 22° 46' 33"S 119° 17' 56"E
- SW Corner 22° 45' 35"S 119° 16' 28"E

The Project is located within the Marillana (pastoral) Station, with land-use in the area comprising predominately pastoral activities and more recently, mining. The regional topography of the Eastern Pilbara is dominated by the Chichester Ranges in the north and the Hamersley Plateau to the south, with these features being divided by the Fortescue Valley. The main drainage system in the area is the Fortescue River, which flows north and then northwest into the Fortescue Marsh.

The regionally significant Weeli Wolli Creek (WWC) flows adjacent to, and downstream of the BCI IV Project. The creek is approximately 70 km in total length, with a catchment area of 4100 km², and the Project location is approx. 60 km from the headwaters and 35 km from where it discharges into Fortescue Marsh. WWC is naturally seasonally flowing, except for a section in its mid-reaches which is fed by Weeli Wolli Spring. The spring, located approximately 20 km upstream (south) of the Project (Figure 1), was historically permanently flowing as a result of groundwater flow being "dammed" by the Brockman Formation, forcing groundwater to the surface. Historically this resulted in perennial surface flows along WWC for approx. 2 km downstream from the spring. However, as a

result of the current discharge regime, approximately 25 - 30 km of the creek is now influenced by surface flows (A.W. Storey, WRM, pers. obs.).

Downstream of the Project, WWC flows to the north, and drains into the Fortescue River via the Fortescue Marsh. The two systems are only connected during flooding associated with intense cyclonic events (Kendrick 2001). The Fortescue Marsh, an episodically inundated samphire marsh, approximately 100 km long and 10 km wide (Kendrick 2001, DEC 2009), is located 25 - 30 km downstream, and to the north-east, of the Project. The Marsh is described as an extensive, irregularly inundated inland floodplain system, and is considered to be a highly unique wetland landform in Western Australia (Environment Australia 2001). It is listed on the national Directory of Important Wetlands of Australia (WA066), and is a Priority 1 Priority Ecological Community (PEC) under the DPaW list of Priority Ecological Communities (DPaW 2014). It is also acknowledged that if nominated, the Marsh meets the criteria for listing as a Wetland of International Importance under the Ramsar Convention (Jaensch & Watkins 1999).

Baseline (pre-development) condition WWC

Prior to Rio Tinto's Hope Downs 1 mine commencing dewatering and discharge operations along WWC in January 2007, the system was naturally seasonally flowing, except for a section in its mid-reaches which is fed by Weeli Wolli Spring. The spring located approximately 20 km upstream (south) of the Project, was historically permanently flowing as a result of groundwater flow being impeded or "dammed" by low permeability basement rock (the Brockman Formation), forcing groundwater to the surface. The source of the spring (point at which the groundwater intersected the surface) is located at 725595 E 7463816 N. The location of the spring head waters likely varied owing to seasonal fluctuations in groundwater levels and the impact of periodic major flooding that erode or deposit alluvial sediment (Wade Dodson, Rio Tinto Hydrogeologist, pers comm.). Historically this resulted in perennial surface flows along WWC for approx. 2 km downstream from the spring, with an average dry season baseflow of approx. 4 ML/day (Aquaterra 2002), beyond which water infiltrated into the subsurface environment. Based on topography, it is likely a series of isolated semi-permanent / permanent pools existed for up to 4 km downstream of the spring source, reflecting where the stream bed intersected sub-surface flows. Downstream of this reach, flows were episodic (highly ephemeral) and the creek rarely contained water. Peak flows occurred within 24 hours of a considerable rainfall event, with flows generally continuing for several days (Hamersley Iron Pty Ltd 1995).

Prior to any discharge occurring (i.e. pre-development minimally-disturbed baseline condition), it can be assumed Lower WWC (reach downstream of isolated pools) was uniform in hydrological regime, exhibited episodic surface flows following rainfall, had no permanent/semi-permanent pools, and had a relatively homogenous faunal assemblage structure composed of species adapted to intermittent flows (i.e. species with adaptations to survive desiccation). Additionally, the alluvium was likely dry for the majority of the year, therefore, it is reasonable to suggest there was no hyporheic fauna in the near-surface alluvium, with the only subterranean fauna limited to stygofauna in the deeper groundwater.

Current (2016) condition WWC*Hydrological regime*

The Rio Tinto mine at Hope Downs 1 (HD1), in the East Pilbara region of Western Australia, is currently de-watering and discharging excess water directly into Weeli Wolli Creek. Discharge from HD1 commenced in January 2007, and is predominantly via a single gabion structure adjacent to the main creek, however a system of spur lines deliver water as seepage flows to maintain phreatophytic trees and pools upstream of the gabion, in the area of the historic springs and permanent pools. The aim of the spurs is to maintain groundwater levels around the historical springs. This has created perennial flow of pools and riffles from Weeli Wolli Spring to just beyond the confluence of Weeli Wolli and Marillana Creeks. In 2014, Hope Downs 1 discharged a combined total (via spurs and gabion) of 38 GL into Weeli Wolli Creek (WRM 2015b). Additionally, since late 2007, excess water from Rio Tinto's Yandicoogina operations has been discharged into WWC (from discharge outlet D06). In April 2013, discharge at Yandi was rationalised and now occurs primarily via a new discharge outlet (D09), located on Marillana Creek approximately 3 km upstream of the Weeli Wolli / Marillana Creek confluence, whilst some discharge still occurs at the existing D06, directly into Weeli Wolli Creek (WRM 2015b). Additional discharge into Marillana Creek occurs upstream of Rio Tinto's Yandicoogina mine, at BHP Billiton Iron Ore's (BHPBIO) Yandi mine. This mine has been in operation since 1994, and also dewateres their developing pit, with excess dewatering water discharged into the upstream section of Marillana Creek.

Including discharge from all outlets into both creeklines, a combined total of approximately 66 GL was discharged to the environment (lower Weeli Wolli Creek) by Rio Tinto operations in 2014. BHPBIO discharge volumes are surplus to this, entering Marillana Creek (MC) upstream of Rio Tinto's Yandi mine, but volumes are not publicly available. For the purpose of this assessment it can be considered discharge volumes entering lower WWC in 2015 were comparable to that documented in 2014. Subsequently, perennial flow of pools and riffles as a result of upstream dewatering discharge operations now extend from the source of Weeli Wolli Spring into the lower WWC approx. 6-7km downstream of the confluence of MC and WWC (i.e. WWC3, Figure 2). Therefore, current (2016) condition represents extensive change in surface water regime, surface water quality, and aquatic fauna values from pristine/minimally-disturbed condition.

Current condition of WWC adjacent the project can be separated into four separate surface water regimes (Figure 2), including:

- I. Upper Adjacent Reach of WWC which consists of perennial flow of pools and riffles, extending approximately 6-7km downstream from the confluence of Marillana Creek and Weeli Wolli Creek (i.e. to sampling site WWC3). This reach is characterised by a diverse macroinvertebrate assemblage (lentic and lotic species), rich hyporheic fauna (stygobitic and SRE species), and abundance of fish species;
- II. Off-channel Pools, which are most likely perched permanent/semi-permanent pools, and are elevated above, and to the west of the Upper Adjacent Reach of WWC (and therefore not likely to be influenced by cumulative discharge operations upstream). These off-channel pools typically reflect a standing or slow-flowing (lentic condition) hydrological regime, and are characterised by a diverse microinvertebrate (zooplankton) assemblage, but low diversity of macroinvertebrate and fish fauna;
- III. Lower Adjacent Reach of WWC which consists of surface expression in the form of isolated permanent and semi-permanent pools upstream and adjacent to the Project that are unconnected by surface flows, except following rainfall events. Pool location shifts

depending on the magnitude and duration of rainfall events, and upstream dewatering discharge volumes entering WWC at any point in time. This reach is characterised by little instream habitat, lentic macroinvertebrate assemblage, rich hyporheic fauna (stygotitic and SRE species), and low diversity and abundance of fish species;

- IV. Downstream Reach of WWC is the reach downstream of the Project area and exhibits episodic surface flows following rainfall, has no permanent/semi-permanent pools, and has a relatively homogenous faunal assemblage structure composed of species adapted to intermittent flows (i.e. species with adaptations to survive desiccation).

Water Quality

Surface water quality is relatively homogenous along the length of lower WWC, both within the Upper Adjacent Reach receiving continuous flow, Lower Adjacent Reach of isolated pools, and further downstream, within the ephemeral, seasonally flowing reach of WWC. Surface waters are generally circum-neutral to slightly alkaline, well buffered, classified as “fresh” ($< 1500 \mu\text{S}/\text{cm}$) as defined by the DoE (2003), with dissolved oxygen concentrations ranging from low to supersaturated (WRM 2015a, WRM 2015b). Nutrient concentrations (nitrogen oxide; N_{NO_x} , total nitrogen; TN, and total phosphorus; TP) vary between season, however, at times exceed respective ANZECC/ARMCANZ TVs for protection against eutrophication. This reflects a combination of first flush catchment effects (TN and TP), and dewatering discharge activities upstream (i.e. elevated N_{NO_x} in groundwaters being dewatered, WRM 2015a, WRM 2015b). Concentrations of dissolved metals are generally low, however, dissolved boron (dB) and dissolved zinc (dZn) at times are elevated above respective 99% ANZECC/ARMCANZ (2000) guidelines. This is of little ecological concern as naturally elevated dB levels are widely recorded from surface waters across the Pilbara, including the Fortescue River, Kalgan Creek, Marillana Creek, Mindy Mindy Creek, Coondiner Creek, Caves Creek and Duck Creek (WRM 2015b), and dZn levels are below hardness-modified trigger values (HMTVs) when water hardness is taken into consideration.

Current condition of the creekline within the Upper Adjacent Reach of WWC (reach of continuous surface flows) suggests no evidence of calcite precipitation or resultant ‘armouring’ of the creek bed, which is occurring further upstream in WWC (downstream of the HD1 discharge outlet). Additionally, there is no evidence to date that discharge has resulted in a significant increase in average water temperature in the downstream receiving environment of Lower WWC (WRM 2015a), although this evident in upper WWC downstream of the HD1 discharge outlet as a result of discharge of groundwater with elevated temperature (WRM, 2015b)

Off-channel permanent/semi-permanent pool water quality differs slightly from the main channel of WWC, with differences related in part to the standing (lentic conditions) nature of isolated off-channel pools, which showed evidence of impacts from unrestricted livestock access. Surface waters show effects of evapo-concentration with spot measurements indicating brackish waters, with associated elevated concentrations of dissolved ions and nutrient enrichment (TN and TP; WRM 2015a).

Currently, there are distinct differences in aquatic fauna assemblages of WWC between the reach of creekline receiving continuous flows, and the reach downstream, which remains ephemeral, holding isolated pools following rainfall.

Microinvertebrates (i.e. zooplankton) are relatively depauperate along the main channel of WWC, particularly within the Upper Adjacent Reach of WWC which receives permanent surface flows from dewatering discharge operations. Conversely, microinvertebrates, in particular periphytic taxa, are abundant in the off-channel permanent/semi-permanent pools (WRM 2015a). This broadly reflects the hydrological preferences of microinvertebrates, which generally favour standing or slow-flowing waters (lentic conditions), with emergence from resting stages dependent on the cues to which they are 'tuned', such as day-length, chemistry, temperature, first flush events, and algal exudates or prey hormones. The majority of microinvertebrate taxa recorded along WWC are common ubiquitous species, with distributions extending throughout Australasia or the world (i.e. cosmopolitan species). Several species of interest have been recorded, and these are either endemic to the Pilbara, Western Australia and/or taxa known to be rare or uncommon throughout their range. Such taxa include the rotifers *Lecane noobijupi*, *Lindia torulosa* and *Heterolepadella heterostyla*, and the copepods *Australoeucyclops karaytugi* and *Mesocyclops holynskae*, and the cladoceran cf. *Anthalona* sp. (WRM 2015a, WRM 2015b).

A number of species considered to be restricted to the hyporheos (stylobites), and of conservation significance are currently present along Lower WWC and include:

- The amphipods Paramelitidae sp. D and Paramelitidae sp. B are both currently undescribed species that appear to be restricted to Marillana Creek and Weeli Wolli Creek (Helix 2010a, b, Helix 2011, WRM 2015a, b) and the Coondewanna Flats Catchment (Stuart Halse, Bennelongia, pers comm.). This suggests they are both short range endemics as defined by Harvey (2002), and therefore of high conservation significance. Both species have been recorded in the reaches receiving continuous flows, and ephemeral/seasonal flows, with Paramelitidae sp. B also recorded at off-channel permanent/semi-permanent pools (WRM 2015a),
- The amphipod *Chydaekata* sp. is also an undescribed SRE. It has been recorded from the Lower WWC receiving ephemeral flows and at off-channel permanent/semi-permanent pools, as well as a small number of systems in close proximity; Marillana Creek, Coondiner Creek and Mindy Mindy Creek (Helix 2010a, Helix 2011, WRM 2015a, b),
- The amphipod *Maarrka weeliwolli* is also an SRE and has previously been recorded from multiple bores at Weeli Wolli and Marillana creeks (Finston *et al.* 2011). It appears to be restricted to these two creeklines. *Maarrka weeliwolli* appears to be less commonly recorded than the other three species of stygobitic SRE amphipods. *M. weeliwolli* has been recorded from the hyporheic habitat of Lower WWC receiving ephemeral flows (WRM 2015b),
- The ostracod *Gomphodella* n. sp. (BOS334) is an undescribed species new to science. The species appears similar to described species such as *G. glomerosa* and *G. hirsuta*, but differs in that it has no ventral stria, is dorso-ventrally compressed and has a different shaped hemipenis (Dr Russ Shiel, University of Adelaide, pers. comm.). *Gomphodella* n. sp. (BOS334) has been recorded from the Lower WWC receiving ephemeral flows (WRM 2015b). This is not the first record of the new species. It has previously been recorded from bores in the Yandi area (Dr Stuart Halse, Bennelongia, pers. comm.), as well as from hyporheic zones on Marillana and Weeli Wolli creeks (WRM 2015b). *Gomphodella* n. sp. (BOS334) appears to be a short range endemic restricted to Marillana and Weeli Wolli creeks, and as such is a species of high conservation significance. Several *Gomphodella* species are known only from one locality and are commonly found in springs (Karanovic 2006, Reeves *et al.* 2007).

Studies along upper WWC indicate a loss in seasonality of macroinvertebrate assemblages associated with the continual discharge, reflecting increased abundance of taxa known to prefer faster-flowing habitats (WRM 2015b). Currently it is unknown if increased flow constancy and habitat heterogeneity of the Upper Adjacent Reach of WWC receiving continuous flow shows a similar trend for macroinvertebrate assemblages, as only a single round of wet season sampling has been undertaken for BCI (WRM 2015b). However, it is apparent, in the Lower Adjacent Reach, seasonal hydrological differences still influence the assemblage structure with higher abundances of taxa which prefer slow-flowing waters (and absences of fauna adapted to flows). Additionally, the intermittent nature of episodic flows in the Downstream Reach of WWC, and short residence time of surface waters (either flowing or pools) likely provided insufficient time for a number of aquatic invertebrates to establish populations prior to sampling in 2015. Further, in accordance with other studies, increased habitat complexity and heterogeneity of in-stream habitat within the Upper Adjacent Reach of WWC has led to an increase in species richness (e.g. Erman & Erman 1984, Heino 2000), compared to that documented further downstream (WRM 2015a).

Macroinvertebrate diversity is relatively low at off-channel sites, compared to main channel sites (all reaches). This was somewhat unexpected, given the documented habitat-species richness patterns observed along the main channel, and considering habitat diversity at off-channel sites was more diverse (macrophytes, algae etc) than main channel sites (WRM 2015a). Low diversity may in part reflect hydrology and water quality at off-channel sites (i.e. low dissolved oxygen, lack of surface flows, elevated ions & metals, etc.), with flowing water in the main channel providing additional habitats (e.g. riffle zones) for lotic (flow-adapted) species.

The Pilbara pin damselfly, *Eurysticta coolawanyah*, listed on the IUCN Redlist as **Near Threatened** has been previously recorded from the Lower Adjacent Reach of WWC (WRM 2015b). However, the IUCN listing of the Pilbara Pin is considered to require revision, as it has been recorded from over 40 locations throughout the Pilbara since initial listing (Pinder *et al.* 2010). This increases its distribution above the 500 km² threshold defined by the IUCN. The absence of *E. coolawanyah* from lower WWC (all reaches) in sampling from 2013-2015 is of interest but not of great concern (WRM 2015a, WRM 2015b). As *E. coolawanyah* is known from areas outside the Weeli Wolli Creek dewatering-discharge impact zones, populations are considered unlikely to be seriously affected at a regional level. The majority of remaining macroinvertebrates encountered are generally common, ubiquitous species, with distributions extending across Northern Australia, Australia or Australasia. However, a number of species endemic to the Pilbara region have been recorded and include:

- Stygobitic amphipod species recorded in the hyporheic zone and also present in surface waters: *Chydaekata* sp., *Maarrka weeliwolli*, Paramelitidae sp. B and Paramelitidae sp. D,
- The Haliplid beetle *Haliplus fortescueensis* is a Pilbara endemic relatively new to science. It was first described from a specimen collected from the Fortescue Marsh during the PBS (Pinder *et al.* 2010, Watts & McRae 2010). It appears to be mainly restricted to the Fortescue River, and most abundant in the Fortescue Marsh (Watts & McRae 2010). However, this species has also been collected once from a claypan near Port Hedland (Watts & McRae 2010), and also from a Claypan on Coondiner Creek (DPaW 2015, WRM unpub. data). *H. fortescueensis* has been recorded within the Downstream Reach of WWC, and appears largely restricted to ephemeral waterbodies (WRM 2015a),
- The diving beetle *Tiporus tambreyi* (Dytiscidae) has been recorded from the Upper Adjacent and Lower Adjacent Reaches of WWC. *T. tambreyi* appears to be common and ubiquitous across the Pilbara region (Pinder *et al.* 2010, DPaW 2015, WRM 2015b).

- The hydrophilid beetle *Laccobius billi* is a Pilbara endemic rarely collected. It was only recorded once during the PBS, from Cangan Pool on the Yule River, approximately 100 km north-west of the Project (Pinder *et al.* 2010). A single specimen has been recorded within the Upper Adjacent Reach of WWC (WRM 2015a). It has also been recorded previously from upper Weeli Wolli Creek, Coondiner Creek and Mindy Mindy Creek (DPaW 2015, WRM 2015b).
- The Pilbara Archtail dragonfly, *Nannophlebia injibandi*, has been recorded from the Lower Adjacent Reach of WWC (WRM 2015b). *N. injibandi* was recorded infrequently during the Pilbara Biological Survey (Pinder *et al.* 2010), however it has been recorded from upper Weeli Wolli Creek, Roy Hill on the Fortescue River, Fortescue Falls in Karijini National Park, and Skull Springs on the DeGrey River (WRM, 2015b). There are also records of *N. injibandi* from Koodaideri Spring (Bennelongia 2011, WRM 2014). As such, this species appears to have a relatively broad, albeit disjunct, distribution throughout the Pilbara, but does not appear to be abundant or commonly recorded.

Three of the twelve freshwater fish species known from the Fortescue River System have been recorded along lower WWC: the spangled perch *Leiopotherapon unicolor*, Pilbara tandan (eel-tailed catfish) *Neosilurus* sp., and the western rainbowfish *Melanotaenia australis*. Low diversity of fish fauna is common in the upper reaches of the Fortescue River and its tributaries (including WWC), in comparison to the lower Fortescue River and other catchments across the Pilbara. Each of these species are common, ubiquitous and widespread across the Pilbara region. Within the lower WWC, fish diversity is highest within the Upper Adjacent Reach of continuous surface flows. Fish diversity and abundance is generally lower further downstream, with short residence time of surface water following recent inundation, and consequent lack of in-stream habitat and food source, not allowing for successful fish colonisation. Abundances of all three fish species may well have benefited (at least in the short-term) from higher diversity of in-stream habitat, heterogeneity and security provided by greater permanence of water from dewatering discharge activities. Additionally, low diversity and abundance of fish at off-channel permanent/semi-permanent pools, compared to main channel sites, may in part reflect predation effects by larger spangled perch and/or avian fauna in the confined off-channel sites, and the lack of connectivity to main channel sites preventing recolonisation of these pools.

Potential change associated with BCI IV Project

Dewatering drawdown

Drawdown associated with BC Iron's Iron Valley (BCI IV) Project resulting in increased depth to groundwater (Figure 4.38, AQ2 2016) is likely to result in what could be regarded as adverse changes to surface water pools in adjacent reaches of WWC, and their aquatic fauna assemblages. Likely changes to the flow regime include loss of permanent surface flows and pools, loss or reduction in sub-surface (alluvial / hyporheic zone) flows through the alluvium of the main channel of the Upper Adjacent Reach WWC (reach of continuous surface flow), as well as potential loss of permanent/semi-permanent off-channel pools west of the main channel of WWC, adjacent to the Project. The reach will still flow intermittently, following sufficient local rainfall, but pools will quickly drain into the underlying alluvium and dry. Additionally, changes to the water quality of surface water pools, such as increased salinity through evapo-concentration is likely to occur in receding pools. Evapo-concentration of these pools as they dry following rainfall-induced flows may also lead to eutrophication and algal blooms. In the Upper Adjacent Reach, the flow regime will shift from its

current state of perennial flow with permanent pools, to an ephemerally flowing regime, with isolated pools present for a short residence time following wet season rainfall events, as is currently present in the lower adjacent reach and in the reach further downstream of the Project (WRM 2015a).

Subsequently, faunal assemblages will likely shift towards those adapted to a seasonal hydrological regime, with an anticipated reduction or complete loss of fauna adapted to flows (i.e. filter feeding macroinvertebrates), replaced by assemblages with adaptations to avoid desiccation and survive in seasonally dry systems. Hyporheic fauna, dependent on saturated alluvium along the creek bed will also be lost as this habitat dries as a result of drawdown. These changes will result in replacement of the fauna with species that adapted to seasonal drying with desiccation-resistant stages (i.e. zooplankton). The extent of any change will depend on the depth of drawdown, and its effect on surface (streams and pools) and subsurface (hyporheic) habitats and associated faunas. Assuming drawdown is sufficient to result in loss of surface flows, loss of permanent pools, and drying of the hyporheic habitat, local populations of a number of stygobitic and SRE hyporheic fauna, microinvertebrate and macroinvertebrate taxa endemic to the Pilbara may be lost from this reach of creekline. However, the majority of these taxa have known regional distributions outside the Project area. Intermittent flows, and short residence time of surface waters (either flowing or pools) will also result in a loss of fish species from this reach of creekline, except where pools remain for a sufficient length of time post-wet season, and wet season flow events provide connectivity of surface waters to either Marillana Creek or upper WWC allowing opportunistic colonisation. Current perennial flows and the saturated alluvium has allowed the establishment of a dense riparian and instream flora, with significant recruitment of eucalypt and melaleuca species along the edge of the active channel.

Although drawdown associated with the BCI IV Project is predicted to have significant effects on current flow regime and current ecological condition of the adjacent reaches, it is important to acknowledge that current condition is an altered baseline which has resulted from various mining activities in the immediate vicinity of the creekline (i.e. operations close enough to cause additive effects on the environment). Although pre-development ecological data for this reach do not exist, WRM have data for comparable seasonally-flowing rivers in the Pilbara, and based on the ecological values of these comparable systems, it can be assumed that pre-development, Lower WWC was uniform in hydrological regime (seasonal flows, ephemeral pools), with a relatively homogenous faunal assemblage structure, with species adapted to intermittent flows, with life history adaptations to avoid desiccation. Additionally, the alluvium was likely dry for the majority of the year, therefore, it is reasonable to suggest groundwater (stygobitic) fauna were absent within the hyporheic zone. Therefore, it can be considered that these predicted change in surface water regime and aquatic fauna assemblages as a result of drawdown associated with the BCI IV Project reflect a shift back towards pre-development 'baseline'.

Groundwater discharge to WWC

Hydrological regime

Current modelling indicates that over the life of the Iron Valley mine (2016 – 2025), taking into account mine use and evaporative losses, approximately 90M KL of surplus water will be discharged into WWC adjacent to the Project tenement (ranging between 2000 – 17000 ML/yr) (AQ2 2016). Preliminary hydrological modelling indicates the wetting front from the discharge of this dewatering water will extend approximately 5km-6km downstream of the proposed discharge outlet, beyond which the water will infiltrate into the subsurface environment (AQ2 2016). Currently, there are three proposed discharge outlets, with dewatering from the South deposit proposed to be discharged directly to WWC discharge point DL1 (in the Upper Adjacent Reach WWC), whilst all groundwater dewatering from the Northern, Centre and East deposits will be pumped to a centrally located turkeys nest, where water surplus to site requirements is proposed to be piped to WWC discharge points DL3 and DL5 (Lower Adjacent Reach WWC; Figure 5.1 AQ2 2016, WRM 2015a).

On the assumption dewatering discharge enters within the Lower Adjacent Reach of WWC, this will alter the current surface water flow regime from isolated permanent and semi-permanent pools, and episodic surface flows further downstream, to permanent surface and sub-surface (alluvial / hyporheic zone) flows through the alluvium of WWC. Baseline surveys of the study area (WRM 2015a) indicated microinvertebrate fauna, which generally favour standing or slow-flowing waters (lentic conditions), and are adapted to a narrow range of water quality, were relatively depauperate at sites receiving permanent surface flows from dewatering discharge operations upstream (i.e. WWC1 – WWC3). Therefore, diversity and abundance of microinvertebrate assemblages may be reduced in the section of WWC receiving permanent surface flows as a result of BC Irons IV dewatering discharge, in comparison to ephemeral and off-channel pools.

Provision of continuous surface flows to WWC *via* dewatering discharge will likely lead to the saturation of the coarse alluvium within the 5-6km discharge footprint, and increase the extent of habitat available for hyporheic fauna. This may in turn lead to the increased presence of short range endemic (SRE)¹ species, such as stygal² amphipods, isopods and syncarids (crustaceans) of high conservation value in the hyporheic zone downstream of the discharge outlet.

Baseline surveys (WRM 2015a) also showed macroinvertebrate and fish diversity and abundance was greatest within the Upper Adjacent Reach of WWC at sites receiving permanent surface flows from discharge operations upstream (i.e. WWC1 & WWC2), declining with increasing distance downstream and as the system became more ephemeral. It was postulated that this was due to the greater extent of permanent aquatic in-stream habitat at upstream sites, compared to the ephemeral and less-complex habitat of pools further downstream. Therefore, the development of permanent surface flows due to dewatering discharge would likely cause an increase in habitat heterogeneity, and thereby an increase in the diversity of macroinvertebrate and fish fauna along the receiving section of WWC. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along the receiving section of WWC (lower adjacent reach), macroinvertebrate and fish assemblage and community structure will likely shift away from those currently occurring. With a hydrological switch to permanent flows, the

¹ Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10, 000 km².

² Taxa which are obligate inhabitants of aquatic subterranean environments, such as aquifers or the hyporheic zone. Common morphological adaptations to subterranean environments include loss of eyes and pigmentation, reduction in body size, and the lengthening of appendages (e.g. antennae).

seasonal/ephemeral signature of fauna will likely be lost, as has been the case on upper Weeli Wolli Creek (WRM 2015b). Further, any ecological values enhanced due to the provision of permanent flows and increased habitat heterogeneity will be lost upon cessation of discharge.

Water quality

Groundwater data from two BC Iron production bores (PB1 and PB2) in the Iron Valley project area were used to provide an indication of the current quality of groundwater that will be discharged (AQ2 2016). This assumes there is no substantial change in bore water quality when discharged on the surface. The available groundwater data included concentrations for a limited suite of dissolved metals, major ions, alkalinity, electrical conductivity (EC), pH, and total dissolved solids (TDS) from a single sampling event for each bore in May 2015. It is acknowledged these data are one-off spot-measurements, which provide only a snap-shot of groundwater quality, with no data provided on water hardness or any forms of dissolved nutrients (specifically forms of nitrogen; AQ2 2016).

The limited data from the two Iron Valley production bores indicated that pH and EC of groundwater within the Project tenement (likely to be discharged to the surface environment) were in exceedance of ANZECC/ARMCANZ (2000) default guidelines for the protection of 95% of species in slightly-moderately disturbed systems in Tropical Northern Australia (Table 1). The values for pH (8.2, 8.3) were however, only slightly above the upper default guideline (pH 8, Table 1) and within the existing annual range for MC (7.0 - 8.5), though slightly lower than WWC downstream of the MC confluence (6.6 - 8.0) (WRM 2015a, WRM2015b, WRM unpubl. data). The pH in the bores was also well within the annual range commonly recorded in other natural freshwater creeks across the Pilbara (pH 6 - 10) (Pinder *et al.* 2010, WRM unpubl. data).

Although EC in both bores (830 $\mu\text{S}/\text{cm}$, 850 $\mu\text{S}/\text{cm}$) exceeded the default guideline (250 $\mu\text{S}/\text{cm}$, Table 1), waters were still considered “fresh” (i.e. < 1500 $\mu\text{S}/\text{cm}$; DoE 2003) and slightly below the existing annual range for MC (900 - 1120 $\mu\text{S}/\text{cm}$) and WWC downstream of the MC confluence (900 - 1,000 $\mu\text{S}/\text{cm}$) (WRM 2015a, WRM2015b, WRM unpubl. data). EC in the bores was also well within the annual range commonly recorded in other natural freshwater creeks across the Pilbara (250 - 2000 $\mu\text{S}/\text{cm}$) (Pinder *et al.* 2010, WRM unpubl. data). An EC of 830 - 850 $\mu\text{S}/\text{cm}$ in groundwater is therefore not expected to have an adverse effect on fauna if released into surface waters however, there is little published information on the sensitivity of Pilbara freshwater organisms to increases in EC and few studies on sub-lethal or long-term effects or more sensitive life stages. It is generally believed that biota of freshwater ecosystems will be adversely affected as the salinity increases to ca. 1,500 $\mu\text{S}/\text{cm}$ (1,000 mg/L) (Hart 1991). Spot measurements indicate groundwater salinity is below this threshold, and therefore presents a low risk to aquatic fauna.

Ionic composition of waters in both bores was dominated by sodium cations (Na^{2+}) and hydrogen carbonate anions (HCO^3). ANZECC/ARMCANZ (2000) do not provide guidelines for major ions or TDS.

Dissolved zinc concentrations were well above ANZECC/ARMCANZ (2000) guidelines for both 95% and 99% species protection at bore PB2 (Table 1). However, elevated levels of total dissolved metals such as zinc do not automatically imply that levels are toxic to aquatic biota. The toxicity of dissolved metals is dependent on the form of metal present and the degree to which it is bioavailable (i.e. labile). Many metals readily bind to organic matter and clays and precipitate out of the water column, making them unavailable for direct uptake by plants and fauna and hence of low toxic risk. It is recommended that once discharge to creeklines commences, and if concentrations of dissolved

metals remain above TVs, then labile concentrations of those metals that exceed TVs should be determined to assess their potential toxicity.

Table 1. Selected physicochemical parameters recorded from two production bores (PB1 & PB2) in the Iron Valley tenement, sampled by AQ2 in May 2015. Corresponding ANZECC/ARMCANZ (2000) trigger values are provided for 99% species protection and 95% species protection for moderately-slightly disturbed systems in Tropical Northern Australia. Note: only parameters with applicable ANZECC/ARMCANZ (2000) guidelines are presented.

Parameter	PB1	PB2	99% species protection	95% species protection
pH	8.3	8.2	-	6 - 8
EC ($\mu\text{S/cm}$)	830	850	-	<250
Dissolved cadmium ($\mu\text{g/L}$)	<0.1*	<0.1*	0.06	0.2
Dissolved copper ($\mu\text{g/L}$)	<1*	<1*	1.0	1.4
Dissolved manganese ($\mu\text{g/L}$)	9	26	1200	1900
Dissolved lead ($\mu\text{g/L}$)	<1*	<1*	1.0	3.4
Dissolved zinc ($\mu\text{g/L}$)	<5*	37	2.4	8.0
Dissolved mercury ($\mu\text{g/L}$)	<0.05*	<0.05*	0.06	0.6
Dissolved nickel ($\mu\text{g/L}$)	<1*	<1*	8	11
Dissolved selenium ($\mu\text{g/L}$)	<1*	<1*	5	11
Dissolved chromium ($\mu\text{g/L}$)	<1*	<1*	0.01	1.0

* value was below the limit of detection (LOD).

Concentrations of other dissolved metals were below ANZECC/ARMCANZ (2000) guidelines for the protection of 95% of species (Table 1). It must be noted, however, that the majority of dissolved metal levels recorded from PB1 and PB2 were below the limits of detection (LOD) (see above Table 1). It should be noted, LODs for dCd (PB1 and PB2) and dZn (PB1) were not sufficiently low as to compare against corresponding ANZECC/ARMCANZ (2000) guidelines for the protection of 99% species.

It should be also noted that a number of physicochemical parameters, which have the potential to impact the surface water environment if elevated, and are known to be elevated in other Pilbara groundwaters, were not recorded by AQ2 (2015). For example, dissolved nutrients, and in particular nitrates were not recorded. Elevated nitrate has been recorded in groundwater environments throughout the Pilbara (WRM unpub. data), which if discharged into surface waters, may lead to eutrophication and algal growth at lower concentrations, and direct toxicity to fauna at higher concentrations (ANZECC/ARMCANZ 2000). There may be some attenuation of nitrates once discharged to the creeks, i.e. in saturated sediments of the creek beds and banks. However, there has been little research on this in Australia, making it difficult to predict how much nitrate might be removed in this way. Further, baseline surveys in the Project area suggest nitrate levels may be inherently elevated in WWC surface waters, possibly due to unrestricted livestock access from pastoral stations nearby, or from water discharged from mines upstream (WRM 2015a). Therefore, it is recommended that nutrient levels in the groundwater to be discharged from Iron Valley be adequately monitored, in order to document levels and assess potential impacts to the surface water environment.

Although dissolved ion and metal concentrations in the groundwater to be discharged into WWC are generally low, changes to the water chemistry (increases in dissolved ions or metals), and dissolution of calcrete, may still occur in the receiving section of WWC as a result of dewatering discharge. When groundwater with high concentrations of calcium and sulphate mix with stream water already

nearly saturated with calcite, degassing of carbon dioxide and the common ion effect quickly causes calcite precipitation. This phenomenon has been observed previously by the authors downstream of other mine dewatering discharge outlets in the Pilbara, resulting in 'armouring' and heavy compaction of the creek bed, and consequent increases in surface flows and reductions in aquatic habitat and aquatic biodiversity.

There is also the potential for changes to surface water temperature (thermal pollution), and associated impacts to the receiving section of WWC, due to the discharge of excess dewatered groundwater of different temperature to surface waters. Surface water temperatures tend to reflect ambient air temperature, but are also influenced by water colour, water depth and degree of riparian shading (ANZECC/ARMCANZ 2000). Groundwater tends to be warmer than ambient surface water, especially as depth of abstraction increases. Discharge of excess dewatering water will likely provide warmer water to the creek in the dry season, when ambient temperatures tend to be lower.

Due to the paucity of groundwater data available from production bores, combined with the absence of data available for any form of dissolved nutrients and a limited suite of dissolved metals, and the unknown quality of groundwater once it is discharged to the surface environment, the implications for aquatic fauna in relation to discharge water quality cannot be accurately quantified at this stage. It is recommended that a greater suite of water quality analytes be monitored in groundwater prior to the commencement of dewatering discharge, including dissolved nutrients, in order to develop a broader understanding of the groundwater quality at Iron Valley to be discharged into WWC. Notwithstanding, the parameters analysed thus far are unlikely to cause ecological stress to the aquatic fauna of WWC, and so, assuming other analytes are similarly at low concentrations relative to default ANZECC/ARMCANZ TVs (or alternatively site-specific trigger values once derived), changes in water quality, are considered unlikely to have an influence on aquatic fauna assemblages following the commencement of dewatering discharge from Iron Valley.

Potential change associated with Rio Tinto PBS Project

Groundwater discharge to WWC

Hydrological regime

Rio Tinto is currently developing three new deposits at Yandi Junction South West (JSW-A & JSW-C) and Yandi Oxbow (Rio Tinto 2014). Rio Tinto is also proposing to develop the Yandicoogina Pocket and Billiard South deposit (the "PBS" project) (Rio Tinto 2014). Additional dewatering and discharge operations are necessary as part of these developments, as around 95% of the ore occurs below the water table (Rio Tinto 2014). Rio Tinto baseline hydrological modelling indicates that under maximum potential discharge, approximately 37 - 43 GL/annum will be released into the surface water environment over the life of the PBS development (2016 – 2031), taking into account evaporative losses and on-site mine usage (total abstraction will be ~53 GL/annum; Rio Tinto 2014). This equates to around 99 - 115 ML/day, but will ultimately depend on dewatering discharge rates by BHPBIO's Yandi operations located further upstream on Marillana Creek, which may further extend any wetting front.

Currently, dewatering discharge operations upstream (Rio Tinto Yandicoogina, Rio Tinto HD1 & BHPBIO Yandi) provide permanent flows extending 6-9 km downstream of the WWC/Marillana Creek confluence, reaching to the south-eastern border of the Iron Valley tenement (AQ2 2016).

WRM field visits confirmed surface water flows extending 6-7km downstream of the WWC/Marillana Creek confluence in March 2015 (WRM 2015a). Should Rio Tinto proceed with the development of their PBS mine (Rio Tinto 2014), preliminary hydrological modelling suggests their excess water disposal will override the predicted drawdown in the Upper and Lower Adjacent reach of WWC, resulting in a net groundwater level increase, and surface flows that would extend past the BCI IV Project tenement to approximately 23kms downstream from the Weeli Wolli Creek and Marillana Creek confluence for the life of the Iron Valley mine (2016 – 2025, Figure 4.34 AQ2 2016). This wetting front will be reduced to 17 km downstream of the WWC/MC confluence once Iron Valley operations cease in 2025 (AQ2 2016).

It is assumed that BCI dewatering and associated drawdown will commence before PBS comes on-line, and therefore the current perennial flows in the Upper Adjacent Reach will become seasonal and the permanent/semi-permanent pools in the Lower Adjacent Reach will be lost, with associated ecological effects as described above. Once PBS comes on-line, the Upper and Lower Adjacent Reaches will receive significant recharge, with mounding, and perennial surface flows will occur throughout this reach. The change once again from ephemeral conditions to permanent surface flows has numerous implications for aquatic fauna, particularly in the lower adjacent reach and reach downstream of the BCI Iron Valley tenement which currently remains ephemeral (episodic flows). Diversity and abundance of microinvertebrate communities may be reduced in the lower adjacent reach of WWC and further downstream, as these fauna generally favour standing or slow-flowing waters (lentic conditions), and are adapted to a narrow range of water quality. Conversely, the provision of permanent flows will increase the extent of subsurface hyporheic habitat, inducing the movement of stygal amphipods, isopods and syncarids (crustaceans) of high conservation value into the hyporheic zone downstream of the discharge outlet. This may provide an apparent increase in the conservation significance of the fauna recorded, and offset any potential losses of stygobitic fauna within the upper adjacent reach of WWC from drawdown effects.

The development of permanent surface flows due to dewatering discharge would likely cause an increase in habitat heterogeneity, and consequent increase in diversity of macroinvertebrate and fish fauna along the currently ephemeral reach of WWC. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along the receiving section of WWC, macroinvertebrate and fish assemblage and community structure will likely shift away from those occurring naturally. With a hydrological switch to permanent flows, the seasonal/ephemeral signature of fauna will likely be lost, as has been the case on upper Weeli Wolli Creek (WRM 2015b). This short-term 'enhancement' of ecological values (2016 – 2025) will then be lost upon cessation of discharge by BCI and then PBS as the wetting front recedes and the system dries. This will give an apparent loss in biodiversity, and loss of species of conservation significance. In reality, however the system will be returning to its pre-development 'baseline' condition, where this reach was dry, had no permanent pools, and flowed episodically following sufficient wet season rainfall, with remanent pools lasting weeks following rainfall.

Water quality

There are currently no data publically available relating to the quality of groundwater to be discharged into WWC from the PBS Project. Therefore, comments on the water quality to be discharged into WWC from the PBS project can only be made in general terms. As the PBS project is located downstream of current dewatering discharge from the HD1 mine, it is possible that the groundwater quality in the area is consistent with the quality of water being discharged from HD1 upstream, as this water is likely to infiltrate groundwater in the vicinity of the PBS and be included in

any proposed dewatering discharge. Discharge from outlet D09 will also include dewatering water from Rio Tinto's Yandicoogina mine, which appears to be elevated in some analytes, particularly nutrients, such as nitrogen oxides, total nitrogen and total phosphorous (WRM 2015b).

As previously mentioned, current discharged surface waters reaching the project area are relatively homogenous and characterised by circum-neutral to slightly alkaline pH, well buffered, low salinity, and low to supersaturated dissolved oxygen concentrations. Dissolved metal levels are generally low with elevated dB and dZn which is not un-expected, whilst nutrient concentrations vary, reflecting a combination of first flush catchment effects, and dewatering discharge activities upstream.

Therefore, groundwater discharge downstream of the D09 outlet is likely to cause relatively homogenous water quality along WWC, between the confluence with Marillana Creek and the Iron Valley tenement. It is also worth noting that flows downstream of the Iron Valley discharge outlet will be a combination of PBS water (40 GL/year) from the D09 outlet, and water from Iron Valley (with a peak of 17 GL/year and a minimum 2 GL/year). During the dry season, dewatering water from Iron Valley will contribute a significant portion of the flows, and so the water quality of WWC downstream of the tenement will be influenced by discharge from Iron Valley. Wet season flows will likely constitute a blend of dewatering water from upstream activities (WWC and Marillana Creek) and catchment flows derived from rainfall. Spot measurements indicate the quality of groundwater to be discharged from Iron Valley presents a low risk to aquatic fauna.

Given no groundwater data are publicly available for the PBS Project, combined with the paucity of data available (and lack of nutrient data) for the BCI IV Project, it is not possible to definitively assess potential water quality impacts on the receiving downstream aquatic environment. Provided surface water quality resultant from groundwater discharge is adequate (i.e. below ANZECC/ARMCANZ trigger values for the protection of 99% of freshwater species or SSTVs once derived), it can be considered changes to hydrological regime following the commencement of cumulative dewatering discharge will enhance biodiversity values (hyporheic, macroinvertebrate, and fish) of the lower WWC.

Conclusion

Cumulative change assessment was undertaken to evaluate potential impacts to the current ecosystem values of aquatic ecosystems in the vicinity of the Project, from proposed BWT mining and dewatering discharge of excess groundwater into WWC. In evaluating potential impacts to aquatic ecosystems, the main issue was considered to be cumulative impacts of combined groundwater dewatering discharge to WWC. The surface water footprint from existing discharge operations upstream of the Project (Rio Tinto HD1 & Yandicoogina, BHPBIO Yandi) currently extends between 6 km and 9 km downstream of the Marillana/WWC confluence. Commencement of discharge in association with Iron Valley and PBS project operations are eventually likely to extend the discharge footprint between 17 - 23 km downstream of the WWC/Marillana Creek confluence over the lives of the mines (2016 – 2025 and 2016 – 2031, respectively).

Prior to the PBS Project coming online, initial drawdown associated with the BCI IV Project will result in increased depth to groundwater within the Upper Adjacent and Lower Adjacent Reach of WWC, and potential loss of permanent surface flows, loss or reduction in sub-surface flows, and loss of permanent/semi-permanent off-channel pools. This will reduce available habitat for a number of conservation significant fauna including the IUCN Redlisted Pilbara pin damselfly, *Eurysticta coolawanyah*, a number of stygobitic and SRE amphipods including Paramelitidae sp. B, Paramelitidae sp. D and *Chydaekata* sp., stygal syncarid species from the families Bathynellidae and Parabathynellidae, which are known to occur in groundwater bores within the tenement and (likely) hyporheic zones of creeks, and the currently undescribed cladoceran (microinvertebrate) cf. *Anthalona* sp. Conversely, reductions in surface water flows may enhance the restricted hydrophilid beetle *Haliphus fortescueensis*, as this species tends to favour ephemeral pools of short residence time. Excluding the cladoceran cf. *Anthalona* sp., populations of all conservation significant taxa have known local and/or regional distributions outside the Project area, therefore distribution and conservation status of these species are unlikely to be impacted by the Project development.

It could be argued surface water discharge of adequate water quality may provide alternative suitable habitat for the above mentioned conservation significant fauna over a distance of approximately 5-6 km downstream of the proposed BCI IV discharge outlet. Continuous surface flows to lower WWC will likely result in an increase in in-stream habitat heterogeneity, and diversity of hyporheic, macroinvertebrate and fish fauna. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along this reach, macroinvertebrate and fish assemblage and community structure will likely shift away from those currently occurring. With a hydrological switch to permanent flows, the seasonal/ephemeral signature of fauna will likely be lost (along with taxa which favour ephemeral conditions such as *Haliphus fortescueensis*). Any short term “enhancement” of ecological values due to the provision of permanent flows and increased habitat heterogeneity will be lost upon cessation of discharge. At this time, it is anticipated aquatic fauna assemblages of lower WWC will shift back towards current altered baseline condition.

There is a risk of creek bed armouring due to carbonate (calcite and dolomite) precipitation from groundwater discharge, as seen in other BWT dewatering projects in the east Pilbara. If calcite precipitation occurs, it is likely to be localised, taking place close to the discharge outlet initially, but with a potential for the longitudinal extent to increase with continuous flow over time. Large magnitude flow events may assist in dislodging or breaking up armoured benthic substrate, however, armouring may re-establish over time. In addition, it is anticipated armouring as a result of

dewatering discharge activities from projects upstream of the BCI IV Project will extend into the upper adjacent reach of WWC over time, regardless of the BCI IV Project.

The formation of the calcite precipitate structurally changes the bed of the creek, and likely impacts habitat availability and heterogeneity for macroinvertebrates by infilling interstices and ‘cementing’ cobbles and pebbles together. Many macroinvertebrate taxa inhabit spaces between and under cobbles, as well as amongst loose surface gravels and pebbles. These habitats are essentially lost when the bed becomes armoured and these substrates are cemented together. Generally, a decrease in habitat diversity leads to a decrease in macroinvertebrate taxa richness.

Given no groundwater data are available for the Rio Tinto PBS Project, combined with the paucity of groundwater data available from BCI IV production bores, absence of dissolved nutrient data, and the unknown quality of groundwater once it is discharged to the surface environment, the implications for aquatic fauna in relation to discharge water quality cannot be accurately quantified at this stage. It is recommended that a greater suite of water quality analytes be monitored in groundwater prior to the commencement of dewatering discharge, including dissolved nutrients and a comprehensive suite of metals, in order to develop a broader understanding of the groundwater quality at Iron Valley to be discharged into WWC. Additionally, efforts should be made to ascertain groundwater quality at PBS to be discharged into WWC, to differentiate potential contaminants between Projects.

Notwithstanding, the groundwater parameters analysed thus far are unlikely to cause ecological stress to the aquatic fauna of WWC, and assuming additional analytes similarly show no elevated concentration, changes to hydrological regime, as opposed to changes in water quality, are considered likely to have more of an influence on aquatic fauna assemblages following the commencement of dewatering discharge from Iron Valley. Provided surface water quality resultant from groundwater discharge is adequate (i.e. below ANZECC/ARMCANZ trigger values for the protection of 99% of freshwater species or SSTVs once derived), it can be considered changes to hydrological regime following the commencement of cumulative dewatering discharge will temporarily enhance biodiversity and conservation values (hyporheic, macroinvertebrate, and fish) of the lower WWC relative to pre-development (pre- 2007) baseline for the duration of dewatering discharge.

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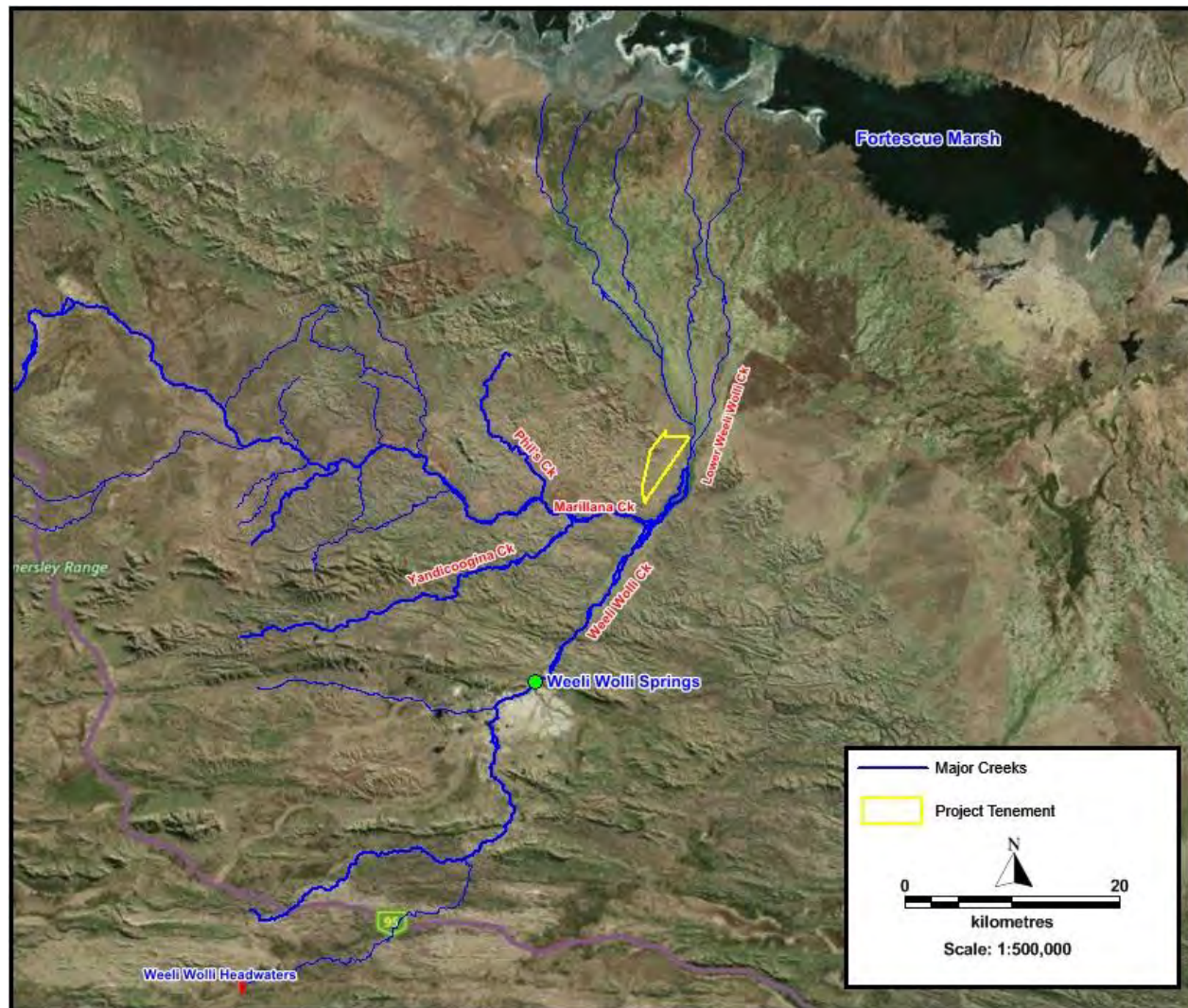


Figure 1. Overview of Weeli Wolli Creek, showing location of headwaters, Weeli Wolli springs, convergence with Marillana Creek, BC Iron's Iron Valley Project Tenement (yellow outline), and the Fortescue Marsh.

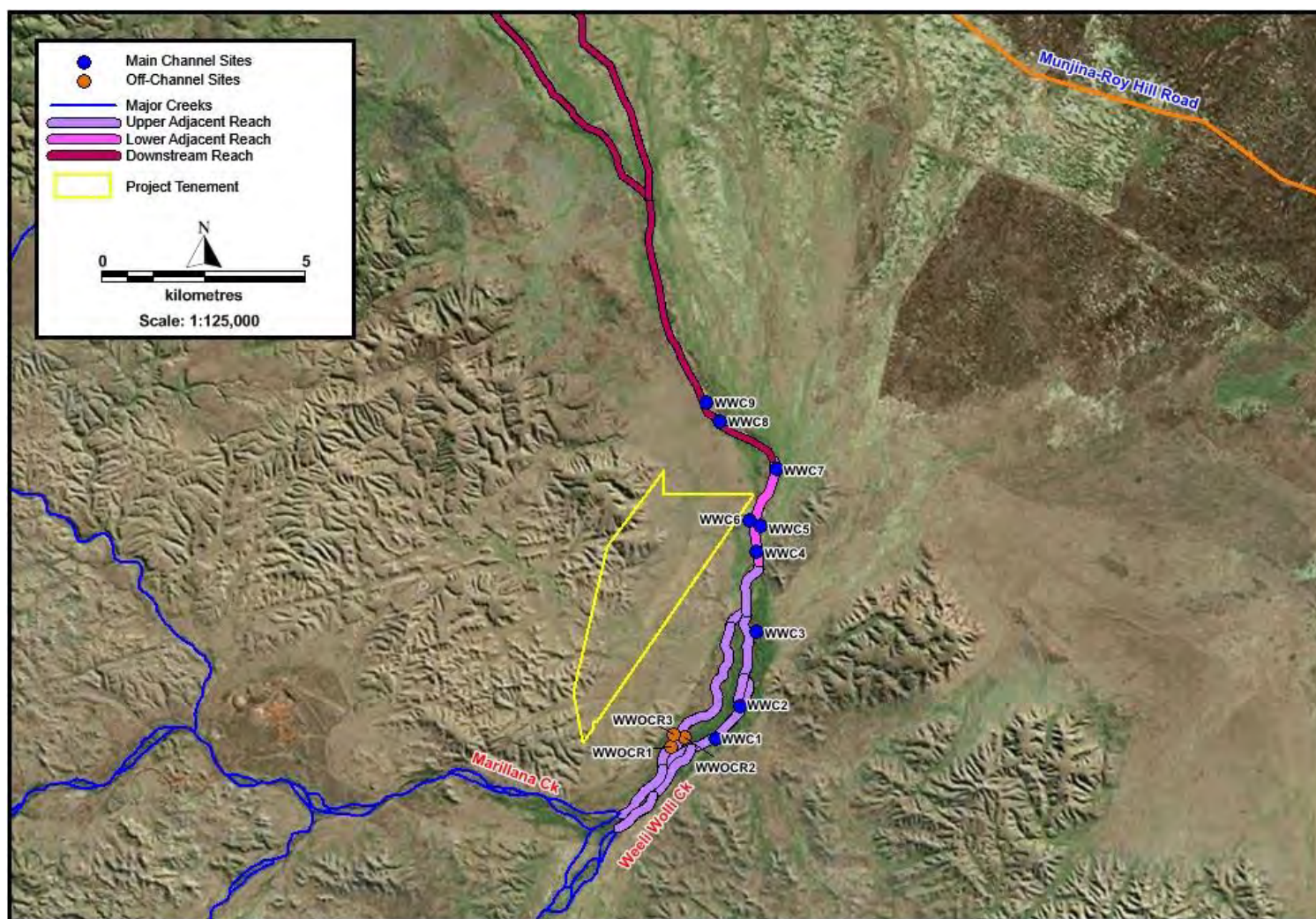
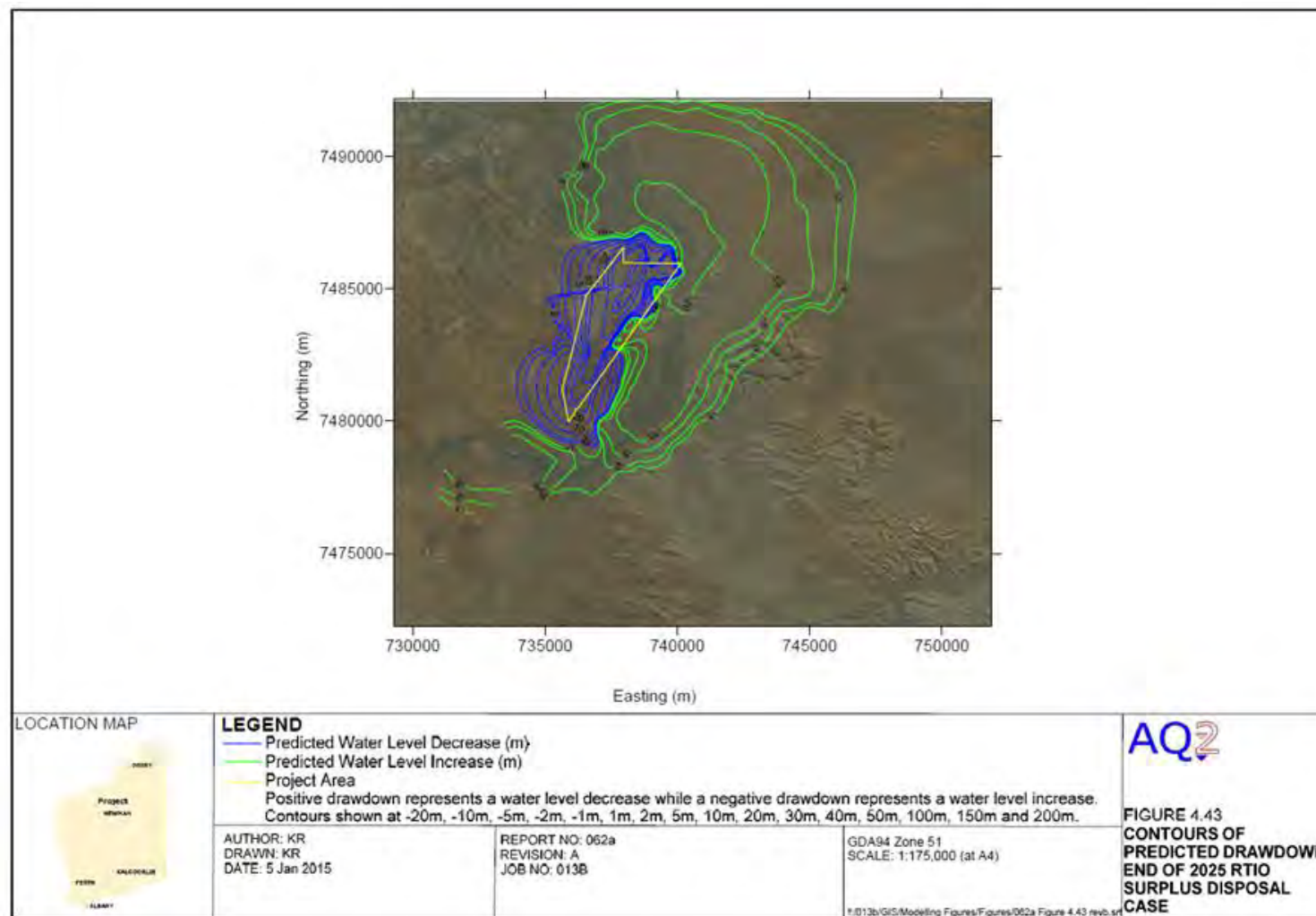
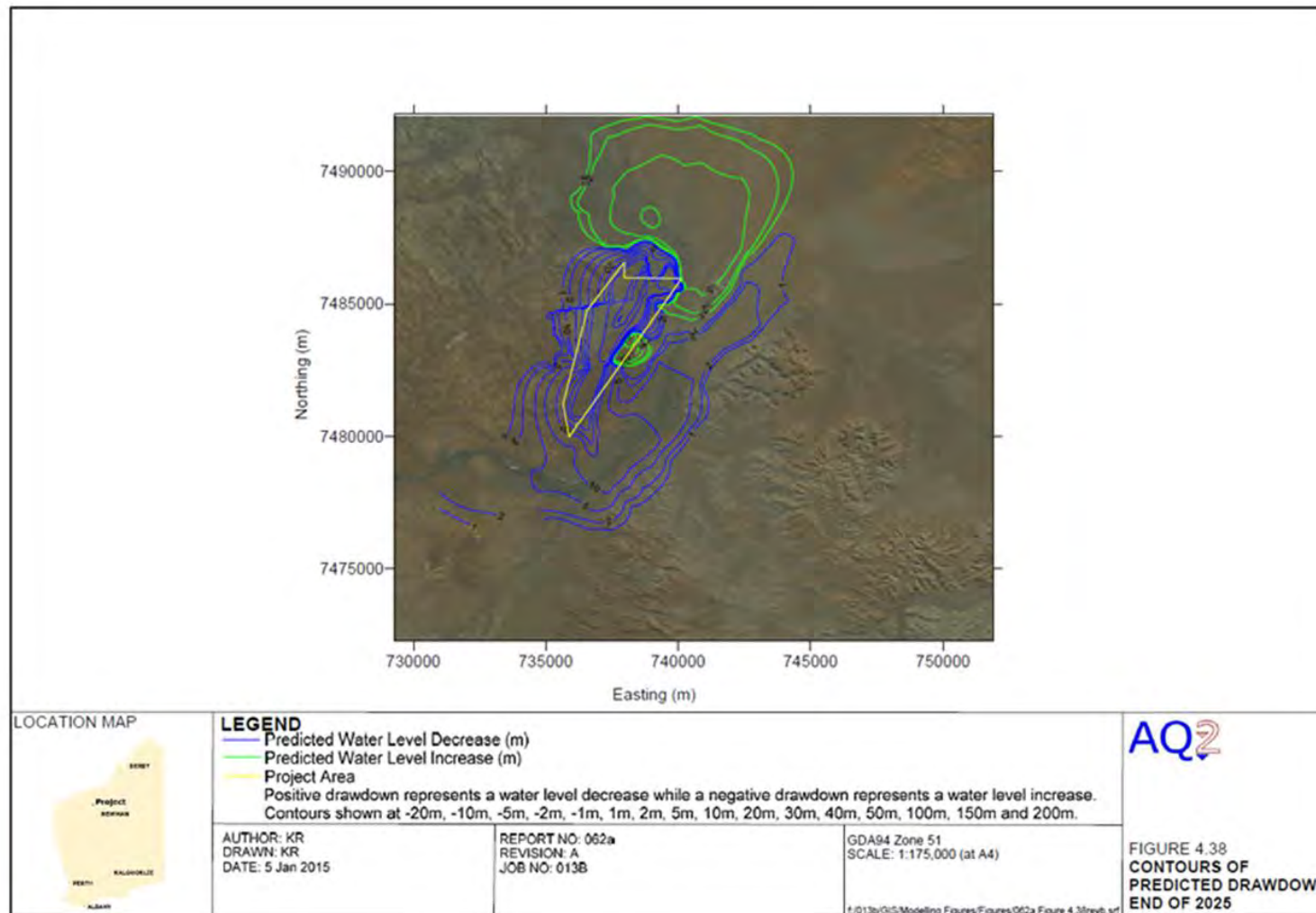
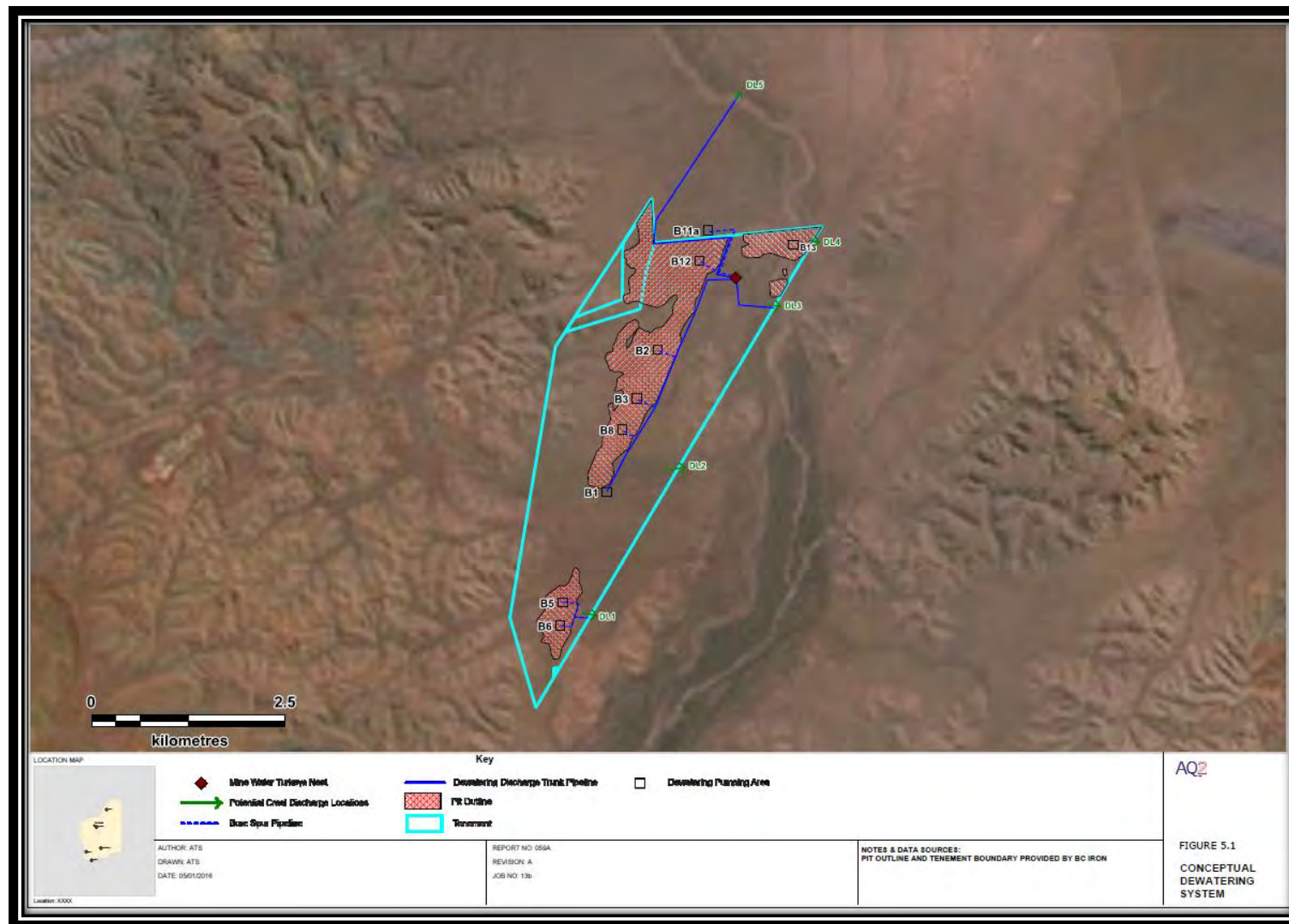


Figure 2. Overview of current nominal reaches of differing hydrological regime along lower Weeli Wolli Creek; Upper Adjacent Reach (purple), Lower Adjacent Reach (pink), and Downstream Reach (red), showing baseline aquatic fauna sites sampled in March 2015. Main channel sites are blue, and off-channel reference sites are orange. The Project tenement is denoted by yellow outline.







Appendix D3 Short Range Endemic



PHOENIX

ENVIRONMENTAL SCIENCES

The distribution of *Aganippe* 'MYG086' (Araneae: Idiopidae) in Western Australia

Prepared for BC Iron Ltd

September 2015

Final Report



The distribution of Aganippe 'MYG086' (Araneae: Idiopidae) in Western Australia

Prepared for BC Iron Ltd

Final Report

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Date: 23 September 2015

Submitted to: Les Purves, Michael Klvac

Chain of authorship and review			
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Volker Framenau	Draft for technical review	1.0	6 May 2015
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Contents

CONTENTS.....	I
LIST OF TABLES.....	I
EXECUTIVE SUMMARY	II
1 INTRODUCTION.....	1
2 SCOPE OF WORKS	1
3 METHODS.....	1
3.1 Desktop review	1
3.2 Molecular analyses	2
4 RESULTS	3
4.1 Desktop review	3
4.2 Molecular analyses	4
5 DISCUSSION.....	6
6 REFERENCES.....	6

List of Tables

Table 3-1 Specimens submitted for molecular analyses	2
Table 4-1 <i>Aganippe</i> species identified by desktop review in vicinity of Iron Valley.....	3
Table 4-2 Cropped (430 bp) COI sequences of <i>Aganippe</i> 'MYG086' from Iron Valley and Rosslyn Paroo Mine used for divergence analysis.....	4
Table 4-3 COI sequence divergence (upper right half) and congruence (lower bottom half) of <i>Aganippe</i> 'MYG086' from Iron Valley and Rosslyn Paroo Mine (COI sequence length = 430bp).....	5

List of Appendices

Appendix 1	Peer-review of original report by Drs M.S. Harvey and M.R. Rix (WA Museum)
Appendix 2	Reply by Phoenix Environmental Sciences to peer-review by Drs M.S. Harvey and M.R. Rix (WA Museum)
Appendix 3	Acceptance of reply to peer-review by WA Museum

EXECUTIVE SUMMARY

Aganippe 'MYG086' is currently considered a short-range endemic species (SRE) and only known from BC Iron Ltd's (BC Iron) Iron Valley Project and Roy Hill, approximately 80 km to the east. The presence of the species at Iron Valley resulted in restrictions in relation to vegetation clearing at the Iron Valley Project (Ministerial Statement 933, MS 933).

Phoenix Environmental Sciences (Phoenix) was commissioned by BC Iron to reassess the distribution of *Aganippe* 'MYG086' and its status as potential SRE.

Morphological identifications suggested that *Aganippe* 'MYG086' also occurs at Rosslyn Paroo Mine near Wiluna approximately 420 km south of Iron Valley. Subsequent molecular analyses (COI barcoding) showed COI sequence divergence values between specimens from Iron Valley and Rosslyn Paroo Mine to be less than 6.7% and therefore less than 9.5%, the current threshold value to differentiate most mygalomorph species.

Due to tissue degeneration, the analysed fragment (430 bp) was shorter than that used for a local barcoding study on mygalomorph spiders (656 bp). Therefore, a pairwise comparison of sequence divergences within Western Australian spiders in the family Idiopidae was conducted both for 452 bp and 658 bp fragments (total number of pairwise comparisons $n = 2,340$) to test the validity of the barcoding gap (9.5%) of the smaller fragment. This analysis showed clearly, that adding the missing data (206 bp) for *Aganippe* 'MYG086' is unlikely to change the divergence values based on the overall pattern of nucleotide variability in this fragment in the Western Australian Idiopidae. Adding data for any specimen pair with divergence under 10 % will add or reduce the divergence by generally less than 1% resulting in a maximum sequence divergence of 7.7% for the longer COI fragment of *Aganippe* 'MYG086' which remains well under the species-level cut-off value of 9.5%.

Therefore, molecular data cannot refute the hypothesis that populations of *Aganippe* 'MYG086' from Iron Valley and Rosslyn Paroo Mine established based on morphology belong to the same species. The distribution of the species spans at least three IBRA regions (Pilbara, Gascoyne, Murchison) and therefore it is not an SRE.

1 INTRODUCTION

Short-range endemics are organisms with a naturally narrow distribution range, in Western Australian nominally less than 10,000 km² (EPA 2009; Harvey 2002). There are uncertainties in determining the range-restrictions of many invertebrates in Western Australia due to lack of surveys, lack of taxonomic resolutions within target taxa and problems in identifying certain life stages. The WA Museum has introduced a three-tier system to account for these uncertainties, confirmed and potential SREs in addition to widespread species (Western Australian Museum 2013).

The Iron Valley Project in the Pilbara region of Western Australia received environmental approval pursuant to Ministerial Statement 933 (MS 933) (Minister for the Environment 2013). In relation to short-range endemic invertebrates, MS 933 states (p. 5):

- *"In order to ensure that the proposal does not result in significant impacts to the population size or distribution of Aganippe MYG086, the proponent shall ensure that no clearing or loss of vegetation occurs within the area of vegetation defined as Zone 1 in Figure 2 of Schedule 1, unless otherwise approved by the CEO under condition 8-2.*
- *Should the proponent demonstrate to the satisfaction of the CEO that Aganippe MYG086 is not a Short Range Endemic species, the proponent may apply to the CEO for approval to disturb vegetation within Zone 1."*

These conditions were based on a short-range endemic (SRE) assessment conducted for the Project that found *Aganippe* 'MYG086' in the Project area but also about 80 km to the south-east (Dalton 2012; Phoenix 2011).

The aim of this report is to re-evaluate the distribution of *Aganippe* 'MYG086' based on morphological and molecular analyses of specimens that became available since MS 933 was issued.

2 SCOPE OF WORKS

The key objective of the assessment is to investigate the SRE status of the potential SRE *Aganippe* 'MYG086'. Specifically, the scope comprises:

- an updated desktop review, in particular a search of the WA Museum Arachnology/Myriapodology database, to ascertain if new populations of *Aganippe* have been discovered since the 2010 and 2011 SRE assessments (Dalton 2012; Phoenix 2011) have been conducted
- ascertaining the identification of unidentifiable historical records from these surveys using DNA sequencing against confirmed specimens, including potential *Aganippe* 'MYG086' recently collected near at Rosslyn Paroo Mine near Wiluna (Phoenix 2015).
- reassessing the SRE status and impact upon *Aganippe* within the project area.

3 METHODS

3.1 DESKTOP REVIEW

A database search for mygalomorph spiders in the family Idiopidae was requested from the WA Museum based on a square of 200 km length centred around Iron Valley and with the geographic coordinates (GDA94) -22.00°S/118.33°E (north-west corner) and 23.75°S/120.25°E (south-east

corner), consistent with the nominal ranges of SREs (i.e. 100 km x 100 km = 1,000 km²) (EPA 2009; Harvey 2002).

3.2 MOLECULAR ANALYSES

The identification of species based on comparisons between DNA sequences is referred to as DNA barcoding. Any gene can be used for barcoding purposes; however, the primary gene targeted by researchers is Cytochrome Oxidase Subunit I (COI) (Hebert *et al.* 2003), which was targeted here. A molecular framework for mygalomorph spiders in relation to COI exists at the WA Museum (Castalanelli *et al.* 2014; Helix 2012).

DNA was amplified by utilising the molecular laboratory of the School of Animal Biology, University of Western Australia and amplified DNA was subsequently sequenced at the AGRF node Perth (Western Australian Institute of Medical Research, WA, Australia).

Six specimens were submitted for molecular analyses (Table 3-1). Standard primers (LCO/HCO) were used for amplification (Folmer *et al.* 1994), with the exception of WAM T114603 and T114604 (CI-j1718/HCO) (Hedin & Maddison 2001).

Following peer-review of the original analysis (Appendix 1) which queried the use of a shorter fragment of COI (430 bp) in comparison to Castalanelli *et al.*'s (2014) 658 bp, a pairwise comparison of sequence divergences for all Western Australian Idiopidae from Castalanelli *et al.*'s (2014) for both the short (452 bp) and the long (658 bp) fragment was conducted. This comparison aimed to explore if adding the missing data (206 bp) would significantly change the results of the original analysis (see Appendix 2 for details of the analysis).

Spider taxonomy follows the World Spider Catalog (2014).

All specimens, DNA extractions and sequence data will be submitted to the WA Museum.

Table 3-1 Specimens submitted for molecular analyses

WAM registration no.	Phoenix database no.	Locality	Latitude (GDA94)	Longitude (GDA94)	Sex
T114604	18703	Iron Valley	-22.4439778	119.18325	Male
T114603	18705	Iron Valley	-22.4437194	119.1837694	Male
T114602	18704	Iron Valley	-22.4338889	119.1958389	Female
T136800	17564	Rosslyn Paroo Mine, ca. 29.7 km WNW of Wiluna	-26.504225	119.9476333	Male
¹	17568	Rosslyn Paroo Mine, ca. 29.7 km WNW of Wiluna	-26.504225	119.9476333	Male
T136799	17574	Rosslyn Paroo Mine, ca. 29.7 km WNW of Wiluna	-26.504225	119.9476333	Male

¹ – Reference specimen retained by Phoenix.

4 RESULTS

4.1 DESKTOP REVIEW

No specimens of *Aganippe* 'MYG086' were identified in the WA Museum database search within approximately 100 km Iron Valley in addition to the specimens identified in 2011. Further, no other specimens of *Aganippe* 'MYG086' were present in the WA Museum database outside the desktop research area (M. Castalanelli, pers. comm. to V.W. Framenau). However, the WA Museum database search identified at least 121 records of *Aganippe* species around Iron Valley in 10 species, five of which were identified by molecular methods (Table 4-1). These mainly represented females and could possibly be conspecific with *Aganippe* 'MYG086', of which COI sequences were not known prior to this study.

Table 4-1 *Aganippe* species identified by desktop review in vicinity of Iron Valley

Species	Number of records in desktop review area	Known sex	Remarks
<i>Aganippe</i> 'Cloudbreak sp. 1'	1	Male	
<i>Aganippe</i> 'MYG085'	14	Male, female	COI sequence known
<i>Aganippe</i> 'MYG086'	6	Male, female	Identification based on morphology
<i>Aganippe</i> 'MYG233'	3	Male, female	Identification based on morphology
<i>Aganippe</i> 'MYG300-DNA'	6	Female	Identified by COI sequence
<i>Aganippe</i> 'MYG303-DNA'	4	Female	Identified by COI sequence
<i>Aganippe</i> 'MYG305-DNA'	2	Female	Identified by COI sequence
<i>Aganippe</i> 'MYG306-DNA'	3	Female	Identified by COI sequence
<i>Aganippe</i> 'MYG384-DNA'	12	Unknown	Identified by COI sequence
<i>Aganippe</i> 'occidentalis?'	1	Male	
Unidentified <i>Aganippe</i>	69	Females, juveniles	
Total	121		

4.2 MOLECULAR ANALYSES

All specimens analysed provided usable DNA (although comparatively short fragments for the specimens from Iron Valley) and divergence analyses were conducted based on cropped alignments of 430 bp (full alignments in Table 4-2). COI barcoding confirmed the initial morphological identification of specimens from Rosslyn Paroo Mine as *Aganippe* 'MYG086' as the specimens did not differ by more than 6.7% (Table 4-3).

The pairwise comparison of smaller (452 bp) and larger (658 bp) fragments of COI divergences showed clearly, that adding the missing data for *Aganippe* 'MYG086' was extremely unlikely to change the divergence past the Castalanelli *et al.* (2014) working threshold of 9.5% (see Appendix 2) based on the overall pattern of nucleotide variability in this fragment in the Idiopidae. Adding data for any specimen pair with divergence under 10 % will add or reduce the divergence by generally less than 1%; in fact, the closer COI divergence approaches 10 %, adding more data will actually make the sequence divergence smaller (i.e. push it under 9.5%) (Appendix 2). This additional analysis was accepted as sufficient to confirm conspecificity of the population from Iron Valley and Rosslyn Paroo Mine by the initial reviewers of the original analysis (Appendix 3).

Comparing COI sequences of *Aganippe* 'MYG086' from Iron Valley with other *Aganippe* species from Western Australian lodged at the WA Museum and available on GenBank (Benson *et al.* 2012; Castalanelli *et al.* 2014) showed that *Aganippe* 'MYG086' is closest to *Aganippe* 'MYG256' known from the Goldfields region of WA, but is clearly a distinct species (sequence divergence > 12.8%). *Aganippe* 'MYG086' is different to any other molecular species identified by the desktop review in the vicinity of Iron Valley.

Table 4-2 COI sequences (452–657 bp) of *Aganippe* 'MYG086' from Iron Valley and Rosslyn Paroo Mine used for divergence analysis

Specimen	COI sequence (cropped to 430 bp)
WAM T114602 (Iron Valley)	GATGTTAGGTGCACCTGATATAGCTTTTCCTCGTATAAATAATTTGAGATTTTGGTTGT TACCTCCTTCTTTGTTTTTTTTGATGGTCTCTTCGTTGGTTGAGGTGGGGGTTGGAGCT GGTTGGACTATTTATCCTCCTTTGTCTTCTGGTGTAGGGCATAGTGGGGGGGAATGGA TTTTGTTATTTTTCTTTACATTTAGCTGGGGCATCTTCGATTATGGGGCTATTAATT TTATTTCTACTATTGTTAATATGCGTGCTGTAGGGATGGTGTGTTGAACGTGTTTCTTTG TTTGTGTGGTCAGTGATAGTGACGGCTGTGTTGCTTTTGTGCTCTTCTCTGTGTTGGC GGGTGCTATTACAATATTATTGACTGATCGAAATTTTAATACTTCTTTTTTTGACCCGG CTGGGGGTGGGGATCCTGTTTTATTTTCAGCATTTATTTT
WAM T114604 (Iron Valley)	GATGTTAGGTGCACCTGATATAGCTTTTCCTCGTATAAATAATTTGAGATTTTGGTTGT TACCTCCTTCTTTGTTTTTTTTGATGGTCTCTTCGTTGGTTGAGGTGGGGGTTGGAGCT GGTTGGACTATTTATCCTCCTTTGTCTTCTGGTGTAGGGCATAGTGGGGGGGAATGGA TTTTGTTATTTTTCTTTACATTTAGCTGGGGCATCTTCGATTATGGGGCTATTAATT TTATTTCTACTATTGTTAATATGCGTGCTGTAGGGATGGTGTGTTGAACGTGTTTCTTTG TTTGTGTGGTCAGTGATAGTGACGGCTGTGTTGCTTTTGTGCTCTTCTCTGTGTTGGC GGGTGCTATTACAATATTATTGACTGATCGAAATTTTAATACTTCTTTTTTTGACCCGG CTGGGGGTGGGGATCCTGTTTTATTTTCAGCATTTATTTT
WAM T114603 (Iron Valley)	AGTTCCTTTGATGTTAGGTGCACCTGATATAGCTTTTCCTCGTATAAATAATTTGAGAT TTTGGTTGTTACCTCCTTCTTTGTTTTTTTTGATGGTCTCTTCGTTGGTTGAGGTGGGG GTTGGAGCTGGTTGGACTATTTATCCTCCTTTGTCTTCTGGTGTAGGGCATAGTGGGGG GGGAATGGATTTTGTATTTTTCTTTACATTTAGCTGGGGCATCTTCGATTATGGGGG CTATTAATTTTATTTCTACTATTGTTAATATGCGTGCTGTAGGGATGGTGTGTTGAACGT GTTTCTTTGTTTGTGTGGTCAGTGATAGTGACGGCTGTGTTGCTTTTGTGCTCTTCC TGTGTTGGCGGGTGCTATTACAATATTATTGACTGATCGAAATTTTAATACTTCTTTTT TTGACCCGGCTGGGGGTGGGGATCCTGTTTTATTTTCAGCATTTATTTT

Specimen	COI sequence (cropped to 430 bp)
WAM T136799 (Rosslyn Paroo Mine)	CTATATATATTATTTGGGTGTGTGGTCGGCGATATTAGGAACAGCAATAAGAGTAGTG ATTCGGACAGAGTTGGGGCAAGTTGGAAGTCTTTTAGGAAATGATCATTTGTATAATGT AGTTGTGACGGTTCATGCTTTAGTTATAATTTTTTTATGGTGATGCCTATTATAATTG GAGGGTTTGGAAATTGATTGGTACCTTTGATGTTAGGGTCGCCGGATATGGCTTTTCCT CGTATAAATAATTTGAGATTTTGGTTGTTGCCTCCTTCTTTATTTTTTTAATGGTTTC TTCGTTAGTTGATGTGGGAGTTGGGGCTGGTTGGACTATTTATCCTCCTTTGTCTTCTA GTATAGGTCATAGAGGGGGGGGAATGGATTTTGTTATTTTTCTTTACATTTAGCTGGT GCATCTTCGATTATGGGAGCTATTAATTTTATTTCTACTATTGTGAATATGCGAGCTGT GGGGATGGTGTTTGAGCGTGTTTCTTTGTTTGTGTGGTCAGTGATGGTGACAGCTGTAT TACTGTTGTTGTCTCTTCTGTGTTGGCGGGGGCTATCACAATATTATTGACTGATCGA AATTTTAATACTTCCTTTTTTCGACCCGGCTGGGGGAGGGGATCCTGTTTTATTTCAACA TTTATTTT
Phoenix 17568 (Rosslyn Paroo Mine)	CTATATATATTATTTGGGTGTGTGGTCGGCGATATTAGGAACAGCAATAAGAGTAGTG ATTCGGACAGAGTTGGGGCAAGTTGGAAGTCTTTTAGGAAATGATCATTTGTATAATGT AGTTGTGACGGTTCATGCTTTAGTTATAATTTTTTTATGGTGATGCCTATTATAATTG GAGGGTTTGGAAATTGATTGGTACCTTTGATGTTAGGGTCGCCGGATATGGCTTTTCCT CGTATAAATAATTTGAGATTTTGGTTGTTGCCTCCTTCTTTATTTTTTTAATGGTTTC TTCGTTAGTTGATGTGGGAGTTGGGGCTGGTTGGACTATTTATCCTCCTTTGTCTTCTA GTATAGGTCATAGAGGGGGGGGAATGGATTTTGTTATTTTTCTTTACATTTAGCTGGT GCATCTTCGATTATGGGAGCTATTAATTTTATTTCTACTATTGTGAATATGCGAGCTGT GGGGATGGTGTTTGAGCGTGTTTCTTTGTTTGTGTGGTCAGTGATGGTGACAGCTGTAT TACTGTTGTTGTCTCTTCTGTGTTGGCGGGGGCTATCACAATATTATTGACTGATCGA AATTTTAATACTTCCTTTTTTCGACCCGGCTGGGGGAGGGGATCCTGTTTTATTTCAACA TTTATTTT
WAM T136800 (Rosslyn Paroo Mine)	CTATATATATTATTTGGGTGTGTGGTCGGCGATATTAGGAACAGCAATAAGAGTAGTG ATTCGGACAGAGTTGGGGCAAGTTGGAAGTCTTTTAGGAAATGATCATTTGTATAATGT AGTTGTGACGGTTCATGCTTTAGTTATAATTTTTTTATGGTGATGCCTATTATAATTG GAGGGTTTGGAAATTGATTGGTACCTTTGATGTTAGGGTCGCCGGATATGGCTTTTCCT CGTATAAATAATTTGAGATTTTGGTTGTTGCCTCCTTCTTTATTTTTTTAATGGTTTC TTCGTTAGTTGATGTGGGAGTTGGGGCTGGTTGGACTATTTATCCTCCTTTGTCTTCTA GTATAGGTCATAGAGGGGGGGGAATGGATTTTGTTATTTTTCTTTACATTTAGCTGGT GCATCTTCGATTATGGGAGCTATTAATTTTATTTCTACTATTGTGAATATGCGAGCTGT GGGGATGGTGTTTGAGCGTGTTTCTTTGTTTGTGTGGTCAGTGATGGTGACAGCTGTAT TACTGTTGTTGTCTCTTCTGTGTTGGCGGGGGCTATCACAATATTATTGACTGATCGA AATTTTAATACTTCCTTTTTTCGACCCGGCTGGGGGAGGGGATCCTGTTTTATTTCAACA TTTATTTT

Table 4-3 COI sequence divergence (upper right half) and congruence (lower bottom half) of *Aganippe* 'MYG086' from Iron Valley and Rosslyn Paroo Mine (COI sequence length = 430bp)

Location	Registration no.	WAM T136800	Phoenix 17568	WAM T136799	WAM T114604	WAM T114602	WAM T114603
Rosslyn Paroo Mine	WAM T136800		0	0	6.7	6.7	6.7
	Phoenix 17568	100		0	6.7	6.7	6.7
	WAM T136799	100	100		6.7	6.7	6.7
Iron Valley	WAM T114604	93.3	93.3	93.3		0	0
	WAM T114602	93.3	93.3	93.3	100		0
	WAM T114603	93.3	93.3	93.3	100	100	

5 DISCUSSION

Species identification based on COI barcoding is not without problems as sequence divergence within species can be high and may exceed that between species in some taxa, including SRE target groups (e. g. Bond 2004; Boyer *et al.* 2007; Köhler & Johnson 2012). A comprehensive study of WA mygalomorph spiders focussing on species from the Pilbara region identified a sequence divergence of approximately 9.5% as proposed cut-off value to differentiate separate species (Castalanelli *et al.* 2014). Based on this study, with a maximum divergence of 6.7% the specimens of *Aganippe* 'MYG086' from Iron Valley and Rosslyn Paroo Mine are unequivocally the same species, in particular taking the large distance of the two populations into account. This result also holds true considering the comparatively short length of the COI fragment analysed (Appendices 1–3).

With a distance of more than 420 km between currently known records of *Aganippe* 'MYG086', the known distribution of the species far exceeds what is currently used as nominal or working range for short-range endemism, i.e. 10,000 km² (= 100 x 100 km²). The distribution of the species spans at least three IBRA bioregions, Pilbara, Gascoyne and Murchison (Department of the Environment 2015). *Aganippe* 'MYG086' appears to reach the northern limits of its distribution at Iron Valley considering the good survey density in the eastern Pilbara and is therefore probably only known from a few localities. Considering the poor collection coverage in the Gascoyne and Murchison region, it is very likely that *Aganippe* 'MYG086' will be found at many more localities throughout these regions.

In summary, *Aganippe* 'MYG086' is not a short-range endemic species and it is suggested to re-evaluate the conditions of MS 933 in relation to this species.

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Appendix 1: Peer-review of original report by Drs M.S. Harvey and M.R. Rix (WA Museum)

(see next page)



25 August 2015

Mr Les Purves
Environmental Adviser
BC Pilbara Iron Ore Pty Ltd
GPO Box 2811
West Perth WA 6872

Re: Report by Phoenix Environmental Sciences (May 2015) "The distribution of *Aganippe* 'MYG086' (Araneae: Idiopidae) in Western Australia"

Dear Mr Purves

In response to your request for a peer review of the above report by Phoenix Environmental Sciences, we have prepared a short summary (below). This review is focused on the molecular conclusions presented in the report, and we have applied the same rigour that we would to a scholarly journal article. We hope it satisfies the conditions of the Office of the Environmental Protection Authority (OEPA).

Please let us know if you require any further information or clarification, and with our very best wishes,

Mark Harvey and Mike Rix
Department of Terrestrial Zoology

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PERTH • MARITIME • FREMANTLE • GERALDTON • KALGOORLIE-BOULDER •
ALBANY

Report by Phoenix Environmental Sciences (May 2015) “The distribution of *Aganippe* ‘MYG086’ (Araneae: Idiopidae) in Western Australia”

Summary Review

This report tests the distribution of the idiopid trapdoor spider *Aganippe* sp. ‘MYG086’, previously known from the Iron Valley Project and Roy Hill, Western Australia. The primary objectives of the work contained in Phoenix (2015) were to test – using molecular data – whether: (A) specimens from Rosslyn Paroo Mine near Wiluna were conspecific with those from Iron Valley/Roy Hill; and thus (B) whether ‘MYG086’ can be considered a short-range endemic species. For the purposes of this review we comment solely on the conclusions made using the molecular dataset presented in Phoenix (2015), and whether our analyses of those data match the results presented in the report.

Table 1. Sequence lengths for the *CO1* sequences presented in Phoenix (2015).

Specimen	Published sequence length (bp)
WAM T114602 (Iron Valley)	452
WAM T114604 (Iron Valley)	452
WAM T114603 (Iron Valley)	461
WAM T136799 (R. Paroo Mine)	657
Phoenix 17568 (R. Paroo Mine)	657
WAM T136800 (R. Paroo Mine)	657

In assessing the molecular results presented in Phoenix (2015), we copied the six published *CO1* sequences from pages 4-5 of the report and analysed them using Geneious 6.1.7. Phoenix (2015: 4) stated that “analyses were conducted based on cropped alignments of 430 bp”. However, three of the sequences presented were not in fact cropped below the length of the standard barcoding segment (which is 658 bp), and none were 430 bp in length, as stated. A summary of the published sequence lengths is shown in Table 1 (above).

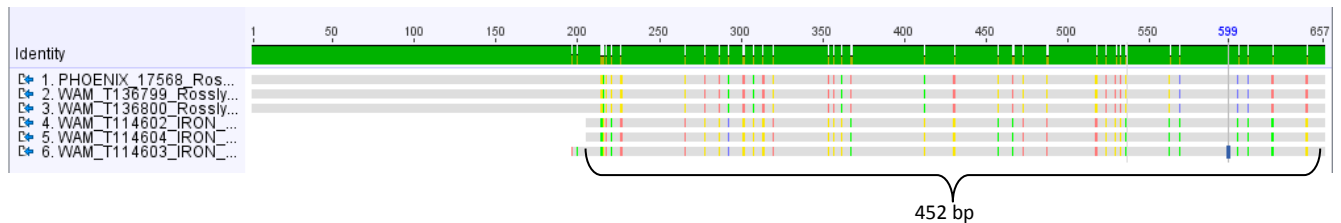


Figure 1. Graphical alignment of the six *CO1* sequences presented in Phoenix (2015), highlighting the 452 bp overlapping region of the barcoding segment.

After alignment of these six sequences in Geneious, a core overlapping region of 452 bp was recovered (see Fig. 1). We therefore cropped the alignment to 452 bp accordingly, and analysed the pairwise divergence values among taxa. These values are summarised in Table 2, in an identical format to that presented in Table 4-3 of Phoenix (2015).

Table 2. *CO1* sequence divergence (upper right half) and congruence (lower bottom half) of *Aganippe* ‘MYG086’ from Iron Valley and Rosslyn Paroo Mine (*CO1* sequence length = **452 bp**). Differences from Phoenix (2015) are highlighted in red.

Location	Registration no.	WAM T136800	Phoenix 17568	WAM T136799	WAM T114604	WAM T114602	WAM T114603
	WAM T136800		0	0	7.5	7.5	7.5
Rosslyn Paroo Mine	Phoenix 17568	100		0	7.5	7.5	7.5
	WAM T136799	100	100		7.5	7.5	7.5
	WAM T114604	92.5	92.5	92.5		0	0
Iron Valley	WAM T114602	92.5	92.5	92.5	100		0
	WAM T114603	92.5	92.5	92.5	100	100	

Conclusions

In short, we recovered different results to those reported in Phoenix (2015), namely that pairwise divergence values between populations of *Aganippe* 'MYG086' from Rosslyn Paroo Mine vs. Iron Valley were higher than previously reported (i.e. 7.5% cf. 6.7%). Our analysed portion was also 22 bp larger than that reported in Phoenix (2015), and this is no doubt the source of the discrepancy. Indeed, if the first 22 bp of our alignment is cropped, then the results presented in Phoenix (2015) are obtained. However, we can see no compelling reason for cropping these data beyond 452 bp – and certainly no reason was given in Phoenix (2015) – especially given that the fragment is already considerably shorter than is generally required for accurate *CO1* barcoding. The cropping of 22 bp by Phoenix (2015) seems further problematic, as there are five variable nucleotide sites in this region which change the results by nearly a percentage point (see Table 2).

In summary, we can conclude that while up to 7.5% *CO1* sequence divergence is still within the threshold that we currently understand to represent conspecific taxa, this value is different (higher) than that presented by Phoenix (2015), due to the latter inexplicably removing usable data (i.e. 22 bp). We also interpret these results with great caution, as the 9.5% divergence conspecific cut-off value suggested by Castalanelli et al. (2014) was based on analysis of the full 658 bp barcoding fragment, and not a highly reduced 452 bp fragment as presented here (see below).

Recommendations

Our recommendations are as follows:

(A) The three specimens from Iron Valley should be re-sequenced, so that the entire barcoding fragment is recovered for these taxa; and

(B) Pairwise divergence calculations should be made using the full-length barcoding fragment of 658 bp, so that the 9.5% threshold can be applied accurately as per Castalanelli et al. (2015). Indeed, as the addition of 22 bp can significantly change a divergence result, the addition of a further 206 bp could likewise alter the result and therefore change one's interpretation.

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Mark Harvey and Mike Rix
Western Australian Museum
24 August 2015

Appendix 2: Reply by Phoenix Environmental Sciences to peer-review by Drs M.S. Harvey and M.R. Rix (WA Museum)

(see next page)

Memo

To: Michael Rix, Mark Harvey

From: Volker Framenau

CC:

Date: 31 August 2015

Subject: Review of Phoenix report on *Aganippe* 'MYG086'



Hi Mark and Mike,

Thank you very much for taking the time to review our report on barcoding *Aganippe* 'MYG086' specimens for our client BC Iron. Les Purves has asked me to have a look at your review and recommend further action, ideally avoiding further molecular work due to time and resources constraints.

We have critically reviewed your document and have a number of comments to make, both in regard to our initial analyses and your review of it, but also in relation to your recommendation to repeat the molecular work to obtain a larger COI sequence, ideally a 'standard fragment' of 658 bp. We are happy to revise our initial document with the details below which in our opinion is sufficient to show that there is not much evidence to support that the specimens analysed represent more than one species.

Overall, our primary test was not, as stated in your review, to "test whether the specimens were conspecific", but to potentially reject the null-hypothesis that they are conspecific, which was established by morphological examination before. In other words, molecular data were used to potentially disprove morphological conclusions that there was little difference between the specimens examined and they represent a single morphospecies. All specimens are morphologically indistinguishable in relation to male pedipalp appendices or somatic characters which only initiated the analysis in the first place. In my opinion and based on the examination of many *Aganippe* males, the genus has very reliable genitalic characters represented by a variation of apophysis on the pedipalp and high inter-specific morphological variability in the embolus, much unlike, for example, in the Nemesiidae. Of course, that would not exclude cryptic speciation, but as argued below, molecular data will very likely fail to disprove conspecificity, even if we add further nucleotide sequences.

Why short fragment of specimens from Iron Valley?

The specimens from Iron Valley were collected in 2011 (fairly old and dubious tissue preparation at Dalcon) and using standard primers/PCRs did not yield longer fragments than 452 bp. Trial PCRs run using both Folmer standard primers (resulting in amplicon lengths of ca. 650 bp) and an additional reverse primer for longer fragments (820 bp) failed to amplify DNA, presumably because the specimens are old and the initial preservation of the specimens was not optimal.

There are two reasons why we only analysed 430 bp of these. :

- The initial analysis included a further unrelated specimen with 430 bp which was omitted in the report. As there was no overall change in the result for 452 bp (i.e. divergence values of *Aganippe* 'MYG086' much lower than current operational threshold), there was no need to redo the analysis.
- We preferred cropping the sequences of 452 bp to 430 bp because the initial 22 bp were close to forward primer sequence and we find that the region that flank primer sequences are often 'messy' and can produce false and/or dubious base call in the chromatogram. We prefer cropping the 5' and 3' ends of the DNA sequences rigorously to avoid inconsistency in molecular data collection. The necessity to do this was quite nicely shown by your analysis of the 452 bp sequences. An increase of a disproportionate 0.8% (from 6.7% to 7.5%) caused by five variable nucleotides when adding only 22 bp to the analysis appears to be caused by

Memo

false reads near the primer site (see our analysis of variability in the missing sequence below).

Within this context, the heading of our Table 4-2 ("Cropped (430 bp) COI sequence...") is an error that was not picked up in our internal review process.

Will adding further data to the dataset increase COI divergence?

The recommendation to re-sequence the Iron Ore Valley specimens to obtain longer sequences makes only sense if there is evidence that the variability in the missing 206 bp is disproportionately higher than in the 430 or 452 bp fragments that have been analysed. No evidence, either from published papers or analyses of data, is put forward in the review with the exception of the high nucleotide variability between 430 and 458 bp which, however, may be explained by false reads. We also stress that, even if the reads were true, the modified divergence values of 7.5 per cent between the sequenced samples I still below the Hebert threshold of 8 per cent for arachnid species that is commonly used, and certainly below the threshold you recently proposed for WA mygalomorph species (Castalanelli *et al.* 2014) (9.5 per cent; with often higher values intrinsically applied if the underlying data in this paper are checked carefully).

Scientifically, there is no accepted minimum length of primers for COI barcoding, nor a standard divergence threshold that defines species. Indeed, many published analyses of barcoding in spiders use much smaller fragments than the 658 bp analysed by Castalanelli *et al.* (2014), for example 420 bp in Robinson *et al.* (2009), and others use larger sequences (e.g. Lopardo & Uhl 2014). The Consortium for the Barcode of Life defines the 'Folmer region' as standard, which includes 648 bp (<http://www.barcodeoflife.org/content/resources/standards-and-guidelines>). They also recommend to use a least 75% contiguous, high quality bases of this sequence (i.e. 486 bp), which is only about 10% more than what we analysed.

Evidently, the most appropriate way to gather some evidence of COI divergence patterns in the missing fragment from the taxon at hand, the genus *Aganippe* or, as there are doubts on current generic limits of this genus, the family Idiopidae, is to analyse the taxon specific data. We have therefore simply re-analysed the idiopid dataset of Castalanelli *et al.* (2014) and calculated COI divergences of all specimen pairs (n = 2,340) of 81 specimens of Idiopidae for 658 bp and 450 bp and plotted a pairwise comparison of these divergence differences (Figure 1). Data for specimen pairs of specimens currently identified as *Aganippe* (30 specimens, 435 species pairs) are also illustrated and of course simply represent a subset of the whole dataset without changing the overall result (Figure 1).

Memo

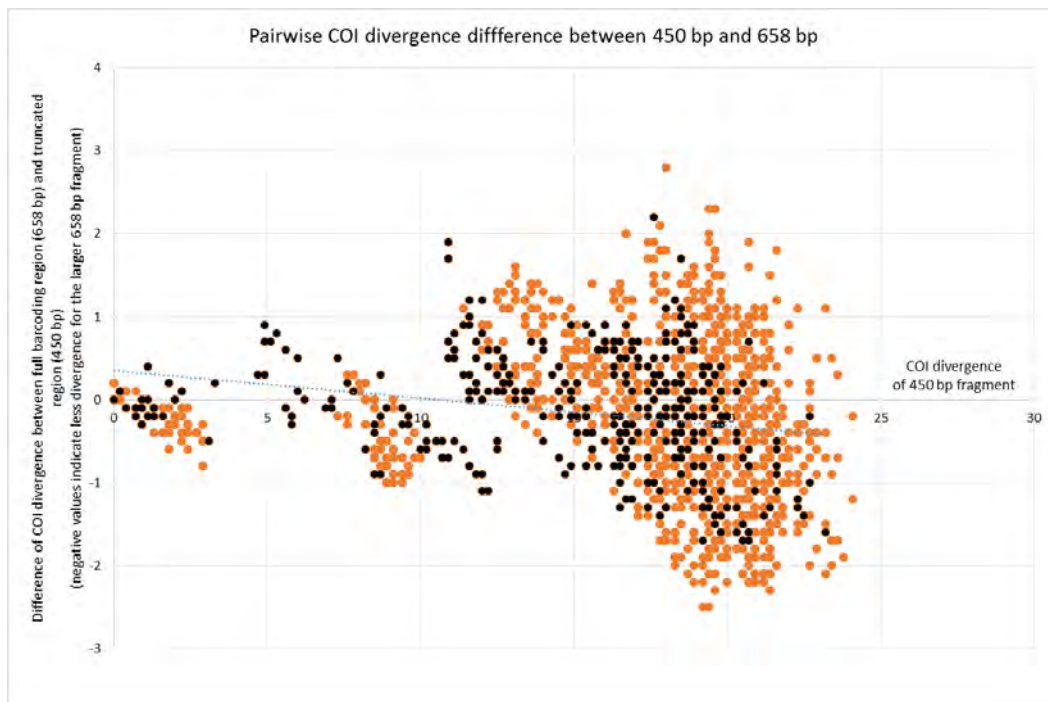


Figure 1: Pairwise differences of COI sequence divergence between 658 bp and 450 bp in relation to COI divergence of the 450 bp fragment for WA *Aganippe* (black dots) or Idiopidae (orange dots) (data from Castalanelli *et al.* 2014)

This analysis shows clearly, that adding the missing data for *Aganippe* 'MYG086' is extremely unlikely to change the divergence over the Castalanelli *et al.* (2014) working threshold of 9.5% (here corroborated as a gap in the scatterplot between ca. 9.5 and 12 %) based on the overall pattern of nucleotide variability in this fragment in the Idiopidae. Adding data for any specimen pair with divergence under 10 % will add or reduce the divergence by generally less than 1%; in fact, the closer COI divergence approaches 10 %, adding more data will actually make the sequence divergence smaller (i.e. push it under 9.5%) as indicated by the differences tending to < 0. In other words, even if we accept that 7.5% is the true divergence at 452bp, adding 206 bp is very unlikely to change the divergence to more than 8.5%, in fact, it is just as likely to reduce it to 6.5%.

In summary, there is currently no scientific evidence to support the position that adding a further 206 bp to the analysis will increase the COI divergence between the specimens collected at Iron Valley and Paroo Rosslyn Mine above the current species level cut-off of 9.5% in the WA Idiopidae. The current null-hypothesis based on morphology is not being refuted by molecular data and, following scientific rigour applied to the data currently available (morphology and molecular), the specimen should be considered the same species.

Memo

Best regards,

Volker Framenau

Director; Manager, Invertebrate Sciences

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References

- Castalanelli, M. A., Teale, R., Rix, M. G., Kennington, J. & Harvey, M. S. 2014. Barcoding of mygalomorph spiders (Araneae: Mygalomorphae) in the Pilbara region of Western Australia *Invertebrate Systematics* **28**: 375–385.
- Lopardo, L. & Uhl, G. 2014. Testing mitochondrial marker efficacy for DNA barcoding in spiders: a test case using the dwarf spider genus *Oedothorax* (Araneae : Linyphiidae : Erigoninae). *Invertebrate Systematics* **28**: 501–521.
- Robinson, E. A., Blagoev, G. A., Hebert, P. D. N. & Adamowicz, S. J. 2009. Prospects for using DNA barcoding to identify spiders in species-rich genera. *ZooKeys* **16**: 27–46.

Appendix 3: Acceptance of reply to peer-review by WA Museum

(see next page)

From: Mark Harvey [<mailto:Mark.Harvey@museum.wa.gov.au>]
Sent: 18 September, 2015 9:46 AM
To: Volker Framenau <volker.framenau@phoenixenv.com.au>
Cc: Michael Rix <Michael.Rix@museum.wa.gov.au>
Subject: RE: Aganippe barcoding

Dear Volker

We have read your email and memo, and are happy to provide the following statement, which you can send to Les with your revised report:

Statement

We have read the addendum provided by Phoenix Environmental Sciences in relation to the Report on *Aganippe* 'MYG086', and agree with the findings therein. We consider this to be a scientifically appropriate and rigorous response to our concerns surrounding the use of only 450 bp of CO1. Our only major recommendation going forward would be that if Castalanelli et al. (2014) is used as a benchmark for hypothesis-testing, the reasoning behind using shorter fragments should be explicitly stated and justified in the first instance (as was done subsequently).

In summary, we agree with the conclusion that:

"In summary, there is currently now scientific evidence to support the position that adding a further 206 bp to the analysis will increase the COI divergence between the specimens collected at Iron Valley and Paroo Rosslyn Mine above the current species level cut-off of 9.5% in the WA Idiopidae. The current null-hypothesis based on morphology is not being refuted by molecular data and, following scientific rigour applied to the data currently available (morphology and molecular), the specimen should be considered the same species."

We thus endorse the findings of the initial report and the supplied addendum, in combination.

Best wishes

Mark Harvey & Mike Rix

.....
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Government of **Western Australia**
Office of the **Environmental Protection Authority**

Mr Les Purves
Environmental Advisor
BC Pilbara Iron Ore Pty Ltd
GPO Box 2811
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Dear Mr Purves

**MINISTERIAL STATEMENT 933 CONDITION 8-1 and 8-2 - SHORT RANGE
ENDEMIC FAUNA**

I refer to your email dated 23 September 2015 in which you submitted the report; *The Distribution of Aganippe MYG086 (Araneae: Idiopidae) September 2015*. The Office of the Environmental Protection Authority (OEPA) notes that the technical rigor of the report has been assessed by representatives from the Western Australian Museum (WAM) as requested by the OEPA in a letter dated 5 August 2015.

The OEPA further notes that WAM representatives have endorsed the findings of the report which conclude that populations of *Aganippe* 'MYG086' at the Iron Valley site are not considered to be a short range endemic species.

The OEPA therefore considers BC Pilbara Iron Ore Pty Ltd to have met the requirements of Conditions 8-1 and 8-2 and the area of vegetation defined as Zone 1 in Figure 2 of Schedule 1 of Ministerial Statement 933 can be cleared.

Please contact Rowan Inglis on 6145 0849 if you require any additional information regarding this matter.

Yours sincerely



Mr Kim Taylor
GENERAL MANAGER

October 2015

Iron Ore Holdings Ltd – Iron Valley Project

Targeted Terrestrial Short-Range Endemic Invertebrate Fauna Survey

Prepared for URS Australia Pty Ltd

August 2012



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environmental

Short Range Endemic Targeted Survey – Iron Valley Project

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Cover Images

Top Left: Mygalomorph trapdoor spider *Missulena* “MYG045”.

Mid Left: Scorpion *Urodacus* “megamastigus short” fluorescing under ultraviolet light.

Bottom Left: Male Mygalomorph trapdoor spider *Aganippe* “MYG086”, rearing up in a typical aggressive posture.

Images courtesy of Ross Gordon, Dalcon Environmental Pty Ltd

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The findings, observations and recommendations expressed by Dalcon Environmental in this report are based upon the professional opinion of Dalcon Environmental according to the data and information supplied to Dalcon Environmental (this includes verbal communications) by the Client for which the work has been undertaken (as stated in this report) and/or information obtained from the examination of documents accessed from the public record these sources of information have been identified in the report wherever possible and reasonable care has been taken by Dalcon Environmental to verify such information however, unless stated otherwise, this may not have been possible. No warranty or guarantee, whether express or implied, is made with respect to the findings, observations, conclusions and/or recommendations expressed in this report and Dalcon Environmental does not represent such findings, observations, conclusions and/or recommendations as true or accurate, and disclaims all liability with respect to the use of such findings, observations, conclusions and/or recommendations

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Acknowledgements

Dalcon Environmental would like to acknowledge the cooperation of URS Australia Pty Ltd staff with whom we have liaised prior to and during the field program and during the reporting phase of this Project, in particular Hannah Fletcher. Thanks also to Iron Ore Holdings Ltd staff at the Iron Valley site for their assistance in the field.

We would also like to thank Volker Framenau of Phoenix Environmental Sciences Pty Ltd for their services identifying the survey's Mygalomorph trapdoor spiders, Erich Volshenk for Scorpion identifications and Barbara Main of Curtin University for her assistance with the identification of the *Aganippe* trapdoor spiders.

Executive Summary

Dalcon Environmental, on behalf of URS Australia Pty Ltd (URS), undertook a targeted Short Range Endemic (SRE) invertebrate fauna survey of the Iron Valley Project (Iron Ore Holdings Ltd) in June 2011, specifically targeting the Mygalomorph trapdoor spider genus *Aganippe* and scorpion genus *Urodacus* at the request of the Department of Environment and Conservation (DEC). This target survey was subsequent to an extensive SRE survey undertaken by Dalcon Environmental in 2010 (Dalcon Environmental 2011).

Iron Ore Holdings Ltd proposes to develop an iron ore mine on its Iron Valley tenement in the Eastern Pilbara Region of Western Australia (WA). Two associated surveys were conducted initially during May and June 2010 (Dalcon Environmental 2011), with this third targeted SRE survey occurring in June 2011. The targeted SRE survey in June 2011 was conducted within Iron Ore Holdings Ltd tenement M47/1439 and adjoining Rio Tinto Iron Ore's tenement M274/SA for the purpose of obtaining more specimens of potential SRE fauna collected in the previous surveys, in the expectation that the taxonomy of these species can be further resolved and their SRE status determined.

Methods appropriate to the targeted collection of SRE invertebrates were employed, including dry pitfall traps with drift net fences, leaf litter collection, hand foraging, night surveys and burrow excavation.

Six specimens of the Mygalomorph spider previously identified from the 2010 surveys as *Aganippe* “sp. (fem)” (Dalcon Environmental 2011) were collected. Five out of the six specimens were identified to species level as *Aganippe* ‘MYG086’; the sixth specimen was a juvenile but is considered to belong to the same species as the other five specimens. Three of the *Aganippe* “MYG086” specimens were each recorded at survey sites IOH Site 01 and RIO Site 02. *Aganippe* “MYG086” is only known from the three surveys of the Iron Valley Project as well as a survey at Roy Hill Station, ca. 80 km southeast of Iron Valley. As these two recorded occurrences of *Aganippe* “MYG086” fall within the currently accepted SRE definition of fauna exhibiting home ranges less than 100,000 km² (Harvey 2002), it is reasonable to consider *Aganippe* “MYG086” as potentially SRE fauna.

The target *Urodacus* sp. found in the previous survey of the area was discovered to be *Urodacus* ‘megamastigus short’ which is not an SRE (Volschenk 2010).

Table of Contents

Acknowledgements.....	iv
Executive Summary	v
Table of Contents	vi
List of Figures.....	viii
List of Tables.....	ix
1. INTRODUCTION.....	1
1.1. Project Background	1
1.2. Objectives.....	4
2. PROJECT AREA.....	6
2.1. Regional Setting	6
2.2. Regional Climate.....	6
2.3. Project Setting	8
2.4. Legislative Framework.....	9
3. SHORT RANGE ENDEMIC FAUNA - BACKGROUND	12
3.1. Potential Threats to Short Range Endemic Populations.....	15
4. METHODS	16
4.1. Survey Timing.....	16
4.2. Weather During the Survey Period	16
4.3. Site Selection.....	17
4.4. Sampling Methodology	23
4.4.1. Dry Pitfall Traps with Drift Net Fencing	23
4.4.2. Scorpion Trapping.....	25
4.4.3. Hand Foraging.....	25
4.4.4. Collection of Leaf Litter.....	25
4.4.5. Burrow Excavation.....	26
4.4.6. Night Surveys.....	26
4.5. Laboratory Methods	26
4.6. Habitat Assessment Methodology.....	28
4.7. Curation and Species Identification	28
5. RESULTS AND DISCUSSION	29
5.1. Arachnida	29

5.1.1.	Araneae, Mygalomorphae (Mygalomorph Spiders).....	29
5.1.2.	Scorpiones (Scorpions)	36
5.2.	Results Summary.....	38
6.	VEGETATION ASSESSMENT	40
6.1.	Vegetation Assessment and Collection Methods	40
6.2.	Results of Habitat Assessment – IOH Sites	43
6.3.	Results of Habitat Assessment - RIO Sites	44
6.3.1.	RIO Site 01	44
6.3.2.	RIO Site 02.....	45
6.4.	IOH and RIO Vegetation Assessment Site Comparisons	45
6.4.1.	RIO Vegetation Assessment Site 01	48
6.4.2.	RIO Vegetation Assessment Site 02	48
6.4.3.	RIO Vegetation Assessment Site 03	49
6.4.4.	RIO Vegetation Assessment Site 04	49
7.	SURVEY ADEQUACY AND LIMITATIONS.....	51
8.	CONCLUSIONS	54
9.	RECOMMENDATIONS.....	57
9.1.	General recommendations.....	57
10.	STUDY TEAM	58
11.	REFERENCES.....	59
12.	Appendix 1 – GPS Coordinates	64
13.	Appendix 2 – Vegetation Survey Results	69
14.	Appendix 3 – Habitat Assessment Sheets	72

List of Figures

Figure 1: Long transect line from the Dalcon Environmental 2010 SRE Survey at IOH.....	2
Figure 2: Key mining components and activities of the proposed Project. White rectangle indicates area depicted in Figure 4 and 16.	3
Figure 3: Average Temperature and Rainfall 1981 – 2010 from Newman Airport weather station (Station ID: 001176) (Bureau of Meteorology 2011a).	7
Figure 4: Daily minimum and maximum temperature and rainfall from the Newman Airport weather (Station ID 001176) in June 2011 (BOM, 2011).	17
Figure 5: Site locations within the Iron Valley (IOH – left side of tenement boundary) and Rio Tinto (RIO – right side of tenement boundary) for the targeted SRE survey.	19
Figure 6: Sites One and Two within the Iron Valley tenement (IOHS01 & IOHS02) for the targeted SRE survey.	20
Figure 7: Rio Tinto Site One locations within the Rio Tinto Iron Ore’s tenement (RIOS01).	21
Figure 8: Rio Tinto Site Two locations within the Rio Tinto Iron Ore’s tenement (RIOS02).	22
Figure 9: A typical dry pitfall Trap without a lid and with two drift net fences.	24
Figure 10: Locating and excavating spider burrows. The scale bar below the “lids” of the Mygalomorph spider burrow = 2.5 cm, the silk-lined tunnels of the excavated burrows extended to a depth of about 30 – 40 cm (May/June 2010 survey).	27
Figure 11: Habitat of RIO Site 02, showing the location of an excavated Aganippe ‘MYG086’ burrow.	32
Figure 12: Aganippe ‘MYG086’ in a typical Mygalomorph aggressive posture (front).	33
Figure 13: Aganippe ‘MYG086’ in a typical Mygalomorph aggressive posture (dorsal).	33
Figure 14: Aganippe ‘MYG086’ trapdoor burrow (closed).	34
Figure 15: Aganippe ‘MYG086’ trapdoor burrow (open).	34
Figure 16: Missulena ‘MYG045’ (lateral).	35
Figure 17: Missulena ‘MYG045’ (front).	36
Figure 18: Representational vegetation map of the survey area using visual differences in vegetation assemblages to distinguish floral borders.	42
Figure 19: IOH Site 01 and 02 - Typical vegetation complex.	44

List of Tables

Table 1: List of expertise used for taxonomic verification of potential SRE taxa found throughout the survey. 28

Table 2: List of the potential SRE taxa recorded for the targeted SRE survey, SRE significance and which site location they were found..... 29

Table 3: Table of all invertebrate groups and individuals collected during the targeted SRE survey. 39

Table 4: The six flora species present in all RIO Vegetation Assessment Sites..... 46

Table 5: Flora species present at IOH and Rio Tinto Iron Ore vegetation assessment sites.. 47

Table 6: Newman Aerodrome weather station monthly average rainfall (mm) over the period 1981 – 2010, running monthly total for 2011 and monthly differences. 52

1. INTRODUCTION

In May 2010 Dalcon Environmental was commissioned by URS Australia Pty Ltd (URS) on behalf of Iron Ore Holdings Ltd (IOH) to undertake a Short Range Endemic (SRE) invertebrate fauna survey at the Iron Valley Project (the Project) in the Pilbara Region of Western Australia. As a result of this survey (Dalcon Environmental 2011), two potential SRE taxa were recorded but neither could be identified to species level and hence their SRE status could not be determined. These potential SRE taxa were a species of scorpion, *Urodachus* sp. juv, and a Mygalomorph (trapdoor) spider, *Aganippe* sp. (fem).

Only a single juvenile specimen of the *Urodachus* was found in the 2010 survey (in a wet pitfall trap on the gravel plains of the “long transect” (Figure 1), and adults are required for identification to species level. Eleven female *Aganippe* trapdoor spiders were excavated from burrows also on the gravel plains of the “long transect” (Figure 1) in the 2010 survey, and male spiders are required for identification to species level and subsequent determination of SRE status.

This report documents the Project background and the methods and results of a targeted survey for the Mygalomorph trapdoor spider genus *Aganippe* and scorpion genus *Urodacus*, which was undertaken during June 2011.

1.1. Project Background

IOH proposes to develop an iron ore mine on its Iron Valley tenement in the Eastern Pilbara Region of Western Australia (WA), for the Iron Valley Project (Figure 2). The Iron Valley deposit lies within Mining Lease M47/1439.

Initial drilling has been undertaken at the Iron Valley deposit since 2008. The Project Area has been previously undisturbed by mining, and has been used by the Marillana Station pastoralists for cattle grazing.

The Project Area is located approximately 90 km north-west of Newman and 150km east of Tom Price and located in close proximity to a number of operating iron ore mines including Rio Tinto Iron Ore’s (RTIO) Yandicoogina operation, BHP Billiton Iron Ore’s (BHPBIO) Yandi operation and Fortescue Metals Group (FMG) Cloudbreak operation.

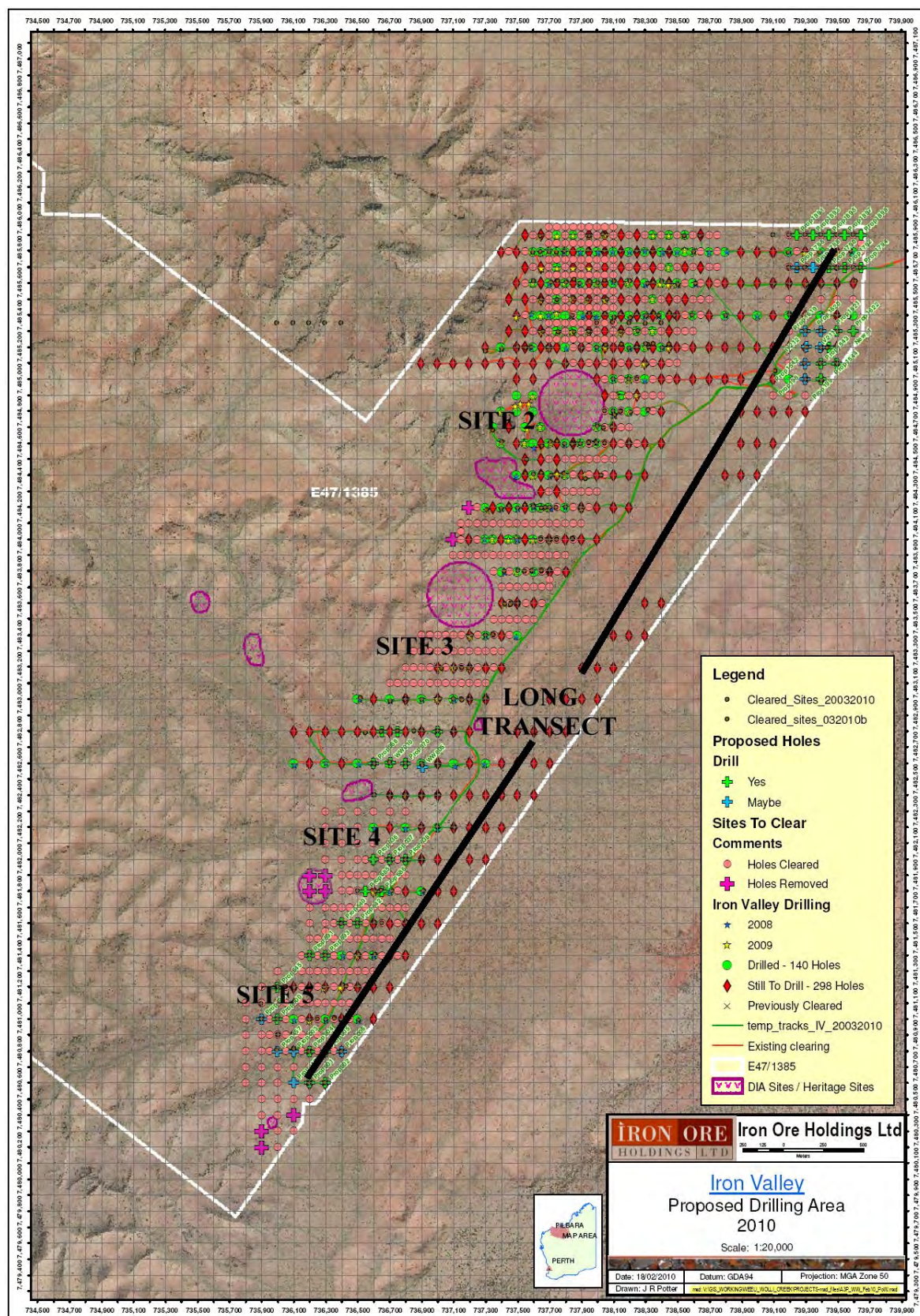


Figure 1: Long transect line from the Dalcon Environmental 2010 SRE Survey at IOH.

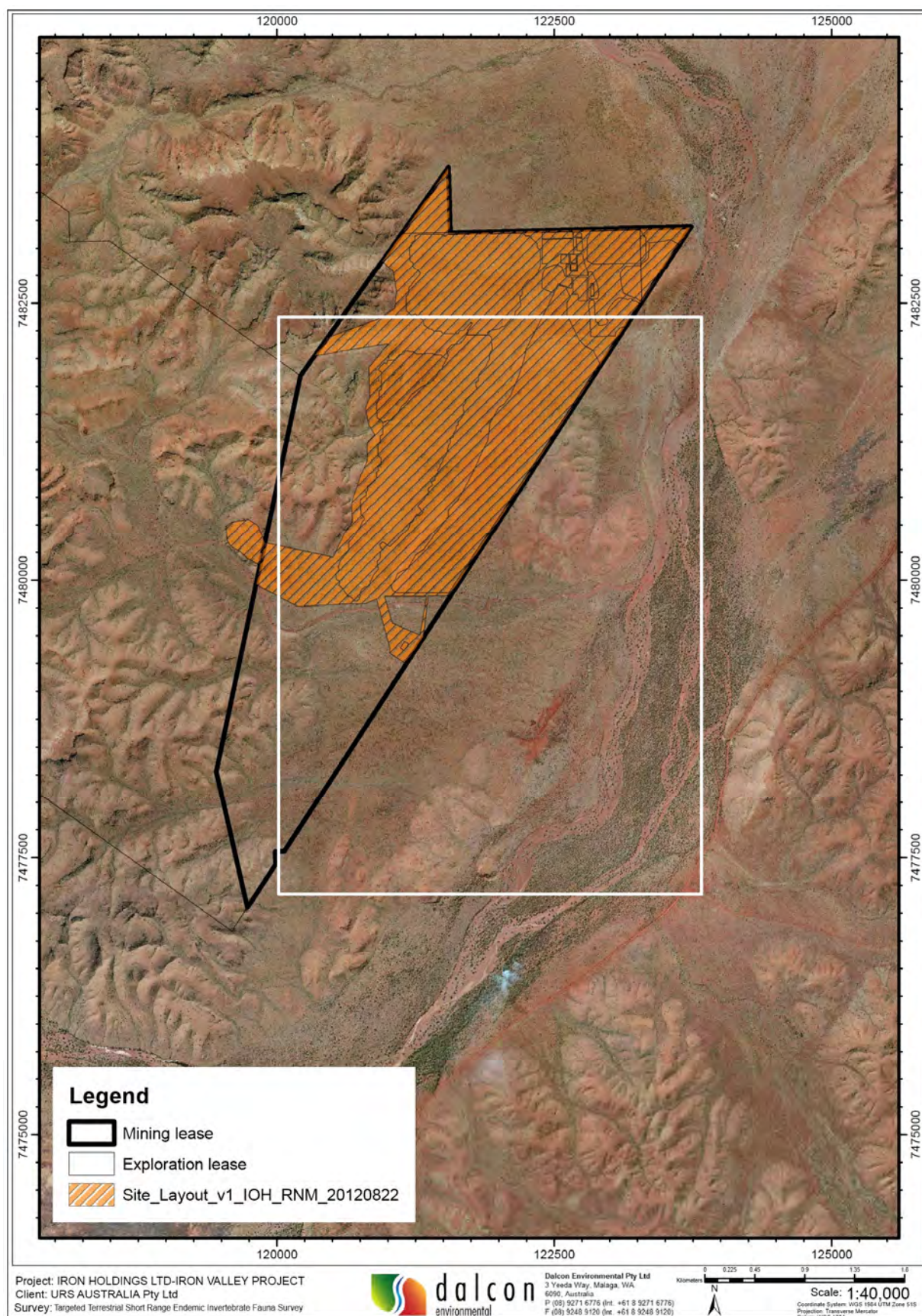


Figure 2: Key mining components and activities of the proposed Project. White rectangle indicates area depicted in Figure 5.

1.2.Objectives

This targeted survey was undertaken as a result of discussions with the Department of Environment and Conservation (DEC) in regards to the findings of the 2010 SRE survey (Dalcon Environmental, 2011), which highlighted the taxonomic uncertainty of the potential SRE taxa *Aganippe* sp. (fem) and *Urodachus* sp. (juv). The response from the DEC outlined the need to obtain mature male specimens for both these taxa so that their SRE status could be determined along with specific habitat information. The collection of male specimens would provide much greater taxonomic certainty and combined with habitat information, should help to address the uncertainty regarding the risk to these taxa from the Project, by demonstrating that these species are found in habitat that is widespread.

The DEC recommended that a targeted survey be undertaken using active searching techniques (such as hand foraging, burrow inspections and excavations, collection of leaf litter and night surveys) and dry pitfall trapping. The targeted survey should be undertaken at locations within the Project Area where these species are known to occur (based on the previous survey) as well where known to occur (based on the previous survey) in areas of similar habitat beyond the Project (impact) Area (Figure 5, 7, 8, 18), with the objective of capturing male specimens of the taxa listed above. In addition to this, habitat descriptions should be recorded of the locations where the targeted taxa are found, which can then be used to provide some risk based assessment. This combined approach should provide adequate data for the DEC to further assess the Project's impact on invertebrate/SRE fauna, as advised by the DEC.

The objectives of this survey therefore are:

- 1) Undertake a targeted survey for male specimens of the trapdoor spider *Aganippe* sp. (fem) at sites recorded in the 2010 survey and from similar habitat within and beyond the Project Area;
- 2) Describe the preferred habitat in which the burrows of the trapdoor spider *Aganippe* sp. (fem) as recorded in the 2010 survey occur;
- 3) Extrapolate the extent of preferred *Aganippe* sp. (fem) habitat throughout the Project Area to the best extent possible in order to estimate distribution and locate new *Aganippe* sp. populations;

- 4) Undertake a targeted survey for male specimens of the scorpion *Urodachus* sp. (juv) at sites recorded in the 2010 survey and from similar habitat within and beyond the Project Area;
- 5) Describe the habitat in which the burrows of the scorpion *Urodachus* sp. (juv) as recorded in the 2010 survey occur;
- 6) Extrapolate the extent of this preferred *Urodachus* sp. (juv) habitat throughout the Project Area.

This survey was conducted as a targeted SRE survey as per the EPA's Guidance Statement No. 20, Sampling of SRE Invertebrate Fauna for Environmental Impact Assessment in WA (EPA, 2009) and the DEC recommendations (Durant B 2011, pers. comm., 15 April) focusing on:

1. Identifying areas in which vegetation is under threat of being cleared or irrevocably damaged in a way which would directly affect SRE fauna habitat.
2. Identifying areas sensitive to and likely subjected to changes in hydrology, fire regimes, introduction of weed or soil pathogens which would directly affect SRE fauna habitat.
3. Identify any other potential impacts which would directly affect SRE fauna habitat.

Permission was granted for Dalcon Environmental to conduct sampling and vegetation surveys in the adjacent Rio Tinto tenement (Best D 2011, pers. comm., 29 May) to find areas similar to IOH sites containing the targeted SRE in the hopes of finding target SRE fauna outside IOH tenement.

2. PROJECT AREA

2.1. Regional Setting

The Project is situated within the Pilbara Region of WA within the Hamersley Range. It lies within the Weeli Wolli Catchment which drains into the Fortescue River Basin (known as the Fortescue Marsh). The Hamersley Range contains large deposits of iron ore and is a source of a high percentage of the iron ore mined in Australia (Department of the Environment, Water, Heritage and the Arts 2001 – now known as Department of Sustainability, Environmental, Water, Population and Communities). It is a mountainous area of Proterozoic (545-2500 million years ago) sedimentary ranges and plateaux, reaching an elevation of 1250 m above sea level (Durrant *et al.*, 2010).

The Project is within the Pilbara Bioregion which consists of mountainous ranges and plateaus with cliffs and deep gorges, alluvial/granite/basalt plains with an arid subtropical climate, mild winters and summer rain. The Pilbara Bioregion is dominated by hummock grasslands (spinifex) with some Acacia shrub land. The region is extensively grazed by cattle (Department of the Environment, Water, Heritage and the Arts, 2001).

Cyclones and local thunderstorms cause major flows in river systems almost every year between December and April. These rivers are generally dry between August and November with only occasional flows (Department of the Environment, Water, Heritage and the Arts, 2001).

2.2. Regional Climate

Climate for the region was collected from the Bureau of Meteorology (BOM) Newman Aerodrome weather station, approximately 90 km north-west of the Project Area. A weather station is present at Marillana Station, however, it is only equipped to record temperature and data is inconsistent (Bureau of Meteorology, 2011b).

The Project Area experiences an arid tropical climate characterised by hot wet summers and mild dry winters. Annual average rainfall of 309.6 mm (200 – 350 mm) occurs between December and June (Figure 3) but can vary widely (Department of the Environment, Water, Heritage and the Arts, 2001). Highest average temperature of 37 °C occurs between November to February, declining to median temperature of 25 °C during winter months (Figure 3) (Department of the Environment, Water, Heritage and the Arts, 2001). Effect of

climate upon potential short-range endemic invertebrate yields is discussed in Section 4.1 and Section 4.2.

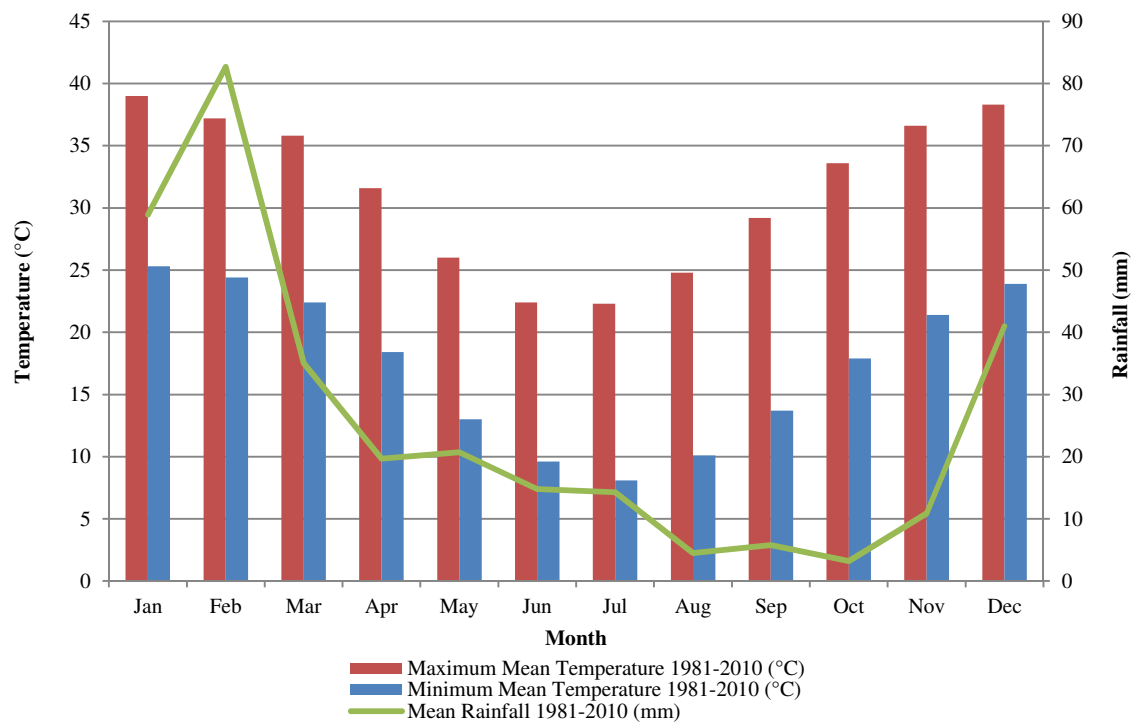


Figure 3: Average Temperature and Rainfall 1981 – 2010 from Newman Airport weather station (Station ID: 001176) (Bureau of Meteorology, 2011a).

2.3. Project Setting

IOH proposes to clear up to 674 ha of vegetation for the Project (excluding any future transport corridors). The Project Area has historically been used for pastoral activities and in the past several years, mineral exploration has also been undertaken within the Project Area. Dalcon observed that a recent fire had occurred within the Project Area, in early 2009.

The Project Area occurs within the Hamersley Plateau Botanical District, which is grouped within the Eremaean Botanical Province (Beard, 1979). The vegetation condition and assemblage, including the presence of any weed species within the Project Area, has been assessed during the flora and vegetation assessments undertaken as part of the EIA for the Project.

The Project is located within the Eastern Pilbara Region and is dominated by the Hamersley Plateau (Van Vreeswyk *et al.*, 2004). The geology in the region comprises lower Proterozoic shale, chert, mudstone, sandstone and dolomite (Van Vreeswyk *et al.*, 2004). The Project Area is located within the Boolgeeda and Newman Land systems which is not prone to soil erosion, or land degradation (Van Vreeswyk *et al.*, 2004). This land system comprises of hills, ridges, plateaux remnants and breakaways of meta-sedimentary and sedimentary rocks, supporting hard Spinifex and predominantly supports hard Spinifex vegetation. The soils generally encountered within the McKay land system comprise stony soils, red deep loamy duplex with minor shallow loams and red loamy earths with river bed soil in channels (Van Vreeswyk *et al.*, 2004). Although not favoured by livestock (Van Vreeswyk *et al.*, 2004), the Project Area has historically been used for pastoral use, and is currently a pastoral station (Marillana Station).

It was evident that the southern part of the tenement had recently been subject to wildfire, with the wildfire occurring in early 2009. The area burnt was south of the creek line (a tributary of Weeli Wolli Creek) which runs in an east-west direction across the southern part of the tenement. This burning had altered the structure of the vegetation community and removed all of the Spinifex and most of the ground cover and litter. The effect this has had on the invertebrate community is largely unknown (see Section 3) and beyond the scope of this survey. Different invertebrate groups respond differently to fire, however there were some differences in the invertebrate communities observed in this burnt region and these will be discussed in Section 6.2, and Section 6.4.

2.4. Legislative Framework

The *Environmental Protection Act 1986* (EP Act) was developed to provide for the formation of an EPA. The Act allows the EPA to carry out measures “for the prevention, control and abatement of pollution and environmental harm, for the conservation, preservation, protection, enhancement and management of the environment and for matters incidental to or connected with the foregoing”. The object and principles of the EP Act are outlined in Section 4a of the Act. This section of the Act lists five principles that are necessary to ensure that the objectives of the Act are maintained. Three of these principles relate to native fauna and flora:

1) The Precautionary Principle

Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

In the application of the precautionary principle, decisions should be guided by:

- a) Careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and
- b) An assessment of the risk-weighted consequences of various options.

2) The Principles of Intergeneration Equity

The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

3) The Principle of the Conservation of Biological Diversity and Ecological Integrity

Conservation of biological diversity and ecological integrity should be a fundamental consideration.

Environmental Impact Assessment projects require the assessor(s) to follow EPA guidelines. With regards to this Project there are three applicable guidelines:

- Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact in Western Australia (EPA, 2004); and
- Position Statement No. 3: Terrestrial Biological Surveys as an element of Biodiversity Protection (EPA, 2002) ; and
- Position Statement No. 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA, 2009).

In relation to SRE Fauna, EPA Guidance Statement No. 56 states:

“Comprehensive systematic reviews of different faunal groups often reveal the presence of short-range endemic species (Harvey, 2002). Among the terrestrial fauna there are numerous regions that possess short-range endemics. Mountainous terrains and freshwater habitats often harbour short-range endemics, but the widespread aridification and forest contraction that has occurred since the Miocene has resulted in the fragmentation of populations and the evolution of many new species. Particular attention should be given to these types of species in environmental impact assessment because habitat loss and degradation will further decrease their prospects for long-term survival.

Harvey (2002) considered that although there were occasional short-range endemics among the vertebrates and insects, there were much higher numbers among the molluscs, earthworms, some spider groups (especially the mygalomorphs), millipedes, and some groups of crustaceans. Short-range endemics generally possessed similar ecological and life history characteristics, especially poor powers of dispersal, confinement to discontinuous habitats, slow growth and low fecundity.

Some better known short-range endemic species have been listed as threatened or endangered under State or Commonwealth legislation but the majority have not. Often the lack of knowledge about these species precludes their consideration for listing as threatened or endangered. Listing under legislation should therefore not be the only conservation consideration in environmental impact assessment. The State is committed to the principles and objectives for the protection of biodiversity as outlined in The National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia, 1996). The EPA expects that environmental impact assessment will consider impacts on conservation of short-range endemics in accordance with these principles and objectives.”

Western Australian native fauna are currently protected under Federal and State Acts, the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the WA *Wildlife Conservation Act 1950* (WC Act) respectively.

The EPBC Act was created to protect native species, to prevent extinction and promote recovery of threatened species, and aid in the conservation of migratory species. Section 3 of the EPBC Act lists a number of key objectives in order to achieve this, some of which include:

- Provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance;
- Promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- Promote the conservation of biodiversity; and
- Provide for the protection and conservation of heritage.

Section 3a of the EPBC Act states “decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations” in addition to the ecologically sustainable development principles listed in Section 4a of the EP Act.

The WC Act is applicable to Western Australian wildlife only, and states that all native flora and fauna and migratory species are to be protected at all times.

This survey was undertaken in accordance with all of the principles and objectives detailed above.

3. SHORT RANGE ENDEMIC FAUNA - BACKGROUND

Previously the use of invertebrates in biodiversity surveys has been regarded as problematic due to the high numbers of species involved (Harvey, 2002). In response to this problem Main (1996) suggested that research be conducted specifically on relict species assemblages to determine their habitat requirements. The concept of recognising the major groups which contained a high number of narrow range relictual species was proposed by Harvey (2002), who called these relictual species SREs. An SRE species is defined as having a naturally small distribution of less than 10 000 km² (100 km x 100 km) (Harvey, 2002). SREs were found to display certain ecological and life history traits:

- Poor dispersal ability (e.g. most spiders can disperse by ballooning, but trapdoors [Mygalomorphs] do not use this method and many are SREs);
- Confinement to discontinuous habitats;
- Highly seasonal activity patterns, often only active during cooler and moister periods, which, typically based on rain variations, can be restricted to certain periods; and
- Lower ability to reproduce offspring, or offspring produced in lower numbers.

The existence of SREs is a result of climatic and vegetation changes that have occurred over geological time. Australia used to be part of a super land mass called Gondwanaland and was thickly vegetated with tropical rainforest. The fragmentation of Australia from Gondwana, and its drift northwards, resulted in a decrease in rainfall, resulting in aridification (Main, 1996; 1997). Invertebrate species that used to be common while the land was covered with rainforest found themselves squeezed into the reduced rainforest areas, and today these relictual species are only found in moist and shaded areas. These areas typically include habitats that are isolated by geographical barriers which impedes dispersal and gene flow. A classic example is islands, where the terrestrial environment is surrounded by a marine environment which prevents dispersal to other islands. In this respect, caves and mesas are like islands, possessing environmental conditions that are totally different to the surrounding landscape. Large landform features, like the Devonian Reef system in the Kimberley Region, host a large number of SREs because they act as a barrier, resulting in speciation as a result of fragmentation of populations.

Typical habitats that often contain SRE species include:

- Vine thickets and rainforest patches (usually in the Kimberley and tropics);
- Areas of high rainfall with short summer drought;
- Boulder and rock piles especially if water is shed from rocks;
- Isolated hills and mesas especially if subject to frequent mist, cloud or drizzle;
- Areas where vegetation can harvest water from fog or cloud;
- Vegetated gullies with deep leaf litter;
- Permanent freshwater pools, rivers and wetlands; swamps; springs;
- Areas of impeded groundwater flow;
- South facing slopes of hills and ranges which are sheltered from summer heat;
- Mouths of caves, inside of caves;
- Mountainous terrain and gorges;
- Islands;
- Granite outcrops (Main, 1997);
- Ridges that create a barrier (e.g. Devonian Reef in the Kimberley); and
- Palaeodrainage channels (Raven, 2008).

Each of these habitats would support a small and spatially isolated population, which would be further restricted due to SRE low dispersal power (Main, 1996; Harvey, 2002).

The process of aridification and rainforest reduction has resulted in the fragmentation of invertebrate populations and a tendency for the evolution of new species with small distribution (EPA, 2009). Due to SREs being restricted to specialized microhabitats they are very vulnerable to anthropogenic disturbances and will often be unable to recover from disturbance and thus face the prospect of extinction. These disturbances can be due to agriculture, mineral extraction, roading and housing developments. Fire can also be a threat because an entire population may be restricted to a single microhabitat (EPA, 2009).

Not all taxa are characterised by a large number of SREs. Although there are insects which could be described as SRE, no insect Orders have a high percentage of SRE. This is mainly because insects are winged and usually highly mobile. Some flightless insects could be considered SREs as their range is limited, but no Order is made up of a high percentage of flightless individuals (Yeates *et al.*, 2002).

Harvey (2002) has identified certain taxa that contain a high proportion of SREs in Australia, these are:

- Mollusca - Gastropoda (land snails);
- Annelida - Oligochaeta (earthworms);
- Onychophora (velvet worms);
- Arachnida - Scorpionida (scorpions);
- Arachnida - Araneae (mostly Mygalomorphae [trapdoor] spiders);
- Arachnida – Pseudoscorpionida (pseudoscorpions);
- Arachnida – Schizomida (schizomids);
- Malacostraca – Isopoda (slaters/woodlice); and
- Diplopoda – Chordeumatida (millipedes).

It should be noted that the identification of known SREs in WA is based on the identification provided by the WA Museum. Due to the poor current state of knowledge of the taxonomy of groups like Isopods (woodlice) they are currently mostly identified to morphospecies level, and as a result SRE identification cannot be achieved. For this reason it is possible that SRE species do occur at a project site but taxonomic difficulties make their complete identification impossible.

From the Iron Valley survey in the Pilbara, it is unlikely that Velvet worms (Onychophora) would be recorded as they are usually found in the moister south-west of WA, avoiding the arid areas of the state (Monge-Najera, 1994). Schizomids are true troglobites found in deep crevices of mesas and are unlikely to be found in the Project Area because of the lack of sufficiently deep caves. Earthworms (Annelida – Oligochaeta) could occur but currently there is no standard acceptable method to survey them. Consequently the groups to be surveyed at the Iron Valley site were landsnails, trapdoor spider, pseudoscorpions, slaters/woodlice and millipedes (Gastropoda, Scorpionida, Mygalomorphae, Pseudoscorpionida, Isopoda and Diplopoda).

It is important to recognise that the potential SRE groups listed above are not exhaustive, and that invertebrates generally are understudied and poorly understood with most species lacking a formal description. Reliable taxonomic evaluation of many species has only recently been commenced and thus there is very little literature relevant to SREs in peer reviewed journals. Bearing these facts in mind, it is important to adhere to the precautionary principle, as adopted by the EPA/DEC under section 4a of the EP Act.

3.1. Potential Threats to Short Range Endemic Populations

A small distribution range of a particular species may be completely natural and stable, or it may represent a historical fragmentation of range or loss of habitat due to past or continuing threats. It is therefore essential to carefully interpret the range patterns of any species and determine any causes for the restricted range before any conservation management is carried out (New and Sands, 2002).

Issues that need to be considered are dispersal ability, habitat preferences, life history attributes, physiological attributes, habitat availability and biotic/abiotic interactions. Due to their relictual nature, any loss or fragmentation of habitat can cause the extinction of a local SRE (Ponder and Colgan, 2002). Threats to habitats suitable to SREs include (Australian Biological Resource Assessment, 2002):

- Clearing of native vegetation;
- Inappropriate and changed fire regimes (altered fire regimes may act to promote premature drying of mesic refuge habitats for SREs);
- Mineral extraction;
- Road and housing development;
- Grazing; and
- Changed hydrology.

SREs are especially vulnerable to anthropogenic activity due to limited dispersal ability and specific habitat requirements (Eberhard *et.al.*, 2009). Their limited dispersal capabilities make any land degradation likely to fragment their habitat and results in a decrease in population numbers, inbreeding and loss of genetic fitness. Thus if a loss of habitat occurs in only a part of their range this could be highly significant due to fragmentation and the consequent inability to exchange genes between the fragments.

4. METHODS

4.1. Survey Timing

The targeted survey was conducted between the 31st May 2011 and 10th June 2011 with dry pitfall traps deployed and additional invertebrate sampling conducted between the 3rd and 8th of June 2011. The timing of the survey was just outside the preferred timing stated in EPA Guidance Statement No. 20 (EPA, 2009), as this Guidance Statement recommends that terrestrial invertebrate fauna (particularly SRE) surveys in the Pilbara should be conducted from November to April (coinciding with the cyclone season as many SRE species are only found during this wet season). During discussions with the DEC in early 2011 (Durant B 2011, pers. comm., 15 April), the DEC recommended that the survey commence sooner rather than later, and that the proposed timing of late May-June was acceptable (Durant B 2011, pers. comm., 15 April) Fortunately, out of season rainfall between the 4th and 10th June 2011 which significantly increased the yield of SRE Mygalomorph spiders in the targeted survey areas.

4.2. Weather During the Survey Period

Data from the Newman Aerodrome weather station (Station ID 001176, located approximately 90 km south east of the Project Area) indicates that temperature during the survey period ranged from 0.3 °C minimum to 28.6 °C maximum. The monthly rainfall total of 9.4 mm was recorded from 5th to 8th June, with the majority, 8.2 mm falling on the 7th June. (BOM, 2011). However, it was noted by the field team that the survey area experienced continuous drizzle to rain for the majority of the survey period with numerous heavy rain events, so it is likely that the rainfall for the survey area was greater than that recorded from the Newman Airport weather station.

Daily maximum and minimum temperatures, as well as rainfall, recorded from the Newman Airport weather station during the targeted survey month of June 2011 are presented in Figure 4.

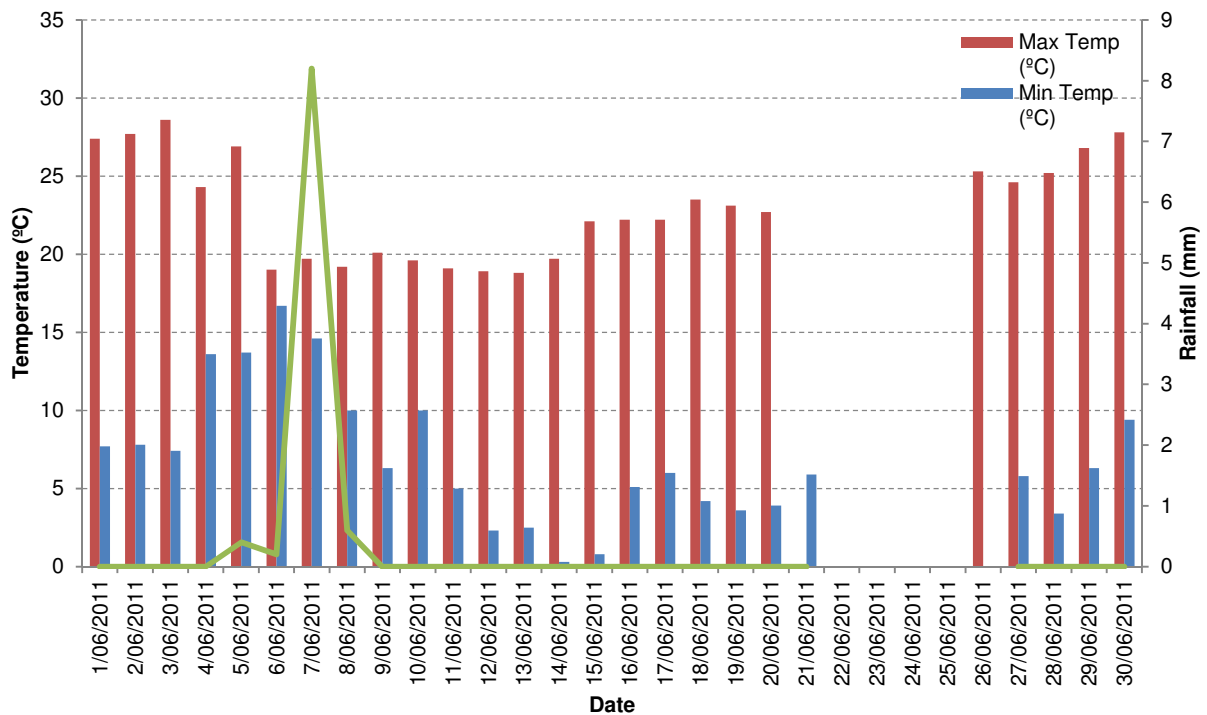


Figure 4: Daily minimum and maximum temperature and rainfall from the Newman Airport weather (Station ID 001176) in June 2011 (BOM, 2011).

4.3. Site Selection

Due to the targeted nature of the current survey, site selection was based upon data collected during previous surveys. Sites were allocated at and around GPS waypoints of previous sites which had recorded instances of the Mygalomorph spider *Aganippe* sp. and scorpions *Urodachus* sp. on the flat plains, around drilling pads and the proposed pit areas (Figure 5). At these targeted sites a grid pattern deployment was utilized to ensure the most comprehensive sampling of the habitat.

As requested by the DEC, sites beyond the Project impact area (the Iron Valley tenement boundary) were also surveyed. Approval was granted to locate sites on Rio Tinto Iron Ore's North Billard tenure (Best D 2011, pers. comm., 29 May) with similar habitats found in the Iron Valley tenement area that is known to contain *Aganippe* and *Urodachus* burrows (Figure 5, 7 and 8).

Rio Tinto survey sites were selected by examining aerial photographs and selecting areas of vegetation exhibiting either: 1) similarities to the Iron Valley Project sites where SRE fauna had been collected previously in the 2010 survey (Dalcon Environmental, 2011), or 2)

vegetation complexes with high probability of containing SRE fauna based on previous Dalcon Environmental surveys and unpublished data, extensive literature review and correspondence with short-range endemic specialists (Harvey, 2002). These potential sites were then verified via ground reconnaissance prior to commencing the surveying (Figure 5, 6, 7 and 8).

Figure 5 displays a distribution overview all site locations associated with the targeted SRE survey. Red icons indicate survey points within the IOH tenement and are expanded upon in Figure 6. Green icons indicate survey points within the adjacent Rio Tinto tenement and are expanded upon in Figure 7 and Figure 8

Figure 6 displays a distribution overview of all sampling sites within the IOH tenement. Two sampling sites, IOH tenement Site 01 (IOHS01 – Figure 6) and IOH tenement Site 02 (IOHS02 – Figure 6) are present. IOHS01 contained 20 dry pitfall traps (Section 4.4.1) in a five-by-four sampling grid matrix. IOHS02, adjacent to IOHS01 contained 10 dry pitfall traps (Section 4.4.1) in a three-by-three sampling grid matrix with one trap positioned at the end of the final sampling row in suitable potential SRE habitat.

Rio Tinto tenement Site 01 (RIOS01 – Figure 7) and Rio Tinto tenement Site 02 (RIOS02 – Figure 8) contained 15 dry pitfall traps (Section 4.4.1) in a five-by-three sampling grid matrix each to standardise sampling methodology.

Total of 60 dry pitfall traps (Section 4.4.1.) were deployed during the targeted survey.

Four vegetation and habitat assessment sites (RIOVEG 01 to 02) were selected in Rio Tinto tenement in areas considered to best represent the vegetation complexes along the tenement boundary line as well as provide suitable habitat for potential SRE fauna (Figure 5).

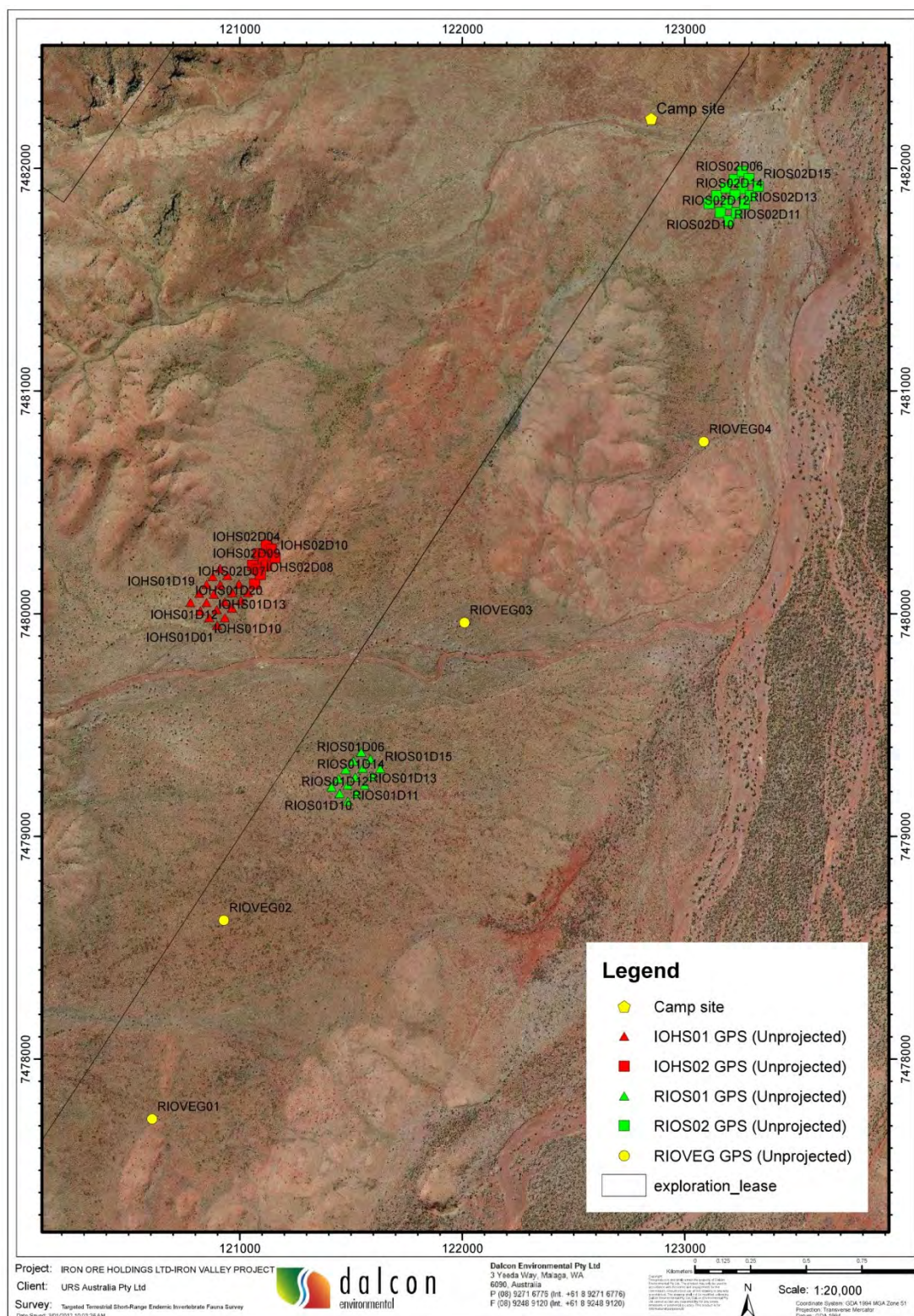


Figure 5: Site locations within the Iron Valley (IOH – left side of tenement boundary) and Rio Tinto (RIO – right side of tenement boundary) for the targeted SRE survey.

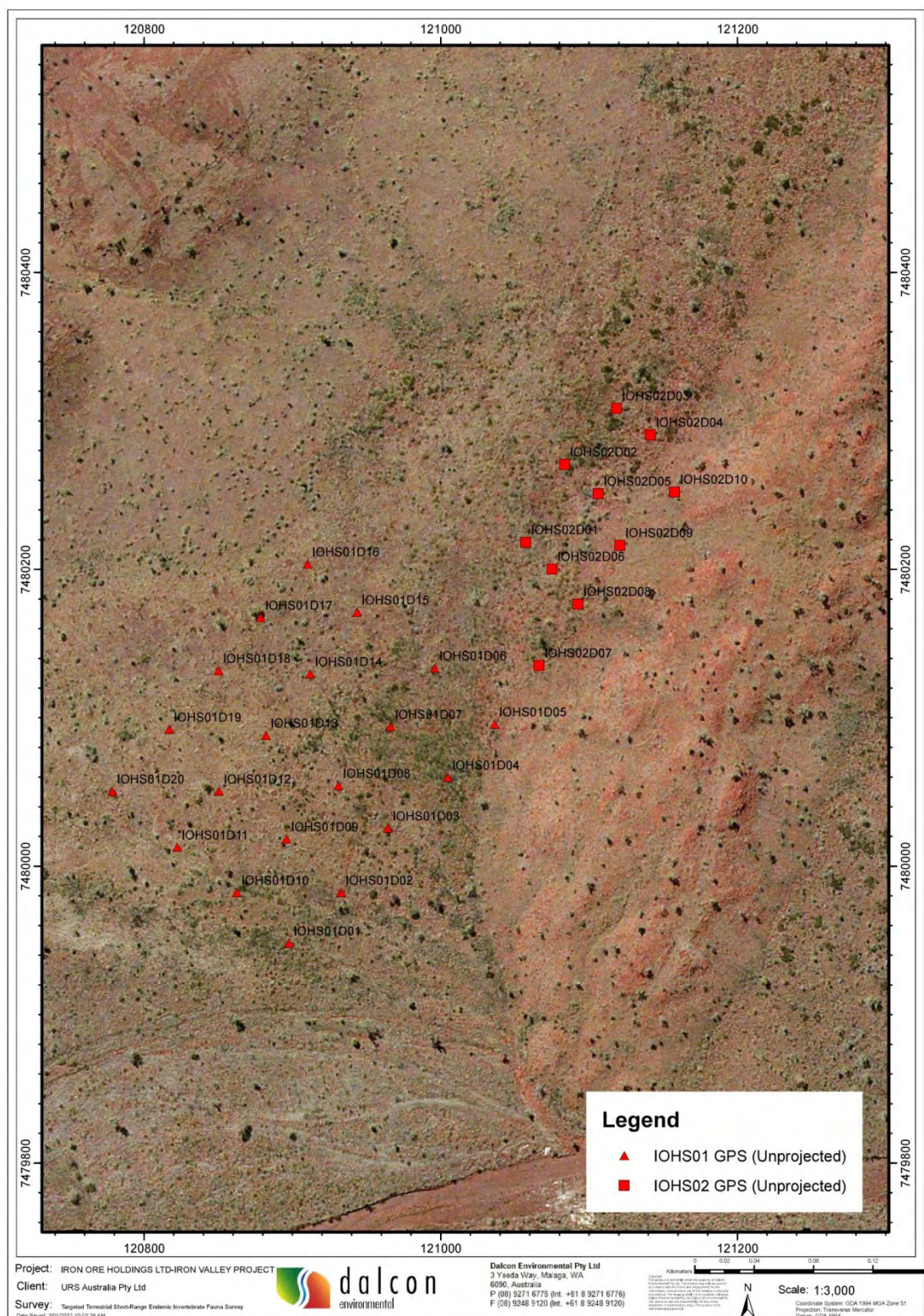


Figure 6: Sites One and Two within the Iron Valley tenement (IOHS01 & IOHS02) for the targeted SRE survey.

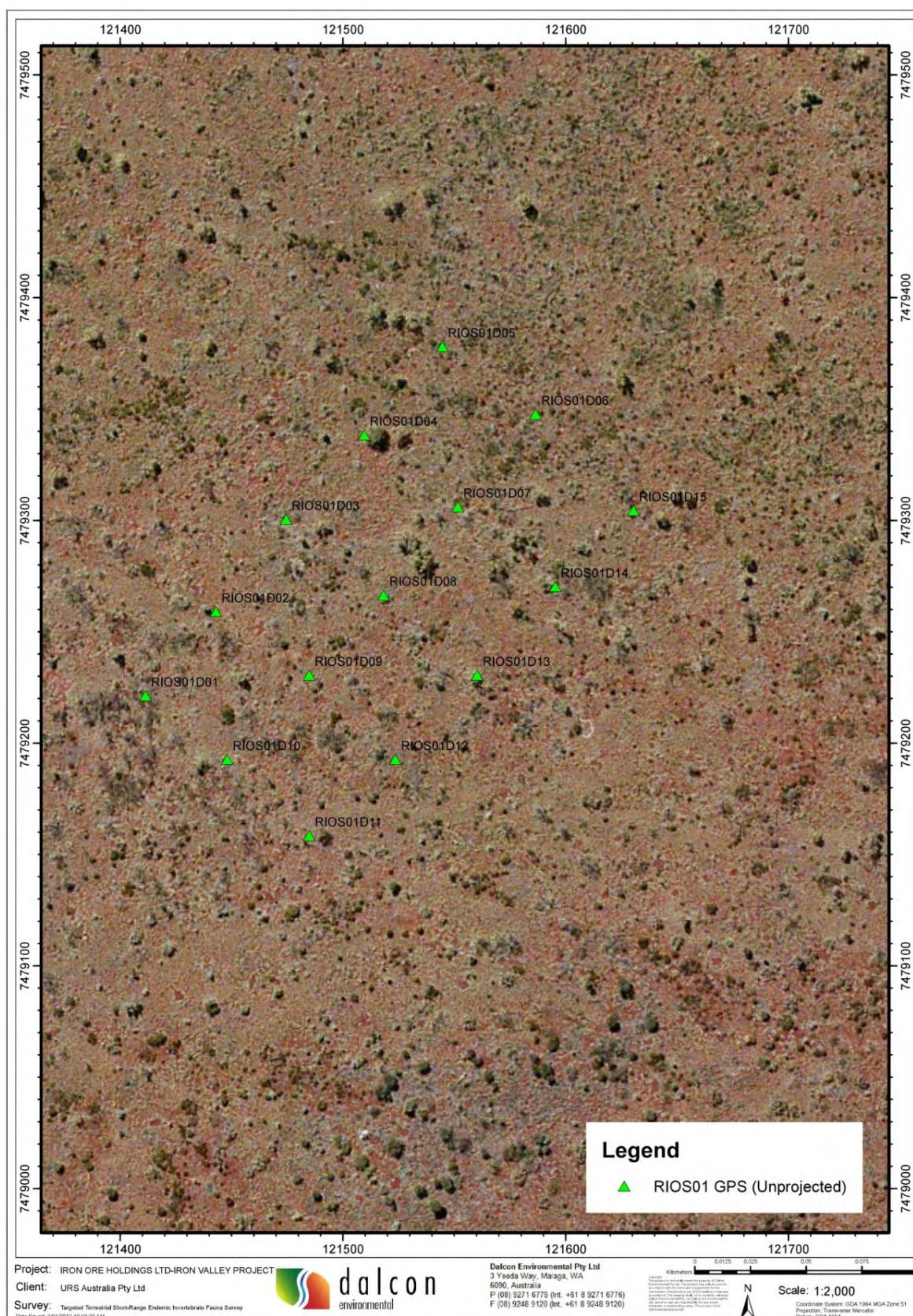


Figure 7: Rio Tinto Site One locations within the Rio Tinto Iron Ore's tenement (RIOS01).

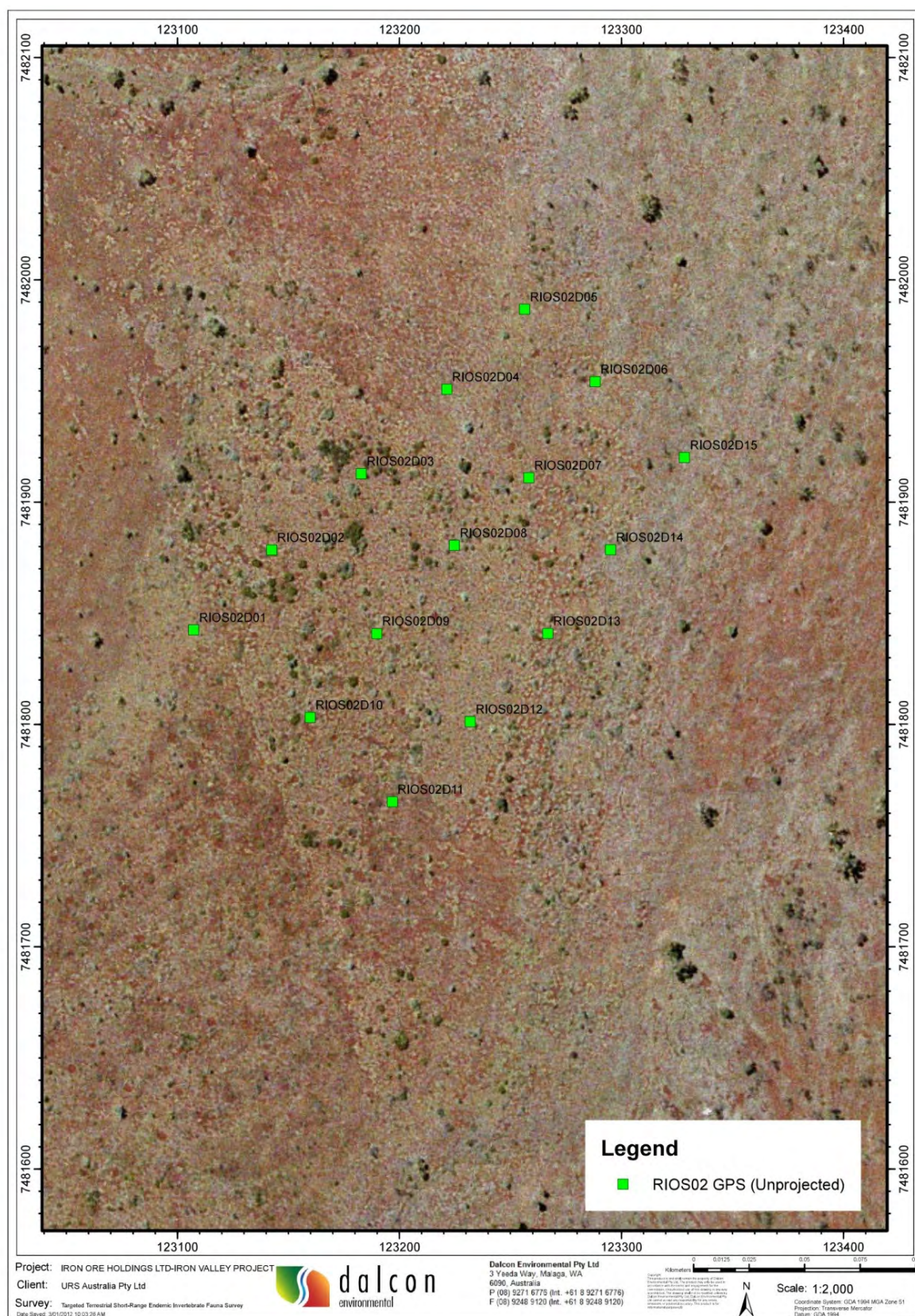


Figure 8: Rio Tinto Site Two locations within the Rio Tinto Iron Ore's tenement (RIOS02).

4.4. Sampling Methodology

Several sampling methodologies were employed for this targeted survey based on the principles outlined in EPA Guidance Statement No. 20: *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA, 2009). This survey focussed on several foraging methodologies (discussed in the following sections) intended to target SRE taxa. Dalcon Environmental presented the DEC with a complete proposed methodology prior to applying for a Regulation 17 License to take (i.e. capture, collect, disturb, study) fauna for scientific purposes (Bradley D 2011, pers. comm., 15 April). These methods were accepted and consequently a Regulation 17 License was awarded to Dalcon Environmental prior to the survey commencing (License No. SF007419).

4.4.1. Dry Pitfall Traps with Drift Net Fencing

Total of 60 dry pitfall traps were deployed during this survey. Dry pitfall traps comprised of a two litre bucket (160 mm diameter, 145 mm depth) dug flush into the ground. To increase sampling efficiency, three drift net fences (metal fly screen, 2 m length, 30 cm height) extending out in a 'Y' configuration (120 degrees apart) each side of the bucket were dug into the ground and ends secured using stakes (Figure 9). Lids were fashioned from the bucket lids and secured by metal pegs to 30 mm above ground level to reduce large vertebrate by catch.

Dry pitfall traps were checked every morning for six days. Potential SRE taxa were collected and vertebrate by-catch carefully released nearby. Dry pitfall traps were constructed in accordance to the regulations imposed by Environmental Protection Authority (2009).

Although recognised that dry pitfall traps have limited success sampling SRE fauna in comparison to other collection methods, their ability to capture fauna live reducing vertebrate by-catch mortality is extremely attractive (Environmental Protection Authority, 2009). Dry pitfall traps have proven very successful in sampling scorpion and mygalomorph fauna during favourable weather conditions (Harvey, 2002).



Figure 9: A typical dry pitfall Trap without a lid and with two drift net fences.

4.4.2. Scorpion Trapping

Targeted scorpion trapping was deployed at each site using plastic cups as small dry pitfall traps, located in close proximity to verified scorpion burrows. Close proximity was standardised by setting the small dry pitfall trap directly in front of and 30 cm away from the scorpion burrow exit. If vegetation or other factors prevented deployment directly in front of the burrow, the trap was deployed 30 cm away from the burrow exit and offset 45 degrees from it. It was the aim of these traps to directly intercept scorpion fauna entering and exiting the burrows for foraging outside of their burrow.

4.4.3. Hand Foraging

Foraging was undertaken by a three person team at all sites for a minimum of three hours each. Hand foraging included turning over rocks, looking under bark and sifting through leaf litter targeting: Araneae (spiders), Scorpiones (scorpions), Pseudoscorpiones (pseudoscorpions), Gastropoda (snails), Isopoda (woodlice) and Diplopoda (millipedes). An organised search pattern following the layout of the trapping regimen at the site and targeted searches under areas of interest (ie. ideal areas of potential SRE habitat) was utilised.

Any specimens collected were carefully picked up and transferred to plastic jars containing 100% ethanol for preservation. A waterproof label was placed in the jar indicating the site location and collection method.

4.4.4. Collection of Leaf Litter

Leaf litter was sparse over much of the Project Area and therefore could not be collected quantitatively. Where available, leaf litter was collected and “double bagged” into large plastic garbage bags. A waterproof label was placed into each bag indicating the site the leaf litter was collected from. These bags were kept in a dark cool place in order to prevent desiccation, and then transported back to the laboratory. Upon arrival at the laboratory, each litter sample was placed into a Tullgren Funnel to extract the invertebrates. Tullgren Funnels are a widely used technique (Upton, 1991) to separate the invertebrates from the leaf litter collected. Leaf litter is placed into a large funnel underneath a heat and light source (in this case a 100W incandescent light globe) for a set duration, commonly two weeks. As the invertebrates move downward through the litter to avoid the heat they eventually fall out of the funnel into a jar containing 100% Glycol to preserve specimens. These jars were then

sorted and specimens collected, labelled and preserved in vials containing 100% ethanol pending analysis.

4.4.5. Burrow Excavation

The ground at all sites was examined visually for the presence of Mygalomorph spider burrows. When these were located, the burrows were documented, photographed and Mygalomorph spider presence and sex verified by using a milliscope. Female spiders rearing young were left undisturbed, however, if no other burrows were found within the site, a singular spider would be excavated for identification purposes. A limited number of females and males were excavated from each site (depending on occurrence) so as to avoid causing unrecoverable damage of the local Mygalomorph population, with the preference to collect male spiders for accurate identification purposes. A representative of each species present would be collected if possible. Excavated spiders were collected, labelled and preserved in vials containing 100% ethanol. Figure 10 illustrates the locating and excavation of a Mygalomorph trap door spider burrow.

Burrow descriptions and photographs of the Mygalomorph specimens collected are presented in Section 5.1.

4.4.6. Night Surveys

Night surveys were conducted using a large ultra violet (UV) blacklight lamp. Scorpions fluoresce under UV light and this method is an excellent technique to find them, as many species of scorpion are nocturnal. This is a standard technique for surveying scorpions (Lowe *et al.*, 2003). Scorpions located were carefully picked up and transferred to labelled jars containing 100% ethanol.

4.5. Laboratory Methods

Upon return to the laboratory, each sample collected during the surveys was entered into Dalcon Environmental's proprietary job track and sample analysis software to record where each sample was collected and a unique numeric sample ID was allocated. An adhesive label was printed out with the sample ID and stuck to the outside of each sample jar.

Samples were processed at varying magnifications under an Olympus SZX7 Zoom Stereo Microscope. Potential SRE taxa were placed into individual vials each labelled with the sample ID.



Figure 10: *Locating and excavating spider burrows. The scale bar below the “lids” of the Mygalomorph spider burrow = 2.5 cm, the silk-lined tunnels of the excavated burrows extended to a depth of about 30 – 40 cm (May/June 2010 survey).*

These samples were passed on to the WA Museum (and other agencies where required) for taxonomic verification together with a database of information including (for each unique sample ID) the date of collection, the site codes, GPS coordinates and the name of the collector(s).

4.6. Habitat Assessment Methodology

Habitat assessment (see Section 6) involved recording at each site:

- Broad SRE habitat type;
- Landscape position;
- Broad vegetation type (including vegetation indicative of suitable SRE habitat);
- Presence of rocky outcrops;
- Suitable soil substrate;
- Leaf litter coverage;
- Presence of SRE fauna;
- Habitat disturbance;
- Habitat physical connectivity.

Dominant vegetation present at each site was labelled and identified by a botanist for vegetation complex comparison. Short-range endemic habitat assessment sheets for all sites are found in Appendix 3.

4.7. Curation and Species Identification

As stated above, taxa belonging to invertebrate groups known to contain SRE species (see Section 3) were forwarded to people from various agencies that have the relevant expertise to identify them to the lowest taxonomic level. The level of taxonomic resolution is dependent upon both the current state of knowledge on a particular taxon and the level of expertise currently available. The experts used for taxonomic verification are presented in Table 1.

Table 1: List of expertise used for taxonomic verification of potential SRE taxa found throughout the survey.

Taxon	Expert	Institution
Aganippe trapdoor spider	Barbara Main	University of Western Australia
Mygalomorph spiders	Volker Framenau	WA Museum
Scorpions	Erich Volshenk	Scorpion ID

5. RESULTS AND DISCUSSION

As per the targeted nature of this survey, invertebrates representing two groups known to contain potential SRE taxa were collected:

- Araneae (mostly Mygalomorphae [trapdoor] spiders);
- Scorpionida (scorpions);

A list of the potential SRE taxa recorded, SRE significance and location collected is presented in Table 2. Results for each of the potential SRE invertebrate groups are discussed in results and discussion.

Table 2: List of the potential SRE taxa recorded for the targeted SRE survey, SRE significance and which site location they were found.

TAXON	Genus/Species	Significance	Site	Total
ARACHNIDA				
Araneae				
Idiopidae	<i>Aganippe</i> sp.	Juvenile	RIO Site 02	1
	<i>Aganippe</i> 'MYG086'	Potentially SRE	IOH Site 01	3
	<i>Aganippe</i> 'MYG086'	Potentially SRE	RIO Site 02	2
			Total	6

5.1. Arachnida

5.1.1. Araneae, Mygalomorphae (Mygalomorph Spiders)

5.1.1.1. Overview

Mygalomorphae are an important group of spiders, many of which are SRE. These spiders have become a focus group in environmental assessment surveys, particularly in recent SRE surveys (Durrant *et al.*, 2010). Their high conservation status is demonstrated by the listing of several mygalomorphs on Schedule 1 (fauna likely to become extinct) of the Wildlife Conservation (Specially Protected Fauna) Notice 2010 by the Western Australian Government. The WA Mygalomorph fauna has impressive biodiversity and is still taxonomically poorly understood with many families and many new species being regularly collected (Durrant *et al.*, 2010).

Spiders can be divided into two groups: the aerially active spiders; and those that live and disperse on the ground. The aerially active spiders use ballooning to disperse their young in the air, and are typically short lived (usually survive one year). They are highly invasive and recolonise quickly after habitat disturbance. Due to their practice of ballooning they tend to be widespread and of no significance regarding SRE. In contrast the Araenomorphae (ground hunters) and Mygalomorphae (trapdoor and funnel-web spiders) are limited to earth bound activity and the young disperse by walking. As a result populations often tend to be very clumped and entire populations can be missed due to the logistical and ethical constraints of wet pitfall trapping programs which limit the number of traps placed (Raven, 2008). Mygalomorphae generally live much longer, up to 20 years old, and are very habitat specific not moving very far from their habitat even if it is under threat. Mygalomorphs are therefore also a useful indicator of the history of disturbance in an area (Raven, 2008).

Raven (2008) has argued that in the Pilbara, Mygalomorph spiders are found where palaeodrainage basins occur, rather than on south facing slopes as suggested by Harvey (2002). Raven bases this argument on the fact that the Pilbara is part of the Western Shield which developed during the Precambrian (600-400 million years ago), has the oldest land surface in the world, and has never been glaciated or submerged. Calcrete channels formed during the Eocene and Oligocene (37-30 million years ago) when the rivers stopping flowing as a result of the dryer conditions, leaving behind the palaeodrainage channels (Karonovic, 2007). For this reason Mygalomorph spiders have had over 200 million years to evolve and adapt to the harsh conditions of the Pilbara. Their main adaptation is the use of burrows, which can extend to a depth of 700 mm (Main, 1982). This Project (and many other iron ore operations in the Pilbara Region) is situated on a Channel Iron Deposit (CID [Iron Ore Holdings Ltd, 2010]). These CIDs are iron-rich fluvial sedimentary deposits which occupy the meandering palaeochannels of the region dating back to the Early to Mid-Tertiary period.

Raven further argues that in the very open country of the Pilbara the gullies are dry and hot by 8am, even in mid-winter and, as a result, may not provide suitable habitat for Mygalomorph spiders. He argues that Mygalomorph spiders will tend to be more common on the flatter areas with more soil, especially those areas associated with palaeodrainage basins. Both Harvey and Raven present valid arguments, and Dalcon Environmental is not in a position to validate one or the other as our experience indicates that both arguments have merit depending upon the nature of the site being surveyed.

Harvey's argument can be considered to refer to SREs in general, which do prefer habitats where they are sheltered from the heat of the day (such as south facing slopes) whereas the argument of Raven is specific to Mygalomorph spiders.

The argument presented by Raven, particularly with respect to Mygalomorph spiders being more common on the flatter areas with more soil in areas associated with palaeodrainage basins (as is the case for this Project), appears to have been confirmed in this survey with Mygalomorph burrows only being located on the flat ground on the 'long transect' (Figure 1). Mygalomorph burrows are cryptic, however and may have not been present but not observed in the rockier terrain throughout the Project during the initial 2010 short-range endemic and 2011 targeted short-range endemic surveys.

Seven Mygalomorph spiders were collected over the duration of the targeted survey. Six of these belong to the genus *Aganippe* and one to genus *Missulena*. Twelve *Aganippe* sp. (fem) specimens were collected during the 2010 short-range endemic IOH survey, however, no similarity can be drawn between 2011 targeted survey yields and the initial 2010 survey as the original 2010 survey specimens were unidentifiable due to incorrect sex (absent sufficient taxonomic features for species identification). The singular *Misulena* specimen collected during the targeted survey (2011) was not previously found during the initial 2010 short-range endemic IOH survey.

5.1.1.2. *Aganippe* 'MYG086' - (Family Idiopidae)

The Mygalomorph family Idiopidae are common throughout Australia and are considered 'typical' trapdoor spiders; spiders that close their burrow with a hinged door. The genus *Aganippe* is common throughout Western Australia with fourteen species described in Australia and many new species awaiting descriptions (Main, 1985). Six specimens of *Aganippe* were collected during the targeted survey, with five of the six specimens accurately identified as *Aganippe* 'MYG086' and one as an unidentifiable juvenile. Three specimens were recorded at IOH Site 01 and two specimens, as well as the juvenile *Aganippe* sp. (which is believed to be the same species as *Aganippe* 'MYG086'), at RIO Site 02. Figure 11 shows a typical example of ideal *Aganippe* Mygalomorph trapdoor spider habitat: open soil area in spinifex grasslands under stands of *Acacia* which provide leaf litter for trap door construction.

Aganippe 'MYG086' (Figures 12 and 13) is only known from two locations, the two surveys of the Iron Valley Project (May/June 2010 and June 2011) and from Roy Hill Station, approximately 80 km southeast of the Iron Valley Project. As these two recorded occurrences

of *Aganippe* ‘MYG086’ fall within the currently accepted SRE definition of fauna exhibiting home ranges less than 10,000 km², it is reasonable to consider *Aganippe* ‘MYG086’ as potentially SRE fauna.



Figure 11: Habitat of RIO Site 02, showing the location of an excavated *Aganippe* ‘MYG086’ burrow.

Due to the diversity of *Aganippe* species known throughout Western Australia, it is difficult to generalise the characteristics of the burrows and trapdoors of the genus. However, *Aganippe* ‘MYG086’ found throughout the survey exhibited a preference to burrowing in open patches of soil under *Acacia* stands with only a moderate amount of leaf litter around the base (Figure 11). This enables the *Aganippe* ‘MYG086’ to use the leaf litter to construct an extremely cryptic door (Figure 14 and 15), while exploiting the increase in open area to better ambush prey. *Aganippe* ‘MYG086’ burrows excavated during the survey were typically 2 to 3 cm in diameter and 30 to 60 cm deep.



Figure 12: *Aganippe 'MYG086' in a typical Mygalomorph aggressive posture (front).*



Figure 13: *Aganippe 'MYG086' in a typical Mygalomorph aggressive posture (dorsal).*



Figure 14: Aganippe ‘MYG086’ trapdoor burrow (closed).



Figure 15: Aganippe ‘MYG086’ trapdoor burrow (open).

5.1.1.3. *Missulena* ‘MYG045’ - (Family Actinopodidae)

A single specimen of *Missulena* ‘MYG045’ (Figures 16 and 17) was collected in a dry trap within the Rio Tinto Iron Ore tenement Site 02 (See Appendix 1 for coordinates). *Missulena* are commonly referred to as ‘Mouse Spiders’ with *M.* ‘MYG045’ being widely distributed throughout the Hamersley subregion of the Pilbara and possibly further south according to the WA Museum database collections (Durrant *et al.* 2010). Because of this it is not considered a SRE. No burrow was found in the location of the dry trap where the *Missulena* ‘MYG045’ was collected during hand foraging due to mygalomorph burrows being cryptic in nature; therefore, no burrow description or images are available.



Figure 16: *Missulena* ‘MYG045’ (lateral).



Figure 17: *Missulena* 'MYG045' (front).

5.1.2. Scorpiones (Scorpions)

5.1.2.1. Overview

Scorpions are found throughout Australia but are particularly common in arid areas. These species excavate deep spiral burrows from which they emerge at night to catch prey. Scorpions are often found under logs and rocks (Harvey and Yen, 1989). Scorpions are represented in WA by two families, Buthidae and Urodacidae.

The family Buthidae is the most widespread of all scorpion families, and in WA are represented by the genera *Isometrus*, *Isometroides* and *Lychas*. The taxonomy of the species making up these genera is problematic as each genus contains numerous undescribed species, this is especially true for *Lychas*. Most Australian Buthidae appear to have wide distributions, however, few taxa have confirmed SRE distributions (Volschenk, 2010).

The family Urodacidae is endemic to Australia where it is represented by the genera *Urodachus* and *Aops*. The greatest issue confronting *Urodachus* taxonomy is the large

number of undescribed species being recognised as a result of current ongoing research on the group. At present there are 22 species of *Urodachus*, but this may represent only 20% of the real diversity in Australia. *Urodachus* is most diverse in WA and only a few species are recorded east of the Great Dividing Range in eastern Australia (Volschenk, 2010).

Two species of scorpion were recorded during the targeted SRE survey totalling four specimens collected. Specimens from both the Buthidae and Urodacidae families were collected. One specimen of *Lychas* “multipunctatus” (from the Buthidae family) was recorded at IOH site 01. Two specimens of *Urodacus* “megamastigus short” (from the Urodacidae family) were recorded at IOH Site 01 and a singular specimen at RIO Site 01. The only specimen of *Lychas* “multipunctatus” was recorded at IHO Site 01.

5.1.2.2. *Lychas* ‘multipunctatus’ - (Family Buthidae)

The genus *Lychas* is widespread throughout Australia and suffers from a lack of taxonomic work. While also represented in Africa, India and eastern Asia, all known Australian taxa are considered endemic. While *Lychas* have wide distributions, however, a small number are known to be SRE.

One specimen of *Lychas* ‘multipunctatus’ was found during the targeted SRE survey at IOH Site 01. This undescribed species is one of the most common and widely distributed scorpions throughout the Western Australia Pilbara region. The species *Lychas* ‘multipunctatus’ is considered non-SRE (Volschenk, 2011). (Note: *Lychas* ‘multipunctatus’ is a well-defined and clearly identified unpublished morphospecies¹).

5.1.2.3. *Urodacus* ‘megamastigus short’ - (Family Urodacidae)

Urodacus is the most diverse scorpion genus in Western Australia and contains both widespread and SRE species. Three specimens of *Urodacus* ‘megamastigus short’ were collected during the survey, two at IOH Site 01 and one at RIO Site 02. This undefined species as been recorded throughout the greater Pilbara bioregion and all subregions, and therefore is considered non-SRE. (Volschenk, 2011).

¹ Morphospecies: A taxonomic species based wholly on morphological differences from related species (Merriam-Webster 2012a)

It is believed that the unidentifiable *Urodacus* sp. collected in the previous survey (May/June 2010) is conspecific with *Urodacus* ‘megamastigus short’ and therefore considered to be non-SRE.

5.2. Results Summary

A list of all invertebrates recorded and numbers found for each sampling method is presented in Table 3, with SREs found only in the Mygalomorph family Idiopidae, species *Aganippe* ‘MYG086’. The majority of taxa listed here are non-SRE taxa but have been included as additional information.

Table 3: Table of all invertebrate groups and individuals collected during the targeted SRE survey.

TAXON	Genus/Species	Significance	Site	Method	Total
ARACHNIDA					
Araneae					
Actinopodidae	<i>Missulena</i> 'MYG045'	Not SRE, Widespread	RIO Site 02	Dry Pitfall	1
Idiopidae	<i>Aganippe</i> sp.	Juvenile	RIO Site 02	Excavation	1
	<i>Aganippe</i> 'MYG086'	Potentially SRE	IOH Site 01	Dry Pitfall	3
	<i>Aganippe</i> 'MYG086'	Potentially SRE	RIO Site 02	Dry Pitfall	2
ARACHNIDA					
Scorpiones					
Urodacidae	<i>Urodacus</i> 'megamastigus short'	Not SRE, Widespread	IOH Site 01	UV Lamp	2
	<i>Urodacus</i> 'megamastigus short'	Not SRE, Widespread	RIO Site 01	UV Lamp	1
Buthidae	<i>Lychas</i> 'multipunctatus'	Not SRE, Widespread	IOH Site 01	UV Lamp	1
Total					11

6. VEGETATION ASSESSMENT

6.1. Vegetation Assessment and Collection Methods

As requested by the DEC for the Targeted SRE survey, a habitat assessment of major flora was undertaken at each site (Durrant B 2011, pers. comm. 15 April). This was undertaken to enable comparison between different survey areas in order to better determine the likelihood of target SRE fauna being present.

The habitat assessment consisted of observing the sites and recording

- Broad habitat type
- Specialised habitat type
- Vegetation complex assemblage
- Substrate analysis
- Presence of geological and topographic points of interest suitable as SRE habitat
- Leaf litter cover and composition
- Level and type of habitat disturbance
- Area physical connectivity and extent
- Visual confirmation during site hand foraging (Section 4.4.3.) of the presence or absence of Mygalomorph trap door spider and scorpion fauna burrows.

The vegetation assemblage at IOH Site 01 and 02 are considered ‘floristic control sites’ to compare the other site vegetation assemblages recorded during the study as these sites already contain target SRE fauna from the previous IOH survey collections (Dalcon Environmental 2011). A comprehensive flora assessment was conducted at IOH Site 01 and 02, however, due to the increased thoroughness (more samples collected) of the vegetation assessment conducted, it is difficult to directly compare vegetation complexes directly due the non-standardised sampling methodology used at the other sites. Vegetation present at each site was collected, labelled and pressed to be identified by a flora taxonomic specialist.

The vegetation boundaries and types indicated on the vegetation map (Figure 18) are drawn using visual differences in perceived vegetation assemblages while in the field and using high resolution aerial photography in the laboratory, not data collected from the vegetation

assessment. This map is for reference only and should by no means be considered an official map of the vegetation complexes occurring within the site.

The objective of vegetation mapping was to provide further certainty ‘that neither species is at risk from the Project. To address this uncertainty more specific habitat information should be provided illustrating that the species are found in habitat that is widespread and not conducive to SREs’ (Durrant B 2010, pers. comm. 15 April). However this habitat information, while indicating that the risk to the species is potentially low, there is however, a risk that it won’t (Durrant B 2010, pers. comm. 15 April).

Although it is confirmed that potential SRE taxa are in habitat that is located in the adjacent Rio Tinto tenement, these taxa still fall within the 10,000 km² restricted population distribution which defines the taxa as a potential SRE (Harvey 2002). As Dalcon Environmental cannot confirm the long term security of SRE populations on the Rio Tinto tenement, these taxa are potentially still at risk.

Vegetation map creation was aided by the vegetation map produced by Astron Environmental Services vegetation and flora survey report (Astron Environmental Services 2011).

Vegetation type 1 is indicative of rocky hillocks and crests containing low *Eucalyptus leucophloia* subsp. *leucophloia* trees with *Grevillea wickhamii* subsp. *hispidula* and *Acacia bivenoso* shrubs over *Triodia* sp. hummock grassland.

Vegetation type 2 is indicative of creek and drainage lines predominated by *Grevillea wickhamii* subsp. *hispidula* over wide and open *Triodia* sp. hummock grassland.

Vegetation type 3 is indicative of family Malvaceae flora including numerous *Corchorus* species, *Hibiscus coatesii* and *Sida* species collected. Vegetation type 3 is also characterised by *Triodia* sp. open grassland, however, there are scattered stands of *Aristida holathera* var. *holathera* and the weed grass *Cenchrus ciliaris*.

Vegetation type 4 is indicative of vegetation adjacent creek and drainage areas by *Grevillea wickhamii* subsp. *hispidula* over open *Triodia* sp. hummock grassland with scattered *Indigofera monophylla* and *Senna* species. This vegetation type is a mix between Vegetation type 2 and Vegetation type 3 although is different enough in assemblage and age to warrant its own vegetation type allocation.

Vegetation type 5 is indicative of scattered *Hakea lorea* subsp. *lorea* over *Petalostylis labicheoides* over open *Triodia* species grassland.

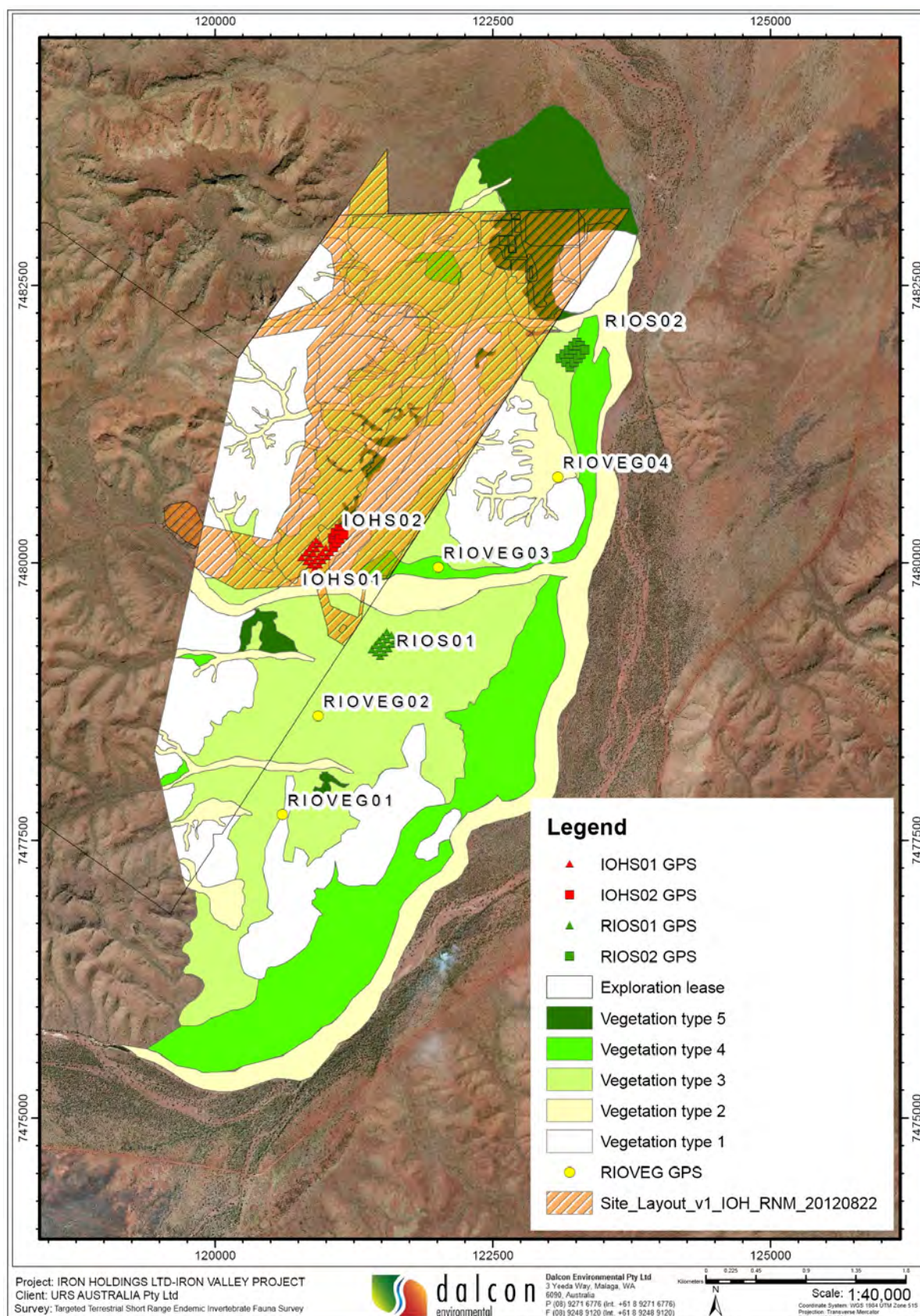


Figure 18: Representational vegetation map of the survey area using visual differences in vegetation assemblages to distinguish perceived floral borders.

6.2. Results of Habitat Assessment – IOH Sites

Due to their close proximity and identical biology and geography, IOH Site 01 (IOH-S01) and IOH Site 02 (IOH-S02) were combined for the vegetation assessment. These two sites were surveyed due to the likelihood of containing the SRE fauna the survey was specifically targeting.

The two IOH sites are broadly characterised as spinifex grassland with open ground scattered Eucalyptus over-storey and Acacia under-storey, transitioning to open grasslands towards the elevated terrain to the west (Figure 19). The substrate is suitable for Mygalomorph spiders and scorpions as it consists of loosely compacted red soil with scattered rocks and pebbles (35% coverage) with spinifex clumps providing shelter and microhabitat. Leaf litter coverage was minimal within both sites. However, in the south west corner of IOH Site 02, young vegetation recovering from previous fires formed thick stands with up to 60 % leaf litter coverage. The north east corner of IOH Site 02 exhibits a transition area in geography, with ground substrate consisting of 15 % small pebbles, 85 % large rocks as the site progressed into a nearby rocky ridgeline. This impenetrable rocky habitat is unsuitable for the burrow dwelling Mygalomorph trapdoor spiders and scorpion fauna. This vegetation type is broadly represented in Figure 18 as Vegetation Type 3, however, IOH Site 02 also passes briefly into Vegetation type 5.

IOH Site 01 and IOH Site 02 are located within the proposed disturbance area for the project, with drill lines, drill pads and severe soil disturbance already present throughout the sites. The IOH sites are also heavily eroded in areas by artificial drainage lines created from exploration disturbances. Evidence of cattle grazing, anthropogenic disturbances and weed invasion are also present (Astron Environmental Services 2011).

A total of 54 flora species were collected during the vegetation assessment at both IOH sites (see Appendix 2).



Figure 19: IOH Site 01 and 02 - Typical vegetation complex.

6.3. Results of Habitat Assessment - RIO Sites

6.3.1. RIO Site 01

Rio Tinto Iron Ore Site 01 (RIO-S01) is characterised by spinifex grassland with open soil patches and sparse Eucalyptus over-storey (Table 5, Appendix 3). Soil substrate is suitable for Mygalomorph trapdoor and scorpion fauna to burrow in, although slightly more compacted than the IOH sites. Overall leaf litter coverage throughout the site is minimal, however, a moderate to high amount of leaf litter was present under localised Acacia stands which are ideal for Mygalomorph trapdoor spiders as they commonly use leaf litter in the construction of burrow doors. This vegetation type is broadly represented in Figure 18 as Vegetation Type 3. Mygalomorph trapdoor spiders and scorpions were present at the site (refer to SRE fauna collected in Table 2).

Fire is the dominant disturbance observed at RIO-S01 and is likely responsible for the age and composition of the vegetation assemblage present. Minor signs of cattle grazing and runoff erosion are also present. Twenty two representative flora species were collected at RIO-S01,

exhibiting the highest percentage similarity in comparison to both the IOH sites at 41 %. Only two species of RIO-S01 are unique to the site.

6.3.2. RIO Site 02

Rio Tinto Iron Ore Site 02 (RIO-S02) is a flat plain situated adjacent land subjected to inundation associated with the seasonal flow of Weeli Wolli Creek. Vegetation complex is characterised by spinifex grassland with a mixed Acacia woodland over-storey (Table 5, Appendix 3). The open areas of this site have medium compacted soil between clumps of spinifex which are ideal for SRE Mygalomorph trapdoor spiders and scorpion fauna. The medium to high concentrations (60 – 100 %) of leaf litter under Acacia stands are also ideal for SRE Mygalomorph trapdoor spiders and scorpion fauna, despite overall leaf litter coverage of the site being insignificant. This vegetation type is broadly represented in Figure 18 as Vegetation Type 3 and Vegetation Type 4. Mygalomorph trapdoor spiders were present in RIO-S02 under the Acacia stands, however, no scorpion burrows were found.

Eleven flora species dominated the vegetation complex present at Rio Tinto Iron Ore Site 02 (Table 5). Of these eleven species, three percent were unique to the site: *Acacia colei* var. *ileocarpa* and *Velleia connata*. The site, however, exhibits a 16 % similarity in species composition with IOH Sites 01 and 02.

6.4. IOH and RIO Vegetation Assessment Site Comparisons

Due to their close proximity and identical flora complex and geography, IOH Site 01 (IOH-S01) and IOH Site 02 (IOH-S02) were combined for the vegetation assessment. In contrast, the Rio Tinto Iron Ore vegetation assessment sites were sufficiently isolated by distance and contain unique floristic complexes that they are discussed separately here.

Only six species were present in all four Rio Tinto tenement vegetation assessment sites (Table 4). It is important to note that no SRE fauna sampling regimen was deployed at the RIO vegetation assessment sites

Table 4: The six flora species present in all RIO Vegetation Assessment Sites.

Name	Family
<i>Corchorus lasiocarpus</i> subsp. <i>lasiocarpus</i>	Malvaceae
<i>Corchorus sidoides</i> subsp. <i>sidoides</i>	Malvaceae
<i>Petalostylis labichieoides</i>	Fabaceae
<i>Ptilotus exaltatus</i>	Amaranthaceae
<i>Ptilotus helipteroides</i>	Amaranthaceae
<i>Senna artemisioides</i> subsp. <i>helmsii</i>	Fabaceae

On average, the RIO vegetation survey sites exhibit 18 % to 27 % floristic uniqueness in comparison to both the IOH survey sites. An average of 18 species were collected to represent the dominant vegetation complexes present per site, however, there is only 25 – 43% species composition similarity between the four vegetation assessment sites.

Flora species composition and similarities between the IOH and the four RIO vegetation survey sites is displayed in Table 5.

Table 5: Flora species present at IOH and Rio Tinto Iron Ore vegetation assessment sites.

Name	Site				
	IOH	RIOVEG-1	RIOVEG-2	RIOVEG-3	RIOVEG-4
<i>Acacia adoxa</i> var. <i>adoxo</i>	X	X			
<i>Acacia ancistrocarpa</i>	X				X
<i>Acacia colei</i> var. <i>ileocarpa</i>		X			
<i>Acacia dictyophleba</i>					X
<i>Acacia hilliana</i>	X	X			X
<i>Acacia inaequilatera</i>	X		X	X	
<i>Acacia pachyachra</i>	X		X	X	X
<i>Acacia pruinocarpa</i>	X			X	
<i>Acacia pyriformis</i>				X	
<i>Acacia spondylophylla</i>				X	
<i>Acacia tumida</i> var. <i>pilbarensis</i>	X	X		X	X
<i>Aristida holathera</i> var. <i>holathera</i>	X			X	
* <i>Cenchrus ciliaris</i>	X			X	X
<i>Corchorus lasiocarpus</i> subsp. <i>lasiocarpus</i>		X	X	X	X
<i>Corchorus sidoides</i> subsp. <i>sidoides</i>	X	X	X	X	X
<i>Corymbia hamersleyana</i>	X				X
<i>Dicrastylis cordifolia</i>		X	X	X	
<i>Eragrostis setifolia</i>		X		X	
<i>Eucalyptus gamophylla</i>	X			X	
<i>Gomphrena cunninghamii</i>				X	
<i>Goodenia microptera</i>	X	X			
<i>Gossypium robinsonii</i>	X	X			X
<i>Grevillea wickhamii</i> subsp. <i>hispidula</i>	X		X	X	
<i>Hakea chordopylla</i>			X	X	X
<i>Hakea lorea</i> subsp. <i>lorea</i>	X		X	X	X
<i>Paraneurachne muellerii</i>	X	X			
<i>Petalostylis labichieoides</i>	X	X	X	X	X
<i>Ptilotus calostachyus</i>	X	X	X		
<i>Ptilotus exaltatus</i>	X	X	X	X	X
<i>Ptilotus helipteroides</i>	X	X	X	X	X
<i>Ptilotus obovatus</i>	X			X	
<i>Salsola australis</i>				X	
<i>Scaevola parvifolia</i>					X
<i>Senna artemisioides</i> subsp. <i>helmsii</i>		X	X	X	X
<i>Sida echinocarpa</i>	X	X	X	X	
<i>Solanum phlomoides</i>	X	X			
<i>Trianthema pilosa</i>	X				X

* indicates weed species

6.4.1. RIO Vegetation Assessment Site 01

Vegetation of RIO vegetation assessment Site 01 (RIOVEG-1, Figure 18) consisted entirely of herbaceous species with no discernable living over-storey due to previous fire. A total of 18 dominant flora species were collected during the survey (Table 5). Only nine percent of the species collected are shared with the IOH tenement sites, with 44 % being unique to the site (see Appendix 2).

RIOVEG-1 is a plain landscape, sparse in features with few undulations and hillocks. Rocky outcrops may be suitable for harbouring SRE Gastropods (snails), and while being absent from the site, may be substituted by the presence of the rocky hillocks which in some cases can provide suitable habitat. Soil substrate is ideal for burrowing SRE fauna, however, the evidence of fire having removed all leaf litter has reduced the potential areas of refuge, habitat and construction materials for Mygalomorph trapdoors. This vegetation type is broadly represented in Figure 18 as Vegetation Type 1 flanked either side by Vegetation Type 2.

No scorpion or trapdoor spider burrows were found and no specimens collected during the site visual assessment. No sampling regime was deployed at RIOVEG-1.

6.4.2. RIO Vegetation Assessment Site 02

RIO Site 02 (RIOVEG-2, Figure 18) vegetation consists entirely of herbaceous species due to previous fire, as all previous over-storey vegetation is deceased. Fourteen species were collected, 57% of which are unique to RIOVEG-2 (see Table 5, Appendix 2). Four of the total fourteen species are shared with the IOH sites (7 % similarity).

RIOVEG-2 is a plain flanked by small ranges on either side. Soil substrate is suitable for Mygalomorph spider and scorpion fauna, however, presence of either is unconfirmed. Leaf litter is absent from the site due to previous fire. This vegetation type is broadly represented in Figure 18 as the broad Vegetation Type 3; however, the site does cross into Vegetation Type 5. No scorpion or trapdoor spider burrows were found and no specimens collected during the site visual assessment. No sampling regime was deployed at RIOVEG-2.

6.4.3. RIO Vegetation Assessment Site 03

RIO vegetation Site 03 (RIOVEG-3, Figure 18) is characterised by spinifex grasslands with scattered herbs and Eucalyptus over-storey. The spinifex grasslands transitions to general grasslands and towards a creek line which flows near the site (Figure 18). The soil substrate is suitable for SRE fauna, however, no evidence of Mygalomorph trapdoor spider or scorpion burrows or species were found. This may be contributed to some extent by the lack of over-storey and leaf litter throughout the site. This vegetation type is broadly represented in Figure 18 as Vegetation Type 4.

Twenty four species were collected during the vegetation assessment, the greatest diversity exhibited by any of the RIO vegetation assessment sites. Thirty three percent of the 24 flora species collected are unique to RIOVEG-3, only nine species are shared with the IOH sites (16 %) (see Appendix 2).

No scorpion or trapdoor spider burrows were found and no specimens collected during the site visual assessment. No sampling regime was deployed at RIOVEG-3.

6.4.4. RIO Vegetation Assessment Site 04

The vegetation of RIO vegetation Site 03 (RIOVEG-4, Figure 18) is characterised by spinifex grassland with Acacia shrub level over-storey with areas of open soil and scattered Eucalyptus (Table 5, Appendix 3). While rocky outcrops are ideal for SRE Gastropods (snails), this species was absent within the survey area, although they were present in the surrounding rocky hills. Substrate was suitable for SRE trapdoor spider and scorpion burrow building, especially between grass and spinifex clumps present under Eucalyptus and Acacia stands where elevated levels (40 – 60 %) of leaf litter coverage provides ample habitat construction materials and camouflage. Overall, however, there was minimal leaf litter covering the site. Although no evidence of Mygalomorph trapdoor spider or scorpion burrows or species were found, it is highly likely that they are present within the area. Existing disturbances are localised with depressions and drainage lines running throughout the survey site accompanied by evidence of seasonal or periodic inundation and heavy runoff into the nearby Weeli Wolli Creek catchment area.

Visually, RIOVEG-4 is very similar to RIO Site 01. This vegetation type is broadly represented in Figure 18 as the broad Vegetation Type 1 and differs however from RIO Site 01 due to be restricted to areas of increased soil moisture, inundation and drainage.

A total of 18 species were collected at RIOVEG-4 during the vegetation (see Appendix 2). Fourteen of the 18 species collected (24 %) are present at both RIOVEG-4 and the IOH sites, with only five species (9 %) being unique to the site. These results of similarity and uniqueness are identical to that of RIO vegetation assessment site 01. Both sites (RIOVEG-1 and RIOVEG-4) vegetation complexes are represented by 18 species, of which over 55 % (10 species) are common.

No scorpion or trapdoor spider burrows were found and no specimens collected during the site visual assessment. No sampling regime was deployed at RIOVEG-4.

7. SURVEY ADEQUACY AND LIMITATIONS

The main potential limitation of this survey was that the timing was later in the year than optimal, as stated in EPA Guidance Statement No. 20, which recommends that SRE surveys in the Pilbara region be conducted during the wet season (November – April) (EPA, 2009). However, Department of Environment and Conservation advised that the May and June survey period was acceptable (Durrant B 2011, pers. comm., 15 April).

Durant *et al.* (2010) has stated that Pilbara rainfall is very unreliable and highly variable, with these rainfall events largely driving the activity of the local fauna. Extended periods of dry conditions and inappropriate rainfall can induce torpor², however, SRE assemblages respond very quickly to appropriate isolated rainfall events. The 12 month period prior to the survey had less than average rainfall and although there was good rainfall recorded on site during April immediately before this survey (Bureau of Meteorology 2011a), rainfall during the survey periods themselves (May and June) was below average (Table 6). This would have potentially effected specimen yields as SREs, specifically mygalomorphs, which known to be active immediately prior to, during and after rainfall events (Main BY 2011, pers. comm., July).

Ultimately, the precise rainfall requirements which are most favourable for sampling SRE taxa (and their subsequent capture) are not known and there are many mitigating circumstances which affect the suitability of these rain events (i.e. soil type, topography, vegetation, SRE species). Because of this it cannot be said categorically that the lower than average rainfall in the 12 months prior to the survey and the months of the survey itself resulted in reduced SRE mobility and capture but it must be considered herein as a potential limitation to the survey.

Marillana station weather station is not equipped with rainfall measuring equipment (Bureau of Meteorology 2011b), therefore, although rain was present during the survey it is unable to be locally quantified and weather data at Newman Airport is the most accurate rainfall data available.

² Torpor: A state of physiological lowered activity typically characterized by reduced metabolism, heart rate, respiration, and body temperature that occurs in varying degrees especially in hibernating and estivating animals (Merriam-Webster 2012b).

Table 6: Newman Aerodrome weather station monthly average rainfall (mm) over the period 1981 – 2010, running monthly total for 2011 and monthly differences.

	Duration		Difference
	1981-2010	2011	2011
Month	Mean for 30 yrs	Monthly	Monthly
January	58.9	59	0.1
February	82.7	145.8	63.1
March	35	26	-9
April	19.7	31.4	11.7
May	20.7	5.6	-15.1
June	14.8	9.4	-5.4
July	14.3	32.2	17.9
August	4.5	0	-4.5
September	5.8	-	-
October	3.2	-	-
November	10.9	-	-
December	41	-	-
TOTAL	311.5	309.4	

Lack of habitat diversity per site during the targeted SRE survey is not considered a limitation of this study as the targeted nature of the survey restricted sampling sites to areas which SRE specimens had been collected in the previous SRE survey in the Iron Valley Project and similar habitats where the target fauna may occur.

Although part of the survey area had been burnt (refer Section 2.3), Dalcon Environmental does not consider this to have been a limitation to the survey as it does not seem to have affected the abundance of any of the SRE taxa recorded when compared to unburnt sites. This is due to collections of the Mygalomorphae trap door spider *Aganippe* 'MYG086' and the scorpion *Urodacus* 'megamastigus short' from both IOH and RIO survey areas (Table 3).

As discussed in Section 6.1 the comprehensive floristic assessment conducted at IOH sites 01 and 02 in comparison to the Rio Tinto Iron Ore sites makes a direct floral comparison between sites difficult due to the non-standardised sampling methodology used at all sites. Future flora assessments should have methodology to ensure similar sampling regimes between sites. It is possible with an identical scope of flora surveying at RIO sites as was conducted at the IOH sites, an increased number of flora samples may have been identified and vegetation complexes between sites increase or decrease in similarity in respect to the values presented in this report. However, considering that the objective of the flora assessment was to define SRE habitat as the basis of a risk assessment, rather than make

direct floristic comparisons between sites (see Section 8), Dalcon Environmental considers the assessment to be adequate.

8. CONCLUSIONS

The targeted short-range endemic invertebrate survey conducted in June 2011, consisted of a total of four sampling sites within the Iron Ore Holdings Ltd Iron Valley M47/1439 mining lease and the adjacent Rio Tinto M274/SA tenement. Total of 60 dry pitfall traps were deployed in the project area: 30 dry pitfall traps within between two IOH tenement sampling sites and 30 dry pitfall traps between two RIO tenement sampling sites. Extensive hand foraging was also conducted at each sampling site as well as UV night surveys specifically to sample for scorpion fauna. Four vegetation and habitat assessment sites were situated along the length of the adjacent Rio Tinto M274/SA tenement boundary to access the extent of potentially suitable SRE habitat outside the IOH project area.

Recommendations made by the Department of Environment and Conservation (Durrant B 2011, pers. comm. 15 April) and the Environmental Protection Authority guidance statement 20 (Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia; EPA, 2009) were used as a guideline in determining the most appropriate sampling regime to selectively sample the target short-range endemic invertebrates. The deployment of dry pitfall traps (EPA, 2009) was deemed the best survey method over time to survey in conjunction with extensive hand foraging (Durrant B 2011, pers. comm. 15 April; EPA 2009) for target burrows of mygalomorphs and scorpions. Due to the range of area in the Rio Tinto tenement, vegetation assessments were conducted at regular intervals to determine the extent of suitable SRE habitat and composition similarity to IOH sites (Durrant B 2011, pers. comm. 15 April; EPA, 2009).

A total of 11 specimens were yielded over five species, with a single potential SRE identified (Table 3).

A single *Aganippe* species, *Aganippe* 'MYG086' was collected within the project area (Table 3). *Aganippe* 'MYG086' is considered to be a potential SRE (Section 5.1.1.2). *Aganippe* 'MYG086' is only known from the Iron Valley Project (May/June 2010 and June 2011) and from Roy Hill Station, approximately 80 km southeast of the Project area.

Aganippe 'MYG086' is present within the Iron Valley tenement (IOH Site 01) and the adjoining Rio Tinto Iron Ore tenement (RIO Site 02). This may indicate a larger population of *Aganippe* 'MYG086' in the area which may be unlikely to be adversely impacted upon by Iron Valley infrastructure development. This conclusion is dependent upon the long term security of habitats in the adjacent Rio Tinto Iron Ore.

Although these two *Aganippe* ‘MYG086’ populations may be unrelated and may experience no interconnectivity (i.e. due to topographical and habitat barriers, lack of population dispersal) due to the definition of SRE fauna stating that populations range less than 10 000 km², the significance of these localised populations is still relevant. Based on the current known distribution of this species (only known at the Project and 80 km southeast), Dalcon Environmental cannot assume that this species is widespread, but can infer that at least within the region of the IOH/RIO tenements, that it may be present within areas that have been defined as suitable habitat (see Section 5.1.1, Section 6, Figure 18). This is only verifiable by further targeted surveys conducted throughout the two tenements and is complicated by the vegetation condition of the RIO Site 02.

The vegetation complex currently present at RIO Site 02 has been directly influenced by a recent fire event. There is evidence surrounding the burnt area at RIO Site 02 that suggests that a different vegetation type once existed within the site than was present during the survey.

As the area recovers from the fire event (date unknown, possibly in early 2009) the surrounding vegetation complex will recolonise the area with its assemblage making it less synonymous with the vegetation present at IOH Site 01 and 02. While it is inevitable that RIO Site 02 will share some flora species present at IOH sites, between the two sites there are currently differences in:

- Flora composition complexity (primarily of understory species);
- Flora age;
- Flora stability (flora composition will continue to change while colonising species die off and are replaced over time with more permanent species);
- Soil dynamics and burrowing suitability;
- Leaf litter composition and percent coverage;
- Percent open bare soil;
- Food sources.

SRE fauna experience difficulty dispersing (Harvey 2002) rendering them vulnerable to rapid re-colonisation of damaged and disturbed areas by flora and habitat changes. For example, Mygalomorph trap door spiders will burrow and inhabit only one burrow for the entirety of their life, rendering them extremely susceptible to habitat changes over time (Main BY 2011, pers. comm., July). Locally restricted species tend to have a high conservation status because

they are more vulnerable to extinction following habitat destruction and environmental change (Eberhard *et al.*, 2009; Ponder and Colgan, 2002). SRE migration from the older stable IOH habitat to the burnt transitional habitat at RIO Site 2 is extremely unlikely.

A single *Urodacus* species, *Urodacus* ‘megamastigus short’, was collected during UV night survey’s at IOH Site 01 and RIO Site 02 (Table 3). *Urodacus* ‘megamastigus short’ is widespread and not a SRE (Section 5.1.2.3) (Volschenk, 2010, 2011).

It is important to note concerning possible SRE distributions and populations within the potential suitable habitat zones within the IOH and adjacent RIO tenements, as per Figure 18 that without a survey to physically confirm population presence that the known populations in the IOH tenement may still be at risk. This is because the IOH tenement populations are known where the extent of possible RIO tenement populations is not. Any future plans to develop the RIO tenement is unknown by Dalcon Environmental casting uncertainty about the future of potential SRE populations present and increasing the importance of SRE populations found within the IOH project area.

9. RECOMMENDATIONS

9.1. General recommendations

In order to limit the impacts on *Aganippe* ‘MYG086’ present within the Project area, Dalcon recommends that:

- Clearing of native vegetation should be kept to a minimum. This applies particularly to any spinifex grasslands.
- Habitat that is likely to contain *Aganippe* ‘MYG086’, such as spinifex grasslands with acacia over-storeys, should not be disturbed if possible. It is apparent that much of the *Aganippe* ‘MYG086’ habitat on the IOH tenement occurs within areas that are proposed to be disturbed as a result of the Project. Whilst suitable *Aganippe* ‘MYG086’ habitat was found on the adjacent Rio Tinto Iron Ore tenement, this habitat was in a state of flux as a result of previous fire with the vegetation community which is likely to change over time, and as a result, may become less conducive habitat for *Aganippe* ‘MYG086’. Any possible future development within this tenement is unknown.
- Any areas that will be cleared should be rehabilitated by plants endemic to the area as immediately after use to encourage SRE (and general) floral and faunal recolonisation.
- To minimise the danger of increased fire frequency as a result of the Project, a fire prevention strategy should be implemented. Fire is a recognised threat to spinifex grasslands (Kendrick, 2001).
- Every effort is taken to ensure vehicles do not introduce or spread any weeds (i.e. implement a weed management strategy) or soil pathogens which will impact potential SRE habitat.

10. STUDY TEAM

The Iron Valley Project Targeted Short Range Endemic Invertebrate Fauna Survey detailed in this document was planned, coordinated and executed by Dalcon Environmental Pty Ltd in close consultation with URS Australia Pty Ltd and Iron Ore Holdings Pty Ltd.

The Project team, their responsibilities and qualifications were as follows:

Stuart Hellen BSc (Hon), MSc

Principal Scientist/Director/Project Management

Phillip Mark Heath BSc (Hon)

Senior Environmental Scientist/Invertebrate Zoologist/Field Program

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We would also like to thank the taxonomic experts listed in Table 1 for the identification of potential SRE taxa.

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12. Appendix 1 – GPS Coordinates

12.1. IOH Site 01 GPS Coordinates

IOH Site 01		Position (WSG 84)	
Trap Number	Lat/Long	UTM	Notes
IOHS01D01	S22 44 43.1 E119 18 34.1	50 K 737165 7482824	
IOHS01D02	S22 44 42.1 E119 18 35.3	50 K 737201 7482857	
IOHS01D03	S22 44 40.7 E119 18 36.5	50 K 737234 7482899	
IOHS01D04	S22 44 39.6 E119 18 37.9	50 K 737276 7482932	
IOHS01D05	S22 44 38.5 E119 18 39.1	50 K 737309 7482966	
IOHS01D06	S22 44 37.2 E119 18 37.7	50 K 737270 7483006	
IOHS01D07	S22 44 38.5 E119 18 36.6	50 K 737239 7482967	
IOHS01D08	S22 44 39.7 E119 18 35.3	50 K 737202 7482929	
IOHS01D09	S22 44 40.9 E119 18 34.1	50 K 737166 7482895	
IOHS01D10	S22 44 42.0 E119 18 32.9	50 K 737131 7482860	
IOHS01D11	S22 44 41.0 E119 18 31.5	50 K 737092 7482892	
IOHS01D12	S22 44 39.8 E119 18 32.5	50 K 737122 7482928	
IOHS01D13	S22 44 38.6 E119 18 33.7	50 K 737155 7482965	
IOHS01D14	S22 44 37.3 E119 18 34.7	50 K 737186 7483005	
IOHS01D15	S22 44 35.9 E119 18 35.9	50 K 737220 7483045	
IOHS01D16	S22 44 34.9 E119 18 34.7	50 K 737188 7483079	
IOHS01D17	S22 44 36.0 E119 18 33.6	50 K 737154 7483044	
IOHS01D18	S22 44 37.1 E119 18 32.6	50 K 737125 7483010	
IOHS01D19	S22 44 38.4 E119 18 31.4	50 K 737090 7482971	
IOHS01D20	S22 44 39.7 E119 18 30.0	50 K 737050 7482931	
IOHS01S01	S22 44 41.2 E119 18 35.7	50 K 737212 7482885	Scorpion Burrow
IOHS01S02	S22 44 41.1 E119 18 35.6	50 K 737210 7482886	Scorpion Burrow
IOHS01S03	S22 44 40.7 E119 18 35.9	50 K 737219 7482897	Scorpion Burrow
IOHS01S04	S22 44 40.4 E119 18 36.8	50 K 737243 7482908	Scorpion Burrow
IOHS01S05	S22 44 38.5 E119 18 37.9	50 K 737275 7482967	Scorpion Burrow
IOHS01S06	S22 44 38.3 E119 18 37.6	50 K 737268 7482971	Scorpion Burrow
IOHS01S07	S22 44 38.3 E119 18 37.7	50 K 737271 7482972	Scorpion Burrow
IOHS01S08	S22 44 39.7 E119 18 35.3	50 K 737202 7482929	Scorpion Burrow
IOHS01S09	S22 44 37.7 E119 18 37.0	50 K 737251 7482989	Scorpion Burrow
IOHS01S10	S22 44 38.6 E119 18 36.6	50 K 737239 7482962	Scorpion Burrow
IOHS01S11	S22 44 38.8 E119 18 36.4	50 K 737232 7482958	Scorpion Burrow
IOHS01S12	S22 44 39.7 E119 18 35.6	50 K 737211 7482931	Scorpion Burrow
IOHS01S13	S22 44 40.1 E119 18 35.3	50 K 737200 7482918	Scorpion Burrow
IOHS01TD01	S22 44 39.5 E119 18 37.7	50 K 737269 7482935	Trapdoor
IOHS01TD02-03	S22 44 38.3 E119 18 33.5	50 K 737152 7482974	Trapdoor 02 and 03 close together

Note: ‘IOH’ indicates site location within the Iron Valley Project (IOH tenement). ‘S0_x’ indicates site number. ‘D_{xx}’ indicated dry pitfall Trap number. ‘S_{xx}’ indicates Scorpion burrow number found on site. ‘TD0_x’ indicates trapdoor number found on site.

12.2. IOH Site 02 GPS Coordinates

IOH Site 02		Position (WSG 84)	
Trap Number	Lat/Long	UTM	Notes
IOHS02D01	S22 44 34.5 E119 18 39.9	50 K 737335 7483088	
IOHS02D02	S22 44 32.8 E119 18 40.9	50 K 737363 7483139	
IOHS02D03	S22 44 31.6 E119 18 42.1	50 K 737400 7483175	
IOHS02D04	S22 44 32.2 E119 18 42.9	50 K 737422 7483156	
IOHS02D05	S22 44 33.5 E119 18 41.6	50 K 737385 7483118	
IOHS02D06	S22 44 35.1 E119 18 40.5	50 K 737352 7483069	
IOHS02D07	S22 44 37.2 E119 18 40.1	50 K 737340 7483004	
IOHS02D08	S22 44 35.9 E119 18 41.1	50 K 737369 7483045	
IOHS02D09	S22 44 34.6 E119 18 42.1	50 K 737398 7483083	
IOHS02D10	S22 44 33.5 E119 18 43.4	50 K 737436 7483117	
IOHS02S01	S22 44 34.9 E119 18 39.1	50 K 737312 7483077	Scorpion Burrow

Note: 'IOH' indicates site location within the Iron Valley Project (IOH tenement). 'S0_x' indicates site number. 'D_{xx}' indicated dry pitfall Trap number. 'S_{xx}' indicates Scorpion burrow number found on site.

12.3. RIO Site 01 GPS Coordinates

RIO Site 01		Position (WSG 84)	
Trap Number	Lat/Long	UTM	Notes
RIOS01D01	S22 45 07.1 E119 18 51.4	50 K 737648 7482078	
RIOS01D02	S22 45 05.9 E119 18 52.6	50 K 737681 7482115	
RIOS01D03	S22 45 04.6 E119 18 53.7	50 K 737714 7482155	
RIOS01D04	S22 45 03.4 E119 18 55.0	50 K 737751 7482191	
RIOS01D05	S22 45 02.2 E119 18 56.2	50 K 737787 7482229	
RIOS01D06	S22 45 03.2 E119 18 57.7	50 K 737828 7482197	
RIOS01D07	S22 45 04.5 E119 18 56.4	50 K 737791 7482157	
RIOS01D08	S22 45 05.8 E119 18 55.2	50 K 737757 7482119	
RIOS01D09	S22 45 06.9 E119 18 54.0	50 K 737722 7482085	
RIOS01D10	S22 45 08.1 E119 18 52.7	50 K 737683 7482048	
RIOS01D11	S22 45 09.2 E119 18 53.9	50 K 737719 7482013	
RIOS01D12	S22 45 08.2 E119 18 55.3	50 K 737759 7482045	
RIOS01D13	S22 45 07.0 E119 18 56.6	50 K 737797 7482081	
RIOS01D14	S22 45 05.7 E119 18 57.9	50 K 737834 7482120	
RIOS01D15	S22 45 04.6 E119 18 59.2	50 K 737870 7482152	
RIOS01S01	S22 45 05.3 E119 18 53.6	50 K 737712 7482133	Scorpion Burrow
RIOS01S02	S22 45 05.0 E119 18 53.8	50 K 737716 7482142	Scorpion Burrow
RIOS01S03	S22 45 04.3 E119 18 54.1	50 K 737726 7482164	Scorpion Burrow
RIOS01S04	S22 45 06.5 E119 18 54.1	50 K 737724 7482097	Scorpion Burrow
RIOS01S05	S22 45 06.2 E119 18 53.3	50 K 737702 7482107	Scorpion Burrow
RIOS01S06-07	S22 45 06.5 E119 18 55.1	50 K 737754 7482097	Scorpion Burrow
RIOS01S08	S22 45 06.7 E119 18 55.2	50 K 737756 7482090	Scorpion Burrow
RIOS01S09	S22 45 06.9 E119 18 56.6	50 K 737797 7482083	Scorpion Burrow
RIOS01S10	S22 45 07.4 E119 18 54.8	50 K 737744 7482068	Scorpion Burrow
RIOS01S11	S22 45 06.7 E119 18 48.9	50 K 737576 7482094	Scorpion Burrow
RIOS01TD01	S22 45 08.9 E119 18 52.9	50 K 737688 7482024	Trapdoor
RIOS01TD02	S22 45 10.4 E119 18 52.9	50 K 737689 7481976	Trapdoor
RIOS01TD03	S22 45 10.1 E119 18 55.0	50 K 737749 7481986	Trapdoor

Note: ‘RIO’ indicates site location within Rio Tinto Iron Ore’s tenement (adjacent to the Iron Valley Project). ‘S0_x’ indicates site number. ‘D_{xx}’ indicated dry pitfall trap number. ‘S_{xx}’ indicates Scorpion burrow number found on site. ‘TD0_x’ indicates trapdoor number found on site.

12.4. RIO Site 02 GPS Coordinates

RIO Site 02		Position (WSG 84)	
Trap Number	Lat/Long	UTM	Notes
RIOS02D01	S22 43 43.4 E119 19 53.0	50 K 739447 7484626	
RIOS02D02	S22 43 42.3 E119 19 54.3	50 K 739483 7484660	
RIOS02D03	S22 43 41.2 E119 19 55.7	50 K 739525 7484693	
RIOS02D04	S22 43 40.0 E119 19 57.1	50 K 739565 7484729	
RIOS02D05	S22 43 38.9 E119 19 58.4	50 K 739601 7484764	
RIOS02D06	S22 43 40.0 E119 19 59.5	50 K 739632 7484730	
RIOS02D07	S22 43 41.3 E119 19 58.4	50 K 739600 7484688	
RIOS02D08	S22 43 42.3 E119 19 57.2	50 K 739566 7484659	
RIOS02D09	S22 43 43.6 E119 19 55.9	50 K 739529 7484621	
RIOS02D10	S22 43 44.8 E119 19 54.8	50 K 739498 7484584	
RIOS02D11	S22 43 46.0 E119 19 56.1	50 K 739533 7484545	
RIOS02D12	S22 43 44.9 E119 19 57.4	50 K 739569 7484580	
RIOS02D13	S22 43 43.6 E119 19 58.6	50 K 739606 7484618	
RIOS02D14	S22 43 42.4 E119 19 59.6	50 K 739636 7484654	
RIOS02D15	S22 43 41.1 E119 20 00.8	50 K 739671 7484694	
RIOS02S01	S22 43 43.8 E119 19 52.5	50 K 739431 7484615	Scorpion Burrow
RIOS02S02	S22 43 43.3 E119 19 53.3	50 K 739454 7484631	Scorpion Burrow
RIOS02S03	S22 43 39.2 E119 19 57.5	50 K 739577 7484753	Scorpion Burrow
RIOS02S04	S22 43 38.7 E119 19 58.7	50 K 739610 7484769	Scorpion Burrow
RIOS02TD01	S22 43 44.9 E119 19 55.0	50 K 739501 7484579	Trapdoor
RIOS02TD02	S22 43 43.5 E119 19 53.9	50 K 739473 7484624	Trapdoor
RIOS02TD03	S22 43 45.1 E119 19 54.2	50 K 739479 7484576	Trapdoor

Note: ‘RIO’ indicates site location within Rio Tinto Iron Ore’s tenement (adjacent to the Iron Valley Project). ‘S0_x’ indicates site number. ‘D_{xx}’ indicated dry pitfall trap number. ‘S_{xx}’ indicates Scorpion burrow number found on site. ‘TD0_x’ indicates trapdoor spider number found on site.

12.5. RIO Site 02 GPS Coordinates

Trap Number	Position (WSG 84)		Notes
	Lat/Long	UTM	
RIOVEG01	S22 45 54.8 E119 18 21.9	50 K 736783 7480624	Vegetation Assessment point
RIOVEG02	S22 45 26.2 E119 18 34.0	50 K 737141 7481501	Vegetation Assessment point
RIOVEG03	S22 44 43.6 E119 19 13.0	50 K 738274 7482792	Vegetation Assessment point
RIOVEG04	S22 44 18.1 E119 19 51.3	50 K 739380 7483560	Vegetation Assessment point

Note: ‘RIO’ indicates site location within Rio Tinto Iron Ore’s tenement (adjacent to the Iron Valley Project). ‘S0_x’ indicates site number. ‘D_{xx}’ indicated dry pitfall trap number. ‘S_{xx}’ indicates Scorpion burrow number found on site. ‘TD0_x’ indicates trapdoor spider number found on site.

13. Appendix 2 – Vegetation Survey Results

Name	Site						
	IOH	RIO-S01	RIO-S02	RIOVEG-1	RIOVEG-2	RIOVEG-3	RIOVEG-4
<i>Acacia adoxa</i> var. <i>adoxo</i>	X			X			
<i>Acacia ancistrocarpa</i>	X		X				X
<i>Acacia bivenosa</i>	X		X				
<i>Acacia colei</i> var. <i>ileocarpa</i>			X	X			
<i>Acacia dictyophleba</i>							X
<i>Acacia hilliana</i>	X			X			X
<i>Acacia inaequilatera</i>	X	X			X	X	
<i>Acacia pachyachra</i>	X				X	X	X
<i>Acacia pruinocarpa</i>	X					X	
<i>Acacia pteraneura</i>	X	X					
<i>Acacia pyriformis</i>						X	
<i>Acacia spondylophylla</i>						X	
<i>Acacia tumida</i> var. <i>pilbarensis</i>	X			X		X	X
<i>Aristida holathera</i> var. <i>holathera</i>	X	X				X	
* <i>Cenchrus ciliaris</i>	X	X	X			X	X
<i>Cleome viscosa</i>	X	X	X				
<i>Corchorus lasiocarpus</i> subsp. <i>lasiocarpus</i>		X		X	X	X	X
<i>Corchorus sidoides</i> subsp. <i>sidoides</i>	X	X		X	X	X	X
<i>Corymbia hamersleyana</i>	X						X
<i>Cucumis maderaspatanus</i>	X						
<i>Dicrastylis cordifolia</i>				X	X	X	
<i>Dysphania kalparri</i>	X						
<i>Eragrostis setifolia</i>				X		X	

<i>Eremophila forrestii</i> subsp. <i>forrestii</i>	X	X					
<i>Eremophila longifolia</i>	X						
<i>Eucalyptus gamophylla</i>	X		X			X	
<i>Eucalyptus ?leucophloia</i> subsp. <i>leucophloia</i>	X						
<i>Euphorbia australis</i>	X	X					
<i>Gomphrena cunninghamii</i>						X	
<i>Goodenia microptera</i>	X			X			
<i>Gossypium robinsonii</i>	X			X			X
<i>Grevillea wickhamii</i> subsp. <i>hispidula</i>	X		X		X	X	
<i>Hakea chordopylla</i>		X			X	X	X
<i>Hakea lorea</i> subsp. <i>lorea</i>	X	X			X	X	X
<i>Heliotropium pachyphyllum</i>	X						
<i>Hibiscus coatesii</i>	X	X					
<i>Indigofera monophylla</i>	X	X					
<i>Oldenlandia crouchiana</i>	X						
<i>Paraneurachne muellerii</i>	X	X		X			
<i>Petalostylis labichieoides</i>	X		X	X	X	X	X
<i>Phyllanthus erwinii</i>	X						
<i>Polycarpea corymbosa</i>	X						
<i>Portulaca oleracea</i>	X						
<i>Ptilotus astrolasius</i>	X						
<i>Ptilotus auriculifolius</i>	X						
<i>Ptilotus calostachyus</i>	X	X		X	X		
<i>Ptilotus exaltatus</i>	X	X		X	X	X	X
<i>Ptilotus helipteroides</i>	X	X		X	X	X	X
<i>Ptilotus macrocephalus</i>	X	X					
<i>Ptilotus obovatus</i>	X					X	
<i>Salsola australis</i>						X	

<i>Scaevola parvifolia</i>						X
<i>Senna artemisioides</i> subsp. <i>helmsii</i>			X	X	X	X
<i>Senna ferraria</i>	X	X	X			
<i>Senna glutinosa</i> subsp. <i>x. luerssenii</i>	X	X				
<i>Senna glutinosa</i> subsp. <i>pruinosa</i>	X	X				
<i>Sida echinocarpa</i>	X	X		X	X	X
<i>Sida fibulifera</i>	X					
<i>Sida</i> Spiciform Panicles (E. Leyland s.n. 14/8/90)	X					
<i>Solanum phlomoides</i>	X			X		
<i>Solanum sturtianum</i>	X	X				
<i>Trianthema pilosa</i>	X	X				X
<i>Trichodesma zeylanicum</i> var. <i>zeylanicum</i>	X		X			
<i>Triodia pungens</i>	X					
<i>Triodia</i> sp.	X					
<i>Velleia connata</i>			X			
<i>Yakirra australiensis</i>	X					

14. Appendix 3 – Habitat Assessment Sheets

14.1. IOH Site 01 and 02 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	IOHS01 & IOHS02	Date	2-Jun-11	Surveyor	Heath.M
GPS (Easting/Northing)	50K 737165 7482824	Site #	S01 & S02		
		Photo #			
Broad SRE Habitat Type	Spinifex grassland w/h open ground. Transitional grassland	Landscape Position	Plain between ridges		

VEGETATION

Broad Vegetation Type	Spinifex, grass, scattered Eucalyptus spp. & Acacia spp.			
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present	☒	Absent	☐
Spinifex Grassland				

SUBSTRATE

Rock outcrop which may harbour land snails	Present	☐	Absent	☒
-				
Substrate suitable for Mygalomorph spiders or scorpions	Present	☒	Absent	☐
Loose compacted soil w/h scattered rock & spinifex clumps. Open bare ground.				
Litter Cover	Low (0-40%)	☒	Moderate (40-60%)	☐
			High (60-100%)	☐
-				

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present	☒	Absent	☐
Trapdoor burrows present. Scorpion burrows present.				

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☒ Absent ☐
Drilling lines, road, minimal cattle sign (inc. grazing), drainage lines, disturbance specialist pioneer vegetation present.	
Physical Connectivity	Continuous vegetation type throughout plain between ridges.
Extent of Habitat	Similar habitat for +4 km as per walked during previous year survey.
Other Comments	Final transect of IOHS02 (D07-10) in rocky area at foot of hill - Rock cover 80-100%

14.2. RIO Site 01 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOS01	Date	3-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 737648 7482078		Site #	RIOS01	
			Photo #		
Broad SRE Habitat Type	Spinifex grassland w/h open soil patches	Landscape Position	v.large open plain between two ranges		

VEGETATION

Broad Vegetation Type	Spinifex grassland w/h sparse Eucalyptus spp. overstorey		
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present	☐	Absent
			☒
-			

SUBSTRATE

Rock outcrop which may harbour land snails	Present	☒	Absent	☐
There are patches of rocky cobble possibly suitable - v.unlikely however.				
Substrate suitable for Mygalomorph spiders or scorpions	Present	☒	Absent	☐
Open sandy areas between spinifex clumps - soil burrowable. Good Myg habitat under scattered Acacia spp. stands w/h leaf litter.				
Litter Cover	Low (0-40%)	☒	Moderate (40-60%)	☐
			High (60-100%)	☐
Mainly under overstorey vegetation & shrubs. No loose litter.				

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present	☒	Absent	☐
Scorpion & Myg burrows present & excavated. Scorpion & myg's collected.				

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☒ Absent ☐
Fire, v.minor drainage erosion, major cattle sign	
Physical Connectivity	
Extent of Habitat	
Other Comments	

14.3. RIO Site 02 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOS02	Date	3-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 739447 7484626		Site #	RIOS02	
			Photo #		
Broad SRE Habitat Type	Spinifex grassland w/h mixed Acacia spp. woodland overstorey		Landscape Position	Plain adjacent creekline	

VEGETATION

Broad Vegetation Type	Spinifex grassland w/h mixed Acacia spp. woodland overstorey	
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present ☐	Absent ☒
V.suitable under/around Acacia spp. stands		

SUBSTRATE

Rock outcrop which may harbour land snails	Present ☐	Absent ☒
-		
Substrate suitable for Mygalomorph spiders or scorpions	Present ☒	Absent ☐
Open soil patches between Spinifex. Perfect under Acacia spp. stands in Leaf.L		
Litter Cover	Low (0-40%) ☒	Moderate (40-60%) ☐ High (60-100%) ☐
Overall low, however, moderate-high under Acacia spp. stands		

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present ☒	Absent ☐
Scorpion burrows absent. Myg PRESENT, found under Acacia spp. stands.		

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☐ Absent ☒
-	
Physical Connectivity	Plain. fringes adjoining creek land vegetation and flooding area of Weeli Wollie Creek
Extent of Habitat	
Other Comments	

14.4. RIO Vegetation Assessment Site 01 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOVEG01	Date	8-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 736783 7480624		Site #	RIOVEG01	
			Photo #		
Broad SRE Habitat Type	Herbs and open areas fire affected	Landscape Position	Plain - Minor undulations & Hillocks		

VEGETATION

Broad Vegetation Type	Herbs			
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present	☐	Absent	☒
-				

SUBSTRATE

Rock outcrop which may harbour land snails	Present	☐	Absent	☒
Rocky hillocks possibly suitable				
Substrate suitable for Mygalomorph spiders or scorpions	Present	☒	Absent	☐
Easily burrowable				
Litter Cover	Low (0-40%)	☒	Moderate (40-60%)	☐
			High (60-100%)	☐
Evidence of fire which would have burnt leaf litter off				

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present	☐	Absent	☒
-not checked, vegetation assessment only-				

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☒ Absent ☐
Fire, minor cattle sign	
Physical Connectivity	Plain running between two ranges running length of transect.
Extent of Habitat	
Other Comments	

14.5. RIO Vegetation Assessment Site 02 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOVEG02	Date	8-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 737141 7481501	Site #	RIOVEG02		
		Photo #			
Broad SRE Habitat Type	Open herb plain	Landscape Position	Plain between two ranges		

VEGETATION

Broad Vegetation Type	Herbs - Less flowering than RIOVEG01 & less species		
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present ☐	Absent ☒	
-			

SUBSTRATE

Rock outcrop which may harbour land snails	Present ☐	Absent ☒	
-			
Substrate suitable for Mygalomorph spiders or scorpions	Present ☐	Absent ☐	
Litter Cover	Low (0-40%) ☒	Moderate (40-60%) ☐	High (60-100%) ☐
Fire would have burnt leaf litter off. Herbs not contributing to litter cover.			

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present ☐	Absent ☒	
-not checked, vegetation assessment only-			

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☒ Absent ☐
Fire, minor cattle signs	
Physical Connectivity	
Extent of Habitat	
Other Comments	

14.6. RIO Vegetation Assessment Site 03 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOVEG03	Date	8-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 738274 748297		Site #	RIOVEG03	
			Photo #		
Broad SRE Habitat Type	Spinifex grassland	Landscape Position	Open drainage area near creek surrounded by hills		

VEGETATION

Broad Vegetation Type	Spinifex grassland with herbs & Eucalyptus spp			
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present	☐	Absent	☒
-				

SUBSTRATE

Rock outcrop which may harbour land snails	Present	☐	Absent	☒
Substrate suitable for Mygalomorph spiders or scorpions	Present	☒	Absent	☐
Soil is suitable				
Litter Cover	Low (0-40%)	☒	Moderate (40-60%)	☐
			High (60-100%)	☐

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present	☐	Absent	☒
None observed				

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☐ Absent ☒
None observed	
Physical Connectivity	Part of plain running EW between ranges
Extent of Habitat	
Other Comments	

14.7. RIO Vegetation Assessment Site 04 – Habitat Assessment Sheet

SHORT-RANGE ENDEMIC ASSESSMENT - HABITAT ASSESSMENT SHEET

GENERAL INFORMATION

Location	RIOVEG04	Date	9-Jun-11	Surveyor	Mark.H
GPS (Easting/Northing)	50K 739380 7483560		Site #	RIOVEG04	
			Photo #		
Broad SRE Habitat Type	Spinifex & Acacia spp. w/h Open Soil Patches	Landscape Position	Transitional zone between 2 hills & riverbed		

VEGETATION

Broad Vegetation Type	Spinifex & Grassland with Acacia spp. & Eucalyptus spp. overstorey		
Vegetation indicative of SRE habitat (eg. Ficus, ferns)	Present	☐	Absent
			☒
-			

SUBSTRATE

Rock outcrop which may harbour land snails	Present	☐	Absent
			☒
Not in area sampled - POSSIBILITY in surrounding rocky hills			
Substrate suitable for Mygalomorph spiders or scorpions	Present	☒	Absent
			☐
Soil Suitable for burrowing, open areas of soil between trees & grass/spinifex clumps			
Litter Cover	Low (0-40%)	☒	Moderate (40-60%)
			☐
			High (60-100%)
			☐
Mainly below overstorey flora			

EVIDENCE OF TARGET SRE GROUPS

Presence of Mygalomorph spider/scorpion burrows	Present	☐	Absent
			☒
No visual confirmation. Low/Med possibility of Myg/Scorpions. Looks good though...			

HABITAT

Area of Habitat (based on aerial photographs)	
Existing Disturbance	Present ☒ Absent ☐
Drainage lines, v.minor cattle sign, areas (small) of depressions w/h evidence of seasonal/periodical inundation	
Physical Connectivity	-See landscape position above- Catchment area flowing into nearby Weeli Wollie Creek
Extent of Habitat	
Other Comments	Looks v.similar to RIOS01 - Potential for Mygs

Appendix D4 Subterranean Fauna



BC Iron Limited

Iron Valley Project: Subterranean Fauna Assessment



Final Report

Prepared for Iron Ore Holdings Ltd
by Bennelongia Pty Ltd

February 2016
Report 2016/256

Iron Valley Project: Subterranean Fauna Assessment

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February 2016

Report 2015/256

Cover photo: Iron Valley

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Client – BC Iron

Report	Version	Prepared by	Checked by	Submitted to Client Method	Date
Draft report	Vers. 1	Andrew Trotter Danilo Harms	Stuart Halse	email	28.i.2016
Final report		Stuart Halse		email	2.iii.2016

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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 troglafauna 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 troglafauna 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.

Troglafauna sampling yielded 112 troglafaunal 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 troglafauna 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.

v.

CONTENTS

EXECUTIVE SUMMARY	III
1. INTRODUCTION	1
2. HYDROGEOLOGY	3
3. EXISTING INFORMATION ON SUBTERRANEAN FAUNA	3
3.1. TROGLOFAUNA.....	3
3.2. STYGOFANA.....	4
4. PROJECT IMPACTS	4
5. METHODS.....	5
5.1. SURVEY RATIONALE.....	5
5.2. TROGLOFAUNA.....	6
5.2.1. <i>Sampling Effort</i>	6
5.2.2. <i>Sampling Methods</i>	8
5.3. STYGOFANA.....	8
5.3.1. <i>Sampling Effort</i>	8
5.3.2. <i>Sampling Methods</i>	9
5.4. SAMPLE SORTING AND SPECIES IDENTIFICATION.....	9
5.5. COMPILING SPECIES LISTS.....	10
5.6. PERSONNEL	10
5.7. OTHER SAMPLING.....	10
6. RESULTS	10
6.1. TROGLOFAUNA.....	10
6.1.1. <i>Troglofauna at the Iron Valley Project</i>	10
6.1.2. <i>Troglofauna Species in the Proposed Mine Pits</i>	15
6.1.3. <i>Troglofauna Distributions</i>	15
6.1.4. <i>Sampling Efficiency</i>	15
6.2. STYGOFANA.....	15
6.2.1. <i>Stygofauna Occurrence and Abundance</i>	15
6.2.2. <i>Species Identification Issues</i>	16
6.2.3. <i>Stygofauna Distributions</i>	20
7. DISCUSSION.....	22
7.1. TROGLOFAUNA.....	22
7.1.1. <i>Iron Valley Troglofauna Community</i>	22
7.1.2. <i>Habitat Characterisation</i>	22
7.1.3. <i>Troglofauna Distributions as Indicators of Habitat Connectivity</i>	22
7.1.4. <i>Conservation Threats to Species</i>	23
7.2. STYGOFANA.....	23
7.2.1. <i>Iron Valley Stygofauna Community</i>	23
7.2.2. <i>Habitat Characterisation</i>	23
7.2.3. <i>Stygofauna Distributions and Conservation Threats to Species</i>	24
8. CONCLUSION	25
8.1. TROGLOFAUNA.....	25
8.2. STYGOFANA.....	26
9. REFERENCES	26
10. APPENDICES	29
Appendix 1: <i>Geology of the Iron Valley Project</i>	29
Appendix 2: <i>Conceptual Groundwater Flow</i>	30
Appendix 3: <i>Interpreted Hydrostatic Sections</i>	31
Appendix 4: <i>Co-ordinates of Drill Holes Sampled for Troglofauna at the Iron Valley Project</i>	32
Appendix 5: <i>Co-ordinates of Drill Holes Sampled for Stygofauna at the Iron Valley Project</i>	35
Appendix 6: <i>Locations of Troglofauna (A) and Stygofauna (B) Species in Relation the Dolerite Dyke that Transects the Iron Valley Project</i>	37
Appendix 7: <i>Locations of Isopods and Amphipods</i>	38

LIST OF FIGURES

FIGURE 1-1. LOCATION OF THE IRON VALLEY PROJECT.	2
FIGURE 5-1. LOCATIONS OF DRILL HOLES SAMPLED FOR TROGLOFAUNA AND STYGOFUNA AT THE IRON VALLEY PROJECT.	7
FIGURE 6-1. STYGOFUNA (A-D) AND TROGLOFAUNA PHOTOGRAPHS (E-F).	12
FIGURE 6-2. LOCATIONS OF TROGLOFAUNA SPECIES POTENTIALLY KNOWN ONLY FROM IMPACT AREAS.....	13
FIGURE 6-3. CAPTURE ABUNDANCE OF EACH TROGLOFAUNA SPECIES AT THE IRON VALLEY PROJECT.	14
FIGURE 6-5. CAPTURE ABUNDANCE OF EACH STYGOFUNA SPECIES AT THE IRON VALLEY PROJECT.	16
FIGURE 6-6. LOCATIONS OF SELECTED STYGOFUNA SPECIES IN RELATION TO IMPACT AREA.....	19
FIGURE 6-7. DEPTH TO GROUNDWATER AT IRON VALLEY.....	21

LIST OF TABLES

TABLE 5.1. NUMBERS OF TROGLOFAUNA SAMPLES COLLECTED FROM IRON VALLEY.	6
TABLE 5.2. NUMBERS OF STYGOFUNA SAMPLES COLLECTED FROM IRON VALLEY.	8
TABLE 6.1. TROGLOFAUNA SPECIES RECORDED AT THE IRON VALLEY PROJECT WITH KNOWN DISTRIBUTION INDICATED.	11
TABLE 6.2. TROGLOFAUNA IDENTIFIED ONLY TO HIGHER LEVEL (IMMATURE OR INCOMPLETE SPECIMENS).	14
TABLE 6.3. SUMMARY STATISTICS FOR TROGLOFAUNA SAMPLING AT THE IRON VALLEY PROJECT.	14
TABLE 6.4. STYGOFUNA SPECIES RECORDED FROM THE IRON VALLEY PROJECT, WITH KNOWN DISTRIBUTIONS INDICATED.	17
TABLE 6.5. STYGOFUNA IDENTIFIED ONLY TO HIGHER LEVEL (IMMATURE OR INCOMPLETE SPECIMENS; SPECIMENS NOT AVAILABLE FOR STUDY).	18

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 (56.8km² 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 km². 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.

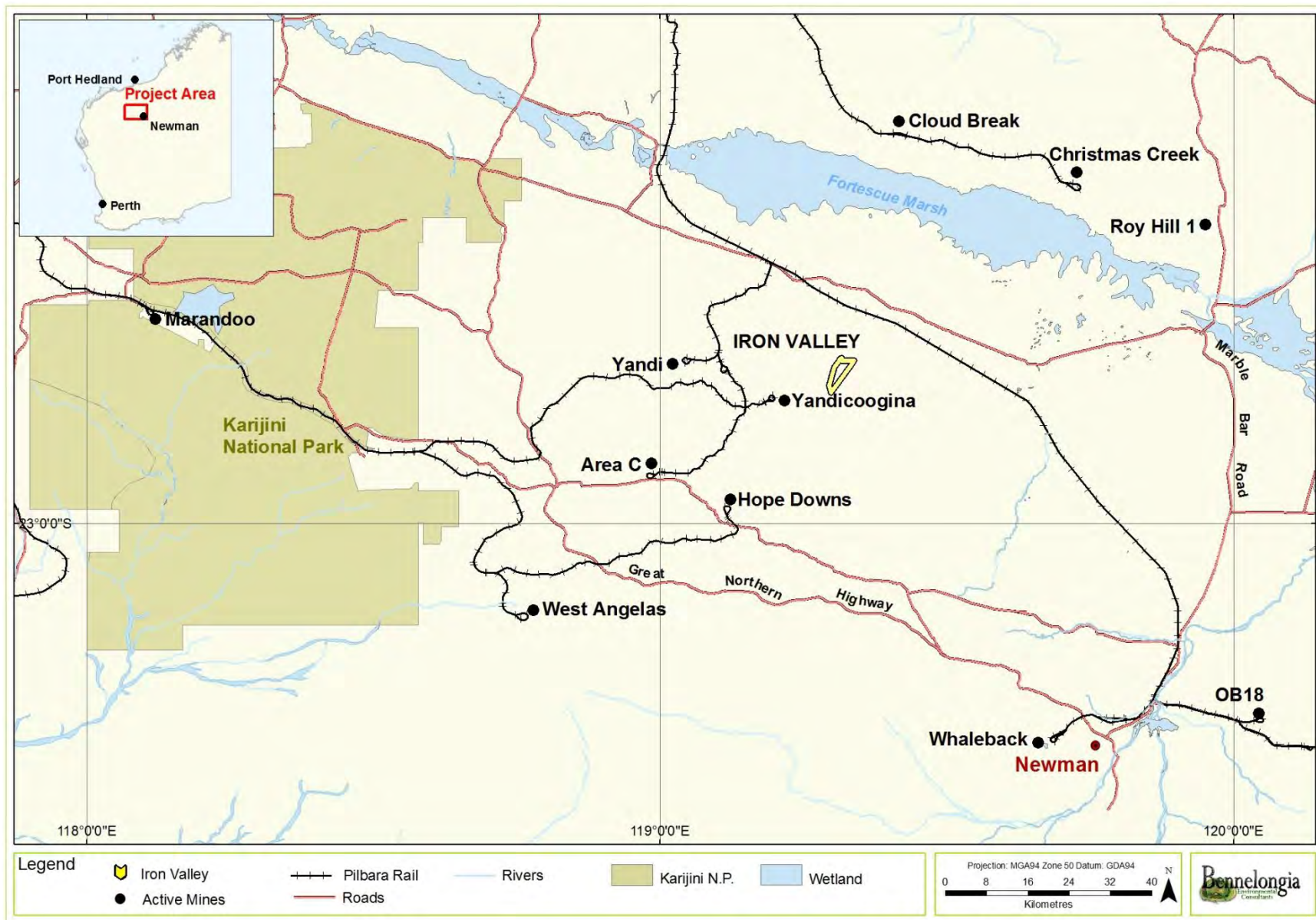


Figure 1-1. Location of the Iron Valley Project.

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 decreases 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 of 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 troglafauna. Stygofauna are aquatic and occur in groundwater. Troglafauna 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 troglafaunal 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 troglafauna (see Halse and Pearson 2014).

3.1. Troglafauna

While the earliest work on troglafauna was focussed on their occurrence in caves, surveys during the past five years have shown that troglafauna are widespread in the landscape matrix of the Pilbara and are represented by many invertebrate groups, including isopods, paligrads, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus-gnats. Although abundance and diversity of troglafauna appear to be greatest in the Pilbara, at a regional scale troglafauna 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 km² 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 km². 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 vadose¹ 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 chemoautotrophy² 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 through 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
<i>Samples</i>	<i>54*</i>	<i>20</i>
Round 2		
Scrape	43	17
S Trap	28	14
D Trap	16	3
<i>Samples</i>	<i>44*</i>	<i>17</i>
Round 3		
Scrape		33
S Trap		25
D Trap		8
<i>Samples</i>		<i>33</i>
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 scrape 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.

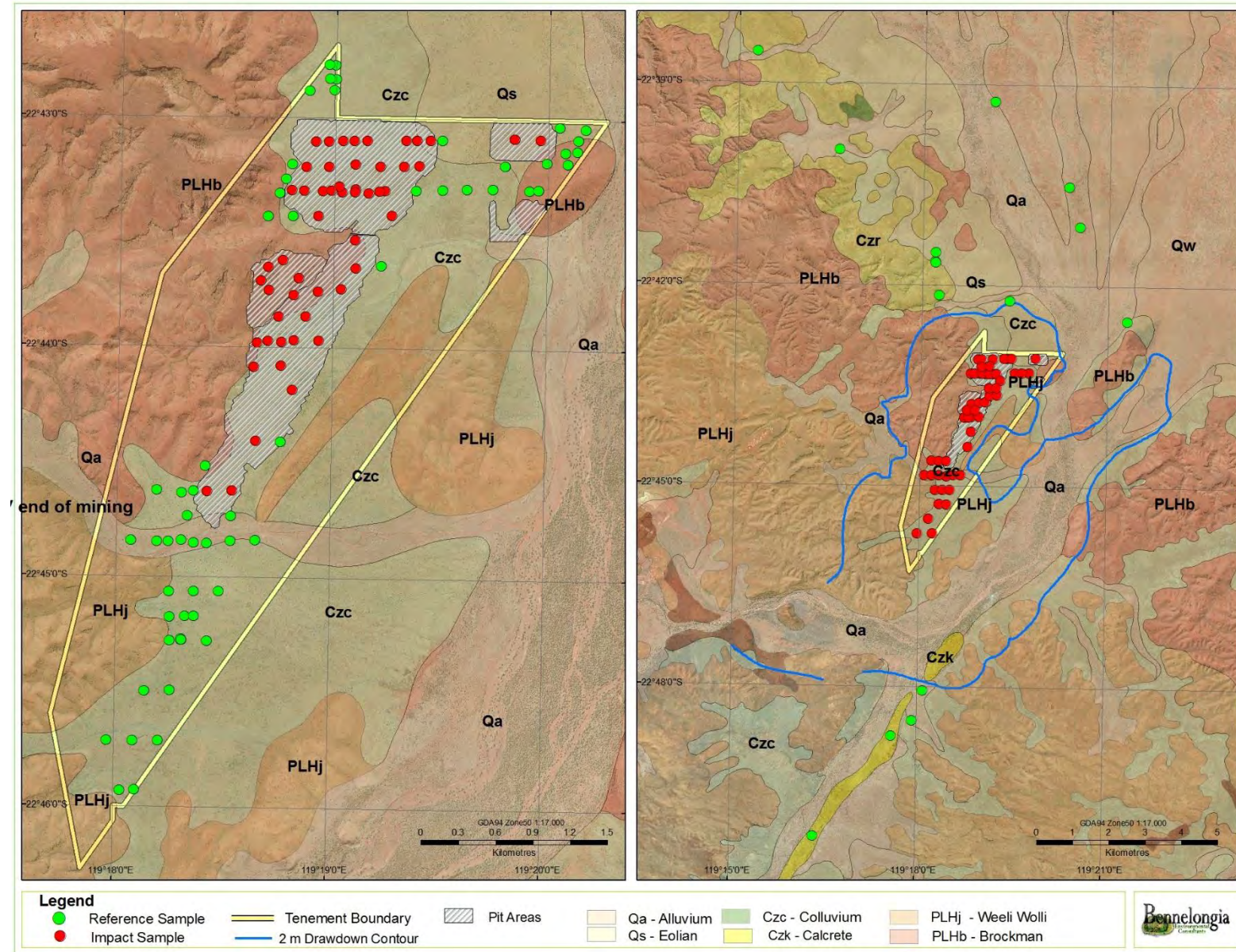


Figure 5-1. Locations of drill holes sampled for troglafauna and stygoafauna at the Iron Valley Project.

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 the sampling 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.

Staphylinidae 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. Troglotauna 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			
	<i>Lagynochthonius</i> 'PSE043'	1		Probably more widespread in the Iron Valley
	Schizomida			
	<i>Draculoides</i> 'SCH020'	2	1	Yes
Crustacea	Isopoda			
	<i>Armadillidae</i> sp. B04	1		Yes, known elsewhere in the Hamersley Range ²
	<i>Troglarmadillo</i> sp. B26	5		Yes, known elsewhere in the Hamersley Range ²
	nr <i>Andricophiloscia</i> sp. B03		1	Yes, from reference bores only
Chilopoda				
	<i>Chilopoda</i> sp.	1		Uncertain
Diplopoda				
	Polyxenida			
	<i>Lophoproctidae</i> sp. B01	3		Yes - very widespread species ¹
Symphyla				
	Cephalostigmata			
	<i>Symphyella</i> sp. B05		1	Yes, from reference bore and from Phil's Creek ²
Entognatha				
	Diplura			
	<i>Projapygidae</i> sp. B02		1	Yes, from reference bore only
	<i>Japygidae</i> sp. B04	1		Yes - very widespread species ¹
Insecta				
	Blattodea			
	<i>Nocticola</i> sp. B01	3		Yes - very widespread species ¹
	<i>Nocticola</i> sp. B09	2	1	Yes
	Hemiptera			
	<i>Meenoplidae</i> sp.		6	Probably - one of two widespread species ¹
	Hemiptera sp. B01	1		Yes - very widespread species ¹
	Coleoptera			
	<i>Staphylinidae</i> sp. B01		43	Yes, from reference bores only
	Diptera			
	<i>Sciaridae</i> sp. B01	8	22	Yes - very widespread species ¹

¹Bennelongia 2009a; ²Bennelongia unpublished data.

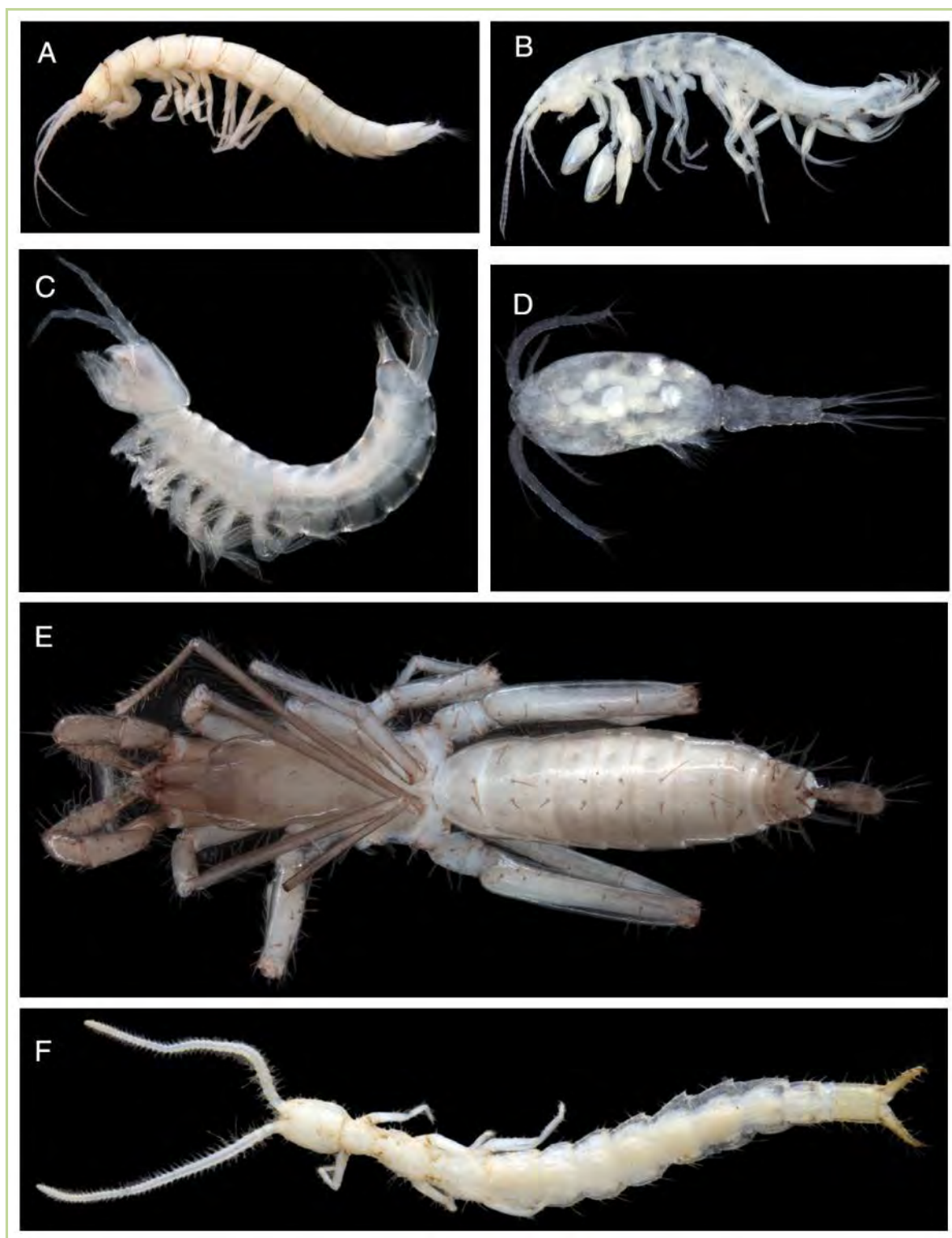


Figure 6-1. Stygofauna (A-D) and troglafauna photographs (E-F).

(A) *Pygolabis* sp. B06 (B) *Maarrka weeliwoollii* (C) nr *Billibathynella* sp. B01 (D) *Thermocyclops aberrans* (E) *Draculoides* 'SCH020' (F) *Japygidae* sp. B04.

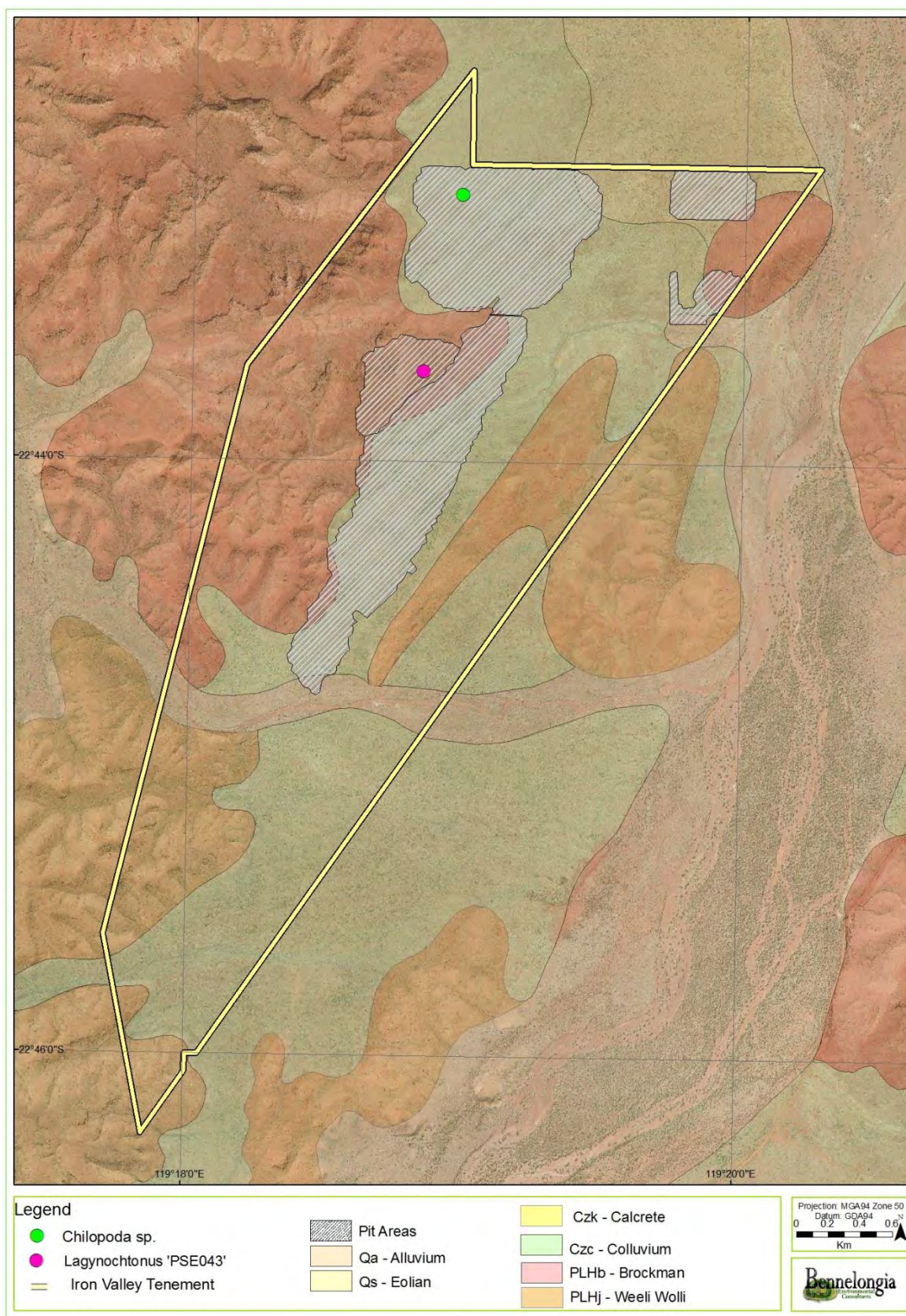
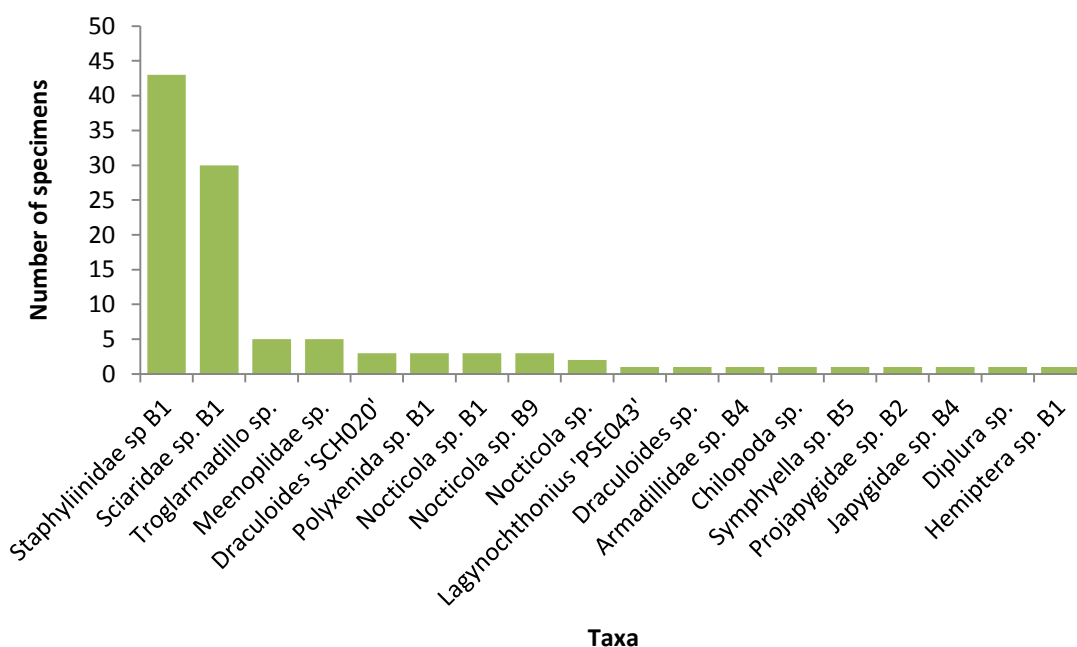


Figure 6-2. Locations of troglifauna species potentially known only from impact areas.

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			
	<i>Draculoides</i> sp.		2	<i>Draculoides</i> 'SCH020'
Entognatha				
	Diplura			
	Diplura sp.	1		Projapygidae sp. B02 or Japygidae sp. B04
Insecta				
	Blattodea			
	<i>Nocticola</i> sp.	2	3	<i>Nocticola</i> sp. B01 or <i>Nocticola</i> 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 symphylian *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

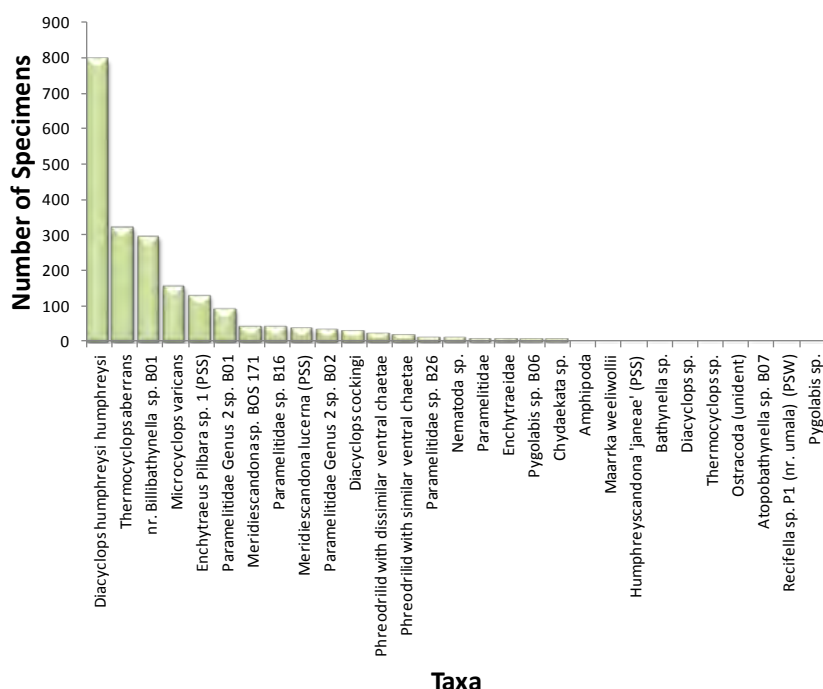
Stygofauna sampling in 2009 and 2011 yielded 2,152 specimens consisting of at least 22 species of eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (6 species), Isopoda (1 species) and nematodes of unknown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



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
	<i>Enchytraeus</i> Pilbara sp. 1	132	Yes, Pilbara-wide ¹
Acariformes			
	Hydracarina		
	<i>Recifella</i> sp. P1 (nr <i>umala</i>)	1	Yes, central Pilbara ¹
Crustacea	Ostracoda		
	<i>Humphreyscandona</i> 'janeae'	3	Yes, Fortescue catchment ¹
	<i>Meridiescandona lucerna</i>	40	Yes, Fortescue catchment ¹
	<i>Meridiescandona</i> sp. BOS171	47	No
	Copepoda		
	<i>Microcyclops varicans</i>	158	Yes, Pilbara-wide and beyond ²
	<i>Diacyclops cockingi</i>	34	Yes, Pilbara-wide ³
	<i>Diacyclops humphreysi humphreysi</i>	795	Yes, Pilbara-wide and beyond ⁴
	<i>Thermocyclops aberrans</i>	323	Yes, central Pilbara ⁵
	Syncarida		
	<i>Bathynella</i> sp. B23	2	Yes, 2015 target survey
	sp. B24	3	Uncertain
	nr <i>Billibathynella</i> sp. B01	298	Yes, known from lower Weeli Wolli and Marillana Creeks ⁶
	<i>Atopobathynella</i> sp. B07	2	Yes, known from Marillana Creek ⁶
	Amphipoda		
	<i>Maarrka weeliwollii</i>	3	Yes, widespread in Weeli Wolli/Marillana catchment ^{6,7}
	<i>Chydaekata</i> 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		
	<i>Pygolabis</i> sp. B06	11	Yes, known from lower Weeli Wolli and Marillana Creeks ⁶

¹Halse *et al.* unpublished data; ²Sars (1863); ³Karanovic (2006); ⁴Pesce and De Laurentiis (1996); ⁵Lindberg (1952); ⁶Bennelongia unpublished data; ⁷Finston *et al.* (2011); ⁸Finston *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	<i>Enchytraeus</i> Pilbara sp. 1
Crustacea			
Ostracoda	Ostracoda sp.	2	One of the three ostracods in Table 6.4
Copepoda	<i>Diacyclops</i> sp.	2	<i>Diacyclops humphreysi humphreysi</i> or <i>Diacyclops cockingi</i>
	<i>Thermocyclops</i> sp.	2	<i>Thermocyclops aberrans</i>
Amphipoda	Amphipoda sp.	3	One of the amphipods in Table 6.4
	Paramelitidae sp.	13	One of the paramelitid in Table 6.4
Isopoda	<i>Pygolabis</i> sp.	1	<i>Pygolabis</i> sp. B06
Syncarida	<i>Bathynella</i> sp.	NA	Possibly <i>Bathynella</i> sp. 24

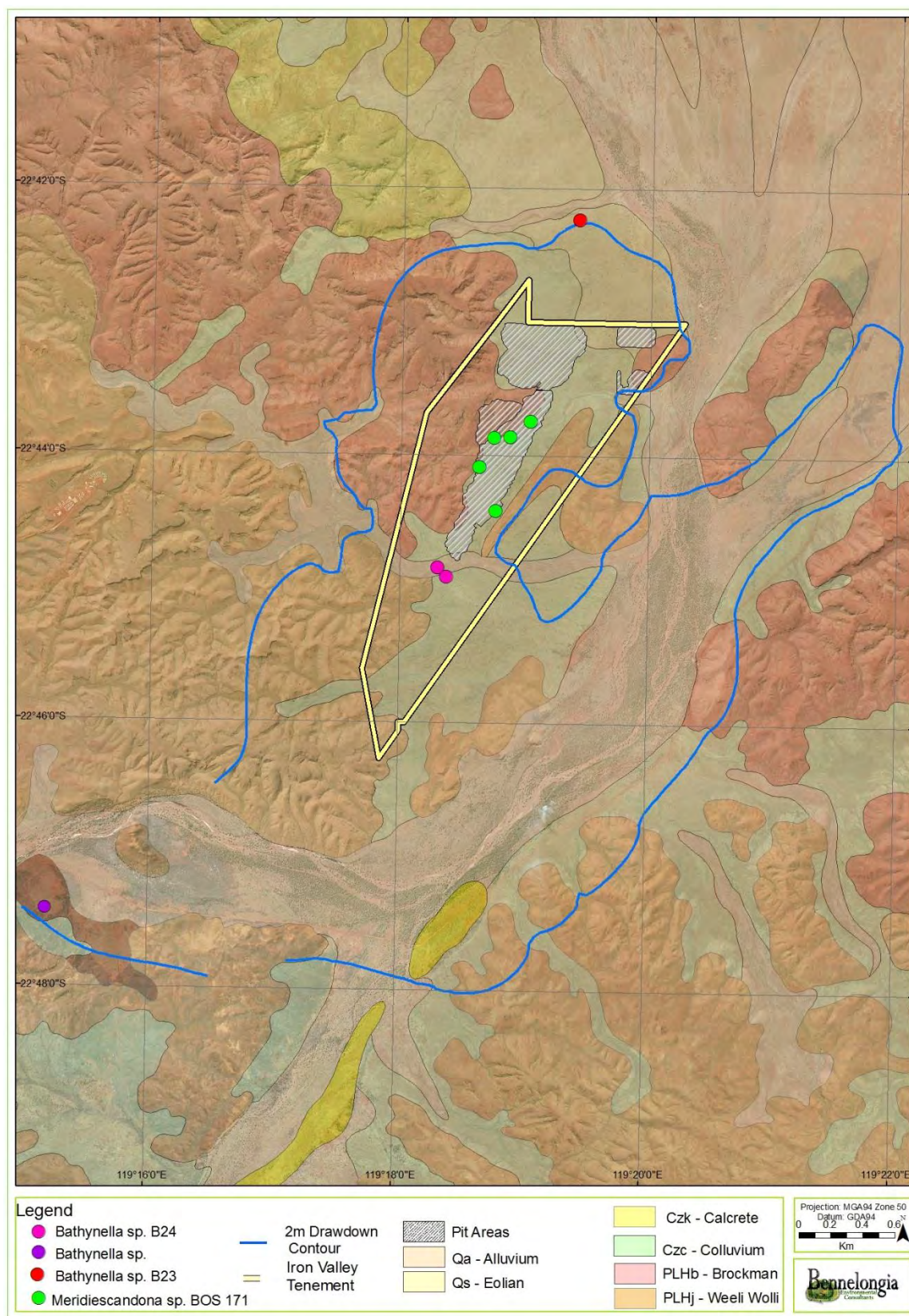


Figure 6-5. Locations of selected stygofauna species in relation to impact area.

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

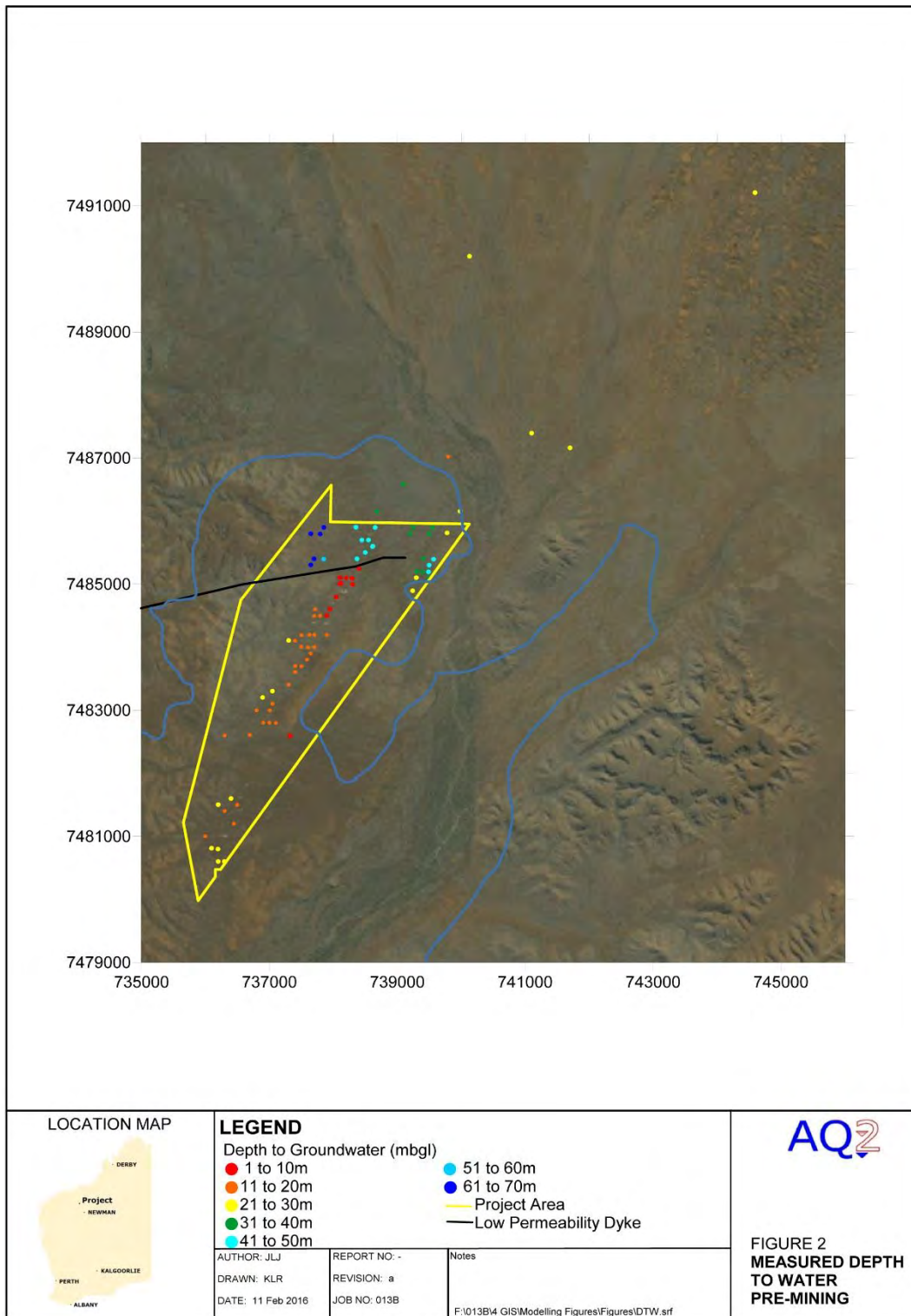


Figure 6-6. Depth to groundwater at Iron Valley.

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. Troglafauna

7.1.1. Iron Valley Troglafauna Community

The 16 species collected from 168 troglafauna samples indicate that the Iron Valley troglafauna community is moderately species rich by Pilbara standards. Large areas such as the Jirrapalpur 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 Ophthalmia Range, 0.70 in the Jirrapalpur 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 troglafauna than the commercial grade ore of the pit areas, reference hole abundance was boosted by high capture of two species that tend to cluster (Staphylinidae 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 troglafauna is dependent on geology and, if no fissures or voids are present in the strata, no troglafauna will occur. If subterranean spaces are present, the pattern of their occurrence will largely determine the density and distribution of troglafauna. 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. Troglafauna Distributions as Indicators of Habitat Connectivity

Many of the troglafauna 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 troglaphiles 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 its 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. Troglifauna

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

- The troglifauna 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 troglifauna 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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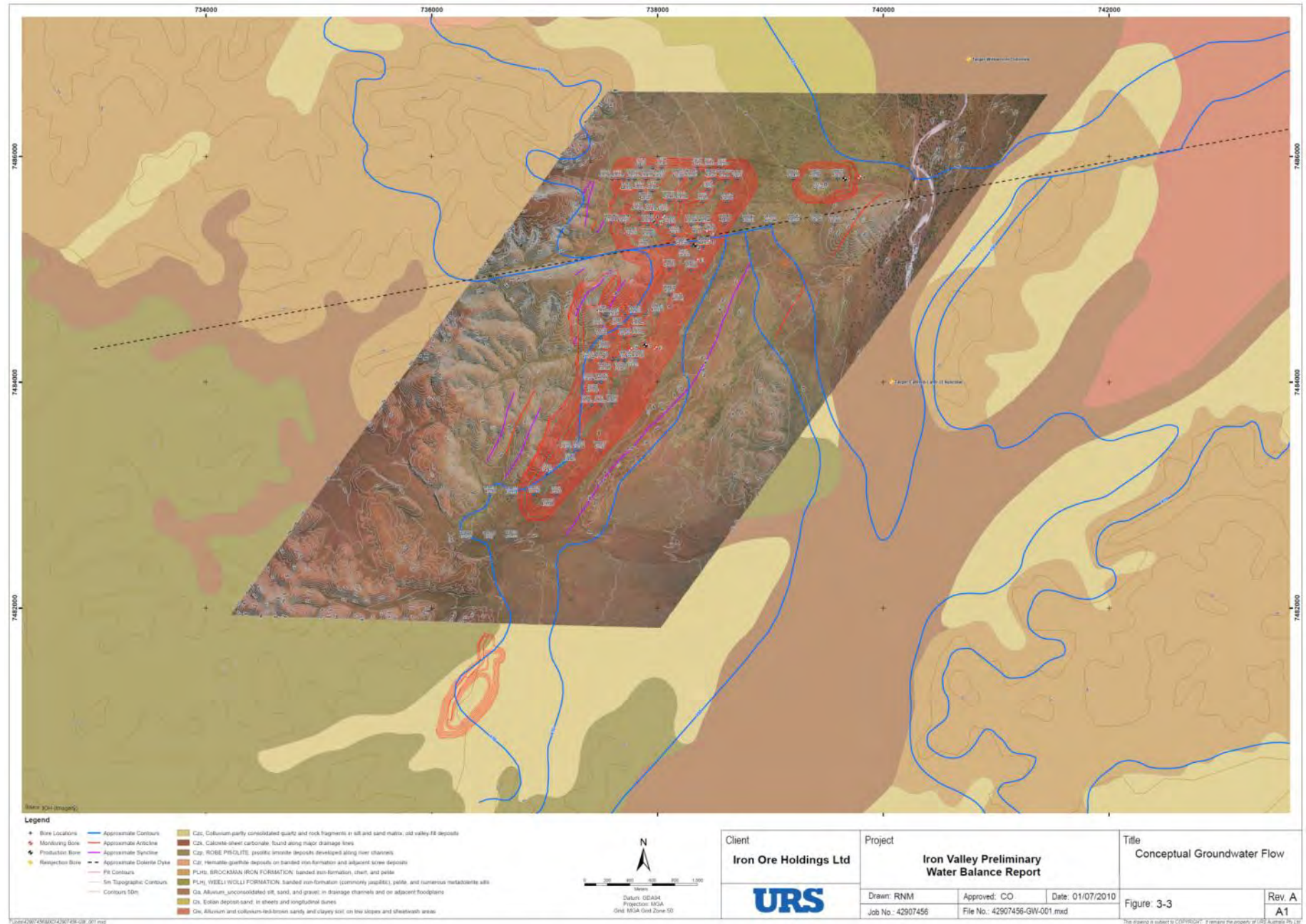
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Appendix 1: Geology of the Iron Valley Project



Appendix 2: Conceptual Groundwater Flow



N. 7485400

N. 7483800

N. 7484800

Legend

- Bore
- Fault
- Grid
- IV
- Level
- Lines
- Pit Shell
- Slot
- Dates Gorge Member
- Brockman Iron Formation - Dates Gorge Member
- Dolomite
- Joffre
- Weeli Wili
- Whaleback Shale

Source: Iron Ore Holdings Ltd

Client XXX	Project XX	Title Interpreted Hydrostatic Sections	
URS	Drawn: RNM	Approved: CO	Date: 30/06/2010
	Job No.: 42907456	File No.: 42907456-GW-005.mxd	
		Figure: X	Rev. A A3

Appendix 4: Co-ordinates of Drill Holes Sampled for Troglafauna 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

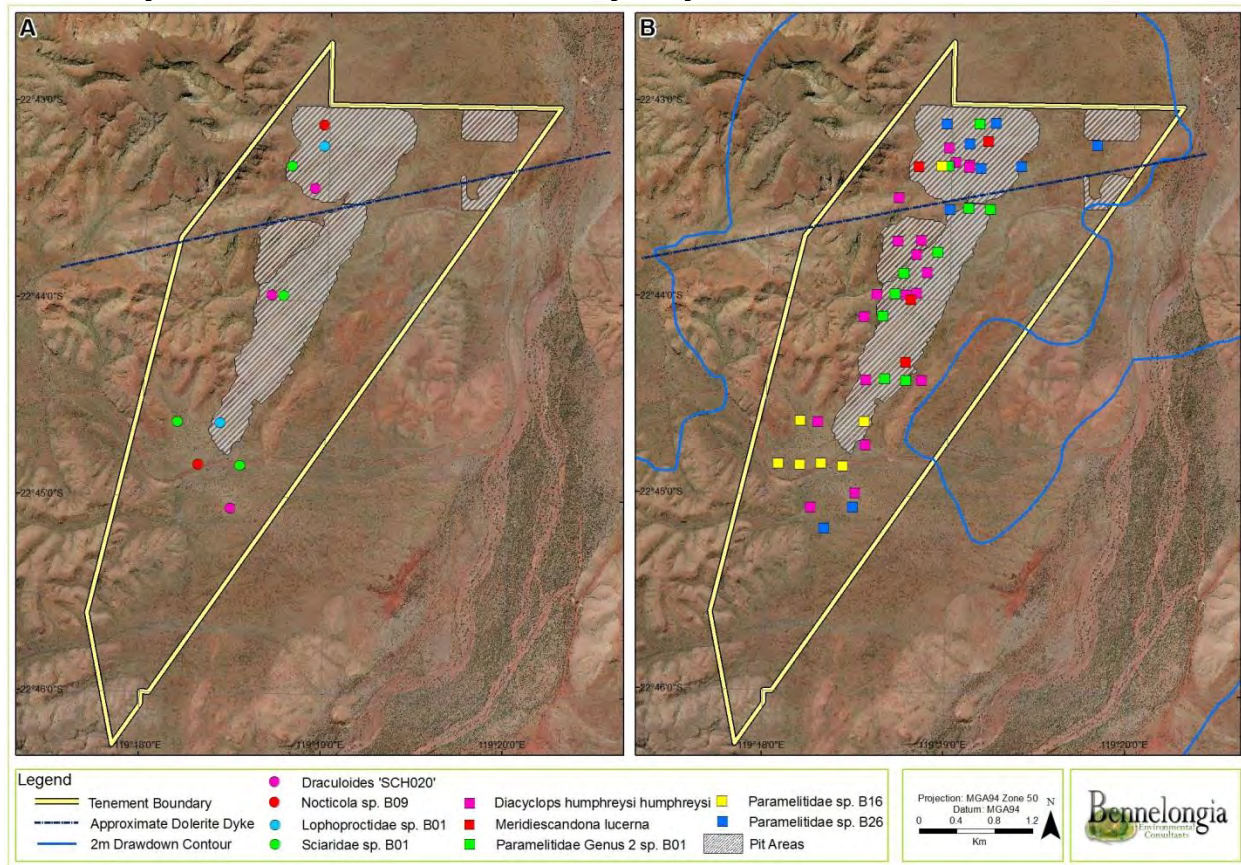
Bore Code	Site type	Latitude	Longitude
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IV452	Control	-22.717194	119.334083
IV453	Control	-22.719833	119.33475
IV454	Control	-22.718917	119.3355
IV460	Control	-22.718083	119.335583
IV463	Control	-22.717306	119.336139
IV464	Control	-22.719028	119.334556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

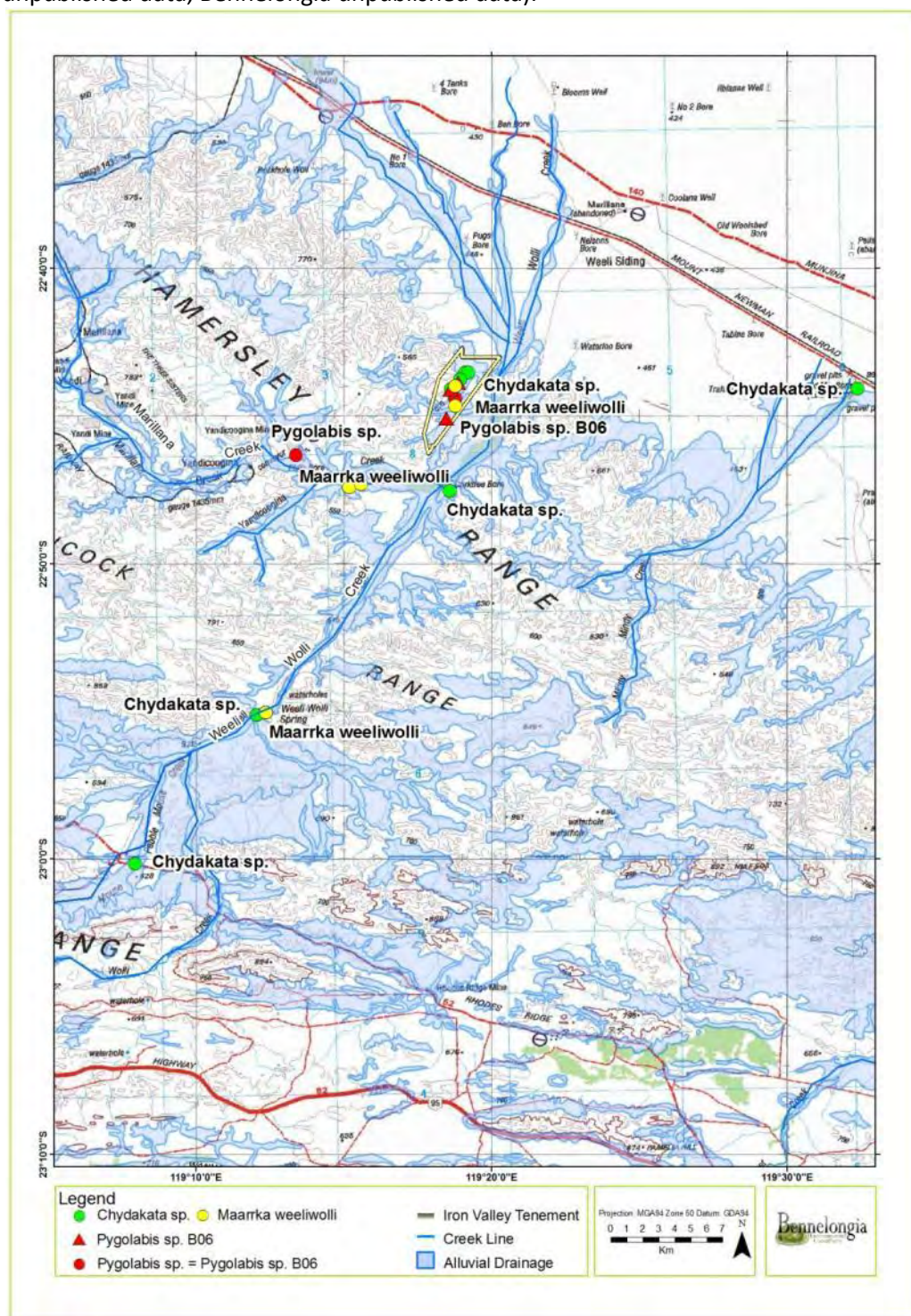
Bore code	Site type	Latitude	Longitude
WW050	Reference	-22.72175	119.326889
WW049	Reference	-22.721806	119.325
WW014	Reference	-22.74375	119.303056
WW015	Reference	-22.743917	119.304972

Appendix 6: Locations of Troglafauna (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); *Chydakata* sp. (Halse *et al.* unpublished data, Bennelongia unpublished data).



Iron Ore Holdings Ltd

Iron Valley Project: Subterranean Fauna Assessment

Final Report

Prepared for Iron Ore Holdings Ltd
by Bennelongia Pty Ltd

September 2012
Report 2012/81



Iron Valley Project: Subterranean Fauna Assessment

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ACN 124 110 167

September 2012

Report 2012/81

Cover photo: Iron Valley

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Client – Iron Ore holdings Limited

Report	Version	Prepared by	Checked by	Submitted to Client	
				Method	Date
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	Vers. 1	Andrew Trotter	Stuart Halse	email	22.ii.12
		Michael Curran			
	Vers. 2	Stuart Halse		email	1.iii.12
	Vers. 3	Andrew Trotter	Stuart Halse	email	31.vii.12
	Vers. 4	Andrew Trotter		email	6.ix.12

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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).

This subterranean fauna report presents results of troglafauna and stygofauna surveys conducted in 2009 and 2011 (the latter sampling at the request of the Department of Environment and Conservation) 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 troglafauna and 84 stygofauna samples being collected from bores inside the impact zone of the proposed mine.

The troglafauna sampling yielded 112 troglafaunal 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 troglafauna species recorded at the Iron Valley Project were recorded within the proposed mine pits. Of these 11 species, 10 species are known to occur in reference areas outside the mine pits or at deposits elsewhere in the Pilbara. One species of troglafauna (Chilopoda sp.) is currently known only from within the proposed mine pits at the Iron Valley Project. Chilopoda sp. was recorded as a singleton. The conservation status of this species is very difficult to quantify because it was damaged and its identification could not be taken further and, therefore, its range could not be determined. Based on the geology of the Iron Valley Project and the distribution of other Chilopoda in the Pilbara, it is expected that this species occurs beyond the Iron Valley mine pits.

Stygofauna sampling yielded 2,153 specimens consisting of at least 23 species of at least eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (7 species), Isopoda (1 species) and nematodes of unknown order/s. Copepods were the numerically dominant group at the Iron Valley Project, with species of oligochaetes, amphipods and syncarids also relatively abundant.

Twenty-two of the 23 stygofauna species recorded at Iron Valley were recorded from within the proposed drawdown cone, importantly all but two of these species are known from elsewhere. The remaining two species potentially have more localised ranges. These species, the ostracod *Meridiescandona* sp. BOS 171 and, to a lesser extent, the syncarid *Bathynella* sp. may be potentially threatened by drawdown. *Meridiescandona* sp. BOS 171 was collected from five drill holes within the Iron Valley Project, while *Bathynella* sp. was collected from a single hole. However, it is likely that both species exploit the habitat connectivity between the Project and surrounding areas in the same way as demonstrated by most of the stygofauna species at Iron Valley.

CONTENTS

EXECUTIVE SUMMARY	III
1. INTRODUCTION	1
2. HYDROGEOLOGY	3
3. EXISTING INFORMATION ON SUBTERRANEAN FAUNA	3
3.1. TROGLOFAUNA.....	3
3.2. STYGOFANA.....	4
4. PROJECT IMPACTS	4
5. METHODS.....	5
5.1. SURVEY RATIONALE.....	5
5.2. TROGLOFAUNA.....	6
5.2.1. <i>Sampling Effort</i>	6
5.2.2. <i>Sampling Methods</i>	6
5.2.3. <i>Sample Sorting and Species Identification</i>	8
5.3. STYGOFANA.....	8
5.3.1. <i>Sampling Effort</i>	8
5.3.2. <i>Sampling Methods</i>	8
5.3.3. <i>Species Sorting and Identification</i>	9
5.4. COMPILING SPECIES LISTS.....	9
5.5. PERSONNEL	9
5.6. OTHER SAMPLING.....	9
6. RESULTS	9
6.1. TROGLOFAUNA.....	9
6.1.1. <i>Troglofauna Occurrence and Abundance</i>	9
6.1.2. <i>Troglofauna Species of the Proposed Mine Pits</i>	13
6.1.3. <i>Troglofauna Distributions</i>	13
6.1.4. <i>Sampling Efficiency</i>	13
6.2. STYGOFANA.....	15
6.2.1. <i>Stygofauna Occurrence and Abundance</i>	15
6.2.2. <i>Species Identification Issues</i>	15
6.2.3. <i>Stygofauna Species of the Proposed Drawdown Cone</i>	18
6.2.4. <i>Stygofauna Distributions</i>	18
7. DISCUSSION.....	21
7.1. TROGLOFAUNA.....	21
7.1.1. <i>Troglofauna Distributions and Conservation Risks for Species</i>	21
7.1.2. <i>Habitat Characterisation</i>	21
7.1.3. <i>Iron Valley Troglofauna Community</i>	22
7.2. STYGOFANA.....	22
7.2.1. <i>Stygofauna Distributions and Conservation Risk for Species</i>	22
7.2.2. <i>Habitat Characterisation</i>	23
7.2.3. <i>Iron Valley Stygofauna Community</i>	23
8. CONCLUSION	23
8.1. TROGLOFAUNA.....	23
8.2. STYGOFANA.....	24
9. REFERENCES	24
10. APPENDICES	27
Appendix 1: <i>Geology of the Iron Valley Project</i>	27
Appendix 2: <i>Conceptual Groundwater Flow</i>	28
Appendix 3: <i>Interpreted Hydrostatic Sections</i>	29
Appendix 4: <i>Co-ordinates of Bores Sampled for Troglofauna at the Iron Valley Project</i>	30
Appendix 5: <i>Co-ordinates of Bores Sampled for Stygofauna at the Iron Valley Project</i>	33
Appendix 6: <i>Locations of Troglofauna (A) and Stygofauna (B) Species in Relation the Dolerite Dyke that Transects the Iron Valley Project</i>	35
Appendix 7: <i>Locations of Isopods and Amphipods</i>	36

LIST OF FIGURES

FIGURE 1.1. LOCATION OF THE IRON VALLEY PROJECT.	2
FIGURE 5.1. LOCATIONS OF DRILL HOLES SAMPLED FOR TROGLOFAUNA (A) AND STYGOFANA (B) AT THE IRON VALLEY PROJECT.....	7
FIGURE 6.1. STYGOFANA (A-D) AND TROGLOFAUNA PHOTOGRAPHS (E-F).	11
FIGURE 6.2. CAPTURE ABUNDANCE OF EACH TROGLOFAUNA SPECIES AT THE IRON VALLEY PROJECT.....	12
FIGURE 6.3. LOCATIONS OF SPECIMENS OF TROGLOFAUNA SPECIES COLLECTED ONLY FROM IMPACT BORES.	14
FIGURE 6.4. COMPARISON OF CAPTURE RATES BETWEEN SCRAPING AND TRAPPING.	15
FIGURE 6.5. CAPTURE ABUNDANCE OF EACH STYGOFANA SPECIES AT THE IRON VALLEY PROJECT.....	18
FIGURE 6.6. LOCATIONS OF STYGOFANA SPECIES COLLECTED ONLY FROM BORES AT THE IRON VALLEY PROJECT.....	19
FIGURE 6.7. LOCATIONS OF <i>BATHYNELLA</i> SPECIMENS IN THE VICINITY OF THE IRON VALLEY PROJECT.....	20

LIST OF TABLES

TABLE 5.1. NUMBERS OF TROGLOFAUNA SAMPLES COLLECTED FROM IRON VALLEY.	6
TABLE 5.2. NUMBERS OF STYGOFANA SAMPLES COLLECTED FROM IRON VALLEY.	8
TABLE 6.1. TROGLOFAUNA SPECIES RECORDED AT THE IRON VALLEY PROJECT WITH KNOWN DISTRIBUTION INDICATED.	10
TABLE 6.2. HIGHER LEVEL IDENTIFICATIONS (IMMATURE OR INCOMPLETE SPECIMENS).	12
TABLE 6.3. SUMMARY STATISTICS OF TROGLOFAUNA SAMPLING AT THE IRON VALLEY PROJECT.....	13
TABLE 6.4. STYGOFANA SPECIES RECORDED FROM THE IRON VALLEY PROJECT.	16
TABLE 6.5. HIGHER LEVEL STYGOFANA IDENTIFICATIONS (IMMATURE OR INCOMPLETE SPECIMENS).....	17
TABLE 6.6. SUMMARY STATISTICS OF STYGOFANA SAMPLING AT THE IRON VALLEY PROJECT.	18

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). The Iron Valley Project encompasses the following tenements: Exploration Licence E 47/1385 and M47/1439. IOH proposes to commence construction in Quarter 3, 2013, with operations commencing in Quarter 1, 2014. The life of the Project is expected to be approximately seven years. Decommissioning and closure is expected to occur between years 2021 and 2023, and closure would continue for a further 10 years until 2033.

Key mining components and activities of the proposed Project include:

- Mining of the ore deposit by conventional open pit methods over a 7 year mine life. Mining will only take place above the water table. This will involve drilling and blasting, digging and loading using hydraulic excavators and front-end loaders, and transport by haul trucks.
- Processing of ore on-site, with waste dumps located outside of the pit;
- Supporting infrastructure including an accommodation village, mine site offices and utilities; and
- Water supply borefield for potable and non-potable water.

The proposed area of mine pits at the Iron Valley Project is expected to total approximately 245 ha with a maximum depth of 70 m (depending on the water table). The watertable lies at approximately 6-18 m below ground surface to the south of the dyke and up to 70 m north of the dyke. Although the area of impact is small relative to the ranges of most restricted species, the pit excavation and drawdown (for water supply) proposed 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 – defined by Harvey 2002 as species with ranges of <10,000 km²). 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 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. About 70% of stygofauna in the Pilbara meet the criterion for being an SRE species (Eberhard *et al.* 2009) and the proportion of troglotauna that are SREs is likely to be even higher (see Lamoreux 2004).

The specific aims of the troglotauna 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.

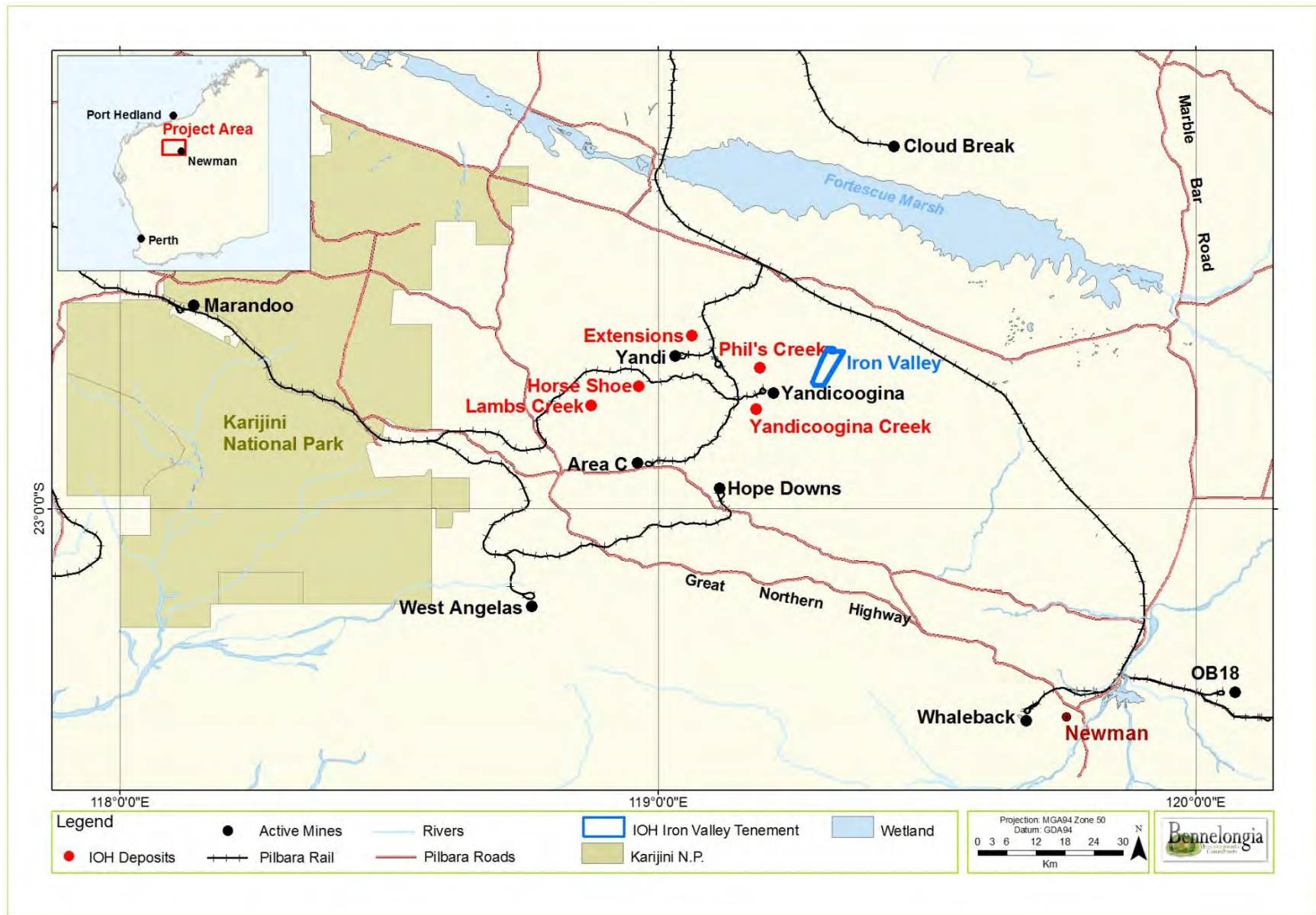


Figure 1.1. Location of the Iron Valley Project.

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 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.

The local aquifer system at the Iron Valley Project extends to a depth of at least 170 m and the system comprises three main aquifers:

- Alluvium, colluvium and Tertiary detritals
- Weathered and fractured bedrock of the Brockman Iron Formation and Weeli Wolli Formation
- Mineralised zones that comprise the orebody within the Brockman Iron Formation

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 pit, and much of the Iron Valley deposit, is separated from the regional aquifer. In contrast, the northern 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 troglafauna. Stygofauna are aquatic and occur in groundwater. Troglafauna 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 troglafaunal 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 troglafauna (see Biota 2005a, 2006; Subterranean Ecology 2007; Bennelongia 2008a, b, c, 2009a, b).

3.1. Troglafauna

While the earliest work on troglafauna was focussed on their occurrence in caves, surveys during the past five years have shown that troglafauna are widespread in the landscape matrix of the Pilbara and are represented by many invertebrate groups, including isopods, paligrads, spiders, schizomids, pseudoscorpions, harvestmen, millipedes, centipedes, pauropods, symphylans, diplurans, silverfish, cockroaches, bugs, beetles and fungus-gnats. Although abundance and diversity of troglafauna appear to be greatest in the Pilbara, at a regional scale troglafauna 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 prep.).

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. *Groundwater drawdown.* Drawdown of aquifers to for potable and non-potable water supply is likely to lead to some 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. *Groundwater drawdown 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 vadose¹ zone is affected by depth to the watertable is unclear. Given that pockets of residual water probably remain trapped throughout areas drawn-down and keep the overlying substrate saturated with water vapour, drawdown 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,

¹ The zone between the surface and groundwater

drawdown 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 chemoautotrophy² 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 through 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

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, is defined as the area which would be drawn-down for potable and non-potable water supply and was set as groundwater drawdown of greater than 2 m. This is above the natural seasonal variation of about 2 m (Johnson and Wright 2001) has typically been accepted as beginning to have the potential to impact on stygofauna in the Pilbara. It should be noted that the groundwater drawdown at the Iron Valley Project is expected to have a maximum depth of only 8 m.

² Microbial oxidation of inorganic compounds as an energy source

5.2. Troglotauna

5.2.1. Sampling Effort

A total of 86 impact and 82 reference samples were collected during three sampling rounds from 115 drill holes 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). Round 3 sampling was conducted at the request of the Department of Environment and Conservation (DEC) on the 11 October 2011 (scraping and setting traps). Traps were retrieved on 6 December 2011. The purpose of the sampling was to make further efforts to collect species previously known only from within the mine pit. A list of bores sampled is given in Appendix 4.

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

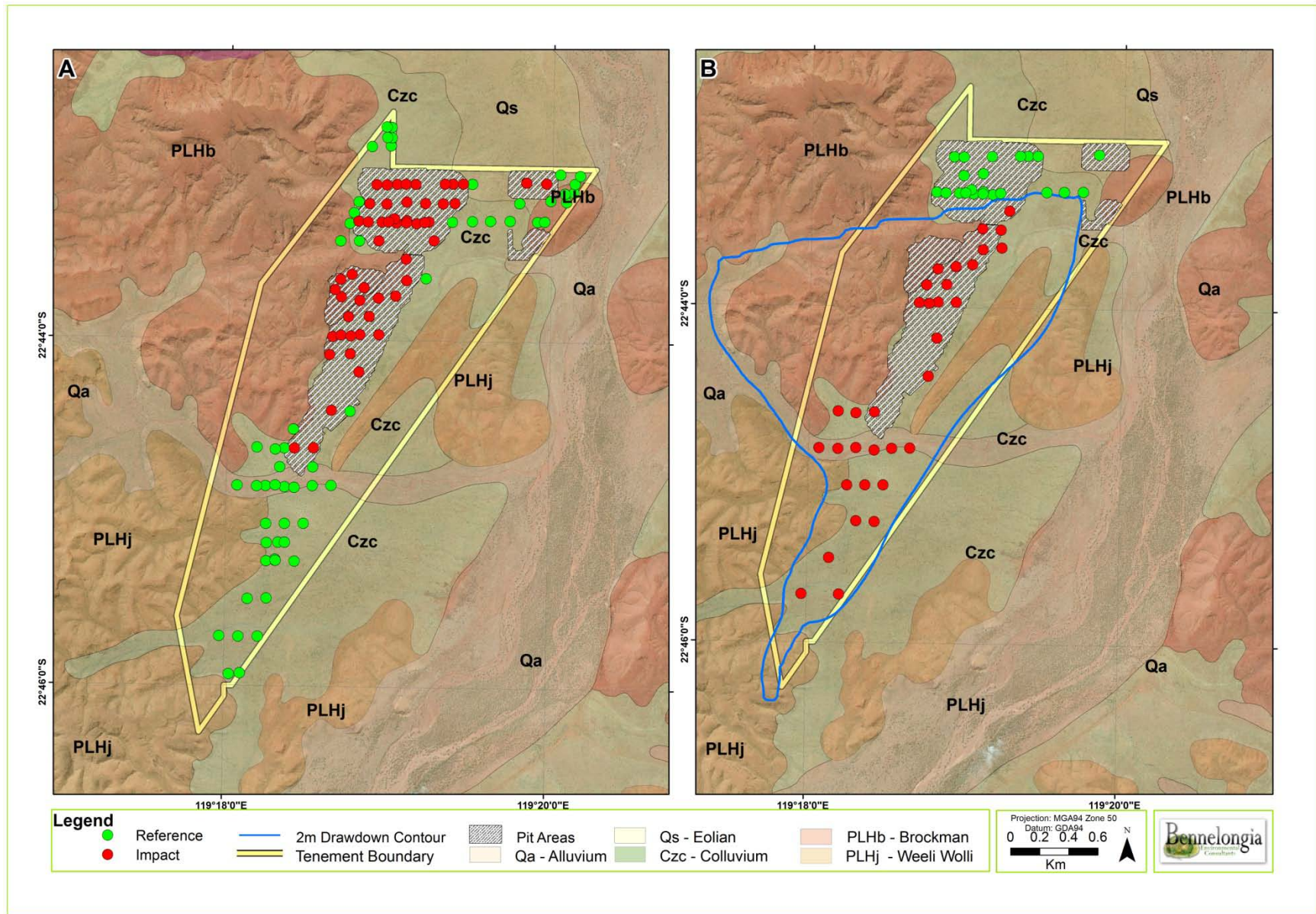
Round 1	Impact	Reference
Scrape	47	27
S Trap	32	20
D Trap	14	7
Samples	47*	27
Round 2		
Scrape	38	22
S Trap	25	17
D Trap	14	5
Samples	39*	22
Round 3		
Scrape		33
S Trap		25
D Trap		8
Samples		33
Total Samples	86	82

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.

5.2.2. Sampling Methods

In nearly all cases, each troglotauna 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 troglotauna 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 troglotauna 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.

5.3. Stygofauna

5.3.1. Sampling Effort

A total of 49 impact and 35 reference 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. To comply with DEC's request that further stygofauna sampling should be conducted outside the expected extent of groundwater drawdown, a further 27 bores were sampled at IOH's Yandicoogina, Boundary and Phil's Creek deposits in the Weeli Wolli catchment between 10 and 13 October 2011. These deposits are 15, 44 and 12 km from Iron Valley (Figure 1.1). Sampling details are not provided because no relevant stygofauna species were collected and the sampling occurred in tenements that are not the subject of this assessment. The purpose of the sampling was to demonstrate wider distribution of stygofauna species currently known only from Iron Valley. A list of bores sampled is given in Appendix 5.

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

	Impact	Reference
Round 1	21	20
Round 2	28	15
Total Samples	49	35

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. B04 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. B04. The purpose of this criterion was to prevent higher level identifications falsely inflating species richness.

5.5. Personnel

Fieldwork was undertaken by Sean Bennett, Jim Cocking, Mike Scanlon, 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.

5.6. Other Sampling

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

6. RESULTS

6.1. Troglofauna

6.1.1. Troglofauna Occurrence and Abundance

Sampling at Iron Valley yielded 112 troglofaunal animals, representing seven Classes, 11 Orders and 16 species (Table 6.1, Table 6.2). 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).

Table 6.1. Troglafauna 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				
		<i>Lagynochthonius</i> sp. B02	1		Yes, known from IOH Yandicoogina tenement; and elsewhere in the Hamersley Range ^{1,2}
	Schizomida				
		<i>Draculoides</i> sp. B04	2	1	Yes
Crustacea					
	Isopoda				
		Armadillidae sp. B04	1		Yes, known elsewhere in the Hamersley Range ²
		<i>Troglarmadillo</i> sp. B26	5		Yes, known elsewhere in the Hamersley Range ²
		nr <i>Andricophiloscia</i> 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				
		<i>Symphyella</i> 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				
		<i>Nocticola</i> sp. B01	3		Yes - very widespread species ¹
		<i>Nocticola</i> 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				
		Staphylinidae sp. B01		43	Yes, from reference bores only
	Diptera				
		Sciaridae sp. B01	8	22	Yes - very widespread species ¹

¹Bennelongia 2009a; ²Bennelongia unpublished data.

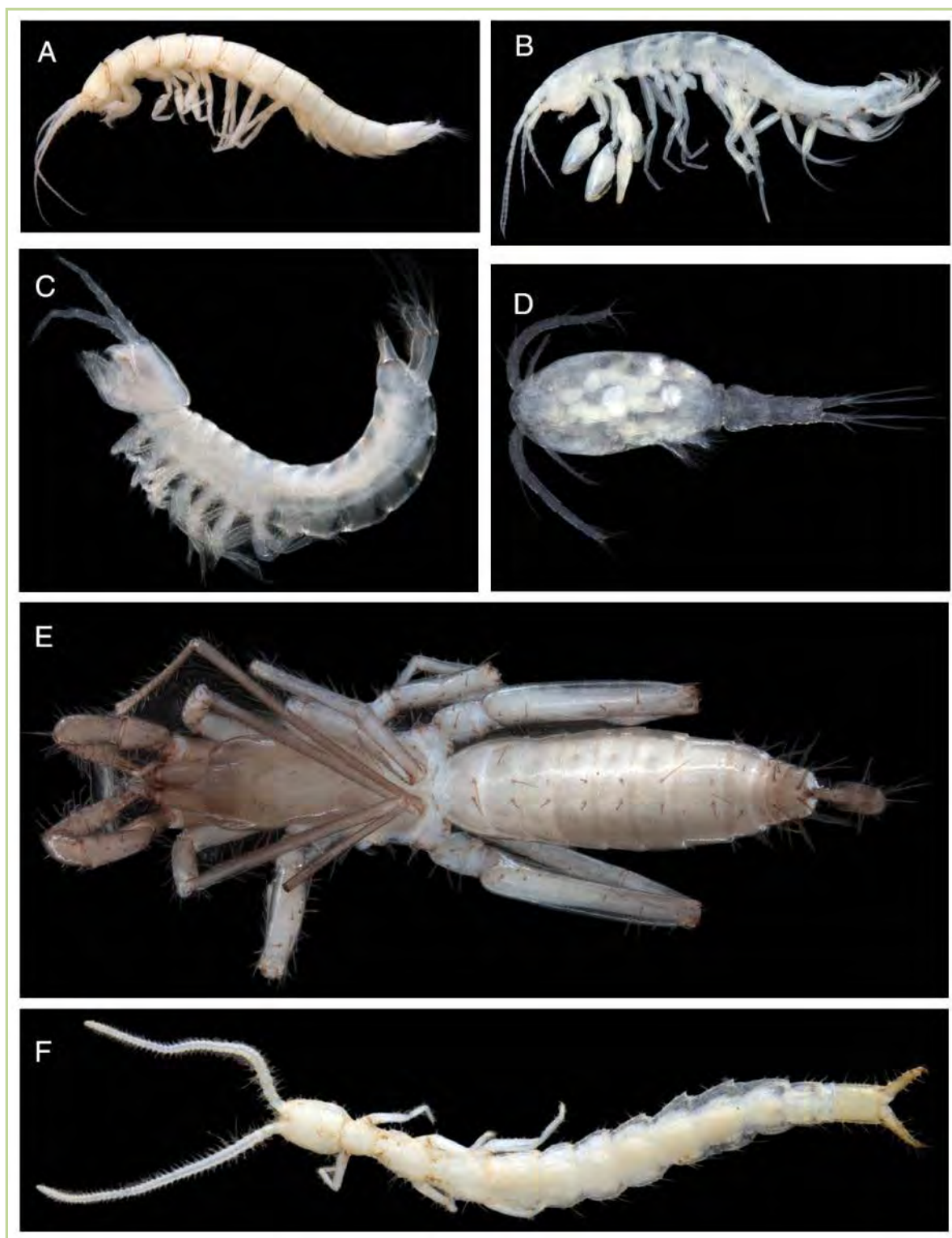
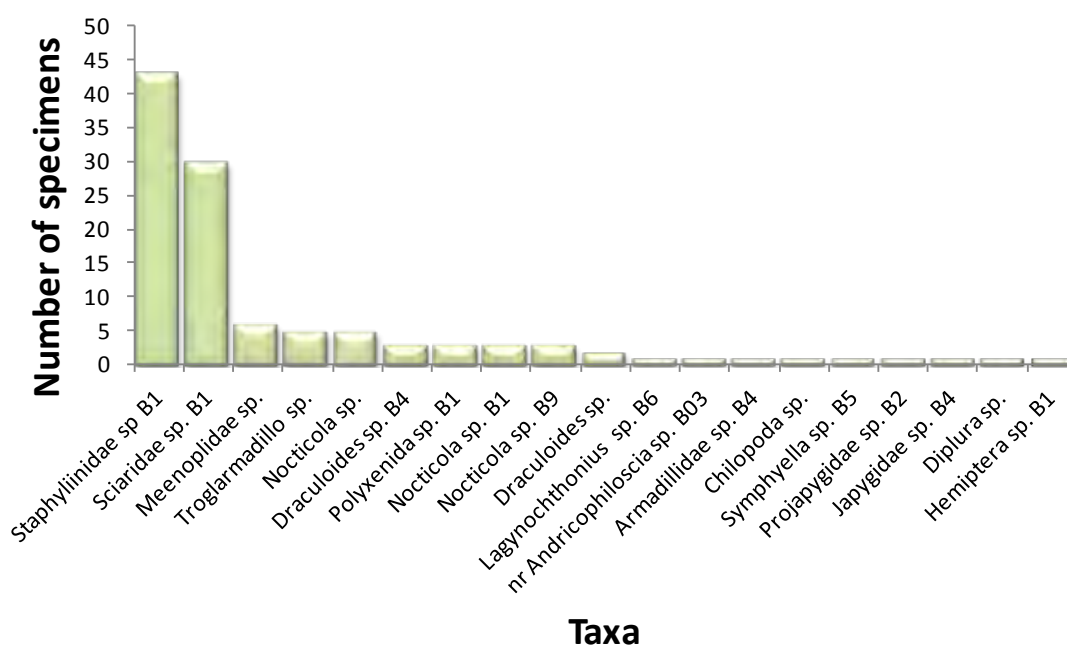


Figure 6.1. Stygofauna (A-D) and troglafauna photographs (E-F).

(A) *Pygolabis* sp. B06 (B) *Maarrka weeliwoollii* (C) nr *Billibathynella* sp. B01 (D) *Thermocyclops aberrans*
(E) *Draculoides* sp. B04 (F) *Japygidae* sp. B04.

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

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

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

Seven animals were collected that did not appear to represent additional species, but which 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.

Staphylinidae sp. B01 and Sciaridae sp. B01 were the numerically dominant species within the Iron Valley Project (Table 6.1, Figure 6.2). Nearly all other species were collected in low abundances (≤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; excluding unidentifiable specimens). 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 bores than impact bores (Table 6.3). However, the number of species per sample was essentially the same for reference and impact bores (Table 6.3). The number of species collected within the mine pit (11) was higher than in the reference area (8) (Table 6.3).

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
<i>Impact</i>	86	31	0.36	11	0.20 ± 0.06
<i>Reference</i>	82	81	0.99	8	0.20 ± 0.02

6.1.2. Troglofauna Species of 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, 10 species are known to occur in reference areas outside the mine pits or at deposits elsewhere in the Pilbara. One species, Chilopoda sp. (recorded as a singleton based on a damaged specimen) is only known from the proposed mine pit (Figure 6.3). The taxonomy of this specimen cannot be taken further and, therefore, its range cannot be determined.

6.1.3. Troglofauna Distributions

Overall, about two-thirds of the troglofauna species collected are known from outside the Project area. Given that three species are known only from their singleton records at Iron Valley and most animals occurred in low abundance, making it likely their ranges are under-estimated; it appears that the troglofauna community of Iron Valley is not restricted to the Project area.

For example, five species (Lophoproctidae sp. B01, Japygidae sp. B04, *Nocticola* sp. B01, Hemiptera sp. B01 and Sciaridae sp. B01) 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 hole), probably belongs to one of two species that are very widespread in the Pilbara (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 and an additional three species, *Lagynochthonius* sp. B02, Armadillidae sp. B04 and *Troglarmadillo* sp. B26, are known more locally in the Hamersley Range (Table 6.1).

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. At the Project site, 13% of all troglofaunal animals represented two-thirds of all species. Only two species were represented by more than five animals (Figure 6.2).

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 (0.99 specimens per sample versus 0.36, in Table 6.3). Scraping and trapping gave similar yields but reference bores yielded better than impact bores (Figure 6.4).

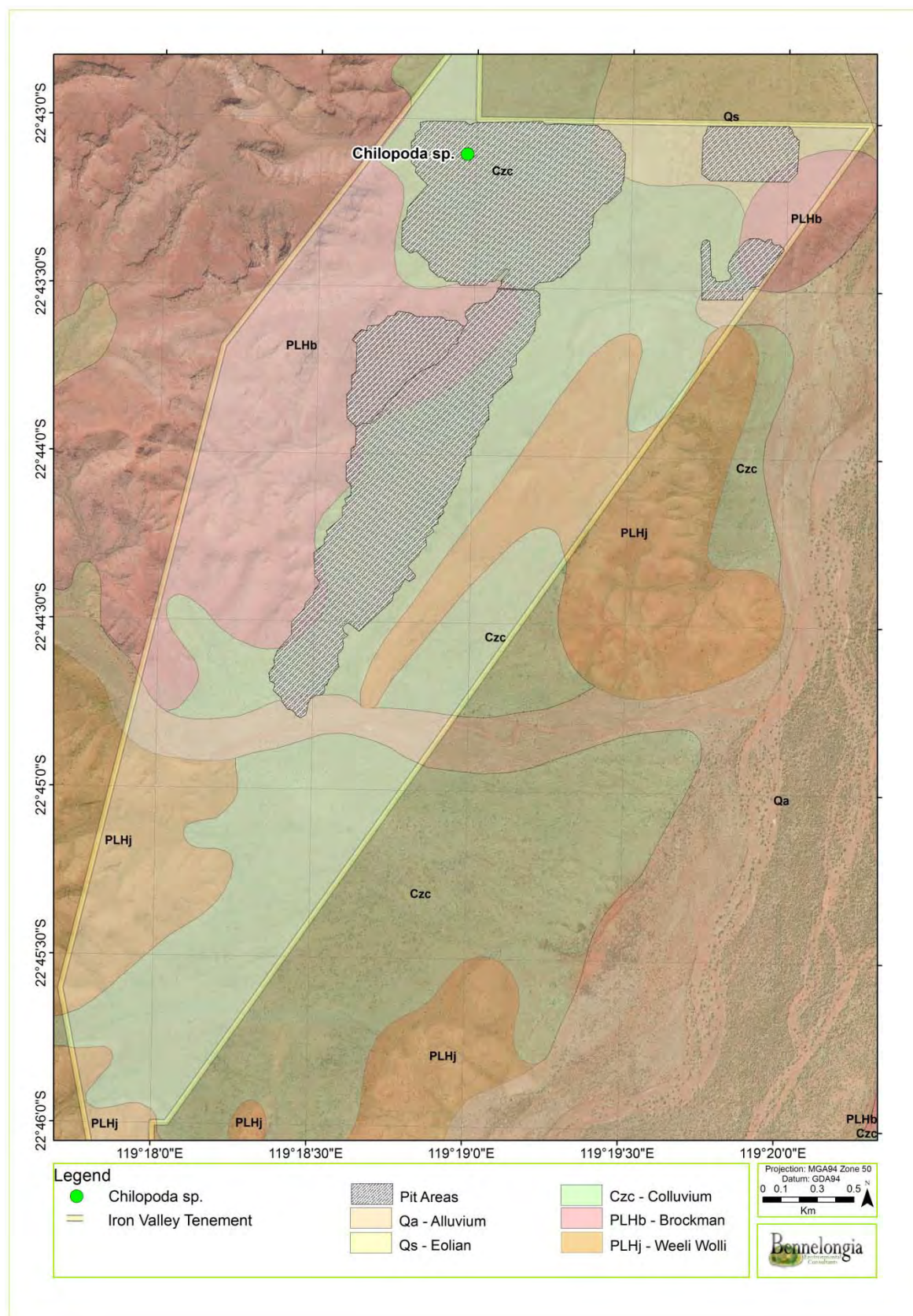


Figure 6.3. Locations of specimens of troglofauna species collected only from impact bores.

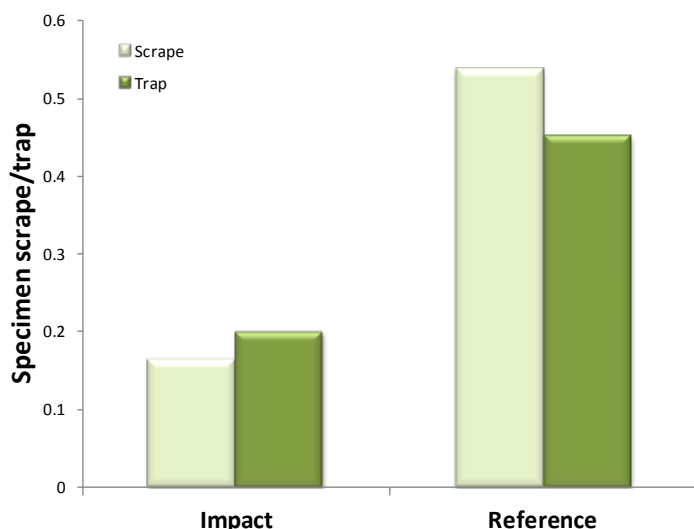


Figure 6.4. Comparison of capture rates between scraping and trapping.

6.2. Stygofauna

6.2.1. Stygofauna Occurrence and Abundance

Stygofauna sampling yielded 2,153 specimens of at least 23 species of eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (7 species), Isopoda (1 species) and nematodes of unknown order/s (Table 6.4, Figure 6.1).

Copepods were the numerically dominant group within the Iron Valley Project, with species of oligochaetes, amphipods and syncarids also relatively abundant (Table 6.4, Figure 6.5). *Diacyclops humphreysi humphreysi*, *Thermocyclops aberrans* 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).

The number of stygofaunal specimens collected per sample was about three times higher from impact bores than bores reference (Table 6.6). While, the number of species per sample was about double that in impact bores compared to reference bores (Table 6.6). The number of species collected from impact bores (22) was higher than that from reference bores (13) (Table 6.6).

6.2.2. Species Identification Issues

Some stygofauna could not be identified to species level (Table 6.3). 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 one species identified only to genus level (*Bathynella* sp.).

The taxonomy of *Bathynella* in Australia 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. 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.

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	Impact	Reference	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
	<i>Enchytraeus</i> Pilbara sp. 1	126	6	Yes, Pilbara-wide ¹
Acariformes				
	Hydracarina			
	<i>Recifella</i> sp. P1 (nr <i>umala</i>)	1		Yes, central Pilbara ¹
Crustacea	Ostracoda			
	<i>Humphreyscandona</i> 'janeae'		3	Reference are only, and widespread in the Fortescue catchment ¹
	<i>Meridiescandona lucerna</i>	9	31	Yes, and also more widely in the Fortescue catchment ¹
	<i>Meridiescandona</i> sp. BOS 171	47		No
	Copepoda			
	<i>Microcyclops varicans</i>	158		Yes, Pilbara-wide and beyond ²
	<i>Diacyclops cockingi</i>	1	33	Yes, Pilbara-wide ³
	<i>Diacyclops humphreysi humphreysi</i>	617	178	Yes, Pilbara-wide and beyond ⁴
	<i>Thermocyclops aberrans</i>	223	100	Yes, central Pilbara ⁵
	Syncarida			
	<i>Bathynella</i> sp.	3		Uncertain
	nr <i>Billibathynella</i> sp. B01	298		Yes, known from lower Weeli Wolli and Marillana Creeks ⁶
	<i>Atopobathynella</i> sp. B07	2		Yes, known from Marillana Creek ⁶
	Amphipoda			
	<i>Maarrka weeliwollii</i>	2	1	Yes, widespread in Weeli Wolli/Marillana catchment ^{6,7}
	<i>Chydaekata</i> sp. E	9	1	Yes, widespread in Weeli Wolli/Marillana catchment ^{6,8}
	Paramelitidae Genus 2 sp. B01	87	6	Yes, lower Weeli Wolli Creek ²
	Paramelitidae Genus 2 sp. B02	30	7	Yes, widespread in Weeli Wolli/Marillana catchment ⁶
	Paramelitidae sp. B16	44	1	Yes, known from lower Weeli Wolli and Marillana Creeks ⁶
	Paramelitidae sp. B03	2	1	Yes, widespread in Weeli Wolli/Marillana catchment ⁶
	Paramelitidae sp. B26	3	10	Yes, known from southern floodplain of the Fortescue Marsh ⁶
	Isopoda			
	<i>Pygolabis</i> sp. B06	11		Yes, known from lower Weeli Wolli and Marillana Creeks ⁶

¹Halse *et al.* unpublished data; ²Sars (1863); ³Karanovic (2006); ⁴Pesce and De Laurentiis (1996); ⁵Lindberg (1952); ⁶Bennelongia unpublished data; ⁷Finston *et al.* (2011); ⁸Finston *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	Impact	Reference	Probable species
Oligochaeta				
Tubificida				
	Enchytraeidae sp.	12	1	<i>Enchytraeus</i> Pilbara sp. 1
Crustacea				
Ostracoda	Ostracoda sp.	2		One of the three ostracods in Table 6.4
Copepoda				
	<i>Diacyclops</i> sp.		2	<i>Diacyclops humphreysi humphreysi</i> or <i>Diacyclops cockingi</i>
	<i>Thermocyclops</i> sp.	2		<i>Thermocyclops aberrans</i>
Amphipoda				
	Amphipoda sp.	1	3	One of the amphipods in Table 6.4
	Paramelitidae sp.	10	3	One of the paramelitid in Table 6.4
Isopoda				
	<i>Pygolabis</i> sp.	1		<i>Pygolabis</i> sp. B06

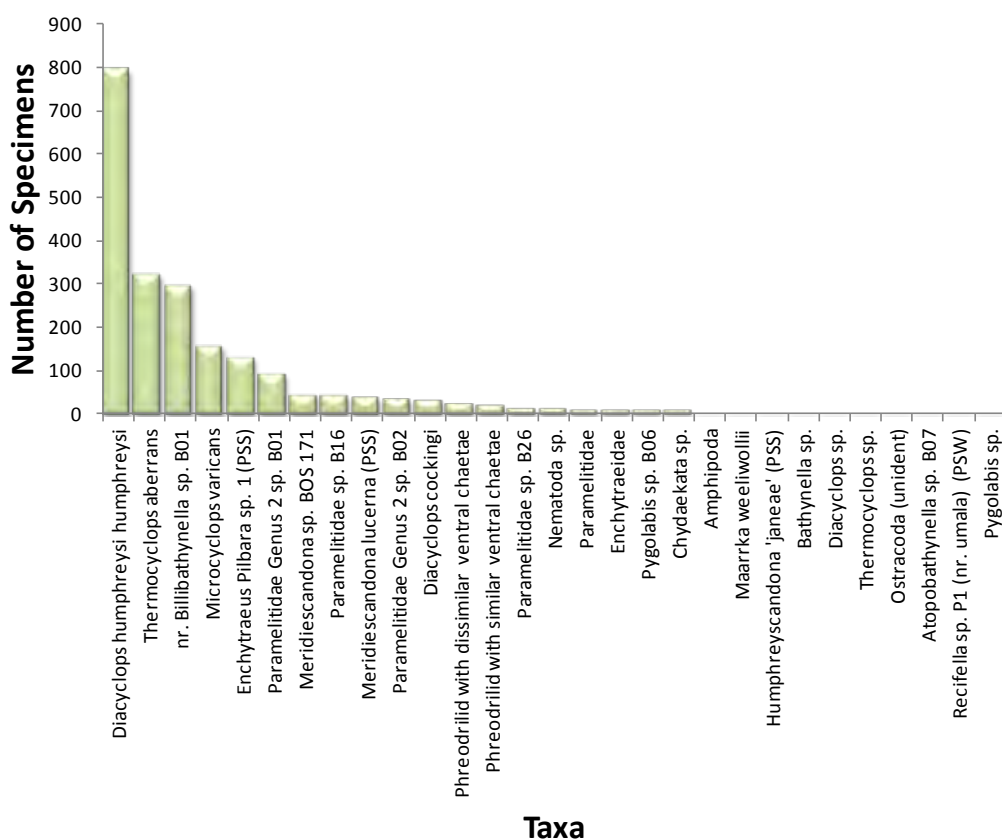


Figure 6.5. Capture abundance of each stygofauna species at the Iron Valley Project.

Table 6.6. Summary statistics of stygofauna 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	49	1764	36	22	1.77 ± 0.27
Reference	35	389	11.1	13	0.71 ± 0.12

6.2.3. Stygofauna Species of the Proposed Drawdown Cone

Twenty-two stygofauna species were recorded from within the proposed drawdown cone and all but two of these species are known from elsewhere (Table 6.4). The remaining two species potentially have more localised ranges (Figure 6.6). The ostracod *Meridiescandona* sp. BOS 171 has to date been collected only from the area that will be impacted by groundwater drawdown, where it has been found in five drill holes. The syncarid *Bathynella* sp. has also been collected only from the area that will be impacted by groundwater drawdown (twice at bore WW010). However, it is uncertain if *Bathynella* sp. is a new species (due to the genus level identification) and these specimens may be conspecific with specimens of *Bathynella* that have been previously collected about seven kilometres south-west of the Iron Valley Project (Figure 6.7).

6.2.4. Stygofauna Distributions

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

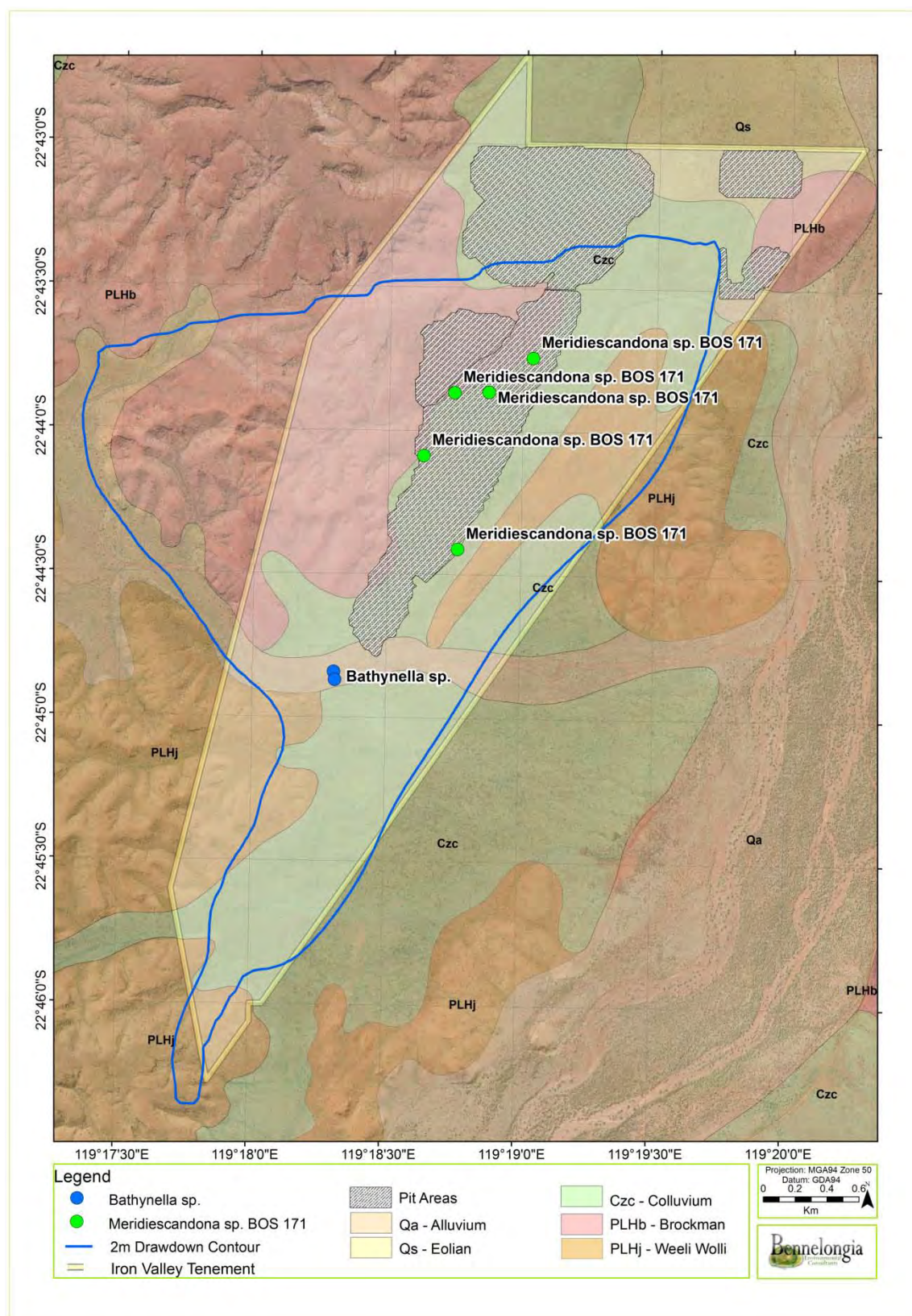
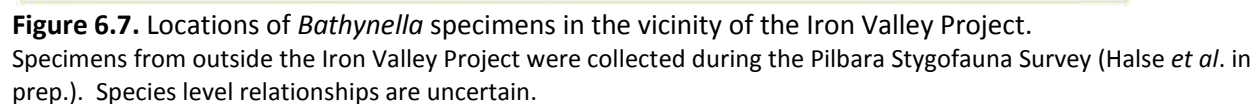


Figure 6.6. Locations of stygofauna species collected only from bores at the Iron Valley Project. Drawdown cones are expected to extend beyond all of the bores indicated.



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.

Many of 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 obligate troglofauna is sometimes questioned and many such species probably have a surface dispersal phase. However, there seems little doubt that the arachnid species *Draculoides* sp. B04 is a troglobiont. *Draculoides* sp. B04 was found in both impact and reference bores at Iron Valley, suggesting that subterranean habitats within the impact and reference areas are connected. In fact, the true range of *Draculoides* sp. B04 may be considerably greater than demonstrated, owing to the confined distribution of the sampling at the Iron Valley Project and subterranean habitat connections may extend well outside the Iron Valley Project into surrounding areas (see Section 7.1.3).

One species of troglofauna (Chilopoda sp.) is currently known only from within the proposed mine pits at the Iron Valley Project. Chilopoda sp. was recorded as a singleton. The conservation status of this species cannot be quantified because the specimen was too damaged for species identification. It should be noted, however, that:

- All species of Chilopoda collected by Bennelongia in the Pilbara have been collected at very low abundance (110 specimens from over 10,000 troglofauna samples), which makes determination of range very difficult.
- 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 1). The 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 6). Two of these species are very widespread (*Lophoproctidae* sp. B01 and *Sciaridae* sp. B1) and may not be obligate troglofauna but *Nocticola* sp. B09 and *Draculoides* sp. B04 are troglobites.

7.1.3. 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 Jirrapur 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 Ophthalmia Range, 0.70 in the Jirrapur 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). 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 hole abundance was boosted by high capture of two species (*Staphylinidae* sp. B01 and *Sciaridae* sp. B01).

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, one species appears to be possibly threatened by Project development (the ostracod *Meridiescandona* sp. BOS 171), while the status of syncarid species identified only to genus (*Bathynella* sp.) is unclear and it must also be regarded as potentially impacted. 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 *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 weeliwollii* and *Pygolabis* sp. B06 (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 7). 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. *Bathynella* sp. represents a genus level identification because of the absence of a satisfactory taxonomic foundation for recognizing boundaries of Australian species. Whether *Bathynella* sp. is known only from the Project area is unclear. The occurrence of larger stygofauna species such as *Maarrka weeliwoollii* and *Pygolabis* sp. B06 more widely in the Marillana/Weeli Wolli Creek catchment (see Appendix 7) suggests it is unlikely that the small *Bathynella* sp. would be restricted to the Project area. Therefore, *Bathynella* sp. found at Iron Valley may be the same as the *Bathynella* species that was collected seven kilometres away in previous surveys (Figure 6.7). The only evidence suggesting that the species may be different is that two-thirds of known syncarid species have linear ranges of <10 km (Camacho and Valdecasas 2008).

When the 8 m drawdown cone is put into context of the total depth of the local aquifer system (at least 170 m deep, see Section 2 and Appendix 3), drawdown probably does not represent a significant threat to stygofauna species, unless such species are further restricted to particular units of the local aquifer system.

7.2.2. Habitat Characterisation

The dolerite dyke that transects the Project trending in an 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 three amphipods, a copepod and an ostracod found 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).

7.2.3. 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, 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. Troglifauna

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

- The troglifauna 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). Of these 11 species, 10 species are known to occur in reference areas outside the mine pits or at deposits elsewhere in the Pilbara.

- One species of troglofauna (Chilopoda sp.) is currently known only from within the proposed mine pits at the Iron Valley Project. Chilopoda sp. was recorded as a singleton. The conservation status of this species cannot be quantified because the specimen was too damaged for species identification.

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:

- Stygofauna sampling yielded 2,153 specimens consisting of at least 23 species of at least eight Orders, including Tubificida (3 species), Hydracarina (1 species), Ostracoda (3 species), Copepoda (4 species), Syncarida (3 species), Amphipoda (7 species), Isopoda (1 species) and nematodes of unknown order/s.
- Many species of stygofauna collected in the Iron Valley Project area (including the largest species *Pygolabis* sp. B01) 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.
- To date the ostracod *Meridiescandona* sp. BOS 171 and, possibly, the syncarid *Bathynella* sp. have been collected only from the Iron Valley Project impact footprint.
- Consequently, the ostracod *Meridiescandona* sp. BOS 171 and, to lesser extent, the syncarid *Bathynella* sp. are possibly threatened by Project development. However, it is likely that both species exploit the habitat connectivity between the Project and surrounding areas in the same way as demonstrated by most of the stygofauna species at Iron Valley.

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Appendix 1: Geology of the Iron Valley Project



N. 7485400

N. 7483800

N. 7484800

Legend

- Bore
- Dales Gorge Member
- Brockman Iron Formation - Dales Gorge Member
- Dolomite
- Joffe
- Weeli Walli
- Whaleback Shale
- Fault
- Grid
- Level
- Lines
- Pit Shell
- Slot

Source: Iron Ore Holdings Ltd

Client XXX	Project XX	Title Interpreted Hydrostatic Sections	
URS	Drawn: RNM	Approved: CO	Date: 30/06/2010
	Job No.: 42907456	File No.: 42907456-GW-005.mxd	
		Figure: X	Rev. A A3

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

Bore Code	Site type	Latitude	Longitude
WW022	Reference	-22.7619	119.2994
WW023	Reference	-22.7619	119.3014
WW024	Reference	-22.7619	119.3034
WW026	Reference	-22.7583	119.3043
WW025	Reference	-22.7583	119.3023
WW028	Reference	-22.7547	119.3071
WW027	Reference	-22.7546	119.3051
WW013	Reference	-22.751	119.308
WW011	Reference	-22.7511	119.3041
WW012	Reference	-22.7511	119.306
WW007	Reference	-22.7473	119.3108
WW006	Reference	-22.7474	119.3088
WW005	Reference	-22.7476	119.307
WW010	Reference	-22.7474	119.305
WW009	Reference	-22.7475	119.3031
WW004	Reference	-22.7474	119.3011
WW014	Reference	-22.7438	119.3031
WW015	Reference	-22.7439	119.305
WW016	Impact	-22.7438	119.3069
WW017	Impact	-22.7438	119.3089
WW019	Reference	-22.7402	119.3126
WW018	Impact	-22.7401	119.3107
WW021	Impact	-22.7364	119.3135
WW082	Impact	-22.7347	119.3126
WW081	Impact	-22.7348	119.3104
WW001	Impact	-22.7329	119.3116
WW029	Impact	-22.7329	119.3126
WW002	Impact	-22.7328	119.3136
WW051	Impact	-22.7295	119.3135
WW052	Impact	-22.7293	119.3154
WW080	Impact	-22.7311	119.3145
WW079	Impact	-22.7311	119.3123
WW077	Impact	-22.7255	119.3182
WW003	Impact	-22.7328	119.3155
WW053	Impact	-22.7291	119.3172
WW076	Reference	-22.7274	119.3203
WW075	Impact	-22.7276	119.3183
WW068	Impact	-22.7237	119.3211
WW048	Reference	-22.7219	119.3229
WW044	Impact	-22.7219	119.3205
WW074	Impact	-22.7201	119.3232
WW073	Impact	-22.7201	119.322
WW036	Reference	-22.7182	119.325
WW062	Impact	-22.7182	119.324
WW045	Impact	-22.7218	119.3182
WW046	Impact	-22.7216	119.3169
WW047	Reference	-22.7217	119.3289

Bore Code	Site type	Latitude	Longitude
WW050	Reference	-22.7218	119.3269
WW049	Reference	-22.7218	119.325
WW037	Impact	-22.7181	119.3326
WW038	Impact	-22.718	119.3306
WW039	Impact	-22.718	119.3306
WW061	Impact	-22.7183	119.3221
WW033	Impact	-22.7183	119.3191
WW059	Impact	-22.7183	119.3181
WW035	Impact	-22.7182	119.323
WW032	Impact	-22.7183	119.3172
WW058	Impact	-22.7184	119.3161
WW031	Impact	-22.7184	119.3151
WW069	Impact	-22.7202	119.3144
WW070	Impact	-22.7202	119.3161
WW071	Impact	-22.72	119.3182
WW072	Impact	-22.7201	119.3201
WW057	Impact	-22.7219	119.3201
WW043	Impact	-22.7221	119.3193
WW056	Impact	-22.722	119.3182
WW042	Impact	-22.722	119.3172
WW055	Impact	-22.7219	119.3163
WW041	Impact	-22.722	119.3157
WW054	Impact	-22.722	119.3142
WW040	Impact	-22.7219	119.3133
WW065	Impact	-22.7238	119.3154
WW063	Reference	-22.7238	119.3114
WW064	Reference	-22.7238	119.3134
IV135	Impact	-22.733	119.3107
IV095	Impact	-22.727	119.3126
IV097	Impact	-22.7275	119.3115
IV098	Impact	-22.7283	119.3139
IV100	Impact	-22.7285	119.3109
IV099	Impact	-22.7292	119.3116
IV182	Reference	-22.7221	119.3123
IV209	Reference	-22.7218	119.3318
IVUNK01	Reference	-22.7218	119.3325
IV207	Reference	-22.72	119.3299
IV208	Reference	-22.72	119.3299
IV204	Reference	-22.7198	119.3331
IV453	Reference	-22.7198	119.3348
IV454	Reference	-22.7189	119.3355
IV464	Reference	-22.719	119.3346
IV460	Reference	-22.7181	119.3356
IV452	Reference	-22.7172	119.3341
IV463	Reference	-22.7173	119.3361
IV444	Reference	-22.7146	119.3165
IV448	Reference	-22.7147	119.3145
IV445	Reference	-22.7139	119.3166
IV449	Reference	-22.7138	119.3161

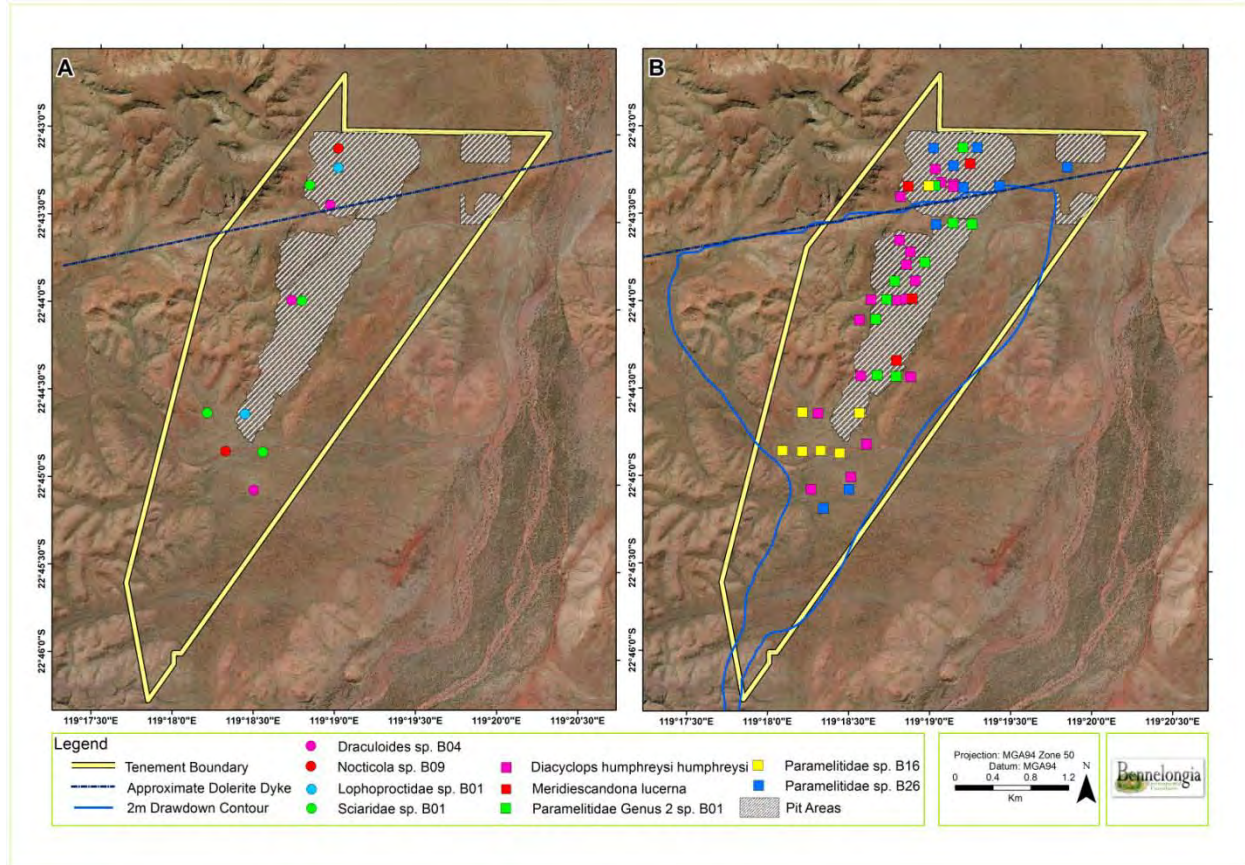
Bore Code	Site type	Latitude	Longitude
IV446	Reference	-22.7129	119.3165
IV450	Reference	-22.7128	119.316
IV109	Reference	-22.7201	119.3133
IV367	Reference	-22.7211	119.3128
IV344	Reference	-22.742	119.3068
IV338	Reference	-22.7438	119.3059
IV247	Reference	-22.7656	119.3004
IV248	Reference	-22.7655	119.3016
IV223	Reference	-22.7546	119.3051
IV273	Reference	-22.7547	119.3042
IV276	Reference	-22.7529	119.3061
IV275	Reference	-22.7529	119.3054
IV274	Reference	-22.7529	119.3042
IV244	Reference	-22.7475	119.306
IV242	Reference	-22.7475	119.304
IV241	Reference	-22.7456	119.3089
IV235	Reference	-22.7456	119.3054
IV239	Reference	-22.7545	119.3051

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

Bore code	Site type	Latitude	Longitude
WW024	Impact	-22.7619	119.3034
WW025	Impact	-22.7583	119.3023
WW028	Impact	-22.7547	119.3071
WW027	Impact	-22.7546	119.3051
WW013	Impact	-22.751	119.308
WW011	Impact	-22.7511	119.3041
WW012	Impact	-22.7511	119.306
WW007	Impact	-22.7473	119.3108
WW006	Impact	-22.7474	119.3088
WW005	Impact	-22.7476	119.307
WW010	Impact	-22.7474	119.305
WW009	Impact	-22.7475	119.3031
WW004	Impact	-22.7474	119.3011
WW001	Impact	-22.7329	119.3116
WW029	Impact	-22.7329	119.3126
WW002	Impact	-22.7328	119.3136
WW051	Impact	-22.7295	119.3135
WW052	Impact	-22.7293	119.3154
WW080	Impact	-22.7311	119.3145
WW079	Impact	-22.7311	119.3123
WW077	Impact	-22.7255	119.3182
WW045	Reference	-22.7218	119.3182
WW046	Reference	-22.7216	119.3169
WW047	Reference	-22.7217	119.3289
WW050	Reference	-22.7218	119.3269
WW049	Reference	-22.7218	119.325
WW038	Reference	-22.718	119.3306
WW061	Reference	-22.7183	119.3221
WW033	Reference	-22.7183	119.3191
WW035	Reference	-22.7182	119.323
WW058	Reference	-22.7184	119.3161
WW070	Reference	-22.7202	119.3161
WW057	Reference	-22.7219	119.3201
WW043	Reference	-22.7221	119.3193
WW056	Reference	-22.722	119.3182
WW042	Reference	-22.722	119.3172
WW055	Reference	-22.7219	119.3163
WW054	Reference	-22.722	119.3142
WW040	Reference	-22.7219	119.3133
WW031	Reference	-22.7184	119.3151
WW071	Reference	-22.72	119.3182
WW022	Impact	-22.7619	119.2994
WW024	Impact	-22.7619	119.3034
WW025	Impact	-22.7583	119.3023
WW013	Impact	-22.751	119.308
WW011	Impact	-22.7511	119.3041
WW007	Impact	-22.7473	119.3108

Bore code	Site type	Latitude	Longitude
WW005	Impact	-22.7476	119.307
WW010	Impact	-22.7474	119.305
WW004	Impact	-22.7474	119.3011
WW014	Impact	-22.7438	119.3031
WW015	Impact	-22.7439	119.305
WW016	Impact	-22.7438	119.3069
WW019	Impact	-22.7402	119.3126
WW021	Impact	-22.7364	119.3135
WW001	Impact	-22.7329	119.3116
WW029	Impact	-22.7329	119.3126
WW002	Impact	-22.7328	119.3136
WW080	Impact	-22.7311	119.3145
WW079	Impact	-22.7311	119.3123
WW003	Impact	-22.7328	119.3155
WW053	Impact	-22.7291	119.3172
WW052	Impact	-22.7293	119.3154
WW051	Impact	-22.7295	119.3135
WW077	Impact	-22.7255	119.3182
WW076	Impact	-22.7274	119.3203
WW075	Impact	-22.7276	119.3183
WW068	Impact	-22.7237	119.3211
WW045	Reference	-22.7218	119.3182
WW046	Reference	-22.7216	119.3169
WW057	Reference	-22.7219	119.3201
WW043	Reference	-22.7221	119.3193
WW042	Reference	-22.722	119.3172
WW055	Reference	-22.7219	119.3163
WW041	Reference	-22.722	119.3157
WW054	Reference	-22.722	119.3142
WW040	Reference	-22.7219	119.3133
WW070	Reference	-22.7202	119.3161
WW078	Impact	-22.7256	119.3202
WW062	Reference	-22.7182	119.324
WW061	Reference	-22.7183	119.3221
WW058	Reference	-22.7184	119.3161
WW033	Reference	-22.7183	119.3191
WW035	Reference	-22.7182	119.323

Appendix 6: Locations of Troglafauna (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 weeliwolli* 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 weeliwolli* (Halse *et al.* unpublished data); *Chydakata* sp. (Halse *et al.* unpublished data, Bennelongia unpublished data).

