Iron Valley Project

Potential Impacts to Aquatic Systems: Literature Review

September 2015

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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 (stygofauna), 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 epigean 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 atleast 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					
Australoeucyclops karaytugi	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)
Paracyclops sp. 6	Copepod(micro-crustacean)	Pilbara endemic	Marillana Ck	High	Uncertain
Hyporheos					
Vestenula n. sp.	Ostracod (seed shrimp, micro-crustacean)	Species new to science	Weeli Wolli Spring	High	Deep wells in the Ashburton catchment; likely Pilbara-wide
Chydaekata sp.	Stygal paramelitid amphipod	Stygal SRE	Bores within tenement; Weeli Wolli Ck; Marillana Ck	Does occur	Coondiner Ck; Mindy Mindy Ck; Kalgan Ck
Paramelitidae sp. B and sp. D.	Stygal paramelitid amphipods	Stygal SRE	Bores within tenement; Weeli Wolli Spring, Weeli Wolli Ck; Marillana Ck	Does occur	Fortescue R.; Kalgan Ck;Coondewanna Flats area
Maarrka weeliwolli	Stygal paramelitid amphipods	Stygal SRE	Bores within Project tenement; Weeli Wolli Ck; Marillana Ck	Does occur	Uncertain
Pygolabis weeliwolli	Stygal isopod	Stygal SRE	Weeli Wolli Ck; Marillana Ck	High	Uncertain
Pygolabis sp. (nr. *humphreysi*)	Stygal isopod	Stygal SRE	Bores within tenement;	Does occur	Uncertain
Bathynellidae species	Stygal syncarid	Stygal SRE	Bores within tenement;	Does occur	Uncertain. Family widespread but species have restricted distributions
Parabathynellidae species	Stygal syncarid	Stygal SRE	Bores within tenement;	Does occur	Uncertain. Family widespread but species have restricted distributions
Macroinvertebrates					
Hemicordulia koomina	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
Eurysticta coolawanyah	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
Ictinogomphus dobsoni	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
Nannophlebia injibandi	Pilbara archtail dragonfly	Pilbara endemic; restricted distribution	Marillana Ck	High	Fortescue R. catchment, but uncommonly collected
Laccobius billi	Aquatic beetle	Pilbara endemic; restricted distribution	Marillana Ck	High	Yual River (Cangan Pool); rarely encountered
Haliplus fortescueensis	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
Haliplus halsei	Aquatic beetle	Pilbara endemic relatively new to science	Unkown	Moderate-High	Fortescue Marsh; Pilbara-wide but rarely encountered
Aspidiobates pilbara	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
Wandesia sp.	Water mite	Pilbara endemic; restricted distribution	Weeli Wolli Spring	Low-Moderate	De Grey R. (Minigarra Creek); Yule R. (Cangan Pool)
Fish					
Leiopotherapon aheneus	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 refered to 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 km^2) 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 km^2, 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 was been 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 *et al.* (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 *et al.* (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 *et al.* (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 availiable 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 adversley 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 capibilities, 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 restriced 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, depite their close geographyical 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 and 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

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[1] Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10, 000 km^2.

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), Leptidoptera (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:

- *Haliplus fortescueensis* (haliplid beetle);
- *Haliplus 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 rivering 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 km^2, 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 km^2, 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).

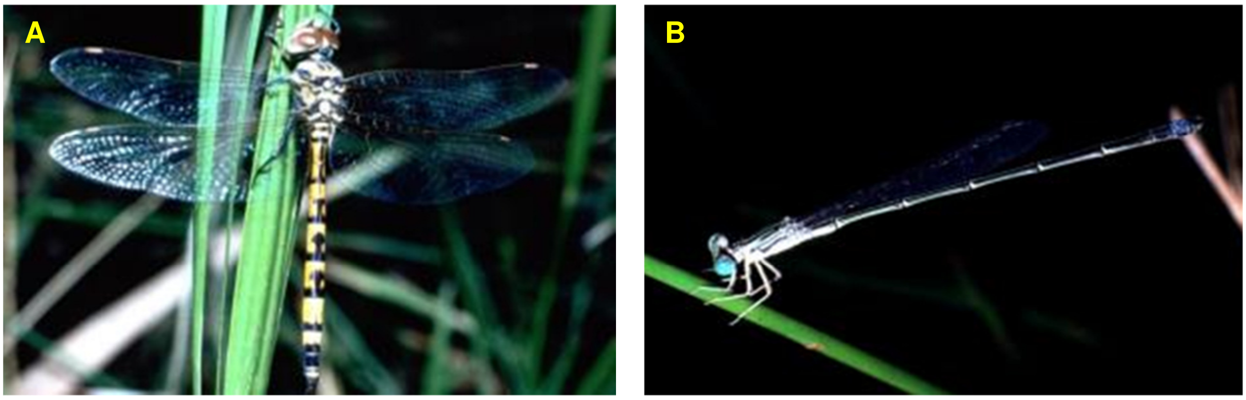

Plate 1. (A) Adult Pilbara emerald dragonly, *Hemicordulia koomina*, and (B) adult Pilbara pin damselfly, *Eurysticta coolawanyah* (photos taken and provided by Jan Taylor ©). Larval stages of all dragonflies and damselflies are aquatic.

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 Restriced taxa relatively new to science

The haliplid beetle *Haliplus 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).

Haliplus halsei is endemic to the Pilbara, but appears to occur widely throughout the region (Watts and McRae 2010). *Haliplus 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 un-named 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 hyrtlii*) (Plate 2).

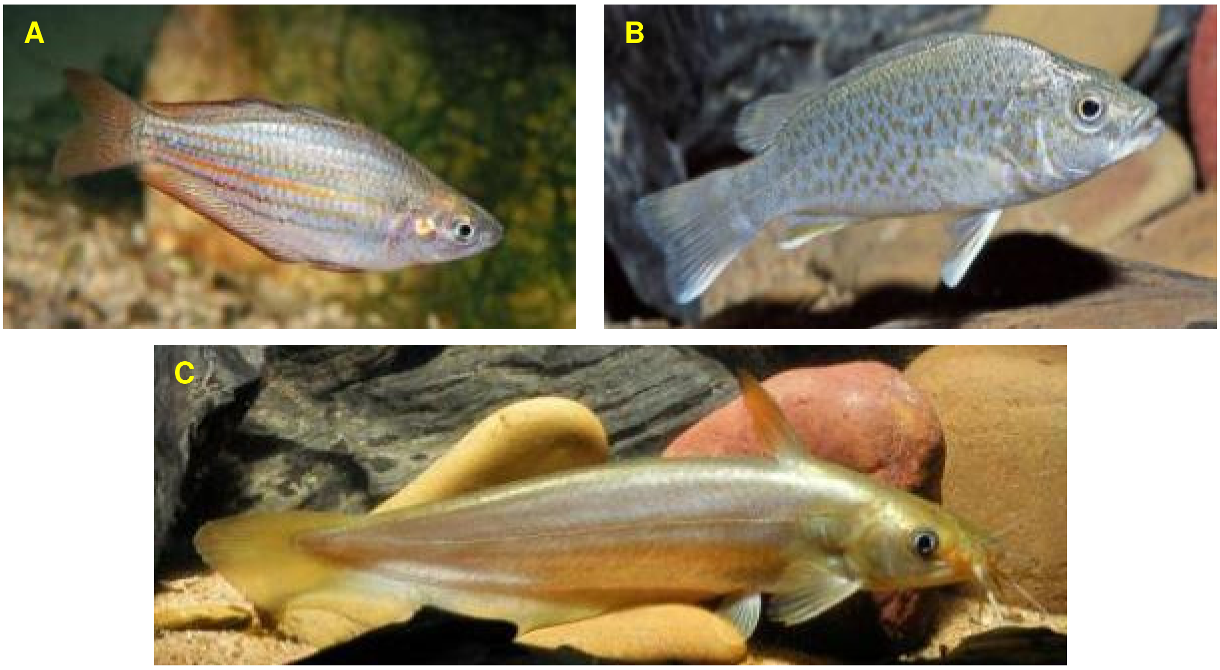

Plate 2. Fish species recorded from Marillana Creek by WRM; (A) western rainbowfish *Melanotaenia australis*, (B) spangled perch *Leiopotherapon unicolor* and (C) Hyrtl's tandan *Neosilurus hyrtlii* (photos taken and provided by Mark Allen ©).

The fish fauna of the Pilbara is characterised by low species diversity and high levels of endemicity; 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 terrestial 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 vunerable 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 physicochemisty.
- 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 overhaning 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 relseased 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 Rutherfurd 1999, Rutherfurd 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 macroinverterbrate 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 degress 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 superceeded (Gerhardt *et al.* 2004). The lack 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 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 futher 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 separting 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 incudes 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 epigean 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 atleast 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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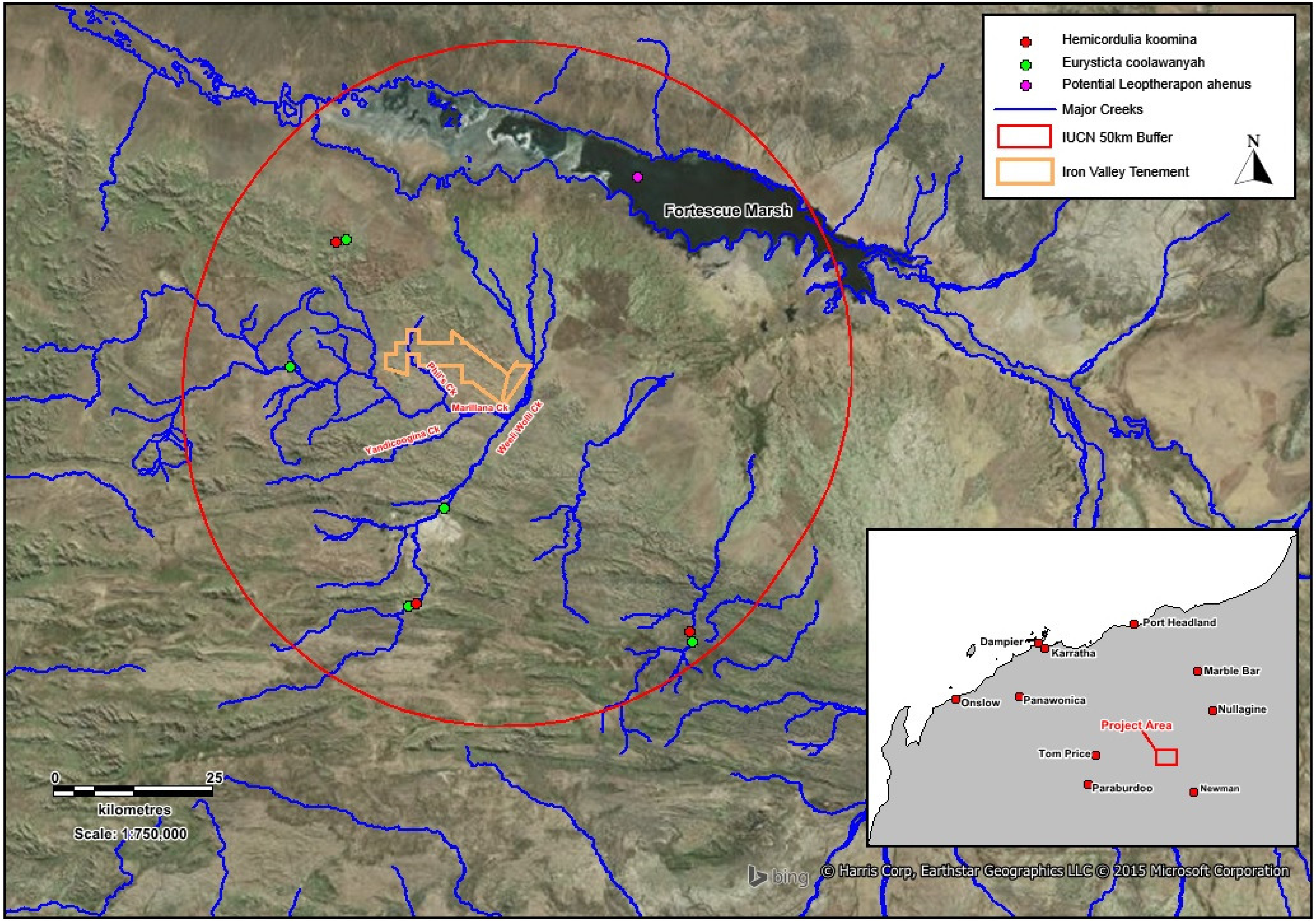
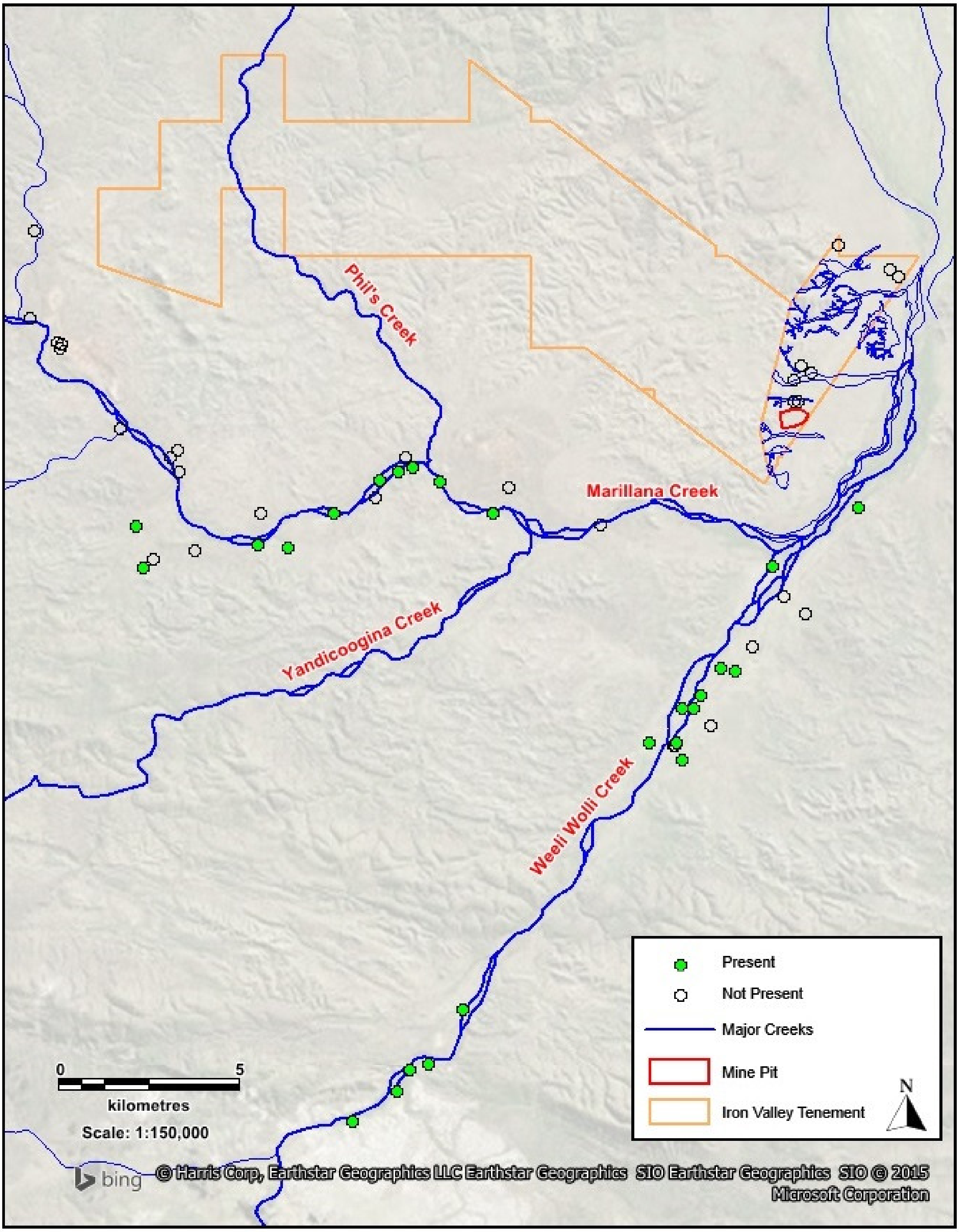
APPENDICES

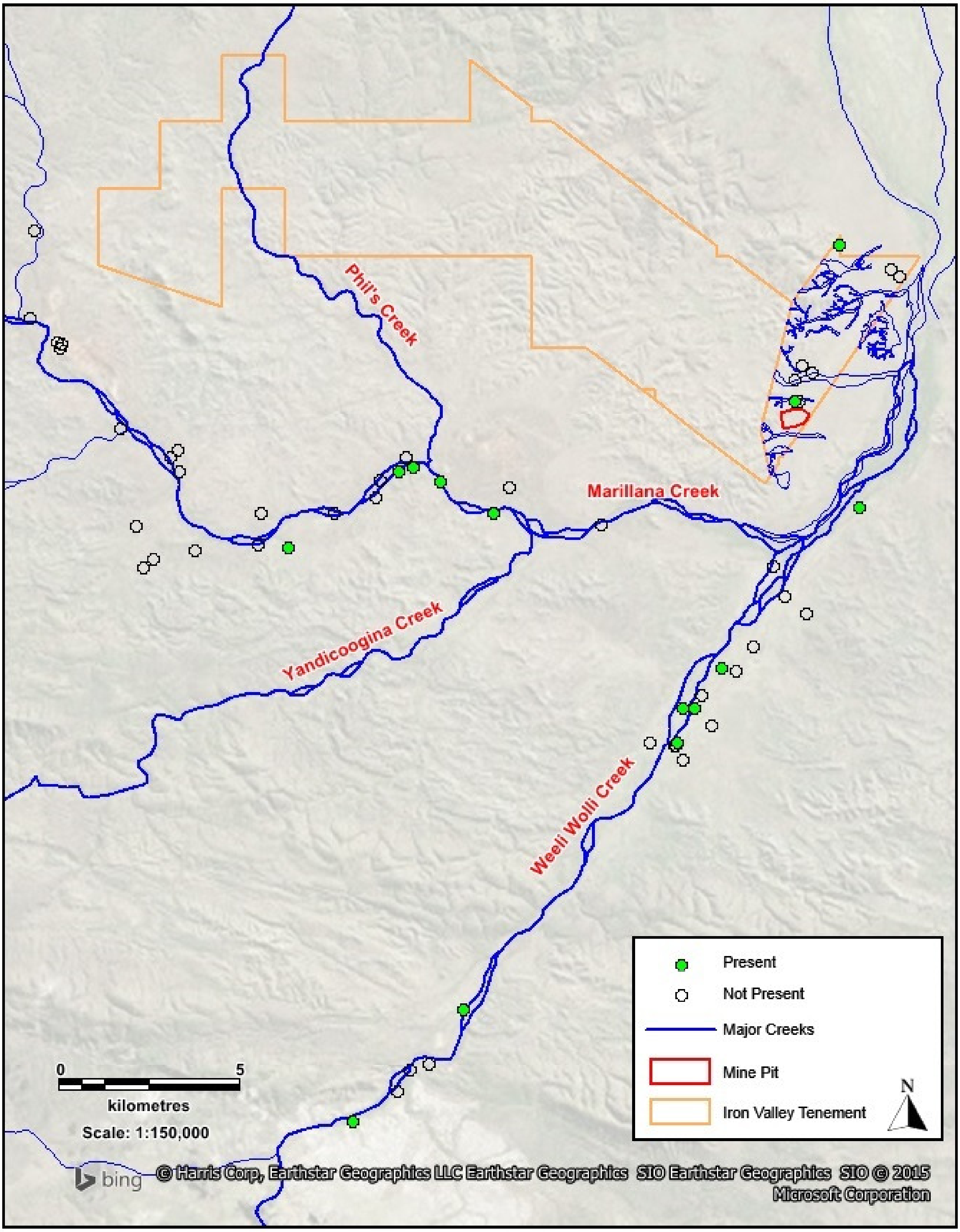
Appendix 1. Locations of IUCN listed aquatic fauna within 50 km of the Project area



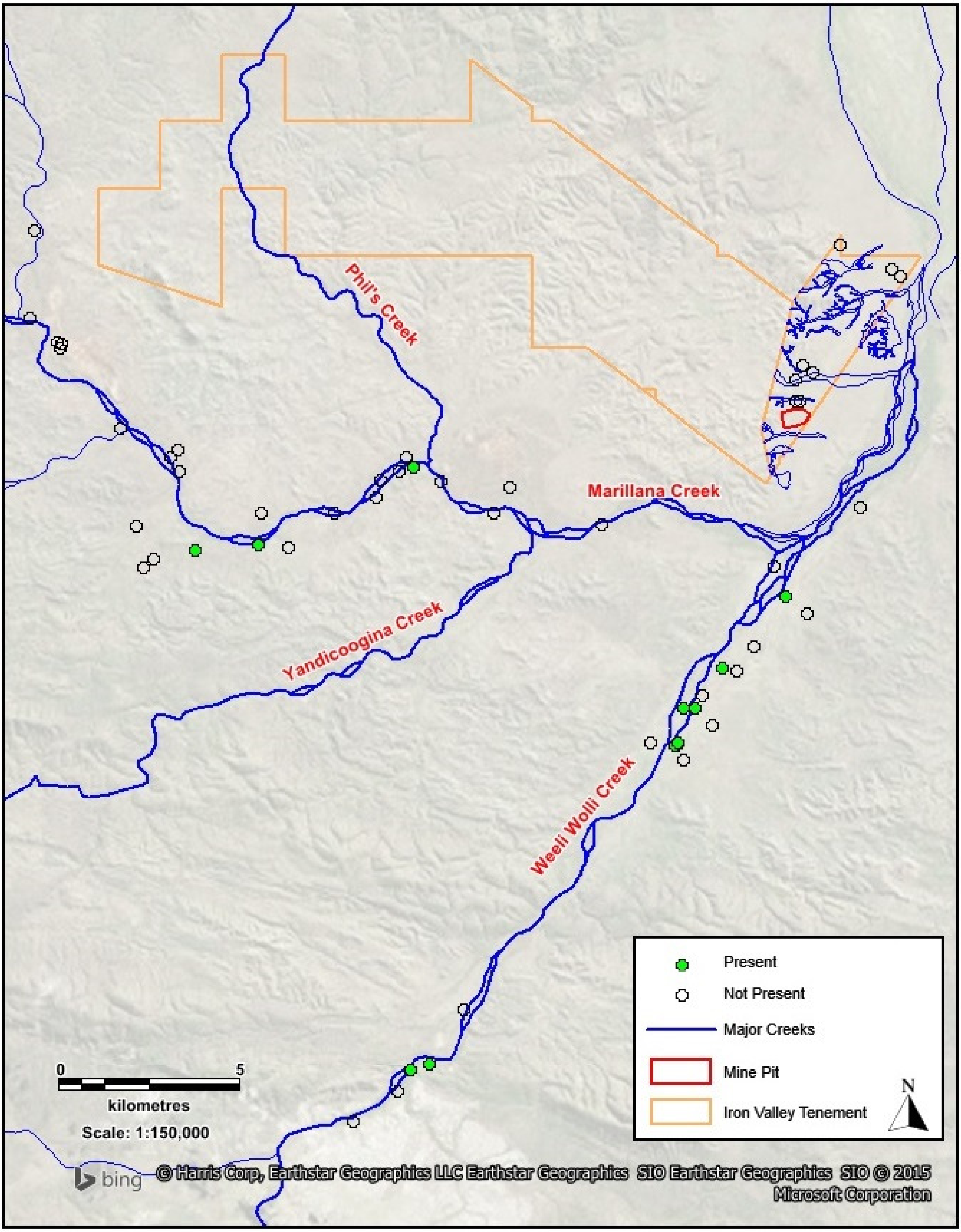
Appendix 2. Locations of stygal short-range endemic amphipod, *Chydaekata* sp.



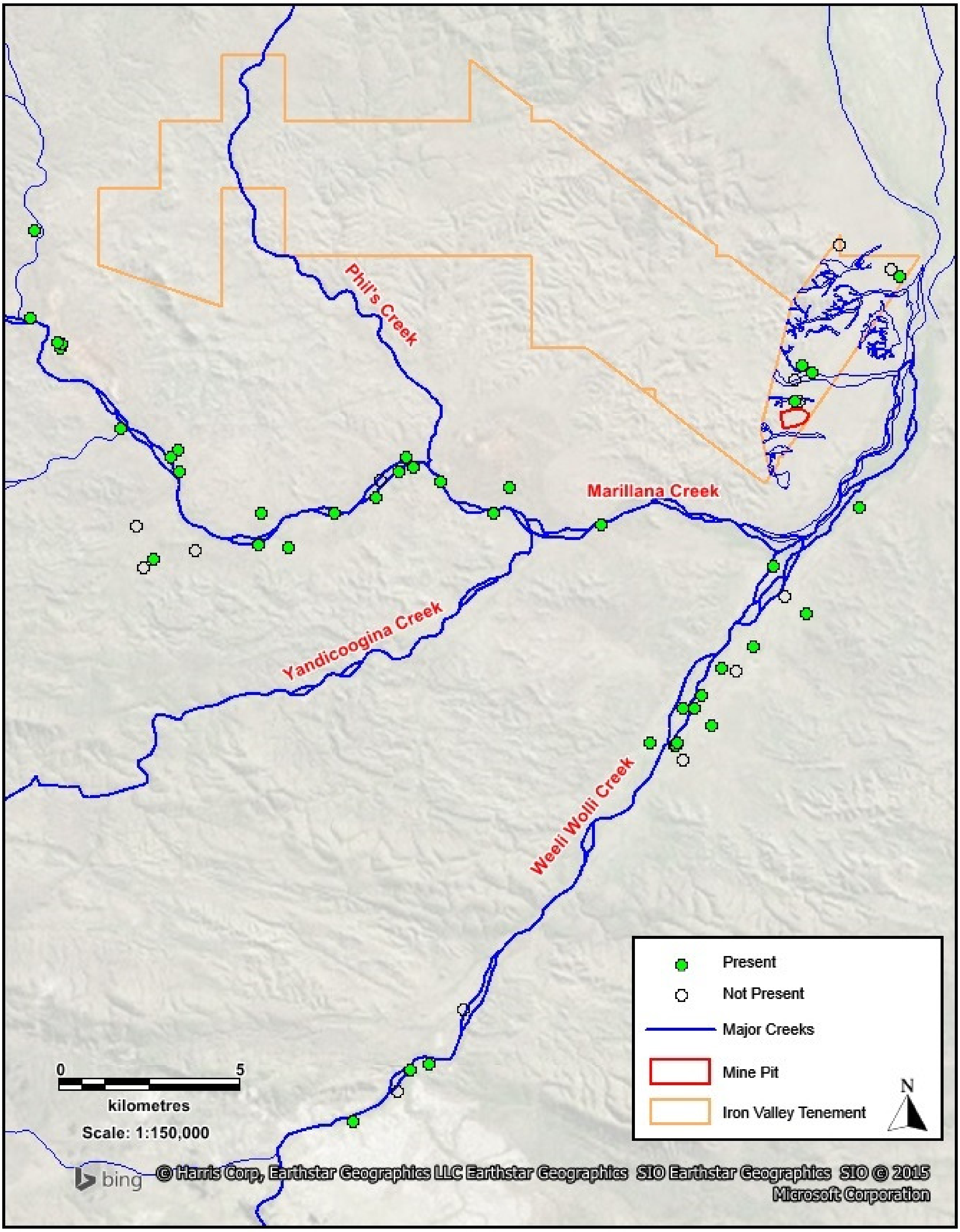
Appendix 3. Locations of stygal short-range endemic amphipod, *Maarrka weeliwolli*.



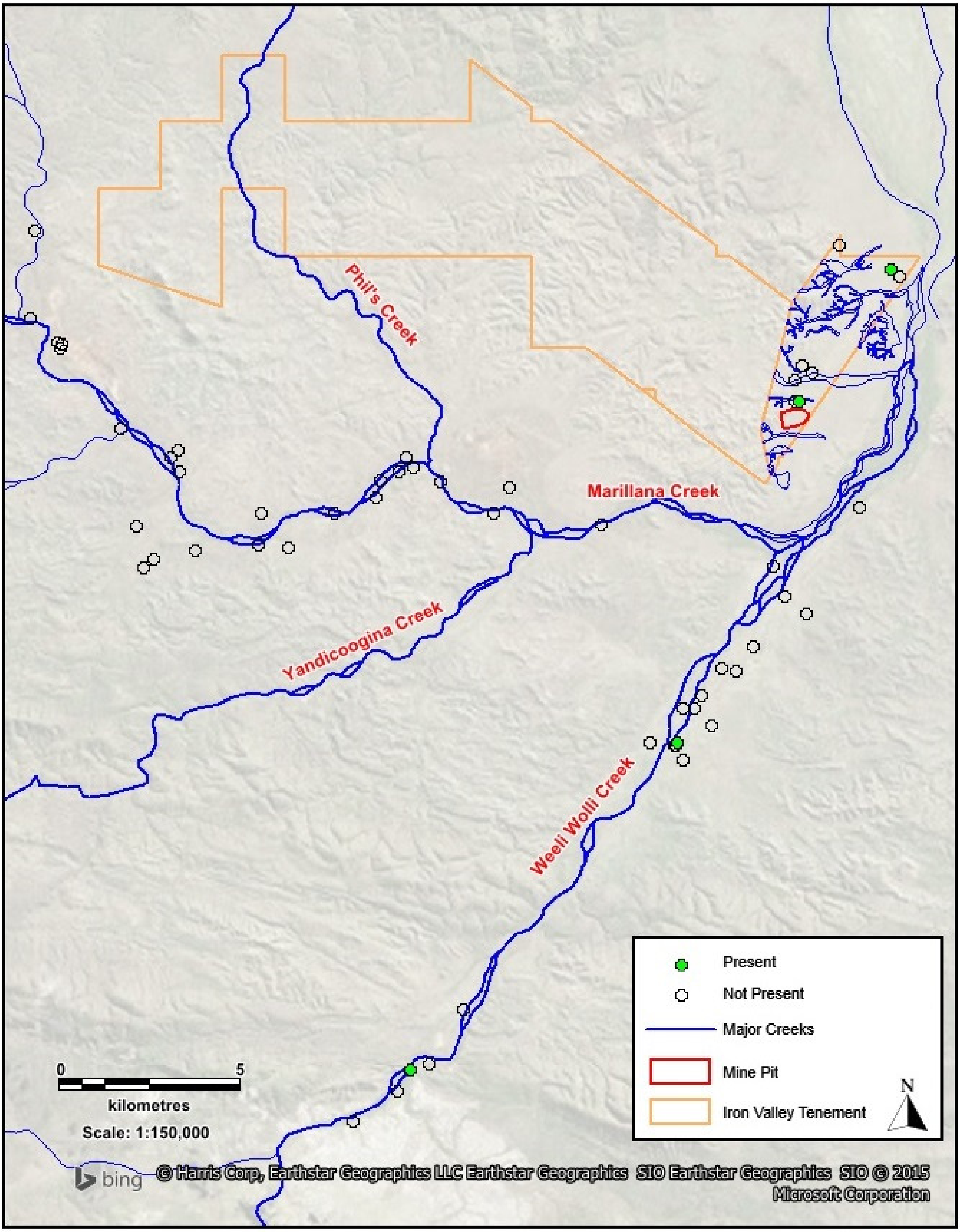
Appendix 4. Locations of stygal short-range endemic amphipod, *Pygolabis weeliwolli*.



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